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RESEARCH ARTICLE

Investigation of Compressive Strength of Plaster and Masonry Mortar Prepared with Waste Stone Dust, Nano Carbon Black and Cement

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HIGHLIGHTS

> This study aims to recycle a waste material that can contribute to the investigation of concrete containing carbon black.
> Making plaster mortar with stone flour has also been studied.
> Results strongly suggest that mixing carbon black and stone flour is not a good idea

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ABSTRACT

Mortar and concrete produced by replacing the cement or aggregate in the traditional concrete mixture or a certain proportion thereof with natural or artificial mineral admixtures are becoming increasingly common. With these admixtures, the properties of fresh and hardened mortar are aimed to be improved. Wall and plaster mortars are expected to be as durable and waterproof as bricks. Especially, the freezing-thawing resistance of exterior plaster materials and flooring materials should be high. In addition, soil surfaces are susceptible to wind and water erosion effects. It is known that such surfaces are covered with abrasion resistant plaster material in order to protect it against abrasion on soil surfaces. In this study, the usability of the mixture obtained by incorporating waste materials, such as stone dust and nano carbon black, with a certain amount of binder, such as cement, as ready plaster, masonry mortar or ground coating material are investigated. When soil surfaces under the effect of wind and water erosion are covered with the mortar obtained with this fine powdered ready-made material, a strength against erosion will be displayed. If the material meets the current standards in terms of both tension and durability, it can be put on the market as a ready-made plaster mixture in 20-40 kg bags in fine powder form. Currently, nano carbon black is available on the market in 20 kg paper bags. Stone dust is found in mining companies that process mud or rock in dry form.

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1. Introduction

This article describes the stages and results of an experimental study on the properties of waste stone dust (SD) released in natural stone cutting and processing enterprises. To eliminate the shortage of fine aggregate in the construction industry, valuable wastes such as stone dust, fly ash and limestone must be reused. The use of appropriate waste material will also reduce the burden on natural aggregate supply, and may also reduce the cost of concrete. Therefore, the use of the wastes of the quarry and stone processing industry in concrete or mortar production, as well as new products, will provide economic and environmental benefits.

The difficulty of obtaining materials such as sand, lime and cement separately in the construction in residential areas can be overcome by selling these materials in ready-made. Under normal conditions, fine sand, lime and cement as masonry and plaster material should be brought to the construction site separately and the necessary mixture should be made roughly by hand. At the same time, if surface coating is made for the stabilization of slopes, it is necessary to bring together materials such as cement and sand. In this case, each batch causes the mixture to differ from one another in terms of strength and durability. The mixture prepared with digitally controlled devices in a workshop can be delivered to the consumer in packages that are easy to carry and easy to transport.

One of the main objectives of this study is to meet the surface finishing material that people need in construction works in a single item in the shortest and most practical way. Our work was not made locally, but consisted of materials that are easy to supply throughout the country.

Çelik et al. [1] stated that the in their study entitled "Effects of crushed stone dust on some properties of concrete," it increases the dust content of concrete by increasing the compressive strength of concrete up to 10%. For higher than 10% dust content, the pressure gradually decreased.

Stone dust, which is defined as a very fine material in the standard of TS 706 EN 12620 [2] concrete aggregates, passes through a sieve with an opening of 63 μm (No. 230). Although stone dust has a very fine grain size, it does not behave like clay when mixed with water. It is considered harmful by some researchers [3]with the idea that it will increase the concrete mixing water and water/ cement ratio (W/C). However, in our opinion, Stone dust in accompany with carbon black, which we added into the mixture, turned this material into the main filling material, like aggregate in concrete.

Carbon black (CB) is a material that can pass through a 38 μm (No. 400) sieve. CB is not possible to react or interact with water. Because of a hydrophobic material, escapes from water. In this study, an attempt has been made to find the suitability of the stone dust industrial wastes as a possible substitute for conventional fine aggregate.

In practice, if the amount of material passing through 75 μm (No. 200) mesh is above the limits, the aggregate can be used in concrete production only after washing. The material passing through the mesh 75 μm (No.200) is a fine material. Therefore, it is assumed to contain clay and similar organic matter and it is subjected to a washing process. In this study, we regard stone dust as the main material of the mortar plaster, which is in contrast to existing trends. It is known that stone dust affects the strength of concrete.

In order to investigate the strength and some engineering properties of stone dust, mixtures were made with cement, as well as other binder materials such as plaster. Ready plaster mixture obtained was produced in powder form.

According to ASTM C 33-11 [4], stone dust is allowed to present at 7% in fine aggregate. In TS 706, fine aggregate is generally classified as washable materials such as clay, silt and stone dust passing through a 63 μm (No.230) mesh screen. Washable substances are allowed to be in the aggregate by at most 4% [5].

Crushing and screening plants are known as stone crushing plants and they are called the facilities that produce aggregates necessary for concrete production. In these facilities, in addition to the concrete aggregate obtained in various diameters by breaking the rocks, very fine material called stone dust accumulates at the bottom of the screen. This stone dust is not used in concrete production and is stored as waste. It can be used as a filling aggregate for different purposes. The stone dust used in this study is not the material obtained in this way.

Studies on crushed stone dust go back to the 1990s. Initially, studies were conducted on the effect of stone dust on concrete strength, and a positive opinion was reported in almost all studies. However, stone dust and carbon black were not used together in any of these studies. It is discussed for the first time in the present study. Özgan [5], conducted an experimental research on the effect of stone dust content in crushed stone aggregate on compressive strength of concrete. According to the results obtained from the research, it has been observed that stone dust positively affects the compressive strength, compared to concrete produced with no fines crushed aggregate. Ramyar et al. [6] studied that the effect of stone powder on concrete properties and found that when 10% of the fine aggregate contains stone powder in the mixture, the tensile strength of concrete increases.

Using mineral admixtures to reduce concrete permeability is much more effective than reducing water /cement ratio. Şengül et al. [7] conducted an experimental research on the design, mechanical properties and durability of concretes

containing natural and industrial mineral admixtures, and found that the use ratio of mineral admixtures significantly affect the performance of the concrete. They reported that while fly ash and ground blast furnace slag can be used in concrete at high ratios, silica fume and metacaolin are effective enough even if used at low ratios. It has also reported as a last word that various optimization techniques should be applied to determine appropriate mixing ratios. Germi [8]studied effects of recycled nano carbon black powder (NCBP) on some of physıcal and mechanıcal properties of concrete. In this master's thesis study of Germi [8], mechanical properties and durability of water-cured concrete samples composed of NCBP, at the dosage of 450 kg/m3 of cement with four different mixing ratios of NCBP replaced with the indicated percentages of cement, used for the production of concrete were investigated. According to the results of the experiment, all of the concrete groups are in the structural concrete class. Considering all groups of concrete samples, the best results in both the compressive strength and the pressurized water permeability tests have been observed the sample group-containing 4% of NCBP.

Waste stone dust was obtained from the stone processing factory. This material was mixed with different doses of carbon black and cement on volume basis in the laboratory in Erzurum Vocational College and a dry mortar mixture was obtained. The unit weight of cement is much more than the unit weight of carbon black. About 5.5-6 times. The specific surface of carbon black is many times more than cement and stone dust. Especially in this study, it is ensured that cement is as little as possible and carbon black is as much. Because CB is thinner than cement, it completely covers the surface of the cement in a mix. SD was not subjected to any washing processes in the laboratory. It only sieved through a 63 µm (No.230) screen.

In this study we planned to investigate the compressive strength, unit weight, water permeability of mortars obtained using the lowest W/C ratio. As a result of the experiments and observations, mixtures were prepared such that the ratio of stone dust and carbon black to total components is around 60-80-100%. The mixed water was added to the ready mix at the place where the application was made, in the amount recommended on the package.

2. Material and Method

2.1. Material

2.1.1. Obtaining andesite stone dust and properties

The andesite stone is extracted from the Kızıltaş village quarry, 15 km from Erzurum-Turkey. When cutting stones by spraying diamond saw blades and water, stone dust, like fine sawdust, comes out in the form of mud. The Andesite stone, known as the red stone (Kamber stone) in the region, is a type of porphyry formed in the new time. Porphyry is a textural term for an igneous rock consisting of large-grained crystals such as feldspar or quartz dispersed in a fine-gained silicate rich, generally aphanitic matrix or groundmass [9]. It has pink and grey color. It is resistant to abrasion and prevents slipping. When wet, there is no slipperiness on the surface. It is decorative. It is not affected by frost and temperature differences, does not require maintenance and lose its color feature. It preserves its properties for years. Various decorative features can be given using polished and unpolished. Motifs, pictures, texts and figures can be given according to the designers' wishes. It is an easily degradable stone. It is used in facade cladding of buildings, flooring, stair steps and docks, paving stones and borders, pool and fountain construction, columns, handrails and arches, swimming pool coatings, tombs and tombstones, monuments and sculptures, garden walls and mosques (Figure 1).



Figure 1 Example of usage areas after andesite stone processing

The same type of stone is not processed in natural stone processing and cutting workshops. Granite and basalt rocks can be cut in addition to andesite depending on the condition of the material from the order and the quarry. The waste stone dust formed in this case contains not only andesite but also other rock types. The microscope image given in Figure 2, shows colored natural silica minerals in grey andesite. Andesite are rocks formed due to volcanic movements in tertiary and quaternary periods. Andesite stone occurs underneath the black cotton soil and its dust is a waste product available in large quantity from basalt and andesite stone crushing units.

While the color of the material passing through the 75 µm (No.200) screen is grey, it is seen in various colors from red brown to crystalline transparent glass color when magnified 100 times under the microscope. Andesite rock has a very porous structure. Andesite is greyish-pink in color and have different weathering degrees. Due to the volcano-sedimentary structure, flow planes, cooling and tectonism cracks are observed [10].

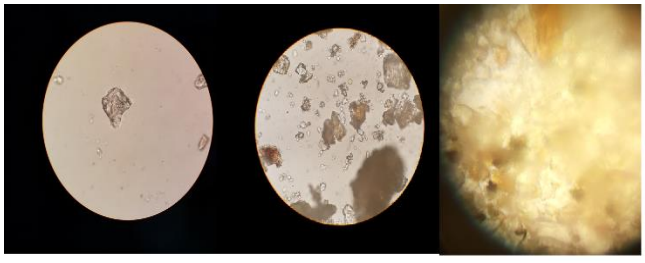


Figure 2 Microscope image of stone dust (X100) (at left, quartz minerals, at middle and right Other natural silicon oxide minerals.

Some differences can be observed between andesite stones produced in Erzurum, Kayseri, Manisa, Afyon and Ankara provinces. These differences include pores and occupancy ratios, etc. it depends on the situations. The mineralogical and chemical composition of stone dust depends on their parent rock. The engineering properties of andesite stone are

given in Table 1, and chemical compounds are given in Table 2.

Table 1 Physical properties of andesite stone

Property	Value
Specific weight	2.67
Natural unit weight *	3.37 g / cm3
Solidity ratio	16.0%
Compressive strength	70.21 MPa
Crush Strength**	16 MPa
Impact resistance	1.17 MPa
Abrasion resistance	18.1 cm2
Water absorption by weight	9.51%
Porosity	6.54%
Humidity	1.14%
These features may vary slightly depending on the natural location of the andesite stone	
The loose unit weight of the stone dust was determined to be 1.345 gr/cm3 in the measurements made on 100 cm3 samples. (*) Measured on the cube-shaped andesite stone. ** The resistance that a rock offers to vertical pressure placed upon it.	

Table 2 Chemical analysis of andesite stone

Matter	%
Si O2	66.41
Fe2 O3	4.34
Al2O3	12.80
CaO	5.80
MgO	3.85
K2O	4.00
Na2 O	2.10
Loss of ignition	0.70

2.1.2. Carbon black

The term carbon black refers to a group of industrial products that include thermal, furnace, channel and acetylene. These products consist mainly of colloidal size and elemental carbon, which are approximately spherical particles and agglomerate and form aggregates and are obtained as a result of partial combustion or decomposition of hydrocarbons. The use of this material by the Indians and the Chinese as a black ink colorant goes back centuries before that, until the third century BC [11]. Today, the majority of carbon black produced by oil furnace methods.

The carbon black used in the study was obtained from a company named Prokom, which recycled scrap tires in Erzincan. The company firstly produces steel wire and granule rubber parts by crushing scrap tires, and in the second stage, it obtains pyrolytic oil and carbon black by pyrolysis method. Işık and Akbulut [12] determined in their study that carbon black is a hydrophobic material and the grain size varies between 40 and 45 nanometers.

2.1.3. Cement

CEM VI B (P) 32.5 R-SR type cement of 2019 product of local cement factory was used in the experiments. The properties of cement are given in TS EN 197-1 [13]. This type of cement is resistant to sulfate effect and it is preferred in applications such as plaster, screed and mortar.

2.1.4. Perlite plaster gypsum

In this study, different binders were tried to investigate the mechanical properties of stone dust. One of these is Perlite plaster gypsum. Perlite plaster gypsum is local product and its technical features are given in TS EN 13279- 1 [14]. It is a healthy and natural ready-mixed gypsum plaster product that can be applied directly to rough surfaces such as concrete, gas concrete, brick and pumice block without any pretreatment. Other features are given in Table 3. In this study, it was investigated how the mixture prepared by adding weight to stone dust affects its process ability and strength.

Table 3 Properties of Perlite plaster Gypsum.

Feature	Value
Dry Unit Volume Weight	1.150 kg / m3
Flexural Strength	min. 1.0 MPa
Pressure Strength	min. 2.5 MPa
Thermal Conductivity	0.30W / mK (0.26 Kcal / mhºC)
Surface Hardness	40 Shore D

2.2. Method

2.2.1. Determining unit weight of carbon black

In preliminary investigations to identify material behavior, an aluminum sample container was used. Mixing ratios were adjusted volumetrically. It was possible to calculate the weight of the mixture since the materials of the mixture were known unit weight. The empty weight of the aluminum soil sample container used in the first trials (Wa) is 15.10 g and the empty volume (V) is 82.68 cm3.

In the loose unit weight determination for CB, an aluminum sample container was used and the measured as (container+CB) = 55.21 g. The weight of the container is 15.10 g. CB's weight = 55.21-15.10 = 40.11 g calculated. Since the volume of the container is 82.68 cm3 loose unit weight of CB calculated as 0.485 g/cm3. Carbon black (CB) are ultra-light and hydrophobic. When mixed with stone dust or Portland cement concrete, the CB tend to float and can result in poor mix distribution and segregation.

2.2.2. Sieve analysis of stone dust

Material washing sieve analysis experiment was performed according to ASTM D-421 [15]. In this context, 243.5g of dry sample was weighed as the initial dry weight and was sieved by washing with water from 75 μm (No.200) sieve. The residue on the sieve was collected and dried in the oven for 1 day. The dry sample that was removed from the oven the next day was sieved from the pre-determined sieve series. As a result of sieve analysis, it has been calculated that approximately 80% of the sample studied passes through 75 μm (No.200) sieve and it is determined that it is generally a fine grained sample.

2.2.3. Hydrometer experiment

Hydrometer analysis was performed to determine the grain size distribution of the studied sample passed from 75 μm (No. 200) sieve. This experiment was performed according to the ASTM D-421 [15] standard. In this context, while performing the washing sieve analysis, the part passing through the 75 μm (No. 200) sieve collected in a tray and dried in the oven. The next day, 50g of dry sample weighed and subjected to hydrometer test. As a result of the

hydrometer analysis, approximately 50% of the sample studied was silt and approximately 30% was clay (Figure 3).



Figure 3 Hydrometer test setup.

As a result of sieve and hydrometer analysis, it has been determined that the stone dust studied generally contains 20% sand, 50% silt and 30% clay particles as summarized in Table 4. The grain diameter distribution curve of the sample subjected to sieve and hydrometer analysis is presented in Figure 4.

Table 4 Grain contents of waste stone dust

Grain Feature	Rate
Sand	20%
Silt	50%
Clay	30%

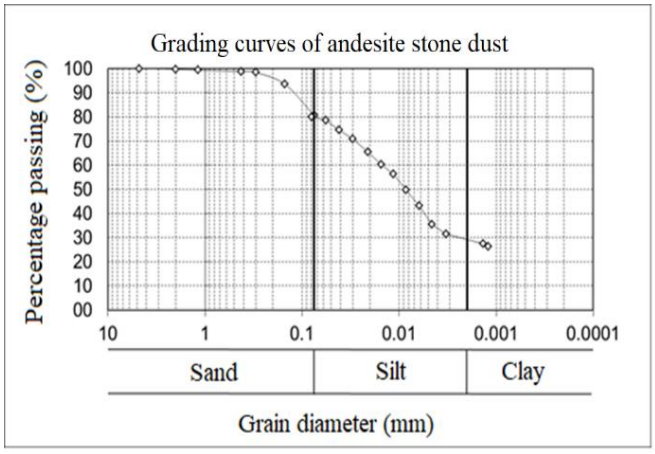


Figure 4 Gradation curve of stone dust

2.2.4. Consistency limits

In order to classify the stone dust from the geotechnical point of view, consistency limits (liquid limit and plastic limit) experiments were carried out. The liquid limit test of the material was carried out using the Casagrande test instrument according to the ASTM D-4318 [16] (Figure 5). However, the liquid limit value of the material could not be determined. Very little water added and mixed to the sample prepared for the liquid limit test at first. With this water content, the sample placed in the Casagrande experimental setup broke into the middle of the groove. When the water content was increased by about 2%, the groove closed in 4 blows (N). Due to the specified situation, the liquid limit value of the waste material could not be determined. On the other hand, it has been determined from the plastic limit experiment that the waste material shows non-plastic behavior.



Figure 5 Liquid limit test (test setup in Casagrande)

2.2.5. Compressive strength test

The incremental loading is continued until the specimen failed. The compressive strength is the ratio of load at the failure to the cross-sectional area of the specimens. The average compressive strength of the concrete specimen is calculated by the ratio of the maximum load applied to the cross-sectional area of the specimen. To investigate the compressive strength of stone dust concrete, two separate mixtures were prepared of containing cement and plaster gypsum. For this purpose, a standard 38 mm diameter, 76 mm high aluminum cylinder mold and 95x45x20 mm MDF prism mold were used as shown in Figure 7 and Figure 8. As described in Section 2.2.1, CB are extremely light with densities of only 0.485 g/cm3. In addition, CB, hydrophobic and water absorption is zero, which results in poor bonding to cement paste. The CB tends to floats and can result in poor mix distribution and segregation. To overcome the problems of dispersing CB in concrete, as shown in Figure 8, were prevented the mortar from swelling upwards by putting weight on the molds. To improve the concrete strength, the interfacial bonding amongst ingredient materials and pore sizes plays a vital role.

2.2.5.1. Cement and stone dust mixture

The compressive strength of the mortar consisting of 500 grams of SD, 500 gr of cement and 250 ml of water was investigated. Although the obtained mortar is 0.50 by weight, the workability of the mortar is very low. It constantly releases its water in vibration. This is not good for cement hydration. The increasing level of the stone dust replacement in concrete decreases workability as in parallel with the findings of other researchers [17, 18].

Since the cement unit weight is 3.10 g / cm3, 500 / 3.10 = 161 cm3 volume cement is used. W/C ratio is 250/161 = 1.55 by volumetric. W/C ratio is made by weight in concrete mixture calculations. Cylinder samples were kept at room temperature for 24 hours. In the meantime, a weight was placed on the samples as the water pressure in the mixture pushed the circular surface of the sample outwards since the stone dust did not absorb water. At the end of this period, the samples were removed from the molds and weighed and placed in the pool for water cure. After 28 days, pressure test was performed on the samples taken from the pool. As a result of the experiment, satisfactory results were found as summarized in Table 5.

Table 5 Cement + Stone Dust concrete resistance of roller samples

Sample number	Dry weights gr	Dry Unit weight g / cm3	28-day cylinder Compressive strength MPa
1	156.84	1.819	13
2	161.77	1.876	10.3
3	151.06	1.752	14.5
4	153.79	1.784	12.7
Average	155.87	1.808	126.25
A = 11.34 cm2		V = 86.18 cm3	



Figure 6 Fracture shape of cement and stone dust concrete in unconfined compressive strength test device

2.2.5.2. Satin plaster gypsum and stone dust mixture

The compressive strength of the mortar consisting of a 250 grams of SD, 250 grams of satin plaster gypsum and 125 ml of water was investigated. Although the water / binder ratio of the obtained mortar was as high as 0.5, its workability was very small. Difficulty was experienced in mixing the mortar. Adding more water caused a decrease in strength and this has been avoided.

Table 6 Satin plaster and stone dust concrete properties

Sample number	Dry weight of Cylinder samples (g)	Dry Unit Weight of Mortar gr / cm3	Compressive strength MPa
1	142.16	1.649	6.132
2	138.41	1.605	6.070
3	147.89	1.716	6.022
Average	142.82	1.657	6.075
A = 11.34 cm2		V = 86.18 cm3	



Figure 7 Cement + stone dust mortar prism samples



Figure 8 Cement + stone dust mortar cylinder samples and weights.

3. Result and Discussion

In the light of the results obtained from sieve analysis, hydrometer and consistency limits experiments carried out in Construction Technology Laboratory on the waste material, the following results have been reached.

The waste material used in the project is a material with less coarse grain and more fine grain. It consists of grains of 20% sand, 50% silt and 30% clay size.

Waste material could not be classified from a geotechnical point of view. However, as expected, this waste material produced by sawing the rocks of natural rocks such as andesite, basalt and granite is a thin-sized and non-plastic behavior material.

3.1. Stone Dust Mortar-Drying Behaviors

The obtained results are given following;

1-The dough exhibiting the sticky clay behavior obtained by mixing a volume of stone dust with water was plastered on a surface that does not absorb water with a thickness of 3 mm and 150 mm in diameter, and left to dry in a laboratory environment at 21°C. In the observation made 24 hours later, it was observed that the plaster was completely cracked. Only stone dust and water mortar formed cracks because of drying.

2-The mixture consisting of a volume of SD and two volumes of CB was obtained in a mortar in moist soil consistency and left to dry in a laboratory temperature at 21°C by making a plaster with a diameter of 3 mm and a diameter of 150 mm. In the observation made 24 hours later, the cracks were observed to form long and thick. Carbon black increased cracks. Carbon black had no other function than to change the color of mortar and test instruments to black.

3- One volume of SD, one volume of cement, a mixture of moist soil is obtained and a 3 mm thick 150 mm diameter plaster is made and left to dry in a laboratory temperature at 21°C. In the observation made 24 hours later, it was observed that the cracks formed shorter and less. Crack formation is relatively reduced in cement-reinforced stone dust mortar plasters.

4- 3 volumes CB, 3 volumes cement, 8 volumes SD are used. By adding 250 cc of water to this mixture, mortar in moist soil consistency and consistency that can be plastered was obtained. This mortar is filled into molds, one 3 mm thick

and 150 mm in diameter, three aluminum sample container and two in the cylindrical sample container. The presence of more CB in the mixture has been observed to both increase cracks and decrease strength.

The finer fraction from andesite stone units is mixed with soil mass to modify the shaping, drying and firing behavior of bricks. The stone dust recommended for use as an additive with brick, it should be fine (passing 1 mm sieve), free from coarse materials or mica flakes and should be of non-calcitic or dolomitic origin.

3.2. Compressive Strength Results

The unit weight of the mortar made of stone dust and satin plaster mixture is 1.657 g / cm3. If Table 6 is examined, the 7-day compressive strength of the mortar was found to be 6,075 MPa. This value is approximately 2,5 times the plaster's compressive strength as seen in Table 3. It is a much better material than plaster for plaster molding applications such as cornice, wall relief, and indoor sculpture.

The unit weights of concretes made of stone dust and cement mixture are 1.8 g/cm3. It is seen in Table 5 that the average compressive strength of concrete is 12.6 MPa. This compressive strength is an acceptable strong value. Cylinder samples were broken in the pressure machine after being kept in water for 28 days. It was observed that the crushing forms of the samples were brittle. As seen in Figure 6, satisfactory crushing patterns were observed in cylinder samples. In this type of crushing is sudden and brittle. It is observed in high strength concrete. It is possible to obtain durable concrete as long as stone dust and cement are mixed in a ratio of 1/1 and W / C ratio is less than 0.50. But this is not economical in the construction of concrete carrier elements. It does not exhibit the behavior we expect from a concrete. Instead, it can be used in reinforced with fiberglass soil coverings, column head, and concrete flowerbed.

4. Conclusion

In cement and without cement mortars made with stone dust and carbon black, it has been observed that the mortar does not change its mechanical properties. In addition, if this material is used, individual protective equipment such as gloves and dust mask should be used. It is an extremely thin and smeared material.

From the mortar consisting of satin plaster gypsum and Stone dust mixture, can mold production, products such as cornice, jamb and ceiling decoration can be obtained. These products are fixed by fixing them on the ceiling or wall, thus preventing earthquake rupture.

CB increased cracks. CB had no other function than to change the colour of mortar and test instruments to black.

Stone dust is a waste material. Producer companies are looking for ways to participate in this material in production. This study tried to contribute to the researchers in this regard. Sand stone scraps being a hindrance for the further excavation of the stone in the quarries can be used to meet the demand of fine aggregates in the construction industry.

In order to achieve clearer projection about the usability of stone dust at these kind of applications, tests are recommended to be continued for further studies.

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