Architectural Sciences Sustainable Materials and Built Environment

EDITORS
Ümit Turgay ARPACIOĞLU
Sibel AKTEN

OCTOBER-2023

İKSAD
Publishing House

Institution of Economic Development and Social Researches

(The Licence Number of Publishing House: 2014/31220)

TÜRKİYE TR: +90 342 606 06 75 USA: +1 631 685 0 853

E mail: iksadyayinevi@gmail.com

www.iksadyayinevi.com

Architectural Sciences, Sustainable Materials and Built Environment

ISBN: 978-625-367-287-4

October 1, 2023

Ankara / TÜRKİYE

EDITORS

Ümit Turgay ARPACIOĞLU

Sibel AKTEN

AUTHORS

(The authors were listed in alphabetical order)

Ahmet KURNAZ

Ahmet Cüneyd DİRİ

Bahar ŞAHİN

Çiğdem BİLGEN

Didem BARAN ERGÜL

Derin Hilal BİLMEZ

Emre KAVUT

Erkan AVLAR

Hande EYÜBOĞLU

Hüsniye Sueda YILDIRIM

Merve SAVRUNLU

Murat AKTEN

Nazife ÖZER

Seden ACUN ÖZGÜNLER

Serhat ANIKTAR

Serkan Yaşar ERDİNÇ

Türkan İRGİN UZUN

Ümit Turgay ARPACIOĞLU

Ürün BİÇER

Yaşar BAYRAKTAROĞLU

Zeynep YANILMAZ

İKSAD Publishing House

REVIEWER LIST

(The reviewers were listed in alphabetical order)

A. Cüneyt DİRİ	Mimar Sinan Güzel Sanatlar Üniversitesi
Çiğdem TEKİN	Mimar Sinan Güzel Sanatlar Üniversitesi
Damla ATİK	Trakya Üniversitesi
Elif ÖZDOĞLAR	Kütahya Dumlupınar Üniversitesi
Ezgi KORKMAZ	Yıldız Teknik Üniversitesi
Gülçin KAHRAMAN	İstanbul Sabahattin Zaim Üniversitesi
H. Hale KOZLU	Erciyes Üniversitesi
Hülya SOYDAŞ ÇAKIR	Fenerbahçe Üniversitesi
Mert ÇAKIR	Süleyman Demirel Üniversitesi
Mustafa ÖZGÜNLER	Mimar Sinan Güzel Sanatlar Üniversitesi
Nazire Papatya SEÇKİN TAHTALIOĞLU	Mimar Sinan Güzel Sanatlar Üniversitesi
Nur URFALIOĞLU	Yıldız Teknik Üniversitesi
Özlem AYDIN	Karadeniz Teknik Üniversitesi
Seden ACUN ÖZGÜNLER	İstanbul Teknik Üniversitesi
Serap FAİZ BÜYÜKÇAM	Ondokuz Mayıs Üniversitesi
Sevgül LİMONCU	Yıldız Teknik Üniversitesi

REVIEWER LIST

(The reviewers were listed in alphabetical order)

Atila GÜL	Süleyman Demirel Üniversitesi
A. Cüneyt DİRİ	Mimar Sinan Güzel Sanatlar Üniversitesi
Çiğdem TEKİN	Mimar Sinan Güzel Sanatlar Üniversitesi
Damla ATİK	Trakya Üniversitesi
Elif ÖZDOĞLAR	Kütahya Dumlupınar Üniversitesi
Ezgi KORKMAZ	Yıldız Teknik Üniversitesi
Gülçin KAHRAMAN	İstanbul Sabahattin Zaim Üniversitesi
H. Hale KOZLU	Erciyes Üniversitesi
Hülya SOYDAŞ ÇAKIR	Fenerbahçe Üniversitesi
Mert ÇAKIR	Süleyman Demirel Üniversitesi
Mustafa ÖZGÜNLER	Mimar Sinan Güzel Sanatlar Üniversitesi
Nazire Papatya SEÇKİN TAHTALIOĞLU	Mimar Sinan Güzel Sanatlar Üniversitesi
Nur URFALIOĞLU	Yıldız Teknik Üniversitesi
Özlem AYDIN	Karadeniz Teknik Üniversitesi
Seden ACUN ÖZGÜNLER	İstanbul Teknik Üniversitesi
Serap FAİZ BÜYÜKÇAM	Ondokuz Mayıs Üniversitesi
Sevgül LİMONCU	Yıldız Teknik Üniversitesi

PREFACE

The platform, which was established under the initiative and leadership of Prof. Dr. Atila GÜL with the motto of "Common Platform Where Spatial Planning and Design, Building, Landscape and Construction Meets", has been organized since 2021 (1st and 2nd International Symposium on Architectural Sciences and Applications 2021/2022), the books he edited (Architectural Sciences and Sustainability and Architectural Sciences and Conservation), and the Journal of Architectural Sciences and Applications (JASA), which left its 8th year behind, are excited to add a new one to these academic studies that he brought to the scientific life.

In this context, the "Journal of Architectural Sciences and Applications" (JASA) was established in 2016 for cooperation, knowledge production, and sharing at the international level. (JASA link: https://dergipark.org.tr/en/pub/mbud)

As JASA's Journal Editors, scientific journals and scientific books are published to develop inter and multi-disciplinary cooperation and joint studies. In addition, international scientific symposiums are also organized.

We wish to continue this process that we have started in the coming years, and we will ensure the continuity of the books with successive numbers. We are proud to have reached these numbers with the contributions and supports from you.

First of all, I would like to thank the Reviewer Committee, Architectural Sciences and Applications Academic Platform, who contributed greatly to the publication of both books, and İKSAD Publishing House and its responsibles who successfully followed the process. Many thanks to Sibel AKTEN, Lecturer, who has meticulously dealt with all the details of the book and has taken care of the book's success from the editorial processes to the referee processes with great determination and stability....

The biggest thank you deserves you, the authors of the book chapter. Thank you for sharing the quality and valuable works you have prepared with us.

We hope that our book " Architectural Sciences, Sustainable Materials and Built Environment" will be useful to readers.

Best regards.

October 1, 2023

EDITORS

Ümit Turgay ARPACIOĞLU
Sibel AKTEN

CONTENTS	Pages
	244-302

The Mysterious Doors of Hagia Sophia

Asst. Prof. Dr. Çiğdem BİLGEN [1]

[1]Fenerbahce University, Faculty of Engineering and Architecture,
Department of Architecture, Atasehir, Istanbul/Türkiye.
ORCID: 0000-0002-6513-4267
E-mail: cigdem.bilgen@fbu.edu.tr

.

Citation: Bilgen, Ç. (2023). The Mysterious Doors of Hagia Sophia. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment, (*1-56). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

Hagia Sophia not only reflects the power, but also the downfall of the Byzantine Empire in the 14th and 15th centuries. The book named "Hagia Sophia Museum" reflects this "A Russian priest, who visited Constantinople in 1350, saw the doors of the church barricaded because they could not be repaired*."* (Dirimtekin, 1964).

According to another story: *"The Cactillan ambassador, Clavijo, who came in 1402, ound the building in a state of great dilapidation. Most of the doors had fallen down and were lying on the floor"* (Akgündüz et al., 2005).

The purpose of this study is to look into the doors of this landmark construction comprehensively. Every door of this building has been alive with unique stories behind it. When we stand in front of the doors, we start to think about these stories, and we their reflections behind us. This paper deals with the appearing doors of Hagia Sophia by giving information about the characteristic features including their materials, locations, symbols, and meanings.

The study also aims to be an archive to contribute to having a list of precious inventory of assets of a historical masterpiece within our cultural heritage. The academic research efforts until now do not provide such a list within the scope of Hagia Sophia. The inventories of our cultural heritage is the starting point for serving the preservance of our valuable historical heritage.

1.1. Overview of Hagia Sophia and Its Materials

Built in 537 AD during the reign of Emperor Justinian, it is the largest building in the world and an engineering marvel of its time. It is considered a masterpiece of Byzantine architecture and is said to have changed the history of architecture. Hagia Sophia is a stone building. The brick-to-mortar joint is 1.5 times his width of the brick. Mortar joints consist of a combination of sand and small ceramic pieces evenly distributed throughout the mortar joint. This combination of sand and ceramic pieces can be considered the modern equivalent of concrete.

The building was built between 532 AD and 537 AD by order of the Byzantine Emperor Justinian I as his third Church of the Holy Wisdom on this site. It was designed by the Greek geometers Isidore of Miletus and Anthemius of Tralles.

1.2. Overview of Door Architecture up to Byzantine

In the construction of doors throughout history is used of wood, stone, metal, glass, paper, sheet, leather, or a combination of materials.

Early doors used in Mesopotamia and antiquity were simply leather or fabric. Doors made of strong and durable materials appeared at the same time as monumental architecture. Doors to important rooms were often made of stone or bronze.

Stone doors, usually hung on upper and lower spigots, were often used in tombs. Examples of marble panels, probably from the time of Augustus, have been found in Pompeii. A Greek door (circa 200 AD) from a tomb in Rangaza, Türkiye, is preserved in a museum in Istanbul.

The use of monumental bronze doors is a tradition that continued into the 20th century. The gates of Greek temples were often fitted with grilles of cast bronze. The Romans characteristically used solid bronze double doors. They were usually supported by pegs attached to sills and lintel sockets. The earliest large example is the 7.3-meter-long double doors of the Pantheon in Rome. Roman planking design and assembly techniques carried over into Byzantine and Romanesque architecture. The art of door casting survived in the Eastern Empire, the most notable example being the double doors of the Hagia Sophia in Constantinople (Tikkanen, 2023).

2. Material and Method

In this chapter, it is aimed to be beneficial in expanding general aspects of the doors in understanding the whole monumental structure. While doing this, the materials of the doors are also mentioned in detail.

All doors have myths about its own characteristic features. For example, the origin of wood doors Hagia Sophia had a striking myth. These were clad in bronze. The motif is a Byzantine interpretation of classical motifs such as the 6th century acanthus. The Byzantines were famous for their bronze doors inlaid with gold and silver, which were sent across the Mediterranean. Western clergy and monks ordered door sets directly from manufacturers when visiting Constantinople. Many sets of these doors have survived.

3. Findings and Discussion

Many works have been written about Hagia Sophia, which has a special place in the history of architecture. However, very few of these writings chose the doors of this great building as their subject. In general, the locations and numbers of the narthex doors that provide entrance to the temple from the west were mentioned in the publications, and more research was carried out on these doors' architectural details such as their wings, frames and materials. This situation makes it difficult for us to determine the setup of the doors in Hagia Sophia, which has a complex structure. The ongoing destructions throughout history have affected the structure, and especially the doors of Hagia Sophia have been greatly affected by these destructions. It is seen that many door frames of Hagia Sophia were produced according to their positions in the building. As the result of researches, it is understood that many various materials are used in the door architecture of Hagia Sophia such as wood, different kinds of marble, bronze, gold, silver etc. Within the scope of this study, the building will be entered through these mysterious doors and many issues related to the doors architecture particularly their materials will be illuminated.

3.1. The Lower Floor and Its Doors

3.1.1. The atrium and the theodosis church

In Justinian's time, the church was entered by an atrium on its west side that created an enclosed area extending westward from the existing exonarthex about forty-two meters. And also there was a phiale at its center (Broilo, 2016). According to Paul the Silentary's explanations: "*On the west side of the church you will see a court surrounded by four stoas or colonnaded walks; one is joined to the narthex and the others open, and various paths lead to them. At the center of the court stands a* *spacious fountain cut from Iasian peaks; from it a burbling stream of water leaps into the air."* (Freely & Çakmak, 2005).

The main entrances to the atrium on the south side of Hagia Sophia were opened towards the Augusteion era. However, the atrium has now completely disappeared, and in place of the atrium, there is currently a garden on the west side.

3.1.1.1. The atrium doors

The main entrance to Hagia Sophia currently is on the west atrium. The church previously had seven doors providing entrance to the gate from the atrium on the west side once. Today, there are only three remaining doors in use (Figure 1). The other four doors had been closed during repairs and are currently out of use (Dirimtekin, 1961). According to Dirimtekin's article, the wrecked wings of the three doors in use are not original, because they had been renovated (Figure 2 and Figure 3).

Figure 1. Three remaining doors of Hagia Sophia (Bilgen, 2011).

Figure 2 and Figure 3. Three wrecked wings of three remaining doors of Hagia Sophia (Bilgen, 2011).

3.1.2. The exonarthex (Outer Narthex)

After entering from the courtyard, there was the exonarthex part of the church which occurred in nine divided parts, covered with cross-vaults. This area 5.75 meters in width, now is used as the exhibition of a small collection of Byzantine stonework. This space is very plain and has not much ornamentation such as mosaics, marble, and distinctive architectural properties (Eyice, 1984). In the Byzantine age, if the penitent person could not pass the exam of religious lessons, he wasn't allowed to enter this exonarthex area (Boyar, 1943).

3.1.2.1. The exonarthex doors

The five doors are existing now. The middle door (Figure 4) and the other two doors (Figure 5 and Figure 6) next to the middle door have been kept in their original aspects. Unlikely, the southern (Figure 7) and the northern (Figure 8) doors unfortunately have currently lost their originality partially. All these doors have been made of thick oak, covered with bronze veneering 5 to 8 mms thick (Dirimtekin, 1961). The Marmara Marble has been used as lintels and door frame material (Özügül, 2010).

These doors had been ornamented with demonstrations of large crosses. The horizontal crosses had been removed by Ottomans (Dirimtekin, 1966), whereas the shaped circles which symbolize eternity (Kurian & Lamport, 2016), vases with handles and the flowers filled in, and also various small animal figures are still in place (Figure 9, Figure 10, Figure 11 and Figure 12), (Dirimtekin, 1964).

Figure 4. The mid exonarthex door of Hagia Sophia (Bilgen, 2011).

Figure 5 and Figure 6. The other exonarthex doors next to mid exonarthex door of Hagia Sophia (Bilgen, 2011).

Figure 7. The southern exonarthex door of Hagia Sophia (Bilgen, 2011).

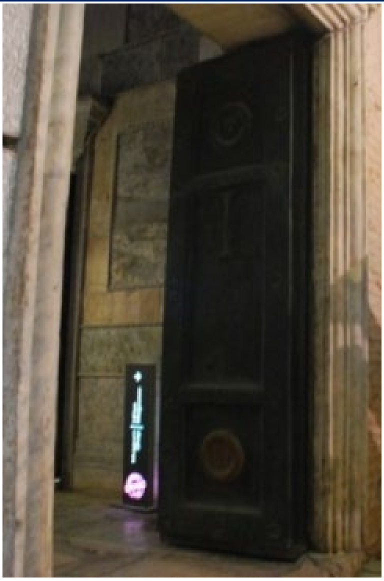


Figure 8. The northern exonarthex door of Hagia Sophia (Bilgen, 2011).

Figure 9, Figure 10, Figure 11 and Figure 12. The symbols of exonarthex doors of Hagia Sophia (Bilgen, 2011).

The Doors of Minarets in the Exonarthex

In this area, there are also two small doors (Figure 13 and Figure 14) of Turkish workmanship on the north and south walls, which open to the minarets of the architect Sinan (Dirimtekin, 1964). According to Çakmak and Freely, these doors have replaced earlier Byzantine portals (Freely & Çakmak, 2004).

Figure 13 and Figure 14. The doors in the north and south side walls of minarets in Hagia Sophia (Bilgen, 2011).

The Northwest and Southwest Doors in the Exonarthex

The door in the north end and another door in the south end of this area provided passage to two galleries having been medhal of the atrium, which was built vertically to the outer narthex. As soon as the mosque was converted to a museum, the north galley was used to exhibit the Byzantine bricks (Dirimtekin, 1966). Now, this space is closed (Figure 15). And the south gallery was used as storage. However, this gallery (Figure 16) has been transformed into a shop that sells many products related to the Hagia Sophia.

Figure 15. The north gallery door in the exonarthex of Hagia Sophia (Bilgen, 2011).

Figure 16. The South gallery door in the exonarthex of Hagia Sophia (Bilgen, 2011).

3.1.3. The narthex (Inner Narthex)

After passing through the five doors, the narthex area can be reached which has 6.90 meters in length, and 11.64 meters in width. This part which has very rich architectural elements is much more decorative and higher than the exonarthex section. The ceiling is covered with impressive mosaics, and two sides of the walls have been decorated with very colorful stones (Dirimtekin, 1966). Like the exonarthex area, the narthex part's divided into nine sections, and it has arches running parallel to the axis of building (Eyice, 1984).

3.1.3.1. The narthex doors

The central doors from the narthex to the nave of the Hagia Sophia were not available for common use. The doors' use was restricted to the patriarch and the imperial retinue on important incidents, whence their name, "the imperial doors". The central doors of this building themselves were also an object of adoration. Despite the fact that these doors were covered with metal plates, as were the other doors customarily they were wrought of the valuable wood of Noah's ship, as the Russian Anonymous, Alexander and Zosima confirm, even though the original Justinianic doors were seemingly carried off by the Latins in the thirteenth century and afterward replaced (Majeska, 1984).

The Doors Opened from the Narthex to Naos

The main part of the building or the naos area was entered by nine magnificent doors. These doors are three groups of three that provide passage into the nave defined by columns from each of the nine bays of the narthex (Freely & Çakmak, 2005). The three doors in the south (Figure 17, Figure 18 and Figure 19) were used by the public, the middle three doors (Figure 20, Figure 21 and Figure 22) only belonged to the emperor and his entourage, and the other three doors in the north (Figure 23, Figure 24 and Figure 25) belonged to the people who looked for melce (Koçu, 1960). The three each door in the south and north were made quite simply. The door frames of the doors (Figure 17 and Figure 23) have been applied Proconnesian Marble, still, the crosses can be seen on their lintels (Freely & Çakmak, 2005). However, the frames of the highest door in the middle called "The Imperial Gate" which will have been explained later, were covered with silver and gold plates gilded in bronze (Dirimtekin, 1966). Also, there are seen bent fingers above all the inner narthex doors like exonarthex doors. They were used to hang curtains that were called vela in the Byzantine era. In the Turkish period, these doors were covered with thick curtains (Dirimtekin, 1964).

Figure 17, Figure 18 and Figure 19. The three doors (for the public) opened from the narthex to the naos of Hagia Sophia (Bilgen, 2011).

Figure 20, Figure 21 and Figure 22. The other three doors (for the emperor and his entourage) opened from the narthex to the naos of Hagia Sophia (Bilgen, 2011).

Figure 23, Figure 24 and Figure 25. The mid three doors (for the people who looked for “melce”) opened from the narthex to the naos of Hagia Sophia (Bilgen, 2011).

The Imperial Doors

These doors have been located in the middle of the narthex. Because only the emperor and his suites used them, the doors were named as "The Imperial Doors". "The tradition that the imperial doors of Hagia Sophia were made of Noah's ark, however, lived on, and not only among the Russian visitors." (Lethaby & Swainson, 2004). The current doors were installed as part of the restoration made by the Fossati brothers in the nineteenth century (Majeska, 1984). Except for the highest major door (Figure 26), the jambs of the other two doors (Figure 27 and Figure 28) being adjacent to the Imperial Gate, have been made from the Verde Antico marble, as are their lintels on the side facing the narthex (Özügül, 2010). Only the inner face of the lintel of the south door which is next to the highest middle, the Marmara Marble was used (Freely & Çakmak, 2005).

Figure 26. The highest Imperial Door of Hagia Sophia (Bilgen, 2011).

Figure 27 and Figure 28. The other two Imperial Doors of Hagia Sophia (Bilgen, 2011).

The Highest Imperial Gate

<u>The Dimensions:</u>

External dimensions; height: 8 m, width: 4,89 m, Internal dimensions; height: 6,6 m, width: 3,75 m (Dursun, 2011).

This door (Figure 29) is the largest and the central one through which the emperor, accompanied by the patriarch entered the church. The important feature of this door is that this is aligned with the central gate providing passage from the exonarthex to the narthex, but the other gates are not tracked with one another (Freely & Çalmak, 2004). This door has lost its originality because its silver and gold plates guilted in bronze were sacked during the Crusaders in the Fourth Crusade. In the Byzantine era, the material of the door frame has named an electron. Additionally, this door also had been repaired like the other doors (Dirimtekin, 1961).

Çakmak and Freely say about this door's material like this making a comparison: *"The Imperial Gate is surrounded by a casketlike cornice; this and the marble frame of the portal are sheathed in dark bronze, elaborately decorated in relief* (Figure 30 and Figure 31)*"* (Freely & Çakmak, 2005).

About this door, Heinz Kähler says: *"Above its bronze cornice and beneath an arch carried by two pilasters may be seen the only extant plastic composition dating from the founding period of the church."* (Kähler, 1967).

Figure 29. The highest Imperial Gate with other Imperior Doors to enter the main area of Hagia Sophia, (https://hagiasophiaturkey.com/emperor-door/).

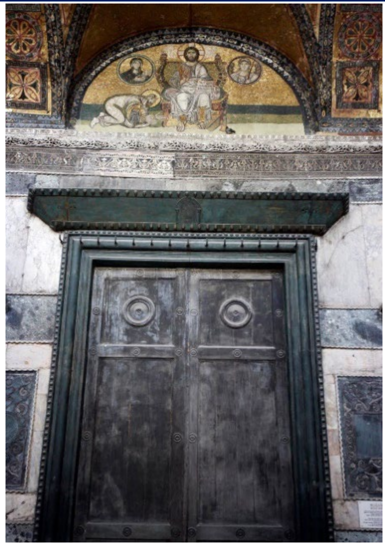
 

Figure 30 and Figure 31. The Emperor Door of Hagia Sophia, (Rachel Offardahl, 2010).

The Emperor Door was also known as the Door of Repentance, above in the arch is the mosaic of Leo VI dating to the 9th century (Figure 32). This unique mosaic has an amusing story. The Byzantine Emperor Leo the Wise married a pious woman who preferred to sleep on a mat to be able to rise to pray constantly. Not having had an heir, Leo VI Emperor married Zoe once his wife died. Nevertheless, Zoe died just by giving him a daughter. When the Emperor married the third time, he was condemned by the clergy. However, his new wife gave him a son who died at birth. The Emperor didn't forego and made a decision to marry again. Eventually, he had a son from his fourth wife. However, this time he was punished by the church (Hagiasophiatr, 2020). Therefore, in this mosaic, we see that Leo VI with a halo over his head is giving proskynesis, an act of respect- to Christ, who is sitting on a jeweled throne. With his right hand, Christ is blessing Leo VI, and his left hand is holding a book written “Peace be upon you. I am the light of the world” on it. Christ is enthroned with two roundels of His Mother Mary and Archangel Gabriel. This image is purposed to show the endless power of the emperor and his subjects blessed by Christ (Figure 33, Figure 34, Figure 35 and Figure 36), (hagiasophia.com, 2020).

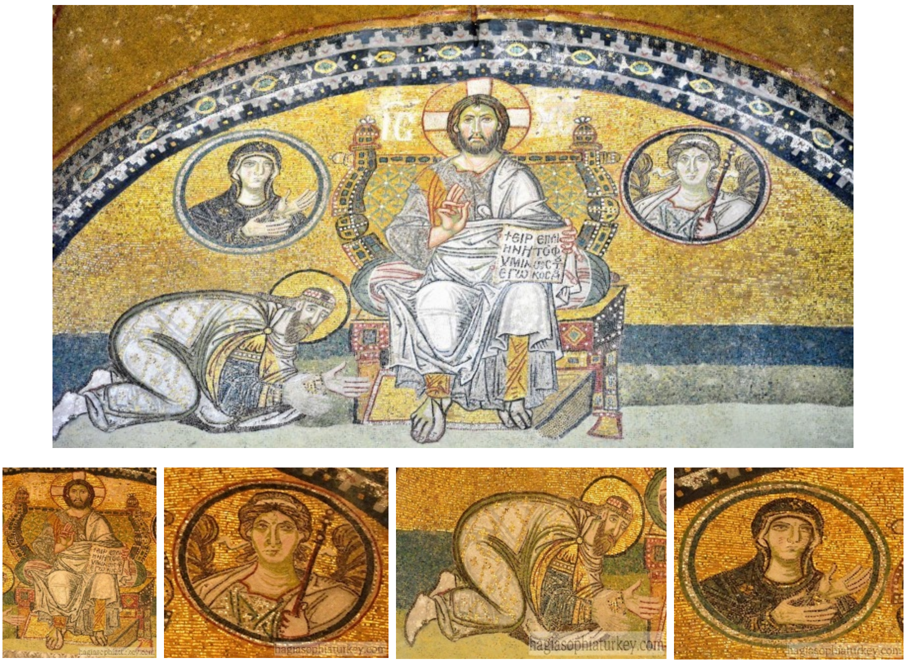


Figure 32, Figure 33, Figure 34, Figure 35 and Figure 36. The outer mosaic of Leo VI located on the Emperor Door of Hagia Sophia, (https://hagiasophiaturkey.com/mosaic-leo-vi/).

The Symbols of Reliefs on the Imperial Gate are very interesting, and every meaningful symbol gives a message. There is an image in the middle of the cornice over the central axis of the entrance demonstrates an archway on columns framing an open book that frames an open Gospel and above a dove which symbolizes the Holy Ghost is flying straight downward (Figure 37 and Figure 38.). According to the leaf of the Gospel's 10:7-9: "I am the door of the sheep; if anyone enters by me, he will be saved and will go in and out and find pasture (Eyice, 1984).

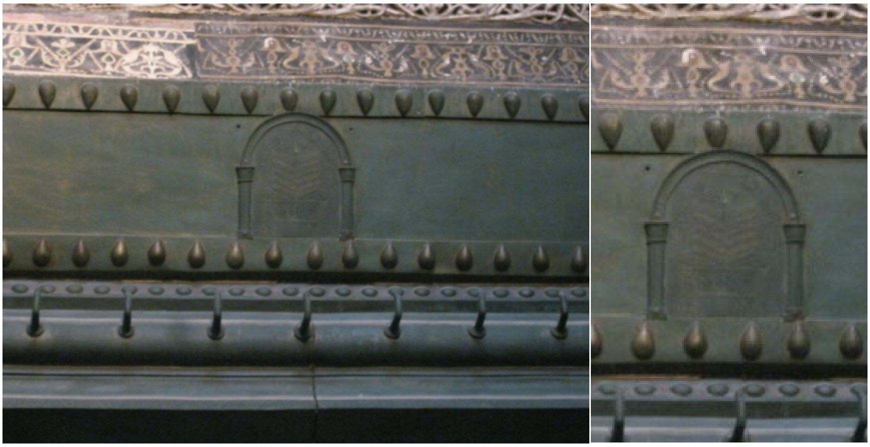


Figure 37 and Figure 38. The symbol on the Emperor Door of Hagia Sophia, (Bilgen, 2011).

There are marble plates colored green and black where are above the Imperial Gate (Figure 39). There is some impressive opus sectile work here of two each dolphin around the shaped circles. And at the middle, there are three forks belonging to the pagan god of the Greeks (Atchison, 2020). Additionally, there is another mosaic inside the Calvary cross (a kind of Christian cross) that represents the Christ was crucified on the hill of Golgotha (Figure 40), (Akgündüz et al., 2005).

Figure 39. The marble plates on the Emperor Door of Hagia Sophia, (Bilgen, 2011).

Figure 40. The inner mosaic on the Emperor Door of Hagia Sophia, (Bilgen, 2011).

The Southern Doors in the Narthex

This door opens to the courtyard of the church (Figure 41). There is also another door (Figure 42) next to it, which connects to a ramp rising upper floor gallery in which the door frame has been made of Marmara marble (Özügül, 2010).

Figure 41. The southern door (opens to the courtyard) in the Narthex of Hagia Sophia, (Bilgen, 2011).

Figure 42. The southern door (connects to the ramp rising to the upper floor gallery) in the Narthex of Hagia Sophia, (Bilgen, 2011).

The Door at the South End of the Narthex (Horologion Door)

There is a door at the south end of the narthex known as the “Horologion Door” (Figure 43 and Figure 44). In the I. Mahmut’s time, this door was also known as “Muvakkithane Door” after being built Muvakkithane (Akgündüz et al., 2005). When the emperor came into Hagia Sophia, this door was used as an important passageway during the ceremonies. About this place, Eyice says this: *“An Arab, Harun İbn Yahya, who was brought to Byzantium as a slave in the tenth century, briefly describes a “device to tell the time rising up at one corner of the Hagia Sophia. The mechanism inside this “Horologion”, which was at the west corner of the church, indicated the time by means of a puppet that emerged from a small aperture once an hour on the hour, followed by more puppets emerging in turn from other apertures”* (Eyice, 1984). Its door frames have been made of Marmara marble (Özügül, 2010).

Figure 43 and Figure 44. The Horologion Door in the Narthex of Hagia Sophia, (Bilgen, 2011).

The Vestibule Exit Door in the Narthex (Orea Porta or Beautiful Door)

<u>The Dimensions:</u>

Door Height: 4.33 m + 0,51 m, (the below ground part) = 4,84 m. One part of the door wing's width is 1,51 m, the Door depth is 14 cm, the Length from jamb to jamb is 2,99 m, being opened door's width is 2,76 m. Now, this door (Figure 45, Figure 46 and Figure 47) is used as an exit door which has been placed in the inner narthex's south exit. This bronze door was taken from an ancient pagan temple in Tarsus that belonged to Hellenistic- Roman period 2 B.C. and was brought to church as the oldest collecting element (Dirimtekin, 1964). The wings of this door have been made from thick oak timber covered by bronze screens that are connected to each other. These door frames are made from Marmara marble (Özügül, 2010). This door has great artistic and historical values that were settled in the church in the 9th century by Emperor Theophilus and refined the date 838 on door (Türkoğlu, 1989). The annual 5 of Hagia Sophia writes about the subject of being buried situation of the door like this: *"The ornate bronze doors at the present entrance to Hagia Sophia were cleaned by the Restoration Institute of Rome, and it's seen that the lower part remained 60 cm below the present ground level. The doors were taken off in order to be repaired. This makes it necessary to rearrange the entrance, and lower the floor by 60 cm, so that the doors may be used after the restoration, and opened and shut easily. This work will be done in the spring of 1964 (Annual of Hagia Sophia No: 5).*

Today, this is left as the same position because of for the conservation of the door." (Gürşan, 2011).

Figure 45, Figure 46 and Figure 47. The Beautiful Door in the Narthex of Hagia Sophia, (Bilgen, 2011).

The ornamentation of the door is very impressive. The door is ornamented with plant and geometrical motifs and holds many monograms (Figure 48, Figure 49 and Figure 50) that belong to the Emperors Theophilus and Michael and Empress Theodora. It was used by the Emperors in liturgies. In addition, there is another monogram that says *"God and Christ help us"*. Another monogram says *"Victorious Michael."* (Dirimtekin, 1964).

Figure 48, Figure 49 and Figure 50. The ornamentation details of Beautiful Door in the Narthex of Hagia Sophia, (Bilgen, 2011).

The Door on the South Vestibule's East Wall in the Narthex

In the south vestibule area, there was a plain mihrab on the middle face of the east walls which was made by the Conqueror. Even, this was said that the prayer was performed firstly in this area. Substantially, this mihrab was the door of the ramp leading to gallery (Türkoğlu, 2002). So the door (Figure 51) is the gate of the connection to that ramp. The Marmara marble is used on the door jamb (Özügül, 2010).

Figure 51. The door on the south vestibule’s east wall in the Narthex of Hagia Sophia, (Bilgen, 2011).

3.1.4. The Naos Space (The Main Building)

When you enter through the Imperial Door, you meet a magnificent spacious world like a tale. The impressive dome, various ornamentations, and very colored columns, walls, floors, etc. This is the main space Hagia Sophia is divided into three sections with vertical bearers and columns.

3.1.4.1. The Doors in the Naos Space (The Main Building)

The Doors of I. Mahmut’s Library

There are two doors connected to I. Mahmud’s library directly (Figure 52 and Figure 53). The door shown (Figure 54) is inside library (Akgündüz et al., 2005).

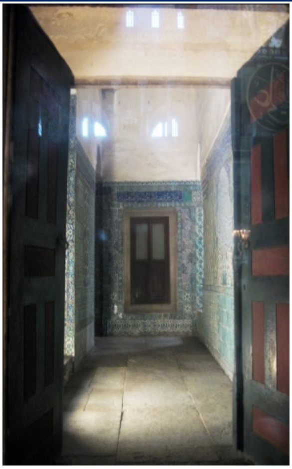



Figure 52 and Figure 53. The two doors of I. Mahmud's library of Hagia Sophia, (Bilgen, 2011).

Figure 54. One of I. Mahmud's library's door inside view of Hagia Sophia, (Bilgen, 2011).

The door handle of I. Mahmud's library is so interesting (Figure 55). In this door handle belonged to I. Mahmut's term, "Ya Fettah" has been written on it (Dursun, 2011). Ya Fettah is one of the names of God. And it means that is the one who opens all ways. Additionally, it carries the meaning of conquest. Since it is the symbol of the conquest of Istanbul, so it’s fixed to many doors of Hagia Sophia.

Figure 55. The door handle of I. Mahmud's library of Hagia Sophia, (Bilgen, 2011).

The Doors on the South Side Wall in the Naos

There are three doors on the south side wall in the naos space. Looking at the order in (Figure 56); the first seen door is opened bottom space of the flying buttresses. The Marmara marble has been used on the door jamb. The second seen door (Figure 57) was used as a gateway to the tombs in the past. Today, it’s closed with masonry. The Rosso Antico marble has been used on the door jamb. The third seen door (Figure 58) is opened outside of the courtyard, and the Tombs area. The Rosso Antico marble has been used on the door jamb (Özügül, 2010).

Figure 56, Figure 57 and Figure 58. The doors on the south side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

The Doors on the East Side Wall in the Naos

There are three doors on the east side wall in the Naos space. The door called as "Meyyit Door": As Grelot defined this door was used by the public which's known as Meyyit Door (Figure 59). The Meyyit Door leads into a wide, and high section in which vaults are lying through the east. This section is still used as storage. There is a closed entranceway of a door in the middle of the north wall of this section. There is an exit way of this section's east wall which is across the Meyyit Door. In this exit, there is an arcaded part on column (Akgündüz et al., 2005).

There was a hall named Metatorium dedicated to the emperor's usage. After praying, the emperors came to this area, and they met the courtiers of the palace. After eating something, they exited from the Meyyit door. They reached the palace by using Chalcea door (Dirimtekin, 1964). The Rosso Antico marble has been used on the door jamb (Özügül, 2010).

There is another door that is not one of the main exit doors (Figure 60). It is opened to a small corridor. The essence of this corridor isn't known (Akgündüz et al., 2005). The Marmara marble has been used on the door jamb. The last door is the exit gate of the upper gallery ramp (Figure 61). The Rosso Antico marble has been used on the door jamb (Özügül, 2010).

Figure 59. The door called as "Meyyit Door" s on the east side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

Figure 60. The door to the small corridor on the east side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

Figure 61. The exit door of the upper gallery ramp on the east side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

The Doors on the North Side Wall in the Naos

There are four doors on the north side wall in the naos. The door that this paper will initially mention is not related to the Byzantine era but rather belongs to the late Ottoman period (Figure 62). In the late Ottoman period, it was constructed for rising up Sultan Mahfi inside of the mosque. There is a continuing wood staircase that reaches the balcony of Sultan Mahfi. In the other door shown in (Figure 63), maybe there was a window. It converted into a door that encounters the Skevophylakion. Between this door and the Skevophylakion, there is a hypaethral small room or ventilation area (Akgündüz et al., 2005). The Rosso Antico marble has been used on the door jamb.

Another door shown in (Figure 64) is called as “Vizier Door”. The door leads into a garden defined as “Vizier Garden”. Except for this door, there is an entrance hall adjacent to a door that opens a grave in the vizier garden. This is said that there is a chamber room inside grave (Akgündüz et al., 2005). The Rosso Antico marble has been used on the door jamb. The last door shown in (Figure 65), opens to a small storage area. Now, the inside is empty. The Marmara marble has been used on the door jamb.

Figure 62. The firstly mentioned door on the north side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

Figure 63. The secondly mentioned door on the north side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

Figure 64. The thirdly mentioned door called as Vizier Door on the north side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

Figure 65. The lastly mentioned door on the north side wall in the Naos space of Hagia Sophia, (Bilgen, 2011).

3.2. The Upper Floor and Its Doors

3.2.1. Upper gallery

Once upon a time, four ramps were used to go upper gallery. However, only three of them have been available today. The fourth pad of the ramp was closed because of making "contrefort" (Dirimtekin, 1961). At the present, as this article mentioned before in the narthex title, the ramp way on the north side of the narthex is used. Because of the fact that the Emperor and the Empress (Chaise a Porteur) could be able to go the upper gallery tirelessly by using a "sedan chair" (Figure 66), many ramps had been constructed (Wikipedia, 2012).

Upper-floor galleries occur from the north, the south, and the west galleries which combine the north and south galleries with each other.

Figure 66. A Korean gama, (Library of Congress).

3.2.1.1. Upper floor doors

The Doors of the Ramp Way Gated to Upper Floor Gallery

The door shown in (Figure 67), connects to the ramp way which rises upper floor. Except this, the door is quite simple. The other door on this floor shown in (Figure 68), at the end of the ramp, provides a passage to the upper gallery. The Marmara marble has been used on the door jamb.

Figure 67. The door that opens to the ramp connecting to the upper floor of Hagia Sophia, (Bilgen, 2011).

Figure 68. The door that connects to the upper gallery of Hagia Sophia, (Bilgen, 2011).

The Doors of Ramp Way Sloped Down to the Lower Floor Gallery

All these doors are very simple. The doors are in the slope way of the ramp (Figure 69 and Figure 70) and look at emptiness on the ramp way. The door is connected to a door that provides a gateway to open the Sultan Mahfi (Figure 71). The Rosso Antico marble has been used on the door jamb. The door can have a connection to the Skevophylakion (Figure 72).


Figure 69 and Figure 70. The doors on the slope way of Hagia Sophia, (Bilgen, 2011).

Figure 71. The door that connects to Sultan Mahfi's door of Hagia Sophia, (Bilgen, 2011).

Figure 72. The door that connects to Skevophylakion of Hagia Sophia, (Bilgen, 2011).

The Marble Door (The Heaven and the Hell Door)

The Marble Door is located in the southern gallery. This door (Figure 73 and Figure 74) separated the south gallery from the west gallery. This space was used for solemn meetings by patriarchate officials which included important religious affairs of the state since Hagia Sophia was an imperial church. The received decisions of the meeting in this space written on marble plates were hanging on the wall of exonarthex space (Atchison, 2020). One side of the door represents paradise while the other one represents hell. For this, this is also named “The Heaven and The Hell Door”. The door reflects the Hellenistic term’s features, and white marble has been used. This carved marble partition is like a copy of wood and bronze doors (Tunç, 2018).


Figure 73 and Figure 74. The Marble Door on the upper floor of Hagia Sophia, (Bilgen, 2011).

The Symbols of the Marble Door (The Heaven and The Hell Door)

The door has occurred from two parts and its surface is filled with plant, fruit, and fish motives in panels (Figure 75, Figure 76 and Figure 77).



Figure 75, Figure 76 and Figure 77. The Symbols of the Marble Door on the upper floor of Hagia Sophia, (Bilgen, 2011).

The Door on the West Side Wall of the West Gallery on the Upper Floor

The door is opened outside of the building directly (Figure 78). The Marmara marble has been used on the door jamb.

Figure 78. The door on the west side wall of the west gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

The Door on the South Side Wall of the West Gallery on the Upper Floor

This door leads the way to the office of the patriarchate, and also is at the connection to a convenient rampway to the upper levels (Figure 79). However, this has been closed by the management of the museum. On the jamb of this door, a kind of limestone has been used.

Figure 79. The door on the south side wall of the west gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

The Doors on the South Side Wall of the South Gallery on the Upper Floor

The door is opened to the room of the patriarchate (Figure 80). The other door is opened to a narrow hall space that connects to the inside of the chapel (Figure 81). The other door is opened a small area which have a connection inside of the flying buttresses (Figure 82). The last door is also opened inside of the flying buttresses (Figure 83). The doors (Figure 81, Figure 82 and Figure 83) have Marmara marble door jambs.

Figure 80. The Patriarchate room door on the south side wall of the south gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

Figure 81. The door that connects to the inside of the chapel on the south side wall of the south gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

Figure 82. The door that connects to the inside of the flying buttresses on the south side wall of the south gallery on the upper floor of Sophia, (Bilgen, 2011).

Figure 83. The other door also connects to the inside of the flying buttresses on the south side wall of the south gallery on the upper floor of Sophia, (Bilgen, 2011).

The Door on the East Side Wall of the South Gallery on the Upper Floor

This door (Figure 84) is at the same axis as the “Meyyit Door”. This door is closed near the brick minaret. It is also called the “Suicide Door” because it is opened to the emptiness of the building (Figure 85). According to Gürşan, this side of the building is a connection to Big Palace. The holy swell was connected to the Skevophylakion placed on the northeast side and also the Chalkea gate of the Big Palace. The emperors came to Holy Swell by using the colonnade way which connect the Chalkea gate and Holy Swell to each other. Today, the existence of this door on this facade makes this theory stronger (Gürşan, 2011). The Marmara marble has been used on the door jamb.

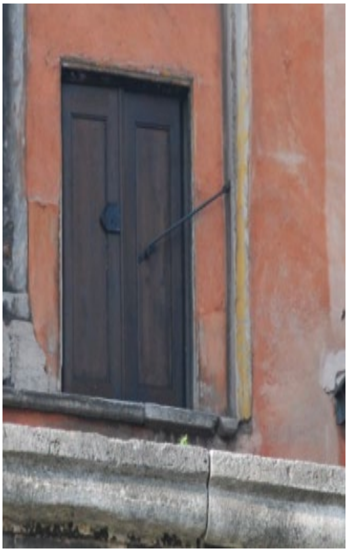



Figure 84 and Figure 85. The inside and outside view of the Suicide Door on the east side wall of the south gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

The Doors on the North and Northeast Side Walls of the North Gallery on the Upper Floor

This door (Figure 86) is opened to a small room. Another door (Figure 87 and Figure 88) connects to the slope way of the ramp. The Marmara marble has been used on both door jambs.

Figure 86. The door connects to a small room on the north and northeast side walls of the north gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

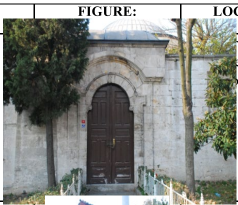
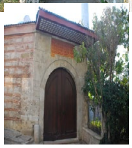
Figure 87 and Figure 88. The door connects to a small room on the north and northeast side walls of the north gallery on the upper floor of Hagia Sophia, (Bilgen, 2011).

Until this part, many doors belonging to the building have been grouped according to the floors and the spaces of the building and examined under certain main headings and subheadings. The other doors belonged to Hagia Sophia covered in this study are detailed in two different tables (Table 1 and Table 2).

Table 1. The Other Doors of Hagia Sophia Part I (Bilgen, 2011).

FIGURE:	LOCATION:	SPACE:	FIGURE:	LOCATION:	SPACE:
	The door to the north porticus from the north wall of atrium of Hagia Sophia.	Madrasa gate of the ramp.		The door into the courtyard is located to the west of Hagia Sophia.	The door of closed warehouse.
	The door is located outside of the Horologion door of Hagia Sophia.	The door of the Baptistery.		The door into the courtyard is located to the south of Hagia Sophia.	The door of two-layer place with headset distribution.
	The door is adjacent to the Baptistery.	The door of the Baptistery.		The door into the courtyard is located to the south of Hagia Sophia.	The door of closed warehouse which is connected to two-layer place with headset distribution.

Table 2. The Other Doors of Hagia Sophia Part II (Bilgen, 2011).

FIGURE:	LOCATION:	SPACE:	FIGURE:	LOCATION:	SPACE:
	The door into the courtyard is located to the west of Hagia Sophia.	The door of "Muvakkithane".		… that opens … courtyard of …phia.	The door to the street.
	The door into the courtyard is located to the west of Hagia Sophia.	The door of Mütevelli room.		The door that opens out of the courtyard of Hagia Sophia.	The door to the street.
	The door into the courtyard is located to the southwest of Hagia Sophia.	The door of To…		…nto …ed …ia	The door of "Hünkar Kasrı".

4. Conclusion and Suggestions

There are various types of doors in Hagia Sophia. This article aims to look at Hagia Sophia from another perspective and tries to understand the monumental Hagia Sophia by analyzing and explaining the doors of the building. Additionally, the purpose of this article is to show that Hagia Sophia is very special not only with its magnificent structure but also with its each and every gate and door. In the construction process of Hagia Sophia, each door was added to the structure according to a separate setup and purpose.

In this article, as a method, an inventory of the doors of Hagia Sophia has been prepared, additionally, information such as the location of the doors within the building, their materials, technical details and other characteristics have been looked into. Especially the effect created by the material used in the doors of the building is great. As emphasized by the expression that *"Material gains strength only when a builder thinks and uses it."* (Arpacıoğlu & Kuruç, 2010) the material chosen in the construction of the doors of the building becomes stronger with the doors. Because the doors of the building serve different purposes and it is important that the material chosen for each has different meanings.

On the other hand, the study has aimed to be brought to a more interesting and remarkable point by mentioning the known legends, stories, and mysteries about the doors.

In fact, with the unfortunate event that the building has experienced recently, the doors of this huge building have gained special importance. The major damage to the gate of Hagia Sophia, known as the imperial gates, necessitates that all the gates of this structure should be taken under serious protection and that the records of the gates are kept properly and completely.

There is a possibility that there are gates and doors still undiscovered. But it is a fact that a more detailed investigation of the doors of Hagia Sophia will provide a better understanding of the history and use of the building. This article can be considered as an effort to make a contribution in this sense.

Thanks and Information Note

The e-book section complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

This e-book section has a single author. There is no conflict of interest.

References

Akgündüz, A., Öztürk, S. & Baş, Y. (2005). *Üç Devirde Bir Mabed Ayasofya*, Osmanlı Araştırmaları Vakfı, İstanbul.

Arpacıoğlu, Ü. & Kuruç, A. (2010). Zamansız Malzemelerin Zamanda Yolculuğu, *Mimarlıkta Malzeme,*15, 47-51.

Atchison, B. (2020). Nave and Aisles of Hagia Sophia, https://www.pallasweb.com/deesis/nave-of-hagia-sophia.html (28.05.2020, Accessed in May).

Atchison, B. (2020). A Collection of Doors in Hagia Sophia, https://www.pallasweb.com/deesis/nave-of-hagia-sophia.html (28.05.2020, Accessed in May).

Broilo, F. (2016). A dome for the water: canopied fountains and cypress trees in Byzantine and early Ottoman Constantinople. *Fountains and Water Culture in Byzantium,* Edited by Brooke Shilling and Paul Stephenson, Cambridge University Press, United Kingdom.

Boyar, A. S. (1943). *Ayasofya ve Tarihi*, Maarif Matbaası, İstanbul.

Dirimtekin, F. (1961). Ayasofya'nın Bronz Kapıları. *Ayasofya Müzesi Yıllığı*, nr 3, İstanbul Matbaası, İstanbul, p. 10-14.

Dirimtekin, F. (1964). *Saint Sophia Museum,* Touring and Automobile Club of Türkiye, İstanbul.

Dirimtekin, F. (1966). *Ayasofya Kılavuzu*, Ayasofya Müzesi Yayınları.

Dursun, A. H. (2011). *Ayasofya Müzesi Kültür Envanteri*, İstanbul Bilgi Üniversitesi Yayınları, İstanbul.

Eyice, S. (1984). *Ayasofya 1,* Eng. Translation: Virginia Taylor Saçlıoğlu, Yapı Kredi Yayınları, İstanbul.

Freely, J. & Çakmak, A. S. (2004). *Byzantine Monuments of Istanbul*, Cambridge University Press, London.

Freely, J. & Çakmak, A. S. (2005). *İstanbul'un Bizans Anıtları*, Çeviren. F. Gülru Tanman, Yapı Kredi Yayınları, İstanbul.

Gürşan, N. (2011). *Yapıların Efendisi: Ayasofya'nın Hikayesi*, Cinius Yayınları, İstanbul.

Hagiasophiatr, (2020). Mosaic of Leo VI, https://hagiasophiaturkey.com/mosaic-leo-vi/, (13.04.2020, Accessed in April).

Kähler, H. (1967). *Hagia Sophia*, Translated by Ellyn Childs, A. Zwemmer Ltd Publishers, London.

Koçu, R. E. (1960). Ayasofya, *İstanbul Ansiklopedisi*, Volume 3, İstanbul Ansiklopedisi ve Neşriyat Kollektif Şirketi, p. 1442.

Kurian, G. T. & Lamport, M. A. (2016). *Encyclopedia of Christianity in the United States,* Volume 5, Published by Rowman&Littlefield.

Lethaby W. R. & Swainson, H. (2004). *The Church of Sancta Sophia, Constantinople a Study of Byzantine Building*, Kessinger Publishing.

Majeska, G. P. (1984). *Russian Travelers to Constantinople in the Fourteeenth and Fifteenth Centuries*, Dumbarton Oaks Research Library and Collection Washington, District of Columbia, p. 207.

Özügül, A. (2010). *İstanbul'daki Geç Antik ve Bizans Yapıları Kapı Çerçevesi*. Doktora Tezi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.

Tikkanen, A. (2023). Door, Encyclopedia Britannica, https://www.britannica.com/technology/door (19.09.2023, Accessed in September).

Tunç, Ş. (2018). *İstanbul'un Antik Gizemi Ayasofya Geçmişin Kehaneti,* Motto Yayınları, İstanbul.

Türkoğlu, S. (1989). *Hagia Sophia,* Net Turistik Yayınları, 5th edition, İstanbul.

Türkoğlu, S. (2002). *Ayasofya'nın Öyküsü,* Yazıcı Basım, İstanbul.

Wikipedia, (2012). http://www.wikipedia.com (19.12.2012, Accessed in December).

https://www.hagiasophia.com/imperial-door-mosaic/, (13.04.2020, Accessed in April).

Çiğdem BİLGEN
E-mail: cigdem.bilgen@fbu.edu.tr
Educational Status
License: Interior Architecture and Enviromental Design
Degree: History of Architecture
Doctorate: Architectural History and Theory
Professional Experience:
Çiğdem Bilgen has been Assistant Professor in the Faculty of Engineering and Architecture at Fenerbahçe University since 2022. She had bachelor from Bilkent University. She had Msc degrees in architecture from Istanbul Technical University. She made Phd in Architectural History and Theory program in Yıldız Technical University. She also worked in different companies as an interior architect designing projects and being project manager. She has many publications, studies and researches about Architectural History, Historiography, Museology, and Urban History.

Analysis of Geographical Settlements in the Context of Economy and Population Movements from the Perspective of Small and Mobile Housing in Türkiye and the World in the Historical Process

Yaşar BAYRAKTAROĞLU[1]

[1]Mimar Sinan Fine Arts University, Faculty of Architecture, Department of İnterieur Architecture, İstanbul/Türkiye.
ORCID: 0000-0001-6341-4487
E-mail: 987110168@ogr.msgsu.edu.tr

Assoc. Prof. Dr. Emre KAVUT[2]

[2]Mimar Sinan Fine Arts University, Faculty of Architecture, Department of İnterieur Architecture, İstanbul/Türkiye.
ORCID: 0000-0003-2672-4122
E-mail: emre.kavut@msgsu.edu.tr

Citation: Bayraktaroğlu, Y. & Kavut, E. (2023). Analysis of Geographical Settlements in the Context of Economy and Population Movements from the Perspective of Small and Mobile Housing in Türkiye and the World in the Historical Process. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (57-103). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

The concept of housing carries a vital weight for humanity and directly refers to people. An example such as the common thought that the concepts of humans and housing come together at everypoint in the world where people are present and should not exist in the other two concepts. In many branches of science, scientists work on the concepts of settlement, housing, housing, rural settlement, and urban settlement.

Geography science and geography scientists are the main branches of these sciences. Human geography, which is one of the sub-headings of the science of geography, characterizes all the activities that people carry out in order to survive on earth as social activities. The main one of these activities is settlement activity. The concepts of shelter, house, dwelling, and dwelling form the core of "settlement". The place, residence, or settlement unit is the product of economic activity and is examined within the scope of economic geography.

Settlement is a concept that exists with human beings and carries meaning. It is an indisputable fact that man has needed shelter since the day he started to live on Earth. When considered in this context, settlement is the oldest human social activity that has never lost its importance. Therefore, it would not be wrong to define the settlement as "shelter units created by people depending on the space in order to continue their life and activities on earth". Since the settlements are developed on planet Earth in a broad sense, that is, on the piece of land where people live and operate, all settlements will be affected by the natural environmental conditions of the Earth. In addition, the social and cultural conditions of te people are also effective in shaping the settlements (Taş, 2016).

The settlements, which have a dynamic structure, are affected by many factors and undergo changes. This change can sometimes result in extinction. Belen (Hatay), which is an urban settlement today, is an example of the growth and urbanization of a highland settlement gaining function over time (Cited by Taş; Çetin, 2012). Climate, natural factors, changes in administrative and political structure, wars, rebellion movements, riots, global political effects, migrations due to economic reasons, and population movements are the causes of change. In settlements that are subject to change or evolution with all these factors, it leads to new economic relations, and new solutions to emerging problems, according to new needs, problems, and socio-economic situation.

2. Purpose of the Research

The aim of this study is to examine the basic need for shelter in the geography or social environment of societies in the context of small and mobile housing, from a historical perspective. The target audience is low-income groups struggling to survive economically and socially in their natural environment or in the city they migrated to. Both the acquisition and production of housing, which is an economic activity and the types of housing acquired by societies according to their economic activities will be examined. The production and presentation of small and mobile housing (Tiny House), designed by designers with high standards, and technical and aesthetic equipment demanded by high-income groups, is excluded from this review.

3. Scope (Main Objectives of the Study)

There are many studies that reveal the situation and development of the basic need for shelter, which has become a problem for societies, throughout the world. The housing problem and its details are important issues of scientific research and investigations, apart from administrations. The objectives of this review are;

- The approach of developed states to the problem, their search for temporary or permanent solutions, and their results will be examined.
- To examine the development and results of minimal solution proposals in meeting the housing need.
- It is to examine the approaches of the countries exposed to mass population flow to the problem, as in Türkiye, and to investigate the applicability of the applied examples to homeless people or communities living in the depressed areas of the city.
- One of the objectives of this study is to evaluate the transitivity of the concepts of shelter-shelter-house-housing-slum-small house-mobile house within the scope of economic and cultural activities.
- Settlement areas and their physiognomy, and their relationship with population pressure will be examined.
- The culture of societies, traditional approach to housing, people's search for solutions to the problem of housing in modern cities,

solution approaches of administrations, and scientific approaches are within the scope of this study.

- How the need for "shelter", which is the basic right of people, causes sociological divisions in societies,
- Within the scope of the concept of housing, it will be tried to be explained by examining that housing or acquiring a house has become an indicator of the sharing of wealth in societies.
- In addition, the search for a solution with the small house model will be followed and the results of the propositions in this area will be examined.

4. Literature (General Definitions and Concepts)

The state takes measures to meet the housing needs within the framework of planning that considers the characteristics of cities and environmental conditions and also supports mass housing enterprises (T.R. Constitution; Article 57). The right to housing (housing) is seen as a part of the right to life, protected and supported in Turkish constitutional texts. From the establishment of the Republic to the present, especially the citizens of the low and middle-income groups, who are economically limited, have been supported in every period within the scope of the possibilities with the policies implemented so that they can continue their lives in a shelter and a healthy environment, as a requirement of the social state understanding. (Kalağan, 2021).

The right to housing is a fundamental human right that includes but exceeds, the right to housing. Article-25 of the Universal Declaration of

Human Rights 1. Everyone has the right to a standard of living adequate for the health and well-being of himself and his family. This right includes the right to food, clothing, housing, medical care, and necessary social services and security in the event of unemployment, sickness, disability, widowhood, old age, or other inability to earn a living due to circumstances beyond one's control. In its form, it defines housing in a much broader framework. A human right and the right to shelter, which is guaranteed by the Constitution, has become a problem throughout the world and in our country. The sources of the problem and the solution proposals are the subjects of scientific studies. It is one of the main problems of management. Economics, sociology, urbanization, environmental problems, health policies, education, etc. are the source of many problems. In this context, research has been done on the concepts that have been examined by literature review.

Many studies have been made on the functionality of small and mobile homes in solving this problem. Countries that are faced with the housing problem, including countries with developed economies, seek a solution, albeit temporarily, by establishing mobile and small houses and settlements.

4.1. Settlement Physiognomy

With the development of technology and advances in science, economic activities, and social developments, especially in urban areas, have also changed. In growing cities, the problem of housing continues to increase. Population movements have led to the formation of cities with high population density in our country as well as all over the world. The increasing population has affected the physiognomy of cities. Housing areas play a leading role in this physiognomy. The concept of settlement physiognomy can be defined as shape, form, and appearance. Settlement morphology is also used instead of the concept of physiognomy (Özgür, 2022).

In cities where new economic and social activities are active, the industry sector, service sector, and trade sector come to the fore according to different functions and needs, while agriculture-livestock farming remains a rural settlement activity. As the branches of economic activity increase and diversify, cities grow, and their functions increase (Özgür, 2022). Cities, residential areas, industrial areas, commercial areas, and public areas (green areas) are planned by changing their nature. When examined at the plan level, housing areas and their content have been the main problem of cities, and they are also the largest areas that make up the city.

4.2. Cities with High Population Density

As a concept, the city is described within the framework of economic and social relations. It is characterized by the concepts of culture, housing, economy, trade, industry, and transportation. In the historical development, the conceptual change of the city continued, and the concepts used in more or less close meanings such as "cite", "polis", "medina", and city in the past have been replaced by "Bourg", "ville", The words "city" and urban are taken from the metropolis. On the other hand, there have been important changes in the content of the city concept depending on socio-economic developments, and in the old periods, "castle" or "wall" was used as an important element in defining the concept of the city. For example, the most important city definition of the Middle Ages is Marver's expression of "human settlements surrounded by walls" (Demirer et al., 1999; 29 Cited by Taş, 2016). However, today, in the definition of the city concept, employment structure, economic activity, population density, tourism center, commercial center, etc. different criteria are used. Especially with the industrial revolution, the changes in the form and functions of urban spaces have completely changed the content of the concept of the city, and different approaches have been exhibited in "defining the city" due to the fact that many disciplines such as sociology, history, geography, and ecology have entered the field of study (Topal, 2004). Population alone is not a factor in the formation of the city, but it is one of the main factors and directly affects the basic need for shelter. The concept of "Housing" is always the most important element in these regulations.

4.3. Geographical Region, Housing Areas, Housing, Small Housing, Mobile Housing

Agriculture and animal husbandry are the main economic activities in rural settlements. Although thousands of years have passed, this situation has not changed and it seems that it will not change in the near future. Humans discovered forestry activities after agriculture and animal husbandry and learned to benefit from forest products (Taş, 2016).

Housing production or housing construction is one of the first vital activities for human beings. In the nomadic or settled life, people learned to process and use natural materials in the geography they lived in, and especially wood, stone, soil, and plants became the main materials in the construction of housing. Shelters, tents, dwellings, barns, sheep pens, warehouses, haylofts, etc., are the building needs of the rural settlement. The buildings have been built in plan and size according to the needs, with natural materials procured from the immediate surroundings.

Figure 1. Construction of dwellings with stone and vegetation (Taş, 2016). **Figure 2.** Dwelling made with earth. (Photo Stone,20). **Figure 3.** Shelter made of natural stone; highland house. (Photo; https://www.yaz-break.com, 2022).

The geography and culture of the society determine the material, plan type, and dimensions of the house it builds. Stone houses and portable tent houses are the traditional accommodation units in Anatolian plateaus or settlements in high geographical areas. Photo 3 It is a highland settlement far from forest areas in the Eastern Black Sea Region in Türkiye. It is for short-term use, such as a month, in summer to protect crops in village settlements and to benefit from pastures. Natural stone, which is the most easily obtained material resistant to severe climatic conditions, comes to the fore in housing construction.

Figure 4. Bristle tent
(Photo; http://www.dogubayazitgazetesi.com/resimler/2020).

Traditional bristle tent examples of communities engaged in animal husbandry in our country. Communities engaged in animal husbandry in the Eastern Anatolia region of Türkiye use bristle tents for a short time in summer. Large tents can be made from approximately 150 goat hairs. Tents are waterproof and a living space that can be comfortably accommodated.

Figure 5. In the desert geography nomad traditional bristle tent. Sahara Desert, Morocco. North Africa (Photo; https://s3.amazonaws.com/klein-media/wp-content/blogs.dir/sites/23/2010/02/27102222/DSC_0625-Sprawling-low-and-mimicking-the-distant-hills-Sahara-Desert-Morocco-North-Africa.-December-2007.-940x612.jpg).
Figure 6. In the desert geography, the soil is a shelter made with wood and grass. Sahara Desert, Morocco. North Africa (Photo; https://s3.amazonaws.com/kleinmedia/wpcontent/blogs.dir/sites/23/2010/02/27102032/D20_0099-As-evening-shadows-fall-Dead-Sea-Jordan.-January-2009.1-280x187.jpg).

Figure 7. Traditional stone-wood small house in the highland settlement Bolu/ Türkiye. (Photo, http://hizliresim.com/ZN26no,2014).

In the examples, in the geographies where people live, they have established settlements suitable for their culture of life and economic activities as mobile housing (traced as tents in history) and small housing. People met their housing and other building needs with the most easily accessible material. In the example of Photo 8, there is a plateau settlement on the Ardıç hill with an altitude of 1700 meters, located in the south of Bolu, in the Western Black Sea region of Türkiye. In the settlement, which is close to the forest area, wooden materials come to the fore. Geography conditions are a factor in housing construction. Photos 2-3-7-8 are examples of societies building houses with materials they can access in the conditions in which they live or in their geography.

Figure 8. An example of canopy in desert geography. Material grass-wood local products. Dead Sea-Jordan. (Photo; https://s3.amazonaws.com/kleinmedia/wpcontent/blogs.dir/sites/23/2010/02/27102032/D20_0099-As-evening-shadows-fall-Dead-Sea-Jordan.-January-2009.1-280x187.jpg).
Figure 9. Traditional tent shelter in mass migration movements such as war, etc. (Photo, Katz, 2017, The architecture of power and resistance in Israel-Palestine).

Small and mobile home has always existed with small changes according to the culture of humanity in the historical process. The small house need of the people who started a settled life with agriculture and trade activities has not disappeared. Today, shelters in cities, summer houses for vacation, Tiny houses for weekends, mobile homes or caravans for travelers, temporary shelters in disasters such as earthquakes, and floods, highland houses in rural areas, shelters for refugees and asylum seekers, etc. The need and demand for small and mobile housing, defined by names, continues.

Housing type and size vary according to primary economic activities (livestock breeding, hunting, gathering, agriculture, forestry, cultivation of cultivated plants, etc.). Primary economic activities are those that take place directly by utilizing the natural environment (Taş, 2016). The need for housing has also developed in accordance with this lifestyle and geography. Rural dwellings can be evaluated in two ways. The first of these is the building material of the house and the other is the plan. The building materials used in rural dwellings are natural and materials obtained from the immediate environment (Cited by Doğanay; Tunçdilek, 1967). A rural housing plan is shaped according to the culture, economic activities, and the conditions of the environment (Doğanay, 2010). While the plan typologies vary from region to region and culture to culture, the kitchen, room, and sofa are the main elements of the residential plan type. Housing sizes vary according to economic activities and the economic status of individuals.

Depending on the agriculture and animal husbandry functions in rural settlements in our country, dwellings appear in the form of Plateau, Oba, Canik, Kom, Agil, Dam, Barracks-Kışlak, Guzle-Güzlek, Bargah-Bahargah-Banı-Pey, Bağ-Garden Houses and plan typologies. As these concepts express settlements, they also express housing units. (Karagel, 2017). Tent emerges as a mobile (mobile housing) dwelling, especially based on the livestock function. These plan types are small dwellings of 8-10 m2, used once or twice a year, such as a plateau, com, roof, barn, oba, saya, gazebo, fall, and barla (Doğanay, 2014).

In urban settlement, there is a definite planning approach as cities, residential areas, industrial areas, commercial areas, transportation areas, and green areas. Housing areas, housing, and housing typology is the target of this study. Small and mobile housing, which is the subject of this review, is at the center of urban planning.

Population pressure has created a housing problem in cities and governments, scientists, and society have tried many solutions to solve the problem. Mass housing, building society, build&sell, sell&build, flat for a flat, detached house, flat, site, suburb, urban transformation, slum, 1+1, 2+1, 3+1, and studio flats, and many concepts such as these have entered the architectural literature as a result of these studies or the economic dynamic in the city.

4.4. Housing Typology: Slums/Small Houses and Studio Apartments

The housing problem, which is getting more and more complex and growing, is the research subject of many disciplines and is being tried to be solved with many methods. While the housing problem is solved in rural settlements through personal work and collaboration, similar methods are used in cities, but legal infrastructure and strong organization (mass housing administrations), real estate investment companies, private companies, and other capital owners (building cooperatives) come into play.

In the process from traditional to modern, from modern to post-modern, living spaces are also changing and transforming, like many things about people and society. For example, while a detached house was accepted as an ideal living space for previous generations, most people living today do not see a detached house as an option. Now, depending on the material and cultural indicators of individuals or families, we are faced with options such as secure sites, multi-story apartments, and studio apartments (Ünlü, 2014).

4.5. Slum

The rapid advancement of technology has led to the rapid continuation of migration to cities. This population pressure has revealed the housing problem in the same way in big cities in every country of the world. Low-income people tried to solve this huge problem, which the administrations could not solve, by the habit of the rural settlement or the method they knew. The solution has been the Slum. The housing problem was solved with slums, but thousands of unhealthy and illegal housing, problematic big neighborhoods, and even unhealthy and unplanned urban parts were created. The slums that make up these urban parts are the manifestation of the habit of making primitive housing in the rural area and the applied predecessor of the small house or mobile housing in the city. The image evoked by the definitions expressing the "housing problem" or "physical space", which is a common problem of the world, is the same throughout the world.

Slum (Türkiye), Canister house (India), Tin House (Philippines), Favela (Brazil), Slum (Syria), Sarifas (Iran), Elenqurtier (South Korea), Squatter (South Africa), Shantitown (Algeria), Tin houses (Africa). This problem or method of housing, which usually occurs in underdeveloped countries, can be considered the predecessor of small housing (Karaboran, 1988). The slum problem is a phenomenon that emerged in our country towards the end of the Second World War, in parallel with the political and economic developments between 1945-1950s. Migration movement for economic and social reasons lies at the basis of the formation of slums, which has not been considered a normal change or development since then and has always been described as a "problem" (Çakır, 2011).

4.6. Mass Housing and Studio Flats

Tang, who prepared the thesis about the housing problem in Australia in the context of "small house", sees the small house model as a light in solving the problem. Cities around the world are grappling with a profound housing crisis where access to affordable, safe, and secure housing is becoming difficult to obtain. A particular viable product emerged as a potential solution to tackle this crisis: tiny houses. A suitable product emerging in tackling the growing crisis is a housing typology known as tiny houses (Tang, 2021).

However, interest in small-home use potential is rapidly expanding with the growing trend known as the "tiny house movement". In the field of social housing, small houses are becoming more and more common as a means of accommodation. This includes small home village projects for survivors or at risk of homelessness around the world and apparently in Melbourne (Evans, 2020; Raynor, 2018; Needham, 2021; Bird, 2021). Quoted (Tang, 2021).

In our country, the State prepared the infrastructure with the Mass Housing Law, which came into force on March 1, 1984, in order to combat slums or unzoned construction, to develop and transform cities with structures or sites that received urbanism, architecture, and engineering services, and realized projects in this field, especially in big cities. Similar projects, which are exemplary for the private sector, are carried out in every city of the country. Many residential plan types are used in these projects. Studio apartments or 1+1 plans are widely used. Generally, these apartments are designed in a secure site format, but these apartments, which are adopted by society, are also implemented as projects that cannot be secure sites (Ünlü, 2014).

4.7. Discussions on Residence/Studio Flat

There are no discussions, prejudices, or illusions about studio apartments, which have an important place in housing production. One of the most concrete indicators of this situation is that studio apartment are perceived in society as almost no different from a hotel room. However, the most basic point where the studio apartment is separated from the hotel room is that it is a "house". People determine a living space in studio apartments in the same way they determine a living space in their homes (Ünlü, 2014). Michelle describes the hotel room in her book "History of Rooms" as follows; "The hotel room is a necessary or sufficient condition for the contemporary traveler to have a good time. The passenger wants to withdraw to his room at the hotel and leave the group. The traveler needs the quiet needed for sleep, a bed suitable for rest, effective ventilation, warmth, especially in winter, a writing desk, a soft light that is not too intense or insufficient, cupboards for his clothes, and, above all, a bathroom and a toilet. (Perrot, 2010, Cited by Ünlü, 2014). The hotel room that Perrot describes should in no way be equated with the studio apartment. Because although there is a fact that individuals do not plan to live in studio apartments for many years, hotel rooms certainly do not offer the layout offered by studio apartments.

The most discussed thing about studio flats is that such urban constructions are incompatible with the historical and cultural infrastructure of Turkish society. So much so that in the recent past, the state has banned and limited the construction of studio houses in 1+1 format (Ünlü, 2014). Similar discussions and criticisms are followed in the world. 1. What is the evolution of social housing policy so far and where are small houses located in this discourse? 2. How are Tiny Houses treated as permanent social housing in socio-economically legal frameworks? 3. What social challenges are of concern when considering Tiny Houses as a Social Housing option? (Tang, 2021), seeking answers to questions such as Tang tells us that similar concerns exist in a far corner of the world compared to our country.

A similar debate is taking place in the United States. About 18 million low-income residents live in mobile home parks in the United States. The debate in the USA continues on the socio-space, social segregation, and property rights of low-income people living in mobile housing (Sullivan, 2018).

4.8. Housing and Minimal Approach in Cities

While projects and sites including small houses were being built in our country, discussions on small houses by the society and the state continued. Despite the discussions, studies on the subject continue by designers and producers in our country and in the world. There are studies on experimental or small residential development. Many projects have been developed that can meet every demand, even if they are not implemented or at the idea level. These discussions also raise some concerns. It is thought that it will cause discrimination in society, as in the example of Australia. A tiny house is different from a typical suburban residence and what many Australians might envision as the Australian dream.

The decision to actively say yes to the tiny house lifestyle brings with it the challenges of conforming to societal norms. Selectively deviating from the norms potentially increases the risk of small-home tenants being exposed to discrimination, prejudice, and conflict (McDonald & Crandall, 2015; Wyatt, 2005, Cited by Tang. 2021). The problem will cause social scientists to conduct extensive research on this issue.

It is a fact that the population of cities will gradually increase, let alone the socioeconomic debates on small houses. The need for small houses will continue to increase. With the changing social structure, the demand for small residences in developing industrial centers and other cities, especially in big cities, continues in Türkiye.

5. Material and Method

This study includes the research of small and mobile home types used according to geographical settlements and settlements throughout Türkiye and the world.

Research Universe: Selected countries from Türkiye-World.

Sample: Rural settlements, temporary settlements, and urban settlements.

Sampling: Non-random sampling method / Purposeful sampling; In order to conduct in-depth research, examples rich in information were selected in the context of the purpose of the study.

Data collection method: It was done by searching the books on the subject, examining the documents, and collecting and analyzing data and images.

5.1.Small Housing Understanding and Plan Solution Approach of Countries with High Population and İmmigration

Population Movements;

1. Legal migrations from rural areas to industrial areas mostly within the country for economic reasons,
2. Legal migration between countries for economic reasons
3. Again, legal migrations between countries for economic reasons.
4. International migrations for economic and political reasons through illegal means.
5. Mobilization of the population within or outside the country through colonialism practices
6. Occurrence of population movements with geopolitical policy applications.
7. Movement of a segment of the society due to political fights within the country.
8. Population movements as a result of religious and ethnic conflicts.

For whatever reason, mass migration movements or legal migrations cause mass population change and spread within the country, sometimes around the borders of two countries, even beyond the borders of several countries, and raise the problem of housing. Housing continues to be a management problem that must always be worked on for states and also plays a role in economic activity as an important economic product. In

Türkiye, a significant amount of 1+1 or studio-type apartments is produced and offered for sale in mass housing estates built by the government, TOKİ, Emlak Konut, and the private sector. In search of a solution to the rapidly growing housing problem, which has arisen due to migration in Türkiye and in the world, the administrations are looking for a "small house" formula. The planning approach of the house typology is also different due to the cultural differences of the small houses that are the solution tool.

5.2. Searching for A Solution to the Housing Problem in Cities with Small and Mobile Living Units

With the literature review, we follow the search for solutions to the housing problem in the world with discussions on small housing in the world and many application examples. While acting with the understanding of creating a place to shelter the homeless, a new social problem arises as villages become difficult to manage in cities (Tang, 2021). Since it is not possible to equalize the incomes of individuals living in the city, it is a necessity of the social state understanding to make supportive arrangements for disadvantaged groups. The search for solutions by the administrations throughout the urban settlement and the results of scientific research reveals the concept of the right to the city. The main purpose of the concept of urban rights or the right to the city is to increase the standard and quality of urban life. The measure of urban life quality is determined by the level of provision of urban infrastructure, communication, transportation, housing, and similar opportunities in terms of social, economic, and spatial factors (Geray, 2000). In this context, the problem of housing emerges as a problem of urban rights. Spontaneous solutions and solutions approach examples applied by management are similar to each other in the world.

5.2.1. Example of South Africa / Race of Housing

While examining the small house-shelter through the concept of the slum, it is impossible not to look at the South African example. There is no other example where problems based on racial discrimination, ranging from colonization, exploitation, and violations of human rights, to civil war, are intertwined. Plan solutions of small houses, as in the example of South Africa (Mamelodi Pod), a solution is sought for the housing problem of millions with the "small house" designed in minimal dimensions. The issue of shelter, which is the most important problem of humanity, is divided over racism in South Africa. The application of the "Apartheid" regime in the country on the fundamental right of life, such as housing, is a research topic in itself.

Figure 10. Johannesburg/South Africa, (Photo; johnny@millefoto.com;2016)

The beauty of being able to fly is to see things from a new perspective to see things as they really are (Johnny Miller, 2006).

5.2.1.1. Tiny house prototype called mamelodi pod

An example of a prefab unit was designed and built in the slum settlement of Mamelodi, South Africa, by Johannesburg-based design studio Architecture For A Change (AFAC). The small prototype called the Mamelodi Pod, was designed to improve local living conditions while also providing an affordable housing solution for residential areas.

Figure 11. Small housing unit staffed by Architecture For A Change (AFAC). (Photo; https://www.archdaily.com/418486/mamelodi-pod-architecture-for-a-change).

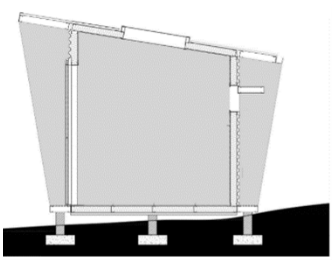



Figure 12. and Figure 13. Small housing unit designed by Architecture For A Change (AFAC).
Section (Photo; https://www.archdaily.com/418486/mamelodi-pod-architecture-for-a-change).

The house consists of composite wall panels of galvanized zinc sheets, a Sisalation layer (a highly reflective foil material), Isotherm thermal insulation, and interior plywood panels. Thus, the tiny house is equipped with excellent insulation, unlike the common zinc sheds in the region, which can freeze in winter and be extremely hot in summer, and solutions are sought for technical problems. Mainly consisting of a bedroom designed to fit two bunk beds (four beds in total), Mamelodi Pod is currently a small house, prefabricated, and provides mass housing solutions with minimal time assembly (Architecture For A Change/AFAC. 2013). Governments are developing many projects to improve the conditions of those living in illegal (slum) settlements, including infrastructure and housing improvements.


Figure 14. Kya Sands, Bloubosrand, Johannesburg, South Africa (Photo; johnny@millefoto.com;2016).
Figure 15. South Africa Johannesburg (Photo; johnny@millefoto.com, 2016).

Tiny houses sometimes tell how wealth is shared. Imizamo Yethu slum and Hout Bay neighborhood Johannesburg, (Johnny Miller, 2006).

5.2.2. European example/France

In mass population movements, the administrations carry out projects for temporary accommodation centers. European countries see mass migration movements as a threat to the economy and national purity and take precautions. In addition, it creates settlement camps with "small house" accommodation units for immigrants entering the country (Katz, 2017).

Figure 16. La Linière Refugee Camp Grande-Synthe, France. (Photo, Katz, 2017). **Figure 17.** Calais Jungle refugee camp, Fransa. (Photo, Kat, 2017). **Figure 18.** Calais Jungle Refugee Camp, France. (Photo, Katz, 2017).

5.2.3. Germany

There is also a housing problem in Germany, which is among the most technologically and economically developed countries in the world. Although there is a housing problem, it is one of the countries that do not have "slum" or "slum"-like collapsed urban parts. There is no concept of a slum in German. "Bruchbude" meaning shabby or run-down does not mean shantytown. Despite this, solutions to the housing problem are discussed in Germany. The concept of Tiny House is also discussed and scientific researches are carried out. Research has revealed that a Tiny House (a small house) will not be suitable for the German lifestyle, will cause social breaks, etc. It seems that Tiny House will not be able to show its effect in Germany, which is a high-income and luxury consumption society on average. Despite all these results, evaluating the approach of the German mentality to any subject can contribute to our understanding of the subject.

The popularity of the tiny house movement has grown since the 2008 economic crisis. It can be interpreted that the movement in the USA can be seen as a movement against the "bigger is better" lifestyle (Mangold & Zschau, 2019). While there is no official definition to classify tiny homes, a tiny home is smaller than 19 square meters, consisting of a bed and bathroom, kitchen, and storage. (Mingoya, 2015). It can also be placed on a static pedestal or a trailer to make it mobile (Boeckermann, Kaczynski, & King, 2018; Cited by Kouijzer, 2019). Although the tiny house movement seems to be a viable solution to social problems such as housing shortage, indebtedness, and homelessness, there are obstacles to constructing or living in a tiny house. German zoning laws do not allow such tiny houses to be built (Lewis, 2019). There are also economic reasons and legal restrictions on the use of legal gray areas. (Kouijzer, 2019).

5.2.4. Türkiye

In Türkiye, which is under the pressure of mass migration due to its geopolitical position, has created refugee camps in the Syrian border region and Syria. Despite its economic difficulties, it has found a solution to the problem by making thousands of "Small Houses" applications with the prefabricated system that has a production infrastructure in the market. The precaution taken by the state for the resettlement of the mass population pushed to Türkiye due to the war for years has been to establish small houses and settlements. It emerges as the shortest way to solve this huge problem in our country, where the production infrastructure is available. The application of this method for the ongoing housing problem in our country will cause a waste of resources, except for emergencies and temporary reasons. It will be the right solution to continue mass housing production over the years with planning. In addition to the correct use of resources, it will be a more correct solution to produce housing in different m^2 options and supply them to the society in terms of strengthening the sense of equality and justice in the society and preventing social divisions.


Figure 19. AFAD's Kahramanmaraş refugee camp is an example of a small house application.09.04.2019 (https://idsb.tmgrup.com.tr/ly/uploads/images/2020/11/06/70221.jpg).
Figure 20. Adana/ Sarıçam Temporary Accommodation Center (Photo; İbrahim Erikan,.2019; A.A website).

5.2.5. Greece

Greece, which is on the European migration route and is almost defenseless with its geography open to transportation by sea, is under migration pressure. It has created many refugee camps in various parts of the country. In Greece, it seeks a solution to the problem with "Small House" and tent applications.


Figure 21. Refugee camp on Samos, Greece (Foto DW Türkçe 19.09.2021- 15:05). **Figure 22**. Tent refugee camp in Greece. By Annie Charalambous (Photo, in-cyprus. Philenews. Com, 2020).

5.3. A Critical Look at the Mobile Tiny House Form on the Planning of Residential Sites

Tiny House example Blob VB3 designed by DMVA ARCHITECTEN in Belgium. The material used in the construction of the shell is polyester, and the house is 20 m^2. The mobilizable design includes a bathroom, kitchen, bedroom, and cabinet niches on the interior. The form of the design, which is suitable for the understanding of minimal life, is remarkable in two respects. Aesthetic and formal. Blob VB3, which meets vital functions with its ergonomic design approach, cannot be discussed in terms of aesthetics. Formally, its contribution to multi-site planning is controversial. Ranking in a street direction will cause space losses. Settling another unit on the upper level will either be expensive or not. It is understood that the design is not in a form suitable for multiple settlements.

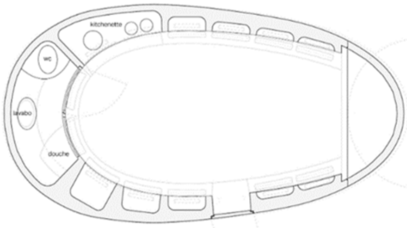


Figure 23. "Blob VB3", mobile Tiny House plan designed by dmvA ARCHITECTEN, (2009, www.verbekefoundation.com-Photo: Frederik Vercruysse). **Figure 24.** Tiny House of Blob VB3" mobile (2009, www.verbekefoundation.com- Photo: Frederik Vercruysse. Design team: David Driesen, Tom Verschueren, Thomas Denturck). **Figure 25.** Mobile home "Y CABIN" (Photo by Bart Gosselin, 2009, www.verbekefoundation.com- Design by: David Driesen, Tom Verschueren, Thomas Denturck).

"Blob VB3" prototype proposed by DMVA ARCHITECTEN, a minimal design tiny house that can be transported by truck instead of the minimal egg-like design that was abandoned due to being expensive, "Y CABIN" containing 12 m2 living unit, toilet, shower, and upper-level sleeping area " is designed. Solar panels on the roof provide renewable energy to the residential unit. A revolving door is designed on the entrance façade. (dmvA, 2019).

When evaluated independently of cost, it is observed that both designs are suitable for multiple productions. In the planning of a residential site, the shape and form of the mobile housing gain importance in order to use the land effectively. Based on the principle of minimum infrastructure costs in settlement planning on any land, it is suitable for more effective use of the land with its "Y CABIN" shape and form. Both designs have shipping problems. For multi-unit layout design, houses need to be separated into architectural components (floor, wall, ceiling, windows, doors) for transportation cost and convenience. The proposal to benefit from solar energy contributes to the design of the living unit in terms of its contribution to sustainability, energy saving, and environmental health.

5.4. Global Economic Power and Housing Issue/United States

Urban segregation with the concepts of slum, ghetto, enclave, suburban, and spatial clustering and slums that emerged on the basis of this separation, the USA, which is much more fragmented on an ethnic, class, and economic basis, receives immigrants from the world with its economic size and high capacity in every field. Despite its large resources and economic size, the USA is faced with a housing problem (Çetin, 2012).

It tries to cope with the homeless or housing problem, which reaches millions in the USA, with the "small house" formula. Small houses plan type is similar to other examples in the world, solved with a minimal approach over basic vital functions.

In the case of a residential area studied, the typology of small houses for the homeless is designed by minimizing private space (houses less than 14 m^2), including front porches. Public interaction is created by placing rest and cooking in one common place. Small commercially available homes have special sanitary facilities for bathrooms and waste disposal, while small homes for the homeless rarely have such facilities and are solved with shared, central bathrooms (Mingoya, 2015).

Solution studies with Tiny House to the growing housing problem in America are the subject of scientific research and studies are supported. The popularity of tiny houses is increasing in the USA (Dion, 2015; Ford & Gom-Lanier 2017; cited by Evans, 2020). There is no official definition of Tiny House, although much larger units are included in the definition, with most proponents saying they are around 37m^2 at most. Tiny houses on wheels are also often used synonymously with the term tiny house. (Evans, 2020, Shearer & Burton, 2019).



Figure 26. USA - An example of dozens of homeless parks in downtown Portland/Oregon (Graves, 2021). **Figure 27.** Veterans Community Project in Kansas City, Missouri, one of the homeless small home villages (photo; www.veteranscommunityproject.org). **Figure 28.** The Veterans Community Project (photo; www.veteranscommunityproject.org).



Figure 29. Veterans Community Project in Kansas City, Missouri, one of the homeless small home villages (www.veteranscommunityproject.org). **Figure 30.** Veterans Community Project in Kansas City, Missouri, one of the homeless small home villages (www.veteranscommunityproject.org). **Figure 31.** USA- An example of dozens of homeless parks in downtown Portland/Oregon. Searching for solutions with a small and mobile housing unit. (Photo Pete GOLIS, August 7.2022).


Figure 32. Tent city set up by the U.S. military with a "mobile home." (Photo; https://upload.wikimedia.org). **Figure 33.** The camp and natural shelter established by refugees in the United States is under the bridge. (https://nypost.com/wpcontent/uploads/sites/2/2021/09/bridge02.jpg?quality=90&strip=all&w=1024).

In the City of Los Angeles, the architectural firm uses prefabricated shelters to create an efficient and functional design. It adds features to the project with colors in the design to create a new sense of community for users.

Figure 34. A public camp for the homeless in the United States (/961229/lehrer-architects-designs-tiny-house-communities-for-the-homeless-of-los-angeles/6093b6f2f91c81c3090000c8-lehrer-architects-designs-tiny-house-communities-for-the-homeless-of-los-angeles-image). **Figure 35.** A camp for the homeless in the United States (https://www.google.com.tr/url?sa=i&url=https%3A%2F%2Fwww.azcentral.com).

In US cities with a shortage of millions of housing, they establish residential areas with small housing or tent houses, which are followed in the examples of empty public spaces in cities

Figure 36. Camping for the homeless in downtown Vancouver, Canada. https://cdn.theconversation.com/static/tc/@theconversation/ui/dist/esm/logos/logo-en-b159aca2598f351db37072c75294e4c8.svg,(Photo, Nanaimo, B.C. 2018), Publisher: 2019).

Homeless camps like this one in downtown Vancouver, Canada, can be seen all over North America. It is understood that the problem cannot be solved in a short time. City administrations are trying to overcome the problem of mobile homes and tent houses.

Figure 37. An example of a multi-storey application of small housing is New York (Pablo Enriquez, Iwan Baan 2016). **Figure 38.** An example of a multi-storey application of small housing is New York (Pablo Enriquez, Iwan Baan, 2016).

Land values are very high in city centers. Residences with a minimal plan solution can obtain more residences with a multi-story application. Studio apartments play a role in the effective evaluation of the land in such project applications.

5.5. A Look at Art-Entertainment-Show-Festival Events from the Window of the Mobile Home

The concept of the settlement will continue in the context of the basic need of shelter-asylum in the historical development process of societies, for whatever purpose, for how long, and for whatever reason. It is understood that it will not change its place in the lives of societies with the transitive definition of accommodation unit, shelter-dwelling-house-residence-villa-flat-small house, and mobile housing, which are the vital needs of people. Mobile housing plays an important role in the socio-cultural and socio-economic movements of societies, apart from vital necessities in the context of the concept of housing. Music, entertainment, carnival, local cultural events, and art performances, etc. with mass participation. as in the examples. The mobile accommodation unit undertakes the task, as in the case of music and art activities that take place with the participation of tens of thousands of people and last for a few days, or in the highland migration where a small village settlement will spend a month or two. The basic components of all these socio-economic and cultural activities are the concepts of settlement and accommodation, independent of time limitations, while the mobile home is the complementary element.

5.5.1. Belgium

One of the events with mass participation from various countries of the world is the Tomorrowland Festival in Belgium. It is held on the last weekend of June every year for a period of 3 days. As of 2005, the festival settlement, built on an area of approximately 3.6 square kilometers, hosts tens of thousands of people (https://www.tomorrowland.com/).

Figure 39. Tomorrowland Festival residential area, Belgium. (tomorrowland.com website, 2023). **Figure 40-41.** Mobile shelter units in the Tomorrowland Festival residential area. Tomorrowland Festival, Belgium (tomorrowland.com website, 2023).

5.5.2. United Kingdom

Hundreds of thousands of people gather for five days each year for the Glastonbury festival. Visitors come from all over the world to the area with a capacity of 210,000 people. Tens of thousands of tents are set up for shelter.

Figure 42. Glastonbury festival venue Picture: Aaron Chown/PA Wire/PA Images (https://images.radiox.co.uk/images/59440?crop=16_9&width=660&relax=1&signature=6NmqWB-_fHwdPt6d4XGLgfPPKug=).
Figure 43. Glastonbury festival residential area, England, Photo; ttps://www.glastonburyfestivals.co.uk ;2022).

5.5.3. United States /Extraordinary City

According to the settlement plan prepared in the desert known as Black Rock City, about 70,000 people come from all over the world with "mobile housing units" to build a temporary city, but it is dismantled after a week. The accommodation units of the participants were placed on a more compact piece of land with the plan prepared for settlement, with walkable and cycling paths (Patton, 2019), (https://www.governing.com/authors/Zach-Patton.html).


Figure 44. Burning Man festival residential area, USA. (https://webinars.governing.com 2019 Zach Patton). **Figure 45.** Burning Man festival residential area, USA. Photo Google Earth (2023).

5.5.4. A place of refuge in natural disasters; home of fear "Little House"

Natural disasters occur in our country and in many parts of the world, and the first instrument that governments apply for shelter is a small house or shelter. Earthquakes, floods, fires, etc. Meeting the need for mass housing is a need that both governments and individuals have to solve first. In difficult situations where no comfort is sought in emergency situations, especially prefabricated living units serve as a lifeguard. In this context, it is very important that prefabricated living units have the necessary production capacity in our country with active fault zones.



Figure 46. Burning Man festival residential area, USA. Photo Google Earth (2023 5,857 by the Ministry of Public Works and Settlement in Sakarya, and 4,518 by different voluntary organizations; A total of 10,375 prefabricated temporary houses were built. (Limoncu S., Özata S, 2014). **Figure 47.** Van Earthquake, 2011. Anatolian Container City, (Photo, Sargın S. and Diğ.2016).

In the 2011 Van earthquake, according to AFAD reports, 19,130 people were placed in 3.030 tents, and 147,319 people were placed in 24,500 containers during the earthquake period (Sargın et al., 2016).

Figure 48. Elazig Earthquake 2020. Temporary prefabricated settlement Anadolu Agency; (23.02.2020, https://cdnuploads.aa.com.tr/uploads/Contents/2020/02/23/thumbs_b_c_e456b430747bc15ec68794771d460811.jpg).

5,222 container settlements are planned in Elâzığ, of which 4,790 are planned to be placed in temporary shelters that are being established in 6 different regions in the Sivrice district (https://www.aa.com.tr/tr).

Figure 49. Izmir earthquake,2020. Temporary container placement area. (https://www.aa.com.tr/uploads/userFiles/caec1b32-8257-4f58-87b0-6657c62b92b3/New%20folder%20(9)%2Fizmir-earthquake victim02.jpg).

6. Findings and Evaluation

The cultural activities and needs of the societies emerge in the geographical and climatic conditions in which they live. They determine the plan and size of the living unit they will use according to their economic activities. As a solution to the housing problem that arises in the lower strata of society due to low-income groups, internal migration, or international migration in cities, the search for solutions continues with the formula of small and mobile housing. In case of earthquakes and other natural disasters, the need for shelter is solved with small houses. Housing, which is a social and economic commodity, is understood to cause deep social segregation in some countries. It is understood that the housing problem will continue to be a problem for individuals and governments around the world. Although the culture of each country is different, the housing requirement and even the house plan typologies are very similar. The approach to the solution of the housing problem with the small house formula is also similar all over the world.

Our country, which is insufficient in housing production in parallel with the population growth rate, and the middle-income and lower-tier groups of our society, which have problems in purchasing housing, are faced with a housing deficit that increases with the effect of the destructive earthquakes frequently created by the active fault lines in our country. On the other hand, catastrophic disasters cause great resources of our society to be wasted. In our country, where there are not enough resources, only 15,000 of the earthquake permanent residences, which were planned by the state in Sakarya during the 1999 earthquake, could be completed 2 years later. (Limoncu & Özata, 2014). Although the housing problem in our country is similar to the world, natural disasters make the solution to the problem increasingly difficult. It seems essential to develop and disseminate rapid housing production technologies. Similar efforts are being followed in our country and in the world for the healthy development of cities. Efforts to solve the housing demand, which will continue to be a problem in the world and in our country, will also continue. The creation of resources and the development of rapid production technology stand as an important problem for both our country and the states seeking a solution to the problem

7. Conclusion and Discussion

It is understood that small and mobile houses will be an important instrument of the solution studies of the housing problem. Homeless people, mostly low-income or immigrants, will not leave cities to take advantage of the city's economic dynamic. Due to the fact that the industry and service sectors are the labor force, it is necessary to re-plan the cities and develop solutions specific to housing.

Prefabricated small houses should not be made a part of cities. For temporary solutions in mandatory situations, models should be developed that can be installed in one day with the help of the easy-to-carry user, by avoiding the on-site construction method with a prefabricated production solution. The efficient use of energy in "house" cities, which will consist of recycled materials and insulated building components (floor wall, roof), will contribute to the protection of the environment and resources.

In the years after the 1999 Marmara earthquake, in the 2003 Bingöl, 2011 Van, 2020 Elâzığ-Malatya, and 2020 İzmir earthquakes, thousands of our citizens lost their lives and caused destruction the number of tens of thousands. These disasters deeply injure not only the earthquake zones but also our entire society and the country's economy. In order to be protected from deadly and major economic disasters, urban settlements should be shifted to solid grounds in their geographical regions within the framework of scientific studies. In these works, small houses will continue to take on duties, albeit temporarily.

Due to the economic activity of our society living in rural areas, it is necessary to work towards the shelters it needs. It will be beneficial for society to design and manufacture easily assembled-disassembled and portable products with contemporary materials in the relevant ministry and to support them with an easy-to-buy price policy. Supporting this segment of society that creates its own economy will also contribute to the healthy development of cities.

In order to solve the housing problem in general, to protect public health, to strengthen the sense of social justice in society, and to strengthen the sense of equality, projects should be developed with scientific studies and housing production should become a national policy. The housing problem of our country, which is increasing in population, should develop new policies before it reaches insurmountable points. Long-term payment financing opportunities should be provided for the houses that will meet the housing needs of the society, serve all income groups, and will be produced with different m2 options. Urban areas planned under the supervision of the Ministry of Urbanization should be created and their infrastructures should be completed. Housing production should not be left to the mercy of the private sector by implementing the developed projects through public means.

Small and mobile housing production demanded by upper-income groups:

The situation is different in small houses or mobile houses, which are demanded by high-income groups for various reasons, without spending restrictions. The product is designed and produced by competent people. It is offered to the user in urban areas that are planned according to zoning laws and have completed infrastructure. Due to the absence of economic and legal restrictions, it is examined at an artistic and scientific level over aesthetics, ergonomics, design, engineering, and environmental values. The result to be obtained will have the least problem for the user and society.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to The e-book section / Or 1st Author %50 2nd, Author %.50. contributed. There is no conflict of interest.

References

Architecture For A Change (AFAC), (2013). https://www.archdaily.com/418486/mamelodi-pod-architecture-for-a-change

Anadolu Ajansı, (https://www.aa.com.tr/tr)

Böller, S. (2019). Motivations to build a tiny house and continuie despite obstacles-a multiple qualitive methods study. University of Twente, Department of Positive Psychology and Technology. Bechalor Thesis. https://essay.utwente.nl/78090/1/BAThesis.PaulineB%C3%B6llert.Final.pdf 1080/00330124.2020.1744170

Çakır, S. (2011). Türkiye'de Göç, Kentleşme/Gecekondu Sorunu ve Üretilen Politikalar *SDÜ Fen Edebiyat Fakültesi Sosyal Bilimler Dergisi*, Sayı;23.

Çetin, S. (2012). İdealken Dergisi, Sayı 7, ss 160-186; ISSN: 1307-9905.

Doğanay, S. (2010). İşlevsel Değişim Sürecinde Çakırgöl Çevresinde Yaylalar Yaylacılık. *Uluslararası İnsan Bilimleri Dergisi* Cilt;7 Sayı;2.

DmvA Architecten Tasarım ekibi: David Driesen, Tom Verschueren, (2019).

Evans, K. (2020). Tackling Homelessness with Tiny Houses: An Inventory of Tiny House Villagesin the United States.

Geray, C. (2000). *Kenttaşlık Hakları,* İnsan Hakları Yıllığı, C.21.

Kalağan, G. (2021). *M.Akif Ersoy Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, ISSN: 2149-1658 Cilt: 8 Sayı: 1 s.85-106 Volume: 8 Issue: 1 p.85-106.

Karaboran, H. H. (1988). Dünyada ve Türkiye'de Gecekondu Sorunu-Gecekondular, Slamlar, Bidonevler, *A.Ü. DTCF Coğrafya Araştırmaları Dergisi*, S. 11 s.111- 130.

Karagel, D.Ü. (2017). *Mustafa Kemal Üniversitesi, Fen-Edebiyat Fakültesi,Coğrafya Bölümü Ders Notları,* Hatay/2017.

Katz, I. (2017). Between Bare Life and Everyday Life: Spatializing Europe's MigrantCamps Migrant Camps.' Architecture_MPS, 12(1): 2, DOI: https://doi.org/10.14324/111.444.amps.2017v12i2.001.

Kouijzer, M. (2019). Motivations to build a tiny house and continuie despite, Obstacles-a multiple qualitative metods study. *University of Twente, Department of Positive Psychology and Technology*.

Limoncu, S. & Özata, Ş. (2014). 16. ve 20. yy. Arası İstanbul ve Yakın Çevresinde Meydana Gelen Deprem Sonrası Barınma Uygulamalarının İncelenmesi, MEGARON 2014; 9(3):217-227 DOI:10.5505/MEGARON.2014.04706.

Mingoya, C. (2015). Building Together Tiny House Villages for the Homeless: A Comparative Case Study, *Massachusetts Instıtute Of Technology.*

NTV Arşiv, (2019) http://arsiv.ntv.com.tr/news/default.asp.

Özgür, E. M. (2022). Ankara Üniv. Dil ve Tarih-Coğrafya Fakültesi Coğrafya Bölümü.

Patton Zach, (2019). https://www.governing.com/authors/Zach-Patton.html,2019

Sargın, S., Alaeddinoğlu, F., Okudum, R. (2016). 2011 Van Depremi ve Kentsel Nüfusta Mekânsal Farklılaşmalar; *SDÜ Fen Edebiyat*

Fakültesi Sosyal Bilimler Dergisi, Aralık 2016, Sayı: 39, ss. 133-149.

Taş, B. (2016). *Türkiye'nin Kırsal Yerleşmeleri*. Yeditepe Yayınevi.

Topal, A. K. (2004). Kavramsal olarak Kent Nedir ve Türkiye'de Kent Neresidir? *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi,* Cilt 6, Sayı; 1.

Sullivan, E. (2018). Manufactured Insecurity, – Mobile Home Parks and American's Tenuous Right to Place *University of California* Press, 250 pp.

Tang, R.H. (2021). Tiny Houses, a long-term option of Social Housing in Melbourne, An Investigation of the Policy, Planning and Social tensions Honours thesis for ARCH 1403 Planning Thesis *RMIT University School of Global Urban and Social Studies*.

Tunçdilek, N. (1967). Kır İskânı (Köy Altı İskân Şekileri) İstanbul Üniversitesi, Coğrafya Enstitüsü yayınları.1283.

Ünlü, S. (2014). *1+1 Stüdyo Yaşamlar*, Küreselleşen Dünyada Yeni Kentsel Kurgular. Çizgi Kitabevi.

Emre KAVUT

E-mail: emre.kavut@msgsu.edu.tr

Educational Status: Doctorate

License: 1997 Mimar Sinan Unıversıty, Faculty of Archıtecture / Interior Architecture

Degree: 2000 Mimar Sinan Unıversıty, Instıtute of Scıence/ Interior Architecture

Doctorate: 2004 Mimar Sinan Unıversıty, Instıtute of Scıence / Interior Architecture

Professional Experience: Mimar Sinan Fine Arts Unıversıty/Faculty Of Archıtecture 1997 to present

Yaşar Bayraktaroğlu

E-mail: 987110168@ogr.msgsu.edu.tr

Educational Status

License: 1987 Yıldız Teknik Unıversıty/Faculty of Archıtecture Architecture

Degree: Mimar Sinan Fine Arts Unıversıty, Instıtute of Scıence/ Interior Architecture

A Research on Natural Cement as A Sustainable Hydraulic Binder for Buildings

Ress. Asist. Nazife ÖZER [1]

[1]Istanbul Technical University, Department of Architecture, Faculty of Architecture, Istanbul/Türkiye
ORCID: 0000-0003-1072-0493
E-mail: onaln15@itu.edu.tr

Prof. Dr. Seden ACUN ÖZGÜNLER [2]

[2]Istanbul Technical University, Department of Architecture, Faculty of Architecture, Istanbul/Türkiye
ORCID: 0000-0001-5975-5115
E-mail: acunsed@itu.edu.tr

Citation: Özer,N. & Özgünler Acun, S. (2023). A Research on Natural Cement as A Sustainable Hydraulic Binder for Buildings. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (104-134). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

Binders are building materials that hold granular or fibrous materials together in a composition. Throughout history, various natural and artificial binders have been used in our buildings. Lime, which has been used since ancient times, was the most frequently used binder in buildings until the invention of Portland cement. However, lime has no hydraulic character and is not resistant to water. Therefore, it is known that the properties of lime mortars were improved by adding various artificial and natural pozzolans after 300 BC. The production of hydraulic binders started in the 18th century. The word cement is derived from the Latin word “caementum”. This word, which means chipped stone fragments, began to be used as "cement" in Europe after the 14th century, meaning "binding or uniting" (Türk & Engin, 2021). Cement, in the most general sense, is an inorganic-based binder obtained by calcining and grinding a mixture of clay, limestone, and iron oxide at high temperatures and is hardening in both air and water (Eriç, 2016). The natural cement produced and patented by James Parker using cement rocks in 1796 can be counted as the first steps of cement. At the beginning of the 19th century, Louis Vicat investigated the hydraulic properties of binders. It has been revealed that the hydraulic feature is provided by the calcium silicates and calcium aluminates in the material (Eriç, 2016; Erdoğan & Erdoğan, 2007). Vicat produced a synthetic hydraulic binder as calcined a 33-40% clay and limestone mixture. This binder was used to construct one of the legs of the Souillac Bridge. In 1824, Portland cement was first produced by Joseph Aspdin. (Erdoğan & Erdoğan, 2007). Today, various proportions of natural and artificial pozzolans can be substituted for Portland cement clinker within the scope of energy consumption and reducing the carbon footprint of cement (Almutairi et al., 2021).

Hydraulic binders are inorganic-based materials that harden in air and water. When hydraulic binders are mixed with water, hydration begins. During the hydration process, Calcium Silicate Hydrate (C-S-H) products compose Calcium Hydroxide ($CaOH_2$) and other hydration products. C-S-H products form an intricate structure in the paste, allowing it to harden and gain strength over time (Strother, 2019).

Natural hydraulic limes (NHL), hydraulic limes, natural cement, and Portland cement can be examples of hydraulic binders. Although there are similar and different aspects in producing all these binders, they are generally made by calcining stones with suitable chemical content at certain temperatures. The difference between hydraulic binders described as "natural" is using a clayey limestone, or marl, with naturally appropriate chemical content as a raw material. While natural cement is produced by calcining limestones with a high clay content (Hughes et al., 2007a; Livesey, 2015; Yöney, 2013), natural hydraulic lime is produced by calcining limestones with a low clay content. On the other hand, the chemical content of the raw meal is adjusted by blending clay and limestone sources and calcined in the production of Portland cement (Table 1).

Table 1. Comparison table of natural hydraulic lime, natural cement, and portland cement

Comparison criteria		Natural Hydraulic Lime (NHL)	Natural Cement (NC)	Portland Cement (PC)
Production of binder	**Raw material**	100% Clayey limestone or marl (has 10-20% clayey substances chemically)	100% Clayey limestone or marl (has 15-35% clayey substances chemically)	30% Clay + 70% limestone + 3% Gypsum
	Calcination temperature	Low temperature (Approximately 900° C)	Low temperature (800°-1200° C)	High temperature (Approximately 1450° C)
	Last procedure of production	Slaking	Grinding, not slaking	Grinding, not slaking
Properties of binder	**Compressive strength**	2-15 N/mm^2 *	10-25 N/mm^2 **	32.5-62.5 N/mm^2 ***
	Color	White-cream colored	Yellow-brown colored	Blue-grey colored
	Density	Approximately 2.6 g/cm^3	2.7-3.1 g/cm^3	3.0-3.2 g/cm^3
	Initial setting time	>60 min*	1-7 min	45-75 min ***

*Turkish Standards, 2015; **Gurtner et al., 2008; ***BSI Standards Publications, 2011

This study mentions the historical development and usage areas of natural cement, its hydration mechanism and production, standards, and experimental studies in the literature related to natural cement. The last section is given the experimental study with different clayey limestones obtained from Adana, Türkiye.

1.1. Natural Cement

Natural cement is a hydraulic binder. Although called "cement," natural cement has similar production or material properties, both natural hydraulic lime and ordinary Portland cement. In the literature, natural cement is referred to as Roman cement, water cement, or black cement (Yöney, 2013). Roman cement was patented in England in 1796 under the name Parker's Cement or Roman cement by James Parker (Parker, 1796), (Figure 1). This material was produced by calcining and grinding clay-containing limestones known as septaria (cement rock) from Sheppey Island, London (Hughes et al., 2007a; Edison, 2007; Kozlowski et al., 2010).

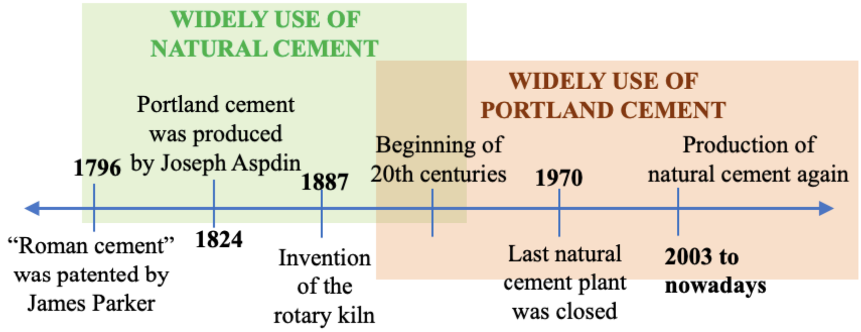


Figure 1. Timeline of natural cement history.

Roman Cement has a characteristic brown color due to its iron oxide residues (Trout, 2019). In England, it is seen that it is branded with the name of the natural cement manufacturer or the name of the place where the raw material is extracted (Hurst, 2002). During this period, many hydraulic lime and natural cements were called Roman cement (Yöney, 2013). After 1850, natural cement production began in the European mainland using marly limestone deposits (Kozlowski et al., 2010). At the end of the 19th and the beginning of the 20th century, especially natural cement produced in the Beočin factory in Serbia was sold to Romania, Bulgaria, Türkiye, and Syria. This historic binder use in Türkiye is not as well-known as in Europe (Gurtner et al., 2008). Ersen et al., 2010 examined the artificial stones frequently used on the facades of buildings in the late 19th and early 20th centuries in Istanbul. They determined that natural/artificial cement was used in the samples taken from the buildings given in Figure 2.

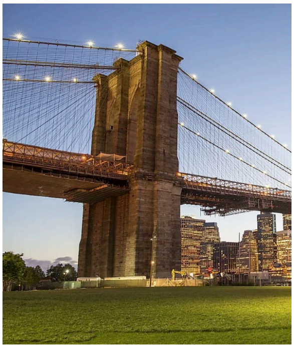
Figure 2. Artificial stones, which include natural/artificial cement binder, on building façades of the late 19th and early 20th centuries in Istanbul (Yöney, 2008).

Portland cement became very popular in the 20th century. Later, the last natural cement production plant, Rosendale Plant in the USA, was closed in 1970 (Edison, 2007). The chemical contents of the cement rocks vary according to where they are extracted. American natural cements' magnesium carbonate content is higher than European natural cement. Therefore, American natural cement is calcinated at a lower temperature. Compared to European natural cement, it sets more slowly and has a lower modulus of elasticity. Because of these properties, it has been used in masonry mortar and stucco works without lime additives. Compared to American natural cement, European natural cements containing low magnesium carbonate and calcinated at relatively higher temperatures have higher strength and are suitable for use in pre-casting works (Edison, 2007). Some examples of structures that are used natural cement are given in Figure 3.

(a)

(b)

(c)



(d)

Figure 3. Examples of structures used natural cement **(a)** Vassy Church Façade, France, 1859-1962 (Bouichou et al., 2013), **(b)** The pedestal of the Statue of Liberty, USA, 1876-1886 (Werner & Burmeister, 2007), **(c)** Trade Academy Façade, Poland, 1904-1905 (Klisińska-Kopacz et al., 2010), **(d)** The Brooklyn Bridge, USA, 1883 (Bouichou et al., 2013).

ROCEM (2003-2006) and ROCARE (2009-2012) projects were carried out to produce natural cement in Europe. In addition, seven American Natural Cement Conferences were held in America. The ROCEM

(Roman cement to restore built heritage effectively) project that ensures natural cement reproduction was carried out to optimize the calcinations of cement rock in laboratory and commercial kilns between 2003 and 2006. The second project was started in 2009 as a continuation of this project. The aim of ROCARE (Roman Cements for Architectural Restoration to New High Standards) is to ensure the industrial production and commercialization of natural cement and to encourage its use. Scope of this project, Roman cement standard was published. In this standard, the requirements and classification of Roman cement are given. Roman cement is classified according to compressive strength at age 3 hours as A, B, and C. In addition, they are classified as I, II, and III according to their long-term (91 days) compressive strength (Gurtner et al., 2008). In a study carried out within the scope of this project, researchers developed the DARC (De-Activated Roman Cement) technique, which can be used instead of chemical setting retarders such as citric acid, to extend the setting time of fast-setting natural cement up to 3 hours without losing strength (Starinieri et al., 2013), (Hughes and Starinieri, 2014). Another study determined the mixing ratios and curing conditions to minimize the shrinkage cracks in natural cement applications (Wilk et al., 2013). Two American Natural Cement Conferences were held in the USA in 2005 and 2006 (Edison, 2007). An American Standard named “Standard Specification for Natural Cement” (ASTM International Standards, 2019) was published in 2008 in the USA. The comparative table of natural cement standards is given in Table 2.

Table 2. The comparative table of natural cement standards.

<table>
<tr><th colspan="2" rowspan="2">Requirements</th><th colspan="2">ASTM C10/C10M − 19</th><th rowspan="2">*ROCARE Standard (Gurtner et al., 2008)</th></tr>
<tr><th>Natural Cement**</th><th>Quick-Setting Natural Cement</th></tr>
<tr><td rowspan="5">Chemical Requirements</td><td>Loss on Ignition</td><td><12%</td><td><12%</td><td>≥2% ≤ 14%</td></tr>
<tr><td>Insoluble residue</td><td><2%</td><td><2%</td><td>≤ 12</td></tr>
<tr><td>Sulfate content (as SO_3)</td><td><3%</td><td><3%</td><td>≤ 4%</td></tr>
<tr><td>Chloride content</td><td></td><td></td><td>≤ 0.1%</td></tr>
<tr><td>C_3S content</td><td></td><td></td><td>≤ 5%</td></tr>
<tr><td rowspan="8">Physical Requirements</td><td>Soundness</td><td>Autoclave length change, max, 0.8%</td><td>Autoclave length change, max, 0.8%</td><td>≤ 15 mm</td></tr>
<tr><td>Initial Setting</td><td>Not less than 30 min</td><td>Not less than 10 min</td><td>≤ 10 min</td></tr>
<tr><td>Final Setting</td><td></td><td>Not more than 30 min</td><td>≤ 15 min</td></tr>
<tr><td>Surface Area</td><td>** 1954-1976: Minimum 550 m^2/kg fineness (air-permeability method)</td><td>**1954-1976: Minimum 550 m^2/kg fineness (air-permeability method).</td><td>4000 – 8000 m^2/g (measured by laser diffraction)</td></tr>
<tr><td>Sieve residue</td><td>** 1937-1954: Maximum 15% retained on a 75-µm (No. 200) sieve.
1904-1937: Maximum 10% retained on a 150-µm (No. 100) sieve, maximum 30 % retained on a 75-µm (No. 200) sieve.</td><td>** 1937-1954: Maximum 15% retained on a 75-µm (No. 200) sieve.
1904-1937: Maximum 10% retained on a 150-µm (No. 100) sieve, maximum 30 % retained on a 75-µm (No. 200) sieve.</td><td>1% on a 300µm sieve</td></tr>
<tr><td>Air content of mortar</td><td>Volume %, max 12</td><td>Volume %, max 12</td><td></td></tr>
<tr><td>Shrinkage</td><td></td><td></td><td>< 2 mm/m</td></tr>
<tr><td colspan="4" style="display:none"></td></tr>
<tr><td>Mechanical Requirements</td><td>Compressive Strength (MPa)</td><td><table><tr><th>Age (days)</th><th>Compressive strength (MPa)</th></tr><tr><td>7</td><td>min 3.5</td></tr><tr><td>28</td><td>min 7</td></tr></table></td><td><table><tr><th>Age (days)</th><th>Compressive strength (MPa)</th></tr><tr><td>7</td><td>min 3.5</td></tr><tr><td>28</td><td>min 7</td></tr></table></td><td><table><tr><th>Type</th><th>3 hours</th></tr><tr><td>A</td><td>≥ 5.0</td></tr><tr><td>B</td><td>< 5.0 ≥1.0</td></tr><tr><td>C</td><td>< 1.0</td></tr></table><table><tr><th>Type</th><th>3 hours</th><th>91 days</th></tr><tr><td>I</td><td>≥ 5.0</td><td>≥ 25</td></tr><tr><td>II</td><td>< 5.0 ≥1.0</td><td>≥ 15</td></tr><tr><td>III</td><td>< 1.0</td><td>≥ 10</td></tr></table></td></tr>
<tr><td colspan="5">*In some cases, it is possible for a cement to meet all the specifications of a Roman cement other than the setting time criteria. In this case the cement would be classified as a slow setting Roman cement.
** Variable at the option of the purchaser to match historic cements. If no data on historic cement fineness are available, the purchaser may wish to consider that previous editions of this specification from 1904 to 1976 required minimum values.</td></tr>
</table>

1.2. Calcination of raw material

Natural cement is produced by calcining raw material, which is clayey limestones or marl, at a temperature of approximately 800-1200 ^oC, and after the calcining process, clinkers are not slaked but grinding (Hughes et al. (2007a), Livesey (2015), Yöney (2013). Examples of raw materials known as cement rock are clayey limestone (Eckel, 1922), marls or marlstone (Gurtner et al., 2008), argillaceous marlstone, marls-limestones (Kozlowski et al., 2010), marls-calcareous rock (Hughes et al., 2009), argillaceous dolostones (Weber et al., 2007). Some researchers give the furnace temperature 850-1000 ^oC (Gurtner et al., 2008).

The raw material of hydraulic binders usually consists of calcium carbonate ($CaCO_3$) and/or magnesium carbonate ($MgCO_3$), silica (SiO_2) and clay minerals (hydrated aluminosilicates), and iron oxide (Fe_2O_3). At 400 ^oC, magnesium carbonate begins to decompose ($MgCO_3 \rightarrow MgO + CO_2$). When the temperature exceeds 600 ^oC, calcium carbonate composes ($CaCO_3$) as CaO and CO_2. Between 900-1100 ^oC, silica and clay react to form $2CaO.SiO_2$ (C2S, Belite). When the temperature exceeds 1200 ^oC, $3CaO.SiO_2$ (C_3S, Alite) and $3CaO.Al_2O_3$ (C_3A, Aluminate phase) begins to form (Eckel, 1922). The main hydraulic phase is C_2S (dicalcium silicate, Belite) for natural cement, while the main hydraulic phase is C_3S (tricalcium silicate, Alite) for Portland cement (Kozlowski et al., 2010).

Today, repairs to historical natural cement applications are made with Portland cement or natural hydraulic lime when the original binder is not found. These repair mistakes often cause irreversible damage and aesthetic deterioration (Figure 4). Owing to conferences and projects in Europe and America since 2003, it has been possible to produce natural cement today. The Venice Charter emphasized preserving original construction techniques and materials with minimum intervention and using appropriate materials and construction techniques. Restoration is high-budget work that requires expertise and knowledge. In addition, experts are accountable to institutions such as ICOMOS and UNESCO, especially in restoring common heritage buildings. From this point of view, the work's quality primarily depends on using appropriate materials in the restoration.

(a) **(b)** **(c)**

Figure 4. Repair historical natural cement applications with unsuitable materials (Weber et al., 2007). **(a)** Repair with Portland cement (grey), **(b)** Coating with paint, **(c)** Coating with Portland cement by spraying method.

Natural cement mortar is between natural hydraulic limes mortar and Portland cement mortar in terms of material properties. Compared to natural cement mortar, Portland cement mortar has higher adherence, lower porosity, water absorption coefficient, and vapor permeability. In terms of color matching, Portland cement is darker gray than natural cement and hardens later. On the other hand, natural hydraulic lime mortars have lower strength and higher water absorption and water vapor permeability coefficients than natural cement mortars. In terms of color harmony, natural hydraulic lime is lighter in color. In addition, natural hydraulic lime mortar has low early strength and hardens later (Gurtner et al., 2008).

Hughes et al. (2008) produced natural cement from cement rock containing 64% calcite, 10% quartz, 25% clay, and a small amount of pyrite from Whitby (England). Firstly, the mineralogical composition and porosity of the cement rock were determined. Then, it was ground to below 10 mm and calcined at temperatures varying between 825-1100 ^{o}C and changing times. The produced clinker was ground in a mill and sieved under a 150 μm sieve. X-ray diffraction (XRD) for mineralogical analysis, Philips Environmental Scanning Electron Microscope (ESEM) for morphological analysis, and chemical analyses to determine oxide content were carried out. Afterward, mortar mixtures were prepared with a water/binder ratio of 0.65, and determined compressive strength and setting time in these mortars. The study showed that the properties of the natural cement vary depending on the calcination conditions (calcination temperature and time at maximum temperature) and the age of the samples. The study showed that optimum conditions for calcination change depending on the sample's age, and binders that provide optimum values are produced at low temperatures and harden quickly.

Hughes et al. (2007b), within the scope of the ROCEM project, calcined marls from Austria and Poland in the laboratory and examined the possibilities of producing natural cement. Firstly, the chemical composition, mineralogical composition, and porosity of the raw materials were determined. After raw materials were ground 7-10 mm, clinkers were produced at temperatures ranging from 750-1100 ^{o}C in a kiln. Kiln's oxygen rate was controlled to be at least 12% during calcination. The clinkers were ground and sieved. Afterward, mortars were prepared with a water/binder ratio 0.65, and compressive strength and setting time were determined. According to the test results, the compressive strength of both binders decreased as the calcination temperature increased. In addition, the strength of the binders depends on the calcination temperature rather than the calcination time. It was determined that there was a dormant period of strength for a few weeks, and the increase in strength continued after this period.

Hughes et al. (2009) aimed to determine the optimum calcination conditions of natural cement. In the study, cement rocks were taken from Austria, Poland, and England. Cement rocks were ground to 7-10 mm and calcinated between 750 to 1150 ^{o}C. According to their preliminary studies, bricks were placed inner surface to ensure equal heating in the furnace. The mineralogical composition of the types of cement was determined with XRD analysis. Mortar mixtures were prepared at a water/cement ratio of 0.65 to determine the setting time and strength. The samples prepared for strength determination were cured in water. In order to prolong the setting time, 0.4% citric acid or 0.6% potassium citrate was added to mortars. In the control samples with a typical setting time of 1-3 minutes, the setting time was extended with these additives. Strength loss was observed in the samples using potassium citrate compared to the control sample. As a result of the study, it is emphasized that the strength of the types of cement produced depends on the calcination conditions, especially furnace temperature. It has been concluded that the optimum natural cement production is produced at temperatures as low as 750 ^{o}C.

2. Material and Method

Clayey limestones or marls are the most preferred raw materials in cement production. An average of 70% limestone and 30% clay mixture is used in ordinary Portland cement production. However, clayey limestones naturally contain this chemical content and can be used in Portland cement and natural cement production. For this reason, this type of rock is called "cement rock" or "American rock." Another advantage of this raw material is easy extraction. It provides economy in operation, grinding, and fuel in mixing and incineration (Madencilik ÖİK Raporu, 2001) (Taşkın, n.d.). Türkiye is rich in limestone formations. Limestone and calcareous rocks (marl, clayey limestone, etc.) constitute approximately one-fifth of Turkey's surface area (Taşkın, n.d.).

Natural cement is widely used in repairing and conserving historical buildings. Additionally, it is an alternative binder to Portland cement in producing plasters and mortars at contemporary buildings since it offers good physical and mechanical properties. In Türkiye, natural cement is imported to be used in construction. This preliminary experimental study aims to produce natural cement using clayey limestones extracted from Adana, Türkiye. Five different types of clayey limestones were obtained from Adana Cement Factory. The experimental study consists of two parts: determining raw material and determining properties of binders and mortars. Mortars produced were compared with the physical and mechanical properties of eminently natural hydraulic lime (NHL 5) mortars. X-ray diffraction (XRD) analysis was determined raw materials' mineralogical characteristics. In addition, raw materials were tested for specific density, acid loss, and ignition loss tests. Production of natural cement is given Figure 5.

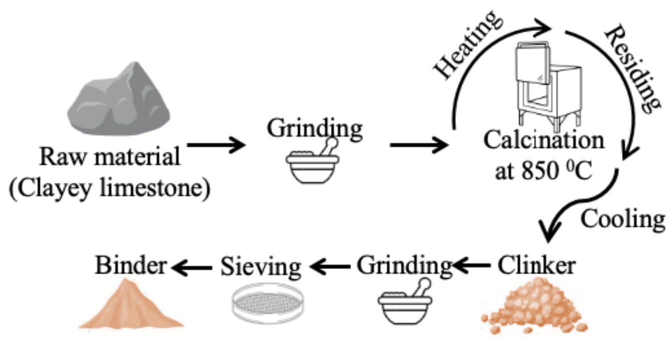


Figure 5. Production of natural cement.

2.1.Determination of calcination conditions and grinding

Natural cement is produced by calcining clayey limestone at low temperatures (800-1200 ^{o}C) below the sintering point. Previous studies given in Table 3 were taken into account to determine of calcination conditions. Raw materials were ground into small pieces (<10mm) before the calcining process. The furnace used in the study is 7.3 l inner volume.

Therefore, the raw material was a maximum of 1800 g in the furnace during calcination. Refractory bricks were placed on inner surfaces to ensure equal heating in the furnace (Figure 6). Raw materials were calcinated at 850 ^{o}C.

Table 3. Calcination conditions in literature and in this study.

Conditions	Literature			In this study
	Hughes et al. (2008)	Hughes et al. (2007b)	Hughes et al. (2009)	
Grinding size of raw material	10 mm	7-10 mm	7-10 mm	< 10 mm
Calcination temperature	825-1100 ^{o}C	750-1100 ^{o}C	810-930 ^{o}C	850 ^{o}C
Residence time	90-330 min	120-180 min	500 min	300 min
Cooling regime	In furnace, slow cooling	In furnace, slow cooling	In furnace, slow cooling	In furnace, slow cooling

The clinker production takes 24 hours in a furnace and has three phases: heating, residing at 850 ^{o}C, and cooling. The residence time was selected as 300 minutes. Cooling clinkers were ground in the ball mill for 3 hours. Then binders were sieved under 300 μm according to ROCARE Standard (Gurtner et al., 2008). Binders were tested for specific density, acid loss, and ignition loss tests. In addition, sieve analysis and specific surface area of binders were determined.

Figure 6. Refractory bricks were placed on inner surfaces to ensure equal heating in the furnace.

2.2. Determination of mortar mixture ratio and curing

Water/binder ratio and binder/aggregate ratio were 1:1 and 1:3, respectively. Standard sand conforming to EN 196-1 was used in the mortar. Curing conditions are based on BS EN 459-2 (BSI Standards Publications, 2021) and BS EN 196-1 (BSI Standards Publications, 2016). In the BS EN 459-2 (BSI Standards Publications, 2021) standard, curing is recommended for natural hydraulic limes in a curing cabinet at 20±1 ^{o}C and ≥90% relative humidity until the day of the test. Mortar samples cured in a 28-day curing cabinet were tested for compressive strength, flexural strength, water absorption rate, density, open porosity, and ultrasonic pulse velocity.

3. Findings and Discussion

Test results and their discussion are given in three parts raw materials, binders, and mortars.

3.1. Raw materials

The experimental study was conducted on five stone samples extracted from the quarry in Adana, Yüreğir district, Çal Mountain Locality

(Figure 7). Since the stones numbered A3-A5 were similar in the preliminary examination, only the A5 sample was examined in the XRD analysis.

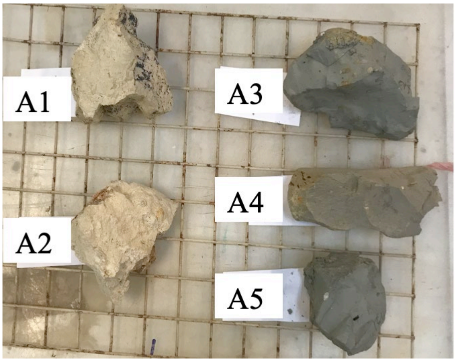


Figure 7. Stone samples extracted from the quarry in Adana.

The raw material used to produce natural cement includes calcite ($CaCO_3$), clay minerals (mica, illite, smectite, chlorite and kaolinite) and quartz. Some raw material sources may contain dolomite ($CaMg(CO_3)_2$). In addition to these, it may contain minor components such as feldspar and pyrite. Silica from the clay in the raw material reacts chemically with CaO better than coarse quartz particles (Gurtner et al., 2008). According to Table 4, while the Calcite ($CaCO_3$) ratio was 90-95% in the A2 sample, the clay ratio was below 5%. The XRD results of the A4 and A5 samples are quite similar, and A1 contains the highest calcite ratio.

Table 4. Test results of raw materials.

Properties		A1	A2	A3	A4	A5
Density (g/cm^3)		2.20	2.30	2.46	2.45	2.38
Acid loss (%)		59.37	66.12	16.20	16.20	26.64
Ignition loss (%)		31.47	40.18	17.21	17.21	19.51
Mineralogic composition (XRD analysis)	Calcite (%)	45-50	90-95	n.m.	40-45	40-45
	Quartz (%)	10-15	<5	n.m.	15-20	10-20
	Clayey content (%)	35-40 *Smectite (15-20%) + Illite-Mica (15-20%) + Amorphous phases*	<5	n.m.	40-45 *Smectite (15-20%) + Illite-Mica (5-10%) + Clorit-Kaolinite (10-15%) + Amorphous phases*	40-45 *Smectite (10-15%) + Illite-Mica (15-20%) + Clorit-Kaolinite (10-15%) + Amorphous phases*

n.m.: not measured

3.2. Binders

Five different types of clayey limestones were obtained from Adana Cement Factory. Raw materials were calcinated at 850 ^{o}C. Cooling clinkers were ground in the ball mill for 3 hours. Then binders were sieved under 300 µm according to ROCARE Standard (Gurtner et al., 2008). Acid loss, ignition loss, and specific density of binder are given in Table 5. A2/850 binder that is produced from high calcite content stone has high acid loss and ignition loss. Therefore, it is thought that this binder is without hydraulic character. In addition, the exothermic reaction occurred in hydration of A2/850.

Table 5. Acid loss, ignition loss, and specific density of binder.

Properties	A1/850	A2/850	A3/850	A4/850	A5/850	NHL 5
Specific density (g/cm^3)	2.64	2.65	2.52	2.66	2.64	2.94
Acid loss (%)	42.45	81.09	14.09	5.61	9.05	38.14
Ignition loss (%)	13.51	73.94	14.28	5.38	8.77	17.84
Specific surface area (cm^2/g)	8844	n.m.	n.m.	8648	n.m.	8110

n.m.: not measured

Sieve and specific surface area analyses were determined on A1/850, A4/850 and NHL 5 (Figure 8). Cement fineness directly affects cement hydration, setting and hardening, strength, and heat of hydration (Aïtcin, 2016).

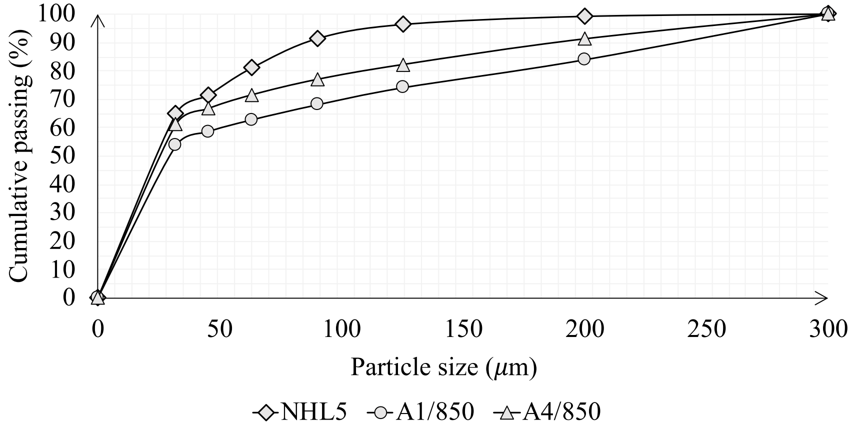


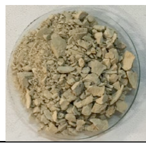
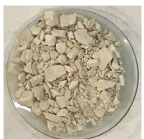
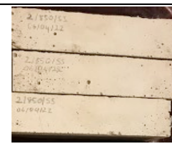
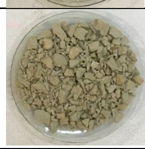
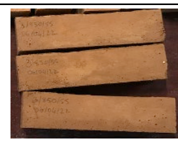
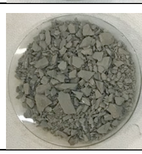
Figure 8. Sieve analysis of binders.

Cement fineness is determined by a sieve or specific surface area analyses (Zhang, 2011). Fine cement particles have a high total surface area contact with water. Therefore, hydration and setting occur quickly. In addition, as the surface area increases, the early strength and the shrinkage increase during hardening (Aïtcin, 2016). The fineness of NHL 5 is higher than other binders.

3.3. Mortars

Water/binder ratio (1:1) was kept constant for comparison. Mortar samples cured in a 28-day curing cabinet (20±1 ^{o}C and ≥90% RH). Raw materials, clinkers, fresh mortars, and hardening mortars samples are given in Table 6.

Table 6. Raw materials, clinkers, fresh mortars, and hardening mortars samples.

Binder Code	Raw material	Clinker	Fresh mortar	Hardened mortar
A1				
A2				
A3				
A4				
A5				

Physical and mechanical test results are given in Table 7. The consistency of NHL 5 fresh mortars was flowable because of water/binder ratio (1:1). Therefore, its compressive and flexural strength were low. Density, water absorption rate, and open porosity of mortars were similar.

Table 7. Physical and mechanical test results of mortars.

Code	Water/ binder ratio	Fresh mortar density (g/cm^3)	Density (g/cm^3)	Water absorption (%)	Open porosity (%)	Flexural strength (N/mm^2)	Compressive strength (N/mm^2)
A1/850	1:1	2.08	1.65	19.48	32.07	1.27	6.86
A2/850	1:1	2.08	1.62	20.36	32.98	0.42	1.00
A3/850	1:1	2.11	1.65	19.92	32.86	0.88	2.18
A4/850	1:1	2.08	1.66	19.46	32.26	1.35	4.90
A5/850	1:1	2.16	1.62	19.71	32.52	0.77	2.39
NHL5	1:1	1.98	1.64	19.48	31.92	0.88	2.20

A1/850 and A4/850 mortars showed high mechanical properties while mortars were flowable. Mortars A1/850 and A4/850 considerably showed higher compressive strength than NHL 5. It is thought that A1 and A4 stones can be used in natural cement production.

4. Conclusion and Suggestions

Natural cement is a historical binder known as Roman cement, and it has a short setting time, warm yellow to brown color, and good durability to atmospheric conditions. It is a more sustainable binder because of low calcination temperature; extraction and grinding of raw materials requires less energy than Portland cement. After Rosendale factory was closed in 1970 in the USA, at the beginning of the 21 YY, increasing awareness of natural cement led to a search for production. When historical natural cement applications repair unsuitable materials like Portland cement or natural hydraulic lime, repair mistakes often cause irreversible damage and aesthetic deterioration. Therefore, the production of natural cement has gained importance. In addition, its good physical and mechanical properties can be used in contemporary buildings as plaster or mortar.

Clayey limestones extracted from Adana were calcinated at 850 ^{o}C to produce natural cement. A1 and A4 stones have potential as natural cement raw materials. While A1/850 and A4/850 mortars have similar density, water absorption rate, and open porosity, they have good compressive strength. It is suggested that A1 and A4 stones can be calcined at varying temperatures under the sintering temperature and determine their mechanical and physical properties.

Thanks and Information Note

This study was supported by GAP Project, Scientific Research Projects Coordination Unit of İstanbul Technical University, Project ID: 43094.

The e-book section is produced from a doctoral thesis in İstanbul Technical University in the Construction Science Doctorate program. The e-book section complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the e-book section. There is no conflict of interest.

References

Aïtcin, P. C. (2016). 3 - Portland cement, *Science and Technology of Concrete Admixtures*. Aïtcin & Flatt (Ed.). Woodhead Publishing. (p.27-51), ISBN: 9780081006931. Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/B9780081006931000035?via%3Dihub

Almutairi, A. L., Tayeh, B. A., Adesina , A., Isleem, H. F. & Zeyad, A. M. (2021). Potential applications of geopolymer concrete in construction: A review, *Case Studies in Construction Materials*, Volume 15, Online ISSN: 2214-5095.

ASTM International Standards, (2019). *Standard Specification for Natural Cement* (C10/C10M − 19), https://www.astm.org/c0010_c0010m-19.html

Bouichou, M., Mearie-Victoire, E., Texier, A. & Blondiaux, T. (2013). How to identify a natural cement : case study of the Vassy Church, France. *3rd Historic Mortars 11-14 September 2013, Glasgow, Scotland*.

BSI Standards Publications, (2011). *Cement. Composition, specifications and conformity criteria for common cements* (BS EN 197-1:2011). https://bsol.bsigroup.com/Bibliographic/BibliographicInfoData/000000000030391002

BSI Standards Publications, (2016). *Methods of testing cement. Determination of strength* (BS EN 196-1:2016). https://knowledge.bsigroup.com/products/methods-of-testing-cement-determination-of-strength/tracked-changes

BSI Standards Publications, (2021). *Building lime - Test methods* (BS EN 459-2:2021). https://knowledge.bsigroup.com/products/building-lime-test-methods-3/tracked-changes

Eckel, E. C. (1922). *Cements, Limes, and Plasters : Their Materials, Manufacture, and Properties* / by Edwin C. Eckel. Donhead; 1922.

Access Address (27.05.2023): https://research.ebsco.com/linkprocessor/plink?id=235b3179-8017-349c-af7a-e16858230f6a.

Edison, L. L. (2007). Perspectives: The Reintroduction of Natural Cement. *Journal of ASTM International*, Vol. 4, No. 8. Access Address (27.05.2023): https://www.astm.org/jai100801.html

Erdoğan, S. T. & Erdoğan, T. Y. (2007). *Bağlayıcı malzemelerin ve betonun onbinyıllık tarihi.* ODTÜ Yayıncılık.

Eriç, M. (2016). *Yapı fiziği ve malzemesi*. İstanbul: Literatür Yayıncılık.

Ersen, A., Gürdal, E., Güleç, A., Yöney, N. B., Pekmezci, I. P., & Verdon, I. (2010). An Evaluation of Binders and Aggregates Used in Artificial Stone Architectural Claddings and Elements in Late 19Th-Early 20Th Centuries. Metu Journal Of The Faculty Of Architecture, 27(2), 207–221, Access Address (01.06.2023): http://jfa.arch.metu.edu.tr/archive/0258-5316/2010/cilt27/sayi_2/207-221.pdf

Gurtner, C., Hilbert, G., Hughes, D., Kozlowski, R. & Weber, J. (2008) *Manual on best practice in the application of Roman cements: Roman cement, past and present Conservation theory and practice*. (EU-PROJECT No. 226898).

Hughes, D. , Swann, S. & Gardner A. (2007a). Roman Cement Part One: Its Origins and Properties. *Journal of Architectural Conservation*. 13:1. (p.21-36), Access Address (27.05.2023): https://www.tandfonline.com/doi/abs/10.1080/13556207.2007.10784986

Hughes, D. C. , Jaglin, D., Kozlowski, R., Mayr, N., Mucha, D., & Weber, J. (2007b). Calcination of Marls to Produce Roman Cement, *Journal of ASTM International*, Vol. 4, No. 1, Access Address (27.05.2023): https://www.astm.org/jai100661.html

Hughes, D. C., Jaglin, D., Kozłowski, R. & Mucha, D. (2009). Roman cements—Belite cements calcined at low temperature. *Cement and Concrete Research*, (p.77-89). Access Address (27.05.2023):https://www.sciencedirect.com/science/article/pii/S0008884608002147

Hughes, D. C., Sugden, D. B., Jaglin, D. & Mucha, D. (2008). Calcination of Roman cement: A pilot study using cement-stones from Whitby. *(p.*1446-1455). ISSN: 0950-0618. Access Address (01.01.2022) https://www.sciencedirect.com/science/article/pii/S0950061807001055

Hughes, D.C. & Starinieri, V. (2014). Formulating mortars for use in restoration practice, *ZKG International*, 2, (p.48-53).

Hurst, L. (2002). The Properties and Uses of Roman Cement. Construction History, 18, (p.21–35). Access Address (27.05.2023): http://www.jstor.org/stable/41613844

Klisińska-Kopacz, A., Tišlova, R., Adamski, G. & Kozłowski, R. (2010). Pore structure of historic and repair Roman cement mortars to establish their compatibility. *Journal of Cultural Heritage*, 11(4), (p.404-410). Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/S1296207410000531?casa_token=eFVhnIWS4DQAAAAA:NdSggFFFju2Jv4cgrCRhrf0Bm-oMbydp_BdNOi6adH1CFVh9DsNnOwivbIG9Z7NMcp6Ys2X50A

Kozlowski, R., Hughes, D. & Weber, J. (2010). Roman Cements: Key Materials of the Built Heritage of the 19th Century. *Materials, Technologies and Practice in Historic Heritage Structures*, Chapter 14, (p.259-277). Access Address (27.05.2023): https://link.springer.com/chapter/10.1007/978-90-481-2684-2_14

Livesey, P. (2015). *The Rise, Fall And Revival of Natural Cements in The Developing Pattern Of Binders*. Institute of Concrete Technology

Year Book 2013-14, publieshed by The Concrete Society.

Madencilik ÖİK Raporu. (2001). *Endüstriyel Hammaddeler Alt Komisyonu Toprak Sanayii Hammaddeleri IV (Çimento Hammaddeleri) Çalışma Grubu Raporu.* Access Address (25.01.2022): https://www.sbb.gov.tr/wp-content/uploads/2022/08/Sekizinci-Bes-Yillik-Kalkinma-Plani-Madencilik-OIK-Raporu-EndustriyelHammaddelerAltKomisyonu-ToprakSanayiHammaddeleri-IV-CalismaGrubuRaporu.pdf

Parker, J. (1796). A certain Cement or Terras to be used in Aquatic and other Buildings, and Stucco Work. *British Patent*, 2120, 27.

Starinieri, V., Hughes, D. C., Gosselin, C., Wilk, D. & Bayer, K. (2013). Pre-hydration as a technique for the retardation of Roman cement mortars. *Cement and Concrete Research*, 46, (p.1–13). Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/S0008884613000112

Strother, P. D. (2019). 2 - Manufacture of Portland Cement. O. Hewlett and Liska (Ed.). *Lea's Chemistry of Cement and Concrete (Fifth Edition)*. Butterworth-Heinemann (2019), (p.31-56). Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/B9780081007730000022

Taşkın, C. (n.d.). *Çimento Hammadde Kaynakları (kalker, kil, marn, alçıtaşı, tras, demir cevheri, kömür-asfaltit, bitümlü şist ve doğal gaz)*. Türkiye Çimento Müstahsilleri Birliği. Ankara.

Trout, A. R. E (2019). Part 1-The History of Calcareous Cements. O. Hewlett and Liska (Ed.). *Lea's Chemistry of Cement and Concrete (Fifth Edition)*. Butterworth-Heinemann (2019), (p.1-29). Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/B9780081007730000010?via%3Dihub

Türk, S. & Engin, Y. (2021). ÇİMENTO "Geçmişten geleceğe inovatif yapı malzemesi". Access address (01. 06. 2022): https://www.turkcimento.org.tr/uploads/pdf/%C3%87%C4%B0MENTOge%C3%A7mi%C5%9Ften_gelece%C4%9Fe_inovatif_yap%C4%B1_malzemesi1.pdf

Turkish Standards, (2015). *Building lime - Part 1: Definitions, specifications and conformity criteria* (TS EN 459-1). https://intweb.tse.org.tr/Standard/Standard/Standard.aspx?081118051110811180511151080511041191101040550471051021200881110431131008111805111510805110411911

Weber, J., Gadermayr, N., Bayer, K., Vyskocilova, R., Hughes, D., Kozlowski, R., ... & Ullrich, D. (2007). Roman cement mortars in Europe's architectural heritage of the 19th century. *Journal of ASTM International*, 4(8), (p.1-15). Access Address (27.05.2023): https://www.astm.org/stp45747s.html

Werner, D., & Burmeister, K. (2007). An overview of the history and economic geology of the natural cement industry at Rosendale, Ulster County, *New York. Journal of ASTM International,* 4(6), (p.1-14). Access Address (27.05.2023): https://www.astm.org/stp45742s.html

Wilk, D., Bratasz, Ł. & Kozłowski, R. (2013). Shrinkage cracking in Roman cement pastes and mortars. *Cement and concrete research*, 53, (p.168-175). ISBN: 0008-8846. Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/S0008884613000665

Yöney, N. B. (2008). *19. yüzyıl sonu ve 20. yüzyıl başı yapı cephelerinde kullanılan yapay taşların mimarlık ve koruma bilimi açısından değerlendirilmesi (Ph.D. thesis). İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul. Accessed from database Access Address (27.05.2023)*: *İstanbul Technical University Catalog*

Yöney, N. B. (2013). 'Roma Çimentosu' Tarihçesi, Özellikleri ve Onarımı. *Restorasyon ve Konservasyon Çalışmaları Dergisi* , 10, (p.53-66), Access Address (01.01.2022):https://research.ebsco.com/linkprocessor/plink?id=ce9a3952-64c4-36b1-b441-d1281f1dc454

Zhang, H. (2011). 4 - Cement, *Building Materials in Civil Engineering*. Zhang (Ed.). Woodhead Publishing, (p.46-423). ISBN: 9781845699550. Access Address (27.05.2023): https://www.sciencedirect.com/science/article/pii/B9781845699550500049?via%3Dihub

Nazife ÖZER

E-mail: onaln15@itu.edu.tr

Educational Status: M.Sc.

License: Architect/ Karadeniz Technical University

Degree: M.Sc. in Architecture/ Istanbul Technical University

Doctorate: Ph.D. Student/ Istanbul Technical University

Professional experience: Graduated from Karadeniz Technical University Faculty of Architecture in 2014, and completed her master's degree in Environmental Control and Building Technology in Istanbul Technical University, in 2018. She is studying in Construction Sciences Ph.D. Program in Istanbul Technical University. She studies on Material and Technology in Architecture. She is currently working as a Research Assistant at Istanbul Technical University.

Seden ACUN ÖZGÜNLER

E-mail: acunsed@itu.edu.tr

Educational Status: Doctorate, Istanbul Technical University

License: Istanbul Technical University

Degree: Ph. D. in Architecture

Doctorate: Istanbul Technical University

Professional experience: Prof. at İstanbul Technical University Prof. Dr. Seden Acun Özgünler graduated from Department of Architecture in Yıldız Technical University in 1997. She completed her M.Arch and Ph.D degrees in Building Sciences Programme of İstanbul Technical University. She is a faculty member in the Department of Architecture at Istanbul Technical University. She studies on Material and Technology in Architecture. There are many articles, book chapters and research projects related to her profession. Moreover, she provides consultancy support to private companies and public institutions.

Preserving the Past, Securing the Future: Energy Efficiency in Historical Buildings

Bahar ŞAHİN [1]

[1] Mimar Sinan Fine Arts University, Faculty of Architecture, PhD Student Fındıklı Campus, Istanbul/Türkiye.
ORCID: 0000-0002-5704-7665
E-mail: 20183101012@ogr.msgsu.edu.tr

Lecturer Didem BARAN ERGÜL [2]

[2] İstanbul Technical University, Faculty of Architecture, PhD Student Taşkışla Campus, Istanbul/Türkiye.
ORCID: 0000-0001-5705-8885
E-mail: ergul19@itu.edu.tr

Assoc. Prof. Dr. Ümit Turgay ARPACIOĞLU [3]

[3] Mimar Sinan Fine Arts University, Faculty of Architecture, Fındıklı Campus, Istanbul/Türkiye
ORCID: 0000-0001-8858-7499
E-mail: umit.arpacioglu@msgsu.edu.tr

Prof. Dr. Seden ACUN ÖZGÜNLER [4]

[4] İstanbul Technical University, Faculty of Architecture, Taşkışla Campus, Istanbul/Türkiye.
ORCID: 0000-0001-5975-5115
E-mail: acunsed@itu.edu.tr

Citation: Şahin, B., Baran Ergül, D., Arpacıoğlu, Ü.T. & Acun Özgünler, S. (2023). Preserving the Past, Securing the Future: Energy Efficiency in Historical Buildings. In Ü.T. Arpacıoğlu & S. Akten (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment,* (135-184). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

Buildings account for approximately 31% of the global energy demand and contribute to about one-third of energy-related carbon dioxide emissions (Castaldo, Cabeza, Boarin, Petrozzi & Cotana, 2017). Consequently, making the existing building stock energy efficient has emerged as a prominent objective in numerous countries' endeavors to curtail energy consumption. Given that energy use largely occurs in the built environment, efforts to minimize energy consumption have become a focal point. Attaining the climate and energy targets set by the European Union for 2020 necessitates not only optimizing energy efficiency in newly constructed dwellings but also addressing the energy usage of existing buildings.

Among the existing building stock, historical structures that have withstood the test of time in terms of structural integrity and functionality present opportunities for renovation and rejuvenation. These buildings await intervention to enhance their energy performance and align with sustainable practices.

Historical buildings hold significant cultural value, serving as invaluable repositories of our heritage and providing communities with a distinct sense of place and identity. Preserving these structures poses distinctive challenges, particularly regarding energy efficiency considerations.

Deep energy retrofits take into account various aspects simultaneously, including the building fabric, services, and user behavior. When applied in a way that respects heritage values, energy efficiency methods compatible with historic buildings can be created. This approach allows for the potential integration of both energy conservation and historic preservation objectives (Paschoalin, 2022).

By adopting a sympathetic and holistic approach, deep energy retrofits offer the opportunity to enhance energy efficiency in historic buildings while preserving their cultural significance. This approach considers the unique characteristics and values associated with these structures, thus ensuring their long-term sustainability and contributing to both increasing energy efficiency and preserving our cultural heritage.

1.1. The Importance Of Energy Efficiency In Historical Buildings

While practices aimed at enhancing energy efficiency in historic buildings entail certain risks, they also offer substantial advantages across various dimensions. This section delves into the importance of augmenting energy efficiency in historic buildings, scrutinizing key aspects under distinct headings.

Cultural Heritage Preservation: Preserving cultural heritage is a fundamental priority when prioritizing energy efficiency in historical buildings. By implementing energy efficient measures, these buildings can be conserved, ensuring the protection and continuation of valuable architectural and historical assets for future generations (Martinez-Molina, Tort-Ausina, Cho & Vivancos, 2016).

Contribution to Sustainable Development: The pursuit of energy efficiency in historical buildings aligns with broader sustainable development goals. By reducing energy consumption and associated carbon emissions, these buildings play a crucial role in mitigating climate change and promoting environmentally responsible practices (Kim & Felkner, 2018).

Economic Benefits: Efforts to enhance energy efficiency in historical buildings yield significant economic benefits. The reduction in energy consumption translates to lower operational costs, relieving financial burdens on building owners and ensuring the economic viability and longevity of these structures (Tadeu, Rodrigues, Tadeu, Freire & Simões, 2015).

Improved User Comfort: Energy efficient upgrades in historical buildings lead to improved user comfort. Through the implementation of insulation, efficient HVAC systems, and proper ventilation, occupants can enjoy an enhanced indoor environment with optimal thermal comfort, improved air quality, and effective lighting conditions (Berg, Flyen, Godbolt & Broström, 2017)

Facilitating Adaptive Reuse: Prioritizing energy efficiency enables the adaptive reuse of historical buildings while maintaining their architectural and historical significance. By integrating energy efficient features, these buildings can be repurposed for modern functions without compromising their intrinsic value, allowing for sustainable and viable adaptation (Foster &Saleh, 2021).

Compliance with Regulations: The operations that increase energy efficiency in historic buildings can ensure compliance with relevant regulations and codes. Adhering to these guidelines guarantees the preservation of cultural heritage and facilitates access to financial incentives, grants, and certifications that support energy efficiency initiatives for historical buildings (Cabeza, Petrozzi, Castaldo & Cotana, 2016).

In conclusion, the examination of priorities in increasing energy efficiency in historical buildings highlights its crucial role in cultural heritage preservation, contributing to sustainable development objectives, delivering economic benefits, improving user comfort, enabling adaptive reuse, and ensuring compliance with relevant regulations.

1.2. The Challenges Of Improving Energy Efficiency In Historical Buildings

The task of enhancing energy efficiency in historical buildings presents a multitude of challenges that demand meticulous attention and innovative solutions. These venerable structures, cherished for their historical and architectural significance, present unique hurdles owing to their age, construction methods, and cultural heritage value. Achieving a delicate equilibrium between preserving cultural heritage and minimizing energy consumption while mitigating environmental impact necessitates a comprehensive understanding of the intricate complexities involved. This scholarly article endeavors to examine the multifaceted challenges inherent in augmenting energy efficiency in historical buildings, offering insights into potential strategies that can surmount these impediments. Ultimately, the aim is to reconcile the preservation of cultural heritage with the imperative of sustainable practices, ensuring a harmonious coexistence between the past and the present.

Balancing energy efficiency with historic preservation: Preserving the building's historic and authentic character poses one of the primary challenges in tandem with devising energy efficient solutions. Many historic buildings have architectural and cultural significance that must be respected. This can make it challenging to implement energy efficient measures that may alter the building's appearance or historic fabric (Mazzarella, 2015).

Chemical compatibility of the original material and the new material: The behavior of historic building components can be different compared to modern structures. Historic buildings are often built on thick, permeable and breathable cladding materials such as stone, brick or wood, without moisture-resistant or vapor barrier membranes. This creates a different balance of heat and moisture than modern lightweight, vapor-tight structures. Any addition to a historic building should not compromise this balanced behavior; otherwise, the consequences can be devastating for the preservation of historic fabric and values. (Ginks & Painter, 2017).

Limited space for insulation: Many historic buildings were constructed without modern insulation materials, which can make it difficult to implement solutions to improve energy efficiency. The limited space for insulation may also be complicated by architectural features, such as ornate moldings, cornices, or facades that cannot be altered (Qu, Chen, Wang, Calautit, Riffat & Cui, 2021).

Incompatibility with modern building codes: Historic buildings may not be compatible with modern building codes and regulations that require energy efficient features, such as insulation, air sealing, and high-performance windows. Compliance with these codes can be difficult without compromising the historic integrity of the building (Ginks & Painter, 2017).

The behavior of historic building components can be different compared to modern structures. Historic buildings are often built on thick, permeable and breathable cladding materials such as stone, brick or wood, without moisture-resistant or vapor barrier membranes. This creates a different balance of heat and moisture than modern lightweight, vapor-tight structures. Any addition to a historic building should not compromise this balanced behavior; otherwise, the consequences can be devastating for the preservation of historic fabric and values (Blumberga, Chen, Ozarska, Indzere & Lauka, 2019).

High cost: The expense of boosting energy efficiency in historic buildings can escalate, particularly if the building demands extensive structural repairs or upgrades. This can make it challenging for building owners to justify the cost of these improvements (Gulbinas & Taylor, 2014).

Lack of awareness and expertise: There may be a lack of awareness and expertise among building owners, architects and contractors on the best energy efficiency solutions for historic buildings. This can result in suboptimal or ineffective energy efficient measures that do not provide the desired benefits (Gulbinas & Taylor, 2014).

Complex ownership structures: Historic buildings may have complex ownership structures, which can make it challenging to coordinate and fund energy efficient improvements. Some buildings may be owned by multiple parties, such as government agencies, non-profit organizations, or private individuals, each with their own interests and priorities (Castaldo et al., 2017).

Overall, increasing energy efficiency in historic buildings presents several challenges and problems. However, with careful planning, innovative solutions, and collaboration among stakeholders, it is possible to overcome these challenges and preserve historic buildings for future generations while improving their energy performance.

2. Material and Method

This study centers on the interplay between historic buildings and energy efficiency improvements, aiming to present general approaches that can effectively increase energy efficiency. In addition to these, thermal insulation materials, window solutions, energy efficient luminaires, heat recovery and automation systems as well as different innovative technologies and materials are also emphasized. As a method, approaches based on legislation and regulations related to energy efficiency in Turkey and the world are explained and discussed through examples.

The study begins by providing an overview of the challenges and benefits associated with the energy efficient transformation of historical buildings. It then discusses the different techniques for the energy efficient transformation of historic buildings, with a focus on thermal insulation, window replacement, renewable energy systems, and energy efficient lighting. The study also discusses the importance of considering the cultural heritage value of historic buildings when making decisions about energy efficiency interventions.

The study concludes by arguing that the energy efficient transformation of historical buildings is a complex and challenging task, but that it is an important one that can contribute to both environmental protection and economic sustainability. The study also recommends further research on energy efficient conversion of historic buildings in order to develop more effective and sustainable approaches.

3. Findings and Discussion

The literature-based research suggests that energy efficient transformation of historical buildings is a complex and challenging task, but it is an important one that can contribute to both environmental protection and economic sustainability. The energy efficiency of historical buildings can be improved through the implementation of diverse techniques, including thermal insulation, window replacement, renewable energy systems, and energy efficient lighting. When making decisions about energy efficiency interventions, it is important to ensure that the cultural heritage character of historic buildings is preserved. More in-depth studies are warranted to cultivate better and sustainable approaches for the energy efficient transformation of historical buildings.

The findings of this study suggest that energy efficient renovation of historical buildings is important for both the environment and the economy. Reducing energy consumption in historic buildings can lead to benefits such as reducing carbon emissions and improving quality of life. These findings also demonstrate that energy efficient transformation of historic buildings can be a valuable tool for policy makers and practitioners.

However, energy efficient conversion of historic buildings is still a relatively new field and there is limited data on its long-term effects. Future research should focus on evaluating the economic and structural sustainability of energy efficient transformation of historic buildings over the long term. Additionally, it is important to carefully define the limits of intervention in order to avoid practices that conflict with the preservation of the original state of the buildings.

The following are some of the key points that are made in the paragraph:

- The energy efficient transformation of historic buildings is a complex and challenging task, but it is an important one that can contribute to both environmental protection and economic sustainability.
- There are a number of different techniques that can be used to improve the energy efficiency of historical buildings.
- Since the behavior and visual impact of additional treatments and materials in historic buildings may be different than in modern buildings, it is important to work on the development of new materials and technologies.
- It is important to consider the cultural heritage value of historic buildings when making decisions about energy efficiency interventions.
- Further research is needed to develop more effective and sustainable approaches to energy efficiency in historical buildings.
- The long-term effects of energy efficient transformation of historic buildings are not yet fully understood.
- It is important to carefully define the limits of intervention in order to avoid practices that conflict with the preservation of the original state of the buildings.

3.1. Energy Efficiency Approaches in Türkiye

Turkey has seen the fastest growth in energy demand among the Organization for Economic Cooperation and Development (OECD) countries over the past 20 years. During this period, Türkiye ranked second in the world after China in terms of electricity and natural gas demand growth (Turkey's International Energy Strategy, 2023).

On energy efficiency, Turkey is committed to developing national strategies. The Ministry of Environment, Urbanisation and Climate Change and The Ministry of Energy and Natural Resources are the leading institutions in Turkey's energy efficiency and building activities.

The Ministry of Environment, Urbanisation and Climate Change is an organization responsible for environmental and urban planning and aims to create sustainable cities and settlements, ensure effective and efficient use of energy and energy resources in buildings, prevent energy waste and protect the environment. On 25 February 2022, the Ministry of Environment, Urbanization and Climate Change organized the Climate Council 2022. Some of the important decisions taken at the Climate Council include preparation of a Long Term Energy Plan in line with the 2053 Net Zero Emission Target, carrying out the necessary work to maximize the use and diversification of renewable energy resources, preparation of a National Energy Efficiency Action Plan (2024-2030) by mid-2023, expanding heat pump, district heating (geothermal, biomass, etc.) and solar collector heating applications for emission reduction in heating and cooling, increasing the use of renewable energy resources, advancing renewable energy technologies and developing support mechanisms for R&D activities and production of these technologies. (Climate Council Decisions, 2022).

One of the authorized institutions responsible for promoting the efficient utilization of energy and natural resources in Turkey is the Ministry of Energy and Natural Resources.

Some of the committees and organizations related to energy efficiency of which Turkey is a member are as follows:

IEA (International Energy Agency): The IEA plays a central role in shaping the global energy conversation by offering authoritative analysis, data, policy guidance, and practical solutions, enabling nations to ensure secure and sustainable energy access for everyoneTurkey is among the founding members of the IEA (Turkey's International Energy Strategy, 2023).

IRENA (International Renewable Energy Agency): Turkey is a founding member of the International Renewable Energy Agency (IRENA). IRENA, established in 2011, is a global organization with a primary goal of fostering the extensive adoption and growth of renewable energy to achieve sustainable development. (Turkey's International Energy Strategy, 2023).

Energy Charter Treaty: The Energy Charter Treaty is a pact designed to uphold energy security by fostering transparent, competitive markets, and advancing sustainable development principles. Within this framework, provisions encompass regulations pertaining to energy investments, energy trade, energy efficiency, and mechanisms for resolving disputes. (Turkey's International Energy Strategy, 2023).

ICOMOS ISCES (International Committee on Energy and Sustainability): ISCES is one of the technical bodies of ICOMOS. ISCES researches and promotes the understanding, protection, conservation, preservation and management of built cultural heritage, taking into account energy, sustainability and climate change requirements (ICOMOS, 1965).

3.1.1. The Laws And Regulations In Turkey That Promote Energy Efficiency In Historical Buildings

Below are descriptions of several laws and regulations implemented by Turkey to enhance energy efficiency in buildings.

Energy Efficiency Law No. 5627: Energy Efficiency Law entered into force in 2007. It provides a 10-year transition period. It is obligatory to apply especially in buildings to be constructed after the publication date of the Law. By focusing on increasing efficiency and promoting responsible energy consumption, the Law aims to protect the environment, minimize energy waste, and alleviate the economic impact of energy costs. Furthermore, it advocates for the utilization of renewable energy and strives to increase public consciousness about energy concerns. Buildings or monuments under protection are excluded from the scope of this Law (Energy Efficiency Law 5627, 2007).

Building Energy Performance Regulation: Based on Law No. 5627, the Regulation was published in 2007. Included in the document are insights into the building's energy needs and consumption classification, along with comprehensive data on insulation properties and the efficiency of heating and cooling systems. Its ultimate objective is to foster the effective and efficient utilization of energy and resources in buildings, prevent energy waste, decrease energy expenses, and uphold environmental protection. Article 2d of the Regulation, which concerns historical buildings, reads as follows; "It covers the measures and practices for increasing energy efficiency in buildings registered as cultural assets that need to be protected, and the works and procedures related to taking the opinion of the Cultural and Natural Heritage

Preservation Board and making energy efficiency-enhancing applications in a way that does not affect the characteristics and external appearance of the building in line with this opinion." (Building Energy Performance Regulation, 2007)

With the "Regulation Amending the Building Energy Performance Regulation" prepared by the Ministry and published in the Official Newspaper dated February 19, 2022, the renewable energy obligation in buildings starts on January 1, 2023. With the regulation, the transition to the concept of "Nearly Zero Energy Buildings", which are more energy efficient than normal buildings and provide a certain portion of the energy they use from renewable energy sources, has been gradually made compulsory (Renewable Energy Obligation in Buildings, 2022).

Building Energy Certificate: The Energy Efficiency Law and the Building Energy Performance Regulation necessitate the preparation of a 'Building Energy Certificate (Enerji Kimlik Belgesi),' which contains information about the building's minimum energy requirements, energy performance classification (ranging from A as the best to G as the worst), insulation properties, efficiency of heating-cooling systems, and general building details. This certificate remains valid for a period of ten years. The certification requirement applies to both new buildings and existing buildings with a total area of use exceeding 1000m2. Existing buildings must obtain an energy performance certificate within ten years from the date of the Energy Efficiency Law's publication. Certification for new buildings is mandatory from January 2011 (Ulu, 2018).

A software program called BEP-TR, which runs on the servers of the Ministry of Environment, Urbanization and Climate Change and performs the energy calculations of the building, is used to create the Building Energy Certificate.

TS 825- Thermal Insulation Requirements for Buildings: The final version was published in December 2013. The purpose of the TS 825 standard is to minimize the energy consumption involved in heating of buildings to increase energy savings and to determine the standard calculation method and values of energy requirements (TS 825, 2013). Furthermore, this standard serves various purposes, including identifying the optimal energy performance design option for new buildings, evaluating the net heating energy consumption of existing buildings, and assessing potential energy-saving measures that can be implemented in existing buildings prior to renovation. (Genç, 2022).

National Energy Efficiency Action Plan: In 2017, Turkey developed a National Energy Efficiency Action Plan, which sets out a roadmap for enhancing energy conservation in all sectors, including buildings. The plan includes measures such as increasing public awareness of energy efficiency, promoting energy efficient technologies, and developing financial mechanisms to support energy efficiency investments (NEEAP, 2017).

Green Building Certification Systems: Turkey has several green building certification systems, such as the LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) certifications. These certifications recognize buildings that meet high standards of energy efficiency, sustainability, and environmental performance. Historic buildings can receive Green Building Certification (Kurnaz, 2021).

Incentives for Energy Efficiency Investments: Turkey provides various incentives for energy efficiency investments, such as subsidies, loans, and tax incentives. For example, the government offers a grant program for energy efficiency investments in buildings, and tax incentives for companies that invest in energy efficient technologies (Kurnaz, 2021).

Energy Efficiency Guide for Historic Buildings: Developed by the Association for the Protection of Cultural Heritage within the scope of the KORU PROJECT. The primary objective of this guide is to provide valuable recommendations to owners and occupants of historic buildings regarding energy efficiency solutions. These solutions not only enhance heating performance, reduce carbon emissions, and lower fuel expenses but also achieve increased energy efficiency without compromising the authentic charm of these historically significant structures. (Data Bank Koru Project, 2020).

It is important to note that these laws and regulations apply to both new and existing buildings, and aim to improve energy efficiency across the entire building stock in Turkey.

3.1.2. Case Studies Of Successful Energy Efficiency Transformations In Historical Buildings In Turkey

In Turkey, there are instances of historical buildings that have undergone energy efficiency improvements.

Private Saint-Joseph French High School, Block C: One of the examples of energy efficient restoration is the Historic Bakery Building at the Private Saint-Joseph French High School in Istanbul (Figure 1).

Figure 1. Historic Bakery Building (Block C) (İstanbul Saint-Joseph Lisesi'nden Çevre Dostu Bina, 2022).

The Historic Bakery Building (Block C) has been awarded a Gold level certificate in the LEED v4 Building Design and Construction category. The building, which was built in 1913 and met the school's bread needs until the end of the 1950s, was restored in accordance with its historical texture in line with the LEED target (İstanbul Saint-Joseph Lisesi'nden Çevre Dostu Bina, 2022).

As part of the restoration project, care was taken to preserve the architectural integrity and use original building materials, while focusing on low energy consumption to contribute to sustainable development. The building is now used as the workspace of the high school's communication department and hosts the activities of the Robotics, Coding, Maker Lab and Cooking clubs (İstanbul Saint-Joseph Lisesi'nden Çevre Dostu Bina, 2022).

The building's main structural system and exterior walls were preserved, while flooring and roofing materials were restored and reused. In the newly selected construction materials, priority was given to materials with recycled content and the use of certified wood. Facade glazing, lighting systems and mechanical system selections were designed in accordance with ASHRAE 90.1-2010 standards. With the PV system installed in the campus, some of the energy needs of the building are met from solar energy. The use of mains water has been reduced with the selection of water fixtures with low water consumption. To improve indoor air quality, the amount of fresh air supplied to the spaces is kept above the ASHRAE 62.1 standard. Adequate daylighting was prioritized during glass selection and interior design (Altensis, 2023).

Tamirevi: Another example of energy efficient restoration is the 200-year-old stone residential building in Mardin.

Tamirevi, a historical building, is an example of a traditional Mardin house. As part of the KORU Project, the restoration site of the Tamirevi has hosted a conservation camp for university students as well as workshops with local carpenters and stonemasons since 2017. Throughout the restoration process, tours were organized with the participation of local residents and students. The lower floor was designed as an exhibition space and the upper floor as an artist's residence. In 2019, the restoration process was completed and opened (Figure 2) (Tamirevi, 2020).

(b)

(a) (c)

Figure 2. (a) Front facade of the building, (b) Courtyard, and (c) Interior space (Tamirevi, 2020).

The Tamirevi restoration is an energy efficient architectural conservation model that will support capacity building in the domain of preserving cultural heritage in the Mardin region. In addition to passive energy efficiency methods, technologies such as photovoltaic panels, air source heat pump and heat recovery device were used in the restoration project and implementation (Tamirevi, 2020).

Within the scope of the building envelope improvements, thermal insulation was applied on the roof and ground floor, since covering the interior or exterior of the masonry stone walls of the Tamirevi would cause it to lose its originality. Since the original windows of the building were lost, a double-glazed window was designed and applied based on the traditional window typology (Topaloğlu, 2020).

Since the photovoltaic panels placed on the roof have the risk of damaging the historical silhouette of Mardin, they were placed at a low angle facing east-west to minimize the visibility of the panels (Figure 3). The air-source heat pump was determined as the most suitable heating system for Mardin's climate and geography. The hot or cool water pipes coming from the heat pump's boiler were placed under the floor in order not to damage the original texture (Figure 4). The electrical system was also run through the pans under the slab. In addition to this, a simple cover was produced to prevent the overheating problem on the south facade and to make the terrace more comfortable to use in summer. The courtyard and terrace were landscaped with potted plants to create a cooling effect in the open spaces (Topaloğlu, 2020).

Figure 3. The photovoltaic panels placed on the roof (Topaloğlu, 2020).

Figure 4. The hot and cool water pipes (Topaloğlu, 2020).

3.1.3. Challenges and limitations to energy efficiency in historical buildings in Turkey

Limitations:

The law on the protection of cultural assets in Turkey is the Law No. 2863 on the Protection of Cultural and Natural Assets. This law aims to define and protect movable and immovable cultural and natural assets, regulate related transactions and activities, and establish an organization responsible for making essential decisions and overseeing the implementation of these principles. Pursuant to Law No. 2863, the institutions that determine the forms of intervention in historical buildings and establish restrictions are the "High Council for the Protection of Cultural Assets" under the ministry and the "Regional Board Directorates for the Protection of Cultural Assets" authorized in the regions to be determined by the ministry (Law No. 2863, 1983).

The types of interventions to historical buildings are determined by the Resolution No. 660 (Grouping, Maintenance and Repairs of Immovable Cultural Assets) taken by the Republic of Turkey Ministry of Culture, High Council for the Protection of Cultural and Natural Assets. According to this law, historical buildings are divided into two groups (Resolution No. 660, 1999).

1st Group Buildings:

These are the structures that must be preserved with their historical, symbolic, memorial and aesthetic qualities within the cultural data that constitute the material history of the society.

2nd Group Buildings:

They are cultural assets that contribute to the urban and environmental identity and reflect the local way of life.

The types of interventions to historic buildings will be determined according to the specific conditions of each building. The types of interventions determined by this law are maintenance, simple repair, major repair (restoration) and reconstruction (Resolution No. 660, 1999).

Challenges:

Energy efficiency in historical buildings in Turkey faces several challenges and limitations due to their unique architectural and structural characteristics. Some of these challenges are;

Architectural Constraints: Historical buildings in Turkey often have architectural features and construction methods that were not designed with energy efficiency in mind. Thick stone or brick walls, vaulted ceilings, and small windows are common features that make it difficult to implement modern energy-saving measures without compromising the historical integrity of the structure (Gálvez, Hita, Martín, Conde & Liñán, 2013).

Preservation Requirements: Historical buildings are subject to strict preservation regulations and guidelines to protect their cultural and historical significance. These regulations may limit the extent to which energy efficient retrofits can be implemented, as they often prioritize preserving the original features and materials. Introducing new insulation materials or altering the building envelope may be restricted or require special permission (Fabbri, Gabrielli &Ruggeri, 2018).

Lack of Awareness and Education: The benefits and methods of energy efficiency might not be well-known or understood by numerous historical building owners, occupants, and stakeholders. They may prioritize preserving the historical value over energy savings or may be unaware of available technologies and funding options for energy efficient upgrades.

Funding and Financial Constraints: Retrofitting historical buildings with energy efficient measures can be costly, and the financial resources required may not always be available. Many historical buildings are privately owned or used for cultural purposes, making it challenging to secure funding for energy efficiency projects. The return on investment may also be perceived as less attractive compared to other types of buildings (Işık, 2022).

HVAC Limitations: Historical buildings often lack modern heating, ventilation, and air conditioning (HVAC) systems. Integrating energy efficient HVAC systems can be challenging due to limited space for ductwork, ventilation shafts, and equipment. Balancing the need for improved indoor comfort with preserving the original architectural features can be a complex task.

Heritage Compatibility: Energy efficiency measures, such as adding insulation or upgrading windows, may need to be carefully selected and customized to match the architectural style and heritage of the building. Finding solutions that are both effective in reducing energy consumption and compatible with the historical aesthetics can be a significant challenge (Sekularac, Ivanović-Šekularac, Petrovski, Macut & Radojević, 2020).

Limited Technical Expertise: Implementing energy efficiency measures in historical buildings requires specialized knowledge and expertise. The availability of professionals with experience in retrofitting historical buildings to improve energy efficiency may be limited, leading to a lack of technical support for owners and occupants.

3.2. Energy Efficiency Approaches Around the World

Energy efficiency approaches around the world vary depending on the country's priorities, available resources, and technological advancements. The energy efficiency approaches of some countries are described below.

European Union (EU): The Energy Performance of Buildings Directive (EPBD) is a key piece of legislation in the EU that aims to improve the energy performance of buildings, including historic buildings. The EPBD lays down minimum energy performance standards for both new and existing buildings, and it stipulates that all new constructions must achieve almost zero-energy status by the end of 2020. The EU also provides funding for energy efficiency projects in historic buildings through the Horizon 2020 program, which includes funding for research, demonstration projects, and market uptake of energy efficient solutions (Mazzarella, 2015).

United States (US): The Secretary of the Interior's Standards for the Treatment of Historic Properties, developed by the National Park Service (NPS), offer guidance on striking a balance between preservation and energy efficiency when dealing with historic buildings. The NPS also provides technical assistance and funding for energy efficiency improvements to historic buildings through its Preservation Assistance Grants program. The Energy Policy Act of 2005 provides tax incentives for energy efficient improvements to historic buildings, including a tax deduction of up to $1.80 per square foot for building owners who make energy efficient improvements to commercial buildings (Luo, Lu, & Ge, 2020).

United Kingdom (UK): The UK government provides grants and loans for energy efficiency improvements to historic buildings through the Green Deal and the Heritage Lottery Fund. The Green Deal provides loans to homeowners and businesses to make energy efficient improvements to their properties, while the Heritage Lottery Fund provides grants for heritage projects, including energy efficiency improvements. The Building Regulations require all new buildings to meet certain energy efficiency standards, and the Code for Sustainable Homes provides a framework for assessing and improving the sustainability of new homes (Jahed, Aktaş, Rickaby, & Altınöz, 2020).

Australia: In Australia, the National Construction Code (NCC) offers guidance on energy efficiency retrofits for buildings, including historic ones, considering their distinctive features and conservation needs. The NCC incorporates provisions for insulation, glazing, lighting, and HVAC systems to enhance energy efficiency in buildings, including heritage structures. Additionally, specific states and territories in Australia have their own regulations and guidelines for energy efficiency in historic buildings. For instance, the New South Wales Heritage Energy Efficiency Guidelines provide detailed instructions on retrofitting heritage buildings to improve energy efficiency while preserving their heritage values. These guidelines cover aspects such as insulation, window upgrades, and heating and cooling systems. (Trencher, Broto, Takagi, Sprigings, Nishida & Yarime, 2016).

In Japan, the Act on the Promotion of Renovation for Energy Conservation of Existing Buildings (RECB) was enacted in 2009 to promote energy efficiency improvements in existing buildings, including historic buildings. The RECB provides financial incentives and support for building owners to undertake energy efficiency renovations, including those in historic buildings. The act encourages the use of energy efficient technologies, such as insulation, efficient lighting, and HVAC systems, in the renovation process. Furthermore, Japan has established the Certified Traditional Buildings Energy Conservation System (CTBECS) to address the unique challenges of energy efficiency in traditional and historic buildings. CTBECS offers a structured approach to assess and certify the energy effectiveness of traditional architecture, considering their architectural and cultural importance. This system promotes the integration of energy efficient practices while preserving the buildings' traditional characteristics (Kimura & Noda, 2014).

3.2.1. Overview Of International Laws And Regulations That Promote Energy Efficiency In Historical Buildings

The Energy Performance of Buildings Directive (EPBD) (2002/91/EC) directly impacts the building sector as the key regulatory framework in energy efficiency policy.The Directive entered into force on January 4, 2003. It was recast as the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) on 19 May 2010. On 19 June 2018, it was revised for the 2nd time and published as the Energy Performance of Building Directive (EPBD) (2018/844/EU) (Ulu, 2018).

Energy Efficiency Directive (EED) (2012/27/EU): The Directive, as the most recent EU framework for energy efficiency, was legally adopted on

October 25, 2012, following the Energy Efficiency Plan 2011 (Ulu, 2018).

In 2012, under the organization of ICOMOS International Council on Monuments and Sites, a separate unit called ISCES - International Scientific Committee on Energy and Sustainability (2012) was established, of which Turkey is a member. This unit was established by ICOMOS for the protection of heritage sites and for the healthy implementation of energy saving and sustainable development principles in heritage sites (Genç, 2022).

The European standard EN 16883:2017 (Conservation of cultural heritage - Guidelines for improving the energy performance of historic buildings) aims to facilitate a systematic interdisciplinary planning process that recognizes the challenges and opportunities for improving the energy performance of historic buildings and identifies solutions on a case-by-case basis (Leijonhufvud, Broström & Buda, 2021).

GBC Historic Building® is a certification tool to guide and assess the environmental sustainability and energy efficiency of historic buildings. It was published in 2015. This new Italian rating system was developed to address challenges concerning the synthesis of environmental, energy efficiency, and indoor environmental quality goals during the restoration process. The tool's purpose is to assist stakeholders in effectively and comprehensively planning all phases of the building process, promoting a conscious and sustainable conservation approach. By doing so, the historic building can continue to serve as a cultural identity while fulfilling contemporary requirements. (GBC Historic Building, 2015).

Enerphit Passive House criteria, Passive House Institute, founded in 1996, standardized the concept of passive house. With the institute established in the city of Darmstadt, over 25 thousand passive houses have been built, mostly in Germany and Austria. With this criterion, it is aimed to create a building standard that is economical, comfortable, environmentally sensitive and energy efficient. The Passive House Institute has developed a quality-approved energy renovation certificate for existing and protected buildings called "Passive House Components EnerPhit" together with the new building standards it has set. With this certificate system, renovation projects in historical buildings are evaluated and graded (Genç, 2022).

3.2.2. Case Studies Of Successful Energy Efficiency Transformations In Historical Buildings Around The World

The Empire State Building, New York City, USA: The energy efficiency upgrades at the building included the installation of new windows with insulating properties that reduce heat loss, a building management system that optimizes heating, cooling, and lighting based on occupancy and other factors, and the application of insulation to the building's walls and roof (Figure 5). The upgrades also included the installation of high-efficiency lighting and HVAC systems. These upgrades helped the building reduce its energy consumption by 38% and save $4.4 million per year on energy costs (The Empire State Building, 2023).

Figure 5. The Empire State Building (Rahmanan, 2022).

The Reichstag Parliament Building, Berlin, GERMANY: Before the fire, it was one of the most important historical buildings in Germany. However, after its restoration, it is both an important and exemplary building and is known all over the world as a low-energy, environmentally friendly historical building (Figure 6). The Reichstag building uses geothermal energy, natural ventilation, natural lighting and integrated solar cells from active solar energy systems. The 100 PV panels installed on the terrace roof floor provide approximately 40 kW of energy (Figure 7) (Özeler Kaan, 2012).

Figure 6.The Reichstag Parliament Building (Reichstag New German Parliament, 2023).

Figure 7. PV Panels installed on the roof of the Reichstag Parliament Building (Recharge, 2023).

Ca Foscari University Building, Venice, Italy: It was designed by architect Bartolomeo Bon for the Foscari family and built in 1453. The building has been used for many functions over time and as of 1868, it continues to function as the general building of Ca Foscari University (Figure 8) (Balçık & Yamaçlı, 2022).

Figure 8. Ca Foscari University Building, Venice, Italy (University Ca Foscari of Venice, 2023).

In 2013, the building received LEED certification as a result of the energy efficiency measures implemented in the building. Some of the energy efficiency measures implemented in the building include obtaining all the energy used from renewable sources, using energy efficient lamps, upgrading electrical systems and installing a high-efficiency heat generator (Balçık & Yamaçlı, 2022).

When the building received its certificate, it became the oldest LEED certified building. In addition to energy efficiency practices, the building includes other sustainability activities such as water efficiency, waste management, and the development of sustainable living behaviors (Balçık & Yamaçlı, 2022).

3.3. Energy Efficiency Improvements In Historical Buildings

Energy efficiency transformations in historical buildings can be challenging due to the need to preserve the building's historical character and architecture while also making energy efficiency improvements. However, there are several improvements and methods that can be used to improve energy efficiency in historical buildings. Here are some of these methods:

Building envelope improvements: One of the most effective ways to improve energy efficiency in historic buildings is to make improvements to the building envelope. This can be achieved by adding insulation to walls, floors and roofs, replacing windows with high-performance windows, ensuring air tightness and optimizing daylighting techniques through proper design and the use of advanced materials and components to reduce thermal losses of structures. The use of insulation or advanced materials, together with the implementation of natural ventilation techniques, improves the thermal performance of buildings. However, these improvements need to be carefully planned to ensure that they do not harm the historic fabric of the building. For example, insulation can be added to the interior of the walls instead of the exterior to preserve the historic façade of the building (Garín, García, Betanzos, Minguillón & Baïri, 2020).

HVAC upgrades: The HVAC system consists of various components that perform tasks such as heating, cooling, providing fresh air, humidifying, dehumidifying. In historic buildings, the HVAC system either does not exist or cannot fulfill its function, so the addition of these systems is an important part of the renovation plan. However, the distinctive architectural elements and legal constraints could pose limitations on the implementation or substitution of HVAC systems with different technologies in historic buildings (Abdelrazek, 2019).

Artificial lighting systems: Artificial lighting accounts for nearly one-fifth of the global electricity consumption, contributing to heat buildup within the space and subsequently increasing the building's cooling load.

Consequently, employing more efficient lamps plays a significant role in conserving energy. Presently, there is a wide range of lamp options with varying efficiencies, such as incandescent, tungsten halogen, fluorescent, metal halide, low-pressure sodium, high-pressure sodium, and light-emitting diodes (LEDs) (Bayraktar, 2015). In addition, lighting automation systems are an important factor that reduces energy use by providing the necessary lighting needs at different times of the day and year in a controlled manner.

Renewable energy: Renewable energy systems can be used to generate electricity or provide heating and cooling to historic buildings.

Solar thermal systems, photovoltaics, solar hybrid collectors can be listed as solutions to effectively reduce energy consumption. These include heat pumps as heating and cooling systems that utilize outdoor air, groundwater, and heat stored in the ground (Sesana, Bertolin, Gagnon & Hughes, 2019). There are difficulties in the use of these systems in historic buildings due to the risk of deterioration of original, aesthetic features and legal restrictions. These risks should be considered when integrating renewable energy systems into historic buildings, for example with the use of building integrated PV systems such as photovoltaic tiles, it may be possible to increase energy efficiency without damaging the original values of historical buildings.

Energy management systems: Energy management systems can be used to monitor and control energy use in historical buildings. These systems can help building owners and managers identify areas of high energy use and make adjustments to reduce energy consumption. For example, lighting and HVAC systems can be automated to turn off when not in use, and building occupants can be encouraged to use energy efficient practices, such as turning off lights and unplugging electronics when not in use (Berg et al.,2017).

Green roofs and walls: Green roofs and walls can help improve energy efficiency in historical buildings by providing insulation and reducing heat gain. Furthermore, green roofs and walls have the potential to enhance air quality and offer wildlife habitats in urban environments (Mazzarella, 2015).

These are just a few examples of technologies and methods for energy efficiency conversions in historic buildings. Ultimately, the most effective approach will depend on the building and its historic context. It is important to work with experienced professionals who understand the unique challenges and opportunities of improving energy efficiency in historic buildings.

3.3.1. New And Innovative Technologies And Materials That Are Being Used To Improve Energy Efficiency In Historical Buildings

Innovative Technologies:

Digitalization of historic buildings, energy analyses, life cycle monitoring, etc. are also essential factors for monitoring and improving the energy efficient transformation of buildings. Here are some examples:

Historic Building Information Modeling (HBIM): HBIM serves as an integrated methodology for modeling, monitoring, managing, and maintaining energy retrofit projects in historical buildings (Piselli et al., 2020). HBIM combines digital modeling techniques with building monitoring and supervision systems to optimize energy performance and indoor comfort (Piselli, Guastaveglia, Romanelli, Cotana & Cabeza, 2020).

Airtightness Analysis: Airtightness analysis, conducted through blower door tests, is being employed to assess the energy efficiency of historical buildings. By identifying and addressing air leakage issues, energy losses can be minimized, leading to improved energy performance (Garín et al., 2020).

Technological Innovations: Technological innovations, such as smart building concepts, automated lighting control systems, and digital technologies like three-dimensional laser scanning and virtual reality, are being utilized to improve energy efficiency and preservation efforts in historical buildings (Martinez-Molina et al., 2016; Mazzarella, 2015).

Wireless sensors and controls: Wireless sensors and controls can be used to monitor and control energy use in historical buildings. They can be used to adjust lighting and HVAC systems based on occupancy, temperature, and other factors. Wireless sensors and controls can be particularly effective in historical buildings where the installation of traditional wired systems may not be possible or may be prohibitively expensive. They can also be used to provide real-time energy data, which can help building owners and managers identify areas of high energy use and implement strategies to reduce energy consumption (Bourdeau, Waeytens, Aouani, Basset & Nefzaoui, 2023).

These examples demonstrate the diverse range of technologies and methods being employed to improve energy efficiency in historical buildings. By combining innovative approaches with preservation considerations, it is possible to achieve sustainable and energy efficient solutions while respecting the historical and cultural significance of these buildings.

Innovative Materials:

With the development of technology, innovative materials, insulation materials, panels, smart glasses, etc. are produced in thinner thicknesses, in different forms, with features that can adapt to historical buildings. Some of these materials are described below.

Vacuum insulated panels (VIPs): VIPs are ultra-thin, high-performance insulation panels that are made up of a core material, such as fiberglass or aerogel, which is enclosed in a vacuum-sealed panel. This design helps to reduce heat transfer by eliminating air pockets and convection currents within the insulation. VIPs are highly effective at reducing heat loss through walls and roofs, and they can be installed in very thin layers, making them ideal for use in historical buildings where space is limited (Alotaibi & Riffat, 2014).

Aerogel insulation materials: Aerogels are the least dense open porous materials among the synthesized solid porous and porous materials. These materials are being developed to fill areas with suitable gaps between walls and claddings. In addition, these materials can be produced in a water-resistant water vapor permeable form in order not to damage the historic building envelope (Genç, 2022).

Radiant reflective coatings: Radiant reflective coatings are an application that can improve thermal insulation performance without having an intrusive effect on the historic building envelope. For example, a high infrared (IR) reflective coating was developed in the EU-funded EFFESUS research program to promote energy efficiency improvements in historic buildings. This coating reduces the solar heat absorbed by the building envelope. This material is water vapor permeable and does not damage the building envelope (Genç, 2022).

Phase change materials (PCMs): PCMs are materials that can absorb and release heat as they change phase from a solid to a liquid or from a liquid to a gas. They are often incorporated into building materials, such as wallboard or plaster, to help regulate temperature and reduce energy use. PCMs can be particularly effective in historical buildings where temperature regulation can be challenging due to the building's construction and materials. They can also be used to reduce peak demand on HVAC systems, which can help to lower energy costs (Lencer, Salinga, Grabowski, Hıckel, Neugebauer & Wuttig, 2009).

Smart glass: Smart glass is a type of glazing that can change its opacity based on external conditions. It can be used to reduce solar heat gain in the summer, while still allowing natural light into the building. Smart glass can be particularly effective in historical buildings where the installation of traditional shading systems, such as blinds or shutters, may not be possible or desirable. Smart glass can also be used to enhance the aesthetic appeal of the building by providing a modern, high-tech appearance (Ke, Zhou, Zhou, Wang, Chan & Long, 2018).

Light-emitting diodes (LEDs): LEDs are a type of lighting technology that can provide high-quality, energy efficient lighting. They are particularly well-suited for use in historical buildings where traditional lighting fixtures may not be energy efficient or may not be compatible with the building's electrical system. LEDs can also be used to highlight architectural features of the building, such as moldings or artwork. They are highly durable and long-lasting, which can help to reduce maintenance costs over time (Pode, 2020).

4. Conclusion and Suggestions

The energy efficient transformation of historic buildings is a significant issue for both the environment and the economy. Historic buildings are generally less energy efficient than new buildings, but they can be made more energy efficient through the use of appropriate techniques.

In Turkey and around the world, there are many projects underway to improve the energy effectiveness of heritage buildings. The primary objectives of these projects are to decrease energy consumption, diminish carbon emissions, and enhance the overall living conditions in historical buildings.

There are both threats and opportunities associated with the initiative to improve energy performance in heritage buildings. Threats include the preservation of the authenticity of historic buildings, financing issues, and technical challenges. Opportunities include energy savings, reduced carbon emissions, and improved quality of life.

Energy efficient conversion of historic buildings is an important issue for both the environment and the economy. Threats and opportunities should be recognized and projects for energy efficient conversion of historic buildings should be carried out with these threats and opportunities in mind. This conversion reduces energy consumption, lowers carbon emissions and improves the quality of life in historic buildings. Therefore, it is a necessary step for a sustainable future.

It is important to work on reducing the constraints and challenges of energy efficient conversion and promoting energy efficiency in historic buildings. This includes research and development of innovative solutions, raising awareness, providing financial incentives and support, finding appropriate and sensitive energy efficient conversion options for historic buildings, and encouraging collaboration between stakeholders such as users, engineers, preservationists, etc.

Some research and studies are being conducted worldwide on innovative technologies and materials applied in historic buildings. With the development and continuation of these studies, it will be possible to create the most appropriate solutions that will not deteriorate the original features of historical buildings and to diversify the interventions that can be made to historical buildings.

Technologies such as digitization of historic buildings, energy analytics, life cycle monitoring, etc. will provide opportunities for monitoring energy efficient transformation of buildings, tracking and improving energy gains.

Thanks and Information Note

This study was supported by the 2023 MSGSU BAP Project titled "Investigation of Energy Efficiency of Historic Buildings in Perşembe Pazarı Area".

The e-book section complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to The e-book section.

References

Abdelrazek, H. (2019). *A Methodology Towards Cost-Optimal And Energy Efficient Retrofiting Of Historic Buildings: A Case Study Of Istanbul University (Master's thesis). The Republic of Turkey Bahcesehir University, İstanbul.*

Alotaibi, S. S. & Riffat, S. (2014). Vacuum İnsulated Panels For Sustainable Buildings: A Review Of Research And Applications. *International Journal Of Energy Research*, (38), 1–19. DOI:10.1002/er.3101.

Altensis, (2023). Private Saint Joseph French High School Bakery Building-Block C. Access Address (16.07.2023): https://www.altensis.com/proje/ozel-saint-joseph-fransiz-lisesi-firin-binasi-c-blok/

Balçık, S. & Yamaçlı, R. (2022). Mimarlık Mirası Yapıların İşlevlendirilmesi ve Enerji Verimliliği. *Inonu University Journal of Art and Design.* https://doi.org/10.16950/iujad.1103402.

Bayraktar, M. (2015). *A Methodology For Energy Optimization Of Buildings Considering Simultaneously Building Envelope Hvac And Renewable System Parameters. (*Ph.D. thesis). Polytechnic University Of Turin, Turin.

Berg, F., Flyen, A. C., Godbolt, Å. L. & Broström, T. (2017). User-driven Energy Efficiency In Historic Buildings: a Review. *Journal of Cultural Heritage,* (28), 188-195. https://doi.org/10.1016/j.culher.2017.05.009.

Blumberga, D., Chen, B., Ozarska, A., Indzere, Z. & Lauka, D. (2019). Energy, Bioeconomy, Climate Changes and Environment Nexus. *Environmental and Climate Technologies, 3*(23), 370-392. https://doi.org/10.2478/rtuect-2019-0102.

Bourdeau, M., Waeytens, J., Aouani, N., Basset, P. & Nefzaoui, E. (2023). A Wireless Sensor Network for Residential Building Energy and Indoor Environmental Quality Monitoring: Design, Instrumentation, *Data Analysis and Feedback. Sensors 2023*, 23, 5580. https://doi.org/ 10.3390/s23125580.

Building Energy Performance Regulation. (2007) Ministry of Public

Works and Settlement Ankara. Access Address (16.07.2023): https://www.resmigazete.gov.tr/eskiler/2008/12/20081205-9.htm

Cabeza, L. F., Petrozzi, A., Castaldo, V. L. & Cotana, F. (2016). On An Innovative Integrated Technique For Energy Refurbishment Of Historical Buildings: Thermal-energy, Economic and Environmental Analysis Of A Case Study. Applied *Energy,* (162), 1313-1322. https://doi.org/10.1016/j.apenergy.2015.05.061.

Castaldo, V. L., Cabeza, L. F., Boarin, P., Petrozzi, A.& Cotana, F. (2017). The Experience Of International Sustainability Protocols For Retrofitting Historical Buildings In Italy. *Buildings,* 4(7), 52. https://doi.org/10.3390/buildings7020052

Climate Council Decisions. (2022) Climate Council 2022. Access Address (16.07.2023): https://iklimsurasi.gov.tr/sayfa/sonuc-bildirgesi

Data Bank Koru Project (2020). Association for the Protection of Cultural Heritage. Access Address (16.07.2023): http://www.koruprojesi.org/?p=bilgi-bankasi

Energy Efficiency Law, 5627. (2007). Ministry of Energy and Natural Resources. Ankara.

Fabbri, R., Gabrielli, L. & Ruggeri, A. G. (2018). Interactions Between Restoration and Financial Analysis: The Case Of Cuneo War Wounded House. *JCHMSD,* 2(8), 145-161. https://doi.org/10.1108/jchmsd-05-2017-0026.

Foster, G. J. & Saleh, R. (2021). The Adaptive Reuse Of Cultural Heritage In European Circular City Plans: a Systematic Review. *Sustainability,* 5(13), 2889. https://doi.org/10.3390/su13052889.

Gálvez, F. P., Hita, P. R. d., Martín, M. O., Conde, M. M. & Liñán, C. R. (2013). Sustainable Restoration Of Traditional Building Systems In the Historical Centre of Sevilla (Spain). *Energy and Buildings*, (62), 648-659. https://doi.org/10.1016/j.enbuild.2012.05.009.

Museum, Jordan. *AEJ,* 3(7), 03-12. https://doi.org/10.23968/2500-0055-2022-7-3-03-12.

Garín, A. M., García, J. L., Betanzos, J. M., Minguillón, R. J. H. & Baïri, A. (2020). Airtightness Analysis Of the Built Heritage–field

Measurements Of Nineteenth Century Buildings Through Blower Door Tests. *Energies,* 24(13), 6727. https://doi.org/10.3390/en13246727

GBC Historic Building (2015) Green Building Council. ITALY. Access Address (16.07.2023): https://gbcitalia.org/certificazione/gbc-historic-building/

Genç, G. (2022). *Tarihi Yapıların Enerji Verimli İyileştirilmesi İçin Bir Karar Destek Sistemi Önerisi. (Ph.D. thesis). Gazi University, Ankara.*

Ginks, N. & Painter, B. (2017). Energy Retrofit Interventions In Historic Buildings: Exploring Guidance and Attitudes Of Conservation Professionals To Slim Double Glazing In The Uk. *Energy and Buildings,* (149), 391-399. https://doi.org/10.1016/j.enbuild.2017.05.039

Gulbinas, R. & Taylor, J. E. (2014). Effects Of Real-time Eco-feedback and Organizational Network Dynamics On Energy Efficient Behavior In Commercial Buildings. *Energy and Buildings,* (84), 493-500. https://doi.org/10.1016/j.enbuild.2014.08.017

ICOMOS. (1965). International Council on Monuments and Sites. Committees. Access Address (16.07.2023):http://www.icomos.org.tr/?Sayfa=Uluslararasibilimselkomiteler&sayfa_no=3&dil=tr

Işık, G. (2022). Sustainable Financing Of Urban Transformation Projects In Environments With High Market Uncertainty: the Case Of Türkiye. *IJPTE,* 02(1), 73-81. https://doi.org/10.56158/jpte.2022.32.1.02

İstanbul Saint-Joseph Lisesi'nden Çevre Dostu Bina (2022). *Yeşil Bina Sürdürülebilir Yapı Teknolojileri Dergisi,* (55). Access Address (16.07.2023): https://www.yesilbinadergisi.com/yayin/1049/istanbul-saint-joseph-lisesi-nden-cevre-dostu-bina_29507.html

Jahed, N., Aktaş, Y. Y., Rickaby, P. A. & Altınöz, A. E. (2020). Policy Framework For Energy Retrofitting Of Built Heritage: a Critical Comparison Of Uk And Turkey. *Atmosphere*, 6(11), 674. https://doi.org/10.3390/atmos11060674.

Ke, Y., Zhou, C., Zhou, Y., Wang, S., Chan, S. H. & Long, Y. (2018). Emerging Thermal-Responsive Materials and Integrated Techniques Targeting the Energy efficient Smart Window Application. *Advanced Functional Materials,* 28(22), 1800113. DOI:10.1002/adfm.201800113.

Kim, D. & Felkner, J. (2018). A Sustainable Approach To the Adaptive Reuse Of Historic Brick Buildings: analysis Of Energy Efficiency Strategies For Historic Facade Retrofits. *Healthy, Intelligent and Resilient Buildings and Urban Environments.* https://doi.org/10.14305/ibpc.2018.be-7.01.

Kimura, O. & Noda, F. (2014). Does regulation of energy management systems work? – A case study of the Energy Conservation Law in Japan. *Eceee Industrial Summer Study Proceedings* 647-657

Kurnaz, A. (2021). Green Building Certificate Systems As A Greenwashing Strategy In Architecture. *Bartın University International Journal of Natural and Applied Sciences*, 4 (1) , 72-88. Access Address (16.07.2023): https://dergipark.org.tr/en/pub/jonas/issue/60051/892270

Law No. 2863 on the Protection of Cultural and Natural Heritage. (1983). Ministry of Culture and Tourism. ANKARA. Access Address (16.07.2023): https://teftis.ktb.gov.tr/TR-14230/2863-sayili-kultur-ve-tabiat-varliklarini-koruma-kanunu.html

Leijonhufvud, G., Broström T. & Buda, A., (2021) An Evaluation of EN 16883: Suggestions for enhancing the European guidelines for improving the energy performance of historic buildings. SHC Task 59, EBC Annex 76, Report D.B2 DOI: 10.18777/ieashc-task59-2021-0002

Lencer, D., Salinga, M., Grabowski, B., Hıckel, T., Neugebauer, J. & Wuttig, M. (2009). A Map For Phase-Change Materials. *Nature Materials* , 7(12), 972-7. doi:10.1038/nmat2330

Luo, X., Lu, J. & Ge, J. (2020). Green and Energy-saving Reform Technology Research In Traditional Houses – Taking Luo's House In Hangzhou As An Example. *Journal of Asian Architecture and Building Engineering,* 2(20), 165-178. https://doi.org/10.1080/13467581.2020.1782217

Martinez-Molina, A., Tort-Ausina, I., Cho, S. & Vivancos, J. (2016). Energy Efficiency and Thermal Comfort In Historic Buildings: A Review. *Renewable and Sustainable Energy Reviews*, (61), 70-85. https://doi.org/10.1016/j.rser.2016.03.018

Mazzarella, L. (2015). Energy Retrofit Of Historic and Existing Buildings. The Legislative And Regulatory Point Of View. *Energy and Buildings,* (95), 23-31. https://doi.org/10.1016/j.enbuild.2014.10.073

National Energy Efficiency Action Plan (NEEAP) 2017. Republic Of Turkey Ministry Of Energy And Natural Resources, Access Address (16.07.2023): https://policy.asiapacificenergy.org/sites/default/files/National%20Energy%20Efficiency%20Action%20Plan%20%28NEEAP%29%202017-2023%20%28EN%29.pdf

Özeler Kaan N. (2012). Tarihi Yapılarda Enerji Kazancı Sağlamak Amacıyla Çatı ve Cephe Bütünleşik Aktif Sistemlerin Kullanımı. 6. Ulusal Çatı & Cephe Sempozyumu.

Paschoalin, R. F. (2022). Energy renovation of historic buildings in New Zealand, Towards a holistic method for reducing environmental impact (Ph.D. thesis). Victoria University of Wellington, Wellington.

Piselli, C., Guastaveglia, A., Romanelli, J., Cotana, F. & Cabeza, L. F. (2020). Facility Energy Management Application Of Hbim For Historical Low-carbon Communities: Design, Modelling and Operation Control Of Geothermal Energy Retrofit In A Real Italian Case Study. *Energies*, 23(13), 6338. https://doi.org/10.3390/en13236338

Pode, R. (2020). Organic light emitting diode devices: An energy efficient solid state lighting for applications. *Renewable and Sustainable Energy Reviews,* 133. https://doi.org/10.1016/j.rser.2020.110043

Qu, K., Chen, X., Wang, Y., Calautit, J. K., Riffat, S. & Cui, X. (2021). Comprehensive Energy, Economic and Thermal Comfort Assessments For The Passive Energy Retrofit Of Historical Buildings - A Case Study Of A Late Nineteenth-century Victorian

House Renovation In The Uk. *Energy,* (220), 119646. https://doi.org/10.1016/j.energy.2020.119646

Rahmanan A. (2022). The Empire State Building will shine purple tonight in memory of the late Queen Elizabeth II. *Timeout,* Access Address (16.07.2023): https://www.timeout.com/newyork/news/the-empire-state-building-will-shine-purple-tonight-in-memory-of-the-late-queen-elizabeth-ii-090822

Recharge. Access Address (16.07.2023): https://www.rechargenews.com/transition/cloudy-berlin-targets-25-solar-power-by-2050/2-1-771846

Reichstag New German Parliament. Foster and Partners. Access Address (16.07.2023):https://www.fosterandpartners.com/projects/reichstag-new-german-parliament

Renewable Energy Obligation in Buildings (2022). Republic of Turkey, Ministry of Environment, Urbanization and Climate Change Ankara Access Address (16.07.2023): https://www.csb.gov.tr/binalarda-yenilenebilir-enerji-zorunlulugu-1-ocakta-basliyor-bakanlik-faaliyetleri-37361#:~:text=Bakanl%C4%B1k%20taraf%C4%B1ndan%20haz%C4%B1rlanan%20ve%2019,1%20Ocak%202023%20tarihinde%20ba%C5%9Fl%C4%B1yor.

Resolution No. 660, Grouping, Maintenance and Repairs of Immovable Cultural Assets (1999). Republic of Turkey Ministry of Culture Ankara Access Address (16.07.2023): https://korumakurullari.ktb.gov.tr/Eklenti/18338,660-nolu-ilke-kararipdf.pdf?0

Sekularac, N., Ivanović-Šekularac, J., Petrovski, A., Macut, N. & Radojević, M. (2020). Restoration Of a Historic Building In Order To Improve Energy Efficiency And Energy Saving—case Study—the Dining Room Within The ŽIča Monastery Property. *Sustainability,* 15(12), 6271. https://doi.org/10.3390/su12156271

Sesana, E., Bertolin, C., Gagnon, A. & Hughes, J. P. (2019). Mitigating Climate Change In the Cultural Built Heritage Sector. *Climate*, 7(7), 90. https://doi.org/10.3390/cli7070090

Tadeu, S. F., Rodrigues, C., Tadeu, A., Freire, F. & Simões, N. (2015). Energy Retrofit Of Historic Buildings: Environmental Assessment Of Cost-optimal Solutions. *Journal of Building Engineering,* (4), 167-176. https://doi.org/10.1016/j.jobe.2015.09.009

Tamirevi, Koru Project (2020). Association for the Protection of Cultural Heritage. Access Address (16.07.2023): http://koruprojesi.org/?p=tamirevi

The Empire State Building. (2023). Sustainability. Access Address (16.07.2023): https://www.esbnyc.com/about/sustainability#:~:text=In%20addition%2C%20much%20of%20the,replaced%20with%20energy%20efficient%20fixtures.&text=The%20Empire%20State%20Building%20has%20an%20incredible%206%2C514%20windows.,of%20existing%20materials%20all%20onsite.

Topaloğlu, S. (2020). Sürdürülebilir Koruma İçin Harekete Geçmek: Tamirevi'nde Enerji Verimliliği. Yeşilist. Access Address (16.07.2023): https://www.yesilist.com/surdurulebilir-koruma-icin-harekete-gecmek-tamirevinde-enerji-verimliligi/

Trencher, G., Broto, V. C., Takagi, T., Sprigings, Z., Nishida, Y. & Yarime, M. (2016). Innovative Policy Practices To Advance Building Energy Efficiency And Retrofitting: Approaches, İmpacts And Challenges İn Ten C40 Cities. *Environmental Science & Policy* Volume 66, December 2016, Pages 353-365 https://doi.org/10.1016/j.envsci.2016.06.021

TS 825. Thermal Insulation Requirements for Buildings (2013). Turkish Standards Institute, Ankara.

Turkey's International Energy Strategy. (2023) Republic of Turkey, Ministry of Foreign Affairs. Ankara. Access Address (16.07.2023): https://www.mfa.gov.tr/turkiye_nin-enerji-stratejisi.tr.mfa.

Ulu, M. (2018). *Retrofit Strategies For Energy Efficiency In Historic Urban Fabric: A Case Study In Basmane District, (Master's thesis). İzmir Institute of Technology, İzmir.*

University Ca Foscari of Venice. Meda Overseas Education Consultancy. Access Address (16.07.2023):

https://www.medaegitim.com/universitelerimiz/italyada-universite-egitimi/university-ca-foscari-of-venice.

Bahar ŞAHİN
E-mail: baharshn@gmail.com
Educational Status
License: Karadeniz Technical University Faculty of Architecture
Degree: MS (Yıldız Technical University Faculty of Architecture Building Physics Program)
Doctorate: Mimar Sinan Fine Arts University Faculty of Architecture Building Physics and Materials Phd Program
Professional Experience: Architect at Artemel Architecture Office, Architect at Arcad Architecture Office, Architect (Restoration Specialist) at Istanbul Metropolitan Municipality-The Cultural Assets Project Directorate

Didem BARAN ERGÜL
E-mail: ergul19@itu.edu.tr
Educational Status
License: Yıldız Technical University Faculty of Architecture
Degree: MS (Yıldız Technical University)
Doctorate: İstanbul Technical University Faculty of Architecture Construction Science Phd Program
Professional Experience: Lecturer at Beykoz University, Lecturer at Bilgi University

Ümit T. ARPACIOĞLU

E-mail: umit.arpacioglu@msgsu.edu.tr

Educational Status:

License: Mimar Sinan University, Architecture

Degree: Assoc Prof Dr

Doctorate: Mimar Sinan University, Building Physics and Material

Professional Experience: He graduated from Mimar Sinan Fine ArtsUniversity, Department of Architecture in 2001. He completed his master's degree in 2005 and his doctorate in 2010 at the sameuniversity. He earned the title of Associate Professor at MSGSU in 2018. Currently, the Department of Building Physics and Materials is accepted as academic.

Seden ACUN ÖZGÜNLER

E-mail: acunsed@itu.edu.tr

Educational Status: Doctorate, Istanbul Technical University

License: Istanbul Technical University

Degree: Ph. D. in Architecture

Doctorate: Istanbul Technical University

Professional experience: Prof. at İstanbul Technical University Prof. Dr. Seden Acun Özgünler graduated from Department of Architecture in Yıldız Technical University in 1997. She completed her M.Arch and Ph.D degrees in Building Sciences Programme of İstanbul Technical University. She is a faculty member in the Department of Architecture at Istanbul Technical University. She studies on Material and Technology in Architecture. There are many articles, book chapters and research projects related to her profession. Moreover, she provides consultancy support to private companies and public institutions.

The Use of Recycled Plastics in the Production of Building Materials in the Context of Sustainability

Res. Assist. Hande EYÜBOĞLU [1]

[1]Samsun University, Faculty of Architecture and Design, Department of Interior Architecture and Environmental Design. Samsun/Türkiye.
ORCID: 0000-0003-0504-2886
E-mail: hande.eyuboglu@samsun.edu.tr

Res. Assist. Zeynep YANILMAZ [2]

[2]Karadeniz Technical University, Faculty of Architecture, Department of Interior Architecture. Trabzon/Türkiye
ORCID: 0000-0002-5686-3548
E-mail: zeynepyanilmaz@ktu.edu.tr

Citation: Eyüboğlu, H. & Yanılmaz, Z. (2023). The Use of Recycled Plastics in the Production of Building Materials in the Context of Sustainability. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (185-207). ISBN: 978-625-367-287-4. Ankara: Iksad Publications.

1. Introduction

Sustainability is an approach that includes environmental, social and economic dimensions based on the principle of using resources in a balanced way to meet the needs of current and future generations. Sustainable building design is defined as the planning, design and construction of buildings in accordance with the principles of environmental, social and economic sustainability. While environmental sustainability focuses on the conservation of natural resources, waste management, energy and water use in building design; social sustainability is aimed at meeting the comfort conditions and user needs of users. Economic sustainability is associated with financial savings in the long term (Arpacıoğlu, 2015; Bauer, Mösle & Schwarz, 2009). In line with these principles, sustainable building design aims to increase energy and resource efficiency, minimise environmental impacts, meet comfort conditions and provide economic benefits.

In the changing and developing world, the fact that sensitivity to resource and energy conservation is at the forefront in building design for the needs of users increases the interest in sustainable building materials day by day. Sustainable building materials are materials that do not harm the environment in the process from raw material production to processing, from use to maintenance, repair and waste generation, require minimum energy and provide maximum efficiency throughout the life cycle (Iyengar, 2015).

Sustainable material selection plays an important role in sustainable building design. These materials should be materials that require low energy and resource consumption during the production phase. They should have low potential to harm the nature during production and use. In addition, sustainable materials should not adversely affect human health and should improve the quality of interior space. On the other hand, sustainable building materials should be easy to maintain, long-lasting and high strength. This situation allows the buildings to be used for a longer period of time and allows the resources to be used more effectively (Calkins, 2008; Kubba, 2012; Topal & Arpacıoğlu, 2020). While natural, local and environmentally friendly materials can be used as sustainable building materials, reusable or recyclable materials are also preferred materials in sustainable building design. Recyclable building materials are materials that can be used in the production of new products by transforming materials that have reached the end of their useful life. These materials contribute to the conservation of natural resources by reducing waste generation and reduce environmental impacts (Asdrubali, D'Alessandro & Schiavoni, 2015). Recyclable building materials support economic and environmental sustainability while helping to solve the problem of waste management in the construction industry.

The study aims to reveal the use of recycled plastics as a sustainable building material. When the relevant literature is reviewed, it is thought that the study will contribute to the literature due to the limited number of resources on the subject. This study, which will provide an awareness on the recycling and reuse of waste plastics, focuses on the use of recycled plastics in the construction industry.

1.1. Use of Recycled Materials in Building Production

In recent years, when natural resources are rapidly depleting, there is an increasing tendency to utilise the possibilities of using waste materials in different industrial areas. The fact that the type and formation of waste is increasing day by day and this situation leaves irreversible damage to the environment has made it necessary to take measures on the subject.

Millions of tonnes of waste are produced every year in the world and most of them cannot be recycled. However, recycling of wastes often leads to energy consumption and waste generation again (Tavakoli, Hashempour & Heidari, 2018). Waste materials are one of the most important threats to the environment. Therefore, reusing or disposing of these materials with the right methods is extremely important in terms of ensuring efficient use of resources, environmental protection and energy saving (Dachowskia & Kostrzeawaa, 2016; Tandoğan, 2018).

Recycling, in its most general definition, is the use of waste as virgin material for other applications. In this process, it is aimed to use waste materials in the production of new materials (Topal, 2009). Wastes obtained from different sources can be used in the production of various building products. For example; consumption wastes from commercial, domestic, institutional or industrial uses can be recycled for use in building production (Oyedele, Ajayi & Kadiri, 2014). Recycling also saves the total amount of energy that materials and products have and that is generated by the initial production. The amount of energy required for recycling can often be much less than that used for the initial production (İpekçi, Coşkun & Karadayı, 2017). By recycling products, the amount of waste is reduced, less energy is lost during transport and storage, and at the same time economic benefits are achieved. The construction industry consumes approximately 50% of all material resources from nature (Anink, Mak & Boonstra, 1996). This leads to a significant amount of waste generation. One way to overcome the negative environmental impacts caused by the constant search for new resources and waste generation is the use of recycled materials (Oyedele, Ajayi & Kadiri, 2014). In this context, in recent years, as recycled waste has been recognised as a more reliable and cost-effective source of supply for raw materials, material producers have modified existing products or started to develop new products to use recycled products more efficiently (Winkler, 2010). The use of recycled materials in the building sector contributes to the national economy and environmental sustainability by limiting the consumption of raw materials and energy required during the production of buildings (Çüçen & Altuncı, 2022). In this sense, the construction industry recycles many waste materials such as paper, glass, plastic, metal, textile wastes, herbal and animal wastes, etc. and includes them in the production chain.

1.1.1. Use of recycled plastic in building material production

Plastics are one of the solid wastes that are produced in high quantities and pose a serious threat to environmental sustainability. Polymer production has increased significantly in the last 50 years and plastic products have become an important part of modern lifestyle. In particular, plastic materials have gained a wide place in the production market due to low density, high strength / weight ratio, high durability, long life, ease of design and production, low cost, etc. Today, plastic products are widely used in almost every field, especially in packaging, building and construction, automotive, electrical / electronics, agriculture and other industries (Gu & Ozbakkaloglu, 2016).

Polymer production is increasing more and more every year. The vast majority of plastics produced are used for disposable consumer products, which have a large share in waste generation. Most types of plastics are non-biodegradable and chemically non-reactive in the natural environment. Therefore, such polymer products can preserve their existence in nature for centuries (Gu & Ozbakkaloglu, 2016). The mixing of plastic wastes into the oceans causes great damage to ecology, economy and aesthetic elements (Jambeck, Hardesty, Brooks, Friend, Teleki, Fabres, Beaudoin, Bamba, Francis, Ribbink, Baleta, Bouwman, Knox & Wilcox, 2018). It is estimated that approximately 300 million metric tonnes of plastic waste is generated annually (Singh & Sharma, 2016). It is possible to utilise a significant amount of these waste plastics by recycling in various sectors.

Plastic wastes can be recycled by mechanical, chemical or thermal means (Awoyera & Adesine, 2020). In mechanical recycling, processes such as grinding and/or shredding are used to physically degrade the waste. It is known that this method is somewhat inefficient due to the complex structure of plastic waste mixtures and that most of the waste is incinerated (Khoo, 2019). However, when the literature is examined, it is seen that the mechanical recycling method is still the most widely used method in plastic recycling due to its fast and effective (Awoyera & Adesine, 2020). Plastic wastes can be chemically decomposed into monomers for recycling or chemically modified. They can then be used instead of unprocessed raw materials in the production of new products. In thermal recycling, waste plastics are melted at high temperatures to create moulds for new products (Awoyera & Adesine, 2020).

The development of new building materials using recycled plastics is very important for both the construction and recycling industry (Siddique, Khatib & Kaur, 2007). The reuse or recycling of waste plastics in the construction industry is recognised as one of the most ideal methods for waste disposal among various recycling management approaches. In this way, recycled plastics can be reused intact throughout the service cycle and, more importantly, these plastics replace virgin construction materials (Gu & Ozbakkaloglu, 2016).

In order for waste plastics to be used in building products, the intended application must meet both mechanical and durability properties. In addition, it is expected to be less costly and sustainable than other types of materials in order to encourage the use of building materials produced with plastic waste (Awoyera & Adesine, 2020). Waste plastics can be used in the production of many building materials such as concrete, bricks, ceramics, composites, etc. The use of waste plastics instead of raw material plastics in the production of these materials is extremely important both in terms of reducing production costs and environmental sustainability.

2. Material and Method

This study, which aims to reveal the use of recycled plastics as a building material in sustainable building design, was designed with a descriptive design from quantitative research designs. In this study, which focuses on the use of recycled plastic materials as an alternative to the use of materials in building production, the availability of explanatory and sufficient written and visual documents related to the material was decisive in determining the sample group. Eight materials obtained by using the search management in international databases constitute the sample group of the study. These materials were evaluated in terms of their prominent technical features and places of use.

3. Findings and Discussion

The generation of a significant amount of plastic waste in almost every sector has led to a widespread tendency to use these wastes in the production of building materials in order to utilise them. In this context, 8 building materials produced from plastic wastes were accessed through literature review and analysed in terms of their structural properties.

A start-up in Colombia has transformed plastic waste into an alternative building material in order to reduce the negative impact of plastic waste on the environment (Figure 1). The "Plastic Concept", designed by Fernando Ilanos of Conceptos Plásticos and architect Oscar Mendez, is based on the principle of shredding plastic waste and tyres into bricks used in housing construction. The aim of the plastic concepts is to respond to the different problems affecting society today by contributing to reducing the negative impact of plastic waste on global warming as well as environmental pollution. To make Lego-like blocks, plastics that not everyone recycles and other hard-to-dispose of plastics are used. Each type of plastic provides a different property to the bricks. They are mixed in different ways to obtain the desired product. As a result; easy to install, robust and low cost bricks are obtained. They are also stronger than traditional building materials, thermo acoustic (can be used in hot and cold weather), anti-seismic and non-flammable (URL-1).

Figure 1. Recycle plastic waste into bricks (URL,1).

Kenya-based initiative Gjenge Makers aims to transform plastic waste into an alternative building material in order to reduce the negative impact of plastic waste on the environment. Based on this goal, they have contributed to the construction of lighter and cost-effective structures with the bricks they produce. In the production process; plastic wastes are first melted and then mixed with sand in the machine by acting as a binder. This blended paste-like structure is compressed into brick form in the machine. Thanks to the fibrous structure of the plastic, very durable materials are obtained after the compression process (Figure 2). The bricks produced are 3 to 5 times lighter than normal bricks. Transport operations are also easier (URL, 2).

Figure 2. Recycle plastic waste into bricks (URL, 2).

Thermo Poly Rock (TPR), manufactured by Wales-based Research and Development company Affresol, is a synthetic concrete product containing 70% recycled plastic (Figure 3). Granulated plastic waste is mixed with a mineral/resin compound. The final product, which is poured like concrete and dries in two and a half hours, is about 12% less costly to produce than standard bricks or blocks. It also has a much smaller carbon footprint than composites made from plastics melted at high temperatures. The manufacturer states that the product is a sustainable alternative to concrete (URL, 3).

Figure 3. Thermo poly rock by affresol (URL, 3).

The ByFusion company has produced a building material called ByBlock from waste plastics to create an environmentally friendly alternative to standard concrete blocks (Figure 4). In the production of these structural blocks, all recyclable or non-recyclable plastics can be used. The waste plastics used in production do not need to be cleaned or sorted, and production is carried out with minimum energy and zero waste. The blocks, which are produced in two sizes, standard (40 x 20 x 22 cm) and flat (40 x 20 x 20 cm), are produced in such a way that they interlock with each other, eliminating the need for mortar or adhesive during assembly. While concrete blocks tend to crack and crumble over time, ByBlock is resistant to cracking, crumbling, high pressure and water. Thanks to its easy and fast installation possibilities, it saves time while reducing labour costs. Since the waste plastics, which are the raw material, vary, each block comes out in different colours and patterns. This situation adds an aesthetic value to the blocks and offers the opportunity to be used without coating the outer surface. However, if desired, plaster, paint, plaster panel etc. It is also possible to cover with materials (URL, 4).

Figure 4. ByBlocks by ByFusion (URL, 4).

Precious Plastic has produced a brick constructed from 100% recycled plastic using the interlocking technique (Figure 5). The bricks are as easy and inexpensive to assemble as they are to produce. Thanks to its easy and fast assembly features, it offers a useful solution for temporary structures or low-cost housing, especially after natural disasters.

Approximately 1.5 kilograms of waste plastic is used in the production of one brick and its production takes approximately 4 minutes (URL, 5).

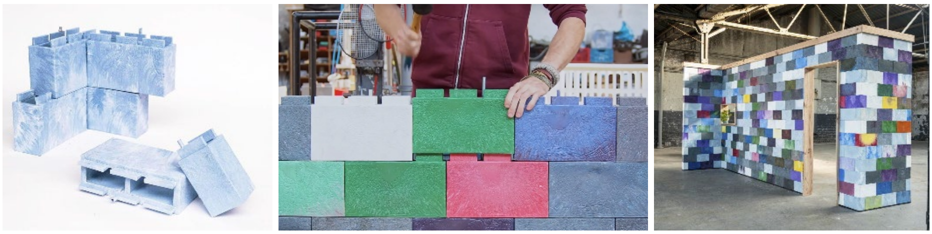


Figure 5. Brick by precious plastic (URL, 5).

A group of engineers in the state of Kerala in India have started to produce bricks from plastic waste in order to develop a solution to the waste problem, arguing that waste should be managed properly instead of banning the use of plastics. The strength of the plastic bricks they developed using a technology that is a combination of pyrolysis and dry mixing is equivalent to the strength of standard fired bricks. Regardless of the quality and density of the waste plastic used, it is melted at a certain temperature and other substances such as sand and ash are added. The mixture is then sent to the moulding machine and the production takes place within 2 hours. The bricks produced in the size of 15x30 cm for use on the floor are ready for use after a seven-day curing period. Experiments have proved that this brick is twice as strong and longer lasting than the existing interlocking bricks used for paving roads. Five tonnes of plastic waste can produce 2500 bricks (URL, 6).

Figure 6. Recycle plastic waste into bricks (URL, 6).

Rhino Machines, a company operating in India, produced a brick called silica-plastic block (SPB) using a combination of sand and plastic waste (Figure 7). In the production of SPB, 80% recycled waste foundry sand/powder and 20% mixed plastic waste were used. The plastic used as a binder completely eliminated the need for water during the mixing and subsequent hardening stages. With this method, the bricks can be used directly after cooling during the moulding process. Produced in 19x9x9 cm dimensions, SPB has 2.5 times the durability of ordinary red clay bricks (URL,7).

Figure 7. Silica-plastic block by rhino machines (URL, 7).

In addition to the production of block building materials, waste plastics are also used in 3D printing technology. Nagami, a design studio that stands out with its sustainable and innovative 3D printing designs, built a 90 m² store for Ecoalf (Figure 8). The structure, which was built using a total of 3.3 tonnes of plastic waste, has the ability to be reused, recycled infinitely, losing only %1 of its structural performance with each use. All the walls, shelves and display products inside the store were built with 3D printing to resemble a melting glacier, aiming to raise awareness of how new technologies can mitigate climate change. The plastics used in 3D printing were mainly obtained from hospitals (URL, 8).

Figure 8. 3D Printed interior with upcycled plastic (URL, 8).

4. Conclusion and Suggestions

The use of recycled materials in building production is very important for building environmentally friendly and sustainable structures. Traditional construction methods mainly lead to depletion of natural resources, environmental pollution and increase in the amount of waste. Therefore, using recycled materials is an effective way to reduce these negative impacts. The use of recycled materials plays a key role for a more sustainable life while reducing the negative impacts on the environment. At this point, the use of recycled plastics as building materials has become increasingly popular. Considering the damages caused by plastic wastes to the environment, recycling and using these materials in the construction sector is an important step. Recycled plastic wastes can be used in various places such as floors, walls and furniture in building production. These materials, which are mainly applied with the fitting technique, stand out with their features such as easy and fast assembly, high strength, lightness, low carbon footprint and zero waste generation (Table 1). Especially the materials applied with the fitting technique reduce the use of resources by eliminating the need for any binding material, thus providing benefits in terms of environmental and economic sustainability. In addition, thanks to the possibility of easy assembly in a short time, it offers an economical and functional solution in cases such as after disasters, etc. where temporary shelter is needed.

Table 1. Building materials made from waste plastics

Material	Usage Areas of Materials			Technical Properties of the Material
	Floor	**Wall**	**Furniture**	
 				• Implementation with passing technique • Easy and fast installation • Robust and cost-effective • Thermo acoustic, anti-seismic and flame retardant
				• Lightweight and cost-effective • 3-5 times lighter than normal bricks • Easy transport
				• Low carbon footprint • %12 less cost • 2.5 hours drying time
				• Implementation with passing technique • Zero waste generation • High pressure and impact resistance

				• Resistance against water • Easy and fast installation • Aesthetic appearance • Can be coated with any material
				• Implementation with passing technique • Fast production and assembly • Easy transport
				• Interlocking brick model • High strength • Low cost • Long life
				• 2.5 times more strength than normal brick • Reducing the need for water in the production phase • High impact resistance
				• Infinite recyclability • Zero waste generation • Aesthetic appearance

In terms of sustainability, it is a serious problem that plastic wastes do not dissolve in nature for long periods of time and cause environmental pollution. For this reason, the widespread use of recycled plastics in the building industry and the use of recycled plastics in the production of both building and building elements make a significant contribution to the process of achieving a cleaner and more sustainable environment.

Thanks and Information Note

The e-book section complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to The e-book section. There is no conflict of interest.

References

Anink, D., Mak, J. & Boonstra, C. (1996). *Handbook of sustainable building: an environmental preference method for selection of materials for use in construction and refurbishment*. London: James and James.

Arpacıoğlu, Ü. (2015). Restorasyon çalışmalarında alınan fiziksel çevre kararlarının enerji kullanımına etkisinin değerlendirilmesi. *Yapı Dergisi,* 409, 142-149. ISSN: 1300-3437. Access Address (01.09.2023): https://www.academia.edu/31687272/Restorasyon_%C3%87al%C4%B1%C5%9Fmalar%C4%B1nda_Al%C4%B1nan_Fiziksel_%C3%87evre_Kararlar%C4%B1n%C4%B1n_Enerji_Kullan%C4%B1m%C4%B1na_Etkisinin_De%C4%9Ferlendirilmesi_Divanhane_%C3%96rne%C4%9Fi

Asdrubali, F., D'Alessandro, F. & Schiavoni, S. (2015). A review of unconventional sustainable building insulation materials. *Sustainable Materials and Technologies*, 4, 1-17. Online ISSN: 2214-9937. Access Address (15.07.2023): https://www.sciencedirect.com/science/article/pii/S2214993715000068

Awoyera, P. O. & Adesina, A. (2020). Plastic wastes to construction products: Status, limitations and future perspective. *Case Studies in Construction Materials*, 12, 1-11. Online ISSN: 2214-5095. Access Address (14.07.2023): https://www.sciencedirect.com/journal/case-studies-in-construction-materials/about/insights

Bauer, M., Mösle, P. & Schwarz, M. (2009). *Green building: guidebook for sustainable architecture*. Berlin: Springer Science & Business Media.

Calkins, M. (2008). *Materials for sustainable sites: a complete guide to the evaluation, selection, and use of sustainable construction materials*. New York: John Wiley & Sons.

Çüçen, A. & Altuncı, Y. T. (2022). Geri dönüştürülmüş yapı malzemelerinin mimaride kullanımının incelenmesi. *Selçuk Üniversitesi Sosyal ve Teknik Araştırmalar Dergisi USTEK'2022 Özel Sayısı*, 20 (1), 191-199. Online ISSN: 2146-7226. Access Address (20.07.2023): https://dergipark.org.tr/en/download/article-file/3278142

Dachowskia, R. & Kostrzewaa, P. (2016). The use of waste materials in the construction industry. *Procedia Engineering*, 161, 754-758. Online ISSN: 1877-7058. Access Address (21.07.2023): https://www.sciencedirect.com/science/article/pii/S1877705816329939

Gu, L. & Ozbakkaloglu, T. (2016). Use of recycled plastics in concrete: a critical review, *Waste Management*, 51, 19-42.

Iyengar, K. (2015). *Sustainable architectural design: An overview.* United Kingdom: Routledge.

İpekçi, C., Coşkun, N. & Karadayı, T. (2017). İnşaat sektöründe geri kazanılmış malzeme kullanımının sürdürülebilirlik açısından önemi. *TÜBAV Bilim,* 10 (2), 43-50. Online ISSN: 1308-4933. Access Address (22.07.2023): https://dergipark.org.tr/tr/download/article-file/309730

Jambeck, J., Hardesty, B. D., Brooks, A. L., Friend, T., Teleki, K., Fabres, J., Beaudoin, Y. C., Bamba, A., Francis, J., Ribbink, A., Baleta, T., Bouwman, H., Knox, C. & Wilcox, C. (2018). Challenges and emerging solutions to the land-based plastic waste issue in Africa. *Marine Policy*, 96, 256-263. Online ISSN: 1872-9460. Access Address (20.07.2023): https://www.sciencedirect.com/science/article/pii/S0308597X17305286

Khoo, H. H. (2019). LCA of plastic waste recovery into recycled materials, energy and fuels in Singapore. *Resources, Conservation & Recycling,* 145, 67-77. Online ISSN: 1879-0658. Access Address

(25.07.2023):https://www.sciencedirect.com/science/article/abs/pii/S0921344919300679

Kubba, S. (2012). *Handbook of green building design and construction: LEED, BREEAM, and Green Globes*. Oxford: Butterworth-Heinemann.

Oyedele, L. O., Ajayi, S. O. & Kadiri, K. O. (2014). Use of recycled products in UK construction industry: An empirical investigation into critical impediments and strategies for improvement. *Resources, Conservation and Recycling*, 93, 23-31. Online ISSN: 1879-0658. Access Address (05.07.2023): https://www.sciencedirect.com/science/article/abs/pii/S0921344914002018

Siddique, R., Khatib, J. & Kaur, I. (2007). Use of recycled plastic in concrete: A review. *Waste Management*, 28, 1835-1852.

Singh, P. & Sharma, V. P. (2016). Integrated plastic waste management: Environmental and improved health approaches, *Procedia Environmental Sciences*, 35, 692-700. Online ISSN: 1879-2456. Access Address (07.07.2023): https://www.sciencedirect.com/science/article/abs/pii/S0956053X07003054

Tandoğan, O. (2018). Atık malzemelerin mimaride kullanımı. *Ulusal Çevre Bilimleri Araştırma Dergisi*, 1(4),189-202. Online ISSN: 2636-7483. Access Address (10.07.2023): https://dergipark.org.tr/tr/download/article-file/595528

Topal, S. (2009). *Yapısal atıkların geri dönüşüm potansiyellerinin araştırılması (Yüksek Lisans Tezi). Gebze Yüksek Teknoloji Enstitüsü YÖK Ulusal Tez Merkezi Accessed from databes Access Address (25.07.2023): https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=zXbHyJK_Gwi9hLwDPuM-GQ&no=gG6Hn_f7n8uYpzLv76kGvQ*

Topal, A.S. & Arpacıoğlu, Ü. (2020). Mimarlıkta akıllı malzeme. *Mimarlık Bilimleri ve Uygulamaları Dergisi*, 5(2), 241-254. Online ISSN: 2548-0170. Access Address (01.09.2023): https://dergipark.org.tr/en/download/article-file/1254166

Tavakoli, D., Hashempour, M. & Heidari, A. (2018). Use of waste materials in concrete: A review. *Science & Technology*, 26 (2), 499-522. Online ISSN: 0128-7680. Accessed Address (29.06.2023):https://www.researchgate.net/publication/325296325_Use_of_waste_materials_in_concrete_A_review

URL-1, https://www.ekoyapidergisi.org/bu-evler-atik-plastikten-uretilen-tuglalarla-yapildi (Date of access: 05.06.2023).

URL-2, https://sagliklimarkalar.com/haberler/saglikli-girisimler/plastik-atiklardan-uretilen-guclu-ve-hafif-tuglalar/ (Date of access: 05.06.2023).

URL-3, https://www.builderonline.com/building/building-science/can-plastics-supplant-wood-and-concrete-as-a-structural-building-material_o (Date of access: 05.06.2023).

URL-4, https://www.byfusion.com/byblock/ (Date of access: 12.06.2023).

URL-5, https://designwanted.com/precious-plastic-brick/ (Date of access: 12.06.2023).

URL-6, https://www.thenewsminute.com/article/building-waste-these-young-kerala-engineers-recycle-plastic-waste-bricks-57550 (Date of access: 12.06.2023).

URL-7, https://bigumigu.com/haber/plastik-atik-lardan-ve-atik-dokum-kumu-ndan-yapilan-surdurulebilir-tugla/ (Date of access: 12.06.2023).

URL-8, https://www.archdaily.com/996782/3d-printed-interior-with-upcycled-plastic-reducing-waste-enhancing-design?ad_campaign=normal-tag (Date of access: 20.06.2023).

Winkler, G. (2010). *Recycling construction & Demolition waste: A LEED-Based toolkit.* McGraw Hill.

Hande EYÜBOĞLU
E-mail: hande.eyuboglu@samsun.edu.tr
Educational Status:
License: Karadeniz Technical University Faculty of Architecture, Department of Interior Architecture (2013-2017)
Degree: Karadeniz Technical University Faculty of Architecture, Department of Interior Architecture (2017-2021)
Doctorate: Karadeniz Technical University Faculty of Architecture, Department of Architecture (2021-…)
Professional Experience: Samsun University, Faculty of Architecture and Design, Department of Interior Architecture and Environmental Design (2019-…) (Research Assistant)

Zeynep YANILMAZ
E-mail: zeynepyanilmaz@ktu.edu.tr
Educational Status:
Licence: Karadeniz Technical University, Faculty of Architecture, Department of Interior Architecture (2009-2013).
Degree: Karadeniz Technical University, Institute of Science, Department of Interior Architecture (2017-2020).
Doctorate: Karadeniz Technical University, Institute of Science, Department of Architecture (2020-…).
Professional Experience: Karadeniz Technical University, Faculty of Architecture, Department of Interior Architecture (2020-…). (Research Assistant)

Planning and Design Principles of Open Green Areas as Disaster and Emergency Assembly Areas

Prof. Dr. Murat AKTEN [1]

[1]Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, West Campus, Isparta/Türkiye.
ORCID: 0000-0003-4255-926X
E-mail: muratakten@sdu.edu.tr

Citation: Akten, M. (2023). Planning and Design Principles of Open Green Areas as Disaster and Emergency Assembly Areas. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment,* (208-243). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

Our cities have faced great risks due to the fact that the phenomenon of disaster has not found enough space in the developing planning practice and the legislation that accompanies it. Although the painful consequences of the recent earthquakes that resulted in great destruction and losses are before us, it has not been possible to solve the current problems at the expected level and through strategies to reduce risks. Moreover, the aim of increasing urban resilience by reducing social and spatial vulnerability to disaster events began to occupy an important place on the world agenda, especially after 1990. For this reason, today, many theoretical and academic studies aim to both identify risks and develop solution suggestions, making this issue a main topic of discussion on many platforms.

At this point, disaster management is important for institutions and organizations as well as for the public's preparedness for disasters, and it has a wide range of content, from the use of urban space to the definition of duties and responsibilities, training, drills, and preparation of materials and equipment. In the risk management phase in terms of urban space use, main evacuation routes, secondary routes and alternative evacuation areas are determined, and decisions are made regarding how and where the services required to meet temporary shelter, cleaning, food and beverage and other mandatory needs that become urgent after the disaster will be provided. Crisis management includes activities such as receiving information, transportation, search, rescue, first aid, treatment, evacuation, temporary housing, food, beverage, clothing, fuel supply, security, environmental health and removal of hazardous debris, starting from the moment the disaster occurs. The realization of these activities varies depending on the places such as shelter areas, assembly areas, evacuation areas and deployment areas, which are critical for disaster management, and their coordination. While the deployment area emerges as an important place for disaster response teams, the others are places of importance for both disaster response teams and the public (Mengi & Erdin, 2018).

Of course, the issue has many different dimensions that need to be addressed. As a matter of fact, in the "National Strategy for Earthquake Damage Mitigation" report of the Turkish National Earthquake Council dated 2002, this situation was expressed in two separate components of any earthquake policy designed on a national scale: "Disaster Damage Mitigation System" and "Disaster Response System". While the report emphasizes the need to focus on "risk management and avoidance planning" studies in order to "Minimize Earthquake Damages", it also draws attention to the need for research to determine the earthquake hazard and urban defects. These determinations undoubtedly make Disaster Management a top heading and show that the contributions of different disciplines from their own areas of expertise regarding disaster management can be diversified in the context of risk reduction studies.

As a matter of fact, when considered from the perspective of urban planning, it can be seen that a scope has been created for the development of space organization-based approaches for before, during and after disasters in the context of reducing possible disaster damages and the implementation of applications within this scope, and a contribution to disaster management is made in this direction. However, this field, which will be discussed as "Spatial Organization", also has wide-ranging expansions. Here we encounter two important fields of study, which can be defined as the prevention-based planning of an entire city against disaster risks and the development of measures that will minimize the loss of life and property in cities within the existing urban problems. It brings. In structuring planning strategies that take these two areas into consideration, a three-stage determination must be made: before, during and after the disaster. In this context, there is a need to ensure that preparations for emergency rescue and aid are made effectively before the natural disasters that may be encountered in our cities, and to produce strategies to meet the needs of urban residents for gathering during the disaster and temporary shelter after the disaster. However, at this point, the most fundamental problem that exists for our country's cities is the lack of a structure that will support the said strategies and the required space organization in cities structured with unhealthy development tendencies (Zengin et al., 2014).

Cities all over the world have become the areas most at risk, especially in terms of natural events turning into disasters, as a result of increasing population density and unplanned and uncontrolled construction. For this reason, determining the hazards that pose a risk in advance and carrying out a disaster-sensitive planning study will not only affect the physical aspects of the city; It is of great importance as it will also reduce social and economic risk factors. For this reason, the disaster-sensitive planning approach comes to the fore in reducing this risk, especially during the structuring process of cities.

Starting from such a point, this study aims to make evaluations regarding gathering areas and to discuss the characteristics and effects of the variables that should be decisive in defining a piece of land as a gathering area. The variables that play an important role in determining the gathering areas are tried to be revealed on the basis of location, size, spatial distribution, capacity, physical and natural features and in relation to application, management and plan decisions.

2. Changing Policies in the World for Disaster Management

Natural disasters have been a part of human life from past to present and there is no way to prevent them from occurring. However, for centuries, humanity has made efforts to overcome disasters with the least loss and damage, either personally or by those living in the region. Nowadays, in the shrinking world (global), many international organizations conduct research on natural disasters and warn people, local, national and international institutions about the increasing effects of disasters and the pressure these disasters put on both the natural and built environment. United Nations (UN), Organization for Economic Co-operation and Development (OECD), UN Office for the Coordination of Humanitarian Assistance (OCHA), UN Disaster Assessment and Coordination System (UNDAC), On-Site Operations Coordination Center (OSOCC), Virtual OSOCC (Virtual OSOCC), North Atlantic Pact (NATO), HABITAT (United Nations), World Bank–Global Service Corps for Disaster Reduction and Recovery (WB-GFDRR), International Federation of Red Cross and Red Crescent Societies (IFRCRCS), International Civil Defense Organization (ICDO) and SwissRe and MunichRe, the world's important reinsurance institutions, are examples of these institutions (Özmen & Özden, 2013). Traditionally, the way of dealing with disasters was generally oriented towards post-disaster intervention and recovery, and since it was seen that these understandings were not sufficient, policies that brought about significant changes in the understanding of disaster management began to be adopted after the 1990s. It has been realized that preventing hazards from turning into disasters is only possible with good risk planning. If the existence of these dangers is known and appropriate prevention approaches are implemented, it will be possible to at least minimize the risk of disaster. This policy change envisages the transformation from the "Traditional Disaster Management System" to the "Disaster Risk Management System". Important regulations regarding the implementation of this new disaster risk management system transformation are listed as follows (Karataş & Kaya, 2022):

- In order to emphasize that social, economic and political analyzes are mandatory in explaining the causes and effects of natural disasters accurately, the United Nations declared the decade between 1990 and 1999 as "The International Decade for Reducing Natural Disasters" (The International Decade) with the General Assembly Resolution No. 44/236 in 1989. for Natural Disaster Reduction - IDNDR).
- Publication of the plan, known as the Johannesburg Plan of Implementation, which was accepted at the international organization (The World Summit on Sustainable Development - WSSD) held in South Africa in 1992. In the accepted document, it was stated that an integrated, comprehensive disaster management approach that foresees multiple hazards is needed in order to make the world a safer place in the 21st Century.

  The aim is to enable countries - especially those facing disaster risk - to reduce the negative effects of natural and man-made disasters on human settlements, national economies and the environment. Three different areas of activity are envisaged within the scope of this program. These; development of "safety culture", "pre-disaster planning" and "post-disaster reconstruction".

- Implementation of "The Yokohama Strategy and Plan of Action for a Safer World" at the International Yokohama Conference held in 1994; With this strategy, new strategies and principles in combating disasters were determined, detailed criteria for risk analysis and harm reduction were determined, the concept of "risk management" was discussed, and it was emphasized that disaster prevention and preparation activities are of primary importance. This plan served as a guide in the development of subsequent disaster management policies.
- Strategy for Disaster Reduction (ISDR) unit was established within the United Nations in order to implement the decisions taken at the Yokohama Conference and to encourage and monitor their implementation by countries. The International Strategy for Disaster Reduction (ISDR), the successor to the IDNDR in 2000, supported this need by moving from an emphasis on protection against previous hazards to a process that included awareness, assessment and risk management, and encouraged actions to reduce social vulnerability and the risks of natural disasters and related technological and environmental disasters. It is intended to be.

- The Millennium Development Goals were declared at the Eighth General Assembly Meeting of the United Nations in 2000. These goals include exponentially increasing international cooperation to urgently reduce the increasing number and impacts of natural and man-made disasters.
- The publication of the OECD's Large-Scale Disasters, Lessons Learned report in 2004; It is a study about the consequences of disasters that have occurred and what lessons have been learned from these disasters.
- At the 2nd World Conference on Disaster Reduction held in Kobe, Japan in 2005, the Hyogo Framework Action Plan (HÇEP) was prepared, aiming to reduce the damages caused by disasters between 2005 and 2015. This framework plan has been adopted by 168 countries that are members of the United Nations. In this context, the years 2005-2015 were declared as the new "Decade of Natural Disaster Risk Reduction". HÇEP, which is an action plan for disaster risk reduction, consists of 3 strategic goals and 5 priority action plans. Strategic goals; more effectively integrate disaster risk considerations into sustainable development policies, planning and programming at all levels, with a particular emphasis on disaster prevention, mitigation, preparedness and vulnerability reduction; developing and strengthening institutions, mechanisms and capacities at all levels, especially at the

community level, that can systematically contribute to building resilience to hazards; The systematic inclusion of risk reduction approaches in the design and implementation of emergency preparedness, response and recovery programs in rebuilding affected communities.

- In 2007, the Global Platform Biennial on Disaster Risk Reduction was held at the United Nations General Assembly to support the implementation of the Hyogo Framework Action Plan.
- In 2009, the Incheon Conference with the theme of Building a Local Government Agreement for Disaster Risk Reduction was organized by the United Nations in South Korea. With the prediction that risk reduction practices are generally carried out at the local level, it gave local governments the identity of global actors (independent of the central governments) and defined risk reduction expenses as 'investments', not 'costs'.
- Shanghai Session was held in China on 27-28 October 2011. The role of civil society and social capital in post-disaster reconstruction and disaster prevention, and the importance of using advanced technologies to reduce earthquake damage to buildings were emphasized. Issues such as earthquake damage and countermeasures of civil engineering structures, disaster relief network along the border, disaster prevention, post-disaster

reconstruction and international cooperation, safety, risk and human resources training were discussed.

- The Sendai Framework for Disaster Risk Reduction (2015-2030) was adopted at the Third UN World Conference in Sendai, Japan, on 18 March 2015. In March 2015, the Hyogo Framework ended and was replaced by the Sendai Framework. In this framework, four priorities have come to the fore: understanding disaster risk, strengthening disaster risk management to manage disaster risk, investing in disaster risk reduction for resilience, increasing disaster preparedness and rehabilitation for an effective response, and building back better for reconstruction and recovery. is taken.

3. Assembly Areas in Disaster and Emergency Situations

Gathering areas are vital areas that enable people to be in an area where they can feel safe after a disaster, to overcome the great shock they have experienced, and to come together or communicate with their relatives. The first 12 - 24 hours after the disaster occurs is the most important time period for people exposed to the disaster to access the safe gathering areas they need, to access healthy information, to inform local authorities, and to prevent possible chaos (Maral et al., 2015). On the other hand, these areas are important for the provision of temporary shelter in the later stages, the distribution of first aid and all other aid services, and provide some opportunities for returning to the flow of daily life as quickly as possible. For this reason, the locations of assembly areas should be strategically planned in case of a possible disaster in urban areas and deficiencies, if any, should be eliminated. In order to eliminate the existing deficiency, it is of great importance to determine potential areas that can be used as gathering areas in cities.

In 1997, various non-governmental organizations on an international scale developed two basic principles regarding post-disaster living conditions:

(1) Disaster victims deserve the necessary aid and support due to their current conditions,

(2) all necessary precautions should be taken if people are exposed to disaster.

Therefore, it is extremely important to determine the gathering areas that people exposed to disasters may need in cities and to eliminate any deficiencies. However, research conducted with reference to theoretical and academic studies has shown that there are no clear definitions and criteria in this regard to date. The studies have a content that draws attention to the importance of the subject.

As a matter of fact, in the Integrated Urban Development Strategy and Action Plan (KENTGES) (2010-2023) prepared by the Ministry of Environment and Urbanization in 2010, "reducing disaster and settlement risks" was determined as one of the goals and within this context, strengthening the emergency communication infrastructure for effective response to disasters. The need to ensure the organization and implementation of facilities such as evacuation corridors, assembly, temporary shelter, disaster support centers and emergency facilities was emphasized. The report titled "National Earthquake Strategy and Action Plan 2012-2023" prepared by the Prime Ministry Disaster and Emergency Management Presidency in 2011 has been published. In this report, it is emphasized to prevent the physical, economic, social, environmental and political damages and losses that earthquakes may cause, to reduce their effects and earthquake risk, and to create new earthquake-resistant, safe, prepared and sustainable new living environments. In addition, it was stated that it is necessary to carry out studies on determining the health facilities and social facilities to be used in emergency situations, defining the evacuation corridor, gathering and temporary shelter areas and facilities to be used in emergency situations, determining their standards, and handling functions such as transportation, temporary shelter and logistics as a whole. For this reason, the areas to be determined as gathering areas should be chosen among areas that are easily accessible and have spatial potential that will not be affected by any disasters (fire, flood, etc.). In this context, the arrangement of gathering and building blocks and the establishment of a right-angled road system are also important in terms of "passive fire protection" on an environmental scale (Ceylan & Arpacıoğlu, 2017).

Passive fire protection studies, which should be analyzed starting from the design phase of a building and can be defined as a series of measures aimed at building physics, also include architectural elements that are natural parts of the buildings. The main purpose of passive fire protection is to prevent the outbreak of fire, to prevent the spread of a fire, to provide the necessary time for people to escape, and at the same time to keep property loss to a minimum (Arpacıoğlu, 2009).

In case of a disaster, open spaces, parks and unstructured urban uses such as squares, marketplaces and sports fields become important in transporting communities living in urban areas to safe areas. In extraordinary post-disaster conditions, it is important that there is no limiter in the gathering areas that can be accessed as soon as possible and ensure safety at the closest distance, preventing access to these areas. In other words, areas that can be easily entered/passed through should be designated as gathering areas. At this point, schools, official institutions or health facilities have walls, fences, etc. for security reasons. The fact that they are closed and surrounded by limiters prevents such uses from being easily accessible at first. Considering that such areas will be locked outside working hours, it becomes necessary to make a quality classification in terms of meeting areas. This is of course a situation to be taken into consideration in terms of our country's conditions. Considering the administrative/procedural framework valid for all cities, it is clear that it would be healthier to plan such areas as second-stage gathering areas and to develop a gradual usage forecast to support the open areas used in the first stage of the disaster, especially when necessary, depending on seasonal conditions.

Another issue that needs to be taken into consideration in such a classification is the structure of the social infrastructure areas to be determined as potential assembly areas (PTA) and the different risks they create in this context.

In this regard, one of the most basic assumptions put forward by the study in terms of gathering areas is that legal and administrative functioning should be a basic starting point in shaping the organization of space (Erdin at al., 2023).

According to this;

1st Level Assembly Areas: Parks and green areas, recreation areas, open sports areas, squares and open market places,

2nd Level Assembly Areas: Consists of public institutions, official schools (kindergartens, primary schools, secondary schools, high schools and universities), health facilities, indoor sports fields and closed market places.

Since the 2nd stage assembly areas have a closed area, unlike the 1st stage assembly areas, they will provide the opportunity to be in a more protected area, especially in adverse climatic conditions. In addition, these gathering areas are equipped with toilets, water tanks, generators, emergency equipment, first aid materials, etc. It will provide a spatial opportunity to meet needs. If such a classification is used as a basis, it is clear that measures must be taken to meet such needs in places designated as 2nd stage gathering areas. Temporary settlement areas, whose standards will be different from the gathering areas in the first two stages, need to be organized in the last stage for the shelter need that will arise due to the impact of the disaster (Figure 1).

Figure 1. Stages of space organization in case of disaster (Erdin at al., 2023).

The criteria for determining gathering areas need to be based on some parameters. Parameters in this study;

(a) Availability,

(b) Security and

(c) Defined as accessibility.

If a social infrastructure area meets the necessary conditions in terms of these three parameters listed, in other words, if it is usable, safe and accessible, it is appropriate to use it as a gathering area. However, it may not be possible for an area to meet all three parameters at an ideal level. In this case, a priority ranking should be made by taking into account the strengths and weaknesses of the evaluated area on the basis of criteria. In this case, while usability, accessibility and security parameters at the gathering area scale become important in terms of selection of

SUITABLE areas; It becomes important whether it is SUFFICIENT within the framework of the relationship with the total capacity and walking distance on a regional scale (Erdin at al., 2023).

3.1. The Need for Open and Green Spaces as Gathering Areas in Disaster and Emergency Situations

Sustainable development, based on the idea of both securing human existence and protecting human social, economic and environmental values, aims at the health and well-being of the entire society, now and in the future. Sustainable city; It is a city whose social, economic and physical development can be sustained. A sustainable city is also a city with a high quality of life that is safe against disasters and environmental pollution and preserves its ecological values. In this context, it is important for cities to be resilient to the effects of disasters, on the one hand, and to ensure their ecological, economic and social sustainability in the environment they are located in (Akten, 2021).

In Disaster Response Plans, decisions are developed regarding how and where the necessary services will be provided before and after the disaster, in terms of space use. These are generally requirements for the determination of main evacuation routes, secondary routes and alternative evacuation areas before the disaster, and for temporary shelter, cleaning, food and beverage and other mandatory needs that become urgent after the disaster. The realization of these activities is shaped depending on the urban space and spatial organization required to carry out that activity. The main purpose of such a study is to create a disaster management infrastructure and to meet vital activities at a minimum level. Thus, places designated as gathering areas emerge as areas of critical importance in terms of disaster management.

In addition to meeting the space needs of areas that fulfill a certain urban function within residential areas, urban voids, public spaces and open spaces are also important in terms of creating gathering areas and temporary shelter areas. In the first stage (the moment of the earthquake or the first minutes of the earthquake, zero-minute planning), when panic occurs after the disaster and people generally turn from closed areas to open areas, there is a greater need for easily accessible and safe open spaces. In such times of crisis, public areas that are easily noticed by those living in the region due to their location, can be accessed quickly and regularly, are of sufficient size, and consist largely of open spaces and parks, can be described as post-disaster gathering areas (Erdin et al., 2017).

The general character of a city is determined by architectural structures, open-green areas and their relationships and integrity with each other. Open-green areas have an important position in balancing the deteriorating relationship between humans and nature and improving urban living conditions. For this reason, in developed countries, the quality and quantity of open-green areas are accepted as an indicator of civilization and quality of life (Gül & Küçük, 2001).

Usage opportunities of open and green areas before the earthquake, during the earthquake

It plays an effective role during the disaster period with its functional transformation and subsequent functional transformation. Protecting and improving the function and structure of open and green spaces in cities has important application value to improve living spaces in the disaster area. For example, open and green area vegetation in the disaster area helps to change the negative effects of the changing city air from ruins and rubble and supports the renewal of the microclimate. In addition to the bioclimatic and health functions of these areas, they also have the protection function of the physical environment, such as creating oxygen and providing temperature and humidity control (Akten, 2023).

The function of reducing damage and impacts cannot be realized because the locations and sizes of the existing open-green areas in Turkey do not provide a safe environment for fires and similar problems that occur after the earthquake. Active green areas, which meet the recreational needs and demands of the public before the earthquake, should be increased by taking into account the green area standards and should be made functional with the necessary equipment for the post-earthquake period. After the earthquake, green areas where urgent needs, especially security, are met, interventions can be made, and urban services are shifted, will be places where life begins again (Kırçın et al., 2017).

In making and developing conservation-use decisions, the character of the urban or rural landscape should be determined by ensuring the continuity of the processes taking place in that place. Natural or cultural values that enable the place or object to be protected to gain meaning become a living place when the events that have been going on since the past continue (Akten & Akten, 2021).

It is extremely important to determine the post-disaster gathering areas in advance and raise public awareness in order to minimize the damage to people after the disaster and to ensure the necessary planning, communication and coordination to combat the devastating effects of the disaster and to prevent chaos and panic. For this reason, it is essential to determine and inform the emergency meeting areas of each neighborhood in advance on a district basis. The fact that some neighborhoods are narrow and do not have enough space makes it impossible to determine emergency assembly areas (Ekin & Sarıkaya, 2021).

In the context of disaster management, open and green areas in the city generally have three important contributions to disasters. The first of these is its use as an evacuation and gathering area for earthquake victims, the second is its contribution to reducing risks and damages, and the third is its healing effect. In the design of open and green areas in cities, attention should be paid to the selection of places for vital support, considering that they can be used as a gathering area, temporary tent area or shelter area for urban residents in case of possible disasters. In this regard, in the development plans to be made in our provinces after the earthquake, the existing open and green areas should be reviewed and the open and green areas should be increased in quality and quantity (Akten, 2023).

3.2. Planning and Design Principles of Assembly Areas in Disaster and Emergency Situations

Considering the current spatial and social conditions in our country, the standards of assembly areas that can be used in disasters and emergencies in our cities, almost all of which are at earthquake risk, need to be re-evaluated and reshaped depending on the settlement dynamics. It is also clear that it is a necessity to develop new recommendations that can be used on a national and international scale. It is extremely important that these suggestions are in coordination with the zoning plan decisions in cities and that they have qualities that can be evaluated within the scope of the provincial disaster response plan. Therefore, it must be ensured that the development plan decisions and the disaster management system establish a partnership with each other on a principled basis. It is also important to evaluate the various standards determined and used around the world for such areas that will be needed during and after the disaster, and to take into account the experiences of countries where earthquakes occur frequently (Erdin et al., 2023).

Open and green areas play an effective role during the disaster period with their usage opportunities before the earthquake and their functional transformation during and after the earthquake. Protecting and improving the function and structure of open and green areas in cities has important application value to improve living spaces in the disaster area. For example, open and green area vegetation in the disaster area helps to change the negative effects of the changing city air from ruins and rubble and supports the renewal of the microclimate. In addition to the bioclimatic and health functions of these areas, they also have the protection function of the physical environment, such as creating oxygen and providing temperature and humidity control (Akten, 2023).

Open and green areas should be planned and designed considering the social use during and after the disaster, in addition to the functional features they had before the disaster. Disaster management processes are plans that include analysis, synthesis and evaluations to be prepared for all possible hazards, to minimize damages, to intervene in a timely manner, and to repair and improve existing situations (Yiğiter, 2006).

In the disaster management process, in addition to increasing the sensitivity and resilience of residential areas to disasters, making effective preparations for emergency rescue and first aid before disasters, meeting people's meeting and temporary shelter needs during disasters, and being prepared for crisis situations that may arise after disasters. It is necessary to create strategies for this and pay attention to the following management stages (Özcan et al., 2013).

Preparedness: In the face of disasters, managers must be able to effectively fulfill their responsibilities with predetermined measures in the face of emergencies. Therefore, one should be prepared before experiencing any disaster. Within the scope of the disaster management process for city centers, the management of disaster risks that may occur in the city (such as earthquake, landslide, fire, rockfall, flood) and the necessary procedures before, during and after the disaster must be organized and carried out as soon as possible. The primary aim in the preparation phase against disasters is to be prepared to carry out rescue-first aid activities and to minimize damages (Güler, 2006). In preparation for natural events such as earthquakes and planning processes, opportunities to benefit from open and green areas that will meet needs under emergency conditions should be developed.

Risk and Damage Mitigation includes measures to prevent the effects of disaster and reduce risks. Creating strategies aimed at reducing risks and harms will contribute to the healthy development of cities and reduce the risks arising from possible hazards (Türkoğlu et al., 2002).

Response is the stage where the necessary assistance and needs of disaster victims are met. This phase begins immediately after the disaster. During the response process, search and rescue activities are carried out, meeting the shelter and basic needs of people affected by the disaster, carrying out evacuations, providing medical aid services, informing, taking decisions regarding damage and mitigating the damage, and decision-making actions regarding the assistance to be requested from outside the region when needed (Türkoğlu et al., 2002).

Recovery covers the process of returning the social and economic life of disaster victims to normal. It is a long-lasting phase (reconstruction of public buildings and permanent residences, establishment of economic mobility) that includes returning the disaster-affected area to normal and repairing all damage. However, temporary shelter, security and gathering areas should be created for families whose homes are damaged or destroyed as soon as possible after the disaster, and necessary infrastructure systems such as basic living needs (eating, drinking), social needs and communication should be established.

In the context of disaster management, open and green areas in the city generally have three important contributions to disasters. The first of these is its use as an evacuation and gathering area for earthquakes, the second is its contribution to reducing risks and damages, and the third is its healing effect (Akten, 2023).

In the design of open and green areas in cities, attention should be paid to the selection of places for vital support, considering that they can be used as a gathering area, temporary tent area or shelter area for urban residents in case of possible disasters. In this regard, in the development plans to be made in our provinces after the earthquake, the existing open and green areas should be reviewed and the open and green areas should be increased in quality and quantity.

The use of parks and open green areas after disasters has led administrations to create disaster parks in disaster-prone areas. While such parks meet the recreational needs of the society in normal times, they serve as a center where disaster management is carried out after a disaster. Why do open-green spaces function as a disaster management center after a disaster? Because parks have a greater capacity to support people than other areas. Parks have fewer structured areas and larger open areas. For this reason, approximately 80% of a park should be reserved as open vegetal area. In addition, since they are mostly public, temporary structures can be created, so problems such as obtaining permission and ownership are not encountered (Masoumi, 2017).

Active green areas, which meet the people's wishes and needs for recreation before the earthquake, should be increased by taking into account green area standards and should be made functional with the necessary equipment after the earthquake (Kahyaoğlu, 2016). Tokyo residents who survived the 1923 great Kanto earthquake in Japan fled the risk of fire in the city center and took shelter in forests and agricultural areas, which were safer areas. After the 1923 earthquake, the need for open green spaces in urban areas became clear. Especially in recent years, importance has been given to the planning of post-disaster shelter parks. It is aimed to increase the green areas of the city by building a new disaster and survival park of 185 ha in Tokyo by 2020 (Sarıçam, 2019).

There should be at least one disaster park in every neighborhood (Gülgün et al., 2016). Neighborhood parks are used as temporary shelters during or after an earthquake, temporary health services, food distribution, storage of future aid materials and other technical equipment. For this reason, open and green areas, which play a very important role in ensuring the continuation of vital activities after the earthquake, should be connected to the main transportation network and obstacles that would prevent access to these areas should not be allowed. Squares used for various purposes in cities constitute a resource for the establishment of a disaster management center in the work of governorships, district governorships and related institutions during disasters. Since squares represent cities and are known by everyone, they are meeting areas that everyone can easily reach in case of surprise and shock during a disaster. For this reason, it undertakes very important duties in organizing the aftermath of the earthquake, collecting aid to earthquake victims, and distributing aid. Additionally, exhibition and fair areas are areas that can be used for the same purpose. Open car parks and sports areas are areas where aid materials arriving after the earthquake are collected and where the needs for gathering, temporary shelter and tent cities are met. In addition, all urban open and green areas outside these areas can be converted into temporary assembly/evacuation, tent cities and temporary settlement areas after the earthquake (Kahyaoğlu, 2016).

Appropriate access to disaster parks should be provided from main roads and side roads, and the minimum road width should not be less than 12 meters. Such parks should not be created next to uses such as rivers, waterways, natural gas lines, and electricity grids (Masoumi, 2017). In order to prevent power lines from breaking or damaging the environment during an earthquake, they must be taken underground and all kinds of infrastructure galleries must be built under median strips left between traffic tracks (Çavuş, 2013). In addition, creating usage areas based on natural environmental data focused on daylight and energy plays an important role (Arpacıoğlu & Ersoy, 2013).

The scale of the park is determined by the population it can support for temporary and emergency accommodation. The park size should be a minimum of 2 decares within the city and a minimum of 5 decares outside the city (Masoumi, 2017). While creating an earthquake park, especially those that are not suitable for settlement and are non-functional; Areas that can meet the need should be selected according to density (Çavuş, 2013).

Open and green area sizes should be between minimum 3.5 - 4.5 m² and maximum 7.5 m² per person in cases where a large number of tents are needed to create a tent living space for shelter and the impact of the disaster. Tent areas should be planned in groups of 20-25, which can accommodate 4 people, and arranged in small islands (Sergeant, 2013).

For disaster parks; A helipad, a dining hall, an administration building, facilities that can be used for drinking and domestic use, and a sufficient number of toilets and bathrooms should be provided. These shuttles can be mobile or mountable. Solar panels, accommodation platforms and audiovisual notification tools should be used to provide electricity for the park (Masoumi, 2017).

Open and green areas should be planned to provide sheltered areas against precipitation and groundwater, considering climatic comfort against risks and damages. Care should be taken to ensure that these areas are multifunctional and provide integrity between green areas, rather than small pieces.

Open and green spaces, which contribute to cities in terms of ecological, economic, social and aesthetic aspects, and considering the functional effects they will provide in disaster situations, design approaches that will be good for people's physical, social and spiritual recovery should be developed. For this reason, large open green areas should be left for the establishment of accommodation areas, and evergreen plant species should be preferred in plant designs to emphasize the area entrances. Care should be taken to use thornless, non-poisonous and colorful plant species in areas where children will use them.

4. Conclusion and Recommendations

Pre-disaster work to be carried out with the awareness of harm reduction will not only minimize the loss of life and property; It will prepare our country for all kinds of disasters in advance, enable people to live in peace and safety without fear, minimize panic, pain and sadness during disasters and also help the country economically. It will relax you. Preparing for a disaster begins with accepting disaster preparation as one of the main policies of the state. Believing in this job and working with discipline, widespread and effective education, obtaining and updating information correctly, establishing practices, management, command and control centers, local governments and professional chambers. It continues with dozens of issues such as the active involvement of people and voluntary organizations in this work. Disaster preparation and disaster management are not as easy as they seem on paper. For this reason, first of all, the state and local governments must believe in this work, allocate their resources to this work, and work scientifically and in a highly disciplined manner. Otherwise, this important issue will remain limited to the efforts of a few professional chambers and voluntary organizations, and much more losses will occur after each disaster than necessary.

Assembly areas are of critical importance in informing and guiding the public in combating disasters. In this context, gathering areas need to be considered in a very broad framework and as a holistic system for different times, places and actions, from product design to service design. Accessibility of gathering areas and their effective use in disasters can only be achieved with sound information and guidance.

An important issue in determining collection areas is adequate and up-to-date data infrastructure for cities. There are also varying institutional capacities in different settlements in the context of data assets. Institutions need to develop their data infrastructure in order to be prepared in terms of determining disaster recovery areas. The developed data infrastructure can also be used in development plan studies that will include spatial uses related to disaster management. In addition, the main source of disaster risk reduction studies is inter-institutional cooperation, and an interdisciplinary flow of information is needed to achieve healthy results in this field.

In addition, it should be taken into account that the population of different regions of the city will differ according to temporal and seasonal changes, and it should be known that making calculations only based on address-based population data will not be sufficient for these regions.

In the context of assembly areas, it is clear that capacity and spatial distribution within the city are very important issues and that the task of determining assembly areas should be handled with a systematic approach to ensure that these areas serve the entire city. This systematic approach requires disaster emphasis and sensitivity at all stages of the planning process. In this context, it is expected that the proposed method will create a guiding content in urban planning studies and subsequently function as an intermediate section that will integrate zoning plans with Provincial Disaster Response Plans.

Author Contribution and Conflict of Interest Disclosure Information

The author has no conflict of interest.

References

Akten, S. (2021). Effects and Sustainability of Open and Green Spaces on Society Relations During the Pandemic Process. Şebnem Ertaş Beşir, M. Bihter Bingül Bulut and İrem Bekar (Eds.). Architectural Sciences and Sustainability. 2021, Volume:2, 51-84. ISBN: 978-625-8061-43-7. Iksad Publications.

Akten, S. & Akten, M. (2021). Korunan Alanlarda Rekreasyonel Aktivitilere Yönelik Yönetim Yaklaşımları. Rekreasyon (Disiplinlerarası Yaklaşım ve Örnek Olaylar) / Editörler: S. Gül Güneş - Fatih Varol. Nobel Akademik Yayıncılık Eğitim Danışmanlık Tic. Ltd. Şt. ISBN: 978-625-439-749-3.

Akten, S. (2023). Afet Yönetim Planlarında Açık ve Yeşil Alanların Önemi ve Gerekliliği Üzerine Bir Araştırma. Kahramanmaraş Merkezli Depremler Sonrası için Akademik Öneriler. Editörler: Doç. Dr. Musa Öztürk - Doç. Dr. Mustafa Kırca. Özgür Publications. DOI: https://doi.org/10.58830/ozgur.pub99. License: CC-BY-NC 4.0.

Arpacıoğlu, Ü.T. (2009). Yangınların Yüksek Yapılarda Yangın Güvenliği Gelişimine Etkisi. Mimar Sinan Güzel Sanatlar Üniversitesi Tasarım + Kuram Dergisi. Cilt: 5 Sayı: 8 - Cilt: 5 Sayı: 8, 30 – 42.

Arpacıoğlu, Ü.T & Ersoy, H.Y. (2013). Daylight and Energy Oriented, Architecture Design Support Model. Gazi University Journal of Science. 26(2):331-346 (2013).

Ceylan, O. & Arpacıoğlu, Ü. T. (2017). Korunması Gerekli Taşınmaz Kültür Varlıklarında Edilgen Yangın Korunumu, İstanbul Örneği. MEGARON 2017;12(1):145-156 DOI: 10.5505/megaron.2017.73645

Çavuş, G. (2013). Deprem Bölgelerindeki Açık-Yeşil Alan Sistemi İlke ve Standartlarının Bolu İli Örneğinde İrdelenmesi, Doktora Tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Peyzaj Mimarlığı Anabilim Dalı, Ankara.

Çelik, H. Z., Özcan, N. S.& Erdin, H. E. (2014). Afet Ve Acil Durumlarda Halkın Toplanma Alanlarının Kullanılabilirliğini Belirleyen Kriterler. 4. Uluslararası Deprem Mühendisliği ve Sismoloji Konferansı, 11-13 Ekim 2017– Anadolu Üniversitesi – Eskişehir.

Ekin, E., Sarıkaya, Z. (2021). Ahp Tabanlı Topsıs Yöntemi ile Afet Sonrası Acil Toplanma Alanlarının Belirlenmesine Yönelik Bir Uygulama. Social Sciences Research Journal, 10 (3), 696-713.

Erdin, E., Kama, S., Metin, T., C. (2017), Afet ve Acil Durumlarda İletişim, Koordinasyon ve Mekanlar; Acil Durum Bilgisi ve Yönetimine Giriş, Bölüm: 7, Editör: Çabuk, S. N., Çabuk, A., Eskişehir.

Erdin H.E., Celik H.Z., Silaydin M.B., Partigoc N.S., 2023. The Determination of Criteria and Method for Social Infrastructure Areas as Gathering Areas in case of Disaster and Emergency Situations, Türk Deprem Arastirma Dergisi 5(1), 1-21, https://doi.org/10.46464/tdad.1251998.

Gül, A. & Küçük, V. (2001). Kentsel Açık-Yeşil Alanlar Ve Isparta Kenti Örneğinde İrdelenmesi. Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi Seri: A, Sayı: 2, Yıl: 2001, ISSN: 1302-7085, Sayfa: 27-48.

Güler, H. H. (2006). Afetlere Hazırlıklı Olma, Edts. Kadıoğlu, M., Özdamar, Ö., Afet Yönetiminin Temel İlkeleri, Japon Uluslararası İşbirliği Ajansı-Türkiye Ofisi, Ankara, 81-91.

Gülgün, B., Yazıcı, K., Dursun, Ş. & Türkyılmaz Tahta, B. (2016). Earthquake Park Design and Some Examples from the World and Turkey, J. Int. Environmental Application & Science, Vol. 11(2): 159-165.

Kahyaoğlu, B. (2016). Tekirdağ Kentinde Doğal Afet ve Eğitim Parkı Planlaması Üzerine Bir Çalışma. Yüksek Lisans Tezi. Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü, Peyzaj Mimarlığı Anabilim Dalı, Tekirdağ.

Karataş, N. & Kaya, M. A. (2022). Deprem Riskinin Kentsel Planlama Sürecine Etkisi: İpsala, Keşan ve Enez İlçeleri (Edirne) Örneği. Mühendislik Bilimleri ve Tasarım Dergisi 10(2), 654 – 679, 2022 e-ISSN: 1308-6693.

Kırçın, P. N., Çabuk, S. Y., Aksoy, K. & Çabuk, A. (2017). Ülkemizde Yeşil Alanların Afet Sonrası Toplanma Alanı Olarak Kullanılma Olanaklarının Artırılması Üzerine Bir Araştırma. 4. Uluslararası Deprem Mühendisliği ve Sismoloji Konferansı 11-13 Ekim 2017. Anadolu Üniversitesi – Eskişehir.

Masoumi, M. (2017). Innovating A New Idea Namely: Disaster Park (Multi Use Park). Int J Sci Stud 2017;5(3):5-10.

Maral, H., Akgün, Y., Çınar, A.K. & Karaveli, A.S. (2015). İzmir'deki Afet Sonrası Toplanma ve Acil Barınma Alanları Üzerine Bir Değerlendirme. 3. Türkiye Deprem Mühendisliği ve Sismoloji Konferansı, Dokuz Eylül Üniversitesi, İzmir.

Mengi, O. & Erdin, H. E., (2018). Afet ve Acil Durumlarda Toplanma Alanlarının Yönetimi: Tasarım ve Sistematik Yaklaşımlar. 2 nd. International Symposium on Natural Hazards and Disaster Management 04-06 MAY 2018 (ISHAD 2018) Sakarya.

Özcan, N.S., Erdin, H.E. & Zengin, H. (2013). Kentlerde Açık ve Yeşil Alan Sistemlerinin Afet Yönetimi Bağlamında Kullanılabilirliğinin Değerlendirilmesinde Coğrafi Bilgi Sistemleri (Cbs): İzmir Örneği. TMMOB Coğrafi Bilgi Sistemleri Kongresi, ss. 1-7, 11-13 Kasım, Ankara.

Sarıçam, S. (2019). Kentsel Açık-Yeşil Alanların Afet Sonrası İşlevleri. GSI Journals Serie B: Advancements in Business and Economics, 1 (2): 1-15.

Türkoğlu, H., Tezer, A., Yiğiter, R. (2002). Şehir Planlamada Afetlere Yönelik Zarar Azaltma Stratejileri, Kentlerin Depreme Hazırlanması ve İstanbul Gerçeği, İ.T.Ü, İstanbul, 8-9 Şubat, 94-106.

Yiğiter, R.G. (2006). Kentsel Yerleşmeleri Afetlere Hazırlama Odaklı Kent Planlaması ve Zarar Azaltma, Edts. Kadıoğlu, M., Özdamar, Ö., Afet Yönetiminin Temel İlkeleri, Japon Uluslararası İşbirliği Ajansı (JICA)-Türkiye Ofisi, Ankara, 59-66.

Murat AKTEN
E-mail: muratakten@sdu.edu.tr
Educational Status:
License: Ankara University Faculty of Agriculture. Department of Landscape Architecture, 1996.
MSc: Süleyman Demirel University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, 2000.
Doctorate: Süleyman Demirel University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, 2008.
Professional experience:
Res. Assist., Süleyman Demirel University, (1997-2010)
Assist. Prof. Dr., Süleyman Demirel University, (2010-2015)
Assoc. Prof. Dr., Süleyman Demirel University, (2015-2020)
Prof. Dr., Süleyman Demirel University, (2020-)

Use of Brick from Past to Present

Assoc. Prof. Dr. Türkan İRGİN UZUN [1]

[1]İstanbul Gelişim University, Faculty of Engineering and Architecture, Department of Architecture. İstanbul/Türkiye.
ORCID: 0000-0002-3306-0101
E-mail: tuuzun@gelisim.edu.tr
turkanuzun72@gmail.com

Merve SAVRUNLU [2]

[2]İstanbul Gelişim University, Instıtute of Graduate Studies, Architecture İstanbul/Türkiye.
ORCID: 0000-0003-4351-2973
E-mail: mervesavrunlu@gmail.com

Citation: Uzun İrgin, T. & Savrunlu, M. (2023). Use of Brick from Past to Present. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (244-302). ISBN: 978-625-367-287-4. Ankara: Iksad Publications.

1. Introduction

While clay was originally used in daily use items, its usage area expanded thanks to the firing of clay. Brick material is also a material obtained by firing clay. B.C. In the 4th century, fired brick was industrially produced for the first time. In order to build structures, besides the use of materials such as stone and wood, which are readily available in nature, bricks have also been used. for the first time, the technique of making a building element has emerged thanks to bringing together units of the same size. As the knowledge and experience in brick making increased, its usage area also expanded.

2. Material and Method

In this article, firstly, information about clay, which is the raw material of brick, was given. It was explained how fired brick and factory-made brick are produced. The differences between fired brick and factory-made brick were mentioned. The brick bonds, brick bonds rules and, technical specifications of bricks were mentioned. Then, the historical development of the brick was explained via selected architectural building examples. In the last part, the use of bricks in buildings was examined.

3. The Production of Bricks

The range of bricks typed is defined in the contex. Raw material of brick is clay. Clays are minerals that are obtained from nature, and they are formed as a result of weathering of rocks such as porphyry and granite. Clay is a raw material that gives color to brick (Table 1). These ones:

Table 1. The substances in clay and the colors (Sezen, n.d.)

Light green	Pyrite or strontium salts	Red	Iron oxide
White	Pure clay, kaolinite	Violet-colored	Organic substance
Brunette	Limonite	Black	Manganese oxide and lignite

Materials are made from clay that are divided into two groups as baked and unbaked. While brick can be given as an example for baked materials, mud brick can be given as an example for unbaked materials. Bricks are divided into two as fired bricks and factory bricks according to their production methods.

3.1. The Production of the Fired Brick

In the production of the fired brick is that the mud is molded by hand and is dried in the open air. As a result of baking with the coal dust, the fired brick is produced. Production of brick consist of 5 stages. They are preparation of raw material, forming by hand, air-drying, firing in a great oven, and packaging.

3.1.1. Preparation of raw material

Raw material is extracted from the area where the soil is suitable (Figure 1a). After the raw material is removed from the area, it is stacked in the mixing zone (Figure 1b). The raw material that is stacked in the field, is filled into the so-called sludge pit (Figure 1c). This pit is filled with water and left during a day. Usually, there are more than one mud pool at the brickyard. Having more than one mud pond is important for the workflow. The sludge, which is rested during a day, is kneaded by passing through the tank (Figure 1d).

3.1.2. Forming by hand

Materials such as scraping tool, sand bench, workbench, brick mold and water are necessary to produce brick. Workforce is used to shape the brick. Therefore, it is important to have an experienced bricklayer in order to shape the brick. Brick molds, which are reinforced with brace for durability, are produced using wood material. At the same time, there is the mark of the manufacturer company inside the mold (Figure 1f). The bricklayer takes a piece of mud that is carried by the woodworker and pugs it on the workbench that is sanded by bricklayer (Figure 1g). The bricklayer presses the muds into the mold and scrapes off the excess mud using the scraping tool (Figure 1h).

3.1.3. Air-drying

Molders moisten the brick molds with water and put them on the sand bench. The surfaces of the molds are covered with a layer of sand and are left on the bricklayer's workbench. Meantime, the bricklayer put mud on the previous mold. Also, the molder takes the mold that is put the mud and turns it upside down and arranges the bricks in the drying area (Figure 1i). As it dries, it is formed a cream layer by the wind. During the drying phase of the clay, its size decreases due to the loss of the absorbed water.

3.1.4. Firing in a furnace

Open Field Oven: "It is a primitive type of oven that is not seen in advanced countries in the ceramic industry. Since they work outdoors, they can burn only in favorable climatic conditions. It is generally used for firing the bricks shaped in brick mixing established in places where suitable clay beds are found (Arcasoy, 1983)" (Picture 1j). The air channels that provide air intake to the furnace are created during the laying of the brick. The size of these air channels, called grilles, is one brick wide and continues from the starting point of the field oven to the end point. They put pieces of charcoal inside the grill, and the air channels keep the furnace burning constantly (Figure 1k).

3.1.5. Production and packaging stage of the brick

The stages from the extraction of the raw material to the packaging of the brick are shown.

Production Stage of the Brick

Figure 1a. Transport of raw material **b**. Brick soil **c.** Preparation of sludge in the mud pond

d. Kneading Mud **e.** Transporting the mud from the pond **f.** Brick mold

g. Sanding of molds **h.** mud pressing into the mold **i.** Arranging the bricks in the drying area

j. Open field oven **k.** Top view of burning open field oven **l.** Bricks **m.** Packed bricks (Er, 2013).

<u>Packaging:</u> While the bricks is being loaded from one side, it can also be unloaded from the other side. The initial bricks in the furnace are unloaded after about twenty days (Figure 1l). This process requires manpower. Bricks are aligned on pallets and packed (Figure 1m).

3.2. Production of Factory-Made Bricks

Brick production takes place by firing the materials mixed with the help of the machine in the factory environment. This advantages is of this methods, any error that may occur during production stages of the factory brick adversely affects the quality of the factory brick (Figure 2).

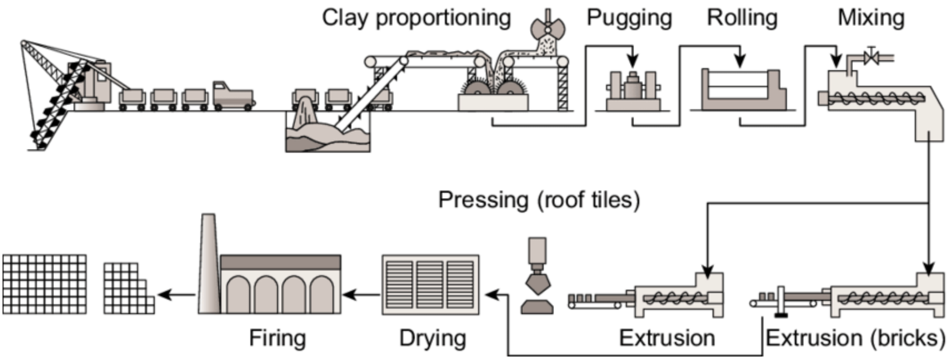


Figure 2. Production stages of the factory brick (Hotza & Maia, 2015).

The clay, which is the main material of the brick, is taken out with the help of tools during the preparation stage and is rested in the rot pond. Necessary materials are added and shrunk by grinding.

Clay can be shaped using different techniques. These techniques are such as spinning, moulding, hand shaping, pressing, meshing or etching. In the drying phase, both water that is added to clay and used for shaping are evaporated with the help of heat. In this way, it becomes ready to be baked. The last stage is baking. As a result of this stage, the production of the brick is realized.

3.2.1. Types of factory brick

Solid brick, perforated brick, hollow brick, and pressed brick are mentioned among the factory brick.

Solid brick: It is light and cavitied. It is also a packing material. It absorbs a small amount of water. Therefore, it is used in facades and waterworks.

Perforated brick: It provides sound and heat insulation. It is light and since the full part is reduced, the load that can carry is reduced.

Hollow brick: It is hollow and light. It provides moisture proofing and heat insulation.

Pressed brick: It is obtained thanks to molding of the brick twice under high pressure. Its exterior surface is smooth and is used on facades.

Beginning of brick production is selecting the proper soil and conveying it to the worksite. The soil is waited for 3 weeks in order to be purified and mature enough. The clay is sieved and at the same time mixed with water. After, the mixture is waited to stabilize and gain the plasticity. Wooden molds are used in order to shape. These molds are laid in an open area for drying stage. After this, air-dried bricks are put in an oven for firing stage. During firing, brick takes its final shape.

Fired brick factories are active only time of year. In Turkey, spring and autumn months are the most suitable for fired brick. The brick must be protected from direct sunlight, because it can cause cracks. Additionally, the area must be suitable for the manufacturing. The area has available water, suitable soil, and transportation facilities.

3.2.2. Differences of fired bricks and factory-made bricks

The production of factory bricks has similar stages as the production of fired bricks. However, factory bricks can be produced faster and systematically thanks to machines. One of the most important differences is that after the raw material is prepared, the size of the clay is reduced by grinding using rotating cylinders. The raw material rests to mature in a humid environment for about 20 days to 3 weeks. To solve the salt problem in the clay, water and barium carbonate are added to the clay and mixed.

4. Technical Specifications of Bricks

The shape of the brick bond is in the form of a rectangular prism, and the brick surfaces are produced in such a way that the surfaces are smooth, and the corners are right-angled. The properties of the brick change according to the mixing ratio of the brick soil, the temperature at which it is fired, fired method and the production technique. Salt is added to the mixture. Salt prevents the reproduction of the plant.

Efflorescence occurs in hollow baked clay material and is a chemical phenomenon. In the efflorescence, the salts in the baked clay materials and the mortar move to the surface by moving from the capillary spaces and accumulate here thanks to the water evaporates. This phenomenon is called efflorescence. Efflorescence may occur in cases such as the formation of Glanber salt, the material is not baked well.

One of the technical features of building materials is the compressive strength against the weight they will carry. Hard bricks, which are molded by compression with a force, are resistant to external factors even without plastering. The width of the brick is sized to fit inside the palm of the hand. The length of the fried bricks varies between 20.5 - 22.7 cm, the width varies between 9.2 - 11.8 cm and the height varies between 5.4 - 6.3 cm. The compressive strength of these bricks is less than 7.5 MPa. Their freeze-thaw resistance and water absorption capacity are low. The water absorption values of factory bricks are also low, and the water is at most 18%. The compressive strength of these bricks varies between 6-10 MPa. In density bricks, the compressive strength is up to 24 MPa.

Due to the nature of the clay, the heat permeability is low in proportion to the degree of firing of the brick. Brick walls provide a certain insulation according to their thickness. Thanks to their porous structure, the bricks allow moisture to pass through (except for glazed bricks such as clinker, etc.), it makes easier for the building to breathe. Due to the closeness of the expansion coefficients and mortar that is used in the implementation phase, cracks do not occur.

4.1. Brick Bonds

Strecher bond, header bond, flemish bond, english bond, english garden wall bond, and flemish garden wall bond are mentioned among the brick bonds.

Strecher Bond: It is placed in such a way that the stretcher part of the bricks is visible (Figure 3a).

Header Bond: It is placed in such a way that the stretcher part of the bricks is exposed (Figure 3b).

Flemish Bond: Stretcher is placed between the headers and the headers are centered on the stretchers below (Figure 3c).

English Bond: In this type of bond, one course of bricks is placed so that the header part is exposed, while the course above or below this course is placed so that only the stretcher part is exposed (Figure 4a).

English Garden Wall Bond: After three or five stretcher courses are placed, one course header is placed (Figure 4b).

Flemish Garden Wall Bond: Each course includes three or five stretchers to one header (Figure 4c).

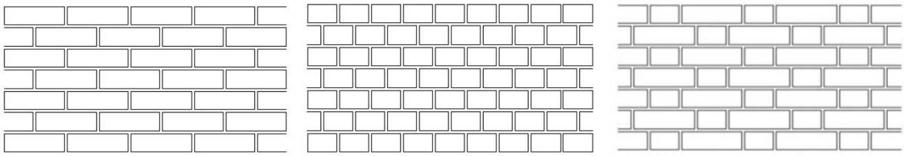


Figure 3a. Strecher Bond **b**. Header Bond **c.** Flemish Bond

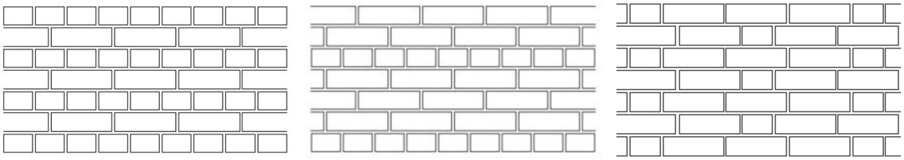


Figure 4a. English Bond **b.** English Garden Wall Bond **c.** Flemish Garden Wall Bond (URL, 1).

4.2. Brick Bond Rules

Vertical joints are made 1 cm thickness, while horizontal joints are made 1.2-1.5 cm thickness. Continuity in horizontal joints must be preserved along the wall length and depth. While the vertical joints should not align on top of each other, the vertical joints should align in every two rows. Vertical joints on load-bearing walls should be staggered ¼ brick length, while vertical joints on non-load-bearing walls should be staggered ½ brick length. It should use thin and full-size brick as far as possible. In addition, in order to ensure the connection, bond should be made with split bricks. Brick walls should not be built at temperatures below -3 degrees. In periods when the weather is hot, the brick should be heated and inserted into the bond.

5. Historical Development of Brick

Regional conditions are important in the use of brick. Especially in Mesopotamia, Iran, Central Asia and Egypt, brick was used instead of stone, due to the limited availability of stone. In these regions, stone was generally used to reinforce the brickwork. Information about brick production is found in Egyptian frescoes and written materials.

The Assyrians used clay both cooked and unbaked. The Great Wall of China in Chinese civilization was built by filling soil and stone between two thick brick walls. The Hebrews also used brick as a building material. According to ancient texts, the Tower of Babel, which is mentioned in mythology, was also built out of adobe brick. Stone, which has an important place in the Roman civilization in the west, left its place to brick in the last periods of this civilization and many buildings were built of brick materials in this period. The use of bricks began to be seen in the buildings of Rome, especially in the Augustus Period (27 BC - 14 AD). In this period, brick was used in the masonry of Hadrian's Bath and Serapis Temple in Bergama, Anatolia.

In the Roman Period, brick ballasts were benefited the water-holding effect as well as the binding effect adding to the mortar and plaster. The kiln-fired Roman brick was fired a higher temperature and laid with lime mortar that contain volcanic ash. In this way, a rigid set wall model could be produced. Thinner walls can be made with this technique. The Roman Colosseum can be given as an example of this technic.

The use of bricks in the Roman period led to the widespread use of bricks in Europe and England. However, due to the fall of the Roman Empire, brickmaking in Britain declined. Still, they built many religious and public buildings from bricks obtained from Roman ruins. In this period, in Europe, with the progress of the Byzantine Empire's brick production, it made its presence felt in Italy and Spain, and it was observed that the use of bricks in their buildings increased.

Thanks to the developing industry, the brick could be manufactured cavernously. With the industrial revolution, construction speed began to increase. The building material industry had to keep up with this change. During the world wars, brick production declined and was replaced by concrete as a material. At the end of the war, brick production increased again in order to repair and rebuild the destroyed structures.

5.1. History of Brick Usage

Naked brick style emphasizes utilization of the brick on carrying superstructures, walls or architectural elements for construction and ornament. Surfaces of this brick are not concealed behind a decorative or protective facing, like glazed or plaster components that cover their surface. On the contrary the structural properties and decorative potentials are accentuated.

The first examples of the naked brick can be seen in the Turkestan region in the 10th century. Brick material was used between the 10th and 12th centuries in the Karakhanids, Ghaznavids and Central Iranian regions. Brick material is the only material used for the construction of buildings in these regions. A technique called Hazarbaf was used. In this technique, the bricks look like a woven and the design is embossed (Figure 5).

Figure 5. Hazarbaf Brickwork, Mudhafaria Minaret (URL, 2).

Thanks to the discovery of the firing process, fired brick was used as a construction material in areas where alluvial clay is concentrated. Brick was preferred for reasons such as easy access, low cost, and being able to be shaped according to the user's preferences. For such reasons, it is called "the first man-made building material".

The naked brick style reached to peak in the works of the Great Seljuks in central Iran in eleventh and twelfth centuries. There are mosques, minarets, Caravanserai, Medrese and tomb towers that are built in this style. Masjid-i Jum’a in Işfahān is one of the quite remarkable examples. Different of bond types were used on the dome and the walls of the north aiwan and the walls and bearing elements on the northeast corner of the mosque. Moreover, there are a few eleventh century tomb towers such as East Tomb Tower the Kharraqān I, the West Tomb Tower the Kharraqān II and Damāvand Tomb that are mentionable for brickwork (Figure 6).

Figure 6. Masjid-i Jum’a in Işfahān and the Kharraqān Towers (URL 3 and URL 4).

The Great mosques in Harput, Kayseri and Sivas that is built in stone and brick together are early 13. Century examples. While in Sivas the shaft and the base are in brick (Figure 7), in Kayseri and Harbut brick shafts rise on stone bases.

Figure 7. Sivas Great Mosque, minaret (URL, 5).

The brick minaret that is located at a short distance from the Great Mosque of Akşehir, has a high rectangular brick base that carries on its front face, use again marble fragments belonging to Roman tomb stones and Byzantine church furniture which are located side by side on the common bond brickwork (Figure 8).

Figure 8. Great Mosque of Akşehir, minaret, 1215 (URL, 6).

Keykavus Hospital that built in 1220 in Sivas donated by the Seljuk Sultan İzzeddin Keykâvus I. this building has a rectangular plan. There is an open courtyard at the center that is encircled by a colonnaded portico and the tomb of the donor at the north eyvan that is placed in the center of the north wing. Keykavus Hospital is built in stone and brick. Brick is used in the octagonal drum rising above the upper structure, the vaulted upper structure of the portico the north eyvan and its front elevation (Figure 9).

Figure 9. Keykavus Hospital, 1220 (URL, 7).

The Ishtar Gate is an 11-meter-high part of a palace structure built in Babylon, one of the Ancient Middle Eastern Empires, between 604-561 BC (Figure 10). The lower parts of the walls on both sides of the street that passes in front of the palace are covered with glazed bricks. On these walls, successive depictions of lions and armed soldiers were made. Reliefs are frequently observed. The relief of the figures applied on glazed bricks is shaped to be convex and rounded.

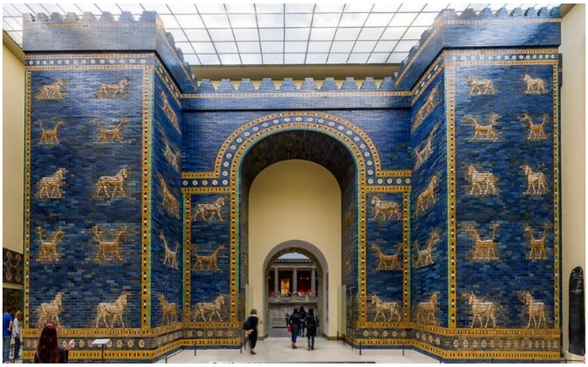


Figure 10. Ishtar Gate, Babylon (URL, 8).

Use in city walls;

The First Walls: Historians of the period say that the construction of these walls was started in 412 and was completed in a very short time. These walls that is 5.7 km long were reinforced with 96 towers. The Land Walls start from Yedikule and connect to the Golden Horn after enclosing the Blachernaean Palace. These walls, the construction of which II. Theodosios started, continued with various additions until the conquest. The land walls were built in three intertwined stages.

There is a ditch in front, an outer and front wall behind it, and an inner or rear wall with a width of 3-8 m and a height of 11-13 m behind it. A bastion was placed between 50 and 75 m of the inner-city walls. These bastions have a round, rectangular plan and their height is 24 m. These bastions protrude 10-11 m from the wall body and their inside is 2-3 floors. Their tops are covered with domes or vaults. It has a colorful appearance with 3-4 rows of stones and 1-2 rows of bricks. This row acts as a bond course and balances the load distribution horizontally (Figure 11).

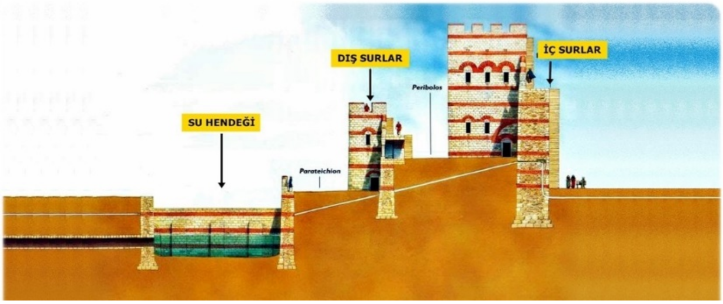


Figure 11. Section of the Land Walls (URL, 9).

There is a flat land that is 12-13 m wide between the inner wall and the outer wall. There are semicircular bastions that protrude forward by 4 m on the body of the outer walls. There are 96 bastions on the land walls. The walls are in the chest wall technique called casemate and are 1 m thick and 8 m high. There are small chambers that is used as weapons storage in the inner parts of these walls called casemates. There are ceremonial gates as well as military-purpose gates on the body of the wall.

Figure 12. Fortification Wall (URL, 10).

Improved brickwork can be seen on the body walls and domes of the religious buildings that have survived to the present day in Byzantine buildings. Byzantine Art is studied 5 different periods. These;

395-527 Succession and Transition Period, 527-726 Early Byzantine Period, 726-842 Iconoclasm (Description), 842-1204 Middle Byzantine Period, 1204-1261 Latin Invasion, 1261-1453 Late Byzantine Period.

The brick, which is known to have been used in bodies and dome of religious building since the Early Roman period, has ensured that the structures have survived for centuries without being demolished, thanks to its high load bearing feature against pressure. Monastery of Stoudios, which is one of the examples that completely covers the body wall of brick material, is an example of the Hellenistic type of basilicas that is built in the early periods of Christianity (Figure 13). Monastery of Stoudios, which is between Yedikule and Samatya, and just behind of the main street, has an immense importance as it is the oldest Byzantine religious structure in Istanbul. The narthex belonging to the Byzantine period, whose northern wall is partially standing, opens to the courtyard with a portico with four marble columns. The body wall is dominated by the red brick appearance.

Figure 13. Monastery of Stoudios (İmrahor Cami), Fatih, İstanbul (URL, 11 and URL, 12).

Brick was used in their construction by The Eastern Roman Empire. They generated bonding patterns that were special for the region. Hagia Sophia is the most important example of Byzantine brickwork. This church built in İstanbul in 532 AD, and It is built almost entirely out of brick (Figure 14).


Figure 14. Hagia Sophia, Fatih, İstanbul, 532-537
(URL, 13 and URL, 14).

Hagia Irene was built in the 4th century during the reign of Constantine I. After the fire in 532, it was rebuilt in 548 by the emperor Justinian I. It is a basilica planned structure that consist of naos, narthex and atrium. The dome of the church is seated on four brick columns (Figure 15).

It is thought that the interior walls of the church were decorated with mosaics, as in the simultaneous structures. However, today there is no evidence to confirm this, the interior surface of the building is completely plastered.

Brick was used for wall of vaults and dome in the Church of Hagia Irene. Brick wall stiffened with stone blocks of various embedded in 4-5 cm thick mortar beds.

Figure 15. The Church of Hagia Irene, İstanbul, 4th century (URL, 15 and URL, 16).

One of the important structures in terms of the use of brick material in the Eastern Roman Empire is the Red Basilica, which was built in Bergama, Izmir. Red Basilica is derived from the brick material that was used in the construction of this building. The main walls of the 2nd century Red Basilica are completely covered with red bricks. Thanks to the influence of Eastern Roman architecture, bricks continued to be used in civil, public, and religious buildings in Anatolian architecture (Figure 16).

Figure 16. Red Basilica, Bergama, İzmir, MS. 2.yy (URL, 17 and URL, 18).

Smooth cut stones, rubble stones and bricks were used in both Ertokuş Inn and Susuz Inn (Figure 17).

Figure 17. (left) Ertokuş Han, Eğirdir, Isparta, 1204 (URL, 19).

Figure 18. (right) Susuz Han, Bucak, Burdur, 1246 (URL, 20).

The name of the medreseh derives from the blue tiles that cover its walls. Its architect is Kaluyan from Konya. The name of the architect of the Bünyan Great Mosque was written as the master Kaluyan el-Konevi on the marble portal and on both sides of the entrance.

Glazed bricks, unglazed bricks and mosaic tiles were used in the minarets of the medrese. Geometric patterned ornaments were made on the lower parts and bodies of the minarets by using colored glazed bricks and tiles (Figure 19).

Figure 19. Sivas Gök Medrese, Sivas, 1271 (Küçükyılmazlar, 2006, 8).

Sivas Gök Medrese dome was started with two rows of bricks stacked horizontally at the bottom, the bricks were lined up to form a small circle at the top of the dome and the top of the dome was covered with a different material (Figure 20). One, two and three unit bricks were used in the dome. In the vertical stack, two-unit bricks were used, while in the horizontal stack one-, two- and three-unit bricks were used. The bricks, which should be five units under the three-unit brick, were formed by placing the two- and three-unit bricks side by side. However, joint was not made between these two bricks. Additionally, dimensions of the bricks that are arranged in horizontal stacks get shorter as they approach the top of the dome.

Figure 20. Sivas Gök Medrese dome (Öter, 2021, 107).

Sivas Gök Medrese Mosque dome was started with two rows of unglazed bricks that was arranged in horizontal stacks (Figure 21). One, two, three and four unit bricks were used in this dome. Joint was not used between the unglazed bricks that were used side by side. The brick dimensions decreased towards the top of the dome and the top part was covered with a different material.

Figure 21. Sivas Gök Medrese Mosque dome (Öter, 2021, 109).

The Great Mosque that located in the city center was built in 1282-1299 during the reign of Seljuk Sultan Gıyasettin Mesud II. (Figure 24). It has considerably lost its originality due to the repairs that have been made at different times. It was restored by foundations in 1967. In this restoration, the entire mosque was renovated, except for its minaret, its two doors opening to prayer place , squinches with muqarnas providing the passage to the dome in front of the mihrab. Its original minaret in the Anatolian Seljuk period was built as cylindrical body brick material on square pedestal. There are tiles with geometrical and floral motifs on the octagonal base and minaret balconies. There is a narthex in the east of the mosque which has a rectangular plan. All five repair inscriptions that found in the building are located on the walls of this narthex.

Geometric, herbal, and figured ornaments on distinctive doors reflect Seljuk tradition. The peribolos of the mosque has a plan that has three naves perpendicular to the mihrab direction and dome in front of the mihrab. The stone pillars are connected to each other by pointed arches.

The square space formed by three wide pointed arches sitting on two pillars in front of the mihrab is covered with a dome.

Figure 22. Melik Gazi Tomb, Kemah, Erzincan, 1164 (URL, 21).
Figure 23. Street in Erzincan (URL, 22).

Figure 24. Bayburt Grand Mosque, Bayburt, 1282- 1299 (Ayduslu, 119, 120,121).

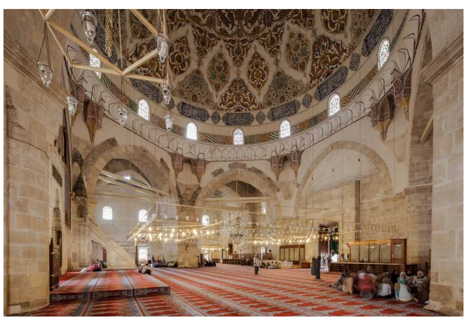


Figure 25. Üç Şerefeli Mosque, Edirne, 1447 (URL, 23).

Üç Şerefeli Mosque, that was built during the Ottoman period, has one large central dome, two small domes on each side, a courtyard with a portico and four minarets. In this structure, which was built with cut stone material, brick was used as the material in the dome transitions and domes (Figure 25).

An intense use of brick is seen on the body walls, the dome and the formation of load-bearing walls and columns in Anatolian Seljuk and Ottoman public and civil architecture. Especially in the dome pattern, the brick laying pattern differs depending on the carrier system pattern. These differences may vary depending on diameter and height of the dome.

Sawteeth are formed by arranging the bricks diagonally side by side (Figure 26). Two or three rows of eaves appear on early examples of Sawteeth such as Alaaddin Mosque, Orhan Mosque, Hızırlık Mosque and Edirne Rüstempaşa Caravanserai.

Figure 26. Pammakaristos Church /Fethiye Mosque, Fatih, Istanbul, Türkiye, 13th century (Şentürk, Urfalıoğlu, 2017, 771) (URL, 24).

It consists of two parts, inner and outer bedesten. While the inner bedesten is used as a caravanserai, the Arasta section is around the bedesten. Bedesten is a square planned structure covered with four domes. These domes are placed on brick arches (Figure 27).

The dome covers the square area in front of the mihrab. The interior of the dome is covered with a bond that creates spirals by placing glazed units between the bricks (Figure 28).



Figure 27. (left) Bedesten ve Arasta, Samsun, 1160 (URL, 25).
Figure 28. (middle and right) Great Mosque of Malatya, Dome, Malatya, 1224 (URL, 26).

The University that is located in the Tuscany region of Siena is one of the old universities. The number of students reaching twenty thousand creates population almost half of the city. The city itself also has historical value and has been included in the UNESCO heritage list (Figure 29).

Figure 29. University of Siena, Italy, 1240 (URL, 27).

The octagonal dome of the Church of Santa Maria del Fiore in the center of Florence is one of the most important works of the Early Renaissance. The dome has self-supporting thanks to enormous array of bricks. It is different from other domes because diameter, width and height ratio of dome decreases upwards from the rim. The first three meters of the dome were made of solid stone, and then it was built as a double-walled brickwork to accommodate the passage and stairs. The hollowness of this part of the dome and the bearing properties of the rotating bricks on an axis also reduced the load on the drum (Figure 30).

Figure 30. Florence Cathedral, Florence, Italy, 1436 (URL, 28 and URL, 29).

Figure 31. Harvard University, United States, 1636 (URL, 30 and URL, 31).

Figure 32. Lund University Library Building, Sweden, 1666 (URL, 32).
Figure 33. Yale University, United States, 1701 (URL, 33).

Edirne Rüstempaşa Caravanserai that is one of the most significant accommodation structures of the period was converted into a hotel in 1966 (Figure 34). It consists of two parts, a large and a small caravanserai.

The main entrance of the caravanserai is probably from the large caravanserai. There is another more modest entrance on the side of the small caravanserai. The shops that give form to this façade are arranged in rows and in the form of an iwan. The wall that forms the façade consists of flemish cross bond on cut stone. Around the windows on the upper floor, there is a rectangular window jamb made of cut stone and a pointed brick arch and pediment on the jamb.

The northwest façade of the building is designed with cut stone corners and flemish cross bond. There are rectangular jamb windows and a crenellated window on this façade. On the southwest and southeast façades, there are rectangular jamb windows with brick pointed arches and unarched on the flemish cross bond. There are also five structural supports on these facades.

The eaves of the building rotate on the entire façade as two rows of brick sawteeth. The upper cover of the large caravanserai is the dome, the other one is the dome and the vault.

Figure 34. Edirne Rüstempaşa Caravanserai (URL, 34 and URL, 35).

The French gateway, that was built in 1860 by a French construction company on behalf of the Ottoman government, is still used today with its solid exterior. (Figure 35).

Figure 35. The French gateway, Karaköy, 1860 (URL, 36).

A row of brick and stone surfaces were used together at the 1st floor level near the entrance door and on the front facade of Jacmund's Sirkeci Station (Figure 36).

Figure 36. Sirkeci Railway Station, Fatih, Istanbul, 1872 (URL, 37 and URL, 38).

The architect of Yıldız Porcelain Factory is Raimondo D'Aronco. This structure is located to the east of Yıldız Outer Garden. Red bricks were used in the factory building. Tile decorations and white stones are interspersed (Figure 37).

Figure 37. Yıldız Porcelain Factory, Beşiktaş, İstanbul, 1894 (URL, 39).

Church of St. Anthony and lodgings was used red bricks (Figure 38).

Figure 38. Phanar Greek Orthodox College, Fatih, Istanbul, 1454 (URL, 40 and URL, 41).
Figure 39. Church of St. Anthony of Padua, Beyoğlu, Istanbul, 1912 (URL, 42 and URL, 43).

There is a significant increase in the construction of masonry structures in city centers, especially in Istanbul, as wooden structures are faced with the danger of extinction by fire. It is known that classical brick systems have been used on the walls of buildings that has been built with masonry construction technology in Şişli Cihangir and Nişantaşı Moda apartments since the 1920s (Figure 40).

Figure 40. Apartment Aesthetics (URL, 44; URL, 45 and URL, 46).

The use of civil housing architectural examples in the streets of Balat, which has survived to the present day, on the exterior surfaces is one of the best examples of the traditional brickwork style. At the same time, it is seen with the brick on edge as arches on windows and windows (Figure 41).

Figure 41. Streets in Balat (URL, 47; URL, 48 and URL, 49).

At the beginning of the 19th century, the hollow-corrugated wall technique that is one of the brickwork systems developed in England and North America began to be used. Thanks to this technique, material savings could be achieved, the walls could be made more resistant to moisture and the thermal insulation could be increased (Figure 42).

Figure 42. Streets in England (URL, 50; URL, 51 and URL, 52).

Brick material has been used in different sizes in the chimney mesh seen in the increasing factory structures since the 1800s. This shows the thin, long, narrow horizontal and vertical strength of the brick.

Closed vertical spaces used in buildings are called chimneys. The smoke and gases released as a result of the chemical reaction are thrown out by the fire chimneys. Brickwork rules are also used in chimney construction.

Fil and Birlik factories were built in Isparta between 1966 and 1976. Of these two factory structures, only the factory chimneys that was built with bricks remained standing. Solid fired clay that is 5.5x10x23 cm in size was used in the chimneys of these factory buildings. It was built with brick and cement-based mortar. The first brickwork that formed the chimney can be seen from the outside (Figure 43).

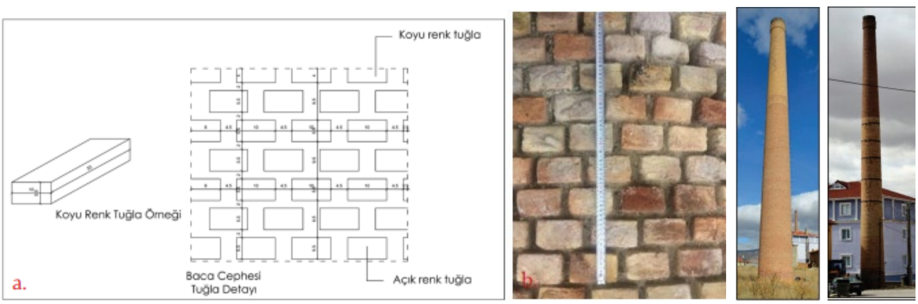


Figure 43. Brickwork of Factory Chimney (a), Facade of the Factory (b), Fil Factory Chimney (c), Birlik Factory Chimney (d) (Tolacı, Karagöz, 2020, 54, 55).

Bricks were used in the thick walls of prisons, rhythmically designed rooms, and other places, which are one of the oldest functions in history. The building that serves as the Four Season's Sultanahmet hotel at the present time is the former Sultanahmet Prison (Figure 44). Brick is still used in today's prisons due to its easy portability and constructability.

Figure 44. Sultanahmet prisoner: It was used from 1918-1919 until the '80s. İshak Paşa Tevkifhanesi (URL, 53 and URL, 54).

America ADX Florence Prison that was built in 1994 is one of these examples (Figure 45).

Figure 45. ADX Florence, United States, 1994 (URL, 55 and URL, 56).

Brick material was used by major architects of the 20th century such as Alvar Aalto, Frank Lloyd Wright and Louis Kahn.

Frank Lloyd Wright frequently used brick in buildings. Robie house is one of the examples of this buildings. This house was built in Chicago in 1909. Roman bond that is a longer and plainer bond than the standard American and English bonds was used for the brick.

Frank Lloyd Wright used roman brick in the Robie House. He also used limestone in the bands where horizontality was emphasized. He paid attention to the details of the bricks in the joint. He preferred the horizontal joint gaps to be thick and light tones in color, while he preferred the vertical joint gaps to be narrow and in the same color as the brick. The color of the brick walls is in shades of red and brown (Figure 46).

Figure 46. Robie House, Frank Lloyd Wright, Chicago, United States, 1909 (URL, 57).

MIT Baker House Dormitory was built in Cambridge in 1948. Alvar Aalto used coarse clinker bricks that have different colors and unequal forms. It looks like it's on the verge of falling off the walls (Figure 47). Alvar Aalto made projections on the surface of this structure.

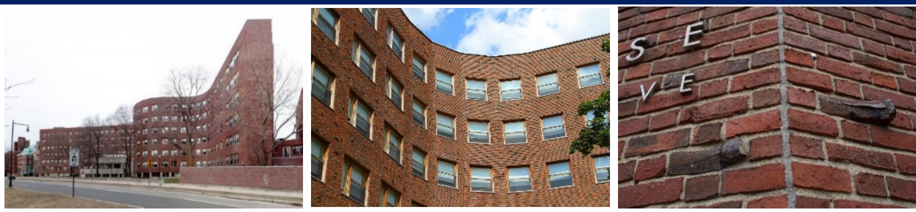


Figure 47. MIT Baker House Dormitory, Alvar Aalto, Cambridge, United States, 1948 (URL, 58; URL, 59 and URL, 60).

Alvar Aalto had made extensive use of red brick. However, in the first time he used in a non-orthogonal form in the House of Culture (Figure 48).

Figure 48. House of Culture, Alvar Aalto, Helsinki, Finland, 1952-1958 (URL, 61).

Volumes of red brick ascend within the staggered terrain and spreading out into wings. The Main Building is of decreased shape with largely windowless walls. Structural system is a concrete frame clad with bricks and slightly with copper (Figure 49).


Figure 49. Helsinki University of Technology, Alvar Aalto, Otaniemi, Finland, 1949–66 (URL, 62 and URL, 63).

Louis Kahn was one of the most leading American architects in the 20th century. He frequently used brick, when he built his structures (Figure 50).


Figure 50. Arts United Center, Louis Kahn, Fort Wayne, United States, 1973 (URL, 64 and URL, 65).

Louis Kahn preferred brick as local material in these buildings where he made large geometrical façade extractions (Figure 51).

Figure 51. Indian Institute of Management, Louis Kahn, Ahmedabah, India, 1974 (URL, 66 and URL, 67).

The use of brick, which is one of the most used materials of the postmodern period, is reflected on the exterior rather than the interior. There is a passage corridor between high brick walls (Figure 52). In its use in the funerary chapel, it emphasized the gross material and the brick (Figure 53).

Figure 52. Bonnefanten Museum, Aldo Rossi, Netherlands, 1990 (URL, 68 and URL, 69).

Figure 53. Funerary Chapel, Aldo Rossi, Italy, 1981(URL, 70) (Graziadei, 2019, 62).

5.2. Theoretical Background in the Use of Bricks

Postmodern architecture is an international style that is assumed to have started in the 1950s and continues its influence in today's architecture. Postmodernity is the return of "wit, embellishment, and reference", as a response to the formalism of the international style of modernism.

In the postmodern architectural movement, there is a conscious opposition to the dominant geometric and solid form understanding in modern architecture. As in other fields, the pragmatic attitude of modernity, which is ahistorical, ignoring social contexts and based on functionality, led to the emergence of a postmodern sensitivity in the 1950s. Instead of formulated solid designs, it was aimed to build structures with brick and stone materials that were more interesting and reminiscent of ancient architecture at the beginning. Elements that are frequently encountered in postmodern architecture are based on originality. Although postmodern architecture theoretically dates to the 1950s, the main approach began to take shape in the 1970s. The space perception, that modern architecture detached from history and context, was began to redefine by adding multiple meanings to multiple histories and social contexts. In this context, a return to the traditional in the use of materials has begun. Especially the use of brick on the facade has become widespread. Maria Botta and his architecture are one of these examples (Figure 54). Botta, who was designed and implemented different functions such as residence, church, memorial museum, Contemporary Art Museum, Science College, Cultural Center, generously used the horizontal, vertical, and diagonal arrangement of the brick in its facade. In the Swisscom Office Building, where the geometric possibilities of the rhythmic arrangement are used to the maximum, the structure is completely covered with the façade that was covered with brick material.

Figure 54. Évry Cathedral, Mario Botta, Évry, France, 1995 (URL, 71; URL, 72 and URL, 73).

Modernists believe in a universal manifesto truth. Postmoderns reject this. Antiquity attaches importance to reference to the Renaissance and the use of materials from the past. Modernism was founded on rational thought, logic, and scientific processes. Postmodernism, on the other hand, argues that everything in life is irrational. The first irrational examples are seen in the examples of Michael Graves, Mario Botto and Aldo Rossi, who reflect the flexibility of use of the horizontal, vertical and split form of the brick material in the facade design (Figure 56).

Figure 55. Museum of the Shenandoah Valley, Michael Graves, Virginia, United States, 2005 (URL, 74 and URL, 75).

Figure 56. The Louwman Car Museum, Michael Graves, Netherlands, 2010 (URL, 76 and URL, 77).

Figure 57. Marta Herford Museum, Frank Gehry, Herford, Germany, 2005 (URL, 78 and URL, 79).

The "crumpled paper bag" that is Frank Gehry's applied irrational technique in Dr Chau Chak Wing building formed by 320 thousand individual molded bricks. Five types of modified bricks were used in order to form curves and folds like 'fluid' appearance of the brickwork (Figure 58).

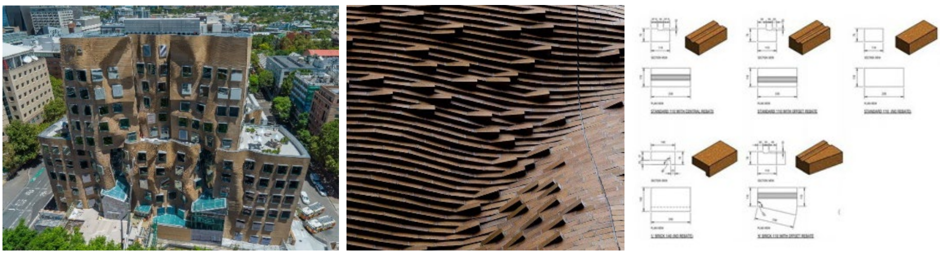


Figure 58. Dr Chau Chak Wing, Frank Gehry, Sydney, Australia, 2012-2014 (URL, 80; URL, 81 and URL, 82).

With Western Modernism, it was tried to base everything on reason and to progress and develop from a materialist perspective in parallel with global economic developments. However, since the romanticism and symbolism ideas based on emotion did not satisfy the western people at first, they left them and chose realism, naturalism and modernism, which are completely based on the rules of reason and logic. Western thinkers know very well that postmodern thoughts have a very complex structure, because postmodernism has a variable structure due to its scattered and uncertain structure.

6. Conclusion

The primitive use of brick has started from the primitive material that mankind has obtained from burnt clay by using the warmth of the sun.

Owing to the firing technique, the brick material has gained properties up to maximum durability in carrier. The material, whose holistic appearance changes with the aesthetic use of the architects who cannot give up the material obtained from nature, is preferred in a context beyond referring to the past today. The fact that it is in a wide range of uses still makes the brick an indispensable material. In addition, the different use of brick in wall, flooring and roof makes it a preferred material in the first place thanks to its atypical arrangement. Rhythmic / arrhythmic facades are seen in cities thanks to designers from antiquity to 21. century with experimental pursuits such as Kahn, Rossi, Botta and Gehry. Brick has been used in residential areas, religious buildings, public buildings, museums and government buildings since ancient times. It allows a wide area of use from prison to hospital. This variety is also used in garden wall and floor coverings in landscape recreation areas. This variety is suitable for use in buildings with different functions, as brick is a unique material. Brick is a traditional material used since antiquity, and it seems that it will continue to be used as a unique material used in local and international styles.

Thanks and Information Note

I would like to thank Prof. M. Rifat ÇELEBI, Doç. Dr. Ümit ARPACIOĞLU and, Işıklar Tuğla for providing the information and documents in this study.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to The e-book section

References

(n.d.). Retrieved from https://sanatsozlugum.blogspot.com/2014/08/kirpisacak.html

(n.d.). Retrieved from https://en.wikipedia.org/wiki/Little_Hagia_Sophia

(n.d.). Retrieved from https://tr.wikipedia.org/wiki/Aya_%C4%B0rini

Abdelsabour, I. (2017). Performative Architecture: Facades' Pattern Effect on Architectural Performance. *Journal of Engineering and Applied Science, 64*(3), pp. 165-187.

Ar, B. (2013). *Osmanlı Döneminde Aya İrini ve Yakın Çevresi.* Doktora Tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Mimarlık Anabilim Dalı.

Arcasoy, A. (1983). Seramik Teknolojisi. *Marmara Üniversitesi, Güzel Sanatlar Fakültesi Seramik Anasanat Dalı Yayınları No:2*.

Arslan, M., & Tuncel, Y. (n.d.). Battalgazi Ulu Camii ve Geometrik Analizler. 1-19.

Ashraf, K. K. (2007). Landscape in the Architecture of Louis Kahn. *Journal of Architectural Education*, pp. 48-58.

Atikoğlu, M. C. (2018). *Meterials Properties of Contemporary Solid Bricks and Their Assessment in Reference to the Historic Bricks.* Orta Doğu Teknik Üniversitesi, Yapı Bilimleri, Mimarlık Bölümü.

Brick Bond Patterns. (n.d.). Retrieved from PGH BRICKS&PAVERS: https://www.pghbricks.com.au/bricks/brick-bond-patterns

Brownlee, D. B., & De Long, D. G. (1997). *Kahn.* London: Thames and Hudson.

Carter, P. (1999). *Mies van der Rohe at Work.* London: Phaidon Press.

Çakmak, A. (2021). Yapı Malzemesinin Tarihsel Gelişimi ve Mimarlığa Etkileri. *ATA Planlama ve Tasarım Dergisi, 5*(1), pp. 41-54.

Çelebi , M. R. (2021). *Yapı Bilgisi* (9. ed.). İstanbul: İKÜ Yayınevi.

Er, A. C. (2013). Geleneksel Harman Tuğlası ve Üretimi. *Mesleki Bilimler Dergisi*, pp. 61-70.

Eroğlu, M., & Akyol, A. A. (2017). Antik Yapı Malzemesi Olarak Tuğla ve Kiremit: Boğsak Adası Bizans Yerleşimi Örnekleri. *STD*, pp. 141-163.

Fiala, J., Mikolas, M., & Krejsova, K. (2019). Full Brick, History and Future. *World Multidisciplinary Earth Sciences Symposium*, (pp. 1-6).

Fiederer, L. (n.d.). *AD Classics: House of Culture / Alvar Aalto*. Retrieved from archdaily: https://www.archdaily.com/783388/ad-classics-house-of-culture-alvar-aalto

Hızlıok, A. (2018). *Tuğlanın Günümüz Sanatında Kullanımı ve Oluklu Tuğla İle Form Araştırmaları.* Yüksek Lisans Tezi, Dokuz Eylül Üniversitesi, Güzel Sanatlar Enstitüsü, Seramik ve Cam Tasarımı Anasanat Dalı.

Hoffmann, A. (2003). Pergamon'daki Kızıl Avlu: Geleceğe Yönelik Perspektiflerle Ayrıntılı Bir Araştırma Tarihçesi. *Anadolu*(25), pp. 37-52.

Hotza, D., & Maia, B. G. (2015). Environmental performance and energy assessment of fired-clay brick masonry. *Eco-Efficient Masonry Bricks and Blocks*, 447-459.

Işık, Ö. (2010). *Konya Şerafeddin Camisi Yakınındaki Türbenin Tuğla Duvar Malzemesinin Arkeometrik Yönden Araştırılması.* Yüksek Lisans Tezi, Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Arkeometri Anabilim Dalı.

Kara, C. E., Selçuk, S. A., & Akan, A. E. (2021). Evolution of Brick Architecture Through Digital Tools and Technologies. *Journal of Science, 9*(4), pp. 329-344.

Kaya, P. (2021). Frank Lloyd Wright'ın Mekan Anlayışı: Frederick Robie Evi Üzerinden Bir Okuma. *Sanat ve Tasarım Dergisi*, pp. 43-62.

Kroger, S. A. (2005). *Architecture Built to Last: The Timelessness of Brick.* Master of Architecture, University of Cincinnati.

Kroll, A. (n.d.). *AD Classics: Indian Institute of Management / Louis Kahn*. Retrieved from archdaily: https://www.archdaily.com/83697/ad-classics-indian-institute-of-management-louis-kahn

Mario Botta: Museum Jean Tinguely Basel. (1997). Benteli.

Niskanen, A. (2022). Alvar Aalto and Cultural Memory. *Journal of Architectural Culture*, pp. 45-66.

Nuttgens, P. (1997). *The Story of Architecture* (2nd edition ed.). Phaidon Press.

Onay, N. S. (2011). Brunelleschi'nin Kubbesinin Sırrı: Deneyle Doğrulanan Çağdaş bir Teori. *Yapı*, pp. 106-111.

Öter, N. (2021). Anadolu Selçuklu Mimarisinde Tuğla Kubbeler. *Gazi Türkiyat*, 103-114.

Özkul, K. (2020). Sivas Gök Medrese Bezemeleri, Semboller ve Anlamları. *Şehir ve Medeniyet Dergisi*, pp. 53-74.

Robie House. (n.d.). Retrieved from Frank Lloyd Wright Foundation: https://franklloydwright.org/site/robie-house/

Roca, P., Cervera, M., Massanas, M., & Arun, G. (2005). Structural analysis of Küçük Ayasofya Mosque in istanbul. In C. Modena, P. B. Lourenço, & P. Roca, *Structural Analysis of Historical Constructions* (pp. 679-686). London: Taylor & Francis Group.

Rossi, A. (1991). *Aldo Rossi: Architecture 1981-1991.* New York: Princeton Architectural Press.

Sağın, E. U. (2017). Anadolu'da Roma önemi yapı tuğlalarının özellikleri. *Gazi Üniversites Mühendislik Mimarlık Fakültesi Dergisi*, pp. 205-214.

Sakellaridou, I. (2000). *Mario Botta: Architectural Poetics.* New York: Universe.

Serin, S. (2009). *Yıldız Çini/Porselen Fabrikası.* Yüksek Lisans Tezi, İstanbul Üniversitesi, Sosyal Bilimler Enstitüsü, Tarih Anabilim Dalı.

Sezen, F. (n.d.). Toprak ve Pişmiş Toprak Kökenli Malzemeler.

Şentürk, H., & Urfalıoğlu, N. (2017). İstanbul'da Bulunan Son Dönem Bizans Yapılarında Cephe Bezemeleri. *Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 6*(2), 763-772.

Şimşek, O. (2003). *Yapı Malzemesi.* Beta Basım Yayım.

Tashi, P., & Tola, A. (2013). The Natural Light In Alvar Aalto's Buildings. *UBT International Conference*, (pp. 63-75).

Tolacı, S. Ş., & Karagöz, M. A. (2020). Endüstri Mirası Onarım Önerisi: Isparta/Yalvaç Birlik ve Fil Tuğla - Kiremit Fabrika Bacaları. *Akdeniz Sanat Dergisi, 14*(25), pp. 45-70.

Toydemir, N. (1991). *Seramik Yapı Malzemeleri.* İstanbul: İTÜ Mimarlık Fakültesi.

Uysal, Z. (2020). Edirne Üç Şerefeli Camii'nin Sıva Üzerine Kalemişi Süslemeleri. *Uluslararası Sosyal Bilimler Dergisi*, pp. 247-283.

Uzun, T. İ. (2008). *Geç Osmanlı - Erken Cumhuriyet Dönemi Mimarlık Pratiği'nde Bilgi ve Yapım Teknolojileri Değişimi : Erken Betonarme İstanbul Örnekleri: 1906-1930.* İstanbul: Yıldız

Teknik Üniversitesi Fen Bilimleri Enstitüsü, Mimarlık Ana Bilim Dalı, Mimarlık Tarihi ve Kuramı Yüksek Lisans Programı.

(URL 1) https://www.allbrickandstone.com/brick-and-stone-advice/brick-bonds/

(URL 2) https://www.chegg.com/flashcards/test-2-65268414-931e-44bc-80a0-57fc02efdf6d/deck

(URL 3) https://en.wikipedia.org/wiki/Jameh_Mosque_of_Isfahan

(URL 4) https://commons.wikimedia.org/wiki/File:Kharaghan.jpg
(URL 5) https://www.tatilana.com/sivas-ulu-cami

(URL 6)
https://aksehir.bel.tr/galeri/aksehir_camii_ve_mescitleri/ulu_cami/

(URL 7) https://www.sanatinyolculugu.com/izzettin-keykavus-sifahanesi/

(URL 8) https://www.chaldeannews.com/features-1/2020/8/27/from-babylon-to-berlin

(URL 9) http://wowturkey.com/forum/viewtopic.php?p=1465448

(URL 10) https://tr.wikipedia.org/wiki/Konstantinopolis_Surlar%C4%B1

(URL 11) https://tr.wikipedia.org/wiki/%C4%B0mrahor_Camii

(URL 12) https://yeditepefatih.com/2021/temmuz-agustos-eylul/yedikulede-imrahor-ilyas-bey-camii/

(URL 13) https://arkeofili.com/ayasofya-hakkinda-bilmeniz-gereken-30-bilgi/

(URL 14) https://hagiasophiaturkey.com/building-materials-hagia-sophia/

(URL 15) https://en.wikipedia.org/wiki/Hagia_Irene

(URL 16) https://www.romeartlover.it/Istanb19.html

(URL 17) https://en.wikipedia.org/wiki/Red_Basilica

(URL 18) https://commons.wikimedia.org/wiki/File:Red_Basilica_with_Modern_Housing_-_Bergama_%28Pergamon%29_-_Turkey_%285747196261%29.jpg

(URL 19) https://www.semerkanddanbosnaya.com/portfolio/ertokus-han/

(URL 20) https://www.kulturportali.gov.tr/turkiye/burdur/gezilecekyer/susuzhan

(URL 21) https://izlerveyansimalar.blogspot.com/2009/08/sultan-melik-turbesi.html

(URL 22) http://www.erzincan.gov.tr/kemaliye-egin

(URL 23) https://www.kulturportali.gov.tr/turkiye/edirne/gezilecekyer/uc-serefeli-cami

(URL 24) https://www.kulturportali.gov.tr/turkiye/istanbul/gezilecekyer/fethiye-muzesi-pammakaristos-manastiri

(URL 25) http://karadeniz.gov.tr/bedesten-ve-arasta/

(URL 26) https://www.facebook.com/SanatTarihiPlatformu/posts/1009093956145322/

(URL 27) https://pavaedu.com/siena-universitesi/

(URL 28) https://en.wikipedia.org/wiki/Florence_Cathedral

(URL 29) https://gulcehalici.wordpress.com/2018/12/14/history-of-architecture-renaissance-and-ottoman-empire/

(URL 30) https://en.wikipedia.org/wiki/Memorial_Hall_%28Harvard_University%29

(URL 31) https://www.isbos.org/about-us/our-campus/virtual-campus-tour/landmarks/harvard-university

(URL 32) https://www.lunduniversity.lu.se/about-university/visit-lund-university/campus-locations/lund-campus-highlights

(URL 33) https://www.expedia.com/Yale-University-Downtown-New-Haven.d502016.Vacation-Attraction?gallery-dialog=gallery-open

(URL 34) (https://www.kulturportali.gov.tr/turkiye/edirne/gezilecekyer/rustempasa-kervansarayi)

(URL 35) (https://www.edirnevisit.com/guide/detail/37/rustempasa-kervansarayi)

(URL 36) https://www.yolculukterapisi.com/karakoyrehberi/

(URL 37) https://tr.wikipedia.org/wiki/Sirkeci_Gar%C4%B1

(URL 38) https://tr.wikipedia.org/wiki/Dosya:056_Sirkeci.112006_resize.JPG

(URL 39) http://arteinfriuli.blogspot.com/2006/03/raimondo-daronco-veramente.html

(URL 40) https://hyetert.org/2016/03/04/batililasan-istanbulun-rum-mimarlari-ve-eserleri/

(URL 41) https://www.armaganportakal.com/fener-rum-lisesi/

(URL 42) https://en.wikipedia.org/wiki/Church_of_St._Anthony_of_Padua,_Istanbul

(URL 43) https://wannart.com/icerik/9359-istanbulda-dev-bir-kilisenin-hikayesi-saint-antoine

(URL 44) https://www.neredekal.com/the-house-apart-cihangir-2-fiyatlari/

(URL 45) https://www.artfulliving.com.tr/edebiyat/cihangir-candir-i-6805

(URL 46) https://tr.pinterest.com/pin/413697915744672885/

(URL 47) https://awaywithdeniz.com/perispri-balat/

(URL 48) https://sa.elennemay.com/

(URL 49) https://www.sihirlitur.com/gezi/istanbul/halic/index.html

(URL 50) https://scenetherapy.com/wp-content/uploads/2018/04/Red-Brick-English-Cottage.jpg

(URL 51) https://www.shutterstock.com/tr/image-photo/christ-hospital-terrace-lincoln-view-cathedral-2280465139

(URL 52) https://www.worldatlas.com/articles/the-richest-streets-in-england.html

(URL 53) http://wikimapia.org/579116/tr/Four-Seasons-Oteli-Eski-Sultanahmet-Cezaevi#/photo/2874198

(URL 54) https://alizemhs.com/referans/otel/

(URL 55) https://www.identiv.com/resources/blog/the-worlds-most-secure-buildings-adx-florence-prison

(URL 56) https://en.wikipedia.org/wiki/ADX_Florence

(URL 57) https://mitchdarbyarchitect.com/blog/2013/6/4/a-visit-to-the-robie-house

(URL 58) https://www.arkitektuel.com/baker-house/

(URL 59) http://alvaraaltosarchitecture.blogspot.com/2015/10/alvar-aalto-at-mit.html

(URL 60) https://pbs.twimg.com/media/CPb2zEbUwAAlIro.jpg

(URL 61) https://www.archdaily.com/783388/ad-classics-house-of-culture-alvar-aalto?ad_medium=gallery

(URL 62) https://www.aalto.fi/en/aalto-university/history

(URL 63) http://www.archipicture.eu/Architekten/Finnland/Aalto%20Alvar/Alvar%20Aalto%20-%20Helsinki%20University%20of%20Technology%20Main%20Building%201.html

(URL 64) https://www.archdaily.com/891939/ad-classics-arts-united-center-louis-kahn

(URL 65) https://twitter.com/JoshLipnik/status/1318002256973844482/photo/4

(URL 66) https://www.archdaily.com/83697/ad-classics-indian-institute-of-management-louis-kahn

(URL 67) https://www.dezeen.com/2021/01/07/louis-kahn-indian-institute-of-management-ahmedabad-dormitories-iima/

(URL 68) https://www.arkitektuel.com/bonnefantenmuseum/

(URL 69) https://www.behance.net/gallery/49734675/BONNEFANTEN-MUSEUM-SHOP

(URL 70) https://tr.pinterest.com/pin/437341813811272980/

(URL 71) https://structurae.net/en/media/16498-cathedral-evry

(URL 72) https://www.flickr.com/photos/jozioau/41456113184 Joe Lewit, on Flickr

(URL 73) https://cathedrale-evry.net/textes/english.htm

(URL 74) https://www.google.com.tr/search?q=Museum+of+the+Shenandoah+Valley&source=lnms&tbm=isch&sa=X&ved=2ahUKEwil2Iax6pP_AhX6Q_EDHQI0DqcQ_AUoAnoECAMQBA&biw=1536&bih=754&dpr=1.25#imgrc=63ZMRrqPs8WveM

(URL 75) https://greenwayeng.com/ge-portfolio/museum-of-the-shenandoah-valley/

(URL 76) https://www.museum.nl/en/louwman-museum

(URL 77) http://themuseumtimes.com/the-louwman-museum-the-hague/

(URL 78) https://ifdesign.com/en/brands-creatives/company/marta-herford/9841

(URL 79) https://en.wikipedia.org/wiki/MARTa_Herford

(URL 80) https://www.businessinsider.com/frank-gehry-crumpled-back-buildingin-sydney-2015-2#there-are-14-levels-11-occupied-floors-a-basement-parking-level-plant-level-and-rooftop-6

(URL 81) https://www.abc.net.au/news/2015-01-20/architect-frank-gehry-to-open-new-wing-at-university/6028726

(URL 82) https://jimmyle9.wordpress.com/blog/week-7-julian-donofrio-rick-benjamin/

Türkan İrgin UZUN
E-mail: tuuzun@gelisim.edu.tr
Educational Status: Lecturer in IGU
License: Yıldız Technical University, Architecture
Degree: Istanbul Technical University, Architecture-Architecture History and Theory
Doctorate: Yıldız Technical University, Architecture-Architecture History and Theory
Professional Experience:

Merve SAVRUNLU
E-mail: mervesavrunlu@gmail.com
Educational Status: Student
License: Kadir Has University, Architecture
Degree: İstanbul Gelişim University, Instıtute of Graduate Studies, Architecture

The Birth and Development of Opera Art in Terms of Auditorium Acoustics

Derin Hilal BİLMEZ[1]

[1] Mimar Sinan Fine Arts University, Institute of Science, Building Physics and Material, Istanbul/Türkiye
ORCID: 0000-0002-3318-1982
E-mail: derinhilalb@gmail.com

A.Cüneyd DİRİ[2]

[2] Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, Istanbul/Türkiye
ORCID: 0000-0003-4217-6381
E-mail: ahmet.cuneyd.diri@msgsu.edu.tr

Assoc. Prof. Dr. Ümit T. ARPACIOĞLU[3]

[3] Mimar Sinan Fine Arts University, Faculty of Architecture, Fındıklı Campus, Istanbul/Türkiye
ORCID: 0000-0001-8858-7499
E-mail: umit.arpacioglu@msgsu.edu.tr

Citation: Bilmez, D.H., Diri A.C. & Arpacıoğlu, Ü.T.(2023). The Birth and Development of Opera Art in Terms of Auditorium Acoustics. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment,* (303-345). ISBN: 978-625-367-287-4. Ankara: Iksad Publications.

1. Introduction

Opera is a visual and auditory art branch that emerged at the intersection of theater and music. It is a younger art than both music and theater. Although it was initially fed from the ancient period in terms of subject, it has developed considerably over time. Almost every subject from daily events to wars can be put forward by a different movement and a different composer within the opera.

It is very important to balance drama and music in opera. Opera consists of moving the drama forward with natural rhythms and making music peak with a beautiful melody. Keeping them in balance is the beauty of opera (Kelly et al., 2023b). Every new subject, singer, composition, music, instrument added to the opera has changed and improved it a little more. The development process of the opera was not linear as in other art branches. In some periods, monophonic (especially continuous bass) and polyphony were used. After the opera became famous and descended to the public level, the variety of subjects was further increased. In some countries the nobles supported this movement, while in others they held back. Due to such circumstances, opera progressed with regional differences until the end of the 19th century. In the 20th century, universal qualities in opera increased thanks to the discovery of electricity, recording devices, cassettes and records. This art branch, which was born and developed in a period of approximately 400 years, is still attracting a lot of attention today. The development process of the opera took place quite quickly. It has been influenced by nations, religions and different branches of art. Therefore, as the opera developed, the place where the opera would be exhibited was elaborated, developed and differentiated. The first operas were exhibited in ballrooms in the palaces of the nobles. Then, theater halls were used. However, these spaces, which were insufficient in terms of space, acoustics and visuals for opera, were abandoned over time and spaces specially designed for opera were moved on. Today, such auditoriums are called "Opera House". Opera houses are a wide variety of structures (symphonic music or ballet) that allow different uses at different times (Barron, 2009). The first opera house was built in Italy in the 17th century, about 130 years after the emergence of opera art, and over time, it has undergone quite a change, especially in the interior. Today, historical opera houses and modern opera houses are compared in many areas such as acoustic, visual and climatic (Prodi et al., 2015).

2. Material and Method

This study explains and examines the effects of the development of opera art since its birth on the auditorium design. In this way, the reason for the differences between any auditorium and the opera house will be briefly determined.

3. Findingd and Discussion

3.1 Opera and Orchestra

Opera: It is an art born through theater and music. Derived from the Latin word “opus” (role, performance) (D’Orazio, 2020). The fusion of theater and music is a form of expression strengthened by the influence of literature (especially poetry) and plastic (visual) arts. Words in the art of theater do not precede the music in the opera, in the same way, music does not overshadow the lyrics. Opera is a branch of art that has been created by adding visual performance to add dramaticness and emotion to music (Say, 1997).

Factors such as the fact that music is a part of religious rituals, the exhibition of short religious theatrical plays in the medieval church and the inclusion of hymns during these plays, the recitation of the religious text "Missa" (mystöre) in the Catholic church with music, the establishment of the (Say, 1997). Academy of Poetry and Music in Paris, the "Pastoral Drama" (in the sacra rappresentazione) exhibited to Italian nobles in Florence in the 15th and 16th centuries, and then widespread and combining dance, song and instrumental music with words, paved the way for the birth of opera (Mimaroğlu, 1970; Say 1997).

The name of the text in which the oral chapters in the opera play are written is "libretto". Libretto is a text written for opera, oratorio and ballets (Özgüden, 1966). Most opera plays consist of libretto sections. Texts are distributed to the players according to the subject. These sections are supported by the orchestra's music and transformed into a more effective performance. Arya: It is the part where an actor reflects his/her emotions alone. Duet: It is the part where two players, Tezet: Three players, Quartet: Four players, Kentet: Five Players reflect their feelings together (mostly singing). The overture, on the other hand, is the opening part of the opera, in which there is an orchestra or choir. Depending on the preference of the playwright (composer), music can be played intermittently or combined in the opera (Wikipedia, 2023). The parts where the actors sing as if they are talking are called "descriptive".

What opera singers have to do has changed over the centuries: Singing only words with music and singing with music, conveying words and emotions… For this reason, special equipment is also needed to become an opera singer. For this, they are trained for years and proceed by paying attention to their voices. Opera is based on the transference of emotions to the audience. Therefore, events and situations can be dramatized more than usual. But if the singer accidentally starts crying, it would be a disaster. Therefore, they should be able to control their emotional state well. Singers should pay attention to octaves. Singers are called soprano (Loud female voice), alto-contralto- (low female voice), tenor (high male voice) and bass (thick male voice). Opera singers are usually sopranos. Lyric soprano (does not do fancy things, sings beautiful lyric-emotional-strings when needed) and dramatic soprano (who raises her voice when needed) (Kelly et al., 2023b).

The development of opera art has also influenced the orchestra and instruments. Opera and orchestra are two separate elements that develop together and are influenced by each other. The orchestra can perform without the opera, but the opera needs a large or small orchestra.

3.1.1 The birth of the opera (16. Century Opera)

According to World Opera History, the birth of the opera is considered to be the beginning of the 1600s. The first opera appeared in the 1600s by Luca Marenzo and Gesualdo of Venosa, who wanted to make their music more dramatic (Say, 1997). The first opera plays were performed in

Florence and then in Rome. For this reason, the homeland of Opera is considered Italy. Opera is a branch of art that has its roots in the free thought and humanism brought by the Renaissance. It is based on the idea of opposing church oppression. However, due to the fact that the first opera plays were exhibited around the nobles and the church, the opera was highly loved and embraced by both the nobles and the church. The descent of the opera to the public level and its adoption by the whole society coincides with the Baroque period (Ulusu, 1994).

16th and 17th C.C. Montreverdi is the artist who contributed greatly to the formation of this art by giving the basic works of opera in the centuries. In the history of music, Monteverdi said: “He is one of the greatest composers to have grown up in all ages, and the closest composer to the present age among those before Bach.” (Sachs, 1965), “He used the chord (seventh chord in minor), which other composers had previously used timidly for a temporary (Mimaroğlu, 1970) effect, to strengthen Monteverdi expression” (Say, 1997). Montreverdi included the expression of human emotions in madrigali operas other than religious music, expressed the power of emotions in Samsun, and created a very close set of rules that are still used today and the chords of the operator by using the irregular intervals that no one has used until then. In his works, Montreverdi not only used the orchestra to accompany melodies, but also played music independently. In fact, by writing solo chapters on the instruments, he enabled the sound of each instrument to be heard by Engin. This move gave a brand new breath to the opera. For example, he tried to express the emotions in the battle scenes with four violins and this expression was found very successful. According to that period, such an expression was quite new in the art of music and pioneered enough to be considered a surprise. Monteverdi was the first composer to use the technique of pizzicato on the violin to reinforce this narrative. Monteverdi's orchestral placement and management style are quite unique. This form of settlement was used until the period of the Viennese classics (Haydn's edits) (Altar, 1993).

Opera was born ten years before Monteverdi. However, the first opera example of musical art in the history of opera is Monteverdi's "Orfeo". In Orpheus, leaf-shaped costumes, choral dances, short and funny speeches between villagers singing with the instrument in the hands of the god Apollo, and the Comedy of mythological characters were included (Altar, 1993). Montreverdi is the most successful representative of the new art of opera. He emphasized the importance of text in music, identified expressions with musical impressions, and in doing so, he designed the characters and behaviors of the people in the work in a vivid and effective way (Yener, 1983). With the influence of Montreverdi, the opera became more musical and narrative. Arias, duos, and music were added to the recitals, so the orchestra began to play together to support the play (Hodeir, 1994).

There is a great difference between the period when opera art was born and Monteverdi's understanding of art. His creative identity in music has left a melodic formal harmonic effect on music. Monteverdi combined the musical movement of three generations with his music more vivid and open to all directions and thus opened a new era in opera with the new movement he created. Monteverdi accelerated the development of instrumental music. For this reason, orchestra development and opera development are internal and affect each other. In Monteverdi's orchestra, harps, organ, lava and harp are predominant. These instruments are at the forefront with their ability to extract chords. Their number and placement vary according to the stolen work. These instruments were very frequently preferred until the half of the 18th century (Say, 1997).

The "choir", which started with the Gregorian hymns, was made polyphonic with the church rules softened by the influence of humanism in the 12th and 13th centuries. It has gained a character that both caresses the ears and soul of the listeners and serves the church. It was inevitable that the choir, which was so adopted by the people, would take part in the opera (Yener, 1983). The choir may not be in every game. He/she usually symbolizes the people (shows the public conscience) in the games he/she takes part in (Wikipedia, 2023). In the early operas, dance and choir sections were planned together, and in some sections the balance of stage performance and music was not taken into account (one of them was much more dominant).

Oratorio is a genre of lyrical and epic music that originated in Rome in the second half of the 16th century. Due to its emotional intensity, it is closely related to both church and opera. It emerged in Florence, Italy in the 16th century, when the understanding of mode was replaced by the understanding of tone and accompanied by melody instead of counterpoint. Florentine thinkers wanted to reintroduce the musical drama in Ancient Greece. Rinuccini, who manifested himself with words and poetry, and composers such as Galilei, Caccini, and Peri created the "stilo rappresentativo". This genre means musical poetry with constant bass accompaniment. At the beginning of the 17th century, this movement gained strength and led to the emergence of the "dramma per musica" genre. This genre proceeds by playing more mobile and faster (Hodeir, 1994).

In the early years of the opera, support was received especially from painters in the preparation of intermezzo (the beginning part of the opera). Feasts, festivals, weddings, the great art movements of the Renaissance have been the subject of paintings and carpets used in intermezzo. In the beginning, the episodes of intermezzo included events related to ancient mythology and Christianity, gods and goddesses, people of religion, saints. Over time, these personalities have been replaced by real people and real events of daily life. In 1502, at a wedding in Ferrara, the leading theater city of the Italian Renaissance, gymnastic movements were shown, ballet performances were given, instrumental and musical programs of the song were organized and theatre works were played. Exceptionally rich decor and costumes are included. Thus, the new form "Plautus" is an intermediate section called intermezzo played between the comedy curtains. Intermezzolar has been the starting point of opera art (Altar, 1993).

In the orchestra, the orchestra has an important richness in terms of spring-blown instruments, and its suitability for the real sound in this orchestra is ensured in terms of satisfying sound if necessary. The scope of this orchestra is as follows: viola, violin, lute, guitar, bass guitar, harp, harpsichord, small room organ, flute, trumpet, regal, cornet, trombone. Depending on whether the section in the opera is predominantly speech or music, the strings have superiority over the blowers or the blowers have superiority over the plateaus. Ensuring this balance is a very valuable invention in terms of opera (Altar, 1993).

In addition to the orchestra, he added dance sections and dance pieces to the opera, short instrumental solo sections in front of the melodies, and repeated sections behind them. However, these repetition episodes turned into imitation episodes after a while. These episodes were soon removed from the opera (Altar, 1993).

3.1.2 17th century opera

Thanks to the interest of Opera in Italy and its surroundings, Opera began to spread to other European countries in the 17th Century. In baroque art, emotions are expressed in an exaggerated way. The joy of life is surrounded by the fear of death and the impermanence of life. This statement is also clearly seen in the opera. Exaggerated emotions and the individuality of the fear of death caused the 17th century opera to vary according to nations (Ulusu, 1994). Classical Ancient Greek dramas became quite famous in Florence in the 17th Century. Since almost every nation loves drama, opera has spread rapidly within European countries. Apart from the ancient Greek issues, issues related to the Virgin Mary and the church have started to become widespread in opera (McKinney & Anderson, 1957).

In about a century, opera has moved far away from its initial melodies (Hodeir, 1994). The opera overflowed from the palace and descended to the public level in 17th century Italy. Due to economic reasons, emphasis was placed on arias with reduced orchestra and choir staff. During this period, an opera house was opened in Venice. In these opera houses, flashy and magnificent decorations and bright colors were used. The leading Venetian opera composers were Cavalli and Cesti. (Yener, 1983). The great interest of opera in Italy in the early 17th century deeply impressed the Spaniards. Subsequently, a type of opera called "zarzuella" emerged in Spain. This type of speech was included and no descriptive was used. Music is in the background. The British, inspired by this genre, created a genre called "Masque Games", in which monosyllabic words and sounds are predominant. However, both genres have gained a short place in the history of opera because their opera is inherently far from musicality (Say, 1997).

In the middle of the 17th century, oratorio and cantata emerged and the artistic identity of the opera was reinforced. The oratorio is an option of the opera in non-religious matters. It is semi-religious, semi-actual and semi-permanent stage music. It was created inspired by the religious games of the ancient period. It can be said that it was born from the famous "mystre" plays of the Middle Ages towards the end of the 16th century. The closest example of the Oratorio was seen in the religious ceremonies established by San Filippo dei Neri in the mid-16th century. After 100 years, the ceremonial musical stories of the 16th century turned into a glorious musical form in the 17th century (Say, 1997).

In addition to painting, sculpture and architecture in the Renaissance Age in Italy, Dutch musicians pioneered music in Europe due to the overshadowing of music. As a result, many music and art genres were born in Italy and many composers and artists of Italian origin were raised. Italians also played a leading role in the opera (Say, 1997).

In 1637, the first open opera house started to serve in Venice. This opera house, called Teatro San Cassiano, has allowed many people to listen and watch opera without buying a ticket. This opera house is one of the first steps of the people's association with the opera (Hodeir, 1994).

Venetian opera declined towards the end of the 17th century. Music and poetry have gone into the background, stage performances and stage decor have gained weight. For this reason, the artistic value of the opera has decreased considerably. For example, the Teatro Grimani, built in 1678, has the necessary features of a small opera house. In this period of decoration and exaggeration, there are many decorations, disguise scenes and stage deceptions that fall from the sky and spring from the ground. The decorators who designed these decorations often made more money than the actors. This decoration in the Venetian opera went down in history as "Machining in the Venetian Opera". Even after about 100 years, this mechanization was taken as an example in France, and the concept of a ship moving (swaying) at sea on a stormy day was brought to the stage. The opera movement in Naples in the late 17th century is similar to Roman opera. In the opera supported by a rich orchestra, overtures and arias were developed and used. In addition, he did not pay much attention to the instrumental sections and stage decorations throughout the work in Naples operas. They gave priority to music. Since the Naples opera was generally written in the form of A-B-A, the composers of the period used the nickname "aria bundle" for the Naples opera. With the Naples opera style, the tradition of beautiful singing (Belcanto) has developed and a new dimension has been added to it. In this way, singing culture and voice art mastery have entered the music literatüre (Say, 1997).

In summary; In general terms, the art revolution of opera, which started in the 16th century, accelerated in the 17th century. Events such as the rise of opera and oratorio, the enrichment of instrumental music, and the mastery of instrument making took place in this century. In this way, it ensured the production of works that have a very rich history for 18th century western music and are still popular today (Mimaroğlu, 1970).

3.1.3 18th century opera

In the middle of the 18th century, music became alive. It is more advanced and more mobile than the baroque and classical style. During this period, opera, instrumental music and symphony developed. New sources for musical arts have emerged (Rushton, 1996). The 18th century has been the richest by blending tried and tested methods and forms. However, this enrichment does not mean expanding both music and speech. Initially, speech (language) remained in the background and music came to the fore. It has been simplified. For this reason, emotions are expressed with melodies and songs. Soon the conversation was increased again. The forms that have emerged since the second half of this century have become specific to countries and nations. The most successful works of history were given by master composers and musicians (Mimaroğlu, 1970).

In Italy, "opera buffa" emerged in the first half of the 18th century. Opera buffa rejuvenated Italian opera and created an environment suitable for the birth of "Operacomique" in French. He was born in Naples in the early 18th century (Hodeir, 1994). The opera genre, in which more serious issues, historical or ancient subjects (Hellenistic period) were covered during the period when the opera buffa was famous, is called opera seria (Rushton, 1996).

In the beginning, the opera buffa is a comedy that mocks the opera seria. Over time, it attracted the attention of the public. Opera is more lively and fun than seria (Hodeir, 1994). In Opera seria, the drama element is high, the characters are selected from real life and highlighted with their emotional aspects. A very strong stage performance is designed in Opera Seria. Special effects and various light plays have been used on the stage, so the preliminary design of the opera seria is quite expensive. Special stage designers were hired for these Operas and these people were specially trained. They even worked at higher salaries than opera actors in some periods (Rushton, 1996). Over time, the opera also began to deal with Ancient Greek and Roman subjects in the buffa. In the second half of the 18th century, many works written as musical stage works began to be written in the form of opera buffa (Hodeir, 1994).

In the 18th century, the orchestra was wider in French Opera. French opera texts are more versatile than Italian opera texts. 17. Towards the end of the century, Naples became the center of opera art. In Naples, vocal education was given importance and musicians were highly respected, so there were frequent discussions among composers.

Composers have detached themselves from the characteristics of opera seria in an effort to create their own unique music. For this reason, opera buffa is a very important step in preserving the characteristics of opera art and reaching to the present day (Yener, 1983).

Modern Italian opera was born and developed in Naples thanks to the composer Alessandro Scarlatti. It developed thanks to Handel and Mozart. Purcell in England, Christoph W. in Germany. With Gluck, the tradition of opera has been formed and developed (Yener, 1983).

The 18th century corresponds to the Classical period in music. One of the most important elements of the classical period is the instrumental forms that enable music to be expressed only in its own language. These forms reappeared under the influence of Classicism. The classical period in music developed in the fields of sonata, string quartet and symphony and became definitive in the second half of the 18th Century. The basis of a structural germination in this area is the Sonata form. The symphonic music movement that emerged in Germany in the middle of the 18th century is closer to stage music than pure music in the Italian and French tradition. The birth of the symphony was formed by opera music and overtures in Italy and France. However, it is the Germans who give the symphony the form of cutting. Sinfonia, which was the pure orchestral music of the Italians in the late baroque period, used it on stage, chamber music, academy, concert music. In southern Germany, the "Mannheim School" played an important role in the development of the symphony (Say, 1997). The effect of the classical period is seen in the early periods of the romantic movement (Whittall, 1999).

3.1.4 19th century opera

Although its foundations were laid in the 18th century, "Grand Opera" emerged in the Paris Opera House in the late 1820s and 1830s. It is famous for its magnificent and rich number of instruments. It is a very large opera with a complex stage, talented singers and equipped with technological features. It has a large audience and a large amount of expenses are incurred for the presentation of the large orchestra. In a way, the opera summarizes the history of the opera, has magnificent shows and dances, and dazzles with its wonderful virtuosos (Kelly et al., 2023b). It was born from the social and political influences of the period with its ostentatious artificial air and eye-catching aspects, and symbolizes the developing economic technical and commercial power of the bourgeoisie. Noisy Choirs has a rather exaggerated and dramatic narrative form with flashy anthems, scenes on horseback, scenes of war, volcanic eruptions, burning palaces, noisy orchestra, ballets that appear suddenly (Sachs, 1965). The Grand Opera reveals the impertinence of the bourgeoisie, which has seized power but has not sufficiently assimilated its social leadership in the cultural plan, that is, has not yet grown up. The flamboyant but makeshift scenes artificially introduced into the opera were performed in technical plays, perhaps to support bourgeois consciousness, but this bragging documented what the bourgeoisie was up to and why it was unconscious (Say, 1997).

G. Meyerbeer, G. Verdi, R. Wagner wrote major operas for the Paris Opera House. Thanks to these, the music genre that emerged in the 1820s and 30s is a summary of them. It is very important from a historical point

(Kelly et al., 2023b) of view Grand Operas have their own characteristics. For example: The works with four bassoons were written especially for the Paris Opera (Kelly et al., 2023b).

The first building of the Grand Opera in Paris (1830) is a very special building. (i.e. Le Peletier Opera House, the main opera house). Unfortunately, this structure does not exist today. It is replaced by the Palais Garnier, built in the 1870s, or the Place de Bastille, built in the early 20th century. Place de Bastille is the latest (Kelly et al., 2023b).

19th century operas took a very different form from traditional operas with arias, recitatives and ariosos. While the Italian Opera was declining, the German opera was first performed by Weger and then by R. It has started to rise with Wagner. Wagner blended musical dramas and stage works very well (Hodeir, 1994).

At the end of the 19th century, the French School started to rise. However, this rise did not last long. The 20th century was quite ordinary for French Opera. Because the contemporary understanding in art has led to the boring and old understanding of traditional opera. In the old opera (opera number), the pieces are separate from each other, each of them is a whole in itself. In the new opera, the smallest unit of the opera is the stage, not the piece. Dramatic wholeness and continuous music are present. The scenes are interconnected. The event flow pattern is similar to a long storytelling. For this reason, it is more complete than the old opera. There are no arias, duos or choirs. In the transitions between sections, the orchestra continues to play intermittent music (Hodeir, 1994).

Opera comique or opera buffa differed from opera seria in terms of subject. The fact that the subjects covered are easier and closer to daily life has caused them to be used and preferred more. Towards the end of the 19th century, the interest in this genre increased further, but by that time it had expanded in terms of subject and began to cover the subjects of opera seria. For this reason, it has become difficult to define the opera comique in the 19th century. Opera buffa, the Italian name of the opera comique, originated from the intermezzo used between the curtains of the opera seria. Intermezzo developed in a short time and got a different name as opera buffa. At the beginning of the 19th century, the opera buffa lost its power. While the opera buffa was sinking in Italy, operacomique began to emerge in France. There is also a search for formal innovation in Operacomique. Although it has its formal structure from the opera seria (opera number), there is speech instead of recitatives, which are the chapters with songs in the opera. The "operetta", which emerged from the operacomique towards the middle of the 19th century, differs from other types in terms of its lightness in terms of subject matter. It is a stage work written on fun and light subjects in terms of its literal meaning (Özgüden, 1966). Speech is more, music and song parts are very few, orchestra is unpretentious (Hodeir, 1994)

In the 19th century, the National Russian School played an important role in the development of opera. It enriched the opera in terms of form. Operetta began to be used for short operas in Italy in the 18th century and entered the literature from the 19th century. Fun topics were covered in the opera, and cheerful and exhilarating works were included. In addition, folk dances and fashion dances were included. It originated from the Italian opera buffa, the French opera comique and the German singspiel. In the 19th century, new developments occurred in the course of the operetta. There were differences in terms of music and subject. Names of new operettas: French operetta, Berlin operetta, English operetta, Vienna Opera, American Musical Comedies (Yener, 1983).

Richard Wagner, who does not care about the brain and habits of the opera audience, who is easily thrown from one end of philosophical politics to the other, but represents a new stage in harmonic musicality that gives a new self to the post-opera, is a very important composer in the history of opera. Wagner focused on the problems of literature, poetry, plastic arts, philosophy and music with competence, contemplated how these branches could be synthesized in his own age, and investigated the ways in which they could develop. Wagner is not a pure musician, but an art theorist, and with these theories, he has developed himself quite well in opera works. He argued that art has methods and its structuring should be improved, and he argued that a work designed with a wealth of philosophy and knowledge without inspiration is far from art. Wagner is an extravagant artist who screams represents personality, as it is in the works, but it is original. The view of life in his operas has shown itself similarly in other branches of art (Say, 1997).

Operetta is a light but cute musical stage play with cheerful, distinctive, playful features that dragged the vast majority of the public in the second half of the 19th Century. A cheerful and playful group has been added to the sad pessimistic and heavy atmosphere of Romanticism. In this respect, romance is a reaction to the heavy understanding of opera and a contrast. The operetta is a work of art that is more interesting than the drama theater or even the novel, represents the social situation more naturally and therefore appeals to a wide audience. The most obvious feature for Opel is that it is far from possibilities and your imaginary connection between reality and imagination is weak thanks to the rapid progression of the scenes. It is similar to the idyllic play in the first years. Operetta is the product of a world where everyone is free to do what they want 19. It experienced its brightest period in the third quarter of the century and the greatest works of this period were exhibited in Vienna. The works considered the leader of French operetta were studied at the Paris Conservatory. Works of French operetta were exhibited with the Operacomique orchestra (Say, 1997).

In the second half of the 19th century, French opera and ballet music did not show a bright development, but it attracted the attention of many composers. It has a colorful but easy atmosphere and attracts the attention of average music lovers. Ballet art 19. The tour, which developed over the century and skipped four chapters in three and then five, has transcended forms such as Voice Polka and turned into a real dance show by integrating with music. Russians have a rich ballet tradition. Tchaikovsky's famous fairy tale water ballet swan lake has been exhibited for years in French choreography. Composers have also used it as ballet music for many concert music. Realism and note Ural imprint, which were the priorities in literature in this period, manifested itself especially as note Ural imprint in the art of painting. The effect of social and political events of the 19th century manifested itself in almost every country of Europe. This demonstration also emerged in the music session, and both realistic and natural tendencies also manifested themselves in opera art. Towards the end of the 19th century, the Verismo movement, which means real in Italian Opera, took the reality of literature and the naturalness of music and painting as an example. Thus, a realist world and realist characters moved away from the ideal romantic world created in the opera movement so far. Most composers in Austria and Germany admire Wagner during this period. Wagner's influence is seen in many operas exhibited in Vienna. In fact, during this period, distinctions were made in the form of a real Wagnerite or Wagner wannabe (Say, 1997).

In the 19th century, music is in its romantic period. Romantic behavior can be defined as the artist's explanation of his feelings in their purest form. The start date of Romanticism is not clear. According to historians, the romantic period started from the end of the 18th century and took its strength from the effects of social events on individuals. Beethoven is considered to be the first romantic composer. Beethoven's understanding of music in the romantic period is similar to Socrates' statement: "The change in the rules of music depends on the change in the rules that govern society." The focus is on the effects of the changing world on the human inner World (Mimaroğlu, 1970).

Wagner is a very successful romantic, he has the capacity to turn a medium opera into big money, and he introduced musical drama to the whole world. The artists who came after him followed the German romance through Wagner. Berlioz is one of the greatest representatives of Romanticism in France (Whittall, 1999). In Wagner's operas, music is often played integrally (Wikipedia, 2023). For this, care is taken not to have too long an echo in Wagner operas. R. Wagner's early works were influenced by traditional opera seria. Later, Wagner, who turned to German legends, destroyed the aria-prescriptive structure of musical drama over time and established the accompanying descriptive schema. In this way, music and drama are intertwined. Wagner introduced some new copper-blown instruments into the opera to increase its sound power. In addition to the instrument called the Wagner-tube, there is also the bass-trombone and conturbas-trombone. Orchestral works are not performed much today (Say, 1997). Wagner thought that no theater was good enough for the performance of his own operas, and with the support of the King of Bavaria, he opened his own opera house. Wagner's original concept was to have a single opera (Kelly et al., 2023b).

3.1.5 20th century opera

Along with Wagner, Mahler was one of the brightest composers of a new era in music as it entered the 20th Century (Say, 1997). Mahler is one of the most successful composers of late romance. The dangers of seeing Mahler's symphonies as a direct result of the enthusiasm for Bruckner and hostility towards Brahms are rightly highlighted in Mahler's literature. His operas, which he blends with his love of Bruckner and his hatred of Brahms, are among the highest quality examples of musical drama. In addition, Russian opera art, which started to rise in the 20th century, was especially influenced by German opera by Tchaikovsky (Whittall, 1999).

At the beginning of the 20th century, an anti-Romantic movement began to emerge. The fact that art, in which emotions are so exaggerated and individual expressions are included rather than large masses, has disconnected from the public has been the most important reason for moving away from its romance. The beginning of the anti-romantic period was started towards the end of the 19th century when post-romantics used music and opera to fight with each other (Whittall, 1999).

The neoclassical music movement emerged in the 1920s. The neoclassical movement that followed the romantic movement shows a tendency towards a more natural but more epic music genre (Whittall, 1999). There have also been examples of orientation to the past in the 20th century. Examples of 18th century opera, which is one of the brightest ages of opera, are given. In the 1940s, philosophical debates about music and lyrics began to take place in opera. Philosophical thoughts and works on tragedy, comedy, morality, satire and symbolism are given (Orrey, 1987).

The 20th century has been referred to as the age of experiments for auditory arts. New subject searches or new interpretations have been made in certain forms. Different searches were made on the basis of nation or composer. It is the most vibrant age in history. However, musical obstacles were encountered again. Social events, politics and politics have been very influential on music. Nevertheless, a grammar language was created for music. With the effect of individuality, composers interpreted the events in their own way. For this reason, in the 19th century, consciousness specific to nations became specific to composers and musicians. Styles have become established and stylistic differences have become distinguishable. The consequences of this jumped to the 21st century. Innovations have been experienced especially with the effect of electricity. States used records or had them broadcast on the radio to promote their national arts to the world in the context of contemporary music. Opposite elements such as "extremism" and "simplicity" have begun to emerge (Mimaroğlu, 1970). Forms have become reinterpretable thanks to individual sentimentality. For this reason, the reality movement soon manifested itself in opera. Verismo, which is a movement of realism in opera, has survived to the present day (Şatır, 1977).

In the 20th century, there is a whole new range of sounds made possible by electronics and recorders. By combining traditional music within these possibilities, different and new music could be obtained. The widening of the horizon of the opera has gained a new dimension with some unique problems and opportunities offered by modern technology. First, the invention of the gramophone carried the golden sounds of Caruso Melba and others in their early days to the homes of people who would never be able to listen to these singers live. Nowadays, long player records, compact discs and modern stereophonic recording techniques have brought the sound spectrum to an unattainable perfection in live performance, and we can work opera masterpieces in our home in a way that was unimaginable before. The film had its greatest impact on the opera when it made it possible to turn the opera into a film by adding an audiotape. So far, very few operas have been written specifically for cinema, and it seems that no one has yet made full use of film-specific resources. Modern play techniques not only make the average theatrical medium seem intolerably clumsy, but more importantly make possible all sorts of illusions and magical transformations that offer an entirely new spectrum of visual beauty. This paves the way for a new audiovisual art with the use of cassettes and electronic music (Orrey, 1987).

The full-platform recording of the first opera play was made in the 1970s (Meyerbeer Opera). Before that, fragmented records began to be made in 1962 (Kelly et al., 2023b).

Like the gramophone, radio suffers from the disadvantage of being one-dimensional, yet radio operas, for example, have been written. However, since visuals are missing in radio operas, it is very difficult to say that they are operas in the real sense (technically), even though they are operas by name. Television operas are considered as another category. It reached the audience with limited vision on a small screen. In addition, the sound quality is lower than the radio and gramophone. The proliferation of videotapes has given the gramophone a visual equivalent: recordings of opera house productions can now be viewed and enjoyed in the living room (Orrey, 1987).

3.1.6 Orchestra

Orchestra is a subject intertwined with the topics of "music" and "instrument". Throughout history, the development and change of instruments and music have been experienced. Opera is a relatively newer art than music. However, thanks to the invention of opera and its great interest by people, music and orchestra were influenced by opera. The concepts of "Opera Music" and "Opera Orchestra" have been added to the literature.

The opera orchestra should perform the music in harmony with the stage, the conductor, the actors and the choir. If the orchestra is going to play for an opera play, it must be rehearsed in different situation scenarios. There are many rehearsals without costume, on-site or in the rehearsal room, including when the play is staged. In addition, if an opera play is to be performed in another hall, the orchestra must rehearse before the play. Today, for orchestra management: Orchestra conductor, stage director, sound designer come together and singers are selected. The staging is rehearsed many times. With the changeability of the process, the play on the stage is usually rehearsed and after the play reaches a certain maturity, the orchestra and the singers and actors are brought together. In this process, the conductor and the orchestra rehearse together many times. The rehearsal of the opera to be performed is completed with singers, actors and orchestra. Costumed rehearsals are held several times before the play is staged in front of the audience (Kelly et al., 2023b).

The orchestras were first conducted with a harpsichord and then this process continued with a scepter struck on the ground. When Habeneck was commissioned at the Paris Opera, the orchestra management style changed radically. Habeneck is professor of violin at the Paris Conservatory. Before that, orchestras were led by hitting the ground with a staff, while Habeneck led the orchestra with a violin bow. This was later replaced by "baton". This form of governance is still practiced (Kelly et al., 2023b). Thanks to this form of management, the layout of the orchestra and the material selection of the orchestra section (pit) have been changed.

3.2 Effects of Opera on Auditorium Design

Auditoriums are special-purpose spaces where visual and auditory comfort with a certain stage area and orientation is at the forefront (Olson, 2015). Examples of auditorium types include concert halls, theater halls, opera houses, convention centers, conference halls. Opera plays have been exhibited indoors since their early days. The first venues were usually performed in the pavilions and mansions of the nobles or in the ballrooms in the palaces. With the development and enrichment of the opera in every direction over time, the number of production materials, instruments (musicians) and actors has increased, regardless of the duration of the plays. In addition, how the sound of the exhibited play is heard has also become important. Over time, special venues began to be designed for opera, music recitals and theater performances. Thanks to the adoption of these arts by the public, these spaces have also been privatized. Separate spaces have begun to be designed for the theater, separate spaces for music performance and separate spaces for opera. Opera is a branch of art in which visual and auditory comfort are at the forefront together. For this reason, it needs its own specially designed spaces. These special requirements of Opera have increased and changed over time.

The historical development of opera houses is an issue intertwined with theater buildings. The theater has a lot in common with opera, except that it has a lot of visual weight and is more distant from the public. For this reason, opera plays were played in the theaters and ballet halls in the palaces until the first opera house was built (D'Orazio, 2020). The palace theaters where the first operas are exhibited are in basilica form. This form does not provide suitable acoustic conditions for opera houses. The first opera houses built were inspired by Roman amphitheaters (Beranek, 1962). This geometric form improves the visual and auditory acoustic performance of the hall compared to the previous one (D'Orazio, 2020; Jeon et al., 2008).

The development of opera houses is a matter closely related to society. The formal structures of opera houses were discussed between the end of the 17th century and the beginning of the 19th century (D'Orazio and Nannini, 2019). This time period coincides with the spread of opera to various parts of Europe. Until the 20th century, theaters and opera houses were built as wooden structures. Very rarely, stone structures were built. Wooden construction has been preferred more frequently because it is more profitable in terms of both cost, time and labor. However, many theaters and opera houses were destroyed as a result of the fires.

Compared to the opera house, some operas are performed more and some less. In the Paris Opera House, for example, Verdi's Don Carlo is performed less often than in other operas. Because it is necessary to have ballet in Paris Opera (Kelly et al., 2023b).

The Paris Opera House is one of the most advanced examples of “opera house” structures. It can meet every need needed in opera art. It has an important place in the history of opera in terms of magnificence, ostentation, practicality and flawless functioning. Harvad University, music department Prof. T. Kelly: “When we go to the opera, we see very nice sets and we listen to these great singers and we have a great time. But one of the fascinating aspects of the Paris Opera House is how surprisingly technical it is, at least for me and hopefully for you. How you support all this scenery. How you make these natural effects. How many people have to do it and how you build the house to do it. The Paris Opera house, like many other theatres, was built. With a set of wings and back covers. Nevertheless, it is a very large, very complex version (Kelly et al., 2023b) of this. "He explained the difference of the Paris Opera House from other opera houses.

When we look at opera houses from an acoustic point of view: The first acoustic examinations in opera houses date back to the 17th century. Commercial documents of Venetian rulers in the 17th century provide important information about the acoustics of opera houses (Bianconi and Walker 2008; Rosand, 2007). Today, acoustic calculations are made with sound signals in opera houses (Beranek, 2004; Fausti and Farina, 2000).

Both the stage section and the audience section of the opera houses have developed due to the increasing number of actors and musicians and spectators. In this section, auditoriums (opera houses) are examined under two subheadings: "Stage and Behind the Stage" and "Audience Area".

3.2.1 Stage (Performance Area) and behind the stage

The main performance takes place on the stage. Since opera is a branch of art connected to the place, the opera house, the orchestra and the singers must be brought together. Space is an element that cannot be considered independent of the game. According to the opera play on display (according to the composer), emotions, stage performance or music may be more dominant in plays. Feredico Cortese, Music Director of the Boston Youth Symphony Orchestra and Harvard-Radcliffe Orchestra conductor at Harvard University, said: "… If you are directing a Puccini scene, the conductor is trying to get everything back on track in Don Giovanni's scene, while stretching the harmony and changing the harmony come to the fore (Kelly et al., 2023b). "

Since the operas were planned like a theater play, the stage curtain was used as in the theater before the opera started. On the curtain, there is a portrait of the king of the period or the royal family. These paintings were made specially by painters (Bereson, 2002). This curtain is lifted at the beginning and the picture that appears until the curtain is lifted gives the opera audience information about who gave them this pleasure (Kelly et al., 2023b). The main curtain (foremost curtain) is removed only at the beginning of the game and at the end of the game. Everything is on the stage in full view during the show(Kelly et al., 2023a).

The fin system consists of at least 2 horizontal parts. It is exemplified Figure 1in. Depending on the size of the stage and the variety of the game, the number of wings can be increased or decreased, or the dimensions of the wings can be changed. At least three separate panels are needed to both change the stage size and provide the stage decor (Kelly et al., 2023b).

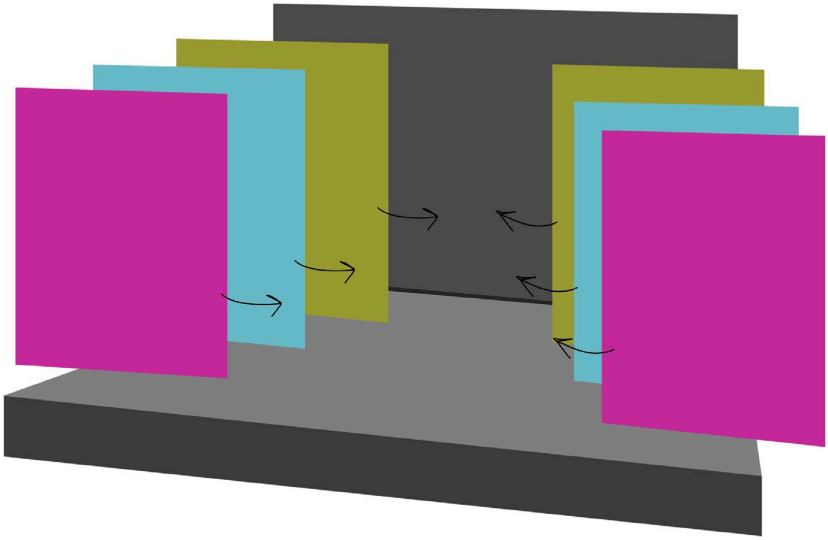


Figure 1. Vane system (Pink, blue and green pair).

Two of them are fins and one of them is up horizontally and can be used when it is desired to Figure 3reduce the stage. The use of vertical and horizontal planes together is shown in. The vertical planes used to change scene sizes are shown Figure 2in, where the scene can be enlarged or reduced by changing the size of the scene opening. The number of these planes varies according to the physical depth of the stage and the number of stages in the opera play.

The signs on the stage floor show the locations of the wings and panels. In most 18th-century opera houses, the stage is flat (Kelly et al., 2023b).

Orchestra, decors, singers are on the same platform. There is no clear field definition. The fin system was used to define the area in such scenes. Example of the wing function; the first scene can be a deep set, and the second scene can be a room in the palace. The wings are painted to perform this function and placed in order (Kelly et al., 2023a). Vertical planes and fines (horizontal planes) basically serve the same function. However, since the fin system can be designed at different heights, it has allowed to create different decorations compared to vertical planes. The fin system is still in use today.

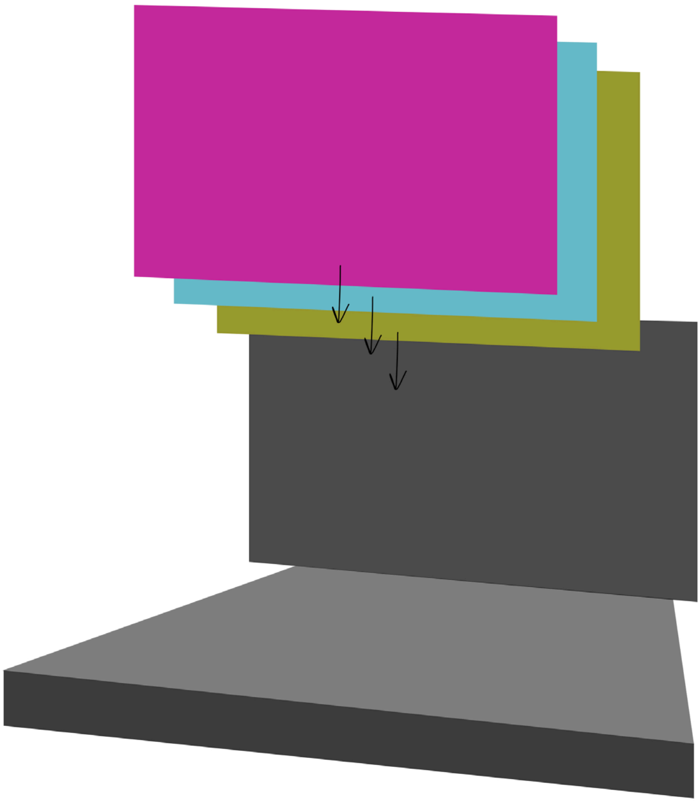


Figure 2. Vertical planes used to change stage sizes.

There are no real stage directors in 18th-century Italian opera. The stage director is usually a librettist (Kelly et al., 2023a). The librettist is responsible for the wing movements.

The main fabric behind the stage is dyed in appropriate colors according to the game. The sloping fins on the sides (sometimes with rails on the floor) form the different stage backgrounds. T. Kelly explained the use of the fins as follows: “Just slide the two panels back, bring the middle two panels forward, and pull it back when you're done.”. Everything happens in a matter of seconds. Since there is no electricity, these must be done mechanically under human influence (Kelly et al., 2023a).

In the 17th and 18th centuries, stage systems were mechanical, not electrical. The parts are usually combined with systems consisting of snap-on details or simple machines. For this reason, the stage designer works behind the stage (or at the bottom of the stage table) while the play is exhibited on the stage. These systems have been used to change the dimensions of the scene or to place scene effects. For example, if it is necessary to build a bridge on the stage for a curtain of the play, a fragmented bridge rising from the stage is designed by passing through the gaps on the stage floor. In the next scene, the bridge could be removed and replaced with another effect. Some kind of modular designs have been installed and the effects are designed to be both portable and removable.

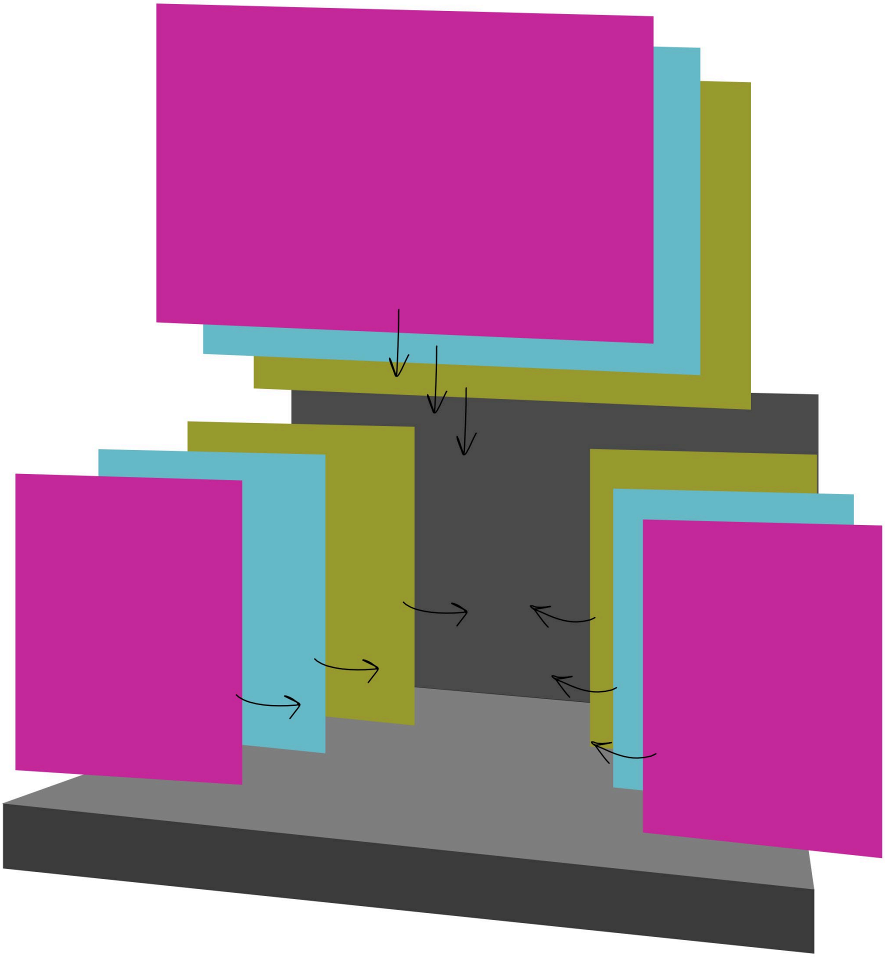


Figure 3. Using the vane system and vertical planes together.

The orchestra, on the other hand, has expanded day by day in terms of both the number of instruments and the type of instruments. In this process, the management style of the orchestra and the positioning of the instruments have also changed. Orchestral pit is a preferred method to physically separate the performance area of the orchestra and the stage and to maintain the visual relationship of the audience with both. Behind the scenes, it has been developed to respond to new needs over time. Various rehearsal rooms, multiple storage areas, technical volumes have been added.

3.2.1 Spectators area

Seating Area: In the first opera houses, the audience area is divided into stands, lodges and galleries. The stands are flat surfaces with a slightly sloping seating arrangement. Although it was settled in the form of U at the beginning, over time, it turned to the bell shape, the semi-elliptical shape and the last horseshoe shape. Lodges are special sections that partially open to the hall. It is positioned to surround the main hall and to have a dominant view of the hall. The orchestra pit is located between the stage area and the audience area. There is a wooden railing between the orchestra pit and the audience section. Thus, the area definition is made. These Italian-style opera houses spread to Europe in this way as they were the first examples. Similar plan types have been implemented in different cities to be larger or smaller (Prodi et al., 2015). The physical separation of the rich and noble from other sections of the people continued until Wagner. Wagner chose to keep the audience indistinguishable, selling long-term tickets to wealthy people and tickets per play to the rest of the public. In other words, it ensured that there was no physical difference between them.

Lighting: In the periods when the opera was born, lighting can be realized thanks to the sun and fire. The plays are played both in the theaters and in the opera in the evening. Therefore, there is a light problem. Both during the game and during the filling and emptying of the hall at the beginning and end of the game. Large candle chandeliers are used for lighting. The set is almost entirely lit by candles. There are also a few oil lamps (Kelly et al., 2023a). Until the invention of electricity, opera houses were illuminated with large chandeliers made of candles. For this reason, it has been very difficult to recreate sudden dark and light scenes during the opera. Candles that are kept ready between stage decorations are placed in the chandelier during stage transitions. The chandelier hangs right in the middle in front of the stage. For this reason, the person whose turn it is goes to the middle of the stage. Today, the atmosphere suitable for the play can be provided with artificial lighting (Burris-Meyer & Cole, 1964; Egan, 2007; Skålevik, 2008). In today's operas, a light is designed that is reflected to the audience. Thanks to this light, the audience is emotionally involved in the game (Kelly et al., 2023b).

In most of the 18th century operas, the actor sings in the middle of the stage. The actor, whose turn it is to sing in the play, goes to the middle of the stage. The center of the stage is also the place where the largest chandelier is located. (Where all singers sing aria) The candles in this chandelier are selected from those that will last for a long time and are extinguished after each curtain. Between the curtains, the candles need to be cut and re-prepared. This preparation is done between the wings, candles come from the back while the wings are pulled forward, lighting and stage placement take place at the same time. Despite these lighting elements, the theater is not as bright as today (Kelly et al., 2023a).

4. Conclusion and Suggestions

Opera was born in Italy and developed under the leadership of Italians for centuries. Other European countries followed Italy. In the second half of the 18th century, this superiority was almost equalized with other countries. Nevertheless, Italian composers such as Rossini, Bellini, Verdi, Puccini were trained in the 19th century (Say, 1997). This opera movement, which started in Italy, attracted a lot of attention in that it enabled almost all of the fine arts to take place together.

Since the homeland of the opera is Italy, the first opera house and the foundations of many things related to the opera were laid in Italy. Nearly 400 years have passed since the first opera house. Despite this, approximately 800 opera houses with volumes ranging from 1,000 m^3 to 10,000 m^3 are still in use in Italy today (Prodi et al., 2015). This is proof that although there have been changes in opera art, the first opera houses can still function.

Many elements in opera houses have been renovated and developed over time (Ryu & Jeon, 2008). The invention and use of electricity is a prime example of this. Thanks to electricity, both visual and auditory comfort have been improved. Apart from electricity, another issue is political and religious views. The audience, which was initially kept separate and classified, has been considered as a whole over time. Lodges have left their places to standard seats.

Opera is undoubtedly an art that includes many visual and auditory arts and therefore needs a special space and thus shapes the space. Opera houses are places where visual and auditory performance is important and appeal to a wide audience. Since it has a multidisciplinary understanding of art, opera needs its own specially designed spaces. It is important for both the listener and the artist. Opera is an art that continues to live and develop. The developments in opera art over the centuries have been on a regional or national scale. Therefore, opera houses have also undergone regional, national and even personal (for example: Wagner) changes. For this reason, as the art of opera continues to develop, the existing standards and designs for opera houses will be renewed and improved.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to The e-book section.

References

Altar, C. M. (1993). *Opera Tarihi*. İstanbul: Kültür Bakanlığı.

Barron, M. (2009). *Auditorium Acoustics and Architectural Design*. Second Edi. New York: Spon Press.

Beranek, L. L. (1962). *Music, Acoustics & Architecture*. edited by G. Stone. New York: John Wiley & Sons Inc.

Beranek, L. L. (2004). *Concert Halls and Opera Houses*. New York, NY: Springer New York.

Bereson, R. (2002). *The Operatic State: Cultural Policy and the Opera House*. Taylor & Francis e-Library.

Bianconi, L. & Walker, T. (2008). *Production, Consumption and Political Function of Seventeenth-Century Opera*. Cambridge University Press.

Burris-Meyer, H. & Edward C. Cole. (1964). *Theatres and Auditoriums*. Second Edi. New York: Reinhold Publishing, Chapman & Hall, Ltd.

D'Orazio, D. & Nannini, S. (2019). Towards Italian Opera Houses: A Review of Acoustic Design in Pre-Sabine Scholars. *Acoustics* 1:252–80.

D'Orazio, D. (2020). Italian-Style Opera Houses: A Historical Review. *Applied Sciences* 10(13).

Egan, M. D. (2007). *Architectural Acoustics*. New York.

Fausti, P. and Farina, A. (2000). Acoustic Measurements in Opera Houses: Comparison Between Different Techniques and Equipment. *Journal of Sound and Vibration1* 232(1):213–29.

Hodeir, A. (1994). *Müzik Türleri ve Biçimleri*. Second Edi. İletişim Yayıncılık.

Jeon, J. Y., Yong H. K., Densil, C. & John, B. (2008). The Effect of Visual and Auditory Cues on Seat Prefence in an Opera Theatre. *Journal Acoustic Society of America2* 123(6):4272–82.

Kelly, T. F., Jascha, S., Callam, K. & Edgar, G. (2023a.) *18th-Century Opera: Handel & Mozart*.

Kelly, T. F., Jascha, S., Callam, K. & Edgar, G. (2023b.) *19th-Century Opera: Meyerbeer, Wagner, & Verdi*.

McKinney, H. & Anderson, W. R. (1957). *Music in History*. Second Edi. USA: American Book Company.

Mimaroğlu, İ. K. (1970). *Müzik Tarihi*. Varlık Yayınları.

Olson, H. F. (2015). Acoustoelectronic Auditorium. *Journal Acoustic Society of America* 31:872–79.

Orrey, L. (1987). *Opera A Concise History*. Singapore: Thames & Hudson Ltd.

Özgüden, İ. (1966). *Müzik Rehberi*. İstanbul: Kitapçılık Ticaret Ltd. Şirketi Yayınları.

Prodi, N., Pompoli, R., Martellota, F. & Shin-ichi, Sato. (2015). "Acoustics of Italian Historical Opera Houses." *Journal Acoustic Society of America* 138:769–81.

Rosand, E. (2007). *Opera in Seventeenth-Century Venice: The Creation of a Genre*. USA: University of California Press.

Rushton, J. (1996). *Classical Music A Concise History from Gluck to Beethoven*. Slovenia: Thames and Hudson Ltd.

Ryu, J. K. & Jin Yong Jeon. (2008). Subjective and Objective Evaluations of a Scattered Sound Field in a Scale Model Opera House. *Journal Acoustic Society of America* 124:1538–49. doi: https://doi.org/10.1121/1.2956474.

Sachs, C. (1965). *Kısa Dünya Musikisi Tarihi*. İstanbul: Milli Eğitim Basımevi.

Şatır, S. (1977). *Operada Gerçekçilik ve Beş Gerçekçi Opera*. Birinci Ba. İstanbul: Pan Yayıncılık.

Say, A. (1997). *Müzik Tarihi*. 3. Baskı. Ankara: Müzik Ansiklopedisi Yayınları.

Skålevik, M. (2008). Room Acoustic Parameters And Theır Distribution Over Concert Hall Seats. in *Proceedings of Auditorium Acoustics*. Vol. 30.

Ulusu, Y. (1994). Operanın Doğuşu ve İtalya'daki Gelişimi. *Marmara İletişim Dergisi* 7:275–77.

Whittall, A. (1999). *Romantic Music A Concise History From Schubert to Sibelius*. Slovenia: Thames and Hudson Ltd.

Wikipedia. (2023). Opera. Retrieved (https://en.wikipedia.org/wiki/Opera).

Yener, F. (1983). *Müzik*. İstanbul: Türkiye Turing ve Otomobil Kurumu Beyaz Köşk (Müzik Sarayı) Yayınları No.1.

A. Cüneyd DİRİ

E-mail: ahmet.cuneyd.diri@msgsu.edu.tr

Educational Status:

License: Mimar Sinan University, Architecture

Degree: PhD

Doctorate: Mimar Sinan University, Building Physics and Material

Professional Experience: He graduated from Mimar Sinan Fine ArtsUniversity, Department of Architecture in 1992. He completed his hisdoctorate in 1994 at the same university. He become a lecturer in sameuniversity in 1993 until today. Currently, the Department of BuildingPhysics and Materials is accepted as academic.

Derin Hilal BİLMEZ

E-mail: derinhilalb@gmail.com

Educational Status

License: Çukurova University, Architecture

Degree: Master Architect (Mimar Sinan Fine Arts University, Building Physics and Materials)

Doctorate: Mimar Sinan Fine Arts University Institute of Science, Building Physics and Materials PhD Student

Professional Experience: She graduated from Çukurova University, Department of Architecture in 2019. In 2022, she completed her master's degree in Yıldız Technical University Construction Management (Civil Engineering). In 2023, she completed her master's degree in Mimar Sinan Fine Arts University (Architecture). Now, she is half time working at TÜBİTAK Marmara ResearchCentre and doing her PhD education in Mimar Sinan Fine ArtsUniversity.

Ümit T. ARPACIOĞLU
E-mail: umit.arpacioglu@msgsu.edu.tr
Educational Status:
License: Mimar Sinan University, Architecture
Degree: Assoc Prof Dr
Doctorate: Mimar Sinan University, Building Physics and Material
Professional Experience: He graduated from Mimar Sinan Fine ArtsUniversity, Department of Architecture in 2001. He completed his master's degree in 2005 and his doctorate in 2010 at the sameuniversity. He earned the title of Associate Professor at MSGSU in 2018. Currently, the Department of Building Physics and Materials is accepted as academic.

Dimensional Analysis of Escape Stairs in the Context of International Rules

Research Assist. H. Sueda YILDIRIM [1]

[1]Yıldız Technical University, Faculty of Architecture, Department of Architecture, Beşiktaş Campus, Istanbul/Türkiye.
ORCID: 0000-0003-2918-3907
E-mail: hsueda@yildiz.edu.tr

Assoc. Prof. Dr. Erkan AVLAR [2]

[2]Yıldız Technical University, Faculty of Architecture, Department of Architecture, Beşiktaş Campus, Istanbul/Türkiye.
ORCID: 0000-0003-0492-8095
E-mail: eavlar@yildiz.edu.tr

Citation: Yıldırım, S. & Avlar, E. (2023). Dimensional Analysis of Escape Stairs in the Context of International Rules. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (346-373). ISBN: 978-625-367-287-4. Ankara: Iksad Publications

1. Introduction

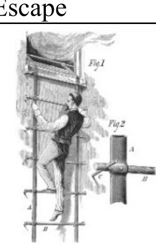
Fires in buildings result in loss of life when fire safety rules in their architectural design are not complied with and adequate precautions are not taken later by the buildings; for that reason, fires keep their prevalence as an issue that closely concerns safety of life. Fire safety design in buildings is not limited to general measures to be taken against fire, but requires a combination of many factors such as the function and features of the building, the profile and the number of building users to be taken into consideration.

Although they are few in number, fires which start unexpectedly, develop suddenly and engulf the building in a short time, end up causing great financial losses whereby rendering the buildings unusable. If the buildings are not designed in accordance with fire safety rules, loss of life and injuries are prone to occur. Loss of life increases even more in buildings such as schools, hospitals and in buildings which have high number of occupants among whom the majority of are not familiar with the building layout. The increase in loss of life also depends on many other factors such as the classification of the building based on its intended use and its height, the flammability ranking of its building materials and spatial installations, the planning of fire escape routes, the number, location and quality of escape stairs, and outer environment conditions.

Correct planning of escape routes in buildings is crucial for fire safety. In the event of a fire, occupants in the building must be evacuated promptly, effortlessly and safely. In buildings with inadequate and/or incorrectly arranged escape routes, people lose their lives by being poisoned from smoke inhalation emitted out during the fire, as a result of the building not being evacuated quickly. For this reason, escape routes should be arranged in such a way as to prevent loss of life and injuries/disablements, and their entrances should be unobstructed and open to allow easy access. In order to prevent loss of life in fires, the design of escape stairs that allow users to evacuate the building safely should also be cared for accurately.

Limiting the use of ignition sources in the building may be considered as the easiest way to prevent a building fire. However, elimination of ignition sources and factors causing fire is an unrealistic method of protection. There are many factors that can cause fire in buildings such as; natural disasters, accidents, carelessness, and arson, as well as sources such as; electrical and gas-powered devices and machines used for heating and cooking purposes. For this reason, safety of life and property, extinguishing operations to proceed uninterruptedly, and protection of the environment are aspects that are taken into account with priority in fire safety. In building designs, the life safety of the users can be ensured by incorporating criteria such as early warning systems, building evacuation strategies, escape route designs, extinguishing efforts, safety of exits, which are among the primary measures to be taken for matters concerning the safety of lives. Obtaining an effective and safe design in terms of fire safety in buildings depends on the determination and implementation of fire safety rules in the building design and during the planning process. Fire safety in buildings is achieved by using active and passive fire safety measures together. While active fire safety measures include fire alarm, smoke ventilation and fire suppression systems, passive fire safety measures are defined as the precautions to be taken during the design phase of the building. Active measures play a supportive role in passive measures. In case active fire safety measures are deactivated or fail, passive measures are of crucial importance in completing the evacuation procedures of the building. Passive fire safety measures are related to many factors, such as; the number, familiarity with the building, mobility (the ability to leave the building without assistance), fire awareness and fire hazard recognition of the occupants, the building evacuation strategies, the construction life of the building, the height of the building, number of the escape stairs, and the adequacy of the exits.

The subject of fire protection and life safety covers a long historical progression that changes and develops in laws and standards in line with the teachings and inferences obtained as a result of fires of the past. At the same time, it shows the application forms of fire stairs in this historical process (Figure 1).

1860 / Holwell's Improved Fire Escape	1860 / London Fire Escape	1872 / Rafter Hook and Fire Escape	1877 / Allen's Improved Fire Escape
			
1877 / Houghton's Fire Escape	1878 / Anonymous	1879 / Oppenheimer	1882 / Shaw's Fire Escape

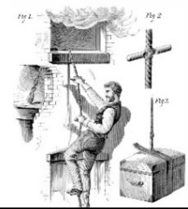
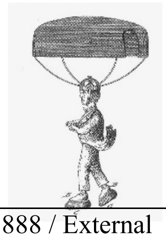
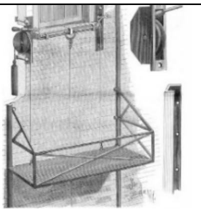
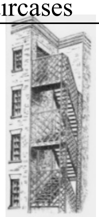
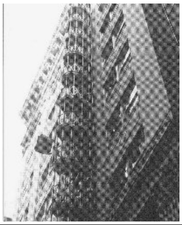
			
1883 / Cassedy's Fire Escape	1885 / Davis Fire Escape	1888 / External Fire Escape Staircases	1899 / Spiral Slide Steel Fire Escape to a School
			
1900 / Boston Office Building	1907 / San Francisco Office Building	1926 / At The Top of The Conveyor	1970 / America School Building
			

Figure 1. Historical progression of escape stairs.

Major fires in the past have identified key issues concerning fire protection in buildings. The fire experts of the countries have carried out various studies in order to prevent loss of life in fires, taking into account these problems, and laws and standards have been prepared that have determined the rules on fire protection (Figure 2).

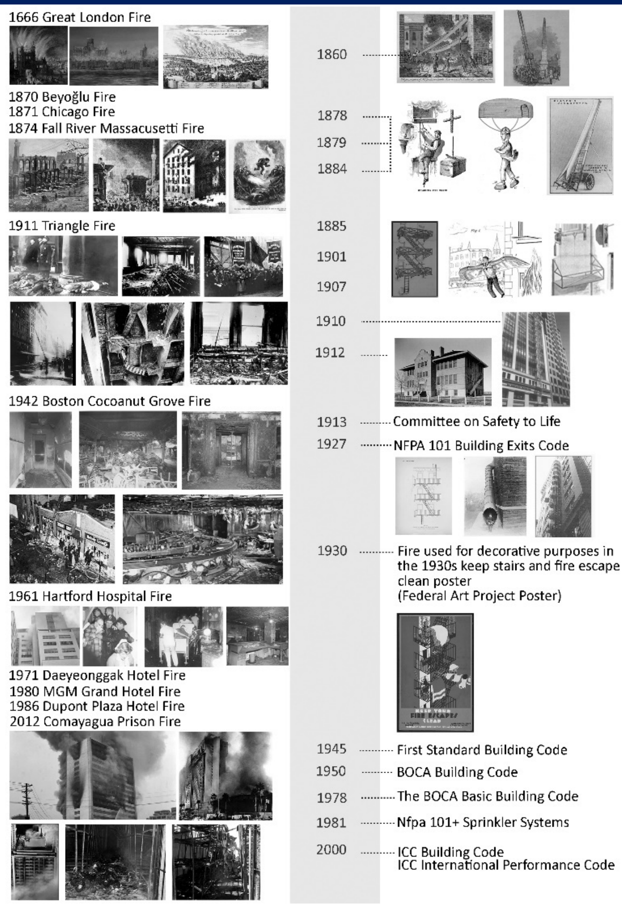


Figure 2. Historical progress of fires and laws and standards developed after them.

While complying with these rules does not ensure the absolute safety of all users in all situations, it often helps to achieve an acceptable level of security if abided by. However, current fires reveal that there is not much difference between the challenges faced in the past and the problems and consequences encountered today. This situation does not mean that the rule makers, building designers and experts of this field have not worked to increase life safety, despite all the important developments achieved in fire safety, but it reflects the complexity of building designs that have emerged with the challenges and problems encountered in the life safety today.

2. Escape Stair Dimensions in International Rules

Fire safety measures in buildings are defined by measurable variables such as; the escape speed of occupants, occupant density, geometry of the stairwell, and the use conditions of the building before evacuation; and these variables are used in measuring the performance of escape systems (Kuligowski et al., 2010). Gathering key data on evacuations and its analysis, establishment of building code requirements, implementation of exit system design, and analysis of emerging issues are the basis for providing insight in the design of escape routes and escape stairs (Peacock et al., 2012).

Escape stairs are defined as stairs that can be used for the safe and rapid evacuation of people in the building in case of fire or other emergencies, arranged in a fire-protected manner and opening to a secure area at ground level (BYKHY, 2021). Measurable and definable classifications have been made in the laws and standards of the countries for the escape stairs in the buildings that take the occupants to the final exit. In these classifications, escape stairs are handled according to the environment they are located in and according to the stair shapes. Escape stairs, which can be built inside or outside the building, are an escape route component that provides normal circulation of users between floors, facilitating emergency exit during a fire, as well as rescue and fire extinguishing efforts of the fire brigade.

Stairs arranged inside and outside in most of the buildings form the main escape routes. According to the environment in which they are located, escape stairs are divided into two groups; internal escape stairs and external escape stairs. Internal escape stairs are stairs that can be accessed from any point of the building, can be constructed with or without fire protection, and reach the final exits directly or through components such as corridors and halls. Since these stairs are in closed environments, unprotected interior stairs can be blocked by smoke and heat during a fire and become unusable. Building internal in a protected shell as a fire escape prevents this situation. In the interior escape stairs, having a door that is wide enough to meet the user load is a must. (BYKHY, 2021).

Exterior escape stairs, on the other hand, are designed similarly to interior stairs, with a few exceptions. Because these stairs are open, smoke and heat impede escapes less than interior escape stairs. However, external escape stairs, which are not required to be placed in a fire-resistant enclosure, are prone to dangers such as falling, fear of heights, and the effects of outdoor whether conditions (Tubbs et al., n.d.). In terms of fire protection, regulations impose some special rules on the exterior wall and wall spaces where the stair is placed.

Located in the access to exit and exit stages of the escape routes, and used frequently in daily life as well as in emergencies, escape stairs are classified under three groups as standard stairs, curved stairs, and spiral stairs, according to their formation. There are different rules in the laws according to the formation of escape stairs. These rules are regulated separately for internal escape stairs, external escape stairs, curved stairs and spiral stairs. In the regulation in Türkiye, rules are given over three groups: escape stairs, external stairs and spiral stairs.

The laws and standards of seven countries, namely the USA, Australia, the United Kingdom, Sweden, Canada, Russia and Türkiye, were examined in order to determine the rules regarding the stair dimensions for escape stairs. Laws and standards examined within the scope of the study are;

USA, International Building Code - ICC 2021 (ICC, 2021),

USA, National Fire Protection Association (NFPA - Life Safety Code 101) 2015 (NFPA, 2019),

Australia, Building Code of Australia - BCA 2015 (BCA, 2015),

UK, Approved Document B 2018 (Approved Document B, 2018),

UK, BSI Standards Publication BS 9999:2017 (BS 9999:2017, 2017),

UK, BSI Standards Publication BS 5395-1:2010 (BS 5395-1:2010, 2010),

Sweden, Boverket's Building Regulation BBR/ BFS 2011: 26 (BBR, 2016),

Canada, National Fire Code of Canada - NFC 2015 (O. Reg. 213/07: FIRE CODE, 2018),

Russia, SNIP 21-01-97 (SNIP 21-01-97, 1998),

Türkiye, Regulation on the Fire Protection of Buildings (BYKHY, 2021).

In these laws and standards, rules regarding the dimensions of escape stairs are given separately for; internal escape stairs, spiral stairs and external escape stairs (single flight, double flight). Rules regarding stairs cover the dimensional rules regarding; flight width, riser height, tread width, step construction, heights between landings, headroom space, landing, baluster and handrail.

2.1. Dimensions in Internal Escape Stairs

An outline of national/international rules regarding the dimensions of interior escape stairs are given in Table 1. According to these rules, the minimum flight width for an interior escape stair is 1000 mm in Australia, 900-910 mm in the USA, Sweden, Canada and Russia, and 800 mm in the UK and Türkiye. This value can be reduced up to 550 mm under special conditions in Canada. There is 200 mm difference between the highest value and the lowest value determined for the minimum flight width. Use on escape stairs is unidirectional and downward. Yet, the escape speed of the users may be different or a person may be escorting the user. Therefore, flight width of the escape stairs must be sufficient so that the fast-moving person can easily pass the slower person during an escape or the user leaving the building can move easily together with the accompanying person. For that reason, in escape stairs, the flight width can be determined for at least two persons descending side by side and can be a minimum of 1200 mm, or 1000 mm in the Australian building code can be accepted as the minimum width.

The maximum riser height of the interior escape stairs has been determined for each country. While the maximum step height is 175 mm in Türkiye, it is 180 mm in America, 190 mm in Australia and UK, 210 mm in Canada and 220 mm in Russia. There is a 45 mm difference between the highest value and the lowest value determined for the maximum riser height. Higher riser heights may make it cumbersome to use these stairs during an escape and may delay the evacuation time.

When determining this height, profiles of the people who would be using these escape stairs should be taken into account. It should be kept in mind that such stairs can be used by children, sick persons, elderly and physically challenged people. Therefore, the upper riser height limit should be specific for each building type and should be determined according to the user profile. In buildings designed for general use, 175 mm indicated in the regulation on fire protection of buildings in effect in Türkiye can be taken as a basis. The countries where the minimum riser height is ascribed are the US, Australia and UK. The minimum riser height for interior escape stairs is 10 cm in the USA, 11 cm in Australia and 15 cm in the UK.

The minimum tread width for interior escape stairs is 280 mm in the USA, 250 mm in Australia, UK, Sweden, Russia and Türkiye, and 220 mm in Canada. There is a 60 mm difference between the highest value and the lowest value in the minimum tread width dimensions. The minimum tread width in Canada's national fire code is considered to be insufficient for foot sizes above size 32 (200 mm), which may cause users to encounter difficulties while escaping. This width should not be less than 250 mm, as in many countries.

The maximum height between the landings is important as it gives the distance to be taken without rest when escaping from the stairs. The value of this height is 3000 mm in the UK and Türkiye, 3660 mm in the USA, and 3700 mm in Canada. Specific values could not be attained for Australia, Sweden and Russia. There is a difference of 700 mm between the highest value and the lowest value for the maximum distance between landings. According to the national fire code of Canada and the USA, a staircase with an average riser height of 170 mm is determined to have 22 steps, and 17 steps in the UK and Türkiye.

The number of steps is crucial in terms of the distance that people using the escape stairs will descend without resting during an emergency. The maximum distance between the landings determines the distance that users must descend at once, and this distance can be at most 3000 mm as in the regulation in effect in Türkiye and the UK. The minimum headroom height for interior escape stairs is 1950 mm in Canada, 2000 mm in Australia, the UK and Sweden, 2030 mm in the USA, 2100 mm in Türkiye and 2200 mm in Russia. There is a 250mm difference between the highest and lowest value for minimum headroom heights. The minimum headroom height given in Canada's national fire code is considered to be insufficient for taller users, concerned that insufficient headroom may cause accidents during an escape.

The minimum baluster height for interior escape stairs is 800 mm in Sweden, 865 mm in the USA, Canada and Australia, 900 mm in the UK and 1200 mm in Russia. There is a 400 mm difference between the highest value and the lowest value. The height of the baluster necessary in terms of escape safety is not included in the regulation in Türkiye. The height of the baluster is important to prevent falling from the stairs and for users with fear of heights to use the stairs comfortably. The minimum railing height of 800 mm indicated in the national regulation of Sweden is considered to be likely to pose a danger to the life safety of the users. This is recommended to be a minimum of 900 mm, as in many countries.

Table 1. National/international rules on the dimensions of interior escape stairs (ICC, 2021), (NFPA, 2019), (BCA, 2015), (Approved Document B, 2018), (BS 5395-1:2010, 2010), (BBR, 2016), (O. Reg. 213/07: FIRE CODE, 2018), (SNIP 21-01-97, 1998), (BYKHY, 2021)

Countries	Flight width (min)	Riser height (max)	Riser height (min)	Tread width (max)	Rules for step construction
USA (ICC)	914 mm	178 mm	102 mm	279 mm	Stair treads and landings must be free of protrusions that may cause tripping.
USA (NFPA)	915 mm	180 mm	100 mm	280 mm	Stair treads and landings must be free of protrusions that may cause tripping.
Australia (BCA)	1000 mm	190 mm	115 mm	250 mm: in public areas, 240 mm: in private areas	Should be constructed as fire resistant.
UK (AD-B)	For normal use areas: 1000 mm For private use areas: 800 mm	190 mm	150 mm	250 mm	Riser heights must all be the same. The stairs may be constructed as open riser but risers must overlap each other by at least 16 mm. The stairs to be used by the physically challenged persons must comply with rules stipulated in Approved Document M. Open riser staircases to be used by children under the age of 5 should be designed in such a way that a sphere with a diameter of 100 mm should not be able to pass through the open riser gap.
UK (BS 5395-1:2010)	For special areas of use: 800 mm, For stairs with two-way flow, the minimum stair width 1000 mm	In private use areas: 200 mm In normal use areas: 180 mm	150 mm	In normal use areas: 300 mm In private use areas: 250 mm	The material chosen for the stairs must be resistant to wear and tear.
Sweden (BBR/ BFS)	900 mm	Not specified	Not specified	250 mm 300 mm	The first step and the last step of the stairs should be marked with contrast lighting on each floor.
Canada (NFC)	900 mm (Except for special areas where a width of 550 mm is permitted)	210 mm	Not specified	220 mm	The tread surfaces must be slip resistant and the must be colored with contrasting colors.
Russia	900 mm	220 mm	Not specified	250 mm	Fire-retardant resistance should not be lower than REI 30.
Türkiye (BYKHY)	800 mm At least 1200 mm in high-rise buildings	175 mm	Not specified	250 mm	Treads must be constructed with anti-slip material.

2.2. Dimensions in Spiral Escape Stairs

An outline of national/international rules regarding the dimensions of spiral escape stairs are given in Table 2a, b. The tread widths of spiral staircases, which are allowed by some countries to be used as fire escape stairs, are not at the same depth at every point (Figure 3).

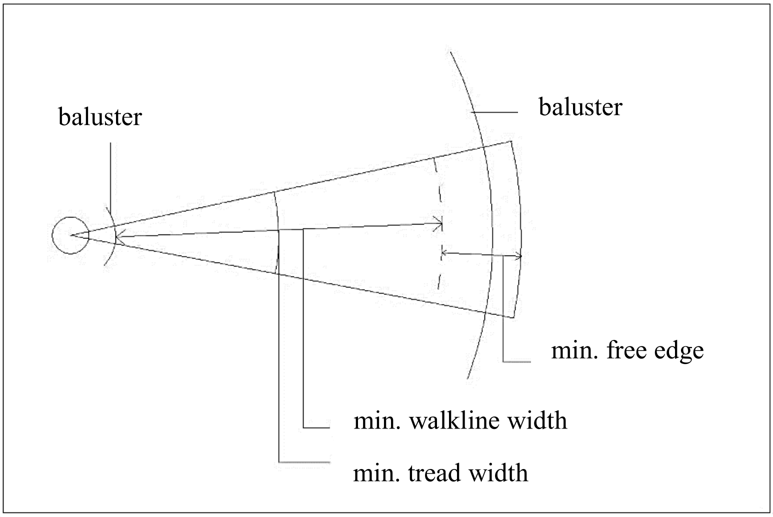


Figure 3. Tread width sizing definitions of spiral staircases.

Considered as more difficult to use compared to standard escape stairs. This type of stairs can cause accidents and loss of time during an evacuation. The use of spiral staircases as escape stairs is subject to special conditions in the codes, standards and regulations of different countries; for example, while it is not allowed to be used as the only escape route in the United Kingdom, in Russia its use as an escape route is prohibited. The Turkish regulation in effect, brings building height limits as well as imposing special conditions. In this regulation, the permissible height limit for spiral escape stairs in new buildings is 9.50 meters, but this limit is higher for existing buildings. In the USA, user load of the area served by the stairs is required not to exceed three people. In addition, spiral staircases are only allowed to be used as escape stairs in areas with less than 23 m² usage area. In Australia, spiral staircases are not permitted to be used as escape stairs in buildings containing entertainment venues. In Sweden, spiral escape stairs are not permitted in buildings classified as 5B (buildings that shelter users with physical or mental illnesses, physical challenges, mental impairments, dementia or other limited ability to maintain their own safety), buildings classified as 5C (healthcare facilities, such as hospitals), buildings classified as 2B (buildings with mass assembly areas which can hold more than 150 users at a time) and buildings classified as 2C (buildings designed to be used by more than 150 people at a time with public meetings areas where alcohol consumption is significant).

According to the values appear in the examined codes, standards and regulations, the minimum flight width for spiral staircases has been determined as 900 mm in Sweden and Canada, 1000 mm in Australia, United Kingdom and Türkiye, and 1500 mm for buildings used for entertainment purposes in Australia. In the UK, this value is 600 mm for small private use areas (rooms, etc.), 800 mm for small and semi-public areas, and 900 mm for semi-public areas. In Türkiye, this value is minimum 800 mm in new buildings where the number of users on the floor exceeds 60 people, while it is 700 mm in existing buildings. In the USA, if the number of users in the area serviced by the stairs does not exceed 3 people, this value decreases to 660 mm. There is a 600 mm difference between the highest value and the lowest value determined for the minimum flight width (for places without special rules for usage). Since the tread width in spiral staircases is not the same at every point, the ideal walk line space for a 600 mm flight bearing spiral staircase can only be obtained 300 mm inside from the narrow edge of the staircase, and this area poses risk of falling for the user. The 600 mm flight width left between the sides of the stair flight parallel to the exit line will be insufficient to be used by two people at the same time, considering the human shoulder width. This dimension should not be reduced below 1000 mm as in internal escape stairs.

In codes, standards and regulations, the maximum riser height is determined also for spiral escape stairs. While the maximum riser height is 175 mm in Türkiye, it is 180 mm in the USA, 190 mm in Australia, 200 mm in Canada and 220 mm in the UK. There is a 45 mm difference between the highest value and the lowest value determined for the maximum riser height. Especially in spiral escape stairs, higher riser heights would make it quite difficult during an escape, furthermore may delay the evacuation time and cause users to lose their balance. This height is crucial in terms of the mobility of the people using the stairs, as is the case with interior escape stairs, and poses a danger if used by children, elderly or ailing people. For this reason, the upper limit of the riser height should be determined according to the building type and should be at most 175 mm in general use buildings as in the regulation on fire protection of buildings in effect in Türkiye.

The minimum tread width for spiral escape stairs is 280 mm in the USA and Australia, 250 mm in the UK, Sweden and Türkiye, and 200 mm in Canada. Furthermore, in the USA, this value has been determined as 190 mm for spiral escape stairs serving areas where the number of users does not exceed 3 people. In the UK, the minimum tread width for spiral escape stairs serving small and private areas is 145 mm, 190 mm for private use areas and 230 mm for public limited use areas. There is 80 mm difference between the highest value and the lowest value for the minimum tread width. The minimum tread width in Canada's national fire code is considered to be insufficient for foot sizes above size 32 (200 mm), which may cause users to encounter difficulties while escaping especially using this type of stairs. This width should not be less than 250 mm, as in many countries.

Spiral escape stairs have a going space that must be left on the outer edge of the staircase which is excluded from the tread width calculations. The minimum going width for spiral staircases is set at 300 mm in Sweden, 270 mm in the USA, UK and Australia, and 230 mm in Canada. There is no rule regarding the dimensions of this space in Türkiye. Since it is difficult to use the outer edges of spiral staircases when determining the minimum flight width, leaving this space allows the stairs to be used more efficiently and safely. The fact that this rule is enforced in Türkiye as in many other countries, is a clear indicator of the necessity of this space for escapes.

According to the codes, regulations and standards of the countries examined, the minimum headroom height for spiral escape stairs is determined as 2500 mm in Türkiye, whereas in Canada it is 2050mm, in Australia, UK and Sweden 2000 mm, and in the USA 1980 mm. There is a 520mm difference between the highest and lowest values for minimum headroom heights. The minimum headroom height in the US national fire code is considered to be insufficient, concerned that insufficient headroom may cause accidents during an escape.

The minimum baluster height for spiral escape stairs is 900 mm in Sweden and the UK, and 865 mm in the USA, Canada and Australia. Baluster height is not specified for spiral escape stairs in Turkish regulations. At the same time, values for handrail heights in the reviewed regulations were determined as 865 mm in the USA and Australia and 900 mm in the United Kingdom, whereas there was no specific dimension determined for handrail heights in Sweden, Canada or Türkiye. As a precautionary structural element preventing falls from the stairs and helping users with fear of heights to use the stairs comfortably, the height of the baluster is important to be specified. Crucial for the safety of the users, the baluster height for spiral escape stairs, which can also be used as external escape stairs, should be determined in Türkiye as well as in other countries.

Table 2a. National/international rules on the dimensions of spiral escape stairs (ICC, 2021), (NFPA, 2019), (BCA, 2015), (Approved Document B, 2018), (BS 5395-1:2010, 2010), (BBR, 2016), (O. Reg. 213/07: FIRE CODE, 2018), (SNIP 21-01-97, 1998), (BYKHY, 2021).

Countries	Special Specifications	Flight Width (min)	Riser Height (max)	Tread width (min)
USA (ICC)	Cannot be used as escape stairs in places over 23 m² in area and in places with more than 5 users	660 mm	241 mm	A spiral stairway shall have a 190 mm minimum clear tread depth at a point 305 mm from the narrow edge of the stairwell.
USA (NFPA)	Spiral staircases can be used as escape stairs in areas where the number of user load served by the stairs does not exceed three persons.	Stairway flight width must provide adequate escape capability for the user load served (stair width/number of persons =should be 10 for live-in senior care centers, 7.6 for hospitals (with sprinklers), 15 for hospitals (without sprinklers), 18 for high-hazard objects, 7.6 for others). In areas where the serviced user load does not exceed three people, min. 660mm	180 mm (In areas where the number of user load served by the stairs does not exceed three person240 mm)	280 mm - (In areas where the number of users served by the stairs does not exceed three-person clear tread depth at a point 305 mm from the narrow edge of the stairwell cannot be less than 190mm).
Australia (BCA)	In entertainment venues, multiple spiral staircases cannot be used as escape stairs.	1000 mm (In buildings predominantly used for entertainment purposes, 1500 mm)	Min. 115 cm Max. 190 mm	Width measured 500 mm inwards from the slender edge of the step, min. 280mm
UK (AD-B)	Spiral staircases should be designed in accordance with BS 5395-2:1984	BS 5395-2:1984	BS 5395-2:1984	BS 5395-2:1984
UK (BS 5395-1:2010)	If spiral staircases are used as escape stairs, they should not be defined as the only escape route.	Small private use areas: 600 mm - Private use areas: 800 mm - Small semi-public use areas: 800 mm - Semi-public use areas: 900 mm - Public use areas: 1000 mm	220 mm	For small private staircases: 145 mm - For private staircases: 190 mm - For small semi-public staircases: 230 mm - For public staircases: 250 mm
Sweden (BBR/ BFS)	Spiral staircases are not permitted to be used as escape stairs in buildings	900 mm	Not specified	250 mm

	with users with climbing difficulties and in buildings classified as 5B, 5C, 2B, and 2C.			
Canada (NFC)	Spiral staircases cannot be used as escape routes unless they meet the specified dimensions.	900 mm	Minimum 125 mm Maximum 200 mm	Cannot be less than 150mm in minimum measured area - Should be minimum 200mm in the center of the walk line space
Russia	Spiral staircases or helical stairs are not permitted to be used as escape routes	-	-	-
Türkiye (BYKHY)	Spiral staircases cannot be used in structures higher than 9500 mm	1000 mm; In existing buildings: At least 700 mm; 800 mm if the number of users on each floor is more than 60 people	175 mm	The clear tread width of the step, at a maximum distance of 500 mm from the center of the stairwell, must be at least 250 mm.

Table 2b. National/international rules on the dimensions of spiral escape stairs (ICC, 2021), (NFPA, 2019), (BCA, 2015), (Approved Document B, 2018), (BS 5395-1:2010, 2010), (BBR, 2016), (O. Reg. 213/07: FIRE CODE, 2018), (SNIP 21-01-97, 1998), (BYKHY, 2021).

Countries	Free width left on the outside edge of the stair (min)	Headroom Distance (min)	Baluster Height (min)	Handrail Height (min)
USA (ICC)	Not specified	1980 mm	Minimum 864 mm Maximum 965 mm	Must be over 762mm It should not exceed 1067 mm
USA (NFPA)	265 mm	1980 mm	On new stairs: balusters will be arranged within 760 mm distance. On existing stairs: balusters will be arranged within 1120 mm.	On new stairs, should be min. 865 mm - maximum 965 mm. On existing stairs: should not be less than 760 mm and not more than 965 mm. In mandatory cases the height of the handrails shall be allowed to exceed 965 mm, but this height shall never exceed 1065 mm.
Australia (BCA)	270 mm	2000 mm	865 mm	865 m
UK (AD-B)	Not specified	Not specified	Not specified	Not specified
UK (BS 5395-1:2010)	270 mm	Can be reduced to 1900 mm where 2000 mm is not applicable	900 mm	900 mm
Sweden (BBR/ BFS)	300 mm	2000 mm	If spiral staircases narrower than 900 mm are designed to be in a cage, baluster is not required. should be 900mm	Not specified
Canada (NFC)	230 mm	2050 mm	Minimum 865 mm Maximum 965 mm	865 mm
Russia	-	-	-	-
Türkiye (BYKHY)	Not specified	2500 mm	Escape staircases must have a wall, baluster or handrail on both sides.	Escape staircases must have a wall, baluster or handrail on both sides.

2.3. Dimensions in External Escape Stairs

External escape stairs application can be seen in many countries. When the codes, regulations and standards in the world are examined, specific regulations regarding these types of staircases are found. The building height limit of the external escape stairs, which is generally permitted to be used outside of high-rise buildings, varies from country to country. According to the data obtained from the codes, regulations and standards of the seven countries examined, the countries with the lowest building height limit are the United Kingdom and Canada with 18.00 m, and the country with the highest is Australia with 25.00 meters. This value is 24.00 meters in Sweden, 22.50 meters in the USA, 21.50 meters in Türkiye and 20.00 meters in Russia. External escape staircases are generally permitted for buildings where firefighting interventions can only be made from the exterior of the building, and this limit is considered as the access limit of the firefighting systems of the countries. There is no protective enclosure requirement for these staircases.

An outline of national/international rules regarding the dimensions of external escape stairs are given in Table 3a, b. According to the values compiled from the reviewed regulations and standards, the minimum baluster height in external escape stairs is 1200 mm in the USA and Russia, 1100 mm in the United Kingdom, 920 mm in Canada and 900 mm in Sweden. Baluster height is not specified for external escape stairs in Türkiye and Australia. Determining the height of the balusters and regulating the materials they are manufactured with being nontransparent materials that do not show the ground beneath them are important both in terms of prevention of falling from the stairs and for the safety of users with fear of heights. Therefore, it would be beneficial to determine the minimum baluster height limit in Türkiye and Australia where baluster height is not specified.

Table 3a. National/international rules on the dimensions of external escape stairs (ICC, 2021), (NFPA, 2019), (BCA, 2015), (Approved Document B, 2018), (BS 9999:2017, 2017), (BBR, 2016), (O. Reg. 213/07: FIRE CODE, 2018), (SNIP 21-01-97, 1998), (BYKHY, 2021).

Countries	Building Height	Permitted terms of use	Protective Enclosure	Balustrade Height (min)
USA (ICC)	22.86 m	Except for structures classified as use type Group 1 and Group 2, the use of external escape stairs is permitted in buildings with less than 6 floors and in buildings not exceeding 22.90 m from the lowest level of vehicle access of the fire brigade. External escape stairs should be designed in such a way that water does not accumulate on areas of escape.	Not required	Not specified
USA (NFPA)	22.5 m	Where approved by the authorities, the use of external escape stairs is permitted in buildings not exceeding 22,860 m and 6 floors, with the condition that they provide access to the roofs of other parts of a building or the roof of a neighboring building, that the materials and elements are fire resistant, and the escape route from the roof is continuous and secure.	Not required	1200 mm
Australia (BCA)	25.00 m	Use of external escape staircases is permitted only in buildings with a height of less than 25.00 m.	Not required	Not specified
UK (AD-B)	Not specified	Installing external escape stairs on the exterior of public buildings is permitted, provided that the external escape staircase is not used as the only escape route, there is an internal escape staircase in the building, and it only serves office and staff accommodation areas in corporate residential buildings.	Not required	1100 mm
UK (BS 9999:2017)	18.00 m	The use of external escape stairs is permitted provided that the external escape staircase is not used as the only escape route, there is an internal escape staircase in the building and this staircase serves every floor in the building.	Not required	1100 mm
Sweden (BBR/ BFS)	24.00 m	The use of external escape staircases is permitted provided that the staircase is arranged separately from the building to prevent fire and smoke from reaching the staircase, and that a fire-protected hall is accessible from the floors to the staircase.	Not required	900 mm
Canada (NFC)	18.00 m	The use of external escape staircases is permitted in buildings with less than 6 floors.	Not required	920 mm
Russia	20.00 m	External escape stairs are permitted to be used in buildings up to 20 meters high, provided that the relevant obligations are complied with.	Not required	1200 mm

Türkiye (BYKHY)	21.50 m	External escape stairs can be used instead of internal escape stairs in buildings with a building height of up to 21.50 meters, provided that the relevant requirements are complied with. In the section of the same regulation regarding existing buildings, the use of these stairs is allowed up to a building height of 51.50 m in residences and 30.50 m in buildings used for other purposes.	Not required	Not specified

Table 3b. National/international rules on the dimensions of external escape stairs (ICC, 2021), (NFPA, 2019), (BCA, 2015), (Approved Document B, 2018), (BS 9999:2017, 2017), (BBR, 2016), (O. Reg. 213/07: FIRE CODE, 2018), (SNIP 21-01-97, 1998), (BYKHY, 2021).

Countries	Horizontal distance from windows (min)	Fire resistance period of the wall to which it is attached (min)	Flight width between balusters (min)	Wall opening dimensions (min)
USA (ICC)	Not specified	60 minutes at heights below 4 floors, 120 minutes at heights above 4 floors	1220 mm	0.84 m² On side at least 910 mm
USA (NFPA)	3000 mm	60 minutes	Not specified	610 mm x 1980 mm 760 mm x 910 mm
Australia (BCA)	3000 mm	60 minutes	Not specified	800 mm x 1980 mm
UK (AD-B)	3000 mm	30 minutes	Not specified	450 mm x 450 mm
UK (BS 9999:2017)	3000 mm	30 minutes	Not specified	Not specified
Sweden (BBR/ BFS)	Not specified	60 minutes	Not specified	500 mm x 600 mm
Canada (NFC)	3000 mm	45 minutes	Not specified	1100 mm x 900 mm
Russia	1000 mm	REI 30	Not specified	750 mm x 1500 mm
Türkiye (BYKHY)	3000 mm	120 minutes	Not specified	700 mm x 1400 mm

In the codes, standards and regulations examined, it is not allowed to open a wall cavity to any part of the external escape staircase, such as doors and windows that are less protected from the features of the staircase within 3000 mm as the horizontal distance from the sides and the vertical distance from the bottom. However, this measure is 1000 mm in Russia. This small measurement makes it difficult to use stairs and poses a danger to life safety.

The minimum fire resistance period of the wall to which the external escape staircases are connected has been determined in the codes, standards and regulations of the seven countries examined. This time is 120 minutes in Türkiye, 60 minutes in USA, Australia and Sweden, 45 minutes in Canada, 30 minutes in UK and Russia. In Türkiye, there is no limitation for the fire resistance period of the wall to which the external escape stairs are connected. However, users may have slow escape speeds. Stairs and walls may lose their fire resistance before the evacuation from the external escape stairs is completed. For this reason, the minimum fire resistance period of the walls should be determined by considering the user profile.

The minimum flight width between balusters is 1220 mm in the USA and 900 mm in Sweden. No value for flight widths is specified in other countries. As in the interior escape staircases, the use of the external escape staircases is one-way and it is downwards. Considering the different escape speeds of users, the stair flight width should be determined for at least two people using it side-by side and should be at least 1200 mm as specified in the building code in effect in the USA.

Access to escape staircases through an unobstructed space is permitted provided they are within the minimum dimensions of the wall space, such as; 910/910 mm in the USA, 800/1980 mm in Australia, 450/450 mm in the UK, 500/600 mm in Sweden, 1100/900 mm in Canada, 750/1500 mm in Russia and 700/1400 mm in Türkiye. Even if a protective feature is added in any building to facilitate access to the staircase, access to the escape staircase from such an opening is inconvenient in terms of life safety. In addition, a negative situation may arise due to the changing rules in the regulation regarding the type, width and fire resistance of the wall space used for exiting the stairs. Therefore, the rule allowing access to the external escape staircase through any unobstructed opening can be removed.

4. Conclusion and Suggestions

One of the issues that has priority in the design of buildings is fire safety. However, full protection is never possible in fires in buildings. In case when active fire safety precautions are ineffective or insufficient, escape stairs are one of the important escape mechanisms that minimize the loss of life and provide the final exit. These stairs, which are specially designed for the evacuation of people in the building during a fire, are a part of the whole of the escape routes and should not be considered independently from the other escape route components. The laws and standards developed to protect buildings from fire and determining the rules to be followed determine the minimum safety criteria in the building. These rules should be considered as an important input to the building design process.

In this study, the rules of seven countries within the scope of fire safety design rules were examined and the dimensions of the escape stairs were compared. Fires develop depending on the features of the building (type of use of the building, flammability classes of building materials and spatial equipment, fire safety measures, etc.) where the fire broke out and the precautions to be taken against fire also vary according to these features as well as the user profile. However, it was observed that there are many differences among the rules determined, especially among many rules regarding the dimensions of the escape stairs, and even in the applications of external escape stairs and spiral staircases. Among these rules, it is seen that there are rules that prolong the escape period, make it difficult or prevent the use of the escape staircase. It is not possible to base differences by country between rules on the probability of buildings being more durable or less likely to experience fire. For this reason, the rules on fire safety in buildings should be the same for all countries, and differences between countries should be eliminated, replaced with regulations based on technical and scientific data. While eliminating the difference between the rules, buildings should be grouped by taking into account the building risk class, building user profile (child, elderly, pregnant, physically disabled, etc.) and the number, and the rules in these groups should be customized and arranged separately. For example, the escape stair rules in the senior nursing home dormitory buildings and the escape ladder rules in the student dormitory buildings (tread dimensions, flight widths, etc.) should be different from each other.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to The e-book section. There is no conflict of interest.

References

Approved Document B. (2018). The Building Regulations 2010. In Building Regulations in Brief (Vol. 2). England. doi: 10.4324/9781315269153-2

BBR. (2016). *Boverket´s building regulations – mandatory provisions and general recommendations*. *1*(165), 1–165.

BCA. (2015). *National Construction Code Series*. Australia: The National Construction Code (NCC) 2015. Retrieved from https://www.builderassist.com.au/wp-content/uploads/2016/02/NCC2015-BCA-Volume-One.pdf

BS 5395-1:2010. (2010). *BSI Standards Publication* (Second). BSI.

BS 9999:2017. (2017). BSI Standards Publication. In BSI Standards Publication (Issue 1).

BYKHY. (2021). *Binaların Yangından Korunması Hakkında Yönetmelik* (2nd Edition). İstanbul: Türkiye Yangından Korunma Yönetmeliği.

ICC. (2021). Exceptions : Exceptions : In ICC IFC-2021: 2021 International Fire Code. International Code Council (ICC).

Kuligowski, E. D., Peacock, R. D. & Hoskins, B. L. (2010). A Review of Building Evacuation Models; 2nd Edition. *NIST Technical Note 1680*, 36.

NFPA. (2019). *NFPA 101 Life Safety Code*. Quincy, Massachusetts: National Fire Protection Association.

ONTARIO REGULATION. (nd). *ONTARIO REGULATION 213/07 FIRE CODE*.

Peacock, R. D., Hoskins, B. L. & Kuligowski, E. D. (2012). Overall and local movement speeds during fire drill evacuations in buildings up to 31 stories. *Safety Science*, *50*(8), 1655–1664. doi: 10.1016/j.ssci.2012.01.003

SNIP 21-01-97. (1998). *Kositskiy central institute of standard design and urban development, CJSC* (Vol. 7, Issue 495).

Tubbs, J. S. & Meacham, B. J. (nd). *Egress Design Solution A Guide to*

Evacuation and Crowd Management Planning. ARUP, John Wiley & Sons.

Erkan AVLAR

E-mail: eavlar@yildiz.edu.tr

Educational Status: Doctorate

License: Yıldız Technical University, Faculty of Architecture, Department of Architecture

Doctorate: Completed

Professional Experience: Received his B.Arch and MSc. in Archtect from Yıldız Technical University, Faculty of Architecture (1981-1988). Earned his PhD. degree in architecture from Institute of Science of Yıldız Technical University (1996). Currently works as an Associate Professor at Yıldız Technical University. Major research interests water conservation and wooden structures. eavlar@yildiz.edu.tr Department of Architecture, Faculty of Architecture Yıldız Technical University, İstanbul, Türkiye.

H. Sueda YILDIRIM

E-mail: hsueda@yildiz.edu.tr

Educational Status: Postgraduate / **Evaluation Of Escape Stairs In Terms Of Fire Safety** / Yıldız Technical University, Faculty of Architecture, Department of Architecture

License: Karabuk University, Faculty of Architecture, Department of Architecture, Türkiye

Doctorate: Continues

Professional Experience: She started her architectural education at Karabuk University in 2009 and graduated in 2014. She started her graduate education at Yıldız Technical University Faculty of Architecture Divisions of Building Science Program and completed her graduate study titled " **Evaluation Of Escape Stairs In Terms Of Fire Safety** " in 2018. She started to work as a research assistant at Cumhuriyet University, Faculty of Architecture, Department of Architecture between 2014-2016. Since 2016, she has been working as a research assistant at Yıldız Technical University, Faculty of Architecture, Department of Architecture, Divisions of Building Science Program.

"Material" as a Leading Tool in Architectural Design

Assist. Prof. Dr. Ürün BİÇER [1]

[1]İstanbul Beykent University, Faculty of Engineering-Architecture, Department of Interior Architecture, İstanbul/Türkiye.
ORCID: 0000-0002-2436-9844
E-mail: urunbicer@beykent.edu.tr

Assist. Prof. Dr. Serkan Yaşar ERDİNÇ [2]

[2]İstanbul Beykent University, Faculty of Engineering-Architecture, Department of Architecture, İstanbul/Türkiye.
ORCID: 0000-0002-0970-3453
E-mail: yasarerdinc@beykent.edu.tr

Citation: Biçer, Ü. & Erdinç, S.Y. (2023). "Material" as a Leading Tool in Architectural Design. In Ü.T. Arpacıoğlu & S. Akten, (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment,* (374-408). ISBN: 978-625-367-287-4. Ankara: Iksad Publications

1. Introduction

In the realm of architectural design, the selection and application of materials play a pivotal role in shaping the built environment. From ancient civilizations to modern-day construction practices, materials have been instrumental in defining the visual, functional, and experiential qualities of architectural spaces. As Arpacıoğlu states (2010), when talking with designer forms, in a sense, the material is the words he chooses.

Kurt Dietrich defined architectural design as “the method of organizing materials and forms in a specific way to satisfy a definite purpose”. The material is one of the elements used in the process of architectural design as specific part of design solution (Yahya & Samad, 2014). The material gains strength only when a builder thinks and uses it. As soon as what is in nature turns into “what should be used”, questions arise about how and why: there is a construction that needs to be realized. The material is one of the answers to the first question asked to start the “work” (Arpacıooğlu & Kuruç, 2010).

While materials have always held a prominent position in the architectural discourse, recent advancements in material science, fabrication techniques, and digital modeling have given rise to new possibilities and challenges. By understanding the opportunities and constraints presented by materials, architects can push the boundaries of design and create transformative spatial experiences.

In this context, the study seeks to explore the evolving role of materiality in contemporary architectural design, particularly as a leading tool for creativity and innovation. In the study, various case studies and design methodologies that demonstrate the use of materials as a leading tool in architectural practice will be examined. By highlighting successful projects and innovative approaches, it is aimed to inspire architects, designers and researchers to rethink the role of materials in the creative process and embrace their transformative potential. Furthermore, the implications of material-driven design on sustainability, human experience, and the future of architecture will be discussed.

Through this exploration, it is intended to contribute to the ongoing discourse on materiality in architecture and inspire a shift towards holistic design practices that prioritize the seamless integration of form, function, and material expression. By recognizing the instrumental role of materials, architects can unleash their creativity and shape a built environment that is not only visually captivating but also enriching for its inhabitants.

2. Exploring the Role of “Material” in Architectural Design

The selection of correct materials and their effective use play a crucial role in shaping architectural design. Materials have a profound impact on the aesthetics, functionality, sustainability and experience of a building.

Materials affect architectural design, philosophical base of architectural concepts, architectural styles and forms with its inherent nature, its evolution and behavior in nature, its existential metabolism, its form, its surface texture, its inner structure, structural properties, its fluidity and its ability of self-organisation in addition to its performance (Gezer, 2012).

Building materials help to; establish a relationship between visual quality and structural stability; select the appropriate technique of construction; provide character and visual appeal to the structure; decipher the time and era of construction of a building; trace the evolution of the art of construction; mix aesthetic elements with practicality; highlight the theme and concept of design of the building project; determine the appropriate site for a project based on availability of material and suitability to the design; determine the budget of building projects; establish a relationship between quantity and quality (Mishra & Das, 2014).

Furthermore, the selection of materials considering the performance and life cycle plays a crucial role in ensuring the durability and longevity of a building. In recent years, rapid urbanization and developments in the building industry have brought about a wide variety of building materials. The materials obtained naturally in the past and used in construction without much processing have become multifunctional, but of poor quality, with the increase in the performance criteria expected from the material today. This situation has brought with it the issue of mentioning the relationship with the environment in addition to the physical, chemical, mechanical, technological, economic, and availability properties of the material during the selection (Kokulu & Özgünler, 2023). Architects can choose materials that will withstand the test of time by carefully considering factors such as sustainability, structural integrity, weather resistance and maintenance requirements. This is important in areas prone to extreme weather conditions or seismic activity. Additionally, the use of sustainable and eco-friendly materials is becoming increasingly important in the field of architecture. By selecting correct materials, architects can contribute to the sustainability of the built environment.

Throughout history, architects have utilized materials not only as functional building components but also as expressive elements. From the grandeur of stone in classical architecture to the transparency of glass in modernist structures, materials have been chosen for their inherent properties and their ability to evoke emotions. However, the traditional approach to material selection often relied on established conventions and limited the creative potential of architects.

With the advent of digital technologies and a growing emphasis on parametric design, the role of materials in architectural practice has undergone significant transformations. The technological developments we live in today carry the "material" and the perception of the material formed for centuries to different points. Building material, which is perhaps more diverse and evolving than ever before, is being reshaped, tried, noticed and discovered within the design (Arpacıoğlu, 2010). Before the 19th century, it is seen that the materials used in architectural practice were related to the form and function of the building, and traditional building materials such as stone and wood were used with the advantages and disadvantages. The development of materials science along with technology has allowed architects to change and transform material properties suitable for their designs. Thus, the material gained a new perceptual dimension (Yıldız & Seçkin, 2019).

Korkmaz (2023) also states that the rapid development in material technology with the industrial revolution has also had serious effects on building design. These changes are in different ways such as form changes in pre-industrial revolution structures and post-industrial revolution structures, spans passed, increase in floor heights, variation of coating material textures and colors and therefore change of perception created in the user, change of urban texture on a large scale, façades that work like a living organism by responding to different needs become designable, mechanical and visual moving surfaces can be applied in the structure has found a place (Korkmaz, 2023).

By means of the emergence of digital tools, architects are now able to explore materials in more dynamic and experimental ways. Parametric design allows for the manipulation of material properties, such as texture, translucency, and flexibility, enabling the creation of intricate and responsive architectural forms. Furthermore, the integration of sustainable materials and technologies has become a pressing concern in the face of environmental challenges, prompting architects to seek innovative solutions that not only enhance aesthetics but also promote sustainability and resilience.

The development of the use of materials as a leading tool in architectural design has evolved over time, driven by technological advancements, design philosophies, and sustainability imperatives. By embracing materials as expressive elements, exploring sustainable material innovations, adopting material-driven design methodologies, and studying exemplary projects, architects can push the boundaries of creativity and create architectural spaces that are visually captivating, functionally efficient, and environmentally responsible.

In addition, structures are used to reinforce the visual effects on facades since past. Wooden and stone materials were used intensely in primary building shells and facades. Besides technological developments accelerated by industrial revolution, increasing material variation in building sector also played a role in appearance of new structural systems. The popular usage of steel and glass has changed the approach for facade concepts in this period. Furthermore, architecture has gained a new dimension with modular systems built by prefabricated components and constructions as concrete systems, shell system, steel system and tense systems. Thus, architectural manner has appeared related to usage of modern technology and attractive expression of structure (Atik, Arabulan, Benian & Kartal, 2012).

2.1. Evolution of Materiality in Architectural Design

The use of materials as a leading tool in architectural design has evolved over centuries, reflecting the advancements in technology, cultural shifts, and changing design philosophies. Historically, materials were selected based on their availability, durability, and aesthetic appeal. Ancient civilizations such as the Egyptians, Greeks, and Romans utilized materials like stone and timber to create monumental structures that stood the test of time. The choice of materials was often dictated by local resources and construction techniques.

With the advent of the Industrial Revolution, new materials such as iron, steel, and glass revolutionized architectural possibilities. The use of structural steel allowed for the creation of soaring skyscrapers and grand architectural expressions. The transparency and versatility of glass opened up new opportunities for light-filled spaces and seamless connections between indoors and outdoors. Modernist architects like Le Corbusier and Ludwig Mies van der Rohe emphasized the honesty of materials, celebrating their inherent qualities and rejecting ornamentation.

2.2. Material as an Expressive Element

Materials have always played a crucial role in the expressive language of architecture. Their inherent qualities, such as color, texture, and transparency can evoke emotions and create sensory experiences. Architects like Antoni Gaudí and Frank Lloyd Wright embraced materials as expressive elements, integrating seamlessly with form and function.

Today, advancements in digital design tools have enabled architects to manipulate material properties and create complex geometries. Parametric design, for example, allows architects to explore the behavior of materials in response to environmental factors and design constraints. By harnessing the potential of materials, architects can create immersive spaces that engage users on a sensory and emotional level.

2.3. Sustainable Material Innovations

In recent years, the need for sustainable design practices has prompted architects to explore new materials and construction techniques. The environmental impact of building materials, their embodied energy, and their contribution to air pollution and waste have become critical considerations. As a result, architects are increasingly turning to sustainable materials such as recycled materials, low-carbon concrete, and bio-based composites.

The integration of sustainable materials not only reduces the environmental footprint of architectural projects but also offers new aesthetic possibilities. For example, the use of reclaimed wood can add warmth and character to a space, while green roofs and living walls can improve air quality and enhance biodiversity. By embracing sustainable materials, architects can contribute to a more resilient and ecologically conscious built environment.

2.4. Material-Driven Design Methodologies

Material-driven design methodologies have emerged as a way to harness the full potential of materials in architectural practice. These methodologies focus on understanding material behavior, exploring material properties, and leveraging material capabilities to inform the design process. Architects are utilizing computational tools and simulations to study how materials respond to various forces and environmental conditions. By integrating material performance data into the design process, architects can optimize structural efficiency, improve energy performance, and create more resilient buildings

2.5. Case Studies and Exemplary Projects

Numerous case studies and exemplary projects demonstrate the successful use of materials as a leading tool in architectural design. These projects exemplify the integration of materials in innovative ways, showcasing how the choice of materials can shape form, function and user experience. For instance, the use of lightweight tensile membranes in iconic structures like the Beijing National Stadium (Bird's Nest) (Figure 1) demonstrates how materials can create visually striking and structurally efficient spaces.

Figure 1. Beijing National Stadium (Bird's Nest) (URL, 1: https://www.re-thinkingthefuture.com/architectural-facts/a2572-10-things-about-you-did-not-know-about-birds-nest-china/).

Through the analysis of these case studies, architects can gain insights into the design principles, material selection processes, and construction techniques that contribute to successful material-driven design.

3. How Use of “Correct Material” Shapes Architectural Design

The use of "correct" materials plays a crucial role in shaping architectural design in terms of aesthetics, functionality and experience of a building.

The use of materials in architectural design encompasses aesthetics, structural integrity, functionality, sustainability, user experience, and contextual relevance. Architects carefully consider these factors to create buildings that are visually appealing, structurally sound, functional, sustainable, and meaningful to their occupants and surroundings.

3.1. Ways of Use of “Material” in Architectural Design

Aesthetic Expression and Design Intent: Materials contribute to the visual appearance and character of a building. Materials significantly plays an important role for the visual appeal and design intent of a structure. Different materials possess unique textures, colors, patterns and finishes, which architects can utilize to achieve their desired aesthetic goals. For example, the use of glass can create a sleek and modern appearance, while exposed brick can evoke a sense of historic charm. Different materials have unique textures, colors and finishes that can enhance the architectural concept and create a desired aesthetic experience. The selection of materials should align with the design vision, whether it aims for a modern, historic, minimalist or sustainable appearance.

Cultural and Contextual Relevance: Materials can reflect the historical and contextual aspects of a building's location. Architects often consider local materials and construction techniques to create designs that resonate with the surrounding environment and traditions. This approach fosters a sense of identity, connection and continuity with the local culture.

User Experience: Materials influence the sensory experience of occupants within a building. Different materials have different tactile qualities and can evoke particular emotional responses. For example, using natural materials like stone can create a warm and inviting atmosphere, while glass and steel can provide a contemporary feel. Many civilizations have used natural stones, which have been one of the indispensable art branches and building elements of human beings for centuries with their elegance, strength and potential richness, in sculptures, monuments and magnificent structures that have survived to and shed light on the ages (Dal, 2011).

Materials have attributes related to the five senses but the focus for building materials to touch and sight only. The tactile attributes and visual attributes of materials give the aesthetic characteristics of the building. The tactile attributes (hard-soft, cold-warm) and the visual attributes (opaque-transparent, color, reflectivity) (Yahya & Samad, 2014) presents different user experience while they are providing aesthetic expression.

While introducing itself with its material texture, color, light, sound and smell, it defines the surfaces with the place it acquires in our consciousness and the psychological bond it establishes and makes architecture be felt. These messages, which give the identity of tactile and visually perceived surfaces and form, are the most competent design criteria used in architecture. These expressions of surfaces affect the design with various ways of reading psychologically, intuitively and instinctively as well as physically felt at the level of perception (Gezer, 2012).

Functionality, Performance and Innovation: Materials influence the functionality and performance of a building. For instance, glass is often used in facades to provide transparency and natural light, while concrete is commonly employed for its strength and fire resistance. Besides, the choice of insulation materials affects energy efficiency and thermal comfort. Sound-absorbing materials can enhance acoustics in spaces such as concert halls or recording studios. Waterproof and weather-resistant materials are essential for protecting the building from moisture and environmental damage. By selecting appropriate materials, architects can ensure that buildings meet functional requirements such as insulation, acoustics, fire safety, and weather resistance.

There is a relationship, composition, interactive and complex connection between architectural and construction materials, structures and systems. This relationship has become the main driver of architectural innovative design, new smart materials that are starting to emerge in the architectural field highlight this design approach and offer us new possibilities and potentials. Intelligent materials, which are considered to be applied in the field of architecture, do not primarily appear as a texture or surface, but emerge and experience in all architectural depth. As a result, architects should consider the material as a functional element with behavior that can be adaptable and efficient to the environment at every stage of the design process (Topal & Arpacıoğlu, 2020).

Structural Integrity: The choice of materials is essential to ensure the structural integrity of a building. Materials determine the structural stability and strength of a building. Different materials have varying load-bearing capacities, durability and resistance to environmental factors. Architects must consider factors such as the building's height, purpose and location to select materials that can withstand the imposed loads and ensure long-term stability and must select materials that can withstand various loads, forces and environmental conditions. For instance, steel and concrete are commonly used for their high strength and durability, enabling the construction of tall and complex structures.

Durability and Maintenance: The durability of materials affects the longevity and maintenance requirements of a building. Some materials, like steel and concrete, are known for their strength and durability, while others may deteriorate over time or require frequent maintenance. Architects must consider the lifecycle of materials and select those that minimize maintenance costs and maximize the building's lifespan.

Sustainability and Environmental Impact: The selection of materials has a significant impact on the sustainability and the environmental impact of a building. Architects are increasingly considering eco-friendly materials that minimize environmental impact and should prioritize materials that contribute to resource conservation, waste reduction, and improved indoor air quality. This includes using renewable resources, recycled materials, and low-emission products. Sustainable materials can improve energy efficiency, and enhance indoor air quality. Sustainable materials, such as recycled content, renewable resources and low-emission products, can reduce the carbon footprint and promote energy efficiency.

3.2. Exemplifying the Importance of Material Selection

Some buildings, among many others, demonstrate how material selection and effective utilization are vital to achieving architectural excellence, structural integrity, functionality and durability in the built environment.

These examples highlight how the use of specific materials in architectural design can contribute to a building's visual impact, integration with the surroundings, symbolism, functionality and sustainability.

The Sydney Opera House, Australia (Jorn Utzon): The Sydney Opera House is an architectural icon notable for its sail-like shells (Figure 2). This iconic structure showcases the effective use of reinforced concrete and a unique precast ribbed roof system.

The material selection and application allowed for the realization of its distinctive sail-like appearance while ensuring structural integrity. The shells are made of precast concrete panels covered with ceramic tiles. The use of these materials allowed for the creation of unique forms while providing durability and weather resistance. The ceramic tiles reflect sunlight, giving the building a luminous appearance that changes throughout the day.

Figure 2. Sidney Opera House (URL, 2: https://www.arkitektuel.com/sydney-opera-binasi/).

Villa Savoye, France (Le Corbusier): Villa Savoye is a seminal work of the International Style. Reinforced concrete was used extensively in its construction, allowing for a free-flowing, column-free interior space and large glazed windows (Figure 3). The use of concrete as both a structural and finishing material gave the building a clean, minimalist aesthetic and enabled the creation of open, light-filled spaces.

Figure 3. Villa Savoye (URL, 3: https://www.arkitektuel.com/villa-savoye-2/).

Fallingwater, Pennsylvania, USA (Frank Lloyd Wright): Fallingwater is a masterpiece of organic architecture (Figure 4). The extensive use of locally quarried stone and reinforced concrete integrates the house harmoniously with its natural surroundings. The stone walls and cantilevered concrete terraces blend seamlessly with the rugged landscape, creating a sense of unity between the built environment and nature.

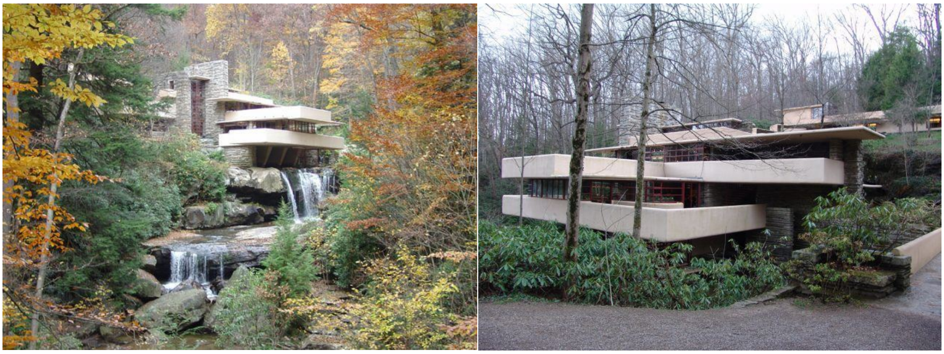


Figure 4. Fallingwater (URL, 4: https://www.arkitektuel.com/fallingwater-evi-selale-evi/).

The Bullitt Center, Seattle, USA (Miller Hull): Called the "greenest office building in the World", the building generates its own electricity and water. The Bullitt Center has been nicknamed a "Living Building" (Mozgovaya, 2019). This building is an example of sustainable design, emphasizing the use of environmentally friendly materials (Figure 5). It incorporates features such as FSC-certified wood, non-toxic finishes and energy-efficient systems, demonstrating the use of material choice in achieving sustainability goals.

Figure 5. Bullitt Center (URL, 5: https://www.wbdg.org/additional-resources/case-studies/bullitt-center).

Louvre Pyramid, France (I. M. Pei): The glass pyramid by I.M. Pei serves as the entrance to the Louvre Museum, showcasing the use of glass and metal, symbolizing a modern and transparent approach (Figure 6).

Figure 6. Loıvre Pyramid (URL, 6: https://www.arkitektuel.com/le-grand-louvre/).

Pompidou Centre, France (Renzo Piano and Richard Rogers): The architects employed an innovative approach by placing the building's functional systems, including steel structures, ductwork and pipes on the exterior facade, they created an iconic industrial aesthetic (Figure 7).


Figure 7. Pompidou Center (URL, 7: https://www.arkitektuel.com/centre-pompidou/).

Sagrada Familia, Spain (Antoni Gaudi): Antoni Gaudí's famous basilica incorporates a combination of stone, brick and reinforced concrete, showcasing intricate detailing and organic forms (Figure 8). The building is a significant example of biomimicry in architectural design.


Figure 8. Sagrada Familia (URL, 8: https://www.arkitektuel.com/la-sagrada-familia/).

4. Effect of "Material" on Creativity in Architectural Design

The use of correct materials effects the level of creativity in architectural design. Materials not only provide the structural framework but also contribute to the aesthetic and functional aspects of a building.

Expression of Concept: The choice of materials allows architects to express their design concept effectively. Different materials possess unique qualities, textures, colors and patterns that can convey specific meanings or evoke certain emotions. For instance, using glass and steel in a modernist design can express transparency and sleekness, while using natural stone and timber in a rustic design can evoke warmth and a connection to nature. By selecting materials that align with their design intent, architects can enhance the creative expression of their ideas.

Design Innovation: The availability of new materials and advancements in technology continually push the boundaries of architectural creativity. Innovations in materials such as carbon fiber, composite panels and sustainable materials like bamboo or recycled materials provide architects with new possibilities for experimentation and innovation. These materials often offer unique properties like lightweight, flexibility or energy efficiency, enabling architects to create designs that were previously unattainable. Architects who embrace these materials can demonstrate their creativity by pushing the limits of traditional architectural design.

Contextual Integration: The choice of materials should consider the building's context, including its surroundings, climate and cultural significance. Architects who carefully select materials that harmonize with the environment demonstrate a deep understanding of the context and showcase their creativity in integrating the building seamlessly into its surroundings. For example, architects may use locally-sourced materials or traditional construction techniques to create a sense of cultural identity and regional character.

5. The "Monuments" of the Brilliant Use of Material

The buildings that exemplify creative selection and the use of materials is important of architecture. These buildings showcase the innovative and thoughtful approach taken by architects to create structures that are not only aesthetically pleasing but also functionally efficient.

One of the main reasons why such buildings are important is their ability to inspire and push the boundaries of traditional architectural norms. By employing creative selection, architects can explore unconventional design solutions, challenge preconceived notions, and create buildings that stand out as unique and innovative. This selection can involve various aspects, such as spatial organization, form, structure, and materiality.

The use of materials is one of the most critical aspects in the creation of exceptional buildings. Materials can greatly influence the aesthetics, durability and sustainability of a structure. Architects who prioritize the use of materials in a creative and thoughtful manner can create buildings that are visually striking, environmentally friendly and technologically advanced. In terms of aesthetics, the creative selection of materials allows architects to experiment with different textures, colors and finishes, giving buildings a distinct character and visual appeal.

The buildings that demonstrate creative selection and the use of materials are important because they inspire innovation, challenge architectural norms, and create visually striking and sustainable structures. These buildings serve as examples for future architects and designers, pushing the boundaries of what is possible in the field of architecture and contributing to the evolution of the built environment.

5.1. The Water Cube, Beijing, China by PTW Architects

The Water Cube, officially known as the National Aquatics Center, is an iconic architectural structure located in Beijing, China. Designed by the architectural firm PTW Architects in collaboration with structural engineering firm Arup, the Water Cube was built for the 2008 Beijing Olympics as the venue for swimming and diving events (Figure 9 & 10). Its unique design and innovative use of materials have made it a landmark.

Figure 9. The Water Cube, Beijing (URL, 9: https://www.westchinatour.com/beijing/attraction/water-cube.html).

The Water Cube in Beijing exemplifies the innovative use of materials in architectural design. The utilization of ETFE as the primary building material, with its lightweight, transparent and energy-efficient properties, contributes to the building's unique aesthetic expression, structural efficiency and sustainability. The material's ability to transmit natural light, its dynamic visual qualities and its role in creating large open spaces enhance the user experience and make the Water Cube a landmark in contemporary architectural design.

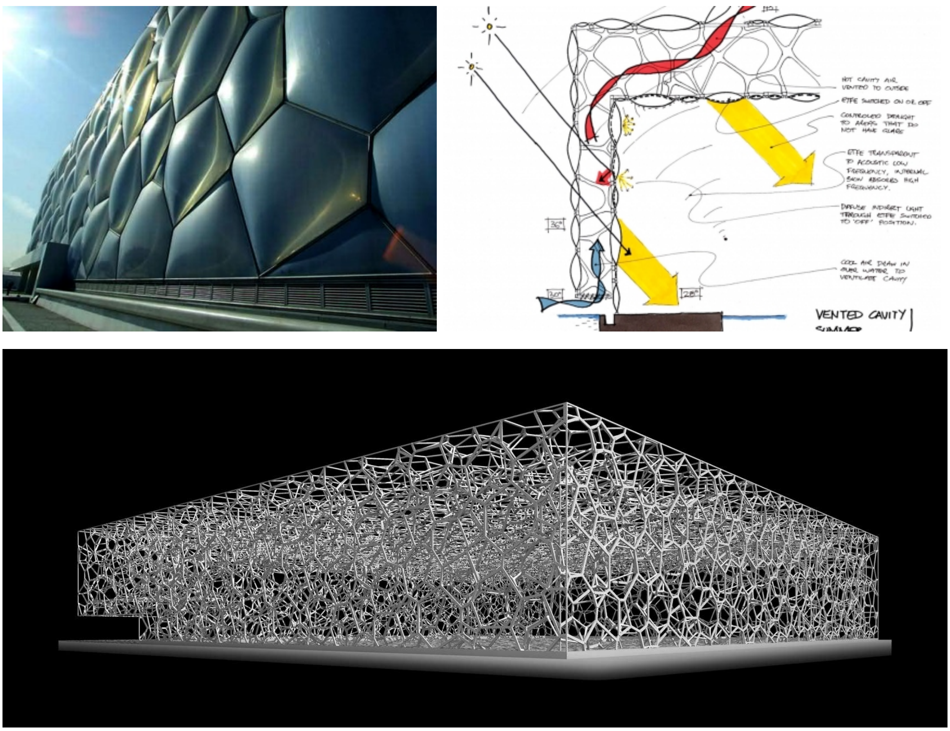


Figure 10. The Water Cube, Beijing (URL, 10: http://www.bubblemania.fr/en/architecture-bulle-cube-deau-2003-2008-pekin-chine/).

Materiality and Aesthetic Expression: The Water Cube's design concept draws inspiration from the natural formation of soap bubbles, which are characterized by their lightweight, translucent and iridescent qualities.

The architects sought to capture this ephemeral and organic quality of bubbles in the design of the building. To achieve this, they employed a material called ETFE (ethylene tetrafluoroethylene) for the building envelope.

ETFE is a lightweight and highly transparent polymer that allows for the transmission of natural light while providing thermal insulation. The use of ETFE in the Water Cube creates a visually striking effect, as the building appears to be enveloped in a shimmering, translucent "bubble-like" structure. The material's inherent transparency and reflectivity give the building a dynamic appearance that changes with the lighting conditions, making it a captivating architectural landmark.

Structural Efficiency and Material Performance: The Water Cube's structural system is another significant aspect of its design. The building features a steel frame structure with a series of interconnected steel members that form a three-dimensional grid. This grid-like structure provides the required structural stability while minimizing the amount of material used, resulting in an efficient and lightweight design.

The ETFE cushions, which form the building's envelope, are supported by the steel grid structure. These cushions are inflated with air to create an insulating layer, improving the building's energy efficiency. The ETFE cushions have excellent tensile strength and are highly resistant to UV radiation, making them durable and suitable for long-term use.

Environmental Sustainability: The Water Cube's design incorporates sustainable strategies in its material selection and energy performance. The use of ETFE as the primary building material offers several environmental benefits. ETFE is recyclable and has a low carbon footprint compared to traditional building materials like glass. Its lightweight nature reduces the energy required for transportation and installation.

Additionally, the ETFE cushions help regulate the internal temperature of the building. The air-filled cushions act as insulators, reducing the need for excessive heating or cooling. This passive design feature contributes to energy savings and reduces the building's overall environmental impact.

User Experience and Spatial Qualities: The use of ETFE in the Water Cube contributes to a unique user experience within the building. The translucent nature of the material allows for the penetration of natural light, creating a visually immersive and vibrant interior environment. The interplay of light and shadow, combined with the dynamic reflections on the ETFE surfaces, creates a sense of ethereal beauty and enhances the overall ambiance of the space.

Furthermore, the use of ETFE cushions enables the creation of large column-free spaces within the Water Cube. This design approach provides unobstructed views for spectators and enhances the spatial quality of the interior, offering an immersive experience for athletes and visitors alike.

5.2. Guggenheim Museum, Bilbao, Spain by Frank Gehry

The Guggenheim Museum Bilbao, located in Bilbao, Spain, is an architectural masterpiece designed by acclaimed architect Frank Gehry (Figure 11 & 12). Completed in 1997, the museum has become an iconic symbol of contemporary architecture, renowned for its innovative design and the transformative use of materials.

Figure 11. Guggenheim Museum, Bilbao (URL, 11: https://www.dezeen.com/2022/05/18/frank-gehry-guggenheim-museum-bilbao-deconstructivism/).

The Guggenheim Museum Bilbao stands as a testament to the transformative power of materials in architectural design. The innovative use of titanium, in combination with other materials such as limestone and glass, not only creates a visually striking aesthetic but also contributes to the museum's structural integrity, functional adaptability and cultural impact. The museum's design and materiality have forever changed the architectural landscape, showcasing the potential of materials to redefine the boundaries of architectural expression.

Figure 12. Guggenheim Museum, Bilbao (URL, 11: https://www.dezeen.com/2022/05/18/frank-gehry-guggenheim-museum-bilbao-deconstructivism/)

Materiality and Aesthetic Expression: The Guggenheim Museum Bilbao is characterized by its striking sculptural form, which is achieved through the creative use of materials. The most prominent material employed in the building's exterior is titanium, which covers the curvilinear surfaces of the structure. The use of titanium contributes to the museum's distinctive, shimmering appearance and its ability to reflect and interact with the surrounding environment.

Titanium was chosen for its lightweight properties and durability allowing for the creation of complex organic shapes. The material's reflective surface responds to changes in natural light, creating a dynamic visual experience for visitors. The use of titanium as the primary cladding material showcases Gehry's commitment to pushing the boundaries of architectural expression through innovative material choices.

Structural Innovation and Material Performance: Beyond its aesthetic qualities, the Guggenheim Bilbao demonstrates the innovative use of materials in its structural design. The building's complex form required a structural system capable of supporting its unconventional shapes. The architects utilized a combination of steel and concrete to achieve structural stability while allowing for the desired curvilinear geometry.

The steel frame structure forms the building's primary support system, providing strength and rigidity. Reinforced concrete was used for the interior spaces, allowing for flexibility in design and accommodating the museum's functional requirements. The integration of these materials allowed for the realization of Gehry's vision while ensuring structural integrity.

Functional Adaptability and Spatial Qualities: The Guggenheim Bilbao's design not only prioritizes visual impact but also addresses functional adaptability and spatial qualities. The interior spaces are characterized by their openness, fluidity and interconnectivity. The use of materials such as limestone and glass reinforces this sense of openness and transparency.

Limestone, a locally sourced material, is used in the interior flooring, walls and columns. Its warm and earthy tones provide a contrasting backdrop to the titanium-clad exterior and create a sense of visual harmony. Glass, another key material, is used extensively in the form of large, floor-to-ceiling windows, allowing natural light to flood the galleries and providing views of the surrounding landscape.

Urban Integration and Cultural Impact: The Guggenheim Bilbao's impact extends beyond its architectural design. The use of materials played a significant role in the building's integration into the urban fabric of Bilbao and its transformation into a cultural landmark. The reflective titanium surface interacts with the surrounding context, including the nearby Nervión River and the cityscape, creating a visual dialogue with its environment.

6. Conclusion and Suggestions

The exploration of material as a leading tool in architectural design has revealed its transformative potential in shaping the built environment and pushing the boundaries of creativity. Throughout this study, how architects have harnessed the power of materials to create innovative, sustainable, and experientially rich architectural spaces has been witnessed. By embracing new technologies, materials and methodologies, architects can redefine the relationship between form, function and material expression.

One of the key findings from this study is the importance of a holistic design approach that considers materials as integral elements in the creative process. By placing materials at the forefront of design thinking, architects can unlock new possibilities for spatial configurations, structural systems and aesthetic expressions.

Furthermore, the emphasis on sustainability and resilience has highlighted the critical role of materials in addressing the environmental challenges faced by the architectural industry. The adoption of sustainable materials, and intelligent technologies can contribute to the creation of environmentally responsible and energy-efficient architectural solutions.

Additionally, the human experience within architectural spaces has been significantly enhanced through the thoughtful integration of materials. The tactile qualities, visual textures, and acoustic properties of materials can evoke emotional responses and create immersive environments that engage the senses. By designing spaces that prioritize human well-being and comfort, architects can foster a sense of connection, harmony, and delight in the built environment. Towards the future of architectural design, the role of material as a leading tool will continue to evolve and shape our built world. Advancements in material science, digital fabrication, and sustainable technologies will drive further innovation in architectural practice. Architects must remain adaptable, curious, and open to interdisciplinary collaborations to fully harness the potential of materials in their design explorations.

In conclusion, the use of material as a leading tool in architectural design has demonstrated its immense capacity to inspire, transform, and create meaningful architectural experiences. By embracing the intrinsic qualities of materials, harnessing the power of digital technologies, and prioritizing sustainable practices, architects can shape a built environment that is not only aesthetically captivating but also responsive, sustainable, and enriching for its inhabitants. With continued exploration, experimentation, and collaboration, architects can unlock the full potential of materials and shape a future where architecture becomes a harmonious synthesis of form, function, and material expression.

Thanks and Information Note

The e-book section complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

1st Author % 50, 2nd Author %50 contributed. There is no conflict of interest.

References

Arpacıoğlu, Ü. (2010). Malzemenin Tasarımdaki İşlevsel Algısı. *TMMOB Mimarlar Odası İstanbul Büyükkent Şubesi Mimarlıkta Malzeme Dergisi,* 16, 16-17, İstanbul.

Arpacıoğlu, Ü. & Kuruç, A. (2010). Zamansız Malzemelerin Zamanda Yolculuğu. *TMMOB Mimarlar Odası İstanbul Büyükkent Şubesi Mimarlıkta Malzeme Dergisi,* 15, 47-51, İstanbul.

Atik, D., Arabulan, S., Benian, E. & Kartal, S. (2012). Effect of Structure on Facade. *International Conference on Civil Engineering Design and Construction* (s. 34-40). Varna, Bulgaria: Varna Free University "Chernorizets Hrabar". Access Address (10.08.2023): https://www.researchgate.net/publication/312497888_EFFECT_OF_STRUCTURE_ON_FACADE

Dal, M. (2011). Mimarinin En Soylu Yapı Malzemesi Olarak Doğal Taş. *TMMOB Mimarlar Odası İstanbul Büyükkent Şubesi Mimarlıkta Malzeme Dergisi,* 19 (3), 90-95, İstanbul.

Gezer, H. (2012). Malzemenin Gizil Güçlerinin Mimariye Katkısı. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi,* 10 (20), 97-118. Access Address (07.06.2023): https://dergipark.org.tr/tr/download/article-file/199586

Kokulu, N. & Özgünler, S. A. (2023). Investigation of Methods and Studies for Determining the Material Selection Criteria with Low Environmental Impact in Hotel Buildings. *Journal of Architectural Sciences and Applications,* 8 (1), 25-37. e-ISSN: 2548-0170. Access Address (15.08.2023): https://dergipark.org.tr/tr/pub/mbud/issue/77339/1185227

Korkmaz, E. (2023). The Effect of Material Technology. M. Dal & L. Karataş (Ed.). *Architectural Sciences and Theory, Practice and New Approaches I.* (s. 229-262). ISBN: 978-625-367-072-6. Ankara: IKSAD Publications. Access address (10.08.2023):

https://iksadyayinevi.com/wp-content/uploads/2023/05/Architectural-Sciences-and-Theory-Practice-and-New-Approaches-I.pdf

Mishra, P. & Das, A. (2014). Building Material: Significance and Impact on Architecture. *Architecture-Time, Space & People*, September 2014, 32-37. Access Address (06.06.2023): https://www.coa.gov.in/show_img.php?fid=181

Mozgovaya, N. (2019). Seattle's Bullitt Center: A Green Building Inspiring Visitors. Access address (06.06.2023): https://www.voanews.com/a/seattles-bullitt-center-a-green-building-inspiring-visitors/4759826.html

Topal, A. S. & Arpacıoğlu, Ü. (2020). Mimarlıkta Akıllı Malzeme. *Journal of Architectural Sciences and Applications*, 5 (2), 241-254. e-ISSN: 2548-0170. Access Address (30.07.2023): https://dergipark.org.tr/tr/download/article-file/1254166

Yahya, H. & Samad, M. H. A. (2014). The Role of Building Materials in Architectural Design. *Applied Mechanics and Materials*, 679, 6-13. DOI: 10.4028/www.scientific.net/AMM.679.6. Access Address (14.07.2023): https://www.researchgate.net/publication/285275391_The_Role_of_Building_Materials_in_Architectural_Design

Yıldız, B. & Seçkin, N. P. (2019). Mimaride Malzemelerin Algısal Farklılıklarının Değerlendirilmesi. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* 1 (2), 6-14. e-ISSN: 2667-792X. Access Address (15.08.2023): https://openaccess.izu.edu.tr/xmlui/handle/20.500.12436/1172

URL 1: https://www.re-thinkingthefuture.com/architectural-facts/a2572-10-things-about-you-did-not-know-about-birds-nest-china/

URL 2: https://www.arkitektuel.com/sydney-opera-binasi/

URL 3: https://www.arkitektuel.com/villa-savoye-2/

URL 4: https://www.arkitektuel.com/fallingwater-evi-selale-evi/

URL 5: https://www.wbdg.org/additional-resources/case-studies/bullitt-center

URL 6: https://www.arkitektuel.com/le-grand-louvre/

URL 7: https://www.arkitektuel.com/centre-pompidou/

URL 8: https://www.arkitektuel.com/la-sagrada-familia/

URL 9: https://www.westchinatour.com/beijing/attraction/water-cube.html

URL 10: http://www.bubblemania.fr/en/architecture-bulle-cube-deau-2003-2008-pekin-chine/

URL 11: https://www.dezeen.com/2022/05/18/frank-gehry-guggenheim-museum-bilbao-deconstructivism/

Ürün BİÇER
E-mail: urunbicer@beykent.edu.tr
Educational Status
License: Yıldız Technical University, 2001
Degree: Yıldız Technical University, 2005
Doctorate: Yıldız Technical University, 2011
Professional Experience: İstanbul Beykent University, Vice Dean of the Faculty of Engineering and Architecture, Assist. Prof. Dr., Department of Interior Architecture

Serkan Yaşar ERDİNÇ
E-mail: yasarerdinc@beykent.edu.tr
Educational Status
License: Yıldız Technical University, 2005
Degree: Yıldız Technical University, 2009
Doctorate: İstanbul Beykent University, 2017
Professional Experience: İstanbul Beykent University, Assist. Prof. Dr. Faculty of Engineering and Architecture, Head of Department of Architecture

Ready – Made Plasters with Synthetic Binders

Dr. A. Cüneyd DİRİ[1]

[1]Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, 34427, Istanbul/Türkiye.
ORCID: 0000-0001-8122-9568
E-mail: acdiri@gmail.com

Citation: Diri, A.C. (2023). Ready – Made Plasters with Synthetic Binders. In Ü.T. Arpacıoğlu, & S. Akten (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (409-453). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

The primary purpose of covering the facades of buildings is to protect the building envelope from the impacts of the external environment while also enhancing the aesthetic appeal of the façade. Moreover, external coatings can perform additional functions such as waterproofing, thermal insulation, passive energy gain, and sound absorption. The differentiation of coatings applied to the exterior walls of buildings is based on various criteria, such as environmental factors, the type and function of the building, the presence of symbolic elements, the dimensions of the facade, and design preferences, such as system and material selection, as well as the relationship with the wall and the method of application. We encounter a wide variety of coating types and their sub–types when classification is established in accordance with these differentiations. Today's coating materials are quite diverse, and there is frequently more than one solution to a specific problem. This study focuses on synthetic–based exterior plasters, which are a type of liquid coating applied directly to the exterior wall.

The term "liquid coating" encompasses materials that are dissolved in a solvent and, upon application as a layer onto a surface, exhibit adhesion to the substrate and subsequently harden into a continuous film. The coating types covered by this definition span a broad spectrum and are applied in various forms and thicknesses depending on the surface to be coated. In the case of coating of metals, it is common practice to use one or two layers with a thickness measured in micrometers. However, when it comes to coating the walls of metals, it is commonly preferred to apply a greater number of layers, typically ranging from three to four.The layers that make up the coating system, on the one hand, adhere to the substrate with sufficient adherence, on the other hand, they form a carrier, smooth surface for the other layers to come on. The main function of the outermost layer (finishing) is to protect the inner layers against all kinds of influences from the external environment. It should be noted that; a coating can fulfill this function as long as it provides and maintains sufficient adhesion with the substrate. In order to achieve this, it is necessary to choose the appropriate coating system according to the environmental conditions and the surface properties of the substrate, to pay attention to the surface preparation, to apply and maintain under conditions suitable for the material. (Hodgson, 2015).

Plasters made with inorganic binders, such as lime, gypsum, and cement, are generally referred to as mineral binder plasters. In addition to this, there is also the production of plasters that use synthetic resin–based organic binders and are colored with a variety of pigments. This particular type of plaster does not require the application of a paint or coating layer and is used as the outermost layer in the formation of the building envelope. Such plasters are known as synthetic–based, ready–made plasters. This study aims to provide a comprehensive explanation of the components, application areas, and general properties of synthetic–based plasters.

2. History and Properties of Synthetic Based Coatings

Plaster have been widely used as a prevalent form of wall–covering material throughout history. Studies show that the use of plaster in buildings may be traced back to the Chalcolithic Era. Prior to the introduction of cement, materials such as clay, calcium, and gypsum were used in the production of plaster, and additives such as straw and vegetable fiber were added to prevent cracking. Following the cement's entry into the building area, plasters made of cement were used, which added a fair amount of strength and impermeability. (Stoye & Freitag, 1998).

When we examine cave and rock drawings and old paints, it is understood that the utilization of organic binders, similar to inorganic binders, can be traced back to prehistoric times. Until the end of the 19th century, natural materials such as animal and vegetable oils and wood resins were used as binders in the production of organic–based coatings. Then synthetic resins such as nitrocellulose, phenolic resins, and alkyd resins started to be produced. (Stoye & Freitag, 1998).

It is estimated that the first pigments used in history were substances such as carbon, iron oxide and manganese oxide, and chalk obtained from burnt wood. Lake pigments developed by the Egyptians still represent an important group of pigments today. In the Middle Ages, varnishes made by dissolving suitable resins in warm linseed, hemp seed, or walnut oil served to protect most paintings, especially those on wood. Towards the end of the eighteenth century, with the increase in demand for all kinds of paints, paint and varnish workshops began to be established. Since the beginning of the 20th century, with the development of the coating industry, the application methods have also undergone great changes, and applications such as high–pressure spraying with compressed air or electrostatic charging have been started. (Lambourne & Strivens, 1999).

Today, plasters are produced and used with mineral–based binders such as gypsum, lime, and cement, as well as by reinforcing these binders with synthetic resins. Apart from these, there are also plasters in which only synthetic resins are used as binders. This third group of plaster, which is ready–mixed in metal or plastic containers, is called "synthetic–based ready–made plaster".

Considering that synthetic–based ready–made plasters emerged around the world in the 1950s and started to be produced in Turkey in the early 1970s, they are among the new materials for our country. Several businesses adopted the production of the aforementioned product in the years that followed. By the 1970s and 1980s, it had become one of the most popular external building finishes, alongside paint and mosaic coatings.

The thicknesses of the synthetic–based ready–made plasters vary from 1 mm to 4 mm, depending on the application surface and method. As this thickness is often insufficient to cover the imperfections of the surface, a proper application surface is required, and is usually done after a mineral–based plaster, (with thickness between 2 cm and 3 cm) is applied on the outer wall. There are also applications made directly on wall surfaces made with exposed concrete or reinforced concrete, aerated concrete or other blocks.

In all these applications, it should be noted that the liquid absorbency of the surface directly affects the adhesion of the plaster to the substrate. The surface on which the ready–made plaster will be applied must be free from foreign materials such as paint, oil, dirt and loose parts that cannot provide adherence. The surface must be moistened before application. The degree of humidification is determined by the surface absorbency. (Packham, 2005).

Furthermore, there are also applications made on thermal insulation layers such as synthetic foam and glass wool placed outside the wall. In the applications made on synthetic foam, a substrate containing a special fiber mesh reinforcement is first formed on the strophore, and after the primer is applied on it, plaster with synthetic binder is applied. In applications on fibrous thermal insulation layers such as glass wool and rock wool, a carrier wire mesh reinforcement mounted on the wall at certain intervals is used. Ready–made plasters are rarely applied directly on wood or metal.

The application of materials on a wall can be done through various methods such as troweling, rolling, or spraying. Synthetic–based plasters have been found to exhibit shorter setting times compared to mineral–based plasters. Additionally, advancements in the internal structure of the binders used in synthetic plasters have led to improvements in their flexibility, impact resistance, and adherence properties. In addition, these materials exhibit higher heat conduction resistance and vapor diffusion resistance factors. They also show sufficient resistance to withstand various weather conditions and chemical exposure. (Reichel et al., 2005).

3. Internal Structure and Components of Ready – Made Plasters with Synthetic Binders

When the internal structure of ready–made plasters with synthetic binders is examined, it is seen that it consists of various components like other surface coatings. These components can be divided into two groups as volatile and non–volatile. Table 1 shows the synthetic–based ready–mixed plaster components.

Table 1. Synthetic based ready–mixed plaster components

Non–volatile components	**Volatile components**
Binders Pigments Filling materials Additives	Organic solvents Water Binding agents

Most of the mixture consists of solvents, binders and pigments. The proportion of additives is small. With some types of binders, chemical curing can lead to condensation products such as water, alcohols and aldehydes released into the atmosphere or their acetals, which are considered volatile components.

In the following sections, the synthetic structure (polymeric structure) and the components of ready–made synthetic plasters are explained.

3.1. Synthetic (polymeric) Structure

Synthetic–based building materials can be classified as liquid coatings, filling materials, insulation materials, and plastics according to their intended use. While wood, another organic material, belongs to its own category due to its unique properties. Although organic materials used in construction often contain inorganic elements (such as pigments, fillers, and additives), these inorganic components blend into the organic matrix. Consequently, the mixture predominantly exhibits the characteristics of organic substances. Differences in the properties of synthetic coatings are mainly due to the molecular weight and type of binder.

Materials that remain self–supporting at operational temperatures without requiring a carrier layer are termed plastic materials. Broadly speaking, any substance showing plasticity at room temperature might be labeled as plastic. However, to earn this designation (to be given this name), the material should be shapeable through pressure, temperature, or both and be able to achieve the desired form. There are hundreds of types of plastic materials, from hard and brittle to soft and flexible. While the distinction between plastics and synthetic liquid coatings is not sharp, a substance is termed plastic when its resin is molten and termed coating when its resin is dissolved. Due to their molecular size, coatings lack the structural integrity to stand alone and require a substrate for support. (Jones et al., 2017).

In the Dictionary of the Turkish Language Association, polymers are defined as "high molecular weight compounds formed by repeated structural units." The name of the polymer comes from the Greek "poly + meros" (many + parts). Polymer molecules are formed by the combination of many small molecules. Each small molecule that makes up the polymer is called a monomer. Carbon, one of the 94 known natural elements, is widely found in nature and can form four covalent bonds simultaneously. Thus, it forms the backbone of organic molecules by making compounds with itself and other elements. Other elements bound to carbon include hydrogen, oxygen, nitrogen, halogens, sulfur, phosphorus, silicon, and their groups.

Organic molecules are formed through chemical synthesis processes by combining multiple monomers, which can be either identical or different from one another. This results in the formation of elongated chains. Macromolecules are composed of a large number of atoms that are connected through covalent bonds. These bonds form long chains, with the potential for hundreds of thousands or even millions of atoms to be linked together. The arrangement of carbon atoms in rings or chains, along with the order of different groups in their composition, leads to the formation of various compounds. The formation of carbonaceous compounds leads to an extensive range of possible compounds. Compounds referred to as natural organic or synthetic organic matter have been extensively discussed in the scientific literature. (Jones et al., 2017).

Synthetic compounds can be differentiated from inorganic materials, with their mechanical behavior and melting points. In comparison to inorganic materials, organic materials have larger molecules but exhibit weaker intermolecular attraction forces. As a result, their mechanical strength and melting points are comparatively lower. This results in reduced mechanical strength and lower melting points. However, these compounds are more malleable and generally less brittle. Unlike stable inorganic compounds, organic ones react with oxygen due to carbon's affinity for it. Particularly at elevated temperatures, they oxidize, emitting CO2 and H2O.

Small organic molecules typically have lower melting and boiling points than their larger counterparts due to weaker intermolecular attractions. For instance, simple carbon and hydrogen compounds like methane, ethane, propane, and butane possess weak attraction forces, making them gaseous at room temperature. Of these, butane is the heaviest, with a molecular weight of 58 g/mol, and liquefies at temperatures below zero degrees Celsius. In contrast, binders in synthetic ready–made plaster consist of heavier molecules with weights between 500 and 30,000 g/mol. Many of these begin melting or decomposing between 300°C and 400°C. Cellulose nitrate, polyacrylate and vinyl chloride copolymers represent the larger molecules, whereas alkyd resins, phenolic resins, polyisocyanates and epoxy resins are on the smaller end.

Polymers can be solid, liquid or solution form, or they can be emulsified. In all these cases, they show different characteristics. In addition to the chemical formula that determines the basic structure of the polymer, the morphology that determines the macro structure, that is, the presence of crystalline or amorphous regions in the solid structure of the polymer, their size, shape, settlement feature and distribution within the structure are also important. Thermal, mechanical and other physical properties are closely related to these different structures.

The polymeric binder's composition of large molecules with high molecular weight contributes to the structural integrity of the layer. This is because the long, complex chains that are tangled with each other create a strong molecular attraction. A synthetic polymer has a mixture of molecular sizes, often represented statistically. Weight–average molecular weight is defined as the product of the weight of each polymer species at a given molecular weight divided by the total molecular mass. Besides the molecular weight, the molecular weight distribution has a significant impact on the coating's performance. For example, for coatings made with resin solutions, normally, the higher the molecular weight, the higher the viscosity. This is a critical consideration in the formulation of high–solids coatings. At the same viscosity, a higher molecular weight resin will require more solvent, resulting in a higher volatile organic compound ratio than the same resin composition at a lower molecular weight. (Schmid, 1988).

Increasing the relative molecular weight of the binder in the polymer film improves properties such as elasticity, hardness, and impact deformation. However, it also leads to a higher solution viscosity of the binder. Additionally, when the molecular size is increased uncontrollably to make the coating layer more resistant, it can be said that the high viscosities of the resins will require the use of excessive amounts of solvent, resulting in thin and ineffective film layers.

3.2. Synthetic Binders

Among the materials used by paint chemists and chemical engineers in the laboratory and in industrial production, there is a group that has certain general characteristics, although they differ in their physical and mechanical behavior, which are high–molecular substances consisting of a number of molecules from a thousand to a few million. The molecules of these substances are made up of the repetitions of certain units linked by covalent bonds in the form of chains or networks. When the chemical structure of synthetic binders used in ready–made plaster or other liquid coatings is examined, these macromolecules called polymers are encountered. These substances, which are used as binders in synthetic based plasters, are the most important and essential components of the mixture. So much so that plasters with synthetic binders are called by the name of their binders.

The most important feature expected from synthetic binders is to keep the components that make up the mixture together and to provide adherence by forming bonds between the chemical structure it contains and the substrate. Most binders used today are alkyd or epoxy resins. Apart from these, polyesters, polycarbonates, cellulose esters, ABS polymers, furan resins, polyacetals, polyurethanes, phenolic resins, silicones, polysulfones can be counted among the examples of binders. Binders determine the application method, drying and curing behavior of the coating and impart characteristics to the substrate such as adhesion, mechanical properties, chemical resistance, weathering resistance.

Ready–made plasters can be examined in two main groups according to the type of binders: water–based and organic solvent–based. In water–based ready–made plasters, the synthetic binder is in emulsion. In organic solvent–based ready–made plasters, it is dissolved in suitable organic solvents. In general, vapor diffusion resistance factors and waterproofing properties of organic solvent–based ready–made plasters are higher than water–based ready–made plasters. Classifications made within these two groups are made according to the type of binder used. Each species has its own unique texture and light reflecting feature. (Tracton, 2006).

3.2.1. Organic solvent binders

Organic solvent binders consist of liquefied substances that evaporate through chemical reaction with oxygen. Typically, the moving air surrounding an organic solvent–based coating helps speed up the reaction, shortening drying times. Organic solvent coatings are less sensitive to environmental conditions such as temperature and humidity during the curing stage than water–based coatings. Moisture can actually prevent water in a water–based coating from evaporating, making it unusable in some climates.

Since the waterproofing properties of synthetic binders with organic solvents are higher than those of emulsion–based ones, they are mostly used in insulation against water and moisture, or in special–purpose coating systems or in parts of buildings exposed to special environmental conditions.

Due to the volatile organic compounds and irritating odors caused by the solvents of the ready–made plasters with organic solvents, their use in indoor environments has become rare. In exterior applications, additional measures such as anolu joint and vapor stabilizer application should be taken for vapor transmission (because their vapor diffusion resistance factors are high) (Flick, 1991).

3.2.2. Emulsion based organic binders

Emulsion–based binders are polymeric materials that are resistant to external effects, compatible with all kinds of colors, and produced for interior and exterior coatings and ready–made plasters. The main types used in plaster production are PVA, acrylic copolymer, pure acrylic and acrylonitrile. Some properties of emulsion–based binders are listed below;

– They are water–based.

– They have pigment binding properties.

– They are generally applied on mineral–based surfaces.

– They form a hard film layer.

– They are resistant to atmospheric effects.

– They allow a certain degree of vapor diffusion.

– They have waterproof properties.

Plasters produced with emulsion–based binders are applied to mineral–based surfaces by trowel, roller, or spraying. It is inconvenient to apply them in environments with relative humidity above 90%.

Emulsion–based binders have their own mild odor and moderate viscosity. Their Film forming temperatures are around 22oC. During their applications in summer and winter conditions, the adherence of the film can be increased by pigmentation and optionally, the film formation can be accelerated or delayed with the help of some additives such as mono ethylene glycol.

Emulsion–based binders are generally compatible with pigments and fillers. While preparing the pigment and filler mixture, the viscosity can be brought to the desired level by adding thickening materials such as hydroxyethylcellulose, polyvinylalcohol, bentonite and casein.

The thickening effect is maximized with polyacrylates. However, it can be inconvenient because the consistency of the material increases uncontrollably.

Plasticizers such as dibutylphthalate (DBP), diisobutylphthalate (DIBP) can be used when a flexible film layer is required for special cases. These plasticizers can mix with acrylic emulsion–based binders in any ratio and form a film. However, the UV of the layer. A decrease in resistance to UV radiation is observed.

All fine–grained dispersions tend to form foam. These can be removed with the help of defoamers consisting of long chain alcohols, polyglycols and silicones. The shelf life of the material can be extended by adding small amounts of antibacterial against the growth of microorganisms and mold.

The main plaster types produced by using such binders are listed below;

– Acrylic polymer – acrylonitrile emulsion binder plaster

– Natural stone brass plaster with acrylic polymer emulsion binder

– Acrylic copolymer emulsion binder plaster

– Natural stone brass plaster with acrylic copolymer emulsion binder

– PVA copolymer emulsion binder plaster

– Natural stone brass plaster with PVA copolymer emulsion binder (Horie, 2010).

3.3. Pigments

As it is known, pigments give color to the mixture they are added to, and inorganic ones also provide coverage. In addition to imparting color to the synthetic blend, some functional properties such as UV resistance, heat resistance, chemical resistance, mechanical strengthening and reduction of polymer degradation are also provided by pigments. Pigments added to the polymeric blend for these purposes do not dissolve in the medium in which they are used but are dispersed as fine particles (heterogeneous blend).Polymeric structures colored with pigments can be transparent or opaque depending on the particle size of the pigment and the relative refractive index difference between the pigment and the polymeric structure. (Philip & Schweitzer, 2005).

3.3.1. Classification of pigments

Pigments, like fillers, can be organic or inorganic. Organic pigments have particle size in the range of 0.05 µm – 0.5 µm, while inorganic pigments have particle size in the range of 0.1 µm – 2.0 µm. Organic pigments are clean, bright and transparent colorants. It is possible to obtain all colors from organic pigments. Their heat resistance and light transmittance vary from low to high depending on the type. However, their durability is generally lower than inorganic pigments and they may show leakage from the structure (phase separation). Inorganic pigments are large in size and can be easily dispersed in resins. They provide better heat and light resistance, opacity and chemical resistance than organic pigments. The leakage rate of inorganic pigments out of the structure is very low. Table 2 shows the main organic and inorganic pigments and their main groups.

Table 2. Major organic and inorganic pigments and their main groups (Philip & Schweitzer, 2005)

Organic pigment main groups		**Inorganic pigment main groups**	
Chemical name	Color	Chemical name	Color
Quinacridone	Red	Titanium dioxide	White
Isoindolinone	Yellow, orange, red	Carbon black	Black
Diazo	Yellow, orange, red	Titanlar	Yellow, green
Benzimidazolone	Yellow, orange, red, brown	Cadmiums	Yellow, green, orange
Monazo	Yellow, orange, red, brown	Iron oxides	Yellow, red, brown
Diazocondensation	Yellow, orange, red, purple	Chromates	Shades of yellow
Phthalocyanine	Green, blue	Molybdates	Shades of orange
		Ferricyanides	Blue
		Chromium oxide	Blue, black, green

Pigments can be classified as organic and inorganic, or they can be divided into 3 groups as natural pigments, artificial pigments and mineral pigments. Artificial pigments are usually organic, while natural pigments can be organic or inorganic. Natural pigments include roughage (calcium carbonate), henna, indigo, slate paint, kaolin, gypsum, talc, redwood, saffron, lignite coal. Some mineral pigments used in coloring paints are lead lily, barium sulfate, white zinc sulfide lead oxide and red iron oxide. Black powders obtained by carbonization of all organic materials are in the group of artificial organic pigments. (Philip & Schweitzer, 2005).

3.3.2. Titanium dioxide

Titanium dioxide with the chemical formula TiO2, has a special place among all pigment types due to its optical properties. It has a certain particle size distribution of very small particles and gives the mixture a white color. As the grain size increases, there is a shift from the ideal white color to the yellow region in the visible light spectrum. There are two types of titanium dioxide minerals called "Anatas" and "Rutile" in nature. Since the crystal structures of these two types of white pigments are not similar, their refractive indices and light reflecting properties are also different.

All types of titanium pigments are subjected to surface treatment.To ensure the resistance of pigment particles to factors like light, heat, and humidity, as well as their homogeneous distribution in the intended environment, the particles are modified with both inorganic and organic substances. This modification also helps in reducing the catalytic effect and ensuring stability.

The covering ability of titanium dioxide pigment is gains importance in surface coating and plastisol applications. The hiding power of a pigment is determined by its ability to cover the color of a surface it is applied to, and its ability to cover a black surface is assessed through experimentation.

In addition to its highly reflective properties, titanium dioxide pigment also offers a high level of opacity. This means that coatings containing titanium dioxide have low light transmittance. The degree of coverage, light transmittance, and opacity are all influenced by the refractive power of light, the ratio of pigment used, and the thickness of the applied film.

The optical properties of titanium dioxide pigment can only be revealed if it is well dispersed in the environment in which it is used. Good dispersion of the pigment means that it breaks down into small particles and is wetted by the medium. The titanium dioxide pigment obtained at the end of the production processes can be considered as the smallest agglomerate particle. If the pigment is not found in the form of agglomerate first, excessive dusting occurs and the processing (dispersion) of the material becomes difficult. The dispersion consists of four processes. These; agglomerate dispersion, wetting, dispersion and stabilization. During dispersion, these four processes proceed simultaneously. At this time, the riskof adverse processes such as agglomerate formation should be considered.

In order for the agglomerate to disperse, it is necessary to overcome the adhesion force between the particles. Mechanical energy is applied to accomplish this

This process should continue until a homogeneous dispersion occurs and the applied force should be large enough to separate the particles from each other. If the applied force is insufficient, there is no benefit in lengthening the time

The type and amount of titanium dioxide pigment in surface coatings affect the brightness and yellow color index. As the amount of pigment increases, the brightness increases and the yellow hue decreases. The color preference is usually in the form of a blue–like type of white. Although Anatas TiO_2 mineral gives a bluish white color, it is not suitable for use against special environmental conditions. In order to obtain a bluish tone, a small amount of dyestuffs (such as indigo, carbon black, aluminum powder) to give a bluish or violet color can be added together with titanium dioxide. However, in this case, such applications are no longer made, as a loss of brightness occurs. Instead, the use of optical lighteners is a more effective method. Optical lightening compounds UV. they convert the radiation into visible blue fluorescent light. Thus, a bluish tone is obtained without loss of brightness. The downside of optical lighteners is that they are expensive and have little resistance to light.

Titanium dioxide pigment has two effects on the coating layer.

1 – Titanium dioxide as a strong UV radiation absorber protects the binder, film–forming polymer material from degradation by direct UV radiation.

2 – Due to its photochemical activity and chemically active state, it accelerates the degradation of the binder polymer under certain conditions. The photochemical activity of the anatase pigment is higher than that of the other titanium dioxide mineral, rutile. For this reason, it is not recommended to use anatase pigment in plastics to be used in outdoor conditions.

As stated above, depending on the type and amount of titanium dioxide pigment, the degradation of the coating can be partially or completely prevented, or conversely, it can be accelerated. For coating layers to be used outdoors, a titanium dioxide pigment, which does not spoil the property of the photochemically stable synthetic binder in air conditions, must be used. Due to its high photochemical activity, the addition of anatase type pigment to the coatings to be used outdoors, as mentioned above, is not suitable. Despite the high degree of UV radiation absorption of rutile pigment and its protection of the coating layer, the use of rutile pigment in outdoor conditions is limited. On the other hand, stabilized rutile pigments enable long–term resistance against color degradation and surface dusting of surface coatings.

Not only does the type of titanium dioxide pigment affect long–term durability, but the concentration of the pigment has also been found to be crucial. Research has shown that a minimum of 3% stabilized rutile pigment should be used in the formulation, and for surfaces that will be exposed to strong sunlight, the ratio should be at least 6%. (Philip & Schweitzer, 2005).

3.4. Fillers and Aggregate

Fillers are defined as inert substances added to polymers in order to improve the mechanical and physical properties of the polymeric material or to reduce the cost. These substances, which only provide a physical mixture, can be natural mineral–based inorganic or organic. Their size can range from micro–sized particles to macro–sizes. The degree of wetting and bonding of the polymeric structure with the filler increases depending on the structure and shape of the filler. Inorganic and organic fillers added to the polymeric material are shown in Table 3.

Table 3. Inorganic and organic fillers used in the production of polymeric materials (Reichel et al., 2005)

Inorganic fillers		**Organic fillers**
Calcium oxide	Alumina	Cellulosic compounds
Magnesium oxide	Zinc oxide	Synthetic fibers
Magnesium hydroxide	Antimony trioxide	Proteins
Magnesium carbonate	Metal powders	Lignin
Calcium carbonate	Carbon black	
Barium carbonate	Glass fibers	
Barium sulfate	Silica	

The effects of fillers on the polymeric structure are as follows;

– The modulus of elasticity of the polymeric structure increases depending on the nature and amount of the filler.

– The dimensional stability of the polymeric structure increases.

– The impact resistance and tensile stress of the polymeric structure increase.

– The resistance of the polymeric structure to abrasion and tearing increases.

– The heat and electrical conduction of the polymeric structure can be changed in the desired direction with fillers.

– Fillers affect consistency, covering and texture.

– Fillers affect the processing properties and shrinkage.

– The product price drops significantly.

In glassy and highly crystalline polymers, fillers do not significantly contribute to mechanical properties. The particle diameter of the aggregate in the ready–made plasters can vary from micron to 1–2 mm. Coarse grains determine the thickness of some plaster types applied with a gauge. A gap in the form of a line remains at the point drawn by the aggregate attached to the gauge. Although these lines, which are generally made horizontally, give the façade a decorative appearance, they have some drawbacks such as the rain water flowing over the façade enters and exits these gaps and accumulates dirt in these gaps over time. (Reichel et al., 2005).

3.5. Additives

Additives are auxiliary materials added to the polymer matrix in small quantities in order to impart different properties to synthetic–based plasters, or to modifye the existing properties. Even at low concentrations, additives can have significant effects, such as enhancing flow behavior, improving wetting of the pigment substrate, and catalyzing the curing process. Plasticizers, defoamers, wetting agents, and antibacterials are among the most important additives. (Reichel et al., 2005).

3.5.1. Plasticizers

Plasticizers are high–boiling organic liquids or low–melting solids that are used to soften polymers and make them more flexible. They can be examined in two main groups as internal and external plasticizers.

1 – Internal plasticizers: They are used during the synthesis of the polymer and contribute to the bond structure of the polymer.

2 – External plasticizers: During the processing of the polymer as a semi–product, it plays a diluting role in the polymeric structure, and provides softening of the structure by entering between the polymer chains.

A good plasticizer should be non–toxic, non–flammable, maintain its effect for a long time, and its physical and mechanical properties should be compatible with the polymer used. In Table 4, the names of some plasticizers used are given.

Table 4. Some plasticizers used in Synthetic Based coatings (Reichel et al., 2005)

Chemical Formula	**Name**
PVC	polyvinyl chloride
BBP	Butylbenzylphthalate
DOA	Di(2–ethylhexyl) adipate
DOTP	Di(2–ethylhexyl) terephthalate
DBP	dibutylphthalate
DBS	Dibutylsebacet
DIBP	Diisobutylphthalate
DOP	dioctylphthalate
DTDP	Ditridecylphthalate
DUP	Diundesilphthalate
TOP	Tris(2–ethylhexyl) phosphate
TOTM	Tris(2–ethylhexyl) trimellitate
TCP	Tricresylphosphate

3.5.2. Defoamers

Foam usually forms within the synthetic–based polymer emulsion during production and packaging and often causes film defects such as bubbles and fine spots during application. To eliminate this problem, materials that destabilize or break the foams are added to the mixture.

These include long–chain alcohols, polyglycols, silicones, organic materials with high carbon molecules. (Reichel et al., 2005).

3.5.3. Wettings

Wetting agents are substances that increase the pigment and filler dispersion and facilitate bonding with the polymer. These dispersing substances also play a role in preventing precipitation. When water with high hardness is used in the production of coatings, additives such as tetrapotassium pyrophosphate are used to help stabilize the coating, preventing precipitation reactions. (Reichel et al., 2005).

3.5.4. Antibacterials

Additives called antibacterials are used in the material to prevent the growth of mold, fungus and all kinds of micro–organisms and to eliminate effects such as micro–biological degradation and mold. Latex coatings for the exterior often contain fungicides that help prevent mold growth on exterior surfaces. Antibacterial additives should be used in small amounts. Too much can disrupt the structure of the polymer. (Reichel et al.,2005).

3.5.5. Flame Retardants

The flammability of the façade material is an important issue since the fire spread on the façades occurs when the flames spread along the façade and pass to the upper floors in case of a fire in any floor of the building. In order for the facade material not to contribute to the spread of flame in the event of a fire, additives that prevent ignition are added to synthetic facade coatings. The role of these additives is that they are involved in the chemistry and physics of the combustion process and produce free radicals to stop the combustion process. Fire–fighting additives can be phosphorus–based, halogen–based, or metal hydrate–based. (Harper, 2003).

3.6. Solvents

Since ready–made plasters with synthetic binders are prepared and applied in liquid form,necessitating the use of a solvent to prepare them for application and in this respect, the solvent is the most critical raw material in synthetic coatings. Solvents dissolve various components during the coating preparation process, directly influencing film formation, viscosity, and processability. The solvent's main feature is its ability to dissolve the synthetic mixture, but other attributes, such as boiling point, reactivity, toxicity, and relative evaporation rate are also important. The evaporation of the solvent impacts the final film properties, coating morphology, and film drying rate.

Thinners and solvents, which can be organic or inorganic, vary depending on the type and properties of the binder in ready–made plasters with synthetic binders. Various organic solvents are used as thinner in organic solution plasters, and water with low hardness degree is used in synthetic emulsion–based plasters. Emissions from organic solvents pose a risk of ignition and can sometimes be harmful to health. Therefore, aqueous solutions have become widespread in recent years.

The volatile organic compound ratio contained in organic solvents is a matter to be considered.

Volatile organic compounds are compounds with high vapor pressure and low solubility in water and are harmful to health. At the same time, on hot summer days, they react with nitrogen oxides and form ozone, an air pollutant. Large amounts of ozone can be harmful to people, vegetation, forests and crops.It can cause throat and eye irritation as well as breathing difficulties in sensitive individuals.

Among organic solvents, aliphatic solvents, aromatic solvents, alcohols such as methanol, ethanol, and isopropanol, esters, glycol ethers, and ketones can be mentioned. (Philip & Schweitzer, 2005).

4. Key Features of Ready–Made Plasters with Synthetic Binders

The features that synthetic binder ready plasters must possess can be grouped into three categories: pre–application, during application, and post–application. Prior to application, there should be no cream layer on the surface when the package is opened, it should become homogeneous after mixing, and there should be no immiscible sediment at the bottom. There should be no clumping, curdling, excessive foaming, and color separation.

During application, the expected features include suitable viscosity, workability, and ease of application. After application, the plaster should not undergo volume changes to the extent that will cause cracking during setting. (Zheng, 2020).

The features that determine the appropriate and healthy use of the material are listed in Table – 5. Among these, the 3 fundamental features, adhesion, water absorption, and water vapor permeability are explained in separate sections below.

Table 5. Key features of ready–made plasters with synthetic binders

Thermal properties	Thermal conductivity Thermal expansion Melting point Freezing point Heat capacity
Water and humidity properties	Water repellency/absorbency Water permeability Vapor permeability
Chemical properties	Corrosion resistance Fire resistance Resistance to alkalis Resistance to acids Resistance to salt efflorescence Adhesion strength pH value
Mechanical properties	Hardness Elasticity Impact resistance Friction and abrasion resistance Rheological structure (yield resistance) Resistance to building movements (settlement of buildings, vibration, etc.)
Resistance to atmospheric effects	Resistance to UV. Radiation Resistance to temperature changes Rain and snow resistance Moisture resistance Frost resistance Resistance to atmospheric abbrasive effects Resistance to atmospheric chemical effects
Features related to health and comfort	Mold, fungus, bacteria formation The amount of volatile compound released into the air Degree of toxicity Odor degree

Morphological features	Fill ability Covering ability Crack bridging ability Thickness
Visual features	Optical properties Loss of gloss Fading Yellowing
Cleaning related features	Dust holding, scumming degree Ease of cleaning
Features related to maintenance and application	Ease of application Ease of maintenance and repair Ease of renewal

4.1. Adherence

Although it exhibitsexcellent properties under climate conditions, a coating is useless unless it also has adequate adherence properties and will not be able to fulfill its primary function of protection, which is expected from it. According to the general belief, adherence is created by the physical and chemical forces between the substrate and the coating material. Therefore, the degree of adherence is determined by the type of coating material as well as the type of surface to be coated. The substrate can be various layers of metal, wood, plastics, stone, brick wall or concrete surface. Another important factor affecting the bond strength is the physical roughness and cleanliness of such surfaces on which the coating layer will be applied.

As an example of the effect of surface roughness, epoxies and cold–rolled steel, which are known for their superior adhesion capabilities to almost all types of substrates, can be given. It is a well–known fact that epoxy adhesives achieve high degree of success in bonding different materials together (almost all metals, wood, ceramics, and many plastics).However, they can only be used as two component primers on cold drawn steel because the surface is very bright and smooth.

Tensile, peeling, scraping, and hydrostatic pressure methods can be mentioned among the adherence measurement methods for synthetic coatings. In the drawing method, the metal sheet, bonded with epoxy on the coating, is pulled. In the another drawing method, after the coating is sliced, a tape is adhered and pulled. In the peeling method, the veneer is sliced into thin long strips and then peeled off by applying a certain force from the end. In the scraping method, the coating is scraped with a metal chisel whose tip ends at a certain angle. In the hydrostatic pressure method, the coating is applied on a layer on which holes of a certain diameter and number have been drilled beforehand. Then hydrostatic pressure is applied from behind. This method is mostly used to measure adherence weakening caused by corrosion. (Lacombe, 2005).

Other important factors affecting the strength of adhesion include the chemical structure of the layer to be applied, (binders, pigments, additives and solvents), the water absorption and permeability of the layer (porosity) and the chemical compositionof the coated surface. Adherence has been extensively studied and researched, resulting in a considerable understanding of the factors that contribute to high or low adhesion strength between layers in a system. Nevertheless, there remain unanswered questions to this day, and each coating system demonstrates distinct behaviors when applied to different substrates. (Packham, 2005).

4.2. Water Absorption

Exterior cladding plays an important role in the interaction of the exterior wall with water. It is generally undesirable for water to penetrate into building materials in the form of liquid or moisture, and it is known that it causes a loss of adherence between layers. This is caused by aggressive ions that are dragged into the layers by water and accelerate the deterioration of materials. Moreover, the high water absorption values of the coatings cause the thermal conductivity of the coating to increase and deformations due to wetting–drying or freezing.

For this reason, it is necessary to know how the coating material to be applied to the facade will behave when interacting with water or moisture and how its performance will be affected. Coatings applied on non–water–absorbing panels such as aluminum or stainless steel are generally used in experiments to determine the water absorption values of exterior cladding. Dry–weighed test samples are stored in environments with varying humidity or immersed in distilled water. After the specified waiting time, it is weighed again and the water absorption percentage by weight is found. Water absorption, which varies between 0.5% and 5% depending on the composition of the coating, increases with temperature and naturally with relative humidity. Usually balance is achieved after 48 hours. This value can increase up to 50% in polyvinyl acetate emulsions and special binders containing high amounts of similar polar groups. (Koleske, 2012).

4.3. Water Vapor Permeability

In general, the vapor resistance of a material indicates how much higher the vapor resistance value of a coating made from that material is compared to an inert air layer of the same thickness. A higher value means lower water vapor permeability. If the outer coating has a high resistance to vapor permeation, it creates unfavorable drying conditions for the materials underneath. This can lead to condensation of water vapor under the outer cladding resulting in reduced durability of the cladding.

Experiments have shown that increasing the vapor resistance of the outer coating leads to increased condensation in the building envelope during moisture accumulation, resulting in decreased durability of both the outer coating and the substrate system. The resistance of coatings made of polyacrylates, silicone solutions obtained using organic solvents or silicone dispersions against climatic influences depends on vapor permeability. Today, the outer walls of the buildings are generally designed as multi–layered. In multi–layered wall systems, the vapor permeability of the layers should increase towards the outer layers. Otherwise, the outer cover layer may become a barrier to water vapor diffusion, leading to moisture accumulation in the outer layers of the building envelope during cold seasons.

Determination of water vapor permeability of binder or paint film layers depends on the production of free film layers. One way to get free film layers is to apply the paint to the thin sheet of tin. After baking or air–drying the paint or binders, tin is dissolved by immersion in mercury.

One of the methods used to determine the water vapor permeability is the mug or cup method. In this method, the mug containing silica gel or CaCl2 is closed with a free film layer or binder layer and made airtight by applying wax or silicone to its edge. The mug is filled with distilled water and the entire equipment is kept in an environment with a temperature of 23oC and a relative humidity of 50%. (wet mug method) The mug is weighed periodically for 24 hours and the water vapor permeability is measured in grams per unit surface according to DlN 53122–1 or BS 3117/1959 standards. All measurements are made with 25 µm thick dry film layers. Table 6 shows the water vapor permeability values in g/m2day measured by the wet cup method at 23oC of 25 µm thick unpigmented transparent film layers of various binder groups.

In the method described for synthetic emulsion–based plasters in TSE, the ready–made plaster is placed in the mouth of a steel container containing CaCl2, which absorbs the humidity of the air. To ensure impermeability, the edges are covered with paraffin and weighed. This container is then placed in a desiccator with NH4H2PO4 solution, which emits moisture to the environment. At the end of a 5 days waiting period, weight gain differences are recorded by weighing at least five days, once a day.

Table 6. Water vapor permeability values in g/m2day of unpigmented 25 µm thick film layers of various binder groups measured by wet cup method at 23 oC (Koleske, 2012).

Binder Type	**Vapor Permeability** [gr/m^2day]
Drying Oxidizing Binders	
– Oils	150–200
– Long oil alkyds	100–150
– Medium oil alkyds	50–100
Curable Modified Binders	
– Modified alkyds	30–50
– Urethane alkyds	30–50
– Phenolic modified oils	20–40
Organic Solvent Based Polymers	
– Chloride rubber–plasticizer	20–40
– PVC Copolymers	10–30
– Strene acrylates	10–30
Water Based Polymer Emulsions	
– PVA and PVB	150–200
– Methacrylic copolymers	80–100
– Styrene–acrylic copolymers	10–20
– PVC copolymers	10–20
– PVDC copolymers	1–5
Two Component Systems	
– PUR–isocyanate systems	10–20
– Epoxy amine or polyamide	10–20

Although there is no close proportional relationship between water absorption and water vapor permeability in exterior cladding, there is a certain correlation between these values. In general, it can be said that when the water absorption of the film layer increases, the water vapor permeability will also increase.

Water vapor permeability is typically measured using freshly dried film layers. However, obtaining free film layers from paints exposed to atmospheric conditions is challenging. As the exposure time to atmospheric effects increases, the film layers become denser and tighter, resulting in lower water vapor permeability. This decrease in permeability is observed not only in oxidation–drying film layers that form crosslinks but also in normal water–based polymer emulsion paints when exposed to atmospheric effects.

Water molecules strongly bonded with hydrogen are generally more numerous and more strongly absorbed in coatings with polar groups. These polar groups can be found in binder molecules, additives and plasticizers.

Air–drying oils and alkyds show high water vapor permeability values. The high values of some water–based vinyl copolymers are due to the inclusion of water–soluble stabilizers and wetting additives In contrast, chlorinated binders such as chlorinated rubber, PVC copolymers and especially polyvinylidene chloride (PVDC) have very low values. Multi–purpose paints are obtained by combining alkyd groups with these chlorinated products. These values are for freshly dried film layers. Under atmospheric effects, intramolecular cross–linking in the film layers gradually increases, and water–soluble additives in water–based binders are washed away by rain and dew. Thus, tighter and denser film layers emerge.

Coatings with a dry film thickness of over 100 µm can be obtained using modern coating techniques made with chlorine rubber, PVC and similar copolymer–based synthetic materials. Especially slow–evaporating solvents remain in these high polymer systems for a very long time. The residual solvents can remain on the coating for months or even years, especially on cold winter days or in high humidity environments. Polar solvents such as alcohols, ketones, glycol ethers and acetates used for these polymers attract water molecules with their polar groups and facilitate their entry into the film layer and their transport by the layer. It has been observed that even after multiple years, swellings in high polymer epoxy coatings applied on steel tanks can still emit solvent odor.

Another effect of long solvent retention is the plasticizing effect on the macromolecules of the binder. These high boiling solvents show true plasticizing effect. The film layers are also smooth in this case and can be easily destroyed. Especially high boiling point chlorinated rubber coatings and similar coatings based on PVC copolymer require long periods of time to dry. If they are not allowed to dry, they may be damaged during transportation.

Pigments also play a role in the water vapor permeability of paint films. In particular, the addition of 50 to 75% of the critical pigment/volume concentration reduces the water vapor permeability somewhat. Thin layered layered pigments (micronized minerals) such as aluminum powder, micaceous iron oxide, talc, glass leaflets have effects on water vapor permeability. The general view is that these pigments create barriers to the entry of water molecules due to their layered structure and lengthen the diffusion path. (Koleske, 2012).

5. Final Words

The choice of coating type to be applied on the exterior wall in buildings is one of the design decisions, and factors such as climatic and environmental characteristics, the function of the building, together with the imaginative feature that is intended to be given to the building, are effective in the selection of the coating system and material. The coating system and materials can also be designed for special purposes such as thermal insulation, passive energy recovery, sound absorption, or giving the building a symbolic feature. However, the main purpose is to protect the structural properties of the coating and the building envelope underneath.

In this study, synthetic–based ready–made plasters, which is one of the coating types used as a topcoat on the exterior of the buildings, are discussed. The components that make up the structure of synthetic coatings and the characteristic properties these components bring to the material are explained. For a healthy exterior cladding application, the water vapor permeability degree, water absorption degree and behavior of the material to be used as a cladding should be known, and care should be taken to ensure that it is protected against UV radiation. The material should be elastic enough to keep up with minor deformations or dimensional changes of the substrate, and should be able to cover small gaps or cracks on the surface to be applied.

It should not be forgotten that the building envelope must also protect the outer coverings in order for the exterior coverings to protect the building envelope in a healthy way. For this, the movement of water and dissolved salts connected to it must be prevented by capillarity in the wall section near the terrace and other wet places or the ground. In addition, in the design of the building envelope, it is important to choose layers so that condensation does not form under the outer covering. If the application is to be made on a building surface in use, condensation analysis should be done, if there is a risk of condensation, it should be prevented by adding thermal insulation and/or vapor barrier.

The variety of coating materials available today is very large, and architects and building manufacturers often come up with more than one option for a solution to a problem or an application for a purpose. For this reason, it is important not to rush the system and material selection and to evaluate the conditions in a versatile way. In this study, general and basic information about material selection and application has been tried to be given. When the information given here differs from the instructions given by the manufacturer for a certain application of a certain material, it should be noted that the decisions under the authority of the authorized manufacturer company or the material authority should be taken into account.

Regardless of the purpose of the coating, a successful application can be considered as long as it provides sufficient adherence to the substrate and maintains its basic properties. In order to achieve this, the coating system should be selected in accordance with the purpose and conditions, maximum attention should be paid to surface preparation, application and maintenance operations should be carried out in accordance with the procedure and under appropriate environmental conditions. It should not be forgotten that synthetic outer coatings are sensitive to external effects in the first stages of drying and environmental conditions during this period affect the entire life of the coating.

Thanks and Information Note

This E-book section produced from the doctoral thesis, “A Research on the Behavior of Ready-Made Plasters with Synthetic Binder against Physical Environmental Effects”, completed in the Mimar Sinan Fine Arts University, Graduate School of science, the Department of Building Physics and Materials.

Ethics Committee approval was not required for the study.

The E-book section complies with national and international research and publication ethics.

Author Contribution and Conflict of Interest Disclosure Information

Single author

References

Flick, E. V. (1991). Industrial Synthetic Resins Handbook. William Andrew Publishing/Noyes, 2nd edition, 1155 pages.

Harper, C.A. (2003). Handbook of Building Materials for Fire Protection. McGraw Hill, 562 pages.

Hodgson, F.T. (2015). Plaster and Plastering: Mortars and Cements, How to Make, and How to Use. Creative Media Partners, LLC, 114 pages.

Horie, C. V. (2010). Materials for Conservation: Organic Consolidants Adhesives and Coatings. Elsevier Science, 2nd ediition, 504 pages

Jones, F. N., Nichols, M. E., Pappas, S. P. (2017). Organic Coatings Science and Technology. John Wiley & Sons, 4th edition, 509 pages.

Koleske, J. V. (2012). Paint and Coating Testing Manual. ASTM International, 15th edition, 1026 pages.

Lacombe, R. (2005). Adhesion Measurement Methods Theory and Practice. CRC Press, 440 pages.

Lambourne, R. & Strivens, T. A. (1999). Paint and Surface Coatings. Woodhead Publishing, 2nd Edition, 755 pages.

Packham, D. E. (2005). Handbook of Adhesion. John Wiley & Sons Ltd, 2nd edition, 677 pages.

Philip, A. & Schweitzer, P.E. (2005). Paint and Coatings: Application and Corrosion Resistance. CRC Press, 671 pages.

Reichel, A., Hochberg, A., Köpke, C. (2005). Plaster, Render, Paint and Coatings. Birkhäuser Architecture, 114 pages.

Schmid, E.V. (1988). Exterior Durability of Organic Coatings. FMJ International Publications Limited, 334 pages.

Stoye, D. & Freitag, W. (1998). Paints Coatings and Solvents. Wiley–VCH, 2nd edition, 423 pages.

Tracton, A. (2006). Coatings Materials and Surface Coatings. CRC Press, 1st edition, 528 pages.

Zheng, S. X. (2020). Principles of Organic Coatings and Finishing. Cambridge Scholars Publishing, 1st edition, 454 pages.

A.Cüneyd DİRİ
E-mail: ahmet.cuneyd.diri@msgsu.edu.tr
Educational Status:
License: Mimar Sinan University, Architecture
Degree: PhD
Doctorate: Mimar Sinan University, Building Physics and Material
Professional Experience: He graduated from Mimar Sinan Fine ArtsUniversity, Department of Architecture in 1992. He completed his hisdoctorate in 1994 at the same university. He become a lecturer in sameuniversity in 1993 until today. Currently, the Department of BuildingPhysics and Materials is accepted as academic.

The Use of Glass Materials in the Design of Contemporary Extensions to Historic Buildings

Asst. Prof. Dr. Serhat ANIKTAR [1]

[1]Istanbul Sabahattin Zaim University, Faculty of Engineering and Natural Sicences, Department of Architecture. Istanbul/Türkiye.
ORCID: 0000-0002-7727-5331
E-mail: serhat.aniktar@izu.edu.tr

Res. Asst. Ahmet KURNAZ [2]

[2] Istanbul Sabahattin Zaim University, Faculty of Engineering and Natural Sicences, Department of Architecture. Istanbul/Türkiye.
ORCID: 0000-0002-9536-870X
E-mail: ahmet.kurnaz@izu.edu.tr

Citation: Anıktar, S. & Kurnaz, A. (2023). The Use of Glass Materials in the Design of Contemporary Extensions to Historic Buildings. In Ü.T. Arpacıoğlu, & S. Akten (Eds.). *Architectural Sciences, Sustainable Materials and Built Environment*, (454-486). ISBN: 978-625-367-287-4. Ankara:Iksad Publications.

1. Introduction

Many structures met the requirements of the time when they were built but could not meet the needs of today's conditions and, therefore, could not be used (Feilden, 2003). Historical buildings may wear out over time or face the danger of extinction. The structure can be damaged by natural disasters, human factors or just the return of time. Cultural heritage must be preserved in order to transfer it to future generations and to prevent the destruction of structures. A multidisciplinary study should be carried out in stages such as determining the causes of wear in the protection of the buildings, determining the damage to the structures and choosing the materials and techniques to be used in the restoration (Uğurlu & Böke, 2009).

Reusing these structures by giving them a different function, instead of causing economic and environmental damage by demolishing and rebuilding them, is a method that has been frequently used in recent years. This situation is especially seen in very old but still intact structures. However, historical buildings may need extensions for their new functions, as they are sized according to the function of the old period. Extension structures can be located on the roof or a facade of historical buildings, or they can be built by forming an outer shell or completing the historical structure without touching the historical buildings. Emphasizing the changes and extensions made in the historical building within the scope of refunctioning, attracting attention, or creating harmonious integrity is ensured by the way the material is used and the design.

One of the most used materials in extension structures is glass. Glass material is flexible as it is suitable to play with its reflection and transmittance. These features of glass and the developing technology, along with the possibility of building in wider openings, have made it possible to use glass materials frequently in extensions. It is used with different shapes and structures according to the function to be regained and the image the designer aims for. It is seen that glass materials are used in the refunctioned buildings for objectives such as meeting the need for a space that needs to receive light, providing the use of scenery, and revealing the main entrance of the building. The study's main purpose is to examine the use of glass materials in the extension and how the extension is attached to the main structure through the sample structures examined. Within the scope of the study, the use of glass in the extension to the historical building and the method of adding it were examined through examples in the context of attachment location, purpose, size, transparency, reflectivity. In this context, the effect of glass materials on extensions was evaluated.

2. Material and Method

In this study, in the literature review direction, refunctioning and extensions to historic buildings, glass material and its use in architecture are explained in systematically created by us. At the same time, examples of glass extensions to historic building are analyzed and evaluated within the scope of attachment location, purpose, size, transparency, reflectivity.

3. Findings and Results

The concept of protection; It aims to provide social continuity in social and cultural terms in order to transfer the past to the future and to preserve the historical traces in the building. Within the scope of the protection and survival of cultural heritage, the transformation of historical buildings by re-functioning has an important place among the types of intervention. Additional structures can be placed on the roofs or facades of historical buildings, or they can be built by creating an outer shell without touching the historical buildings or by completing the historical building. While using additional construction methods in repurposed buildings, the use of glass materials is frequently encountered.

3.1. Refunctioning and Extensions

The aim of architectural preservation is to preserve the physical texture of the building as well as its symbolic and artistic values. Structures must have one or both of these values to be protected. In other words, not only their physical existence is sufficient for the protection of buildings, but they must also have cultural value. Because these values have an important place in the collective memory or history of society or humanity or are aesthetically valuable

(Kurnaz & Anıktar, 2023). In this direction, a historical building structure, form, construction technique, material and artistic value of that period should be preserved as a whole, without deteriorating its original qualities.

Article 3 of the Venice Charter issued by the International Council on Monuments and Sites (ICOMOS) in 1964 states that “The purpose of preserving and restoring monuments is to preserve them as a historical document as well as a work of art” and in Article 4 “The basic attitude in the preservation of monuments is to protect them. to be permanent and to ensure its continuity” (Venedik Tüzüğü, 1964).

In short, conservation can be defined as the transfer of structures that have taken place in the historical memory of a society to future generations without destroying their originality, and the preservation of this cultural heritage by using the right methods with the least intervention in order to ensure the continuity of this cultural heritage (Ünlü & Ünver, 2019). Historical buildings can be protected by various methods according to their functions and existing physical conditions.

These methods are; Consolidation, which means physical interventions made to increase the durability of the existing structure, reintegration, which means integrating the missing parts of the structure with a new material, renewal (renovation), which is the renewal of the parts that make up the whole, documents a destroyed structure and, if any, first in the light of the remains (Kurnaz & Anıktar, 2023). Reconstruction (reconstruction), which is to bring the building into its shape, cleaning (liberation) to remove the excesses added after the first construction of the building, and adaptive reuse, which can be recyclable when necessary, and bringing new functions by making it suitable for contemporary needs and uses (Turanlı & Satıcı, 2021).

Refunctioning; It can be defined as the reuse of existing structures that have lost their function due to many reasons such as environmental, social, cultural and economic, with a different function while preserving their spatial and unique structural characteristics. The fact that a building that continues to exist structurally cannot be used for the purpose of its construction necessitates its re-evaluation with a different function. Advantages such as reducing the damage to nature by evaluating the existing building stock, gaining economic benefits, cultural and historical continuity, and ensuring continuity between the past and the future necessitate this functionalization. Making analyzes and inquiries that take into account the structural and spatial characteristics of the building in the functionalization process; It is important in terms of meeting human actions with the new function and creating livable spaces in this context (Eryiğit & Anıktar, 2021). Functional change also allows historical values to come to life in the city by enabling the society to interact with its past (Gazi & Boduroğlu, 2015).

It may be necessary to make a contemporary extension due to the reuse of historical environments, their active role in contemporary life, and the comfort conditions of historical buildings that have been given a new function (Letzter & Neuman, 2022). Contemporary extensions are a compromise between expanding historic buildings and emphasizing the important values of historic buildings. Extensions add new meanings to the field by acting as a bridge between the past and the future (Casakin, 2006). The resulting new structure has its history and establishes a new relationship with its surroundings. The extension's design must be differentiated regarding the historic building's structure, material, and style.

3.2. Glass and Its Use in Architecture

For the new function to be brought to life in this transformation process, the existing structure should be re-evaluated in terms of design and material. The choice of material and its usage should be determined accordingly. It varies in terms of structural features, such as the relationship between the main structure and the extension, the method of joining, dimensional difference, material harmony, or contrast. The design and the material can achieve effects such as harmony or contrast, being innovative or conservative, and mixed or single use.

Material compatibility or incompatibility differs according to the type or color of the material used in the extension. In this context, the extension can be compatible both in terms of type and color, it can be compatible only in color or type, and sometimes it can be incompatible in both respects. This compatibility or incompatibility also changes according to the perception that the designer wants to create. The effect of the material on the perception desired to be created in the extensions is high. Glass material is frequently used in refunctioning because it has more transparency and flexibility than other materials.

Glass is formed due to the sudden cooling of melted rocks due to volcanic eruptions, lightning strikes, or meteorite falls. Looking at some tools from the Stone Age, it is possible to see that glass has been used since that period (Raymond, 1961). In the 1st century BC, the invention of blown glass in the Syria/Palestine region stands out. The technique of blowing glass has the characteristic of being the first important step in the development of glass in architecture. The technique spread from Egypt and Syria and was also used for boats and large flat bowls, the precursors of windowpanes (Raymond, 1961).

It is thought that the idea of putting glass in the windows of houses came from the Romans. The 30/60 cm glass windows placed on the bronze windows in the Ancient City of Pompeii can be shown as proof of this practice. Glass has been made in increasing sizes and has been a significant component of the architecture of the great churches of eastern and northern Europe, with techniques of attachment inside buildings being developed (Lyons, 2004). With the developing technology, glass usage areas and forms have also changed.

Technological advances in glass and expanded possibilities have made this material increasingly attractive to designers. However, integrating glass and steel in a structure provides the development of contemporary goals in lightness and transparency (Sev et al., 2004). In line with the building style that the designer wants to perceive, thick and precise glass joinery is preferred in some buildings, while frameless, thinly structured glass is used in some buildings.

The reasons for the use of contemporary extensions in historical buildings are not only related to the need to visually separate the main building from the extension. Additional construction with contemporary materials and techniques is also preferred due to the fact that contemporary materials are easy to disassemble, load less on the main structure, and can be integrated into the historical structure with less intervention.

According to Zeren, in historical buildings, suffixes are generally; They are applied horizontally, vertically or both horizontally and vertically as roof completion, facade completion, transition element between two buildings, fire escapes attached to the structure, eaves elements that are articulated to the structure, and structures in the form of integrations made on the facade of the building (Zeren, 2010).

Glass used as material in architectural facades:

Sheet Glasses: They are produced in sheet form. They are used in the windows and exterior cladding of buildings.

Empire Glasses: They are glasses shaped by the pouring-rolling method. The plane is obtained by passing a metal cylinder with an indentation-protrusion pattern over the molten frit poured on a casting table. It is used for decorative purposes in places where it is not wanted to be seen.

Safety Glasses: These are the glasses that break very hard on the balcony facades, where safety is important in buildings, or that do not form cutting pieces in the materials added when broken and do not scatter. It is mostly preferred in balcony facade cladding, stairs and railings (Özalp, 2010).

In the historical process, architectural spaces with building materials such as stone, brick and concrete were completely separated and abstracted from the physical environment in which they are located, while the interior-exterior distinction was eliminated with glass materials, and the borders became more flexible. Glass material, with its transparency feature, brings about variability in perceiving space and building in architecture, abstract dimensions, and unbounded encounters.

Adding an additional structure to a building from the past means combining a completely different building with the old one in terms of construction technique, materials and design principles. The most important point here is that every modern extension to the building reflects its own period. However, it is another attitude that the new structure reflects today's life and technology within the framework of certain respect elements, without ignoring the existence of the old structure. According to research done; The sections to be made "additional" in the historical building can be classified under four main headings (Uluşahin, 1992):

- Extensions made on the roof of the historical building,
- Extensions made in the form of integration, new extension or inner shell on the facade of the historical building,
- Extensions made at the entrance of the historical building,
- Extensions made in the form of a bridge between historical buildings or between the historical building and the new building (Figure 1).

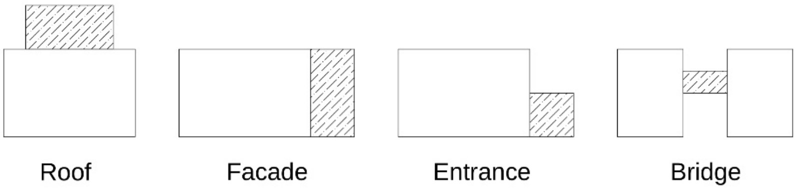


Figure 1. The sections to be made "additional" in the historical building.

In line with the perception that the designer wanted to create, the type of glass used also differed. This situation has revealed different evaluation criteria, such as the purpose of use, size, transparency, and reflectivity of glass in extensions. The study examined these criteria on examples from different regions. Looking at the examples of use of glass as a material in additional structures in historical buildings, it is seen that there are different uses. The samples examined within the scope of the study were selected by paying attention to their location in different regions, attachment locations and the use of glass materials in different ways.

3.3. Examples

Tate Modern:

Tate Modern was built in London, England between 1947-1963 by Architect Sir Giles Gilbert Scott and was formed by converting the Bankside Power Plant, the largest building in the region, into a museum. The task of transforming the building, which was closed in 1982, into a museum with the architectural project competition held in 1994, was given to the Herzog & de Meuron team (Jacques Herzog & Pierre de Meuron).

For Herzog & de Meuron in its transformation into a museum, the building's original character was key. It was designed by preserving the main elements without making too many changes in the building. The chimney, which used to be the symbol of the Bankside Power Plant, has now become the symbol of Tate Modern. The turbine hall, where the old generator room is located, has been transformed into an impressive entrance.

The main building is constructed of 200 meters long steel structure. The exterior of the building is brick. There is a 99 m. long chimney in the north direction. The Herzog & de Meuron team used 5000 tons of steel and 7200 copper plates for the new design of Tate Modern.

The most important change made in the old Power Plant building is in the roof part. A rectangular glass prism with 524 glass partitions was formed on the roof to allow natural light to enter the halls from the roof (Figure 2). Most of the natural light that enters during the day is provided by this glass prism. At night, the glass prisms on the chimney and roof are illuminated with colored lighting. Thus, the presence of the Tate Modern in the city is felt throughout the night.

Figure 2. Tate Modern (Willis, 2020).

The purpose of Tate Modern's glass extension on the roof is to let the light in from the outside. It does not have reflective properties. The transparency effect is from the outside to the inside (Uysal, 2013).

English Museum:

One of the most well-known examples of contemporary extension applications to the historical building is the contemporary roof extension of the British Museum in London, designed by Norman

Foster. With this roof extension, the courtyard was transformed into an inner courtyard, creating a large public space. This extension to the historical building, which was built in 1753, was brought in 2000. The three main purposes of this roof extension designed by Norman Foster; he explained it as creating new areas, reviewing the gaps and revealing the hidden areas. While this area in the courtyard of the historical museum building was described as a lost and unused area, it was brought to life with the contemporary roof extension and opened to active use.

With this designed roof extension, the museum structure has ceased to be just an area to visit and has offered an urban experience to its visitors. With this cover, which also contributes to human circulation and pedestrian organization, the historical structure has been successfully integrated into the city. With its contemporary material and modern curvilinear form, the roof extension, which displays a contrasting approach to the historical structure to which it was added, exhibits a respectful attitude to the surrounding texture with its mass proportions and permeability despite these features. Glass and steel are used in the contemporary crop design. In addition to emphasizing its modernity with its color and texture, it contributed to the social and cultural continuity of the historical building. At the same time, while being structurally articulated to the historical building, it brought less load and ensured that the building was affected to a minimum extent.

There is no doubt that the contemporary roof covering added to the courtyard of the British Museum contributes to the character of the museum (Figure 3).

Figure 3. English Museum glass roof extension (Kayan, 2020).

The purpose of English Museum's glass extension on the roof is to let the light in from the outside. It does not have reflective properties. The transparency effect is from the outside to the inside (Kayan, 2020).

Moritzburg Museum:

Located in Halle, Germany, Moritzburg castle is an ancient building dating from the 15th century. After the changes it has undergone over the years, the surrounding walls, towers at the corners and the central courtyard remained from the castle structure (Figure 4).

Figure 4. Moritzburg Museum glass extensions (Kayan, 2020).

Some extensions were made within the scope of restoration works in order to renew, expand and bring the historical castle structure, which was in ruins for many years, to life. In this context, the exterior wall remains of the historical building were preserved and a contemporary structure was added inside. With its modern roof and facade appearance, this new extension, rising from the ruins of the historical museum, forms the expanded exhibition areas. The angular geometry of the metal tower on the roof of the museum creates a contrasting effect with the existing irregular shape of the historical castle. This contrasting effect emphasized on the facade is also maintained in the contemporary works of art exhibited inside the historical building. The walls of the historical building can be seen from the exhibition area under the contemporary extension of the museum, and thus the historical building can be seen as a historical artifact on display.

The purpose of English Museum's glass extension on the roof and facade is to let the light in from the outside. It does not have reflective properties. The transparency effect is from the outside to the inside (Kayan, 2020).

Mill City Museum:

The mill complex, which went through many changes from the explosion in 1878 until 2000, was transformed into museum and office units by Architect Tom Meyer in 2003 by preserving the north shell of the mill, which was damaged by the fire along the river.

The Mill City Museum establishes a strong relationship with the memory of the place, as well as its industrial past, the explosion and fire event it went through. By establishing his interaction with the space through this damage and neglect, the designer Meyer aims to maintain the feeling that "the wall in the courtyard will collapse in one day" and to preserve the evocative power evoked by the ruins. In the design of the public space, which aims to maintain the spiritual atmosphere of the mill complex, where the old and the new come together and are intertwined at certain points, the conservation and restoration works, which started with the strengthening of the ruins, brought along important difficulties. Stating that these difficulties constitute the power of design, Meyer states that “difficulty reveals the meaning and purpose of the building and organizes the building, does not create it” (LeFevre, 2004).

The destroyed shell in the courtyard is completed with a glass facade and the new shell accepts the old without pretense and fuses the old and the new. The details and connections between the existing building envelope and ruins and new extensions and materials enrich the space while at the same time making the old and the new legible (Çanakkale, 2012), (Figure 5).

Figure 5. Mill City Museum glass extension (Çanakkale, 2012).

The purpose of the glass extension is to preserve the historical facade features and to create transparent spaces. Glass has no reflectivity. Transparency is inside-out and outside-in.

Esma Sultan Mansion:

Esma Sultan Mansion, built by the architect Sarkis Balyan between 1873 and 1877, is located right next to the Ortakoy Mosque in Ortakoy, Istanbul. Esma Sultan Mansion has a masonry and stone carrier system and is a three-storey masonry structure. Its high and rectangular windows are located at the same level on every facade and every floor of the historical mansion. In this way, the historical mansion receives daylight from all four sides. The priority in the restoration works of the historical building was to strengthen the thick stone walls that formed the outer shell that survived the fire. After the stone walls forming the outer shell of the historical building were strengthened, a transparent shell made of glass and steel construction was placed inside the building (Figure 6). This transparent structure is placed inside the historical building in such a way that it does not touch its walls. Although the glass structures are not suitable for hot climates, a layer is formed thanks to the existing stone walls in the outer shell, making them compatible with environmental factors such as sunlight and wind (Kayan, 2020).

Figure 6. Esma Sultan Mansion (Kayan, 2020).

The purpose of the glass used on the facade is to provide the use of view and light due to the location of the historic building. When it is evaluated in terms of glass size, it cannot be fully perceived when viewed from the outside, and when viewed from the inside, the windows and frames are visible. Thus, the landscape is used in a way that does not disturb the historic structure. When evaluated in the context of transparency and reflectivity, it is seen that transparency dominates the structure. Although it is not perceived from the outside, the transparency feature of the glass is used when viewed from the inside. Accordingly, the perception created by the glass in evaluating transparency and reflectivity in the extension is 'from the inside to the outside.

Louviers School of Music:

Louviers, an ancient monastery building complex built in 1659 in Normandy, France, has been used for many years in different functions. As a result of this, some deteriorations and destructions have occurred in the historical structure. The historical building was expanded through a re-functioning process and started to be used as the Louviers Music School. The stone appearance of the existing historical building at the Louviers School of Music and the river flowing under it were decisive in the design of the new extension. By making use of the transparent, permeable and reflective properties of glass, a contrast effect was created between the historical building and the contemporary extension. The new mass, which rises with contemporary extensions from the part of the historical building that was destroyed and lost in time, was planned in a way to highlight the river passing under it.

The additional structure, which is almost invisible by reflecting the sky on its facade during the day, makes its interior visible thanks to its illumination at night. In this way, the resulting conference hall can be perceived from the outside during event times (Figure 7). The contemporary extension, with the mirror glass material used and the modern architectural form, brings it to the forefront by creating a transparent and light effect next to the historical building it was added to (Kayan, 2020).

Figure 7. Loviers School of music (Kayan, 2020).

The glass extension of the music school can be felt from the front. Glasses have reflective properties during the day. The interior can be viewed at night. Transparency is inside-out, outside-out, and outside-in.

Louvre Museum Entry:

Pei wanted to create a transparent, sculptural effect between the historical museum structures in the middle of the courtyard for the entrance structure, which forms an underground system that includes warehouses, galleries and laboratories and also serves as a connection between the units of the historical museum structure (Figure 8).

In this direction, the entrance volume added to the historical museum was designed as a steel and glass pyramid that illuminates the sections under it. The glass pyramid, which has a height of 20.6 meters, consists of rhombus and triangular windows. Around this main pyramid are three small pyramid-shaped skylights to illuminate the other spaces below the courtyard. The glass and steel material used in the monumental pyramid, with its construction technique and architectural style, is a contemporary extension that reflects its own period. In addition to this monumental appearance, it has mass proportions compatible with the scale of the historical building to which it was added. The sloping glass walls of the pyramid refer to the mansard roof of the museum.

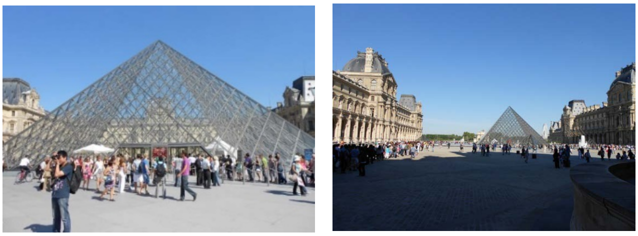


Figure 8. Louvre Museum entry glass extension (Kayan, 2020).

The transparency and permeability of the glass pyramid brought it to the forefront by contrasting the heavy and opaque character of the facade of the historic Louvre. The Louvre Pyramid has brought a lot of controversy since the day it was built. There are those who find this modern extension brought to the historical building incompatible, as well as those who see it as a successful blending of the new and the old by creating a contrast. Despite the criticism about the extension design, the Louvre Museum has become an icon and inseparable part of Paris (Kayan, 2020).

The purpose of museums entry glass extension is to let the light in from the outside. It does not have reflective properties. The transparency effect is from the outside to the inside.

Convent of St. Francesc:

Constructed in 1729 in Spain, the Convent of Sant Francesc continued to be used as a monastery until 1835. The historical building, which was in ruins because it was not used for many years, was opened in 2011 as a multi-purpose cultural center structure under the name of Sant Francesc Monastery Cultural Center after a comprehensive restoration process. In order to bring the historical building to life by preserving the interior features; Circulation elements such as ramps, stairs, which are contemporary materials made of glass and steel, and some technical units have been added to the outside of the building. The gaps formed due to the collapsed roof before the restoration were evaluated after the restoration, allowing the building to benefit from natural light. In addition, long and modern lighting elements suspended from the vaults are also included in the interior.

By using traditional and contemporary materials, which represent the past and the present, it is desired to achieve harmony from contrast. This difference has also been an approach that facilitates the differentiation of the pre- and post-restoration interventions of the building. The intense effect of the existing historical building from the stone material is balanced with the transparency of the glass material used in the contemporary extensions (Kayan, 2020).

Figure 9. Convent of St. Francesc (Kayan, 2020).

The glass extension is arranged at the entrance. When examined in the context of transparency and reflectivity, it is seen that the element of transparency is used for the building (Figure 9). When looking from the outside to the inside, a more frosted appearance is achieved by using coated glass in certain areas of the extension to the side facade. In contrast, the glass frames are hidden in certain areas, resulting in a transparent appearance. No transparency or reflectivity can be perceived in the extensions made to the ceiling. When viewed from the inside out, it is seen that there is transparency in both the facade extension and the ceiling extension. Accordingly, the perception created by the glass in evaluating transparency and reflectivity in the extension is 'from the inside to the outside' and 'from the outside to the inside.

Glass Link In Grimma Castle:

The linear layout is visible in the 13th-century Grimma Castle. The historic castle complex was renovated, reconstructed, and commissioned in 2013. The Grimma Castle became the seat of the court and the prosecutor's office. Three new glass structures were added as part of the utility function transformation. These included a glass corridor along the wall to connect the castle to the tower ruins and the entrance rooms. The link was almost 25 m long, and its structure was made of glass frames with a span of 2.5 m, spaced every 1.5 m. The link, perceived as neutral, was led along the northern wall of the castle.

Hence, it was decided that the connection between the parking lot and the shopping centre building, whose characteristic glass facade was decorated with an ornamental print, would be implemented with a glass housing. Due to the significant distance between the connected buildings, it was necessary to shape the footbridge structure to avoid intermediate support. To eliminate the need to introduce additional support in the Vaughan Way bypass and simultaneously reduce the footbridge span, a cantilever truss was designed to be anchored in the reinforced concrete frame of the shopping centre building. The funnel-shaped truss was introduced into the building body. This solution allowed for a smooth connection between the footbridge and the shopping mall in terms of functionality. The effect of the applied solution is also visible on the facade of the John Lewis Department Store (Jozwik, 2022), (Figure 10).

Figure 10. Glass link in Grimma Castle (Jozwik, 2022).

On the other hand, the footbridge was designed with an extended pier whose interior extends from the side of the car park. From the outside, its end corresponds with the glass facades of the car park. The self-supporting glass structure of the footbridge housing con- sists of glass beams that transfer loads to the walls of its housing; the structure cooperates with a steel railing mounted in the footbridge structure (Jozwik, 2022). The glass add-on establishes a link between historical buildings and new glass extensions. It has no reflective feature. Transparency is inside-out and outside-in.

4. Conclusion

Within the scope of the study, nine different examples, which were refunctionalized and added to the extension due to the new function requirement, were examined. All the examined structures were compared according to the order of explanation and evaluated in the Table 1.

Table 1. Comparison of examples

Buildings	Extension Position	Use Of Glass	Reflectivity	Transparency
Tate Modern	Roof	Lighting	None	Outside to Inside
English Museum	Roof	Lighting	None	Outside to Inside
Moritzburg Museum	Roof + Facade	View, Lighting, Function	None	Inside to Outside, Outside to Inside
Mill City Museum	Facade	View, Lighting, Function	None	Inside to Outside, Outside to Inside
Esma Sultan Mansion	Facade	View, Lighting	None	Inside to Outside
Louviers School of Music	Facade	View, Lighting, Function	Yes	Inside to Outside, Outside to Inside, Outside to Outside
Louvre Museum	Entry	View, Lighting	None	Inside to Outside, Outside to Inside
Convent of Sant Francesc	Entry	View, Lighting	None	Inside to Outside, Outside to Inside
Grimma Castle	Bridge	View, Lighting, Function	None	Inside to Outside, Outside to Inside

Examined examples differ in terms of the way the extension is added, its dimensions against the historical building, and the dimensions of the glass used. However, the purpose of the use of glass also varies in terms of transparency and reflective properties. If these differences are compared in terms of the examined structures;

- The location and size of the add-on differ according to the relationship between the old and new functions of the structure. While the dimensions of the glass masses are larger in the roof and facade extensions, the entrance and bridge extensions are smaller.

- Facade add-ons differ in themselves. Moritzburg and Mill City Museums were used as an integral part of the glass facade. In the Loviers Music School, the glass add-on was added to the facade as a separate building in order to enlarge the space due to the lack of functionality. A glass facade was designed to create a transparent shell inside the historical outer walls, which are the only remains of Esma Sultan Mansion.
- It has been observed that glass attachments are supported by different frames in all structures. The frames of all glass add-ons are in a grid pattern, except for the entrance add-on examples and the British Museum roof add-on. With the examples of entrance attachments, the frames in the British Museum's roof extension were created at different angles to create a dynamic appearance.
- While glass material is preferred especially for the use of natural light in roof attachments, the most important use for all other add-ons is to let daylight in. The historical buildings and the view of the historical environment in the facade, entrance and bridge add-ons are also one of the purposes of use.

Although no generalization can be made for the glass dimensions, it varies according to the nature of the building and the designer's intended use. In connection with this, it has been observed that in the samples examined, the glass is framed or unframed, and its perception from the inside or outside is different.

- Judging by the reflection situation, all glass inserts do not have reflective properties, except for the Loviers School of Music. Since the glass add-on on the Loviers Music School facade is large enough to compete with the historical building, it may have been desired that the add-on reflect the historical environment and sky during the day and not reflect the function at night so that it can be perceived.

- Considering the transparency situation, although all the buildings have differences from each other, less transparency is felt in the roof extensions. It has been observed that all of the facade, entrance and bridge extensions are transparent, and transparency is perceived both from the inside to the outside and from the outside to the inside. Loviers Music School has different transparency features according to day and night.

It is understood that in line with the examples examined, it serves to perceive the historical building, which has been refunctionalized with the use of glass material, or to stand out, draw attention and emphasize the added sections. In this case, it is seen that the material itself, how it is used, and how it comes together with other materials become important.

Based on these evaluations, the use of glass material has an important effect on the role of refunctioning in bringing together the historical and the modern, the old and the new, and the past and the future.

Acknowledgment and Information Note

The article complies with national and international research and publication ethics. Ethics committee approval was not required for the study.

Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. There is no conflict of interest.

References

Casakin, H. P. (2006). Metaphors as an unconventional reflective approach in architectural design. *The Design Journal* 9(1), 37-50.

Çanakkale, E. (2012). *Endüstri mirası kapsamındaki yapıların korunarak yeniden değerlendirilmesinde tasarımcı-mekan etkileşimi.* (Yüksek lisans tezi) İstanbul Teknik Üniveristesi, Fen Bilimleri Enstitüsü, İstanbul.

Eryiğit, Z.B. & Anıktar, S. (2021). Yeniden işlevlendirilmiş endüstri yapılarında mekân algısı. *İdealkent Dergisi*, 32(12), 708-734.

Feilden, B. (2003). Conservation of historic buildings. London: 3rd edn. Routledge.

Gazi, A. & Boduroğlu, E. (2015). İşlev değişikliğinin tarihi yapılar üzerine etkileri "Alsancak Levanten evleri örneği. *Megaron Dergisi*, 10(1), s.57-69.

Jozwik, A. (2022). Application of glass structures in architectural shaping of all-glass pavilions, extensions, and links. *Buildings*, 12, 1254.

Kayan, L. E. (2020). *Tarihi yapılardaki çağdaş eklerin koruma ve tasarım bağlamı üzerine bir araştırma.* (Yüksek lisans tezi) Fatih Sultan Mehmet Vakıf Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul.

Kurnaz, A. & Aniktar, S. (2023). From power plant to energy museum: Spatial perception of Santralistanbul". *Digital International Journal of Architecture Art Heritage*, 2(2), 43-67.

Kurnaz, A. & Aniktar, S. (2023). "Examination of rural architecture that shapes sustainable tourism in emerging economies through stakeholder perspectives: Sile, Istanbul," *Current Issues in Tourism,* 1-17.

LeFevre, C. (2004). Mill City Museum, Minneapolis. *Architectural Record*, February 122-126.

Letzter, J. & Neuman, E. (2022). Addition to historic building: A hermeneutic interpretation. *Cogent Arts and Humanities* 9(1).

Lyons, A. (2004). Materials for architects & builders. 2nd edn.

Özalp, H. (2010). Mimarlık ve İç Mimarlıkta tasarım elemanı olarak cam. *Uluslararası Katılımlı Uygulamalı Cam Sempozyumu*, Anadolu Üniversitesi, Eskişehir.

Raymond, M. (1961). Glass in architecture and decoration. London: The Architectural Press.

Sev, A, Gur V., Ozgen, A. (2004). Cephenin vazgecilmez saydam malzemesi cam. *National Construction Materials Congress*.

Uğurlu, E. & Böke, H. (2009). Tarihi yapıların özgün değerleri ile korunması. *Journal of Restoration and Conservation Studies*, 1(2), 17-19.

Turanlı, A. & Satıcı, B., (2021). Tarihi yapıların yeniden işlevlendirilmesi: Hayriye Hanım Konağı örneği. *Journal of Technology and Applied Sciences* 4(1), 57-71.

Uluşahin, H. (1992). Korunması gerekli bina ve çevreler yapılan eklerin değerlendirilmesi. İTÜ Yayınları, İstanbul.

Uysal, M. (2013). *Müze tasarımında ortaya çıkan kriterler.* (Yüksek lisans tezi) Gazi Üniveristesi, Fen Bilimleri Enstitüsü, Ankara.

Ünlü, B. & Ünver, R. (2019). İşlevi değişen yapılarda aydınlatma - Myrelaion Sarnıcı. 1. *Mimarlık ve Şehircilik Lisansüstü Sempozyumu*, YTÜ, İstanbul.

Venedik Tüzüğü (1964). Uluslararası tarihi anıtları koruma kuralları.

Willis, S. (2020). From https://www.timeout.com/london/news/the-tate-modern-and-tate-britain-reopen-in-london-today-072720, (Retrieved: 05.07.2023)

Zeren, M. T. (2010). Tarihi çevrede yeni ek ve yeni yapı olgusu. Yalın Yayıncılık, İstanbul.

Serhat ANIKTAR

E-mail: serhat.aniktar@izu.edu.tr

Educational Status

BSc: Yıldız Technical University, Faculty of Architecture, Department of Architecture, 2005.

MSc: Yıldız Technical University, Institute of Science, Computer Design Master's Program, 2008.

PhD: Yıldız Technical University, Institute of Science, Architectural Design PhD program, 2017.

Professional Experience: Research Assistant, Istanbul Sabahattin Zaim University, (2012-2015), Lecturer, Istanbul Sabahattin Zaim University, (2015-2017), Asst. Prof. Dr., Istanbul Sabahattin Zaim University, (2017-).

Ahmet KURNAZ

E-mail: ahmet.kurnaz@izu.edu.tr

Educational Status

BSc: Middle East Technical University, Faculty of Architecture, Department of Architecture, 2013.

MSc: Yildiz Technical University, Institute of Science, Architectural Design Master's Program, 2021.

PhD: Istanbul Sabahattin Zaim University, Graduate Education Institute, Department of Architecture, continue.

Professional Experience: Res. Asst., Istanbul Sabahattin Zaim University, (2018-)

Architectural Sciences Sustainable Materials and Built Environment

İKSAD
Publishing House