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Marble manufacturing in Turkey and proposals for the reuse of marble dust in building products.

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Emir Kamis, Mugla white marble quarry, Turkey, 2023

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Abstract

The thesis explores the possibilities of reuse of marble dust - waste from extraction and processing - to create new sustainable products for the construction industry. The marble extraction and processing chain is illustrated with specific reference to Turkey, one of the main marble exporting countries in the world. In particular, thanks to a direct on-siteinvestigation, the activity of the Kentmer quarry of Mugla white marble is explored in depth, using the case study also to introduce the main characteristics of the material, the processing phases and the main uses, both traditional - within the architectural heritage - and innovative. After analysing the different types of marble waste, the thesis focuses on marble dust, highlighting its current uses in Turkey, also considering its level of sustainability. The investigation focuses on a technique used in the artistic field that reuses marble dust. In the scenario of reuse of the waste product investigated in the thesis, this technique, explored in depth with a direct collaboration with artists, is adapted and transferred to the construction field for the production of interior cladding panels. Through the production of laboratory samples, the scenario is explored by highlighting the strengths and weaknesses of reusing marble dust in combination with hemp fibre and lime.

La tesi esplora scenari di impiego di polveri di marmo - scarto dell'estrazione e della lavorazione - per realizzare nuovi prodotti sostenibili per l'edilizia. La filiera di estrazione e lavorazione del marmo viene illustrata con specifico riferimento alla Turchia, uno dei principali paesi esportatori al mondo. In particolare, grazie ad un'indagine diretta sul campo, si approfondisce l'attività della cava Kentmer di marmo bianco di Mugla, utilizzando il caso studio anche per introdurre le principali caratteristiche del materiale, le fasi di lavorazione e i principali usi sia tradizionali - nell'ambito del patrimonio architettonico - che innovativi.
Dopo aver analizzato le diverse tipologie di scarti di marmo, la tesi si concentra sulla polvere di marmo evidenziando gli attuali utilizzi in Turchia, considerandone anche il livello di sostenibilità. Nell'indagine è emerso l'interesse verso una tecnica utilizzata in campo artistico che reimpiega la polvere di marmo. Nello scenario di riutilizzo del prodotto di scarto indagato nella tesi, questa tecnica, approfondita con una collaborazione diretta con artisti, viene adattata e trasferita nel campo dell'edilizia per la produzione di pannelli di rivestimento per interni.
Attraverso la realizzazione di campioni in laboratorio, lo scenario viene esplorato mettendo in evidenza i punti di forza e debolezza del reimpiego della polvere di marmo in combinazione con fibra di canapa e calce.

1. MARBLE IN TURKEY

1.1 The formation of genuine marble and its properties

Minerals change, recrystallize under the influence of pressure and temperature, and the rocks formed as a result of this mineralogical change are called metamorphic rocks, that is, rocks that have undergone metamorphism.
Marble (genuine), which is frequently preferred as a building material due to its bright, colorful appearance, is a type of metamorphic rock.
Since pressure and temperature are essential for the formation of marble, these natural stone types are formed in regions with volcanic activity.
Calcite mineral ($CaCO_3$) constitutes a large proportion of the compounds of marble (90-98%) and as its percentage increases, the marble becomes whiter.
On the other hand if dolomite, which is both a mineral and a rock type, is more abundant than calcite in the structure of marble, the marble is called dolomitic marble.

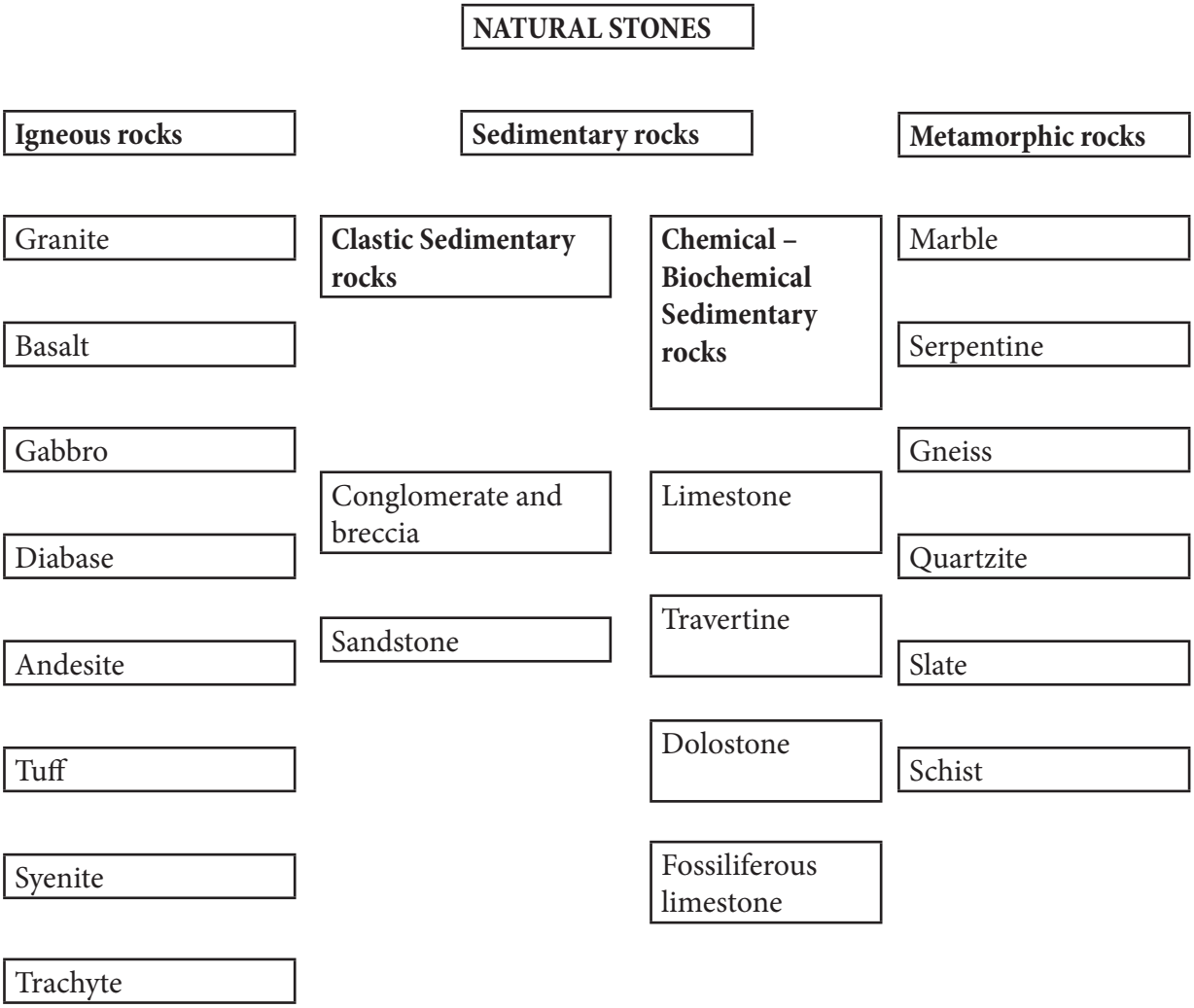
The physical properties of marble become more apparent as the material is processed.
One of the most important point in marble processing is the hardness of marble.
The fact that marble has a hard surface can be seen as an advantage or disadvantage depending on the field where it will be used.
Although natural stones with a softer surface are easily shaped, they are sensitive to impacts and therefore not suitable for every use. In addition to the hardness of marble, its brightness is also an important feature and determines the usage area of the stone. Marbles with a fine crystalline or non-crystalline structure are preferred for interior and exterior wall cladding because they shine more.

On the other hand, the porosity feature of marble provides information about the lifespan of the material. In marbles with large and dense pores, rainwater can penetrate into the inner layers and have a negative impact on the lifespan of the marble. These types of marbles are more frequently preferred in interior designs.

Another important feature that determines the usage area of marble is its veined and cracked structure, which makes it difficult to process the material without breaking into pieces. During the processing of this type of densely veined marbles, the vein structure is examined and the processing of the stone takes time. Marbles, which have a dense vein structure, are used in interior wall claddings due to their aesthetic appeal.

Properties of marble, such as its durability and water absorption, are also among the features that determine the lifespan of the material. It is important that the marble used in floor coverings has low water permeability and high compressive strength due to its contact with water and load placed on it.

Classification of natural stones according to their types



(Yüzer, Güngör, Angı 2008)

About metamorphism

Rock name(pre- metamorphism)	Rock name(post- metamorphism)
Limestone	Marble
Granite	Gneiss
Sandstone	Quartzite

Names of the rocks most used in natural stone processing pre (before metamorphism) and post-metamorphosis (after metamorphism) (Kulaksız 2005)

About minerals

Minerals	Hematite	Limonite	Chlorite	Graphite	Manganese minerals	Sericite
Colors	Red, Pink	Yellow , Brown	Green	Grey or Black	Close to pink	Pearl shine

Minerals that give different colors to marble, conversation with Prof. Dr.Gürsel Yanık, March 1, 2024

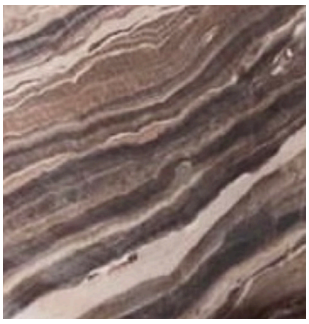
Name of the rock	Limestone	Dolostone
Type of the rock	Sedimentary rock	Sedimentary rock
Mineral ratio	90% Calcite, %10 Dolomite	90% Dolomite , %10 Calcite

Dolomite is both a rock and a type of mineral (Kulaksız 2005)

Marbles according to their chemical content

Although marbles containing the calcite mineral in high amounts are called genuine marbles, some natural stones are called industrial marbles because they resemble marbles in terms of their physical properties, but their chemical content is different.

Genuine marbles	**Common properties**	**Industrial marbles**
Chemical content: 90-98% calcite mineral	Aesthetically pleasing	Chemical content: Different minerals
Physical property: Pure and bright appearance	Commercially valuable	Physical property: Colorful appearance
Example: Mugla marbles		Example: Onyx marbles



(Çal 2024)

Marbles according to their crystalline structure

Having a fine or thick crystalline structure of marble is one of the important features that affect its external appearance. As the marble crystalline structure becomes finer, it has a brighter appearance and this adds commercial value to the marble.

Mugla marble with a thick crystalline structure (Kamis 2024)

Mugla marble with fine crystalline structure (Kamis 2024)

Marbles according to their vein structure

The formations found on the surface areas of natural stones that resemble the veins in the human body are called veins of the stone. Especially marbles have a visible vein structure due to their geological formation, and these are described as having an aesthetic appearance.

Mugla white marble with no obvious vein structure (Bağcı 2023)

Mugla grey marble with prominent vein structure (Bağcı 2023)

Gebze marble with very distinct vein structure (Kamis 2023)

1.2 The use of marble in Turkish architectural heritage

The Republic of Turkey has a multicultural social structure with its geographical location and the different civilizations it hosts. In particular, the fact that the cultural heritage from many Anatolian civilizations is within the borders of the Republic of Turkey today, and that the heritage of important states such as the Seljuk and Ottoman Empire is also located on this territory, has played an important role in the formation of the cultural structure of Turkey.

Many works in Turkish history, especially in terms of architecture, have been inherited from the Seljuk and Ottoman periods and have survived to the present day. Natural stones with aesthetic value, such as marble extracted from quarries especially in the Anatolian region, were used in the construction of these works. While limestone and volcanic tuffs, which are easily processed stones, were used in the architecture of Anatolian civilizations and the Seljuks, the use of marble was preferred in Ottoman architecture (Yüzer, Güngör, Angı 2008). Due to the wide borders of the Ottoman Empire, natural stones from different continents such as marbles from Verona, Italy were brought to Istanbul and used in the construction of important architectural works there.
Natural stones are among the most preferred materials not only in Seljuk and Ottoman architecture but also in Roman architecture.
Limestone, porphyry, marble and serpentine breccia were used in the works made during both the Western and Eastern Roman periods, and some of these architectural works are accepted as a part of the Turkish architectural heritage.

The most important marble quarries for Turkish architectural heritage are Marmara and Afyon marble quarries. Marmara marbles extracted in Marmara Island have been used in the columns, entrance doors, claddings and baths of many historical buildings.
Afyon marbles were mostly preferred for interior and exterior cladding and stand out with their color and texture options.

Important historical buildings where Afyon and Marmara marbles were used in their construction

Columns made of red porphyry , Hagia Sophia, 532-537 AD, Byzantine Emperor Justinian I(Eastern Roman Emperor Justinian I) , Istanbul, Turkey
(https://www.pallasweb.com/deesis/columns-and-capitals-of-hagia-sophia.html)

Hagia Sophia, which has been an important religious building in both Christian and Muslim history from past to present, has an important place in the culture of the Byzantine and Ottoman as it served as both a church and a mosque in different periods. In the construction of Hagia Sophia, which was designed as a work of Byzantine architecture and underwent various transformations in later periods, natural stones such as Marmara marble, porphyry, Afyon marble and serpentine breccia were used (Yüzer, Güngör, Angı 2008).

Gate of Sultan, Dolmabahce Palace, 1843-1856, Sultan Abdulmejid I, Istanbul, Turkey
(https://nalanyilmaz.blogspot.com/2002/11/dolmabahe-saray-kap-sslemeleri.html)

The design of Dolmabahce Palace, which was built in a period when the western influence began in Ottoman architecture (Neo-Baroque), was inspired by different architectural styles. The carvings on the Gate of Sultan, which is one of the entrance of the palace used by the sultans, are made of Marmara marble.

Picture of restoration work on the Gate of the Sultan in 2020, Dolmabahce Palace, Istanbul, Turkey (https://www.haber7.com/seyahat)

Aesthetic figures on the Gate of the Sultan were obtained by carving Marmara marble from the block.

The Hurrem Sultan Hammam, Istanbul, Turkey
(https://www.aa.com.tr/tr/yasam/tarihi-hurrem-sultan-hamaminda)

The Hurrem Sultan Hammam, built between 1556-1557 in the name of the Hurrem Sultan, the wife of Sultan Suleiman (Sultan of Ottoman Empire), is one of the most important baths of Ottoman architecture. Marmara marble was used in the construction of the bath, which was restored many times throughout history.

Sivas *Gökmedrese,* 1271 ,Vizier *Sâhib* Ata, Sivas, Turkey (https://pbase.com/dosseman/image/29239641)

Sivas *Gökmedrese*, where education was given in many different fields during its time, is one of the important works representing the Seljuk architecture with its herbal and geometric motifs in relief, tiles and portal. These reliefs, which are quite common in Seljuk architecture, are obtained by shaping natural stones such as limestone, travertine and volcanic tuffs (Yüzer, Güngör, Angı 2008). The white Marmara marble used in the portal ensures that *Gökmederese* has a brighter entrance.

Important historical buildings where marbles brought from Europe and Arabia were used in their construction

Suleymaniye Mosque, 1551-1557, Sultan Suleiman I, Istanbul, Turkey (https://www.ademder.org.tr/blog/camiilerimiz/suleymaniyecamii)

Many types of marbles in different colors such as Marmara marble brought from the Marmara Island, green marble brought from Arabia, Verona marble brought from Italy were used in the construction of the mosque, which was built by Sinan the Architect by the order of Sultan Suleiman (Yüzer, Güngör, Angı 2008).
Suleymaniye, one of the most important mosques in Istanbul with its architectural style where simplicity comes to the fore and its location to the Golden Horn, also reflects the diversity of Ottoman architecture in terms of building materials.

Columns made from Verona marble, Suleymaniye Mosque (Yüzer, Güngör, Angı 2008)

1.3 Turkey's marble reserve potential and trade

Turkey, which experienced various difficulties in terms of production during the collapse of the Ottoman Empire and the proclamation of the republic, had to provide raw materials from foreign countries for many years. With the investments made in the field of industry in the 1960s and the increasing population, Turkey began to have the opportunity to process its natural resources. The geography of Turkey is very rich in terms of underground resources and has many different natural stone reserves. Afyon marble quarries, Marmara marble quarries, and marble quarries in the Aegean and Mediterranean regions are located within the borders of the Republic of Turkey.

With today's research and the definition of some natural stone types as marble, it is thought that Turkey has more than 40% of the world's marble reserves (Altındağ 2018). Especially with the end of the 90s, the establishment of many different marble manufacturing facilities and the increasing demand in the domestic and foreign markets have positively effected Turkey's marble trade.
Around 1500 marble quarries, most of which are white marble quarries, are located within the borders of Turkey, and it is known that the marbles extracted from these quarries have more than 120 different tone and color options (Çetin 2003). Marmara region (Marmara Island and Balikesir province) which is the region with the most marble reserves in Turkey, is the region where historical Marmara marble is extracted (Şimşek 2019).
In addition, Elazig cherry, Afyon marble, Supren, Gebze marble, Onyx, Mugla white marble, Mugla lilac marble, dolomites are among the important natural stone types that Turkey trades in both the domestic and foreign markets.
Turkey's rich marble reserves also appeal to customer groups with different budgets. While Marmara marble and Afyon marble , which are frequently used in both Byzantine and Ottoman architecture, are used in the claddings of luxury hotels in Israel, America and Arabia; Kavaklidere white marble and Isparta stone are also used in medium-sized projects in China (Çal 2024).

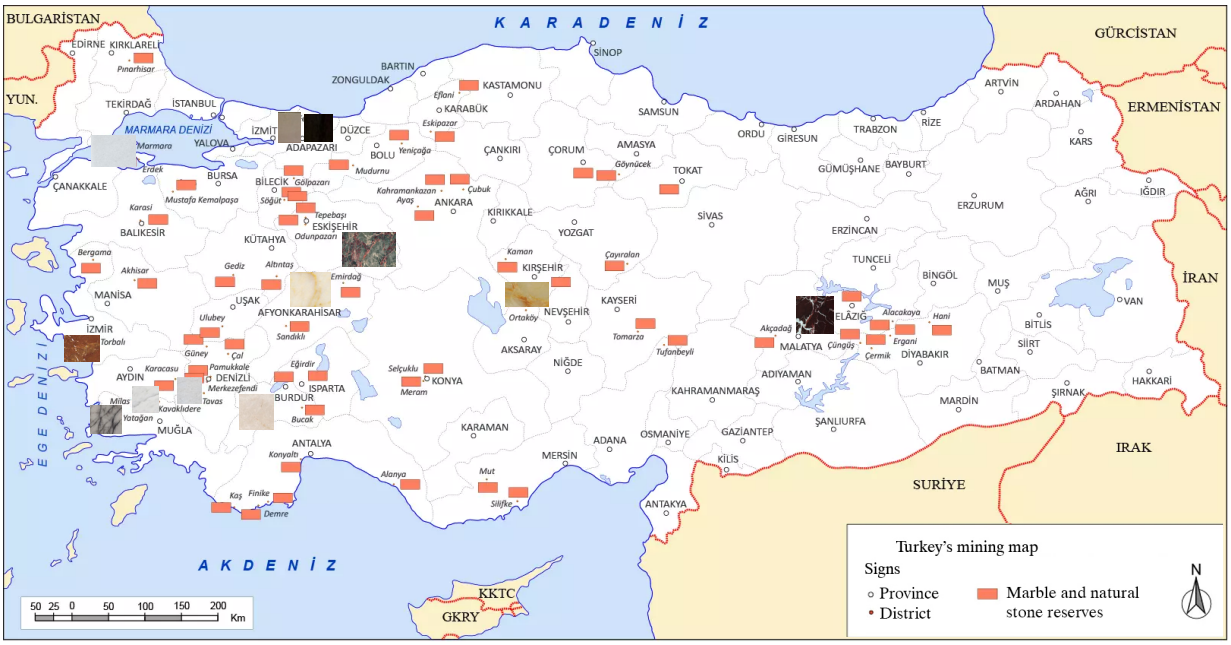
On the other hand, in lower budget markets such as North Africa and Central Asia, non-shining but economically suitable stones such as Kandira and Antalya are preferred. Since Kandira and Antalya stones are lighter, fragile and easily shaped natural stones , they come to the fore in more affordable villa projects, garden decorations, fireplace and fountain designs. These natural stones in white and yellow colors resemble the aesthetics of marble from afar and they are processed in many areas where marble is used.

Turkey's marble reserves

Region	**%**
Mediterranean	13
Eastern anatolia	3
Aegean	25
Southeastern anatolia	2
Central anatolia	17
Black Sea	6
Marmara	34

Distribution of Turkey's marble reserves across regions (Şimşek 2019)

Turkey's main marble and natural stone reserves



(https://www.mermerbank.com/2020) (The legend of the map was translated from Turkish to English by Emir Kamis)

Marmara marble

Kandira stone

Gebze marble

Supren marble

Afyon sugar marble

Aegean brown marble

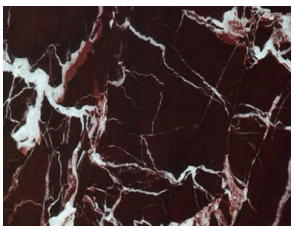
Mugla lilac marble

Mugla white marble

Pearl marble
(Bağcı 2024)

Burdur beige marble

Onyx marble



Elazig cherry marble

Current uses of Turkish marbles

Today, Turkish marbles are processed and used in many different fields such as architecture, art and design. While Marmara marbles are preferred as floor and wall claddings in Turkish baths, they are also used in art. Since onyx marbles are very aesthetic in terms of color and texture, they are preffered in bathroom countertops and sinks.

Use of Turkish marbles in architecture

Turkish bath made of Equator Marmara marble (https://www.efendioglu.com.tr/icerik/ekvator/)

Equator Marmara marble (a type of Marmara marble known as striped) is a marble that is currently exported to America and used in the claddings of hotels in Texas, New York.

Use of Turkish marbles in art

Artwork made from Marmara marble (Kamis 2022)

Marmara marble, brought from the quarry in blocks, was carved and transformed into the work of art shown in the picture.

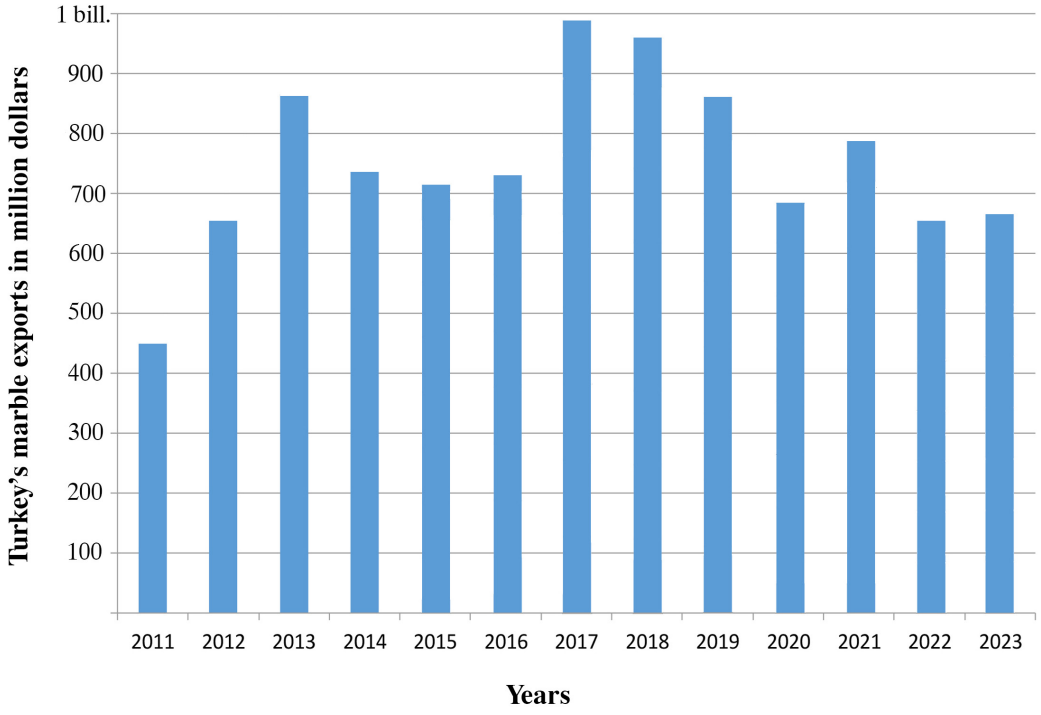
Use of Turkish marbles in design

Countertop and sink made from Onyx marble (Bağcı 2020)

While small-sized blocks of onyx marble are carved and turned into sinks, bathroom countertops are made from those cut into thin slabs.

Turkey's marble trade over the years

Turkey has developed in the marble export market, especially between 2000- 2023, and has become one of the important countries in this field. Especially with the investments and facilities made in the early 2000s, many marble reserves in the country were put into operation and great progress has been made in the 20-year period. Turkey, which exports both block marble and marble plates cut from blocks, is the leading country in the market within 2017.



Representation of Turkey's changing marble exports over the years in million dollars (https://www.mta.gov.tr)

Country	Export($)
Turkey	999.224
Italy	169.308
Spain	57.583
Iran	40.086
India	36.436
Macedonia	34.295
Pakistan	25.055
Namibia	20.989

According to Trademap data, block marble exports of countries in 2017, (1000 $) (Şengüler 2019)

1.4 Mugla marble

1.4.1 Marbles that are extracted in Mugla

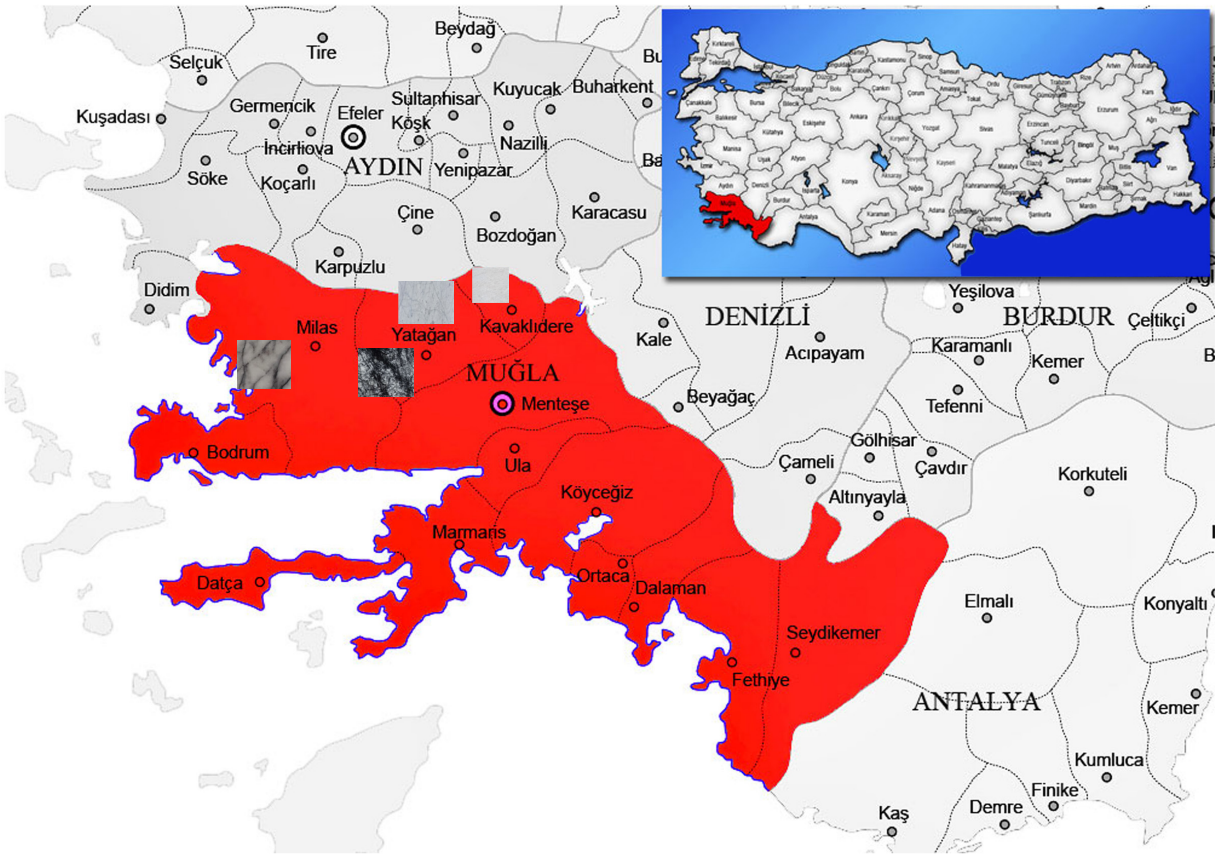
Turkey is a country rich in marble reserves due to its geological location (observation of metamorphism). Ancient marble quarries in Anatolia and the marble quarries in the Marmara region are prominent examples of this reserve richness. Especially the borders of Milas district of Mugla province of the Aegean region of Turkey (the region located in the Menderes massif) is an important reserve area where many different types of marbles are extracted (Ketin 1984).

Mugla, which has these rich marble reserves within its provincial borders, is mostly located in the Aegean region, but also has districts in the Mediterranean region. The province of Mugla, which includes the most valuable districts of the Mediterranean region in terms of tourism such as Datca, Marmaris, Bodrum and Fethiye, was previously a quiet city that hosted small fishing towns. Its natural resources had not yet been discovered and it had a small local population that made its trade mostly through fishing, agriculture and sponge diving. Investments made in the field of tourism during the Republic period after 1965, turned many districts of Mugla, especially Bodrum, into world-renowned holiday destinations (Bağcı 2024).
During this transformation process, Mugla needed more natural resources as a result of the increasing population with new architectural projects. With the supply of natural materials such as marble(required for architectural projects) from the Mediterranean region, Mugla marble quarries have been put into operation in the last 35 years.

Another factor that causes the active use of Mugla marble quarries is the stonemasons who settled in Mugla from Afyon province. Afyon quarries had many stonemasons and investors. After 1950, these people, who were experts in the field of marble, went to Mugla in order to discover new investment areas and started to process the marble reserves in the region (Bağcı 2024). As a result of the researches conducted here, Mugla marble quarries have become known both in the domestic and foreign markets.

Today, marbles such as Mugla white, Lilac, Pearl, Mugla dolomite white, Mugla dolomite gray and Mugla dolomite pink, which are extracted within the borders of Mugla, are among the valuable marble types that Turkey trades. Especially dolomite type marbles are valuable not only in the Turkish market but also in the world marble trade.
Dolomitic marbles have harder surface, brighter appearance and finer crystalline (or non-crystalline) structure than other marble types, and they are defined as more precious due to these features (Çal 2024). Many Mugla marbles such as Mugla dolomite white are used in the interior and exterior claddings of today's architectural designs to provide an aesthetic appearance.

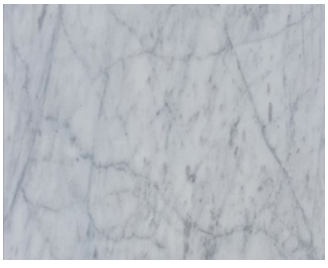
Mugla marble reserves



Important marble reserves in Mugla province (https://www.lafsozluk.com/2009/04/mugla)

Mugla lilac marble

Mugla black marble



Mugla white marble
(Bağcı 2024)

Pearl marble

City	Marble reserve
Mugla	400 million tonnes (total marble reserve)
Mugla	181 million m3(exploitable marble reserve)

Mugla's marble reserve potential (https://geka.gov.tr/tr/sayfa/mugla-sektorlerimiz-ve-yatirim-ortami)

City	District	Marble production (m3)
Mugla	Kavaklidere	3850
Mugla	Yatagan-Bayi (Mugla white)	26500

Monthly average production amounts of Kavaklidere and Yatagan-Bayir districts, which have an important value in marble production in Mugla (Bağcı, Karataş 2017)

1.4.2 Mugla white marble: properties, main applications, comparison with other white marbles

Among the marbles extracted in Mugla, Mugla white has become popular in recent years. Mugla white marble, known internationally as *Bianco Ibiza*, is among the important marble types exported by Turkey. Mugla white marble, which has a bright appearance due to its fine crystalline structure and is resistant to external factors with its surface hardness, is a marble that is highly demanded in both domestic and foreign markets (Çal 2024). With its low porosity, it minimizes water penetration. In this way, the lifespan of the marble is extended. Mugla white marble, produced by multiple marble manufacturing facilities in Mugla (Kentmer, Demircioglu), is exported to countries such as Israel, Arabia and America in the foreign market (Çal 2024).
Nowadays in the domestic market, Mugla white, which is used in hotel projects in the Mediterranean region, is also used in recycling due to the high calcite mineral it contains. Many different calcite facilities and artificial stone producers prefer the dust of Mugla white marble in their production. The fact that Mugla white marble is used in Turkish baths, fountain designs, interior and exterior claddings causes this marble to be compared with other types of marble in the domestic and foreign market.

Applications of Mugla white marble in architecture

Turkish bath made of Mugla white marble, Demircioglu Park Hotel, Mugla, Turkey(https://demircioglu parkhotel.com/spa--fitness-46.html)

Mugla white marble, which is cut from blocks into thin slabs and used as claddings, is also preferred in Turkish baths because it is resistant to temperature and humidity on the applied surface.

Mugla white marble used in bridge restoration Mugla, Turkey (Bağcı 2019)

Mugla white marble claddings, Puerto Venecia shopping center, Spain (https://www.stone-ideas.com/tr)

The most common application of Mugla white marble is exterior cladding. It is preferred on the exteriors of many hotels, especially in Europe, due to its white color, brightness and affordability.

The use of Mugla white marble in art

Abstract artwork (Bağcı 2021)

Blocks of Mugla white marble are carved into abstract works of art, and these works are displayed in the gardens of the villas in Mugla.

The use of Mugla white marble in design

Fountain (Bağcı 2023)

Blocks of Mugla white marble are carved into fountains. These fountains are placed at the entrance of the villas to create an aesthetic appearance.

Comparison of Mugla white marble with other important white marbles

Valuable marble types that Mugla white marble can be compared to are; Marmara, Carrara, Pentelikon (Pentelic) white and Makrana.

Marmara marble (Marmara Island, Balikesir, Turkey) is a marble that heats up and cools down slowly and can stabilize the temperature at a certain degree (Çal 2024). For this reason, it has been preferred in the construction of Turkish baths throughout history. Marmara marble is a more valuable marble type compared to Mugla white marble due to its shiny appearance, texture, surface hardness and the fact that it has been used in many important architectural works in history.

Carrara marble(Tuscany, Italy) is a very valuable type of marble which was used in the construction of important architectural and artistic works in many different periods.
The temperature and pressure during the formation of Carrara marble are at ideal levels, making this marble almost perfect in terms of brightness, hardness and workability.

Pentelikon white marble(Mont Pentelikon in Attica ,Greece), another type of white marble with a near-perfect formation like Carrara marble, was used in the construction of many important architectural works, especially the Parthenon, and was an important building material of the Hellenistic period. Its brightness, hardness and high amount of calcite mineral content are the prominent features of this marble type.

Apart from the valuable marble types in Europe, Makrana marble is extracted in Asia (Rajasthan, India) and has an important place for Mughal architecture.
Makrana marble, which was also used in the construction of Taj Mahal, is one of the brightest and most valuable marble types in the world with its 99 % calcite mineral content.

Although Mugla white marble is among the important marbles of today with its features, it does not have the same value as marbles such as Marmara, Carrara, Pentelikon and Makrana, which were used in the construction of very important works in the historical process.

Marmara marble

Carrara marble

Pentelikon white marble

Makrana marble

(https://www.stonecontact.com/)

Comparison table according to the properties of precious marbles

Name of marble	Carrara marble *(Marmo bianco di Carrara)*	Pentelikon white marble	Mugla white marble
Place of origin	Tuscany, Italy	Penteli region, Attica, Greece	Mugla, Turkey
The most known color	White	White	White
Water absorption	0.10 %	0.09%	0.17-0.20%
Density	2710 kg/m3	2715 kg/m3	2720-2780 kg/m3
Compressive Strength	125.0 -127.0 MPa	111.8 - 113.2 MPa	58.45-60.00 MPa
Important historical work in which marble was used in construction	The Pantheon, Rome, Italy	Parthenon, Athens, Greece	-

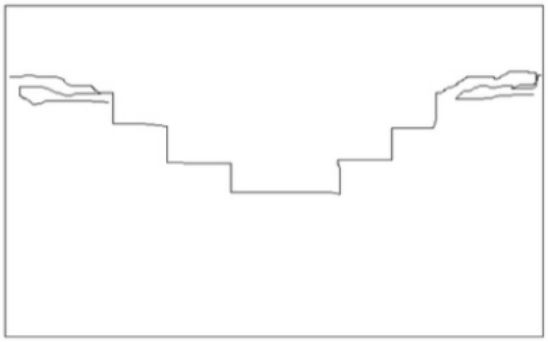
Name of marble	Makrana marble	Marmara marble	Mugla white marble
Place of origin	Makrana(city), Rajasthan(state), India(country)	Marmara Island, Turkey	Mugla, Turkey
The most known color	White	White	White
Water absorption	0.04 %	0.20 %	0.17-0.20%
Density	2690 kg/m^3	2710 kg/m3	2720-2780 kg/m3
Compressive Strength	96.0 MPa	69.04 - 117.7 MPa	58.45-60.00 MPa
Important historical work in which marble was used in construction	Taj Mahal by Ustad Ahmad Lahori (Mughal architect), Agra, India	Gate of Sultan, Dolmabahce Palace, Istanbul, Turkey	-

Comparison table by stonecontact

1.5 Marble manufacturing: extraction and processing methods

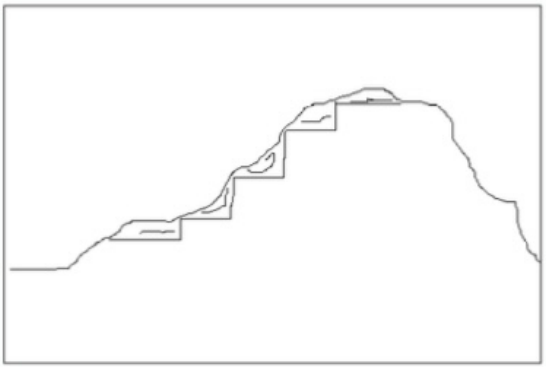
1.5.1 Classification of marble quarries according to their location in nature

Many natural stones, especially marble, are obtained by putting quarries into operation. In order to put these quarries into operation, the reserve area where the stone will be extracted is determined. Especially due to the commercial value of marble, a lot of investment is made in marble reserves around the world. Since the region where the marble manufacturing facility, including the marble quarry, will be built is located in nature, the project to be designed here is very important for production. Correctly determining the location and boundaries of the marble quarry increases block efficiency. Marble quarries are divided into three (plain, hillside, peak) according to their location in nature, and different manufacturing facilities are established for each type of quarry. It is possible to observe these three different quarry types, especially in countries with many different marble reserves, such as Turkey.



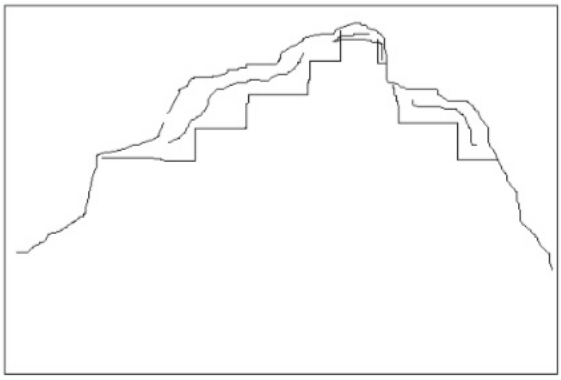
Sample drawing of plain type quarry (Güngör 2011)

Topographic level is very important for all quarry types. The quarries where excavations are carried out below this level and have a plain appearance are called plain type quarries (Güngör 2011). Since marble extraction in these quarries cannot be carried out above the topographic level, groundwater fills the land during the working period. Establishing a separate treatment system to clean these waters from the land is a high-cost process. Emirdag Afyon quarry can be given as an example of plain type quarries from Turkey (Çal 2024).



Sample drawing of a hillside (slope) type quarry (Güngör 2011)

Another important level in marble quarries, apart from the topographic level, is the pit floor level, which defines the lower limit of the quarry. The types of quarries where marble extraction is carried out are above this level are called hillside type quarries (Güngör 2011).
Kentmer Mugla white marble quarry can be given as an example of hillside type quarries from Turkey (Çal 2024).



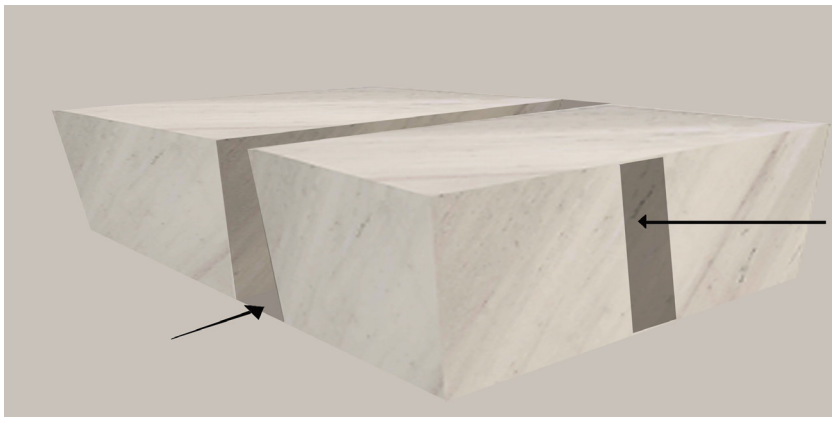
Sample drawing for peak type quarries (Güngör 2011)

The third type of quarries are the peak type quarries. Due to the geographical location of the mountain where they are located, these quarries become suitable for operation in the spring when the snow begins to melt (Güngör 2011). Hbb mining Afyon marble quarry can be given as an example of peak type quarries from Turkey (Çal 2024).

1.5.2 Stone extraction in the past and the stonemasonry

Today's changing technology and needs have also affected the stonemasonry. In the past, stone extraction (marble, travertine, etc.) was a difficult process that took a long time, using manpower and some primitive tools. It used to take months to extract stone blocks of certain sizes from any quarry. The fact that architectural projects in nowadays have to be completed within a certain time has led to the use of new technologies in stone extraction. In the past, three main methods were preferred in the extraction of many natural stones, especially marble. A few of these methods are still preferred in quarries in today's Turkey.

Extraction method 1: The channel opening



Channels are opened from the areas of the marble blocks indicated by the arrow signs (Yüzer, Güngör, Angı 2008) (Image colored by Emir Kamis)

In channel opening method, first the vein structure of the stone is examined and the location where the channel will be opened is determined. Since a force applied to the vein of the stone will cause disintegration, the channels (4 channels; 2 vertical and 2 horizontal) are opened towards the area where the vein density is less. After the channel opening process is completed, the stone block is moved using tools such as chisels and pickaxes (Yüzer, Güngör, Angı 2008).

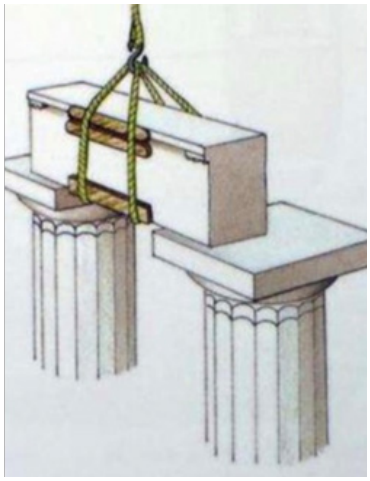
Extraction method 2: The hole drilling

In the second method, the hole drilling method, the veined part of the stone is used. Since the main purpose of this method is to displace a certain part of the stone, holes are opened on the surface of the stone and wedges are placed. The wedges are pushed into the inner layers of the stone with the help of a sledgehammer, as if hammering nails into the wall. During this force applied to the stone, the stone breaks apart from its veined part and the remaining parts become moveable (Yüzer, Güngör, Angı 2008). This method is still used in small-scale quarries in the Marmara region of Turkey.

Extraction method 3: The flat cutting

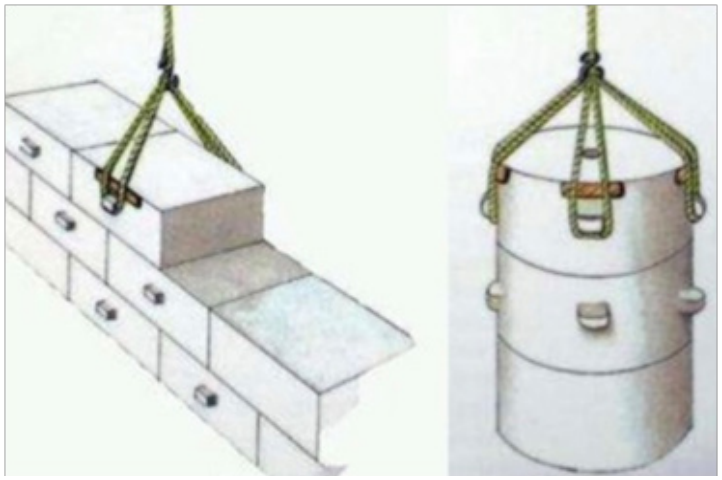
The third method, the flat cutting, is less complicated than other methods. Stone blocks are cut with the help of metal blades, just like cutting wood with a saw, and are made ready to be moved (Yüzer, Güngör, Angı 2008).
Once the stones are extracted in blocks, the process of transporting these blocks begins. Different techniques and methods are observed in this transportation process.

Transportation methods



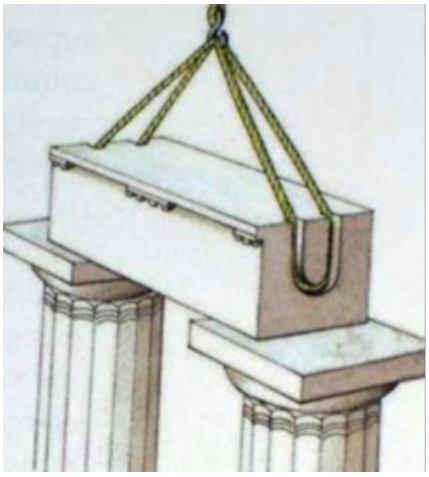
Simple binding (Durando 2002)

In simple binding method, which was one of the most frequently used methods of transporting marble blocks in the past, the stone block is moved from its place with the help of rope and hook. The most important point here is to tie the rope tightly to both the hook and the stone block to be carried.

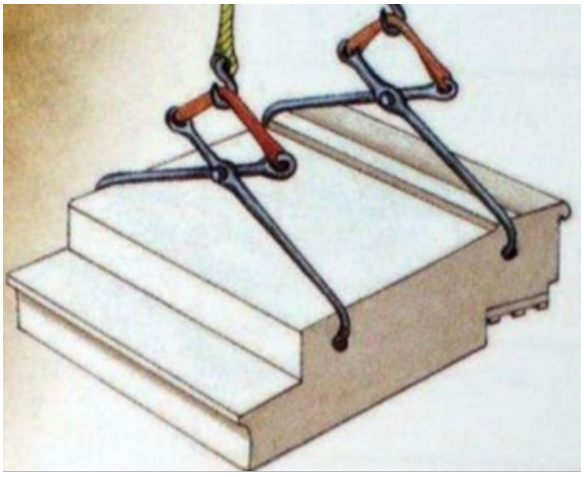


Attachment to lifting bosses (Durando 2002)

In attachment to lifting bosses, certain points of the stone block to be moved are marked and the remaining surface is lightly carved. When the points marked at the beginning protrude outward, a rope is tied to these parts and the stone block is moved.

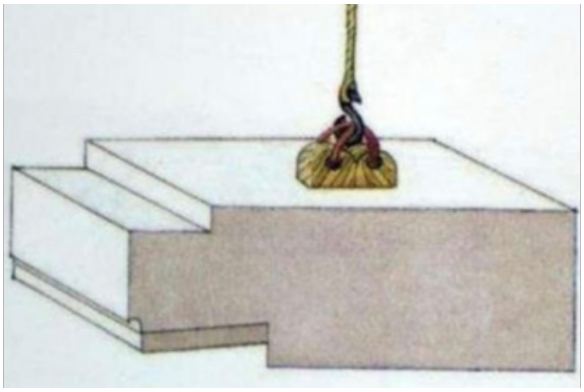


Binding through groove (Durando 2002)



Tying with scissors hook (Durando 2002)

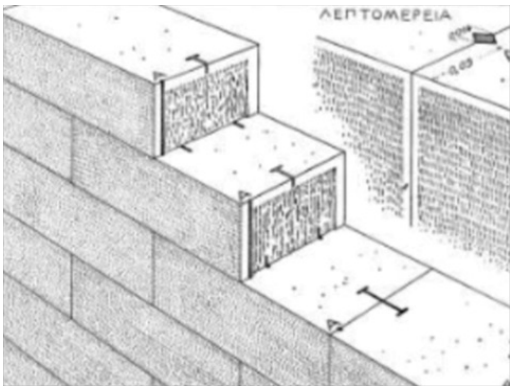
In binding through groove, U-shaped grooves are marked on the stone block. After these grooves are opened without damaging the veins of the stone, the stone block is moved with the help of a rope. The important thing here is to place the rope perfectly in the grooves.



Iron hook (Durando 2002)

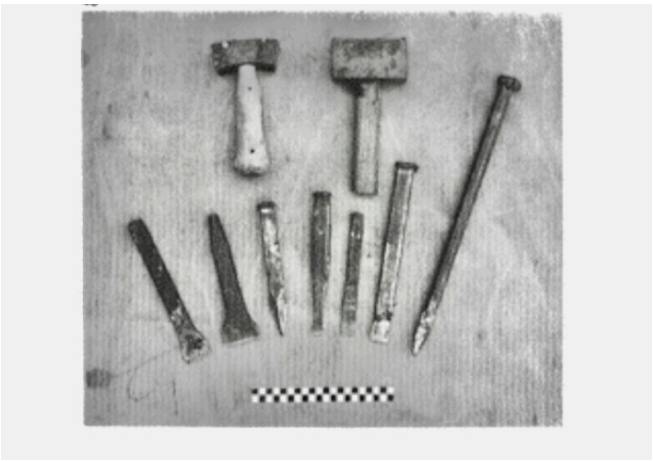
The iron hook, which is used in many different ways to transport stone blocks, is mounted on the upper surface of the stone. The stone blocks moved with the help of a rope attached to this hook are carried to the area where they will be used.

Grips



Connecting stone blocks to each other (Orlandos 1968)

Tools



Hammers and chisels used in stone extraction both in the past and today (Adam 1994)

Image of a stonemason processing a stone block with the help of a hammer and chisel (Adam 1994)

1.5.3 Marble extraction today in Mugla

Three different stages are required to prepare the natural areas where marble will be extracted. The first of these is to analyze the structure of the region and reveal its potential. The second part is the long licensing procedures in which the necessary permissions are obtained from the goverment. Although these licensing procedures generally contain similar protocols in every country, they are more detailed in rich marble reserve countries such as Turkey. The third and last part is the stage of establishing the facility on land whose suitability has been tested and approved.

Region analysis related to Mugla

In Turkey's dense marble reserve areas such as Mugla, regional analysis consists of various researches.
At first the geological maps of the region are examined by looking at the mineral formations, vegetation, rock sequences, accessibility and topographic features of the land. Regions located on earthquake fault lines are dangerous areas for marble extraction. Since any earthquake near the marble quarry may cause serious loss of property and life, excavations are not carried out in these areas (Çal 2024). Once it is confirmed that the region remains outside of tectonic activity, the second important research topic is checked whether the region is rich in calcite minerals.

Marbles contain a high amount of calcite mineral in their structure compare to other different natural stone types. Once it is understood that the formation in the region contains calcite mineral and the rock density is suitable, the region is defined as having marble reserve potential. To obtain accurate information, samples are taken from the rocks (massive rocks) in the field with the help of hammer and chisel, and properties such as color, texture, hardness, brightness and chemical content of the stone begin to be examined. More innovative technologies such as core drilling machine is also used in the sampling process.
If the calcite rate in the samples taken is between 90 to 98%, the region is considered as a marble reserve area. If the features that determine the quality of the marble, such as proper vein structure and color selection (it is important for the design integrity that the extracted marble blocks are in close color tones), are in compliance with the required standards, then the licensing stage begins (Çal 2024).

Licensing procedures

For the licensing protocol in Turkey, first of all, an application is made to the General Directorate of Mining Affairs with the fee and regional coordinates. In this way, the area where marble will be extracted is reserved within certain limits in the name of the applicant. During these procedures, it is examined and approved that the person applying for a license to operate the marble quarry does not have any government debt and that his economic situation is at a level that can support such a facility. Then, the exploration project presentation begins.
The project of the marble manufacturing facility to be built is presented. If everything is suitable up to this stage, a two-stage exploration license is issued.

In the preliminary research, which is the first stage of this license, reports of the samples taken from the massive rocks in the region are sent to institutions for analysis in different ways. The region approved as a marble reserve by the R&D team must also be approved by state institutions in the same reporting format. If it is determined that the region is a marble reserve area and that the marble to be quarried here meets the standards in terms of quality, the next stage begins. For approximately two years from the date of the first application, the boundaries of the marble reserve area within the physical and chemical properties of the marble to be extracted here are officially approved.

In the next stage, the project of marble manufacturing facility is designed once again and an application is made for the environmental impact assessment report. At this point, permits for the region are obtained from eleven different government organizations. The suitability of the region for marble extraction, whether it is a cultural heritage area, and the effects of environmental pollution that may occur in the vicinity on the living habitat are investigated. If deemed appropriate, the report is approved and the final stage of the protocol is carried out.

In the final stage, an application is made for a forestry permit.
If the vegetation and living habitat in the region is dense, the project is canceled no matter how valuable the marble quarry is, in order not to negatively affect the natural life. If there is no density in the vegetation and living population, the project is approved and the installation phase of the facility begins.

Tools used in taking samples from the investigation land

Mason chisel and hammer used to take samples from rocks (Kamis 2024)

Core drilling machine (https://www.fatihsondaj.com)

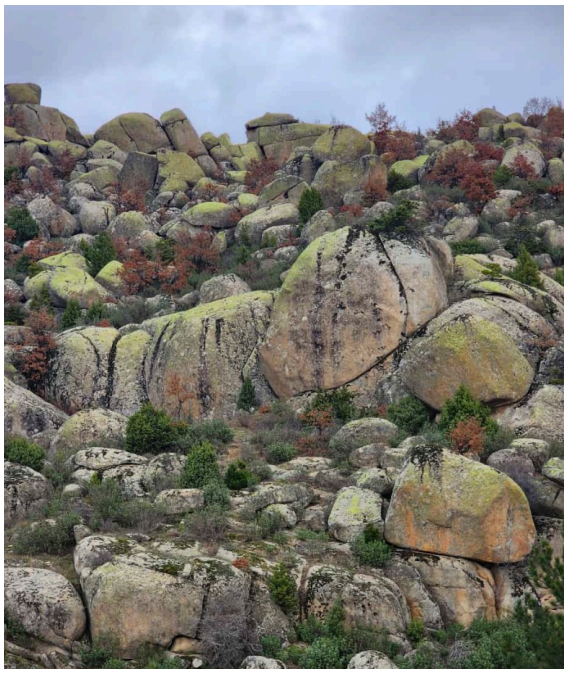
Researches carried out on marble in some provinces of Turkey

Aydın, Turkey (Çal 2024)

Samples obtained from massive rocks with the help of hammer and chisel for examination (Çal 2024)

Research on a land within the borders of the city of Aydın, the location of the massive rocks and the vegetation in the region begin to be examined.

From the research carried out in Kumluca, marble samples taken by using the core drilling machine, Antalya, Turkey (Çal 2023)



Formation of massive rocks in the research area, Bergama, Izmir, Turkey (Çal 2024)

If the research carried out in this field is approved and the license is issued, the region will be made suitable for marble extraction by removing the vegetation.

Marble manufacturing facility

Facilities manufacturing marble consist of 4 sections: offices , quarry (field where marble blocks are extracted), dump site (the area where wastes and remnants are collected), and the factory.
In marble manufacturing facilities, first the location of the quarry, dump site, offices and factory is determined and then, transportation routes are designed.
The accessibility of the marble quarry due to its proximity to main roads provides economic convenience to the operator. Otherwise, it is necessary to open access roads to the facility and ensure commercial flow.
Depending on its type (plain, hillside, peak), the boundaries of the quarry are determined together with the pit floor and peak levels (the lowest and highest points of the quarry).
In addition, determining the size and direction of the quarry where marble will be extracted is important in terms of expanding the quarry in the right direction and getting maximum block efficiency.
At the top of the quarry (the upper part of the topography), a flat surface is opened to extract blocks, the vegetation here is trimmed by using different machines (loader, haul truck, excavator) and the region is made suitable for block extraction (Çal 2024).
Once the quarry is ready, the dump site, offices and factory are designed to be close to each other and the facility is made ready for production.

Marble manufacturing facility: the case of Kentmer, Mugla white marble, Turkey

Map of the facility(Çal 2022)

1-Factory

2-Office

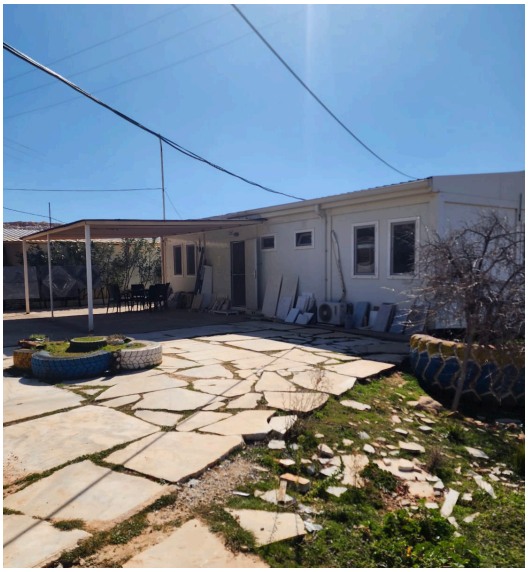
3-Dump site

4-Hillside
(The quarry)

View of Mugla white marble manufacturing facility Kentmer before and after marble extraction (Çal 2008-2024)

The picture on the left shows the natural structure of the marble quarry before the process. As can be seen in the same picture, features such as the abundance of massive rocks, their arrangement, and sparse vegetation mean that this hillside is suitable for marble extraction. The excavations started with scraping the vegetation and continued with the carving of the mountain hillside and the arrangement of the dump site. Finally, with the construction of offices and a factory, the facility took its current view (picture on the right).

Sections of Kentmer Mugla white marble manufacturing facility



Office section of the facility (Çal 2024)

Hillside, the quarry where marble is extracted (Çal 2024)

When Emir Kamis continues his research work in Mugla white marble quarry in Turkey (Çal 2023)

Since Mugla white marble quarry is a hillside type quarry, marble extraction area is located on the slope. This area consists of different levels and roads are designed to reach each level. At the top of the slope, what remains of the natural vegetation can be observed.

Diamond wire saw (Kamis 2023)

The marble is cut into blocks from the hillside's surface with a diamond wire saw, separated from the mainland and taken to the factory for processing. While some marbles are extracted in blocks due to their solid structure and formation maturity, some marbles become more fragmented and lose their form.

Mugla white marble quarry (Kamis 2023)

In these pictures, the machine called loader (loads the weight and unloads it into the haul truck) and the haul truck that collect the marble remnants are shown.
When the marble is cut from its natural formation on the slope and separated into blocks, weathering occurs in the mainland. The biggest reason for these separations is the cracked structure of the marble quarry. Due to this cracked structure, marble pieces of different sizes, remnants, break off from the mainland.

The dump site where marble wastes and remnants are stored (Çal 2024)

While large-sized remnants are taken to the processing area to be cut and turned into blocks, smaller-sized ones are stored in this area together with marble wastes. These wastes and remnants can be used in different industries.

Machinery inside the factory of the marble manufacturing facility

The factory (marble processing area) of Mugla white marble quarry, where the marble processing such as cutting, polishing and packaging is carried out (Çal 2024)

Except for the diamond wire saw, other marble cutting machines are located inside the factory.

Cutting machine used to bring large massive marble pieces into more workable or portable sizes (Bağcı 2023)

MKS Gang-saw machine for marble (https://www.mks.com.tr)

In the gang-saw machine, marble blocks or amorphous marble remnants (rubbles) that extracted from the marble quarry are cut into different thicknesses and turned into marble slabs.


Marble slabs cut from marble blocks (Çal 2024)

While some customer groups prefer thin strips in marble cladding, some others buy larger sized slabs and reshape them to the desired size. This preference varies depending on the customer's application methods.



Block cutting machine (Kamis 2023)

Marble blocks are cut into thin strips in the block cutting machine and taken to the final stage, polishing and packaging.

An excavator loading marble waste into a truck (Kamis 2023)

Since marble waste is also generated during the processing of marble in the factory, these wastes are loaded into trucks and sent to many different manufacturers, such as artificial stone producers.

1.5.4 Marble processing methods

Marble extracted from the quarry in blocks is processed with different methods so that it can be used in fields such as architecture, design and art.
These methods are developed by stonemasons in marble quarries and passed on to subsequent generations. When marble is extracted from the quarry in blocks, it is generally cut into thin slabs and made ready for use in architecture. In some different designs, marble blocks are preferred in block form without being cut into slabs.
Marble processing, which starts after marble extraction, is carried out using two main methods; cladding and shaping.
In order to apply these methods, marble is subjected to different processes.
The most common use of marble, especially in the architectural field, is the cladding.
The marble is purchased in thin slabs cut to the desired dimensions with angle grinder and turned into marble panels. These panels are used for wall, floor and exterior facade coverings. In this method, since marble slabs are purchased pre-polished, they are not polished again unless it is needed during the cladding.
Shaping, the other main method in marble processing, was used more frequently in the past. Especially since it is a very laborious work and takes time, this method is less preferred in today's architecture. In this method, the marble is carved, sanded and polished, but since it is purchased as a block, it is cut with a large angle grinder (in Turkey, this tool is also known as a diamond saw) at the beginning of the process.
Marble waste is generated during the processing of marble as well as during its extraction.

Methods

Cladding	Shaping
Process in cladding	**Process in shaping**
Cutting marble blocks into thin slabs and polishing	Cutting marble blocks into smaller size
Cutting thin slabs into panels	Carving with hammer and chisel
Covering the surface by using these panels with different application methods	Correcting the form with angle grinder (if needed)
	Sanding and polishing

(Bağcı 2024)

Some of the tools in marble processing

The angle grinder

The angle grinder is used to correct the form of the work while large angle grinder used for cutting marble blocks or even marble slabs.

Chisel

Mason chisel in blue color used for carving the marble and other type of chisels used for carving the soft-textured natural stones .

Sandpapers

Sandpapers of different sizes used to smooth the surface. After the coarse sandpaper makes the first contact with the surface, the fine sandpaper provides the final smoothness.

Polishers

Polishers are applied to the surface in different ways.

(Bağcı 2024)

Marble cladding in architecture

Although some different application methods are preferred in marble cladding depending on the properties of the surface, the main processes are similar. After the surface area is prepared, the cladding begins with certain steps.

Example of marble cladding: Wall cladding with marble slabs

First step, checking the spirit level
(All images related to the application taken from https://www.youtube.com/watch)

The surface of the wall to be applied is checked with a spirit level. If there is any level difference on the surface, it will be difficult to stick the marble panels and so that the surface level must be equalized.

Second step, the sizing

When it is understood that the wall surface is smooth and even, the marble taken from the quarry as thin slabs is cut into panels and made suitable for the cladding. A large angle grinder(or even small angle grinder) is used for the sizing.

Third step, application of the mortar

The mortar, which is generally created with cement, sand and water, is applied to the back side of the marble panels.

Fourth step, pasting

After the same mortar is applied to the surface of the wall, the marble panels are pasted to the wall and the cladding is carried out.

Fifth step, the use soft-head hammer

The marble is adhered to the wall with the help of a soft-head hammer.

Final step, checking the level

Finally, whether there is a level difference between the marble panels attached to the wall is checked with a spirit level. Once the mortar between the surface of the wall and the panels dries, the cladding is completed.

Marble shaping in art and design

First step, drawing the stripes (Bağcı 2019)

Shaping marble is carried out with the same methods in both art and design fields. Marble taken from the quarry in blocks is processed in the workshop. While the marble block is carved into a sink form, horizontal and vertical lines are drawn on the oval part.

Second step, breaking the striped part (Bağcı 2019)

Then, this striped part is broken with the help of a hammer and chisel to gain volume towards the inside. Since the chisel fits perfectly into the grooves formed in the scratched part, the marble begins to crumble inwards with each force applied by the hammer and an oval basin emerges.

Third step, cleaning (Bağcı 2019)

The inside of the sink is completely cleaned and its shape becomes clear.

Final step, correcting the form and polishing (Bağcı 2019)

After the rough surface is corrected with an angle grinder and taken into its final shape, the marble sink is polished. For aesthetic reasons, one side of the marble is left in its natural state. In some marbles, especially Mugla marbles, there is a color difference between the outer surface and the inner surface. In such designs, it is possible to observe the color transition of marble.

1.6 The potential risks of marble manufacturing to nature

Until the marble is cut from the mainland in block form and processed into slabs, many different stages in marble manufacturing can threaten natural life. The vegetation in the area where the marble manufacturing facility will be built is removed and this area is reorganized as quarry, factory and offices. Especially the quarry section where marble is extracted covers a large part of the land in the form of a huge pit opening into the middle of nature. The excavations carried out in the region to put the quarry into operation, the roads opened to provide access to the region, and most importantly, the waste generated in all these processes negatively affect the habitat. Compared to the past, the machine technology used today and the increasing number of marble quarries cause this damage to be even greater.
It is impossible to completely prevent the destruction of nature that occurs during marble manufacturing. However, some precautions that can be taken during the construction of the facility and solution suggestions such as recycling of waste will help reduce this damage.

Marble manufacturing stages and their damage to the nature

Excavations	Excessive deepening of the excavations in the area where the marble manufacturing facility will be built will cause groundwater to rise to the surface and fill the land. Discharge of this water causes the soil to become dehydrated and planting becomes impossible.
Explosion carried out in the region	Explosion causes destruction of vegetation and increases the risk of landslides.
Formation of the marble quarry pit	It takes many years for a huge hole opened in the middle of nature to regain its former state.
Release of marble remnants	Especially large-scale marble rubbles prevent the soil in the dump site from being covered with vegetation.
Release of waste (marble dust)	Marble dust covering the vegetation negatively affects carbon dioxide consumption and oxygen production of the plants.
Release of waste (carbonate mud)	Leaving this type of waste to nature, mixing it with water, adding chemicals and decomposing it causes poisoning of the living things.

(https://www.temizmekan.com/mermer-ve-tas-ocaklarinin-cevreye-olumsuz-etkileri)

Animals poisoned by carbonate mud released into nature instead of being recycled, Aydın, Turkey, 2020 (https://www.temizmekan.com)

Olive trees where marble dust covers their steps, roots and leaves (https://www.temizmekan.com)

Precautions that can be taken to minimize the risks

Excavations	The area where the excavation will be carried out should be left at a certain width and depth. In this way, marble can be extracted without reaching groundwater, and nature's self-repair process will also be accelerated. These borders are determined by certain laws in Turkey. The depth and width of the marble quarry are determined in a way that does not adversely affect both the underground water resources and the habitat.
Explosion carried out in the region	By prohibiting any explosions in natural areas, the risk of destruction and landslides in the region is minimized.
Release of marble remnants	Especially in Turkey, there are dump sites where marble remnants are collected. The remnants in these lands are collected for use in different industries and then processed. In this way, marble remnants are cleared from the land in a short time and nature is allowed to heal itself.
Release of waste (marble dust)	Marble dusts are processed in different industries and re-introduced into production through recycling. It is important to collect these dusts in a certain place before being released into the nature and then send them to different enterprises for re-production. In Turkey marble dusts are collected and used in many different industries, from material production to art, from the feed industry to cosmetics.
Release of waste (carbonate mud)	Carbonate mud, like marble dust, should be collected in a certain area and then sent to production facilities that can process this waste. Compared to Europe, in Turkey, the water of these wastes is purified and the pulp is released to nature (Çal 2024). This is an issue that will restructure marble manufacturing in Turkey with certain laws.

(https://www.temizmekan.com/mermer-ve-tas-ocaklarinin-cevreye-olumsuz-etkileri)

2. MARBLE REMNANTS AND WASTES

2.1 The difference between marble remnants and marble wastes

Marble waste is an important issue in marble manufacturing. The fact that the main mineral of marble is calcite increases the value of marble waste, allowing it to be recycled in many different areas and re-introduced into production.
It is necessary to pay attention to the difference between marble wastes and marble remnants, which is a frequently discussed topic.
In the research conducted in this field, the biggest request of the producers is to raise the awareness of marble buyers by clarifying these two concepts. When marble wastes are mentioned, industrial wastes generally come to the customer's mind. However, it should not be forgotten that marble wastes have calcite mineral in their structure just like marble, and they can preserve this structure even if they are in powder form.

The substances that are called marble wastes are substances that have gone out of block form but have preserved their calcite content. In other words, they are substances that are still rich in calcite but mostly they do not have a specific solid form, and these are generally known as dust and carbonate mud. Although they have a solid form, small-sized marble pieces can also be included in the marble waste group because they cannot be turned to marble block form by carving or cutting due to their size. The way to process these wastes is to recycle them.
Marble remnants are marble pieces that, although not as regular as a marble block in shape, they can still produce block forms if they are cut from different surfaces. Especially in the Turkish market, craftsmen who make objects by processing marble remnants are very sensitive in this field (Bağcı 2024).

Marble remnants, are also called marble pieces left over during marble manufacturing and they can take on different forms when they are cut and processed due to their large size. However, since their form is amorphous extra processes are required.
Marble wastes, on the other hand, are substances with small particles in size that have the chemical structure of marble but are far from block form, and they are generally processed by recycling.

2.2 Marble remnants: rubbles, caps, paledians

There are cracks in the structure of marble quarries, either natural due to their geological structure or as a result of the explosion of the area. Moreover the veins and cracks found in the structure of marble negatively affect both the processing and extraction.
A disproportionate force applied to the veined part will cause cracks and even separation. Likewise, while the marble block is being transported, cut or processed, any disproportionate intervention will cause marble block to disintegrate.
Marble pieces, which appear as a result of the processes at different stages in marble manufacturing are called marble remnants. Marble remnants are also found in different sizes.

Rubble (Bağcı 2022)

Caps (Bağcı 2022)

Paledians (Çal 2024)

Rubbles

The rubbles resulting from the disintegration of marble blocks from their veins do not have a regular shape. Large-sized rubbles are cut from four different surface areas, turn into blocks and those blocks are cut into marble slabs. On the other hand, small-sized rubbles are carved and used in different fields such as art and design. There are fields where both large and small-sized rubbles are used together.

Usage areas of rubbles according to their size

Small-sized rubbles (Rubbles with a height and width of less than 1 meter)	**Large-sized rubbles (Rubbles with a height and width of more than 1 meter)**
Cladding (tiles)	Design works
Design works (depending on a scale of the work)	Art works
Art works (depending on a scale of the work)	Infrastructure
	Construction

(Altındağ 2018)

Small-sized rubbles used in art

Fruits made of the small-sized Bilecik marble rubbles

Small-sized rubbles used in design

Lamps made of the small-sized rubbles of Mugla white marble (Bağcı 2020)

Large-sized rubbles used in art

Artwork called mother nature made from the large sized rubbles of Gebze marble (Kamis 2022)

The artwork in which the female body is combined with the arms of tree arms symbolizes fertility.

Large-sized rubbles used in design

Coffee table made of large sized rubbles of Mugla black marble (Bağcı 2022)

Large-sized rubbles used in construction

Large-sized marble rubbles used in highway infrastructure, Mugla white marble quarry (Kamis 2023)

Caps

Marble blocks are extracted in different dimensions. In some cases, if the block is too large to be processed, it is cut and reduced in size, and the remaining pieces are called caps. The caps that are emerged during the cutting of marble blocks in the factory have more regular shape.
Since the caps are thinner than rubbles, they are not carved in the form of blocks, but they are evaluated in different ways in the field of design.

Caps used in design

Chair made of caps (Kamis 2022)

Especially in Turkey, both rubbles and caps are used when creating garden furnitures from marble or other natural stones.

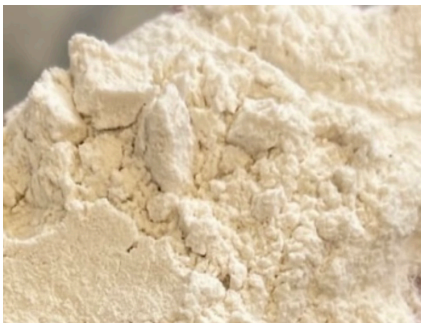
Paledians

Due to measurement errors made during the cutting of marble blocks into slabs, the thin plate breaks apart from its end and these pieces are called paledians.
Paledians are thin and shapeless pieces of marble that are generally used for flooring purposes.

Examples of flooring made with paledian marble pieces (https://silimciahmetusta.com/paledyen)

2.3 Marble wastes: dust , carbonate mud, small-sized marble pieces

The substances emerged during the period from when marble is cut as blocks from the mountain hill and turned into thin slabs in the factory are called marble wastes.
Today, the marble block manufacturing efficiency (the percentage of marble blocks being cut from the hill without fragmentation) of many countries in the world differs in percentage terms. In other words, the quality of the structure of the marble, the capacity of the marble manufacturing facilities, and the level of awareness of the people working in this field directly affect the efficiency of marble processing. Marble wastes occur more in countries such as Turkey where marble blocks are broken into smaller pieces during the extraction due to the structure of the land and those wastes are : marble dust, carbonate mud and small-sized pieces. They are processed and used as filler in different industries.



Marble dust
(Kamis 2024)

Included in the dry waste category

Carbonate mud
(Kamis 2023)

Included in the aqueous waste category

Small-sized marble pieces
(Çal 2024)

These are pieces mostly with a length of 10-25 cm and a thickness of 5-7 cm.

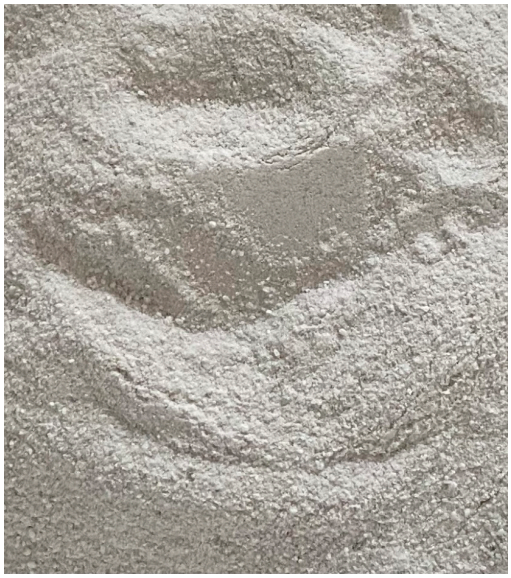
Usage areas of marble wastes

Industries			
Paint manufacturing	Paper manufacturing	Glass production	Feed industry
Cosmetic industry	Chemical industry	Steel production	Plastic industry
Cement production	Brick production	Artificial stone production	Concrete additive production

Some industries where marble waste is used in production (Şimşek 2019)

Marble dust

Marble dust is a type of dry waste that occurs in many different stages of marble manufacturing. It is used in the production of many different sectors due to its lightness, ease of transportation and availability in high quantities. Although the production capacity and operation of the facilities that will utilize marble waste are different, many production facilities both in Turkey and around world use marble dust in their products. One of the fields where marble dust is most frequently preferred is mortar production. Many different studies have shown that the physical properties and performance of mortars to which marble dust is added in certain amounts, have increased (Erdem, Öztürk 2012).
In particular, the inclusion of marble dust in some synthetic accelerators both reduces the use of chemicals and causes the waste material to be used in intensive amounts in production.



Fine grain Bardiglio marble dust (Kamis 2024)

Carbonate mud

Carbonate mud is aqueous type of marble waste containing different types of substances (dust water, oil). These wastes, which are mostly emerged when marble blocks are cut into thin slabs, consist of dust from the marble, oil and water dripping from the cutting machine.
The reason why it is called carbonate mud is that it is obtained from marble, a natural material containing the calcite mineral.
Although it is defined as diluted marble dust in some marble quarries, this type of waste is used in many industries, especially in artificial stone production. The fact that it contains water causes the mixtures produced with carbonate mud to be more aqueous. Therefore, it is important to determine the ratio of materials correctly in the production with carbonate mud.

Carbonate mud, Mugla white marble quarry (Kamis 2023)

While carbonate mud is sent to artificial stone producers in many countries, the situation is different in some marble quarries in Turkey. Some marble manufacturers add substances into this carbonate mud, causing the dust particles in the mixture to settle. In this way, dust particles are separated from water and this water is stored for using in different processes. Dusted marble particles are also thrown away without being re-cycled . This situation is one of the important problems of the marble manufacturing industry in Turkey (Çal 2024).

Small-sized marble pieces (mostly with a length of 10-25 cm and a thickness of 5-7 cm)

Small-sized marble pieces are waste that can be recycled after being subjected to certain processes. Although they are small in size, they have a solid form. These wastes are obtained from marbles that are broken, incorrectly cut, or fragmented during marble processing. Sizes may vary, but they are too small to be carved. Small-sized marble pieces are sent to calcite processing plants and re-entered into production.

Small-sized marble pieces (Çal 2024)

3. MARBLE WASTES IN TURKEY: AN OVERVIEW ON CURRENT USES

3.1 Calcite as filler

There are many different fields where the calcite mineral has been processed and used from past to present. Especially the fact that it is obtained from marble waste and improves the chemical properties of the mixture it is included in makes this mineral very valuable. Calcite, which was mostly used as a filling material in the production of plasters, concrete mortars and artificial stone products in the past, has a wide range of uses today, from cosmetics to agriculture. Increasing the compressive strength by using marble dust in concrete mortars is also due to the effect of the calcite mineral in marble dust. Today, in countries such as Turkey where investments are made in this field, the performance enhancing properties of calcite mineral are used not only in the field of construction but also in many other industries.

3.1.1 Calcite processing plants

Plants that obtain marble wastes of different sizes from quarries and process these wastes as calcite mineral are called calcite processing plants. Each of these facilities has crushing machines and grinding mills, and with the use of these machines, calcite mineral is pulverized and presented as filler to different production field. After turning the calcite into filler, calcite processing plants send it to another manufacturer. This manufacturer uses calcite in its own production field and meets its needs for filler from marble wastes. Although the machinery and production capacities of facilities vary, they play an important role in evaluating marble wastes. Since Turkey's marble quarries have a high amount of marble waste, many calcite processing plants, both domestic and foreign, are being established near the quarries.

Process

Supplying small-sized marble pieces as waste from the quarry
Crushing of the marble pieces supplied
Grinding of marble pieces that is crushed
Packaging of the resulting dust as calcite and distributing to other manufacturers
Manufacturers producing in different industrial fields use calcite(in the form of dust) as a filler in their production and reduce the need for natural raw materials

(https://www.sbm-mill.com/materials/calcite.html)

Calcite processing plants generally work with small-sized marble pieces due to their machinery.

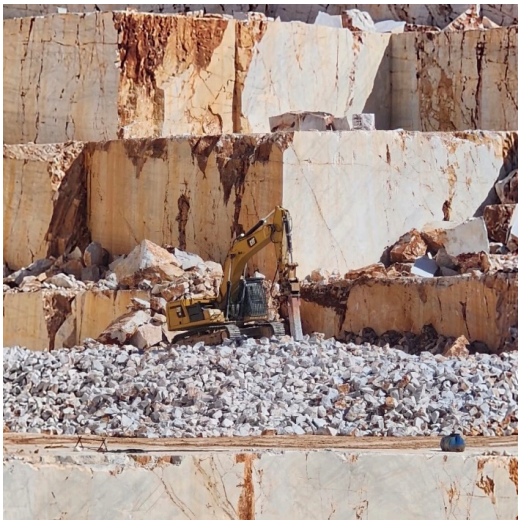
3.1.2 The case of Omya®

Calcite is not the only mineral that is produced through various processes.
Minerals such as barite, talc and dolomite are as important as calcite and contribute to production as fillers when they are ground. Industrial mineral producing companies in many different countries around the world grind valuable minerals in their facilities and enable them to participate in production. One of the most well-known of these companies is Omya (Swiss company).
Omya, which procures small-sized marble pieces from marble quarries just like calcite processing plants, processes these wastes as calcite in its facilities, turns them into filler and uses them in the production. Other than calcite, Omya processes minerals such as kaolin, barite, dolomite, talc, and it makes production in many different industries.
Omya, which also has facilities in Turkey, procures especially marble waste from its own quarries or from quarries where marble containing high calcite is extracted.
One of the quarries from which Omya supplies marble waste to its facilities in Turkey is Kentmer Mugla white marble quarry (Çal 2024).

Omya products based on calcite as filler and some other minerals

Building and construction	**Agriculture**	**Food, pharma and nutrition**	**Personal care and Home care**
Omyawood®	Omya Calciprill®	Omyanutra 300®	Omyaskin®

Some of Omya products that can be used in different fields (https://www.omya.com/en/products)



Marble wastes prepared to be sent to Omya, Mugla marble quarry (Çal 2024)

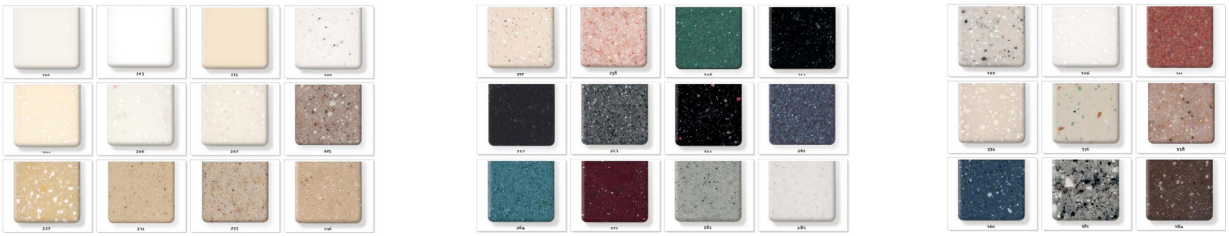
3.2 Artificial stone products

Artificial stone products have emerged with the aim of providing alternative solutions to problems, especially in natural stone production. Environmental pollution, high costs and difficulty in application that occur during the extraction of natural stones with high aesthetic value, such as marble and travertine, have brought the idea of production of alternative materials in this field. Artificial stone products like natural stones, can be used in cladding, especially in the field of architecture, and can give the natural appearance of the stone in terms of aesthetics. These artificial products, in which marble waste is used also contain various chemicals. Although they have advantages such as color integrity, lightness and affordability, the chemical content of artificial stone products is still being developed.

3.2.1 The case of Mermerit®

Mermerit is an artificial stone product produced by using marble dust and various different substances in local workshops in Turkey. Although it is generally produced as a kitchen countertop, it can also be used as a bathroom countertop. It is preferred in low-budget projects with its marble appearance, affordable price and lightness. Due to the substances it contains, the use of a mask is required during the production. Mermerit production workshops located in Turkey's marble reserve areas obtain marble dust from quarries and add it directly to their mixtures.

Color options



(https://cihanmermeritgranit.wordpress.com/renk-katologlarimiz/mermerit-kartelasi/)

The Content of Mermerit

Polijel 213 gelcoat within Polipol 3455/ 353®: In general terms, gelcoat is a material obtained by changing or modifying the structure of polyester resins with different chemical processes, which increases the surface appearance quality of the composite material and it makes the material more resistant to external factors. Polijel 213 gelcoat is a high-performance type of gelcoat that makes the material resistant to effects such as temperature change, scratching, matting, and within these properties, it is frequently used in the production of kitchen countertops.
Calcite / Dolomite: Calcite and dolomite minerals are generally obtained from marble waste, and the powders of both dolomitic marbles with high dolomite content and marbles with high calcite content are used in artificial stone products to give extra durability to the material.

Cobalt 6: Cobalt 6, a Cobalt-containing alloy that is resistant to high temperatures and mechanical impacts , it is also used in different ways as a catalyst accelerator for polyesters and a dryer for oil paints.
Mek-P® : Organic peroxide (component group), which stands for methyl ethyl ketene peroxide, Mek-P, is used for the hardening of unsaturated polyster products together with accelerators such as cobalt, dma, etc.
Powder pigment: These pigments, which determine the color and tone, play an important role in the different color range of artificial stone products.

Production process: the case of countertops

First step, preparation process of the countertop mold in which the mixture will be poured (All images related to the production process taken from https://www.youtube.com/)

In the making of Mermerit countertops, firstly, the countertop mold is designed according to the desired size, obtained from different materials. By gluing the sink to this mold, the shape and dimensions of the desired kitchen countertop are prepared.

Second step, application of Polivaks Sv-6 to the surface of the mold

In order to separate the Mermerit countertop from the mold without shattering, a separator called Polivaks SV-6 is applied to the surface of the mold in equal amounts.

Third step, Application of gelcoat

Gelcoat, which will penetrate the surface of the Mermerit countertop, is applied to the surface by spraying method.

Fourth step, preparation of marble dust

Marble dust obtained from the quarry is made ready to be added to the mixture.

Fifth step, mixing process in the container

Approximately 45 minutes after the gelcoat process, marble dust and polyester are mixed in container until it reaches a dough consistency.

Sixth step, adding resin while the mixing process continues

Seventh step, pouring the mixture into the mold and spreading

The dough-like mixture is poured into the previously prepared mold.

Spreading the mixture into the mold with the help of spatula

Eight step, leaving to dry

The mixture, which is processed over the entire surface and takes the shape of the mold, is left to dry.

Ninth step, removing the sink

After the drying process is completed, the Mermerit countertop, which was initially separated from the mold, is taken to another processing area and the attached sink is separated from the countertop.

The final state of the Mermerit countertop

3.3 Use of marble dust in art with Hempcrete

In today's Turkey, it is seen that marble dust is frequently used in different fields such as art. Mixtures obtained by mixing marble dust with different materials can take shapes and gain an aesthetic form before drying. In particular, the physical properties of marble dust change the consistency of the mixture to which it is added and makes it easier to take shape. Marble dust is used to add an aesthetic texture to the outer surfaces of abstract forms created mostly in modern art. The beginning of these applications is based on Hempcrete production.
In Turkey, artists like *Merey Şenocak*[1] combine different material production tecniques and applications such as Hempcrete, Tadelakt (Moroccan plaster) with marble dust and create artworks .

Hempcrete

The use of marble dust in art is primarily related to the content of Hempcrete, the building material. Hempcrete is used as wall panels or bricks in architectural field. This material, which contains hemp hurd, lime and water, can take many different shapes while being prepared. Artists inspired by this mixture use hemp and lime together and produce artworks in different forms. Although the shape of the artwork is satisfactory at first, its surface is not found aesthetically sufficient. For this reason, the surface of the artwork is plastered (mostly with Tadelakt plastering tecnique) and while this plaster is being prepared, marble dust is added to the mixture. It is thought that marble dust will contribute positively to the physical properties of the plaster. Thus, the mixture in Hempcrete is combined with Tadelakt containing marble dust and began to be used in the field of art.

Merey Şenocak[1]
After completing her education at University of Arts London, Turkish artist Merey Şenocak (1993, Izmir) was interested in many different disciplines and managed to combine them in her art. Working with different materials such as hemp, lime and marble dust, the artist also achieves a more aesthetic appearance by covering the surfaces of the works with Tadelakt.

Production of Hempcrete

For the production of Hempcrete, hemp hurd and lime are first prepared in a separate container. Then, hemp hurd and lime are poured into the same container and mixed there. Water is added to ensure that the mixture reaches the desired consistency. The mixture poured into the mold is left to dry, and after the mixture dries, the material is ready for use.

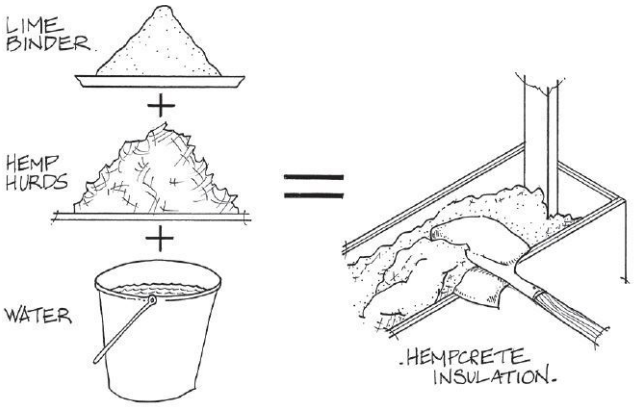


Illustration about the content of Hempcrete (https://greenbuildingcanada.ca/)

Production of Hempcrete (https://medium.com/)

Examples of applications of Hempcrete in architecture

Hempcrete wall (https://medium.com/)

After the Hempcrete mixture is poured into molds suitable for the size of the wall panels and dried, it becomes a wall panel. The main purpose of this usage is to provide thermal insulation.

Use of Hempcrete in design

Hempcrete blocks, Park Associati, Porto, Portugal, 2023
(https://amazingarchitecture.com/installations/tatu)

Hempcrete mixture, which is frequently used in the field of design, is poured into brick molds and used in outdoor designs after it dries. Hempcrete bricks used as bench and contribute to the construction of areas where people can sit.

Use of Hempcrete in art

Hempcrete created by *Merey Şenocak* (Şenocak 2023)

As shown in the picture, many artists create the main form of their artworks with the tecnique used in the production of Hempcrete. Tadelakt is applied to give an aesthetic appearance to the external surface of those kind of artworks. In this technique (mixing the production tecnique of Hempcrete with Tadelakt), which has been used in art over time, marble dust is used in the preparation of the plaster, but only hemp, lime and water are used when preparing the main body of the work.

Artworks in which marble dust is used with Hempcrete

The raw form of the artwork before plastering (Şenocak 2023)

In this work created by *Merey Şenocak*, the technique used in the production of Hempcrete was prefered. Hemp hurd (stem of the plant), lime putty (non-hydraulic lime sold in paste form) and water were used as materials in the production of the mixture that forms the main body of the artwork. After pouring the hemp hurd and lime putty into a container of certain sizes and adding water, the resulting mixture was mixed and shaped in an abstract form and left to dry. When the mixture dries, it becomes the artwork shown in the picture above. It is possible to create different shapes with the mixture used here. The surface of the artwork is prepared for plastering .

The appearance of the artwork after the first stage of Tadelakt (Şenocak 2023)

After the mixture forming the artwork is completely dry, Tadelakt is applied to the surface. Application of Tadelakt (see paragraph 3.5) as a type of plaster consists of different layers and different stages. After the materials in the first mixture are prepared, they are mixed to form the first layer of the plaster. Then, the first layer of the plaster is applied to the surface and waited until the plaster firms. Later, the mixture that will form the second layer of the plaster is prepared and applied to the surface again. The stage of this artwork shown in the picture is the first stage of Tadelakt application. The surface of the artwork is plastered and left to firm up.

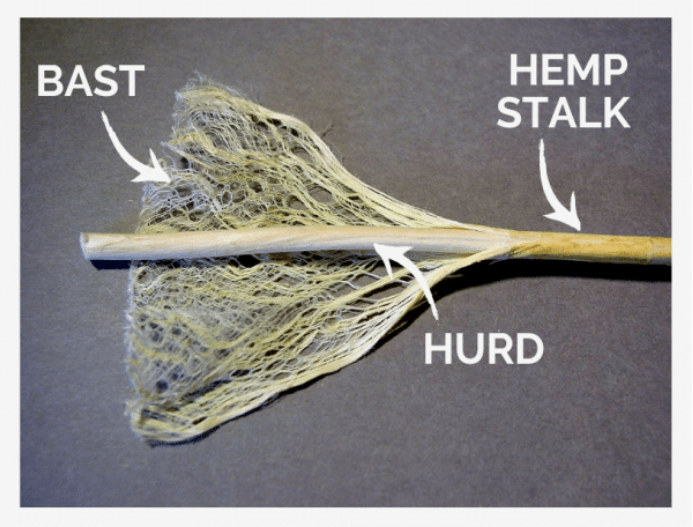
The appearance of the artwork after the second stage of Tadelakt (Şenocak 2023)

After the first stage of Tadelakt is completed, the materials of the mixture that will form the second layer of plaster begin to be prepared. In this part, marble dust and iron oxide pigment are added to the mixture and the mixture is mixed and made ready to apply the second layer of the plaster. After the second stage plastering process is completed, the surface is polished. Tadelakt obtains the aesthetic appearance to the artwork as it is shown in the picture above. The color of the artwork has taken on pink due to the addition of pigment to the mixture during the second stage of Tadelakt. This technique is proof of how aesthetically pleasing aappearance can be achieved when materials such as hemp hurd, lime putty, and marble dust are used together with Tadelakt application.

3.4 Marble dust together with hemp and lime

The increasing use of marble dust, especially in the field of art in recent years, has led to the combination and processing of this waste with different materials. Since the chemical content of marble dust is compatible with lime, the use of these two materials can be considered at any stage of production. On the other hand, the use of industrial hemp in the production of material in the form of particles or hurd, ensures that the material obtained is light. While a mixture of marble dust, lime and hemp can be evaluated in the field of architecture, today we see that this trio is preferred together more in the field of art and design.
Marble dust is not added to hemp hurd and lime, which are used together in the production of materials such as Hempcrete. However, considering the physical properties of the mortars which contain marble dust, including marble dust in mixtures with hemp and lime will contribute to the production of different technologies in the field of architecture.

Usage areas of hemp



Different parts of the hemp plant shown after it was dried (https://thehia.org/the-fiber-council)

Industry
Petroleum and petrochemicals
Pharmaceutical industry
Textile industry (in fabrics)
Automotive industry
Construction industry
Electricity generation
Food industry
Feed industry
Biofuel
Paper industry

Main usage areas of hemp (Kaya, Öner 2020)

Hemp in the construction industry
Panel
Brick
Tile
Insulation material
Hardboard

Some building materials produced by using hemp stalk, hemp fiber and hemp hurd (Yılmaz, Yazici 2022)

Part of hemp	Industry
Hemp hurd	Construction industry (Hempcrete)
Hemp fiber (bast)	Textile industry (in fabrics)
Hemp particles	Contemporary art

Examples of areas where different parts of hemp are used (Yılmaz, Yazici 2022)

Hemp in the textile industry
Rug
Carpet
Work clothes
Tablecloth
Jackets, trousers, dresses etc. made from hemp fabric

Some of the textile products produced with fiber obtained from hemp stalk (Yılmaz, Yazici 2022)

Usage areas of lime

Construction and building industry
Soil stabilization
Iron and steel industry
Aerated concrete production
Drinking water treatment
Hazardous waste treatment
Purification of waste water
Agricultural
Asphalt mixtures
Flue gas purification
Biosolids and sediment treatment

(https://www.kirec.org/)

Example of applications of hemp, lime and marble dust in design

A chair made by using hemp hurd, lime putty,water (Hempcrete) and containing iron construction (Şenocak 2023)

Hemp hurd, lime putty and water are used in some of the furnitures produced by artists in the field of design. These furnitures, which are made based on Hempcrete production, do not contain marble dust in their main content, but marble dust is used on the outer surface to contribute to the aesthetic appearance.

Appearence of the outer surface of the chair after Tadelakt application (Şenocak 2023)

The plaster made while covering the outer surface of the chair contains marble dust and iron oxide pigment.

3.5 Marble dust with Tadelakt

Tadelakt, which emerged as a result of the limestone applications of the local people of Marrakech, Morocco, about 2.000 years ago, is a plaster type.
Since Tadelakt has unique applications, the technique that is used can also be decribed as Tadelakt plastering technique.
In Tadelakt, a mixture consisting of different materials is applied to the surface as plaster, but the content of this mixture has changed over the years.
The first material used in Tadelakt is lime, but when materials such as egg white added to the lime over time do not give the desired result, lime and black soap are used together to make the plaster smooth. In addition, in Tadelakt, which is applied in different layers, the first layer of plaster prepares the surface, while the second layer of plaster gives the final surface its smooth appearance. Today, the main content of Tadelakt is still lime but there are many different materials such as mortar sand, Pozzolan, marble dust can also be added to the mixture. The atmosphere it creates in the applied area, its color variations, smooth surface and texture make Tadelakt aesthetically preferred plaster. Waterproof, easy cleaning, durability and recyclability are among the main features of Tadelakt.

Tadelakt application

First step, preparation of the materials; lime and the fine sand (marble dust can also be preferred instead of fine sand) (All images related to the application taken from https://www.youtube.com)

Lime with the fine sand begin to be prepared for the Tadelakt mixture.

Second step, adding the water

Water is added to the mixture consisting of lime and fine sand.

Third step, adding the optinal materials; pigment, water retainer and fine fiber

Water retainer for slow down the drying process

Fine fiber for preventing cracks

Fourth step, mixing the materials
(lime, fine sand, water, pigment, water retainer and fine fiber)

Fifth step, application to the surfaces

The Tadelakt mixture is applied to the surfaces as the first layer.

Sixth step, application of the second layer

A second layer of Tadelakt (the same mixture is prepared again without the fiber) is applied to the surfaces which indurate but do not dry after a few hours.

Seventh step, polishing the surfaces with soapy water (20% Moroccan black soap to 80% water)

The final step, rubbing the surfaces with the agate stone and leaving to dry

By rubbing with agate stone, the surface becomes smoother and brighter.

Final state of Tadelakt application after a month

4. FROM MARBLE DUST TO RECYCLED MATERIAL

4.1 Introduction to the experimentation

The main purpose of these experiments is to explore the possibility of recycling marble dust in combination with other natural materials with the realization of different samples. As waste material of the marble manufacturing process, marble dust is easy to transport, light and has low production cost.

The need for raw materials, which increases in direct proportion to the amount of consumption, has resulted in carbon emissions, the decrease in natural resources, and the introduction of many recycling materials into our lives. However, the number of these recycling materials can be increased and changes can be made in their production methods.
When the architectural field is considered, it is seen that natural raw materials are replaced by artificials. In some fields where marble is used, artificial stone products are preferred today. While the number of recyled materials is increased, the materials used in this production field must also be selected correctly.

In the experimental part of the thesis, it is aimed to create the most suitable sample that can be used as interior cladding panels (aesthetic wall panel). For this production purpose, marble dust obtained from Mugla and Bardiglio marbles, lime in paste-like consistency (lime putty), hemp (as hurd and particles), pigments, acrilic paint, water and plaster were used as materials in different proportions to analyze effect of different compositions on the physical properties of the samples. The experimental phase was carried out partially in Turkey and partially at the LASTIN (Laboratorio Sistemi Tecnologici Innovativi) of Politecnico di Torino.
Throughout the experiments, natural materials with natural polishers such as soapy water and resin were preferred as much as possible in order not to harm the health of both the producer and the user.

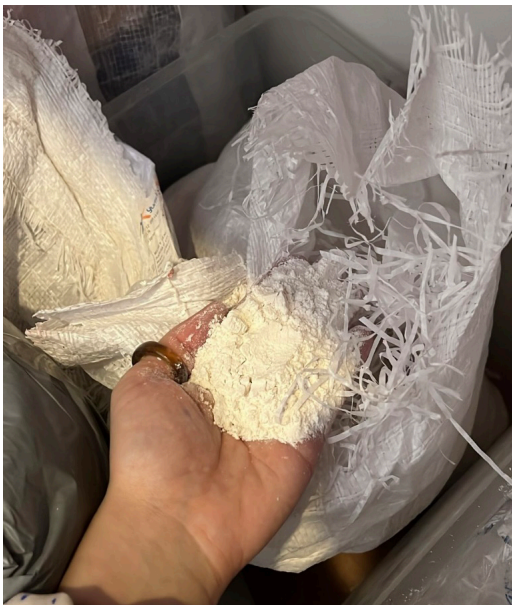
Average prices of the materials required for the experiments

Ingredient	Source	Quantity	Price
Hemp hurd bale	https://www.hempto-pia.com	15 kg	$42.39
Lime putty	https://www.limebase.co.uk/	21L	$27
Marble dust	It is supplied from marble quarries	1kg	$5
Pigment	https://www.kre-mer-pigmente.com	1kg	$30.35

The table shown above shows the average sales prices of the materials used in the experimental part of this thesis. These prices vary depending on the selling company and the average sales amounts are as shown above.

4.2 Materials and methods

Marble dust



Dust of Mugla white marble (Kamis 2024)

Dust of Bardiglio marble (Kamis 2024)

Hemp hurd

Batch of hemp hurd (Kamis 2024)

Different batches of hemp hurd are needed to obtain more hemp particles

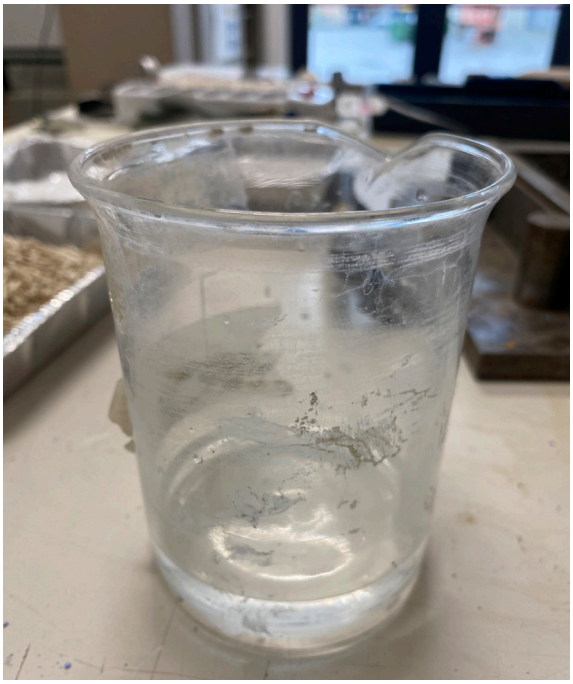
Hemp particles

Hemp particles obtained by sieving the hemp hurd (Kamis 2024)

Lime putty (made by hydrated lime and water)

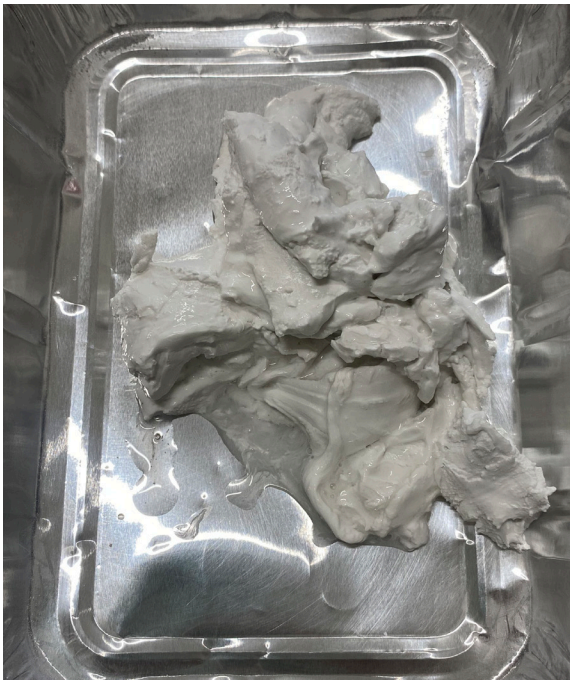
Purchased as ready to use (Kamis 2024)

Water



Tap water (Kamis 2024)

Plaster



Acrilic paint

Golden acrilic paint (Kamis 2024)

Ultramarine acrilic paint (Kamis 2024)

Pigment

Alizarin Carmine color (Kamis 2024)

Black soap

Also known as Moroccan black soap (Kamis 2024)

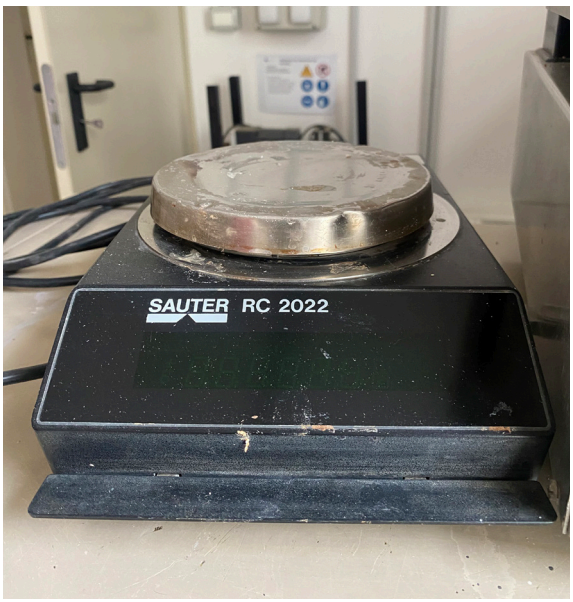
Resin

Acacia tree resin for the polishing (Kamis 2024)

This resin, also known as acacia gum, is obtained from the trunk of the acacia tree, then purified by refining, and made ready by diluting depending on its intended.

Equipments/Tools

Precision weighing scale



Sieve

(Kamis 2024)

Mixing bowls and containers



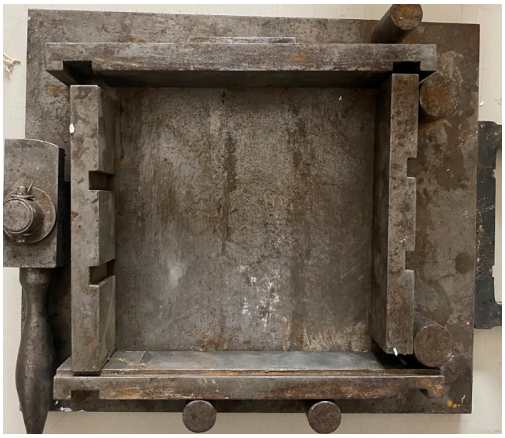
(Kamis 2024)

Molds

Used in the first experiment (Kamis 2024)
Dimensions of the mold: 4x24x10 cm

Used in the second experiment (Kamis 2024)
Dimensions of the mold: 11x20x0.6 cm

Used in the third experiment
(Kamis 2024)
Dimensions of the mold: Ø 8.5x3 cm



Used in the fourth, fifth, sixth, seventh
and eight experiments (Kamis 2024)
Dimensions of the mold: 14x16x4 cm

Patterns

(Kamis 2024)

Stones

Meter

Agate and quartz stones for rubbing (Kamis 2024)

(Kamis 2024)

Spatulas

Spatulas are also needed for creating pattern on the surfaces (Kamis 2024)

Brush

(Kamis 2024)

Equipments for protection

Gloves

(Kamis 2024)

Mask

Sprinkler

It is used to reduce the breathing of dust mixed into the air and to prevent respiratory disorders (Kamis 2024)

Oil and Vaseline

Oil

Vaseline

Oil and Vaseline which allow the produced sample to be removed from the mold easily (Kamis 2024)

4.3 Experimentation

EXPERIMENT 1

Composition of the first experiment

Materials	Amount(gr)
Marble dust (Mugla white marble)	265
Hemp hurd	18
Lime putty	308
Water	152.7

Volume calculations

Volume of the mold (14x24x10)	3.360 cm^3
Expected thickness of the sample	2 cm
Expected volume of the sample (14x24x2)	672 cm^3

Scheme of the experimentation

Materials

Dust of Mugla white marble

Lime putty

Hemp hurd

Water

Production

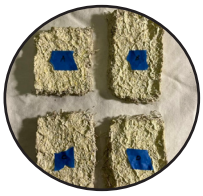
Mixing the materials

Kneading

Leaving to dry

Cutting into pieces

Polishing



Final state before polishing

Polishing with acacia tree resin

Polishing with soapy water

Rubbing with agate stone

Final state after polishing

Sample preparation

First step, preparation of the materials; marble dust, hemp hurd, lime putty, water (Kamis 2024)

As in all experiments, the main materials of the experiment are prepared by placing them in containers; marble dust, hemp hurd, lime putty and water.
The amount and ratio of materials used in experiments were calculated with reference to similar mixtures made previously.

Adding lime putty to hemp hurd

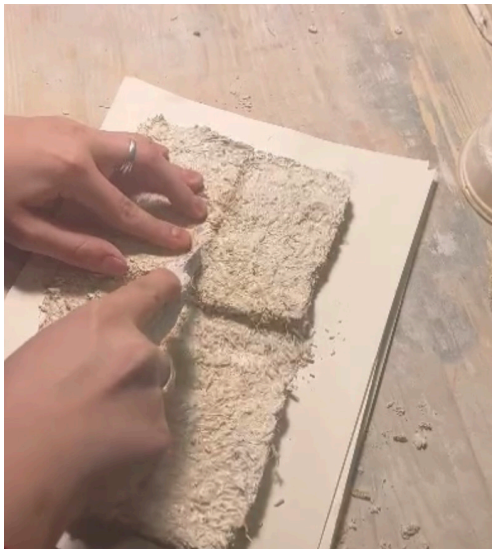
Adding water to hemp hurd and lime putty mix

Adding marble dust to the mixture (Kamis 2024)

The prepared materials are poured into the mold where the sample will be produced.

Second step, mixing, kneading the mixture and leaving to dry at room temperature (Kamis 2024)

With the addition of the water to the marble dust, lime putty and hemp hurd the mixing process begins. While a low amount of water makes it difficult for the materials to mix together, a high amount prolongs the drying time of the mixture. Therefore, it is important to use the right amounts of water for all experiments.
After adding all the materials, the resulting mixture is mixed and kneaded until it reaches the desired consistency. Due to the structure of hemp hurd, it is difficult to obtain a homogeneous mixture. When the kneading process is over the mixture is left to dry in a low-humidity environment away from sunlight.



Third step, cutting into four pieces (Kamis 2024)

The sample, which dried approximately 5 days after the experiment, is cut into four pieces (they are not cut evenly) to be polished using different methods. The surface is touched lightly to make sure whether the sample is dry or not. Any operations carried out before complete drying will cause the sample to disintegrate.

The final state of the sample (Kamis 2024)

The sample obtained from the first experiment and cut into pieces, named as 1A, 1B, 1C, 1D .

Polishing process

Polishing with acacia tree resin

Sample 1A is polished with acacia tree resin and a thin brush is used during this process (Kamis 2024)

The main purpose of this process, which has been tried in different ways before and received positive results, is to ensure that the sample has a shiny surface. The sample is ready one day after polishing with the resin.

Polishing with soapy water

Sample 1C is polished with soapy water and rubed with agate stone (Kamis 2024)

In this application, which is also used in Tadelakt, Moroccan black soap is mixed with water (20% soap to 80% water) to obtain soapy water and this water is applied to the surface with the help of a brush. Later the surface is rubbed with the agate stone to have brighter appearance. The sample is ready one day after polishing with soapy water.

EXPERIMENT 2

Composition of the second experiment

Materials	**Amount(gr)**
Marble dust (Mugla white marble)	61
Hemp particles	9
Lime putty	71.2
Water	24

Volume calculations

Volume of the mold (11x20x0.6)	132 cm^3
Expected thickness of the sample	0.6 cm
Expected volume of the sample(11x20x0.6)	132 cm^3

Scheme of the experimentation

Materials

Dust of Mugla white marble

Lime putty

Hemp particles

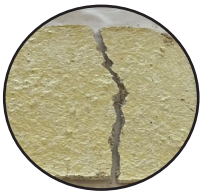
Water

Production

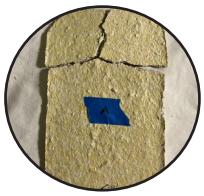
Sieving the hemp hurd to obtain particles

Mixing the materials

Pouring into mold and leaving to dry



Checking the sample



Final state

Sample preparation

First step, preparation of the materials; hemp particles, marble dust, lime putty, water (Kamis 2024)

In the second experiment, which was carried out in many stages in the same way as the previous experiment, hemp hurd is sieved and used in the form of hemp particles. Hemp hurd dominated the mixture in the previous experiment, making it difficult for the materials to fully mix together and reach a paste consistency. In this way, adding hemp to the mixture as particles will enable the mixture to be shaped more easily.

Adding lime putty to marble dust and pouring them together into container

Adding water to the mix

Adding hemp particles (Kamis 2024)

Second step, mixing the mixture, pouring into mold and leaving to dry at room temperature (Kamis 2024)

After all the materials are poured into the same container, the mixing process begins. At the end of the mixing process, hemp particles are spread throughout the entire area and thus the desired consistency is achieved. The ready mixture is poured into a separate mold and left to dry.

Third step, checking the sample (Kamis 2024)

Since the sample is produced thin, its surface is checked within five days. The sample dries and breaks into pieces with obvious cracks appearing on the surface.

Final state of the sample after a week (Kamis 2024)

A week after the end of the second experiment, the completely dried sample still continues to disintegrate. Sample is named as 2A but since it is too thin, it becomes unsuitable for use.

EXPERIMENT 3

Composition of the third experiment

Materials	**Amount(gr)**
Marble dust (Mugla white marble)	79
Hemp particles	11.6
Lime putty	92
Water	45.5

Volume calculations

Volume of the mold	170.2 cm^3
Expected thickness of the sample	3 cm
Expected volume of the sample	170.2 cm^3

Scheme of the experimentation

Materials

Dust of Mugla white marble

Lime putty

Hemp particles

Water

Production

Preparing the materials

Mixing the materials

Pouring into mold and leaving to dry

Final state

Sample preparation

First step, preparation of the materials; hemp particles, lime putty, marble dust, water (Kamis 2024)

When the results obtained from the first and second experiments were evaluated, the production of a sample containing hemp particles with a thickness more than 1 cm was found suitable for the ideal use. The composition and material ratio used in other experiments were the reference for the calculations in this experiment.
As in previous experiments, all materials are poured into the same container and the mixing process begins. The excess hemp particles obtained by sieving the hemp hurd during the second experiment were set aside for use in future experiments, and therefore no attempt was made to obtain hemp particles again for the third experiment.

Second step, mixing the mixture, pouring into mold and leaving to dry on the heater (Kamis 2024)

Final state of the sample after five days (Kamis 2024)

Unlike the other two experiments, the mixture left to dry on the heater. The mixture, which was planned to dry faster with the temperature of the heater, completely dried 5 days after the experiment. This result was caused by the heater's low temperature and not being in constant operation. The sample was easily removed from the mold and did not undergo any decomposition. The sample named as 3A.

EXPERIMENT 4

Composition of the fourth experiment

Main layer

Materials	**Amount(gr)**
Marble dust (Bardiglio marble)	92.8
Hemp particles	19
Lime putty	104
Water	77.9

The required amount of materials of the mixture prepared to form the main layer

Aesthetic outer layer

Materials	**Amount(gr)**
Marble dust (Bardiglio marble)	41.76
Lime putty	52.4
Golden acrilic paint	20

The required amount of materials of the mixture prepared to form the aesthetic outer layer

Volume calculations

Volume of the mold (14x16x4)	896 cm^3
Expected thickness of the main layer of the sample	1 cm
Expected thickness of the outer layer of the sample	0.5 cm
Expected thickness of the sample	1.5 cm
Expected volume of the sample(14x16x1.5)	336 cm^3

Scheme of the experimentation

Materials

Dust of Bardiglio marble

Lime putty

Hemp particles

Water

Golden acrilic paint

Production of the mixture of the main layer

Sieving the hemp to obtain particles

Preparing all materials for the main layer

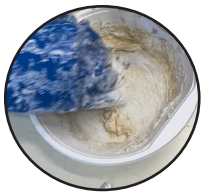
Mixing

Mixture of the main layer

Production of the mixture of the aesthetic outer layer

Preparing all materials for the aesthetic outer layer

Adding acrilic paint



Mixing

Mixture of the aesthetic outer layer

Preparing the mold; placing a pattern

Preparing the mold; applying the oil

Pouring the mixture of aesthetic outer layer

Pouring the mixture of main layer

Leaving to dry

Final state

Sample preparation

First step, preparation of the materials for the first mixture (main layer); hemp particles obtained by sieving the hemp, lime putty, marble dust, water (Kamis 2024)

The purpose of the fourth experiment is to produce a sample whose outer surface is more aesthetic compared to the other samples produced in the previous experiments. For this reason, although the content is almost the same, the experiment is carried out in the laboratory of Politecnico di Torino, Italy (a place more suitable for experimentation). The dust of Bardiglio marble is preferred and, as before, the hemp is sieved to be used in particle form. Based on previous compositions, the volume of the sample to be produced and the ratio of the materials it contains are calculated. The sample will consist of two different layers. The main layer of the sample is intended to be 1 cm thick, and the outer layer to provide an aesthetic appearance is intended to be 0.5 cm thick.

Second step, mixing the mixture to obtain the main layer (Kamis 2024)

By mixing the materials together, the main mixture is ready for application.



Third step, preparation of the materials for the second mixture (outer layer); marble dust, lime putty, golden acrilic paint (Kamis 2024)

Marble dust and lime putty, which are necessary for the mixture that will create an aesthetic appearance, are poured into the same container and acrilic paint is added.

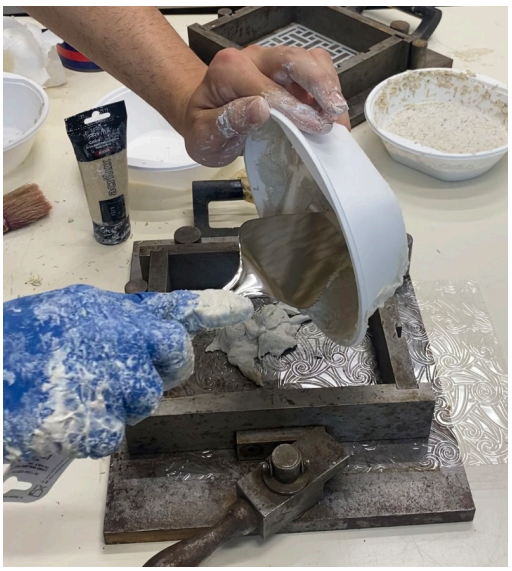

Fourth step, mixing the mixture to obtain the outer layer (Kamis 2024)

Acrylic paint is added until the mixture reaches the desired color. The mixture is ready for application after mixing thoroughly.



Fifth step, preparation of the mold (Kamis 2024)

The levels are marked as cm inside the mold where the mixtures will be poured. The level of each mixture is predetermined. The pattern is placed to the bottom surface of the mold and thus, when the mixture dries, the pattern will be formed on it. Finally oil is applied to the mold to ensure that the mixture can be separated from it more easily.




Sixth step, pouring the second mixture as the outer layer (Kamis 2024)

The second mixture containing marble dust, lime putty and acrylic paint is poured into the mold to have a pattern when it dries.

Seventh step, pouring the first mixture as the main layer and leaving to dry at room temperature (Kamis 2024)

The first mixture containing hemp particles, lime putty, marble dust and water is poured on the second mixture. The mixture, which is ready at the end of the fourth experiment and consists of 2 different layers, is left to dry.

Final state of the sample after 10 days (Kamis 2024)

The sample that is completely dry 10 days after the fourth experiment is named 4A. Although no difficulties were encountered when removing the sample from the mold, cracks are evident on the surface.

EXPERIMENT 5

Composition of the fifth experiment

Main layer

Materials	**Amount(gr)**
Marble dust (Bardiglio marble)	278.4
Hemp particles	48
Lime putty	312
Water	300

The required amount of materials of the mixture prepared to form the main layer

Aesthetic outer layer

Materials	**Amount(gr)**
Marble dust (Bardiglio marble)	120
Lime putty	150
Water	50
Ultramarine acrilic paint	20

The required amount of materials of the mixture prepared to form the aesthetic outer layer

Volume calculations

Volume of the mold (14x16x4)	896 cm^3
Expected thickness of the main layer of the sample	2 cm
Expected thickness of the outer layer of the sample	1 cm
Expected thickness of the sample	3 cm
Expected volume of the sample (14x16x3)	672 cm^3

Scheme of the experimentation

Materials

Dust of Bardiglio marble

Lime putty

Hemp particles

Water

Ultramarine acrilic paint

Production of the mixture of the main layer

Sieving the hemp to obtain particles

Preparing all materials for the main layer

Mixing

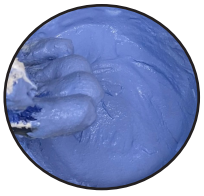
Mixture of the main layer

Production of the mixture of the aesthetic outer layer

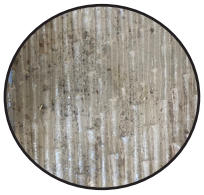
Preparing all materials for the aesthetic outer layer

Adding acrilic paint

Mixing



Mixture of the aesthetic outer layer



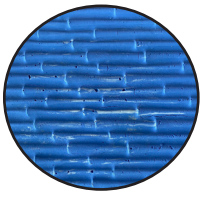
Preparing the mold; placing a pattern

Preparing the mold; applying Vaseline

Pouring the mixture of aesthetic outer layer

Pouring the mixture of main layer

Leaving to dry



Final state

Sample preparation




First step, preparation of the materials for the first mixture (main layer); hemp particles obtained by sieving the hemp, lime putty, marble dust, water (Kamis 2024)

In the fifth experiment, it is aimed to produce a sample whose outer layer has an aesthetic appearance, as in the fourth experiment. The same materials were used in the main content as in previous experiment, only ultramarine was preferred instead of golden as acrylic paint.


Second step, mixing the mixture to obtain the main layer (Kamis 2024)

The main mixture is ready for application.




Third step, preparation of the materials for the second mixture (outer layer); marble dust, lime putty, ultramarine acrilic paint, water (Kamis 2024)

The ultramarine acrylic paint which is added to the lime putty and marble dust adds an intense blue tone to the second mixture. With the addition of water the mixing process begins.


Fourth step, mixing the mixture to obtain the outer layer (Kamis 2024)

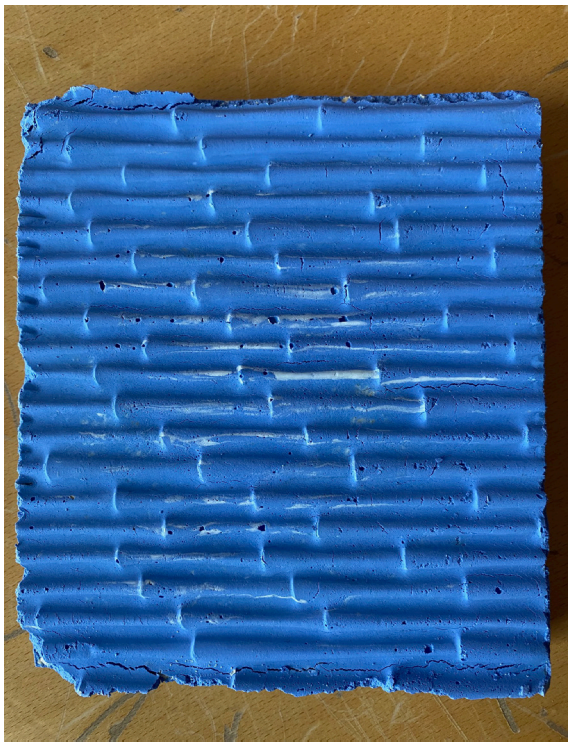
The mixture is stirred until it acquires the desired blue tone.

Fifth step, preparation of the mold (Kamis 2024)

As in the fourth experiment, a different pattern is placed to the bottom surface of the mold and Vaseline is applied to the surface to ensure that the mixture can be separated from it more easily.

Sixth step, pouring the second mixture as the outer layer (Kamis 2024)

Seventh step, pouring the first mixture as the main layer and leaving to dry at room temperature (Kamis 2024)



Final state of the sample after 10 days (Kamis 2024)

The sample was completely dried 10 days after the experiment.
Although the desired results were achieved in terms of aesthetics in this sample, some cracks are observed on the surface. Traces of Vaseline are evident. While removing the sample from the mold, fragmentation is observed in the corners. The sample named as 5A.

EXPERIMENT 6

Composition of the sixth experiment

Main layer

Materials	Amount(gr)
Marble dust (Bardiglio marble)	180
Hemp particles	33
Lime putty	200
Water	117

The required amount of materials of the mixture prepared to form the main layer

Aesthetic outer layer

Materials	Amount(gr)
Marble dust (Bardiglio marble)	120
Plaster	150
Water	25

The required amount of materials of the mixture prepared to form the aesthetic outer layer

Volume calculations

Volume of the mold (14x16x4)	896 cm^3
Expected thickness of the main layer of the sample	1.5 cm
Expected thickness of the outer layer of the sample	1 cm
Expected thickness of the sample	2.5 cm
Expected volume of the sample (14x16x2.5)	560 cm^3

Scheme of the experimentation

Materials

Dust of Bardiglio marble

Lime putty

Hemp particles

Water

Plaster

Production of the mixture of the main layer

Sieving the hemp to obtain particles

Preparing all materials for the main layer

Mixing

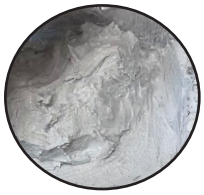
Mixture of the main layer

Production of the mixture of the aesthetic outer layer

Preparing all materials for the aesthetic outer layer

Adding plaster

Mixing



Mixture of the aesthetic outer layer

Preparing the mold; placing a pattern

Preparing the mold; applying oil

Pouring the mixture of aesthetic outer layer

Pouring the mixture of main layer

Leaving to dry

Final state

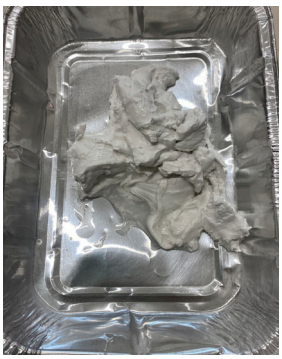
Sample preparation

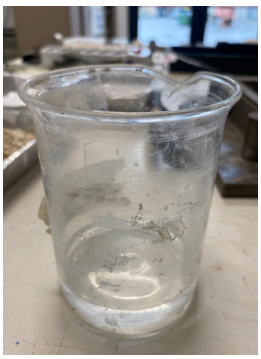
First step, preparation of the materials for the first mixture (main layer); lime putty, marble dust, hemp particles obtained by sieving the hemp, water (Kamis 2024)

In the sith experiment, unlike the previous experiments, plaster was preferred and no pigment was used. The purpose of this is to observe whether marble dust can create an aesthetic appearance without the need for paint when it is mixed with plaster.

Second step, mixing the mixture to obtain the main layer (Kamis 2024)

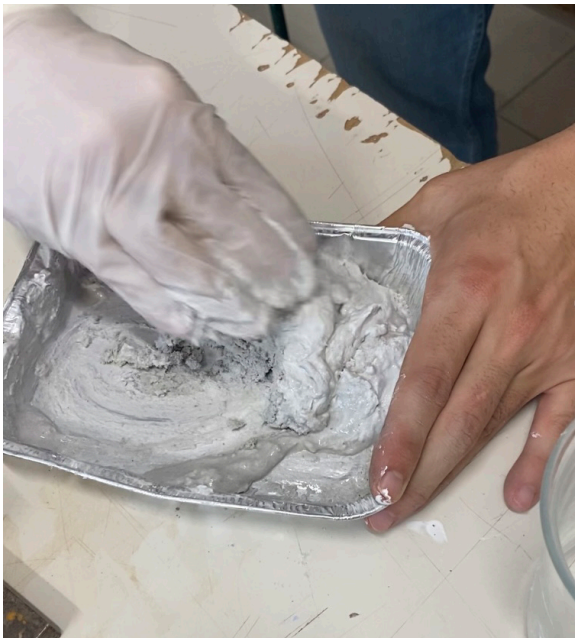
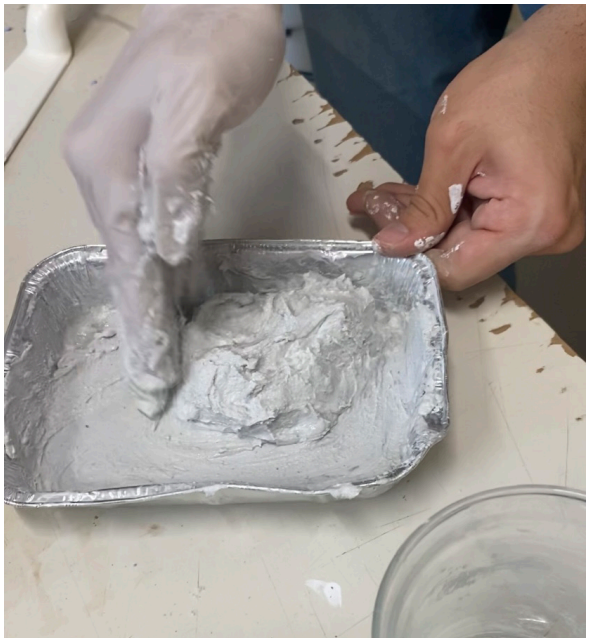
The main mixture is ready for application.






Third step, preparation of the materials for the second mixture (outer layer); plaster, marble dust, water (Kamis 2024)

At this stage of the experiment, the difference is observed by using plaster instead of lime putty.

Fourth step, mixing the mixture to obtain the outer layer (Kamis 2024)




Fifth step, preparation of the mold (Kamis 2024)

Oil is preferred instead of vaseline.


Sixth step, pouring the second mixture as the outer layer (Kamis 2024)

Seventh step, pouring the first mixture as the main layer and leaving to dry at room temperature (Kamis 2024)

Final state of the sample after 10 days (Kamis 2024)

Certain cracks are observed on the front surface of the sample, which is completely dried 10 days after the experiment. The front surface made using plaster and marble dust was more brittle than the surfaces made with lime putty and marble dust. The sample named as 6A.

EXPERIMENT 7

Composition of the seventh experiment

Main layer

Materials	Amount(gr)
Marble dust (Bardiglio marble)	300
Hemp particles	55
Lime putty	333
Water	195

Volume calculations

Volume of the mold (14x16x4)	896 cm^3
Expected thickness of the sample	2.8 cm
Expected volume of the sample (14x16x2.8)	627.2 cm^3

Scheme of the experimentation

Materials

Dust of Bardiglio marble

Lime putty

Hemp particles

Water

Production

Preparing the materials

Mixing the materials

Preparing the mold; applying oil

Pouring into mold and leaving to firm up

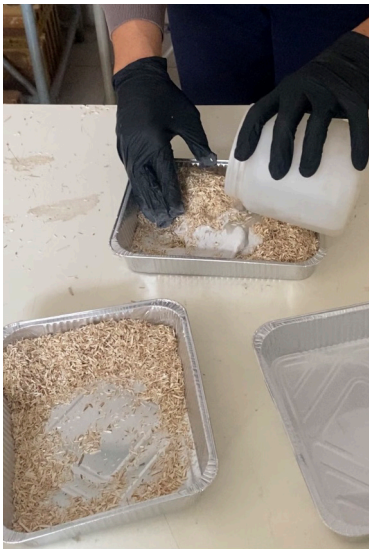
Polishing

Polishing with soapy water

Final state

Sample preparation





First step, preparation of the materials; marble dust, lime putty, hemp particles, water (Kamis 2024)

The purpose of the seventh experiment is to examine whether a different aesthetic touch can be made with the technique used in previous experiments. The experiment starts with adding marble dust to lime putty and continues by adding hemp particles (sieved before) and water.



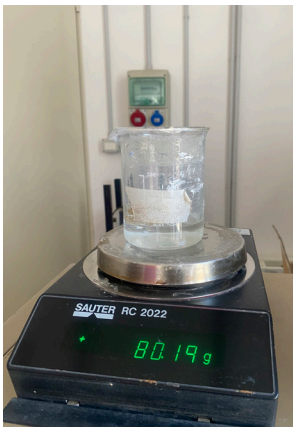
Second step, mixing the mixture, pouring into mold and leaving to firm up at room temperature (Kamis 2024)

Polishing process

Polishing with soapy water


Artistic touch with spatula one day after the experiment (Kamis 2024)

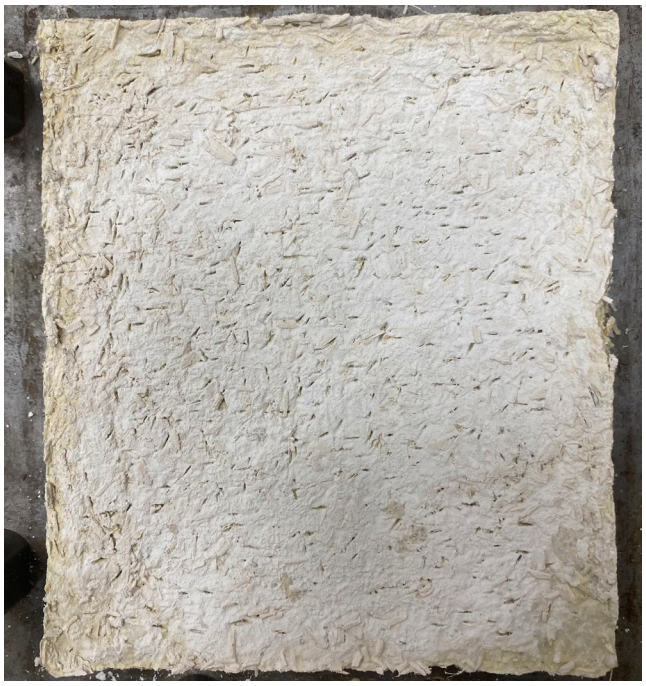
Before polishing with soapy water, a pattern is tried to be created on the surface of the sample with the help of a spatula. However, due to the hemp particles it contains the sample returns to its old flat form and no aesthetic texture can be created.




Preparing the soapy water (Kamis 2024)

20 grams of Moroccan black soap is added to 80 grams of water and mixed until soap particles become invisible.

One day after the experiment, soapy water is applied to the surface of the sample which is still wet and the sample is left to dry at room temperature. At this stage, the surface can be polished by rubbing it with an agate stone.



The final state of the sample after 15 days (Kamis 2024)

The sample was completely dried 15 days after the experiment. The fact that the experiment was carried out in autumn, in a colder environment, prolonged the drying time. The desired aesthetic texture could not be created on the surface of the sample and a significant brightness could not be achieved. No cracks occurred on the surface. The sample is named as 7A.

EXPERIMENT 8

Composition of the eighth experiment

Main layer

Materials	**Amount(gr)**
Marble dust (Bardiglio marble)	180
Hemp particles	33
Lime putty	250
Water	117

The required amount of materials of the mixture prepared to form the main layer

Volume calculations

Volume of the mold (14x16x4)	896 cm^3
Expected thickness of the main layer of the sample	1.5 cm
Expected thickness of the outer layer of the sample	1 cm
Expected thickness of the sample	2.5 cm
Expected volume of the sample (14x16x2.5)	560 cm^3

Aesthetic outer layer (Tadelakt finishing)

Materials	A**mount(gr)**
Marble dust (Bardiglio marble)	120
Lime putty	150
Water	70
Alizarin Carmine pigment	15

The required amount of materials of the mixture prepared to form the aesthetic outer layer

Scheme of the experimentation

Materials

Dust of Bardiglio marble

Lime putty

Hemp particles

Water

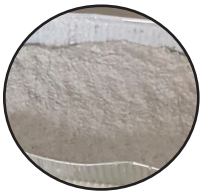
Alizarin Carmine pigment

Production of the mixture of the main layer

Sieving the hemp to obtain particles

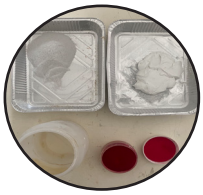
Preparing all materials for the main layer

Mixing



Mixture of the main layer

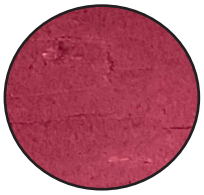
Production of the mixture of the aesthetic outer layer, Tadelakt



Preparing all materials for the aesthetic outer layer, Tadelakt

Adding pigment

Mixing



Mixture of the aesthetic outer layer, Tadelakt

Preparing the mold; applying oil

Pouring the mixture of main layer

Pouring the mixture of aesthetic outer layer, Tadelakt

Creating the pattern with spatula and leaving to firm up

Polishing

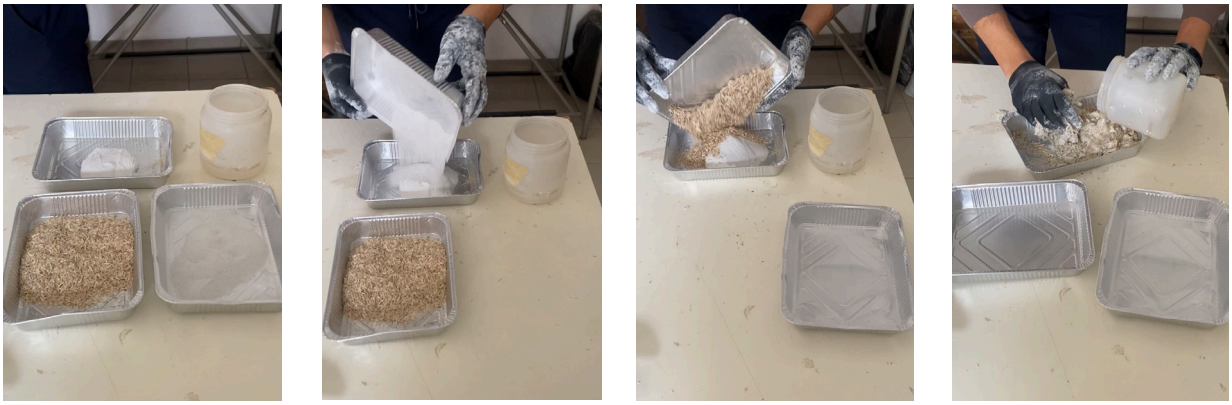
Polishing with soapy water

Recreating the pattern

Leaving to dry

Final state

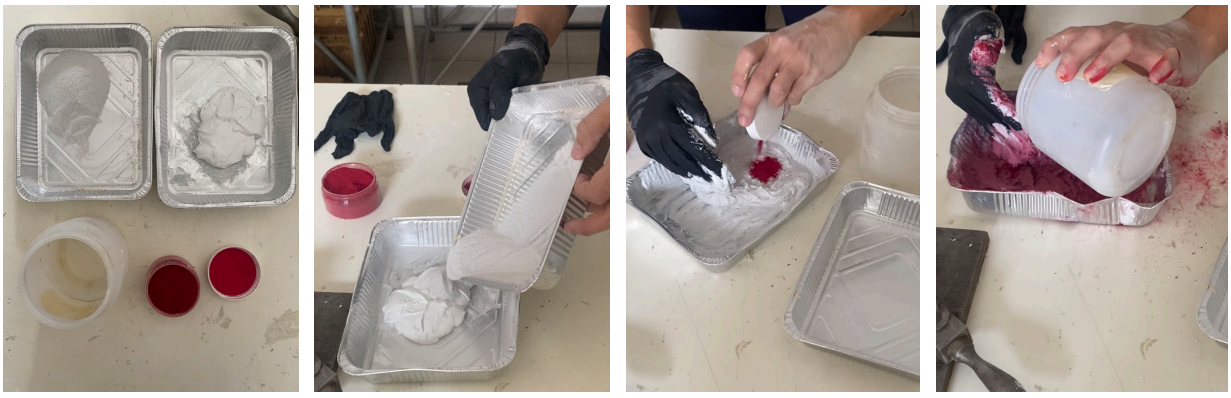
Sample preparation



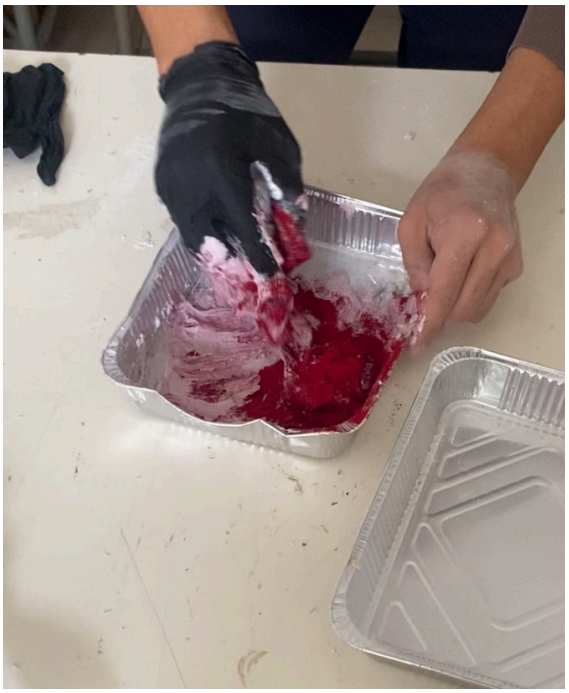
First step, preparation of the materials for the first mixture (main layer); lime putty, marble dust, hemp particles obtained by sieving the hemp, water (Kamis 2024)

The eighth experiment aimed to combine the Tadelakt plastering technique, which has been used for many years, with material production. For this reason, the mixture that will form the Tadelakt plaster was combined with the main mixture used in previous experiments to produce an aesthetic sample.

Second step, mixing the mixture to obtain the main layer (Kamis 2024)



Third step, preparation of the materials for the second mixture (Tadelakt finishing as outer layer); marble dust, lime putty, Alizarin Carmine pigment, water (Kamis 2024)



Fourth step, mixing the mixture to obtain Tadelakt as outer layer (Kamis 2024)

Fifth step, preparation of the mold (Kamis 2024)

Oil is applied to the mold.


Sixth step, pouring the first mixture as the main layer (Kamis 2024)

Unlike other experiments, the mixture that will form the main layer is first poured into the mold.


Seventh step, pouring the second mixture as Tadelakt, creating the pattern on it and leaving to firm up at room temperature (Kamis 2024)

After the Tadelakt mixture is poured into the mold, a pattern is created on the surface with the help of a spatula.

Polishing process

Polishing with soapy water

Polishing with soapy water, recreating the pattern and leaving to dry at room temperature (Kamis 2024)

One day after the experiment, previously prepared soapy water is applied to the surface of the sample. Meanwhile, the pattern on the surface of the sample is deformed. Deterioration occurs in the surface texture due to the fact that the sample is still wet and the amount of soapy water used is too much. After the application of soapy water, a pattern is recreated on the surface with the help of a spatula.

The state of the sample after 10 days (Kamis 2024)

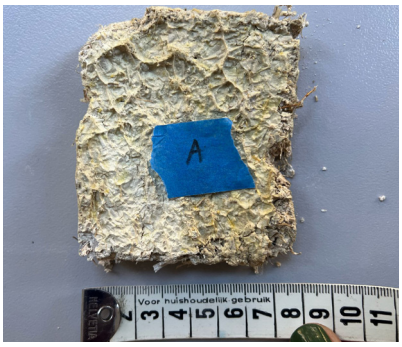
No cracks were found on the surface area of the sample, whose color becomes lighter as it dries. The use of intense amounts of soapy water affected the pigment on the surface. The sample is still drying and it is named as 8A.

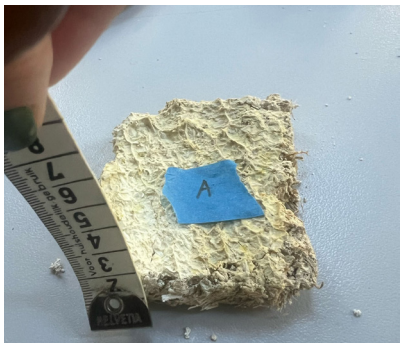
4A, 5A, 6A, 7A and 8A samples after drying (Kamis 2024)

4.3.1 Assessments of the results

Dimensions, volume, mass and the density of the samples after drying

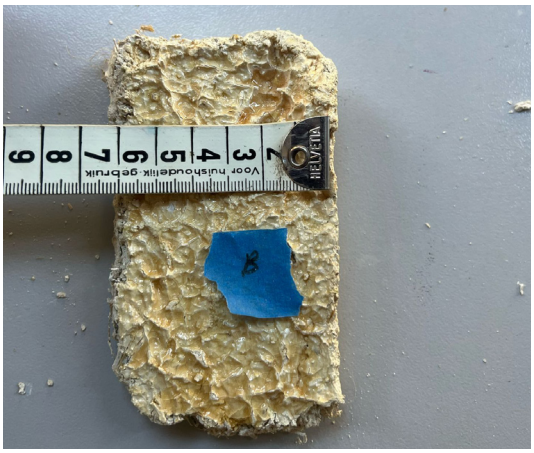
Sample 1A





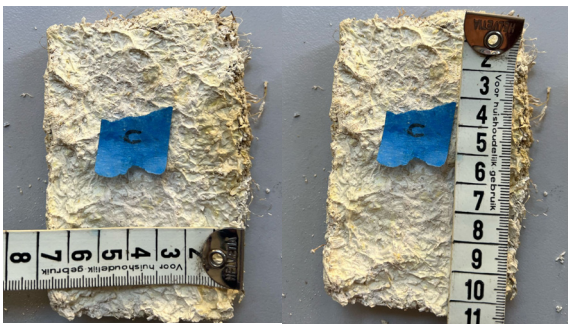
Dimensions are : 8x9x 1.7 cm (Kamis 2024)

Sample 1B



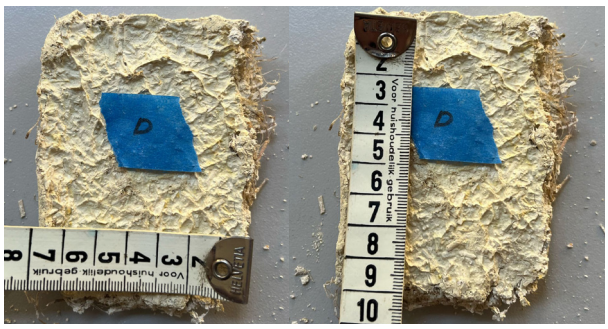

6x11x1.7 cm (Kamis 2024)

Sample 1C



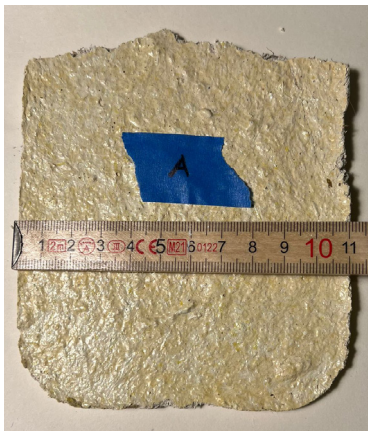
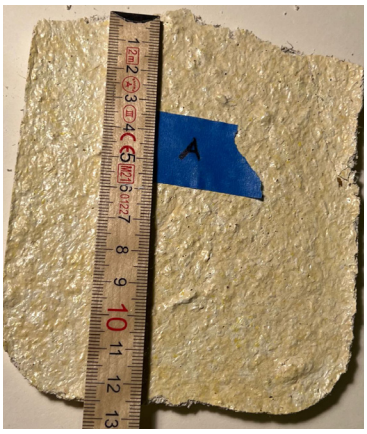
7x10.5x1.7 cm

Sample 1D



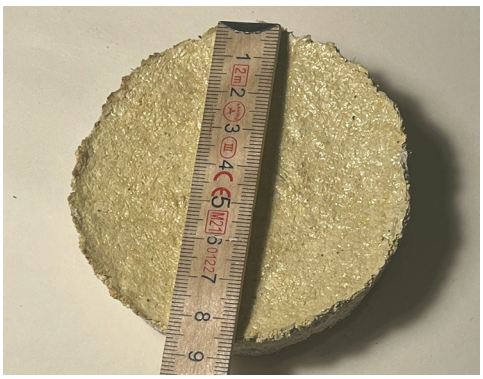
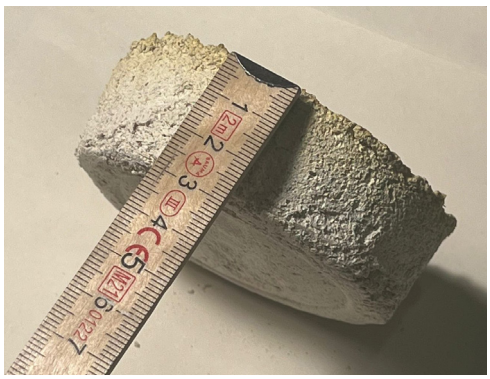
7x9.5x1.7 cm (Kamis 2024)

Sample 2A


11x12.5x0.6 cm (Kamis 2024)

Sample 3A

Ø 8.5x3 cm (Kamis 2024)

Sample 4A



Dimensions are: 14x16x1.3 cm, Volume is: 291.2 cm^3, Mass is: 204.4 g, Density is: 701 kg/m^3 (Kamis 2024)

Sample 5A

Dimensions are: 14x16x2.8 cm, Volume is: 627.2 cm^3, Mass is: 654.4 g, Density is: 1043 kg/m^3 (Kamis 2024)

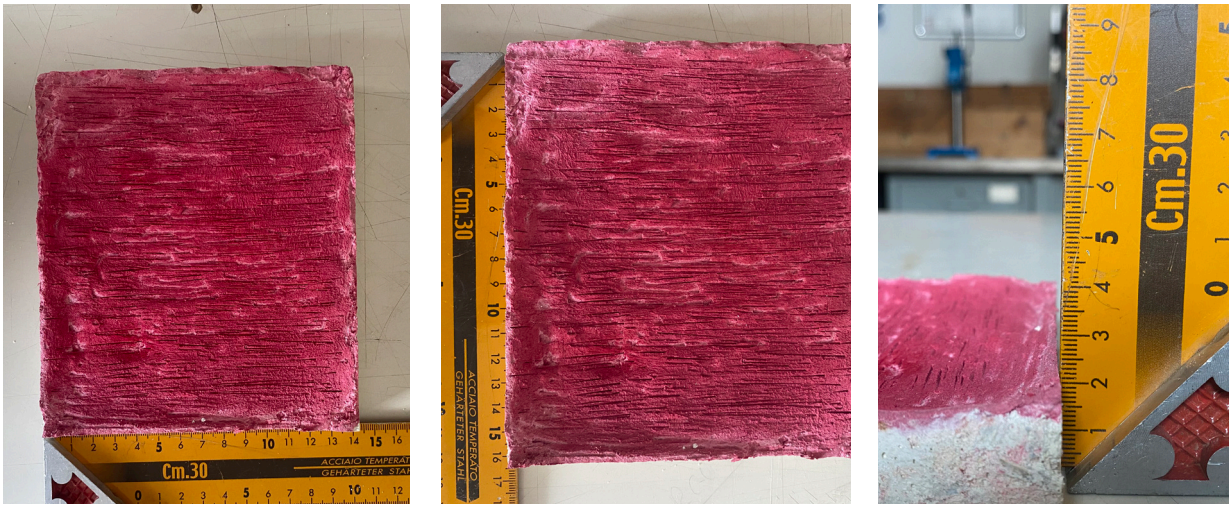
Sample 6A

Dimensions are: 14x16x2.3 cm, Volume is: 515.2 cm^3, Mass is: 519.2 g, Density is: 1007.7 kg/m^3 (Kamis 2024)

Sample 7A

Dimensions are: 14x16x2.6 cm, Volume is: 582.4 cm³, Mass is: 507.1 g, Density is: 870 kg/m³ (Kamis 2024)

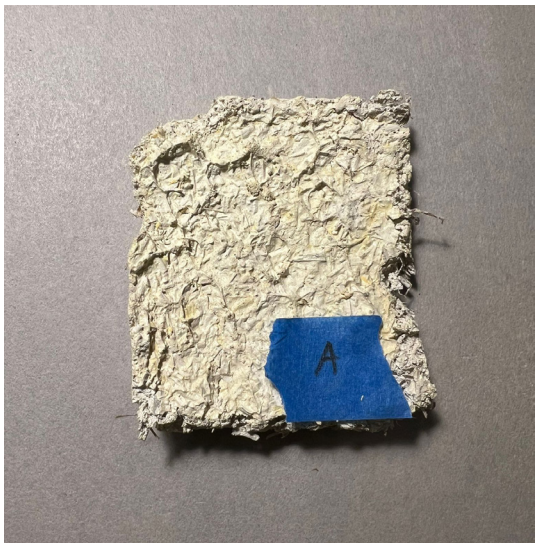
Sample 8A



Dimensions are: 14x16x2.3 cm, Volume is: 515.2 cm³, Mass is: 538.8 g, Density is: 1045 kg/m³ (Kamis 2024)

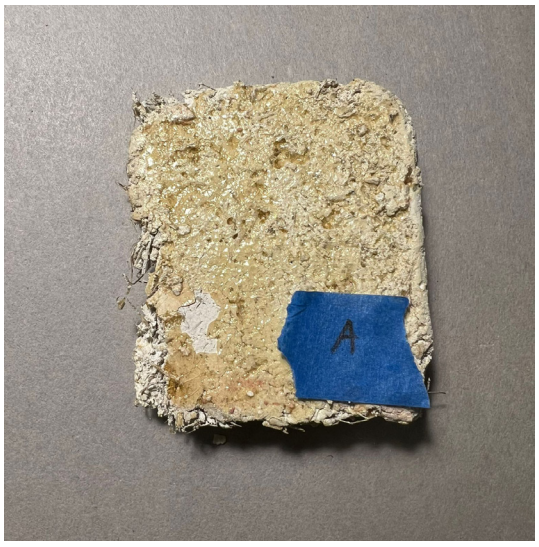
Evaluations

Sample 1



The front surface of sample 1A which was not processed after drying (Kamis 2024)

Since it was not polished in any way after it was completely dried, the color of the sample 1A could not take on a bright tone. A rough texture was obtained on the surface, where no cracks were observed. Due to the texture created by the hemp hurd used on the surface, the sample does not have the desired aesthetic appearance.



The back surface of sample 1A which was polished with acacia tree resin after drying (Kamis 2024)

Since the hemp hurd remained on the front surface of the mixture, the back surface of the sample is smoother. A certain amount of gloss was observed on the surface compared to the unpolished surfaces.

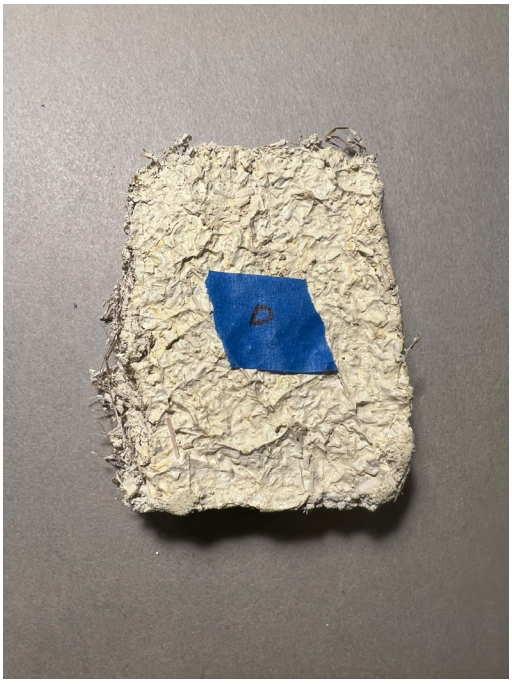
The front surface of sample 1B which was polished with acacia tree resin after drying, the results are the same as in sample 1A (Kamis 2024)

The back surface of sample 1B which was not processed after drying, the results are the same as in sample 1A (Kamis 2024)

The front surface of sample 1C which was polished with soapy water after drying (Kamis 2024)

The desired gloss could not be achieved on the surface. Polishing with acacia tree resin gave better results.

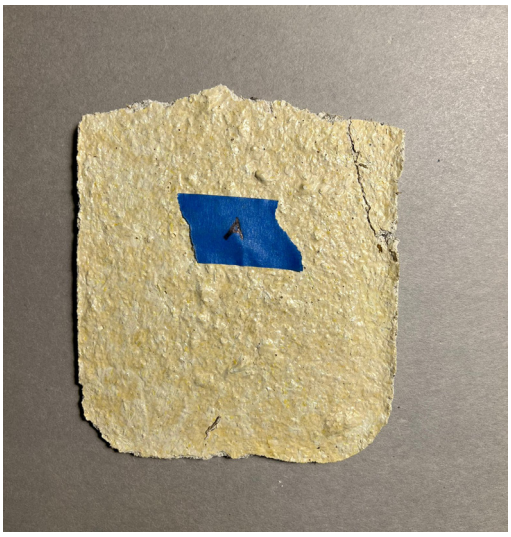
The back surface of sample 1C which was polished with soapy water after drying (Kamis 2024)



The front surface of sample 1D which was not processed after drying (Kamis 2024)

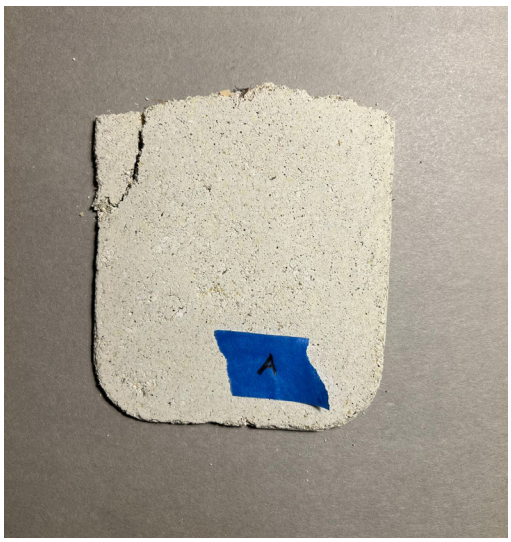
The back surface of sample 1D which was not processed after drying (Kamis 2024)

Sample 2



The front surface of sample 2A which was not processed after drying (Kamis 2024)

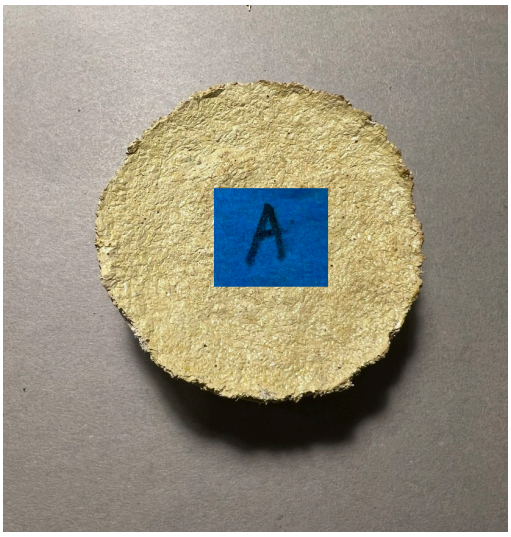
Sample 2A was broken into pieces through cracks on its surface. Although this piece of the sample has not undergone any polishing process, it has a natural shine and a smooth surface. It is thought that the reason for this is the accumulation of hemp particles on the upper layer. The sample is too thin and fragile.



The back surface of sample 2A which was not processed after drying (Kamis 2024)

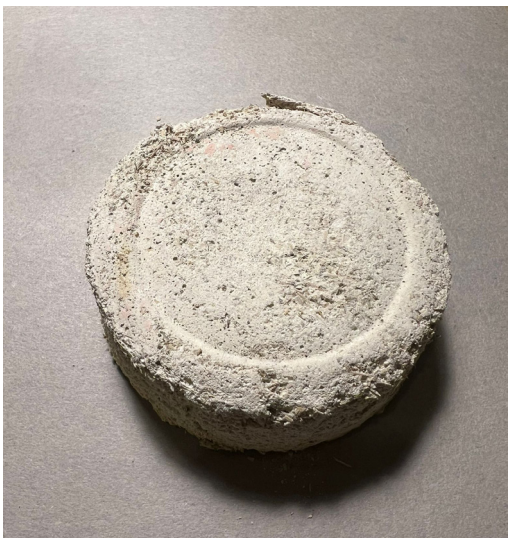
This surface area has a pale color and texture due to hemp particles remaining on the upper layer of the mixture

Sample 3



The front surface of sample 3A which was not processed after drying (Kamis 2024)

The advantage of its thickness and smooth surface due its composition of hemp particles show that the sample has a potential. Although the surface is not polished, it has a natural shine. Even if the composition and the thickness of 3A are close to the desired level, the surface does not have any patterns and the appearance is not aesthetically sufficient.



The back surface of sample 3A which was not processed after drying (Kamis 2024)

There is a significant difference in gloss and appearance between the front and back surfaces.

Sample 4

The front surface of sample 4A (Kamis 2024)

Although 4A sample has an aesthetic appearance with the patterns, it is not suitable for production due to cracks on its surface.

The back surface of sample 4A (Kamis 2024)

No cracks were observed on the back surface, which dried in contact with air and contained hemp particles.

Sample 5

The front surface of sample 5A (Kamis 2024)

After the first 10 days, a change in blue color on the front surface and the cracks were observed. White spots have appeared due to the use of Vaseline.

The back surface of sample 5A (Kamis 2024)

No cracks were observed on the back surface.

Sample 6

The front surface of sample 6A (Kamis 2024)

Sample 6A, which dries completely in 10 days, has the potential to be produced as an aesthetic wall panel with its dimensions and aesthetic texture. The plaster used on the front surface has made the surface more sensitive and for this reason, lime putty can be preferred instead of it. Cracks on the surface of the sample are an issue that must be prevented.

The back surface of sample 6A (Kamis 2024)

No cracks were observed on the back surface.

Sample 7

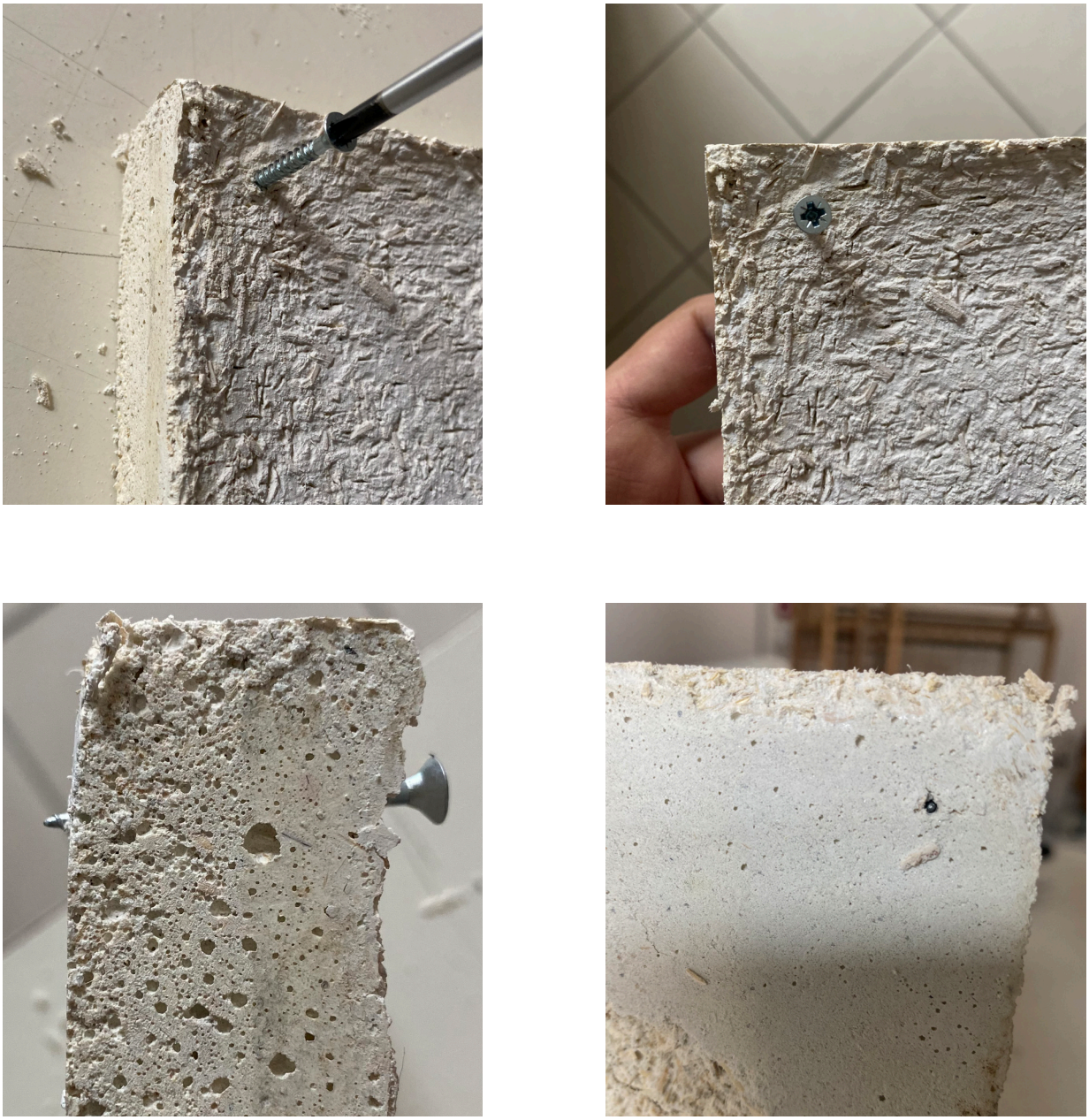
The front surface of sample 7A (Kamis 2024)

The front surface of sample 7A is flat and devoid of aesthetic texture, but no cracking was observed on the surface.

The back surface of sample 7A (Kamis 2024)

Although no cracks were observed on the back surface of sample 7A, fragments occurred when removing it from the mold. Placing plastic on the bottom surface of the mold will eliminate this problem.

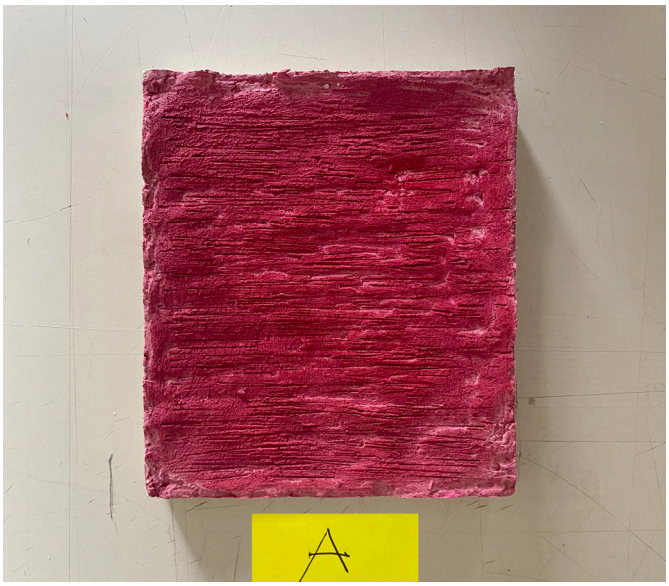
Possible application methods of sample 7A



Mounting sample 7A to the wall using screws (Kamis 2024)

When sample 7A was screwed, no cracking or disintegration was observed.
Different experiments on the samples should be carried out in order to explore and assess the possibilities of application as wall panels.

Sample 8



The front surface of sample 8A (Kamis 2024)

Due to the temperature of the laboratory where the experiment was carried out, sample 8A dried in approximately 20 days. During this period, the red color turned into a pink day by day and the sample achieved an appearance close to the desired aesthetic appearance. No cracks or decomposition were observed on the surface.

The back surface of sample 8A (Kamis 2024)

The back surface of the sample 8A was deformed while being removed from the mold. This problem, also observed in the previous sample, can be prevented by using plastic or paper on the surface of the mold.

Comparison

Sample	Volume (cm^3)	Mass (g)	Density (kg/m^3)	Thickness (cm)	Aesthetic or not	Cracks
1(In one piece)	571.2	-	-	1.7	Not, rough surface	No
2A	132	-	-	0.6	Not, simple color and texture	Yes
3A	170.2	117	687.4	3	Not, simple color and texture	No
4A	291.2	204.4	701	1.3	Not, nice color and texture but cracks occured	Yes
5A	627.2	654.4	1043	2.8	Not, nice color and texture but cracks occured	Yes
6A	515.2	519.2	1007.7	2.3	Not, nice color and texture but cracks occured	Yes
7A	582.4	507.1	870	2.6	Not, simple color and texture	No
8A	515.2	538.8	1045	2.3	Aesthetic, nice color and texture	No

As a result of the experiments, it was observed that all samples had positive and negative features.

Sample 1(In one piece) is not at a sufficient level in terms of aesthetics due to the hemp hurd it contains. Since the hemp was not used in particle form, the materials were not thoroughly mixed together.

Sample 2A is suitable in terms of content but the thickness created a problem and the sample was broken into pieces before complete observation could be made.

Sample 3A is suitable in terms of thickness and composition, but the simplicity in the surface appearance is not aesthetically pleasing.

Sample 4A has a similar composition to sample 3A, the density values are close to each other. Although the aesthetic texture on the surface area is close to the desired appearance, the cracks in the sample are considered a problem that needs to be prevented. The main reason for this problem is that the front surface of the sample dries without contact with air. In terms of mass, sample 4A is composed of approximately 33% marble dust, 4.6% hemp particles, 38.3% lime putty, 19.1% water and 4.9% acrylic paint.

Sample 5A is found to be suitable in terms of general composition and aesthetics but cracks on the surface must be prevented. Vaseline applied to easily remove the sample from the mold left a mark in the form of white spots on the surface, and this negatively affected the aesthetic appearance. In terms of mass, sample 5A is composed of approximately 31.2% marble dust, 3.7% hemp particles, 36.2% lime putty, 27.4% water, and 1.57% acrylic paint. The fact that sample 5A contains lower percentage of acrilic paint than sample 4A has caused a significant difference between the density values of these two samples.

Sample 6A is very close to the desired level in terms of dimensions, composition and aesthetics. It was produced with sample 5A as reference in composition and was evaluated as having potential for future production if cracks on the surface are prevented and lime putty is used instead of plaster. The use of plaster has made the surface of the sample more sensitive.

Sample 7A is produced to test the artistic touch method. A pattern was tried to be created on the front surface with the help of a spatula. Although there were no cracks on the surface of the sample and its general properties were pleasing, the desired aesthetic texture could not be obtained. Since the hemp particles were dispersed throughout the mixture, the sample returned to its former flat shape right after the each spatula stroke. It was concluded that hemp should not be used in mixtures where patterns will be created.

Sample 8A was produced to combine the Tadelakt plastering technique with the material. While sample 8A was produced with the reference taken from sample 5A, the mixture that would form Tadelakt plaster on the surface was preferred. It is aimed to obtain an aesthetic appearance by using the principles of Tadelakt. Considering its general properties and production techniques, sample 8A is the most suitable sample for the production of aesthetic wall panel compared to the others. The composition of the sample, its dimensions, and the fact that it is produced by interpreting different techniques such as Hempcrete and Tadelakt, give an idea about the potential of it in the future. In addition, unlike the smooth Tadelakt plaster, patterns were created on the surface with the help of a spatula and no problems such as cracking or returning to the old form were encountered. The front surface of sample 8A has approached the desired level in terms of both color and texture. Although the surface color and texture change during polishing with soapy water, the appearance close to the desired is achieved as the sample dries. If the amount of soapy water applied is adjusted correctly, sample 8A will have more color and texture options. In terms of mass, sample 8A is composed of approximately 32% marble dust, 3.53% hemp particles, 42.78% lime putty, 20% water, and 1.6% acrylic paint. The fact that sample 8A contains less marble dust in percentage terms than sample 4A does not negatively affect its physical properties.

CONCLUSIONS

Today, many new technologies are being produced to meet the increasing consumption needs but it is almost impossible to meet these needs only by processing the natural raw materials. At this point, materials obtained by recycling with the use of different technologies offer different solutions, especially in the field of construction. Although the solutions offered by these recycled materials aim to meet the need for natural raw materials, the production methods of these materials can harm both human health and nature.

On the other hand, the wastes generated in marble manufacturing have a great potential in terms of recycling. The fact that marble dust is the most frequently used among these wastes and that it is a natural material that has begun to stand out not only in the construction industry but also in art, makes it possible to create new products by using the waste.
This led to the development of the idea of producing materials from marble dust.

In this research which explores the possibilities of reuse of marble dust - waste from extraction and processing - to create new sustainable products for the construction industry, 8 different samples were produced with the similar content. After analysing the different types of marble waste, the thesis focuses on marble dust, highlighting its current uses in Turkey, also considering its level of sustainability. The investigation focuses on a technique used in the artistic field that reuses marble dust. In the scenario of reuse of the waste product investigated in the thesis, this technique, explored in depth with a direct collaboration with artists, is adapted and transferred to the construction field for the production of interior cladding panels. In addition, despite the use of synthetic materials in innovative material production techniques experienced during the research, natural materials such as lime and hemp, along with marble dust, were preferred in the experimental part of the study, minimizing health problems that may occur during production.

Among the samples produced at the end of this research; 8A was identified as the sample with the most potential. Since the surface of sample 8A is plastered with the Tadelakt technique, it has a greater potential than others. Sample 8A offers many different aesthetic options by using a thousands of years old plastering technique in material production. Tadelakt plaster's ability to have different colors, its waterproof properties, easy cleaning and recyclability enable the 8A sample to have wider usage areas in the future.

One aspect of sample 8A that needs improvement is the polishing method.
Since sample 8A was polished with intense soapy water, some color change was observed on the surface. The fact that the pigment used was an intense and vibrant color made it difficult to find the desired color in sample. Applying the right amount of soapy water will make the color tone on the surface more vibrant. On the other hand, it can be seen that the surface plastered with Tadelakt can also have texture. Since the force applied to the surface of the patterned samples will damage the texture, different aesthetic appearances can be obtained polishing only the unpatterned, flat surfaces.

In conclusion, although meeting the need for raw materials by using waste is an important issue, using different synthetics in production causes other negative health problems and environmental pollution. This research shows that cheap, lightweight, aesthetically pleasing materials can be produced by using natural materials such as lime, hemp and waste materials such as marble dust.
If the aesthetic appearance of the 8A sample is further improved with the correct polishing methods, its features such as durability, thermal insulation are researched and developed, the resulting material can be turned into interior cladding panel or a material that can be used in many other fields.

BIBLIOGRAPHY

Adam, Jean-Pierre. *Roman Building: Materials and Techniques.* London: Routledge, 1994.

Akman, Mehmet Süheyl. Yapı Malzemeleri. İTÜ İnşaat Fakültesi Matbaası, 1990.

Akman, Mehmet Süheyl. " Yapı Malzemelerinin Tarihsel Gelişimi." TMH-Türkiye Mühendislik Haberleri, sy.426 (2003): 30-36.

Aktaş, Özgür. "Elmas Tel Kesme Yöntemi ile Mermer İşletmeciliğinde Elmas Tellerin Kesim Performanslarının Araştırılması." Yüksek Lisans Tezi, T.C. Selçuk Üniversitesi, 2012.

Algan, Nusret. "Anadolu Selçuklu Dönemi Mimarisi Taş Yüzey Süslemelerinin İncelenmesi ve Seramik Yorumları." Sanatta Yeterlilik Tezi, T.C. Dokuz Eylül Üniversitesi, 2008.

Algül, Bahadır. "Mermer İşçilerinin Erasmus Sendromu Hakkında Bilgi ve Bilinç Düzeylerinin Belirlenmesi." Yüksek Lisans Tezi, T.C. Burdur Mehmet Akif Ersoy Üniversitesi, 2019.

Altındağ, Raşit. "Doğal Taş Ocaklarında Artık Oluşumunun Önlenmesi ve Artıkların Değerlendirilmesi." Muğla Büyükşehir Belediyesi Kültür Yayınları 6, sy.1 (Ocak 2018): 35-50.

Altındağ, Raşit. "Türkiye Doğal Taş Sektöründe Fırsatlar ve Tehtidler." Tourquise Dergisi, sy.49 (Ocak 2016) :234-37.

Aslanapa, Oktay. *Anadolu'da İlk Türk Mimarisi Başlangıç ve Gelişmesi*. Ankara: Atatürk Kültür Merkezi Yayını , 2007.

Aydan, Ömer, Halil Kumsar. "Kuşini Antik Yeraltı Mermer Ocağının Mühendislik Jeolojisi ve Kaya Mühendisliği Açısından Değerlendirilmesi." Mühendislik Jeoloji Bülteni, sy.20 (2005): 41-60.

Aydoğan, Erkan. "Çekiçler Mermer Fabrikası'nda Kusurlu Fayans Üretiminin Analizi. " Yüksek Lisans Tezi, T.C. Osmangazi Üniversitesi, 2006.

Bağcı, Metin, Mustafa Karataş. " Muğla Bölgesi Mermer Sektörünün Swot Analiz Araştırması." Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, sy.17 (Ağustos 2017): 736-52.

Barani, Kianosuh, H.Esmaili. " Production of Artificial Stone Slabs Using Waste Granite and Marble Stone Sludge Samples." Journal of Mining & Environment, no. 1(January 2016): 135-41.

Başer, İsmet."Lif Bilgisi." *Doğal Lifler*, Prof. Dr. İsmet Başer, 53-54. İstanbul: Marmara Üniversitesi Döner Sermaye İşletme Teknik Eğitim Fakültesi Matbaa Birimi, 2002.

Baş, Yaşar. " İstanbul Yapılarında Karamürsel Od Taşının Kullanımına Dair Bazı Tespitler." Bingöl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, sy.14 (Eylül 2017):46-54.

Bilget, Nuri Burhan. *Sivas'ta Buruciye Medresesi*. Ankara: K.B.Y., 1991.

Boleken, Zeki. “ Bağdat Köşkü’nde Yeniden Kullanılan Antik Renkli Mermerler ve Diğer Taşlar. ” Milli Saraylar, sy.24 (Haziran 2023): 66-87.

Böke, Hasan, Sedat Akkurt, Başak İpekoğlu. “Tarihi Yapılarda Kullanılan Horasan Harcı ve Sıvalarının Özellikleri.” Yapı Dergisi, sy.269 (2004): 90-94.

Bulut, Mustafa. “ Anadolu Selçuklu Dönemi Kayseri Taçkapılarının Genel Özellikleri.” Erciyes Akademi, sy.35 (Mart 2021): 206-20.

Cesur, Zeki. “Osmanlı Dönemi’nin 19.Yüzyılında Dini Yapılarda Modernleşme Etkisi; Nuruosmaniye Camii, Dolmabahçe Camii, Ortaköy Camii, Keçecizade Fuat Paşa Camii ve Türbesi.” Yüksek Lisans Tezi, T.C. Sakarya Üniversitesi, 2021.

Ceylan, Hakan. “ Mermer Fabrikalarındaki Toz Atıklarının Ekonomik Olarak Değerlendirilmesi.” Yüksek Lisans Tezi, T.C. Süleyman Demirel Üniversitesi, 2000.

Cimilli, Hatice Canan. “ Topkapı Sarayı’nın Anıtsal Kapılarının İşlev ve Sembolizm Açısından İncelenmesi.” Doktora Tezi, T.C. İstanbul Üniversitesi, 2007.

Çetin, Turhan. “ Türkiye’nin Mermer Potansiyeli, Üretimi ve İhracatı.” Gazi Eğitim Fakültesi Dergisi, sy.3 (2003): 243-56.

Demiriz, Yıldız. *Osmanlı Mimarisinde Süsleme I. Erken Devir (1300-1453)*. İstanbul: Kültür Bakanlığı, 1979.

Demirkan, Şule. “ Kilikya Bölgesi’nden Seçilmiş Antik Mermer Eserlerin Kökeninin Saptanması.” Yüksek Lisans Tezi, T.C Çukurova Üniversitesi, 2010.

Deniz, Vedat. “ Mermer Atıklarının Mikronize Kalsit Olarak Değerlendirilme Potansiyeli.” Muğla Büyükşehir Belediyesi Kültür Yayınları 6, sy.1 (Ocak 2018): 153-200.

Dora, O.Özcan, Nejat Kun, Osman Candan. “ Menderes Masifi’nin Metamorfik Tarihçesi ve Jeotektonik Konumu.” Türkiye Jeoloji Bülteni, sy.35 (Şubat 1992): 1-14.

Durando, Furio. *Greece: Splendours of an Ancient Civilization*. London: Thames & Hudson, 2002.

Erdem, R.Tuğrul, A.Uğur Öztürk. “Mermer Tozu Katkısının Çimento Harcı Donma-Çözünme Özellikleri Üzerine Etkisi.” BEÜ Fen Bilimleri Dergisi, sy.1 (2012): 85-91.

Erdoğan, Muzaffer. “ Osmanlı Devrinde Anadolu Camilerinde Restorasyon Faaliyetleri.” Vakıflar Dergisi, sy.7(1968): 150-203.

Erguvanlı, Kemal. “ Keserek Taş Çıkarmada Kullanılan Yeni Yöntemler.” Mühendislik Jeolojisi Bülteni, sy.9 (Şubat 1987): 2-6.

Erkan, Yavuz. " Karbonatların Kontakt Metamorfizması ile Oluşan Kayaçlar." Metamorfik Petrografi, Prof. Dr.Yavuz Erkan, 64,65. Ankara: Jeoloji Mühendisleri Odası, 2006.

Erol, İlknur. "TTK Kozlu Müessesesi Ayak İşyerlerinde Solunabilir Toz Yoğunluklarının ve Kuvars İçeriklerinin Araştırılması." Yüksek Lisans Tezi, T.C. Zonguldak Karaelmas Üniversitesi, 2007.

Erzan, Refik, Murat Taşdemir. "Blok Mermer İhracatına Getirilebilecek Kısıtlamalar ve Muhtemel Sonuçları." T.C.Boğaziçi Üniversitesi Ekonomi ve Ekonometri Merkezi, sy.1 (Nisan 2014): 5-12.

Güleç, Ahmet. "Bazı Tarihi Anıt Harç ve Sıvalarının İncelenmesi." Doktora Tezi, T.C. İstanbul Teknik Üniversitesi, 1992.

Güler, Taki, Ercan Polat. " Mermer Madenciliğinde Çevresel Yaklaşımlar." Muğla Büyükşehir Belediyesi Kültür Yayınları 6, sy.1 (Ocak 2018): 205-18.

Gökçer, Bihter, Servet Yıldız, Oğuzhan Keleştemur. " Atık Mermer Tozu ve Cam Lif İçeren Harç Numunelerinin Donma-Çözülme Etkisi Altındaki Davranışları." SDU International Tecnologic Science, no.3 (December 2013): 18-30.

Güngör, Yıldırım. " Kestanbol'un Granit Ocakları." Skylife Dergisi, sy.3 (2007): 62-68.

Güngör, Yüksel. Makine Teknolojisi Ocak Planlaması. Ankara: T.C. Milli Eğitim Bakanlığı, 2011.

Hacıfazlıoğlu ,Hasan. " Çok İnce Öğütme için Alternatif Değirmen Tiplerinin Tanıtılması." AKÜ Fen Bilimleri Dergisi, sy.1 (2009): 17-30.

Kahraman, Zeyneb, Keriman Yürüten Özdemir. "Tozlu Çalışmalarda Meslek Hastalıkları Ve Tozla Mücadele". Soma Meslek Yüksekokulu Teknik Bilimler Dergisi II, sy. 34 (Aralık 2022): 13-29.

Kampa, Marilena, Elias Castanas. "Human Health Effects of Air Pollution." Environmental Pollution, no.2 (January 2008): 362-67.

Kantarcı, M.Doğan. "Açık Taş Ocağı İşletmesinin Çevreye Etkileri ve Sürdürülebilirliği." *7. Ulusal Kırmataş Sempozyumu Bildiriler Kitabı,* Prof.Dr. M.Doğan Kantarcı, 129-139. İstanbul: TMMOB Maden Mühendisleri Odası İstanbul Şubesi, 2015.

Kaplan, Emine, Ayşegül Gürleyen, Damla Köle, A.Aydın Bıyık, Burak Yasun, F.Gülay Gedikli. "Tekstil Sektöründe Tozla Mücadele Rehberi." Çalışma ve Sosyal Güvenlik Bakanlık Yayınları İş Sağlığı ve Güvenliği Genel Müdürlüğü, sy.58 (2016): 5-34.

Kara, Aslı. *Meslek Hastalıkları.* Erzurum: Atatürk Üniversitesi Açıköğretim Fakültesi Yayını, 2017.

Karamani, Arzu. “Dolmabahçe Sarayı Cephe Süslemelerinde Antik Mimari Öğeler.” TBMM Basımevi, sy.4 (1992):30-40.

Kaya, Seher, Eren Öner. “Kenevir Liflerinin Eldesi, Karakteristik Özellikleri ve Tekstil Endüstrisindeki Uygulamaları.” Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi, sy.11 (Nisan 2020): 108-23.

Keleştemur, Oğuzhan, Erdinç Arıcı, Servet Yıldız, Bihter Gökçer. “Performance Evaluation of Cement Mortars Containing Marble Dust and Glass Fiber Exposed to High Temperature by Using Taguchi Method.” Construction and Building Materials, no.60 (June 2014): 17-24.

Ketin, İhsan. *Türk Jeolojisine Genel Bir Bakış.* İstanbul: İstanbul Teknik Üniversitesi Vakfı Yayınları, 1984.

Kuban, Doğan. *Selçuklu Çağında Anadolu Sanatı.* İstanbul: Yapı Kredi Yayınları, 2002.

Kulaksız, Seyfi. *Doğal Taş (Mermer) Maden İşletmeciliği ve İşleme Teknolojileri.* Ankara: TMMOB Maden Mühendisleri Odası, 2005.

Kulaksız, Seyfi. *Madencilikte Çevre Yönetimi.* Afyon:TMMOB Maden Mühendisleri Odası, 2012.

Moropoulou, Antonia, Asteris Bakolas, Sophia Anagnostopoulou. “ Composite Materials in Ancient Structures.” Cement and Concrete Composites, no.2 (February 2005): 295-300.

Mülayim, Selçuk. Anadolu Türk Mimarisinde Geometrik Süslemeler - Selçuklu Çağı. Ankara: Kültür ve Turizm Bakanlığı, 1982.

Oates, J.A.H. *Lime and Limestone: Chemistry and Technology, Production and Uses*. New York: VCH publishers, 1998.

Onargan, Turgay, Halil Köse, Hamdi Deliorm. Mermer. İzmir: TMMOB Maden Mühendisleri Odası, 2005.

Orlandos, Anastasios. *Les Matèriaux de Construction : Et la Technique Architecturale das Anciens Grecs.* Paris: E.de Boccard, 1968.

Ögel, Semra. *Anadolu’nun Selçuklu Çehresi*. İstanbul: Akbank, 1994.

Ögel, Semra. *Anadolu Selçukluları’nın Taş Tezyinatı.* Ankara: Türk Tarih Kurumu Yayınları, 1987.

Önder, Muhammet. “ Marmara Bölgesi Mermerlerinin Mineralojik ve Jeokimyasal İncelenmesi.” Yüksek Lisans Tezi, T.C İstanbul Üniversitesi, 1998.

Öney, Gönül. *Anadolu Selçuklu Mimari Süslemesi ve El Sanatları.* İstanbul: Türkiye İş Bankası KültürYayınları, 1992.

Öztürk, Mustafa. *Mermer Kesiminden Kaynaklanan Çevre Kirliliği ve Önlemler.* Ankara: Çevre ve Şehircilik Bakanlığı, 2018.

Rana, Aditya, Pawan Kalla, H.K.Verme, J.K.Mohnot. ", Recycling of Dimensional Stone Waste in Concrete: A Review." , Journal of Cleaner Production, no.135 (November 2016): 312-31.

Şahin, Murat, Harun Tanyıldızı. " Vişne Çürüğü Mermer Tozu Katkılı Betonun Basınç Dayanımına Donma Çözülme Etkisinin Belirlenmesi." Fırat Üniversitesi Yayınları, sy.12 (2020): 280-89.

Şengüler, Mesut. "Türkiye'nin Mermer Sektörünün ve Rekabet Gücünün İncelenmesi." Yüksek Lisans Tezi, T.C. İstanbul Ticaret Üniversitesi, 2019.

Şenol, Ahmet Ferdi, Cenk Karakurt. "Atık Mermer Tozunun Çimento Harçlarının Dayanım Özelliklerine Etkisi." International Conference on Frontiers in Academic Research, no.1 (February 2023) :427-31.

Şimşek, Selma, Hülya Kaynar. "Sivas'taki Tarihi Eserlerde Mermer Kullanımı." Süleyman Demirel Üniversitesi Güzel Sanatlar Fakültesi Sanat Dergisi, sy.8 (Kasım 2011):1-14.

Şimşek, Seza. " Mermer Atıklarının Yapı Malzemesi Üretiminde Kullanım Olanakları Üzerine Bir Araştırma." Yüksek Lisans Tezi, T.C. Bursa Uludağ Üniversitesi, 2019.

Tansuğ, Sezer. *Karşıtı Aramak.* İstanbul: Arkeoloji ve Sanat Tarihi Yayınları, 1983.

Taşlıgil, Nuran, Güven Şahin. " Yapı Malzemesi Olarak Kullanılan Doğal Taşların İktisadi Coğrafya Odağında Analizi." Marmara Coğrafya Dergisi, sy.33 (Ocak 2016): 607-40.

Temizkan, Meltem. "Kommagene Krallığı'ndaki Diplomatik Evliliklerin Hellenistik Kültür Yayılımına Etkileri." Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, sy.44 (Ağustos 2023): 263-81.

Tuğlacı, Pars. *The Role of Balyan Family in Ottoman Architecture.* İstanbul: Yeniçığır bookstore, 1990.

Türkmenoğlu, Z.Funda, A.Mahmut Kılıç, Tolga Depci. "Van Pomzası ve Mermer Tozu Atıkları ile Üretilmiş Kendiliğinden Yerleşen Hafif Betonların Mekanik Özelliklerinin İncelenmesi." Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, sy.30 (Haziran 2015):105-16.

Uçurum, Metin. "Kaplı Kalsit Üretimi ve Ürün Özellikleri." Yeraltı Kaynakları Dergisi, sy.6 (Temmuz 2014) : 1-10.

Uğur, Tülay, Ahmet Güleç. “Harç, Sıva Ve Diğer Kompozit Malzemelerde Kullanılan Bağlayıcılar Ve Özellikleri”. Restorasyon Ve Konservasyon Çalışmaları Dergisi, sy. 17 (Aralık 2016): 77-91.

Ulaş, Erdem. *Gerçek Köye Dönüş Projesi: Kenevir.* İstanbul: Hiperlink Yayınları, 2018.

Ulubeyli, Gulden Cagin, Recep Artir. “Properties of Hardened Concrete Produced by Waste Marble Powder.” Procedia - Social and Behavioral Sciences, no. 195 (July 2015): 2181-190.

Ünal, Rahmi Hüseyin. *Osmanlı öncesi Anadolu-Türk Mimarisinde Taçkapılar.* İzmir: Ege Üniversitesi Edebiyat Fakültesi Yayınları, 1982.

Vardar, Kadriye. “ Yavuz Sultan Selim Camii Taş Süslemeleri.” Art-Sanat Dergisi, sy. 2 (Temmuz 2014): 101-27.

Vargün, Elif, Özden Evren. “ Mermer Tozu/Polimer Kompozitlerinin Araştırılması ve Yapay Mermer Blok/Levha Üretimi.” Muğla Büyükşehir Belediyesi Kültür Yayınları 6, sy.1 (Ocak 2018): 253-71.

Yasa, Azize Aktaş. “Anadolu Selçuklu Ve Beylikler Dönemi Konya Yapılarında Malzeme Kullanımı Ve Yapım Teknikleri.” Vakılar Dergisi, sy.45 (Haziran 2016): 143-76.

Yergün, Uzay. *Kagir Yapı Birim Malzemeleri ve İmalat Yöntemleri.* İstanbul: Yıldız Teknik Üniversitesi, 2019.

Yıldız, Ahmet Husrev. “ Mermer Toz Atıklarının Yol İnşaatlarında Değerlendirilmesi.” Doktora Tezi, T.C. Süleyman Demirel Üniversitesi, 2008.

Yılmaz, Güngör, Levent Yazici. “Dünya’da Yükselen Değer; Endüstriyel Kenevir (Cannabis sativa L.)” Bozok Tarım ve Doğa Bilimleri Dergisi, sy.1 (Haziran 2022): 54-61.

Yılmaz, Yaşar. *Anadolu Doğal Taşlarının Dünyadaki İzleri.* İstanbul: İstanbul Maden İhracatçıları Birliği, 2020.

Yüzer, Erdoğan, Yıldırım Güngör, Serdar Aydoğan. *Doğal Taşın Öyküsü.* İstanbul: Kare Tasarım, 2016.

Yüzer, Erdoğan, Yıldırım Güngör, Serkan Angı. *Doğal Taş Deyince…!,* 63-144. İstanbul:Granitaş Taş Kültürü Yayını, 2008.

SITOGRAPHY

http://anadoluselcuklumimarisi.com/tr-tr/tas, 29/02/2024

http://iscehisar.gov.tr/mermerin-ocaktan-cikartilmasi, 18/02/2024

https://adanakarosilim.com/paledyen-silim.html, 23/02/2024

https://amazingarchitecture.com/installations/tatu-by-park-associati-an-installation-made-of-hempcrete-blocks-to-highlight-the-potential-of-bio-based-materials-in-architecture, 26/03/2024

https://artofmaking.ac.uk/explore/sources/124/PR204_01_02, 25/02/2024

https://bulkhempwarehouse.com/100-hemp-hurd-10mm-1-4in-per-pound/ , 25/03/2024

https://ch.linkedin.com/company/omya, 16/02/2024

https://cihanmermeritgranit.wordpress.com/renk-katologlarimiz/mermerit-kartelasi/, 23/01/2024

https://coatings.specialchem.com/product/a-omya-omyasphere-212-t-fq, 16/02/2024

https://cromwell-intl.com/travel/turkey/nemrut-dagi/, 10/04/2024

https://demircioglu parkhotel.com/spa--fitness-46.html, 28/02/2024

https://esenler.bel.tr/esgev/takvim/sirkeci-tren-gari-muzesi/, 24/02/2024

https://fourel.com.tr/banyo-tezgahi, 28/03/2024

https://geka.gov.tr/tr/sayfa/mugla-sektorlerimiz-ve-yatirim-ortami, 12/03/2024

https://grecoroman.library.villanova.edu/ancient-greece/cities/athens/parthenon , 25/02/2024

https://greenbuildingcanada.ca/advantages-building-hempcrete/, 26/03/2024

https://insteading.com/blog/building-with-hempcrete/, 29/03/2024

https://istanbulticaretgazetesi.com/tr/mermer-islenince-ihracattaki-kg-degeri-25-katina-cikiyor, 26/02/2024

https://kenevirhaber.com/disi-veya-erkek-kenevir-tohumu-nasil-ayirt-edilir/, 24/03/2024

https://keneviryagi.com/disi-ve-erkek-kenevir-nasil-ayirt-edilir/, 24/03/2024

https://kulturenvanteri.com/tr/yer/bab-us-saade/, 12/04/2024

https://kusbakisi.com/portfolio/demircioglu-park-hotel/, 28/02/2024

https://limecrete.co.uk/hempcrete-factsheet/, 26/03/2024

https://madencilikrehberi.files.wordpress.com/2012/02/mermer-blok-uretimi.pdf, 06/04/2024

https://medium.com/@hempsaveearth/the-basics-of-a-cast-in-place-hempcrete-wall, 26/03/2024

https://mercak.com/bej-mermer-burdur-bej.php, 25/02/2024

https://mermeritizmir.com/bornova-mermerit-0543-674-01-53/, 23/01/2024

https://m.haber7.com/seyahat/haber/2983318-dolmabahce-sarayindaki-164-yillik-tugralar-restore-ediliyor, 15/02/2024

https://nalanyilmaz.blogspot.com/2002/11/dolmabahe-saray-kap-sslemeleri.html, 29/02/2024

https://newsociety.com/blogs/news/the-benefits-of-using-hempcrete-in-your-construction-projects, 26/03/2024

https://oztasmermergranit.com/wp-content/uploads/2020/02/oztas-mermer-granit-ankara-urunlerimiz-granit-aksehir-siyahi.jpg, 25/02/2024

https://pbase.com/dosseman/image/168105557, 27/02/2024

https://pbase.com/dosseman/image/168105561, 27/02/2024

https://pbase.com/dosseman/image/168105567, 27/02/2024

https://pbase.com/dosseman/image/29239633, 27/02/2024

https://pbase.com/dosseman/image/29239641, 27/02/2024

https://pbase.com/dosseman/image/35088686, 27/02/2024

https://pbase.com/dosseman/image/35088689, 27/02/2024

https://sertasmermer.com/urunler/toros-siyahi/, 25/02/2024

https://smfmermer.com/files/17/93/737/2103/ege_kahve.jpg, 25/02/2024

https://tarihegitimi.blogspot.com/2020/02/istanbul-universitesi-merkez-binas.html, 12/04/2024

https://tekstilsayfasi.blogspot.com/2020/12/kenevir-kumas-nedir-kenevir-ozellikleri.html, 25/03/2024

https://thehia.org/the-fiber-council/, 25/03/2024

https://turkisharchaeonews.net/site/yazılıkaya-midas-monument, 10/04/2024

https://whc.unesco.org/en/list/404/, 25/02/2024

https://www.aa.com.tr/tr/yasam/tarihi-hurrem-sultan-hamaminda, 20/11/2024

https://www.ademder.org.tr/blog/camiilerimiz/suleymaniyecamii, 29/02/2024

https://www.andersonintl.com/hemp-oil-vs-cbd-oil-the-difference-between-seed-oil-and-cannabis-oil/, 25/03/2024

https://www.atlasobscura.com/places/aspendos-theater, 10/04/2024

https://www.bizevdeyokuz.com/ayasofya/, 12/04/2024

https://www.blackpine.co.nz/exterior-products/hempcrete/, 26/03/2024

https://www.building.co.uk/focus/hempcrete-a-natural-solution-in-the-quest-for-better-materials/5115430.article, 29/03/2024

https://www.csgb.gov.tr/yayinlar/uzmanlik-tezleri/casgem/, 05/04/2024

https://www.dailysabah.com/arts/new-digital-maps-details-izmir-ancient-pergamon-city/news, 10/04/2024

https://www.deltamarble.com/tr/dolomit-mermer/, 26/02/2024

https://www.dunya.com/kose-yazisi/mugladan-turkiye-mermerleri-muzesi-onerisi/341311, 21/03/2024

https://www.efendioglu.com.tr/icerik/ekvator/, 28/02/2024

https://www.efendioglu.com.tr/icerik/the-rbs-bank-texas/, 28/02/2024

https://www.efeoglumermer.com.tr/bursa-onyx.html#group, 25/02/2024

https://www.ekoyapidergisi.org/ic-mekanlarda-osb-panelleri-mutevazi-bir-malzemeden-tasarim-ozelligine, 29/03/2024

https://www.emindemirelmaden.com/tr/ocaklar/mugla-dolomit-ocagi/, 25/02/2024

https://www.etimolojiturkce.com/kelime/mermer, 22/03/2024

https://www.fatihsondaj.com/benzinli-karot-makinasi-fiyatlari.htm, 22/03/2024

https://www.gubbamodern.com/blogs/trend-malzemeler/tadelakt-siva, 06.06.2024

https://www.hellenicompanyofmarble.com/a, 25/02/2024

https://www.hemptopia.com/hemp-hurd-bale-15-kg-33-lbs/, 02/04/2024

https://www.hurriyetdailynews.com/aphrodisias-awaits-record-high-visitors-130696, 10/04/2024

https://www.indiamart.com/proddetail/hemp-pellet-fish-feed-21193715530.html, 25/03/2024

https://www.kirec.org/sayfa-kirec_kullanim_alanlari-3, 16/03/2024

https://www.kompozitpazari.com/kategori/kobalt, 08/03/2024

https://www.kompozitpazari.com/urun/213-seffaf-performans-jelkotu, 08/03/2024

https://www.kremer-pigmente.com/en/shop/pigments/pigments-of-modern-age/ultramarine-pigments/45000-ultramarine-blue-very-dark.html, 02/04/2024

https://www.lafsozluk.com/2009/04/mugla, 20/11/2024

https://www.limebase.co.uk/product/buxton-super-fine-lime-putty-21l/, 16/03/2024

https://www.linkedin.com/pulse/calcite-processing-plant-shibang-group, 01/03/2024

https://www.lookphotos.com/en/images/71139254-Library, 10/04/2024

https://www.mermerbank.com/2020, 5/11/2024

https://www.metasmermer.com/urun/sari-honey-onyx, 25/02/2024

https://www.mikewye.co.uk/product/lime-putty/, 16/03/2024

https://www.mks.com.tr/en/product/gang-saw--gangsaw-for-marble-.html,19/02/2024

https://www.mks.com.tr/tr/urun/katrak-makinesi-.html, 29/02/2024

https://www.molinopeila.it/en/products/legumi-e-superfood/hemp-seeds-flour, 25/03/2024

https://www.mta.gov.tr/v3.0/bilgi-merkezi/kalsit, 14/02/2024

https://www.mta.gov.tr/v3.0/bilgi-merkezi/2018-maden-ithalat-degerleri, 10/03/2024

https://www.mta.gov.tr/v3.0/hizmetler/maden-yataklari, 12/03/2024

https://www.mta.gov.tr/v3.0/hizmetler/mta-yayinlari, 23/02/2024

https://www.mta.gov.tr/v3.0/sayfalar/bilgi-merkezi/turkiyede-madencilik/2019-yili-maden-dis-ticaret.pdf, 10/03/2024

https://www.mta.gov.tr/v3.0/sayfalar/bilgi-merkezi/turkiyede-madencilik/2021-yili-maden-dis-ticaret.pdf, 10/03/2024

https://www.mta.gov.tr/v3.0/sayfalar/bilgi-merkezi/turkiyede-madencilik/2022-yili-maden-dis-ticaret.pdf, 10/03/2024

https://www.mta.gov.tr/v3.0/sayfalar/hizmetler/kutuphane/ekonomi-bultenleri/2020-29/18.pdf, 10/03/2024

https://www.omya.com/en/industries/building-materials/engineered-wood-products, 16/02/2024

https://www.omya.com/en/products/building-construction/betocarb, 16/02/2024

https://www.omya.com/en/products/building-construction/omya-flex, 16/02/2024

https://www.omya.com/en/products/paints-and-coatings/omyasphere, 16/02/2024

https://www.pallasweb.com/deesis/columns-and-capitals-of-hagia-sophia.html, 12/04/2024

https://www.sabtagranite.com/products/calacatta-gold/bianco-ibiza.html, 25/02/2024

https://www.sbm-mill.com/materials/calcite.html, 06/06/2024

https://www.sciencedirect.com/topics/engineering/ball-mill, 15/02/2024

https://www.scribd.com/document/688365777/, 07/04/2024

https://www.selcuklumirasi.com/architecture-detail/haci-ferruh-mescidi, 29/02/2024

https://www.stoneadd.com/Bilecik-Pembe-Mermer-P17650, 25/02/2024

https://www.stonecontact.com/bianco-carrara-marble/s188, 26/02/2024

https://www.stonecontact.com/makrana-white-marble/s4018, 26/02/2024

https://www.stonecontact.com/marmara-white-marble/s8357, 28/02/2024

https://www.stonecontact.com/mugla-white-marble/s1713, 28/02/2024

https://www.stonecontact.com/pentelikon-white-marble/s2743, 26/02/2024

https://www.stone-ideas.com/tr/2345/briefly-noted-blanco-ibiza-marble-for-the-facade-and-the-interior/, 27/02/2024

https://www.temizmekan.com/mermer-ve-tas-ocaklarinin-cevreye-olumsuz-etkileri, 01/03/2024

https://www.tummer.org.tr/tr/urunDetay.aspx?urun_id=3873, 25/02/2024

https://www.worldhistory.org/image/3794/the-bath-gymnasium-complex-at-sardis/, 10/04/2024

https://www.yapikatalogu.com/blog/geleneksel-mimari-esintiler-tadelakt-sivasi, 26/03/2024

https://www.yenisafak.com/foto-galeri/hayat/mimar-sinanin--ustalik-eseri”-selimiye-camii-2014091, 12/04/2024

https://www.youtube.com/watch?v=Bw8X40mDgVg, 28/03/2024

https://www.youtube.com/watch?v=ELWL6zHUZug&t=454s, 08/03/2024

https://www.youtube.com/watch?v=jMdsna-e1bE, 29/02/2024

http://www.barshanmadencilik.com/kufeki-tasinin-ozellikleri.html, 02/02/2024

http://www.fatih.gov.tr/iii-ahmet-cesmesi, 23/02/2024

http://yazilikayamermer.com/?s=urunler&id=19, 25/02/2024

APPENDIX

Interview 1: *Gökhan Çal*

Researches carried out by *Gökhan Çal*

Interview 2: *İlyas Bağcı*

Marble designs made by *İlyas Bağcı*

Interview 3: *Merey Şenocak*

Artworks of *Merey Şenocak*

Artworks of Emir Kamis

Interview 1: *Gökhan Çal*

Interview with *Gökhan Çal*, 08/02/2024, Mugla, Turkey

Gökhan Çal (1983, Mugla, Turkey), the consultant of Mugla white marble quarry, focused on mining after his education. *Çal,* who received training from various geologists and spent years researching the fertile lands of Turkey, has been carrying out researches on marble called Mugla white since 2008. Concentrating especially on the topography of the Mediterranean and Aegean regions, he carries out various studies on the potential lands he discovers at regular intervals, leading to the discovery of marble quarries and their processing in the right direction. He also does researches on marble waste and artificial stone products.

First of all, I would like to thank you very much for your help regarding the thesis. How did you encounter marble quarries and how long did it take you to specialize in this field?

Marble is a material that I have studied with admiration since my childhood. Like many people, I was attracted by its aesthetic texture. In the following years, both the people I met and my passion for the material focused me entirely on this field. I have been doing researches on marble quarries in Mugla for many years. In coordination with many friends around me who are mining engineers, geologists and material scientists, we discover and license different marble quarries in many provinces of Turkey, especially in Mugla.

Since 2008, we have been extracting Mugla white marble together with Mr. *Hüseyin Sakaoğlu*. Although I am mostly involved in the the research and exploration part of this marble manufacturing facility, I also work on the discovery of other valuable marble quarries in Turkey.

Well, let's talk about the marble you extracted. What kind of quarry do you run, what are the details?

The marble extracted in our quarry is known as Mugla white in the local market. Since a large number of white marbles are extracted in Mugla, marble types are generally referred to by foreign names in order to avoid confusion between marble types. I will elaborate on this subject of name and types later.
Apart from our quarry, quality facilities such as Demircioglu extract this marble from different quarries in Mugla and use it as interior and exterior cladding in their hotel projects. This marble is a type of marble that is highly valued both in the domestic and foreign markets with its white texture, vein structure and brightness.

Can you give more information about production and extraction details?

As for the production part, efficiency in this field is primarily related to facilities.
In other words, a marble manufacturing facility, its office, the quarry section where the marble is extracted, and the processing area within the factory where the marble is processed must work in harmony as one body. A malfunction in any of these departments will negatively affect the entire production. The size of the machinery park and the structure of the geography are also factors that directly affect production. For example, Turkish marble quarries are not advantageous in terms of marble block efficiency compared to Europe. Due to improper installation and geographical characteristics, block efficiency is low and marble waste rate is quite high in some regions. The productivity rate in Mugla is around 5%, what I mean by productivity here is the rate of marble cut into blocks from nature.
The main process in marble quarries is done with these blocks, but when the blocks are separated from nature, fragmentation and crumbling cause marble remnants. Re-cutting and shaping these remnants is an extra process and economic burden. For this reason, marble quarries prefer regions with high potential for block marble extraction. We make decisions by examining the structures of such regions with mining engineers. If the structure of the region has not been exposed to any tectonic movement, the vegetation and living space are sparse, the investigation is started by taking samples from the massive rocks. While old methods such as hammer and chisel can be used during sampling, high-cost machines can also be used depending on the budget. After examining the color, texture and chemical structure of the samples, they are approved as marble and if we are convinced that they have commercial value, licensing process begins.
At the end of licensing , the region begins to be processed to make it suitable for marble extraction with the approval of various state institutions.
Going back to our production topic, we produce 5 tons of marble blocks from an average unloading area of 100 tons. What we call this 100-ton unloading area is actually all the rock formations that emerge when marble blocks are removed from the marble quarry; marble wastes, marble remnants and blocks...

Percentage-wise, only 5 % of this ratio is marble blocks, and the remaining 95% is evaluated in different areas as waste and remnant. Although this efficiency rate seems low, since the value of marble is high, its trade can bring profit. Finally, if we talk about our annual production on a plate basis,our production is 18,000 tons of marble plate per year.

Since you pointed out the market, can we talk about the market portfolio of marble and sales strategies?

In the domestic market, we mostly work on projects in touristic areas. We have a type of marble that is preferred in hotel projects in tourism provinces such as Mugla and in tourism investments in the Aegean region. In these areas, marble slabs are cut to the desired dimensions and used mainly for interior and exterior claddings. Especially Mugla white has become a preferred marble in Turkish baths every year. If we are talking about the foreign market, Mugla white marble that extracted from Demircioglu's marble quarries, has very fine crystals and is mostly preferred in luxury projects of America, Saudi Arabia and Israel.
Mugla white marble, produced in our quarries, also finds buyers in the foreign market, mostly in Israel. In our trade, we export 250,000 m2 annually and approximately 75 containers of marble blocks monthly. The advantage of the Israel market is that it has consumers from all different budgets. Mugla white marble has a fine crystalline and shiny appearance, but in some cases slightly thicker crystalline, less shiny marble blocks can also be extracted. Although there is a difference in quality, this type of marbles may find buyers in the Israel market.

Lower quality marbles are also evaluated in countries such as Egypt, Bangladesh, Pakistan, Vietnam, Thailand, Indonesia or by lower group marble buyers in Turkey. Speaking of the marble market, I would like to add that we divide our exports into raw marble blocks and processed marble slabs, then present this data to certain institutions in reports.
Although natural stone types such as travertine have been added to this data in recent years, we only share the export rates of our white marble which includes high amount of calcite mineral.

What about the usage areas of marble and quarries in Turkey? Can we describe them more?

Projects where the most unique marbles are preferred are evaluated much higher than average designs. In addition, since many types of marble are memorable with their striking colors and different patterns, they make the project memorable in a way. The best examples in this field are the use of marble in tourism both abroad and in Turkey. Onyx, Afyon and Marmara marbles are the unique marble types that are extracted in Turkey. In addition, different and valuable marble types such as Elazig Cherry, Mugla lilac, Mugla dolomitic marble are preferred in the interior claddings of luxury hotels.
Dolomitic marbles are very valuable compared to other marbles with their high dolomite mineral content, which makes the marble have a brighter appearance and a harder surface.
On the other hand Marmara marble, extracted in the Marmara Island of Balikesir, with its feature of maintaining the temperature of the interior and its place in the history, it is still the most frequently used marble type in Turkish baths today.

Pearl marble that is extracted only in Mugla, is one of the most unique and rare marble types in the world. As for the domestic usage areas of Turkish marbles , they are frequently used in the lobbies of private hospitals, restaurant entrances, and many different villa projects designed outside the city. In addition, among the villa designs in Turkey, many fountains bearing Ottoman architecture inspiration are made of different types of white marble such as Marmara and Mugla white.
Speaking of Turkey's marbles, we should also mention the variety of names of these marbles. Turkey is a very rich country in terms of marble reserves and many different colored marbles are extracted in the same region. Although the marbles quarried in Mugla or Marmara Island are referred to as Mugla or Marmara marble, they can also be defined by different foreign names according to their color and texture.

What do you think about the future of marble related to the artificial stone products, can it be replaced one day?

Marble is a material that has always existed in human history and will continue to exist. Even though I have been working on it for many years, new marble types and new reserves still fascinate me. Of course, the damage caused to the environment while extracting the marble and the depletion of marble in marble quarries due to its structure bring to mind the use of alternative materials instead of marble. Artificial stone products can be preferred for the sake of appearance integrity. While marble blocks are extracted from nature, it is difficult to ensure integrity in the design because they have different tones and vein structures.
However, artificial stone manufacturers can offer designs with individual integrity in any desired texture and color. For this reason, the usage areas of marble may become narrower, but it never goes out of fashion.
If you ask me, glass is the material of the future, although it is not a rival to marble. Today, we see that the place and usage area of glass is constantly expanding in architectural designs.

But still, remember that marble is a timeless material that will never go out of style...

My last question is actually related to the main topic of this thesis ; Marble wastes… What do you do with those wastes and what do you know about recycling them?

This is a subject that I have been thinking about for years. Marble waste has a huge potential. As I said before, there are marble quarries in Turkey with a low block efficiency rate and these quarries are very rich in marble wastes. When the calcite mineral, which marble contains in high amounts, is ground, it can be used as a filling or raw material in many different industries. In this regard, we send small-sized marble pieces to Omya's facilities in Turkey and they evaluate these marble wastes as calcite, grind them, and use them as raw materials or fillers in their own products.
Omya is actually an industrial mineral producer that is different from other calcite processing facilities and grinds also different minerals other than calcite. Omya only works with the quality marble quarries whose marble contains high amount of calcite.
The products it produces are used in a wide range of areas, from architecture to animal feed, and we use our wastes to support their production in this way.

Except for the small-sized marble pieces sent to calcite facilities, marble dust or carbonate mud are sent to artificial stone producers and they optionally use these wastes in their production. However, unlike Europe, in Turkey, carbonate mud is generally separated from its particles and we reuse the separated water. Then we dispose or throw away the remaining particles. This is an important problem that needs to be fixed in the future.

Researches carried out by *Gökhan Çal*

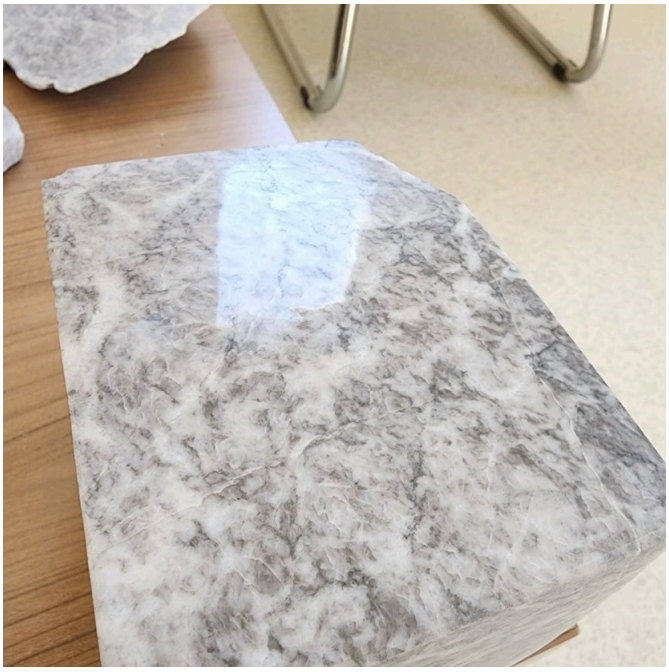
Antalya, Turkey (Çal 2021)

Gökhan Çal carries out research and quarry licensing regarding the limestone quarried in Antalya.

Samples of limestone, Antalya, Turkey (Çal 2021)

Mugla, Turkey (Çal 2022)

Gökhan Çal has started to work on another research area, Aegean silver marble, and the land where the marble will be extracted.



Sample of Aegean silver marble, Mugla, Turkey (Çal 2022)

Bursa, Turkey (Çal 2023)

Çal, who carries out research in Bursa province of Turkey, is also involved in the licensing of the land shown in the picture.

Bursa, Turkey (Çal 2023)

Interview 2: *İlyas Bağcı*

Interview with *İlyas Bağcı,* 19/02/2024, Mugla, Turkey

İlyas Bağcı (1987,Afyonkarahisar, Turkey) has been making his living by processing marble and natural stones in the Mugla province of Turkey. After meeting *Gökhan Çal, Bağcı* had the opportunity to work with different types of marbles and he has specialized in processing natural stones over the years by creating ornamental objects, tables, chairs and fountains .
Bağcı, who focuses especially on marble remnants, produces different works from marble for many architectural design projects in Mugla.

How did you become acquainted with marble and natural stones, how did you learn to process these materials?

Just like you, I became interested in marble and natural stones because I saw it in my family. Its colours, textures and veins have influenced me since my childhood. Also, seeing my father working with marble, I decided to improve myself in this field. I expanded the atelier that I inherited from my father and started to create different objects. As the products I made were appreciated, I wanted to improve myself further, and today I have the opportunity to make a living by creating marble designs in Mugla.

One of the topics I want to touch upon in this thesis is the difference between marble waste and marble remnant. What are your thoughts on this topic that we share in common with you?

At first I started working with marble remnants. I was collecting the marble pieces that people did not use and causing visual pollution and I was carving them.
Now, I create very different design products such as plates, vases, tables and chairs from these marble remnants.

What I feel sorry for, especially in Turkey, is the definition of marble waste. People think that everything except marble blocks is waste. This is a very wrong perception.
I would like to point out that marble wastes and marble remnants are different things, and there are many fields where both wastes and remnants are evaluated.
Marble waste should never be confused with industrial waste. What we call as waste is the dust and carbonate mud. Depending on your point of view, the small-sized marble pieces can also be considered waste.
I personally prefer to add those marble pieces to white cement and make a coffee table. In this way, I turn them into an aesthetic object.
Some marble manufacturers send these pieces to calcite processing facilities to be processed as calcite. However, some even describe rubble as waste, which I think is a very wrong definition. Rubbles can be cut and turned into blocks, and the remaining small pieces can be carved and turned into decorative marble objects such as plates and vases. Likewise, caps and paledians can be used in many different areas. Objects can also be created by using them.
Marble wastes, on the other hand, are on a smaller scale and you cannot carve, cut or process them. In addition, researching, finding, collecting and processing marble remnants require great effort.
People need to know how valuable a process this is. Any kind of work made from marble remnants is very valuable work and should be appreciated.

Let's talk about the marble potential of Mugla. As someone who processes marble here, what information would you like to give?

Mugla is one of the cities with important potential in Turkey with its mines, bays, natural beauty. However, in recent years, factors such as the increasing population with tourism in districts like Bodrum, new architectural projects and the need for raw materials resulting from these projects have led to more research on Mugla marble quarries.
As a result of these researches, which continue today, not only existing marble reserves but also ancient marble quarries are being discovered.
In addition, stonemasons who came to Mugla from Afyon province played an important role in the processing of Mugla marbles and even trained apprentices to continue this culture. Today, we can say that Mugla province has many of Turkey's most important marble reserves.
You can find marble in many different colors and textures here. In fact, as you know well , the marbles here are often confused with each other and they take the name of foreign origin. I am more in favor of using local names. Instead of saying *Bianco Ibiza,* I prefer to say Mugla white marble. One of the most well-known marbles here is Mugla white, but there are also very valuable dolomitic marbles . Apart from this, there is a very special marble that I call Mugla black, but in the market it is known as *Pineta black.* There is also Mugla lilac marble, which is extracted only in Mugla province of Turkey in the world. They are all special marbles that are generally used as interior and exterior cladding in luxury projects. I mostly create sinks or coffee tables from the remnants of these marbles.

Especially the texture and color of the sinks look very impressive from the outside. I also make different objects from Mugla black marble, thus creating a contrast between the white marbles quarried in Mugla and the dark colored ones. We use them in hotel or luxury villa projects. Also, fireplaces with different designs can be created from the marbles extracted in Mugla. One of the important works I have done in recent years using Mugla marble is to work in restoration project of the bridges from the 20th century.
The Italians who came to the region during the Turkish War of Independence(1919-1923) built bridges while they were exploring the mines in Mugla. During this research, which was welcomed by the local people, they built stone bridges for transportation purposes in many different places. In our collaboration with 'Seka Restoration Company' in 2019, we covered especially the upper layers of the bridges with Mugla white marble.

Which other precious natural stones in Turkey have you worked with?

Apart from Mugla marble, I also had the opportunity to work with Antalya marble and onyx marble. The marbles extracted from Antalya are quite different in texture and color. Onyx marbles are different from all marble types. Since they are industrial type marbles, their structure differs from genuine marbles containing calcite minerals, and with all these features, onyxes are very delicate stones to process.They require extra care and attention, but for me, they are the most aesthetic marble types in the world in terms of visuality. In addition, I examined different types of natural stones quarried in Anatolia.
I worked with volcanic tuffs and limestones, which are frequently seen in the architecture of Anatolian civilizations. I also made designs by using granite and basalt. Volcanic tuffs and limestone are easier to shape compare to marble in terms of processing, but they are not as aesthetic as marble.
The travertines found in Denizli province of Turkey,are natural stones that are also easy to process , but they are less visually appealing compared to marble.

What equipment do you generally prefer for marble processing?

The tools and techniques used when processing marble are actually similar all over the world. Angle grinders, hammers, chisels and different types of polishers actually serve the same purpose. The use of grinding engines such as the angle grinders is more common in our country. We can also deform the surfaces with hammers and chisels. Those who do coating need extra mortar and adhesives. In Turkey, marble pieces that are broken or separated from their veins are turned into small objects and they are not wasted. It is important not to break the marble plates while coating, because since the size is certain, the broken plates can be thrown away.

Marble designs made by *İlyas Bağcı*

Table which Mugla white and Mugla black marbles are used together in its design, Mugla, Turkey (Bağcı 2023)

Table which Mugla white and Mugla black marbles are used together in its design, Mugla, Turkey (Bağcı 2022)

Interview 3: *Merey Şenocak*

Interview with *Merey Şenocak*, 30/03/2024, Istanbul, Turkey

Merey Şenocak (1993, Izmir, Turkey) completed her undergraduate studies at the University of Arts London before returning to Turkey, where she continued her practice in Izmir and Istanbul. She has produced works in writing, sound, visual, and sensory realms, currently utilizing these tools simultaneously. Exploring ways to transcend a human-centered ontology with works carrying information about the nature of materials and sensory feedback, she contemplates the relationship between matter and humans. Among the materials she has recently researched and worked with are hemp, lime, oxides, soil, and organic pigments. She combines Hempcrete, a contemporary method, with lime plaster, using the ancient Moroccan plastering technique of Tadelakt to cover forms created with hemp and lime mortar.

When and how did your interest in art begin? Can we talk about your education and passion about art?

My interest extends beyond any particular medium, encompassing a broad spectrum of artistic and academic disciplines.

Despite my penchant for arts and crafts as a child, it was biology that truly captured my imagination during my school years. Never did I envision myself as an artist who integrates insights from biology, sociology, psychology, and beyond into my work, all simultaneously. My journey led me to pursue Fine Arts at the University of Art London, where I embarked on a quest to understand both myself and the materials I work with. Through experimentation with a diverse array of mediums, I gained a profound appreciation for their inherent qualities.

What are your thoughts about the use of materials? How did the idea of using hemp in your works develop? What difficulties did you encounter during the process of this material?

This exploration across various mediums and materials, afforded me a meta-analytical lens through which to investigate concepts. I focused on the human processes involved in creation and their implications for the subject matter at hand. Discussing topics such as oppression, exploitation, labor, and even compassion necessitated careful consideration of the materials I employed as an artist. Consequently, I deliberately selected materials with a sense of mindfulness, striving for a level of purity and innocence in their utilization.
This discerning approach led me to gravitate towards biomaterials and sound, recognizing their ephemeral nature as reflective of my fascinations and also concerns on natureculture .
Initially drawn to biomaterials, my interest was piqued by pigments, driven by a desire to select the most innocent options (those less industrialized and mass-produced) to paint with. In 2020, amidst the challenges of the Covid pandemic, I began experimenting with earth pigments, seeking solace in new forms of entertainment. This process of exploration (walking, foraging, and investigating) unveiled new dialogues within me, igniting a profound connection with the material world. Tadelakt emerged as a transformative medium, bridging the gap from two dimensions to three, as I delved into the realm of plasters. This exploration led me to experiment with various substrates for Tadelakt application, including earth and paper pulp, before discovering the plant-based solution: hemp.
Hemp, a remarkable plant renowned for its soil-cleansing properties, negative radiation, and impeccable textile and construction qualities, captured my attention.
In the construction sector, hemp hurd holds significant potential, as every part of the hemp plant can be utilized in valuable ways. However, working with hemp presented logistical challenges.
Securing my initial batch of hemp was facilitated by Prof. Muhammet Uzun, whom I had sought out in my quest for hemp.
Despite the scarcity of hemp hurd processors in Turkey, I persevered, engaging with multiple suppliers until discovering the research and development cooperative, *Döngü,* located in Izmir.

Let's move on to the tadelakt technique. How was your development process in this technique, where did you get your inspiration from, how long did you practice? How long do you think it will take to achieve near-perfect smoothness on the surface with Tadelakt?

I have been studying the technique of Tadelakt for nearly two years now. It all began when a friend introduced me to the method through YouTube tutorials. Intrigued, I reached out to several experts in the field to glean insights and tips from their expertise although much of the valuable information I acquired was sourced from the vast wealth of resources available on the internet.

While I have achieved near-perfect results at times, it's essential to acknowledge that perfection is not always attainable. Various factors such as climate conditions, surface textures, and the quality of materials can influence the outcome, leading to occasional setbacks. Embracing these challenges is an integral part of working with natural plasters, and each failure serves as a valuable learning experience in this ongoing journey.

How do you determine the pigments and forms you use in your works? How do you decide which color tone is better for which form? Also, did you achieve this color tone by experiments or do you have a source that you get support from?

The process of determining forms and pigments is intricately linked to the act thinking with and through the material, and its instrumentalization. Through this process, I have developed a keen interest in how we interact with and utilize elements such as mountains, rocks, and bodies, which has significantly influenced the forms and colors I employ in my work.
For instance, observing utilitarian objects like benches and chairs rendered in flesh-like hues may be interpreted as a reflection of this exploration.

What do you think about the usability and durability of these furnitures you have created in the architectural field?

Hempcrete and Tadelakt have both demonstrated their durability through extensive research and widespread applications worldwide. Hempcrete has gained increasing popularity over the past decade. Conversely, Tadelakt has stood the test of time for over 2000 years, showcasing its hydrophobic and mold-resistant properties.
In my practice, I integrate both techniques, experimenting with various forms and occasionally reinforcing structures with inner metal frameworks to enhance strength, particularly in forms with thinner legs. My aim is to create enduring forms that can withstand the test of time and be passed down through generations with proper care.

Artworks of *Merey Şenocak*

Untitled (Şenocak 2023)

Hemp hurd and lime putty were used in the inner layer (Hempcrete); marble dust, lime putty and earth pigment were used in the outer layer (Tadelakt). Tadelakt as plaster applied on the surface of the work.

Untitled (Şenocak 2023)

Untitled (Şenocak 2023)

Hemp hurd and lime putty were used in the inner layer; marble dust, lime putty and indigo ferra tinctoria pigment were used in the outer layer. Tadelakt as plaster applied on the surface of the work.

Untitled (Şenocak 2023)

Hemp hurd and lime putty were used in the inner layer; marble dust, lime putty and indigo pigment were used in the outer layer. Tadelakt as plaster applied on the surface of the work.

Untitled (Şenocak 2023)

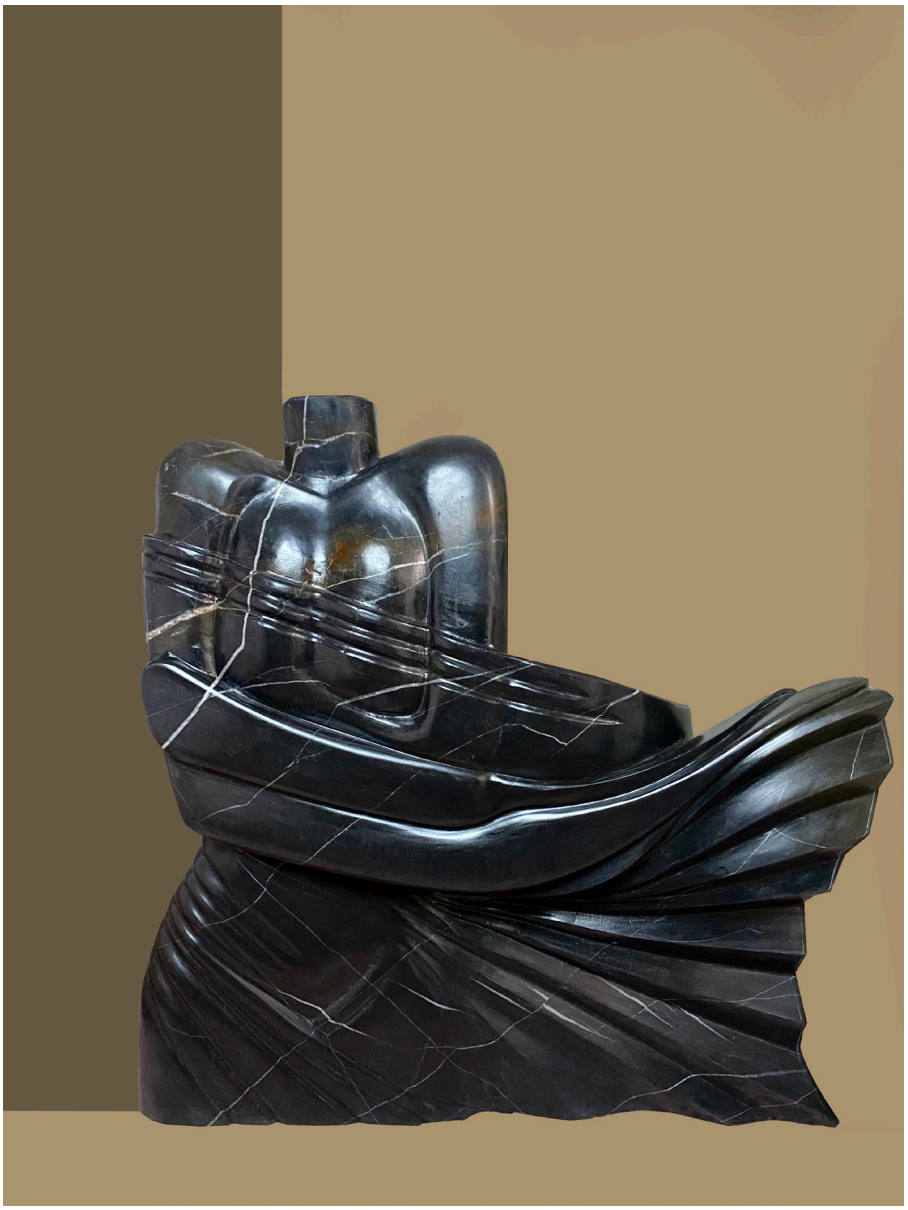
Hemp hurd and lime putty were used in the inner layer; marble dust, lime putty, indigo and the earth pigment were used in the outer layer. Tadelakt as plaster applied on the surface of the work.

Artworks of Emir Kamis

Artwork from Verona marble (Kamis 2023)

Artwork from natural stone (Kamis 2023)

Artwork from black marble (Kamis 2021)



Artwork from black marble (Kamis 2022)

Fashion collection from black marble (Kamis 2021)

Fashion collection from black marble (Kamis 2021)

Fashion collection from black marble (Kamis 2021)

Fashion collection from black marble (Kamis 2022)