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Strength Assessment of RCC Beam With Partial Replacement of Metakaolin and Marble Dust

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Abstract: The most popular and adaptable building material is concrete, which is typically used to withstand compressive stress. A few pozzolanic elements can be added as admixtures to improve the various qualities of concrete. Calcified clay, or metakaolin, is widely accessible in Gujarat, Maharashtra, Bombay, and other places. It is the clay mineral kaolinite in a dehydroxylated state. Metakaolin particles are smaller than cement particles in size. Marble dust is produced by the industries that cut and manufacture marble. Approximately 3500 metric tons of marble dust slurry is produced daily in India. Therefore, marble dust may be found extremely cheaply and simply. Because marble dust has some advantages over cement, it is recommended to utilize it in part. The current study details an experimental program designed to explore the flexural behavior of reinforced concrete beams where river sand was partially replaced with marble powder in preparation for concrete and metakaolin was used in place of some of the cement. In this work, partial cement replacement has been carried out using MK (Metakaolin) at 5% and 10% and MP (Marble Powder) at 5%, 10%, 15%, and 20%. Concrete manufactured with MK-MP has been compared to conventional concrete of grade M30 in terms of both compressive and tensile strength. The Rapid Chloride Migration Test, or RCMT, was also used to examine the durability of concrete.
Keywords: Metakaolin, Marble Powder, Flexural Behavior, Rapid chloride Migration Test

I. INTRODUCTION

In this study, partial substitution of cement with metakaolin and marble powder was conducted because the usage of cement in the construction sector is growing daily along with its cost. Calcinied clay, or metakaolin, is widely accessible in Gujarat, Maharashtra, Bombay, and other places. It is the clay mineral kaolinite in a dehydroxylated state. China clay, also referred to as kaolin, is a stone with a larger percentage of Kaolinite that was traditionally utilized in the production of porcelain, or ceramic material. Metakaolin particles are smaller than cement particles in size. Marble dust is produced by the industries that cut and manufacture marble. Approximately 3500 metric tons of marble dust slurry are produced daily in India. Therefore, marble dust may be found extremely cheaply and simply. Certain enterprises used to use natural streams to wash away this marble powder, which pollutes the water and harms the ecosystem. Similar to this, using MK results in "green concrete" because no carbon dioxide is released during its manufacturing. MK is also a useful admixture for high early-age strength, or HPC, among other properties. Because making cement and clinker releases a lot of carbon dioxide into the atmosphere, this leads to a 3-5% rise in greenhouse gas emissions and global warming.

OBJECTIVES

- To investigate mechanical characteristics at 7, 14, and 28 days of curing by substituting metakaoline and marble powder for some of the cement under standard curing conditions. This includes compressive strength, split tensile strength, and flexural strength.
- To lessen pollution in the environment by using waste materials in concrete.
- To create environmentally friendly concrete.

- To investigate the characteristics of recently cast concrete using marble dust and metakaoline.
- To assess the concrete's compressive, tensile, and flexural strengths in order to determine whether metakaoline and marble powder combined are feasible.

2. METHODOLOGY

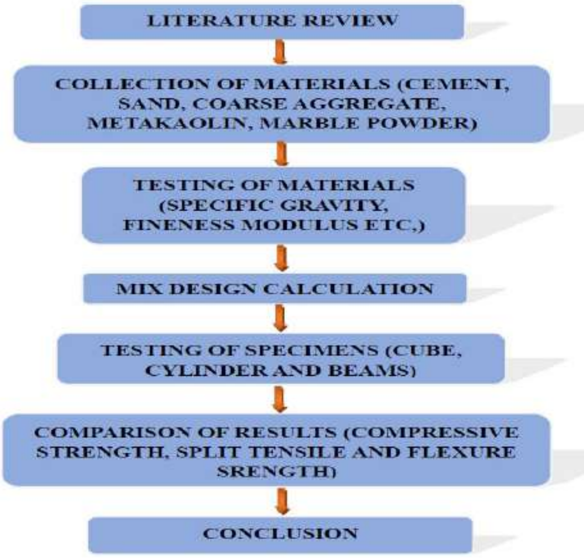

Fig. 1 Methodology

3. MATERIALS

Cement

Fine mineral powder, or cement, is produced using extremely exacting procedures. When this powder is combined with water, it becomes a paste that solidifies and bonds when submerged in water. Cement's composition determines its qualities because the powder's composition and fineness can differ.

Fig. 2 Cement

Fine Aggregate

Sand should not contain any noticeable amount of clay and should be firm, long-lasting, clean, and free of organic materials and sticky coatings. Hazardous impurities such as iron, pyrites, coal particles, lignite, mica shale, or other laminated material, alkali, and organic impurities in amounts or forms that compromise the durability or strength of mortar or concrete are not allowed in sand.

Fig. 3 Fine Aggregate

Coarse Aggregate

Fig. 4 Coarse Aggregate

The nearby quarry provided the crushed material for the project. The aggregate used in this experiment was tested in accordance with IS: 2386-1963(I, II, III) specifications, with a depth of 20 mm.

Metakaolin

Among pozzolanic materials for use in concrete, metakaolin is arguably the most effective. It is created when China clay, a mineral known as kaolin, is heated to a temperature of 600–800 degrees Celsius. It is a product that is intended for use rather than a by-product. Metakaolin is kaolin clay that has been subjected to control heating to produce an amorphous alumino silicate that reacts with concrete in a manner akin to that of other pozzalans. Calcium hydroxide interacts with metakaolin. and mixes with it to create more cementing chemicals, which give concrete its strength.

Fig. 5 Metakaolin

Marble Powder

It is a necessary part of rocks that are metamorphic and igneous. The size ranges from tiny granules that glitter on rock surfaces to specimens that weigh a metric ton. White powder, which is crushed marble powder, is substituted for fine aggregate in regular concrete in these studies. The used range of particle sizes is 10–45 m. Calcite, dolomite, or serpentine minerals make up the majority of the crystalline rocks that make up marbles. The cutting operation produces a significant amount of powder. The environment is harmed by the waste stuff produced.

Fig. 6 Marble Powder

4. MIX DESIGN

Cement = 359 kg/m^3
Water = 158 l/m^3
Fine aggregate = 815 kg/m^3
Coarse aggregate 20mm = 932 kg/m^3
12mm = 233 kg/m^3 (20% By Total weight of Coarse Aggregate)
Chemical admixture = 1.436 kg/m^3 (0.4% by the weight of cement)
Density of concrete = 2430 kg/m^3
Water-cement ratio = 0.44
Mix Proportion by weight = 1: 2.27: 3.25

Table 1 Mix Ratio

Water	Cement	Fine Aggregate	Coarse Aggregate
158	359	815	1165
0.44	1	2.27	3.25

5. RESULT & DISCUSSION

Compressive Strength

The ability of a material or structure to resist pressing pressures directed axially is known as its compressive strength. 150 x 150 x 150 mm cubes were cast, and specimens were subjected to compressive strength tests after 7, 14, and 28 days. The specimens are put in a compression testing apparatus, the cube is loaded, and the load at failure is recorded as the failure load.

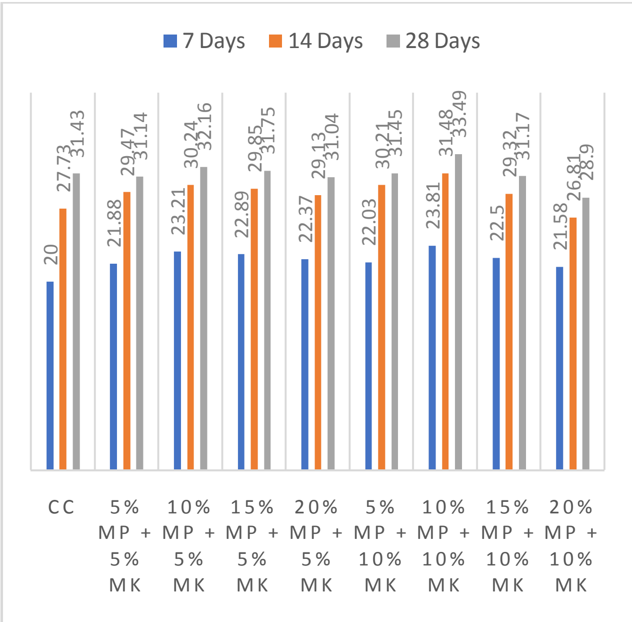

Fig. 7 Comparison of Compressive Strength of Concrete

Split Tensile Strength

One of the fundamental and significant characteristics of concrete that has a significant impact on the degree and amount of cracking in structures is its tensile strength.

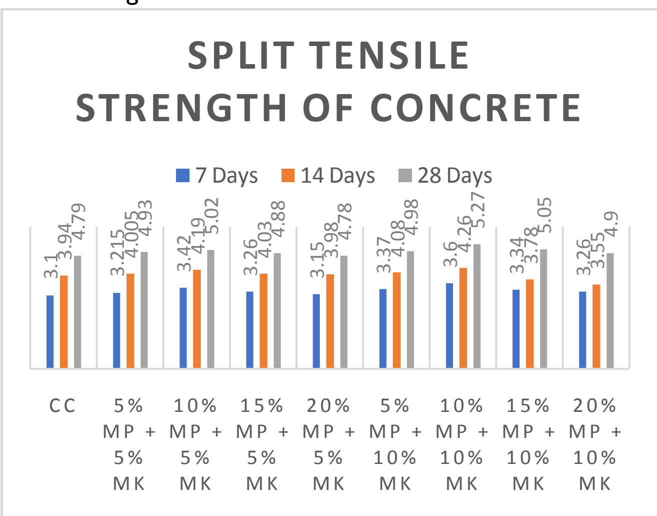

Fig. 8 Comparison of Split Tensile Strength of Concrete

Furthermore, because of its brittle character, the concrete is exceedingly weak under tension.. It is therefore not anticipated to withstand the direct tension. In other words, when tensile pressures are greater than tensile strength, concrete fractures. Therefore, in order to ascertain the load at which the concrete members may break, it is imperative to ascertain the tensile strength of concrete. Additionally, one way to ascertain the tensile strength of concrete is to conduct a splitting tensile strength test on a concrete cylinder. A 150 mm by 300 mm concrete cylinder's tensile strength was measured using split tensile strength according to code IS 5816:1999 technique. The specimens are cured under ambient temperatures.

Flexural Strength

The tensile strength of concrete slabs or beams is measured by their flexural strength. The amount of stress and force that an unreinforced concrete slab, beam, or other structure can sustain before bending or failing is known as its flexural strength. Bend strength modulus of rupture and fracture strength are other names for flexural strength. The flexural test provides an indirect assessment of the tensile strength of concrete. It evaluates the capacity of unreinforced concrete slabs or beams to tolerate bending failure. The modulus of rupture (MR), which stands for MPa or psi, is the outcome of the flexural test on concrete. One of two methods may be used for the concrete flexural test: the center-point load test (ASTM C293) or the three-point load test (ASTM C78).

Table 2 Flexural Strength of Concrete

S. No.	Mix	No. of Days Curing	Load (kN)	Flexural Strength in N/mm^2
1	CC	7 Days	14	2.90
2		14 Days	17	3.53
3		28 Days	20	4.15
4	5% MP + 5% MK	7 Days	15	3.11
5		14 Days	18	3.73
6		28 Days	21	4.36
7	10% MP + 5% MK	7 Days	16	3.32
8		14 Days	20	4.15
9		28 Days	23	4.77
10	15% MP + 5% MK	7 Days	15	3.11
11		14 Days	19	3.94
12		28 Days	22	4.56
13	20% MP + 5% MK	7 Days	15	3.11
14		14 Days	18	3.73
15		28 Days	21	4.36
16	5% MP + 10% MK	7 Days	16	3.32
17		14 Days	19	3.94
18		28 Days	22	4.56
19	10% MP + 10% MK	7 Days	19	3.94
20		14 Days	22	4.56
21		28 Days	25	5.19
22	15% MP + 10% MK	7 Days	15	3.11
23		14 Days	18	3.73
24		28 Days	21	4.36
25	20% MP + 10% MK	7 Days	14	2.90
26		14 Days	16	3.32
27		28 Days	19	3.94

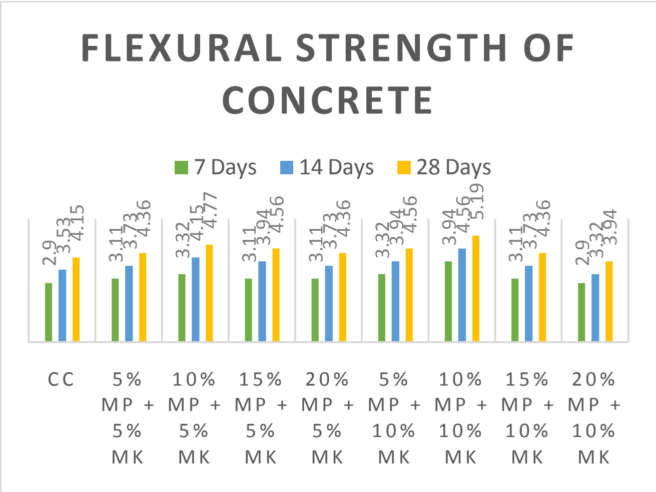

Fig. 9 Comparison of Flexural Strength of Concrete

Rapid Chloride Migration Test

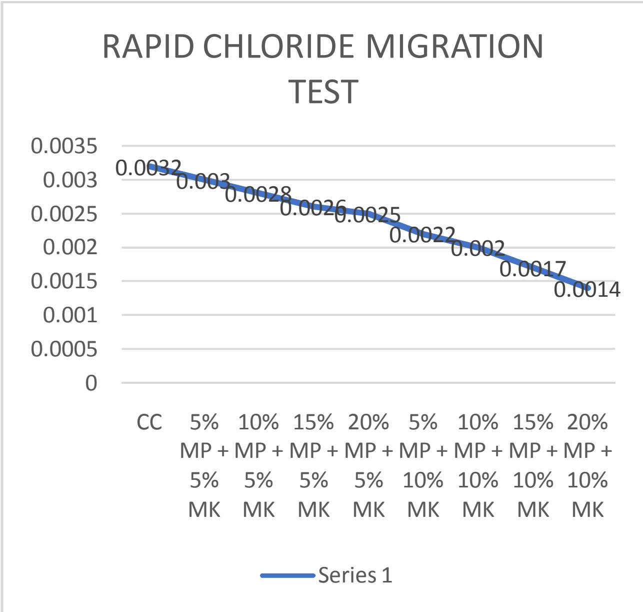

Fig. 10 Rapid Chloride Migration Test

The longevity of concrete has a crucial role in the longevity of concrete constructions. Many researchers are currently examining the qualities of metakaolin as premium pozzolanic materials. In addition, the microstructure of the cement pastes including MP and kaolin was examined using EDAX tests. The specimen was subjected to the Rapid Chloride Migration Test (RCMT) at 7 and 28 Days in order to calculate the amount of chloride ion penetration. The specimen was also maintained at 60V of current for 18 hours.

Load vs Deflection Comparison

In comparison to CC beams, the 10% MP + 5% MK beams displayed a little higher cracking load. The first crack loads decreased by 5.56% greater for 15% MP + 5% MK than for 10% MP + 5% MK. First crack load raised by 18.75% to CC for 10% MP + 10% MK. First fracture load was higher in the 10% MP + 10% MK beams than in the CC beams.

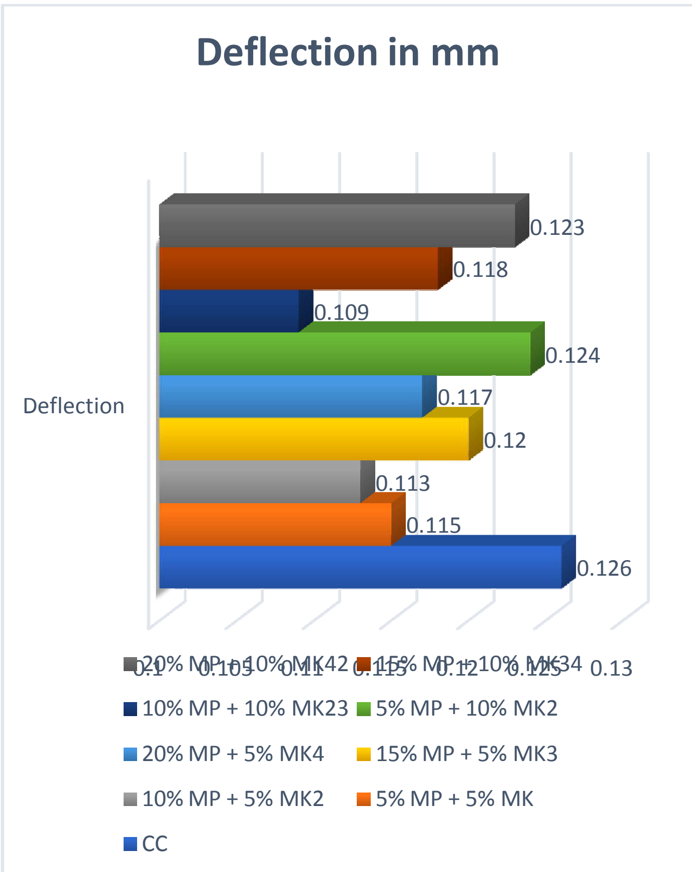

Fig. 11 Deflection of Beams

6. CONCLUSION

- By replacing some of the fine aggregate with 10% marble powder and some of the cement with 10% metakaolin, the maximum value of compressive strength for concrete cubes was achieved.
- By replacing some of the fine aggregate with 10% marble powder and some of the cement with 10% metakaolin, the maximum value of split tensile strength of concrete cylinders was achieved.
- By replacing some of the fine aggregate in concrete beams with 10% marble powder and 10% metakaolin in place of some of the cement, the maximum value of flexural strength was achieved.
- • Analysis was also done on the load versus mid-span deflection behavior of beams cast using regular and modified concrete beams. It is discovered that the MK5MP10 and MK10MP10 concretes have significant failure and initial fracture loads, respectively.
- In comparison to conventional and other partial replacement beams, beams that contain 10% Metakaolin as a partial substitute for cement and 10% Marble powder as a partial replacement for fine aggregate may resist far higher loads. Modified concrete MK10MP10 performs better when compared in terms of load factor, relative stiffness, and characteristic compressive strength normalized values. Modified concrete MK10MP10 is demonstrated to be reasonably ductile by comparing the normalized values of characteristic compressive strength and relative ductility.
- Metakaolin and marble powder are superior substitute materials that may be used to partially replace cement and fine aggregate. Replace 10% of the fine aggregate with marble powder and 5% of the cement with metakaolin.

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