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The Use Of Waste From Marble Workshops As An Alternative To Fine And Coarse Aggregates For The Production Of Concrete

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Abstract :

The wastes of the marble industry have a negative impact on the environment in which they are thrown as industrial wastes, and only a small amount of it is used in some works. These large quantities of waste may reduce the porosity of the soil and its permeability to absorb water, which causes diseases, especially related to the respiratory system of some of the residents close to the area, and also causes groundwater pollution. It also negatively affects the landscape of the area. Therefore, this study dealt with the use of waste from marble workshops as coarse aggregate as an alternative to the local aggregate found in Libya (plowing and blasting aggregate) in varying proportions in the manufacture of regular concrete. The waste from marble workshops was also used as fine aggregate at rates (10, 30, 50)% of the local fine aggregate. (sand) in the normal concrete mix. The suitability of using fine and coarse marble waste aggregates w[1]as evaluated through a number of tests represented in the mechanical and physical tests of the aggregates, in addition to the well-known concrete tests such as determining the operational properties and pressure. The obtained results encouraged the use of marble residues as coarse and fine aggregates in ordinary concrete. It was found that the mechanical properties of coarse and finer marble aggregates were within the limits of specifications. As for the compressive strength, it was noted that the concrete containing coarse marble aggregates by 50% with blasting aggregates gave values of compressive strength higher than the resistance obtained in the mixtures manufactured from local aggregates (plowing and blasting). As for the concrete containing the rubble left over from fine marble spraying with 30% of the local fine aggregate (sand), it gave higher compressive strength than the resistance given by the regular concrete, which contains local fine aggregate. Based on these results, it is recommended to use the rubble left over from the marble workshops as an alternative to the local rubble, according to the limits of this research .

Keywords: Waste Marble/Marble Powder /Aggregate/Concrete/Portland Cement/Strength/Hydration Products/FLY-ASH/Durability.

1. INTRODUCTION

The topic of solid waste management has been gaining increasing attention worldwide due to the numerous problems it causes. In certain cities, industrial, residential, and commercial areas are intermixed, leading to overlapping issues concerning industrial waste disposal and residential areas. This is primarily due to the lack of adequate waste management facilities

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in the industrial areas located within or close to city limits. In some developing countries like Libya, the problem is compounded by the limited scope of local agencies, which can only handle street cleaning and residential waste transportation, thereby exacerbating the accumulation of solid industrial waste in factory sites. The use of aggregates in public construction projects worldwide is estimated to be around 26.8 billion tons per year, with aggregates comprising 70-80% of the total volume of concrete mix components[1][2]. Libya's construction industry is rapidly growing, leading to an increased use of natural aggregates. In the mid-20th century, there was a growing interest in using economically inexpensive materials during the production and manufacture of concrete. This led to research being conducted on the use of non-traditional sources of aggregates, such as industrial waste, building materials residues, and manufacturing residues. Utilizing such materials as fine or coarse aggregates in cement mortar and concrete can help to solve the problem of aggregate scarcity at various construction sites while simultaneously reducing environmental issues associated with the accumulation of such materials around extractive mills. Throughout history, the versatile material of marble has found its way into various industries, including art, architecture, and design. This metamorphic rock is created through the recrystallization of calcite or dolomite, with a significant amount of calcium carbonate ($CaCO_3$) comprising its composition [3][4]. It is believed that the world currently possesses around 15 billion cubic meters of marble reserves[5]. Nonetheless, the extraction and processing of this resource often result in a considerable amount of waste, with estimates ranging from 30% to 75% [6][7]. In factories, marble waste typically comes in the form of flat stones, pallediens (Through the process of slicing plates into specific dimensions and the subsequent fracturing of said plates, minuscule remnants were left behind), and marble powder. Pallediens are often used for flooring, while flat stones are used for making kitchen sinks, gifts, and ornaments[8]. Marble powder is a residue that results from wet cutting and polishing, with a majority of it being less than 250µm in size[9]. During cutting, up to 50% of the waste produced may be in the form of powder, which is then purified of water and compressed or stacked in sedimentation pools[10]. And With the accumulation of thousands of tons of waste from the marble industry, the negative impact on the surrounding area is becoming increasingly evident. Although marble is a valuable material, the majority of this waste is still considered industrial waste and only a small amount is used in the tile industry. The disposal of this waste can lead to environmental issues, such as reducing soil porosity and permeability, causing respiratory problems for nearby residents, polluting groundwater, and harming the natural appearance of the area[9]. Furthermore, there are cost-related problems as well. The demand for building materials is increasing while the availability of raw materials is becoming scarce and energy prices are rising. Therefore, finding alternative materials that are environmentally friendly and sustainable is crucial. This research proposes using waste from the marble industry as an alternative material for local aggregates in concrete production, which can reduce costs and be more energy-efficient than blasting natural aggregates. As a result, exploring new sources for building materials should be a priority to ensure the preservation of natural resources and energy conservation. While there have been some efforts to use recycled materials in concrete production, including the use of fly ash and slag as partial replacements for cement, there is still a need for more sustainable alternatives to natural aggregates such as sand and gravel[11][12]. The global demand for concrete is expected to continue to increase, with a projected 23% increase in demand by 2050[13], making the development of more sustainable practices in the construction industry critical for reducing environmental impact. The use of waste from marble workshops as an alternative to fine and coarse aggregates in concrete production represents a promising opportunity to address this issue. However, there are still significant gaps in our understanding of the physical and mechanical properties of concrete produced using waste from marble workshops as a complete substitute for natural aggregates[14][15]. In particular, it is important to assess the durability and long-term performance of this concrete, as well as its potential for scaling up to industrial levels. part from environmental concerns, there are also cost-related issues.

As demand for building materials increases, the cost of raw materials and energy prices also rise. As a result, there is a global interest in finding alternative building materials that are sustainable and eco-friendly. This research proposes the use of marble waste as a substitute for local aggregates, which can reduce the cost of concrete. Crushing marble waste is a more cost-effective process compared to blasting natural aggregates, which takes longer and is more expensive. By exploring new sources for building materials, we can save energy and protect natural resources. The marble industry produces an excessive amount of waste that can have a negative impact on the surrounding environment. This waste is currently classified as industrial waste, and only a small portion of it is utilized in industries such as tile production. Disposing of this waste in landfills can lead to soil porosity reduction, water saturation, and groundwater pollution, which can cause respiratory illnesses in nearby residents and harm the natural beauty of the area[16][17]. However, there is limited research on the use of waste from marble workshops as an alternative to fine and coarse aggregates for the production of concrete. Therefore, the aim of this study is to investigate the potential use of waste from marble workshops as an alternative to fine and coarse aggregates for the production of concrete. The study will evaluate the physical and mechanical properties of the resulting concrete and compare them to those of conventional concrete made with natural aggregates. The goal of the study is to provide a better understanding of the potential of using waste from the marble industry as a sustainable and environmentally friendly alternative to conventional concrete materials[18].

2. MATERIAL USED

2.1. ORDINARY PORTLAND CEMENT

Ordinary Portland cement was used with physical properties conform to British specifications [19].

Table(1) Properties of used Portland cement .

The test	Results	British Standard Limits (BS.12:1996).
The time of initial doubt	174 minutes	not less than 45 minutes
The time of final doubt	4:28 hours	no more than 10 hours
The softness	3297	Not less than 2500
Dilation	0.6 mm	no more than 10 mm
Specific weight	3.15	-

Table (2) shows the properties of the used Portland cement, and Table (1) shows the chemical composition of the cement .

Table (2) The chemical composition of cement .

Chemical Composition	Percentage (%)
Silica SiO_2	21.3
Iron oxide Fe_2O_3	3.78
Alumina Al_2O_3	4.99
Calcium oxide CaO	62.87
Magnesium Oxide MgO	3.47
Sulfur trioxide SO_3	2.24

L.O.I	0.39
Tricalcium silicate C_3S	43.73
Dicalcium silicate C_2S	27.73
Tricalcium aluminate C3A	5.83
C4AF Quaternary Calcium Ferric Aluminate C_4AF	11.49
Free calcium oxide FCaO	1.21

2.2. FINE AGGREGATE

Fine aggregate that used in this search is a natural sand free from impurities. The results of the laboratory tests showed that its physical properties conform to British specifications [20]. Table (3) shows the results The chemical composition.

Table (3) Chemical composition of fine aggregate.

Chemical Composition	Percentage (%)
Silicon oxide (SiO_2)	20.14
Iron oxide (Fe_2O_3)	2.99
Aluminum oxide (Al_2O_3)	5.91

Table (4) shows the results of the physical properties, Table (5) shows the results of the sieve analysis, and Figure (1) shows the minimum and maximum levels of granular gradation according to British specifications (BS812:1992)[20].

Table (4) Physical properties of fine aggregate.

The test	Test results	Specification limits (BS:812)
Specific weight	2.64	2.7 - 2.5
Soft material %	%2.55	not more than 4%
Apparent density	1650 kg/m^3	1800 - 1400

Table (5) Sieve analysis of fine aggregate according to British specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS:812:1992).
2.36	0	0	0	100	80 - 100
1.18	0	0	0	100	70 - 100
0.6	3.1	3.1	0.62	99.38	55 - 100
0.3	268.7	271.8	54.36	45.64	5 - 70
0.15	215.6	487.4	97.48	2.52	0 - 5
0.075	9.3	496.7	99.34	0.66	-
Pan	3.3	500	100	0	-

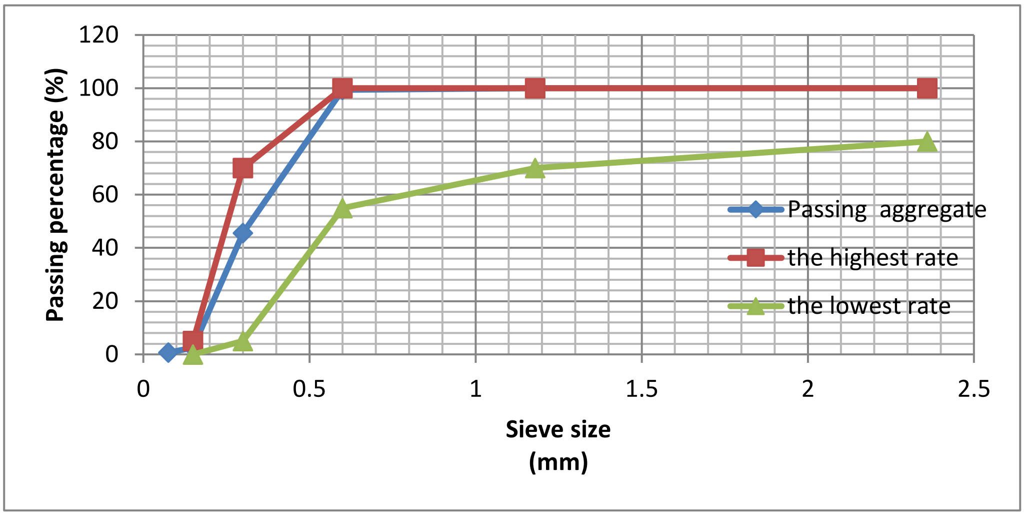


Figure (1) Gradual gradation of fine aggregate.

2.3. BLASTING COARSE AGGREGATE

The blasting rubble is an angular shaped rubble with a maximum nominal size of 19 mm. Table (6) shows the results of the sieve analysis of the aggregates according to the approved British specifications (BS882:2002) [20].

Table (6) Sieve analysis of blasting aggregate according to British specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS.882:2002)
37.5	0	0	0	100	100
19	698	698	13.96	86.04	100-85
14	3375	4073	81.46	18.54	70-0
10	764	4837	96.74	3.26	25-0
4.75	142	4079	99.58	0.42	5-0
Pan	21	5000	100	0	-

Figure (2) shows the minimum and maximum limits of granular gradation according to British specifications

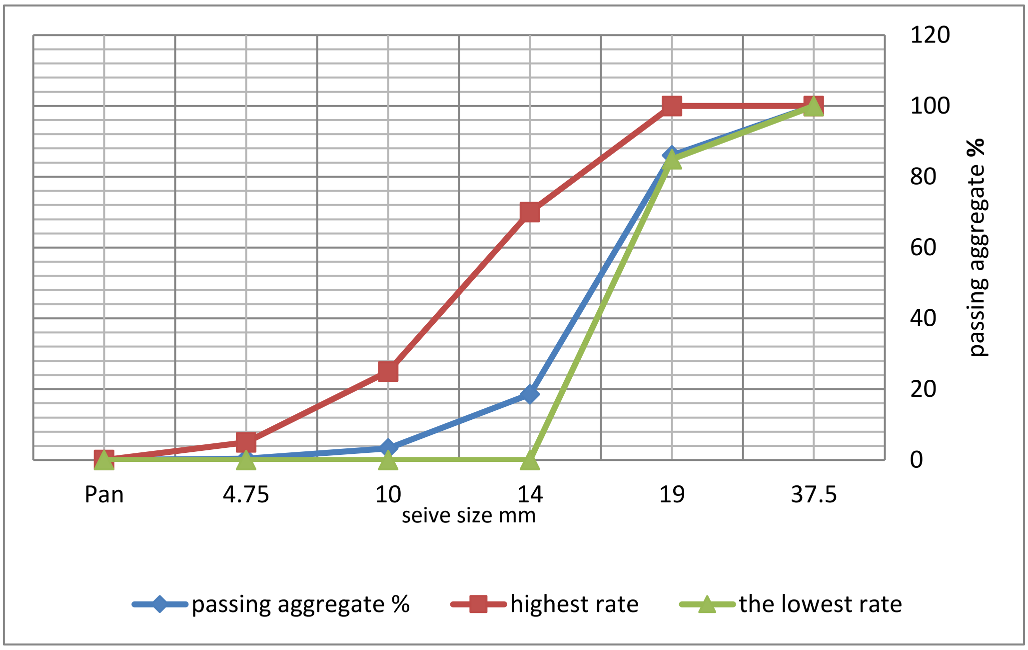


Figure (2) Gradual gradation of blasting aggregate.

2.4. PLOWED COARSE AGGREGATE

This type of aggregate is a crushed gravel resulting from the plowing operations of non-hard rocks with a maximum nominal size of 19 mm, and Table (7) shows the results of the sieve analysis of the aggregate according to the approved British specifications (BS882:2002) [20]. Figure (3) shows the minimum and maximum levels of granular gradation according to British specifications.

Table (7) Sieve analysis of plowed aggregate according to British specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS.882:2002)
37.5	0	0	0	100	100
19	210	210	4.2	95.8	100-85
14	3461	3671	73.42	26.58	70-0
10	1210	4881	97.62	2.38	25-0
4.75	113	4994	99.88	0.12	5-0
Pan	6	5000	100	0	-

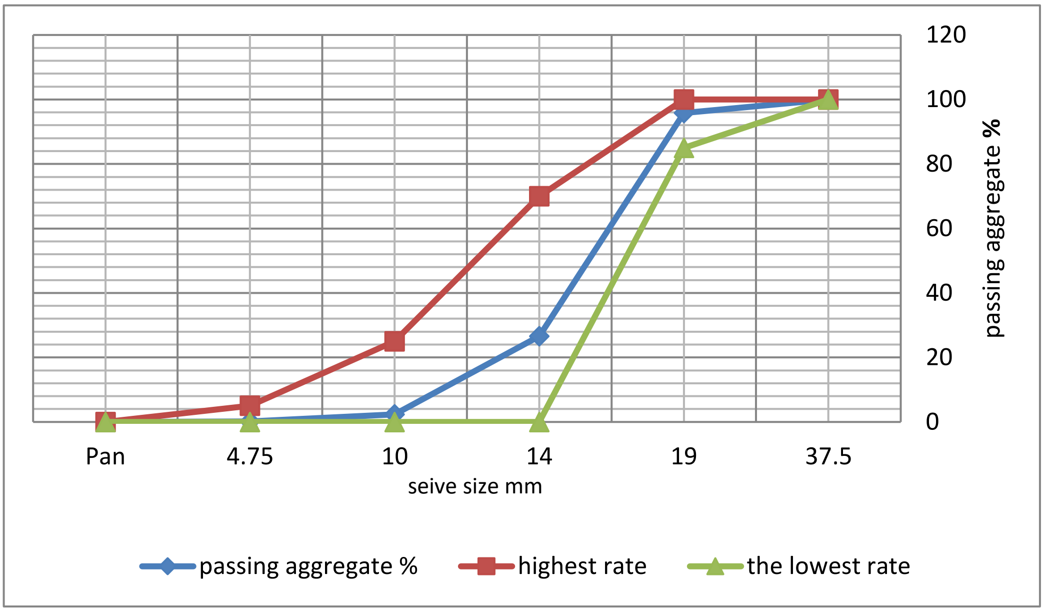


Figure (3) Gradual gradation of plowed aggregate.

2.5. WASTE AGGREGATE FROM MARBLE

2.5.1. COARSE MARBLE AGGREGATE

Coarse marble aggregate was manufactured from the remnants of marble factories, The type used is Teresita-marble and the original homeland of this marble is Egypt. where it was crushed and sieved on standard sieves, and the sediment was collected on each sieve, and then it was mixed according to the granular gradation of the limits of British specifications (BS.882:2002)[20].

Table (8) Sieve analysis of coarse marble aggregate according to British specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS.882:2002)
37.5	0	0	0	100	100
19	583	583	11.66	88.34	100-85
14	2816	3399	67.98	32.02	70-0
10	1054	4453	89.06	10.94	25-0
4.75	512	4965	99.3	0.7	5-0
Pan	35	5000	100	0	-

Table (8) shows the results of the sieve analysis, and Figure (4) shows the lower and upper limits of the granular gradation according to British specifications .

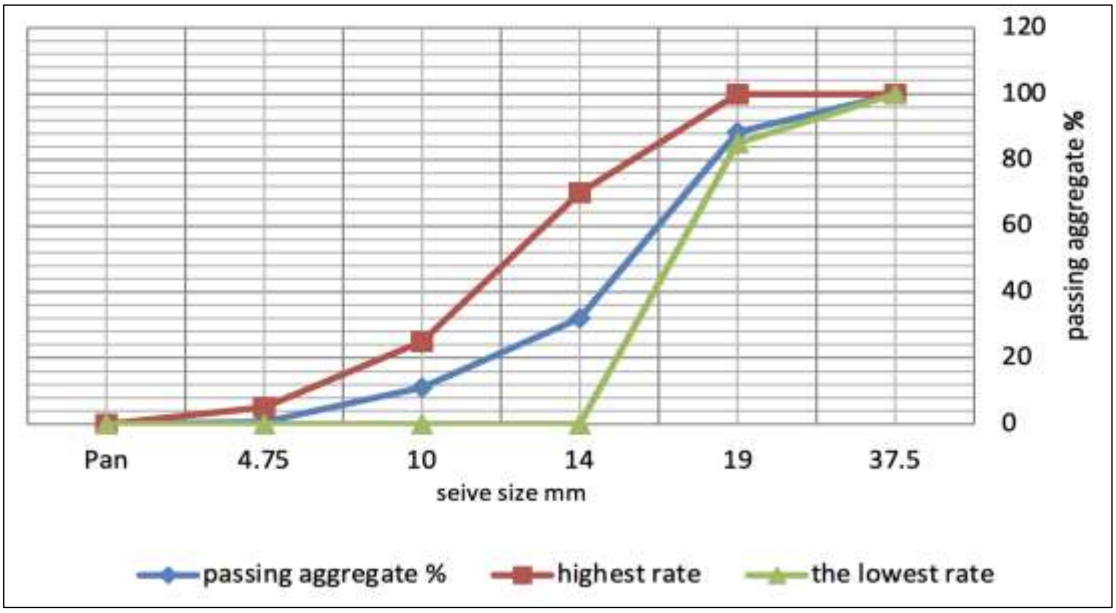


Figure (4) Gradual gradation of coarse marble aggregate.

2.5.2. FINE MARBLE AGGREGATE

Fine marble aggregate was manufactured by crushing the wastes of marble factories and sieving them on standard sieves and collecting the sequestrate on each sieve, and then it was mixed in proportions according to the limits of British specifications (BS812:1992)[20]. Table (9) shows the results of the sieve analysis and Figure (5) shows the lower and upper limits for granular gradation .

Table (9) Sieve analysis of fine marble aggregate according to British specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS:812:1992) .
2.36	0	0	0	100	80 - 100
1.18	0	0	0	100	70 - 100
0.6	83	83	16.6	83.4	55 - 100
0.3	176.3	259.3	51.86	48.14	5 - 70
0.15	228.9	488.2	97.64	2.36	0 - 5
0.075	8.4	496.6	99.32	0.68	-
Pan	3.4	500	100	0	-

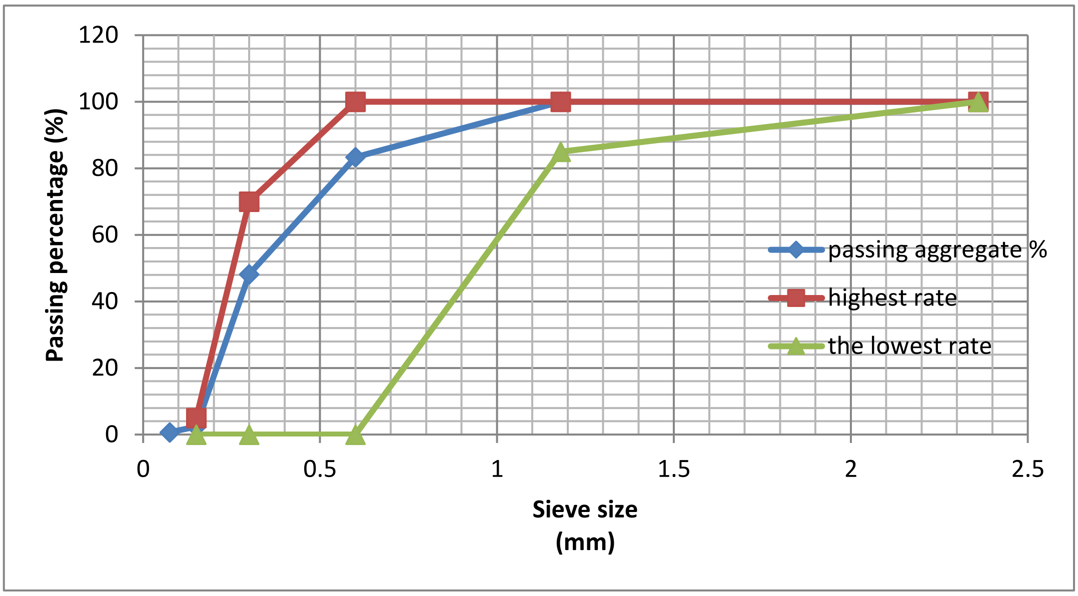


Figure (5) Gradual gradation of fine marble aggregate.

3.6. MIXING WATER

The water used in the mixing available in the concrete plant is free of organic matter and according to the limits of the Libyan specifications (QS 294) [21], which shows that the limits of chlorides allowed for mixing and curing concrete are less than 500 parts per million, and for sulfates, carbonates and bicarbonates, they are less than 1000 ppm.

4. CONCRETE MIX DESIGNE

The experimental study involved the use of different concrete mixtures, and their composition and quantities were recorded in Table (10). These mixtures were produced in varying percentages of coarse aggregate (33.33%, 50%, and 100%). In addition, fine marble aggregates were introduced to the mix in different ratios, which were 10%, 30%, and 50% of the weight of fine aggregate to concrete. The study aimed to investigate the effect of varying the percentage of coarse aggregate and the use of fine marble aggregates on the properties of concrete. The quantities of materials used to produce one cubic meter of concrete mixture were carefully measured and recorded in Table (10). The varying percentages of coarse aggregate in the mixture were intended to study their impact on the properties of concrete. The use of fine marble aggregates in different ratios was another parameter studied in the experiment. Table (11) shows the ratios of fine marble aggregates used in the mixtures. It should also be noted that 32 concrete cubes were made, divided into 9 basic sections, in order to conduct all the necessary tests .

TABLE (10) The proportions of the components of each mixture .

MIXURES	CEMENT Kg/m^3	WATER Lit/m^3	COARSE MARBLE AGGREGATE Kg/m^3	FINE MARBLE AGGREGATE Kg/m^3	BLASTING COARSE AGGREGATE Kg/m^3	PLOWED COARSE AGGREGATE Kg/m^3	FINE AGGREGATE Kg/m^3
M0	450	198	0	0	898	0	898
M1	450	198	449	0	449	0	898
M2	450	198	898	0	0	0	898
M3	450	198	0	0	0	898	898
M4	450	198	449	0	0	449	898
M5	450	198	299.33	0	299.33	299.33	898
M6	450	198	0	89.8	898	0	808.2
M7	450	198	0	269.5	898	0	628.6

M8	450	198	0	449	898	0	449

TABLE (11) The percentage of replacing marble from aggregate .

	M0	M1	M2	M3	M4	M5	M6	M7	M8
FINE MARBLE AGGREGATE	0%	0%	0%	0%	0%	0%	10%	30%	50%
FINE AGGREGATE	100%	100%	100%	100%	100%	100%	90%	70%	50%
COARSE MARBLE AGGREGATE	0	50%	100%	0%	50%	33.33%	0%	0%	0%
BLASTING COARSE AGGREGATE	100%	50%	0%	0%	0%	33.33%	100%	100%	100%
PLOWED COARSE AGGREGATE	0%	0%	0%	100%	50%	33.33%	0%	0%	0%

5. TESTS AND SPECIFICATION

5.1. AGGREGATE TESTS

5.1.1. specific weight and adsorption ratio of coarse aggregate

This test aims to determine the specific weight of the aggregate that is used in the design of concrete mixtures. The test is performed according to British specifications [22] .The specific weight and absorption ratio are calculated through equations next:

$$G_{st} = \frac{w3}{w1-w2} \qquad (1)$$

$$A\ (\%) = \frac{w2-w1}{w1} \times 100 \qquad (2)$$

$$G_s = \frac{w3}{w3-w2} \qquad (3)$$

Where:
W_1 : Sample weight saturated with surface dry .
W_2 : Weigh the sample immersed in water.
W_3 : Sample dry weight.
G_{st} : : Total specific weight.
G_s : : Apparent specific gravity of aggregates
A (%) : Absorption rate.

5.1.2. Crushing test for coarse aggregates

This test aims to determine the resistance of coarse aggregate to crushing, which is important in concrete subject to wear, wear and friction. The test is carried out according to British specifications [23] .Calculation is calculated The crushing coefficient is from the following equations

$$C = M_1 - M_0 \dots (4)$$

$$\dots \quad (5) A_{CV}(\%) = \frac{C - M2}{C} \times 100$$

Where :
M_0 : pan weight only .
M_1 :pan and sample weight .
C : sample weight .
A_{CV} : crushing coefficient.

5.1.3. Wild coefficient (Los Angeles) test for coarse aggregates

This test was conducted within the American specifications [24]. This test aims to measure the wear resistance of medium and large-grained aggregates when subjected to impact. And the wear coefficient is calculated from the following equation:

$$\dots\dots (6) AB(\%) = \frac{m_1 - m_2}{m_1} \times 100$$

Where :

m_1: Weigh the sample before testing.

m_2 : The weight of the impoundment on the sieve is (2.36 mm).

AB (%) :wild (Los Angeles) coefficient .

5.1.4. Impact test of coarse aggregate

This test aims to determine the impact coefficient of the aggregate. The test is conducted according to British specifications [23] .The impact coefficient is calculated from the following equation:

$$\dots\dots (7) K(\%) = \frac{m_1 - m_2}{m_1} \times 100$$

Where :

m_1: Weigh the sample before testing.

m_2 : The weight of the impoundment on the sieve is (2.36 mm).

K(%) : impact coefficient .

5.2. CONCRETE TESTS

5.2.1. Slump test for fresh concrete

This test aims to determine the strength of the concrete by knowing the amount of slump. The test is carried out according to British specifications. [25]

5.2.2. Compressive strength test of hardened concrete

Cubes measuring 150 x 150 x 150 mm were used. The test was carried out according to the British specifications[26]. and according to the study plan, 3 samples were tested after 7 days and 3 other samples after 28 days, in order to know the pressure hardened concrete resistance.

5.2.3. Indirect tensile test (Brazilian method)

This test was carried out in accordance with British Standards [27]. A cylinder with dimensions of 150×300 mm was used. The cylinder was placed in the testing machine, where the loading was carried out gradually and at a regular rate until reaching the final value of the load in a period of approximately one minute. The indirect tensile strength was calculated from the following equation**:**

$$f_t = \frac{2p}{\pi l d} \quad \dots \dots (8)$$

Where :

p : precipitation that leads to sample collapse .

l : Cylinder net length .

d : cylinder diameter .

f_t : Indirect tensile value .

5.2.4. Ultrasound test

The test aims to detect cracks, gaps, and in homogeneities in the density of concrete. The idea of this test depends on the fact that the pulses (ultrasonic waves) do not flow in a vacuum, so the wave takes a longer path if it encounters a crack or a gap, and accordingly the speed varies and the transmission time of the pulses increases. This test uses the same samples used to find the compressive strength. To measure the speed of ultrasound, the V-Metric Mark III was used. The direct method of measurement was used, that is, placing the transmitter and the receiver on two opposite sides, according to the British specifications[28]. After measuring the ultrasonic velocity, the mold is left for the purpose of performing a pressure test. The number is an expression of the time T for the flow of the pulses through the tested part, and the speed of the pulses, V, is as follows :

$$(9) V = \frac{L}{T} \left(\frac{Km}{sec}\right) \quad \dots \dots$$

Where :
L : Measured track length.
T : wave travel time.
V : The speed of the pulses .

6. RESULTS AND DISCUSSIONS

6.1. AGGREGATES TESTS RESULTS

6.1.1 Crush coefficient tests results for coarse aggregates

The calculation and results of this test are shown in Table (12), and Figure (6) shows the crushing coefficient for all types of aggregates used .

Table(12) Laboratory crushing test results for used aggregates.

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Crushing coefficient %	28.8	19.77	28.3	Less than 30%

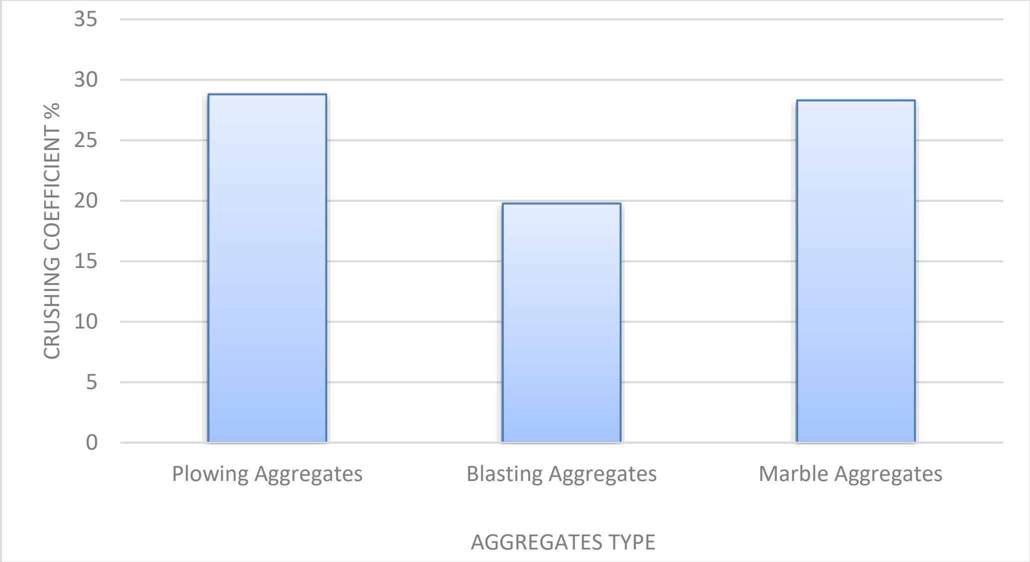


Figure (6) Crushing coefficient of used aggregate .

Through the results of the crushing coefficient of aggregates, it was found that the crushing coefficient of marble aggregates is less than the crushing coefficient of plowing aggregate by 0.5% and higher than the crushing coefficient of blasting aggregates by 8.53%.

6.1.2. Wear coefficient (LOS ANGELES) for coarse aggregates

The calculation and results of this test are shown in Table (13), and Figure (7) shows the wear coefficient for all types of aggregates used.

Table (13) Results of wear coefficient test for used aggregates

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Wear coefficient %	27.54	17.64	28.9	Less than 30%

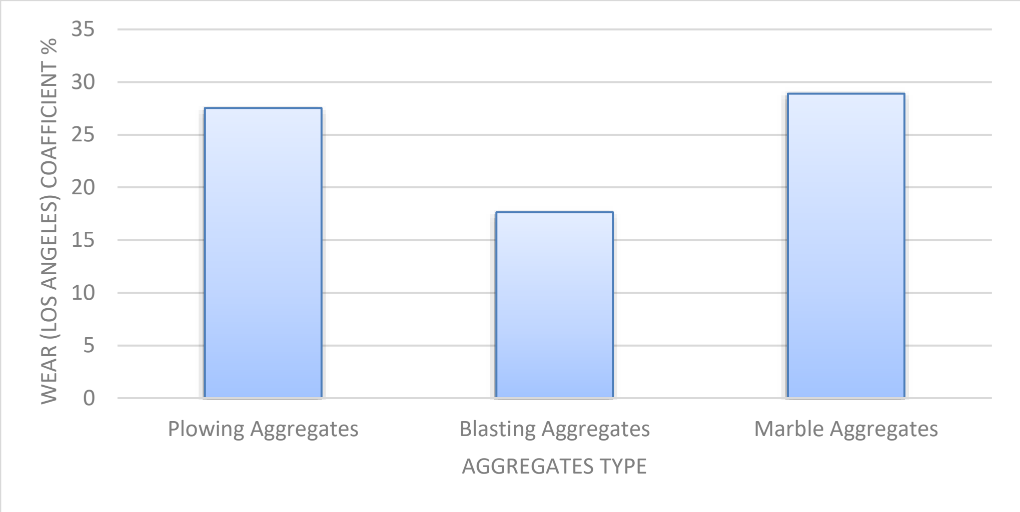


Figure (7) Wear (Los Angeles) coefficient of used aggregates .

By measuring the wear coefficient for all types of aggregates, it was found that the marble aggregates have a wear coefficient higher than the plowing aggregates by 1.36% and also higher than the blasting aggregates by 11.26%.

6.1.3. Impact test results for coarse aggregates

The calculation and results of this test are shown in Table (14), and Figure (8) shows the impact coefficient for all types of aggregates used .

Table (14) Impact lab test results for used aggregates .

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Impact coefficient %	11.55	12.6	15.38	Less than 30%

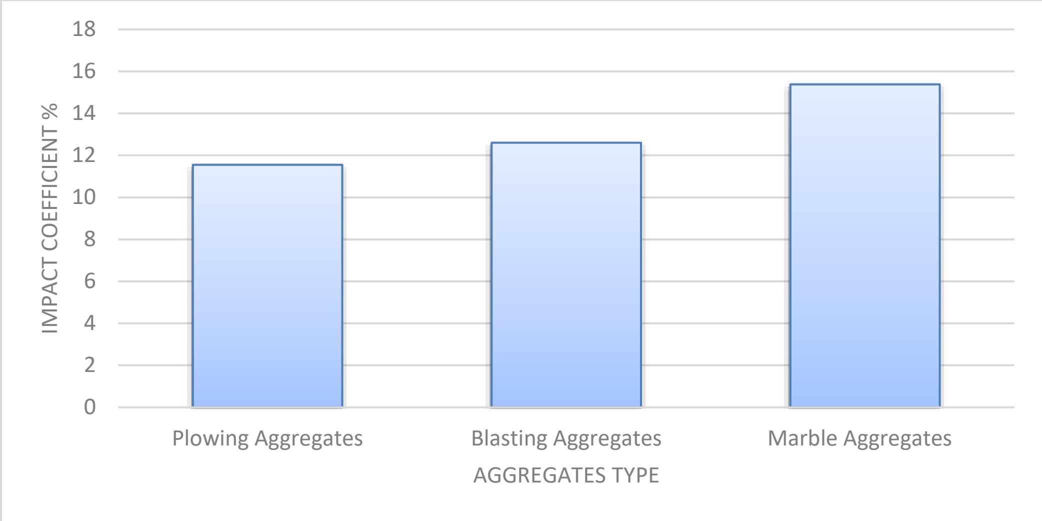


Figure (8) Impact modulus of used aggregate .

Through the results of the impact coefficient test of the aggregates, it was found that the impact coefficient of marble aggregates is higher than the impact coefficient of plowing aggregates by 3.83% and higher than the impact coefficient of blasting aggregates by 2.78%

6.1.4. Results of the specific weight and absorption ratio of coarse aggregates

The calculation and results of this test are shown in Table (15) and Figure (9).

Table (15) Specific weight test results for used aggregates

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Specific weight	2.52	2.63	2.51	2.5-2.75%
Absorption rate	2.8	2.63	0.4	Less than 3%

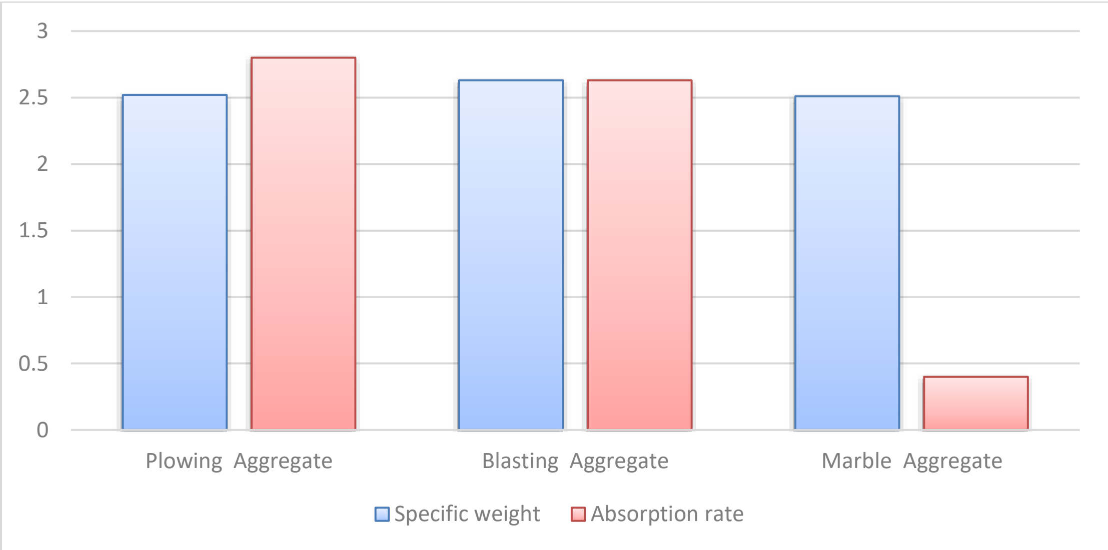


Figure (9) Specific weight and absorption percentage of the used aggregate.

In the results, we note that marble aggregates, blasting aggregates, and plowing aggregates fall within the standard limits of the specific weight of aggregates (2.5-2.75), but we note that the specific weight of marble aggregates is 0.12% less compared to blasting aggregates and 0.01% less than plowing aggregates. We note that the absorption rate of marble is 2.4% lower than that of plowing aggregate and 2.23% that of blasting aggregate.

6.2. RESULTS OF SOFT CONCRETE

6.2.1. Slump test results

Figure (10)and table (16) shows the slump of soft concrete for all admixtures.

Table (16) shows the slump of soft concrete for all admixtures.

Sample	M0	M1	M2	M3	M4	M5	M6	M7	M8
Slump amount (mm)	36	42	45	34.5	24	35	41.5	39	43

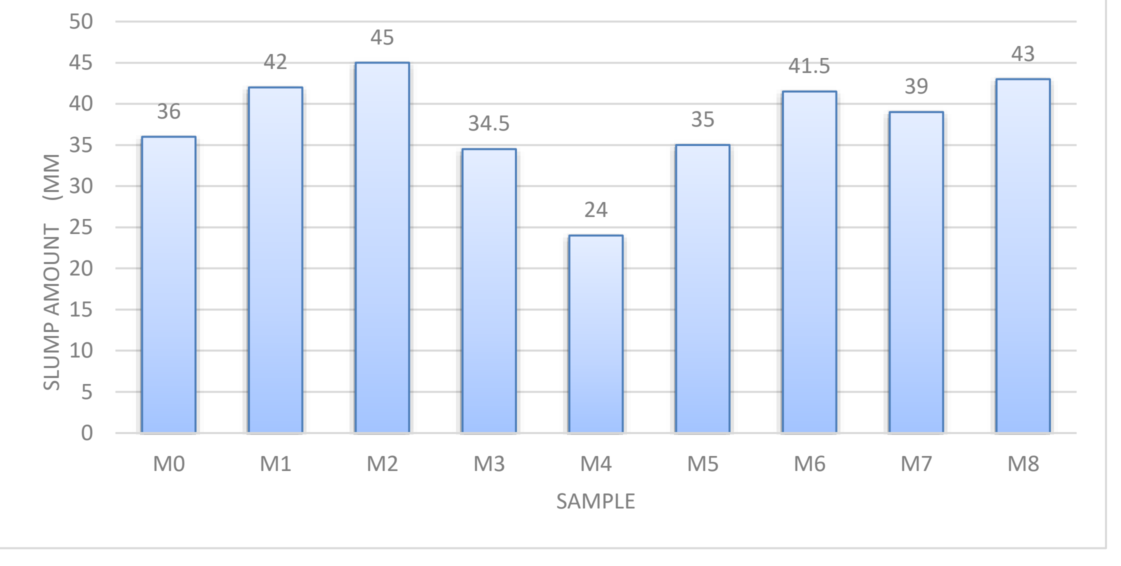


Figure (10) shows the slump of soft concrete for all admixtures.

Where it is noted that the drop value ranges between 24 and 45 mm As M0, which contains 100% blasting aggregate and 100% fine aggregate (sand), and compared with M1, M2, and M5, which contain coarse marble aggregate, it can be noted that M1 increased by 16.66%, M2 increased by 25%, and M5 decreased by 2.77% when compared with the reference mixture M0. It is known also that M3, which contains 100% plowed aggregate and 100% fine aggregate (sand), and when compared with M5, M4 and M2, it can be noted that M2 increased by 30.43%, M4 decreased by 30.43%, and M5 increased by 1.45% compared to M3 reference mix. As for the mixtures M8, M7, and M6, which contain 100% blasting aggregates and varying proportions of fine marble aggregates and fine aggregates (sand), it can be seen that M6 increased by 15.27%, M7 increased by 8.33%, and M8 increased by 19.44%.

6.3. RESULTS OF HARDENED CONCRETE TEST

6.3.1. Effect of coarse marble aggregate ratio on compressive strength of concrete

Figure (11) shows the effect of the ratio of coarse marble aggregates with blasting aggregates on the compressive strength of the concrete. Through the figure, we notice that the compressive strength increased by 5.78%, 10.2%, and 4.08%, after 7 days for samples that contain aggregates. Marble with a substitution ratio of 33.33%, 50%, and 100%, respectively, when compared to the reference samples. At 28 days, the resistance increased by 7.6%, 1.84%, and 0.69% for the samples that contained a replacement percentage of 33.33%, 50%, and 100%, respectively, compared to the reference samples. Through these results, we note the possibility of using marble aggregates with high substitution rates without any decrease in the resistance of the excess moisture content, and thus it works to reduce the water percentage of the cement, which results in an increase in the resistance. pressure, especially with the increase in the age of the samples, and this may be due to the improvement in the absorption resistance of the marble .

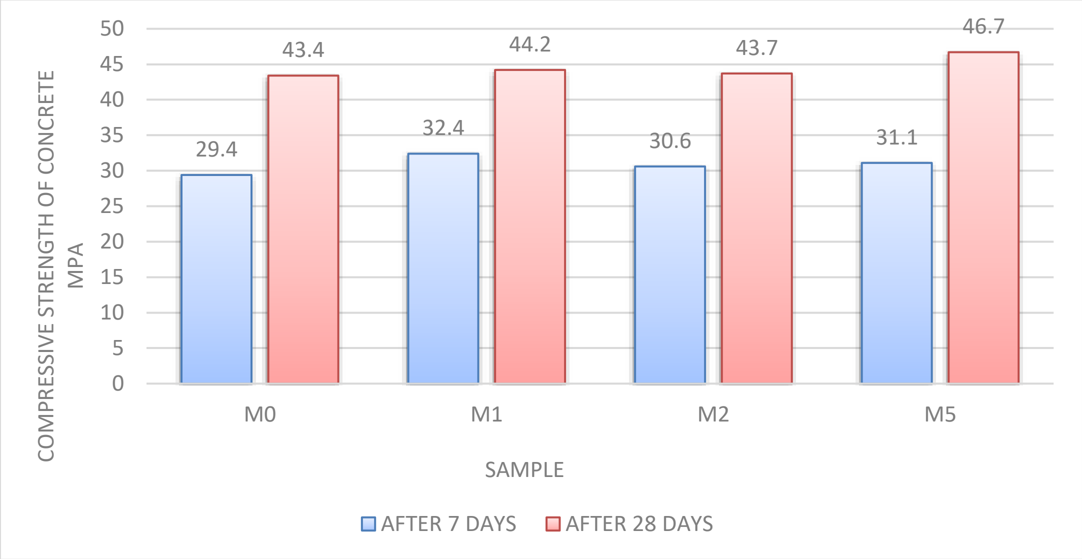


Figure (11) Concrete compressive strength when adding marble as coarse aggregate with blasting aggregate .

Figure (12) shows the effect of the ratio of coarse marble aggregates with plowing aggregates on the compressive strength of the concrete. Through the figure, we notice that the compressive strength decreased by 4.6%, 3.98%, and 6.13% after 7 days for samples that contain a percentage of marble aggregates by Substitution of 33.33%, 50%, and 100%, respectively, when compared to the reference samples. At 28 days, the resistance increased by 8.35%, 5.57%, and 1.39% for the samples that contained a replacement percentage of 33.33%, 50%, and 100%, respectively, compared to the reference samples. Through these results, we note the possibility of using marble aggregates with the used substitution ratios.

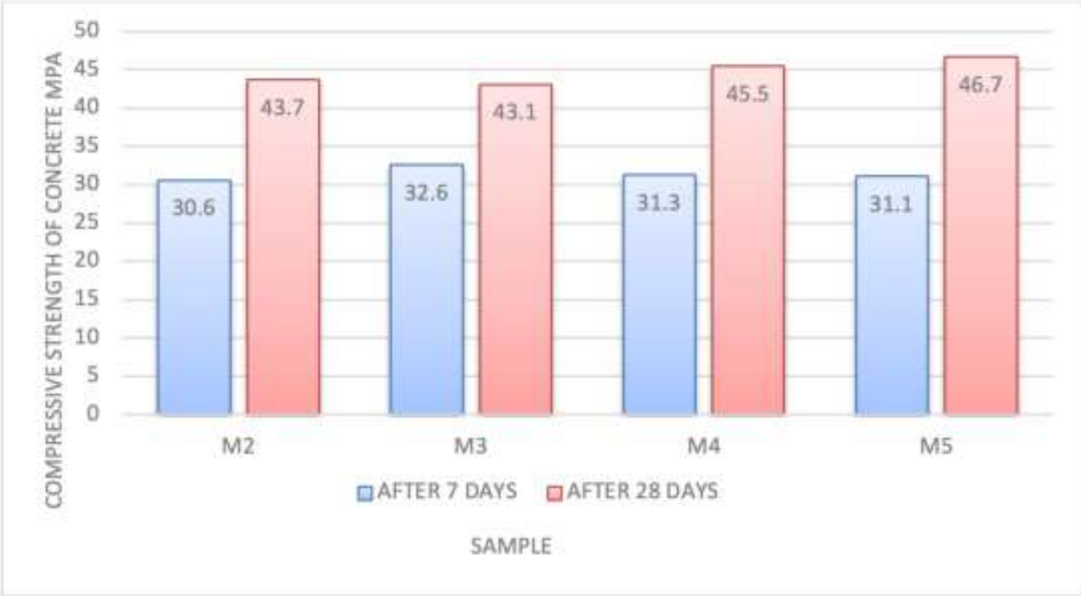


Figure (12) Compressive strength of concrete when marble is added as coarse aggregate with Plowed aggregate .

6.3.2. Effect of coarse marble aggregate ratio on compressive strength of concrete

Figure (13) shows the effect of the percentage of fine marble aggregates on the pressure resistance, and through the figure we notice that the pressure resistance after 7 days decreased by adding fine marble aggregates, as it decreased by 0.68% of the resistance of the standard mixture for 10% marble and increased by 26.19% for 30% marble, while The compressive strength of 50% marble decreased 2.72% to that of the standard mixture, and at 28 days it decreased by 2.53% of the strength of the standard mixture of 10% marble, while it increased by 20,96% for 30% marble and increased by 12.21% for 50% marble. We also note that the pressure resistance of the mixtures containing fine marble aggregates increases significantly with time, as observed at the age of 28 days. This indicates the delay in obtaining the early pressure resistance of the mixtures containing fine marble, given that the soft marble contains fine soft particles that fill the voids between the cement particles. Roughness and acting as pozzolanic materials slow down the hydration process, and this was confirmed by previous studies.

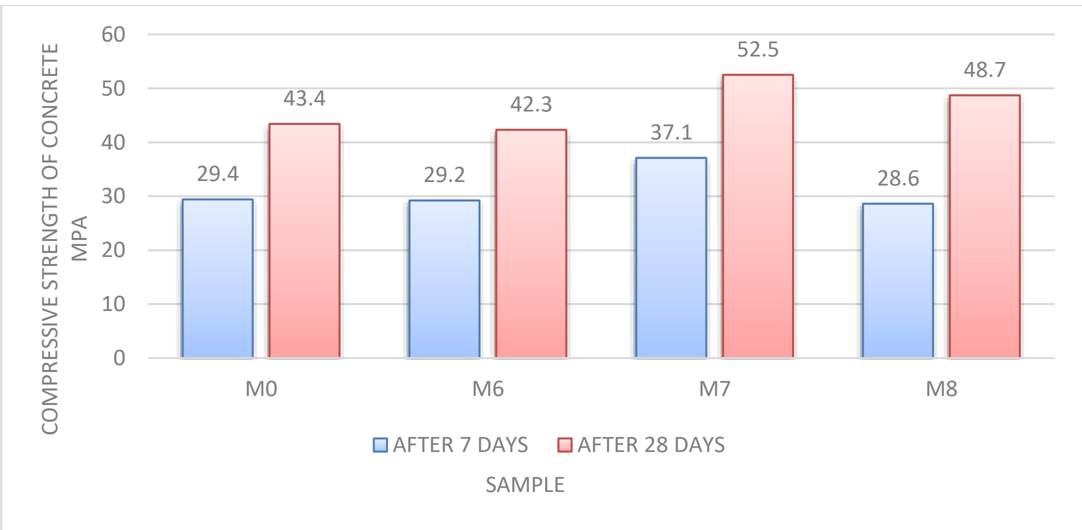


Figure (13) Compressive strength of concrete when marble is added as fine aggregate .

6.4. RESULTS OF THE INDIRECT TENSILE STRENGHT TEST

6.4.1. Effect of coarse marble aggregate ratio on indirect tensile strength

Figure (14) shows the effect of the ratio of coarse marble aggregates with blasting aggregates on the indirect tensile strength, and through the figure we notice that the tensile strength after 7 days gave similar results by adding coarse marble aggregate for 50% marble and decreased by 5.55% for 100% marble, and decreased by 11.11% for 33.33% marble. And at 28 days it increased by 8.69% from the resistance of the standard mixture of 50% marble, And increased by 7.69% for 100% marble, while it decreased by 13.64% from the resistance of the standard mixture of 33.33% marble .

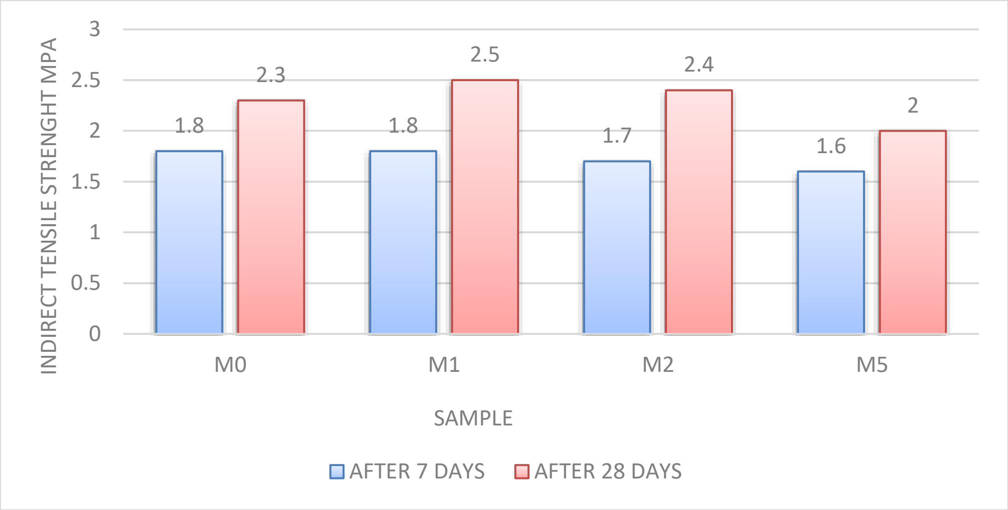


Figure (14) Concrete indirect tensile strength when adding marble as coarse aggregate with blasting aggregate .

And in Figure (15) shows the effect of the ratio of coarse marble aggregates with plowed aggregates on the indirect tensile strength, and through the figure we notice that the tensile strength after 7 days gave similar results by adding coarse marble aggregate for 100% marble and decreased by 5.88% for 50% marble, and decreased by 5.88% for 33.33% marble. And at 28 days it increased by 20% from the resistance of the standard mixture of 100% marble, And decreased by 5% for 50% marble, while it gave similar results by adding coarse marble aggregate for 33.33% .

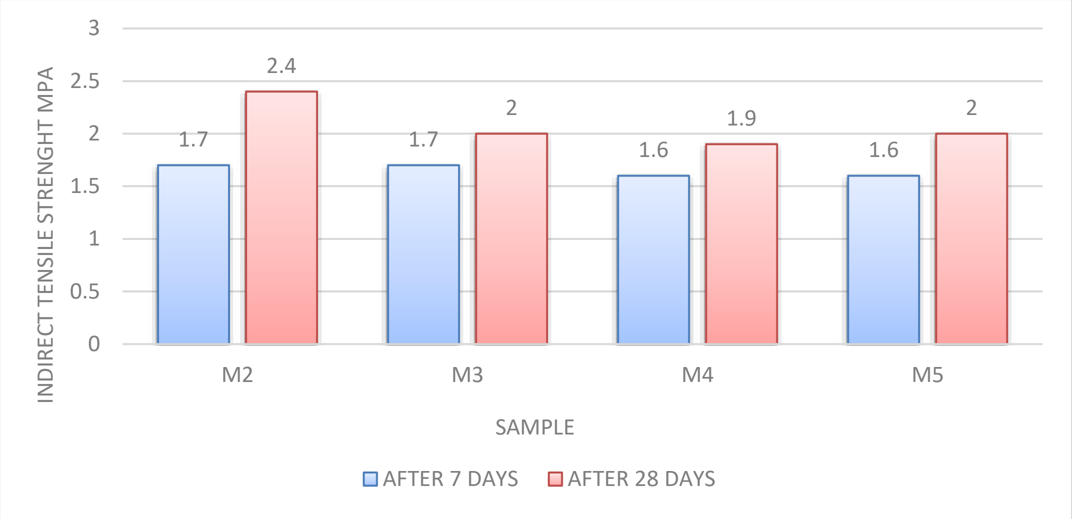


Figure (15) Concrete indirect tensile strength when adding marble as coarse aggregate with plowed aggregate .

6.4.2. Effect of fine marble aggregate ratio on indirect tensile strength

Figure (16) shows the effect of the percentage of fine marble aggregate on the indirect tensile strength, and through the figure we notice that the indirect tensile strength after 7 days changes with the addition of fine marble aggregate, as it decreased by 11.11% of the strength of the standard mixture for marble 10% and increased by 5.55% for marble 30 %, while it decreased by 11.11% for 50% marble, and at 28 days the indirect tensile strength decreased by 4.35% for 10% marble and increased by 4.35% for 30% marble, while equaled the resistance of the standard mixture for 50% marble.

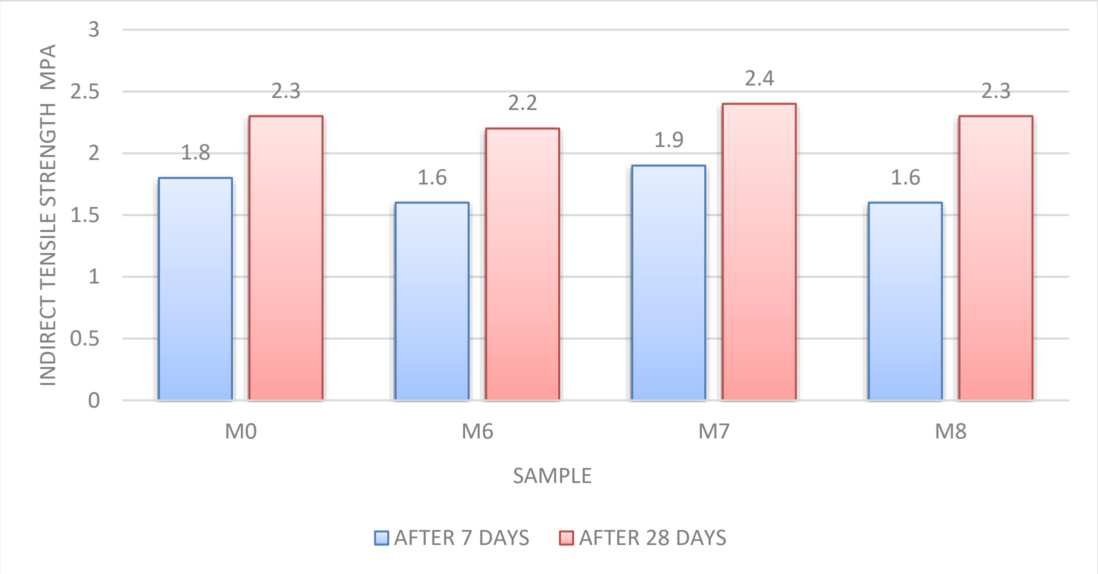
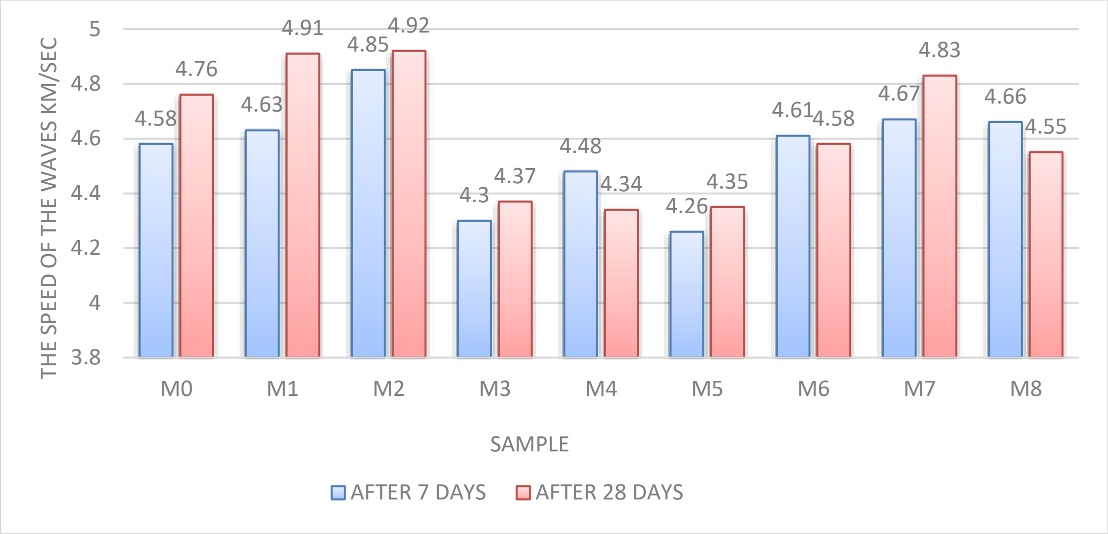


Figure (16) Indirect tensile strength when adding marble as a fine aggregate.

6.5. ULTRASOUND TEST RESULTS

The test was conducted by the direct method, where the distance between the transmitter and the receiver was 15 cm. figure (4.12) shows the results of the velocity of sound waves at 7 and 28 days. As shown in the figure, all samples that contain marble, whether they contain fine marble aggregate or coarse marble aggregate, gave good results according to the specifications. Unlike samples M4 and M5, which contain 50% and 33% coarse marble aggregate, all samples gave high results. Although these two samples also gave good results.



6.6. CONCLOTIONS

Based on the laboratory results reached in this study, and after discussing these results, the following conclusions could be reached :

1. The results of laboratory tests related to the engineering properties of the studied aggregates showed the acceptance of marble waste aggregates for the formation of normal concrete mixtures, where it was found that the values of granular gradation, specific weight, absorption ratio, unit volume weight, crushing, impact and wear coefficients, had a positive effect compared to the aggregates available locally. This would increase the resistance of the concrete to the loads it is subjected to and improve its resistance to wear and various weather factors, and the bearing of concrete with time and the volumetric changes of concrete are all considered to be achieved with such characteristics that characterize the rubble of marble waste.
2. The processes of incorporating the aggregates of marble waste as one of the components of the normal concrete mixture lead to a noticeable increase in the strength, as a resistance of 44.2 and 45.5 MPa was obtained when mixing 50% with the local aggregate and 46.7 MPa when mixed with the local aggregate 33.33% after 28 days of curing. This resistance is very excellent compared to the reference mixture, which gave a resistance of 43.2 and 43.7 MPa under normal conditions.
3. The inclusion of marble powder in the concrete mix did not adversely affect the workability.
4. The best substitution percentage for marble powder instead of fine aggregate is 30% as this mixture has met all acceptance requirements in the British Standard Specifications.
5. The search results were also compared to the Turkish code, and the test results were within the Turkish code[29].

6.7. RECOMMENDATIONS

Through the tests carried out in this study, it was noted that there are a large number of ideas and suggestions that may be included in some future studies to complete this research in order to achieve more information and data that may contribute to the preparation of a guide for the use of marble waste in an economical and environmental way. Among these recommendations are the following:

1. We recommend studying the effect of acids on concrete to which coarse and fine marble aggregates are added.
2. We recommend studying the effect of adding marble aggregates on the reaction activity between active alkali produced from rehydration and active silica in natural aggregates.
3. We recommend studying the flexural strength when adding fine marble aggregates greater than 50%.
4. We recommend studying the compressive, tensile and bending resistance of concrete with marble aggregate added at advanced ages (90 and 180) days, because marble is considered as a pozzolanic material that slows down the hydration process and shows its effect at later ages.
5. We recommend an indirect tensile strength study for proportions greater than 50% of fine marble aggregates.
6. We recommend studying the effect of adding marble aggregates on modulus of elasticity of concrete.
7. We recommend studying the permeability of concrete with marble aggregate added.
8. Encouraging the use of waste from marble industry workshops as rubble in order to reduce the damage of marble waste to the environment.
9. We recommend working on benefiting from marble waste in the cities and other cities as an additive to concrete made from local materials in order to reduce the damage of marble waste to the environment.
10. We recommend working on benefiting from marble waste in the cities and other cities as an additive to concrete made from local materials in order to reduce the damage of marble waste to the environment.

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