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The effect of partial and total replacement of marble waste as coarse aggregate in concrete mix on mechanical properties

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تأثير الاستبدال الجزئي والكلي لمخلفات الرخام كركام خشن في الخلطة الخرسانية على الخواص الميكانيكية

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Abstract:
Waste from the manufacture of building materials (marble) causes many problems in the environment, which requires research into ways to benefit from it around the world. In some developing countries, such as Libya, there is no management of industrial solid waste because local agencies (cleaning agencies) are limited only to cleaning Streets and residential waste transportation only. This may further exacerbate the problem of solid industrial waste accumulation around factory sites.

As the remains of marble manufacturing waste are increasing, they may be useful if used as fine or coarse aggregate in cement mortar and concrete. Using marble waste can solve the problem of aggregate shortage, and on the other hand, the cost of building materials. The use of alternative components is now a source of global concern, so new sources must be researched and explored to produce building materials that achieve sustainability and are environmentally friendly.

In this study, marble waste was used as an alternative to coarse aggregate in the design of regular concrete. Concrete mixtures containing marble waste were designed in proportions (0%, 25%, 50%, 75%, 100%) and tests were conducted, including absorption and specific gravity tests. The volumetric weight of marble, slump and compressive strength to study its effect on concrete.

As it was observed from the compressive strength test of concrete samples when replacing coarse aggregate with marble aggregate, no increase was observed when replacing 25%, but rather it decreases by (7.56%), while it begins to increase when replacing 50% at a rate of (15.39%), as well as in the modulus of elasticity at a rate of (8%). Then it gradually decreases to 75% and 100% replacement rates.

Keywords: Marble Waste, Percentage of Replacement of Coarse Aggregate, Concrete Specimens, Compressive Strength, Modulus of Elasticity.

الملخص
إن مخلفات تصنيع مواد البناء(الرخام) تسبب في العديد من المشاكل في البيئة مما يتطلب الامر الي البحث في طرق الاستفادة منها حول العالم، ففي بعض الدول النامية مثل ليبيا لا توجد إدارة للنفايات الصلبة الصناعية لأن الاجهزة المحلية (جهاز النظافة) مقتصر فقط على تنظيف الشوارع ونقل المخلفات السكنية فقط وهذا الأمر قد يزيد من تفاقم مشكلة تكدس النفايات الصناعية الصلبة حول مواقع المصانع.

حيث ان بقايا مخلفات تصنيع الرخام في زيادة قد يمكن الاستفادة منها إذا استخدمت كركام ناعم او خشن في المونة الاسمنتية والخرسانة، فاستخدام مخلفات الرخام يمكن ان يحل مشكلة نقص الركام، ومن جهة اخري تكلفة مواد البناء. فان استخدام مكونات بديلة هو الان مصدر اهتمام عالمي لهذا يتعين البحث واستكشاف مصادر جديدة لإنتاج مواد بناء تحقق الاستدامة وتكون صديقة للبيئة.
في هذه الدراسة تم استخدام مخلفات الرخام كبديل عن الركام الخشن في تصنيع الخرسانة العادية، حيث تم تصميم خلطات خرسانية محتوية على مخلفات الرخام بنسب (0% , 25% , 50% , 75% , 100%) واجراء الاختبارات المتمثلة في اختبارات الامتصاص والوزن النوعي والوزن الحجمي للرخام والهبوط ومقاومة الضغط لدراسة تأثيره على الخرسانة.
حيث لوحظ من اختبار مقاومة الضغط للعينات الخرسانية عند استبدال الركام الخشن بركام الرخام لم تلاحظ زيادة عند استبدال 25% بل تتناقص بمقدار (7.56%) بينما تبدأ في الزيادة عند استبدال 50% بمعدل (15.39%) وكذألك في معامل المرونة بمعدل (8%)، ثم تنخفض تدريجيا في نسب استبدال 75% و100%.

الكلمات المفتاحية: نفايات الرخام، نسبة استبدال المواد الخام الخشنة، عينات الخرسانة، قوة الضغط، معامل المرونة.

Introduction

The persistence and increase in solid waste, which causes many problems, has made it necessary to search for ways to dispose of it all over the world. In some cities, industrial, residential and commercial areas are mixed, and thus industrial waste problems overlap with residential areas. This is because the industrial areas located within or within the city limits do not have sufficient facilities to enable industries to collect and dispose of liquid and solid waste. In some countries, there is no management of industrial solid waste, and this issue may exacerbate the problem of accumulation of industrial solid waste around factory sites [1,2,3].

Factory waste has a negative impact on the environment, as it is dumped as industrial waste, and a small amount of it is only used in some works. These large amounts of waste may reduce soil porosity, permeability, and water absorption, which causes some respiratory illnesses for residents near the area and causes groundwater pollution. It also negatively affects the natural appearance of the area [4,5].

Materials used in this study and their tests

Cement

Ordinary Portland cement (42.5N) with a specific gravity of (3.15) N/m^3 was used in all concrete mixtures prepared during this study and produced by the Arab Union Contracting Company (Al-Burj Factory - Zliten City). The physical and mechanical properties of cement conform to what is stipulated in the Libyan Cement Specifications (340:2009) [6].

Water

Use safe drinking water free of pollutants, organic materials, alkalis, acids and oils, and it is prepared in Al-Ittihad Company’s laboratories. Any potable water is suitable for use in any concrete mixing process.

Fine aggregate

Natural fine aggregate prepared from Al-Ittihad Company’s departments was used, and the results of the sieve analysis conformed to British specifications (Part 2 BS 882:1992) as shown in Figure (1) and Table (1) shows the gradation of fine aggregate according to the specifications [7].

Table 1 shows the sieve analysis of fine aggregate**.**

Sieve size (mm)	Reserved weight (g)	Total reserved weight (g)	Reserved percentage	Passing ratio (%)	British specifications (BS 882: 1992)
5	4.6	4.6	0.23	99.7	100-100
2.36	6	10.6	0.53	99.47	100-60
1.18	4.6	15.2	0.73	99.24	100-30
0.6	20.8	36	1.8	98.2	100-15
0.3	1564.4	1600.4	80	20	70-5
0.15	315.5	1915.9	95.80	4.2	15-2.92
pan	38.9	1999.8	100	0	

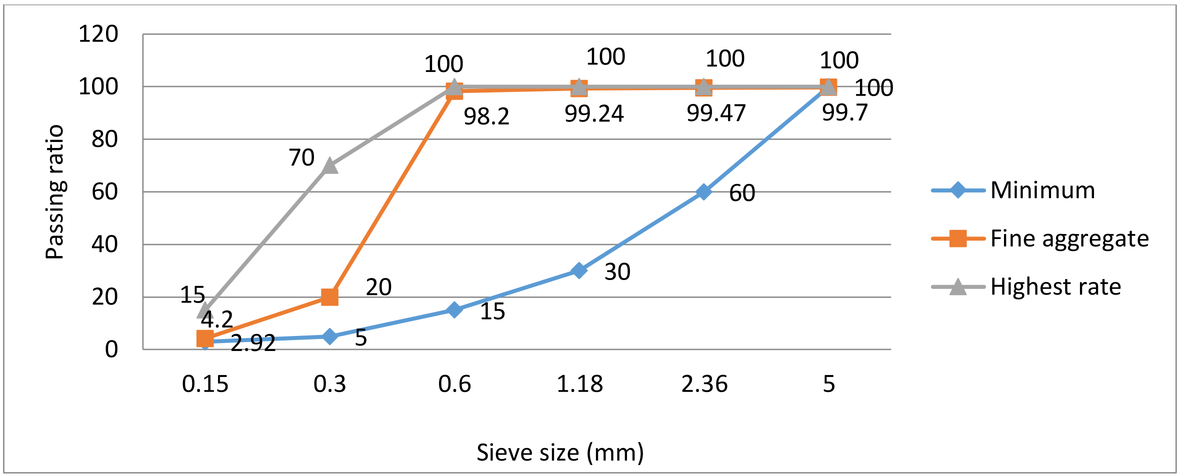

Figure 1 The results of the sieve analysis test for fine aggregate**.**

Coarse aggregate

Coarse aggregate from Al-Ittihad Company sections measuring 15 mm and 10 mm, conforming to British specifications (BS 882:1992 part 30), was used and mixed in a ratio of 1:1. Table (2) shows the sieve analysis of the coarse aggregate, and Figure (2) shows the results of the sieve analysis of the coarse aggregate [7].

Table 1 shows the sieve analysis of coarse aggregate**.**

Sieve size (mm)	Reserved weight (g)	Total reserved weight (g)	Reserved percentage	Passing ratio (%)	British specifications (BS 882: 1992)
37.5	0	0	0	100	100-100
20	0	0	0	100	100-90
14	106.5	106.5	4.76	95.24	40-80
10	1536.7	1643.2	73.54	26.46	30-60
5	583.6	2226.8	99.65	0.35	0-10
pan	7.6	2234.4	100	0	/

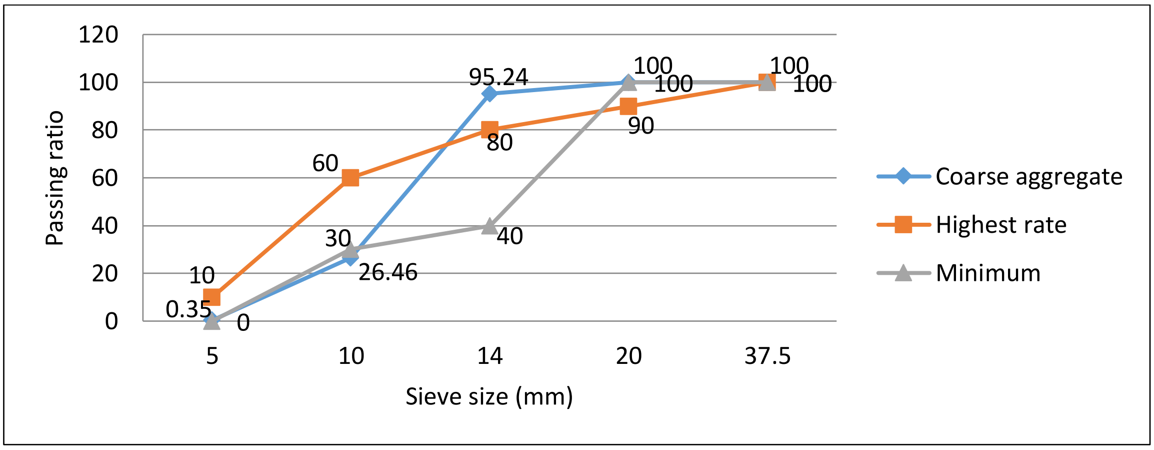

Figure 2 The results of the sieve analysis test for coarse aggregate**.**

Marble waste

Marble aggregate waste was supplied from marble manufacturing workshops in the city of Tripoli, where it was brought in different sizes and weights. It was crushed into smaller stones to obtain an aggregate of a similar gradation to traditional aggregate. The sieve size was 14 mm and Figure (3) shows the marble used in the study.

Figure 3 Marble waste (a) Before crushing (b) After crushing.

In the marble aggregate test, fineness standards are calculated and the largest nominal size of the marble aggregate is known. In the sieve analysis test, the percentage of loss in the sample must not exceed 2% of the original sample weight. Percentage of loss= Total sieves weights/ Original sample weight×100.

The test results were according to British specifications (1992: BS 882) for sieves No. (3.75, 19, and 14, 5) mm, while the result did not conform to the specification limits for sieve No. 10, as the percentage of passing through it was 6%, i.e. less than the minimum permissible in this sieve. Which equals 30% by 24%. Table (3) shows the sieve analysis test on a marble aggregate sample, and Figure (4) shows the graphical representation of the test results [7].

Table 3 shows sieve analysis of marble aggregate**.**

Sieve size (mm)	Reserved weight (g)	Total reserved weight (g)	Reserved percentage	Passing ratio (%)	British specifications (BS 882: 1992)
37.5	0	0	0	100	100-100
19	75	75	7.5	92.5	100-90
14	480	555	55.5	44.5	40-80
10	385	940	94	6	30-60
5	58	998	99.8	0.2	0-10
pan	0	0	0	0	/

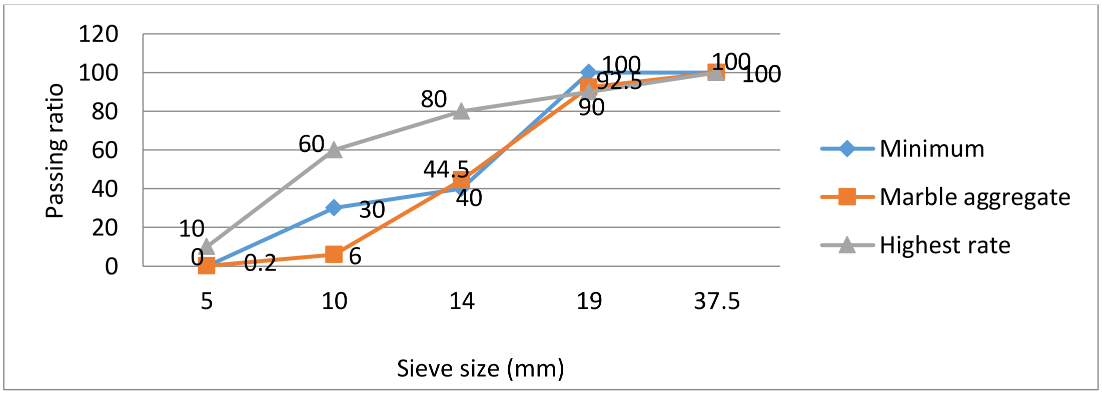

Figure 4 Results of sieve analysis of marble aggregate.

Specific gravity and absorption percentage of marble aggregate

After conducting the test on marble aggregate samples, the results obtained in terms of specific gravity were by British specifications. As for the absorption rate, the marble aggregate showed a relatively high absorption rate as a result of its chemical composition, while the result of the volumetric weight of the marble aggregate was also outside the limits of the specification, Table (4) shows the limits. Results and specification limits [8,9].

Table 4 The properties and test results of the marble aggregate sample.

Test type	Test result	Specification limits	Specification type
apparent specific gravity	2.61	2.7-2.5	(BS 812-2:1995)
Dry density	2.42	/	(BS 812-2:1995)
Wet density	2.49	/	(BS 812-2:1995)
Absorption percentage (%)	2.97	not exceed 3%	(BS 812-2:1995)
Unit weight volume	1209	1400-1800Kg/m^3	(ASTM C29 C29M)

Design of concrete mixtures used in the study and mixing ratios for each mixture

The absolute volume method was used, which provides accuracy in determining proportions and reduces the possibility of error related to changes in density and humidity between different materials. The design was made at a level of 25 N/mm^2, where Table (5) lists the percentage of marble aggregate and the weights of the components of the concrete mixtures used in this study [10].

$$Absolute\ Volume = \frac{C}{G_c} + \frac{S}{G_S} + \frac{G}{G_g} + \frac{W}{1.0} = 1000$$

Where:
C = content of cement (kg/m^3)
W = content of mixing water (kg/m^3)
S = content of fine aggregate (kg/m^3)
G = content of coarse aggregate (kg/m^3)
G_C = specific gravity of cement
Gg = specific gravity of coarse aggregate
Gs = specific gravity of fine aggregate

Table 5 Proportions and components of materials for all mixtures used in the study.

Mix number	Marble %	Cement (kg)	W/C	Water liter	Marble aggregate (kg)	Coarse aggregates (kg)	Fine aggregates (kg)
Mix1	%0	10.125	0.55	5.5	0	41.76	23.32
Mix2	%25	10.125	0.55	5.5	9.2	31.32	23.32
Mix3	%50	10.125	0.55	5.5	18.4	20.88	23.32
Mix4	%75	10.125	0.55	5.5	27.6	10.44	23.32
Mix5	%100	10.125	0.55	5.5	36.8	0	23.32

Testing of concrete in fresh condition (slump test)

Workability expresses the amount of water content of the concrete mix in its fresh state and its ability to form, as the test was conducted in accordance with the American standard (ASTM C143-C143M). Table (6) displays the slump values obtained for the concrete mixes, as it became clear that the slump value decreases as the percentage of replacing coarse aggregate with aggregate increases. Marble, as the mixture that did not contain marble slurry was 55 mm, and it gradually decreased with an increase in the replacement ratio until it reached 10 mm when the ratio of replacing aggregate with marble was 100%, meaning that the marble aggregate needs a larger amount of water to reach a suitable operating degree compared to the aggregate obtained. It is affected by crushers as a result of its high degree of absorption and roughness compared to the coarse aggregate used in this study. Figure (5) shows a comparison between the replacement ratios and the decline values for mixtures with different percentages of marble aggregate as a substitute for the coarse aggregate [11].

Table 6 The slump test for concrete mixtures**.**

Mix number	Marble aggregate %	slump results (mm)	Specification (ASTM C143 – C143M)
Mix1	%0	55	10-75
Mix2	%25	40	10-75
Mix3	%50	25	10-75
Mix4	%75	17	10-75
Mix5	%100	10	10-75

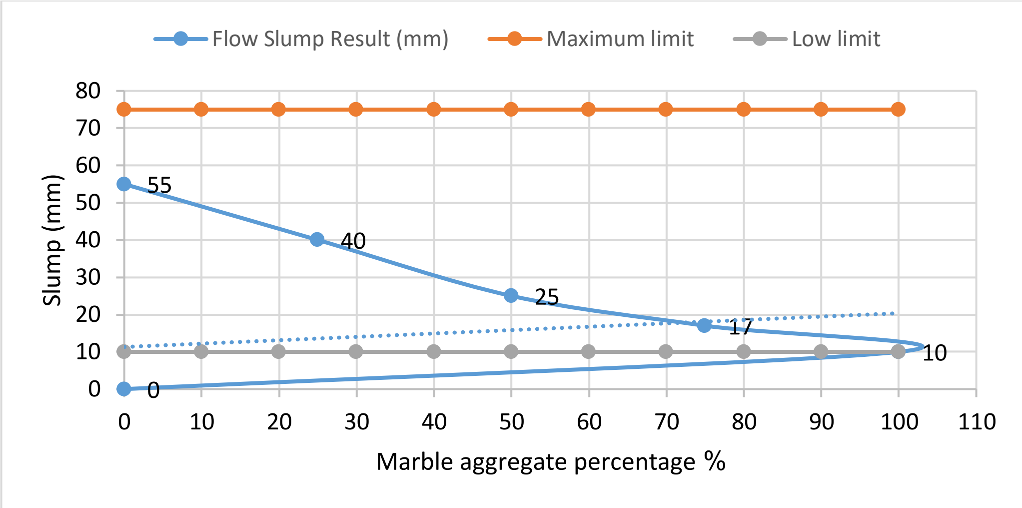

Figure 5 The results of slump tests**.**

Preparing samples and pouring concrete

Several 30 iron cubes were prepared for the five concrete mixtures with dimensions (150 × 150 × 150 cm). The inner faces of the iron molds were coated with a layer of oil, which facilitates the process of disassembling the concrete cubes after 24 hours of curing at normal room temperature.

The mixture of concrete paste is poured and compacted with manual tampers. The molds are filled in three layers, each representing a third of the cube, and compression is applied 25 times for each layer using a metal rod.

Sample processing

After preparing, hardening and dismantling the samples, they will be processed by immersing them in the treatment water basin at a temperature of 20-25 degrees Celsius. Several samples will be processed, each according to the required period of testing (7) days and (28) days. Figure (6) shows the preparation and immersion of the samples. With water in the treatment basin.

Figure 6 Sample processing process**.**

Compressive strength test

The test will be conducted to determine the mechanical property of compressive strength of hardened concrete in accordance with British specifications (BS EN 12390-3:2009). It was observed that the compressive strength of concrete samples when replacing coarse aggregate with marble aggregate increases slightly, starting at a 25% replacement rate and continues to increase at a 50% replacement rate, then gradually decreases at 75% and 100% replacement rates. It is noted from the average results that the replacement rate is 50 % is the highest value for compressive strength, as it is 15.39% higher than the reference mix with completely coarse aggregate at 28 days and 22.77% higher than the mixture with completely marble aggregate at 7 days. Table (7) shows the results obtained when conducting a compression test for all samples according to the treatment specified for each concrete mixture, and Figure (7) shows the relationship between compressive strength and the percentage of marble aggregate [12].

Table 7 Results of the compressive strength after 7 days and 28 days.

Mix number	Marble aggregate %	compressive strength (MPa)	
		7 Day	28 Days
Mix1	%0	21.411	29.96
Mix2	%25	21.61	30.03
Mix3	%50	27.727	35.410
Mix4	%75	22.478	30.366
Mix5	%100	20.531	28.276

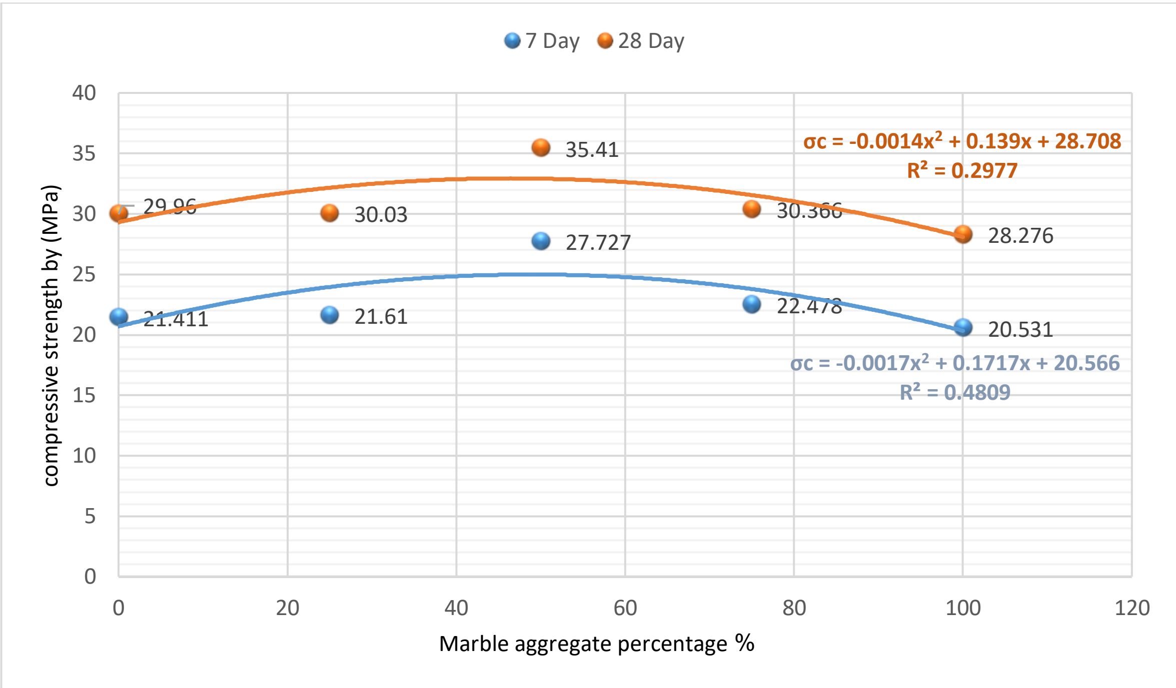

Figure 7 The relationship between compressive strength and marble aggregate percentage.

Modulus of elasticity test

The modulus of elasticity is one of the most important properties of concrete or any such material, because it represents the ability of the material to resist deformation under the applied load, as it reflects the ability of concrete to deviate elastically, and the modulus of elasticity of concrete is sensitive to the proportions of aggregate in the concrete. The modulus of elasticity was calculated according to code(ACI 318M-08)and Table 8 shows the effect of the percentage of marble aggregate on the compressive strength and modulus of elasticity, and Figure 8 shows the relationship between the compressive strength and elastic parameters of marble aggregate [13].

$$E_c = 4700\sqrt{f_{c'}}$$

Table 8 The results of compressive strength and modulus of elasticity.

Mix number	Marble aggregate %	Compressive strength (MPa)	Modulus of elasticity (MPa)
Mix1	%0	29.96	25725.79
Mix2	%25	30.03	25755.83
Mix3	%50	35.410	27967.96
Mix4	%75	30.366	25899.52
Mix5	%100	28.276	24992.34

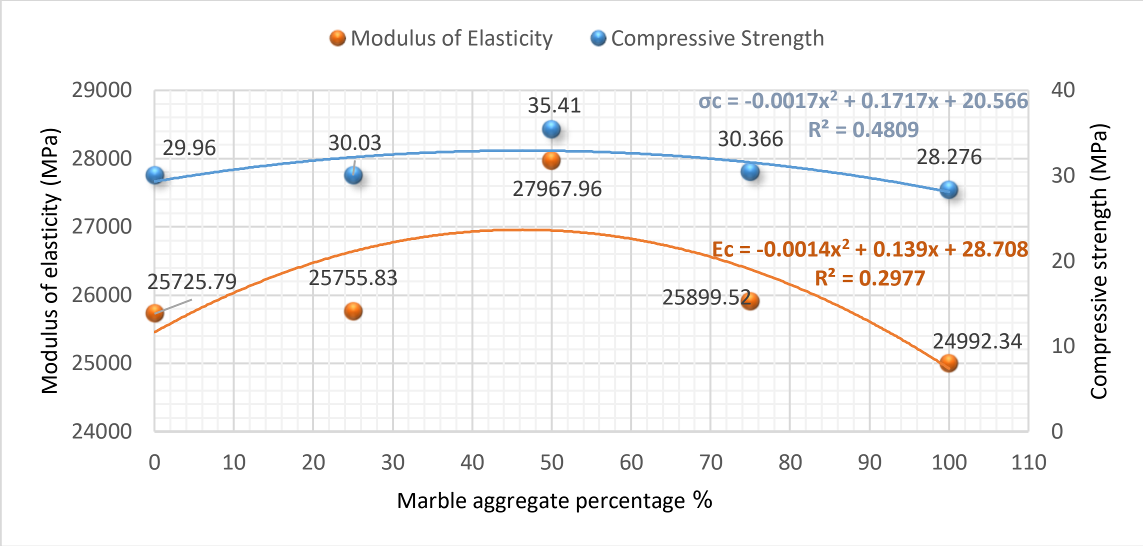

Figure 8 The relationship between compressive strength and modulus of elasticity of marble aggregate proportions.

Conclusion

From our study in both theoretical and practical aspects and the results obtained from the tests specified in the study, the study can be summarized in the form of the following points:

1. The results of laboratory tests related to the engineering properties of the studied aggregate showed the acceptance of waste aggregate for the formation of ordinary concrete mixtures, as it was found that the values of gradation, specific gravity, and absorption are similar to the properties of the aggregate.
2. The process of incorporating waste aggregate into the concrete mixture produces a mixture similar to the mixture in which coarse aggregate obtained from ordinary crushers is used in terms of pressure resistance.
3. According to this study, the optimal percentage for replacing coarse aggregate with broken marble is 50%, as the compressive strength increased by 15.39% over concrete with complete aggregate (Reference mixture).
4. In the concrete mix with a replacement ratio of 75%, the compressive strength decreased by only 1.34% compared to the concrete that did not contain marble waste, which indicates the possibility of using marble waste as coarse aggregate for concrete.
5. Operability gradually decreases with increasing marble waste. When marble waste is completely used (100% replacement rate), the amount of decrease is 10 mm compared to 55 mm when using coarse aggregate obtained from crushers.
6. The modulus of elasticity was shown to increase by 8% when replacing coarse aggregate with waste aggregate at a rate of 50% and decrease when the percentage of replacing aggregate with marble waste increases at 75 and 100% for the mixture that does not contain waste aggregate.

Recommendations

Based on what was done in the study, expanding and completing it, a set of recommendations were proposed, the most important of which are:

1. It is recommended to work on utilizing marble waste as an additive to concrete made from local materials in the form of coarse aggregate in order to improve its properties.
2. We recommend that the competent authorities work to reduce the problem of the accumulation of marble workshop waste by establishing a central crusher in each region so that marble waste and other waste building materials are supplied to this crusher and thus problems related to cost and the environment can be reduced.
3. When using marble fragments, the water content should be increased to obtain good workability due to the relatively high absorption of marble fragments.
4. Using marble waste as fine aggregate by grinding it to study its effect on the properties of concrete.
5. Conduct more laboratory tests on the marble aggregate, such as the crushing and wear coefficient, and compare the results obtained with the results of the aggregate obtained from crushers.

References

[1] Corinaldesi V.Giacomo G. Tarun R. (2010). "Characterization of marble powder for its use in mortar and concrete". Construction and Building Materials. 24 (2) pp: 113-117.
[2] Fredonia. F. (2007). "World Construction Aggregates" Industry study with forecasts for 2011 and 2016 ‹The Freedonia Group ‹USA.

[3] Hanifi Binici, Tahir Shah, Orhan Aksogan, Hasan Kaplan, Durability of concrete made with granite and marble as recycle aggregates, Journal of materials processing technology, Vol.208,Issues 1-3, PP 299–308, 21 November 2008.
[4] H.Hebhoub ,H.Aoun ,M.Belachia, H.Houari, E.Ghorbel, Use of waste marble aggregates in concrete, Construction and Building Materials,PP 1167-1171,25.
[5] Antonio andre, Jorge de Brio, Alexandra Rosa, DiogoPedro. C ,Durability performance of concrete incorporating coarse aggregate from marble industry waste, Journal of cleaner Production 65,289-396, 2014.
[6] Libyan Standard Specifications No. (340), Portland Cement, for the year 2009.
[7] BS 882 (1992) Specification for Aggregates from Natural Sources for Concrete. British Standards Institution, London.
[8] BS 812-2 1995.Testing aggregates. Methods for determination of density. British Standards Institute, London, United Kingdom.
[9] Standard Test Methods for unit weight and voids in aggregates, American Society for Testing and Materials, Washington.USA,2003, pp C29/M29
[10] ACI PRC-211.1-91: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (Reapproved 2009)
[11] ASTM C143/C143M-15 Standard Test Method for Slump of Hydraulic-Cement Concrete (Superseded), ASTM International, West Conshohocken, PA, 2010
[12] BS EN 12390-3:2009 Testing hardened concrete. Compressive strength of test specimens (Incorporating corrigendum August 2011) (Withdrawn)
[13] AMERICAN CONCRETE INSTITUTE (2008) Building Code Requirements for Structural Concrete, ACI 318M-08.