Study on Waste Marble as Partial Replacement of Coarse Aggregate in Concrete

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Abstract— Marble wastes is an industrial waste produced from cutting of marble stone for usage in various construction applications in India. Also, a large amount of marble is accumulating in the environment due to demolition of old structures having marble. This causes environmental pollution. Also, the process of manufacturing of natural aggregates uses a lot of energy and causes pollution. The use of waste marble as coarse aggregate in concrete reduces the amount of natural aggregate required. This work is concerned with studying the feasibility of partial replacement of coarse aggregates with marble. Varying percentages of replacement is considered (0%, 25%, 50%, 75% and 100%) for the cube specimens and the optimum percentage of replacement is found out.

Index Terms—- Coarse Aggregate, Waste Marble

1 INTRODUCTION

Marble waste is produced from marble industries as a result of production. More production equals more waste, more waste creates environmental contamination. A high volume of marble production has generated a considerable amount of waste materials; almost 70% of the minerals gets wasted in the mining, processing and polishing stages which have a serious impact on the environment. Also, a large amount of marble is accumulating in the environment due to demolition of old structures having marble. This causes environmental pollution. An economically viable solution to this problem should include utilization of these waste materials for new products especially in construction applications which in turn minimizes the heavy burden on the nation's landfills, saves natural resources, energy and reduces environmental pollution.

If the waste product of one industry is recycled as a substitute for the raw material of another industry, it will thereby reduce the environmental impact of both. Use of recycled aggregate in concrete can be useful for environment protection. Recycled aggregates are the materials for the future. Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate. The use of marble chips as coarse aggregate in concrete reduces the amount of natural aggregate required. This displaces mining process of natural aggregate, an energetically expensive and environmentally problematic process, while reducing both the need for land area for extracting resources and amount of industrial waste that must be disposed of. Now, waste marble has been found to be more useful and research has been conducted to examine their application. Waste marble is well usable instead of the usual aggregate in the concrete paving block production also.

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2 LITERATURE REVIEW

2.1 GENERAL

Literature survey is done by referring and going through articles and journals published in the related area of the studies to get detailed subject knowledge. Literature review refers to review of scholarly articles and journal papers. It helps us to evaluate and understand about previous findings in the topic of study.

2.2 LITERATURE SURVEY

Kore Sudarshan Dattatraya (2016) In this work, the impact of marble waste as a partial replacement for conventional coarse aggregate on the properties of concrete mixes such as workability, compressive strength, permeability, abrasion, etc. was evaluated. Coarse aggregate (75% by weight) was replaced by aggregate obtained from marble mining waste. The test results revealed that the compressive strength was comparable to that of control concrete. Other properties such as workability of concrete increased, water absorption reduced by 17%, and resistance to abrasion was marginally increased by 2% as compared to that of control concrete.

Jay P. Chotaliya et al. (2015) The objective of this study is to provide a more scientific evidence to support the reuse of accumulated marbles waste in India by investigating into the following hardened properties of concrete with waste marble chips - compressive strength, split tensile strength and flexure strength. These properties were studied by casting cube specimens, cylindrical specimens and beam specimens. Waste marble chips are fully replaced with natural coarse aggregate. The water cement ratio used was 0.45% by weight.

2.3 OBJECTIVE

The objective of project is to find out the suitability of using marble as partial replacement for coarse aggregate in concrete. Also, the optimum percentage of replacement is found out by casting cubes for different percentages of replacement and finding out their compressive strength.

2.4 SCOPE

The scope of the study is to research about sustainable concrete by incorporating waste marble as coarse aggregate. Using waste marble as aggregate will reduce the amount of natural aggregate required. It will displace the mining process of natural aggregate. It will utilize the marble waste which is usually dumped in landfills, thus providing possible solution to environmental contamination. It will reduce the overall cost of construction.

3 Methodology

Literature review of available journals on the topic is studied. Then, the first process of the project is the determination of the properties of materials by carrying out preliminary tests. Then, mix design of concrete is done. Slump tests are also carried out. Casting of cube specimens is done. Compression tests are carried out on the cast cubes. The last step of the project is the analysis and discussion of results.

4 Material Properties

This chapter is an introduction to the materials and their properties, used in the study. Properties of material used in this study were obtained either by testing of the material as per relevant BIS standards or were taken from the users manuals provided by the manufacturers

4.1 CEMENT

Portland Pozzolona Cement (PPC) is used for this study. Unlike Ordinary Portland Cement, Portland Pozzolana Cement (PPC) is manufactured by combination of pozzolanic materials. Pozzolana is an artificial or natural material which has silica in it in a reactive form. Along with pozzolanic materials in specific proportions, PPC also contains OPC clinker and gypsum. These pozzolanic materials include volcanic ash, calcined clay or silica fumes and fly ash which make around 15 percent to 35 percent of cement weight. It has low initial setting strength compared to OPC but hardens over a period of time with proper curing. Specific gravity of cement is determined. Siliceous material is added to concrete mixtures, to potentially lower the mix cost without harming the performance characteristics.

4.2 AGGREGATE

The role of the aggregate is to provide much better dimensional stability and wear resistance. Also, because they are less expensive than Portland cement, aggregates lead to the production of more economical concretes. Fine and coarse aggregates are the one of the major constituents in concrete. Manufactured sand (M-Sand) was used as fine aggregate for the test. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word. M-Sand is a substitute of river sand for concrete construction and it is produced from hard granite stone by crushing. Crushed rock of 10-20 mm size is used as coarse aggregates. Specific gravity, water absorption, sieve analysis tests were conducted to determine the properties.

4.3 WASTE MARBLE COARSE AGGREGATE (WMCA)

Marble has been used as an important building material, especially for decorative purposes for centuries. Disposal and re-using of the waste materials of the marble industry is one of the environmental problems all over the world. As a solution to these negative effects, the literature suggests that the marble waste can be used in the construction industry as partial percent substitutes for aggregate. Waste Marble Coarse Aggregate (WMCA) used is shown in Figure 1.

Figure 1 : WMCA

4.3.1 Specific Gravity (IS:2386-1963)

Specific gravity of aggregate is the ratio of the weight of given volume of aggregates to the weight of equal volume of water. Take about 500 g of sample and place it in the pycnometer and weigh. Pour distilled water into it until it is full. Eliminate the entrapped air by rotating the pycnometer on its side, the hole in the apex of the cone being covered. Wipe out the outer surface of pycnometer and weigh it (W4). Transfer the contents of the pycnometer into a tray, care being taken to ensure that all the aggregate is transferred. Fill the pycnometer with distilled water to the same level. Find out the weight (W2). Drain water from the sample through alter paper. Place the sample in oven in a tray at a temperature of 100°C to 110°C for 24 hours, during which period, it is stirred occasionally to facilitate drying. Cool the sample and weigh it (W3). Weight of pycnometer noted as (W1).

$$\text{Specific gravity of aggregate} = \frac{(W3-W1)}{(W2-W1) - (W4-W3)}$$

Figure 2 : Le- Chatelier Apparatus

4.3.2 Water Absorption of Aggregate (IS:2386-1963)

Water absorption gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests. Specific gravity test of aggregates is done to measure the strength or quality of the material while water absorption test determines the water holding capacity of the coarse and fine aggregates. The sample should be thoroughly washed to remove particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22°C and 32°C. After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 hrs afterwards. The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket onto one of the dry clothes and gently surface dried with the cloth, transferring it to a second dry cloth when the rest would remove no further moisture. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface- dry. The aggregates should be weighed (Weight W1). The aggregates should then be placed in an oven at a temperature of 100°C to 110°C for 24 hrs. It should then be removed from the oven, cooled and weighed (Weight W2).

Water absorption = $\frac{(W2-W1)}{W2} \times 100\%$

4.3.3 Sieve Analysis of Aggregates (IS:2386 (Part I) 1963)

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves. The test sample is dried to a constant weight at a temperature of 110 degree celsius and weighed. The sample is sieved by using a set of IS Sieves. On completion of sieving, the material on each sieve is weighed. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

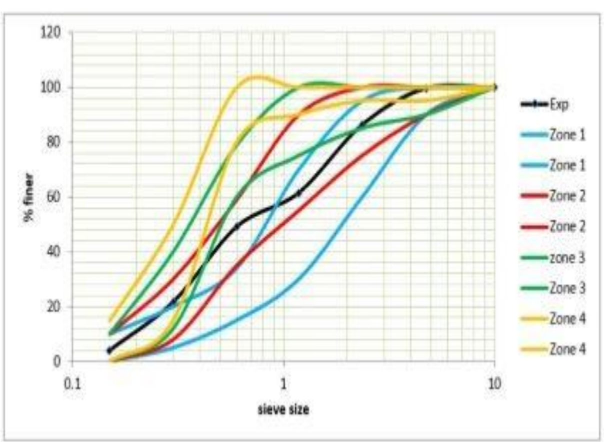

Figure 3 : Particle Size Distribution of Fine Aggregates

The results should be calculated and reported as:

i. The cumulative percentage by weight of the total sample
ii. Percentage by weight of total sample passing through one sieve and retained on next smaller sieve, to nearest 0.1 percent.

The results of the sieve analysis may be recorded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

4.3.4 Properties of Aggregates

The properties of aggregates taken are shown in Table 1.

Table 1: Properties of Aggregates

Properties	Fine aggregate	Coarse aggregate	WMCA
Specific gravity	2.69	2.74	2.72
Water absorption	0.806%	0.6%	0.5%
Sieve analysis	Zone II		

4.4 WATER

Water is an important ingredient of concrete. It chemically participates in the reactions with cement to form the hydration product, C-S-H gel. The strength of cement mortar depends mainly from the binding action of the hydrated cement paste gel. Potable drinking water having pH value ranging between 6 and 8 can be used for construction. The quantity and quality of water should be very carefully inspected and it should be free from any foreign materials. The strength of cement mortar depends mainly from the binding action of the hydrated cement paste gel. The attention is required to see that the initial hydration rate of cement should not be significantly affected. Potable water from the source was used for mixing and curing of concrete. Water used was free from any impurities and amount of acid, alkali, salt, organic materials etc. are within limit.

4.5 SUPER PLASTICIZER

Super plasticizers are admixtures for concrete, which is added in order to reduce the water content in a mixture or to slow the setting rate of the concrete while retaining the flowing properties of a concrete mixture. Ceraplast is one of the examples for super plasticizer.

Figure 4 : Super Plasticiser

4.6 REINFORCEMENT BAR

Thermally and Mechanically Treated bars (TMT) of grade Fe 500 is used as longitudinal and transverse reinforcement. For longitudinal reinforcement 10 mm diameter bars are used. 6 mm diameter bars are used as stirrups.

Figure 5 : Reinforcement bars tied with stirrups

5 MIX DESIGN

In this study, the waste marble aggregate was varied as 0%, 25%, 50%, 75%, and 100%.

Mix design parameters

Control mix:

For M20 Concrete,

Target Strength, f = fck + 1.65*S

= 20+ (1.65*4)

= 26.6 N/mm²

I. 0 % replacement or standard mix :

Water content, w = 210 L

Cement content, c = 210/0.45 = 467 kg

Super plasticizer = 0.35 % (Cement)

Volume of coarse aggregate = 0.63

Volume of fine aggregate = 0.37

1000 = W + C/SC + F.A/SFA +C.A/SCA + P.A/SPA

1000 = 210+ (467/2.92) + (FA/2.69*(1/0.37)) + (0.35*467/(1.15X100))

FA = 626kg

1000 = 210 + (467/2.92) + (CA/2.74*(1/0.63)) + (0.35*467/(1.15X100))

CA = 1085 kg

Mix proportion; 0.45: 1:1.34:2.33

II. 100 % replacement of coarse aggregate with WMCA:

Water content, w = 210 L

Cement content, c = 210/0.45 = 467 kg

Super plasticizer = 0.35 % (Cement)

Volume of coarse aggregate = 0.63

Volume of fine aggregate = 0.37

1000 = W + C/SC + F.A/SFA +C.A/SCA + P.A/SPA

1000 = 210+ (467/2.92) + (FA/2.69*(1/0.37)) + (0.35*467/(1.15*100))

FA = 626 kg

1000 = 210 + (467/2.92) + (CA/2.72*(1/0.63)) + (0.35*467/(1.15*100))

CA = 1077 kg

Mix proportion; 0.45: 1:1.34:2.30

Similarily, for 25%, 50%, and 75%, the required quantities of materials was found out and shown in Table 2.

Table 2 : Quantities of Materials for Mix

w/c ratio	Replace ment (%)	Water (kg/m³)	Cement (kg/m³)	FA (kg/m³)	CA (kg/m³)	WMCA (kg/m³)
0.45	0	210	467	626	1085	0
	25	210	467	626	808	270
	50	210	467	626	539	539
	75	210	467	626	270	808
	100	210	467	626	0	1077

6 WORKABILITY OF THE MIX

Workability of concrete is the property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. Workability is directly proportional to water cement ratio. An increase in water-cement ratio increases the workability of concrete. It also related compaction as well as strength of concrete.

After actually mixing concrete in the mix proportion, the workability is checked in the wet stage. For the water cement ratio 0.45 and water content of 210 litres, the slump is found to be 75 mm. The slump obtained, 75 mm, is less than 90 mm. As per IS 7320: 1974, the slump value 75 mm is taken for medium workability (60 to 90mm).

7 TESTING OF CUBES

Casting of concrete specimens is done as per Indian Standards. M20 mix is chosen and mix design is done. Mix ratio obtained is 0.45: 1: 1.34: 2.29. Compressive strength of concrete is determined by making cubes of size 150 mm x 150 mm x 150 mm. Cubes are made by finding out the required amount of quantities of materials using mix proportion. Mixing of concrete is carried out manually.

First, the coarse aggregate and fine aggregate are mixed. After that, the cement is poured into the mixer. Required amount of water is added. And the resulting concrete with uniform appearance is transferred to moulds. In assembling the mould for use, the joints between the sections of mould is thinly coated with mould oil and a similar coating of mould oil is applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling.

Figure 6 : Standard cubes removed from mould for testing

The interior surfaces of the assembled mould are thinly coated with mould oil to prevent adhesion of the concrete. Necessary compaction is given and the specimens to be tested are stored on the site, under sacks for 24 hours from the time of adding the water to the other ingredients. After 24 hours of air curing, the specimens are transferred to the curing tank.

Figure 7 : WMCA replaced cubes out of mould for testing

Figure 8 : Cube placed in CTM for loading

Figure 9 : Cube specimen after failure

Figure 6 and Figure 7 show the unmolded cubes for testing. After 28 days of curing, the compressive strength of cubes were found out. The test is done in Compressive Testing Machine (CTM).

8 TEST RESULTS

Test results are shown in Table 3 and Table 4. Table 3 shows the compressive strength test results of standard cubes. Table 4 shows the compressive strength test results of cubes with WMCA. Highest strength was obtained at 50% replacement by marble aggregate.

Table 3 : Compressive strength test results of standard cubes

CUBE No.	C/S (mm^2)	LOAD (N)	28 DAY STRENGTH (N/mm^2)
1	150 x 150	630000	28.00
2	150 x 150	639000	28.40
3	150 x 150	628000	27.91
Average			28.10

Table 4 : Compressive strength test results of cubes with WMCA

Percentage of WMCA	C/S Area (mm^2)	Load (N)	28 day average compressive strength (N/mm^2)
0%	150 x 150	632000	28.10
25%	150 x 150	573000	25.46
50%	150 x 150	635000	28.22
75%	150 x 150	558000	24.80
100%	150 x 150	505000	22.44

9 CONCLUSION

The physical properties of marble (specific gravity, water absorption, etc) satisfies the IS code specifications for coarse aggregates. So, marble can be used as coarse aggregate in concrete. Hardened properties such as compressive strength, split tensile strength and flexural strength increases with increase in marble content upto 50%, and then shows a decreasing trend. The compressive strength of the concrete mix containing 50% WMCA is greater than that of control mix. Concluding the observations, the optimum percentage replacement of marble waste as coarse aggregate in concrete is 50%.

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11 REFERENCES

[1] Gupta (2019), " Effect of Various Coarse Aggre- gate Sizes and Different Marble Chip Proportions on Properties of Pervious Concrete", *International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN 2278-3075, Volume 8, Issue-10, August 2019*

[2] Kok Yung Chang, Wai Hoe Kwan, Hui Bun (2018), " The Application of Waste Marble as Coarse Aggregate in Concrete Production" *Scientific Research Journal Vol 15 No.1 (2018)*

[3] Locati Francisco, Falcone Dario, Marfil Silvina (2014) "Dedolomitisation and Alkali-silica Reactions in Low-expansive Marbles from the Province of Cordoba, Argentina – A microstructural and chemical study" , *Elsevier,Construction and Building Materials 58 (2014) 171–181*

[4] Hanifi Binici, Tahir Shah, Orhan Aksogan, Hasan Kaplan (2008) " Durability of Concrete Made with Granite and Marble as Recycle Aggregate", *Elsevier, Journal of Materials Processing Technology 208 (2008) 299–308*

[5] Kore Sudarshan Dattatraya and Vyas A. K. (2016), "Performance Evaluation of Concrete using Marble Mining Waste ",*SSP - Journal of Civil Engineer- ing Vol. 11, Issue 2, 2016*

[6] IS 383-1970 : Specification for Coarse and Fine Aggregates From Natural Sources For Concrete, Bureau of Indian standards.

[7] IS 2386-1963(1-8) : Methods of Test for Aggregates for Concrete, Bureau of Indian standards.

[8] IS 456-2000 : Plain and Reinforced Concrete - Code of Practice, Bureau of Indian standards.

[9] IS 10262-2009 : Guidelines for Concrete Mix Design Proportioning, Bureau of Indian standards.

[10] Shetty M.S., Concrete Technology - Theory and Practice, *S Chand Publication, 2013*