Research Article

An Analysis of The Use of Natural Stone and Marble in Contemporary Architectural Designs

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Abstract

Throughout history, many products have been used as construction materials. One of the oldest of these materials is natural stone. Natural stones can be processable with different techniques and be freely used in any desired place. It has been observed that the use of natural stone in architectural designs has changed compared to the past, with the discovery of new construction materials and techniques. The aim of this study is to make known the situation of natural stones in today's architectural designs by revealing the changes. For this reason, the use of natural stone has been examined through contemporary architectural designs. In the selected designs, what types of natural stones are selected according to their characteristics and design ideas have been examined. Due to the fact that each design has its own characteristics, the application details are specified by looking at the form, function, colour, pattern and texture of the natural stones. The reasons why natural stones continue to be preferred in architectural designs have been determined as a result of the examinations made. Accordingly, it can be ascertained that natural stones are durable, long-lasting, maintenance-free, and can be found in various functions, shapes, colours, patterns and textures according to their conditions. They are also subjected to different processes. In addition, they can be included in different solutions through application details, have wide reserves in our country, are recyclable and sustainable. For this reason, it is clear that natural stones will be the preferred materials in architectural designs in the future.

Keywords: Architectural Design, Marble, Natural Stone.

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Araştırma Makalesi

Çağdaş Mimari Tasarımlarda Doğal Taş ve Mermer Kullanımının İncelenmesi

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Özet

Tarih boyunca yapı malzemesi olarak pek çok ürün kullanılmıştır. Bu malzemelerin en eskilerinden biri doğal taşlardır. Doğal taşlar farklı tekniklerle işlenebilmekte ve istenilen her yerde özgürce kullanılabilmektedir. Yeni yapı malzemeleri ve tekniklerinin keşfiyle birlikte mimari tasarımlarda doğal taş kullanımının geçmişe göre değiştiği gözlemlenmiştir. Bu çalışmanın amacı, doğal taşların günümüz mimari tasarımlarındaki kullanımlarını inceleyerek malzemenin günümüzdeki durumunu ortaya koymaktır. Bu nedenle çalışmada doğal taşlar, çağdaş mimari tasarımlar üzerinden incelenmiştir. Seçilen tasarımlarda kullanılan doğal taşların özelliklerine ve tasarım fikirlerine göre hangi türünün seçildiği incelenmiştir. Her tasarımın kendine has özellikleri olması nedeniyle doğal taşların formu, fonksiyonu, rengi, deseni ve dokusuna bakılarak uygulama detayları belirtilmiştir. Doğal taşların mimari tasarımlarda tercih edilmeye devam edilmesinin nedenleri yapılan incelemeler sonucunda ortaya konulmuştur. Buna göre doğal taşların dayanıklı, uzun ömürlü, bakım gerektirmeyen bir malzeme olduğu, durumuna göre çeşitli fonksiyon, şekil, renk, desen ve dokularda bulunabileceği tespit edilmiştir. Ayrıca farklı işlemlere tabi tutulabilmeleri, uygulama detayları ile farklı çözümlere dahil edilebilmeleri, ülkemizde geniş rezervlere sahip olmaları, geri dönüştürülebilir ve sürdürülebilir olmaları da doğal taşların mimari tasarımlarda tercih edilmelerinin nedenleri olduğu belirlenmiştir. Bu nedenle gelecekte mimari tasarımlarda doğal taşların tercih edilecek bir malzeme olacağı açıktır.

Anahtar Kelimeler: Mimari Tasarım, Mermer, Doğal Taş.

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INTRODUCTION

Natural stones have been used by humanity in different forms since ancient times. Primitive periods when even writing did not exist took their names from natural stones. People used natural stones to make tools, equipment and weapons. While stone is the main element of caves that people sometimes use as shelter, it has also been the preferred material in the making of simple figurines. The use of fire, which is one of the important inventions of history, was discovered thanks to the use of flint.

People extracted the local stones found in their surroundings and processed them using various methods. Natural stones have been used in different areas, from dye production to leather processing. A material with such a wide range of uses has also affected an educational department such as architecture. Natural stone was used especially in many structures that have survived to the present day and are acknowledged monumentality (Taşlıgil & Şahin, 2016).

There are different reasons behind the preference for natural stone as a construction material throughout history. The most obvious reason is the presence of natural stones as raw material in the environment where the buildings are constructed. Although the natural stone materials used in buildings are local, the processing methods of the materials are also developed in parallel. Another reason is related to the structural features of natural stones. Natural stones are more resistant to external factors than adobe and wooden materials. For this reason, the use of natural stone stands out in the majority of buildings that were built many years ago and have survived to the present without much damage. Considering the historical process of architectural structures, natural stones appear in different forms, such as an element used in the foundation of buildings, a structural element or a covering element (Erbaş, 2018).

In recent years, the use of natural stones in the construction sector has been increasing due to awareness of issues such as sustainability and recycling. This situation leads to a comparison of natural stones with other materials. Natural stones are long-lasting, sustainable and environmentally friendly. Their maintenance costs are low. They are durable and solid. In addition to their heat and sound insulation properties, they also show fire resistance. They can be used together with other building materials. Since they offer a wide variety of colours, textures and patterns, they also have unique aesthetic possibilities (Angı et al., 2023).

According to Krüger, natural stones are more efficient in production than other construction materials. They require less energy and can be used in buildings. However, they must go through some processes before they can be used (Krüger, 2022; Yıldırım et al., 2023). When these processes are completed, natural stones can be used in many different areas thanks to their structure, appearance and processing methods. The important point here is that natural stone, which exists originally only as a block of stone, comes together with the structure as a result of the right method and design decisions (Yıldırım et al., 2023).

However, there is a lack of information about the material. There is much written about the usage possibilities of materials such as wood, adobe, straw, clay and sand, along with a discussion of their place in different environmental conditions and application techniques. As for natural stones, similar resources are limited or focused on traditional architectural methods. The study aims to explain the subject through selected examples by examining the use of natural stones in today's architectural designs. In this context, the usage of natural stone material

and its reflections on architecture are explained. In this way, it is thought that a wide range of information will be provided about the application details and aesthetic conditions of natural stone material, which will facilitate the selection of this material in the sector.

Material and Method

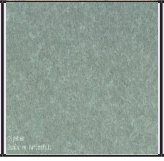
The aim of this study is to make inferences about the status of natural stone used in architectural and landscape designs, by examining various criteria. Detailed information about the application areas will be obtained by revealing data about natural stones through structures.

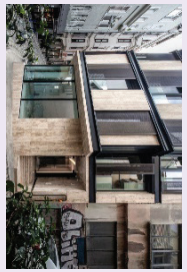
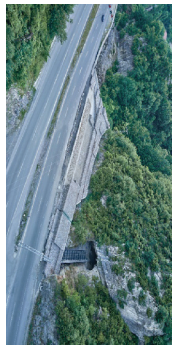
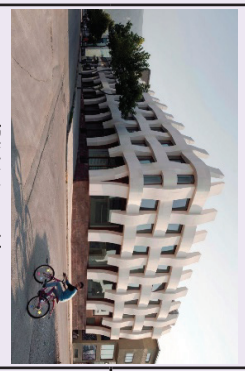
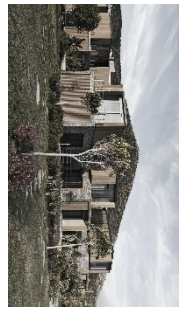
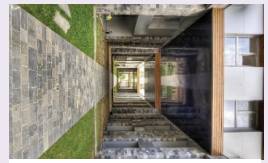
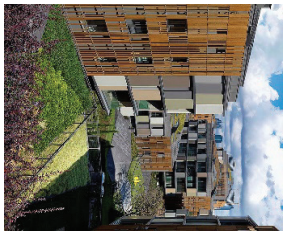
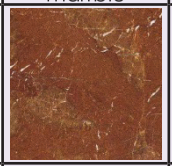
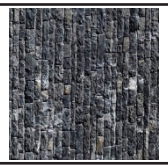
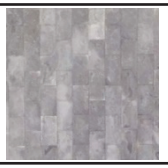
For this purpose, architectural designs containing natural stones were determined through online or printed architecture magazines, and by getting the opinions of natural stone supply companies and architects in the sector. To this point, 20 different architectural projects were selected and examined. The limitation of the selected projects was determined according to the following criteria:

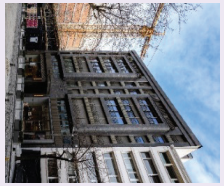
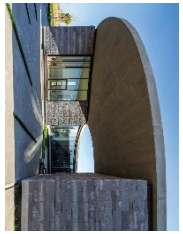
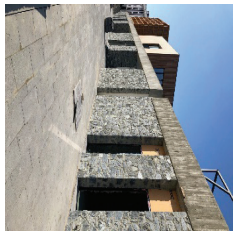
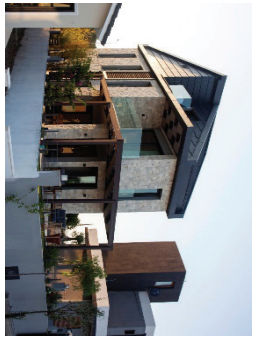
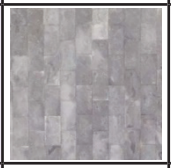
- It has been observed from the data obtained that the use of natural stone in architectural designs has increased in the last 25 years. For this reason, projects designed in the last quarter century were discussed.
- Buildings built in Türkiye were chosen as locations.
- The use of natural stones in architectural designs was focused on. Since architectural designs are taken as a whole with their surroundings, landscape designs are also included in the study.
- Since it was thought that architectural designs in the private sector would be freer in material selection, such structures were concentrated on and public buildings were not included.

The selected architectural designs and information about them are shown in Table 1.

Table 1. Selected architectural designs.

PROJECT	ARCHITECTS/ PROJECT YEAR	PROJECT IMAGE	NATURAL STONES	IMAGE	AREA OF USAGE
Square of Medipol University Kavacık Campus	DS Mimarlık/ 2016-2018	 (DS Mimarlık, n.d.)	Basalt		Floor covering
Four Seasons Hotel Courtyard	DS Mimarlık/ 1997	 (DS Mimarlık, n.d.)	Basalt		Floor covering
			Slate		Landscape element
			Diabase		Seperating different landscape textures

Galata Apartment	Zonguldak Caves Visitor Centre		Argül Weave		Vicem Bodrum	Kemerlife XXI Landscape Project		Housing of Ulus Savoy Landscape Project
WE're Mimarlık/ 2016-2019	Yalın Mimarlık/ 2021		BINAA 2012-2014		DS Mimarlık- EAA Architects 2010-2013	DS Mimarlık/ 2005-2008		DS Mimarlık/ 2012-2013
(WE're Mimarlık) 	(Karakaya, 2022) 		(BINAA, n.d.) 		(DS mimarlık, n.d.) 	(EAA, n.d)  		(Uzunkaya, 2013) 
Travertine	Granite	Limestone	Aegean burgundy marrble	Patara Marble	Slate	Slate	Tarvertine	Basalt
								
Façade element	Floor covering	Wall covering	Wall covering	Wall covering	Wall covering	Landscape element	Floor covering	Wall and floor covering

No. 45	Farm of 38° 30°		House of Karahan Landscape Project		Fatma Ana Djemevi and Cultural Centre		Latus Park	House of NTA	
Rhizome Architects- Toner Mimarlık/ 2016-2018	Slash Architects- Arkizon Architects/ 2014-2016		DS Mimarlık- Rota Mimarlık/ 2008-2009		9016 Mimarlık / 2016-2020		NTT Mimarlık/ 2016-020	GIG Office/ 2017-2018	
 (Rhizome Architects, n.d.)	 (Slash Architects)		 (DS Mimarlık, n.d.)		 (9016 Mimarlık)		 (NTT Mimarlık,n.d.)	 (GIG Office)	
Quartzite	Andesite	Basalt	Onyx	Granite	Basalt	Slate	Limestone	Travertine	Urla Stone
									
Wall covering	Floor covering	Wall covering	Lighting element	Separating different landscape textures	Floor covering	Wall covering	Wall covering and seperating different landscape textures	Floor covering	Wall covering

House of BD	Paker Mimarlık/ 2018	(Paker Mimarlık)	Slate		Wall covering
House of Has-Kisakürek	Paker Mimarlık/ 2018	(Paker Mimarlık)	Slate		Wall covering
House of Danişment	SARD Studio/ 2021	(Sard Studio)	Limestone		Main wall element
			Travertine		Floor covering
Folkart Blu	DILEKCI Architects-DDA/2017	(DDA Mimarlık)	Limestone		Wall covering
House of Barbaros	Onurcan Çakır-Önderler İnşaat/ 2015	(Çakır, n.d.)	Composite stones		Wall covering
Binnaz Hatun Mosque	ARCHIST Mimarlık/ 2015	(ARCHIST Mimarlık)	Andesite		Wall covering
			Basalt		Floor covering

Criteria were generated for the analysis of natural stones. While creating these standards, the physical and chemical properties of natural stones, their economic status and application details, function, form, colour, pattern and texture were analysed. Artistic and technical features were blended in creating the criteria. These criteria were determined according to the following contexts:

• Unction is the reason for the use of the element in which the natural stone is used in the design. Accordingly, different usage functions of natural stones have been found, such as cladding elements, facade panels, and separating elements between different textures. The relationship between the properties and functions of natural stone was examined. The function in this subheading is the quantitative purpose of natural stone. The functions of natural stones in design are mentioned in the general information section.

- Form covers the appearance of shapes; they can be handled in geometric or non-geometric situations (Güngör, 2005). In this study, form is used in a geometric sense, and the physical appearance and measurements of the natural stones used are included. Inferences about this information were obtained from architectural drawings and photographs of the designs.

- Colour refers to the stone's main colour. The colour undertones of the natural stones in the designs are taken from the photographs of the design obtained from the offices or the catalogues of the manufacturers. Thanks to a computer web program, the dominant primary colours of the natural stone images and the undertones of these colours were determined. The information obtained is grouped in the tables. The connection between the design idea and the natural stone colour is expressed verbally.

- Although the concept of texture is thought to appeal especially to the sense of touch, it also creates a visual effect. According to this visual effect, textures may be perceived as contradictory concepts, such as hard or soft (Köylü & Yılmaz, 2021). Therefore, visual inferences were made about the textures of natural stones in the designs examined, and the textures were expressed with adjectives such as simple and complex, hard and soft, dynamic and static, limited and unlimited, cold and warm. While expressing the concept of texture, general information given by the designers was used. Since the concept of pattern is thought to appeal to the visual sense, the two concepts have been combined and the relationship between the intended design idea in architectural design and the texture and pattern of the natural stone used is specified. Using a computer program, the light, reflection, shadow and depth conditions of natural stone images were obtained and presented. An ambient occ map containing illumination data was used for the light condition, a specular map containing glare data on the surface was used for the brightness condition, and a displacement map was used for shadow and depth.

The economic situation is included in the study because it affects the choice of materials in the designs.

In the application details, particulars about the natural stones included in the architectural drawings such as plans, sections and views obtained from architectural offices about architectural designs are included. Since the function and form of use of natural stone are different for each project, the application details are shaped accordingly. For this reason, it has been stated that in some cases natural stone is used simply, and in other cases it is combined with different materials to form a design whole.

The determined criteria are grouped according to architectural projects and presented in separate figures. The findings obtained as a result of the analyses are stated. According to the data obtained about the examined projects, architects' opinions were taken about the semantic context between the design goals and the use of natural stone. The sample projects examined in the study were questioned in line with the determined criteria.

In the Conclusion and Recommendations section, the results of the findings are presented. At this point, suggestions have been determined in light of the results obtained regarding the use of natural stone in designs. In this context, the properties of natural stones suitable for use in designs are explained. It is thought that the suggestions presented as a result of the examinations will be a guiding resource regarding the use of natural stones in architectural designs.

GENERAL INFORMATION ABOUT NATURAL STONES

Some of the earth's stratums, which were formed in different periods of geological stages and hardened over time, are called stones. Stones are divided into three groups: magmatic, sedimentary and metamorphic, according to their formation status. Magmatic stone is a group of natural stones formed by the hardening of magma. This group of natural stones is also called igneous stone because it has been formed as a result of the eruption of magma. Sedimentary stones are natural stones formed from sediments in layers. Metamorphic stones are formed as a result of the transformation of igneous and sedimentary stones under suitable temperature and pressure conditions (Karahan, 2018). Table 2 shows the grouping of natural stones and marble according to the types described.

Table 2. Natural stones and marbles by type.

MAGMATIC	SEDIMENTARY	METAMORPHIC
• Granite • Syenite • Serpentine • Andesite • Basalt	• Limestone • Travertine • Sandstone • Dolomite • Conglomerate	• Gneiss • Marble • Quartzite

During the process, one natural stone group can transform into another stone group under suitable conditions. This situation is called the rock cycle (Karahan, 2018).

Physical and Chemical Properties of Natural Stone and Marble

Stones contain many physical and chemical properties. They appear in different areas and shapes according to these features. Physical and chemical properties affect the appearance and patterns of natural stones as well as their resistance to external factors. Natural Stones are used in combination with other materials such as concrete, metal and wood. Knowing the physical and chemical structure of the material used is important in terms of predicting its behaviour with other materials and finding appropriate detailed solutions in the face of a possible negative situation.

Physical properties of natural stones and marble include conditions such as porosity, grain size, colour, hardness, water absorption, resistance, thermal conductivity and sound insulation. The chemical properties are generally closely related to the components the stone contains along with the proportions of these components. Depending on their chemical structure, the reactions of natural stones with acids or carbon dioxide and their transformations under high temperatures vary. However, at this point it should be noted that the state of the chemical components of natural stone is often reflected in its physical properties, causing its colours, patterns and textures to differ from each other.

Porosity

Natural stones contain a certain number of voids. These volumetric gaps determine whether they can accept polish, their durability and the state of structural cracks. Porosity is a feature found in every natural stone, but turning this feature into visible structural cracks is a situation that reduces the quality of the material. Porosity is expressed as a percent. This value is the ratio of the volume of the pore space to the total volume (Görcelioğlu, 2014).

Grain size

Natural stones are classified as fine, coarse and coarse- grained according to the grain size of the components they contain (Karahan, 2018). While marble with small mineral grain sizes is generally less common, marble with large mineral sizes is more common. This makes marble varieties with small mineral grain sizes more valuable. This characteristic directly impacts the cost of natural stones. While the costs of common natural stones are low, the costs of rare stones are high.

Colour

Natural stones take on different colours depending on the type and ratio of minerals they contain. Marble, which is a type of natural stone, is called massive, laminal, schist and brecciated, accordingly. Massive marble intensity of colour and pattern changes are minimal. Laminal marble has a coloured stripe appearance and contains different mineral structures. Schisti marble has a leafy structure and contains a significant amount of mica. Brecciated marble is filled with secondary minerals. The main fillings can be of different colours and mineral content (Karahan, 2018).

Natural stones come in a wide range of colours due to the different minerals they contain or the substances within their structure. This diversity in colour and texture offers versatile design opportunities in architectural projects. When used in the right combinations, natural stones can harmonize with the surrounding environment, while also helping to highlight specific design elements. This makes it possible to create designs that blend seamlessly with nature and stand out in their own right depending on the main design approach.

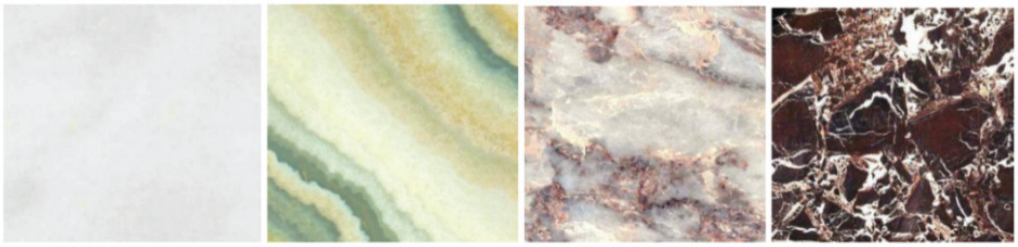


Figure 1. Stones' appearances by colour (Karahan, 2018).

Hardness

The hardness of natural stones is classified according to the Mohs scale of mineral hardness. Although soft stones can be processed more easily, they also may be more easily eroded due to external factors. Hard stones, on the other hand, are much more difficult to process, and this causes the material cost to increase (Bilgin, n.d.). Cost plays a significant role in the construction processes. An increase in overall costs can delay the timely completion of designs. For this reason, natural stone is sometimes not preferred in structures due to its expense.

Water absorption

Natural stones show different capacities depending on the amount of water they absorb, depending on their grain size and porosity properties. Natural stones with high water absorption capacity are also likely to stain. However, this situation can be prevented with surface protection techniques (Angı, 2023).

Resistance

The resistance of natural stones is measured by their ability to remain intact against environmental factors over a long time. The change in the structures of natural stones due to environmental influences is called weathering. While natural factors such as gases in the atmosphere, salty sea water and earthquakes may

be effective in weathering, artificial factors such as vandalism, restoration, faulty workmanship and use of natural stone in the wrong place are also effective (Angı, 2023).

Thermal conductivity and sound insulation

Natural stones have properties such as thermal conductivity and sound insulation. This affects the selection of natural stones to be used in the building. For example, basalt, one of the natural stones, is known for its thermal conductivity and heat absorption (Günerhan, 2004). Each material has a unique thermal conductivity coefficient. Materials with a low heat conduction coefficient have high heat conduction resistance. Therefore, such materials have high thermal insulation performance (Karakoç et al., 2011). The sound insulation feature is related to how much energy the material can absorb when exposed to a certain sound intensity. Sound intensity is expressed in decibels (Kaya et al., 2017).

Chemical components

The chemical components and their ratios in all natural stones differ from each other. Properties of natural stones such as colour, texture, hardness and resistance vary, depending on the chemical components they contain and their ratios. In addition, the ratio of chemical components plays a determining role in issues such as the extraction and processing of natural stones from reserves and, accordingly, ease of application. The main chemical components of classically named marble originate from different regions of our country and are named accordingly (Yavuz et al., 2002). Although the wide variety of natural stones enables the creation of diverse designs, it makes the process of compiling an extensive catalogue quite difficult. Therefore, fully understanding the material and using it correctly in architecture becomes more challenging.

Usage Areas of Natural Stone and Marble

The architectural use of natural stones as construction materials is seen after the Palaeolithic Period (Erbaş, 2018). Before this period, natural stone used structurally consisted of the carving out of caves only to meet the need for shelter. Afterwards, natural stones appear as building materials, carrier elements, covering elements and architectural decorations.

The fact that natural stones used as building materials dates back to the Palaeolithic Period shows that this material has a long history. Humanity, which started using natural stone with tools and weapons, used this material in all kinds of monuments, temples, tombs, castles, religious buildings, stadiums, etc., especially with the transition to settled life. In this period, natural stone appears as the main element that keeps the structure standing, such as foundations, basements, load-bearing columns and walls. The fact that lighter materials were initially preferred for the covering system changed over time with the development of stone processing knowledge and the tools used. There was a tendency to use natural stone for the covering system.

Natural stone structures are the most commonly found throughout history. They have survived to the present with little damage. Natural stone is one of the oldest construction materials and is more resistant to external factors such as weather, climate and people compared to other materials used in the historical period. For this reason, it is seen that most buildings have survived to the present day.

The area where natural stones are most commonly used today is flooring. This is followed by interior and exterior cladding, monuments and cemeteries, ornamental and decoration manufacturing and other areas (Ekincioğlu et al., 2014; Taşlıgil & Şahin, 2016). Other areas include baths, fountains, fireplaces,

lintels, jambs, gargoyles- (which allow the water accumulated on the roofs to be transmitted to the ground and found abundantly on old buildings), mosques, kitchen and bathroom counters, tabletops, shower trays, railings and other staircase elements, containers, bowls. Thanks to newly developed techniques, many different pieces of furniture and all kinds of materials that people use in daily life are shown as examples.

Structurally, natural stone and marble appeared as the main structural elements in the early days. The main material in most of the masonry buildings at that time was natural stone, used in more or less processed forms. While we sometimes encounter structures made entirely of stone, sometimes natural stone is used in the foundations of wooden or adobe structures. With the process, people improved their tool- making. In this way, they were able to process natural stones more easily and use them in their structures. Thus, they added natural stone and marble decorations to their structures. Some architectural elements such as jambs, gargoyles and finials, can be seen used in different places.

Nowadays, it is possible to process natural stones using robotic technology. Thanks to CNC (Computer Numerical Control) machines, which are controlled by computer programs, it has become possible to process natural stones in different shapes and sizes. Designers transfer the desired drawing into the program in three dimensions, and digital models are created. In this way, natural stones can be easily processed for designs that look challenging. This not only saves time but also increases quality (Krüger, 2022). These advantages show that things that could not be done before in an architectural sense could now be done. The use of these materials in architecture could not be abandoned.

FINDINGS AND DISCUSSION

Findings Regarding Designs

The study focuses on the use of natural stones in architectural designs. Since architectural designs affect landscape designs in the projects examined, these projects are also included in the study. For this reason, the projects examined are divided into three categories: architectural design, landscape design, and designs that contain both.

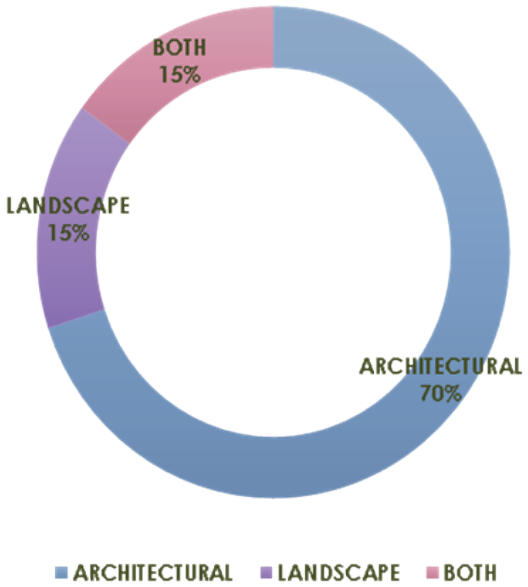


Figure 2. Distribution of project types.

According to Figure 2, the designs selected and analysed are 70% architectural and 15% landscape design. The proportion of natural stones in both landscape and building design is 15%. Accordingly, it is determined that natural stones were mostly used in architectural designs in the projects examined.

The usage functions of the designs examined vary. It has been determined that the project functions in the designs are housing, gardens, squares/-parks, social facilities, residences, religious facilities, office- store- showrooms, factory sales centres and hotels. According to Figure 3, 40% of the designs examined are residential buildings. These were followed by garden designs for private residences with a rate of 16%. Squares and parks, social facilities, commercial housing and religious facilities are 8%. Other functions remained at 4%. According to the findings in the graph, the greatest use of natural stone was found in residential buildings.

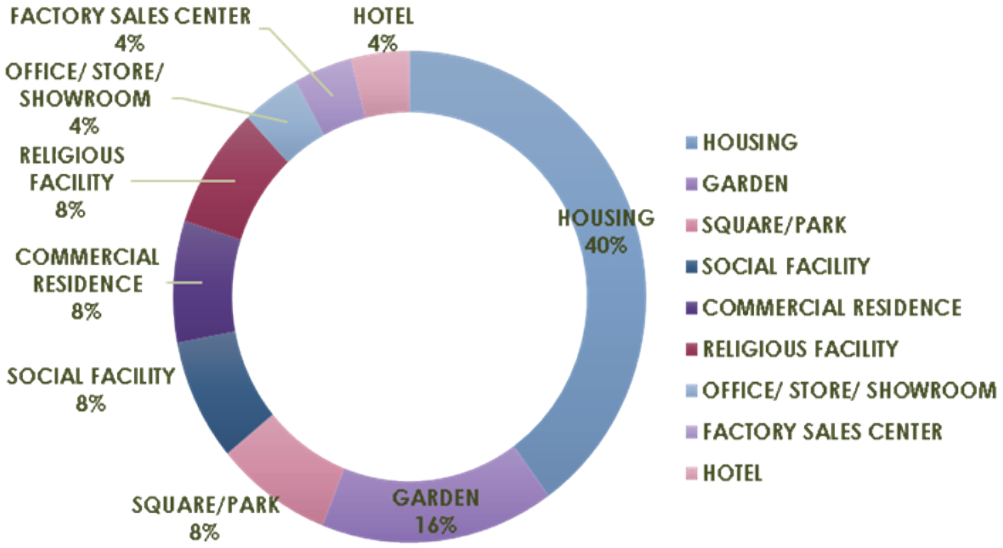


Figure 3. Distribution of project functions.

Data regarding the construction years of the designs are presented in Figure 4. Accordingly, the designs examined were completed mostly in the year 2019, with a rate of 20%. This is followed by 2008, 2013, 2015, 2020 and 2021 with a rate of 10%. Again, according to the data in the figure, the construction of the projects was completed in 1997, 2009, 2014, 2016, 2017 and 2019 with a rate of 5%.

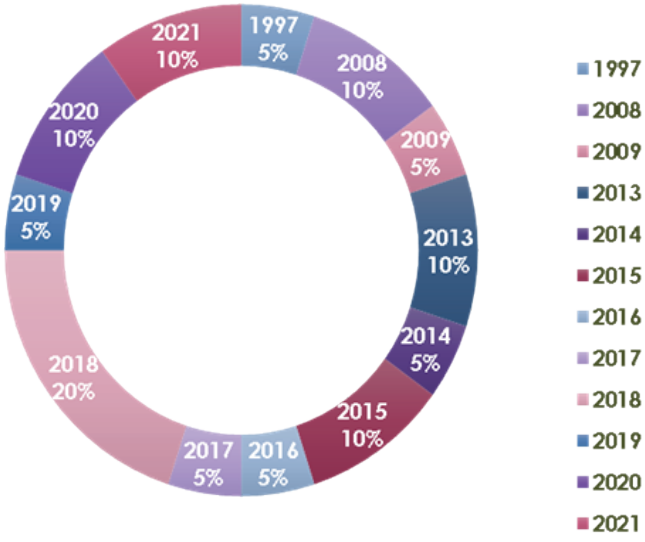


Figure 4. Distribution of project construction years.

As a result of the selection criteria of the study, designs in our country were selected. However, the provinces where the designs are located differ from each other. Findings regarding the construction locations of the designs are given in Figure 5. The designs examined were mostly located in Istanbul with a rate of 45%, followed by Izmir with 15% and Muğla with 10%. In provinces such as Bursa, Çanakkale, Adana, Afyon, Zonguldak and Kayseri, the rate is 5%.

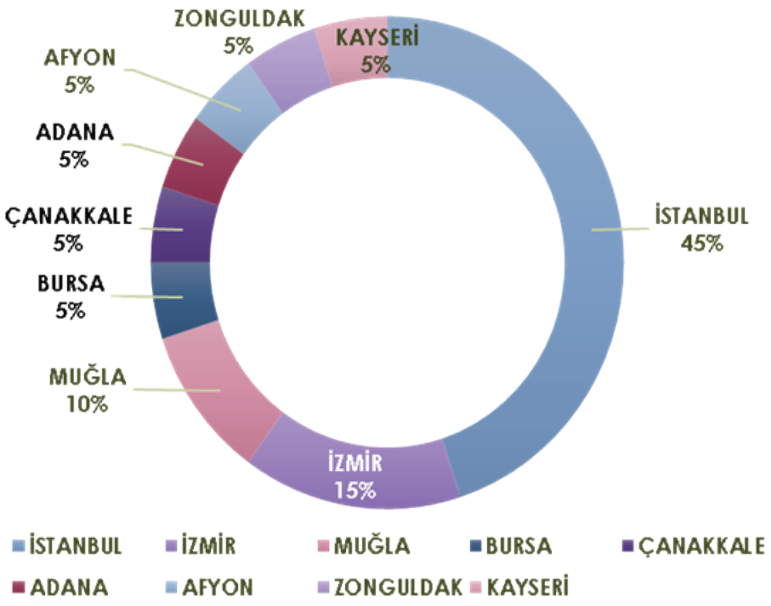


Figure 5. Distribution of project locations by province.

Findings on the Use of Natural Stone in Designs

The natural stones used in the architectural designs examined according to the determined criteria are listed in Figure 6. Accordingly, the most common natural stones used in designs are basalt, limestone and slate. These three natural stones are followed by marble, travertine, granite and andesite. The fact that basalt, limestone and slate are most common in the structures can be explained by the fact that these natural stones are easily extracted from our country's reserves, processed and generally cost-effective. Since the ease of use of the material is higher than with other natural stones, it is seen that it was more preferred in the designs examined.

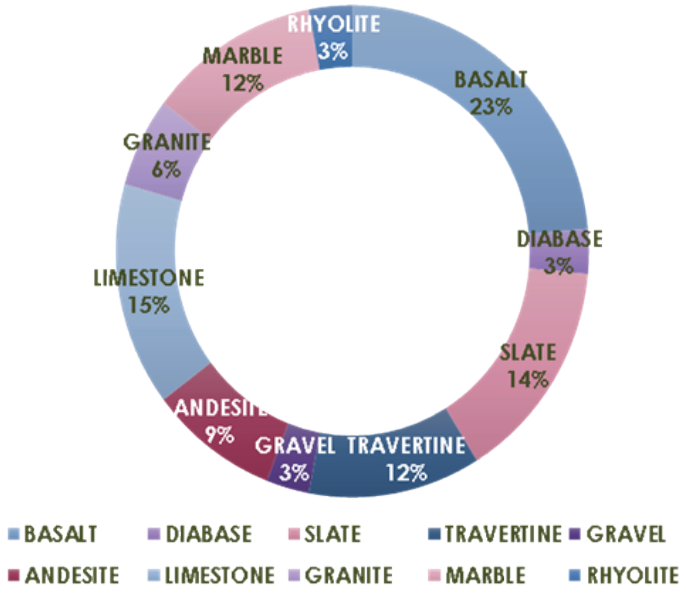


Figure 6. Used natural stones on selected projects.

In Figure 7, the functions of natural stones used in the architectural projects are examined. Consequently, it is seen that natural stones are mostly preferred as cladding elements on exteriors and facades of today's buildings. This is followed by the use of the stones as an outdoor floor covering material. The aim is to protect the structure against uncontrollable external factors and to extend the life of the structure. In addition, considering that the first part of the architectural buildings that will be experienced by the human eye is the building facade and its general appearance, it should not be overlooked that the aesthetic status of the natural stones preferred on the facades also affects this.

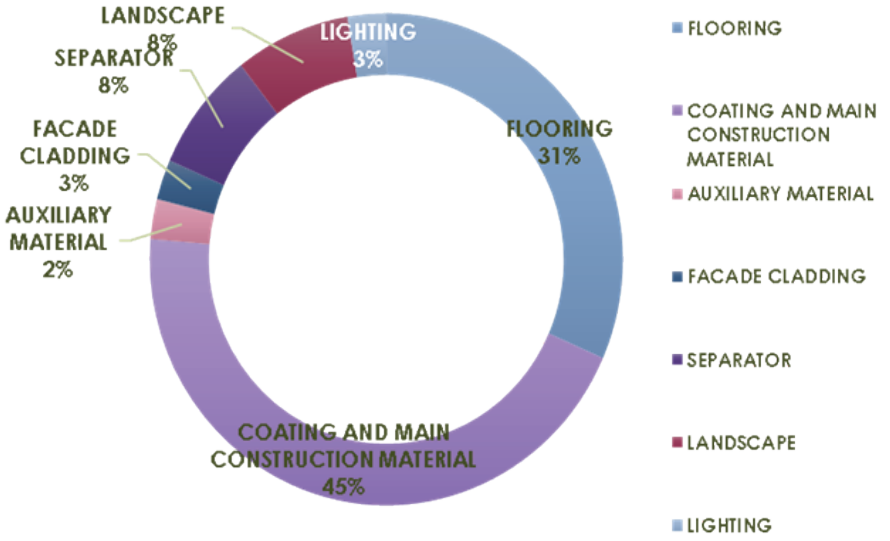


Figure 7. Functions of natural stones.

The forms of natural stones used in the architectural projects are examined in Figure 8. Natural stones appear in three different forms. These forms are the processed and specially shaped rectangular form, the curvilinear form shaped according to the design and generally used with computer-aided programs, and the free form used with the more natural state of the stones.

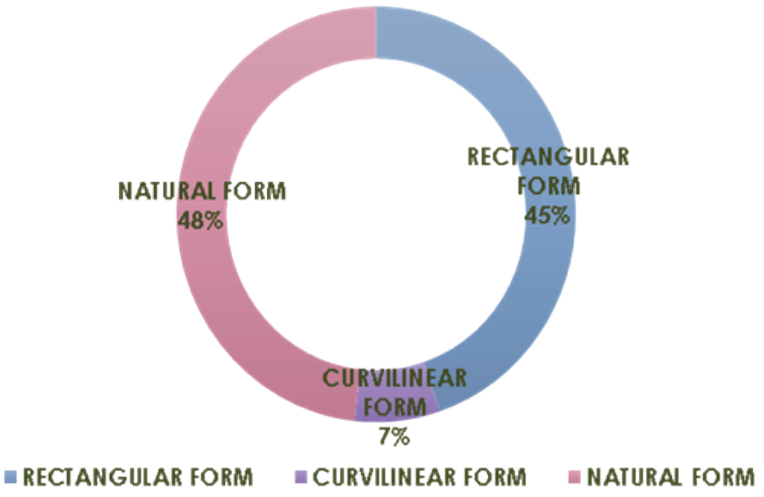


Figure 8. Forms of natural stones.

However, there is no connection between the type of natural stone and the difference in shape. For example, limestone is included in its free form in some projects, while in others it is shaped rectangularly. This situation seems to depend on the design structure rather than the physical and chemical properties of the natural stone.

Figure 9 gives the main colours of the natural stones in the designs. It is seen that the natural stones in the selected projects are used in six different main colours. However, natural stones are mostly found in shades of grey. This is followed by yellow. The reason for this situation is the physical and chemical properties of natural stones. The fact that a single type of natural stone has more than one colour results in diversity in designs. Most of the time, this feature of the material allows the design to take shape.

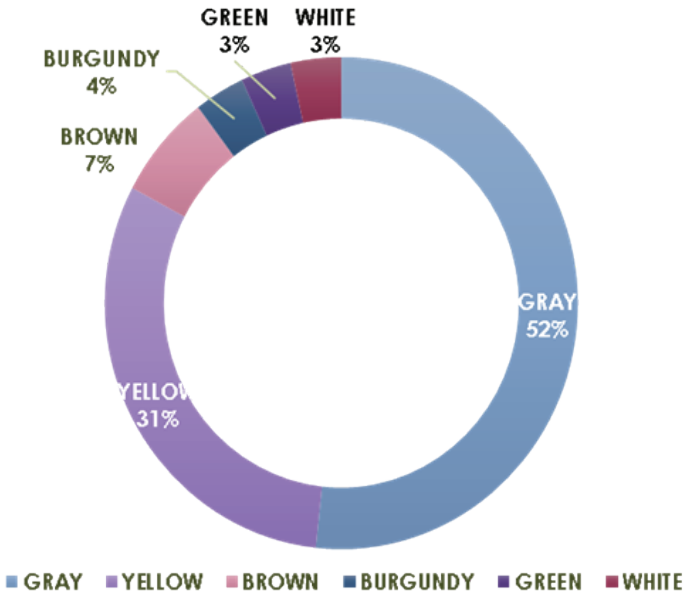


Figure 9. Colours of natural stones.

The texture and pattern perceptions of natural stones used in the examined architectural projects are given in Figure 10. In reference to this, even if the type of natural stone is the same, the perception of texture and pattern also changes as its other properties differ. For this reason, the relationship between the natural stone used and its texture and pattern is unique for each project.

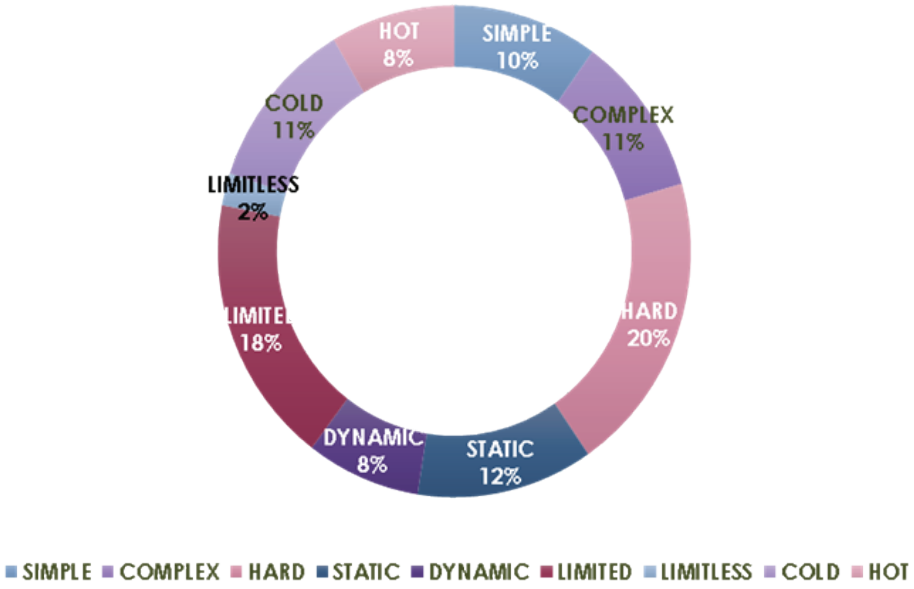


Figure 10. Perception of texture and pattern of natural stones.

The physical and chemical properties of natural stones vary depending on their type, place of extraction and rate of foreign matter in their components. This situation not only affects the economic dimensions, but also affects the processing and ease of application of natural stone, either positively or

negatively. When the natural stones included in the designs are examined, many different features are encountered. However, there is no common point between the usage situations and the physical-chemical properties of the selected natural stones in the project. Although the factors affecting the choice of natural stone depend on physical and chemical properties, the choice of natural stone used in a project depends on its colour, while the use of the same natural stone in a different project is to adapt to the locale, and in another, the ease of application of natural stone independent of each other.

A similar situation can be discussed for the economic dimension. All natural stones used in the projects are supplied from our country's reserves. However, natural stone that is seen and applied as an economic choice for a project cannot necessarily be seen as an economic choice for a different project because the reserve could be located far from the building construction area. Therefore, the economic dimension varies from project to project.

The application details of natural stones in the designs examined can be grouped under four main headings: jointed application, free application with mortar, jointless anchoring application, and other applications. In jointed applications, the natural stone used as flooring or facade cladding is formed into the desired shapes and then mounted with an auxiliary material, such as adhesive, and the joints are filled. The material between the joints varies depending on where the natural stone is used and whether it is flooring or the facade cladding. The material between the joints in facade cladding may be a chemical compound. In floor coverings, permeable materials can be used for the joints. The free application is the more traditional masonry technique. Even if this technique is applied in the projects examined, except for the garden wall, the main load-bearing system of the structures differs from reinforced concrete and steel. Even if the free technique were applied, natural stone was not used as the main load-bearing masonry system in any of the projects examined, but was included as an auxiliary and support element to the main system. In jointless anchoring applications, an auxiliary structure is created that is mounted on the main carrier system, and natural stone plates are mounted to this system chemically or physically. This method has been preferred, especially in more complex designs. In other applications, natural stone is made suitable for use with different materials such as a honeycomb. In this application, the natural stone is thinned considerably, preserving its strength and reducing fragility. Figure 11 shows the application situations of natural stones divided into 4 main headings.

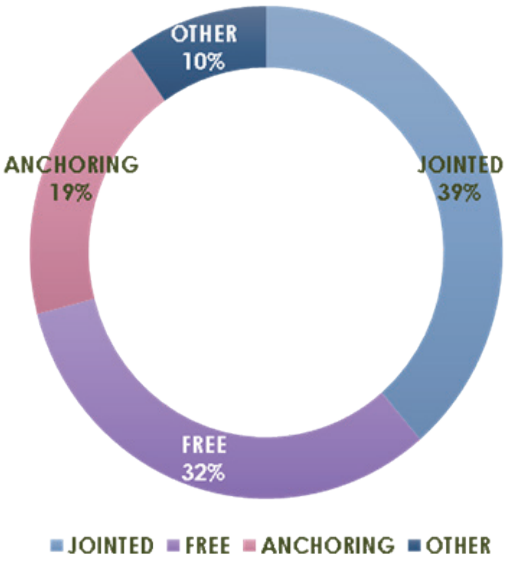


Figure 11. Application techniques of natural stones

The most preferred application detail in designs is the joint application. Subsequently, comes a free application. This technique, which is seen as more traditional, is used less currently. This is followed by the anchoring application and other techniques.

Each project examined has required a different design decision. For this reason, the reasons behind material selection also vary from project to project. Accordingly, the design goals of natural stone selection in projects are different from each other, especially regarding the durability of the material, its aesthetic status such as colour-texture-pattern, its adaptation to the local texture, its ability to be processed in different ways, and its ability to transmit light, space formation and cost. The design goals of the same type of natural stone in different projects are also different.

Natural stones have been used structurally in projects such as flooring, roofing and facade covering materials, hard flooring, elevation and boundary determination, masonry construction elements and lighting elements. They are located on vertical and horizontal planes.

When interviews were conducted with architectural project designers, it was determined that some meanings were attributed to the natural stones in the projects. Of the 32 natural stones used in the samples examined, the number of natural stones with a significance of design is 11. In this case, different meanings were attributed to proportionally 34% of the use of natural stone.

Each natural stone used was used with different materials. These materials are concrete, steel and other metals, glass, brick, wood and other natural stones, respectively. Even natural stones used as masonry are supported with different materials.

A total of 27 of the natural stones are not considered local materials. However, it was determined that for 22 of them, even if there was no local material, they were supplied from nearby regions. Our country is rich in natural stone reserves. In this way, each natural stone included in the projects was procured from local reserves.

Although some of the selected natural stones may seem a little more costly at first, the situation changes when the lifespan of the structures is considered. In terms of general cost, the maintenance cost of each natural stone is low, easy to clean and long-lasting. They are also thought to be a more environmentally friendly and natural material than newly produced construction materials. It is clear that the material will provide an advantage in the long run in terms of the economic situation, thanks to these properties.

Our country is also rich in underground natural stone resources, and there is a variety of natural stone types. Local stones extracted from different regions have been used as the main carrier material of buildings for centuries. Historical buildings using natural stone, one of the oldest construction materials can be found almost everywhere in our country.

New materials discovered along with technological developments have pushed the use of natural stone in the construction sector into the background. In today's conditions, the use of natural stone as the main construction material in buildings is very rare, except for restoration projects. However, in today's architectural projects, the situation of this material being pushed into the background is changing.

According to this study:

- Natural stones are mostly found in architectural designs and housing projects. This situation is related to the higher rates of architectural design and housing projects compared to all projects. Additionally, private housing projects provide flexibility in terms of design and material selection.
- Since 2018, the use of natural stone has become more prevalent. The return to natural materials also increases the use of natural stones. This situation is increasing in today's projects.
- Istanbul stands out on a provincial basis, which is the centre of the construction industry.
- The most commonly used natural stone is basalt. The general properties, durability and cost, are the main factors. It is preferred for practical reasons; its design and aesthetic features are in the background. This natural stone is found especially in large areas and in places that are not protected against external influences.
- Natural stones are more common in the facade designs of the exteriors of buildings. Different types of natural stones allow diversification of facade designs.
- A rectangular form is more preferred. However, the use of free forms is also quite common.
- Natural stones are used in grey colours. In general, harmony is at the forefront of colour selection.
- Texture-pattern perception is complex, hard, static, limited and cold. The structural properties of natural stones are reflected in this situation.
- The purpose of using natural stones in designs is related to the durability of the material.
- Natural stone is mostly used as a structural coating material. It does not have a structural bearing feature. However, support is provided to the structure in projects used together with steel structures.
- The meanings attributed to natural stones in design are in the background, but they stand out with their physical and chemical properties. The significance of stone is ensuring adaptation to the local texture. However, this is only valid in places where the natural texture does not deteriorate much.
- In each project, natural stones were used with different materials or textures.
- Preference for local materials is in the background, but it is preferable to procure the materials from nearby places.
- The material has low maintenance costs, is long-lasting and resistant to external factors, and is a highly accessible material.
- In today's conditions, natural stones have many application details to meet different problems. The important point is to use the appropriate detail in the appropriate place.

CONCLUSION AND RECOMMENDATIONS

Natural stones have been used in the load-bearing systems of buildings and in creating space since the times when humanity's need for shelter arose. The periodic use of natural stones in a structural sense was originally limited to local stones obtained from the immediate environment. This has led to the materials used in buildings in a particular region being similar. In addition, its use has

played a major role in the development of knowledge and the processing of local natural stones. Although the physical and chemical properties of natural stones are quite different from each other, they are generally resistant to external factors and human use, are long-lasting and require little maintenance. For this reason, the use of natural stone stands out in the majority of period structures that have survived to the present.

The discovery of new construction materials and methods along with technological developments causes the use of natural stone in today's buildings to change. Compared to historical buildings, natural stones are applied with different details today. It is seen that the developments in construction materials and methods first put the use of natural stone into the background. However, the interest in natural, environmentally friendly, long-lasting and sustainable materials that has emerged in recent years has led to the return of natural stones in the building and construction sector. Unlike its past use, criteria such as colour, texture, pattern, shape, size, physical and chemical properties, different application details, economic and aesthetic status of natural stones have also become important in today's buildings.

When sample projects were examined, many advantages were identified regarding the use of natural stones in buildings. It can be seen that natural stones are very durable materials. Despite their durability, they can be processed differently. Each different process enables the usage area of natural stone to expand. They can be found in different colours, patterns and textures depending on the proportions of the components in their structure. This helps create a wide catalogue in terms of aesthetics. It also provides diversification of architectural designs.

When the application details are examined, it is seen that a different detailed solution has been developed for each problem that may be encountered. In particular, combining stones with other materials is one of the detailed solutions developed.
It has been stated that the use of natural stone increases the overall cost in the initial process, especially when compared to artificial materials. However, since the material can be obtained from our country's resources, the cost of transportation of natural stones to the construction site decreases. In addition, being a long-lasting and low-maintenance material provides an advantage in the long term.

The loss rate of natural stones as waste material is very low. For example, if the stone used as a facade cladding material in a building turns out to be damaged, it is possible to use the material as crushed stone in landscape designs. In addition, if the natural stone used in a structure is durable, it can be reused in other structures. This is an important point in making natural stones sustainable materials. Similarly, the possibility of reusing the material also provides an advantage in the overall cost.

Technological developments in the construction sector have, for the first time in the historical process, negatively affected the use of natural stone. These new and artificial materials are lighter and less costly than natural stones. However, they are inferior to natural stones in terms of durability and longevity. They cannot be used to support the main structure system, as seen in the examples in the examined projects. The main purpose of the production of artificial stones is to, as much as possible, make them visually similar to natural stones. For this reason, their surfaces are coloured with harmful chemicals to imitate natural stones. Although this increases the resistance of artificial stones used outdoors

to weather conditions, it also increases the possibility of the material harming human health. For this reason, the use of artificial materials that look like natural stones in designs is not encouraged.

However, there are also many benefits that technological developments have brought to the use of natural stone, especially in the last 25 years. Thanks to computer-aided machines, natural stones can be shaped in precise dimensions, organic lines and as thin a section as possible. In this way, the desired design can be presented with clean workmanship, regardless of the design scale. Similarly, shaping natural stones into thin sections to be light and flexible paves the way for their use in different designs, especially furniture.

Despite all these advantages, the structural properties of even the same type of natural stones vary depending on where they are mined, making effective cataloguing difficult. Differences in structural features also limit the prediction of problems that will be encountered during application. However, it is thought that examining the condition of the materials on the structures built in recent years will reduce prejudices about natural stones and improve the details of their use in practice. In this way, the way is paved for this natural material to be preferred in contemporary buildings.

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Conflict of Interest

No conflict of interest was declared by the authors.

Authors' Contributions

The authors contributed equally to the study.

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Ethics Committee Approval

Ethics committee approval was not required for this article.

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BIOGRAPHY OF AUTHORS

Göksu Yıldırım graduated with a bachelor's degree in architecture from Anadolu University in 2019, Her academic journey continued with a Master's degree at Kocaeli University between 2020 and 2023, where she focused on natural stones in Contemporary Architecture, and is currently pursuing doctoral studies in the same department. Since 2019, she has been a part of the private sector, contributing diverse projects of varying scales.

Nevnihal Erdoğan received her architecture diploma from İstanbul Technical University in 1982, and her M.S. and Ph.D. in 1984 and 1992. She taught at Trakya University's Department of Architecture from 1992 to 2006 and is now a professor at Kocaeli University, Department of Architecture. She has been a visiting scholar at UC Irvine's Department of Urban and Regional Planning and UW-Milwaukee's School of Architecture. She teaches undergraduate and graduate courses in architecture design and theory and supervises master's and doctoral theses. Her research interests include the relationship between culture and architecture, housing and settlement, architecture design, and architecture and literature.