An Experimental Study on Enrichment of Concrete Strength by Partial Replacement of Cement by Metakaolin and Replacement of Fine Aggregate by Manufactured Sand

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Abstract— In the present investigation an attempt has been made to study strength characteristics of M30 Grade concrete mixes with the partial replacement of cement by Metakaolin and fully replacement of Fine aggregate by M sand. Further the replacement of Metakaolin ranging from 5-25% by weight of cement and resulting compressive strength for M30 grade concrete using M sand was found out to be marginally 6% - 9% higher when compared to the concrete with river sand.

Key words: Compressive Strength, Lateraite Soil, Metakaolin, Ordinary Portland Cement

I. INTRODUCTION

Concrete is the most commonly used construction material in the world. It is basically composed of two components paste and aggregate. The paste contains cement and water and sometimes other cementitious and chemical admixtures, whereas the aggregate contains sand and gravel or crushed stone. Scarcity of natural sand due to depletion of natural resources and restrictions due to environmental considerations made concrete manufacturers to look for suitable alternative fine aggregate. One such alternative is "Manufactured Sand". Manufactured sand is the quarry dust or the crushed granite stone that is sieved and made to suite particle size of natural sand so as to be used as fine aggregate. It is also called as M-sand.

Nagabhushana and Sharadabai studied the properties of mortar and concrete in which crushed rock powder (CRP) is used as a partial and full replacement for natural sand. Rajendra Prasad D.S. et al his research was conducted to study the effect of crushed rock powder (CRP) as fine aggregate and partial replacement of cement with admixtures subjected to different water, carbon dioxide and air curing periods. Raman et al in his paper reports the experimental study undertaken to investigate the influence of partial replacement of sand with quarry dust, and cement with fly ash on the concrete compressive strength development.

Ordinary Portland cement is recognized as a major construction material throughout the world. Researchers all over the world today are focusing on ways of utilizing either industrial or Agricultural waste, as a source of raw materials for industry. This waste, utilization would not only be economical, but may also result in foreign exchange earnings and environmental pollution control.

Industrial wastes, such as blast furnace slag, Metakaolin, fly ash and silica fume are being used as supplementary cement replacement materials. Therefore it is possible to use Metakaolin as cement replacement material to improve quality such as mortar, concrete pavers, concrete roof tiles and soil cement inter-locking block.

This report analyzes the effect of Metakaolin in concrete by partial replacement of cement with 0%, 5%, 10%, 15%, 20% and 25% by weight. The experimental study examines the compressive strength and split tensile strength at 7, 14 and 28 days.

II. MATERIALS

A. Cement

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster of the various ingredients used in concrete, cement is the most energetically and expensive.

B. Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. Lower water to concrete ratio yields a stronger, more durable concrete, while more water gives a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

C. Metakaolin

Metakaolin is a Dehydroxylated form of the clay mineral Kaolinite. Stone that are rich in kaolinite are known as China clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of Metakaolin is smaller than the cement particles. Considering to having twice the reactivity of most other Puzzolanas, Metakaolin is a valuable admixtures for concrete/cement applications.

Replacing of Portland cement with 8 to 20% by its weight, Metakaolin powder produces a concrete mix, which exhibits favorable engineering properties, including the filler effect, the acceleration of OPC hydration, and the Puzzolanic reaction.

The filler effect is immediate, while the effect of Puzzolanic reaction occurs between 3 to 14 days.

D. Manufactured Sand

Sand is used as fine aggregate in mortar and concrete. Natural river sand is the most preferred choice as a fine aggregate material. River sand is a product of natural weathering of rocks over a period of millions of years. It is mined from the river beds and sand mining has disastrous environmental consequences. River sand is becoming a scarce commodity and hence exploring alternatives to it has become imminent. Rock crushed to the required grain size distribution is termed as Manufactured Sand (M Sand). In order to arrive at a required grain size distribution the coarser stone aggregates are crushed in a special rock crusher and some of the crushed material is washed to

remove fines. This investigation is an attempt to evaluate the characteristics of mortar and concrete using M Sand as fine aggregate. For the purposes of comparison characteristics of mortar and concrete with river sand has also been explored.

III. METHODOLOGY

A. Tests on Materials

1) Cement

Elements	Content
Specific Gravity	3.14
Fineness Modulus	6.23%
Standard Consistency	29%
Initial Setting time	40min
Final Setting time	285min

Table 1: Physical properties of Cement

Oxides	Percentages
Cao	62.85
SiO_2	20.98
Al_2O_3	5.42
Fe_2O_3	3.92
MgO	1.76
SO_3	2.36
Na_2O	0.28
K_2O	0.53
Loss of Ignition	1.90

Table 2: Chemical properties of Cement

2) Metakaolin

Chemical Composition	Mass (%)
SiO_2	52.0-54.0
Al_2O_3	44.0-46.0
Fe_2O_3	0.60-1.20
TiO_2	0.65
CaO	0.09
MgO	0.03
Na_2O	0.10
K_2O	0.03

Table 3: Chemical Properties

Particulars	Values
Specific Gravity	2.6
Standard Consistency	28%

Table 4: Physical Properties

Sl No	Particulars	Obtained values
1	Specific gravity	2.68
2	Sieve analysis	2.68%
3	Water absorption	1.30%

Table 5: Physical properties of Manufactured Sand

Sl No	Particulars	Obtained values
1	Specific gravity	2.70
2	Sieve analysis	2.26%
3	Water absorption	0.80%

Table 6: Physical properties of coarse aggregate

IV. RESULTS AND DISCUSSIONS

ID	**Factored load KN**	**Compressive strength MP_a**	**Average Compressive strength MP_a**
NCC	740	32.89	**33.55**
NCC	755	33.55	
NCC	770	34.22	
MK 5%	790	35.11	**36.66**
MK 5%	835	37.11	
MK 5%	850	37.77	
MK 10%	890	39.55	**39.10**
MK 10%	865	38.44	
MK 10%	85	39.33	
MK 15%	960	42.66	**42.55**
MK 15%	935	41.55	
MK 15%	980	43.55	
MK 20%	945	42.00	**42.44**
MK 20%	970	43.11	
MK 20%	950	42.22	
MK 25%	955	42.44	**42.29**
MK 25%	965	42.88	
MK 25%	935	41.55	

Table 7: 28days compressive strength for different percentage of Metakaolin used for M30 grade

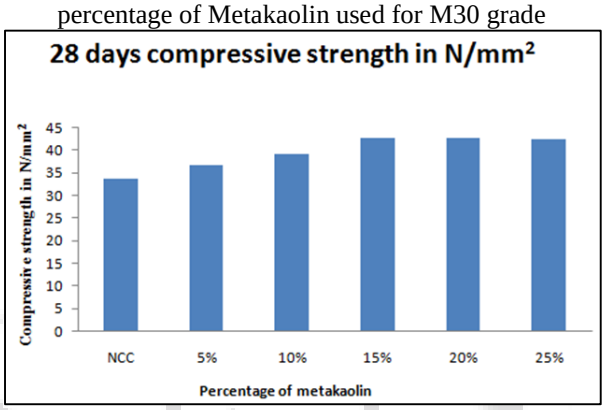

Fig. 1: Shows the variation of 28 days compressive strength values for different percentages of Metakaolin

The above graph indicates 28 days compressive strength with various percentage of Metakaolin replaced in cement in the concrete mixes. Let us consider the optimum strength gained after 28 days curing period is C15% MK strength increases with increase in percentage of Metakaolin up to 15% and thereafter decreases considerably with remaining percentages of Metakaolin.

ID	**Failure load KN**	**Split tensile strength MPa**	**Average Split tensile strength MPa**
NCC	355	5.02	**5.02**
NCC	360	5.09	
NCC	350	4.95	
MK 5%	370	5.23	**5.23**
MK 5%	365	5.16	
MK 5%	375	5.30	
MK 10%	395	5.58	**5.67**
MK 10%	410	5.80	
MK 10%	400	5.65	
MK 15%	425	6.01	**6.01**
MK 15%	435	6.15	
MK 15%	450	5.87	
MK 20%	365	5.16	**5.47**
MK 20%	400	5.65	
MK 20%	395	5.59	
MK 25%	360	5.09	**5.49**
MK 25%	405	5.73	
MK 25%	400	5.65	

Table 8: Split tensile strength test for 28 days

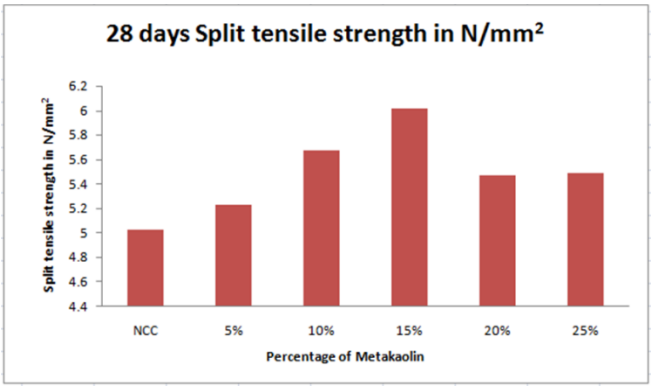

Fig. 2: Graph shows the variation of split tensile strength for different percentages of Metakaolin

The above graph indicates 28 days split tensile strength with various percentage of Metakaolin replaced with cement in the concrete mixes. Let us consider the optimum strength gained after 28 days curing period is C15%MK replacement and strength increases with increase in percentage of Metakaolin and decreases with the reaming replacement percentages of Metakaolin.

V. CONCLUSIONS

1) At the Partial replacement of Ordinary Portland Cement by Metakaolin results in a better compressive strength.
2) The compressive strength results of the concrete have revealed that the concrete with 15% cement replacement by Metakaolin have shown a compressive strength improvement at 28 days over the control concrete with the 100% Ordinary Portland Cement.
3) Partial replacement of cement by Metakaolin increases workability of fresh concrete; therefore use of super plasticizers is not substantial.
4) The compressive strength of concrete (M30) with M sand is marginally higher (6% - 9%) when compared to the concrete with river sand.

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