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Durability Assessment of Concrete Incorporating Marble Waste Powder and Ceramic Waste Powder

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ABSTRACT: Cement is a major construction material worldwide. Cement manufacturing industry is one of the carbon dioxides emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of greenhouse gases, such as CO₂ to the atmosphere. And the increase in the concrete demand due to the rapid industrialization and urbanization may lead to a shortage of natural resources. Therefore, the use of recycled material in the batching of concrete will be helpful to meet the demands of the time without compromising the quality of concrete production. One such waste material produced in India is Marble Waste Powder (MWP) that is generated from the marble factories during cutting of the marble stones. Second is the Ceramic Waste Powder (CWP), the ceramic industry inevitable generates wastes, irrespective of the improvements introduced in the manufacturing process. In the ceramic industry, about 15%-30% production goes as waste, which in turn have a damaging effect on the environment. In this project, the cement has been combined replaced by ceramic waste powder and marble waste powder accordingly in the range of 0%, 5%, 10%, 15% & 20% by weight for M-20 grade concrete and their durability properties are found out.

KEYWORDS: Marble waste powder, Ceramic waste powder, concrete, etc.

I. INTRODUCTION

1.1 Marble Waste Powder:

The estimated values for the world's marble reserves is approximately 15 billion cubic meters, and marble industries are working in almost fifty countries globally. The factories in India utilize water for the cutting of the marble stones, which in turn generate a significant amount of marble slurry. Upon drying, this slurry transforms into marble waste powder (MWP), with 90 percent of the particles being smaller than 200 μm . The accumulation of such waste powder is harmful to the environment.

Marble blocks are extracted from the quarries and processed at marble factories. Dust and broken aggregates are the by-products of marble, produced in the marble processing like cutting and polishing stages. Around 20–30% of the marble blocks transform into powder residue. Millions of tons of waste material are produced in this process which is blindly disposed of to a nearby environment. The waste slurry created is aimlessly dumped on empty land, waterway banks, and wood regions. Due to the high degree of fineness of the slurry particles, pores within fertile soil are filled by these particles which prevent the water percolation in the soil and reduce its fertility. Slurry particles when dried are lifted into the air, by winds, and can bring about respiratory issues to nearby people.

To cope with such overexploitation of the resources and negative impacts of MWP on the environment, it is therefore important to consume and treat these wastes in a well-planned manner and legitimize the use of MWP in the development of auxiliary concrete mixes.

1.2 Ceramic Waste Powder:

Ceramic waste from factories producing materials for the construction industry has been accumulating frequently, creating increasingly large piles. Although they are usually chemically inert, the waste accumulates depending upon their size and the scant environmental control exercised, have a significant visual impact that destroys the intrinsic quality of the Landscape.

Indian ceramic production is 100 Million ton per year. In ceramic industry, about 15%-30% waste Material generated from the total production. This waste Is not recycled in any form at present. However, the Ceramic waste is



durable, hard and highly resistant to Biological, chemical, and physical degradation forces. In addition to helping protect the environment, use of such waste offers a series of advantages such as a reduction in the use of other raw materials, contributing to an economy of natural resources. Moreover, reuse also offers benefits in terms of energy, primarily when the waste is from kiln industries (the ceramics industry) Where highly endothermic decomposition reactions have already taken place, thus recovering the energy previously incorporated during production.

Factors associated with the large-scale use of the resources are the growth of population, technological advancement, industrialization, and the desire to arrive at a better quality of life for the people. As an outcome, the idea of manageability has developed, characterized as a harmony between the utilization and assurance of a good future life. Therefore, the usage of some alternative resources is the utmost need of the hour to maintain natural quarries.

II. EXPERIMENTAL PROGRAM

2.1 Materials Used

- **Cement:** Portland Pozzolana Cement of Coromandel King Company is used in present research.
- **Coarse Aggregate:** The fractions from 10 mm to 8 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is being use.
- **Fine Aggregate:** Those fractions from 2.36 mm to 150 microns are termed as fine aggregate. The river sand is used in combination as fine aggregate conforming to the requirements of IS: 383.

Table No. 2.1: Physical properties of cement & aggregates

Properties	Cement	Fine Aggregate	Coarse Aggregate
Specific Gravity	3.15	2.69	2.85
Initial Setting Time	32 Minutes	--	--
Final Setting Time	580 Minutes	--	--
Standard Consistency of Cement	30 %	--	--
Free Moisture Content	--	2 %	--
Water Absorption	--	1.2 %	0.5 %
Max. Size	--	2.36m	10m

- **Marble Waste Powder:**MWP used in this research is obtained from locally available marble quarrying factory.
- **Ceramic Waste Powder:** CWP used in this research is obtained from indiamart.



Fig. No. 2.1: Marble Waste Powder Fig. No. 2.2: Ceramic Waste Powder

Table No. 2.2: Physical properties of marble waste powder and ceramic waste powder

Physical Properties	Marble Powder	Ceramic Powder
Specific Gravity	2.71	3.11
Dry Moisture Content	1.58 %	1.62 %
Bulk Density (kg/m3)	1118	1323.43
Fineness Modulus	2.03	2.43



Table No. 2.3: Chemical properties of marble waste powder and ceramic waste powder

Chemical Properties	Marble Powder(%)	Ceramic Powder (%)
SiO2	0.63	63.29
Al2O3	0.40	18.29
Fe2O3	0.20	4.32
CaO	55.6	4.46
MgO	0.10	0.72
CaCo3	90	--
P2O5	--	0.16
K2O	--	2.18
Na2O	--	0.75
SO3	--	0.10
CL	0.10	0.005
TiO2	--	0.61
SrO2	--	0.02
Mn2O3	--	0.05
L.O. I	43	1.61

- **Water:**Free from deleterious matter and shall fulfil the requirement as per IS 456:2000.
- **H₂SO₄:**Sulphuric Acid
- **MgSO₄:**Magnesium Sulphate
- **NaCl:**Sodium Chloride
- **AgNO₃:**Silver Nitrate Solution
- **AgCl :**Silver Chloride

2.2 Design Mix

A mix M20 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples. Water/Cement ratio: 0.5&Mix proportion: 1: 2.11: 2.07

Table No. 2.4: Mix proportion for 1 cubic meter **Table No. 2.5: Mix proportion**

Content	In Kg
Cement/ Marble/ Ceramic	416
Water	208
Fine aggregate	881.24
Coarse aggregate	861.84

Sr. No.	Concrete Type	Concrete Design Mix Proportion				
		C	MWP	CWP	FA	CA
1	M0	1.00	-	-	2.11	2.07
2	M1	0.95	0.025	0.025	2.11	2.07
3	M2	0.90	0.05	0.05	2.11	2.07
4	M3	0.85	0.075	0.075	2.11	2.07
5	M4	0.80	0.10	0.10	2.11	2.07

Table No. 2.6: Mix proportion

Sr. No.	Concrete Type	PPC cement Replacement with Ceramic waste powder	PPC cement Replacement with Marble waste powder
1	M0	0 %	0 %
2	M1	2.5 %	2.5 %
3	M2	5 %	5 %
4	M3	7.5 %	7.5 %
5	M4	10 %	10 %

2.3 Methodology

2.3.1 Sorptivity:

To examine the durability characteristics of concrete, sorptivity is employed. Sorptivity characteristics of concrete for structures located above ground level would be more appropriate, sorptivity coefficient can be determined by means of a simple test allowing one face of concrete specimen be in contact with water.

Test Method:

In this test method standard 80mm diameter and 50mm thick specimen is casted. In the following day of casting, the specimens are de-moulded and located in water curing condition for the period of 28days. Water absorption (sorptivity) tests is carried out to determine the sorptivity coefficient of concrete specimens which is preconditioned in oven at 105°C for 24 hr. and then cooled down within desiccators for 24h to achieve a constant moisture level. Then, sides of the concrete

specimens are sealed by electrical tape to avoid evaporative effect as well as to maintain uniaxial water flow during the test and the opposite faces left open see in fig. Before locating the specimens on water, their initial weight is recorded. One face of specimen is in contact with water, while the water absorption at 30 minutes is noted by taking weight. The specimen is submerged 5 mm in water. Sorptivity coefficient can be calculated by the following expression.

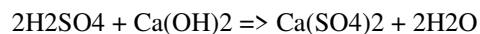
$$S = I / t^{1/2}$$

Where, S = sorptivity in mm, T = elapsed time in mint. $I = \Delta w / Ad$ ΔW = change in weight = $W_2 - W_1$ W_1 = Oven dry weight of cylinder in grams W_2 = Weight of cylinder after 30 minutes capillary suction of water in grams. A = surface area of the specimen through which water penetrated. D = density of water

2.3.2 Acid Attack:

The chemical resistance of the concrete is studied through chemical attack by immersing concrete blocks of size 100mm x 100 mm x 100mm in sulphuric acid (H₂SO₄) solution. After period of curing the specimens is removed from the curing tank and their surfaces is cleaned with soft nylon brush to remove weak reaction products and loose material from the specimen. The initial weights are measured and the specimens are identified with number. The specimens are immersed in 3% H₂SO₄ solution. The solution is replaced at regular intervals to maintain constant pH4 throughout the test period.

Concrete is susceptible to acid attack because of its alkaline nature. The components of the concrete paste break down during contact with acids. Most pronounced is the dissolution of calcium hydroxide which occurs according to the reaction.



The results of acid attack are in terms of the weight loss after 28 days for all the concrete specimens. Weight loss, reduction in compressive strength is used to evaluate the extent of concrete deterioration due to sulphuric acid attack.

$$\text{Weight loss in percentage} = (W_1 - W_2) / W_1 \times 100$$

2.3.3 Sulphate Attack:

For this purpose, cube specimens of size 100mm x 100mm x 100mm were cast. The test was conducted after 28 days of water curing. The specimens were then subjected to a solution with magnesium sulphate. The chemical resistance of the concrete is studied through chemical attack by immersing concrete block in magnesium sulphate (MgSO₄) solution. After period of curing tank and their surfaces are cleaned with soft nylon brush to remove weak reaction products and loose material from the specimens identified with number. The method for investigation of the damage has been measurement of surface scaling of material by weighing at the age of 28 days.

Chemistry of Sulphate Attack

The end result of sulphate attack can be excessive expansion, delamination, cracking and loss of strength. Concrete may suffer sulphate attack that magnesium sulphate can be more aggressive. Magnesium Sulphate (MgSO₄) has a more far reaching action than other sulphate it reacts not only with calcium hydroxide and calcium hydrated aluminates like other sulphates but also decomposes the hydrated calcium silicate completely and make it a fireable mass.



2.3.4 Salt Ponding Test (Chloride Diffusion Test):

The salt ponding test (SPT) is the most widely accepted test method for determining the chloride diffusivity of concrete and is conducted as per the guidelines described in ASTM C 154312 and AASHTO T259. It is used to determine the diffusion coefficient (Dp) of concretes. At the age of 28 days of curing, five cylindrical specimens of 100mm diameter and 200mm height are air dried and lateral surface of the specimens are coated with epoxy. One edge of the specimen is sealed around outside using acrylic sheet to create the dam/pond for NaCl solution. The specimens are subjected to continuous ponding with 3% NaCl solution to a depth of 15 mm for 28 days and a temperature of 24-25° is maintained throughout the test period. The top of the dam is sealed with plastic wrap to minimize the evaporation and additional solution is added if necessary to maintain the depth of 15 mm. At the end of 28 days exposure, the specimens are allowed to dry and the surface is wire brushed until all the salt crystal build up is completely removed. Chloride penetration depth and then the diffusion coefficient is evaluated for concrete.

Following two procedures are followed to evaluate chloride diffusion coefficient: Colorimetric Method:

In colorimetric method, 0.1 N silver nitrate solution (AgNO3) will be sprayed on a cross-section of freshly split concrete to identify the depth of chloride ion penetration. The sprayed solution creates a chemical reaction where the chlorides present in concrete react and produce a visibly clear white or silver precipitate (AgCl). A brownish colour will appear on the surface where no chlorides were present (AgNO3 reacts with hydroxides present in concrete). In the present study, two specimens are used for colorimetric study. The specimens are broken into two halves and 0.1 N AgNO3 is sprayed on freshly split specimens. Chloride penetration depth is measured when the white silver chloride precipitation on the split surface is clearly visible (nearly after about 15 min.).

$$D_{pc} = \frac{\left[\frac{x_d}{\operatorname{erf}^{-1}\left(1 - \frac{C}{C_o}\right)} \right]^2}{4t}$$

Where, Dpc = Diffusion Coefficient xd = average penetration depth (cm) C = Chloride concentration at the colour change boundary, C = 0.07 N Co = Chloride concentration in the salt ponded solution Co = 0.52 N t = Exposure duration (sec)

III. RESULTS AND DISCUSSION

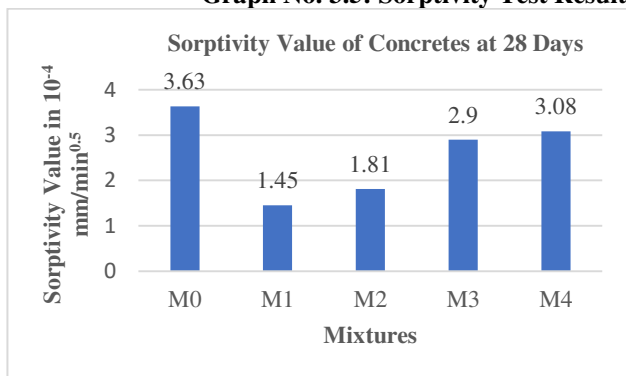
3.1 Sorptivity

In this test method standard 80mm diameter and 50mm thick specimen is casted.

Table No. 3.5: Sorptivity at 28 day

Mix	Dry Weight in grams (W1)	Wet Weight in grams (W2)	Sorptivity value in 10 ⁻⁴ mm/min ^{0.5}
M0	592	602	3.63
M1	592	596	1.45
M2	598	603	1.81
M3	656	662	2.9
M4	632	540.5	3.08

Graph No. 3.5: Sorptivity Test Results



3.2 Acid Attack

The chemical resistance of the concrete is studied through chemical attack by immersing concrete blocks of size 100mm x 100 mm x 100mm in sulphuric acid (H₂SO₄) solution.



Table No. 3.6: Weight Loss After Acid Attack Graph No. 3.6: Weight Loss After Acid Attack

Mix	Weight Before Acid Attack in grams (W1)	Weight After Acid Attack in grams (W2)	Weight Loss in %
M0	2950	2793	5.32
M1	2893	2733	5.53
M2	2914	2742	5.90
M3	2829	2654	6.18
M4	2847	2667	6.32

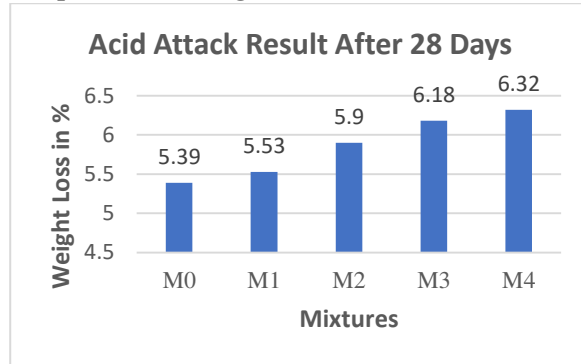
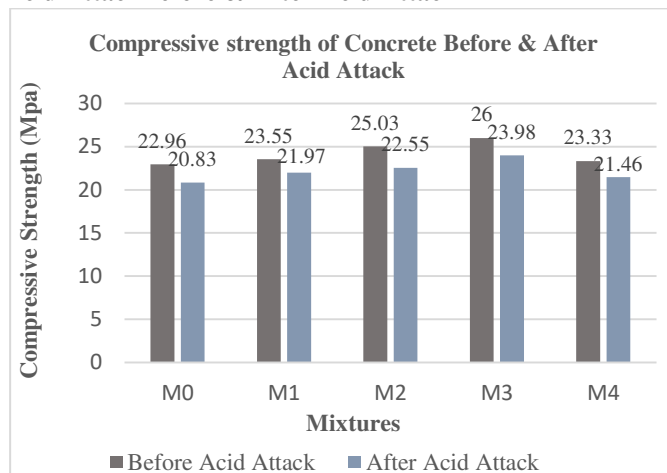


Table No. 3.7: Compressive Strength Before & After Acid Attack Graph No. 3.7: Compressive Strength Before & After Acid Attack

Mix	Compressive Strength Before Acid Attack (Mpa)	Compressive Strength After Acid Attack (Mpa)
M0	22.96	20.83
M1	23.55	21.97
M2	25.03	22.55
M3	26	23.98
M4	23.33	21.46



3.3 Sulphate Attack

For this purpose, cube specimens of size 100mm x 100mm x 100mm were casted.

Table No. 3.8: Weight Loss After Sulphate Attack Graph No. 3.8: Weight Loss After Sulphate Attack

Mix	Weight Before Sulphate Attack in grams (W1)	Weight After Sulphate Attack in grams (W2)	Weight Loss in %
M0	2889	2819	2.42
M1	2831	2770	2.15
M2	2799	2744	1.96
M3	2862	2797	2.27
M4	2787	2717	2.62

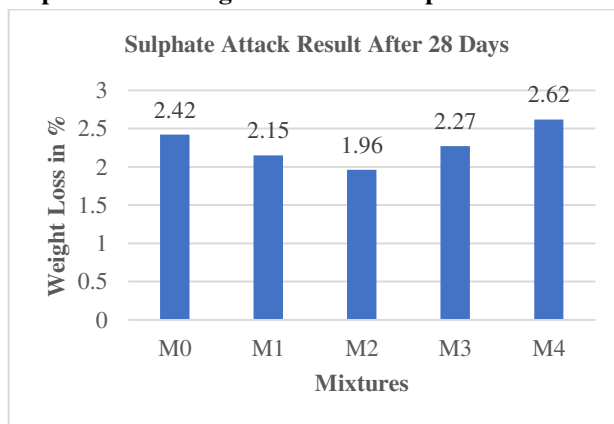
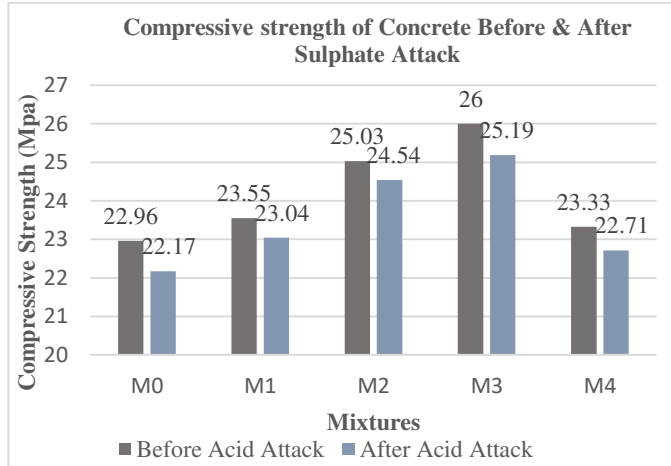




Table No. 3.9: Compressive Strength Before & After Sulphate Attack

Mix	Compressive Strength Before Sulphate Attack (Mpa)	Compressive Strength After Sulphate Attack (Mpa)
M0	22.96	20.83
M1	23.055	21.97
M2	25.03	22.55
M3	26	23.98
M4	23.33	21.46

Graph No. 3.9: Compressive Strength Before & After Sulphate Attack



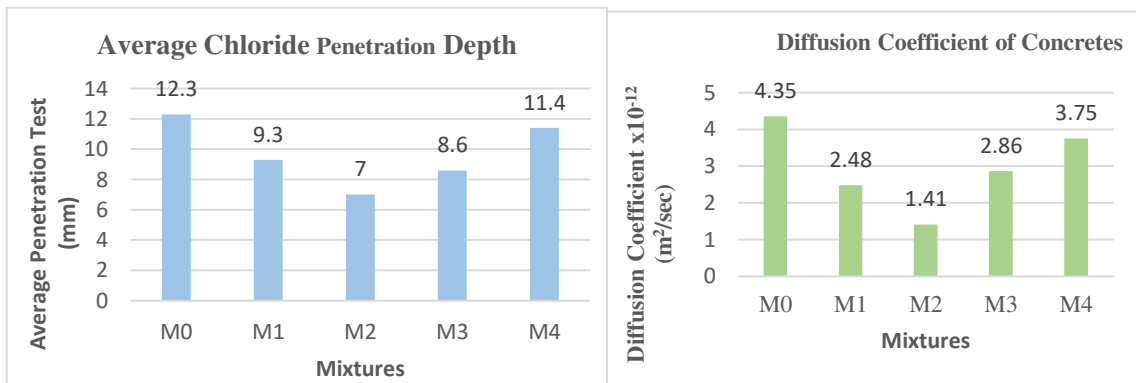
3.4 Salt Ponding Test (Chloride Diffusion Test)

Five cylindrical specimens of 100mm diameter and 200mm height were casted.

Table No. 3.10: 28 Days Salt Ponding Test Result

Mix	Average penetration depth (mm)	Diffusion coefficient, (m ² /sec)
M0	12.3	4.35 x 10 ⁻¹²
M1	9.3	2.48 x 10 ⁻¹²
M2	7.0	1.41 x 10 ⁻¹²
M3	8.6	2.86 x 10 ⁻¹²
M4	11.4	3.75 x 10 ⁻¹²

Graph No. 3.10: Average Chloride Penetration Depth Graph No. 3.11: Diffusion coefficient of Chloride



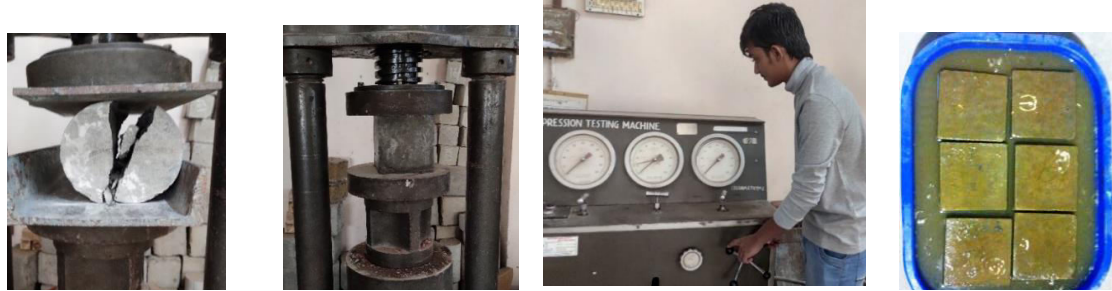


Fig. No. 3.1: Compression & Split Tensile Strength Test on CTM Fig. No. 3.2: Cubes Immersed in H₂SO₄

IV. CONCLUSION

From the experimental work carried out following results were achieved:

- Sorptivity value of normal concrete specimen is 60% more as compared to a concrete specimen in which cement is replaced by 5 % with MWP and CWP. Above 5% replacement sorptivity value is increased gradually with increase in cement percentage replaced.
- After acid attack test we have seen that normal concrete specimen has 5.32% loss in weight and other cement replaced concrete specimens show weight loss between 5.53% to 6.32 %. Weight loss is gradually increased with increase in percentage cement replaced.
- After sulphate attack test we have seen that normal concrete specimen has 2.42% loss in weight and concrete specimen of which cement is replaced with MWP and CWP by 10% shows 1.96% loss in weight. Loss in weight is decreased till 10% replacement of cement after that weight loss is gradually increased with increase in percentage cement replaced.
- After salt ponding test we have seen that normal concrete has 12.3 mm average penetration depth and concrete specimen of which cement is replaced with MWP and CWP by 10% shows 7 mm average penetration depth which is 43 % less as compared to normal concrete specimen.
- It is the possible alternative solution of safe disposal of MWP and CWP.
- Durability properties of concrete specimens are directly proportional to percentage of cement replaced till a certain point.

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