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Effects of Partially and Totally Substitution of Marble Waste as a Fine Aggregate on Workability and Mechanical Performance of Concrete

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Abstract

It has been recommended that; the disposal of industrial waste would be greatly reduced if it could be incorporated in concrete production. One of these possibilities is the substitution of the fine aggregate by marble waste (MW), which contributes to the reduction of natural resources consumption, while solving a waste management problem. The basic objective of this investigation is to examine the characteristics of concrete using MW as fine aggregate in proportions 0%, 20%, 40%, 60%, 80% and 100% by weight of cement. Several fresh and harden properties have been reviewed in the current paper. The results observed from the various tests depict that increase the slump value with the increase the percentage level of MW. Moreover, strength was increase up to 60% substitution of MW and then decreases gradually. Therefore, it is recommended to MW as fine aggregate up to 60% substitution.

Keywords: Marble waste • Slump • Split tensile strength • Flexure strength • Compressive strength

Introduction

The idea of sustainable development assumes that natural resources should be treated as limited goods and the wastes should be rationally managed. Increasing amounts of collected waste, up to 2500 million tons per year over the world [1] are encourage researcher to developed new method of disposal. In cement construction industry there are many possibilities to used waste materials in concrete [2]. Waste can be used as a aggregate or cement in concrete.

For a good concrete mix, fine aggregates need to be clean, hard, strong, and free of absorbed chemicals and other fine materials that could cause the deterioration of concrete. Unfortunately, majority of the natural sand used (rolled sand: sand of river, dune sand, and sand of sea) is selected for the price and the availability [3]. Properties of sand affect the durability and performance of mortar, as fine aggregate is an essential component of concrete.

Different industries are the source of waste which is produce as a by-product during manufacturing process. It is suggested that Marble can be easily used in construction industry to prepare Cement Concrete [4]. The subject of this paper is to used waste marble as fine aggregate obtain from marble industry. Actual figures about the quantity of waste produced in Pakistan from the marble industry are inaccessible since it is not calculated or monitored by the government or any other party. Other references estimate that 20 to 25% of the marble produced results in powder in the form of slurry during the cutting process [5]. These by-products are present in the environment and contribute to pollution.

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Since the ancient times marble has been frequently used as a building material. The industry's disposing of the marble powder materials, which consist of very fine powder, today composes one of the environmental issues around the globe [6] usage of the marble dust in different industrial areas especially the paper, agriculture, glass and construction industries would help to protect the environment [7]. During the mining process and in the polishing of marble stone, marble dust is perceived as a waste material [8].

Many developed countries have put in motion legal regulations with respect to the recovery of structural waste aiming to reduce the amount of waste and to ensure waste recycling [9]. We have the example of Japan in front of us; a country which successfully increased the recycling rate of concrete waste up to 98% using waste material as aggregate [10]. They recognized that the Marble Stone slurry produced during processing corresponds to about 40% of the final product from stone industry [11]. They also reported that slump decrease with addition marble waste. Katuwal et al. also indicate that marble as fine aggregate decrease slump [12]. They observed that compressive strength is increased up to 50% replacement of fine aggregate with marble waste which is about 12% higher than from control mix [13]. Compressive strength and flexural strength of concrete is increased about 28% and 13% respectively at 50% replacement and then gradually decrease with the addition WMP [14]. Resistance to acid of concrete containing waste marble was marginally low as in comparison to that of control concrete [15]. The Resistance to acid of concrete containing waste marble was marginally low as in comparison to that of control concrete [15] suggests that marble slurry can be easily used in construction industry to prepare Cement Concrete [4].

In existing literature shows that a very scarce number of studies investigated the effects of marble as fine aggregate in cement concrete production. Therefore, more research is required to explore property of concrete modified with marble waste as a fine aggregate. Therefore, the present work used marble waste as fine aggregate in proportion of 0%, 20%, 40%, 60%, 80% and 100% by weight to evaluate fresh and harden properties of concrete modified with marble waste.

Materials and Experimental Design

Cement

Accordance to ASTM C150 [16], Ordinary Portland cement (OPC) type-1 was used in this research. Its chemical and physical properties are displayed in Table 1.

Fine aggregate and coarse aggregate

Locally available natural sand was used as a fine aggregate in all the mixes in saturated surface dry condition (SSD). Normal weight crush stone was used as coarse aggregate in saturated dry condition which was obtained from Margallah Wah Cantt Punjab, Pakistan. Different tests were performed on aggregate to evaluate its physical property as shown in Table 2 while gradation curve were shown in Figure 1 and Figure 2 respectively.

Waste Marble (MW)

Waste Marble (Mw) was procured from National marble factory industrial zone Peshawar Pakistan and grinded at PCSIR lab Peshawar. Different tests were performed on aggregate to evaluate its physical property as shown in Table 3 while gradation curve was shown in Figure 3.

Table 1. Physical and chemical property of OPC.

Chemical Property	Percentage (%)	Physical Property	Results
CaO	64.7	Size	≤ 75 µ
SiO_2	23.9	Fineness	92%
Al_2O_3	5.4	Normal Consistency	31%
Fe_2O_3	3.7	Initial Stetting Time	33 min
MgO	3.5	Final Stetting Time	410 min
SO_3	2.9	Specific surface	322 m^2/kg
K_2O	2.4	Soundness	1.70%
Na_2O	1.2	28-days compressive Strength	42 Mpa

Table 2. Physical property of fine and coarse aggregate.

Physical Property	Fine aggregate	Coarse Aggregate
Particle size	4.75 mm to 0.075 mm	19.5 mm to 4.75
Fineness modulus	2.63	4.23
Absorption capacity	4.08%	2.9%
Moisture content	1.8%	1.2%
Bulk density (kg/m^3)	1566	1575

Size of specimen

Slump cone was used to determine the workability of fresh concrete as per ASTM [17]. ASTM C39/C39M [18]. Cylinder of standard size (150 × 150 mm) will be used to measure the compressive strength at 7 days & 28 days. Similar cylinders of standard size (150 × 300 mm) will be cast & tested to find their tensile strength. Beam of size (150 × 150 × 500 mm) will be casted and tested to find their flexure strength as per ASTM [19]. Three specimens are tested for each test at 7&28 days and the mean value of the specimens is considered as strength" (Figures 2-4).

Sample preparation method

ASTM C-31 [20] method was followed for the preparation of the specimens and compaction was done manually by Roding in three layers having 25 blows per layer. A total of 108 samples having a standard size will be cast & then will be tested. To study the effect of MW on the behaviors of hardened and fresh concrete, six mixes were prepared. Details of the mixes were provided in Table 4.

Results and Discussion

Fresh property

Slump: Consistency of fresh concrete is a mix property which incorporates the different necessities of stability, mobility, compatibility, finish ability and place ability [21]. Workability of Concrete increased as the percentage of MW increased. Slump value of 0%, 20%, 40%, 60%, 80% and 100% of MW added to concrete mixes were 55 mm, 67 mm, 73 mm, 88 mm, 102 mm and 130

Table 3. Physical and chemical property of marble waste.

Chemical Property	Percentage (%)	Physical Property	Results
CaO	47.55	Color	White
SiO_2	5.13	Specific Gravity	2.60
Al_2O_3	22.20	Clay (%)	0.6
Fe_2O_3	8.23	Bulk density (kg/m^3)	1480
MgO	3.32	Absorption Capacity	2.30
SO_3	1.07	Moisture Content	0.60
K_2O	2.9	Fineness Modulus	2.52
Na_2O	2.6		

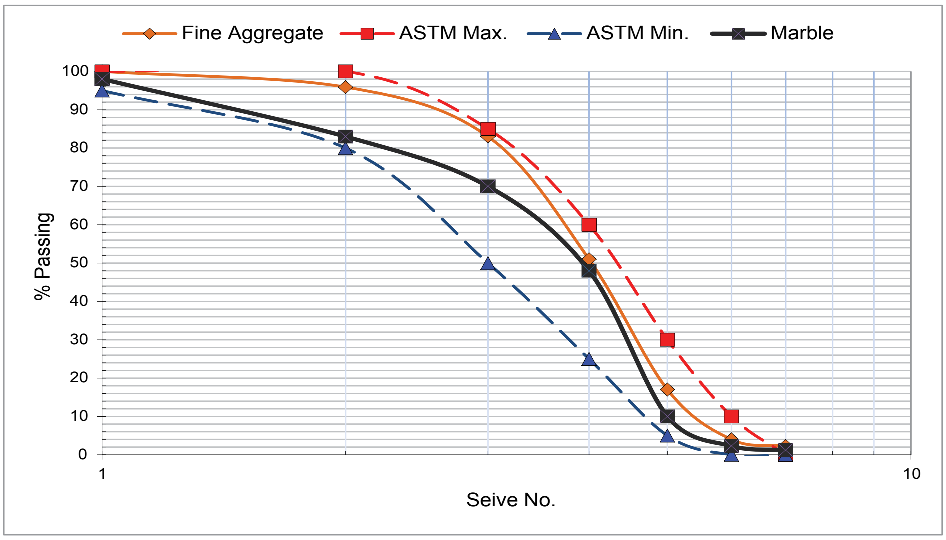

Figure 1. Gradation curve of marble and fine aggregate.

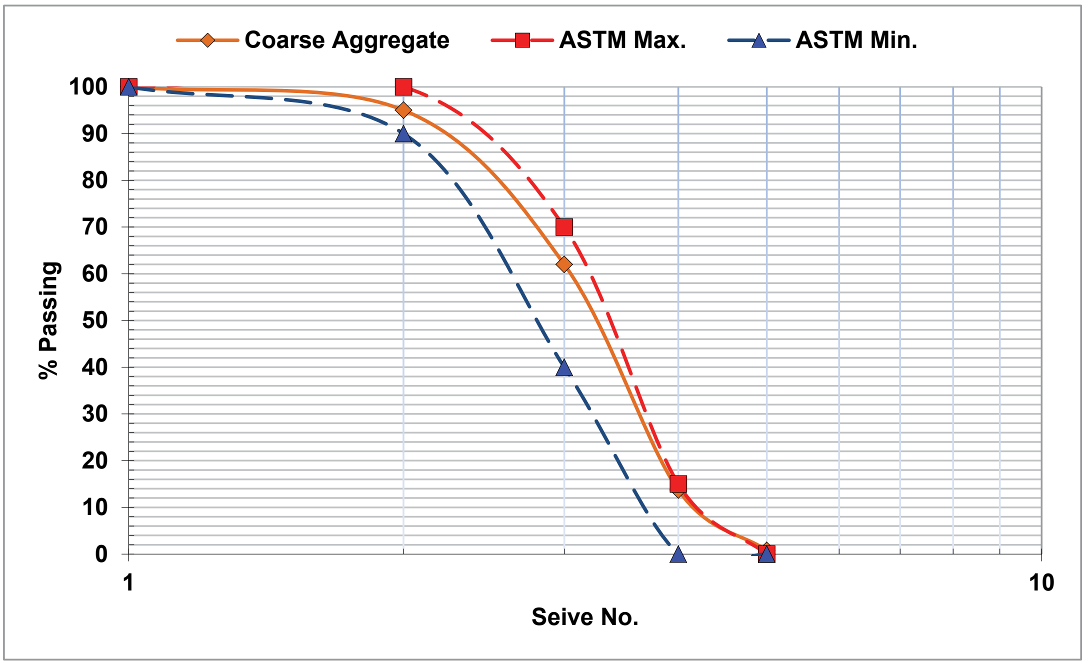

Figure 2. Gradation curve coarse aggregate.

Figure 3. Sample preparation.

Table 4. Quantification of materials.

Materials	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Cement	1	1	1	`1	1	1
Sand/F. A	1.5	1.5	1.5	1.5	1.5	1.5
Coarse Aggregate	3	3	3	3	3	3
W/C	0.50	0.50	0.50	0.50	0.50	0.50
Marble Waste	0%	20%	40%	60%	80%	100%

mm which were 21%, 32%, 60%, 85% and 136% higher than from blank mix (reference concrete) as shown in Figure 5. This can be an attributed due the fact that marble waste has less water absorption than natural sand reason for increased in workability it due less water absorption [8]. Another possible reasons for increased in workability its due micro filler. Marble acts as a micro filler which fills the voids in sand and aggregate and it helps to reduce total voids in concrete due which to less water is required for lubricant [22]. Therefore, workability is increased due to incorporation marble waste.

Figure 4. Slump test.

Harden properties

Compressive strength: Compressive strength is the property of material to resist stresses when it is compressed. The compressive strength test was done with compliance to the standard procedure of ASTM as ASTM C39/C39M [18] for cylindrical specimens having standard dimensions as 150 mm diameter and 300 mm length. In this test concrete specimens (cylinders) were exposed to compressive axial force at a rate within recommended limit till the concrete failure. Compressive strength was then determined from greatest failure load divided by X-sectional area of the specimen as shown in Figure 6.

Compressive strength with varying dosage of marble was shown in

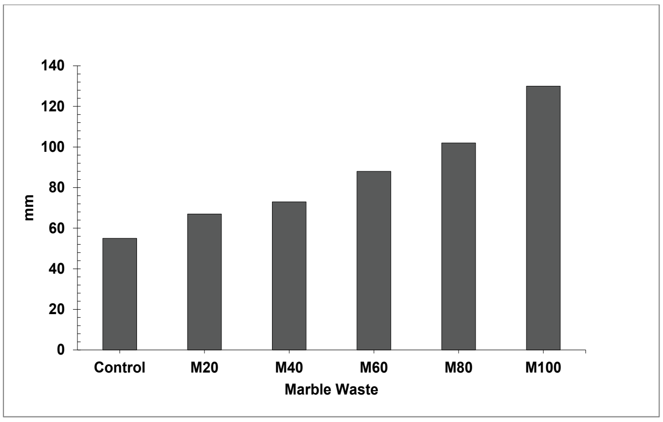

Figure 5. Slump test results.

Figure 6. Compressive strength test.

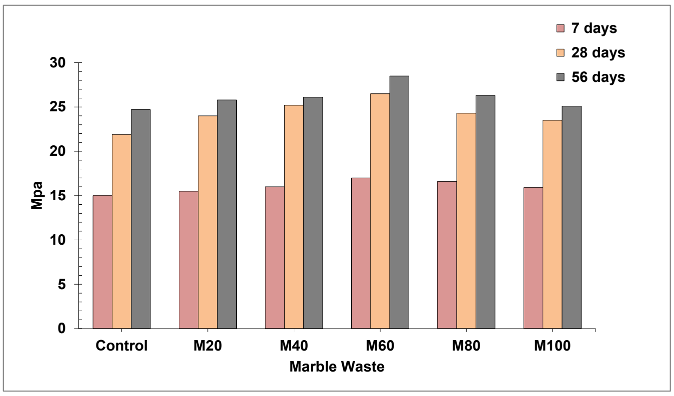

Figure 7. Compressive strength results.

Figure 7. General trend, Compressive strength rise as the percentage of marble waste increased up to 60% substitute and then reduced as shown in Figure 7. Maximum strength was obtained at 60% replacement and minimum strength was obtained at 0% replacement of marble waste. At 60% substitution of marble, compressive strength was 26.5 Mpa which were almost 21% higher than blank mix after 28 days curing. This may be due the fact that marble act as micro filler because they less fines modulus as compared to sand which fills the voids giving compact dense mass and as a result strength were increased [22]. The marble aggregate have higher carbonate content than the natural aggregate, which improves the aggregate cement paste bond that is the reason for the increase in compressive strength of concrete at different curing ages [15]. However, decreased in strength was observed beyond 60% replacements of marble because they less water absorption capacity as compared to sand which caused bleeding beyond 60% replacement and as a result strength was decreased.

Split tensile strength: Split Tensile strength for concrete samples is called the tensile stresses generated due to applying of the compressive load at which the concrete sample may fail. It is indirect method to find the tensile stress in concrete. According to ASTM C496-71 [23], split tensile test was carried out on cylindrical specimens of 150 mm diameter and 300 mm height at the ages of 7, 28 and 56 days curing (Figure 8).

Split tensile strength with varying dosages of marble waste was presented in Figure 9. Like compressive strength, split tensile were also increased as percentage of marble waste increased up to 60% substitution and then decreased gradually. According to test observation maximum split tensile strength were obtain with 60% substitution of marble waste and split tensile strength were obtained with 0% substitution of marble waste (blank mix). At 60% substitution of marble, split tensile strength were 2.1Mpa which were almost 23% higher than blank mix after 28 days curing. The marble aggregate have higher carbonate content than the natural aggregate, which improves the aggregate cement paste bond that is the reason for the increase in compressive strength of concrete at different curing ages [15]. Also, due to its finesse, MGW is a promising material which acts as a micro-filler in cement aggregate matrix [24].

As already mention that split tensile Strength follow same pattern as compressive strength. Therefore, a strong co relation was existing in between compressive and split tensile strength. Regression model having R2 greater

Figure 8. Split tensile strength test.

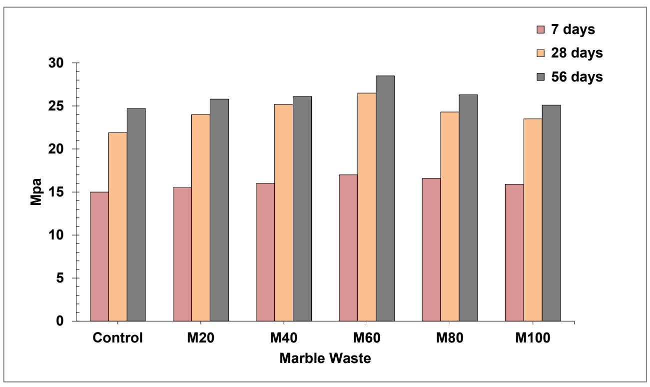

Figure 9. Split tensile strength results.

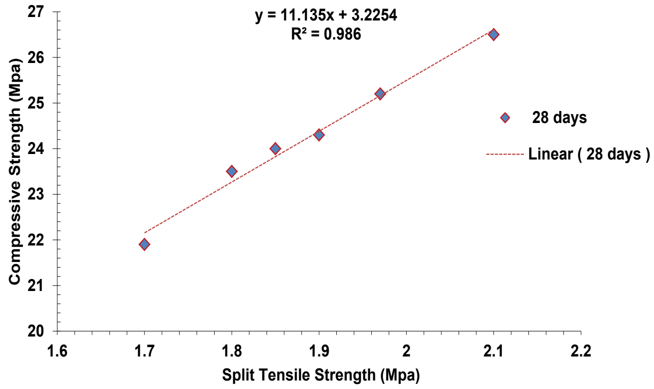

Figure 10. Co - relation between compressive and split tensile strength.

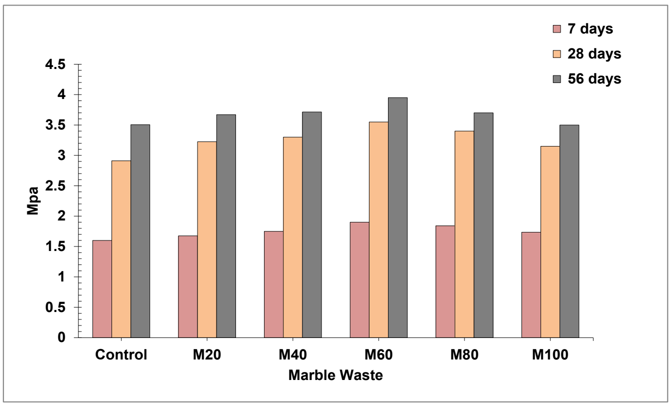

Figure 11. Flexure strength results.

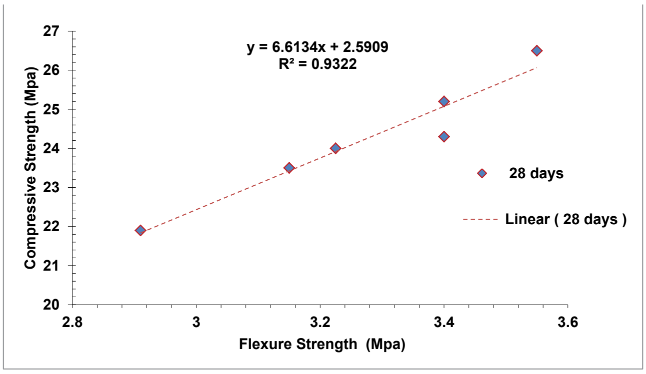

Figure 12. Co - relation between compressive and flexure strength.

than 90% as shown in Figure 10.

Flexure strength: Flexural strength, also known as bend strength, or modulus of rupture, is a material characteristics, that can be defined as in a flexure test, the stress in a material just before it fails [25]. Flexure test was carried out on beam specimens of 150 × 150 × 500 mm at the ages of 7, 14 and 28 days.

Flexure strength with varying dosages of Mw was presented in Figure 11. Similar to compressive strength, Flexure strength were also increased as percentage of marble waste increased up to 60% substitution and then decreased gradually. According to test observation maximum Flexure strength were obtain with 60% substitution of marble waste and Flexure strength were obtained with 0% substitution of marble waste (blank mix). At 60% substitution of marble, Flexure strength were 3.55 Mpa which were almost 18% higher than blank mix after 28 days curing. Regression model show that a strong co relation was existing in between compressive and flexure strength having R2 greater than 90% as shown in Figure 12.

Conclusion

In this research marble waste was used as a fine aggregate in proportion of 0%, 20%, 40%, 60%, 80% and 100% by weight of fine aggregate. Based on experimental work following conclusion has been drawn.

- Workability of concrete increased as percentage of marble waste increased. Highest slump was achieved at 100% substitutions of marble waste. It is due fact that marble has water absorption than natural sand. Hence more water is available for lubricant between the coarse aggregate particles.

- Strength (compressive, flexure and split tensile) increased up to 60% substitution of marble waste and beyond 60% the strength gradually decreased. It is due to fact that marble acts as a micro filler as they have less fineness modulus than natural sand, which fills the voids in sand and coarse aggregate, giving more dense concrete which results to enhance the mechanical performance.

- It can be concluded that, marble waste as fine aggregate can be used to improve the mechanical properties of conventional concrete. From the economic and environmental point of view this waste can be successfully used as fine aggregates in concrete production.

Conflict of Interest

The authors have no conflict of interest to declare.

References

1. Agrawal, D, Hinge P, Waghe UP and Raut SP. "Utilization of industrial waste in construction material–A review" *Int J Innov Res Sci Eng Technol* 3 (2014): 8390-8397.
2. Saikia, Nabajyoti and Jorge de de Brito. "Use of industrial waste and municipality solid waste as aggregate, filler or fiber in cement mortar and concrete" *Adv Mater Sci Res* 3 (2009): 65-116.
3. Bederina, M, Makhloufi Z, Bounoua A and T. Bouziani, et al. "Effect of partial and total replacement of siliceous river sand with limestone crushed sand on the durability of mortars exposed to chemical solutions" *Constr Build Mater* 47 (2013): 146-158.
4. Singh Kuswah, Raj EP, Ishwar Chand Sharma and PBL Chaurasia. "Utilization of Marble Slurry in Cement Concrete Replacing Fine Aggregate." *Am J Eng Res* 4 (2015): 55-58.
5. El Haggar, Salah. "Sustainable industrial design and waste management: cradle-to-cradle for sustainable development. *Academic Press* (2010).
6. Corinaldesi, Valeria, Giacomo Moriconi G and Tarun R. Naik. "Characterization of marble powder for its use in mortar and concrete" *Constr Build Mater* 24 (2010):113-117.
7. Karaşahin, Mustafa, Serdal Terzi. "Evaluation of marble waste dust in the mixture of asphaltic concrete" *Constr Build Mater* 21 (2007): 616-620.
8. Hebhoub, H, Aoun H, Belachia M and H Houari, et al. "Use of waste marble aggregates in concrete" *Constr Build Mater* 25 (2011):1167-1171.
9. Ismail, Sallehan, Ramli M. "Engineering properties of treated recycled concrete aggregate (RCA) for structural applications" *Constr Build Mater* 44 (2013): 464-476.
10. Dosho, Yasuhiro. "Development of a sustainable concrete waste recycling system" *J Adv Concr Technol* 5 (2007): 27-42.
11. Shirulea, PA, Ataur Rahman, and Rakesh D Gupta. "Partial Replacement of Cement with Marble Dust Powder" *Int J Adv Eng Res Stud* 1 (2012):175-177.

12. Katuwal, Kapil, Arnav Duarah, Manoj Kumar Sarma and Motiur Rahman, et al. "Comparative Study of M35 Concrete using Marble Dust as Partial Replacement of Cement and Fine Aggregate" *International Journal of Innovative Research in Science, Engineering and Technology* 6:2017.
13. Latha, G, A. Suchith Reddy and K Mounika. "Experimental investigation on strength characteristics of concrete using waste marble powder as cementitious material" *International Journal of Innovative Research in Science, Engineering and Technology* (2015).
14. Vigneshpandian, GV, Shruthi EA, Venkatasubramanian C and Muthu D. "Utilisation of Waste Marble Dust as Fine Aggregate in Concrete" *IOP Conference Series: Earth and Environmental Science* 12007 (2017).
15. Kore, Sudarshn D and AK Vyas. "Impact of marble waste as coarse aggregate on properties of lean cement concrete" *Case Stud Constr Mater* 4 (2016): 85-92.
16. Cement AP ASTM C150 of the following type: 1. Concr which will be contact with Sew Type II, Moderate Sulfate Resist 2:
17. Grout F ASTM C 476, except with a maximum slump of 4 inches, as measured according to ASTM C 143. C 143M
18. C39/C39M A Standard test method for compressive strength of cylindrical concrete specimens. Annu B ASTM Stand (2003).
19. Standard A. C78. 2010. Stand test method flexural strength concr (using simple beam with third-point load (ASTM C78-10) West Conshohocken, PA ASTM Int (2010).
20. Specimen CT ASTM C 31; one set of four standard cylinders for each compressive-strength test, unless otherwise directed. Mold store Cylind Lab test specimens except when field-cured test specimens are required.
21. Aggarwal, Yogesh and Rafat Siddique. "Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates" *Constr Build Mater* 54 (2014): 210-223.
22. Hameed, M Shahul, ASS Sekar and V Saraswathy. "Strength and permeability characteristics study of self-compacting concrete using crusher rock dust and marble sludge powder" Arab J Sci Eng 37 (2012): 561-574.
23. Designation A C496-71. "Stand Method Test Split Tensile Strength" *Cylind Concr Specimens* (1976).
24. Amin, Shereen K, Mostafa E Allam, Gihan L Garas and Hisham Ezz. "A study of the chemical effect of marble and granite slurry on green mortar compressive strength" *Bull Natl Res Cent* 44 (2020):19.
25. Ashby, MF. "Materials selection in mechanical design" (2011).

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