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Heavy aggregate and different admixtures efffect on parquets: chrome, magnetite, and quartz-based surface hardener

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Abstract: This paper presents the mechanical and micro-structure results of concrete parquet blocks. The blocks were generated by utilizing the same part in the bottom part and by substituting different proportions (40%, 30%, 20%, and 10%) of heavy aggregate like chromite aggregate, magnetite aggregate, normal aggregate, and surface hardener in the upper part. The parquet sample tests were conducted on TS 2824 EN 1338. The test outcomes indicated that utilizing diverse aggregate and chemical materials boosted the abrasion resistance, 40% magnetite and quartz-based concrete parquet block samples demonstrated the best abrasion resistance values. Also, the minimum amount of mass loss was discovered in the samples that possess high water absorption at the freezing-thaw test. The different material substitutions in the sheet of the surface of the concrete parquet block samples altered the tensile strength of the samples, even though they did not bring about an outstanding variation in the compressive strength of the concrete parquet samples.

Keywords: Chromite aggregate, magnetite aggregate, surface abrasion resistance, SEM.

1. Introduction

Concrete pavement blocks are structural elements that can withstand natural conditions and heavy traffic loads for many years and can be disassembled and reused when necessary after their manufacture. Concrete pavement blocks have aspects that are superior to building materials such as concrete, asphalt, natural stone coatings, and floor tiles. Owing to the pre-production of the blocks as prefabricated, they are laid quickly at the construction site and thus the area to be used is opened to traffic early. It offers the opportunity to easily replace the parquets damaged by the detrimental effect of the environment. The main advantages of parquets against other floor coverings are that they offer the opportunity to remove the previously laid parquets and use them again in the same area, in the manufacture of infrastructure, repair, or new manufacture of installation pipes. Interlocking concrete pavers and decorative stones have an absorbency of less than 5-6%, so they last longer than asphalt and other parquet materials (Canpolat, 2018). In this way, the harmful effects of salts and chemicals that most damage the life and appearance of floor covering materials are minimized. The use of parquets in areas subject to the freeze-thaw effect is preferred in terms of resistance to cold weather. Easy applicability, aesthetics and durability, production with domestic materials, and repeated use in infrastructure works are the superior aspects of parquets compared to other coating materials. Parquets are one of the lowest-cost covering elements because they do not have compatibility problems with new and old materials, have various color, texture, and pattern options, prevent water pooling, and adapt to the environment.

When producing concrete parquets, are produced in two layers the upper and lower layers. The lower layers of concrete parquets are the carrier layer. The lower layer is to increase the resistance of concrete against freezing and thawing, the reason for the existence of the upper layer is to provide abrasion and aesthetics. Surface hardening additives are developed and produced to provide the abrasion resistance of the upper layer in concrete parquet. These materials are produced to protect concrete surfaces that will be exposed to much lighter and simpler uses than very heavy-duty and heavy-moving loads, to stop dusting and abrasion problems of concrete, and/or to prolong their usage period. With parquets, special surfaces that require very high abrasion resistance, standard-type factory floor traffic, floors exposed to medium and low traffic, surfaces that require partial chemical resistance, and sulfate-resistant surfaces can be produced. Concrete surfaces that are exposed to natural conditions outdoors, resistant to freezing and thawing, can be used in areas close to sea waters or seasides, under the possibility of continuous exposure to various external factors and different corrosion can be obtained.

There are many experiments and methods related to the determination of the resistance levels of concrete parquets. However, first of all, to ensure that the products to be produced have better properties as a result of the production of concrete pavements while being produced in concrete plants, the appropriate material selection, composition, and mixture of these materials (concrete design), including water, must have sufficient heat of hydration in the compaction, curing and setting process, and then not be affected by defects caused by temperature differences (TS EN 206-1, 2002). Concrete consists of two main phases which are the coarse aggregate phase and the paste phase. The abrasion resistance improves over the more resistant of these two (Baradan end Felekoğlu, 2004). According to the ASTM C 936-01 standard (2001), after 50 repetitions of freeze-thaw, the mass loss of the cobblestones is required to be no more than 1%. In the ASTM C 936–01 standard (2001), the maximum amount of wear is required to be 15 cm^3/ 50 cm^2. Table 1 gives the allowable wear depths, American classification, based on the Chaplin abrasion test instrument and the impacted traffic (ACI 302.1R-15, 2015). In addition, in Table 2, ground concrete classes and British classifications are given depending on wear (BS 8204-1 2003-A1, 2009; URL-1, 2006). Other technical features of the parquet stones are 20 cm^3/50 cm^2 of resistance to surface abrasion, 6% average water absorption rate, 1 kg/m^2 resistance to freeze-thaw effect, and average splitting tensile strength of 3.6 MPa. Strength levels of concrete pavements are determined by using tests and methods specified according to TS 2824 EN 1338 concrete parquet blocks for flooring-required conditions and test methods standard (TS 2824 EN 1338, 2005). These tests and methods, determination of resistance to freeze-thaw with the effect of deicing salt, determination of total water absorption, measurement of strength (breaking loads, splitting tensile strengths, and unit length breaking loads), measurement of resistance to vertical abrasion, unpolished slip resistance value (USRV) determination of the surface hardness of the parquets with Schmidt test hammer (TS 2824 EN 1338, 2005; TS EN 12390-3, 2010).

Surface hardeners are cement-based materials produced with silicon carbide aggregate, corundum aggregate, and quartz aggregate additive. Floor primers are one-component, styrene/acrylate-based, multi-purpose concentrated floor primers. Curing materials are water dispersion (homogeneously spreading) acrylic emulsions with components, which provide curing, surface hardening, and coating of fresh or hardened concrete. Protective coatings are produced as two-part, hard elastic, pigmented, colored, solvent-containing, epoxy, water-based, polyurethane, felt coating with very low VOC release (URL-2, 1998). Apart from the additives listed above, many by-products and waste materials were added to the lower and upper layers of the concrete parquets and the performance strength levels were measured by experiments. According to TS EN 934-2 standard (TS EN 934-2, 2002); water-reducing, water-retaining, air-entraining, and setting accelerator additives are utilized in the production of concrete parquets. Concrete pavement blocks allow the use of concrete and other waste (Uygunoglu et al., 2012; Ozalp et al., 2016; Kumar, 2017). Recycling aggregate from parquets and construction waste concrete can also be used in pavement blocks. In this way, parquets are at peace with nature thanks to their recycling. It provides economic benefits by reducing the amount of cement required to achieve the same strength compared to normal concrete. At the same time, additional economic and environmental benefits must be taken into account, as a waste product is evaluated (Corinaldesi and Moriconi, 2004; Topçu and Canbaz, 2004).

Yahlizade (2007), 10%, 20%, and 30% mass of glass powder were replaced by sand in the cobblestones. Freeze-thaw, abrasion, and fire resistances of concrete parquet stones containing waste glass powder were investigated and compared with the control sample without waste glass powder. Waste glass powder in the concrete parquet stone did not have any harmful effects in 50 repeated freeze-thaws. Açıkgöz (2008), in her study, produced concrete pavements by using fly ash obtained from different power plants at rates such as 10%, 20%, 30%, and 40% instead of cement. As a result of the study, the water requirement of fresh concrete went up with the rise in the fly ash rate. Accordingly, test results of abrasion resistance and water absorption determination in cobblestone samples were high, and decreases were observed in splitting tensile strength determination. Karpuz and Akpınar (2009) examined the abrasion resistance of concrete used on roads, depending on the abrasion resistance of fine aggregate. Concretes were produced with limestone, limestone+basalt mixed, and basalt-type crushed stone fine aggregates. According to the test data, raising the resistance values of the fine aggregate can significantly increase the abrasion resistance of the concrete. Sahbaz (2010) investigated the properties of Afyonkarahisar İscehisar andesite, Beyyazı dolomitic limestone, and Kütahya Ilıca regional basalt raw materials, made concrete parquet blocks by using natural aggregates with 0-4 mm, 4-12 mm, 12-22 mm sieve diameters at a rate of 75% in concrete. In the concrete parquet stone samples, the average split tensile strength results on the 3rd day were 2.39 MPa for andesite, 2.94 MPa for basalt, and 2.75 MPa for dolomitic limestone. The average split tensile strength at day 7 was 2.96 MPa for andesite, 3.85 MPa for basalt, and 3.67 MPa for dolomitic limestone. Yıldız (2013) investigated the use of Elazig ferrochrome slag as an aggregate in parquet production. In concrete parquets produced with Elazig ferrochrome slag, it has been observed that the splitting tensile strength of the 90-day concrete parquet samples is 5.4 MPa on average, and this value is 3.4 MPa in the control group samples. Çimen (2015) searched the use of the recycling material obtained as a result of the rebound of the aggregate and concrete fibers from the surface during the application of shotcrete on the concrete surface, in the production of parquet stones. Canpolat (2018) studied the physical and mechanical features of concrete parquet stones produced with a waste aggregate of the Kayseri zinc-lead production facility. 90-day results showed better values compared to 28-day results. In addition, it has been found that all test results of concrete parquet stones with control and zinc lead waste aggregate, which do not contain chemical additives, are better. Abu el Hassan et al. (2024) tried to explain the effect of replacing 100% of fine and coarse aggregates with heavy aggregates and the addition of nano titanium and nano silica on radiation shielding and mechanical properties of heavy high strength concrete (HWHSC). For this purpose, they prepared a total of 20 different mixtures by substituting hematite and steel slag aggregate with nano silica or nano titanium at 1% and 3% of cement weight. In addition to mechanical tests such as compressive strength and modulus of elasticity, they performed absorption tests to determine radiation shielding properties. As a result, they found that the substitution of 3% (nano silica or nano titanium) and 100% steel slag and hematite as coarse and fine aggregates produced the best mechanical and absorption properties. Teymen (2023) studied to develop practical equations for the evaluation of the general properties of concrete during the preliminary concrete design phase. For this purpose, a series of experimental studies were carried out to determine the effect of 20 different aggregates on the properties of concrete. His equations and statistical results demonstrated that the extremely high coefficients of determination obtained with NMRA, ranging from 0.81 to 0.96, revealed that fundamental concrete properties can be very accurately predicted by aggregate properties and some non-destructive concrete properties.

The revision of literature showed that there are many studies about the effect of different aggregates, including heavy aggregates, on the mechanical and absorption properties of concrete. However, when it comes to the effect of paving and heavy aggregates, the studies are very limited. Based on this situation, expanding the limited scientific knowledge on this topic is the research motivation of this study. The study aims to investigate how fine aggregates containing heavy aggregates like chromite, magnetite, and quartz powder affect the surface wear resistance of concrete parquets. Concrete floors are surfaces that are in direct contact with pedestrian and vehicle traffic and are under the influence of abrasive forces. In addition to producing wear-resistant concrete with appropriate aggregate gradation and water/cement ratio with concrete design, by using surface hardeners, the abrasion resistance of parquets is boosted and they serve for a long service time. It is aimed to go up the surface wear resistance of concrete parquets. To improve the surface resistance, a concrete mixture design was made by using different surface hardening additives to the TS 2824 EN 1338-concrete parquet blocks for flooring-required conditions and test methods standard (TS 2824 EN 1338, 2005), and a comparison was made between the concrete parquets and the additives in line with the tests specified in this standard. Since chromium and magnetite are heavy aggregates, they are generally used for absorption in parts of structures exposed to radiation (Ustabas et al., 2022). This study aims to increase the life of parquets by improving their abrasion resistance, taking advantage of the rigidity of this type of aggregate.

2. Materials and methods

In this study, concrete pavement blocks (parquet) were produced in a laboratory environment in four groups additive-free, chromite-added, magnetite-added, and quartz-added by following TS 2824 EN 1338 (2005) standards. Aggregates with two different granulometry and mineralogical properties were used in the lower and upper layer concretes of the parquets.

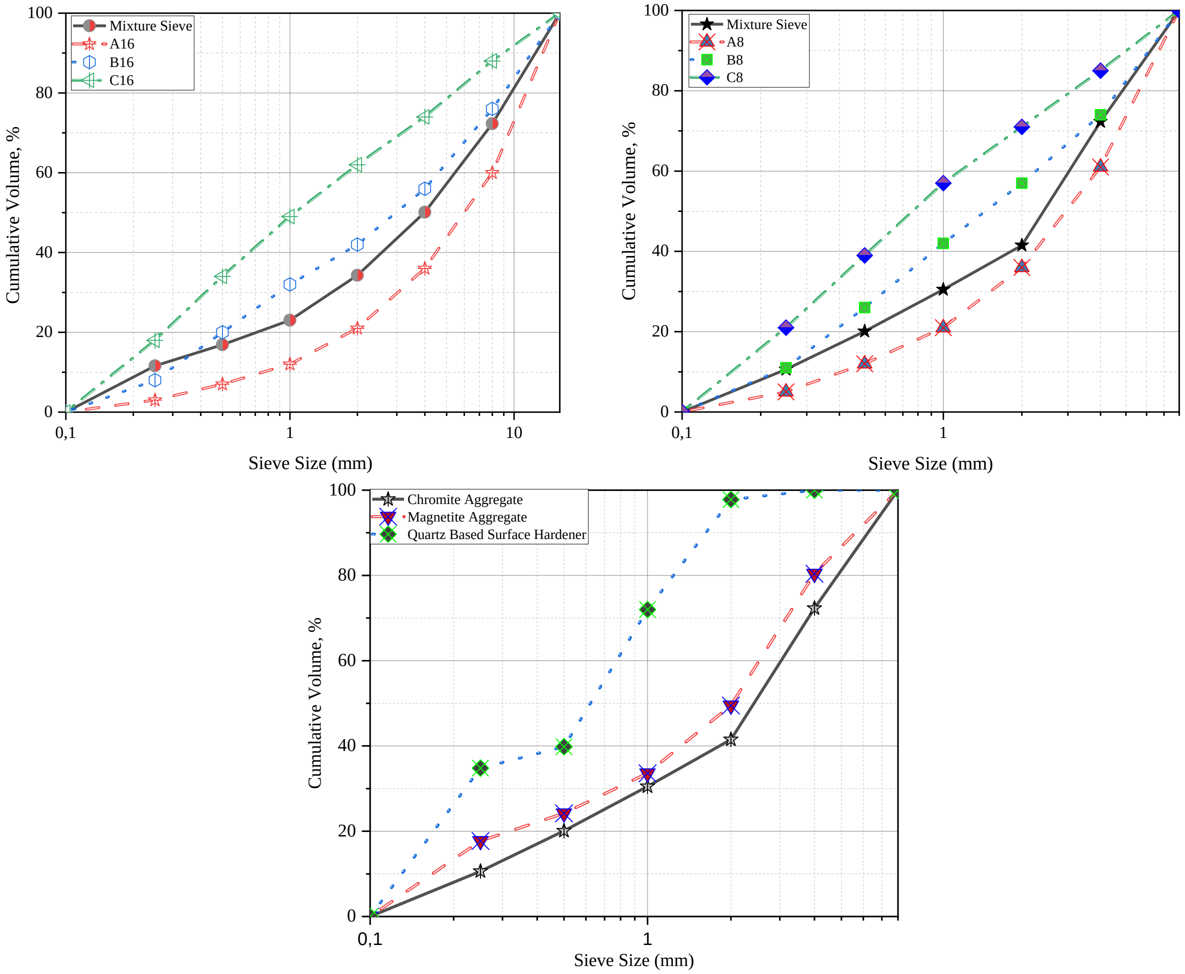

Figure 1. (a) Aggregate granulometric curve used in the lower layer, (b) curve of aggregate granulometry used in the top layer, (c) chromite, magnetite aggregate, and quartz-based surface hardener granulometry curve.

Admixture-free parquets were produced by using the aggregate, the percentages of which passed the sieve in Figure 1(a), in the lower layer concrete of the parquets, and the aggregate, the percentages of which sieved in Figure 1(b), in the upper layer concrete of the parquets. On the other hand, in chromite and magnetite parquets, it is produced by substituting chromite and magnetite aggregates instead of the aggregate whose percentage passing through the sieve in Figure 1(c) is seen only in the upper layer concrete of the parquets, and the mass that is reduced by 10%, 20%, 30%, and 40% according to this aggregate mass. Thus, parquets with 10%, 20%, 30%, and 40% chromite and magnetite aggregates and four groups of additives were obtained. In addition, a product sold as a quartz-based surface hardener in the market is applied to the upper layer of the parquets following the amount and application description specified in the user manual, and another group is produced in quartz parquets.

Table 1. Permissible depth of wear (American classification) based on Chaplin abrasion test instrument and impacted traffic (ACI 302.1R-15, 2015).

Class	Traffic exposure	Use of	Maximum depth of wear (mm)
1	Light pedestrian	Residences or tiled spaces	0.800
2	Pedestrian	Offices, schools and hospitals	0.800
3	Pedestrian and light wheel	Garages and car spaces	0.400
4	Pedestrian and wheels	Light-density industrial and commercial areas	0.200
5	Pedestrian, wheels and abrasive wear	Industrial areas and monolithic toppings	0.100
6	Pedestrian and hard wheels	Linked toppings for heavy industry	0.050
7	Class 3, 4, 5, 6	Unbound toppings	0.400-0.050

Table 3 shows the specific masses and water absorption values of the aggregates used in this study. The bottom layer and top layer aggregate in Table 3 were obtained from the mixture of four aggregates. Aggregates with chromite and magnetite were obtained from a mixture of two aggregates, coarse and fine. The reason why these aggregates are called chromite and magnetite is that the aggregates produced by crushing the jaw crusher contain chromite and magnetite in the host rock.

Table 2. Floor concrete classes depending on wear (BS 8204-1 2003+A1, 2009).

Feature	Slab class				
	Special	AR1	AR2	AR3	Nominal
Wear resistance rating	Too high	Very high	High	Good	Normal
Maximum depth of wear* (mm)	0.050	0.100	0.200	0.400	0.800
Typical use	Factories in heavy use	Factories and warehouses in heavy use	Medium-density factories and warehouses	Underutilized factories and warehouses	Areas exposed to construction traffic
Typical traffic exposure	Heavy-duty steel wheels, impact and drag loads	Steel wheels and impact	Lightly loaded steel wheels and hard plastic wheels	Rubber wheels	Rubber wheels and walking traffic
Concrete compressive strength	Special blends	60 MPa	50 Mpa	40 Mpa	40 MPa
Maximum amount of cement	Special blends	475 kg/m^3	400 kg/m^3	325 kg/m^3	325 kg/m^3
Fine aggregate	Special blends	Natural sand conforming to the standard, but soft limestone or should not be sandstone		Natural sand conforming to the standard	No special requests
Final fix	Special blends	Smooth trowel correction	Smooth trowel correction	Smooth trowel smoothing or early age sanding	Trowel smoothing or early-age sanding

Table 3. Specific gravity and water absorption values of aggregates and pyrite aggregates used in the lower- and upper-layer concretes of the parquet.

Bottom layer aggregate	Course 1	Course 2	Fine 1	Fine 2
Specific gravity (g/cm^3)	2.720	2.710	2.470	2.410
Water absorbtion (%)	1.270	0.890	3.740	7.060
Upper layer aggregate	Course 1	Course 2	Fine 1	Fine 2
Specific gravity (g/cm^3)	2.990	2.590	2.550	2.460
Water absorbtion (%)	4.200	2.720	4.630	2.940
Pyrited aggregate	Course 1	-	Fine 1	-
Specific gravity (g/cm^3)	2.790	-	2.510	-
Water absorbtion (%)	2.300	-	3.430	-

Table 4 shows the chemical composition and proportions of the aggregate with chromite and magnetite. There is 35.8% chromium-oxide in the chromite aggregate and 35.8% iron-oxide in the ferrous aggregate.

2.1. Determination of freeze-thaw resistance with de-icing salt effect

After 28 days of cure, the side surfaces of the parquets were coated, and after pouring water with 3% NaCl concentration on the surface, they were placed in the air-conditioning cabinet where the freeze-thaw test was applied. Then, it was subjected to a 28-day freeze-thaw cycle and the mass loss per square meter was measured. 3% NaCl solution prepared using potable water at a height of 5±2 mm was placed on the surfaces of the parquets. The air-conditioning cabinet was temperature-time cycled and exposed to a 28-day cycle between +20 C° and -20 C° in a 24-hour period. At the end of the cycle, the material surface was washed with water and the lost material mass was measured The pieces of parquet were weighed and the mass loss was measured and divided by the sample surface area.

$$L=M/A \qquad (1)$$

The mass loss value was calculated by its relation (1). L in the relation shows the mass loss per unit area (kg/mm^2), M shows the mass loss in the parquet (kg), and A shows the surface area of the parquet (m^2). The entire experimental process and the outputs obtained are shown in Figure 2.

Table 4. Chemical composition and proportions of aggregates with chromite and magnetite (%).

	Chromite agregate	Magnetite agregate
Al_2O_3	7.150	1.760
BaO	0.000	0.020
CaO	0.500	20.500
Cr_2O_3	35.800	0.082
Fe_2O_3	16.900	35.800
K_2O	0.010	0.020
MgO	23.000	2.170
MnO	0.190	1.050
Na_2O	0.000	0.210
P_2O5	0.001	0.230
SO_3	0.060	0.240
SiO_2	10.900	31.800
TiO_2	0.100	0.040
V2O5	0.083	0.006
ZnO	0.066	0.954
ZrO_2	0.000	0.000
Loss of ignition	5.100	5.200
Total	99.860	100.020

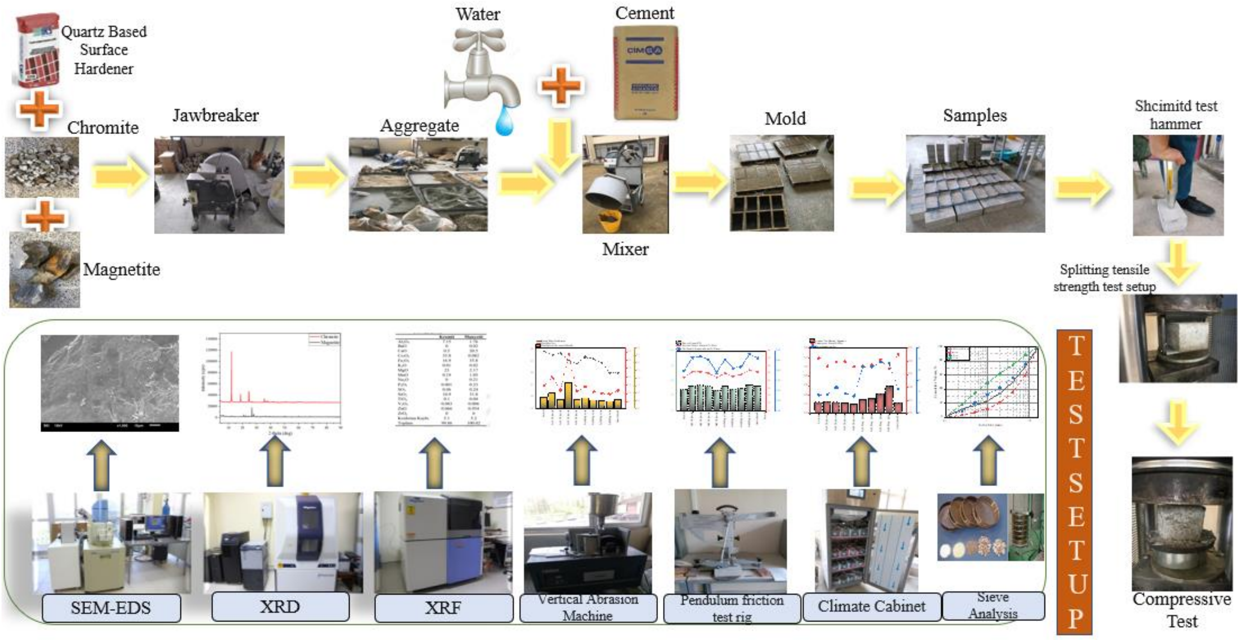

Figure 2 (a). Experiment process, and outcomes.

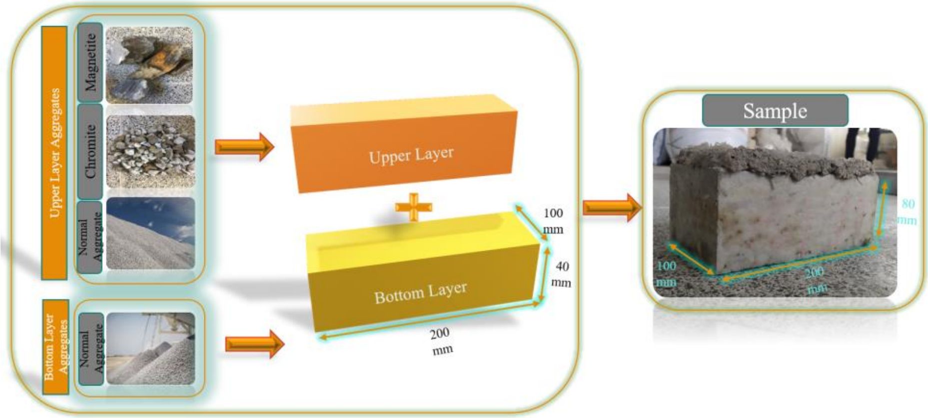

Figure 2 (b). Parquet samples.

According to the amount of material entering the mixture in Table 5, the concretes of the parquets were produced in a pan type mixer. CEM I 42.5 R class cement was used in the parquets.

Table 5. Materials used in parquet concretes for 1 m^3 (kg).

	Cement	Water	Course aggregate	Fine aggregate
Bottom layer	250	159	1497	405
Upper layer	470	235	947	591

2.2. Determination of total water absorption

After the parquets were conditioned in an environment at a temperature of (20±5) C°, they were immersed in water until they reached a constant mass and then dried to reach a constant mass. The mass loss in the parquets was calculated as a percentage of the dry mass of the sample according to the following equation.

$$Wa = (M1-M2)/M1 \qquad (2)$$

Wa in equation (2) shows the water absorption of the parquet, M1 is the water-saturated mass, and M2 is the oven-dry mass. The parquets, whose surface roughness was corrected, were plunged in water at (20±5) °C for (24±3) hours, then dried with a cloth and immediately subjected to the test. Fracture plane areas of the tested concrete blocks were calculated using the equation given below.

$$S = lt \qquad (3)$$

S is the fracture area (mm^2), l is the length of the fracture section (mm) as the average of two evaluations made at the up and down part of the sample, t is the thickness of the concrete block in the fracture plane (mm) as the average of three evaluations, one in the middle and the other two evaluations at the ends.

The strength T of the tested parquets was calculated with the following equation.

For the cobblestone thickness calculated from T strength (MPa), P breaking load (N), $k=1.3-30(0.18-t/1000)^2$ (if $140mm<t\leq180mm$) or taken from Table 6 is the correction coefficient.

$$T = 0.637\,kP/S \qquad (4)$$

Table 6. Correction coefficient k according to parquet thickness.

t(mm)	40	50	60	70	80	90	100	110	120	130	140
k	0.710	0.790	0.870	0.940	1.000	1.060	1.110	1.150	1.190	1.230	1.250

The breaking load per unit length was calculated using the equation given below.

$$F = P/L \qquad (5)$$

2.3. Measuring resistance to wear

The abrasion resistance of the parquets was calculated with a vertical abrasion device. After the parquet is placed in the device, its surface is brought close to contact with the large abrasion disc. The wear dust control valve was opened and at the same time, the engine was started in such a way that the wide abrasive disc made 75 revolutions in (60±3) seconds. After the disc made 75 revolutions, the flow of abrasive powder and the disc was automatically stopped by the device. The height of the wear mark on the parquet was measured.

2.4. Method for determination of unpolished slip resistance value (USRV)

The unpolished slip resistance value (USRV) of the parquets was determined by evaluating the slip properties on the top surface of the sample using a pendulum friction (pendulum) test rig. After the test sample is placed in the pendulum friction device, the pendulum moves freely when the button that releases the pendulum is pressed. The rotation of the pendulum was prevented by holding it by hand and the friction value was read from the indicator. The same process was repeated five times and the slip resistance value was calculated.

2.5. Determination of surface hardness of parquets with schmidt test hammer

The surface hardness of the parquets was measured by hitting vertically on the parquet placed on the concrete surface with a Schmidt test hammer.

3. Results and discussion

3.1. Vertical wear length, mass loss and mass loss per unit area

In Figure 3, the mass loss and mass loss values per unit area measured in the parquets with freeze-thaw application are seen. The mass loss (L) per unit area in Figure 3 is calculated according to equation (1). The tested sample surface area is 200 x 100= 20000 mm^2. This value provides the space requirement of the sample to be tested as specified in the TS 2824 EN 1338 standard ($A<25000$ mm^2). TS 2824 EN 1338 standard (2005) expresses freeze-thaw resistant blocks with the de-icing salt effect as Class 3, class designation D, and the average unit area mass loss of parquets with this feature is less than 1.0 kg/m^2 and each single value is 1.5. The values in Figure 3 are the average values calculated over three samples and meet the conditions specified by the standard. The value of 1.68 seen in the samples with 30% chromite in Figure 3 was considered as a measurement error due to the error during sample production because it was not compatible with other values. In Figure 3, more mass loss occurred in the parquets with 30% chromite aggregate replacement than the mass loss detected in other parquets. It is thought that the mass loss in these parquets is due to the heterogeneous structure due to the production. Except for parquets with 30% chromite aggregate and parquets with 10% chromite, as the mineral additive ratio increased, there was a decrease in mass loss in parquets exposed to freeze-thaw. Freeze-thaw mass losses in parquets using quartz-based surface hardeners are less than in normal parquets. This situation shows that the traffic-bearing surfaces of mineral-added and quartz-based surface hardener parquets are more resistant to freezing and thawing than pure parquets. The increase in the surface abrasion resistance and splitting tensile strength of the mineral-added aggregate-substituted and quartz-based surface-hardened parquets increased the durability of the parquets against freezing and thawing.

Table 7. Friction values measured with a pendulum foot.

Sample name	Friction values measured with a pendulum foot
Normal	0.451
10% chromite	0.552
20% chromite	0.518
30% chromite	0.542
40% chromite	0.543
10% magnetite	0.556
20% magnetite	0.548
30% magnetite	0.562
40% magnetite	0.552
Quartz based	0.607

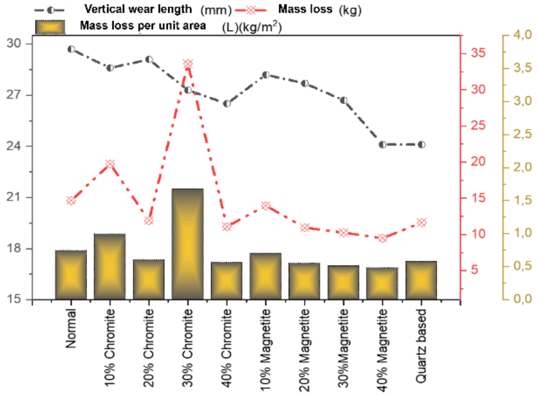

Figure 3. Vertical wear length, mass loss, and mass loss per unit area values of normal, 10% chromite, 20% chromite, 30% chromite, 40% chromite, 10% magnetite, 20% magnetite, 30% magnetite, 40% magnetite and quartz-based samples.

In this study, it was aimed to increase the surface wear resistance of parquets with chromite, magnetite, and quartz-based fine aggregates. Quartz-based surface hardeners are used in the market to increase the abrasion resistance of the concrete surface, especially for field concretes Aggregates with chromite and magnetite are mineralogically valuable minerals. However, chromite and magnetite containing chromium and rocks that have no economic value in terms of the iron industry can find use in the surface layers of concrete or parquet as in this study.

Figure 3 shows twelve vertical length readings read from six parquets for each group. In Figure 3, it is seen that the concrete with the highest wear is the concrete without additives, and the vertical wear length decreases as the additive ratio increases in the parquets with additives. In the parquet types in Figure 3, it was found that normal parquets do not contribute to the maximum vertical wear length. Applying chromite, magnetite fine aggregate, and quartz-based surface hardener to the upper layer (surface layer) of the parquet decreased the vertical wear length of the parquet. As the incorporation rate of chromite and magnetite aggregate added to the surface layer increased, the vertical wear length decreased. This shows that aggregates with chromite and magnetite increase the surface wear resistance of the parquet. The minimum vertical wear length was determined in parquets using agrega with 40% magnetite and parquets with quartz-based surface hardener. Quartz-based surface hardener is a material used in market concrete and its surface hardening properties are known. The fact that the vertical wear lengths measured in the fine aggregate parquet containing 40% magnetite and the parquet using quartz-based surface hardener in this study are equal to each other shows that 40% magnetite aggregate can be used as a surface hardening product in parquets.

Uygunoğlu (2012) measured the vertical wear lengths of 23 mm to 30 mm in the parquets produced with crushed aggregate, recycled concrete aggregate, and marble waste aggregate concrete. In the splitting with crushed stone aggregate, a vertical wear length of around 23 mm was determined in parquets with a tensile strength of 5 MPa and a compressive strength of 29 MPa. When compared to the parquet concretes in the study of Uygunoğlu (2012), it is seen that the vertical wear length of around 29 mm measured in normal aggregate concretes in this study is compatible with each other. Özalp (2016) produced recycled and normal aggregate concrete pavements in his research and measured vertical wear lengths of around 23 mm in normal aggregate concrete. When the parquet concrete in Özalp's (2016) study was compared with the parquet concrete in this study, it was seen that the vertical wear lengths were close to each other. This shows that the vertical wear lengths measured in the parquets produced in this study are in line with the literature when considering the concrete properties used. The use of chromite aggregate, magnetite aggregate, and quartz-based surface hardener on the surface layer of the parquets increases the wear resistance of the parquets.

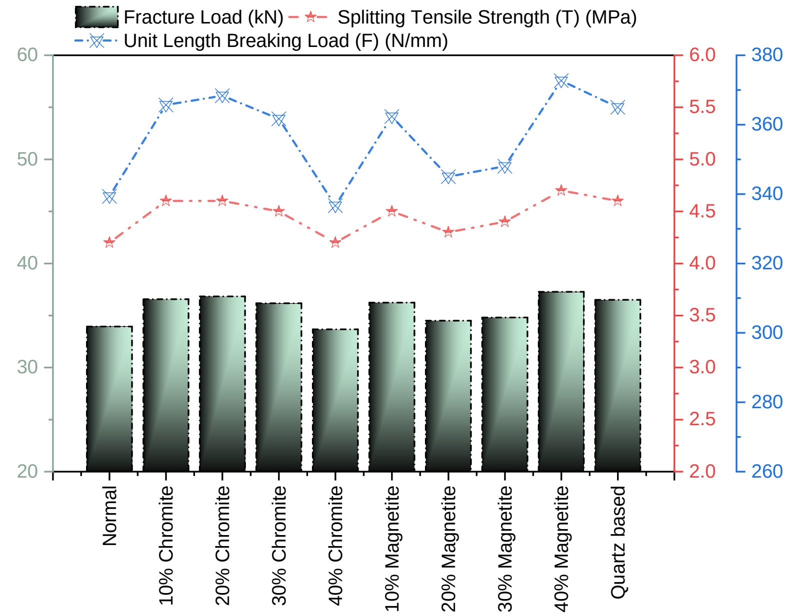

Figure 4. Fracture load, splitting tensile strength, and unit length breaking load values of normal, 10% chromite, 20% chromite, 30% chromite, 40% chromite, 10% magnetite, 20% magnetite, 30% magnetite, 40% magnetite, and quartz-based samples.

3.2. Compressive strength, splitting tensile strength and fracture load tests

Figure 4 shows the fracture load, breaking load per unit length, and splitting tensile strength determined in the strength measurements. The splitting tensile strengths in Figure 4 were calculated according to the equation (4) and the unit length fracture load (5). To the TS 2824 EN 1338 standard conditions, the splitting tensile strength (T) should not be less than 3.6 MPa, none of the single test results should be less than 2.9 MPa and none of the sample breaking loads should be less than 250 N/mm. All of the values in Figure 4 provide the requirements of the standard. In Figure 4, splitting tensile strengths measured in parquets are shown. The split tensile strengths seen in Figure 4 have values between 4.2 and 4.7 MPa. The flexural strength of the mineral aggregate added parquets in Figure 4 is higher than the normal parquets without additives. As the contribution rate of mineral aggregates added to the surface layer of the parquets increased, there was no significant linear increase in the split strength. In Figure 4, the highest splitting tensile strength was found in 40% magnetite parquets, followed by 10% chromite, 20% chromite, and quartz-based parquets, respectively. In most of the parquets used in this study, it was observed that the parquets with high surface abrasion resistance also had high tensile strength in splitting. Yıldız (2013), in his studies, increased the splitting tensile strength to 5.4 MPa with an increase of 59% by using ferrochrome in parquets with a splitting tensile strength of 3.4 MPa. In this study, an increase in split tensile strength between 10% and 13% was determined in the parquets with 20% chromite aggregate and 40% magnetite aggregate replacement.

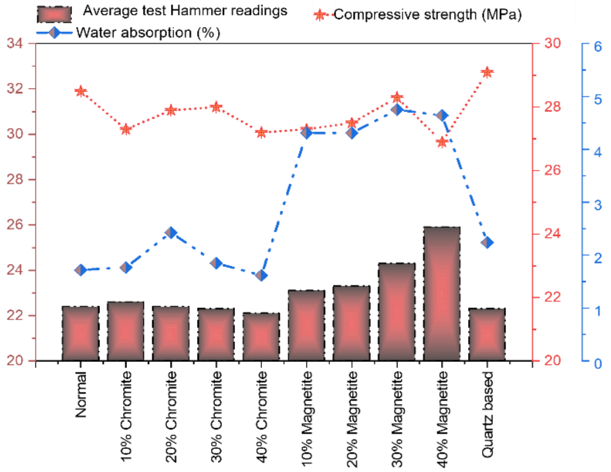

Figure 5. Average test hammer readings, compressive strength, and water absorption values of normal, 10% chromite, 20% chromite, 30% chromite, 40% chromite, 10% magnetite, 20% magnetite, 30% magnetite, 40% magnetite, and quartz-based samples.

In Figure 5, the measured compressive strengths of the parquets are shown. The compressive strength was achieved by applying force to the 100x100 mm surface of the block with dimensions of 100x100x80 mm. Substitution of chromite, magnetite aggregate, and quartz-based surface hardener to the upper layer of the parquets did not cause a significant change in the type of decrease or increase in compressive strength. The highest compressive strength was obtained from parquet with quartz-based surface hardener. The compressive strengths of the parquet with only quartz-based surface hardener substitution were higher than the normal specimens, while the strengths of the parquet with other aggregate substitutions were lower than the normal parquet. It is seen that the substitution rate does not cause very high differences between the strengths. However, the lowest strengths were obtained when chromite and magnetite substitution was 40%. The differences in the compressive strength of the parquets in Figure 5 are the differences that can be seen between the concretes belonging to the same concrete class resulting from the production and experimental methods during the pouring, molding, curing, and pressure test of the parquet concrete. It was obtained the highest compressive strength of 30 MPa in 28 days from concrete block paving blocks produced in different sizes by automatic machines (Lumingkewas et al. 2023). It is seen that the study is consistent with the literature.

3.3. USRV and Schmidt test hammer and water absorption

In Table 7, the unpolished slip resistance values (USRV) of the parquets, and numerical values determined by evaluating the sliding properties on the upper surface of the samples using pendulum friction (pendulum) test equipment are given in table. The friction values in Table 7 are the values measured and averaged on three parquets for each group. In Table 7, as the surface roughness of the parquet increases, the slip resistance value of the parquet increases. After placing the layered concrete on the parquets in Table 7 with the shaking table, the surfaces of the parquets were leveled manually with a trowel. In Table 6, it is seen that the unpolished slip resistance value (USRV) of quartz-based surface hardener-added parquets is higher than the unpolished slip resistance values of normal (unadded), chromite and magnetite-added parquets. This shows that the surface of the parquets with quartz-based surface hardener applied is rougher than the other parquets. Certainly, making the surface smoothing of the parquets not by hand but by suitable machines will affect the values in Table 7. Figure 5 shows the Schmidt test hammer values measured on the parquets. Values in Figure 5 are the average of thirty test hammer readings on three samples. In Figure 5, there was no significant change in the Schmidt test hammer values of the parquet as the chromite substitution ratio increased. Schmidt test hammer values increased as the magnetite substitution ratio in parquet increased. The highest Schmidt test hammer values were found in parquets with 40% magnetite replacement. The increase in the Schmidt test hammer values of the parquets would be interpreted as an increase in the surface resistance of the parquet as a result of the increase in the surface hardness of the parquet. However, no significant differences could be detected in the Schmidt test hammer values of the other parquets, except for the magnetic parquet.

While determining the relationship between the surface wear resistance of the parquets, and the differences created by the material changes in the surface layers of the parquets, it was seen that the vertical wear lengths were a better method in the evaluation of the surface wear resistance compared to the Schmidt test hammer values. Figure 5 shows the water absorption values measured on the parquets. The water absorption values are the average values calculated from three samples. In Figure 5, it is seen that the water absorption values of normal parquets without additives, chromite, and quartz-based parquets are close to each other. The water absorption rates of the magnetite parquets were significantly higher compared to the other parquets. The water absorption rate of 40% magnetite parquet is 2.76 times higher than normal type parquet. This was because the amount of water absorption of the magnetite aggregate was higher than that of other aggregates. It means that the void ratio of the magnetite parquets with high water absorption amount is high. This is one of the reasons why the floorings with the highest resistance among the floorings exposed to freeze-thaw are the floorings containing magnetite. The amount of air gap of the magnetite aggregate-substituted parquet with high water absorption value is high, which reduces the mass loss that will occur in the form of fragments on the surface of the parquet, which is exposed to freezing and thawing.

3.4. SEM analysis

Figure 6 displays SEM images of parquet composed of chromium, magnetite, and normal aggregates. The SEM images generally depict the presence of unreacted particles, cracks, and voids. The relationship between compressive strength and parameters such as compact structures, the presence, and density of hydration products such as CH and C-S-H, etc., is clearly evident in the SEM images. Upon SEM analysis, the highest compressive strengths are obtained from parquet specimens made with normal aggregate, magnetite aggregate, and chromite aggregate, respectively. The relationship between compressive strength and microstructures is clearly observed when analyzing SEM images. It is noted that the occurrence of microcracks and voids in the pavement decreases with an increase in compressive strength. Specifically, it is evident that the most microcracks and voids are found in the paving specimens made with chromite aggregate in Figure 6(a), and the least are found in those made with normal aggregate in Figure 6(c). Additionally, there is a clear correlation between compressive strength and structures such as C-S-H and CH. As compressive strength increases, C-S-H gels become more compact and continuous, whereas as compressive strength decreases, the density of C-S-H gels decreases, and their continuity deteriorates.

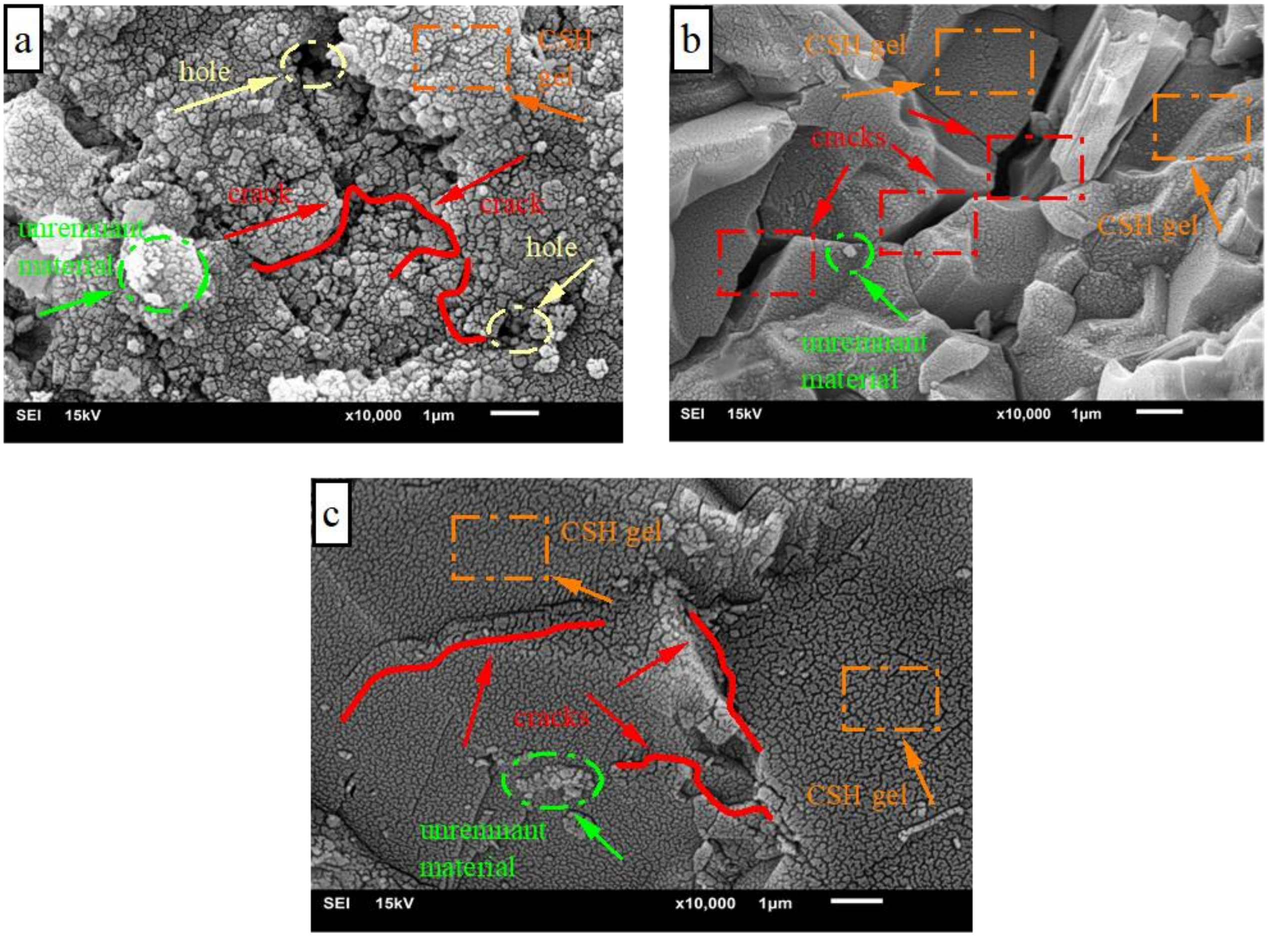

Figure 6. SEM images of samples with (a) chromite aggregate, (b) magnetite aggregate, and (c) normal aggregate.

4. Conclusions

In this study, the effects of diverse heavy aggregate types and chemical materials on the strength and wear resistance of concrete parquets were investigated. In the light of the findings, the following results were obtained

1. The use of chromite, magnetite and quartz-based fine aggregates in the surface coating of the parquets has increased the resistance of the parquets to abrasion.
2. Among the parquets produced in this study, it was observed that 40% magnetite and quartz-based parquets had the highest surface abrasion resistance.
3. The vertical abrasion depths of the parquets that were subjected to vertical abrasion test and that used 40% magnetite-containing aggregate in the upper layer and the parquets produced with the product sold as a quartz-based surface hardener in the market were measured at the same level.
4. The highest splitting tensile strength was observed in 40% magnetite parquets, then 10% and 20% chromite parquets and quartz-based parquets.
5. It has been determined that the surface abrasion resistance of the parquets with high splitting tensile strength is also high. The increase in splitting tensile strength has been interpreted as an increase in the abrasion resistance of the parquets.
6. The use of mineral additive substitution and quartz-based surface hardener in the surface layer did not cause significant changes in the compressive strength of the parquets. It is thought that the small-scale differences in the compressive strength of the parquets are caused by the concrete production and the application of the compressive strength test.

7. It has been observed that the unpolished slip resistance value (USRV) of quartz-based surface hardener added parquets is higher than the unpolished slip resistance values of normal (unadded) parquets and substituted parquets with chromite and magnetite additives.
8. It was observed that the Schmidt test hammer values increased as the substitution rate increased in fine aggregate replacements of magnetite-reinforced parquets. It has been observed that fine aggregate substitutes of magnetite-added parquets give higher results compared to the Schmidt test hammer values of normal (no additives), quartz-based, and chromite-added fine aggregate-substituted parquets.
9. The high void structure of the magnetite parquets with high water absorption showed that one of the reasons why the parquets with the lowest mass loss per unit area after the freeze-thaw test are the magnetite-containing parquets. Due to the hollow structure of magnetite parquets, it has been observed that magnetite substituted parquets may be the reason for the high Schmidt test hammer values. In addition, the fact that the highest splitting tensile strength was observed in 40% magnetite substituted parquets showed that the magnetite parquets may be due to the cavities.

Concrete paving has a great structural and architectural use in the world. Since it has a large sector, it is necessary to work on it so that it can be produced more efficiently. It is thought that the effects of the different aggregates and chemicals used will guide the professionals working in the sector.

Although parquet is not widely used in the construction sector as a structural load-bearing material, it is an important material that is used for vehicles, pedestrian traffic and architectural or decorative purposes. Therefore, it is considered important to expand the literature on its development, production and functional use. For this reason, it is thought that different researchers investigating the effect of heavy aggregates with geologically different properties on parquet will contribute to the literature.

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