RECENT ADVANCES IN MATERIAL SCIENCE AND ENGINEERING SYSTEMS

EDITED BY
DR. RAMAZAN ŞENER

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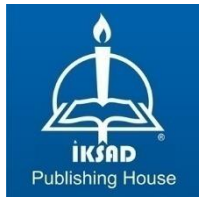

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PREFACE

Who was the first engineer? Imhotep, Archimedes, or Ismail al-Jazari? I am not sure. However, I can definitely say that until today, every one of them, wonderful engineers lived and made incredible contributions to science and technology. If it is described the science as a building, every engineer until today has put a big or a small brick in this building. Step by step and systematically, modern science has emerged and continues to evolve.

Recent engineering research is included in this book, which consists of chapters from different fields of engineering sciences. In addition to these studies covering a wide area, current issues on strength assessment of aluminum fiber/epoxy sandwich panels, various protectives and medical aromatic plant extract impregnation in the wood industry, usage of waste plastic materials for asphalt roads, properties of magnesium phosphate cement, hatching eggs detection based on multi-channel statistical features.

We thank the authors who contributed to this book with their valuable works. It is our sincere hope that these studies shed light on future studies and contribute to the development of engineering sciences.

Dr. Ramazan ŞENER [1]

May 2021

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CHAPTER 1

STRENGTH ASSESSMENT OF ALUMINUM-FIBER/EPOXY SANDWICH PANELS

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INTRODUCTION

Sandwich structure is a type of composite material obtained by bonding thin layer materials (Dinesh, Rajasekaran, Dhanasekaran, Vigneshwaran, 2018). Sandwich structures are generally lighter than their metal counterparts, with the strength of their surface materials and the hardness of their cores. Therefore, their application potential is high in places such as automotive components where such features are sought (Liu, Zhang, Li, 2017). Fiber metal laminates (FMLs) are layered materials based on stacked arrangements of aluminum and fiber-reinforced plastic (FRP) layers (Torshizi, Dariushi, Sadighi, Safarpour, 2010). FMLs are good candidates for advanced aerospace applications, thanks to their high specific strength and particularly high fatigue life (Kumaresan and Vasanthaseelan, 2018). Fiber-metal composites combine the advantages of metallic and fiber-reinforced matrix materials. Metals are isotropic, impact resistance, have a high bearing strength, and are easy to repair (Tamilarasan, Karunamoorthy, Palanikumar, 2015). Aramid reinforced aluminum laminate (ARALL) composites produced with adhesive bonding exhibited better impact and fatigue resistance than similar types of adhesive bonded structures (Santhosh et. al.). Most of the studies in the literature are about glass fiber reinforced steel or aluminum alloys. Carbon fiber reinforced composites (CFRP) find application in flight and related fields. Cost is reduced by creating sandwich structures (Suthan, Jayakumar, Madhu, 2018).

Sandwich panels are used in varieties of engineering structures and they play an important role in industries. In this study, sandwich panels were produced by combining glass, kevlar, and carbon fiber-reinforced composites with aluminum sheets, and the properties of these panels such as tension and compression were investigated for use in engineering applications.

1. MATERIAL AND METHODS

Composite material is a new material that is formed as a result of the combination of two or more materials that differ in terms of physical and chemical properties. (Nayak, et. al., 2020). The use of compression molding in laminated aluminum reinforced epoxy composites provides better mechanical properties (Santhos et. al. 2019). The kevlar in Figure 1(a) and the carbon fabrics in Figure 1(b) were cut in 17x40 cm dimensions and prepared for hand lay-up and compression hot molding.

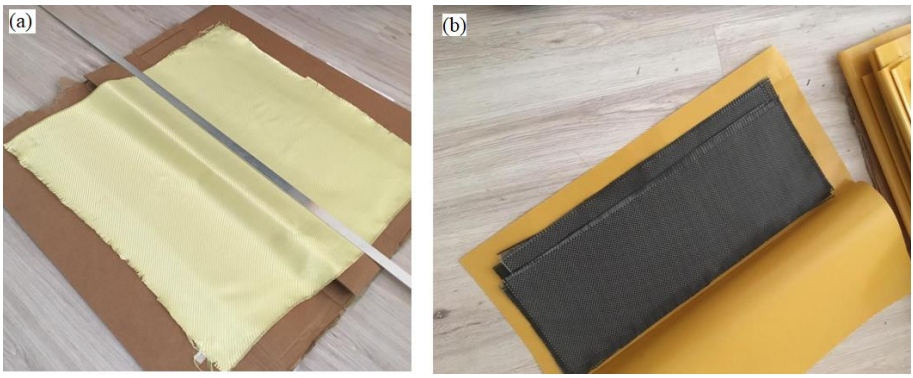

Figure 1. Composite reinforcement elements, twill kevlar fabric (a), plain carbon fabric (b).

The resin used is a standard epoxy diglycidyl ether bisphenol (DGEBA). The resin and curing agent were mixed at 70-30% according to the manufacturer's instructions as in Figure 2. This resin mixture was applied to 17x40cm sized fabrics by hand lay-up method.

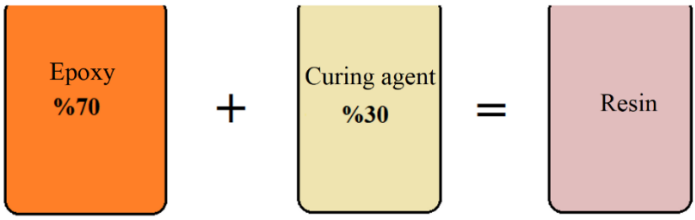

Figure 2. Epoxy resin mixture.

After the hand lay-up method glass/epoxy, carbon/epoxy, and kevlar/epoxy were pressed at 7 bar for 3 hours, and with this process, it was provided that core materials were cured (Figure. 3(a)). The cutting of aluminum and composite laminates was made with a water jet in 20x140 mm dimensions as shown in Figure 3 (b).

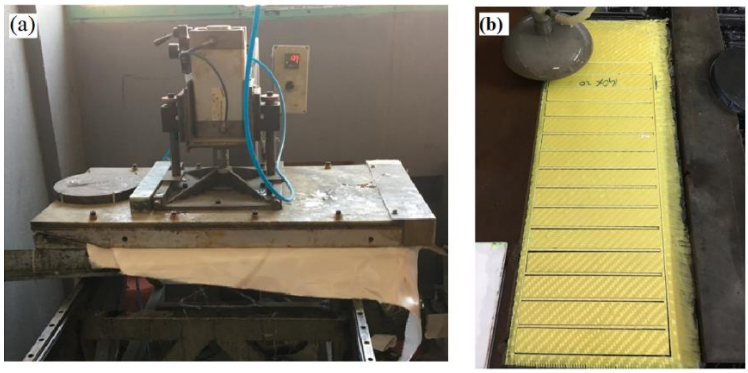

Figure 3. Hot molding press (a), waterjet cutting of kevlar/epoxy (b).

To produce the sandwich panels Weicon RK-7100 two-component methyl methacrylate-based adhesive was used for surface bonding of the aluminum 5754 and composite laminates. The bonded aluminum

and composite laminates were pressed at room temperature for three days. After the bonding process, the form in Figure 4 formed.

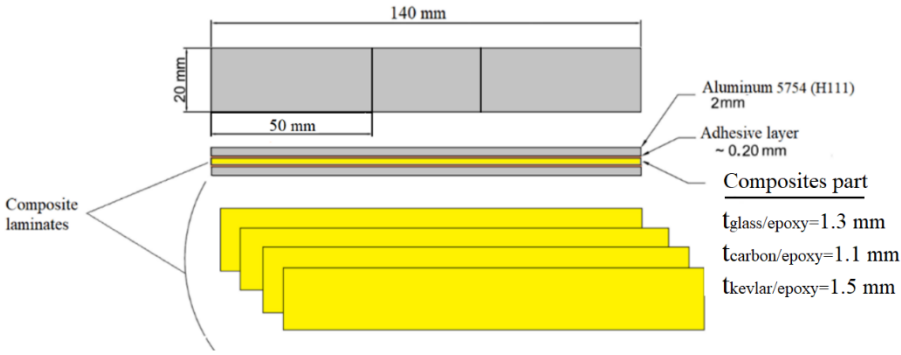

Figure 4. Schematic representation of the test sample.

1.1 Experimental Studies

Tensile and compression tests were performed in the tensile-compression test device in Figure 5(a) under ambient temperature and ambient humidity conditions. The experiments were carried out with 1mm/min tensile and compression speeds with displacement control. Figure 5(b) shows a typical tensile test. During the tensile tests, the fibers forming the core were damaged first. Figure 5(c) shows a damaged tensile test sample. Figure 5(d) typical compression test. No separation was observed between the plates during the compression experiments. Therefore, it can be stated that the adhesion between the plates is of good quality. The compression test sample is shown in Figure 5(e). The only deformation occurred in the compression sample.

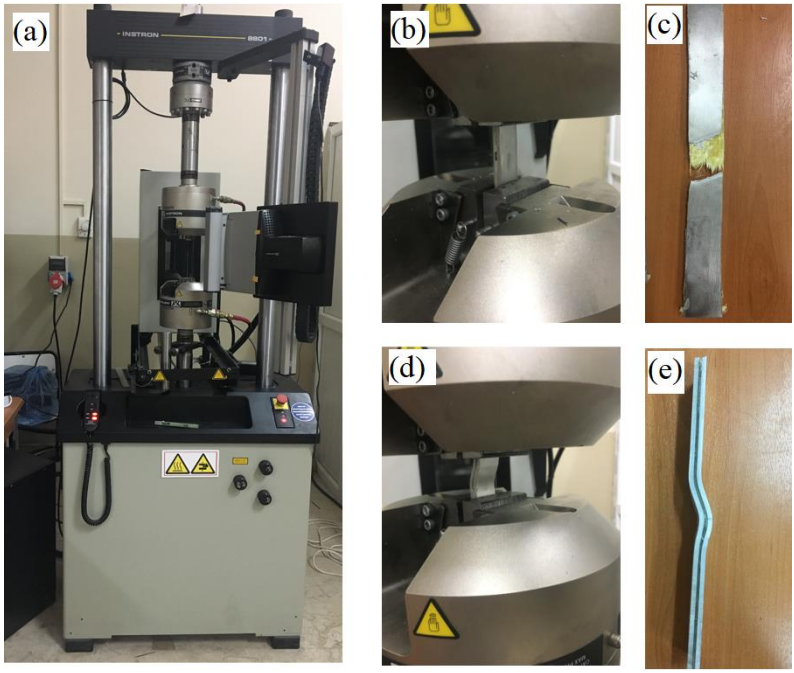

Figure 5. Instron 8801 tensile-compression device (a), tensile test(b), damaged tensile test sample (c), compression test (d), damaged compression test sample (e).

2. RESULTS AND DISCUSSION

Tensile stress-strain and compressive stress-extension graphs were obtained in line with the results obtained from the experiments. Figure 6(a) shows the stress-strain curve of the aluminum-glass/epoxy-aluminum sandwich panel. As can be seen, its tensile strength is approximately 190 MPa. Figures 6(b) and 6(c) the ultimate tensile strengths of aluminum-carbon/epoxy-aluminum and aluminum-kevlar/epoxy-aluminum are 230 and 320 MPa respectively.

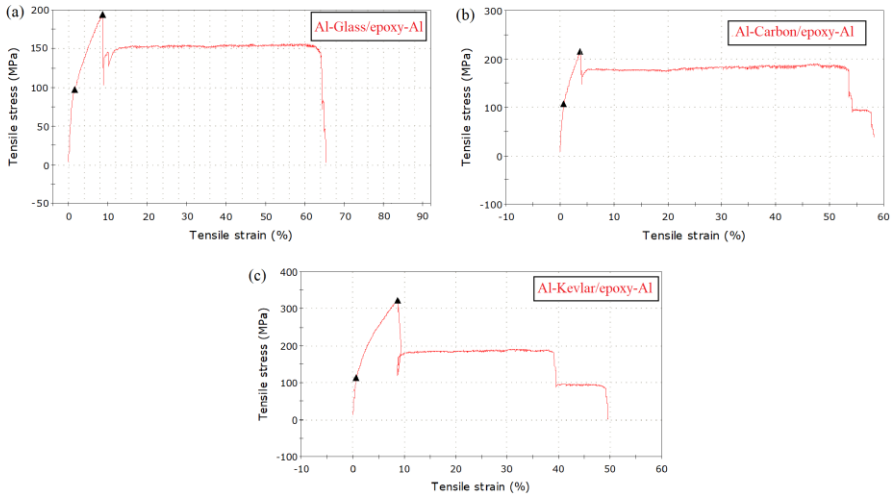

Figure 6. Tensile stress-strain curves; aluminum-glass/epoxy-aluminum (a), aluminum-carbon/epoxy-aluminum (b), aluminum-kevlar/epoxy-aluminum (c).

The results obtained from the compression tests are presented in Figure 7. Firstly, aluminum-glass/epoxy-aluminum composite panels were tested, and their compressive strength was determined as approximately 130 MPa (Figure 7(a)). Then the compressive strength of aluminum-carbon/epoxy-aluminum and aluminum-kevlar/epoxy-aluminum panels was determined. Compressive strength is 105 MPa and 110 MPa, respectively (Figure 7(b) and (c)).

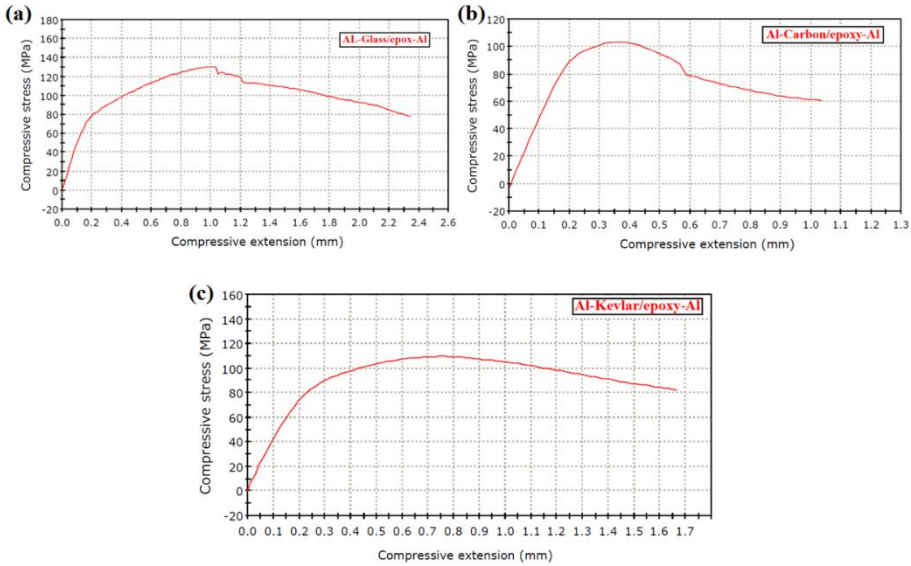

Figure 7. Compressive stress-extension curves: aluminum-glass/epoxy-aluminum (a), aluminum-carbon/epoxy-aluminum (b), aluminum-kevlar/epoxy-aluminum (c).

3. CONCLUSION

The following conclusions have been reached from the tensile and compression tests of three different sandwich panels produced.

- In the first phase of the static tensile test, most of the load is transferred to the composites as aluminum is a flexible material, thus the composite core was damaged first.
- As can be understood from the fractures of damaged samples, the loads are evenly distributed on the structures.
- The strengths of sandwich composites vary greatly according to the elements that make up the structure and their quantities.
- The compatibility between the sandwich elements used is promising for engineering applications.

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CHAPTER 2

VARIOUS PROTECTIVES IN THE WOOD INDUSTRY AND TECHNOLOGICAL CHANGE (PRESSURE STRENGTH)

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INTRODUCTION

Wood material, which has a long and perfect history in the development process of human life and culture, has been used for hundreds of years as bearing elements, siding, flooring and roofing materials in various parts of buildings, bridges in industrial constructions, traverses, piers and many other areas. According to the hundreds of years of use of the wood material, relatively recently, materials such as steel, aluminum, concrete have entered the building industry as an alternative to the construction industry and have been successfully used in many areas. In this case, a wide range of building materials has been arised for consumers to choose from. In the past, the criteria affecting the consumers' choice of building materials were mainly "material suitability", "price", "availability" and "appearance". Nowadays, consumers have begun to question the effects of building materials on the environment. In addition to the criteria listed above when choosing a product, consumers want to establish a material relationship with issues such as global warming, energy consumption, pollution, waste problem and human health, and to recognize and use environmentally friendly products. In determining environmental pollution for life cycle analysis; The amount of solid and liquid wastes, greenhouse gases, toxic substances and particles generated during the production and production phase, the cost of fabrication, waste sites and packaging to the environment, The impact of buildings on the environment due to heating, cooling, lighting during their service life, at the end of the service life of buildings, criteria such as

their impact on the environment are used (Erdin, 2003). Wood is a significant raw material that humanity has used in many areas since existence of humankind. With the development of technology in the world, the usage area of wood has increased with the diversification of the use of wood. However, due to the organic structure of wood material, it is destroyed by biotic/abiotic factors. This disadvantage of wood can be reduced by various protection methods and techniques. Wood can become resistant with some precautions without the use of various chemicals. However, the diversity and continuity of risks necessitate chemical processes Kartal et al. (2004). Tomak et al. (2012) today, synthetic structure/toxic components continue to be preferred in the protection of wood, but the discovery/development of new environmentally friendly protective materials has become inevitable, and the toxic/non-toxic vegetable oil structure creates a hydrophobic layer in the wood cell, thus dimensional stability (water repellency) that has also been determined that it can be considered protective by providing stability. Aytaşkın (2009) investigated the technological properties of "lime, poplar, chestnut" species by impregnating some boron compounds with "borax and boric acid" materials and determined that the density/thermal conductivity value increased, but there was a decrease in the flexural resistance/elastic modulus.

Impregnated wood (biotic/abiotic, etc.) has a significant place in the construction industry with its economic, aesthetic appearance, as well as being resistant to factors. Water-based soluble impregnations have

increased significantly in railways, traverses, marine support poles, cooling towers, landscaping, outdoor furniture, and construction structures. Water-based impregnating agents generally destroy the odor structure in treated wood, and a wide variety of surface treatments can be performed after impregnation. It can be easily preferred in places of use and during transportation (Kartal, 1998).

Within the scope of the study, using various mordants, the environment/human friendly boric acid, aluminum sulphate, sodium chloride, water-based varnish, water-based varnish + aluminum sulphate, water-based varnish + sodium chloride, water-based varnish+ boric acid are used to perform both single and dual processes on the pressure resistance. change is determined.

1. MATERIAL and METHOD

1.1. Wood Material and Treatment

Within the scope of the study, Scotch pine (*Pinus sylvestris L.*) wood, which is frequently grown in our country and preferred in the wood/construction industry, was preferred. Transactions were carried out according to TS 2470 principles; The sapwood part is used by cutting in a radial direction. Impregnated and mordan boric acid, sodium chloride (NaCl) and aluminum sulphate $(Al_2SO_4)_3$ were used; Water-based varnish was preferred as a varnish type (TS 2470, 1976).

1.2. Preparation of Experiment Samples

It was paid attention that the wood materials used in the study were sapwood parts with smooth fibers, no cracks, no knots, no density and

color difference, no reaction wood, not damaged by fungi and insects, and were processed according to TS 2471 standards. For the pressure resistance test parallel to the fibers, a test sample of 20x20x30 ± 1 mm was prepared according to TS 2595 principles. (TS 2471,197; TS 2595, 1977).

1.3. Impregnation Process

The impregnation process was carried out in accordance with the conditions specified in the ASTM-D 1413-76 standard. In the impregnation process, the solution temperature was adjusted to 20 ± 2 ºC and the full-cell method was preferred. The measured samples were subjected to the impregnation process in vacuum and various diffusion times of 20/40 minutes (ASTM D 1413–76,1984).

1.4. Water Based Varnish Application

The sample Varnishing process has been applied according to ASTM D 3023. The manufacturer's recommendations were taken into account in the preparation and application of varnishes. Without making a different filling layer, the paint and varnish were applied in two coats as filling and top coat. 48 hours were waited between coats for the varnish applied to dry. Considering the solid content of the water-soluble paint and varnish, the application was made at 70 g/m^2 for each layer. Then, the samples were kept in the conditioning cabinet at 20 ± 2 ºC temperature and 65 ± 5% relative humidity until they reached equilibrium humidity (ASTM D 3023, 1998).

1.5. Percentage Retention (net dry matter amount)

After impregnation, the amount of substance remained (% retention) compared to dry wood was calculated from the specified formula.

$$R\ (\%) = \frac{Moes - Moeö}{Moeö} \times 100 \qquad (1)$$

Moes = Sample full dry weight after impregnation (g)
Moeö = Sample full dry weight before impregnation (g)

1.6. Compressive Strength Parallel to Fibers

In the pressure resistance tests parallel to the fibers, samples with a cross section of 20 x 20 mm and a length of 30 mm (210) were conditioned and brought to air dry (12%) moisture, and then they were subjected to pressure in the wood material testing machine in the direction parallel to the fibers and thus the maximum pressure value at the moment of breaking was measured. Then, the pressure resistance in kg/cm² was found by dividing the maximal pressure value at the moment of breaking on the machine to the cross-sectional area (TS 2595, 1977).

Formulas used in calculation: (2)

Ȯw// : P_{max}/a.b (N/mm²)

σ w// : Compressive strength parallel to fibers

P_{max} : Maximum load (N)

a and b : Cross-sectional dimensions

1.7. Evaluation of Data

SPSS statistics program was applied to evaluate the data. Homogeneity groups were formed by analyzing values resulting from wood type effect and % concentration change and simple variance analysis was applied.

2. RESULTS AND DISCUSSION

2.1. Solution Properties

Solution properties are given in Table 1. There was no significant change in solution pH and densities. This situation must be taken into consideration as the change in acidic and basic values will cause hydrolysis in wood. It has been reported in the literature that especially the acidic structure will affect the physical and mechanical properties of wood.

Table 1. Solution Properties.

Impregnation Material	**Solvent**	**Temperature (ºC)**	**pH**		**Density (g/ml)**	
			BI	**AI**	**BI**	**AI**
Boric Acid	DS	22ºC	4.72	4.73	1.02	1020
Aluminum Sulphate	DS	22ºC	3.71	3.71	1.07	1065
Sodium Chloride	DS	22ºC	7.20	7.22	1070	1070

2.2. Retention Amount (% Retention)

The net dry impregnation material (adhesion) remaining amount as (%) is given in Table 2. The highest % retention was determined in aluminum sulphate (9.44%) and the lowest in sodium chloride (2.47%).

Table 2. Retention (%)

Impregnated Material	**Vacuum/ Diffusion Time (**min**)**	**Retention (%)**	
		Mean	**Standard deviation**
Boric Acid	40	7.34	3.39
Aluminum Sulphate	40	9.44	3.33
Sodium Chloride	40	2.47	2.47

2.3. Pressure Resistance (N/mm^2)

The pressure resistance change is given in Table 3. The highest-pressure resistance change was determined in Boric acid (68.53 N/mm^2) and the lowest in Water Based Varnish + Aluminum sulphate (48.10 N/mm^2).

Table 3. Pressure Resistance (N/mm^2)

Impegrenated material	Vacuum/ Diffusion Time	Pressure Resistance (N/mm^2)	HG
Control	40 min	51,62	F
Boric Acid		68,53	A
Aluminum Sulphate		61,47	B
Sodium Chloride		48,60	G
Water Based Varnish		55,07	E
Water Based Varnish + Borikasit		57,14	D
Water Based Varnish + Aluminium Sulphate		48,10	G
Water Based Varnish + Sodium Chloride		58,58	C

CONCLUSION

There was no significant difference in densities and pH values of the solutions measured before and after the impregnation process. This may be due to working with the new solution with each impregnation variation. It is reported that boric acid, aluminum sulphate and sodium chloride concentrations among the preservatives used are close to the acidic structure, negatively affecting the polysaccharides in the wood and increasing the possibility of hydrolysis (Özçifçi, 2001). Despite these properties, no negative effects on mechanical properties have been observed.

Impregnation process of scotch pine (*Pinus sylvestris L*) wood with a solution obtained from boron compounds and mixtures of natural preservatives. It is found that the amount of retention in bee pine, which is one of the natural preservatives, is lower than that of kebraco, and the total amount of retention increases as the solution concentration increases. The highest retention values were observed in samples impregnated with 1% solution. It is stated that the retention ratio varies due to the properties of the solutions and the anatomical structure (Alkan, 2016). In the results of working, it seems possible that aluminum sulphate, sodium chloride, boric acid materials from our country's resources can be used as preservatives. The use of water-based varnish or impregnation without varnish with the preservatives used positively show the ability to be used in the furniture industry (park, garden, urban furniture, construction industry, etc.) Having positive results in physical-mechanical properties makes it feasible and requires additional studies to be carried out together. It seems possible to investigate the usability status with other water-based preservatives that do not harm human health and to obtain healthier positive structures. It is necessary to use these materials, which seem possible to be used in parks and gardens, pergolas, benches or flower beds in all outdoor areas, together with the top surface treatments and to be tested (gloss, surface adhesion, color, surface hardness, etc.). And also, its effect on human health and the duration of material strength should be determined.

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Note: ICOEST 2020, Various Protectives in The Wood Industry and Technological Change (Pressure Strength), 6th International Conference on Environmental Science and Technology, October 23, 73-77, 2020, Belgrade, Serbia. (The results are presented at the symposium and the study has been expanded)

CHAPTER 3

VARIOUS MEDICAL AROMATIC PLANT EXTRACT IMPREGNATION ABILITY AND TGA TESTS IN WOODEN MATERIAL

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INTRODUCTION

There are many prescriptions written for therapeutic purposes on the tablets that have survived from the Hittites in Anatolia. In addition to herbs, herbal drugs brought from other countries; poppy, liquorice, saffron, mandrake, etc. grown in Anatolia were also found in these recipes. Greeks: Hippocrates, born in Kos Island in the 5th century BC, is known as the "Father of Medicine". He talked extensively about herbal drugs in his books written in his period. Galinus, born in Pergamon in the 2nd century, was known both for his medicine and for the drugs he prepared and was accepted as the "Father of Pharmacy". He mentioned approximately 500 herbal and animal drugs in his publications and stated their effects (Özata, 2006).

Medicinal and aromatic plants constitute a significant part of the plants that are produced and traded today. While most of these plant species in trade are collected from nature, very few of them are planted in the field and presented to trade. Finding new active ingredients to be used in the treatment of diseases provides the continuation of research on plant properties. 3500 new active ingredients obtained as a result of the studies carried out in 1985, 2618 of them were found to be of plant origin. With such research to be carried out on plants, it is aimed to reach active substances that can be used in the treatment of diseases such as cancer that have not yet been fully cured. Human beings should take care to collect the plants found in nature and benefit from these plants with the principle of protection and use. This is an important finding not only in terms of maintaining

the continuity of plant species, but also preventing the consumption of all natural resources and increasing the usage areas in line with the principle of "sustainable use" and being able to use them for many years (Güler, 2004).

Since the excessive use of the toxic component structure in wood preservation causes the increase of significant environmental pressures and prohibitions, it has become necessary to create/develop new materials that are in harmony with the environment and humans. (Tomak, 2010). Peker (2015) subjected the extract obtained from the waste tea to the impregnation process and subsequently investigated the surface hardness by applying it as a secondary treatment with water-based varnish and determined that the tea extract gave positive results in scotch pine/beech wood when used with water-based varnish.

Kartal (2006) investigated the effects of boron compounds and heat treatment on wood properties (washing boron compounds and fungal and termite resistance) and found that the heat treatment did not have an effect on washing boron compounds; neither boric acid nor disodium octaboratedehydrate-treated samples had increased fungal resistance against brown rot fungi.

Thermal resistance ranking of wood components at low temperature; hemicellulose lignin cellulose form and there is an order as hemicellulose cellulose lignin at high temperatures. Thermal decomposition of hemicelluloses starts at 180-200 °C. Thermal degradation of cellulose starts at 210-220 °C, reaches the highest level

at 270-280 °C and is completed between 300 °C and 340 °C. It is reported that decomposition of lignin begins between 220 °C and 280 °C and is completed between 400°C and 450°C (Hill, 2006).

In the study, retention formation was achieved by impregnation with Esgin plant extract (1% and 3%) and the usability of the material and wood material to be used as impregnation material was evaluated by TGA.

1. MATERIAL AND METHOD

1.1. Wood Material and Plant type

Scotch pine wood grown in our country were used in the study. Operations were carried out by cutting in radial direction according to TS 2470 principles. Esgin (*Rheumribes L.*) plant, whose antibacterial/antioxidant properties were determined in previous studies, was preferred (TS 2470, 1976).

1.2. Impregnation Process

The impregnation process was applied in accordance with the conditions in "ASTM-D 1413-76". Experimental samples were prepared in the dimensions of 20x20x300±1mm and subjected to 45 minutes vacuum/45 minutes diffusion process. In order to prevent impregnated material from being affected by wood moisture, the test specimens were completely dried (ASTM D 1413–76,1984).

1.3. Obtaining Plant Extract (extract)

The sample weight determined for the experiment was put into 200 ml of hot distilled water or water at least equal to this purity, and it was heated at a temperature below the boiling point in the refluxing apparatus for 1 hour by mixing at certain intervals. After filtering in the previously prepared porous capsule in the presence of vacuum, the process was continued so that no sample remained in the flask with distilled water several times. The insoluble part was completely left inside the porous capsule. Finally, the residue was washed with 200 ml of hot distilled water and after the residue was dehydrated by a pump or another device that would serve as a suction, the porous capsule and its contents were dried by keeping them in an oven set at 103oC for 16 hours, then cooled in a desiccator and weighed with 0.001 g precision (Ceylan, 1997).

1.4. Thermogravimetric Analysis (TGA)

According to TGA analysis was applied according to ASTM E1131-08 (104) with about 10 mg wood flour passing through a 40 mesh sieve, not passing through a 60 mesh sieve, under nitrogen gas at a flow rate of 57 for 50 ml/min, by increasing the temperature from 25 °C to 700 °C with the rate of temperature increase as 10 °C/min. As a result of the experiment, the percent weight loss occurred in the sample at the highest temperature point, the time period in which the instant weight loss amount was highest, and the fast pyrolysis temperature points were determined (ASTM E1131-08 (104).

2. RESULTS AND DISCUSSION

2.1. Solution Properties

Solution properties are given in Table 1.

Table 1. Solution Properties.

Plant Extract	Solvent	Temperature	pH		Density (g/ml)	
			EÖ	ES	EÖ	ES
Esgin plant extract 1%	water	22ºC	6.92	6.92	0.9226	0.926
Esgin plant extract 3%	water	22ºC	6.86	6.86	0.913	0.913

Solution properties did not vary significantly in pH and density values before and after impregnation.

2.2. Retention Amount (% retention)

The net dry impregnation material (retention) remaining amount as (%) is given in Table 2.

Table 2. % Retention.

Wood type	Extract Concentration	Vacuum time	Diffusion time	Retention
Scotch wood	Esgin extract (1%)	25 min	30 min	0.41%
	Esgin extract (3%)			0.27%

The highest retention was determined as (0.41%) in scotch pine wood with 1% Esgin extract, and the lowest as (0.27%) 3% extract. This

situation may be caused from the wood type, anatomical structure, impregnation method, impregnation material.

2.3. TGA Analysis

Thermogravimetric analysis (TGA) graphics are given in Figure 1 in scotch pine wood.

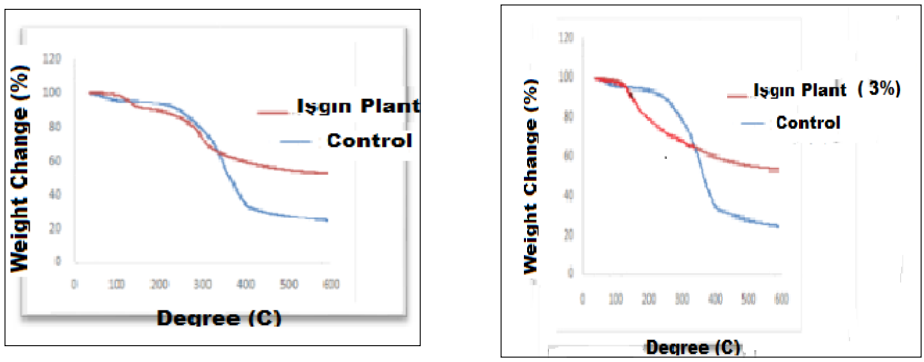

Figure 1. TGA Change in Scots Pine Wood

When the graphics are examined in the TGA analysis, 1% Esgin extract in Scotch pine wood showed a positive result compared to 3% in terms of weight loss.

CONCLUSION

In the study, retention formation was achieved by impregnation with Esgin plant extract (1% and 3%) and the usability of the material and wood material to be used as impregnation material was evaluated by TGA. The increase in lignin and inorganic material (ash) ratio decreases the burning resistance. According to the experiment results; The highest retention rate was determined as 3% extract in 25 minutes vacuum and 30 minutes diffusion (0.41%) as the highest in scoth pine. While 1% structure of Esgin plant gave negative results in terms of

burning degrees, decomposition temperature points and residue amount in TGA experiment.

TGA results can be applied in the production of wood material such as medium-density fiberboard (MDF), particle board, plywood and wood/plastic composites, to explain some of the behavior of wood material against combustion, to evaluate the performance of fire retardants and to obtain fuel from biomass.

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ASTM E1131-08 104, Standard Test Method for Compositional Analysis By Thermogravimetry.

Note: ICOEST 2020, Various Medical Aromatic Plant Extract Impregnation Ability and TGA Tests in Wooden Material, 6th International Conference on Environmental Scıence and Technology, October 23, 73-77, 2020, Belgrade, Serbia. (The results are presented at the symposium and the study has been expanded)

CHAPTER 4

USE OF WASTE PLASTIC MATERIALS FOR ASPHALT ROADS: GREEN ENGINEERING APPROACH

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INTRODUCTION

This book chapter demonstrates use of as a source of raw material of waste plastic materials for asphalt roads. In the asphalt industry, this work collects information on the use of recycled materials. In addition, crucial factor affecting the road constructions performance, such as traffic load on asphalt, local environmental conditions, interaction of materials in coating composition are also mentioned. Moreover, a significant effect on asphalt behavior is seasonal change in temperature because of its viscoelastic nature. Thus, recycling plastic wastes can decrease their negative environmental effects andpreserve renewable resources.

Harmful and waste materials due to industrial activity have one of the most important problems in the world. Among the numerous chemical pollutants, plastic wastes are reported as the hazardous materials for public health, flora, fauna and aqueous environment. To solve this problem, different solutions are being developed regarding the decomposition and recycling of plastic wastes. Thus, plastic is being reused as raw material for many industries. One of these solutions, both for the environment and for the economy, is the use of plastics in roads.

Plastic materials have become an integral part of our everyday life because of their easy and economical manufacturing and the wide range of uses. People use plastic plates, cups and knives for outdoor picnics without dirt. Also, they use plastic boxes when transporting

food. In addition to, people drink water from plastic bottles, and they use nylon bags (Worm, 2017).

All plastics have a higher mechanical resistance than bituminous mixtures. Taking these characteristics of plastics into consideration, plastics used in road coverings by joining into asphalt concrete in order to evaluate and destroy wastes. The addition of plastics into the asphalt concrete has three effects depending on the structure of chemical, dimensions and the plastic physical properties. Binding effect, reinforcement effect and aggregate effect. According to first effect, the viscosity of the binder is increased by dissolution or dispersion of the plastic materials in the binder.

This book chapter aims the use of waste plastics for asphalt industries. Figure 1 represents plastic production in the World.

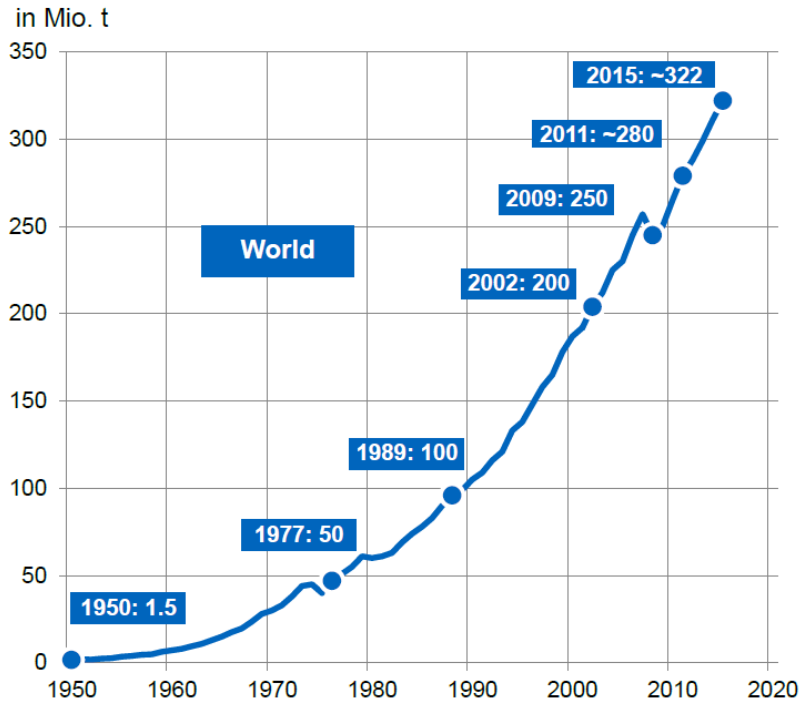

Figure 1. Word Plastic Production (1950-2015). https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf

Table 1. represents recovery rate of used plastic wastes by country. In Turkey, 25.8 million tons of wastes were produced in 2015. Approximately 20 per cent of the amount produced accounted for 5 million tons of packaging waste (https://www.pagev.org/turkiye-de-plastik-geri-donusumu-avrupa-nin-odaginda).

Table 1. Recovery rate of used plastic wastes by country (veils 2014; Hsu 2010).

Country	Recycling rate	Disposal rate	Disposal rate
Norway	37%	55%	8%
Hungary	21%	21%	58%
Czech Republic	32%	18%	50%
Poland	25%	17%	58%
Romania	27%	15%	58%
Sweden	34%	61%	5%
Spain	28%	16%	56%
Great Britain	22%	9%	69%
Austria	24%	72%	4%
Finland	18%	44%	38%
Belgium	32%	62%	6%
Denmark	28%	66%	6%
France	19%	43%	38%
Italy	26%	16%	48%
Germany	33%	63%	4%
Ireland	31%	25%	44%
Netherlands	33%	59%	8%
Luxemburg	24%	70%	6%

Blown bitumen recycling industries and plastic wastes and is playing important role for decrease the plastic wastes (Unnisaa and Hassanpour, 2017; Huang et al., 2007).

Advantages to asphalt mixture of plastic wastes

Products made from natural and synthetic rubbers complete their useful life after their use. they are used in many changing sectors such as automobile, bicycle, giant excavators. The rubber used in automobile tires is bendable, flexible, durable and abrasion resistant. Old tires have become a major environmental issue. Old tires can burn to get energy. This technique is both difficult and expensive. Because of steel and other materials. Reuse of old tires in the asphalt industry is becoming increasingly widespread. It has been determined that the addition of waste rubber will reduce traffic accidents. Also, asphalt roads will provide better grip (İlker SUGÖZÜ, İbrahim MUTLU, 2009).

Recycled plastic can be used in transportation related components such as bridge panels, median barriers and railroad ties (Siddique et al., 2008).

Railway junctions, platform supports used for highways and safety barriers reduces vehicle damage for made of granule rubber. Many sound bars are made from used rubber. Vibrations from sound can be reduced up to 20% and vibrations from vehicles can be reduced up to 15%. In many of the designs are used waste tires. They absorbed the voice successfully. In highways and high speed train rails have proven to greatly reduce noise. Recent research and development on recycled rubber granules has led to the emergence of a variety of new products used both on trains and tramways. The noise can be reduced to 40% and the vibration can be limited up to 30%, in densely populated city

centers and high speed train tracks. The asphalt mixture, also known as drainage asphalt, has a very high void content that reduces water and spray and allows the rainwater to be drawn off the surface. The tires maintain contact with the coated surface by preventing high speed gliding in wet roads. It reduces light reflections and flicker (Korkmaz, 2005; Yeşilata, 2007).

The use of plastic instead of bitumen in asphalt construction contributes to the protection of the environment. Participation of waste plastics on the asphalt reduces the cost of road construction. Moreover, the repair frequency of roads is also reduced. More durable and smooth roads that are free from pits also reduce the likelihood of accidents.

In asphalt mixing, different fibers, polyvinyl chloride (PVC), ethylene vinyl acetate (EVA), Polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE) and polyurethane (PU) are the most common waste polymers.

Nowadays, asphalt mixture of polymer modified is an expensively mixture for paving roads. Cost can be reduced by using cheap polymers such as waste polymers (Ahmed, 2007).

Moreno et al., (2013), used end of life crumb rubber to asphalt mixes. They tested wet and dye process (Rokdey, 2015).
Many researcher emphasis that end of life many plastic wastes for instance polyvinyl chloride, polyethylene, polyurethane, ethylene

vinyl acetate, polypropylene, polyethylene terephthalate, uses in roads (Poulikakos, 2017; Kalantar 2012).

Polyethylene terephthalate (PET)

Polyethylene terephthalate is in polyester family. PET is used indisposable dishes, synthetic fibers, beverage bottles and other similar plastic containers (Ahmadinia, 2011). Figure 2 shows plastic bottles.

Figure 2. Plastic Bottles (https://futurestartup.com/2016/12/02/this-company-turns-your-discarded-plastic-bottles-into-money-and-jobs/)

Previous studies emphasis that waste plastic bottles reuse of bituminous mixtures components (Ahmadinia et al., 2012; Rahman and Wahab,2013).

Modarres and Hamedi (2014) studied that effect of waste plastic bottles on the fatigue and stiffness properties of modified asphalt mixes. Also, One of the most common damages for roads is fatigue failure. Researchers search that fatigue properties and hardness of stone mastic asphalt mixtures were investigated by adding different percentages PET to asphalt mixtures. According to the results fatigue properties of SMA mixture significantly improved (Moghaddam et al., 2012). Asphalt concrete with PET (20%) was no significant loss in marshal stability (Gandjidoust, 2005).

There are many advantages using to asphalt of PET such as much ductile, lighter,excellent sound insulating concrete and less thermally conductive (Dalhat, 2016).

Polyethylene (PE)

According to some researcher polyethylene is using asphalt. However, it is not satisfactory or sufficient (Al-Hadidy et al., 2009). It is necessary further research on PE adding to asphalt mixing. Hence, addition of plastic wastes to neat binder can play a considerable role in improving the elastic behavior of binder.

Additionally, the use of recycled wastes will play a major in reducing the environmental impacts of waste disposal at dumpsites and in constructing sustainable pavements (Khan et al., 2016).

Abreu et al., (2015) produced recycled asphalt mixtures with with waste materials such as polyethylene (4.0%). They emphasis that the

use of recyclable materials in asphalt mixtures is seen as an increasing environmental solution.

Arabani and Pedram (2016), are using plastic bottle (PE) for glassphalt mixture in the wet method. Results indicated that creep, fatigue resistance and modulus of resilience are increased.

Fang et al., (2015) were used waste PE as a modifier for base asphalt. The aim of study is to determine the temperature effects and aging properties. According to the results 190 ^{0}C is the most suitable preparation temperature. Figure 3 shows Polyethylene (PE).

Figure 3. PE (https://en.wikipedia.org/wiki/Polyethylene)

Polypropylene (PP)

Many years, PP fibers are used in concrete mixtures. The concrete becomes both durable and tough because of they have three-dimensional shape. The polymer modifiers uses motorways, busiest junctions, climbing lanes, parking lots, airports and racetracks (Yıldırım, 2007). Figure 4 shows Polypropylene (PP).

Figure 4. PP (https://omnexus.specialchem.com/selection-guide/polypropylene-pp-plastic)

Flexible coatings produced by polymer modification have been proven to be highly resistant to gouging, low temperature cracks, fatigue cracks, peeling and temperature effects, and that service lives are longer compared to normal flexible coatings (Terrel and Walter 1986). The more bitumens that are modified using these additives, the more elastic recovery should have a greater viscosity, higher softening point, greater ductility and better bonding ability. The polypropylene fibers are an additive material produced in Turkey and it removes the meaning of dependence on foreign countries. Polypropylene fibers are known in the United States for many years and can be added to asphalt mixtures on a dry or wet basis. In particular, the Ohio State Department of Transportation (ODOT) polypropylene fibers tested for

years in flexible pavement fabrication have yielded really good results and have even been published by a standard ODOT (ODOT 1998). This standard provides very detailed information on the manufacture, laying and compression of flexible mixtures.

Chavan (2003) used waste PP for roads. According to the results, plastic coating can be used to improve performance of poor quality aggregate.

Yu et al., (2014) emphasis that PRA mixture is more environmental-friendly such as energy consumption.

2.Polyurethane (PU)

PU is used in furniture, cars, shoes, medical devices and food cold chain. After their end of life, it is incinerated or landfilled (90%) and small percentage is recycled (10%). PU there is no degradation at high temperature. Figure 5 represents Polyurethane (PU).

Figure 5. PU (https://en.wikipedia.org/wiki/Polyurethane)

Ethylene vinyl acetate (EVA)

In the World,the use of polymer in asphalt started in 1980s (Karakas, 2017). EVA copolymer is an irregularly structured thermoplastic material produced by co-polymerization of ethylene and vinyl acetate. EVA addition to bitumen blends, not only to improve the performance of the coating It is also used in considerable amounts in cold weather applications. EVA increases the workability of the mixture due to its sensitivity to shear force. A hard crust is formed on the surface of the coating exposed to cold and wind (Verhaeghe B.M.J.A et al., 1994). Figure 6 shows Ethylene vinyl acetate (EVA).

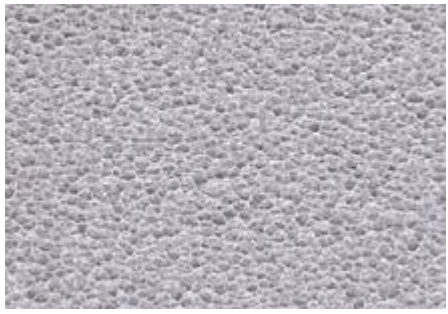

Figure 6. EVA (https://en.wikipedia.org/wiki/Ethylene-vinyl_acetate)

Polyvinyl chloride (PVC)

PVC used in the packaging of water and liquid detergents, certain chemical substances, health and cosmetic products. Today, PVC is the most problematic plastic. When waste of PVC burned in fires or in incinerators, they have been a leading cause of dioxin pollution. Behl et al., (2014) used PVC pipe waste as a modifier up to a level of 3%-5% of bitumen. When PVC burned, it releases dioxins. The waste

makes a homogeneous blend with bitumen at 160°C and then it can only be used safely. The results show that in road construction waste of PVC pipe can be used successful. Stability andstrength of the mix increased after incorporation of PVC pipe waste (Behl, 2014). Figure 7 shows Polyvinyl chloride (PVC).

Figure 7. Polyvinyl chloride (PVC)
(https://en.wikipedia.org/wiki/Polyvinyl_chloride)

CONCLUSION

One of the most important factors for solving environmental problems is reusing of waste materials such as PET, PE, PU, EVA and PVC. When waste plastics are added asphalt concrete, the new mixture is less affected by heat exchange. Also, resistance to water is increasing, easy to handle or tighten and saving energy. Additionally, all

household plastic wastes in bituminous mixtures can be used without washing and selecting them. Thus, the addition of waste plastics has a significant positive effect on asphalts and as an environmentally friendly way, it can promote the reuse of waste plastics in asphalts.

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CHAPTER 5

PROPERTIES OF MAGNESIUM PHOSPHATE CEMENT

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INTRODUCTION

In last decades, a major parameter for construction materials selection was evolved into sustainability surpassing the overall cost. Thus, the construction industry is highly concentrated on new kinds of green materials to decrease the net effect of the construction processes on the environment. Substantial attention is drawn into cement production which is responsible for 5-6 % of the carbon dioxide emissions worldwide. MPC is a highly promising material for both mechanical and environmental advantages. Magnesium oxide (MgO), the main ingredient of MPC is capable of utilizing CO_2 in the environment when forming new compounds and such carbon-neutralizer cement material has gained utmost attention from both commercial and academic authorities. MPC is a new type of acid-base cementitious material composed of dead burned magnesia with a phosphate source and also a retarding additive. Mono ammonium diphosphate and potassium phosphate are two different sources of phosphate. MPC mixtures with potassium phosphate is found to overcome the problem of ammonia gas release that occurs during the hydration reactions and also in the molding process. MPC mixtures were primarily used for dental purposes in the 19^{th} century.

MPC mixtures have several advantages such as high early-age strength, excellent volume stability, fast setting, and good bond characteristics. Thus, several characteristics were observed to be superior with respect to traditional portland cement such low water requirement, lower drying shrinkage, lower pH content that makes it

suitable for various materials to incorporate in to achieve composites of extreme characteristics. Such advantages were employed as the benefits of rapid repair materials. For those purposes, in recent years use of MPC in damages in concrete structures, stabilization of toxic and nuclear wastes, and treatment of wastewater are impregnated. The major reason of this chapter is to portray the overall mechanism of MPC and the findings of several studies on the net effects of these mixtures. Thus fundamental information is given with examples from recent practical applications.

1. FUNDAMENTALS OF MPC

When contacted with water, the soluble phosphate in MPC dissolves promptly to procure saturation according to the following equations.

$$MH_4PO_4(aq) \Leftrightarrow H_2PO_4^-(aq) + M^+(aq)$$
$$H_2PO_4^-(aq) \Leftrightarrow HPO_4^{2-}(aq) + H^+(aq)$$
$$HPO_4^{2-}(aq) \Leftrightarrow PO_4^{3-}(aq) + H^+(aq)$$

where M = NH_4 or K according to phosphate source used in the mix.

Within the first minute of the contact, the dissolution of the phosphate induces a sudden drop to a pH drop. Dead burned magnesia dissolves slower relative to phosphate. Magnesium oxide particles react with one molecule of water and then react with two more and subsequently separation of $Mg(OH)_2$ and one Mg^{2+} and two OH^- ions are formed in the solution. The presence of the OH^- ions leads to pH increase thus

increasing the solubility of magnesium oxide as given in the following equations.

$$\begin{aligned} &MgO + H_2O \rightarrow MgOH^+ + OH^- \\ &MgOH^+ + 2H_2O \rightarrow Mg(OH)_2 + H_3O^+ \\ &Mg(OH)_2 \rightarrow Mg^{2+} + 2OH^- \end{aligned} \quad (1)$$

1.1. Hydration Products

Hydration occurs very rapidly and such that heat output rate forms a peak within a half hour. Then downward deceleration stage occurs and in this stage, the content of phosphate ions decreases constantly all over time which is interpreted as the constant consumption of phosphate ions throughout the hydration process. Struvite is the main hydration product responsible for the setting properties of MPC. Sarkar (1990) investigated the reaction phases by several observation techniques and other than struvite, it was observed ditmarite ($NH_4MgPO_4.H_2O$), schertelite ($(NH_4)_2Mg(HPO_4)_2.4H_2O$), bobierrite ($Mg_3(PO_4)_2.4H_2O$), and newberyite ($MgHPO_4.3H_2O$), MgO and low amount of $Mg(OH)_2$.

1.2. Setting Mechanism of MPC

The hydration mechanism of MPC is not well understood although it is a basic exothermic acid-based reaction. Several researchers basically handled the reaction mechanism as the dissolution of MgO and phosphate whereas some researchers concentrated on the view of topochemical mechanism.Neiman and Sarma (1980) studied the MgO

– $NH_4H_2PO_4$ system and deduced the presence of a multimolecular framework which was surrounded by hydrogen-rich molecules forming hydrogen bonds with water and eventually result in colloidal particles that coagulate around an excessive amount of MgO initiating the setting process. Sugama and Kukacka (1983) asserted the effect of polar reaction of Mg^{2+} on the initiation of cementing reactions. Sarkar (1990) suggested the presence of an insoluble diffusion barrier around the MgO grains that have been formed by the cross-link between Mg^{2+} ions and polyphosphate ions.

2. PROPERTIES OF MPC

2.1 Retarders

Retarders are used in many cementitious mixing processes particularly to regulate the intensity of exothermic reactions. Retarders usage in MPC mixing is of extreme significance regarding the instant reaction of magnesium oxide and phosphate when mixed with water. Polyphosphate, oxy-boron, and water-soluble fluoride-based compounds are the most efficient retarders being used for the proper mixing of MPC mixtures. The most popular that are being used in recent years are borax ($NaB_4O_7.10H_2O$), sodium triphosphate (STP, $Na_5P_3O_{10}$), and boric acid (H_3BO_3). When retarding mechanism of borax used in MPC is analyzed, it is seen that borax is hydrolyzed into the solution releasing $B_4O_7^{2-}$ ions creating a film around the magnesium oxide grains thus retarding the reaction mechanism. STP is another popular retarder that reacts with the Mg^{2+} ions producing a complex salt that prevents the water contact of the MgO particles thus

retarding the reaction. Yang and Wu (1999) observed the retarding effect is not related to $NH_4H_2PO_4$, is directly related to MgO content. Regarding this information, the amount of additives to be used in MPC mixtures should be adjusted according to MgO content.

2.2. Additives

Pozzolanic mineral admixtures have many advantages for cementitious materials including better pore structure, resistance to elevated temperatures, denser microstructure, and improved interfacial transition zone. In MPC mixtures, most frequently fly ash, metakaolin, and silica fume are incorporated as additives to both improve the properties of MPC and utilize cost-effective waste materials. Fly ash which is a by-product of coal production is employed through MPC mixtures besides reducing the overall cost has several advantages for the internal structure of MPC. Major advantageous points are (i) improvement of strength (ii) improvement of workability, (iii) cancelation of extra heat during the exothermic hydration process, (iv) increasing the setting time. Li and Chen (2013) discussed the addition of calcium fly ash and indicated that workability increased with fly ash addition and also setting time was retarded. The authors also indicated that fly ash participates in the setting reaction and forms strong silico-phosphate bonds with curing time.

Silica fume may also be added to MPC to improve both the durable and mechanical characteristics of mixtures. Silica fume acts as a microfiller and densifies the microstructural integration together with

the net increment in the secondary hydration products (Caliskan, 2003). Silica fume also improves several different characteristics such bond strength, imporous structures, resistance against aggressive agents. Silica fume was found to be immensely helpful when used in MPC mixtures. Ahmad and Chen (2020) investigated the effect of silica fume addition in MPC and concluded that susceptibility of MCP was significantly lowered and additionally resistance to high temperatures (300 and 600 ^{o}C) was found to be greatly enhanced. And also reported that inclusion of silica fume also improved the pore structure that volume of larger pores were found to be lowered and total porosity was decreased. The authors revealed the formation of a secondary reaction product ($MgSiO_3$) and also aluminum phosphate phases were detected along with the struvite particles improving the bonding of MPC. In another study, Ahmad and Chen (2018) investigated the mechanical properties of silica fume included MPC mixtures, and concluded that silica fume increased the flexural strength however no improvement in ductility was monitored for plain mixtures. Significant improvement was noticed for specimens including both silica fume and basalt fibers which should be interpreted as the increment in the bonding behavior with the silica fume content. Also, metakaolin is used in MPC mixtures as a supplementary high pozzolanic material which was found to be effective in decreasing the reaction speed and accordingly the hydration heat. Also, very early age strength increments and improvement in water resistance were monitored in another study. (Lu and Chen, 2016). Zheng et al. (2016) studied the concurrent use of

silica fume and fly ash and concluded that both supplementary binders filled the pores and cracks improving the pore structure and density of MKPC.

2.3. Parameters Affecting Properties of MPC

Several studies in the literature have investigated on several parameters that affect the properties of MPC. The mixing ratio of the ingredients, curing environment, and temperature are all important parameters that should be carefully dealt with. The molar ratio of MgO to phosphate ratio and water to binder ratio were important parameters that change important characteristics. Chong et al. (2017) studied factors affecting the water corrosion behavior of MKPC, residual compressive strength, and mass loss ratio were used as deterioration indexes, and authors concluded that prolonged initial air curing improved the initial strength. Also, flow water curing was compared with static water curing and static water curing exhibited less adverse effects on the specimens. Hydration products were decomposed when cured in water thus creating a looser inner interstructure. Also, the temperature dependence of MPC casting was noted by researchers declaring that the setting time of MPC decreased with the increase in temperature.

The phosphate to MgO ratio (P/M) is the main parameter creating a recipe for generating an MPC mixture. P/M ratio is closely related to hydration rate and setting time. An excessive amount of MgO is observed to accelerate the reaction time thus decreasing the setting

time. Yang and Wu (1999) suggested an optimum P/M ratio between ¼ and 1/5.

The primary ingredients of standard MPC mixtures are MgO and phosphate hydrates. The strength of MgO is appreciably higher than phosphate hydrates. Hence the amount of phosphate hydrates is enough to fill the gaps between MgO particles, excess unhydrated MgO act as aggregates enhancing the overall strength of the system (Yang et al., 2014).

The fineness of MgO was reported to have a significant effect on the mechanical properties of MPC. A larger specific surface area was directly proportional to the early strength development, however, no net influence was detected for final strength (Yang and Wu, 1999).

Xu et al. (2018) discussed water-to-solid ratio of highly different water-to-solid ratios (0.5 and 5) Lower water-to-solid ratio leads to higher amount of potassium, phosphate, and magnesium concentrations and as a result, a faster reaction rate.

Li and Chen (2013) asserted that setting time was significantly dependent on the w/c ratio and temperature of casting. Setting time was found to be increasing with w/c ratio. The authors were able to cast MPC specimens at a temperature of -20 ^{o}C.

CONCLUSION

In this chapter, the fundamental properties of magnesium phosphate cement are discussed and given. Magnesium phosphate cement is generally different from portland cement and may be used in several applications that ordinary portland cement is not capable of. The following conclusion can be drawn from the chapter:

Retarder usage is compulsory and should be carefully adjusted since MPC without retarder sets rapidly in 4-5 minutes.

Supplementary cementitious materials like fly ash, metakaolin, and silica fume were found to be effective for both fresh and hardened state properties.

Several properties specify the overall properties of MPC such as molar ratio phosphate to MgO, water-to-binder ratio, amount of MgO, and MgO fineness.

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CHAPTER 6

HATCHING EGGS DETECTION BASED ON MULTI-CHANNEL STATISTICAL FEATURES

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INTRODUCTION

During the incubation in egg farms, fertility detection is a critical economic process influenced by egg transport, hatching areas, and many other factors. Nowadays, fertile eggs out of the hatching eggs are selected manually by experts. This process increases the time and labor-force waste during the transfer of the eggs to the hatching areas. Besides, the cramped storage areas and the breaking of dead eggs cause pollution, and therefore the fertile eggs also die (Geng et al., 2018; Huang et al., 2019). For all these reasons, this study aims to develop an automated system based on image processing and machine learning (Zhu and Ma, 2011; Geng et al., 2018; Huang et al., 2019). In this way, automatic separation of fertile eggs can be made, increasing production efficiency, and saving time and space. At the same time, preventing pollution, it will make a much more hygienic environment possible. Thus, thanks to this system, while increasing the profit percentage of production farms, on the other hand, also incubation costs can be reduced.

In the literature, imaging systems such as infrared thermal (Lin et al., 2013), and hyperspectral (Lawrence et al., 2006; Liu and Ngadi, 2013; Zhang et al., 2014) have been reported for the separation of fertile eggs. A few studies using these systems have reached between 90-97% classification performance. Besides these systems, CCD imaging with LED candling system is also used for productivity detection in incubation eggs. This system based on a CCD camera is less costly than other imaging systems. Therefore, most researchers have focused

on working out the problem using this system based on separating fertile eggs.

Many studies have been carried out using machine learning and image processing methods based on CCD imaging with LED candling systems in fertility detection in incubation eggs. For example, Hashemzadeh and Farajzadeh(2016) developed a fertility-detection machine vision system based on image processing techniques. In the experimental works, 240 incubated eggs, including 190 fertile and 50 infertile, were used. They achieved fertility detection accuracy of 98.25% using an artificial neural network (ANN) classifier. Similarly, Xu and Cui (2014) designed a non-destructive detection system based on machine vision. In this study, image processing methods were applied to extract feature parameters from fertile egg images, and a KNN classifier was used for the classification phase. Classification accuracy in this study was 97.78%. Geng et al. (2019) presented a novel method combining a convolution neural network (CNN) and a heartbeat signal of the hatching eggs. The proposed model included a sequential CNN and end-to-end trainable CNN. The experimental results show that the best detection accuracy is 99.62%. Geng et al. (2018) proposed a model based on deep learning. This model comprised a combination of a pre-trained AlexNet model and a multi-layer network containing six convolutional layers and four pooling layers. They achieved an accuracy score of 99.5%. Huang et al. (2019) proposed a novel multi-feature fusion based on Deep Convolutional Neural Network (DCNN) architecture. They used Speeded Up Robust Feature (SURF) and Histogram of Oriented Gradient (HOG) and pre-

trained deep AlexNet and GoogleNet models in the feature extraction phase. A Support Vector Machine (SVM) was trained with deep and local features. This study achieved an average classification accuracy rate of 98.4%. Geng et al. (2020) proposed the CNN classification model based on channel weighting (squeeze and excitation module) and joint supervision for hatching eggs classification. This proposed model's classification accuracy was 98.8%.

This study introduced a novel approach based on multi-channel statistical features for the automatic separation of fertile hatching eggs. First, different color space images were obtained by using color transformations. Then by using statistical formulas, color properties were extracted from these color spaces. Finally, the five-classifier method was used in the classification stage. In experimental studies, 100% accuracy was achieved for fertility detection based on hatching egg images. According to these results, the proposed system will effectively contribute to this massive and escalating egg sector with many manufacturers today. This application will provide companies with higher earnings, reduced workforce, time-saving. This application will prevent possible pollution and eliminate a lot of operative negativity in the enterprise.

The main contributions of current study are given below:

- By using the proposed system, better efficiency and accuracy have been achieved without mutating the egg and causing the death of the embryo.

- Thanks to the developed system, the eggs are transferred from the development machines to the hatchers on the 18th day of the incubation period, and so the separation of fertile and infertile eggs facilitates hatching and saves space.
- The proposed model is advantageous in determining the closest live eggs rate of hatchery eggs.
- Thanks to the developed system, the pollution caused by dead embryos in egg hatchery significantly reduce.
- The proposed system is simple to use and can be used in real-time applications.

The study was organized as follows: The hatching imaging system and dataset were summarized in Chapter 1. The proposed model and its theoretical infrastructure were mentioned in Chapter 2, while the experimental studies and the results took place numerically and visually in Chapter 3. The comparison of the results of the existing studies with the proposed model was presented in Chapter 4. Finally, the results were discussed, and information about future works was given in section 5.

1. MATERIAL

In this study, a real-time imaging system has been developed to obtain images of hatching eggs (Figure 1). This system consists of an egg viol tray, camera, and led light bulbs. Detailed information about these tools is below:

- In the egg viol tray, 3x3 cm size ten holes are available. In this tray, the eggs were arranged horizontally.
- Hatching eggs were photoed at a fixed distance using the Nikon d7200 camera featuring a 24.2 megapixel, 6 FPS Continuous Shooting, Full HD, and 51 focus points.
- Cold white LED bulbs were used to view the inside of the hatching eggs. These LEDs have the characteristics of color temperature 10000-15000K, operating voltage 9-12V, operating current 900 mA, and flux 900-1000LM.

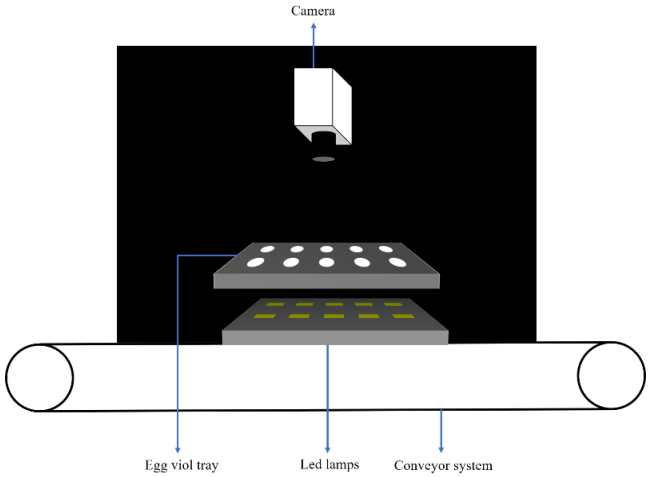
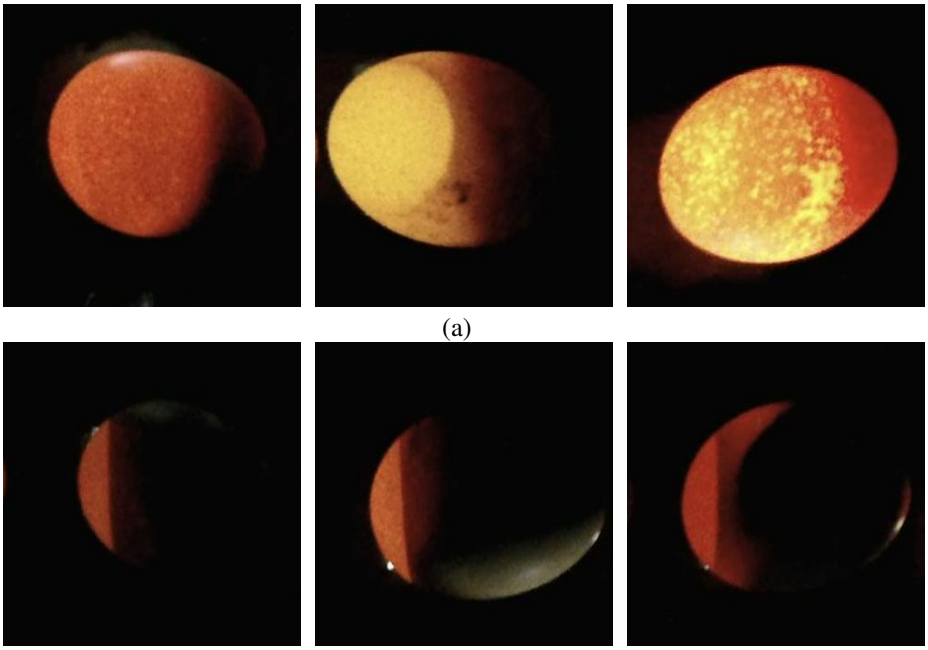


Figure 1. Improved Imaging System

In this study, the images shown in Figure 1 were taken while transferring the eggs from development machines to hatching machines on the 18th day of the incubation. For this purpose, 204 hatching eggs were used, and 120 infertile and 84 fertile egg images were obtained through the imaging system shown in Figure 1. Some of these images are in Figure 2.



(a)

(b)

Figure 2. Dataset's Sample Images, a) Non-fertile, b) Fertile.

2. PROPOSED METHODOLOGY

In this paper, to detect hatching eggs' fertility, a novel approach based on multi-channel statistical features was presented. This proposed approach consists of three stages: color transform, feature extraction, and classification. The graphical representation of the proposed model is in Figure 3.

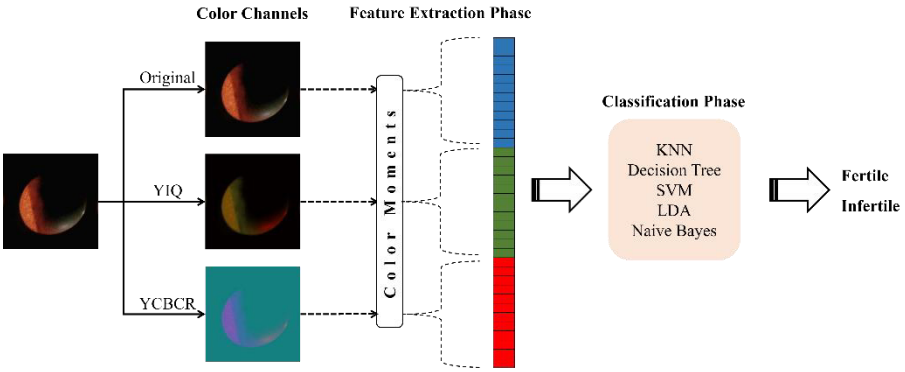


Figure 3. The Graphical Representation of The Proposed Model

The stages making up the proposed model are detailed under subheadings.

2.1. Color transform

Color spaces are powerful discriminators representing color information. Generally, color analysis processes are performed using RGB color space (Altuntaş and Kocamaz, 2019). This color space comprises three different color channels: Red, Green, and Blue. In this study, YCbCr and YIQ color spaces are used as well as RGB color space. YCbCr Color Space is a color format used in digital videos (Buğday, 2010; Şişeci and Çetişli, 2012). This color space consists of luminance (Y) and chrominance (Cb and Cr) values. YIQ includes luminance (Y), hue (I), and saturation (Q) color values (Buğday, 2010; Şişeci and Çetişli, 2012).

Conversions to YCbCr and YIQ color spaces based on RGB images are performed using the following equations:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.256 & 0.504 & 0.098 \\ -0.148 & -0.292 & 0.441 \\ 0.441 & -0.369 & -0.071 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \quad (2)$$

2.2. Statistical features

Color features are a significant distinguishing factor in object recognition and classification. The application of these features provides simple and effective results (Turkoglu and Hanbay, 2019). In this study, color distributions of egg images were obtained using statistical moments such as mean, standard deviation, skewness, and kurtosis. The formulas of these statistical moments and related explanations are in Table 1 (Turkoglu and Hanbay, 2019; Turkoglu, 2019).

In the equations given in Table 1, M and N demonstrate the size of the A image. i and j represent the pixel values of the row and column, respectively.

Table 1. Statistical Moment

	Formulation
Mean:	$\frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N} A_{i,j}$
Standard Deviation:	$\frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N} (A_{i,j} - \mu_A)^2$

Kurtosis:	$\frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N}(\frac{A_{i,j}-\mu_A}{\sigma_A})^3$
Skewness:	$\frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N}(\frac{A_{i,j}-\mu_A}{\sigma_A})^4-3$

Definitions of statistical moments given in Table 1 are as follows:

- **Mean:** It is the average value of the color distribution in the image.
- **Standard Deviation:** It is the density change around the mean.
- **Kurtosis:** It determines the asymmetry of the image color distribution.
- **Skewness:** It is the symmetry or smoothness of the image color distribution.

2.3. Classification

Statistical features representing egg images' color distributions are used as the input of the classifier methods. In this study, we used five classifier methods: Decision tree (DT) (Safavian, and Landgrebe, 1991), Support Vector Machine (SVM) (Cortes, and Vapnik, 1995; Aslan, 2020; Turkoglu, 2021), k-Nearest Neighbours (kNN) (Hu et al., 2008; Das, and Sengur, 2010; Turkoglu, and Hanbay, 2018), Naïve Bayes (NB) (Rish, 2001), Linear discriminant analysis (LDA) (Chen, and Yang, 2004). MATLAB Classification Learner toolbox was used to check the performance of these classifiers. The parameters of these classifiers are in Table 2.

Table 2. Classifier Methods and Parameters

Classifier	Parameter	Value
DT	Maximum number of splits: Split Criterion:	100 Gini's diversity index
LDA	Covariance structure:	Full
kNN	Number of neighbors: Distance metric: Distance weight:	1 Euclidean Equal
SVM	Kernel function: Kernel scale: Box constraint level: Multiclass method:	Quadratic Automatic 1 one-vs-one
NB	Distribution name for numeric predictors: Distribution name for categorical predictors:	Gaussian MVMN

Classifier parameters given in Table 1 were achieved by the trial-and-error approach for best classification performance.

3. EXPERİMENTAL WORKS

The experimental studies were performed using MATLAB (R2020a) software on a computer equipped with RTX 2080 GPU card, 32 GB Ram, and Intel Core i7. In experimental studies, 204 hatching egg images were used. Additionally, 10-fold cross-validation data partitioning was performed, and in this way, all data samples were used in both training and test datasets.

In the first experimental study, four statistical equations in Table 1 were applied to each channel of RGB, YIQ, and YCbCr color spaces. Twelve features were obtained for each color space. In the classification stage, the DT, LDA, kNN, SVM, and NB methods were

used, and individual performances of each color space were calculated by MATLAB. These results are in Table 3.

Table 3. Accuracy Scores (%) of Each Color Space

Classifier Methods	RGB	YIQ	YCbCr	Average
DT	98	99	98.5	98.5
LDA	97.5	96.6	96.6	96.9
NB	95.1	97.5	98	96.87
SVM	94.6	97.1	96.1	95.94
kNN	92.6	93.6	94.1	93.43

Table 3 shows the accuracy scores of five different classifiers based on the features obtained from color spaces. According to these results, the highest accuracy score among color spaces is 99% in the Decision Tree classifier based on the YIQ color space (Figure 1 (a)). Besides, RGB and YCbCr color spaces based on the Decision Tree classifier achieved 98% and 98.5% accuracy, respectively (Figure 3 (b-c)). On the other hand, considering the average accuracy scores of the classifiers used for all three-color spaces, Decision Tree was the best classifier, while LDA and Naïve Bayes methods were observed to be the second-best classifier.

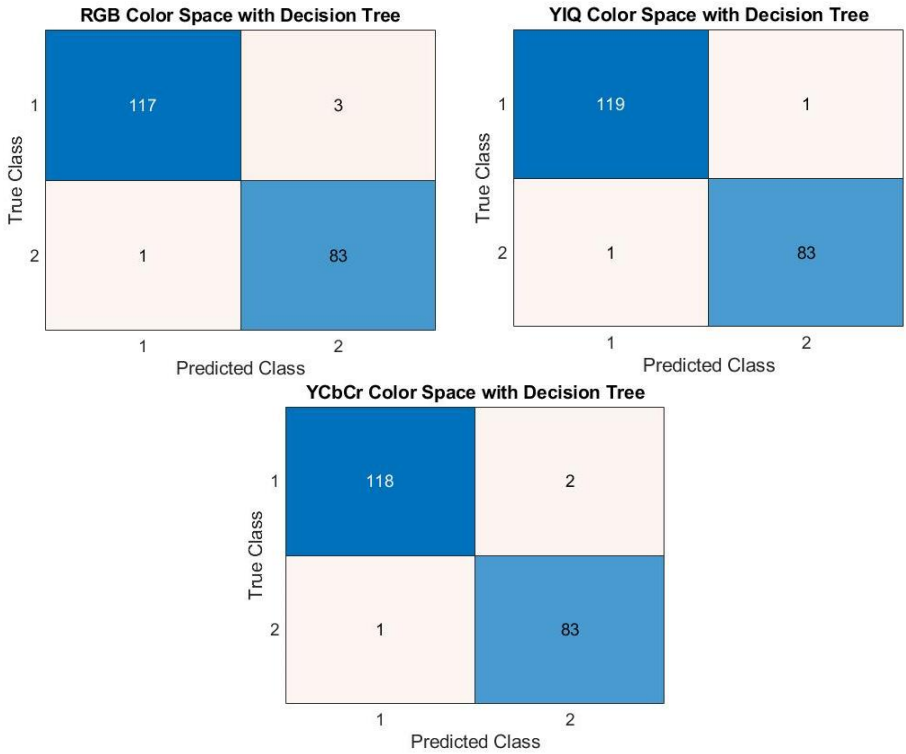


Figure 3. Confusion Matrixes Chart for Each Color Spaces Based on Decision Tree

Figure 3 shows the confusion matrixes for three color spaces based on the Decision Tree, which has the best accuracy score. According to these confusion matrices, the number of false classifications for RGB, YIQ, and YCbCr color spaces is 4, 2, and 3, respectively.

In the other experimental study, the proposed MCSF model based on the combination of features obtained from three different color spaces was used. Five classifiers were used in the classification stage of the proposed model. Accuracy scores obtained from this experimental study are in Table 4.

Table 4. Accuracy Scores (%) of the Proposed MCSF Model

	DT	LDA	NB	SVM	KNN
Proposed MCSF model	100	98	97.1	97.5	95.1

As seen in Table 4, the highest accuracy score using the proposed MCSF model was obtained as 100% with the Decision Tree classifier (Figure 4). Besides, the accuracy scores of LDA, Naïve Bayes, SVM, and KNN classifiers using the proposed MCSF model are 98%, 97.1%, 97.5%, and 95.1%, respectively.

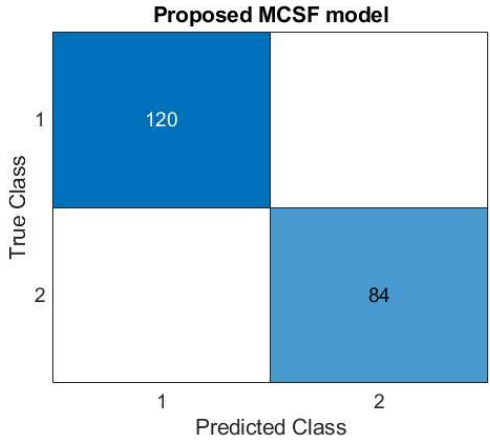


Figure 4. Confusion Matrixes Chart for Each Color Spaces Based on Decision Tree

4. DISCUSSION

Fertility detection in hatching eggs is very significant in terms of health and economy. Many studies based on machine learning and image processing have been carried out to solve this problem. These studies aim to achieve high performance in fertility determination by developing an automatic system. In this direction, accuracy scores

obtained from previous studies are given in Table 5 and compared with the current proposed model.

Table 5. Comparison of Accuracy Scores of Previous Studies with The Current Proposed Model

References	**Accuracy (%)**
Liu and Ngadi, (2013)	84.1
Zhu and Ma, (2011)	92.5
Xu et al., (2015)	96.25
Xu and Cui, (2014)	97.78
Hashemzadeh and Farajzadeh, (2016)	98.25
Huang et al., (2019)	98.4
Geng et al., (2020)	98.8
Geng et al., (2018)	99.5
Geng et al., (2019)	99.62
Proposed MCSF model	100

As seen in Table 5, the proposed model has a higher performance than other models. Previously conducted studies have accuracy scores of approximately 95%-99%. Furthermore, deep learning methods were used in most of the prior researches given in Table 5, and these results show that the proposed model presents more excellent performance.

The advantages of the proposed model are as follows:

- The proposed model can be applied to small and large data sets.
- Does not contain complex processes.
- It has high performance.
- Real-time images of hatching eggs were used in experimental studies. Thus, the proposed model can be used for the food industry.

CONCLUSION

This paper proposed a novel approach based on multi-channel statistical features (MCSF) for the classification of fertile eggs in the hatching period. This model includes the five classifier methods and the statistical features based on RGB, YCbCr, and YIQ color spaces. The experimental works were carried on 18-days hatching eggs for their protection while transferring them from the development machines to the hatchery machines. The proposed model produced 100% accuracy in the classification of hatching eggs. This result shows that the proposed model is simpler and more successful than previous studies based on deep and local methods. Our future work will focus on dataset improvement and the development of deep network models.

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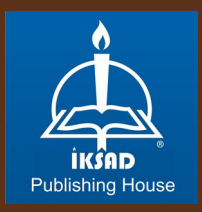

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