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AN EXPLORATORY STUDY ON REPLACEMENT OF CEMENT WITH METAKAOLIN, MARBLE DUST, AND SLAG SAND

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ABSTRACT:

The modernization and industrialization of the country making to initiate a huge number of construction activities. In view of this natural resources are exploited and used to the greatest extent thus increasing pollution and resources are deprived. So to curtain and alleviate all these negative effects an experiment was carried out on alternate materials for the purpose of replacement such as Metakaolin (MK) and Marble Dust (MP) to the cement. As river sand plays a prominent role it has been expeditiously extracted from the sea, thereby adverse effects result in fertility of the soil getting reduced, decreasing the vegetation rate, eroding the soil, removing the top fine layer, interfering with the water table level, and disorders the aquatic life. In order to satisfy the demands an alternative material artificial Sand was used. Slag sand is used as a complete replacement to the river sand and has found out the strengths of the mix. Tests as Compressive strength, Split tensile Strength, and flexure strength was conducted on the sample with the replacement percentages of Metakaolin 0%,5%,10%,15%,20%, Marble dust 0%,10%,20%, and slag sand as a complete replacement.

1.0 INTRODUCTION:

In the construction industry, cement is highly regarded. When cement is being produced on a huge scale, Carbon dioxide is being released. Nowadays, the significance of high-strength concrete continues developing as all high-rise structures, shear walls, and foundations are built using the high-strength mix. As a result, the quantities of raw materials utilized to make high-strength concrete are increasing. This has a negative impact on the ecosystem since it causes significant degradation of natural resources. As a result, an attempt has been made to pick alternate cement and sand ingredients. For cement, pozzolanic substances such as Metakaolin and naturally occurring solid waste Marble Dust are employed. Sand is utilised in construction projects just as extensively as cement. Slag sand is used to completely replace river sand. Slag sand is a by-product in the Iron and Steel Industry. Slag sand is a non-metallic substance formed by cooling molten iron in water or steam and then drying and grinding it to a fine powder.

Metakaolin is produced by heating Kaolin at a temperature range of 600-800OC. Because metakaolin has a greater specific surface area, increasing the rate of the heat of hydration enhances strength at the early stage. Metakaolin does not have cementitious capabilities on its own, but when it reacts with cement and water, the reactions are carried out and advanced forward. Marble dust is created during the manufacturing process of marble. It is produced in

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vast amounts since it is produced as dust during polishing, sawing, and other processes. When it is left in the environment the powder combines with the water and turbidity gets enhanced also when it is exposed it lefts out to be a large solid waste. As a result, all materials such as Metakaolin, Marble Dust, and Slag Sand are employed. For each sample combination, the slump value and compaction factor are determined.

The Cement grade adopted was OPC 53 grade, admixture was SP 430 Fosrac. The pH of the water taken was 6-7. The mix adopted was M60.

1.1 OBJECTIVES:

1. To investigate the Compressive Strength, Flexure Strength, and Split Tensile Strength acquired by the mix at 3 days,7 days, and 28 days respectively.
2. To reduce environmental pollution by utilizing solid wastes.
3. To make an ecologically sustainable concrete mix.
4. To know the optimum replacement percentage corresponding to which strength has increased.

1.2 LITERATURE REVIEW:

Amritpaul Kaur[1], Rajwinder Singh Banswal[2] They noted that Metakaolin and marble dust strength tests ranged from 0% to 13% and that they were done. The mix used was M25. The replacement experiments were carried out using 72 conventional cubic specimens of size 150mm*150mm*150mm, as well as 72 cylinders of 15cm and 20cm in height. The grade of the cement used was OPC 43 duly following the standards of IS 8112. The results showed that the replacement of cement with 9% Metakaolin and 10% Marble powder gave better results. When the percentage of Metakaolin is above 9% and by not altering the percentage of Marble powder to 10% there is a reduction in the strength of the concrete. The use of Metakaolin with marble powder saves the environment and produces green concrete. The ideal proportion for Metakaolin is 9%, while for Marble powder it is 10%.

Vineeth Kumar[1], Akash Prakash[2] objective was to find the compressive and split tensile strength at 7,14,28 Days by partially replacing cement with Metakaolin and marble powder First M30 mix was prepared, and then in each successive trails Metakaolin and marble dust were replaced. The percentage replacements were 5%MK+5%MP,10%MK+10%MP,12.5%MK+12.5%MP, and 15%MK+15%MP. Results showed that the compressive strength and split tensile strength of concrete is more at 10%MP+10%MK.

Shala S. Utkar The goal was to investigate the ideal replacement of marble powder with cement and examine how the strength grew from 0% replacement to 25% replacement levels, which were staged at 5%, 10%, 15%, and 20%. The cement grade utilized was OPC 43, and the mix was M20. The results reveal that 20% is the ideal replacement, and the compressive and split tensile strengths have increased significantly.

Ch. Jyothi Nikhila[1], J.D Chaitanya Kumar [2] The goal was to assess the strength of the cement mix while being substituted with Metakaolin with cement. The concrete mix grade used

was M70. The percentages of replacement-induced replacement were 0%, 5%, 10%, 15%, 20%, and 25%. The term "electronic commerce" refers to the sale of goods and services through the internet.

N. GooruMurthy[1] aim was to concentrate on the point of marble dust replacement with cement. As cement is a basic material in all construction activities, so to have fewer burdens on the raw materials for the cement an alternative material was taken and conducted on research. The replacement percentages were 0%,10%,20%,25%, and 30%. Cubes and cylinders were prepared for each and every mix. Tests such as Compressive strength, Split tensile strength and flexure strength were carried out on those samples at 7 Days,28 Days, and 90 Days respectively. Results have shown that there was a slight increment from 0% to 25% and at the stage of 30%, there was a decrement in the strength.

2. MATERIALS:

2.1 Cement: In this research work Cement of OPC grade 53 with the Indian Standards 8112-2013 was used. The results of the cement are as follows

Table 2.1 Preliminary Tests on Cement.

S.No	Preliminary Tests	Results
1	Fineness of Cement	**6.5%**
2	Standard Consistency	**32%**
3	Initial Setting Time	**35 Min**
4	Final Setting Time	**450 Min**
5	Soundness of Cement	**5 mm**
6	Specific Gravity	**3.11**

2.2 Metakaolin: Metakaolin is a pozzolonic substance that is unreactive when finely split, but becomes cementitious when it combines with cement and water. Metakaolin is not a by-product. it is created when kaolin is heated between 600^{o}C -800^{o}C.

Table 2.2 Preliminary Tests on Metakaolin.

S.No	Preliminary Tests	Results
1	Fineness Modulus	2.86
2	Bulk Density	1010Kg/m^3
3	Specific Gravity	3.26

2.3 Marble Dust: Marble Dust is obtained as a by-product in the manufacture of marble. It is one of the solid wastes ejected into the environment. It is obtained in large quantities at the stages of polishing, and sawing of marble. Marble dust does not have cementitious properties, it has a positive effect on filling the voids in the concrete mix. Marble Dust has a high percentage of lime so the efficiency of reactivity increases thereby there is a positive impact on compressive strength. Environmental benefits are also obtained because we can relieve

some part of the land to not clog with all these solid wastes and thus improving the fertility of the soil and ensuring nutrients to retain in it.

Table 2.3 Preliminary Tests on Marble Dust.

S.No	Preliminary Tests	Results
1	Fineness Modulus	3.36
2	Bulk Density	1336Kg/m^3
3	Specific Gravity	2.58

2.4 Fine Aggregate- Slag Sand: Slag Sand is an alternate material to River Sand. Natural resources are being disrupted sensitively as a result of the rapid extraction of river sand, which is being employed widely in the building sector as per with cement. Natural sand gives less compressive strength when compared with slag sand. The bonding strength varies due to the kind of stones used. When the truck changes the fineness modulus is changed so the mix has to be changed often and then. Slag sand is obtained at the end from the iron and steel industry. It is formed by quenching molten iron in a blast furnace slag in water or steam and then drying and finally grinding it to a fine powder. It is a non-metallic product. Slag sand has a major constituent CaO which increases compressive Strength. The major advantage of Slag sand is it limits the increase of temperature and makes the heat of hydration reaction a bit slower.

Table 2.4 Preliminary Tests on Slag Sand.

S.No	Preliminary Tests	Results
1	Specific Gravity	**2.65**
2	Bulking of Sand	**46.15%**

2.5 Coarse Aggregates: After cement, aggregates are one of the most significant ingredients used in concrete. They form the matrix's binding and sticky nature. They account for 60-70% of the total. For the efficiency in bonding 20 mm and 12 mm, aggregates are taken. The nearby quarry provides coarse aggregates

Table 2.5 Preliminary Tests on Coarse Aggregate.

S.No	Preliminary Tests	Results for 20mm	Results for 12mm
1	Specific Gravity	2.90	2.55
2	Water Absorption	0.25%	1.0%
3	Flakiness Index	10	18
4	Elongation Index	17.3	21
5	Fineness Modulus	5.61	3
6	Bulk Density	1566.3Kg/m^3	1553.14Kg/m^3

3. METHODOLOGY:

3.1 Workability:

Workability is defined as the ease with which the mix is transported, compacted, and placed.

The following tests with respect to workability are done

3.1.1 Slump Cone Test: The slump test is one of the most basic and easiest tests for assessing workability. It can be done in the lab or in the field. It is made up of a slump cone with a top diameter of 100 mm, a bottom diameter of 200 mm, and a total height of 300 mm. Three layers of sample mix are placed in the cone. The height of the sinking of the concrete mix when the cone is raised is known as a Slump of concrete. It is not ideal for highly wet or extremely dry mixtures.

3.1.2 Compaction Factor Test: The compaction factor test is a completely lab-based test. The cement's densification and compacting are influenced by this. The compaction factor is calculated as the weight ratio of partly compacted concrete to fully compacted concrete.

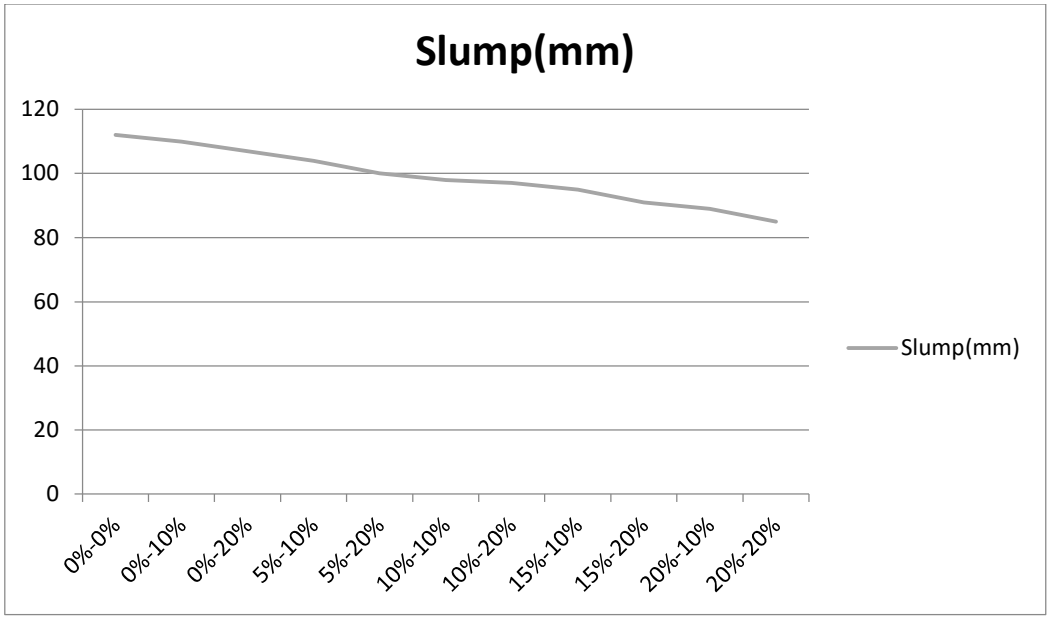
3.2 Compressive Strength: Compressive strength of the sample is calculated at after 3,7,28 Days of curing. The 3 Days strength is known as early strength, 7 days the first stage strength, and the strength at 28 days is known as Characteristic compressive strength. The strength obtained at 28 days is 99% of the target strength. Cubes of standard size 150mm*150mm*150mm are taken. Samples are brought from the curing tank and are made to dry under the hot sun. Then after the sample is placed under the compressive testing machine. Compressive strength is calculated as follows $\frac{Load\ applied\ in\ kN}{Area\ of\ the\ sample}$.

4. RESULTS AND DISCUSSION:

4.1 Slump Cone Test Results:

Table 4.1 Slump Values of all Sample mixes.

S.no	Metakaolin Replacement (%)	Marble Dust Replacement(%)	Slump (mm)
1	0%	0%	112
2	0%	10%	110
3	0%	20%	107
4	5%	10%	104
5	5%	20%	100
6	10%	10%	98
7	10%	20%	97
8	15%	10%	95
9	15%	20%	91
10	20%	10%	89
11	20%	20%	85



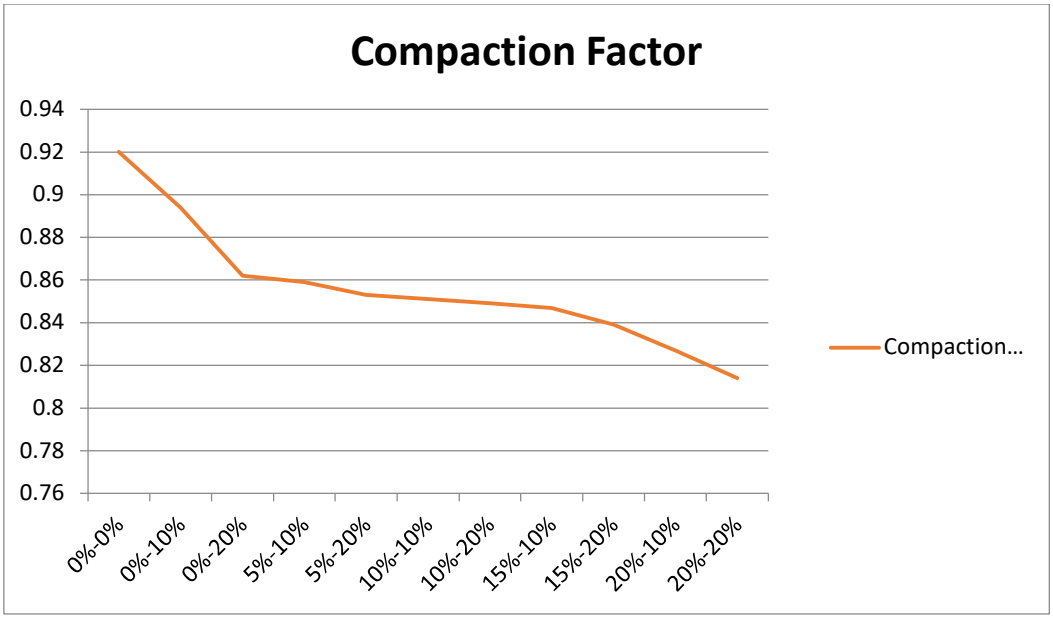
Graph 4.1 Slump value for various sample mixes

The maximum slump value was 0% replacement, while the lowest slump value was 20% replacement. The overall average slump recorded was 98mm. The droop ranged from 120mm to 80mm. The mix had a minor decline.

4.2 Compaction Factor Test Results:

Table 4.2 Compaction Factor of all Sample mixes

S.no	MK(%)	MP(%)	C.F
1	0%	0%	0.92
2	0%	10%	0.894
3	0%	20%	0.862
4	5%	10%	0.859
5	5%	20%	0.853
6	10%	10%	0.851
7	10%	20%	0.849
8	15%	10%	0.847
9	15%	20%	0.839
10	20%	10%	0.827
11	20%	20%	0.814



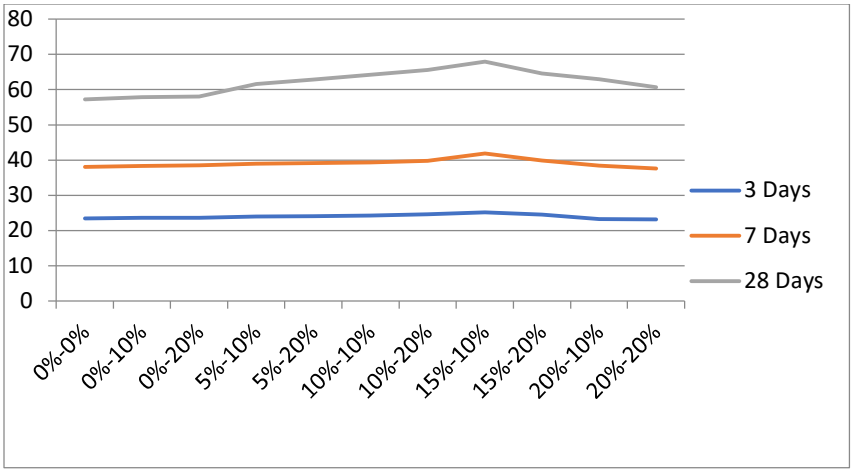
Graph 4.2 Compaction Factor for various sample mixes

The greatest value is seen at 0% percentage replacement. The least value recorded at 20% replacement. The range was between 0.920 to 0.814. Because the values are limited, the mix is extremely easy to handle, and compacting was not difficult.

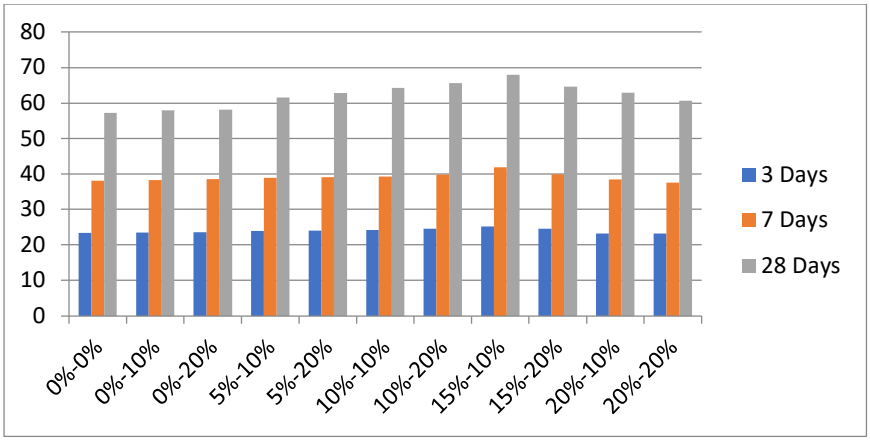
4.3 Compressive Strength Test Results:

Table 4.3 Compressive Strength for all Mix Proportions

S.No	MK(%)	MP(%)	3 Days Strength	7 Days Strength	28 Days Strength
1	0%	0%	23.39	38.10	57.21
2	0%	10%	23.51	38.3	57.92
3	0%	20%	23.62	38.48	58.07
4	5%	10%	23.96	38.9	61.54
5	5%	20%	24.04	39.1	62.83
6	10%	10%	24.22	39.3	64.26
7	10%	20%	24.56	39.8	65.61
8	15%	10%	25.17	41.9	67.94
9	15%	20%	24.51	39.9	64.60
10	20%	10%	23.23	38.45	62.95
11	20%	20%	23.17	37.6	60.67



Graph 4.3 Line Graph representing Compressive Strength at 3,7,28 Days Strength



Graph 4.4 Bar Graph representing Compressive Strength at 3,7,28 Days for M60 mix.

In this study, extra cementitious elements such as marble dust and metakaolin are employed. C-S-H gel, made of calcium silicate and hydrate, is created in the early stages of the cement's hydration reaction. The secondary calcium silicate hydrate C-S-H gel ettringite is produced when the pozzolonic reaction between metakaolin and cement begins. It is less dense than the primary C-S-H gel and is useful for filling and segmenting large capillary pores into small, discontinuous capillary pores through pore size refinement, reducing the total permeability of cement-based composites and forming a packed structure. Because Metakaolin has a finer particle size (1 m) than cement (12 m), it offers more nucleation sites that aid in faster hydration, improve packaging, and increase the density of the cement matrix's pore structure. As a result, the addition of Metakaolin not only increases strength but also mechanical properties. Calcium carbo aluminate, which aids in speeding the hydration rate and development of Compressive Strength, is created when the calcium carbonate in marble dust reacts with tricalcium aluminate, one of the main bogue compounds in cement. Marble Dust possess a higher degree of fineness which results in the cohesiveness of concrete and by incorporation of marble dust decreases water absorption and porosity which in turn increases the compressive strength. So at the early stages, compressive strength starts getting increased

slightly and reached an optimum percentage at 15% Metakaolin and 10 % Marble dust respectively. So from the above results that this replacement level of 15% Metakaolin and 10% Marble Dust is best suitable in attaining strength to the mix. Hence it turned out as an eco-friendly and sustainable material.

5. CONCLUSIONS:

1. Each and every sample mixed is prepared with utmost care. There was an increase in the strength from 0% to 15% in the Metakaolin and at 10% marble dust replacement. At the stage of 20% replacement of Marble Dust, there was a decrement in the strength.
2. Compressive strength was started at 57.21N/mm^2 at 0% replacement. The strength increased from 57.21 N/mm^2 to 67.94 N/mm^2 at 15%MP+10%MK and started a decreasing trend from 15%MK+20%MP. And finally, there was a complete decrease at 20%MK+20%MP replacement.
3. When cement is being replaced with Metakaolin and marble dust a major amount of solid waste is reduced in the environment. Though it might be a small scale when we take cement in small kilograms when we have cement production in tonnes then Metakaolin and marble dust replacement would be in huge kilograms replacement. The effect of replacement is greatly appreciable when the cement production is in large tonnes.

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