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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 7th 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 hope that our book "ARCHITECTURAL SCIENCES and BUILDING MATERIALS" will be useful to readers.

Best regards.

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Sustainable Innovative Materials in Architecture

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1. Introduction

Worldwide, the share of the building sector in energy expenditures has exceeded 30%, and its share in electricity consumption has exceeded 50%. However, one third of carbon emissions originate from the construction sector (Kabakçı, 2019). One of the main factors affecting this consumption in the building sector is the rapid population growth and the increasing structuring to meet the housing demand it brings (Gallo & Romano, 2017).

In addition to energy costs, the share of the construction sector in material consumption is quite large. For this reason, material selection in building design is one of the issues that should be emphasized. Features such as the strength, functionality and aesthetics of the building are closely related to the selected building material. On the other hand, the amount of energy consumed by the building and its environmental effects increase or decrease according to the properties of the selected material. Therefore, with the material selection decisions to be made at the design stage, it can be ensured that the structure has high performance properties in terms of energy efficiency.

The search for solutions against the destructive effects of the construction industry on the environment has brought new discoveries in the fields of art and science (Lodson & Jahromi, 2017). In addition, it is seen that construction systems and materials are diversified with innovative approaches in the light of technological and scientific developments. In addition to the construction sector, great importance is attached to the use of innovative and smart materials in order to increase environmental sustainability, cost effectiveness and safety in many sectors.

The concept of sustainability refers to the continuity of ecological systems and the capacity to carry them to the future in architecture as in every field. The main purpose in sustainable architecture is to reduce energy costs by centering the use of renewable energy sources, to offer users healthy and comfortable spaces, and to minimize the damage to ecology. In addition to the construction systems, the sustainable nature of the building materials used in architecture reveals a holistic design.

Sustainable building material; minimum energy cost during production and use, ease of renewal and repair of the material, recycling and reuse of the material that has completed its life, etc. within the framework of the issues, the building should ensure the economic, environmental and social sustainability of the life cycle (Abyzov, Pushkarova, Kochevykh, Honchar & Bazeliuk, 2020). Today, there are innovative materials produced in the light of modern technological developments, including traditional materials, among sustainable building materials. In the modern scientific literature, there are different views on the typology of innovative building materials. According to Ritter (2007), innovative materials are classified under 9 headings according to their properties and structures. These are recyclable materials, biodegradable materials, biomaterials, nonvariable materials, functional substances, smart materials, hybrid materials, functionally gradient materials and nanomaterials.

Innovative materials can provide ease of application and use, as well as environmental and economic benefits such as carbon emissions, energy production and reduction of product usage costs. Innovative building materials can be produced with a completely new and different raw material, as well as by integrating new features into traditional building materials with a technological and utilitarian approach. From this point of view, the aim of this study; to identify innovative building materials with a high sustainable capacity and to examine their use in architecture.

2. Material and Method

The study was designed with a descriptive design to provide a perspective on the innovations brought by today's technology in building materials. The study was handled in a qualitative framework and was carried out with document analysis and literature review. Document analysis includes the analysis of visual materials such as films, videos, photographs, as well as written sources containing information about the phenomenon or phenomena to be researched (Yıldırım & Şimsek, 2011). The literature on the subject was reviewed by using articles, theses, books and online resources. Innovative building materials identified as a result of research and scanning; polluted air\self-cleaning materials, materials that reduce carbon emissions, energy-producing materials and materials that provide insulation were examined under 4 groups. The architectural application possibilities of the examined innovative materials are presented through examples and the advantages they offer in terms of sustainability are discussed.

3. Findings and Discussion

Innovative building materials are developed within the framework of technological and scientific innovations to be used in many areas such as carrier system, building elements, building components, interior design in architecture. The materials examined within the scope of the study are listed in Table 1. These materials have been handled in a wide range in terms of their contents and properties.

Table 1. Sustainable Innovative Building Materials

Sustainable Feature	Name of Material
Polluted air\self-cleaning materials	Photocatalyst TiO_2 coated surfaces
	Superhydrophobic surfaces
Materials that reduce carbon emissions	Bendable concrete
	Bricks Breathe
Energy-producing materials	Solar tile
	Light-emitting concrete
Materials that provide insulation	Magnesite building sheet
	Aluminum foam
	Aerogels
	Transparent wood

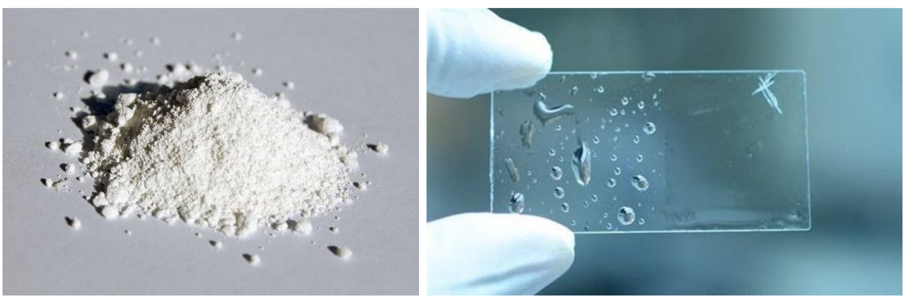
3.1. Polluted Air\Self-Cleaning Materials

Polluted air or self-cleaning of materials is explained by nanotechnology. Derived from the word "nano", meaning one billionth of any physical size, nanotechnology was born from the use of individual atoms and molecules to create functional structures (Gordijn, 2005). Nanotechnology has emerged in the construction industry in the form of nanomaterials and the development of technology (Gür, 2010). Nanotechnology in architecture; It brings innovations in terms of durability, lightness, construction system, continuity of the shell, permeability, changing and developing forms (Johansen, 2002). Advantages of nanotechnology in the construction industry; self-cleaning surfaces, easy-to-clean surfaces, materials that improve air quality by cleaning the air, antibacterial materials, etc. appears in many forms (Gür, 2010; Demirdöven & Karaçar, 2013).

One of the examples of self-cleaning materials is materials whose surface is coated with photocatalyst titanium dioxide (TiO_2) (Figure 1). Photocatalyst nano coating; It is a special photocatalyst nano-coating combined with TiO_2-based nano-level particles. TiO_2 becomes superhydrophilic when exposed to light. This feature of TiO_2 provides non-fogging and self-cleaning surfaces (Wang, et al., 1997). Dirt and dust flow with rain on photocatalyst-applied surfaces. TiO_2, which can be applied to glass, ceramic, metal etc. surfaces, has the ability to clean the air by neutralizing nitrogen oxides in the air as well as self-cleaning

(Orhon, 2013). It is produced as a coating material or by adding pigment to the material.

(a)



(b)

Figure 1. (a) Photocatalyst TiO_2 Glass Coating Before and After Application (Url-1) **(b)** TiO_2 Powder and Photocatalyst Coated Glass (Url-2)

Examples of TiO_2 coated facade applications are the MSV Arena in Germany and the Bertram and Judith Kohl Building in the USA (Figure

2). Photocatalytic solar control glasses were used in MSV Arena, and photocatalytic aluminum facade panels were used in Bertram and Judith Kohl Buildings.

(a) **(b)**

Figure 2. (a) MSV Arena, Germany, 2004 (URL-3) **(b)** The Bertram and Judith Kohl Building, United States, 2010 (Url-4)

Another material with self-cleaning feature is materials with superhydrophobic surface properties. The water repellent feature of superhydrophobic surfaces is called the "Lotus Effect" (Barthlott & Ehler, (1977). Today, exterior paints with lotus effect are used. It is applied to masonry surfaces such as concrete, stone, masonry with a brush, roller or airless spray (Orhon, 2013). One of the examples of the application of hydrophobic paint with lotus features is the Ara Pacis Museum in Italy (Figure 3). Designed by Richard Meier, the building is white in color, and superhydrophobic paint is used on its façade to prevent contamination.

Figure 3. Ara Pacis Museum, Italy, 2006 (UrL-5)

3.2. Materials That Reduce Carbon Emissions

Carbon emissions are directly related to urbanization and the accompanying increase in energy consumption. Therefore, in line with the sustainability approach, which has an important place in the construction sector, it has become necessary to make applications to reduce carbon emissions. The studies developed for this purpose in the building sector necessitated the design and revision of building materials with an environmentally friendly approach.

One of the innovative materials developed to reduce carbon emissions is bendable concrete (Figure 4). Concrete is one of the most used building materials in the world, but it is not bendable. In addition, the cement used in concrete production is produced at very high temperatures and causes an increase in the greenhouse gas effect. Developed to increase the tensile strength of concrete, bendable concrete also prevents carbon emissions by reducing the amount of cement use. The raw material of flexible concrete consists of fly ash from burning coals and synthetic fibers. Thus, while the concrete gains

400 times more bendability, it also reduces carbon emissions by 76% (URL-6). Thanks to the bending feature of concrete, it will also be possible to produce structures that are resistant to earthquakes.

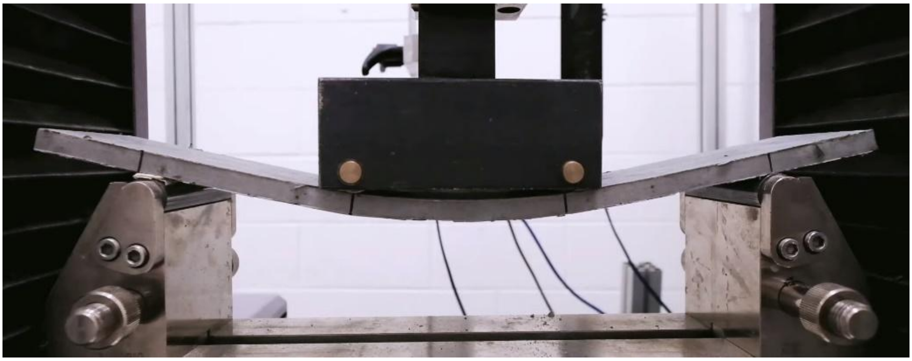


Figure 4. Bendable Concrete (Url-6)

Another material that reduces carbon emissions and cleans polluted air is pollution-absorbing bricks (Figure 5). These innovative bricks are manufactured to work as part of the building's ventilation system, absorbing atmospheric pollutants before releasing the filtered air. As a result of the tests, it has been seen that it has the capacity to filter 30% of fine pollutant particles and 100% of coarser particles (Url-7).

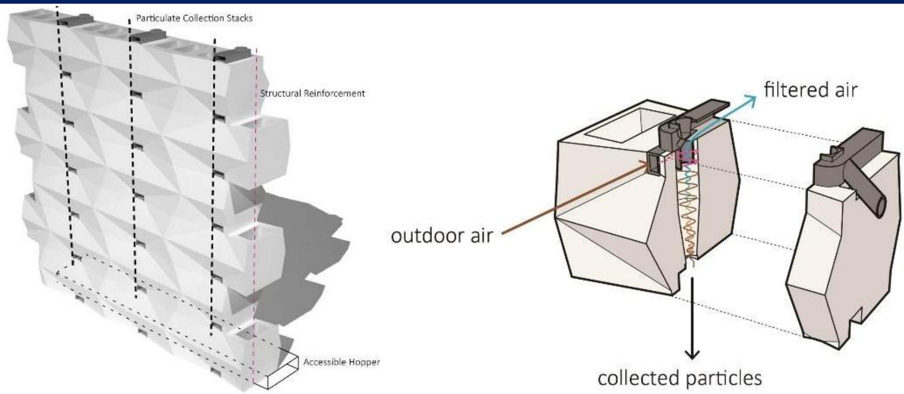


Figure 4. Bricks Breathe (Url-7)

3.3. Energy-Producing Materials

In recent years, when the energy requirement has increased considerably, it has been understood that fossil fuels are not environmentally friendly and alternative energy sources should be used instead (Dikmen, 2011). In this context, some searches have been made to reduce the damage to the environment with the use of renewable energy sources. Renewable energy resources are clean energy resources that exist in nature and maintain their continuity by renewing themselves, and can be supplied as long as the world exists. The main ones are solar, wind, geothermal, biomass and water energy (Uslusoy, 2012).

In the production of building materials, the integration of systems using solar energy among renewable energy sources into the material has been frequently used in recent years. One of the innovative materials produced for this purpose is solar tile. Solar tile can be produced in two ways. One method of producing solar tiles is to integrate a photovoltaic panel into a conventional tile (Figure 6). In this method, a photovoltaic panel is placed in the partition arranged on the tile. The other method is to produce tiles with photovoltaic panel feature (Figure 7). In this system, the roofing material is produced as a photovoltaic panel.

Figure 6. PV Integrated Tile (Url-8)

Figure 7. Solar Roof Tile (Url-8)

In this system, which produces the necessary energy for the building by converting the sunlight it receives into electrical energy, each tile is connected to the power distribution panel with cables (Alim, et al., 2020). Unlike traditional solar energy systems, this system does not require large system elements on the roof, prevents visual pollution and provides an aesthetic appearance. It also protects the photovoltaic system on the roof from weather conditions such as rain and wind.

Another material that provides energy production by utilizing solar energy is light-emitting concrete (Figure 8). Developed by scientist José Carlos Rubio, the material provides illumination by releasing solar energy stored during the day, at night. It has the ability to emit light for 12 hours during the day with the energy it stores. The material contains sand, silica, industrial waste, alkali and water. To impart the light-emitting property, the materials are subjected to a polycondensation process carried out at room temperature. The only residue left from the manufacture of the material is steam. Therefore, it is a sustainable material as it saves energy and does not cause waste. The material can be produced in green and blue for now (Url-9).

Figure 8. Light-Emitting Concrete (Url-9)

3.4. Materials That Provide Insulation

Energy efficiency is of great importance in the process of providing comfort conditions in buildings. Especially the heat losses and gains in the building envelope increase energy consumption. At this point, it is necessary to prevent the passage of heat between indoor and outdoor spaces by means of passive systems. One of the innovative materials produced to provide insulation in buildings is magnesite construction board (Figure 9). This board has many features such as A1 class flammability, waterproof, impact resistance, heat and sound insulation. It can be used in many building components such as exterior cladding, interior partition wall, ceiling, raised floor system. At the same time, the sheet, which does not emit harmful and toxic gases, prevents the formation of mold, fungus and bacteria in humid environments (Url-10).

Figure 9. Magnesite Building Board (Url-10)

Another innovative building material is aluminum foam (Figure 10). This material is produced by making aluminum or aluminum alloy powders porous at high temperature using foaming materials (TiH_2, $CaCO_3$). Aluminum foam has superior physical and mechanical properties such as low density, high specific stiffness and high absorbency (Deng, et al., 2020). It is produced in three different densities as large, medium and small cell. Aluminum foam, which can be used as insulation material because it reduces sound and vibration, also does not contain toxic content and is 100% recyclable. It is seen that aluminum foam is used both as a building envelope and indoors at the CaixaForum Sevilla Cultural Center in Spain (Figure 11).

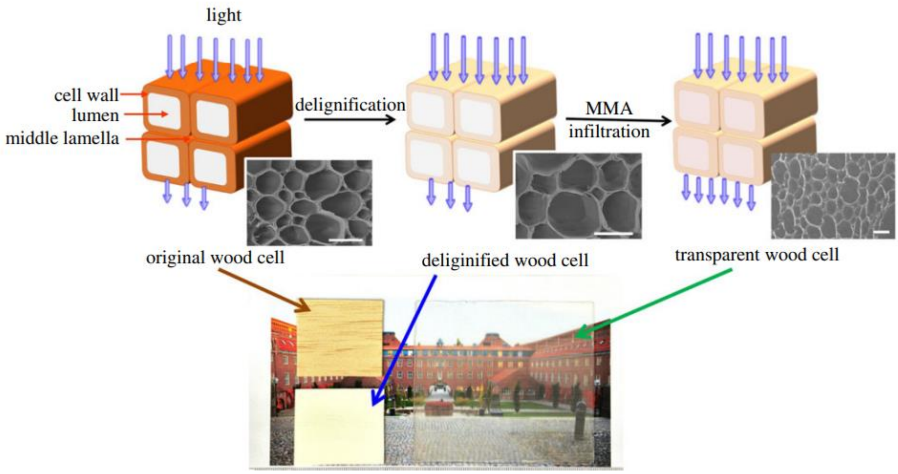
Figure 10. Aluminum Foam (Url-11)

Figure 11. CaixaForum Sevilla, Spain, 2017 (Url-12)

Another innovative material that has better properties than traditional insulation materials and has been developed by utilizing nanotechnology is aerogels (Figure 12). It is used as an insulation material in buildings, especially in order to reduce heat losses in facade cladding and to provide less energy consumption. Aerogels are solid materials that are formed by the displacement of the liquid substance it contains during the synthesis and the air. Due to the high amount of pores in its structure, it has the feature of being much lighter and more insulating than other insulation materials. Despite its low strength, it can carry 1000 times its own weight. It is therefore one of the lightest yet most durable materials. In addition, it has hydrophobic, fire resistant, reusable, crushproof and formless properties, ease of storage, transportation and assembly. In addition, it does not harm human health because it is not toxic, does not contain carcinogenic substances, and silicas are not absorbed by the skin (Özçelik, Soylu & Atmaca, 2017; Gürsoy, 2019).

Figure 12. Aerogel (Url-13)

Wood is one of the most sustainable traditional building materials. The opaque structure of wood has limitations in terms of daylight effectiveness, especially in its use as a facade material. Developed to avoid this limitation, transparent wood is formed as a result of the reaction of lignin in the wood structure with hydrogen peroxide (Figure 13) (Li, et al., 2017). Transparent wood has been developed as a more sustainable and insulating material compared to glass and plastic. It helps to increase both daylight and heat insulation efficiency by using it instead of glass and plastic on building facades. Thus, transparent wood is brought to the building sector as an energy efficient material.



(a)

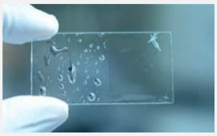
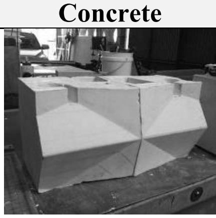
(b)

Figure 13. (a) Sketchshowing Transparent Wood Preparation (Li, et al., 2017) **(b)** Transparent Wood (Url-14)

4. Conclusion and Suggestions

The materials and their properties examined within the scope of the study carried out in order to determine the sustainable and innovative materials developed in the construction sector in recent years are given in Table 2.

Table 2. Properties of Examined Construction Materials

Innovative Material	General Features	
 **Photocatalyst TiO_2 Coated Surfaces**	**Usage Area**	• Building shell (on glass, ceramic, metal etc. surfaces) • Ground
	Physical characteristics	• Nanoparticle structure
	Chemical Properties	• Non-staining • Light sensitivity
 **Superhydrophobic Surfaces**	**Usage Area**	• Building shell (on masonry surfaces) • Ground
	Physical characteristics	• Gel or liquid
	Chemical Properties	• Non-staining • No water retention • Self cleaning
 **Bendable Concrete**	**Usage Area**	• Carrier system
	Physical characteristics	• High tensile strength
	Chemical Properties	• Low carbon emission
 **Pollution Absorbing Brick**	**Usage Area**	• Partition wall
	Physical characteristics	• Porous structure
	Chemical Properties	• Filtering the dirty air
 **Solar Tile**	**Usage Area**	• Roof
	Physical characteristics	• Transparent or opaque appearance
	Chemical Properties	• Collecting the daylight • Photovoltaic feature

 **Light-Emitting Concrete**	**Usage Area**	● Building shell ● Ground
	Physical characteristics	● Resistance to chemical effects and UV rays ● Non-crystalline structure ● Transparent and glossy appearance
	Chemical Properties	● Daylight storage ● 100% recyclable ● Non-toxic content
 **Magnesite Building Board**	**Usage Area**	● Building shell ● Partition wall ● Ceiling ● Floor
	Physical characteristics	● Thermal insulation ● Sound insulation ● A1 class flammability ● Waterproof ● Impact resistance
	Chemical Properties	● Does not release toxic gas ● Prevents the formation of mold, fungus, bacteria
 **Aluminum Foam**	**Usage Area**	● Building shell ● Indoor wall
	Physical characteristics	● Porous and flexible structure ● Low density ● High specific hardness ● High absorption ability ● Sound insulation
	Chemical Properties	● Non-toxic content ● 100% recyclable
 **Aerogel**	**Usage Area**	● Building shell
	Physical characteristics	● Thermal insulation ● Porous and light structure ● Impact resistance ● Fire resistance ● Hydrophobic
	Chemical Properties	● Recycleable
	**Usage Area**	● Buuilding shell ● Indoor wall ● Building components such as windows and doors

Transparent Wood	**Physical characteristics**	● Thermal insulation ● Fire resistance ● Transparent appearance
	Chemical Properties	● Recycleable

The awareness of the destructive effects of the construction industry on the environment in recent years has led manufacturers to seek to produce building materials that are more sustainable, environmentally friendly and do not harm human health. The sustainability of the material as well as its functionality and durability has begun to be accepted as a design criterion. Along with this orientation, developments in the world of technology and science have also made significant contributions to the production of innovative and sustainable materials in the construction industry.

Within the scope of the determinations made, it is seen that innovative materials are mostly used in the building envelope, as a facade cladding material or integrated into the cladding material. Considering that buildings are the areas where energy losses and gains are experienced the most, the development of such innovative materials to provide more environmentally friendly and energy efficient features to the building envelope is extremely important in terms of both environmental sustainability and human health. In addition to the building envelope, it has been determined that it is used in many building units indoors and outdoors (Table 3).

Table 3. Usage Areas of Examined Building Materials

Usage Areas of Materials	● Carrier system ● Building Shell ● Exterior flooring ● Roof ● Ceiling	● Floor ● Indoor wall ● Divider wall ● Building components

The examined materials are shaped and produced on the basis of sustainability principles in terms of their physical and chemical properties. The contents of the materials help to protect human health and the continuity of resources throughout the entire life cycle of the structures. In terms of physical properties, there is a tendency to add structural flexibility and lightness to materials in general. Similarly, it is aimed that the materials will be long-lasting and sustainable by increasing the level of resistance against external factors (Table 4).

Table 4. Physical Properties of Examined Construction Materials

Physical Properties of Materials	● Particulate structure ● Porous structure ● Gel, liquid or solid ● High tensile strength ● Transparent or opaque ● UV resistance	● Thermal insulation ● Sound insulation ● Non-flammability ● Waterproof ● Impact resistance ● Low density ● High specific hardness

It has been determined that frequently used building materials such as concrete, glass and wood have been given features that will contribute to sustainability with some chemical interventions (Table 5). In contemporary materials, it is seen that energy efficiency and the production of materials with healthy content come to the fore, as well as functionality.

Table 5. Chemical Properties of Examined Construction Materials

Chemical Properties of Materials	● Non-staining ● No water retention ● Light sensitivity ● Self cleaning ● Low carbon emission ● Non-toxic content	● Filtering the dirty air ● Daylight collection/storage ● Photovoltaic feature ● 100% recyclability

In addition to newly developed materials, the properties of traditional building materials also need to be improved and developed within the scope of sustainability. It should be among the priorities of the manufacturers that the materials, which are widely preferred due to their features such as easy availability, low cost, and ease of application, have an environmentally friendly content in the production process.

While innovative materials can be preferred due to their positive effects on nature and human health, they also carry the risk of not gaining enough space in the construction sector due to high costs. Therefore, it is extremely necessary to carry out studies on making innovative building materials more affordable and more accessible in order to prevent environmental problems.

Thanks 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 Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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The Importance of Nanotechnological Materials in Interior Design

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1. Introduction

Nanotechnology is a growing interdisciplinary technology often seen as a new industrial revolution. Nanotechnology (NT) deals with materials 1 to 100 nm in length. Nanotechnology refers to the techology dealing with nanometer scaled structures. In modern day, nanotechnology gains strategic importance for many countries whereas the developed states focus this case day by day through determining primary scopes. Nanotechnology also includes nanostructure together with the design, manufacture and application of nano materials. In this respect, this study intends to research nanotechnology and its influence on construction materials in addition to the analysis of application ways in designing spaces and future impacts (Kasap, 2012).

In recent years, the textile industry has development the possibilities of nanotechnology. With the development of nanotechnology in textile, it develops chemically and technologically and brings innovation to also in material technology.

1.1 Nanotechnological Materials and Properties of Nanomaterials

Nanostructured materials science and technologies, “nanoscience” and “nanotechnology” It forms the main structure of the fields and constitutes the most basic core. Basically any species less than 100 nanometers in at least one dimension. materials can be defined as "Nano Structured Materials". Metallic, ceramic, polymeric and composits can clasified as material classification, Its application and use as a "nano-structured material" at nanoscale.

Figure 1. The schematic representation of the fabrication process of superhydrophobic nanocoatings (Yılmaz & Yorgancıoğlu, 2019)

2. Material and Method

As a study method, first of all, literature review was made. canning of both books and Internet resources in the sections where nanotechnology, space design and future concepts are processed.

3. Findings and Discussion

The purpose of the discussion is superior performance materials and systems the fact that it is producible also significantly affects architectural structures. This study the purpose of nanotechnology as a technology of our time and the structure of nanotechnology it is the study of the importance of the effects of materials on the field in terms of space design.

3.1. Areas of application and methods of nanotechnological materials

For the designer, knowing the properties of materials, it has a great importance.When starting to create a designer space, designers have to think about the material which has a technological properties to achieve a successful result. When defining the material in the formation of space know which property of the material is suitable and where to position it correctly is required. These features, the lotus effect of self-cleaning, self ability to clean photocatalysis effect, easy cleaning (etc), cleaning the air, anti-fog effect, fragrance capsules, thermal insulation vip effect (vacuum insulation panels), thermal insulation aerogel effect, temperature regulator pgms, uvprotective, sunscreen, fire protector, anti-graffiti, anti-reflective, it is anti-bacteria, anti-handprint, scratch and abrasion resistance.

3.2. Self-cleaning (lotus effect) nanomaterials

The lotus effect refers to self-cleaning properties that are a result of ultrahydrophobicity as exhibited by the leaves of lotus flower. Dirt particles are picked up by water droplets due to the micro- and nanoscopic architecture on the surface, which minimizes the droplet's (Figure 2) adhesion to that surface (Anonymous,2022).

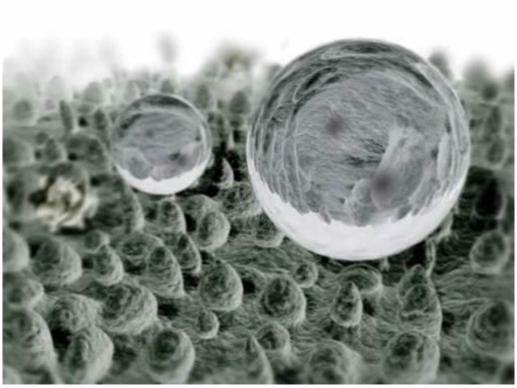

Figure 2. Lotus Effect and Self Cleaning (Anonymous, 2022)

Ara Pacis Museum, Rome Italy

Dense Located in an area with air pollution, the white facade building (Figure 3) has its own Thanks to the transparent nanomaterial with self-cleaning feature, the façade protection of its color is ensured (Gür, 2010).

Figure 3. Ara Pacis Museum, Richard Meier (Anonymous, 2022)

The design of the new museum (Figure 3) is of the highest quality, as are the first class materials that were used to build it. The materials were chosen with a view to integrating the building with its surroundings: the travertine gives continuity in the colour scheme, the plaster and glass, which create a two-way transition between the interior and exterior, give a contemporary effect of volume and transparency, simultaneously full and empty (Anonymous, 2022).

3.3. Self-cleaning (photocatalysis effect) nanomaterials

Self-cleaning by photocatalysis is the most common nanotechnology in building construction. used as a feature. Reactions of photocatalysis with light on material surfaces such as glass, membrane, air combustion of organic impurities and gases on the surface together with moisture and oxygen (Figure 4).

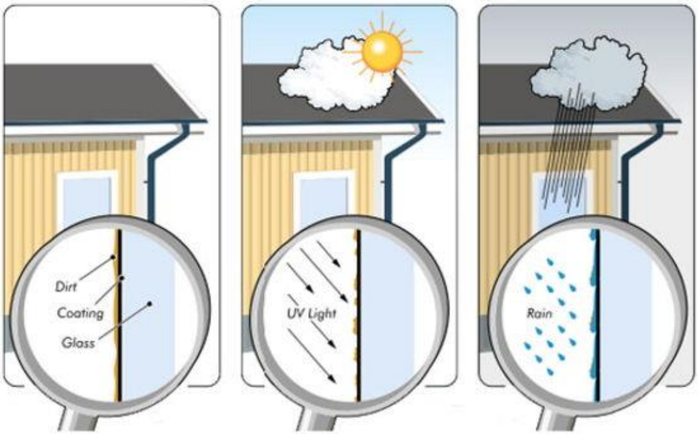

Figure 4. Rainwater Washes Away with Self-Cleaning Effect (Midtdal & Jellea, 2012)

Muhammed Ali Center MAC, Louisville, Kentucky, USA

The famous boxing legend Muhammad Ali, built by turning it into reality MAC, as an international cultural center, with a respected understanding of individual skills supports it. MAC, which is more than a museum, offers various seminars, films, it offers spaces for symposiums and exhibitions. Because of this central facade (Figure 5) it attracts attention with its striking appearance. Ceramic tiles with different color polish which it is arranged by creating a special texture with grids. Tiles, photocatalytic it is prepared with a self-cleaning surface coating (Anonymous, 2022).

Figure 5. Muhammad Ali Center MAC, Louisville, Kentucky, USA (Anonymous, 2022)

3.4. Easy-to-clean (ETC) nanomaterials

Easy to clean feature mixed with self-cleaning feature surfaces with water-repellent properties. The surfaces of these materials are rough instead of being flat, it has a flat structure and thanks to a lower gravitational force it allows water to be removed from the surface by forming drops (El-Samny, 2008). This Such surfaces have both hydrophobic (water repellent) and oleophobic (oil repellent) properties.

Kaldewei Competence Center, KKC, Ahlen, Germany

Figure 6. Kaldewei Competence Center, KKC, Ahlen, Germany (Anonymous, 2022)

The Kaldewei Kompetence Center in Germany (Figure 6) is the center for goods manufactured by Kaldewei. exhibitions, courses, meetings, individual and group visits, It is a building where activities and various tests are carried out on products. Easy steel strips of white, blue and brown coated with a cleaned material are the elements that make up the façade (Figure 6).

3.5. Nanomaterials to clean the air and ımprove air quality

Photocatalysis, which is important in self-cleaning nanomaterials, is the ability to improve air quality boosting is also important in nanomaterials.

The function of improving air quality helps to eliminating bad odors separation of components or some dirt in the air of some building materials, it is realized by absorbing particles such as dust.

Jubilee Church, La Chiesa del Dio Padre Misericordioso, Rome,Italy

Figure 7. Jubilee Church, La Chiesa del Dio Padre Misericordioso (Archdaily, 2009)

Jubilee church is thought to consist of some basic elements such as cube and sphere, as well as the space between them (Archdaily, 2009). Meier pays attention to the pure architectural space and volume, stressing the interspersing effect of solid and void.

The use of three sail-shaped surface to enclose the main structure of the church space, not only the appearance is unique, but also the internal space is full of change, satisfying the requirement of the mysterious atmosphere in religious buildings. Besides, the use of vertical space inside the church and the reflection of natural light achieve the effect of light and shade, which also enhances the sacred feeling in the church (Archdaily, 2009).

The Jubilee Church was built with white walls made of special concrete. draws attention high-density concrete and white in 1996. The success of his building is carrara marble and titanium dioxide added to the mix. In particular, it protects itself from toxic gases from the exhausts of cars. This special concrete, which can clean, allows the unique architecture to be preserved for a longer time (Figure 7).

3.6. Antifogging nanomaterials

Drops on surfaces when steam molecules condense in wet spaces. These droplets cause a cloudy effect on the surfaces leaves. These negative effects can create a clean and clear image on surfaces such as mirrors and glass. The only way to eliminate this effect regularly heating the mirror, (Figure 8) but this effort is both electricity and lost time causes. Nanotechnology has an important role in the field of building materials. Thanks to titanium dioxide, the water and moisture on their surfaces are transferred to a film layer, thus preventing the appearance of steam on the surface.

Figure 8. Antifogging Nano Materials (Leydecker, 2008)

3.7. Fragrance capsules nanomaterials

Produced in microcapsules odor molecules make it effective and permanent for a longer time. It can be used by textile materials, wall panels, curtains and leather.

3.8. Thermal ınsulation VIP effect (vacuum insulation panels) nanomaterials

One of the most important developments regarding thermal insulation in recent years is the interior. It is the thermal insulation of the nanotechnological paints used. Apart from these external Nano insulation paints can be used on facades. Seit strasse Multi-Purpose Building, Germany The seven-floor Seitzstrasse building in Munich, Germany, is home to residential and commercial units. It is a mixed function structure.

4. Conclusion and Suggestions

Nowadays, nanotechnology has a very wide range of applications. This materials science is also at the forefront of the fields. The architectural activity is the building it is impossible to perform it without material. Similarly, nanotechnology textile entered the industry and in many areas studies have focused on this status. Nanotechnology in the future fibers and new functional products will make our lives easier.

Nanomaterials, which have many advantages, have not yet been developed for human health and the environment effects are not fully known. This situation in detail examination is important. As a field of science architecture is a structure that establishes a direct relationship with the environment experienced by nature and, it has existed with the materials, techniques and technologies of the era in which it was realized. This in this context, it is not the case that nanotechnology is lagging behind today. The impact of nanotechnology on architecture depends on the developments in materials science it is expected to increase.

Nanotechnology has respectable contributed in benefiting economic growth as well as improve the capacity and quality in industrial sectors. It can significantly change the human life, social environment and country's economy. Espacially producting and improving new materials benefits new trades about metarial industry. New materials follows new trends and designs in architecture.

Guiding the designs of today and the future and with the building material of nanotechnology, which is an important element that will give the relationship needs to be constructed together with the spatial concept. In this context spatial design and technology are an inseparable whole. Cleaning of the material it is easy, the user can clean it with less effort, so now in terms of the comfort of the spaces being determined by the material the role of technology in material selection is quite large. A new material technology can be the forerunner of a new trend. The value added by nanotechnology to space design and its innovations will help future generations it can be considered the most important personal legacy to leave. In this regard, with the nano power of design to make space designs and to transfer these designs from generation to generation it is an important step for the creators.

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All authors contributed equally to the article. It is a one-authored section.

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Building Envelope Material Properties and Attributes vs Performance Indicators in Thermal Environmental Control: Uncertainties and Barriers

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1. Introduction

Buildings, where we spend most of our time in, represent one-third of the total final energy and are responsible directly and indirectly for nearly 37% of global CO_2 emissions (IEA, 2021). Building envelope materials greatly impact the building performance in terms of environmental control since the envelope performs as the interactive shell between the indoor and outdoor environment. Besides, the envelope accounts for nearly 50-60% of total heat gain and losses in the buildings (Kumar *et al.*, 2020). The energy consumption increase and the rising comfort needs and population growth, as given in Figure 1, assigned importance to legislative actions such as directives, threshold levels, classifications, and limitations.

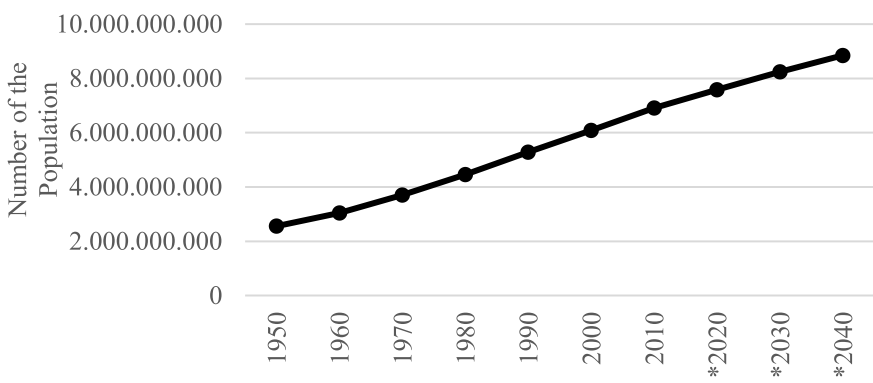

Figure 1. World Population Between 1950 – 2010 and Future Projection (UNPF, 2004)

Energy Performance of Buildings Directive (EPBD) defines the main framework for energy performance and efficiency in the EU countries' buildings (Directive, 2002). The Directive, (2010) highlighted the new targets as a 20% relative reduction of energy consumption and emissions in comparison with 1990, and a 20% introduction of renewable energy use. Additionally, the cost-optimal energy performance concept and the 'nearly zero energy building' (nZEB) concept were introduced as the target for all new buildings by 2020. Moreover, (Directive, 2018) assigns short-term (2030), mid-term (2040), and long-term (2050) objectives, targeting a reduction of 40% by 2030, and 80-95% by 2050 for greenhouse gas emissions. Further, resource efficiency and sustainability are framed through the embodied carbon evaluation for new buildings and major renovations to provide ideal solutions for high-performance building practices (Directive Recast Proposal, 2021).

Particularly, for high-performance building targets, low thermal transmittance (W/m^2K) of a building envelope by applying thermal insulation materials become increasingly significant in the last decades, for both new and existing buildings. Building performance has a safety level, when it is designed in accordance with the building code and requirements' threshold values. However, while providing a level of safety, it may not be sufficient for reaching the ideal solutions which provide a balance within the decision matrix built among the alternatives. Thus, the determination of the ideal thermal insulation solution in terms of material performance and attributes, and performance indicators should also be subject to the decision process of the design.

The recognition of the thermal insulation applications defined an excessive amount of material use where the global material use has already been estimated as 60 billion tons (Gt) per year (Krausmann et al., 2009) where, as an example, the consumption of EPS increased by 50% in the last years (Su et al., 2016). The wide variety of the envelope materials' properties and their reflections on the indicators of the building performance is a major task that needs to be analysed to produce a forward-looking environmental approach to building design. The evaluation of the options to reach an ideal solution requires the definition of the boundaries for the decision matrix, which directly affects the results of the performance indicators.

This chapter discusses the conventional thermal insulation materials' properties and attributes, as independent variables, through how they are handled in different studies and their uncertainties, while also analysing the building performance indicators, as dependent variables, through the environmental thresholds, targets, and barriers.

2. Material and Method

The research on the thermal insulation materials is conducted through the following steps as:

(1) Classification methods of thermal insulation materials and definition of the conventional thermal insulation materials,

(2) Definition of the thermal insulation material properties and attributes.

(3) A review of the properties and attributes of thermal insulation materials in terms of thermal environmental control,

(4) A review of the building performance indicators and the threshold values in terms of thermal environmental control, and

(5) A holistic evaluation of the results in terms of the data uncertainties and target barriers.

2.3. Classification of the Thermal Insulation Materials

In the literature, different classification methods have been proposed for thermal insulation materials. Mainly, the classifications can be defined according to the source (raw material), structure, appearance and form, incombustibility, and binder.

Papadopoulos (2005) classifies the insulating materials according to their origin into four groups such as inorganic, organic, combined, and new technology materials, where the material structure can be foamy, foamy expanded, or fibrous. Pfundstein et al. (2007) classify thermal insulation materials as inorganic, organic, and advanced materials, where they can be natural or synthetic according to their manufacturing process. Aditya et al. (2017), similarly, define both the inorganic insulation materials and organic materials into two: -inorganic natural (expanded perlite, expanded clay, etc.), inorganic synthetic (foam glass, mineral wool, etc.), and organic natural (wood board, cork board, etc.) and organic synthetic (extruded polystyrene, expanded polystyrene, polyurethane foam, etc.). Jelle (2011) groups the thermal insulation materials as traditional, state-of-art, and future materials where the advantages and disadvantages of the thermal insulation materials and solutions are discussed. Anh & Pasztory (2021) classify thermal insulation materials as inorganic (fibrous or cellular), organic (foamed, foamed expanded, and fibrous), combined (boards), and advanced materials. Yang & Chen (2022) evaluate the thermal insulation materials as static (with constant R-value) and dynamic (switchable R-value), where the static thermal insulation solutions vary as conventional, state-of-art, and sustainable types of materials.

In this study, conventional thermal insulation materials are analysed in detail, in terms of their definitions and attributes. Brief descriptions of the analysed thermal insulation materials are given in Table 1, summarizing the studied conventional thermal insulation materials according to their origin, structure, and components.

Table 1. Conventional Thermal Insulation Materials.

	According to their origin	**According to their structure**	**Components (Jelle, 2011)**
Polyurethane foam (PUR)	Organic / Synthetic	Foamy	*reaction between isocyanates and polyols
Extruded polystyrene (XPS)	Organic / Synthetic	Foamy	*melted polystyrene (from crude oil) by adding an expansion gas
Expanded polystyrene (EPS)	Organic / Synthetic	Foamy	*small spheres of polystyrene (from crude oil) expanded with heat
Rockwool (RW)	Inorganic / Synthetic	Fibrous	*melting stone (diabase, dolerite) at about 1500 °C
Glasswool (GW)	Inorganic / Synthetic	Fibrous	*borosilicate glass at a temperature around 1400 °C

Cellular glass (CG)	Inorganic / Synthetic	Foamy	melted used glass bottles with carbon dust added
Phenolic foam board (PF)	Organic	Foamy expanded	mixing high solids and phenolic resin with a surface acting agent

2.3. Insulation materials, properties and attributes in thermal environmental control

Thermal insulation materials, with their several properties such as thermal conductivity, fire performance, mechanical strength, water resistance, environmental impact, etc., have a great impact on the overall performance of buildings. In this chapter, the attributes of the thermal insulation materials are defined as the physical and thermal properties, and the environmental and economical attributes, as described in detail below.

2.2.1. Physical properties

Physical properties of thermal insulation materials, in thermal environmental control, define the physical state of materials as density and water vapor permeability or resistance.

Density (ρ) is a quantitative expression in kg/m^3, as the ratio between the mass of the unit volume and the unit volume of a material. Materials, based on the lower bulk density and the higher distance of the atoms to each other, perform better in terms of insulation.

Moisture behaviour of thermal insulation materials can be defined by their water vapor permeability (or resistance), moisture permeability (or resistance), diffusion thickness, etc.

Water vapor diffusion resistance factor (μ) is a dimensionless attribute that defines the vapor permeability of building materials in comparison to the unitary value assigned to air. When the μ value is higher, the lower the permeability is.

2.2.2. Thermal properties

Thermal properties of the materials are associated with their response to heat as conductivity, heat capacity, and flammability, as described below.

Thermal conductivity (λ) is described as the heat flow that passes through a unit area of a 1-meter-thick homogeneous material, per unit time for 1 K temperature difference, expressed in (W/mK). A low thermal conductivity enables the lower thicknesses of insulation material applications to achieve high thermal resistance (m^2K/W) and a low thermal transmittance value (W/m^2K).

Specific heat capacity (c_p), as a quantitative attribute, is the heat capacity of materials as the amount of heat (Joules) added to 1 kg of mass material to the resulting temperature change as 1 Kelvin, expressed by (J/kgK).

Fire behaviour (flammability) of insulation material is the reaction against fire, determined by the fire classes (EN 13501-1, 2018).

2.2.3. Environmental attributes

The environmental impact of materials can be evaluated under two categories: direct and indirect. Direct environmental impacts are based on the environmental attributes of materials such as embodied energy, global warming potential, etc. Indirect impacts are the result of the contribution of materials to the energy efficiency of buildings, such as reduced energy consumption. This chapter defines the direct environmental impact of the materials, whereas the indirect impact of the materials is discussed as a building performance indicator.

Life Cycle Assessment (LCA) is a methodology, which is used to assess the environmental impacts of commercial products, processes, or services, etc. through some indicators such as global warming, ozone depletion, acidification, water resource depletion, energy demand, etc. (Tingley *et al*., 2015). In this study, cumulative energy demand (embodied energy), and the global warming potential (embodied carbon) are analysed, as described below.

Cumulative Energy Demand (CED) is the primary energy consumed directly and indirectly during the considered life cycle of the material or product.

Global Warming Potential (GWP) is the impact of global warming through gas emissions in terms of kilograms of CO_2 equivalent.

2.2.4. Economical attributes

The economical attribute of thermal insulation materials is here defined as the unit costs.

Unit cost of thermal insulation materials can be designated from the Construction and Installation Unit Prices (CUP) listed by the government or can be collected from the local market to obtain actual prices according to the availability of data for the investment costs. The unit price ($\$/m^3$) of the thermal insulation materials may vary according to the local or imported materials of the market, region, and country.

2.3. Building performance indicators in thermal environmental control

The building performance, in this study, is evaluated based on the relation between the variation of the thermal insulation materials' properties and attributes, and their effects on the building performance. According to this relation, energy, thermal, environmental, and cost performance indicators of buildings and the state of thermal insulation materials within these indicators are discussed.

2.3.1. Energy performance

The energy in buildings is used in three main phases, construction, operation, and demolishment. The life span of buildings mainly determines the operation phase which takes an average of 30 to 50 years life span and holds the highest energy consumption phase, for mostly heating, cooling, and lighting, usually evaluated by the division of the building's total annual energy consumption (kWh/year) to the total conditioned area (m^2) or indicators such as the energy class, energy efficiency index (Bakar et al., 2015), etc. Building design figures as a key factor in energy efficiency since the envelope design and the envelope material attributes' impact on the building performance depend on the building orientation, form, space configuration, etc. as much as the contextual parameters such as the climate, topography, immediate environment, and the macro climate. Thus, studies on the material selection or the highlights of the ideal solutions (should) depend on an integrated design approach. As a result, the ideal solution for the envelope material selection without compromising the building's operational energy performance (indirect performance) through calculations and simulations is essential as the material attributes for a high-performance building design.

2.3.2. Thermal performance

Thermal comfort is one of the most evident criteria to evaluate the performance of a building because an energy and cost-efficient building can be efficient and effective only if thermal comfort is provided to the occupants.

Thermal comfort is the condition of mind which expresses satisfaction with the thermal environment (ISO 7730, 2005). The thermal performance of a building, based on the thermal satisfaction of the occupants with the environment, is a subjective measure that depends on both environmental and personal parameters. Thermal comfort is directly related to indoor air temperature and surface temperatures. Thus, the water resistance and the condensation risk among the envelope section is an important criterion to assess the material properties and the building performance. The commonly used thermal comfort models are the PMV model and the adaptive model, defined by standards such as (ASHRAE, 2020) and (EN 15251, 2012) where the unmet hours of thermal comfort are evaluated. PMV model is commonly applied for mechanically conditioned spaces, whereas the adaptive comfort model is more applicable for spaces such as naturally conditioned or ventilated.

2.3.3. Life-cycle environmental performance

Thermal insulation materials, by their usage of resources, by their impact on the environment, and by their effect on the building energy consumption, influence the Earth either directly and indirectly. Thus, the indirect effects of the materials during the building's operation should be subject to the material selection, to reach to an ideal solution. The environmental benefits of thermal insulation materials on the building performance, in addition to the energy performance, can be assessed using the performance indicators such as GHG emissions mitigation, carbon payback time, etc.

2.3.4. Life-cycle cost performance

Building costs are one of the most significant criteria in decision-making of a building design. Different methods and boundaries have been used in the studies to discuss the building cost performance as, life cycle cost (LCC), simple payback period (SPP), discounted payback period (DPP), net present value (NPV), etc. (Elaouzy & El Fadar, 2022). Besides, other economical parameters such as inflation rate, market interest rate, discount rate, and nominal energy price escalation rate are subject to cost calculations in addition to the unit price of the materials.

In cases where the economic parameters such as inflation, market interest, and nominal energy price escalation rates are not steady or remarkably different in comparison, the results of the life-cycle costs significantly vary.

3. Review and Discussions

The review, within the scope of this study, includes:

- The most recent and relevant studies (Web of Science and Scopus) on thermal insulation material selection, in order to juxtapose the range of the material properties and attributes and discuss the uncertainties, and
- The recent studies on thermal insulation material selection and its building performance evaluation through the indicators, in order to frame and discuss the boundaries and barriers.

A review of the conventional thermal insulation material properties and attributes

The relevant studies, conducted over the last 10 years were analysed through the Web of Science and Scopus indexes. Studies that have focused on the comprehensive review of thermal insulation material properties, and comparison of the thermal insulation materials are reviewed, and the properties and attributes are summarised in Table 2.a and Table 2.b.

The tables define a summary of the physical and thermal properties to the environmental and cost attributes of conventional thermal insulation materials. According to Table 2.a, there are slight differences in the physical and thermal properties of the materials among the studies. However, the wide range of density and thermal conductivity values highlight the sensitivity of these parameters in thermal insulation material comparisons and their effect on energy consumption levels. On the other hand, specific heat capacity does not vary significantly, since it is a mass-dependent property.

According to Table 2.b, cost, embodied energy, and embodied carbon attributes vary significantly, determining the importance of comparing materials on the basis of specific products rather than by types.

The conventional insulation material PUR, with the lowest thermal conductivity option (0.022 *W/m.K*) compared to the others, has the weakest material property in terms of flammability, whereas the material with the best flammability property (FG) has the highest thermal conductivity range as 0.038 - 0060 *W/m.K.*

Table 2a. Material Properties and Attributes for Conventional Thermal Insulation Materials.

	Density	Thermal conductivity	Specific heat capacity	Water vapor diffusion resistance factor	Ref
Symbol	ρ	k	c_p	μ	
Unit	*(kg/m³)*	*(W/m.K)*	*(J/gK)*	-	
PUR	30-160	0.022-0.035	1.30-1.45	50-100	[1]
	15-45	0.022-0.040	1.30-1.45	30-170	[2]
	35	0.023	-	-	[3]
	30-100	0.024-0.30	-	-	[5]
	>30,>45	**0.025 – 0.040**	-	**30 - 100**	**[6]**
XPS	32-40	0.032-0.037	1.45-1.70	80-170	[1]
	32-40	0.032-0.037	1.45-1.70	80-150	[2]
	30	0.034	-	-	[3]
	25-45	0.030 – 0.040	-	-	[5]
	>15,>30	**0.030 – 0.040**	-	**80-250**	**[6]**
	20-80	0.028-0.030			[8]
EPS	18-50	0.029-0.041	1.25	20-100	[1]
	15-35	0.031-0.038	1.25	20-70	[2]
	15	0.0396	-	-	[3]
	15-35	0.035 – 0.040	-	-	[5]
	>15,>30	**0.035 – 0.040**	-	**20-100**	**[6]**
	18-50	0.040-0.042			[8]

RW	40-200	0.033-0.040	0.80-1.00	1.00-1.30	[1]
	40-200	0.033-0.040	0.80-1.00	1.00-1.30	[2]
	30-180	0.033-0.045	-	-	[5]
	8-500	**0.035-0.050**	-	**1.00**	**[6]**
GW	10-100	0.030-0.050	0.80-1.00	1.00-1.30	[1]
	15-75	0.031-0.037	0.90-1.00	1.00-1.10	[2]
	13-100	0.030-0.045	-	-	[5]
	8-500	**0.035-0.050**	-	**1.00**	**[6]**
FG	100-200	0.038-0.055	0.21	∞	[1]
	115-220	0.040-0.060	-	-	[5]
	100-150	**0.045-0.060**	-	-	**[6]**
	160-180	0.058-0.065			[8]
PF	40-160	0.018-0.024	1.30-1.40	35	[1]
	40-160	0.018-0.024	1.30-1.40	35	[2]
	40-160	0.022-0.040	-	-	[5]
	>30	**0.030 – 0.045**	-	**10-50**	**[6]**
	30-100	0.020-0.025			[8]

Table 2.b. Material Properties and Attributes for Conventional Thermal Insulation Materials.

	Flammability	Cost	Embodied energy *(cradle to gate)*	Embodied carbon *(cradle to gate)*	Ref.
Symbol	*Φ*	C_i	*ee*	*ec*	
Unit	*(-)*	*($/m³)*	*(MJ/kg)*	*(kg CO_2eq/kg)*	
PUR	D-F [1] E [2]	24.91 [1] - 156 [5]	74-140.4 [1] 82.6 [3] 99.63 [5]	5.9 [1] 3.33 [3]	
XPS	E [1] E [2]	18-23 [1] 120 [4] 224 [5]	72.8-105 [1] 96.8-104 [3] 127.31 [5] 75 [8]	7.55 [1] 5.21-7.08 [3] 5.45 [8]	
EPS	E [1] E [2]	8.6-17 [1] 47 [4] 155 [5]	80.8-127 [1] 73.8 [3] - 85 [8]	6.3-7.3 [1] 3.25 [3] 4.21 [7] 6.25 [8]	
RW	A1-A2 [1] A1-A2-B [2]	12-20 [1] 82 [4] 95 [5]	16.8 [1] 53.09 [5]	1.05 [1] 1.13 [7]	
GW	A1 [1]	9.3-14.7 [1]	14-30.8 [1]	1.24 [1]	

	A1-A2 [2]	90 [4] 155 [5]	90 [8] 229.02 [5]	8.63 [8]
FG	A1 [1]	46-62 [1]	20.6-27 [1] 208 [8]	- 0.019 [8]
PF	B-C [1] B-C [2]	23 [1]	13-159 [1] - 52 [8]	4.15-7.21 [1] 7.02 [7] 3.50 [8]

[1] (Kumar *et al.*, 2020a), [2] (Schiavoni *et al.*, 2016), [3] (*Pargana et al.,* 2014), [4] (Kumar et al., 2020b), [5] (Anh and Pasztory, 2021), [6] (TSE, 2013), [7] (Tingley *et al.*, 2015), [8] (Su et al., 2016)

There is less focus on the specific heat capacity and the water vapor diffusion resistance of the thermal insulation materials. However, the thermal conductivity and the specific heat capacity have a direct relationship with the moisture content of the material (Anh & Pasztory, 2021).

There is a limited number of studies that comprehensively evaluate the environmental impact of thermal insulation materials. On the other hand, the environmental attributes provided in the studies show similarities, since the data covers only products with environmental impact calculations and declarations that are obtained as a result of comprehensive calculations.

3.2. A review of the building performance indicators

In Turkey, the Turkish Standard of *Thermal insulation requirements for buildings* (TS 825) was first published in 1998 (TS 825, 1998) and revised (TS 825, 2008) by the Engineering Service Expertise Group of the Turkish Standards Institute in order to determine the highest heating energy values allowed in the buildings and to define the calculation principles for the net heating energy needs in buildings through a monthly quasi-steady-state calculation method. Subsequently, the updated standard (TS 825, 2013) was published, with a prominent change in the number of degree-day regions from four to five and a decrement in the limit U-values of the regions.

According to the overall evaluation, presented in Table 3, there is a significant reduction in the recommended U-values of the building envelope components, which brings the thermal insulation application to the forefront.

Table 3. Recommended U-Values.

	(TS 825, 1998)/ (TS 825, 2008)/ (TS 825, 2013)			
	U_{Wall} *	U_{Roof}*	U_{Floor}*	U_{window}*
1st Region	0.80/ **0.70**/ **0.66**	0.50/ **0.45/ 0.43**	0.80/ **0.70/ 0.66**	2.80/ **2.40 / 1.80**
2nd Region	0.60/ 0.60/ **0.57**	0.4 / 0.40/ **0.38**	0.60/ 0.60/ **0.57**	2.80/ **2.40 / 1.80**
3rd Region	0.50/ 0.50/ **0.48**	0.30/ 0.30/ **0.28**	0.45/ 0.45/ **0.43**	2.80/ **2.40 / 1.80**
4th Region	0.40/ 0.40/ **0.38**	0.20/ 0.25/ **0.23**	0.40/ 0.40/ **0.38**	2.80/ **2.40 / 1.80**
5th Region	- / - / **0.36**	- / - / **0.21**	- / - / **0.36**	- / - / **1.80**

* U-value unit: ($W/m^2.K$)

With the progress in the thermal insulation material industry and material properties, the influence of thermal insulation on building energy performance has still been investigated in recent researches. In this section, the studies over the last ten years, on thermal insulation material selection with multiple material alternatives, are summarized in Table 4, according to the covered thermal insulation material, building performance indicator, and the evaluated building typology.

Özel et al. (2015) focused on rockwool and glass wool insulation materials and calculated the optimum insulation thickness through environmental impact and life cycle cost indicators. Aditya et al. (2017) presented a wide review of insulation materials and discussed potential reductions on energy consumption and emissions in buildings through the application of proper insulation materials. Colli et al. (2020) presented the eco-efficiency matrix, built on both environmental and economic performances. Dickson &Pavia (2021) developed a model on the energy performance, environmental impact and cost performance indicators and defined an overall performance indicator for an assessment.

Table 4. Review of the Recent Studies According to the Thermal Insulation Material and Performance Indicator.

Material	Building Performance Indicator	Building Typology	Ref.
RW and GW	entransy, environmental impact, life cycle cost	-	Özel et al. (2015)
PF, EPS, RW	environmental payback, heating requirement	dwelling	Tingley et al. (2015)
PIR, XPS, EPS, Aerogel	embodied energy, operational energy consumption	commercial buildings	Biswas et al. (2016)
-	life-cycle analysis, potential emissions reduction	residential	Aditya et al. (2017)
XPS with two typical wall structures	energy saving, payback period	-	Nematchoua et al. (2017)

Cork, EP, GW, GF, hemp, MW, plywood, POF, PUR, RW	hour of discomfort, CO_2 avoidance, NPV, human health, ecosystem quality, consumed resources	traditional rural building	Kadzinski et al. (2018)
GW, HC*,CF**, EPS, XPS, PUR	life cycle assessment, whole life costing, eco-efficiency matrix	single-family house	Colli et al. (2020)
PF, SW, cork, RW, WW, hemp	energy performance, embodied energy, CO_2 emissions, material and annual cost, overall performance indicator	three-bedroom bungalow	*Dickson and Pavia (2021)

HC: hemp concrete, CF: cellulose fiber, WW: wood wool board, SW: stone wool, EP: expanded perlite, GF: gypsum fibreboard, MW: mineralized wood, POF: polystyrene foam
*only the external insulation alternatives are listed here.

Table 4 frames the boundaries of the recent studies in terms of the most studied thermal insulation materials and the focus of the performance indicators. According to the table, all studies have evaluated the energy and cost performances, whereas some of the studies evaluated the environmental performance and a few of the studies included the thermal performance indicators. The most frequently studied thermal insulation materials are commonly market-leading materials such as EPS, XPS, RW (or stone wool), and GW.

4. Conclusion and Suggestions

According to the tables representing the attributes of the materials, there are slight differences in terms of the materials' physical and thermal properties. However, the unit cost and the environmental impact attributes show a significant difference among the documents analyzed. Current directives and regulations are mainly focused on the building's energy and cost performance. When considered, international financial differences and local market conditions have a great impact on the selection of the ideal thermal insulation solution. Besides, when it is considered to make a decision through a forward-looking approach, the environmental attributes, which also have uncertainties, become determinative of the results. The limitations of the environmental impact data due to the purpose of the data disclosure (EPDs), transform the decision-making logic from a material type-based decision matrix to a product-based decision matrix since the environmental impact boundaries cannot be defined among the material types but the company and the products.

It should be concluded that there is no single thermal insulation material that satisfies all the properties and attributes. But it is crucial to improve the data knowledge and the decision matrix in order to appropriately find the ideal solutions for optimized decision-making.

Thanks and Information Note

The article complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

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All authors contributed equally to the article. There is no conflict of interest.

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Material Analyses and Tests of Kasımpaşa Mosque in Edirne Which Planned to Lift Up

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1. Introduction

In historical masonry buildings, the durability of materials used for the structural members can be impaired by climatic conditions and user interventions, and the building may lose its authenticity as a result of functional changes made over time and might become unsafe for seismic effects, despite other building types especially structures such as mosques are more sensitive to this issue and the building may lose its authenticity as a result of functional changes made over time (Yıldızlar et al. 2020). Before the structures are restored, they must go through various investigations and tests, especially against earthquake loads. Numerical approaches involving structural analyses are preferred to examine the potential effects on such buildings and their seismic strength. Although financial difficulties slow down this research, all work must be done in order to ensure the longevity of the structure. As time passes, new and modern methods emerge, and these provide a more efficient examination of the structure.

Stone, brick, and mortar are the main elements of masonry buildings. They have high compressive strength, but their tensile strength is low. Various methods exist to evaluate historical buildings in terms of structural aspects, and they are mainly adopted to examine if the scope of the proposed intervention for the strengthening of the building is satisfactory. In numerical approaches, various techniques can be adopted based on complex mathematical computations, including analyses in which the material and geometric behaviors are not linear. In masonry buildings, depending on wall surface areas in the concerning direction, the distributions of stresses are concentrated in corners with varying geometries, which affects the lateral structural behavior of the building. In addition, normal vertical stress increases from the upper to the lower sections of a wall and reaches a maximum level at the ground floor (Celep, Güler & Pakdamar 2016).

This paper presents the integral lifting and seismic isolation retrofit of the historical Kasımpaşa Mosque, which was built at 1489 in Edirne-Turkey. Due to the unpreventable problems, such as earthquake risk and water flooding, Kasımpaşa Mosque is needed to be lifted about 3.5 m. It is taken on the base insulated carrier system for protection. Restoration will be done after the mosque is lifted. Before lifting the mosque, some tests such as Flat jack and point loading tests, material chemical analyses (natural stone, brick and mortar) and reports were carried out by the KURAM (Foundation Cultural Heritage Preservation Application and Research Center) to determine the strength values of the mosque structure materials. The definitions of the samples taken from the necessary points and the locations where they were taken are indicated on the plan by the theory experts to characterize different periods and materials in the buildings.

1.1. History

Kasımpaşa Mosque was built at Tunca Riverside, which is one of the arms of Maritza River, at a hollow area in Edirne-Türkiye. Mosque is situated between the road (5 meter high from the mosque floor level), and the river. It is informed that the foundation certificate-charter was formed for Kasımpaşa Mosque, and it is in Topkapı Palace`s archive today (Gökbilgin, 1952) and is written to build at 883/1478-1479 year on its epitaph. Kasımpaşa, as a one domed and a square based mosque, has a cemetery (burial area) at north and east sides shown at Figure 1 (Peremeci, 1939).

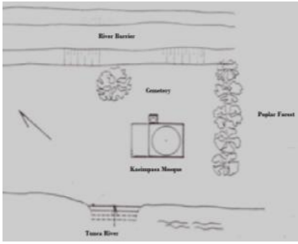


Fig. 1. Kasımpaşa Mosque Layout Plan 1/1000

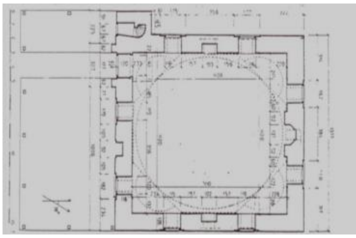


Fig. 2. Kasımpaşa Mosque Restitution Plan (Ayverdi, 1989)

Today it can be hardly seen the marks of narthex area (7.00 m. x 15.00 m) at the north side because of the soil reducing shown at figure2. Some marks on facade wall are figured that there was a Narthex with a wooden roof (Ayverdi, 1989).

Fig. 3. Kasımpaşa Mosque Before 1953 Mosque (Ayverdi 1989)

Fig. 4. Submerged Kasımpaşa (Author's Archive 2018)

1.2. Analysis

Many studies have been conducted in order to improve the historical structures in terms of strength and durability (Bozkurt, et al. 2016), (Montoya, et al. 2004), (Martinet & Quenee, 1999), (Umarogullari & Kartal, 2021). In the studies, macro and micro-structural analyses of materials used in the structures are performed and the characteristics of material can be determined in detail. In addition to this, taking the analyses, information and documents which have been constructed with similar techniques and in similar time lines as a reference for the repair of historical buildings might cause erroneous results as each structure has its own construction practice and material; and this requires the structure-based analyses to be conducted. In this respect; original binders, aggregates and additives should be analyzed during the repair of historical buildings and the proper material content should be determined accordingly.

2. Material and Method

In this study, 1 mortar, 1 natural stone and 1 brick sample taken from the building by KURAM experts, were examined in Prof. Dr. Ahmet Refik Ersen Restoration and Conservation Laboratory. In this context, scientific definitions of the samples were made as a result of macroscopic and microscopic examinations made in the laboratory, and protein, oil and water-soluble salts were investigated by spot tests and he results obtained by performing the properties of the mortars, binder and aggregate ratios, additive content, acid loss, heating loss, petrography analyzes and granulometry, quality and visual analyzes of the aggregates that do not react with acid are given. In addition to this, flat-jack tests were also performed and the results are explained below.

The definitions of the samples taken from the necessary points in the buildings, characterizing different periods and materials, and the locations where they were taken are given separately for each sample below and the points where the samples were taken are shown on the attached plan (Appendix 1).

SAMPLE 01

It is an example of a solid, light cream colored mortar with white masses that can be seen in aggregates up to 3 mm in size, taken from the upper level of the window close to the minaret, on the northeastern wall of the sanctuary.

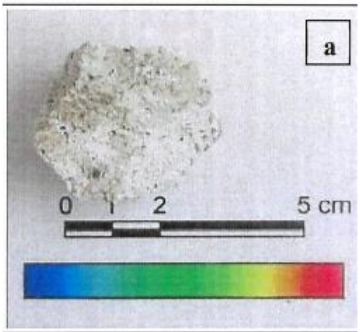
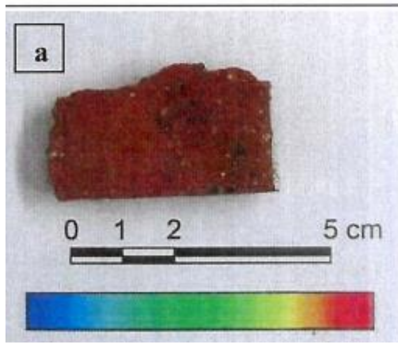


Figure 5. a. General View b. Location Overview c. Location Detail

SAMPLE 02

An orange colored brick sample taken from the window opening near the minaret on the northeastern wall of the sanctuary.



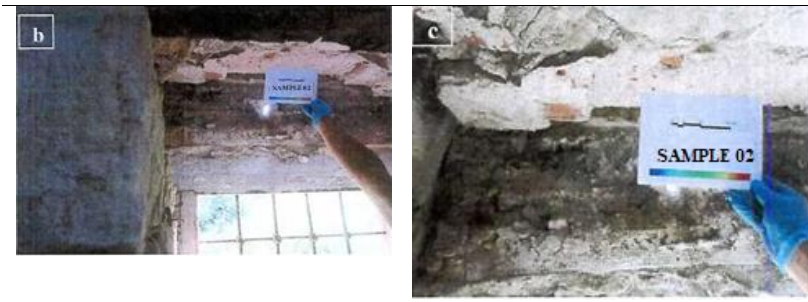


Figure 6. a. General View b. Location Overview c. Location Detail

A flat-jack test was carried out by KURAM experts at the required points in the building to characterize different wall properties and materials. Experimental locations are indicated separately for each point below, and are also shown on the given plan.

The experiments carried out in the building were carried out with semi-circular flat-jacks of 360/260/4 mm dimensions. Test slits in the walls were created with a 36 cm diameter carbide-tipped circular saw. ASTM C1197-14a (Standard Test Method far in Situ Measurement of Masonry Defarmability Properties Using the Flatjack Method) was applied in the experiment.

SAMPLE 03

It is a light cream-colored natural stone sample taken from the first row of wooden beams on the northeastern wall of the sanctuary.

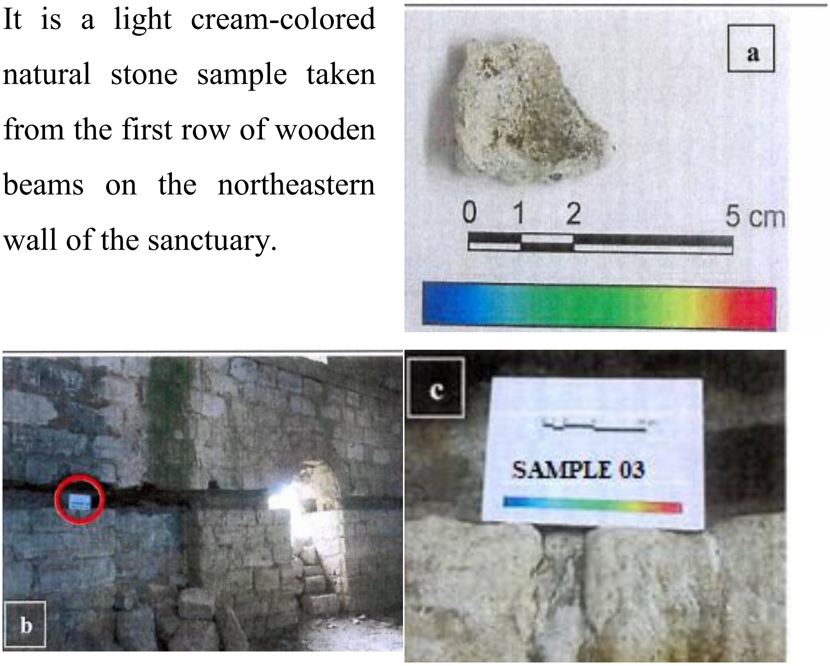


Figure 7. a. General View b. Location Overview c. Location Detail

During the experiment, the required pressure was applied by a pump connected to the flat-jacks with a hydraulic circuit. Pressure measurements were collected in a data recorder by means of an electrical pressure transducer with a scale of 100 bar, directly connected to the manometer of the pump, and transferred to the computer environment from there. Deformation measurements were made by means of four transducers that measure strain, which are also connected to the data acquisition unit. With the uniaxial pressure tests performed in-situ with the flat-jack technique, the mechanical dimensions of the masonry building elements, the modulus of elasticity and the Poisson's ratio, can be determined (Kuran & Dabanli 2016)

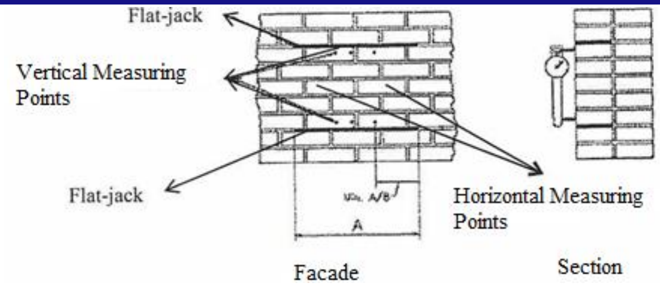


Figure 8. Flat-jack Application Form In The Structure (RILEM, 2004)

Application stages:

a. Two incisions were made parallel to each other and approximately 45 cm apart.

b. 3 pairs of steel pins vertically are fixed to the wall to enable vertical strain gauges to be mounted, and a pair of steel pins horizontally to measure horizontal deformations.

c. Then, uniaxial pressure was loaded on the masonry structure by means of a flat-jack placed in two angled slits in the wall, and axial deformations observed in vertical and horizontal directions were recorded simultaneously by means of transducers placed between the two slits.

d. The test was stopped when the masonry unit reached the compressive strength or when the flat-jack safety stress limit reached 50 bar.

e.The stress-strain curves of the structure were obtained with the recorded values, and the mechanical properties of the structure were determined.

The following equation is used for compressive stress calculation CTr in masonry structure.

$$Gr = Km(p) ‘ Ka \cdot p$$

Km (p): It is the function that expresses the correlation between the pressure applied to the structure by the flat-jack and the pressure applied by the pump.

Ka : Slit constant taking into account the difference in size between the horizontal slit opened in the wall and the flat-jack, equal to the ratio between the cut area and the flat-jack area, p: The applied pressure measured by the pressure transducer positioned in the pump.

Experiments Points

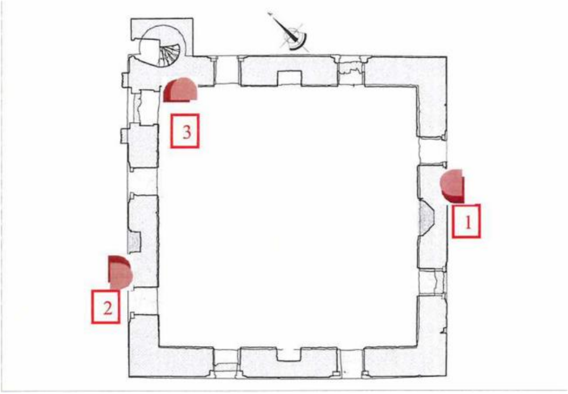


Figure 9. Flat-jack Application Points In The Structure

A total of three flat-jack tests were carried out, two from the outer surface of the body wall and one from the inner surface of the building. The test point no. 1 is on the outer surface of the main wall between the altar and the east window on the south façade of the building. The test point 2 is on the outer surface of the wall between the narthex mihrab and the window in the northwest corner, on the northern façade of the building.

Figure 10. Location Of Test Point 1

Figure 11. Location Of Test Point 2

Figure 12. Location Of Test Point 3

Test point 3 is on the inner surface of the point near the northeast corner of the east wall.

3. Finding and Discussion

Salt, Protein and Oil Analyses

In order to determine the quality and amount of water-soluble salts (chloride, sulfate, carbonate and nitrate) in the samples defined above, and to understand whether additives such as saponifiable oil and protein are added, simple spot tests were carried out in the laboratory and the relevant analysis results are given in Table 1 below. Hanna HI-8633 conductivity device was used in the conductivity measurement for the rough determination of salt amounts.

Chloride (Cl), sulfate (SO_4^2), carbonate ($C0_3^2$) and nitrate (NO_3) salts and protein and oil contents were investigated in the samples taken from the building.

Table 1. Water Soluble Salts and Organic Matter Analysis (-: None; +: Few; ++: Normal; +++: More; INI : Too Much)

Sample Nr	Water Soluble Salts						Organic Matter	
	Cl	SO_4^2	CO_3^2	NO_3	Conductivity (fiS)	Amount of Salt (%)	Protein	Oil
1	-	-	-	-	186	1,10	+	-
2	-	-	-	-	178	1,05	+	-
3	-	-	-	+	305	1,80	+	-

• The nitrate ($N0_3$) salt, which is found in insignificant amount in the example number 3, is not suitable for birds, etc. from the waste of living things,

• Bird, etc. protein detected in all samples. It is thought to originate from the remains of living things.

No saponifiable oil with chloride (Cl^-) sulfate (SO_4^{2-}), and carbonate (CO_3^{2-}) salt was detected in any of the samples.

Loss of Glow, Acid Treatment and Sieve Analysis

The calcination (heat loss) analysis results of the samples at 105±5°C, 550±5°C and 1050±5°C and the ratio of silicate aggregates that remained intact after acid treatment and did not react with acid and the size distributions of these aggregates are given in Table 2.

Table 2. Heating and Acid Loss, Sieve Analysis

Sample Nr	Loss of Glow (%)			Acid Treatment (%)		Sieve Analysis (%)									
	Moisture (105 °C)	(105 °C)	$CaCO_3$	Loss	Residue	> 8.0 mm	> 5.6 mm	> 4.0 mm	> 2.0 mm	> 1.0 mm	> 500µ	> 250µ	> 125µ	> 63µ	> 63µ
1	0,55	3,46	68,70	27,90	72,10	0,00	2,17	2,32	14,29	29,21	35,76	14,01	1,66	0,54	0,05
2		*		5,34	94,66						*				
3		*		4,46	95,54						*				

Since it is a brick or natural stone sample, the relevant analysis was not carried out.

Visual Analysis of Acid-Treated Materials

The silicate materials of the samples, which were destroyed by treatment with acid, were examined under a stereo microscope after sieve analysis and their visible properties are given below. In the definitions, the terms “very little” for less than 1% and “little” for 1-2% are used. The quality and quantity of the remaining materials of the samples after acid treatment are given below.

Sample 1:

<u>Materials smaller than 125u;</u>

10-15%	quartz,
The remainder is	clay-sized material

Materials with dimensions between 125-1000 u;

20-25%	quartz,
The rest is	land sand

Large aggregates larger than 1000 u;

>20-25%	quartz,
The rest is	land sand

For example, the remaining materials in the acid are land sand in 4 mm sieve size.

Petrographic Analysis

Mineral contents were determined by polarizing microscope (double nicol) from thin sections prepared from epoxy-treated samples, and general texture properties and roughly ratios were examined from bright (thick) sections by stereomicroscope, and the results are given below. The term "small" is used for pores less than 10% by area, "moderate" for pores of 10-20%, and "abundant" for pores greater than 20%.

Example 1. Aggregates of the mortar sample, whose binder is ~25% cream lime, are semi-angular and angular in 4 mm sieve size. For example, all of its content, except the binder, is land sand with abundant quartz. For example, the binder-binder phase and the binder-aggregate phase are good, with small amounts of up to 0.4 mm and round pores.

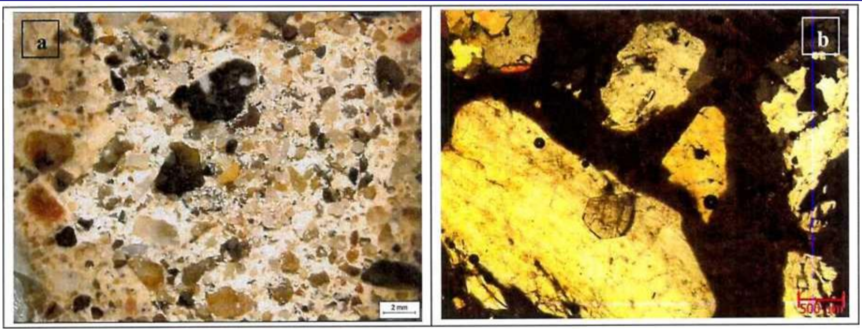


Figure 13. a) Stereo Microscope General Tissue, b) Polarizing Microscope Image (Belonging to sample Number 1).

Example 2. It is an orange colored, well-compacted and well-fired brick containing 3-5% of chamotte up to 2 mm in size, 3-5% of carbonate aggregate and 20-25% of quartz, with plenty of pores up to 1 mm in area.

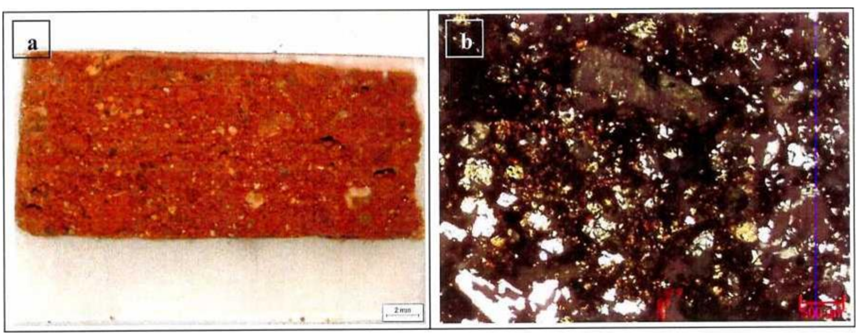


Figure 14. a) Stereo Microscope General Tissue, b) Polarizing Microscope Image (Belonging To Sample Number 2).

Example 3. It is a white-cream colored andesitic tuff sample containing quartz, biotite and amphibole minerals.

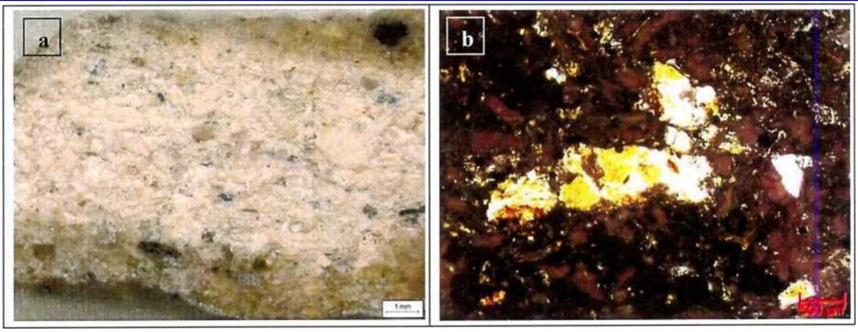


Figure 15. a) Stereo Microscope General Tissue, b) Polarizing Microscope Image.

Below are the stress-strain graphs obtained from the experiments. Modulus of elasticity values were calculated for each cycle.

Experiment No. 1 Results

The stress-strain relationship of the loading cycles of the test No. 1 performed on the structure is shown in the graphs below.

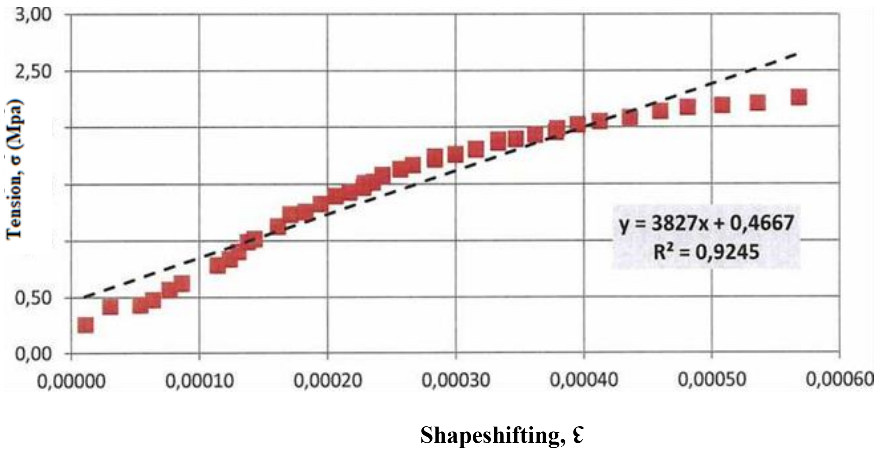


Figure 16. Experiment 1.Cycle: 01, Stress-Shapeshifting Graph

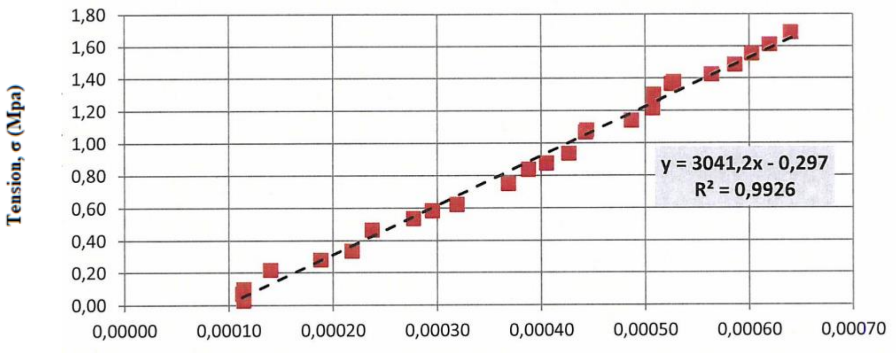


Figure 17. Experiment 1.Cycle: 02, Stress-Shapeshifting Graph

Uniaxial compressive strength test was carried out on samples prepared from brick and mortar samples taken by theory experts in accordance with TS EN 772-1-2011+A1(Masonry units - Test methods - Part 1: Determination of compressive strength) and ASTM C67.3934-14 (Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile 1)standards. The results obtained are given in Table 3 and Table 4.

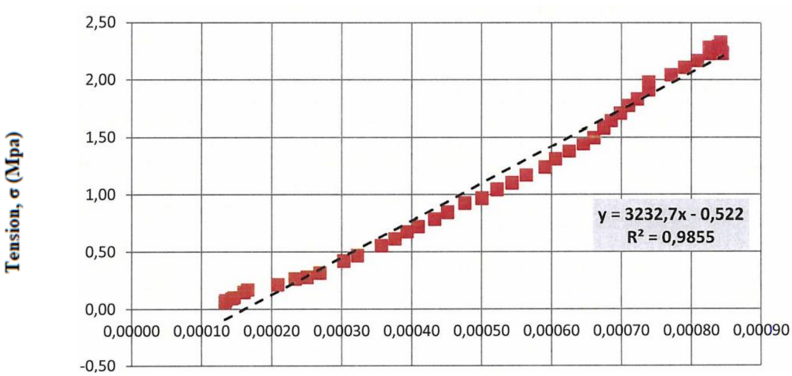


Figure 18. Experiment 1.Cycle: 03, Stress-Shapeshifting Graph

Table 3. Uniaxial compressive strength values of brick samples (sample number 2).

Sample Nr	Sample Sizes (mm)		Uniaxial Compressive Strength (MPa)
	Widht	Length	
2-1	40,18	40,70	7,48
2-2	41,28	40,50	8,18
2-3	39,25	40,38	7,96
2-4	41,30	40,81	8,32
2-5	40,64	39,90	6,80
2-6	40,32	40,18	6,46
2-7	40,71	40,65	7,69
2-8	40,43	40,85	8,06
2-9	40,32	41,72	8,14
2-10	40,12	40,65	7,68
2-11	40,87	40,60	7,43
2-12	40,40	40,60	9,25
		AVERAGE	**7,79**
		STANDARD DEVIATION	**0,72**
		COEFFICIENT OF VARIATION	**0,09**

Table 4. Uniaxial compressive strength values of mortar samples (sample number 1).

Sample Nr	Sample Sizes (mm)		Uniaxial Compressive Strength (MPa)
	Widht	Length	
1-1	40,26	40,93	1,98
1-2	39,69	40,13	1,44
1-3	39,91	40,41	2,16
1-4	40,21	42,16	1,42
1-5	38,71	38,11	1,55
1-6	40,08	39,71	1,44
1-7	40,21	39,29	2,14
1-8	39,60	40,00	1,93
1-9	39,82	39,69	1,59
1-10	40,37	40,39	1,40
1-11	42,29	39,20	1,06
1-12	38,81	39,67	1,70
		AVERAGE	**1,65**
		STANDARD DEVIATION	**0,33**
		COEFFICIENT OF VARIATION	**0,20**

Flat-Jack Experiment:

The mechanical properties obtained from the flat-jack tests performed at 3 different points on the structure are summarized in the table below.

Table 5. Results of Flat-Jack (No 1)

Experiment No. 1	
Experiment	**Modulus of Elasticity (MPa)**
Cycle 1	3827
Cycle 2	3041
Cycle 3	3233
Average	3367

Table 6. Results of Flat-Jack (No 2)

Experiment No. 2	
Experiment	**Modulus of Elasticity (MPa)**
Cycle 1	3261
Cycle 2	3179
Cycle 3	3296
Average	3245

Table 7. Results of Flat-Jack (No 3)

Experiment No. 3	
Experiment	**Modulus of Elasticity (MPa)**
Cycle 1	332
Cycle 2	374
Cycle 3	305
Average	337

4. Conclusion and Suggestions

The nitrate (N03) salt and protein values detected in all samples are not worth considering.

No saponifiable oil with chloride (Cf) sulfate (SO42), and carbonate (C032) salt was detected in any of the samples.

The results of the analysis and examination carried out on the samples taken from Kasımpaşa Mosque in the Merkez district of Edime, and the results of the flat-jack test are given below under the headings.

Mortar: Binder/aggregate ratios, quality and size distribution of the mortar samples taken from the building.

Table 8. Binder/Aggregate Ratios

Sample 1	Ratio	Part	Type
Binding	1	1	Slaked Cream Lime
Aggregate	3	3	4 mm Land Sand

Stone:.

Sample 3**;** It is a white-cream colored andesitic tuff sample containing quartz, biotite and amphibole minerals.

Brick:.

Sample 2; It is an example of orange colored, well compacted and well fired brick, containing 3-5% chamotte up to 2 mm in size, 3-5% carbonated aggregate and 20-25% quartz, with plenty of pores up to 1 mm in area.

It can be said that in the project and implementation process of historical building repairs in our country, on-site experiments are actually necessary, but they are often neglected due to time and financial concerns. It should not be forgotten that these studies aim to leave the building more intact for future generations. It should be encouraged to increase all practices, studies and modern techniques on this subject and, if necessary, to put them in written documents and specifications.

Direct use of test results obtained from material tests on site may not be true for many reasons. Age factor, heterogen material properties and test conditions, test locations may have affect on the results. That is why test results is not used in analysis for this Project.

Average elastic modulus is determined as 3300 MPa for stone wall. One of the flatjact test result (the one made from inner wall) is not taken into consideration because of the deformed (wooden lintel in between was moldered) structure causing the test result to be too low. Compressive strength corresponding 3300 Mpa elastic modulus is calculated as

3300/750=4.4 Mpa as per TBDY 2018 section 11.2.13. But 4.4 Mpa value was not the true number as well because of multi layered wall structure. It is decreased as 0.8*4.4=3.5 Mpa as per TBDY 2018 section 11.2.8. The Guideline for Historical Buildings published by VGM (Vakıflar Genel Müdürlüğü), IPCU (Istanbul Project Coordination Unit and ÇŞB (Environmental and Urbanization Ministry) proposes strenght values for this kind of stone walls as 2.0 Mpa. As as results 2.0 Mpa compressive strength value is accepted for analysis to be on the safe side.

One directional compressive strength test for brick resulted as 7.79-0.72=7.07 Mpa (Fave – standart deviation) and the same value for mortar as 1.65-0.33=1.32 Mpa. Brick wall is consist of brick and mortar. That is why the compressive strength for brick wall is accepted as 2.0 Mpa according to the table 11.2 from TBDY 2018.

Thanks and Information Note

Thank to KURAM technical team, who worked with great devotion during the experiments carried out in the building.

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 Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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Material Transformation in Contemporary Architecture: Glass

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1. Introduction

Cities have changing and transforming identities while hosting daily life functions with continuous dynamism. Different concepts are used for defining cities, and these definitions can now be mentioned ahead of their characteristics such as population, climate, and geography. Concepts such as smart city, green city, sustainable city, slow city, and accessible city are terms used quite frequently today, but actually, define new ways of perception and evaluation of cities. Factors such as the total area of the city, population density, diversity of commercial activities, cosmopolitan structure, as well as images of the city, the way of communication of the city, and the level of livability gain importance. It is questioned what kind of city we want to live in by the summary of the definitions that change and multiply over time.

The increasing potential of digital networks today affects our lives and designs in the urbanization process. All living spaces and the design of various spaces are also affected by the transformation process along with the developing technology. Production and consumption balances are changing with the rapid increase in the world population. The future generations are often ignored in the use of resources to meet the needs of the growing population. Irreversible conditions are created by not taking into account environmental factors and balances in the consumption of natural resources. Changing climate and environmental conditions make it mandatory to take precautions and produce solutions on all platforms. All kinds of environmental and climatic measures and protection proposals that need to be initiated individually must become socially and globally disseminated. It is clear that the quality of life, natural balance and environmental cycle cannot be handled only within the scope of buildings, cities, and countries, but will be beneficial within the scope of global sensitivity and awareness. The selection of recyclable and ecological materials, the widespread use of these materials, and their widespread use in our daily lives have gained much more importance than in previous generations. Glass material is used with wide possibilities in the field of sustainability today. Designs are improved in different dimensions with the help of unique qualities that technology brings to glass in contemporary architectural practices.

1.1. The Rise of the Glass

One of the most important factors causing a change in the world is economic variables and dynamics apart from environmental and climatic conditions. Global markets have become much more sensitive to changes and crises today than in the past. In the economic sense, the effect of each change finds its response in much wider areas. The dimensions of the economic crisis or fluctuation that occur in one part of the world can be felt by all countries and markets. Globalization reveals its power and influence in every sense. In the conditions encountered in the past centuries, but where globalization and digitalization are not at today's levels, a pandemic has not been so perceptible and its impact has not been measurable for humanity. The last Covid-19 pandemic has led to the formation of changes and different experiences that affect societies and countries in terms of its causes and consequences. The demand for changes and new space arrangements appear in parallel with the living conditions. Accessing safer and healthier living spaces has emerged as a priority in our century. A good environmental image gives residents a sense of security, also distinctive and legible spaces support the human experience (Lynch, 1960). These factors have been taken into account in the creation of new spaces and the modification and improvement of existing spaces according to current needs. Space designs that are related to the natural environment and natural air circulation have come to the fore. Transparent spaces and access conditions to these spaces have gained importance. Glass appears as an acceptable material to be used to form such spaces for the users. Glass is an energy-efficient, recyclable, and ecological material that can contribute to the future by the designers and constructors thinking about new products, new aesthetics, and better performance (Ritchie, 2004). Glass material has effective solutions with the advance of technology in terms of sustainability. Energy-effective solutions can be properly found by the use of glass, and energy consumption can be reduced. In many design projects glass is a good solution for thinner and lighter structures.

1.2. Glass in Design

The use and design of glass with rapid development in terms of production and detail, especially with technological developments, has come to the fore in designing transparent spaces. While the expression of technological developments by using glass material in spatial formations is increasing, the fact that its technical features are now met in a wide range supports the widespread use and spread of glass in spaces. Glass material has become preferred in spaces due to its transparency, clarity, brightness, and reflectivity. To provide permeability between indoor and outdoor spaces, relationships of persons with the outdoors, the street, and others can be established through glass materials, especially in social isolation environments. The use of glass can be observed not only in the facade structure but also to provide transparency in interior designs and to benefit from daylight in roof designs.

The high recycling advantage of glass material, being a good option for sustainable designs, easy cleaning in terms of hygienic conditions, and positive features in terms of not containing germs and bacteria have increased its preferability and frequency of application. Concepts can be created by considering different properties of glass in designs. Sometimes the reflectivity, transparency, and neutrality of the glass are emphasized, and sometimes it is observed that glass material is included in designs as a representation of technology and innovation. Glass structures should be designed by selecting the optimal solutions to meet the requirements of the project. The selection of the material speciality such as being laminated, tempered or fire-resistant, the selection of form such as curved or flat, the design of joints and supports, designing alternative load paths and other related issues have importance for the success of the project (Pariafsai, 2016). The multidimensional properties of glass are used in many designs around or integrated with historical buildings. It benefits from the advantages of establishing a connection between the old and the new by making use of its features such as being light and transparent, simplicity, and reflectivity. Recyclability and cost-effectiveness of the glass lead the material to be preferred in many designs.

2. Material and Method

In this chapter, the design approaches and the usage properties of the material are explained in the commonly known buildings exemplifying the use of glass materials in architecture. The role of the glass material in the design of the sample structures and the elements that it provides functionally are specially stated. The fact that these structures were built for various functions and in different years also indicates the technological development of glass material over time.

3. Findings and Discussion

In the design concepts of the buildings discussed in the study, the selection of glass material stands out and often shapes the design. The advantages of glass material are highlighted by the designers from the concept stage and play an important role in the use of buildings and their images in the city. Properties of glass materials such as transparency, sustainability, transparency and reflectivity are mainly used in the design of buildings. Although changing and developing construction techniques and application methods differ, the structural advantages of glass materials are utilized in energy conservation, transparency representation, and plain and simple features. Although the sample buildings have different functions, they are known around the world for their glass material applications. Buildings offer different experiences to both their users and city dwellers. In these building examples, the advantages brought by the glass material emerge by integrating with their designs.

3.1.The Shard

The Shard Building in London is considered a sustainable urban extension, especially in terms of its location next to London Bridge Station, its proximity to public transport, and easy access (Figure 1). It was designed by Renzo Piano Building Workshop and completed in 2012. The building has mixed uses of residential, offices, and retail units with day-long use performance. Offices, restaurants, and public spaces are located at the bottom, the hotel is located in the middle, and the private apartments are located at the top of the building. With the choice of extra white glass, the feeling of lightness and sensitivity in the sky can also be described as a reflection of the changing colour and mood (Renzo Piano Building Workshop, 2021). As an important detail in the city silhouette, the building stands out with its tapering design and disappears into the sky (Figure 2). The eight-curved glass facade provides fragmentation of the building scale and a wide range of reflections of light. A special technical solution has been developed to ensure the performance of the facade in terms of controlling light and heat. Triple-glazed blue glass panels were designed and the building has solar energy conversion systems (Elçin, Arpacioglu, Ozgunler, 2021).

Figure 1. The Shard and the city (Renzo Piano Building Workshop, 2021)

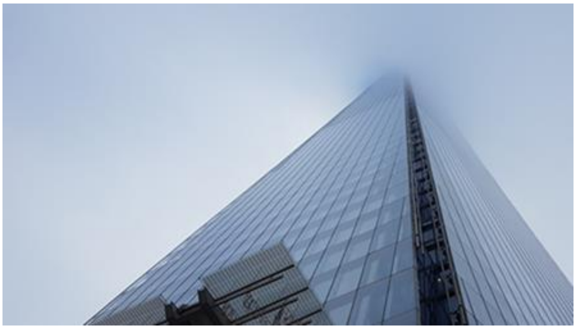

Figure 2. The Shard and the sky (Soydaş Çakır, 2016)

It is argued that the proximity of the building to public transportation and its effect on reducing traffic also contribute positively to sustainable urbanization. The public uses the environment and outside space of the building intensively during the day as it is located on the transportation node (Figure 3).

Figure 3. The public outer space of The Shard (Soydaş Çakır, 2016)

3.2. City Hall London

The City Hall building was designed by Norman Foster in Southwark beside River Thames and served as the headquarters of the Greater London Authority between 2002 and 2021 (Figure 4). The building provides 12 000 m² on ten levels (Foster & Partners, 2021).

Figure 4. City Hall with neighbourhood and River Thames (Soydaş Çakır, 2016)

As a result of modelling a geometrically modified sphere on the computer, the building is designed in a form without a front or back (Figure 5). The form of the building minimizes the surface area exposed to direct sunlight and provides optimum energy performance. The design stands out as a sustainable structure. The glass material in the building expresses the transparency of the democratic process; and allows the assembly to be watched at work (Figure 6).

Figure 5. The form of the City Hall building (Soydaş Çakır, 2016)

Figure 6. Transparency of glass (Foster & Partners, 2021)

The public is allowed to use the building. There is a flexible venue upstairs for exhibitions and events. Accessibility is provided in the building by ramps and elevators.

Optimum energy efficiency was targeted by analyzing sunlight models for the building. Active and passive shading devices are used in the building. Pumped groundwater is used in the cooling system of the building. With energy-saving techniques, there is less need for coolers and additional heating.

3.3. Reichstag building

The original Parliament Building was built between 1884-1894 in Berlin according to the design competition project won by Paul Wallot. The building was heavily damaged by a fire in 1933 and during the Second World War (Archdaily, 2015).

In 1993, a competition was held for the New German Parliament building, which has an important place in the city's memory and aims to symbolize democratic values. After winning the competition, Norman Foster revised his project, keeping the original design of the building, with the symbolic transparent glass dome. The design protects the shell of the heritage building. The skylight with a large dome shape is reflecting the captured daylight within the building (Figure 7).

Figure 7. The Reichstag and the glass dome (Foster & Partners, 2021b)

Under the transparent dome, visitors can view the city panorama thanks to the rising ramps (Figure 8). At the same time, the study hall of the parliament can be watched with the advantage of transparency. The fact that the work of the parliament is visible from above emphasizes openness and transparency in the democratic process of the country. Inverted mirrored panels in the middle of the dome reflect daylight into the space below (Figure 9). A large sun shield moves electronically according to the movement of the sun and blocks the rays from the sun that can disturb those downstairs. This large glass dome is the most visited place as an urban item both with the sense of spaciousness and light it brings to the interior and with the visual effect of the city panorama.

Figure 8. The ramps under the transparent dome (Soydaş Çakır, 2018)

Figure 9. The vision of the Parliament level and inverted cone of mirrored panels (Soydaş Çakır, 2018)

3.4. St Mary axe

The building was designed by Foster and Partners for Swiss Reinsurance Company in London and completed in 2004. It has a 180 m height and an area of 64 469 m² (Figure 10). The building has a circular plan and a radial geometry. The building looks more slender than a rectangular building with its form. It is highly reflective by the glazed facade (Figure 11). The building widens as it rises and tapers at the top and bottom maximizing the public space at ground level. Floor space is allowed without columns with the advantage of a diagonally braced structure (Figure 12, Figure 13). The glazed facade enables to get light into the building and access to the view. The reduced diameter of the floor at the top levels helps not to dominate the skyline. The form of the building minimizes the impact on the local wind environment. There is physical and visual connectivity between floors. The building has an automated natural ventilation system. The facade of the building has openable glass screens and internal sunscreens. With the help of natural light and ventilation, the building needs less energy than most of its neighbours (The Gerkhin, 2022). The building has reduced energy consumption. The upper three levels of the building are covered with a steel and glass dome with 30 m diameter. The spaces are providing corporate facilities and a 360-degree city panorama (Munro, 2004).

Figure 10. St Mary Axe in the city (Soydaş Çakır, 2016)

Figure 11. The glazed facade and the reflective feature of St Mary Axe (Soydaş Çakır, 2016)

Figure 12. The ground level and public outer space of St Mary Axe (Soydaş Çakır, 2016)

Figure 13. Reflection and transparency on the ground level (Soydaş Çakır, 2016)

3.5. Berlin Central Station

The Central Railway Station in Berlin was designed by the architects, Gerkan, Marg and Partners after winning the competition in 1993 and completed in 2006 (Figure 14). The gross floor area is 175 000 m² and the station has 5 transportation levels (Gerkan, Marg & Partners, 2021). The station is a central transportation hub and a mixed-use building complex forming an urban design link. The design of the building emphasizes the existing railway line around the city. The design has two inverted L-shaped office buildings and a glass roof. The cover of the station allows daylight to reach every unit and the platforms under the ground (Figure 15). The platform opening in the east-west direction is covered with a 321 m long glass top shaping the design of the station. The glass cover of the north-south hall connects the buildings on the sides, and the curved glass surface of the roof is supported by beams. There are also longitudinal modules covered with glass on both sides of the curved rail lines (Arkitera, 2008). The daylight can be used effectively by the passengers and the other users in the station (Figure 16). The building has natural ventilation as the glass facade designed with circular forms allows the warm air to rise up and fill the space with fresh air. There is a glass coating that reduces the effect of sun rays and the roof has photovoltaic modules. The steel structure of the station slabs is exposed in front of the facade. The facade has transparency with steel structured glazed covering (Figure 17).

Figure 14. The entrance facade of the Central Station (Soydaş Çakır, 2018)

Figure 15. The railway lines and glazed covering (Gerkan, Marg & Partners, 2021)

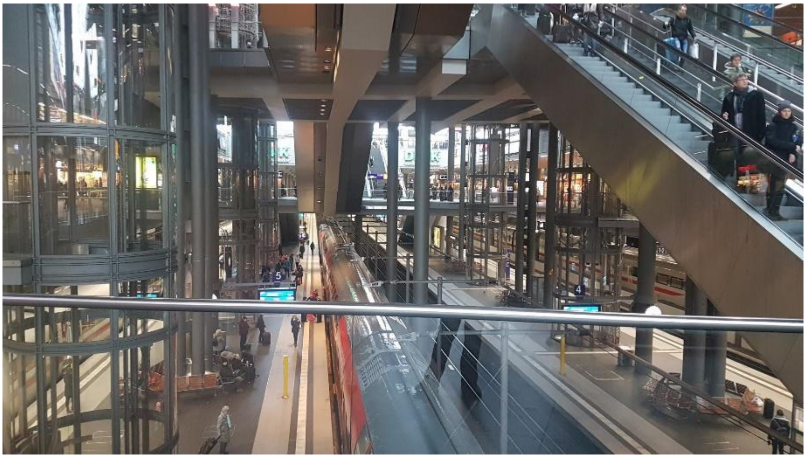

Figure 16. The inner space of the station and the use of daylight (Soydaş Çakır, 2018)

Figure 17. The facade covering system of the station (Soydaş Çakır, 2018)

4. Conclusion and Suggestions

Glass which has been used in architecture for many years; is transforming in parallel with the advancement of technology and increasing requirements of the users and projects. The structural advantages of glass play an important role in its preference for design. Many features such as transparency, simplicity, easy cleaning and hygienic characteristics make it a preferred material in designs with the advantage of allowing lighter and more aesthetic design options in structural terms, the advantage of anti-corrosion, and being a sustainable and natural material. The material decision is often the starting point for many architects in the production of buildings with aesthetic glass designs. The design and structural performances of glass are increasing day by day with the developing technologies. It will continue to be an important material for economical, aesthetic, nature-friendly, and energy-efficient designs in the following years. Various approaches have been provided in terms of transparency and reflectivity with the use of glass material both in the furnishing of public spaces and in exterior and interior designs of the buildings. The new business approach prefers open and transparent spaces to work in recent years. There is a transition to a more flexible working system in spaces. Appropriate structural solutions, and applications in which glass and related materials are dominant, have become alternatives based on the demand for more transparent and flexible working arrangements. It is possible to benefit from the technical properties of glass in establishing appropriate spaces and providing privacy clearly and transparently. Glass provides advantages for both designers and users in spaces, it has gained a new dimension and approach in areas of use from past to present.

Thanks and Information Note

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Use of Glass in Interior Architecture

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1. Introduction

Glass is one of the high-tech products, a new material that provides the required optical properties through the secondary production process of traditional glass or the use of advanced technology (Umaroğulları, 2001). In the scientific sense, the term "glass" refers to a super cooled, frozen liquid without crystallization (Weller et al., 2009). Glass is produced from relatively common ingredients such as sand, limestone and soda. These materials should be mixed in the right proportions according to the recipe (Kantur, 2009). Glass used in the construction industry is the main component of soda lime varieties. In addition to the main component silica, there is also some sodium oxide (Na_2O) in the form of soda as a flow charge. Calcium oxide (CaO) acts as a stabilizer by dissolving the lime added to the mixture. Some different components are also available, depending on the specific raw material and processing conditions (Weller, et al., 2009). Each glass manufacturer uses these mixes in different amounts and forms, depending on their specific needs (Küçükerman, 1985). Glass is used and produced in transparent or non-transparent forms by hand or machine with different methods and forms, colored and colorless, as well as in line with different units, purposes and areas (Aslan, 2007).

1.1. Properties of glass

During the process of preparing the frit or during the production process/after various processes and applications, glass materials differ depending on the number and proportions of their components

(Yanarateş, 1998; Üner, 2001). The properties of glass can be examined under three headings: physical, mechanical and chemical properties. Ordinary glass is brittle due to its amorphous structure and exhibits linear elastic behaviour before breaking. This situation reveals the physical properties of glass (Turhan, 2007). Mechanical properties are considered the ability of glass to resist cracking and bending (hardness) when subjected to great constant pressure or sudden shock. Chemical properties include the resistance of glass to other substances, especially gases and liquids (Kantur, 2009).

1.2. Glass types

There are 12 different types of glass: float glass, tempered glass, laminated safety glass, bulletproof glass, wired glass, glass brick, air-layered glass, low-e glass, impregnated glass, stained glass, enamel glass and mirror.

Float (flat) glass, also known as soda lime glass, is used in glass bottles as well as window glasses (Kantur, 2009). When tempered glass, also known as safety glass, breaks into small pieces, it reduces the risk of injury (Üner, 2001). They can be used in stair railings, parapet glasses and overhead glazing that may be exposed to impacts and bumps and have the risk of thermal cracking (Ömeroğulları, 2012). Laminated safety glass is considered a type of safety glass as it consists of two or more sheets of glass joined together to hold the glass in place when broken and provide safety to the user when damaged (Üner, 2001). As the number of glass layers increases, bulletproof glasses are obtained that bullets cannot pass through. These glasses are used in places where security is a priority, such as banks, prisons and control rooms (Üner, 2001).

Stranded glass is the glass obtained by placing wires inside the glass to increase the breakage resistance of the glass and to prevent the glass from scattering when broken (Toydemir, 1990). Glass bricks are hollow glass blocks used to make translucent walls. Glass bricks can be used on floors, walls and ceilings (Umaroğulları, 2001; Turhan, 2007). Insulating glazing (glasses with air layers) reduces heat loss from windows by 50% and significantly improves sound insulation (Sev, et al., 2004).

Low-e glasses can transfer most of the short-wave radiation energy from the sun to the interior, while keeping most of the long-wavelength radiant energy from radiating through the window and reflecting it back to its source (Umaroğulları, 2001).

Frosted (imprinted) glass gets its name from the resemblance to the appearance of water turning into ice on the glass surface. It is thinner and more easily broken than ordinary glass. It is suitable for use in areas where sharp and clear images are not desired (Üner, 2001).

Stained glass is glass made by painting the glass and placing it in front of a light source (Gökmen Erdoğan, 2011).

Enamel glass with an infinite color scale can be produced on any type of glass by printing methods (Umaroğulları, 2001). Mirrors are reflective glasses commonly used indoors (Üner, 2001).

1.3. History of glass

Glass is one of the materials that has existed in social life for 5000 years (Aydın & Ağatekin, 2010). Natural glass in history was first discovered in the Palaeolithic era, as a result of the interaction between man and the environment around 3000 BC. In this period, glass began to be used due to war and the need for protection (Phillips, 1948; Maloney, 1968). It is known that many civilizations developed a very common ceramic technique in the past. Therefore, it is possible to come across the first examples of glass making in many places from the Eastern Mediterranean to Anatolia, from Mesopotamia to Egypt.
(Küçükerman, 1985).

With the division of the Roman Empire into east and west in 365, the Western Roman Empire was in 476, and the Eastern Roman, that is, Byzantium, in the 4th-15th centuries. Rome has been the center of glass production for centuries. Occasionally in the Roman Thermae and a few wealthy Roman houses, Towards the end of the XIIIth Century, glass plates began to appear in the mansions of the wealthiest inhabitants of Florence, Venice, and Genoa. During the Byzantine period, glass mosaics became the symbol of Christianity together with the catacombs. Churches of the period had narrow windows that illuminated the colorful walls. Glass was also widely used in Islamic civilizations that influenced civilizations in the Near East (Turhan, 2007).

Between XIIth and XVIth centuries, in Gothic architecture, which developed over the centuries, construction competition between cities that developed rapidly around a cathedral led to the development of the technique of stained glass, which consisted of small pieces of colored glass to facilitate the handling of glass panels and increase their resistance to wind. Therefore, stained glass became a characteristic element of Gothic architecture (Graves, 1951). The Renaissance architecture, on the other hand, was characterized by flat-arched or square-headed windows instead of long-arched windows. Baroque architecture influence was seen in the XVIIth and XVIIIth centuries. Mirrors are prominently located in all areas where the space is desired to be brighter, larger and more spacious. Industrial age architecture continued its influence especially towards the end of the 18th century and throughout the IXXth Century (Turhan, 2007). With industrialization, glass production has become the preferred material for families and architects who want to express themselves in a new society. Now, people have begun to seek lightness, transparency, greenery, freshness and hygiene in projects and buildings of all sizes, instead of situations such as overcrowding, pollution, darkness and disease (Sadar, 2008).

Today, glass is widely used by craftsmen, artists, designers and architects for functional, aesthetic and artistic purposes. In the XXIst century, mostly man-made glass is used in almost every field due to its wide variety and useful properties (Yatır, 2020).

2. Material and Method

The coasts are the areas where both domestic and international tourism are most directed in Turkey, and the coastal areas where the demand is concentrated are also concentrated in certain parts of the country. Antalya, which is among these areas, is the most preferred city in Turkey, especially by foreign tourists (Özgüç, 2007). The fact that the demand for Antalya is so high can be explained with factors such as historical tourist attractions, natural beauties, and forest cover extending to the shore are effective. Accommodation facilities have started to attract great attention in this direction. Due to competition, the importance of interior and landscape designs has increased (Kapan & Timor, 2018).

The number of accommodation facilities in Antalya is increasing day by day. According to TÜRSAB (Turkish Travel Agencies Association) statistics, in 1990 there were 693 facilities with operation and investment certificates, while there were 1,929 facilities in 2020 (Table 1).

Table 1. Ministry Certified Accommodation Facility Statistics (Turkish Statistical Institute (TUIK), 2020)

	Business Certified			Investment Certificate		
2020	Number of Facilities	Number of Rooms	Number of Beds	Number of Facilities	Number of Rooms	Number of Beds
Antalya	804	214 680	462 826	97	21 423	47 062
Türkiye Total	**4 198**	**485 791**	**1 017 825**	**654**	**78 480**	**169 322**
Percentile (%)	19.15	44.19	45.47	14.83	27.30	27.79

2.1. Kempinski Hotel the Dome

The interior of Kempinski Hotel the Dome was designed by Art-Mim (Figure 1). The accommodation facility is located in the Kadriye neighborhood of the Serik district of Antalya. Completed on July 15, 2006, the hotel has a total area of 40,000 square meters. The distance to the city center is 30 km, while the distance to the airport is 25 km. Kempinski Hotel, being open for 12 months, has 175 rooms.

Figure 1. Kempinski Hotel Loby - Glass Roof (Art-Mim Archive)

2.2. Royal Holiday Palace

Interior Architecture of Royal Holiday Palace was designed by Art-Mim (Figure 2). The hotel is located in the Kundu neighborhood of the Aksu district of Antalya province. Completed in April 2011, the hotel has a total area of 53.000 square meters. Royal Holiday Palace, which is open for 12 months, has 604 rooms.

Figure 2. Royal Holiday Palace - Glass Roof (Art-Mim Archive)

2.3. Maxx Royal Belek Golf Resort Hotel

The interior design of Maxx Royal Belek Golf Resort Hotel was designed by Art-Mim (Figure 3). The hotel is located in Belek neighborhood of Serik district of Antalya. Completed on May 27, 2011, the hotel has a total area of 1,040,500 m². Maxx Royal, which is open for 12 months, has 531 rooms.

Figure 3. Maxx Royal Belek Golf Resort Hotel – Glass Wall (Art-Mim archive)

2.4. Kosa Hotel

The boutique hotel is located in the Barbaros neighborhood of Antalya's Kaleici District (Figure 4). The hotel, whose restoration was completed in 2015, is open for 12 months and has 17 rooms in total.

Figure 4. Kosa Hotel – Glass Floor (Zuhal Kaynakçı Elinç Archive)

2.5. Ramada Plaza Hotel

The interior architecture of Ramada Plaza Hotel was designed by Art-Mim (Figure 5). Opened in 2010, the hotel has an area of 38,000m². With a total of 93 rooms, 318 visitors can be hosted at the same time.

Figure 5. Ramada Plaza Hotel – Glass Wall (Anonim 2, 2022)

2.6. Land of Legends - Nemo Restaurant

The hotel's architecture was designed by Jack Rouse (Figure 6). The restaurant is located in the Kadriye neighborhood of Antalya's Serik district, within the Land of Legends Kingdom Hotel and Theme Park. Land of Legends, completed in 2016, has a residential area of 662740m², a shopping center of 196,000m², a living park of 146.000m², a water slide park of 280.000m² and a hotel area of 17.000m².

Figure 6. Nemo Restaurant – Glass Wall (Anonim 1, 2022)

The 6 hotels examined in the study were selected from 8 different tourism regions of Antalya (Antalya-City Center, Belek, Beldibi, Kadriye, Kaleiçi, Kundu, Kemer, Tekirova. 10 students from Akdeniz University Interior Architecture branch graduate students and 10 faculty members from the Faculty of Architecture. The results of the survey applied to a total of 20 people, including the staff members determined the locations mentioned above (Table 3). The 6 hotels with the highest score were included in the study. The survey was made out of 50 points and the Hotels Land of Legends (46 points), Maxx Royal (46), Kempinski Hotel (42), Royal Holiday (40), Kosa Hotel (38) and Ramada Plaza (36) were rated. The designs were classified according to the use of glass in the ceiling, column and wall. The survey was prepared according to the 8 basic design principles stated below (Table 2).

Table 2. The survey according to the 8 basic design principles

Please give a score between (1-5) and indicate your opinion on the criteria given below	I strongly disagree (1)	I disagree (2)	I'm undecided (3)	I agree (4)	I absolutely agree (5)	Glass Design Images
Suggestion 1						
It affects the illumination of the space						Image
It is remarkable						
The place has a rhythm						
The design has a form harmony						
It makes a difference in the size of the space						
Adds excitement to the field						
Glass material is used in a balanced proportion						
Suitable for the use of a transparent material						
It is an innovative design						
It is an original design						Source:
TOTAL						

2.7. Basic design principles

In the process of creating a design, there are many determining factors necessary to organize the basic design elements (light and shadow, tone, texture, spacing, color, shape, line, measure-ratio). It guides and facilitates organizing principles in the visual arts and architecture

(Ustaömeroğlu, 1998). The basic design principles include symmetry, hierarchy, repetition, harmony, contrast, balance, emphasis and grouping.

Symmetry is the use of the balanced arrangement of equivalent patterns of shape and space around a center or axis, on opposite sides of a dividing line or plane. There are two basic types of symmetry, bilateral and radial. Bilateral symmetry refers to the balanced arrangement of identical or equivalent elements on opposite sides of a median axis. Radial symmetry, on the other hand, refers to the balanced arrangement of similar, radiating elements so that the composition can be divided into like halves by passing a plane around a center point or at any angle along a central axis. Dominance has less attention value than the primary focus, secondary points of emphasis create visual highlights. These distinctive secondary elements can both accommodate diversity and create visual interest, rhythm and tension in a composition. Repetition and rhythm refer to any movement characterized by the patterned repetition of elements or motifs at regular or irregular intervals (Ching, 1943). Conformity is the integration of basic design elements within an organization. (Doğan, 2020). Compatibility between objects can be achieved by any one or more of their physical shapes, sizes, tones and colors, textures. In order to ensure consistency, there should be perceptible proximity, not absolute sameness, in terms of these elements. Contrast (contrast) is contrast in an arrangement if there are no similar or common standards in key design elements between the objects or groups of objects that fall under the arrangement. Balance is divided into two as symmetrical balance and asymmetrical balance. Symmetrical balance is the balancing of one or more identical or very similar items on opposite sides of an axis. Asymmetrical balance is the balancing of one or more elements on either side of an axis with different or opposite elements. The emphasis is to ensure that the design attracts attention and by bringing the viewer to an active position, directs the design to analysis. Finally, in the grouping principle, it allows us to perceive units and objects that match each other as a group (Ustaömeroğlu, 1998).

3. Findings and Discussion

In this part of the study, an observation-based report has been prepared for the glass designs in hotels as a general visual analysis and the dominant design principles have been determined. The basic design principles of symmetry, hierarchy, repetition, rhythm, harmony, contrast, balance, emphasis and grouping were taken into account for each glass design analyzed regarding the related designs.

3.1. Maxx Royal Resort Hotel

Completed in 2011, Maxx Royal Resort Hotel is located in Belek, Antalya. In this glass facade design, the aim is to make the space brighter and add an aesthetic value. The use of outward half dome shaped projection creates additional space in the interior. The fact that most of the façade is made of glass illuminates the space to a great extent. In addition, the use of glass makes the space more spacious and wider than it is. The hotel's patisserie has a facade design that includes a total of 6 different materials: black painted iron wrought iron, black painted iron joinery, glass facade, white lacquered door frame, white color sprinkling fasarit plaster and smoked marble skirting.

The colors, materials and forms of the wrought iron and woodwork on the facade, starting from the windows, extending to the chair, table, lighting, door, ceiling and floor, cover the principle of repetition and rhythm.

The coexistence of stimulants such as color, material and form on the façade emphasizes that the unit tends to be grouped.

The fact that the patisserie floor and glass design is approximately 2 m from the lobby ensures the integration of the facade with the exterior as well as the interior. In this direction, the principles of balance and harmony have been determined in the occupancy and void ratios of the design.

When the glass facade is examined in volume, it has an organic structure. In addition, the fact that it consists of circle and square units is an indicator of the principle of contrast.

The protruding volumes on the patisserie façade are the focal point of the design and thus are linked to hierarchy and emphasis.

The design itself consists of 3 units: the door, the right and left protrusion. Each unit is designed symmetrically within itself and all units on the facade plane (Table 3).

Table 3. Evaluation of the Maxx Royal Resort Hotel according to the basic design principles

Relationship With Design	Basic Design Principles
√	Symmetry
√	Hierarchy
√	Repetition-Rhythm
√	Suitability
√	Contrast
√	Balance
√	Emphasis
√	Group

3.2. Royal Holiday Palace Hotel

Royal Holiday Palace Hotel was built in 2011 and has 9 glass ceilings. These stained-glass ceilings illuminate the space throughout the day. In the evening, lighting is provided by chandeliers placed in the centers of the glass ceilings.

Contrast could not be detected as a glass design principle.

9 stained glass ceilings and 4 columns at their intersections are positioned symmetrically in the space.

The horizontal lines of the columns show the space flatter. On the other hand, the glass ceiling created a sense of height and spaciousness in the space. As a result of the analysis made in the context of linear movements, the principles of harmony and balance were determined.

Glass ceilings can be defined as guiding elements for the furnishings located in the space. The colors used in stained glass continue their rhythm and repetition on columns, furniture, lighting and walls.

Stained glass ceiling adapts to the concept of the space. When the design is examined in terms of motif, color and lines, it has been observed that it intersects with columns and within itself in group principle. Similar colors, continuous circular lines and motifs close to each other, units that tend to group together, meeting in a common language were observed.

Glass ceiling and pendant lighting, which attract attention with their unique designs, include the principles of emphasis and hierarchy (Table 4).

Table 4. Evaluation of the Royal Holiday Palace Hotel according to the basic design principles

Relationship With Design	Basic Design Principles
√	Symmetry
√	Hierarchy
√	Repetition-Rhythm
√	Suitability
x	Contrast
√	Balance
√	Emphasis
√	Group

3.3. Kempinski the Dome Golf & Spa Resort - Loby

Completed in 2005, Kempinski The Dome Golf & Spa Resort features a glass dome design.

Contrast could not be determined as a glass design principle.

The ceiling decorated with stained glass and the chandelier extending from the center integrates natural and artificial lighting. When these data are examined, the principles of harmony and balance in glass design have been determined.

The glass dome attracts attention as soon as you enter the lobby, thus embodying the principles of hierarchy and emphasis.

When the glass dome is observed from a spatial perspective, its circular form, the movements of the floor, the ceiling decorations and the circular table in the center of the lobby are symmetrically positioned in the space.

The motifs and colors on the stained glass of the dome repeat in line with certain rhythms. There are also shapes that repeat in the same extent with forms and colors, but continue in different sizes. When all these situations were examined in accordance with the basic design principles, group (closeness and continuity), repetition and rhythm principles were determined.

The use of glossy materials on the floor and stained glass on the ceiling creates reflections in the space. The colors and motifs of stained glass are thus seen both on the ceiling and their reflections on the floor (Table 5).

Table 5. Evaluation of the Kempinski the Dome Golf & Spa Resort - loby according to the basic design principles

Relationship With Design	Basic Design Principles
√	Symmetry
√	Hierarchy
√	Repetition-Rhythm
√	Suitability
x	Contrast
√	Balance
√	Emphasis
√	Group

3.4. Kempinski the Dome Golf & Spa Resort - Spa

Located within the glass design spa at Kempinski The Dome Golf & Spa Resort Hotel.

Symmetry as a glass design principle could not be determined.

Enclosing the column with glass and then continuing through the wall is again related to the principles of continuity and proximity.

Spots placed on the floor to indicate the texture of the column and sidewall give the glass a shine effect. The fact that the light makes the textures in the column more prominent and adds shadows creates a contrasting texture with the gloss on the glass. With this feature, the principles of emphasis and contrast have been determined in glass.

In the spa, where dark colors are used intensely, glass balances the dominance ratio in the space.

In addition to the hygienic aspects of the glass column cladding, it also adds dynamism to the space as a play of light and shadow. This mobility allows units to attract attention and connects with the principle of hierarchy.

The vertical glass used in the column and wall, combined with the lighting, makes the space look wider and higher. With this feature, glass designs, stone walls and niches provide integrity with each other and reflect the feature of the harmony principle to the space (Table 6).

Table 6. Evaluation of the Kempinski the Dome Golf & Spa Resort - spa according to the basic design principles

Relationship With Design	Basic Design Principles
x	Symmetry
√	Hierarchy
√	Repetition-Rhythm
√	Suitability
√	Contrast
√	Balance
√	Emphasis
√	Group

3.5. The Land of Legends – Nemo Restaurant & Lounge

Nemo Restaurant & Lounge is located in The Land of Legends Kingdom Hotel, which was completed in 2016. Inside this restaurant, an unusual design welcomes the users. There is an underground aquarium surrounding the place. The restaurant also offers the opportunity to watch the aquatic life during the meal.

Symmetry, hierarchy and contrast could not be determined as the principle of glass design.

When the glass windows are examined in terms of form, it is observed that they are repeated in different locations of the space in various materials and sizes. In this case, design is associated with repetition and rhythm.

The glass material that connects the aquarium with the restaurant is used in a curved shape as well as flat. In addition, it has adopted the principle of balance and harmony in terms of material, direction, form and reflectivity by adapting to sitting units and columns.

The aquarium, which covers most of the interior walls and determines the concept of the space, stands out with its emphasis principle.

The aquarium surrounds the space and also creates continuity in the image by using reflective material on the floor and ceiling. This situation includes the principles of proximity, similarity and continuity from the grouping principle (Table 7).

Table 7. Evaluation of the Kempinski the Dome Golf & Spa Resort - loby according to the basic design principles

Relationship With Design	Basic Design Principles
x	Symmetry
x	Hierarchy
√	Repetition-Rhythm
√	Suitability
x	Contrast
√	Balance
√	Emphasis
√	Group

3.6. Kosa Boutique Hotel

The historical building, whose restoration was completed in 2015, was put into service as Kosa Boutique Hotel. The presentation of the hotel, which has historical artifacts in its lobby, draws attention. The works were left below the lobby level and covered with transparent glass. This design offers the opportunity to examine the works from the top. At the same time, it does not occupy any space in the area and thus there is no obstacle in circulation.

Symmetry and contrast principles could not be determined as glass design principles.

The use of glass material on the floor adds liveliness to the space. This mobility ensures that the works attract attention and establishes a connection with the principle of hierarchy according to their position.

When the design is examined in terms of material, there is a wide and high window of similar dimensions right next to it. When examined in terms of form, it is similar to the ceiling form. In line with these findings, the design includes the principle of repetition and rhythm.

Compatibility with other units in the space has been determined in terms of glass design form and size covering a certain part of the floor. In this case, the design provides integrity with the principles of harmony and balance.

The glass floor, designed for the presentation and preservation of the works, has become the focal point of the space. In this direction, it is associated with the principle of design emphasis.

The fact that the space on the floor is covered with glass and the material is repeated in different areas in the space makes the design related to the grouping principle (Table 8).

Table 8. Evaluation of the Kosa Boutique Hotel according to the basic design principles

Relationship With Design	Basic Design Principles
x	Symmetry
√	Hierarchy
√	Repetition-Rhythm
√	Suitability
x	Contrast
√	Balance
√	Emphasis
√	Group

3.7. Ramada Plaza Hotel

Ramada Plaza is a hotel opened in 2010 and its interior design was designed by Art-Mim. The glass design in the wall in the hotel room unites the two spaces. Glass wall design shows positive results in terms of functionality as well as aesthetics.

Symmetry, emphasis and contrast principles could not be determined as glass design principles.

When examined together with the glass wall frame, even if it does not differ significantly from other similar units in terms of size, it offers a well-defined diversity in the space in terms of location and material. In this direction, it includes the principle of hierarchy, which is one of the basic design principles.

Features such as color, tone and texture were preserved in the glass design and repeated in various units in different areas of the space such as the headboard. All these units are visually related and similarly designed, maintaining their continuity in certain proportions without tiring the eyes and taking on the characteristic features of the room. When this situation was examined within the scope of basic design principles, grouping, balance, repetition and rhythm principles were determined.

There is perceptible harmony with other units in the space in terms of direction, size, material and color in the design. Therefore, the design complies with the principle of harmony (Table 9).

Table 9. Evaluation of the Kosa Boutique Hotel according to the basic design principles

Relationship With Design	Basic Design Principles
x	Symmetry
√	Hierarchy
√	Repetition-Rhythm
√	Suitability
x	Contrast
√	Balance
x	Emphasis
√	Group

4. Conclusion and Suggestions

It seems that glass, which has existed in social life for 5000 years, will continue to be used in living spaces for many years until a material with the same transparency and easy production is found to replace it. The use of glass in living spaces has undergone a great change in recent years and has opened new horizons for designers. Despite this development in the world of design and production, the prejudices of the users towards glass as a material still continue. The biggest reason for this is the idea that glass is always fragile and often causes physical injury. In line with this situation, units with glassware have always prompted us to be careful. The experiences that most of us had in childhood are embedded in our subconscious and continue to affect us into our adulthood. Although glass such as tempered glass is a solid material, the thought that it is fragile makes us all think to be cautious. As a result of the study, the following suggestions are listed in order to increase the designs with the use of original glass as in the examples we examined.

Glass as a material should be well introduced to interior architecture students throughout their education years, and workshops should be prepared on this subject and the use of glass should be encouraged.

The fragile perception of glass should be broken for both the user and the designer.

Glasses produced with the new technology should be well introduced to the designers by the material manufacturers.

Designers believe that glass is not just a window material; should be informed that it is suitable for column, ceiling, wall and even floor use. The effect of natural daylight in the area should be presented to the users. In this regard, it should be stated that the sun's rays can be received through windows and glass ceilings, they can reach the center of the spaces with dividing walls as well.

Glass-related design competitions, scientific research and symposiums should be increased so that people can access different knowledge and experiences. For the glass designs to be made in line with this information, it should be made possible to reveal ideas that go beyond the borders.

Thanks and Information Note

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Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article.

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Earth Buildings from Traditional to Present

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1. Introduction

Earth, which is one of the first materials used by human beings in the production of shelter and goods, continues to be used in many areas with different processing techniques today. Earthen structures, which are frequently encountered especially in regions where other basic material resources such as wood and stone are scarce, have protected people from difficult environmental conditions for centuries and created spaces that provide suitable comfort for their survival and development. Structures built with earth in regions with harsh conditions in the past are still in use today, thanks to the durability and renewability of the material.

The easy accessibility and sustainability features of raw earth building materials can also meet today's design needs. In recent years, earth buildings have also attracted increasing interest from the scientific world since the issue of sustainability has gained importance recently. Research articles in recent years are also considerably higher than in previous years (Pacheco Torgal & Jalali, 2012) Earth-building materials, which are mostly seen in traditional production examples, become producible with innovative construction techniques together with scientific research and developing technology, and traditional earth structure production develops in this way. Thanks to this development of the earth building material, it can be adapted to today's design concept and can also be used in the construction of innovative structures.

The development of earth building design, which takes place in parallel with the developments in material technology, is in the process of adapting to the design understanding of our age by being differentiated by the developments in the design process with computer and digital technologies. Where technology-enhanced earth-building production will go in the future will depend on how much contemporary design products are used.

To adapt traditional earthen building materials to today's design understanding, it is an important requirement to widen the perspective and develop the possibilities of the material. While trying to understand the material, technology is a valuable tool to change our perspective on the production potential of that material and to gain a different understanding of thinking.

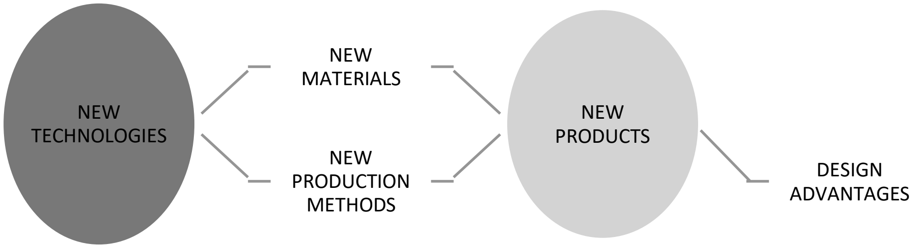

Figure 1. Technology, material, and design relationship diagram (Ashby & Johnson, 2013)

Innovative materials and fabrication methods developed with new technologies lead to the formation of new designs. New products created also bring some design advantages. (Figure 1)

2. Material and Method

In this study, which compiles the journey of earth building systems to the present, literature, and sample research on the use of soil material in architectural design as a method, as well as a detailed examination of earth construction technique and manufacturing technologies, developments in design and improvements in production have been classified. Since the developments in material and construction technology cannot be managed independently from traditional methods, the most used soil construction techniques were examined with examples from all over the world before recent technologies. After these examinations, the developments in today's materials science and fabrication techniques and the effects of computer-aided design on earth building design are discussed.

3. Findings and Discussion

In this section, the compilation of the findings on the history and traditional use of earthen structures and where these techniques can go with today's technology are discussed in two main sections.

3.1 Traditional earth-building systems

Earth buildings have been categorized and examined under four main classes according to their structural systems. (Figure 2) The diversity and richness of earth construction systems are based on the long history of this material. Earth buildings, which vary according to the region they are in, bear traces of the culture, resources, and climate of that region.

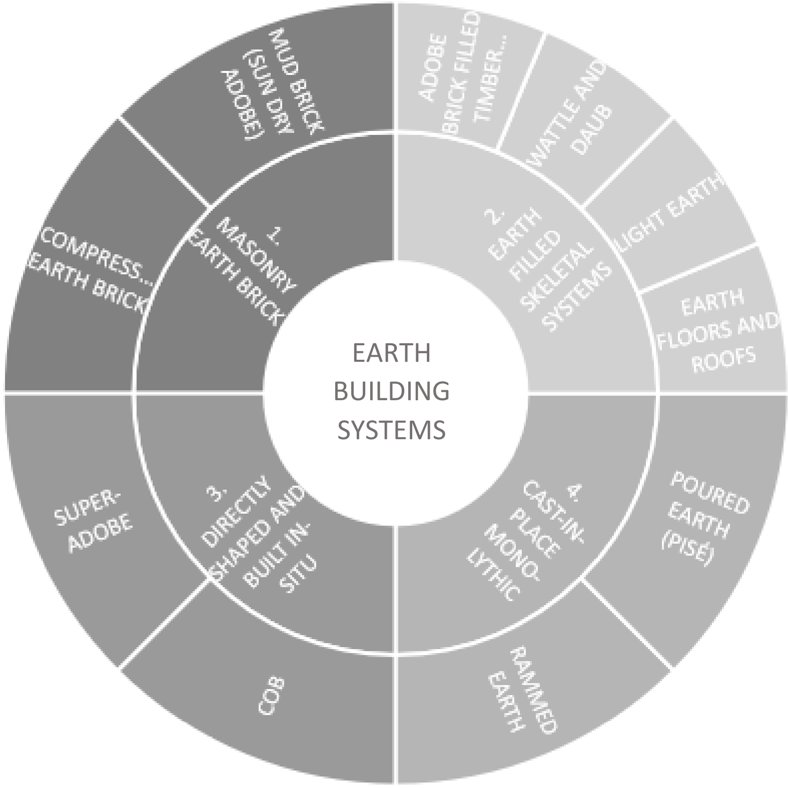

Figure 2. Traditional earth-building techniques according to structural systems

3.1.1. Masonry earth brick systems

Masonry adobe brick construction technique is one of the oldest building construction methods, examples of which are frequently encountered especially in Anatolia, the Middle East, Africa, and Egypt. (Figure 3.) Building with earth blocks is mostly common in all hot-dry, sub-tropical and temperate climates. It is the most widely used method in regions where wood and stone are scarce. In this method, adobe is produced in the form of blocks that can be built into structures such as walls, vaults, and shells.

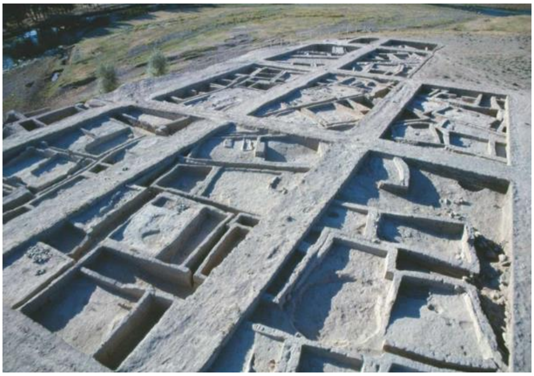

Figure 3. Aşıklı Höyük, the first residential settlement built with adobe bricks in 8000 BC (Özbaşaran et al., 2010)

Earthen blocks produced by hand by pouring wet soil into a mold are called "mud brick", "adobe brick" or "sun-dried earth brick". When moist soil is compacted in a manual or electric press, the compacted elements thus formed are called "compressed earth blocks".(Minke, 2006) Traditional adobe blocks are blocks produced by keeping a mud mixture consisting of dense clay soil (around 30% clay), water, and plant materials such as straw in the pool, filling in molds, and drying in the sun. Water is poured on it and mixed and a slime mixture is obtained. This mixture is rested/fermented for at least one day and mixed again and the molding process is started. This mixture is thrown into the prepared and wetted wooden molds and filled. The upper surface of the mold is smoothed by hand or with wood, a trowel, or wire. (Işık, 2018) (Figure 4)

Figure 4. Adobe brick production process (Chiangmai Life Architects & Construction, n.d.)

Compressed earth block, which is another method, is a building material obtained by compressing the adobe mixture in molds of certain sizes with simple pressing tools. The blocks can be easily produced and used directly on the construction site with a hand press tool. (Figure 5) Compressing the mixture in molds increases the compressive strength of the blocks and their resistance to erosion therefore its structural performance is better than traditional air-dried mud bricks.

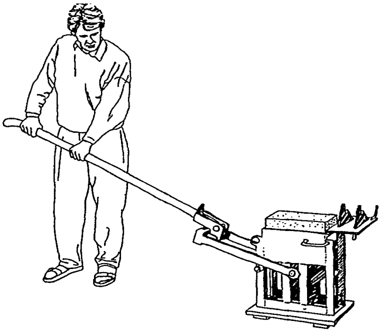

Figure 5. Production of compressed earth bricks with a simple compression tool. (Stulz & Mukerji, 1981)

The clayey mud mixture used is a dry mixture and the water ratio is different from the sun-dried bricks. 30-60% clay soil, 40-70% aggregate, 5-6% cement, and approximately 10% water are used in the mixture of compacted earth blocks. Although these ratios can vary, they are close to each other. (Krosnowski, 2011)

Unlike traditional adobe bricks, compressed earth bricks can be produced with clamps, holes, grooves in the middle, and u-shaped. In this way, the building load and costs are reduced, the sound and heat insulation performance are increased, and the risk of cracks and landslides that may occur against earthquake loads is reduced.

3.1.2. Adobe-filled skeletal building systems

From the past to the present, wood is the most used structural material together with traditional adobe. The use of soil construction materials with a wooden skeleton provides the necessary stresses and increases the out-of-plane strength. Timber-framed earthen structures are lighter than masonry adobe, and multi-story buildings are easier to construct. The use of earthen building material with wood also reduces the cost of timber structures and increases their resistance against fire and pests. Wood and earth, which are natural materials, have a positive effect in terms of building biology and creating comfortable and healthy spaces for their users with their common features of breathing and not containing harmful gas-spreading materials.

Timber-framed earthen buildings have been constructed in distinct parts of the world with different methods. In this section, four different timber-framed earth-building systems are examined: first, adobe brick-filled timber-frame structures (“hımış” in Anatolia), secondly, adobe plaster on wood mesh (“wattle and daub” in Europe, “iğmeli” or “huğ” in Thrace and Anatolia), thirdly light straw, and finally, earthen roofs and intermediate floors.

Adobe brick-filled timber frame (hımış) is the most common adobe construction system in Turkey, especially in regions where wood is plentiful. The adobe block filling is commonly applied in two techniques, staggered plain brick masonry and cross (herringbone) masonry between the wooden frame system. (Perker, 2012) (Figure 6)

Figure 6. Example of a wooden skeleton filled with adobe brick (herringbone masonry)(Anonymous, 2020)

Wooden skeleton walls are built with the main pillars and intermediate pillars placed between the lower head and the upper head, as in other wooden structures. Cross braces are placed between these uprights to increase resistance against lateral loads. (Işık, 2007) The adobe brick walls are built with mortar in the spaces between the wooden skeleton. All surfaces of the walls filled with adobe bricks are plastered with earth plaster. In some adobe brick-filled wooden structures, thin and dense wooden laths are placed on the facade before the external earth plaster is applied. (Ataman, 2007)

In Wattle and Daub buildings, a mesh surface is built with reeds, bamboo, twigs, or strip woods between a wooden skeleton, and these surfaces are covered with an adobe mixture and filled. Besides these earth buildings in Europe and America, there are also some similar construction techniques found in Anatolia. These structures, known as needle (iğmeli) and hug (huğ) in Anatolia, are temporary shelters to meet the needs of ancient societies that lived before Christ but are still used in rural areas for some functions today. (Eres, 2013; Erzurum, 2017) The adobe mixture that covers the wooden mesh surfaces usually includes clay soil, animal manure, and straw (Figure 7).

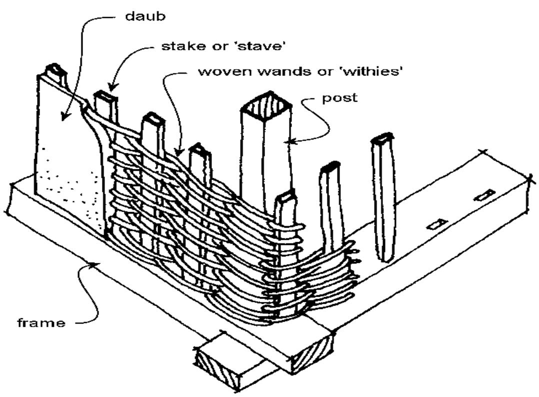

Figure 7. Schematic diagram of wattle and daub building system (Anonymous, 2014)

After the adobe mixture is applied to the twig mesh in multiple layers and left to dry completely, it can be whitewashed to provide better resistance to rain, increase sunlight reflectivity and improve its appearance (Anonymous, n.d.)

The light straw clay, which is used as a filling material in wooden frame walls, does not have a load-bearing capacity on its own. In some examples, it is seen that light adobe material with a thickness of 100-120mm is applied to the roof, floor, and walls as heat insulation material. This technique, which is similar to the straw bale technique, uses a clayey mud mixture with a high vegetable fiber/straw ratio. Local clay is usually mixed with local subsoil and water into a slurry, and straw or wood chips or a similar vegetable fiber is added. Wood chips can vary in size from sawdust to shavings by 5 cm. The ratio of clay to other components can be adapted to increase thermal mass or insulating properties. Wooden molds are used in the construction of these walls, which are built by casting in situ method (Figure 8).

Figure 8. Example of light clay wall between wooden frame (TRC Timberworks, 2010)

In another earth-wood hybrid system, the soil mixture is used as the main filling material that covers the carriers of the timber-framed roof and intermediate floors. Especially in Anatolia, dry or wet soil mixture applied on wicker, reed, sedge, and similar plant-based materials are widely used in flooring and roof construction. (Çiçek, 2014) This roof system, which is frequently encountered in hot climates and rural settlements, is encountered in stone and adobe masonry housing structures. Earthen roofs and floors are constructed by covering thick wooden beams with mostly round cross-sections with planks, placing a 30-40 cm high clay content earth mixture on them, and compacting the soil with a cylinder-like tool or stone. This compression process is repeated especially on roofs for protection before every winter. (İner & Çağlarer, 2013)

3.1.3. Directly shaped and built earth structures: cob and super-adobe

Cob and super-adobe are the most common building systems created by direct shaping of unformed earthen materials with simple tools by human hands. Cob is built by shaping the mud mixture without any other material, and super-adobe is built by shaping and layering the soil mixture with the help of long tube-shaped sacks specially produced for this system. Cob structures, which are built in layers by directly shaping the mud, are seen as different architectural examples in many parts of the world. While the term cob is mostly used in Europe, similar techniques are called “zabur” in Yemen and “dana” in Africa. Although distinctive designs and different application techniques are used in distinct cultures, the construction principles and materials used are the same. A similar adobe mix is used in all of them, and this wet mud mix forms the wall layers after being poured directly before being shaped or made into lumps. The spilled mud mixture is bound and shaped by compression, forging, pressing, or ejection. After the created adobe layer is dried for a while, the building is built in layers by passing to the other layer (Minke, 2006) (Figure 9).

Cob mixture usually contains soil, water, fiber (usually straw), and binding additives that vary according to the region. The clay ratio in the adobe mud mixture is 15%, the straw ratio is around 15%, and the water ratio is 15% and above. The most important feature that distinguishes these techniques from other similar techniques is the high proportion of straw and water in the mixture. For example, while there is no straw in the compacted soil mixture, the water rate is around 10% at most. (Sumerall, n.d.).

Figure 9. Construction of a cob wall layer by stacking mud balls (Vyncke et al., 2018)

Unlike other techniques, customization and locality come to the fore in the construction techniques, which are shaped by hand using a wet mud mixture. Hand-processing of adobe mud provides flexible design opportunities and allows us to see the works of the craftsman who built the building in every detail of the building. For example, in African examples, single-story plans in the form of a circle and exterior plaster and paintings/decorations with ocher paint are seen. In the examples in Yemen, rectangular and multi-story designs are encountered.

Another method, super-adobe, is the name of a technique most developed among textile-earth building experiments, adapted to today's architecture, and widely used in shelter production. This technique, made with sacks, can also be compared to the technique of front and ammunition structures built for military purposes, and sandbag walls built to provide water and erosion control, which have been used since ancient times. Only clayey local soil, water, sandbags, and barbed wire are used as materials for super-adobe structures that do not require large equipment and can be built in a brief time. The earth mixture that fills the sacks usually contains around 25-30% clay and 10% water. The sacks filled with the soil mixture are brought together by the stacking technique (Figure 10).

Super-adobe bags of 200-900 m in length, which are specially produced for this method, with a thickness of 35-50 cm, can also be used, as well as rectangular sandbags, which are widely used all over the world. After the layer of a sack filled with soil is formed, it is stabilized by compacting with a hammer.

Figure 10. Construction of a super-adobe wall with custom made long earth bags (Carneiro, n.d.)

3.1.4. Cast-in-place earth buildings: rammed earth and poured earth (pisé)

The most common traditional earthen structures built with the cast-in-situ technique are rammed earth and poured earth (Pisé de Terre) structures. In some sources, these two techniques can be considered the same, which are made by pouring clay into wooden molds and compressing it until it hardens (Vivian, 2016) (Figure 11). The only difference is that a layer of lime or clay mortar can be added between each rammed earth layer to prevent horizontal cracks that may occur in the pisé technique (Minke, 2006).

Based on the building remains found, it is mentioned in sources that this technique dates to the years before Christ. The Great Wall of China, known as the longest wall in the world, was also built using this technique. It is a construction method alternative especially suitable for regions where high thermal insulation standards are not required. The rammed earth technique has a higher strength than other wet-applied adobe construction techniques, has a lower shrinkage rate due to the small amount of water it contains, and has a longer life (Kafesçioğlu, 2017).

Figure 11. An example of a structure built with the rammed earth technique, BKM Köyceğiz Film Plateau, (Gelirli, 2019)

In this technique, a moist soil mixture containing sand, gravel, and clay is poured into concrete molds and compressed with various compression tools. Binding materials such as cement, gypsum, and lime are added to this mixture depending on the nature of the soil. When the mixture is made traditionally without adding a binding additive, it is called non-stabilized compacted soil. In some mixtures, it can be seen that there are resinous and bituminous additives to increase the resistance to water (Kafesçioğlu, 2018).

The mixture used in the traditional ramming method is at most 10-15% water, and straw-like fibrous material is not found in this mixture. Although the soil used in the rest of the mixture varies according to the region, it usually contains 2.5 parts clay, 2 parts sand, and 2.5 parts gravel (Narloch & Woyciechowski, 2020; Dabaieh, 2014).

3.2. Improvements and innovations in design and production processes in today's earth architecture

Techniques developing over time in earth buildings have led to new searches with the acceleration of technology with innovations in design understanding. While the development of material science has increased the use of industrial methods, the developments in design methods have also been a factor that improves the possibilities of architectural earthen materials. In this part of this section developments in raw earth building materials and construction systems, will be discussed in three sections: material improvement studies, improvements in construction methods/industrialization, and innovations in the design method.

3.2.1. Improvement and stabilization of earth mixture

Earth-building material is a material that is affected by external factors and eroded. In addition to the damage to the soil by water, humidity, wind, and other loads, other materials that act as binders in the adobe mixture can also be affected by intense sunlight and deteriorate. Since ancient times, people have tried to use the most suitable and durable soils in buildings by experimenting with different soils. With the developing technology and increasing test methods, inferences can be made by analyzing which additives can be used at what rate and which additives are required for which region's soil. The most used additives that provide improvement and stabilization in the adobe mixture are gypsum, lime, pozzolanic substances, and cement additives, vegetable and synthetic fibers, artificial resins, bituminous and hydrophobic substances.

The most common gypsum, lime, cement, or pozzolanic materials in adobe mixtures are used to improve the quality of the soil and reduce the need and time for curing and drying, which are used to improve and stabilize the adobe mixture. An exemplary adobe mixture to these studies, which Professor Kafesçioğlu revealed in his studies, was improved with gypsum and lime and was called ALKER as a special material name (Figure 12).

Figure 12. Example of a rammed earth building with ALKER, ITU Ayazağa Campus Trial House, 1995 (Isik & Tulbentci, 2008)

Unlike additives such as cement, gypsum and lime do not destroy the advantageous physical qualities and breathing properties of adobe. In ALKER structures, 10% gypsum and 2% lime are added to the soil mixture to shorten the construction period and increase the resistance of the material against external factors and water (Kafesçioğlu, 2017).

3.2.2. Industrialization, machine use, and robotics

The increase in performance and time advantage brought by mechanization in the production of earth-building materials enable the change and development of the design and bring many advantages. Developments in machine technology also enable the design of comfortable spaces in hard-to-reach places, as they reduce the need for human beings, and shape the design concept of the future with this aspect. Technologies seen in our age in the production of adobe structures, stabilization with compressor machine, shaping with extruder, application into mold or surface with spraying machines; technologies such as additive manufacturing and robotics.

With the extruder machines used in the production of adobe bricks, the stabilized soil mixture is given the desired shape when it is plastic. The blocks produced are generally hollow and can be cut into desired lengths after shaping (Figure 12). The production of stabilized extruded earth blocks can be produced with many different machines that perform intensive compaction. The produced bricks are more homogeneous, stable, and smoother than traditional bricks.

Since it requires suitable weather conditions for on-site production, the rammed earth walls can also be produced in factories under optimum conditions with special molds and electric ramming machines in four seasons. The soil mixture prepared for the wall panels produced in the factories can be made more homogeneous and more accurate than the mixtures produced on-site (Figure 13).

Figure 13. Example of hollow green brick produced by an extruder at the factory (Watershed Materials) (on the left), Factory-made rammed earth wall panels (Rammed Earth Works) (on the right)

Shotcrete machines, which were developed for the use of concrete materials, can also be used in the construction of earth buildings today. Earth structures can be built by spraying stabilized wet adobe mud into molds to form a building element, mostly walls. (Işık, 2018) The shotcrete technique can also be used for earth plastering on wall surfaces. Different textures can be obtained by spraying with pressure.

Robotic production technologies are also one of the most researched topics in earth-building production today. It is a method that allows building quickly in hard-to-reach lands. This unmanned building production technology is a method that has started today but will be needed more due to the needs that will occur in the future (Fabio & Kohler, 2014). There are three types of robotic research related to earth buildings: additive manufacturing and parametric brickwork with robot arms and bio-shotcrete technology with drones (Figure 14). This research makes digitally designed contemporary adobe buildings more economical and technically feasible.

Figure 14. Production of an earth building with additive manufacturing, WASP Tech. Village (on the right), Bio-shotcrete application with drone robots (Chaltiel et al., n.d.)(on the left)

The combined use of computational design and robotic manufacturing is also a tool that will allow the structural and thermal capacity of the adobe wall to be easily adjusted to suit the needs of each climate.

3.2.3. Combining traditional earth-building techniques with computer-aided design tools

The development of computer-aided design technology not only changes the understanding of architectural design but also improves the possibilities of using traditional building materials such as adobe. Parametric structures created with computational design allow the use of traditional materials in different ways, leading to the emergence of innovative construction methods.

The use of traditional adobe with computational design can be examined in two areas. One of them is the design of special molds with computational design for adobe structural elements that require formwork and using traditional adobe methods (such as rammed earth and adobe brick) with these molds in the production of earth building elements (Figure 15).

Figure 15. Commune-action wall. An example of a digitally designed wall built with the rammed earth method (Akipek & Yazar, n.d.)

Another method is the use of a traditionally produced earth-building element, such as compressed earth brick, or adobe brick, in the components of a building designed with computational design. (Figure 16)

Figure 16. An example of a computer-aided designed building using traditional earth bricks, Droneport Project (Norman Foster Foundation, 2016)

Today, many traditional materials such as earth can be used together with digital design tools, thanks to a software called "RhinoVAULT" based on Thrust Network Analysis (TNA), developed by researchers at ETH Zurich University, to integrate the traditional vault technique into digital design tools. It is understood that digital design can be effective in improving building possibilities with this research developed by using the possibilities of traditional construction methods.

4. Conclusion and Suggestions

While the change of design method with current technology and new materials is so parallel, it may still be insignificant for designers to include materials in the design processes today. However, it is possible to produce products that catch the age, by being involved in all phases of the production processes and by contacting the materials. The basis of the design development approach by incorporating the material into the process is to know the material properties well, to know the traditional use of the material and its historical process.

The existence of sustainable earth-building materials, which have become increasingly important with the climate crisis we are experiencing, in the design cycle will be possible with the well-known of these materials and their transfer to future generations.

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All authors contributed equally to the article.

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Classification of Architectural Acoustic Materials

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1. Introduction

Sound is mechanical waves in the audible frequency range. The birth, propagation and perception of sound are related to mechanical vibrations and oscillations. When the sound wave moves, it cannot replace all the air in front of it, but it moves with some of it. When it starts to move in the opposite direction, it draws a little air again. Any density change in the air is related to the pressure change (Tuncer, 2014). Sound can make reflection movements, such as light and electromagnetic waves. As the sound wave spreads in the indoor environment, it loses some of its power and size on each surface it hits and makes a reflection movement. If sound loses most of its energy on the surface it hits, that surface is sound absorbing, and if most of its energy is reflected back, that surface is sound reflecting. Absorbent and reflective surfaces should be considered when making acoustic planning. Acoustic planning in places where auditory actions take place determines the quality of the sound and enables musicians and listeners to have a better quality experience.

Acoustics is a branch of science that studies physical phenomena related to sound. It can be integrated and used with different branches of science. It has a wide range from human hearing system to noise control in the structure.

Architectural acoustics is an area that includes sound planning and material choices made to meet the audio comfort needs of humans. The selection of acoustic materials and the positioning of the materials in the space fall within the scope of the examination of architectural acoustics. In architectural acoustics, materials can be classified according to sound absorption, sound transmittance and structure type. This classification helps to make the acoustic planning of the space.

Building material is one of the most basic building blocks of planning. For this reason, the identification and elaboration of the material is an important step in terms of facilitating the work of a designer. Acoustic building materials are materials that are standardized in order to plan the spaces where hearing is performed and to provide high acoustic comfort to the user. These materials are designed to absorb, insulate and change the direction of sound and can be used in different areas. Acoustic building materials may vary according to physical environmental conditions as sound wave may be affected by physical environmental conditions. Acoustic materials are sensitive to physical environmental conditions and are sensitive to wear, vandalism, moisture, G force. Replacement of the material should be performed as recommended by the manufacturer, otherwise it cannot meet the specified absorbency and reflectivity values and its service life is below the specified value. The tabulation used in this study is presented to the use of the designer in the conclusion section.

2. Material and Method

It is emitted by conducting sound, air and solid transmission. In this study, the application-oriented classification of acoustic materials for air-conducted sounds will be made with the literature research and the characteristics of each class will be discussed and tabulated in order to create ease of use. The table systematic is original and intended for the use of materials.

3. Findings and Discussion

We can group the basic properties of the material that affect its acoustic performance in the form of macroscopic, geometric and mechanical, air feature in the porous structure and specific properties of the material. Macroscopic features: flow resistance, internal structure durability, porosity, pore structure, shape, character(Vidilimen, 2010). The classification of acoustic materials is made by considering these below. Materials: grouped according to their sound absorption, type, sound collectivity and sound permeability.

3.1 Acoustic materials according to sound absorption, reflectivity

Materials exhibit absorbent or reflective behavior in the face of sound. After the sound hits the material surface, some of it is swallowed and some of it is reflected. Since sound is a type of energy, when it encounters a material, it either continues as sound energy or transforms into vibration (kinetic, motion) energy or heat energy.

The sound absorption coefficient is found by the ratio of the swallowed sound intensity to the incoming sound intensity. It is indicated by alpha (〈). 0 ile 1 arasında değer alır. The sound absorption coefficient of any material cannot be exactly 0 or exactly 1. Materials with an alpha value between 0.2-1 exhibit sound absorbing properties while materials with a value between 0-0.2 exhibit sound reflecting properties. The sound absorption value is not a distinguishing feature of the material. The absorption coefficient varies according to the type of material, surface shape, type of assembly, frequency and their interaction. Research has shown that the most effective factor on the absorption factor for the same material type is the surface shape. The frequency factor follows the surface shape(Altunok & Ayan, 2012).

For architectural acoustics, sound is studied in the 6 frequency range, which is called the octave band. These octave bands: 63-125 Hz, 125-250 Hz, 250-500 Hz, 500-1000 Hz, 1000-2000 Hz, 2000-4000 Hz. These different octave bands have different alpha values for each material. Frequency ranges in which materials can exhibit high swallowing reflectivity are variable. Some materials exhibit high swallowing only at certain band intervals, while others exhibit high swallowing at low bands.

The NRC is the sound attenuation multiplier and the absorption coefficient (alpha) of the material is expressed as a single number. It is the arithmetic mean of the absorption coefficients at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. In areas where special calculations will be made such as concert hall, conference hall, the NRC value alone is not sufficient, swallowing values at separate frequencies are needed. Calculations can be made with NRC value in mixed-functional spaces or where values at low frequencies such as common use area, lobby can be ignored(Güler, 2019).

Parameters such as the surface where the material will be used, the main function of the space, the size of the surface area where the material will be used, and the frequency range where the material is desired to show absorption should be evaluated and appropriate material should be selected for the space. While offering acoustic materials for sale, companies share their values and the absorption coefficients they have at different frequencies. Thanks to these data, the values that the space should have are calculated according to its function and the interior surface coatings are determined. In order for these materials to meet the values specified by the company, their assembly and, if specified, cleaning and maintenance must be carried out as recommended by the manufacturer.

3.1.1 Sound absorbing materials

There are 2 different mechanisms underlying the voice swallowing event. The first is the vibration of the material skeletal structure, that is, damping. The second is the structure of friction against the fluid, i.e. viscosity. The behavior of the material in the face of sound is due to the fluctuation in the sound velocity and the change in the sound pressure(Baktır, 2018). Materials with an alpha value between 0.2-1 are sound absorbing. Although these materials are planned to swallow sound, they are sometimes not designed to completely remove sound from the environment. For example, in keyboard percussion instruments, the tube-shaped cavity resonator located under the center of each note allows the instrument's sound to be clearer and of sufficient length(Wikipedia, 2022).

3.1.1.1 Porous materials

These are the types of materials that have sound absorbing properties thanks to the numerous gaps on the material surface. Sound swallowing occurs thanks to its superficial and physical properties rather than the specific properties of the material.

Materials with high damping capacity due to environmental problems are also very effective in reducing fertility. For this reason, materials with high production rates are developed. It has high damping capacity in cellular (porous) materials such as porous materials. The low weight and high damping capacity together made the mechanical materials more attractive. Due to the complexity of porous materials, the mechanical strength of conventional porous materials is very low and mechanical strength applications are limited(Dahil, Başpınar, & Karabulut, 2011).

The surface area of the material is increased thanks to the porous (hollow) structure. Sound waves hitting the surface enter the pores and reflect more on the surface and are subjected to friction. As a result of friction, some of the sound energy is converted into heat and some is converted into vibration energy. As a result of reflections, some of the sound comes out again from the point where it enters the pore and returns to the space. Porous materials generally show better absorption at high frequencies. Increasing the thickness of the porous device for low frequencies can ensure that the material exhibits good absorption from high frequencies to 500Hz. Porous materials: may exhibit different swallowing according to their physical properties such as number of pores, pore depth, internal structure of pores.

Today, acoustic perforated panels (perforated acoustic panels) formed with acoustic sponge or acoustic fabric placed behind the porous plate are among the materials with high sound absorption. Micropores can be used in acoustic perforated panels, the location, orientation and shapes of the pores on the surface can be changed, and options can be created for the main color of the surface. In this way, this material can adapt to the design in terms of aesthetics. The structure, density, weight of the sponge or fabric used in perforated panels, the structure of the pores on the surface of the plate (shape, size, number, depth) are effective in the swallowing of the panel. The fact that different parameters are effective in panel swallowing ensures that special production can be made for the desired frequency value. The panels have a linear or circular surface depending on whether the surface shapes are flat or oval, and the pore structures are called perforation layouts(Eşmebaşı, Çalışkan, & Gül, 2019).

3.1.1.2 Vibrating boards

Vibrating plates are materials that provide absorption by converting sound energy into heat and motion energy. Sound hits the surface of the material and transforms into kinetic energy in the material, allowing the material to vibrate at the sound frequency. The sound vibrates the material and moves away from the environment. The vibration movement takes place according to the eigenfrequency value of the material. Self-frequency is not one of the distinguishing features of the material. Different materials may have the same eigenfrequency value. Low-frequency sounds have higher energies. Vibrating plates show better absorption at low frequencies.

Figure 1: Vibrating Poles Mounted at Different Distances from the Wall

In determining the absorption factors of the vibrating plate, size, self frequency, thickness, detection form, density and the depth of the air (centimeters) between the plate and the ceiling and the mounting method are important. Figure 1 shows two different mounting styles for vibrating plates. It can be said that the left plate vibrates more easily than the right plate. In order for the boards to exhibit good swallowing, they must have low vibration resistance, and the ceiling fixings must be flexible. It can vibrate more and absorb more sound than the larger one, the size of which is smaller, between the two sheets, the fixations of which are made the same and the gap is left in the same size. The air left behind in two plates of the same size, whose fixations are made in the same way, will vibrate more easily and swallow more sound. The cavity (air sheet) acts as a spring and makes a vibration movement with the plate (Mütevellioğlu, 1995).

3.1.1.3 Resonators (volume absorbers)

Resonators are swallowers that exhibit resonance behavior(Wikipedia, 2022). Not only sound, but wave-absorbing materials can be used for both electromagnetic and mechanical waves. Separate resonator types are available for wave types such as sound, electromagnetic, infrared. With resonators, absorption can be achieved for almost every frequency value (in different wave types). For this reason, it can be used with different types of materials and swallowing values can be determined. Thanks to this feature, resonators are also used in different branches of science. For example: Medicine, chemistry, biology, physics (acoustics), geology. The size and dimensions of the resonator vary according to the type and frequency of the sound wave desired to be swallowed. The design (size and material) of the resonator in a concert hall and the design of the resonator in a car are different.

3.1.1.3.1 Helmholtz resonator (hollow / simple resonator)

Hollow resonators are used to absorb electromagnetic, microwave and radio waves or to convert their energy. The type of hollow resonators used for acoustic (sound wave) purposes is called Helmholtz resonator. It is the oldest resonator type. It is also encountered with its use in historical buildings. It has advantages such as being able to be made with different types of materials and not spending a lot of energy for its production. The earliest examples are empty boxes carved from stone.

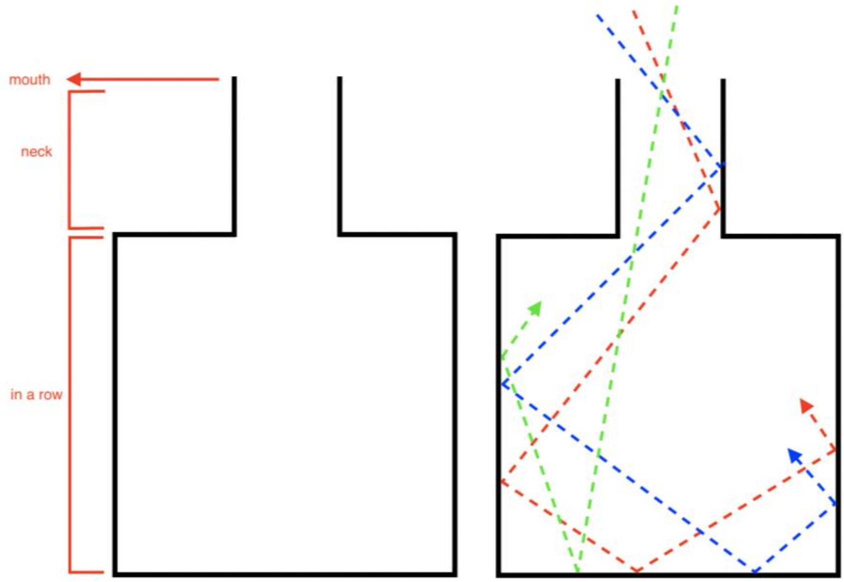

Figure 2: Diagram of Helmholtz Resonator and Reflection of Sound Waves

Cavity resonators consist of an inlet portion, a neck portion, and a relatively large body. Due to the narrow mouth part, the sound coming in cannot come out. The mouth portions are positioned facing the sound source. The sections Figure 2 of the resonator and how the sound wave reflects inside the resonator are shown in. The sound entering in the mouth is caused by the formation of waves moving in the opposite direction due to the reflecting sound wave, and these opposite waves dampen the main wave. The other part reflections inside and undergoes friction and turns into heat energy. Helmholtz resonators show the highest sound absorption close to the resonance frequency. Perforated (fibrous) materials can be placed in the inlet (neck) part to increase the swallowing of the resonator at low frequencies. However, since the resonance frequency will vary due to the addition of these materials, its absorbency will decrease at this value (Kavraz & Abdülhamirov, 2004). In ancient Greek and Roman times, pointed earthen cubes and empty boxes made of stone were used as simple resonators to store wine called "amphora". Although the construction technique is quite simple, they are advanced acoustic systems. The Lyttus Ancient Theater, which was built in accordance with the rules mentioned in Vitruvius' Architectura book in Crete during the Roman period, has 13 stone resonators for three rows. Although Vitruvius did not have detailed information on this subject, he called them acoustic vases and wrote that they were placed to improve acoustics. Vitruvius referred to these acoustic vases as "echea"(Vitruvius, 2015). 20. Centuries after Vitruvius, the ancient theaters mentioned in the Venice traveler Onorio Certain book were re-examined and it was observed that the number and location of these axutic boxes were consistent. After comparing other ancient theatres, Onorio Belli noted: "… Arrangement of these acoustic containers according to the situations in which they should be placed can be described as follows: If the theatre is not large, mark the horizontal spacing halfway and build thirteen arched niches with twelve equal spaces between them… But if the theatre is too large, its height should be divided into four parts, so that three horizontal niche ranges can be determined and created: one for the harmonic, the other for the chromatic and the third for the diathonic system… ". Onoiro Belli's work proves that ancient theaters are advanced in auditory quality and that Helmholtz resonators were used for functional purposes in the ancient period (Falkener, 1854). Thanks to the CAD software used in today's research, it has been observed that these acoustic boxes are especially effective in sounds around 250 Hz frequency (Polychronopoulos, Kougias, Polykarpou, & Skarlatos, 2013).

In the Ottoman period, the earth cubes used by Mimar Sinan in the Suleymaniye Mosque were of the hollow resonator type. Sinan made acoustic planning by placing the soil cubes on the dome base with their mouths facing inwards. In Süleymaniye Mosque, there are 60 cubes in the dome and 4 cubes in total. In addition, these cubes were used in Sokollu Mehmed Pasha Mosque, Şehzade Mosque and Sultan Ahmet Mosque (Kayili, 1988). Ottoman mosques in this period would rise from the ground and cover a large area with a large dome. For this reason, while the carrier systems were made of stone, lighter materials were used on the walls that did not carry loads. Sinan used hollow resonators made of soil, not stone, because the material load did not get heavier.

The discovery of electrical energy is an important event for the development of simple resonators. Hollow resonators have been used since the 19th century, especially for the purpose of absorbing, storing or changing energy types of electromagnetic waves. It is possible to capture sound waves and generate electricity from them using an electromagnetic Helmholtz resonator. The sound wave entering through the cavity creates a pressure differential within the resonator. The resulting pressure difference is converted into mechanical energy. Mechanical energy is converted into electrical energy by means of fasteners. In an experimental study conducted with this type of system, 30mW electrical energy was generated as a result of the detection of a sound pressure event at 160 dB by the resonator. This energy is sufficient to supply energy to small electronic devices (Liu et al., n.d.). In an experiment on Helmholtz resonators in 2003, it was revealed that when the neck length was at least twice the neck diameter and more, the sound absorption was not related to the neck length. The narrow neck diameter in Helmholtz resonators with both cylindrical and conical neck type increased sound absorbency. In addition, in conical neck Helmholtz resonators, the swallowing coefficient of the resonator increased with the thinning of the neck and the increase in the distance (Tang, 2005).

Research has shown that both internal and external interventions and sound absorption of Hellmholtz resonators can vary in both frequency values and magnitude. In a study conducted in Japan in 2009, it was concluded that an air layer placed behind the resonator changed the swallowing value and peak values at different frequencies. The optimum space placed in front of the resonator holes has increased the sound absorber especially at low frequencies (Sugie, Yoshimura, & Iwase, 2009).

A study conducted in Russia in 2017 revealed that the sound absorption values of Helmholz resonators were determined by four variables. These four variables are: the physical characteristics of the neck part of the resonator, the loss of viscosity (fluid losses) on the side facades of the resonator and on the edges of the resonator neck, the space between the holes of the resonator and the wall, and the viscous losses on the front surface of the resonator. Figure 3 It shows the sound absorption variables in Helmholtz resonators. Number 1: Viscosity loss in the neck, number 2: viscous loss on the front surface, number 3: viscous loss on the neck edge, number 4: thermal loss in the resonator cavity. While three of these four parameters can be reached by the calculation method, the loss of viscosity at the edges of the resonator neck can only be achieved by measurement. In addition, the diameter of the resonator neck and the amount of loss of viscosity around the neck increase proportionally. It was concluded that neck length had a low effect on viscosity loss but significantly increased the viscosity loss of short necks (Komkin, Mironov, & Bykov, 2017).

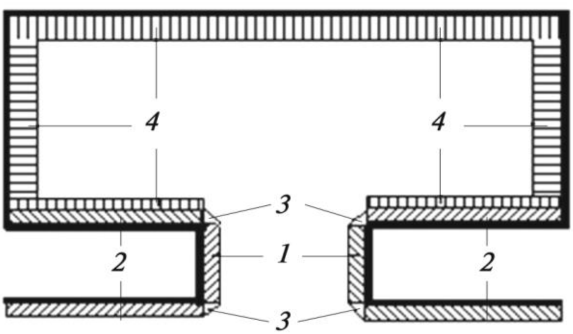

Figure 3: Cross Section of the Helmholtz Resonator (Komkin et al., 2017)

Today, Helmholtz resonators can be integrated with electrical systems as well as performing much more than sound absorption function. Helmholtz resonators are used in fluid regulation, hearing aids, on a wide scale such as electricity generation and energy conversion (Nave, n.d.).

3.1.1.3.2 Membrane type resonator

Membrane type resonators are a type of resonator with a wide surface area consisting of a membrane cover designed to absorb or convert mechanical waves.

Membrane resonators are often named according to the type or abbreviation of the wave they are absorbing. There are types such as electromechanical membrane resonator, thermomechanical membrane resonator, silicon nitride membrane resonator, graphene membrane resonator, mem membrane resonator, piezoelectric membrane resonator (Ballato & Gualtieri, 1994; Wei et al., 2021).

Acoustic membrane resonators: Resonators designed to swallow sound completely or partially. It works with the principle that the membrane surface fixed in a frame reduces the sound power by oscillating like a wave against the sound wave. The frequency range in which it is best absorbed varies according to the type of membrane used, the membrane surface area and the mounting of the membrane on the frame. In order to reduce the possibility that the gravity effect may be effective on the resonator, the dimensions and dimensions of the membrane surface should be adjusted so that it cannot deflect and, if possible, the membrane surface should be placed perpendicular to the G force. In acoustic membrane resonators, the grid in front of the membrane can be designed from different shapes due to aesthetic reasons. The development of this type of resonator continues thanks to its different grid designs and wide range of frequencies (Frommhold, Fuchs, & Sheng, 1994).

The main difference between membrane-type resonators and vibrating plates: The membrane is a membrane-like surface that is stretched into a fixed frame, and the sound wave transforms into motion energy by creating a physical fluctuation event on the middle side of the membrane surface, which is the furthest point from the stability, and since the vibrating plates are usually fixed from a point between the middle and edge points, they can almost all surface fluctuation in case of encountering the wave. In both types of materials, the material for sound absorption moves physically, so membrane-type resonators and vibrating plates are the sound-absorbing materials with the fastest aging share among sound-absorbing materials.

3.1.2 Sound reflective materials

The use of sound-reflective materials indoors affects the sound level and ringing time. It is appropriate to use reflective surface in places where sound amplification is desired. Surface feature or coating may cause the material to reflect sound.

Sound-reflective materials can be grouped into three groups. These are: fiber materials, porous materials and plastic-based materials. Examples of fiber materials are hard fiber boards or glass foam. Since compressed materials lose the gaps in their structure during compression, their absorption feature decreases. Materials that have undergone heat and cooling processes such as glass foam have a rigid structure after the processes. Since the rigid structure causes a flat surface, the absorption coefficients are low. Heat-treated materials with smooth surfaces such as glass and non-porous metal are also sound-reflective (Erol, 2006).

3.2 Acoustic materials by type

Natural and artificial acoustic materials can exhibit similar absorption values. For example, wood and wood-derived materials have a porous structure and show sound absorbing properties, while polymeric sponges also show sound absorbing properties by distributing the energies of sound waves falling on the material with air scattering in polymetric cells and viscous scattering between adjacent polymer chains (Baktır, 2018).

3.2.1 Natural acoustic materials

They are building materials found in nature. The oldest known natural acoustic materials are resonators obtained by carving stone. These resonators, which belonged to centuries ago, still work today. Examples that have survived to the present day: It is located in Beth Shean, the Roman theater in Israel (Long, 2006).

Resonators made of soil used in the Greek Roman and Ottoman periods are also examples of natural materials. While some of these cubes have survived to the present day, some of them have been closed or lost their function with the damage of the building. Since natural fibers exhibit sound absorbing behavior, various studies are carried out for the use of these materials for acoustic purposes. One of these studies was conducted in Burdur and it is the measurement of the swallowing values of wood, coconut, hemp, palm tree, tea tree, gourd, sheep wool and Kenaf in 6 octave band value. According to the results, all fibers are among the absorption standards of acoustic building materialsc (Kaya & Dalgar, 2017).

However, since these fibers are not available in standard production and conditions, they are not currently available in acoustic planning.

Today, acoustic materials, which are completely natural, are not used especially in acoustic planning areas due to the fact that swallowing (alpha) values are not standard.

3.2.2 Artificial acoustic materials

It is obtained by partially or completely unnatural processes (such as high temperature, pressure, freezing) of the materials in nature in artificial environments such as laboratories. The materials obtained may be reinforced of some features of the natural material or may have some features that are not in the natural material. The use of artificial materials, which have become an indispensable part of our lives thanks to technology, is increasing day by day. Acoustic artificial materials are more preferred because they are more common than natural materials, have a more affordable cost and can produce swallowing (alpha) values as standard.

Acoustic Meta Materials: Meta materials are artificial materials that are not found in nature and are created in a laboratory environment. They can be single- or multi-layered. Since they are specially produced, they have properties that are definitely not in the main material. They can interact with electrical and radiation waves, providing energy conversion. In particular, metamaterials used in resonators can enable the sound wave to be swallowed and converted into electrical energy, as in helmholtz resonators. In this respect, meta-materials will gain more place in our lives in the future.

Acoustic meta-materials gain importance in engineering applications. Thanks to meta-materials, abnormal reflection and refractive indices can be produced. A resonator made with meta-materials: it can show advanced wave absorbency, manipulate the wave, focus or distribute the wave, transform the wave into another energy with minimal loss, eliminate negative problems during the voice swallowing event. Acoustic meta-surfaces work like waveforming devices. Helmholtz resonators, resonant membranes, porous materials can be made with meta-material (Ji & Huber, 2022).

3.3 Acoustic Materials by Sound Collector

The surface shape is an important factor in the transmission and propagation of sound in a space. In order to ensure that the sound is collected at a point or distributed from one point to the whole volume, it is necessary to know the behavior of the sound against the surface. The surface shape may allow the sound to be picked up or dispersed.

There is no method in the literature that can calculate or predict the motion, reflection strength and reflection direction of the wave that encounters uneven surfaces. One of the first empirical models of how electrical waves will behave when encountered with concave surfaces is the knife back model (Engül & Hizal, n.d.). No model or formula has been developed yet on how sound waves will behave against these surfaces.

3.3.1 Sound collector (concave) surfaces

They are concave surfaces. Sound reacts physically similar to light when it encounters the surface. Concave surfaces allow the sound to be collected towards the focal point. Figure 4 The reflection movement of the sound encountered with the concave surface is shown in. If not planned well, it may cause the formation of echo and acoustic shade. Although the semicircular plan type in ancient Roman and Greek theaters caused such surfaces to form, this plan type was preferred for many years in terms of visual comfort. Thanks to the natural resonators used in those periods (hollow resonator type), these sound collections were prevented. However, today, in horseshoe and circle plan type halls, the audience rows serve as concave surfaces. This problem is eliminated by ensuring that the number of sound absorbing materials and audience used is at least two-thirds of the hall capacity.

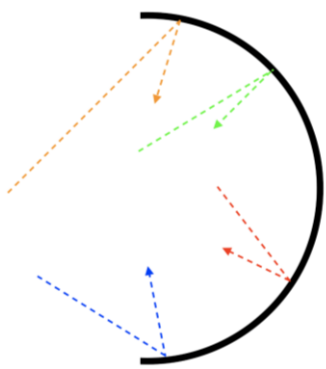

Figure 4: Sound Reflections on the Concave Surface

The corners in the interior show a concave surface from an acoustic point of view. Corner points cause acoustic problems due to the short distance at the intersection point and the high space height. In history, it is known that Sinan used pendant or muqarnas to prevent this problem in the corners of mosques.

3.3.2 Sound dispersant (convex, diffuser) surfaces

They are convex surfaces. Behaves in a way that reflects the sound to the continuation of the focal point. In Figure 5, the behavior of the sound that encounters the convex surface is shown. Today, the use of convex surfaces in the ceiling plane in opera and concert halls ensures that the sound reaches smoothly up to the back row. Convex surfaces prevent the focus (reflection towards the single focal point) of the sound. The degree of curvature of the surface and the material of the surface allow to determine at which frequencies the sounds will be transmitted to more distant points. If it is not planned well, it may cause the sound to spread too much and not reach the listener (Yüğrük Akdağ, 2017). The formation of a dispersant surface may be caused not only by the surface shape, but also by the surface coating. Irregularly rough and coarse surfaces can also cause sound dispersion. Therefore, the choice of material as well as the surface shape is important in the behavior of the voice.

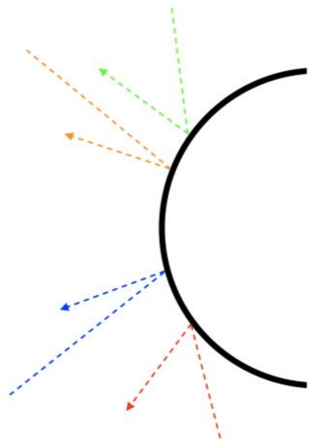

Figure 5. Sound Reflections on the Convex Surface

Sound-reflective surfaces are needed in almost every hall type. While sound-reflective surfaces are used in the halls with speech functions, sound-reflective (scattered) surfaces are needed in the halls with music functions (Yüğrük Akdağ, 2017).

3.4 Acoustic Materials According to Sound Permeability

Flow resistance is the barrier that the material exhibits to the movement of a moving fluid. The greater the fluid resistance of the material, the lower the fluid permeability. Air is a fluid material. The sound transmittance of the materials with low air passage is low. Such materials are suitable for use for insulation purposes. These materials are used in the building acoustics of architectural acoustics(Vidilimen, 2010). It is mainly used for noise insulation. The noise mentioned is both outdoor noise (urban noise) and indoor noise (between spaces). Voice transmittance on a material basis depends on physical macroscopic and microscopic properties. Weight, density, porosity are some of these physical properties.

Materials come together to form separating walls between spaces. The total sound permeability of these walls depends on the other materials used and the way the materials are combined. The resistance of an element to voice transition depends on many factors and all factors cannot be taken into account in many calculation methods. For example, the sound insulation value of a wall may provide different results than calculated depending on the construction conditions. For this reason, the best way to determine the sound insulation performances of the structural elements is to use the measurement method under the closest conditions to the reality (Aksoy & Toktaş, 2011).

The sound transmittance of a material is measured by the sound difference between the spaces where it is the separating surface. This measurement must be performed in a laboratory environment in order to be healthy. The source is found by subtracting the sound level in the receiving space through the sound in the space. Since the sound is a logarithmic magnitude, a sound transition loss value of approximately six decibels will ensure that the noise is perceived as if it has decreased by 10 dB.

4. Conclusion and Suggestions

Acoustic building materials can be classified according to the field of use and classified by sound terminology. Sound absorbing and reflective materials are important for spaces whose main function is auditory events. The sound from the sound source can reach the receiver smoothly with proper acoustic planning. The amount of swallowing of the materials and the frequency ranges in which they exhibit swallowing behavior should be known while making this planning. Building materials can also be classified according to sound permeability, types and sound collectivity. The sound collector of the material can create acoustic defects in the space as well as increase the sound quality of the space. The acoustic designer should place these materials considering the focal points of the sound when planning. Sound permeability is determined by the properties of the material depending on both the self and the physical environment. For example, while the sound permeability of a wooden material located 2000 meters above sea level is low, its sound permeability may increase when it is lowered to sea level. The sound permeability of the materials gives the best results with on-site measurements. Sound permeability is not included in the classification in the tables below as it is a parameter depending on physical conditions and the sound permeability of a wall depends not only on a material but also on all materials and mounting patterns in the wall.

Table 1 Acoustic sound absorbing materials are classified according to their types. This classification was made to provide a more detailed explanation of the characteristics of each group.

Table 1: Classification of Sound Absorbing Materials by Types

		Sound Absorbing Materials		
Materials by Type		Porous Materials	Vibrating Boards	Resonators
	Natural ingredients	**A**	**B**	**G**
	Artificial Materials	**D**	**E**	**F**

When we classify acoustic materials as in the table, the materials are divided into 6 groups. Artificial materials and meta-materials are in the same group. According to this classification, hard sponges, wooden and bamboo-like materials with fibrous structure can be given as examples of natural porous materials in Group A. Since A group materials are obtained from nature, they are not used today because standard data cannot be obtained. In the historical process, these materials were not found in the samples from the ancient period (even if they were used, the remains of this have not reached the present day). At the end of the Middle Ages, wood was used in the opera halls built in Europe. The best acoustic results of this material are in the Renaissance European Opera Halls. Natural vibrating plates in group B: 20. It was discovered with the discovery of electrical energy and better detection of the characteristics of the sound wave towards the end of the 20th century. Vibrating boards are made first with natural materials and then with artificial materials. The fact that the eigenfrequency values of vibrating plates are effective in swallowing and the eigenfrequency of natural materials varies due to physical environmental factors caused these group materials to be short-lived. Group C natural resonators: the earliest examples of acoustic materials. Since the ancient period, the samples have survived to the present day. Stone and soil materials were used as Helmholtz resonators. Those of these resonators that have survived to the present day are still performing their functions. However, since the purpose of these resonators and the places where they were placed in the structures were not known by later civilizations, the mouths of the resonators were closed or filled in some restoration studies. In fact, in some structures, it was thought that these resonators were used to alleviate the structure by creating a cavity effect, and especially closed hollow resonators were placed inside the walls. Such examples of incorrect restoration are also available in our country, it was even included in the reports of the Ministry of Culture and Tourism until 2010. D group artificial porous materials: they are the most commonly used acoustic materials today. Porous materials made with both artificial material and meta-material have standard swallowing values and specific weights. In this way, acoustic planning can be made and optimum reflection time can be achieved. It can be ensured that different requests and needs can be met according to the production type, quantity, cost, thickness, weight and color of the artificial material used. Group E artificial vibrating sheets are the most frequently used artificial acoustic materials after D group materials, which are designed in accordance with today's standards. Thanks to standardized production, the frequency values that it provides minimum and maximum swallowing are fixed. Vibrating plates exhibit a different degree of swallowing depending on the mounting type and the amount of space left behind. Thanks to its ability to be produced in different colors, patterns, shapes and models, it can meet the demands of the designer in terms of aesthetics. For this reason, it is also frequently used in places with wide openings such as concert halls, offices and sports halls. Resonators made with F-group artificial material and meta-material are used in both acoustic and other branches of science. These materials provide standard measurement results and swallowing values. In particular, meta-materials can allow different types of waves or multiple types of waves to be swallowed with a single material. In this way, both energy saving and cost saving can be achieved in terms of production.

Table 2 The data Table 1 in are classified according to the separation of sound collector or distributor surface.

Table 2: Classification of Materials by Type by Sound Collector

Materials by Sound Collector			
Materials by Type		Sound Collector (Concave)	Sound Distributor (Convex)
	Natural ingredients	**1 (A,C)**	**2: (A)**
	Artificial Materials	**3 (D,F)**	**4 (D,E)**

Table 2 Materials that can be included in number 1 according to: natural porous equipment and natural resonators. Porous instruments show the best amount of absorption as placed perpendicular to the sound source.

However, these materials are suitable for surface shaping and can be placed concave or convex. In natural resonators, especially cubes made of soil and clay encounter a concave surface after the sound enters through the mouth. Only natural porous materials are included in number 2. Number 3 includes artificial porous materials and artificial resonators. However, the resonators here are not used acoustically today in terms of practicality. These types are mainly used for electromagnetism and electromechanical waves. Number 4 includes artificial porous materials and artificial vibrating sheets. Especially artificial vibrating plates are frequently used in the ceiling plane in concert halls today. The most important reason is that they can provide reflectivity at another frequency value while providing absorbency for different frequency values, and thus the sound can reach the rearmost rows.

Thanks 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 Disclosure Information

All authors contributed equally to the article.

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The Feasibility of Mass Customisation along with the Changing Producer/Customer Approaches tothe Production of Building Materials/Architecture

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1. Introduction

It is not possible to refer to architectural services in pre-industrialisation society. In such an environment, society created its specific architecture, which was fostered and developed within the conditions of that society. There was a local milieu of architecture that developed on the scale of knowledge transferred across close relationships, accessible resources, and malleability and applicability of these resources. If we had to refer to this milieu by means of an occupation, "craftsmanship" would be a better term, which develops directly with the possibilities of the material. Imagine natural spaces produced by craftsmen, who were called stonemasons and carpenters. Their customers tended to be among the people in their immediate surroundings. For this reason, the expectations from the house were familiar and similar to one another. The customer and the designer were people from the same area, and habits had become traditions over time. In the post-industrialisation era, the local human identity started to transform. Human beings, whose survival and subsistence used to depend on soil, had to move to urban areas with the changes in the means of subsistence. In a way, they were detached from their living space which was unique to their conditions. The improvements in transportation mean accelerated migration, which in turn paved the way for relocation. With this advent of relocation, a different architecture of migration has flourished everywhere in the world depending on the opportunities in each country. More importantly, the "architecture of migration" has perpetuated its impact depending on the countries' level of development. The departure of an individual from a certain geography, where they had been accustomed to living for a long time under certain circumstances, to relocate in another place marks the beginning of the detachment from their traditions, which are often called habits. Or from a different angle, it is the beginning of the process of meeting with and becoming aware of different traditions. This has caused significant changes in the rural individual.

The system in which knowledge and tradition had been confined for years shifted. People began to share knowledge, and differences started to appear. While this shift is positive in terms of sharing and awareness, it has negative implications when it comes to preserving and transferring traditions, and equally so for the changes in the applicable conditions. Although the crafts of a certain region began to be shared with these changes, interest in craftsmanship gradually decreased with the rapid pace of daily life, changing needs, and the increase in industrial products that became easily accessible.

The phenomenon of relocation, the sharing among different geographical cultures, population increase in certain areas, and the changing needs that had to be addressed quickly transformed the familiar knowledge, needs, and expectations.

Industrialisation accelerated and varied production, which in return accelerated and varied life and the desires related to life. The production environment and the customer of crafts transformed as well. This transformation diminished the interest in the culture and teaching of craftsmanship, which for centuries had been moulded with tradition.

While the material of the craftsman only comprised of natural resources directly, that of industry varied through the indirect use of natural resources. Natural resources can be invigorated and shaped within their conditions; in that, the nature of the material itself determines the conditions of its processing. On the other hand, the production conditions of a material of industrial production are determined by needs, desires, and the search for novelty. Industrialisation gradually transformed the means of production and the relationship between the elements of production processes. This transformation has been evident in all areas of life in varying degrees. Naturally, the milieu of architectural production, its means, and customers have become subject to change as well.

1.1. The Changing Consumer

The peasant population of the pre-Industrial era was familiar with and made their living by the lifestyle that depended on soil. However, with the Industrialisation movements, they became urban employees who were not familiar with the new types of work. The struggle for survival was prominent for this new population. Demand and consumption were well below the minimum level. For a long time, human beings maintained their lives as much as the available conditions allowed without any expectations of conveniences due to the change in the sense of belonging triggered by relocation and the anxiety to survive. This was a lifestyle in which only basic needs were met and desires could not flourish. An awareness or even a sense of need that could generate a consumer's demand was out of the question.

While the role of the consumer had almost been non-existent in the predominately rural structure of the pre-Industrialisation era, the rural population that migrated to urban areas with Industrialisation became consumers. However, as consumers, they could merely afford their needs. These needs were met by means of mass production, which was developed in the late 19th century and enabled fast production of goods in high quantities at low costs. In this way, consumers were able to obtain standard products and services that anyone could have. The consumer was homogenous with similar characteristics. Thus, mass production and the atmosphere of consumption that emerged with it remained effective until the 1970s.

Industrial eras since the 18th century have transformed the way people add value to production, and in this way, they have influenced the entire world. In each of the three industrial eras, technologies, political systems, and social institutions have evolved altogether, which has altered not only industries but also the way people perceive themselves, form their relationships with each other and interact with the world (Schwab, 2019).

Many tools of life have inevitably change. Although these tools have made life easier than anticipated, human beings' interest in nature and the natural has not changed much, especially in some aspects of life such as mass production, communication, and transportation vehicles. As a result of this progression, the feeling of being special and different has become prevalent for human beings. This feeling began to be effective in the 1950s with the characteristics of the demands for the goods they can buy in the act of purchasing.

Standard products and services began to fall short of pleasing people. The consumer began to demand and form preferences based on their desires. A study shows that the changing consumer preferences have demonstrated a significant change, especially since the 1950s (Table 1) (Maleki, 1991). When the consumer becomes the one who demands different preference criteria, the producer will have to change as well.

Table 1. Changes in consumer preferences (Maleki, 1991).

1960s	1970s	1980s	1990s
Effectiveness	Effectiveness + Quality	Effectiveness + Quality + Flexibility	Effectiveness + Quality + Flexibility + Novelty

The concept of mass customisation was first formulated by futurist Alvin Toffler (1970). According to Toffler, who quotes Anderson, "*The most creative thing human beings can do 20 years from now is to become a creative consumer. In the future, you will be sitting there to design outfits for yourself or to make changes in the standard design; for this reason, computers will be able to cut one for you using laser and stitch them all on NC machines.*" (quoted by Tomaş, 2012; Toffler, 1980). With this claim, Toffler points out that the consumer will be involved in the production/design process in many ways, and that goods will be produced according to the desires of the consumer.

With the transformation and improvements in information and communication systems, the consumer has acquired a more aware characteristic that can access information more easily. This characteristic enables the consumer to question every single product they purchase and to solve their desires by getting in direct contact with the producer. Apart from being aware and questioning, the consumer with this characteristic is not satisfied with standard products and demands the different, extraordinary/appealing ones. The consumption mode that depends on motives such as needs/obligations has even surpassed the demand for conveniences and started to be shaped by the desire for the luxurious and different, as well as the single/unique.

Following the 1970s, producers started to seek ways to meet the unique demands of the changing consumer. As a result, the efforts to customise goods at low costs became widespread as a strategy of competition to satisfy every customer. The consumer lost its homogeneity and became insatiable, which made one single market strategy impossible, and entailed the division into different market sectors.

This transformation marks the transition from mass production, which was dominant since the early 20th century, into the process of mass customisation, in which the consumer has the leading role. The major factor that has paved the way to the emergence of mass customisation is the division of mass markets based on the changes in the consumer's desires and needs (Hart, 1995: 38; Bardakçı et. al., 2003, 467; Squire et al., 2006: 11).

1.2. The Changing Producer

Low cost and speed are highly important for the producer who is situated in a single market within mass production. Henry Ford, the pioneer of mass production, summarised its basic approach with the following observation: "*You can buy a car whatever colour you like so long as it's black.*" At that time all cars produced in Ford factories were black because it was indicated that black was the fastest drying paint. This emphasises the importance of speed in production. (Davis, 1996; quoted by Bardakçı, 2004)

The division of markets following the changes in the homogenous consumer and their demands assumed a dynamic quality in the production approaches adopted by producers. Until the 1960s, the standard production structure focused on developing technologies. With the energy crisis in 1970 this approach was accompanied by production efficiency, and later in the 1980s high quality and safety were added (Tuna, 2011). (Table 2 is created depending on the current literature).

Table 2. The changes in consumer priorities

1900-1970	**1970s**	**1980s**	**1990 and later**
Mass production	Mass production	Mass production	Mass customisation
Production speed and low cost	Production speed and low cost + Production efficiency	Production speed and low cost + Production efficiency + High quality and safety	Production speed and low cost + Production efficiency + High quality and safety + Consumer's value

Similarly, Çakmak, U. has identified the period between 1950 and 60 as "*the specific quality of the production market, and standardised production for unlimited demand*", and the period between 1970 and 80 as "*differentiated demand, frequently changing consumer preferences and demands, and high-quality products*" (Çakmak, 2004:204). In accordance with these changes, the terms "competition" and "strategy", which is more commonly used in the military field, started to appear in the field of business as of the second half of the 20th century. Competition is a dynamic tool that enables the work done and production to improve (Dursun, 2007). Especially during the 1980s competition intensified with neoliberalism, the conditions of free markets, and globalisation. Every producer joined the battle to increase their market share.

The oil shock of the 1970s triggered the transition from business planning to strategic planning for producers. The concept of the competition comprised the major characteristic of businesses, and Competitive Change became the foremost aim of their strategies. While the main theme of business strategies was "budget planning and control" in the 1950s, it became "strategic innovation" in the 1990s. (Grant, 2001:17-18).

Competitive priorities are determined by the market conditions of the period they reside in. The important factor to influence these priorities was price until mid-1980s, quality until the early 1990s, flexibility until mid-1990s, and later the ability to address demands quickly (Kumar, 2007: 534; Pine, 1993: 34).

Davutoğlu et al., explained this change through a different viewpoint by revealing the main difference between Industry 3.0 and Industry 4.0: "*In Industry 3.0 production is usually ordinary, and there are difficulties in customised production. Stockpiling is common.*" Industry 4.0, on the other hand, "*has the capacity to produce a different product for each customer at the same time. As a result of just-in-time manufacturing and customer-oriented work, there is no stockpiling.*" (Davutoğlu, Akgül, & Yıldız, 2017:556-557).

Mainly with the 1990s, mass production (Fordist) regime lost its validity against the flexible production model / mass customisation (post-Fordism), which is capable of responding to new customer preferences quickly. The customer who did not have a say in mass production now plays an active role again with mass customisation. The term mass customisation is made up of two conflicting words. It refers to tailor-made manufacturing using the three principles of mass production, namely low cost, technology, and speed (Figure 1). The concept of customisation is similar to "craft" manufacturing, which is the production mode of the pre-industrial era.

Customisation is defined as "*manufacturing goods to address the special and unique desires of customers and changing the features of the product or service according to customer needs.*" (AMA Dictionary, Piller, 2007:634).

"*For this reason, mass customisation can be described as the realisation of the ideals pertaining to the craft manufacturing era using modern industrial technology*" (Tomaş, 2012:15).

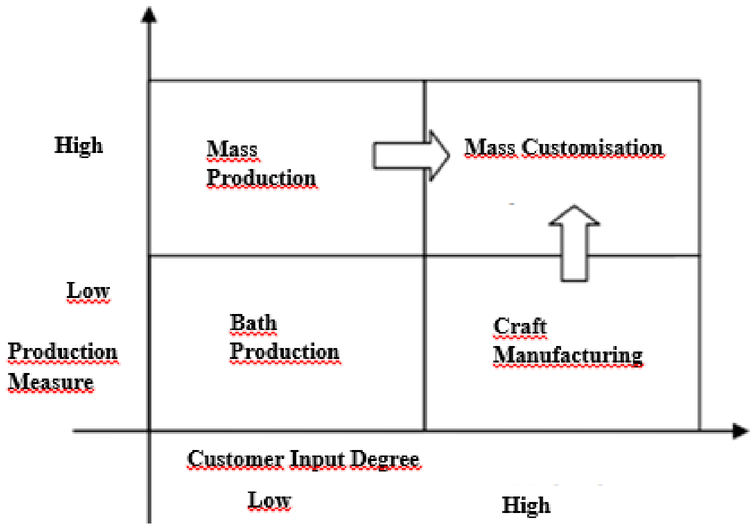

Figure 1. Producer-customer relationship (Squire, et al., 2006: 11)

The change in the producer and the customer can be summarised in terms of the data in Table 3.

Table 3. Producer-customer relationship before and after industrialisation

Pre-Industrial Era	Post-Industrial Era	1970s and Later
Craft	**Mass Production**	**Mass Customisation**
Craft/hand-made	Serial production/ Mass production/ Fordism	Flexible production/ Mass customisation/ post-Fordism
Customised manufacturing/Tailor-made manufacturing	Standard production for all	Customised/Tailor-made production
Low production capacity and speed	High production capacity and speed	High production capacity and speed
Homogenous consumer	Homogenous consumer	Heterogeneous consumer
Focus: customer wishes	Focus: speed and low cost	Focus: customer wishes and low cost

According to McKenna, modern marketing approach has gone through a profound evolution by transforming from the understanding "*you can choose whatever colour you like so long as it is black*" to "*tell us the colour you like, and we'll manufacture the good together*", and finally to the suggestion "*let's come together to reveal the significance of colour and how they influence you within the breadth of your aims.*" (quoted by Bardakçı, 2004; McKenna, 1991).

The understanding that prevails mass production was "*the company does, and the customer buys,*" or "*the company talks, and the customer listens.*" With mass customisation this understanding has transformed completely and became "*the customer talks, and the company listens,*" "*the company and the customer produce the good together,*" or "*the customer desires, and the company does.*" (quoted by Bardakçı, 2004; Peppers, Rogers, 1993).

While the producer determines its competitive strategy, the consumer takes their wishes as a base. The more valued a consumer feels, the more will they prefer that company / producer. Now, the consumer is a highly decisive factor in the competition among producers. It is possible for a producer to outmatch its rivals by adding value to the consumer. The value in question is the ability to address consumer needs or to increase their value (Porter, 1998).

In the past, the value criteria used to be narrower in scope, but now with the division of a single market, they involve various factors (Table 4). (Squire et. al., 2004: 462-463).

Table 4. Value criteria (Squire et. al., 2004: 461)

Value criteria									
Price	Quality	Technical features	Variety of the product	New products	Flexible capacity	Design	Brand	Services	Customisation

Each producer exhibits their difference by means of the value criteria they determine according to the features of the product and service. In this way, they can form a group or groups of consumers that demand these goods and services.

2. Mass Customisation in the Milieu of Architectural Production and the Production of Building Materials

Technological changes have triggered a change not only in production activities, but also in the design processes in production environment. Labour-intensive production mode has transformed into technology-intensive production mode. During this period of transformation, industrial production regimes, which include Taylorism, Fordism, and post-Fordism, have directly affected all aspects of architecture, especially starting from the production of housing.

Başoğlu S.K. has explained the impact of production regimes on architecture with the following remarks: "*Developed by Taylor, Taylorism was a method in industrial production to increase efficiency based on time; Fordism, on the other hand, steered the founding concepts and the practice of modern architecture in Europe as well as the Soviet Union. By applying Taylor's theory in automotive industry to develop the industrial assembly line, Henry Ford organised the 8-hour workday based on the relationship between the actions of work, shelter,* *and consumption, and thus, paved the way to the appearance of mass society, which constitutes the target group of modern planning and architectural practice. As a result, the production of housings, including the premises, blocks, and units of dwelling, became the most common field of architectural practice* (Başoğlu, 2020).

With the direct influence of production regimes on architectural space production, especially serial production (Fordism) developed around the concepts of rationalisation, standardisation, prefabrication, and modular design. As was the case in the Fordist production approach, in architecture, too, serial, fast, and cheap building production became the priority. This interaction inevitably affected the approach to the production of building materials as the most important tools of architecture. In fact, it will not be wrong to suggest that the industrialised sector of building material steered architectural changes. The pattern of rural architecture that had been formed by centuries of local tradition lost its ground to building materials of industrial production as a result of the relocation of rural population triggered by Industrialisation and the lack of material in a certain area. In the building material sector, which was detached from crafts, production processes and approaches have also improved and changed.

Architectural services and tools had to improve/change for society, which started to gain strength within the changing political and socio-cultural structure. Especially "in the 3rd Industrial Age, the advances in information technologies transformed architectural design processes and application methods, creating a tension between '*the familiar and* *traditional*' and '*the experimental and innovative'*. With the appearance of computer-assisted design (CAAD) and production technologies in the processes of design and production, 'linear design' processes evolved to transform into an integrated, single one." (Ediz, Erbil, Akıncıtürk, 2010).

Production approaches that went through a change with post-Fordism not only altered the production milieu, but also all the processes that include design and its actors. Mass customisation began to be effective in the design, production, and construction processes within the sectors of architecture and building materials. Architecture was reiterated for centuries within the boundaries of tradition, then standardised with serial production, and now has assumed a more flexible structure based on the production of building materials and the possibilities of construction technologies. For this reason, the possibilities of building materials/systems have constituted the boundaries and flexibility of architecture.

Mass customisation has created new behaviour possibilities for the building material sector within the behaviour of industrialisation, and anticipating these new possibilities of behaviour will be effective in the processes of architectural formation in the near future. However, mass customisation is not suitable for all areas of production, nor is it applicable to all building materials / products. The pertinence of the producer's products and services to mass customisation and the competition strategy are highly important factors.

2.1.The Competition Strategy of The Producer

The competitive strength of the producer depends on the competition strategy it established according to the available production technologies. While competition strategy refers to the producer's consumer value criterion, the pertinence of production technologies to mass customisation refers to the level of relationship with the consumer during production design. Porter has categorised competition strategies that producers can establish depending on their competitive strength into 3 groups:

- Cost leadership strategy
- Differentiation strategy
- Focus strategy (Porter, 2003)

Cost is one of the most important factors that determine consumers' product preferences. It also constitutes the main principle of mass production. However, differentiation and focus strategies have a different approach, in that they include the consumer in the process and support mass customisation. Differentiation strategy involves producing something that is considered unique in the entire sector by differentiating a certain product or service offered by a company. (Porter, 2003: 47).

For example, for a ceramic tile producer in the flooring materials sector, manufacturing products in different sizes is a differentiation strategy. This opportunity provides a competitive advantage for the producer against its rivals in the market. The conditions of differentiation strategy in national markets differ from those in international markets. The advantage obtained in the national market may not be effective in the international market.

Dursun İ.T. has conducted a study to analyse the ceramic flooring sector with a differentiation strategy. The findings of this study reveal that the producers in this sector give importance to research and development, that product development is the outstanding area in R&D, and the producers mainly focus on developing different product sizes (Dursun, 2007:71).

Focus strategy, on the other hand, involves providing the best possible service for a certain section of the product and service, a certain market, or a certain age group. Focus strategy is formed in 4 ways: Product Range, Customer Type, Channel (urgent buyers), and Geographical Segmentation. The major element in the focus strategy adopted by the ceramic material producers in Turkey has been stated to be geographical segmentation. 51.3% of the export of ceramic flooring materials in Turkey is to EU. This high rate, which is slightly over half the total export in this sector, demonstrates that geographically speaking, Turkey focuses on these countries. In this sense, it could be stated that Turkey determines its production principles according to the needs and desires of this region (Dursun, 2007).

Çidem, S. has conducted a survey with the ceramic tile producers in Turkey, and the findings have revealed that their focus is European countries: "*Since the producers in our country mainly export their goods to EU countries, they have to follow the design trends (fashion) abroad. However, export goods that are produced for other countries* *with different climates, such as Germany, are also put on the market in Turkey. In other words, goods with different colours, textures and sizes are not designed to meet the unique needs in our country and cities or to include the regional and identity approaches"* (Çidem, 2018). Moreover, it is stated that consumers in the national market have different demands about colour, texture, and size. It is added that demands may be considered according to the project size and possible cost. Depending on the producers' selection of one or more of the aforementioned competition strategies, they begin to differentiate from the other producers. However, this alone does not mean mass customisation.

2.2. Mass Customisation Method

Various studies have been made on the methods that could enable mass customisation in terms of production. However, according to Bardakçı, "*although production methods are essentially similar to one another, different terms have been used by different researchers.*" For this reason, he has carried out a study to "*unite the approaches that have been suggested with different terms and could be used in practice under one overarching category.*" In this study, Bardakçı has gathered the suggested methods to implement mass customisation under three categories (Bardakçı, 2004):

*Cooperative customisation is based on the cooperation between the company and the consumer to determine the needs of the latter. It is mainly applied in construction and project bids. No product is finalised without establishing a dialogue between the consumer and the producer.

*Adaptive customisation is implemented by means of the goods that are produced to meet the different needs of different consumers. In this application method, the design phase is more important than the production phase. During the design phase, the good must be designed in such a way that it can adapt to the diverse characteristics of different consumers. There is a product, which can be adapted to different consumers.

*Modularisation is the method that is most commonly applied. During production, standard modules are manufactured. The modules are assembled according to the desires and needs of consumers, and if required, these modules may be changed in time. The convenience of this method lends itself to the capacity to respond to the different desires and needs of the consumer at different times.

In architectural production and the production of building materials, the consumer who does not have a say in the production regime that could be referred to as mass production-serial production or Fordism began to have an active voice in the production regime of mass customisation-flexible production or post-Fordism. However, the feasibility of mass customisation in architectural building production is different (Table 5).

Table 5. Mass Customisation in Architecture

Production milieu	Consumer milieu	Mass customisation in architecture	Method of mass customisation		
			Cooperative	Adaptive	Modular
Mass customisation / Industrial craft	Aware Innovative Active	Project scale	√		√
		Scale of building material	√	√	
		Scale of construction technologies / systems	√	√	√

The consumer is highly active, especially during the design process of architectural projects. In fact, it is impossible to manage and complete the process without the consumer, who is included in the selection of the type(s) of construction technologies or adaptation of different technologies and the design of the system. What is new is that the consumer began to have a say on the scale of building material products and that they are involved in system design. Product design of certain materials began to transform into a process that is directly carried out between the producer and the consumer. The colour, size, texture, and even the curve of the product may change within the limits of production. During the phase of building site production or implementation, these products cannot be changed, such as ceramic, glass, bricks, etc.

In architectural buildings, the consumer's desires demonstrate themselves in the selection of the material's shape, texture, size, and colour. Interior-exterior lining materials and load-bearing systems are the visible surfaces by which consumers can apply their differentiation/customisation demands. After all, not every building material is suitable for the conditions of flexible production. Especially functional building materials whose technical features are important, such as thermal insulation materials, waterproofing materials, construction chemicals, and binding materials are examples of such materials that are not suitable for flexible production. The materials under the category of composite panels, on the other hand, may be customised on a production scale depending on the desired size and surface structure in accordance with the project requirements and system design (Table 6).

Table 6. Mass customisation in the production-use of building materials

Mass customisation in the production and use of building materials		
Phase	Customisation during the phase of material production	Material production is complete / Customisation during the phase of construction
Process	Production design	System design
Cooperation	Producer-Consumer	Designer-Consumer
Outcomes	Only material Lining material; paint, ceramic, glass, brick. Visible system profiles; cap profiles; load-bearing profile.	System Curtain wall, Fitted kitchen, modular systems, roof, wall, floor, drop ceiling designs

Considering the materials produced specifically for the projects in which the consumer is involved with the producer for flexible production/mass customisation purposes, ceramic and glass are seen to be the most common ones. These materials are produced after the system design phase has been completed with the cooperation of producer-designer-consumer according to the project decisions. (Figure 2-3-4-5) (Url-1).

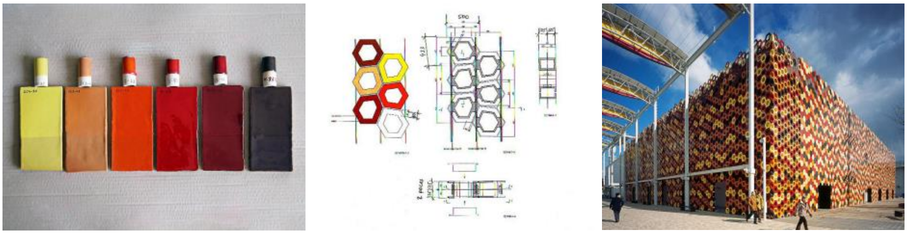

Figure 2. Spanish Pavilion, Aichi (Url-1)

Figure 3. Villa Nurbs (Url-1)

Figure 4. Santa Caterina Market (Url-1)

Figure 5. The use of glass material; La Samaritaine, Paris. Luis Vuitton, Tokyo. Apple, Singapore (Url-2)

3. Conclusion and Suggestions

While consumer desires shape the focus of craft production, mass production focuses on cost and speed. Mass customisation is a hybrid strategy that tries to combine the two for application. In this sense, mass customisation can be described as industrial craft, and as such, it is the implementation of craft manufacturing, which is shaped according to consumer demands, using the industrial technologies in today's conditions.

In architecture, especially in design processes, mass customisation has a long history compared to building material product design, which is a newer field.

In production design, in which consumer demands are prominent, the opportunities offered by the producer's technologies play an essential role. If the technological production environment is not sufficient to respond to the changing circumstances of consumption, cooperation between the consumer and producer will be possible in limited building materials. This cooperation can only be supported with technology.

With Industry 4.0, the opportunities that production technologies can enable will increase customisation areas, variety of materials, and tailor-made material production that is unique to each project.

Thanks 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 Disclosure Information

There is no conflict of interest.

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Investigation of Sound Insulation Performance of Biomaterial-Based Composite Building Materials

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1. Introduction

Appropriate heat, moisture, and sound insulation solutions are required to ensure optimum physical environment conditions in buildings. Insulation levels that would provide comfortable conditions are prescribed by relevant regulations. With a significant impact on physiological and psychological health, sound insulation, one of such parameters above, was investigated in the scope of the present study. The "Regulation on the Protection of Buildings Against Noise" No. 30082, dated May 31st, 2017, was published with an aim to minimize the adverse effects of external noise originating from the surroundings of the building or internal noise, i.e., the neighborhood noise, on human health. The annexes of this regulation included noise and sensitivity grades, acoustic performance classification, sound insulation values, and noise levels by types and volumes of buildings with different usage areas. The acoustic performance was classified in regulation on a scale of A, B, C, D, E, and F; where A indicated the highest and F the lowest performances. The regulation required that the newly constructed buildings and renovated buildings should meet Class C and Class D standards as a minimum, respectively (Regulation on the Protection of Buildings Against Noise, 2017).

The annex of the aforementioned Regulation also prescribed the noise and sensitivity levels of the buildings from receiver and source perspectives by building function and scale of the space. Noise generation levels were classified as low-level noise generation (LN), medium-level noise generation (MN), and high-level noise generation (HN); where sensitivity as very noise-sensitive building and use (I), noise-sensitive building and use (II), and less noise-sensitive building and use (III). The annex of the regulation specified that residential buildings had a medium-level noise in case they were the noise source, and a first degree (I) sensitivity in case they were the receiver. The bedrooms, living rooms, kitchen, bathroom, and circulation areas would have a medium-level noise, whereas the technical offices would have a high-level noise, when the space is the noise source. If the space is the receiver, the bedrooms, living rooms, and kitchen, bathroom, circulation, and technical offices would have a degree of sensitivity of I, II, and III, respectively (Table 1) (Regulation on the Protection of Buildings Against Noise, 2017).

Table 1. Noise sensitivity/noise levels in residential buildings (Regulation on the Protection of Buildings Against Noise, 2017)

BUILDING SCALE			PLACE SCALE		
	SOURCE	RECEIVER		SOURCE	RECEIVER
BUILDING FUNCTION	Noise Level	Sensitivity Degree	PLACE	Noise Level	Sensitivity Degree
Residential Buildings	MN	I	Bedrooms	MN	I
			Living Rooms	MN	II
			Kitchen/ Bathroom	MN	III
			Circulation Areas	MN	III
			Technical Centers	HN	III

The external ambient noise level (L_{gag}) based on day-evening-night average sound levels measured excluding facade reflections and the lowest sound insulation values to be provided in accordance with the sensitivity level of the receiver room are given in Table 2; where the required lowest sound insulation values based on to adjacency relations are given in Table 3. It was required that the sound insulation value should be at least 30 dB, in addition to the values specified in Table 2 for Class A, B, C and D (Regulation on the Protection of Buildings Against Noise, 2017).

Table 2. Required lowest sound insulation values (dB) based on external noise levels and receiver room sensitivity degrees (Regulation on the Protection of Buildings Against Noise, 2017)

RECEIVER ROOM SENSITIVITY	ACOUSTIC PERFORMANCE CLASS[3,4]					
	A	B	C	D	E	F
I	L_{gag}-14	L_{gag}-18	L_{gag}-22	L_{gag}-26	L_{gag}-30	L_{gag}-34
II	L_{gag}-17	L_{gag}-21	L_{gag}-25	L_{gag}-29	L_{gag}-33	L_{gag}-37
III	L_{gag}-20	L_{gag}-24	L_{gag}-28	L_{gag}-32	L_{gag}-36	L_{gag}-40

Table 3. Lowest airborne sound insulation values (dB) as required between adjacent volumes in residential buildings (Regulation on the Protection of Buildings Against Noise, 2017)

Building Function	ADJACENCY		ACOUSTIC PERFORMANCE CLASS[3]					
	Source Room	**Receiver Room**	**A**	**B**	**C**	**D**	**E**	**F**
RESIDENTIAL BUILDINGS	Commercial Business Technical Center	Independent Unit	68	64	58	54	50	46
	Independent Unit Common Area	Independent Unit Common Area	62	58	52	48	44	40
	Bedroom Living Rooms Kitchen/Bathroom	*Located in the same independent unit;* Bedroom Living Rooms	54	50	44	40	36	32

Simulation programs are used for the purposes of measuring sound insulation values in buildings. The KS-Schallschutzrechner program is one of the simulation programs utilized in the calculation of sound insulation values pursuant to DIN 4109-2 standards, and it complies with TS EN ISO 12354 "Building Acoustics – Estimation of Acoustic Performance of Buildings from the Performance of Elements" standard (Yüksel Dicle, 2021). The insulation values are obtained upon calculations based on the volume of the source and receiver room in the building and the density, thickness, or dynamic hardness value of the building materials used in such spaces.

The calculations in the KS-Schallschutzrechner simulation program take the status of the building elements into consideration as external walls and partition walls/flooring. In the case of external wall, the relevant calculations include the outdoor-borne noise by incorporating the window spaces in the place and the characteristics of the selected glass; whereas regards partition wall/flooring, the adjacency relationship is calculated only over the wall surface, without including the window features.

It is of great importance to determine the cross-sections of the building envelope and interior partition elements that meet the values prescribed by the regulations and to provide sound insulation solutions with an aim to control the airborne or solid sound or noise due to conversion of different types of energy into sound energy (Untuç & Yüğrük Akdağ, 2017). Most of the insulation materials used in the construction sector originated from non-renewable sources, which causes waste generation, increases the emission of CO_2 and toxic gases and thus aggravates the effects of global warming. There is ongoing research on building materials originated from living organisms or agricultural waste, which do not contain hazardous substances, can be destroyed without harming the nature, and are obtained from environmentally friendly biomaterials with an aim to mitigate the aforementioned adverse effects induced by the construction sector.

Biomaterials refer to materials designed to drive the functioning of any system through their interaction with living organisms (Williams, 1986). Biomaterials are also defined as substances naturally derived from a living organism, which can be used as material or fuel (Cambridge Dictionary, n.d.). Substances that meet the definition of biomaterials include animal and plant products such as wood, flax, hemp, prina (olive pomace), bamboo, coconut fiber, gourd fiber, sheep wool, mycelium and bacteria, agricultural wastes and living organisms (Uyar Sun & Aydın İpekçi, 2021). Furthermore, wheat straw, corn cobs, sugarcanes, rice husks and peanut shells are also considered biomaterials (Kiran et al., 2018; Paiva et al., 2011; Manohar, et al., 2002; Kaylı et al., 2021).

Biomaterials found increased use in the construction sector amid improved environmental awareness and heightened concerns about human health. In the context thereof, regard, the building materials industry and scholars conduct field studies and observations with an aim to investigate the utility of biomaterial-based composite materials in the construction sector.

Wood has been directly used as a building material for long, while other biomaterials are leveraged as additives in order to obtain composite building materials with desired properties (Plank, 2004). Building materials with biomaterial additives in their composition require fewer chemical reactions, consume less energy and naturally decomposed compared to the building materials manufactured by chemical methods using synthetic binders (Khitab et al., 2016). Along with the direct use of biomaterials as additives, agricultural waste, including rice husk ash, peanut shell ash, wheat stalk ash, and corn cob ash are also used in the function of natural pozzolana (binder) in the manufacture of building materials due to the high silicate content thereof (Kaylı et al., 2021).

The present study aimed to investigate the effect of using biomaterial-based composite insulation materials on sound insulation values in residential buildings. Towards future studies with alternative insulation materials, it was aimed to raise awareness about developing buildings in compliance with the regulations governing protection against noise.

In the scope of the study, biomaterial-based composite insulation materials made of wheat straw, corn cobs, and sugarcane fiber were analyzed using the simulation tool along with rock wool, a widely used insulation material in the sector, as control.

It was assumed that selected four insulation materials were applied to the inner surfaces of the walls of a first-floor apartment of a two-floor residential building away from the heavy traffic noise, with facade facing a playground, built by reinforced concrete carcass system using autoclaved aerated concrete (AAC). Since there was no study in the relevant literature on the use of materials on exterior, the foregoing scenario was not included in the scope of the study.

The sound insulation values provided against the external noise level and the sound insulation values between the adjacent volumes were calculated using the KS-Schallschutzrechner simulation, assuming that the selected insulation materials were applied to the inner surfaces of the walls and without insulation material was applied, and the impact sound level on the floorings of the source room was not included in the scope of the study. Accordingly, the results were assessed with reference to the “Regulation on the Protection of Buildings Against Noise”.

2. Material and Methods

2.1. Material

Biomaterial-based composite insulation materials with accessible thickness and density information were selected pursuant to the calculation principles of the simulation program, on the basis of the framework developed upon literature review. In the context thereof, certain insulation materials made of wheat straw, corn cobs, and sugarcane fiber were analyzed using the simulation program for the purposes of the study. Rock wool, a widely used insulation material in the market, was chosen with an aim to compare the sound insulation values based on the simulation calculations with the selected insulation materials.

Wheat Straw-Based Composite Materials

Kiran et al. (2018) produced boards of different densities to investigate the utility of wheat straw, an agricultural waste, as an indoor heat and sound insulation material. Upon grinding and drying, wheat straws were mixed with melamine urea formaldehyde (MUF) as a binder and hot-pressing procedure was applied thereto, resulting in particleboards sizing 300x300x12 mm. The average density of the insulation boards was 306 kg/m^3, 409 kg/m^3, and 520 kg/m^3. The insulation materials met the corresponding standards on heat and sound insulation (Kiran et al., 2018). The board with the highest density, i.e., 520 kg/m^3 was selected for the purposes of the present study.

Corn Cobs-Based Composite Materials

Paiva et al. (2011) produced composite sheets with an aim to investigate the thermal insulation performance of samples made of corn cobs. Wood glue was used as a binder in the course of the sample production.

The effect of the thickness of the manufactured boards with a density of 334 kg/m^3 sizing 25x25 mm with 30/50/60/80 mm thickness on the thermal insulation performance was analyzed and it was reported that increased thickness had a positive effect on the thermal insulation performance (Paiva et al., 2011). The board with 80 mm thickness, which offered the best thermal insulation performance, was selected for analysis for the purposes of the present study.

Sugarcane-Based Composite Material

Manohar et al., (2002) produced boards with 300x300x25 mm dimensions and 113 kg/m^3 density using corn starch as a binder with an aim to investigate the utility of sugarcane as a heat insulation material. It was reported that the boards were suitable for use as heat insulation material (Manohar et al., 2002).

2.1. Method

In the scope of the present study, it was assumed that the selected samples were used in a first-floor apartment with 2 bedrooms, 1 living room, 1 kitchen, and a bathroom in a two-floor residential building, which was built based on reinforced concrete carcass system. Furthermore, it was assumed that the building was far from heavy traffic noise and its facade faced the playground (Figure 1, 2). The outdoor noise level was taken as 60 dB and accordingly sound insulation levels for the *bedroom–bedroom*, *bedroom–kitchen*, and *living room–kitchen* pairs were analyzed in addition to the sound insulation values against the external noise level as calculated using the KS-Schallschutzrechner simulation program (Figure 3, 4).

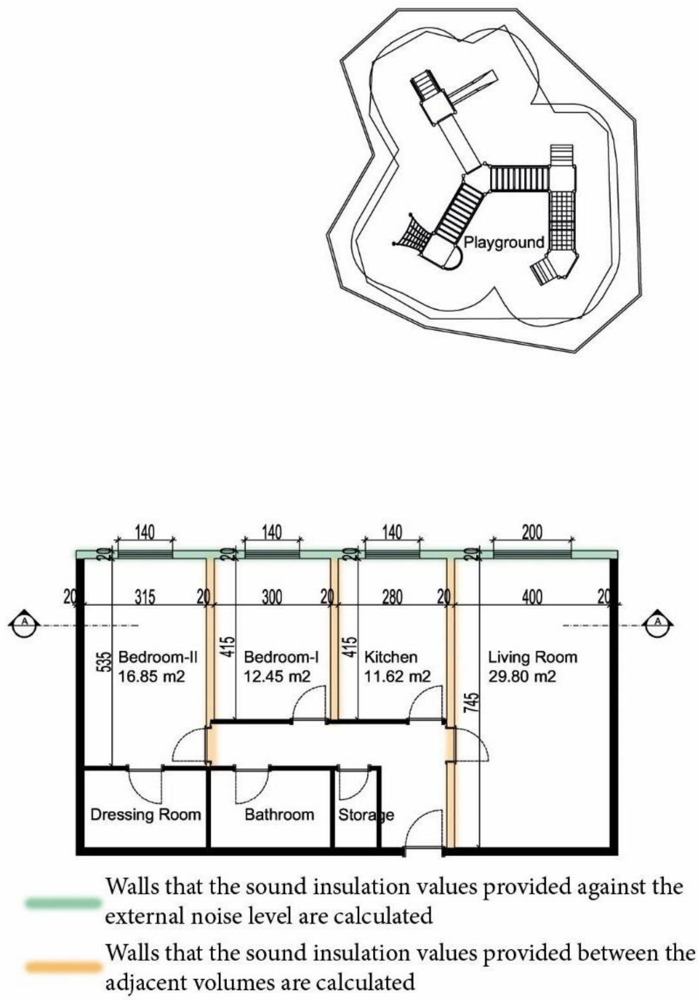

Figure 1. The schematic plan of the residential building analyzed by the simulation program (Unit of measurement is given in cm)

Figure 2. The schematic section of the residential building analyzed by the simulation program (Unit of measurement is given in cm)

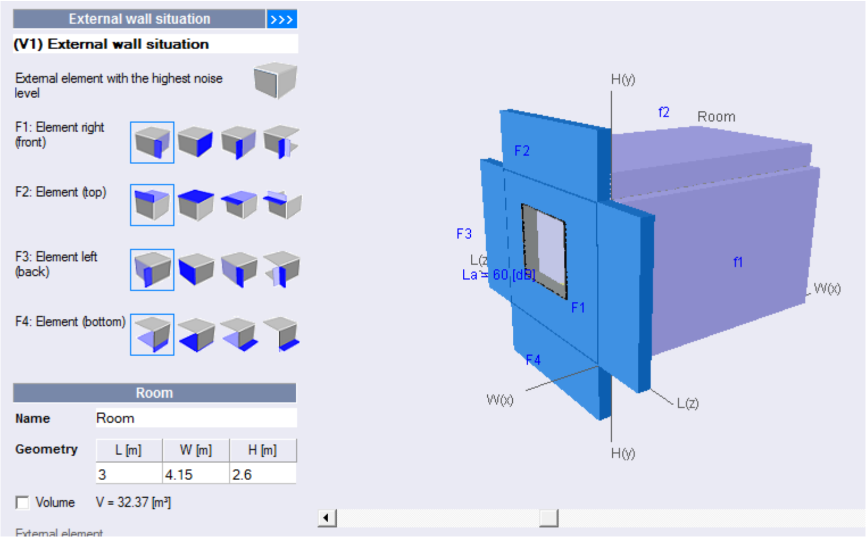

Figure 3. General interface of the KS-Schallschutzrechner simulation program used in calculation of sound insulation value against external noise level

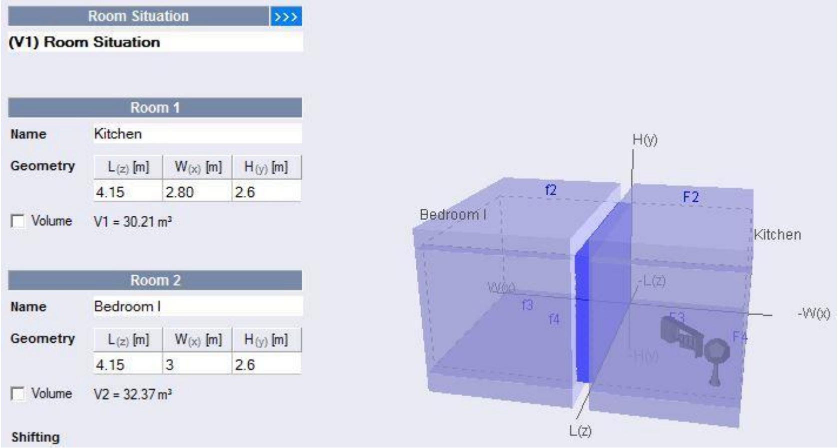

Figure 4. General interface of KS-Schallschutzrechner simulation program used in calculation of sound insulation value between adjacent volumes

In addition to the thickness and density values of the biomaterial-based composite insulation materials, which were selected upon a literature review, and of the rock wool, respective information on the thickness and density of the materials used in the exterior wall, partition wall, ceiling, and flooring layers (Table 4) were obtained from the relevant literature and entered into the simulation program. The contribution of the analyzed insulation materials to noise control was further compared with the scenario, where insulation material was used on the wall surface. Upon analysis, the compliance of the values as retrieved from the simulation program with the Regulation on the Protection of Buildings Against Noise, No. 30082, dated May 31, 2017, was assessed.

Table 4. Thickness and density values of building materials analyzed by the simulation program (Kiran et al. (2018); Paiva, et al. (2011); Manohar, et al. (2002); Özpor Rock Wool; AKG Autoclaved Aerated Concrete; Union of Chambers of Turkish Engineers and Architects Chamber of Civil Engineers; AGT Parquet; Şişecam)

Name of Material	Thickness (mm)	Density (kg/m^3)
Wheat Straw	12	520
Corn Cobs	80	334
Sugarcane	25	113
Rock Wool	50	50
Concrete Slabs	300	2400
Screed	80	2000
Autoclaved Aerated Concrete	200	600
Plaster	15	1000
Laminated Parquet	8	850

It was assumed that acoustic laminated double glazing with a noise insulation value of 40 dB and a thickness of 4 mm with 16 mm gaps was used in the windows.

3. Results and Discussion

For the purposes of the present study the insulation values against the external noise level and the sound insulation between the adjacent volumes were calculated by the KS-Schallschutzrechner simulation program and given in Table 5. The cases where the lowest sound insulation values as prescribed by the regulation were achieved were underlined and expressed in bold. In the context thereof, the calculations were based on different scenarios. These scenarios assumed that biomaterial-based composite insulation materials made of wheat straw, corn cobs, and sugarcane fibers, and rock wool as control were applied in the residential building, where the other scenario assumed that there was without sound insulation material in place.

Table 5. Sound insulation values from the simulation program (dB)

	Sound Insulation Values Against External Noise Level (dB)			**Sound Insulation Values Between Adjacent Volumes (dB)**			
	Bed-room I (32.37 m^3)	Bed-room II (43.82 m^3)	Living Room (77.48 m^3)	Bed-room I – Bed-room II	Bed-room II – Bed-room I	Kitchen – Bed-room I	Kitchen – Living Room
Without Insulation Material	34.5	35.6	**<u>37.3</u>**	35.4	34.1	34.1	38.0
Wheat Straw	35.1	35.9	**<u>37.9</u>**	36.3	35.4	35.4	39.2
Corn Cobs	36.8	37.7	**<u>39.6</u>**	40.2	38.9	38.9	41.4
Sugarcane	34.7	35.8	**<u>37.6</u>**	36.0	34.7	34.7	38.5
Rock Wool	34.7	35.8	**<u>37.6</u>**	35.9	34.6	34.6	38.4

Figure 5 includes a graph showing the change in the sound insulation values against the external noise level in selected spaces in cases where building materials were applied or not, by different volume sizes.

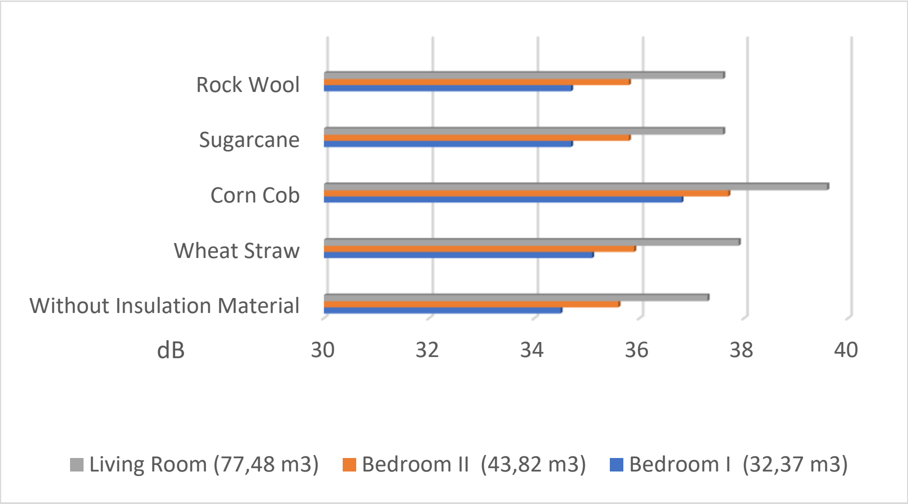

Figure 5. Distribution of calculated sound insulation values (dB) against external noise level by space

Pursuant to the annex of the regulation, the minimum required insulation values against the external noise level, as indicated in Table 2, for bedrooms with a receiver sensitivity of I and living room with a receptor sensitivity of II were L_{gag}-22 dB (60-22=38 dB) and L_{gag}-25 dB (60-25=35 dB), respectively. Upon an analysis of the sound insulation performances of the biomaterial-based composite materials as calculated by the KS-Schallschutzrechner simulation program, it was found that the values specified in the regulation could not be achieved in the bedrooms unlike the living room, in the scenario, which assumed that wheat straw, corn cobs, sugarcane, and rock wool were used, as well as in the without insulation scenario. The results suggested that biomaterial-based composite insulation materials could provide better performance compared to the widely used rock wool in the market.

In cases, where the external noise was at a more reasonable level, e.g., 55 dB, the sound insulation value required for bedrooms was expected to be 33 dB (55-22=33 dB), considering that the sound insulation values prescribed by the regulation were set under the conditions, where the plans were made at the settlement scale. It was found that the said value was achieved by all the materials in question.

Pursuant to the annex of the regulation, the lowest airborne sound insulation value between adjacent volumes should be 44 dB, as indicated in Table 3. A review of the results from the simulation program suggested that the required values could not be achieved in any case.

4. Conclusion and Suggestions

The present study aimed to investigate the effect of biomaterial-based composite insulation materials on sound insulation values in residential buildings. Accordingly, biomaterial-based insulation materials, including wheat straw, corn cobs, and sugarcane fibers, and rock wool as control, were selected upon literature review. The simulation analyses were based on two scenarios of with and without insulation material. Thereafter, the results were assessed within the framework of the "Regulation on the Protection of Buildings Against Noise". In conclusion, the sound insulation values specified in the regulation could not be achieved, especially in bedrooms, as regards all the assumptions, which included the use of biomaterial-based composite insulation materials made of wheat straw, corn cobs, sugarcane fibers, and rock wool. Notwithstanding above, the best performance was seen in the case, which assumed the use of corn cobs-based insulation material. The said result suggested the fact that the mass of corn cubs-based material was greater compared to the other materials in question due to its thickness and density might have accounted for that outcome. It was considered, on the other hand, that the choice of materials that would increase the mass might result in a heavier building and loss of space.

The fact that the sound insulation values as required by the regulation could not be achieved even in the scenario, which assumed the external noise level 60 dB, was indicative of the fact that that it was rather difficult to achieve those values in regions across Turkey, where the external noise level reached up to 75-80 dB. This is suggestive of the necessity of developing plans at the settlement scale as well as prohibiting settlement in areas with high external noise level or making required arrangements.

Upon assessment of the results by the spaces indicated in the graphic included in Figure 5, it was seen that the sound insulation value was higher in the living room, which had a larger volume compared to the other spaces in the apartment. This has been associated with the concentration of sound energy in small volumes and dispersion thereof in large volumes.

Composite insulation materials based on biomaterials derived from wheat straw, corn cobs and sugarcane fiber in question, offered a competitive performance compared to rock wool, which was widely-used as insulation material in the market. In addition to the competitive performance of the biomaterial-based materials, it is also extremely important that their ingredients are originated from renewable resources, that they can be disposed of without harming the nature, that they do not cause toxic gas emission, and thus they are environmentally friendly materials.

Further studies with alternative insulation materials should develop different scenarios, the simulation calculations in the framework of those scenarios should be supported by measurements in the real environment, and such scenarios should be developed vis-a-vis the regulations governing the protection of buildings against noise.

For the purposes of diversification and dissemination of biomaterial-based composite building materials, different properties such as thermal insulation and fire resistance should also be investigated and assessed along with sound insulation.

Thanks 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 Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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Usage of The Agricultural Wastes as A Pozzolan in Concrete Production

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1. Introduction

Today, makes it impossible to protect natural resources, which is our most important responsibility for future generations, the rapid consumption and pollution of natural resources as a result of increasing needs and economic activities in parallel with the increasing population. While different resources are used and consumed by the sector, it cause significant environmental problems the waste materials that emerge as a result of these uses and activities. As in many countries of the world, is becoming more and more important reducing waste sources and recycling existing wastes in our country. Recycling of waste is an extremely important issue in terms of efficient use of resources, environmental problems and economics (Biricik et al. 1996).

Due to people's need for shelter and living space, more and more buildings are being built and the production of concrete is also increasing, which is the most used material in the construction of these buildings. As it is known important environmental problems arise, while the production of concrete and concrete components is consumed by using natural resources to a large extent. Cement and cement production comes, which is used as a binder in concrete, first among these problems. The raw material, energy requirement required in the production and use of cement and the supplied way of this energy is constitute the source of important environmental problems. Therefore, it is great importance in terms of reducing the amount of cement used in concrete consuming natural resources and reducing environmental problems (Yilmaz, 2013).

The only way to reduce the amount of cement in concrete is to use materials with pozzolanic properties. Pozzolans are materials of silica, alumina and iron oxide origin, which have little or no binding property on their own, but show binding properties with water when brought to a fine-grained state. Today, many natural or artificial materials can be used as pozzolans. Volcanic ash, volcanic tuff, diatomaceous earth and baked clay can be classified as “natural pozzolan”, fly ash, granulated blast furnace slag, silica fume, and husk ash can be classified as “artificial pozzolan” (Erdoğan, 2004). In addition, waste materials from different sectors can also be used as pozzolans, and these materials are considered natural in concrete and treated like fine aggregate (Sisman and Yılmaz, 2016).

2. Pozzolan

Puzolan is materials originating from silica, alumina and iron oxide, which have no or very little binding on their own, but gain hydraulic binding properties when they are brought to a fine-grained state and combined with calcium hydroxide formed as a result of hydration in the aqueous environment (Yazıcı, 2006). According to the TS-25 standard of the Turkish Standards Institute (Anonim, 2008) the total content of $SiO_2 + Al_2O_3 + Fe_2O_3$ should be at least 70% in natural pozzolans.

The use of pozzolan goes back thousands of years. This material was first used in the ancient Roman period by with slaked lime and water mixing of volcanic ash around the Vesuvius volcano in the town of

Pozzuoli, near Naples, Italy. In this context, the name of the hydraulic binder is given here, which is used today (Erdoğan, 2007).

Figure 1. First exit area of pozzolan material

Like the ancient Romans, the ancient Greeks used binding materials created by mixing volcanic ashes and fine-structured volcanic tuffs with lime and water. In addition to these materials, small stone particles were added to the mixture and a material similar to today's concrete mixture emerged. Water channels and buildings built with building materials created in this way in France and Italy have been standing for about 2000 years (Malinowski, 1982).

3. Pozzolanic Reaction and Pozzolanic Activity

When fine-grained pozzolans, which are largely composed of silica, alumina and iron oxide, are mixed with slaked lime and water, calcium hydroxide forms calcium-silica-hydrate (C-S-H) gels with hydraulic binding properties as a result of chemical reactions between silica and water, just like in the hydration of portland cement.

$SiO_2 + Ca(OH)_2 \rightarrow CaO.SiO_2.H_2O$

This chemical reaction given above occurs very slowly and is described as a pozzolanic reaction (Erdoğan and Erdoğan, 2007).

The capacity of a material to react and harden in a pozzolanic reaction with calcium hydroxide and water in the environment is defined as puzolanic activity. In other words, pozzolanic activity refers to the ability of a pumble to bind lime and the speed of the bonding process (Mazsazza, 1998).

Pozzolanic activity depends on the amount of silica and its amorphous structure. The fact that silica has an amorphous structure means that it is soluble. The amount of soluble silica can be determined by X-ray diffractometer or chemical methods (Biricik et al., 1996).

The pozzolanic activity of a material is usually determined by mechanical and chemical methods. In the mechanical method, it is determined by bending and compressive strength tests on mortars produced with pozzolan-lime-water or pozzolan-cement-water. In the chemical method, it is based on the detection of Ca(OH)2 formed as a result of hydration of pozzolan cement with water. Another criterion for assessing pozzolanic substances is carried out by measuring the rate of increase of the specific surface in cement pastes containing puzolan. Specific surface increase rates correspond to different calcium hydroxide absorption rates (Mazsazza, 1998).

4. Agricultural Wastes and Pozzolanic Properties

According to the data of 2020, there are approximately 23.5 million hectares of agricultural land in our country and 67.5% of this area is cultivated areas, 13.7% is fallow areas and 18.8% is fruit, vegetable, olive and vineyard areas (Anonimous, 2020a). In our country, where a wide variety of agricultural production is made, a large amount and variety of agricultural waste is generated as a result of these productions. Approximately 50 million tons of agricultural waste that emerges annually is generally left in the fields or burned in the field after harvest, and a very small part is used as raw material in different sectors (Çolakoğu, 2018). In developed countries, such products are not considered waste, but as a new resource, used for the protection of the environment and the design of new materials.

The release or incineration of agricultural wastes on the land has been accepted as a traditional practice style since the existence of humanity and the periods when it started to grow agricultural products. However, with the effect of increasing population and technological conditions increasing productivity in the agricultural sector, the indiscriminate release or burning of large amounts of wastes resulting from the cultivation of more products in the unit area causes the soil to be adversely affected and the habitats of many living things living in the soil to be destroyed (Boztuğ, 2010).

The use of idle agricultural wastes as building materials in different shapes and characteristics directly or after processing has been demonstrated by many scientific researches. In these studies, building materials for different purposes were produced by using wastes such as sunflower, sugar cane, bamboo, jute, kenaf, cotton, rice, banana, wheat, tobacco, pineapple, corn, hemp, oats, hay, barley, flax, rye, etc. (Pappu et al. 2007; Karade, 2010; Sisman and Gezer, 2011; Mo et al. 2016).

The use of agricultural wastes in the production of building materials reduces production costs, reduces the building load due to their light weight, increases insulation properties, reduces transportation costs due to their continuous and ubiquitous presence and reduces the environmental problems caused by these wastes. Among these advantages, lightness is a very important feature for countries in the earthquake zone such as our country (Esin & Yüksek, 2008).

In recent years, the use of agricultural wastes, especially in biomass energy production, has become a very important issue. Many countries in the world obtain alternative energy from agricultural wastes that are suitable for their ecosystems. In this way, while environmental problems are reduced by disposing of an agricultural waste, an economic gain is also achieved by converting a waste material into a useful product (Çolakoğu, 2018).

Ashes formed as a result of agricultural waste or the incineration of biomass produced from these wastes are a potential material that can be used in concrete production and have been the subject of different researches (Pappu et al. 2007; Karade, 2010). The fact that plants take various minerals (silicates) from the soil during the growth process, their fibrous structure, especially the fact that annual plants are rich in silicates due to the cuticle layer, and especially the high alumina and silica ratio in the structure of the ashes formed as a result of their burning have led to the idea that they may be a pozzolan that can be used instead of cement (Mo et al., 2016). In this section, agricultural wastes that can be used as puzolan after being burned directly or biomass are evaluated by considering the ashes.

4.1. Paddy Straw Ash and Rice Husk Ash

Rice is an important grain that is offered for consumption after the stalks, straw and shells of the grain product with pots taken by paddy harvest are separated. Approximately 750 million tons of paddy and around 500 million tons of rice are produced in an average area of 165 million hectares worldwide, mainly in China, India, Bangladesh and Thailand. In our country, approximately 120 thousand hectares of paddy are produced annually, around 900 thousand tons of paddy and around 550 thousand tons of rice are produced (Anonimous, 2020b; Bölükbaş & Kaya, 2018). Practically every 100 kg of paddy production are obtained, 90-100 kg of hay, 55-65 kg of rice, 3-5 kg of rice polish flour, 10-12 kg of broken rice, 18-20 kg of rice husk and 10-13 kg of rice bran (Bölükbaş & Kaya, 2018).

Rice straw is one of the important by-products considering the rice production potential in the world and in our country (Figure 2). The fact that paddy straw contains a high amount of silica and lignin, has a low taste and nutritional value reduces its consumption as feed and is therefore often burned in the fields.

Figure 2. Paddy and paddy straw

If 100 kg of paddy is produced during rice production, around 90-100 kg of paddy straw is formed and if this straw is burned, approximately 15 kg of ash is obtained (Bölükbaş & Kaya, 2018). Therefore, considering the annual paddy production of 750 million tons in the world, approximately 750 million tons of paddy straw and about 112 million tons of paddy straw ash can be obtained. The ash obtained by burning paddy straw is a potential puzolan material due to the fact that it contains a high percentage of silica as 82% (Snellings et al., 2012).

Another waste generated in rice production is the crust on the rice grains. There are two shells on the rice grains, and the first shell, called bran, is the thin membrane-shaped shell that is yellowish in color and surrounds the rice grains (Figure 3). Although this nutritious shell is sometimes left on rice grains, it is often used as animal feed. The second shell, called cap or melon, is the outermost shell of the rice grains (Cook, 1986). This shell, which consists of various organic and inorganic components, contains hemicellulose, lignin and silica. Approximately 20% of paddy husk consists of silica component (Akbaşak & Koral, 2014). Approximately 200 kg (20%) of paddy husk emerge from one ton of paddy in rice production (Cook, 1986), and when the annual paddy production in the world is taken into account, the resulting amount of paddy husk is around 150 million tons. This husk, which is produced during rice production, is used as a fuel in many countries by turning it into poles or briquettes. The amount of ash produced by the burning of the husk is 20% by weight of the shell and the content consists of about 94% silica (Snellings et al., 2012).

Figure 3. Paddy husk and ash

The high silica it contains and the approximately 30 million tons of ash that will be obtained from the annual burning of 150 million tons of paddy husks are a potential pozzolan material (Malhotra, 1993; Zaki & Çelik Sola, 2020).

Paddy husk ash was first used in the construction of adobe blocks and bricks, then these ashes were also used in concrete production, and in 1924 two patents were obtained in Germany on the use of rice husk ash in concrete (Akbaşak & Koral, 2014). In the following years, the use of paddy husk ashes as puzolan in concrete or mortar production as a substitute for cement has been the subject of many researches and continues to be investigated. When all the studies carried out were examined (Cook, 1986; Malhotra, 1993; Sisman & Gezer, 2011; Snellings et al., 2012; Akbaşak &Koral, 2014; Zaki & Çelik Sola, 2020), it was observed that the use of paddy melon ash as puzolan in mortar or concrete production with displacement up to 10% of the cement weight positively affected the physical and mechanical properties of concrete. It has been observed that the use of paddy melon ash reduces the temperature of hydration, positively affects the processability and increases late strengths.

4.2. Wheat Stalk Ash

Wheat is one of the basic nutrients and is an important strategic product produced all over the world. Worldwide, 790 million tons of wheat are produced annually on an area of approximately 220 million hectares, mainly in India, Russia, EU, China and USA. In our country, which is one of the important producers in the world, approximately 21.5 million tons of production is made on an average of 7.5 million hectares of land (Anonimous, 2021a).

The waste generated as a result of wheat production is the stalks left in the field (Figure 4). In the area where approximately 1 kg of wheat is produced, around 2 kg of wheat stalks are formed. However, since 30% of the stems remain on the soil during mowing, 70% of the total stem can be collected. Therefore, the amount of wheat straw that can be collected is 1.1 billion tons worldwide and 30 million tons in our country (Çiçekler, 2012). Although wheat stalks are tried to be disposed of by rotting or burning in the fields in our country, they are used as feed and litter in the livestock sector, as a raw material in the cellulose industry, and as fuel in energy production.

Figure 4. Wheat stalk

In the case of burning wheat straw, the ash ratios vary between 8-10%, and the silica ratio in the ash varies between 88-91%. In the ashes obtained as a result of combustion, the silica between the epidermis cells in the structure of the stems is transformed into amorphous silica and its pozzolanic activity increases (Malhotra, 1993; Biricik, 1995). Considering that 110 million tons of wheat straw ash can be produced annually in the world, it can be said that it has a high potential for use as a pozzolan in the concrete industry.

In the studies conducted by different researchers on the use of wheat straw ash as pozzolan in concrete and cement mortars (Biricik, 199; Ataie & Riding, 2013), it has been determined that the use of wheat straw ash up to 20% instead of cement improves the physical and mechanical properties of concrete by up to 25%, depending on the combustion temperatures.

4.3. Sunflower stalk ash

Sunflower is the most important oil plant grown in the world and in our country, due to its high oil content (35-50%) and its high nutritional value due to the high amount of unsaturated fatty acids in its oil. In addition to the sunflower vegetable oil industry, it is used as a raw material in the chemical, cosmetic and soap industries and as a valuable animal feed because of the high protein it contains (Sisman and Alkaya, 2019). The annual production amount of sunflower, which is cultivated on an area of approximately 26 million hectares, primarily in Ukraine, Russia, EU, Argentina and China, is around 50 million tons. In our country, it is in the 13th place in the world in sunflower production and the sunflower production grown on an area of approximately 750 thousand hectares is around 2 million tons (Anonimous, 2020c).

After the sunflower harvest, approximately 2.7 million tons of straw remain in the fields annually, and although this waste can be turned into biomass and used as fuel, it is mostly burned as stubble in the fields or mixed with the soil. Approximately 10-12% ash is formed from the stalks burned in the field or in the form of biomass. If all the stems are burned, it is possible to obtain 270 thousand tons of ash annually (Binici et al., 2012; Efe & Alma, 2014).

Figure 5. Sunflower stalk

Another area of use that can be applied to the disposal of sunflower stalks and ashes is the construction material and concrete sector. Sunflower stalks can be used as aggregate in concrete production directly by grinding, or the ashes obtained by burning the stalks can be used as a pozzolan in concrete production. It is possible to produce concrete with sufficient strength and durability, low unit weight and thermal conductivity, by using the stalks as aggregate in concrete. It will provide advantages such as reducing the concrete unit weight, reducing the dead load of the building, saving material, increasing the heat and sound insulation properties, and reducing the great loss of life and property as a result of destructions as a result of various natural disasters. However, the hollowness and high water holding capacity of sunflower stalks will increase the water absorption rate in the concrete. For this reason, it must be used by taking measures to reduce water permeability in building elements that will come into contact with water. If the measures for moisture insulation are not taken, since moisture transfer in the concrete will increase, both the mechanical properties and thermal properties of the building elements will be adversely affected. As a result of this situation, the advantages of using lightweight concrete such as low thermal conductivity will turn into a disadvantage (Anonimous, 2021).

The silica ratio of the ashes formed by the burning of sunflower stalks is at the level of 25-30%. The fact that the silica ratio in the ash is very low will cause the pozzolanic activity to be low and the expected benefit from the pozzolan in the concrete will not be fully achieved. However, in a study conducted by Kumaş (2019), it was stated that sunflower stalk ash can be used up to 2% instead of cement in concrete production, and in this case, the strength losses will be at an acceptable level.

4.4. Sugar Cane Bagasse Ash

As an energy source, 21% of sugar, which is an important nutrient and a strategic product in human nutrition, is obtained from sugar beet and 79% from sugar cane (Anonimous, 2022). Approximately 1.743 billion tons of sugar cane is produced on an area of 23.8 million hectares in Brazil, India and China. After sugar cane is processed in factories and its sugar is taken, small-sized wastes called bagasse emerge and these wastes are used as fuel in the form of biomass. 25 kg of ash is obtained from each ton of sugar cane bagasse burned (Chusilp et al., 2009; Sales & Lima, 2010).

Figure 6. Sugar cane bagasse

In studies on the use of sugar cane bagasse ash as a pozzolan in concrete, it was determined that the use of sugar cane bagasse ash instead of cement up to 20% increases the workability and compressive strength of concrete (Chusilp et al., 2009; Yashwanth & Nagarjuna, 2016; Demir & Elmalı, 2020).

4.5. Corn cob ash

Corn is a cereal in the family of grasses used as food for humans, fodder for animals and raw materials for industry (Öztürk et al., 2019). Corn production in the world is around 1.15 billion tons from 197 million hectares, mainly in the USA, China and Brazil. In our country, 6.5 million tons are produced from an area of approximately 640 thousand hectares (Anonimous, 2021b).

Figure 7. Corn cob

Corn cobs are the remaining part of the corn after the kernels and cob sheaths have been completely separated and are usually incinerated after the kernels are separated. It is a material with high pozzolanic activity due to the silica and alumina oxide it contains at 74% of the corn cob ashes formed as a result of combustion (Kumaş, 2019). It is an agricultural waste known to contain significant amounts of silica. In studies where corncob ash is used in the production of concrete and mortar, replacing 0-25% with cement (Binici & Aksogan, 2011;

Kumaş, 2019), it has been observed that it reduces workability. However, it was determined that it increased the compressive strength especially at late ages and it was suggested to be used at a rate of 6-8% instead of cement

4.6. Hazelnut shell ash

Hazelnut is a fruit that is produced at a level of 1.1 million tons in about 1 million hectares of planting area in the world, consumed as a nut, as well as widely used in pastry, halvah, sweets and especially in the chocolate industry. Approximately 60% of the world's annual hazelnut production is carried out in our country with a planting area of 700 000 ha and a production of 670 000 tons (Anonimous, 2021c).

The most important waste that occurs in hazelnut production and constitutes approximately 50% is the shell. While hazelnut shells are used in the production of paint, linoleum and contralite boards in the USA and some European countries, they are used as fuel in our country, either directly or in the form of briquettes, due to their high calorie content (4100–4400 cal/gr). About 5-7% of ash comes out from the burned hazelnut shells, and considering the hazelnut production in our country, it is calculated that the annual potential amount of ash will be between 20000-30000 tons (Tulgar, 1996; Ozocak & Sisman, 2020).

The presence of approximately 70-75% silica, alumina and iron oxide in the composition of hazelnut shell ash indicates that it is a pozzolanic material (Kumaş, 2019; Ozocak & Sisman, 2020). In a study conducted by Baran et al., (2020), it was determined that 5% hazelnut shell ash additive provided a satisfactory compressive strength for cement. In this study, it was suggested to use 5% ash as a setting accelerator. It has been observed that the mechanical properties of concrete produced by using hazelnut shell ash as pozzolan have improved 64% in flexural strength and 43% in compressive strength at late ages (Tulgar, 1996).

Figure 8. Hazelnut shell and ash

In another study investigating the use of briquette ash produced from hazelnut shell as a pozzolan, it was determined that the concretes produced by using 10% hazelnut shell ash and 5% hazelnut shell briquette ash were in the C25 class. It has been determined that concretes that are not affected by freezing and thawing conditions in cold climate conditions give better results with the use of pozzolanic additives in the increasing curing time (Binici et al., 2012).

5. Conclusion

As a result of the excessive and unconscious use of natural resources, which are needed by industrialization and urbanization in the globalizing world, the amount of waste has a continuous increase trend. This waste problem, which occurs on a global scale, affects the society, family and individual negatively. Reprocessing of waste materials and using them by converting them into useful products is an important issue today (Gündüzalp & Güven, 2016). In this context, the use of industrial or agricultural wastes directly or after processing as a raw material in the construction sector in concrete production has gained momentum in recent years.

One of the ways to produce cement cheaply is by using additives. At the beginning of these additives are pozzolanic materials. Concretes made with cement obtained with ash-sourced pozzolans, which are produced on the condition of complying with the norms specified in Turkish Standards and are deliberately used locally, are both cheaper and more robust.

By using ash-based pozzolan material in concrete production, scarce resources can be used efficiently and economically, while sustainable development can be achieved in the construction sector. In particular, the production and use of environmentally friendly building materials originating from agricultural wastes, eliminating the problem of disposal of these wastes, as well as benefits such as protection of natural resources and reduction of energy consumption will be provided. Thus, rational planning for future needs will be possible.

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All authors contributed equally to the article. There is no conflict of interest.

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Use of Wooden Materials in Traditional Akseki Dwelling

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1. Introduction

Wood material is a natural and vivid building material that can be easily supplied to meet the housing needs of people from early history to the present day. Wood has a wide usage area as a building material used in the carrier system, sometimes used in a functional and decorative sense. The use of wooden materials developing and changing in the process that has been ongoing for centuries; He has gained different interpretations in the hands of different masters and with technological facilities. Developments in the wooden industry contribute to the increase in the qualifications of wood and the development of usage areas as durable materials. The industrialization process, which came with the Industrial Revolution, has developed further as of the beginning of the 20th century and gave a different dimension to the production of wooden elements. From the 1950s to the present day, more resistant wood materials with changing needs and living conditions have been produced in construction and different fields (Gürani, 2021).

The use of wooden materials, which has a very important place in our traditional civil architecture, is only one of the methods of creating a design language in traditional architecture. The wood material used in these structures is selected according to the usage area. The tree species in which wood is supplied also play an important role in determining the usage area. The tree material used as an ornament tool in the furniture element and the tree used in the carrier system is also different. Terms of natural and human factors, it is an important factor affecting the use of wood where the wood will be used. The tree's type, color, strength, and smell characterize a traditional structure. The usage of wood, the combination of details, and similar architectural characters formed by these details constitute their diversity of themselves (Gürani, 2021). Examining the usage areas of wood in traditional dwelling architecture constitutes the scope of this study. In this context, the traditional Akseki Dwelling (Düğmeli Evler[1]), which can be reached by preserving as much as possible from the past to the present, has been selected as a working area. As a result of the study, the usage areas and original characters of the wooden material in the traditional Akseki dwellings were identified and evaluated with examples.

1.1. Use and Sustainability of Wood Material

Wood, which is a very old building material in the history of humanity, has been used as the main material and facade coating of building components in buildings for thousands of years. These materials have always survived in the field of architecture despite the changing systems and technologies that have changed from the past to the present. Wood as a building material is among the preferred materials in every period due to its advantages.

It does not cause negative environmental effects during the wooden life cycle (Sayar, Gültekin, Dikmen & Bilgin, 2009). It is among the environmentally friendly and recyclable materials obtained from renewable sources as a wooden, flexible, and sustainable building material. When evaluated as a building material, it is necessary to

[1] The name was given to Akseki traditional dwelling

examine the positive and negative aspects of the wood (Gürani, 2021). Due to its hard and durable structure, its use as a carrier element in construction systems is among the positive features. However, it is also preferred to have a light material.

Wood as a traditional material is the most common building material used in the Traditional Turkish Dwelling (Aydın & Alemdağ, 2014). The wooden material is used in the formation of floor and upper floor walls, doors, windows, roofs, flooring, and furniture elements. The wood material used in traditional Akseki dwellings is provided from the forests located in the region. This shortens the construction and repair process of traditional structures. In addition, wood, which is easy to maintain and repair, can be easily renewed in all damaged wooden systems or structures.

Traditional civil architectural structures are cultural components transferred from generation to generation. However, traditional structures can be re-life by re-functioning or being protected as a living structure. The wooden material used as the construction material of traditional dwellings is a material that is suitable for reorganization, such as structures. In this way, like other building materials, protecting wood and providing new functions is a frequently seen situation in Akseki traditional dwelling architecture. Wooden flooring, ceiling, furniture, and building components in traditional dwellings are used in the decoration details of doors, windows, and these components. Especially the ceiling decorations of the rooms where the "sofa[2]" and

[2] The name was given to the common area on the upper floor of the dwellings

guests are entertained and the wood carving workmanship in the door elements attract attention.

In addition to the many positive aspects of wood materials, negative qualities should be evaluated. Wood with weak water resistance may swell over time and cracks on the surface may occur. Unless the wood's moisture is dried, there may be bends and bends in the wood used in the structure over time. In addition, the sound permeability of wood is weak (Türkçü, 2017). As a wooden anisotropic material, its strength varies at every point (Duman & Ökten, 1988). For this reason, the construction process is made considering the additional places, combines, and supports of the wood used in the carrier system of the structures.

Wood is a living natural material. However, it becomes a living space among other organisms such as plants and animals (Gürani, 2021). To be affected by these negativities, it must be protected by industrial substances. Although there is no protective substance in traditional dwellings, wooden surfaces were painted by traditional methods. One of these traditional methods is the source of wood provided by nature as the source of the cutting time and processing of trees.

Human factors such as fire are considered a great danger to wood materials. However, many studies found that the cause of fire in traditional houses was not caused by wood material used in the carrier system (Gürani, 2021). The source of the wooden material used in the carrier system in traditional Akseki dwellings is the *Cedrus libani* tree, which is intense in the forests of the region. The wooden material obtained from the *Cedrus libani* tree is a material with high strength and strength. The source of another wooden material used in the dwellings of the region is the *Juniperus communis* tree. Wooden dwellings obtained from the Juniperus communis tree are generally used as furniture or ornament. The wooden material obtained from the Juniperus communis tree is a lower resistance than the wooden material obtained from the *Cedrus libani* tree.

Wood obtained from *Cedrus libani* wood is a light, soft, fragrant material. Even if this smell disappears in 4-5 years, the smell is felt again with the grating of the wood. The specific weight of the tree also affects its physical and mechanical properties. The specific weight and resistance of the *Cedrus libani* tree decrease with the expansion of its annual rings. The *Cedrus libani* tree, which has a narrow and annual ring, is used in the construction system of dwellings, stairs, flooring, roof, and furniture. With its unique smell and strength, the wood obtained from the cedar tree continues to exist solid for years by removing moth beetles. In this respect, when traditional houses are examined, it is seen that there is furniture such as “yüklük[3]”, “cabinets”, and 'granary' made of *Cedrus libani* tree at the beginning of furniture that remained intact (Öktem & Sözen, 1992).

In addition to all these features, wood material is seen as a familiar and ordinary material. Because it has been used in different geographies for centuries, is easily supplied from the immediate environment, and attracts attention as an economic material. They reveal the masters of the region who know the power of the material and the dynamics they

[3] Cabinet system for storage purposes in the rooms

have and contribute to a traditional texture by forming the wooden material as architecture. In this texture, we have a character in the dwellings with civil architectural examples (Gürani, 2021). The texture of the wooden material is in harmony with the entire environment of the region despite the deep traces of the time. Using wood in its natural form and discovering its sustainable qualities provide the timelessness of wood materials, such as the timelessness of Akseki traditional dwelling architecture.

2. Material and Method

In the study, the use and qualities of wood material in traditional Akseki dwellings;

- Use in the carrier system,
- Use in structural elements,
- Use in furniture elements,

will be explained under three headings and evaluated with examples.

2.1. Traditional Akseki Dwellings

Akseki traditional dwelling is known as “Düğmeli Evler”. Although it is not known exactly how far the first examples of "Düğmeli Evler" dated, they are usable, and the construction dates of the oldest surviving specimens are dated to 330 years ago. Dwellings, which are representative of the oldest examples, are still widely used (Manav & Çalışkan, 2017). The fact that "Düğmeli Evler" has a limited distribution only in the Akseki-İbradı region in the Taurus Mountains makes this example of traditional dwelling quite interesting (Figure 1). The Akseki-İbradı area is a transition region in terms of climatic features as well as being a cultural transition and cultural intersection area. The fact that this environment is a transition area between the temperate climates of the Mediterranean and the cold continental climates of the interior has also helped to discover this original architectural technique (Manav, 2019).

Figure 1. Examples of traditional dwelling architecture in Akseki

Rural dwellings are designed for two floors. The entrance of the general one is from the ground floor and there are also those designed to receive entrance from each floor depending on the topography (Karayazı, 2015). They are usually located in the middle of the garden or on one or both sides facing the street. The ground floor is divided into fattening and storage sections in residential dwellings. At the entrance of the ground floor, the projection of the sofa is called "evöğün or ahıraltı[4]" in the region. This part has haystacks, cellars, woodsheds, rarely poultry, pens, and barns. This space also includes the staircase entrance or the staircase itself (Figure 2).

[4] The common one to which the ground floor rooms of the dwellings are connected

Figure 2. Akseki traditional dwelling architecture ground floor layout

The living floor is designed with the organization of the cellar and room spaces that open to the sofa, which is a common-use area. When an observation is made by taking into account the classification made by Eldem (1954) on the Turkish dwelling plan types, three types of plan schemes emerge outer sofa, interior sofa, and middle sofa in the houses in the Akseki district center. The plan type without 'sofa' is not found in the district center of Akseki today (Başarır, 2001).

On the living floor, there is a "kafeönü[5]" space raised with "seki[6]" on one side of the sofa. Distribution is provided from the sofa space to the cellar and rooms. Each of the other rooms on the living floor includes furniture named "başmak (fireplace)[7]", "açıkgöz[8]", "yüklük[9]",

[5] The wooden section that forms a part of the sofa in the region also includes the eight. It took this name because it was closed around with wooden bite windows.
[6] The wooden element is located on the sofa and sitting on the ground between 15 cm and 20 cm.
[7] The name was given to the region's wooden hood on the stove.
[8] Small cabinet systems located on the room walls of traditional dwellings
[9] Cabinet system for storage purposes in the rooms

"musandıra[10]", "gusülhane[11]" and "sergen[12]" (Figure 3) where a nuclear family can sustain its life (Figure 3). Portable furniture is also used in the sofa, room, cellar room, and storage spaces. These are the furniture that includes the elements such as crates, warehouses, stumps, jugs, baskets, “sini[13]”, cribs, etc., and includes the functions of putting and storing goods and beverages.

Figure 3. "Kafesönü", “sofa” and room layout

Akseki has characteristic features in terms of the traditional dwelling construction technique and the materials used. For example, in the construction of these dwellings, no binding materials are used in the combination of bearing elements. The dwellings are formed by the use of stone material and Taurus cedar (*Cedrus libani*) (an easy-to-process, water-resistant tree species growing on the Antalya-Kahramanmaraş line in Turkey) and tar juniper (*Juniperus oxycedrus*), which have a limited distribution area in Turkey. Andean tree (*Juniperus drupaceous*), mulberry (*Moraceae*), larch (*Pinus nigra*), and Taurus fir

[10] A wooden grille in front of it is designed on the ‘” yüklük' in the region, intended for storage or fruit drying, without covering the 'yüklük' section.
[11] In the local dwellings, the single lid washing section, forms the farthest part of the entrance door of the load cabinet.
[12] In traditional dwelling rooms, the shelf system, which surrounds all the room walls except the 'load' and around the surrounding area, is at a certain height
[13] The food can also be eaten, made of copper or rice, round-shaped and large tray.

(*Abies cilicica Carr*), (*Pinaceae*) are known as other tree species that are rarely used (Figure 4).

Figure 4. Images of *Cedrus libani* and *Juniperus communis* (Danacı, 2012)

The fact that wood materials are durable, flexible, and suitable for aesthetic purposes in this building system has also made it possible to reach the best examples of the woodwork. Depending on this result, there are dwelling with a service life exceeding 300 years in the basin. However, the intensive use of wood materials in these dwellings caused large fires in the past and caused the original examples in many neighborhoods not to reach the present day. The cabinets and granaries of the dwellings used for storage purposes, the window shutters and covers that facilitate the use of summer and winter use, the door and ceiling details, the "sedir[14]" used as interior seating units, and the way of use in the bearing elements that make up the structure and all the functional and sustainable solutions of the wooden material are seen in every architectural detail that makes up the traditional Akseki dwelling.

[14] Traditional furniture for sitting or lying down, without a backrest, with cushions and pillows on top

3. Findings and Discussion

3.1. Use of wood material in the carrier system

In the traditional Akseki dwelling, the ground floor and upper floors are obtained using a combination of stone and wood. The bond beams with the horizontal support of the stone material are formed from *Cedrus libani* wood, and the protrusions seen on the façade of the dwellings and called "buttons" are formed with wood material obtained from *Juniperus drupacea* or *Juniperus Oxycedrus* trees. In the region, these functional units are called "peştivan/piştuvan[15]" (Manav, 2019). These bond beams keep the walls in balance, reduce the wall load, and most importantly, reduce the danger of collapse by providing the necessary stretching during earthquakes. In addition, thanks to the flexibility gained due to the lack of binding materials in the masonry in addition to the flexibility of the wood materials used, long-term use was also possible as well as earthquake resistance (Figure 5a, 5b).

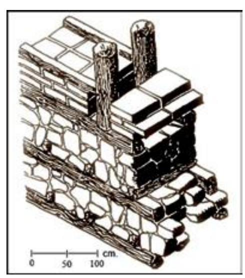
a.  b. 

Figure 5a. The drywalling technique (Kavas, 2011), **5b.** Masonry is similar to the wall structure of "Düğmeli Evler" (Chalcolithic Age 5000-3000 BC) (Manav, 2019)

[15] Wooden protrusions formed by the construction of the dwelling walls in the region in drywall technique without mortar

The courtyard, body walls, and some interior sections of the dwellings were also created using rubble stone and wood materials. The spaces that make up the summer sections of the houses are divided by wooden curtain walls. In addition, round beams made of *Juniperus oxycedrus* wood can be seen in the sofa covers. Carrier elements such as console, “elibelinde[16]” and wooden poles were used in units such as cantilevers, eaves, “hela[17]” and gazebo (Figure 6).

Figure 6. The use of wood material as a carrier in the elements of cantilever, eaves, and flooring

3.2. Use of wood materials in structural elements

Stairs

In the traditional Akseki dwelling with a Sofa plan system, the stairs are completely wooden materials, as well as examples of staircases in some dwellings on one or two digits of stone material elevation. As Eldem (1968) mentioned, rising stairs in the 'sofa' do not change the plan. In this context, the stairs in the traditional Akseki dwelling come to the sofa space within all plan fictions or to the “aralık[18]” space that provides

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[16] The name was given to the pads where wooden systems in the housing front order are supported

[17] toilets in a traditional dwelling

[18] The front hall, which establishes the connection of stairs, sofa, and intermediate space.

a transition to the sofa as an intermediate space. In traditional Akseki dwellings, a ladder system designed in the outdoor space is not observed. The wooden steps and railings of the stairs have a simple language. In the construction of the stairs, wooden material obtained from *Cedrus libani* wood was used. In some examples, wooden material made of *Juniperus communis* wood was also used in the arched systems emphasizing the railing and stair exits (Figure 7).

Figure 7. The use of wooden material in the staircase elements of the traditional Akseki dwelling

Roof and Covering of Ceiling

Duman & Ökten (1988) stated that wood material gives more positive results than steel, especially reinforced concrete, in constructions with less moving loads. Since the share of the wood material in the total loads is small, the weight it reaches the bearings and therefore the foundations will also be small. In roofs built by traditional construction techniques, the under-covering board and the elements that carry the roof are usually solid wood materials. In traditional Akseki dwellings with hipped roofs and eaves, wood material is also used in roof construction and under-roof ceiling cladding. In the interior, wooden ornaments are included in the ceilings depending on the nature of the dwellings and the economic level of the users.

Room ceilings in regional dwellings are usually in the form of flat wooden ceilings protruding from the bottom. The ceiling cladding is divided into squares that intersect each other perpendicular with wooden slats and is formed with the "çitakâri[19]" wooden mergence detail. Eight, or rarely six-armed star-shaped cores are in the middle of the ceiling. Inside this hub are eight-armed stars, palmettes, and rarely tulip motifs that narrow from the wooden material to the center. As another detail, the pomegranate fruit, which is a symbol of religious abundance and fertility in the center of the belly, is symbolized in three dimensions from wooden material. The source of the wood material used in roof construction was *Cedrus libani* wood while *Juniper communis* wood, which is easily processable was preferred for a ceiling covering (Figure 8).

Figure 8. Using wooden materials in ceiling ornament

Floor Cover / Flooring

In the Akseki dwelling, located in the hot-dry climate zone, the floor covering material is wood. The use of stone materials is seen only in the ground floor cover of the dwellings. In all the plan arrangements of the dwellings, the rooms connected with the sofa and sofa are covered with the same wooden material. Only in some dwellings is the staircase

[19] A traditional wooden mergence detail

starting point that provides the transition between the interior/exterior and the upper floor connection covered with stone material raised from the floor. The wooden beams that make up the floor covering are not visible from the exterior due to the masonry technique.

The ground floor and the upper floor are separated from each other by these wooden beams. These wooden beams are placed on the stone blocks in the inner space, in the masonry. The floor cover was created by nailing wooden cladding boards to wooden flooring beams (Gürani, 1999). Regardless of the dwellings' nature or the users' economic structure, the wooden material was applied most simply and simply in the floor covering. In the geography of the region, it is also seen that in the winter months due to climatic reasons, the floor covering is covered with carpets and rug-type weavings (Figure 9).

Figure 9. The use of wooden material in the floor cover

Doors

In the Akseki dwelling, another place of use wood material; is the entrance gate, garden gate, and room gates. In this diversity, the doors' dimensions and the ornaments' details gain importance according to the location of the doors.

The region's garden and main entrance gates are called "Borta[20]". The gardens are surrounded by walls called "kuşkonmaz or semerkandi[21]" in the region. At the top of these walls are fence systems made of the wood material to provide privacy and cut the wind. The masonry rises in the section where the garden gates are located and emphasize the gate. In the upper part of the garden, gates are made of a hipped or porch roof, the eaves are extended inwards and outwards so that they are at least 1 meter. The roofs were originally covered with wooden particle board, of which very few examples have survived (Sağıroğlu, Kınıklıoğlu & Karayazı, 2016). The source wood material used in the doors is *Cedrus libani* and *Juniperus communis* wood. Wooden ornamentation details are also seen on the garden doors of some qualified dwellings (Figure 10).

Figure 10. Examples of garden gates in Akseki traditional dwellings (Sağıroğlu, Kınıklıoğlu & Karayazı, 2016)

The dwellings' main entrance gates are similar to garden gates in quantity and quality. A feature that distinguishes the entrance doors from the garden doors is that they are made of wood material with

[20] The name given to wooden garden gates in the region
[21] The name was given to the stone and wooden masonry system that forms the garden walls in the region

double layers. The entrance doors are designed with double wings made of wooden material. In the double-layered entrance doors, the layer coming to the front part of the wing is made of wooden tables and wooden belts. The layer that comes to the back part is designed only with wooden belts. Between these generations, various wooden pieces are decorated by nailing. It is often seen that wooden triangular pieces and wooden motifs are made in the ornaments (Figure 11).

Figure 11. Examples of the main entrance door and ornament detail of the dwellings

The room doors of the dwellings are designed in two ways, provided that they are opened from the short side of the room or the corner point. The doors on the ground floor are designed with wooden belts and frames, they are designed to be thick and durable. The wood thickness used in these doors is at least 4 cm and the widths vary between 25-40 cm. The widths of the doors designed with a single layer of wood material vary between 120-140 cm and the length varies between 200-220 cm. There are no elements of ornament in the doors (Figure 12).

Figure 12. Examples of ground-floor room doors (Sağıroğlu, Kınıklıoğlu, & Karayazı, 2016)

The upper floor doors are designed in two different ways. Of these, the unadorned and sloppy ones were used for the 'ayazlık[22]' and 'hela' doors. The doors used for the sofa and rooms contain more elaborate and ornate woodwork. The surfaces of these doors, which are double layered, facing the sofa are decorated with wood, and the surfaces facing the room are designed with wooden belts. Wooden ornaments can also be seen on the moldings, door plane, and the panel on the door. These ornaments consist of floral or geometric woodworking (Figure 13).

Figure 13. Examples of upper-floor room doors and ornaments (Sağıroğlu, Kınıklıoğlu & Karayazı, 2016)

[22] used as a balcony in the region, usually taking the entrance from the sofa or the gap, if any,

Windows

It is possible to divide the windows on the entrance facades of the dwellings into two groups exit windows and room windows. All these window systems and joinery of the dwellings are made entirely of wood material. The rectangular-shaped latticed windows are closed from the outside with wooden shutters (Dursun, 2012). The wooden lattice forms in these windows also differ according to the nature of their use. While the wooden cages in the pavilion windows were shuttered from the outside, the wooden shutters of the room windows were designed inside in order not to pass cold. Some dwelling rooms also have wooden lattice windows facing the sofa or cellar (Figure 14a, 14b).

a.  b. 

Figure 14a. Examples of windows with wooden lattices, **14b.** Example of a room window facing the sofa space

The window systems of the dwellings have similar features in terms of construction and ornament features. On the ground floor spaces, the windows are kept quite small. The windows on the upper floors are large and numerous. Room windows are usually located on either side of the hob with a hood. In some dwellings, the stove was removed, and the windows were expanded. The windows of the pantry rooms are designed to be smaller. A distinctive feature in the regional dwellings is the wooden lighting windows that open to the quarry and are called "tütünlük[23]" in the region. While the wood material source of the windows opening to the outside in the cantilever, cage, and room sections of the dwellings was *Cedrus libani* wood, the use of wooden materials obtained from *Cedrus libani* and *Juniperus communis* wood was seen in the windows opening to the sofa in the interior space (Figure 15).

Figure 15. Examples of windows in outdoor and indoor use

3.3. Use of wood materials in structural elements

Akseki traditional dwelling interior furniture elements are usually stable furniture and are fixed to the wall or positioned on the sofa. These elements include "yüklük", "cabinets", "sergen", "granaries" and "fireplace" units. The main material of all these furniture units is wood (Figure 16).

Figure 16. Examples of the use of wooden materials in the furniture in the sofa and room spaces

[23] It is the name given to the gaps opened at the top of the stoves in the dwelling rooms in the region.

In this furniture, the wooden material obtained from *Cedrus libani* wood is used in the "yüklük", "granaries" and "cabinet" units, while the use of wood material obtained from *Juniperus communis* wood is also seen in other furniture elements. In these spaces, chests, granaries, stumps, jugs, baskets, "sini", cribs, etc. are located in portable furniture. It was also found that wood material was used intensively in portable furniture (Figure 17).

Figure 17. Use of wooden materials in portable furniture

"Load" and cabinet doors are usually divided into wooden tables. The surface of these tables is covered with floral and geometric wood ornamental motifs in some dwellings, while it is left empty in some dwellings. On some "yüklük" facades, there are also "gusülhane[24]", "çiçeklik[25]" and "lambalık[26]" sections separated by wooden partitions. There is a "musandıra" section with wooden railings on "yüklük" and "gusülhane". In most dwelling rooms, a wooden shelf system starts from under the "musandıra" and turns the room in three directions and

[24] In local dwellings, a single-door washing section that forms the part of the load closet furnishes the farthest part from the entrance door.
[25] The name was given to the open cabinet systems located on the surface of the load and wall in the region
[26] Wall niche used to store small ornaments or items that should be in the taste of candlestick, kerosene lamp, candle, or hazel in the region

is called "sergen" in the region. Again, wooden ornamentation details can be seen in most of these units (Figure 18).

Figure 18. The use of wooden materials in the elements of "yüklük" and "sergen" as stable furniture

One of the units with a high density of ornament in the furniture used by the regional dwellings is the wooden stove hood. Geometric and floral wood motifs were used in the hoods. Usually, the surfaces of the "yüklük" and "gusülhane" are divided into wooden boards and left empty. However, the "yüklük" and "gusülhane" surfaces of the dwellings with high quality and high economic level are decorated with floral motifs made of wooden material. The use of wood in the built-in wardrobes, which are open in the rooms, is similar to the use of wood used in the load-bearing areas. These cabinets (niches), which are located in the room and sometimes sofa space, can be double or single doors made of the wooden material or there are also types with open sections without a cover. These cabinets, which have open sections, are known as the "lambalık" niche in the region (Figure 19).

Figure 19. The use of wooden materials in hob hoods and cabinet elements

They are the cabinet systems in the section called "kafesönü", which is one of the unique uses for the dwellings of the region. These cabinet systems stand out as the units where the cushions laid on the floor are stored behind the area where the stairs exit, in a position facing the "kafesönü" space of the room walls or in the seating area called "seki". These units are formed with wood material obtained from *Cedrus libani* wood. In some dwellings, as the connection of these cabinets, granaries made entirely of wooden material are also seen, which continue to the sofa space. In another use, they are wooden granaries located in a separate area in the sofa space, on a platform raised from the ground. In the construction of these units, due to their strength and longevity, wood material obtained from *Cedrus libani* wood is used (Figure 20).

Figure 20. Use of wooden materials in cabinet and granary furniture in "Kafesönü" / sofa space

4. Conclusion and Suggestions

Researching the original qualities of traditional dwelling examples, which are our important cultural heritage from the past and should be transferred to the future, is important in terms of ensuring the sustainability of cultural heritage. One of the prerequisites for preserving and surviving traditional civil architecture is the identification of its original qualities. At the beginning of the defined original qualities are the construction techniques and building materials of the dwellings. In this context, in this study, the details of the wooden material used in the Akseki traditional dwelling, which is one of the important examples of Anatolian civil architecture, were investigated to contribute to the transfer of the Turkish wooden dwelling tradition to future generations.

The fact that Akseki traditional dwelling has a limited distribution only in the Akseki-İbradı region in the Taurus Mountains makes this traditional dwelling example interesting. The biggest reason why the traditional dwellings observed in the region have survived to the present day is hidden in the region's geographical features. The high and rugged terrain conditions of the region adversely affected the transportation facilities until a certain period and led to the late acquaintance of the region with modern construction materials and construction techniques. Natural environmental conditions have thus helped to preserve the tradition of wooden dwellings unique to the region over the years. Local people have also been able to discover the best use of wooden materials in the design of dwellings for their own needs by choosing from the natural materials offered by geography.

"Düğmeli Evler", which has a unique character with the use of wooden materials, construction technique, and formal features, also represent an ecological architectural tradition because they are built *from Cedrus libani* and *Juniperus communis* wood, which are easily obtained from the natural environment. The fact that the craftsmen who built the dwellings in wood and stonework were found in almost every settlement contributed to the transmission of the construction of the dwellings from generation to generation and the longevity of this tradition.

The use of wood material as a building material in the geography where it is located takes hundreds of years. Wooden material is thick, formable, and in dwellings, because it is a material that gives the user a feeling of warmth; It is used in the carrier element, structural elements, and furniture elements. In addition to the color and texture of the material, the characteristic features of the material and the fact that it has the industrial quality to the technological conditions of the day makes the place of wood indispensable in human life.

Due to Akseki's location, the wooden material obtained from the immediate surroundings is in harmony with the stone material and constitutes the architectural character of the region. In this study, where the areas of use of wooden material in Akseki traditional dwellings that have survived to the present day are examined, the areas of use of wood material are documented and the place of wood material in terms of cultural heritage is aimed to be emphasized.

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