MERMERLERİN MEKANİK ÖZELLİKLERİYLE PARLATMA KOLAYLIĞI ARASINDAKİ İLİŞKİ

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ÖZET

Dünya tarihinde yazının bulunmasından bile eski devirlerde kullanılmış olan mermer ve mermer ürünleri, günümüzde mşaal sektöründen sus eşyası ve sanat eserlen yapımına kadar bir çok alanda kullanılmaktadır

Mermerlerin cılalanması, üretim sureci içerisinde ont.mli bir yer tutmaktadır Özellikle urunun pazarlanması aşamasında mermerin kalitesini belirleyen unsurların başındadır Parlak ve güzel görünümlü mermerler piyasada daha kolay ve yüksek fiyata alıcı bulabilmektedir

Her tur mermer aynı süreç içerisinde parlatılsa bile eşit düzeyde parlaklık kazanmaz Bazı mermerler kolay ve az işlemle (gerçek mermerler), bazıları zor ve çok işlemle (magmatık kökenli mermerler) parlatılırlar Bazı türler ise hiç parlatılamaz (rravertenler, rufler, Jımra)

Bu çalışmada 9 mermer örneğinin parlatıl ab il ir I ık parametreleri araştırılmıştır Butun mermer, mekanik özelliklen belirlenmiştir Av rica her mermer omeğı eşit koşullar altında otomatik silim makınasmda parlatılmış ve her parlatma sathasında pürüzlülük ve parlaklık değerlen ölçülmüştür Bulunan butun veriler karşılaştırılarak parlaklıkla mermer örneklerinin mekanik özelliklen arasındaki ilişkiler ortaya konmuştur

Anahtar Kelimeler **Mermer, Parlaklık, Mekanik özellikler**

THE RELATIONSHIP BETWEEN EASINES POLISHING AND MECHANICAL PROPERTIES OF MARBLES

ABSTRACT

Marbles and their products, that have been used for thousand years, are used lots of sectors, from building sector to art world now

Polishing, which determines the quality of marble, is an important places in the process Marbles having bright and nice appearance can find customer easily with high price

Every kinds of marble could not be polished at the same level, although in the same process condition. Some marbles can be polished easily, but some can not.

In Üiis study, polishability of marbles by using 9 different marbles speices, was investigated. For each samples, mechanical characteristics were studied. Then each marble were polished by using automatic belt polishing machine in the same process condition. Meanwhile, polishing and roughness values were measured for die each polishing levels. The relationship between marble properties and polishing was found by correlations of the datas.

Key **Words:** Marble, Polishing, Mechanical properties

1. INTRODUCTION

Marble are rocks which can industrially be cut and polished, recovered in block in sufficient sizes from the site where they are located, and having commercial value Generally speaking marbles are studied in five major groups called "real marbles", crystallised calcareous, magmatic origin marbles travertine's and tuff & onyx".

Turkey possesses 1.6 billion tons of apparent, 4.2 billion tons of probable and 8.1 billion tons of possible reserve marble totalling 13.9 billion tons of marble reserve. Export value in 1999 composed of natural stone, granite, marble blocks and processed marble amounting to 150 billion USD has an approximate share of 25.3 % among the mineral products. Marble is currently being processed in 20 integrated plants, 40 medium size enterprises and more than 1500 small scale enterprises in Turkey and added to the economy.

Marble block obtained from quarries and transported to the factories are firstly cut in block-cutting machines to produce slabs and plates. Then, their edges are-shaped by means of cut-to-size machines and finally they are polished and cut to size again to form tiles, kitchen counters, floor covering, etc. and calibrated to be supplied to the market.

In this study any relationship between the polishing operation which constitutes an important part in the production cycle of marble and properties of marble has been researched. For this purpose 9 samples have been considered among those species which have been given importance in the marble market. These marbles are more homogeneous crystallized marbles compared to other types such as Afyon Tiger Skin, Afyon White, Afyon Sugar, Altıntaş White, Mugla White, Muğla Lilac, Uşak White, Uşak Green and Vize Pink.

2. ABRASION AND ABRASIVES

2.1. Concept of Abrasion and Abrasives

The loss of surface formed by separation of thin layers from the surfaces of solid matter is called "abrasion" (Önder, 1995). Abrasives are the materials which are in granular or powder form and used in the polishing of sensitive surfaces (Akkurt, 1985).

Abrasives can be classified into fun main classes as "natural abrasives and artificial abrasives". Natural abrasives are those abrasives like sandstone, emery, corundum, quartz, garnet, flint and diamond which have formed themselves under natural conditions. Artificial

abrasives, on the other hand, are produced material such as synthetic diamond, aluminium oxide, cubical boron nitrite, boron carbide and synthetic corundum.
Abrasives are numbered according to their grain sizes and their quantity in unit area. Small numbers are assigned to Coarse grained and less quantity in unit area abrasives, and vice versa. Abrasion is performed gradually starting from small numbers going to large numbers. In principle, coarse grains abrade coarse irregularities, leave their own mark and the following smaller grained abrasives clean the marks left over from the previous abrasives and leave their own marks. This, after the finest abrasives (the largest number) surface irregularities are minimized. (Figure 1)

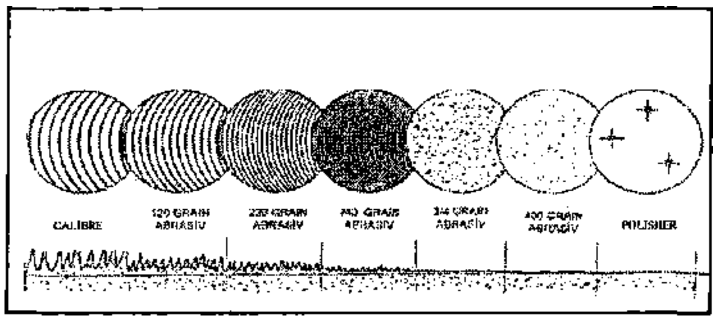

Figure 1 Placement of Abrasives in the Polishing Line and Marble Surfaces (Ozuloğul, 1994).

2.2. Abrasives and Polishers Used in Marbles

Various abrasive materials like silicon carbide and aluminium oxide are used in marble processing after being formed into moulds with proper binding agents and at different mixture ratios. The shape of these moulds varies according to the polishing method and the properties of the machine used. Figure 2 shows abrasives and polishers produced in different forms.

The binding agents which bind the abrasive grains or powders can be magnesite or polyester (synthetic) and have been produced by the placement of silicon carbide ranging from No.16 coarse size to No. 1200 fine size In synthetic diamond abrasive materials metal-resin or polymer binders have been used as binding agents (Davis & Pearce, 1995).

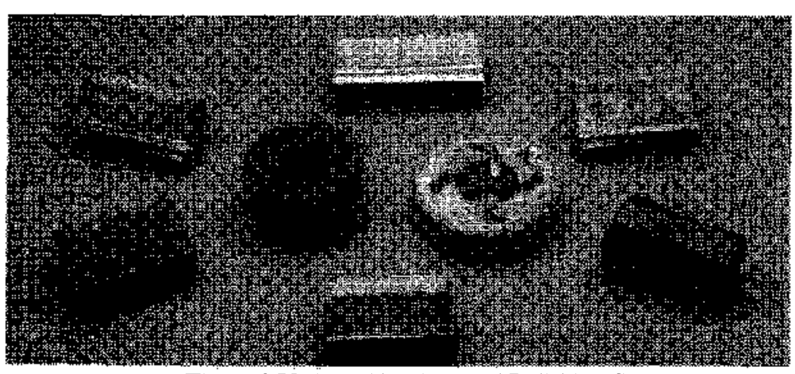

Figure 2 Various Abrasives and Polishing Stones.

Magnesite based abrasives are generally composed of magnesium oxide, magnesium adhesive solution, abrasive materials of various density and size, binders and paint pigment. Point does not have any positive or negative effect in the abrasion process. However different numbered polishing stones are pointed to different colours to avoid usage error during operation.

Synthetic abrasives, on the other hand, contain substances such as carbide and other abrasive materials, sodium chloride and calcium carbonate, polyester resin and paint pigment. The most important property of magnesite bound abrasives is the fact that they do not deteriorate in time and are more efficient in soft marbles; that is, the surface can be made semi gloss. Especially in travertine and limestone type marbles polishing operation can be accomplished by synthetic abrasives with out any need for polishing stone in certain arrangements. (There types of marbles can find customers without being polished) However , synthetic bound abrasives are move sensitive due to their hardness and operate under lower pressure (max. 2 atm.).

Economy type polishing stones are kind of abrasives which are 4 to 5 times more durable than ordinary type polishing stones and perform semi polishing operation and containing totally oxalate acid. Economy type polishing head is operated under a pressure lower than 2 atm and with little water. The polishing principle is the removal of small irregularities chemically under the action of acid. There fore the marble surface is washed with plenty of water at the end of polishing. Polishing stones are abrasives performing the final polishing operation and composed of materials such as dioxalate, tin oxide and aluminium oxide which have total polishing property.

3. POLISHING TECHNIQUE USED IN PRACTICE

Polishing operation has been conducted at Afyon Kocatepe University Vocational School Technical Program Regional Marble Program Application Workshop. For this operation a locally made automatic narrow width polishing machine located at the workshop has been utilised (Figure 3).

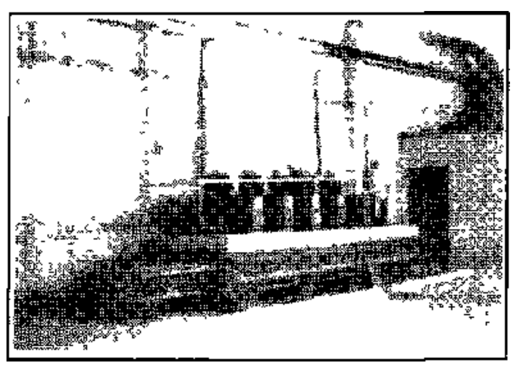

Figure 3 Narrow Width Polishing Machine Used in the Experiment

The machine consists of 1 no. of diamond calibrating head, 4 nos. of polishing heads and 1 no, of smoothening head, The machine is stationary bridge type capable of efficiently polishing slabs of 65 cm width The rotational speed of the heads is constant at 400 rev/mm Furthermore feeding speed, that is, belt speed can be varied between 0 to 3 m/min and the pressure applied to the heads can be varied voluntarily between 0 to 3 atm, Each polishing head motor power is 10 HP and calibrating head motor power is 20 HP

"Vega" brand polishing stones used m the market have been utilised in the polishing operation Number 120 and 220 polishing stones are magnesite bound, and number 360 and 600 polishing stones are synthetic bound (Table 1) After the polishing stones economical polishing stone of the same producer known as Eco-pohshing stone has been used This polishing stone arrangement has been established based on the favourable results obtained in the polishing operations conducted at the installation with this machine During the experiment belt speed and press we applied to the heads have been kept constant at 2m/min and 1 5 atm , respectively, for the purpose of maintaining some active factors fixed All of the marble samples in 9 different kinds have been polished under identical conditions and at one time Later on abrasives and polishing stones have been replaced by the new ones and the next experiments have been conducted In this way each marble has undergone 10 experiments

Table 1 Properties of Abrasives Used in the Experiment (Manufacturer's Data)

s JäEfkS&Mft? Ja *, ™ r	S&&	- „mm. .	NÜ360	mm
Matncs	Magnesite	Magnesite	Synthetic	Synthetic
Grain Size (micron)	+ 100-110	+50-60	+40-45	+2S 30
Grain Dence (tm/mm^1)	5±2	15±2	20±4	80<

4. BRIGHTNESS AND RAUGHNESS

4.1. Brightness and Irregularity

Brightness is the degree of reflection of a surface, that is to say, its reflection capacity Some of the incident rays approaching to a surface with a certain angle of incidence are reflected away from the surface, some of them are absorbed by the surface and some of them are transmitted to do backside after being refracted inside the surface The intensity of the light reflected from the surface, that is, the brightness degree depends on the micro roughness on the surface (Ozul oğul 1994), (Figure 4)

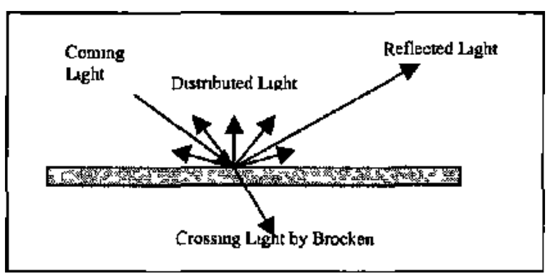

Figure 4 Forms of Reflection of Light

The amount of reflection is the ratio of light reflected from the surface to the incident light to the surface If a light beam incident to a surface is reflected at the some angle as the angle of incidence, then this phenomenon is called full reflection (mirror reflection) If the surface contains Various roughness, some of the incident light beam strikes at the roughness and reflects to different direction Consequently, the surface appears to be dull

Surface roughness measurement also known as Tally surf analysis is one of the important Comparison methods in quality evaluation. Roughness, by definition, are the small irregularities on the surface dependent on the production scheme Furthermore surface might contain defects such as gas bubbles, cracks and various deposits However these defects are not taken into consideration in roughness measurements if not stated so There can be waves over the surface in addition to roughness and defects These waves are called surface morphology. During polishing of the surface the roughness formed on the surface form along a certain direction (Figure 5) Over the nominal surface roughness crests and valleys appear, and the scratches follow a certain direction

In surface roughness measurements values such as Ra, Rz, Rt, etc are read Ra is the universal term accepted as the surface roughness value It is the arithmetic mean of the heights (h,) of the crests above the nominal surface (Figure 6)

$$Ra \cong \frac{h_1 + h_2 + h_3 + ... + h_x}{n} = \frac{1}{L}\int |h| d\chi$$

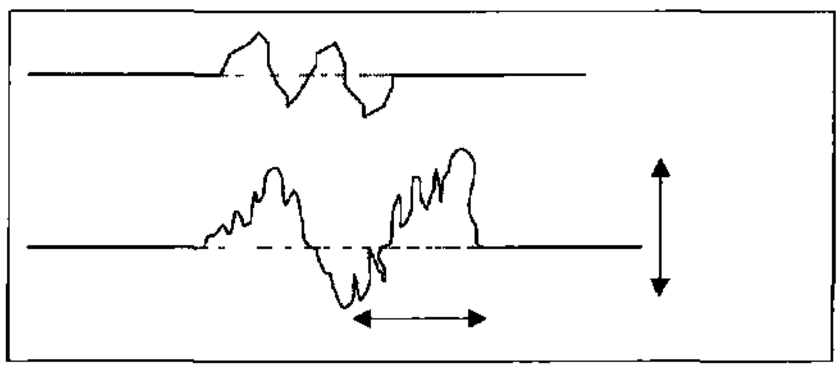

Figure 5 Graphical Definition of Surface Roughness

4.2. Brightness and Roughoess Measurements

In the brightness measurement the anthmetic mean of the values obtained from three different points of each sample, namely 5 cm inward from the corner and edges and right from the center, has been taken Measurements have been repeated on 10 different samples for one type of marble, and the mean of these 10 samples representing that type has been taken

For brightness measurement roughness values have been measured at the spot where brightness measurements have been made on the same samples by means of a Taylor Hobson type 50 ı instrument. Roughness value has been measured in terms of Ra Roughness value representing each type of stone is calculated similar to the one m the brightness value Results of measurements are given m Table 2

Table 2 Brightness-Roughness Values of Marbles

Marble Species	Brightness Roughness	Brightness (%) & Roughness (µ) Values					
		Calibre	№120	№220	№360	№600	Eco-P.
Afyon Tiger Skin	Brightness	1.3	3.0	3 5	4 2	32 5	70 5
	Roughness	4.05	1.46	1.12	0.87	0 30	0 11
Afyon White	Brightness	1.2	2.8	3 5	6 3	48.0	67.5
	Roughness	5 02	2.28	0 84	0 59	0.35	0 11
Afyon Sugar	Brightness	1 3	2.0	4.0	5 8	52 5	75 7
	Roughness	3 10	1 47	0.74	0 50	0.21	0.10
Altıntaş White	Brightness	1 0	4.2	5.7	7 0	59.8	81 8
	Roughness	5.45	2.08	0 73	0.49	0.33	0.09
Muğla White	Brightness	1 2	3 8	5.0	8.7	62 7	89 3
	Roughness	3 69	1.25	0 91	0 62	0 22	0 06
Muğla Lilac	Brightness	1.3	2.0	4 0	5 8	52 5	84 1
	Roughness	3.06	2 08	1.06	0.48	0.24	0.07
Uşak White	Brightness	1.0	4 3	5.8	7.0	59.8	81 8
	Roughness	4.05	1.3	0.71	0 39	0.22	0.07
Uşak Green	Brightness	1.2	3.0	4.0	7 0	44 7	59 7
	Roughness	4 01	1.77	1.17	0 94	0 36	0 13
Vize Pink	Brightness	1.0	3.0	4.0	5.9	33.7	55.8
	Roughness	4.77	3.91	3 5	2 45	1 31	0.18

4.3 Relationship Between Brightness and Roughness

From the graphs plotted it has been understood that the measured brightness value varies in proportion with the number of operations applied to the surface. Similarly, it has been observed that roughness diminishes gradually. (Figure 6)

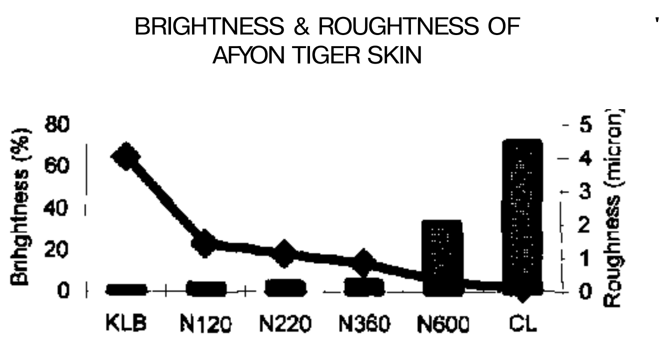

Figure 6 Brightness & Roughness Graph for Afyon Tiger Skin Marble

In order to reveal the ship between brightness and roughness, brightness vs. roughness distribution graphs have been plotted, tendency lines have been passed through the points obtained, recreation equations of the curves have been written and correlation coefficients have been calculated in order to determine the relationship (Figure 7, Table 3).

When the equations İn the form "$y=ax^k$" describing the curves are studied the coefficient "a" has been observed to vary between "2.52" and "4.32" except for Vize Pink, and the expression it has been observed to be around "-71, -0.85" without making any discretion. The reason for value "a" of Vize Pink to come out high is because the slope of the distribution curve is lower when pre-pohshing sample has been measured to be brighter as compared to other samples under higher roughness values. The reason for this is can be due to the full formation of the crystals and obtaining a shiny appearance after the sample was polished.

Table 3 Mathematical Relationships Between Brightness & Roughness
*(y· Roughness(μ), x Brightness (%))

Marble Species	Mathematical Relationship	Corelation
Afyon Tiger Skin	$y=3\ 6509x^{-0\ 8007}$	0,98
Afyon White	$y=3\ 8988x^{-0\ 7854}$	0,93
Afyon Sugar	$y=2\ 5230x^{0\ 7198}$	0,97
Altıntaş White	$y=4\ 3165x^{-0\ 8040}$	0,93
Muğla White	$y=3\ 9902x^{0\ 8446}$	0,97
Muğla Lilac	$y=3.2016x^{0\ 7931}$	0,97
Uşak White	$y=3\ 2993x^{0\ 8041}$	0,96
Uşak Green	$y=4\ 1075x^{0\ 7594}$	0,97
Vize Pink	$y=7\ 4136x^{0\ 7111}$	0,89

In this case if a common equation is generated by taking the mean of coefficients "a" and values "k" for the sample marbles excluding Vize ping, the expression

$$y = 3.6x^{0\ 79}$$

can be written where "x" and "y" denotes brightness and roughness, respectively.

By means of this expression within the range of the sample group not only the roughness of marble under different brightness values can be calculated; but also the value to be reached in order to obtain 100% brightness can also be calculated.

In the expressions of the form "$y=ax^k$" describing the brightness vs. roughness relationship coefficient "a" gets bigger, the transition of the curve from its portion describing the "calibrating no. 120, no.220 and no.360" operations to the portion describing the "no:600 and polish" stone is with less slope meaning soft; and as coefficient "a" gets smaller, this transition is more distinct. There fore, the fact that the graph has a uniform brightness vs. roughness relationship leads to the conclusion that the marble can be polishes more easily and regularly.

Furthermore, whatever the slope of the graph is, there are brightness value of the marbles attained under same conditions which is the sign for that rock to be polished. Those rocks which can extend to the farthest point (100%) along the brightness axis can be stated as prone to be polished well.

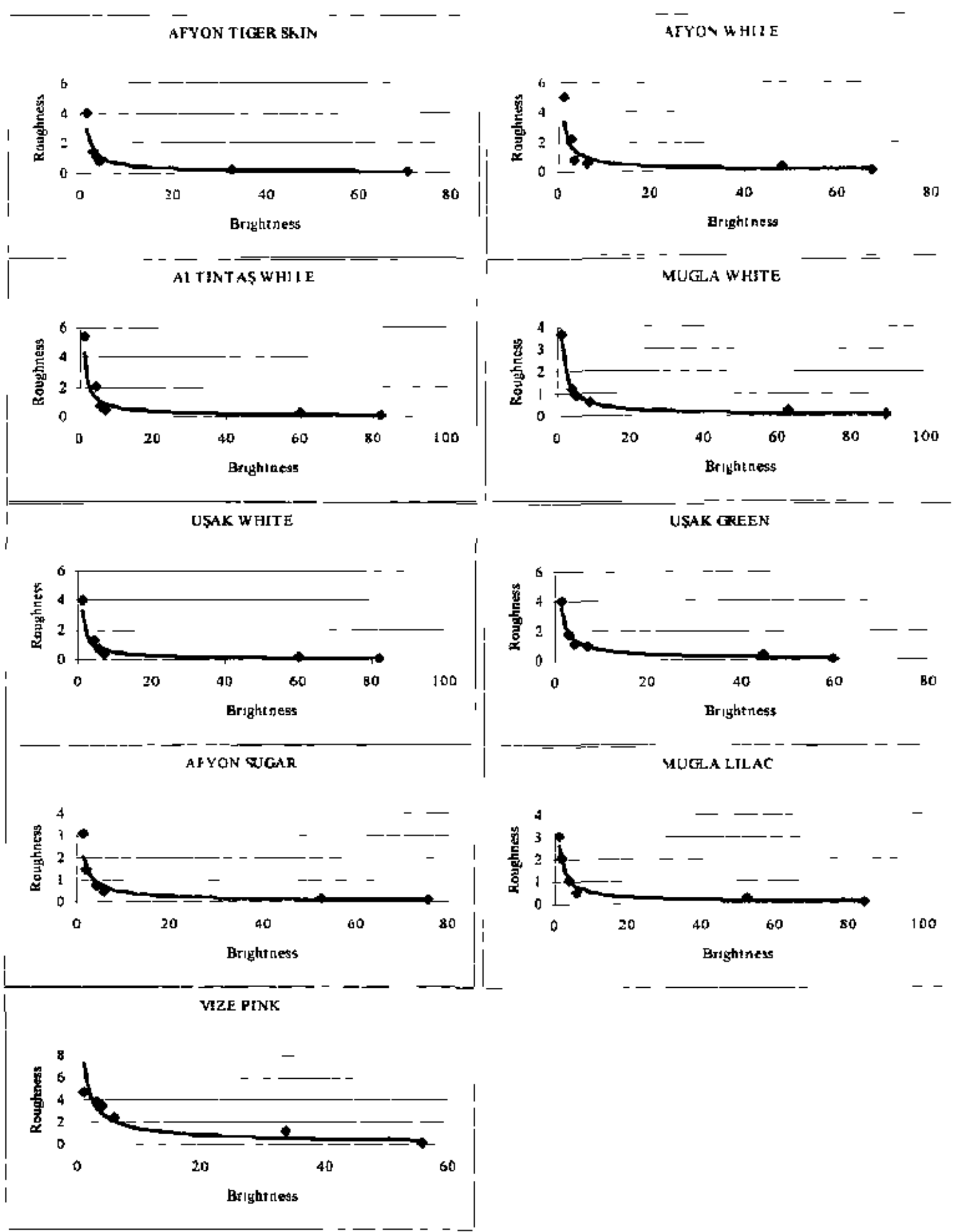

Figure 7 Brightness (%) & Roughness *(\i)* Distribution Graphs

In summary, some marbles attain faster brightness and some others slower. Some marbles can be made brighter more and some others less 9 type of marbles selected for the experiments have been classified in Table 4 for ease in polishing and being prone to be polished.

Table 4 Ease in Polishing and Being Prone to be Polished

Marble Species	Ease in Polishing		Being Prone to be Polished	
	"a"	Explain	Brightness	Explain
Afyon Tiger Skin	3.6509	Easy	70.5	Middle
Afyon White	3.8988	Easy	67.5	Middle
Afyon Sugar	2.5230	Middle	75.7	Good
Altıntaş White	4.3165	Very Easy	81.8	Good
Mugla White	3.9902	Easy	89.3	Very Good
Muğla Lilac	3.2016	Middle	84.1	Good
Uşak White	3.2993	Middle	81.8	Good
Uşak Green	4.1075	Very Easy	59.7	Bad
Vize Pink	7.4136	Very Easy	55.8	Bad

5. MECHANICAL PROPERTIES OF MARBLES

5.1. Determination of Mechanical Properties of Marbles

Mechanical properties such as density, specific gravity, fullness ratio, porosity, hardness (Mohs, Knoop, Rockwell), bending strength, compressive strength and resistance to wear by friction of the marbles have been determinant as described in TS 699. The averages of the findings of several experiments conducted have been given in Table 5.

Table 5 Mechanical Properties of Marbles

Mechanical Properties	Af. T. Skin	Afyon White	Afyon Sugar	Alt. Sugar	Muğla Sugar	Muğla Lilac	Uşak White	Uşak Green	Vize Pink
Mohs Hardness	4.0	3.0	4.0	3.5	3.0	3.0	3.5	4.0	3.0
Knoop Hardness	132.2	161.8	148.6	158.3	164.2	141.7	164.7	144.9	140.5
Rockwell Hardness	61.6	66.5	67.7	62.4	98.8	44.5	69.2	52.5	58.4
Volume Weight Ratio (g/cm^3)	2.71	2.73	2.73	2.74	2.71	2.72	2.72	2.73	2.72
Densty (e/cm^3)	2.73	2.74	2.74	2.75	2.77	2.74	2.74	2.76	2.74
Fullness Ratio %	99.19	99,32	99.47	99.74	97.56	98.99	99.33	98.95	99.46
Porosity	0.81	0.68	0.53	0.26	2.44	1.01	0.67	1.04	0.54
Bending Strength fke/«n^{r})	66.68	157.43	151.35	162.00	144.53	163.50	122.25	146.18	151.95
Compressive St. (kg/cm^1)	649.39	703.38	693.98	846.99	510.03	1015.41	742.60	682.07	781.18
St. to Wear by Frkt. (cnrVsoW)	32.24	25,13	25.27	29.93	16.56	17.08	25.47	28.86	33.23

5.2. The Relationship between the mechanical Properties of Marbles and Brightness.

In order to determine the relation ship between the mechanical properties of the marbles and brightness values, distribution graphs is each property vs. brightness have been plotted, recreation equations have been found and correlation's coefficients have been calculated.
As a result of the studies made it has been determined that no relationship exists between brightness and density, specific gravity fullness ratio, porosity, hardness (Mohs, Knoop, Rockwell), bending strength and compressive strength. Even if the correlation coefficients are in the range of 50 to 55 % for some properties, these values are not sufficient to claim the existence of any relationship.

It has been observed that correlation coefficient is 73% when a linear line connected the distribution graph of strength to wear by friction versus brightness (Figure 8). In this case it can be stated by taking into consideration the slope of the straight line that as strength to wear by friction is reduced the brightness increases.

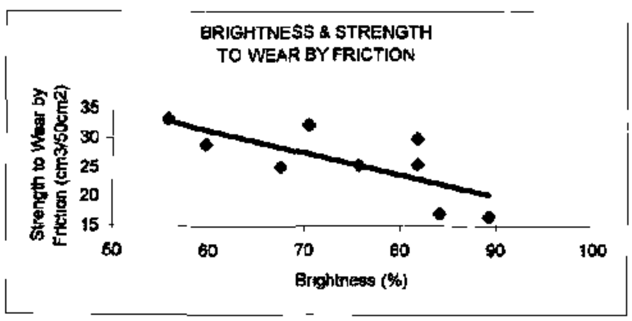

Figure 8 Point Distribution of Brightness vs. Strength to Wear by Friction

6. CONCLUSION

In this study 9 different types of marble samples have been given polishing tests on industrial scale and under some conditions. Brightness and roughness values have been measured over the marble surfaces properties of each marble sample has been determined.

For all of the marble samples brightness and roughness values have been measured at each polishing stage. For all marble samples it has been concluded that there is more than 90% correlation between brightness and roughness, and as roughness reduces brightness.

When the plotted distribution graphs are analysed it has been observed that in the starting stage of polishing roughness drops fast but brightness increases a little, anal in the final stage brightness increases rapidly despite roughness reduces less This condition has been studied in two parts separately as removal of irregularities and fulfilment of polishing, and the difference of the slopes of the distribution graphs has attracted attention. Furthermore, in the exponential expression in the form "y=ax describing the distribution graphs, coefficient "a" concluded to be the function of variance of the slopes for each graph and that this coefficient indicates whether a marble can be made bright easily or with difficulty.

In the light of the findings it can be stated that in the regions of the curve where the slope is high, the polishability is low and vice versa; marble samples with high coefficients "a" can be polished easily and vice versa.

Strength to wear by friction of marble samples has been determined by means of a Böhme abrasion instrument and correlations above 0.70 have been calculated for brightness of real marbles.

Based on this it has been concluded that the strength to wear by friction of marbles effects brightness, and as the abrasion index fall down brightness increased.

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