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Experimental Investigation on the Properties of Concrete Replacing Cement and Natural Sand with Metakaolin and Robo-Sand

M. Jagadeesh Naik[1] and S.M. Gupta[2]

[1]M.Tech (Structural Engineering), Department of Civil Engineering, NIT Kurukshetra
[2]Department of Civil Engineering, NIT Kurukshetra
E-mail: [1]jagadeeshm08@gmail.com, [2]smgupta@nitkkr.ac.in

Abstract—*Concrete is a Composite material made from cement, Fine aggregate, Coarse aggregate and water. The worldwide production of cement has greatly increased since 1990 and this production of cement results in lot of environment pollution as it involves the CO_2 gas. So alternative supplementary cementitious materials like Metakaolin, Fly-ash, GGBS, Rice Husk etc.. are used as partial replacement of cement. Metakaolin is a dehydroxylated aluminum silicate and having pozzolanic action. With increased depletion of Natural Construction material, alternative means must be sought for replacement of the same in the concrete mixes. The paper presents the partial replacement of cement with Metakaolin (0%, 5%, 10%, 15% and 20%) and Natural Sand with ROBO SAND (50%). The Mechanical properties of concrete i.e. Compressive strength, Split tensile strength and Flexural strength are studied of concrete made with partial replacement of MK-RS and compared with conventional concrete.*

Keywords*: Metakaolin (MK), ROBO SAND (RS), Ordinary Portland Cement, Strength Parameters.*

1. INTRODUCTION

Concrete is a major building material which is used in construction throughout the globe. Concrete is becoming backbone of infrastructural development of whole world. It is composite material made from cement, water, fine aggregate and coarse aggregate. The worldwide production of cement has greatly increased and this production of cement results in lot of environmental pollution as it involves CO_2 gas. So now a days the use of supplementary cementitious materials is fundamental in developing strength of concrete. By adding this supplementary materials various properties like workability, durability, Strength, resistance to crack and permeability also improved. The generally using supplementary materials are Metakaolin, Fly-ash, GGBS, rice husk, etc..In present paper Metakaolin is used as a supplementary material in replacement of cement. Metakaolin is dehydroxylated form of clay mineral Kaolinite. The particle size of Metakaolin is finer than cement. It is highly efficient Pozzolana and react rapidly with the excess $Ca(OH)_2$ resulting from cement hydration, due to this better pore refinement, Micro filling action, more resistance to permeability, early gain of strength, higher pozzolanic reaction and helps in reducing the consumption of cement. This lead to saving of natural resources and reduction in the emission of green house gases like CO_2 .Leaving the waste material into environment directly results to damage of natural climatic conditions. The use of this waste material is made at most importance in present study. During the past few decades common river sand has become expensive duo to excessive cost of transport from natural resources. Large scale depletion of these sources have led to many environmental impacts. To overcome these impacts an alternative has to be found in order to replace Natural Sand. The ROBO Sand which is obtained by crushing of granite stone is used as replacement of Natural Sand. This ROBO Sand has similar properties like natural sand and cost is less compare to natural sand.

2. MATERIALS AND METHODOLOGY:

2.1. Materials:

2.1.1. Cement:

The physical properties of the cement used in present investigation i.e. Ordinary Portland Cement of 43 grade (JP cement) confirming to IS 8112: 2013 was shown in table 1.

Table 1: Physical property of the cement sample

S. No	Property	Test Results
1	Normal Consistency	29.75%
2	Specific Gravity	3.14
3	Initial setting time	92 min
4	Final setting time	186 min
5	Soundness of cement	2 mm
6	Compressive strength At 3- days 7- days 28- days	 24.62 N/mm2 33.75 N/mm2 44.21 N/mm2

2.1.2 Fine aggregate:

Locally available river sand of size less than 4.75 mm was used. The specific gravity of fine aggregate is 2.62, Fineness modulus is 3.2 and Grading Confirming to Zone-II. (Specifications as per IS 383:1970).

2.1.3. ROBO Sand:

ROBO Sand is collected from locally available crushing unit. It was initially dry in condition when collected and was sieved by IS 4.75 mm. It has shape of particles as Cubical Particle. The specific gravity of ROBO Sand is 2.68, Fineness modulus is 3.34. Grading Confirming to Zone-II.

2.1.4. Coarse Aggregate:

The material whose particles are of size as are retained on IS. sieve 4.75 mm is termed as coarse aggregates. The size of coarse aggregate depends upon the nature of work. The Coarse aggregate used in this experimental investigation is 20 mm and 10 mm size, crushed and angular in shape. Specific gravity of coarse aggregate 20 mm size is 2.71 and for 10 mm size is 2.67.

2.1.5. Metakaolin:

Metakaolin is brought from vadodara having specific gravity of 2.5 is used in replacement of cement. Chemical formula of Metakaolin is $Al_2O_3\ 2SiO_2\ H_2O$.Chemical reaction as follows

cement + water = C-S-H gel + $Ca(OH)_2$

$Ca(OH)_2$ + Metakaolin = C-S-H gel

Table 2: Chemical composition of Metakaolin

Chemicals	Percentage
SiO2	62.62
Al2 O3	28.63
Fe2 O3	1.07
MgO	0.15
CaO	0.06
Na2 O	1.57
K2 O	3.46
TiO2	0.36
LOI	2.00

2.1.6. Water:

Ordinary potable tap water is available in laboratory was used for mixing and curing of concrete.

3. MIX DESIGN PROCEDURE:

In present study M_{25} grade concrete was designed as per IS: 10262-2009. The weight ratio of mix proportion is 1:1.79:3.05 keeping water cement ratio as 0.48. it was Proposed to investigate the properties of concrete, cast with partial replacement of cement with 0%, 5%, 10%, 15% and 20% of Metakaolin and 50% Natural sand is replaced by ROBO Sand and cured in water.

4. CASTING AND TESTING DETAILS:

In this present study average of 3- cubes, 3- cylinders and 3- beams were casted for each mix for 7- days and 28- days. For every mix after 24 hours the moulds were demoulded and subjected to water curing. The compressive strength, Split Tensile strength and Flexural Strength Test Conducted on Specimens and the results are tabulated below

Table 3: Compressive Strength at 7-days and 28-days

S.NO	Mix Designation	% Of MK	Target Strength (N/mm2)	Comp. Strength at 7 days (N/mm2)	Comp. Strength at 28 days (N/mm2)
1	Control Mix (M)	CM	31.6	19.68	33.12
2	0% MK (M1)	0	31.6	20.57	33.93
3	5% MK (M2)	5	31.6	24.67	34.59
4	10% MK (M3)	10	31.6	25.76	36.16
5	15% MK (M4)	15	31.6	23.26	34.14
6	20% MK (M5)	20	31.6	21.42	32.67

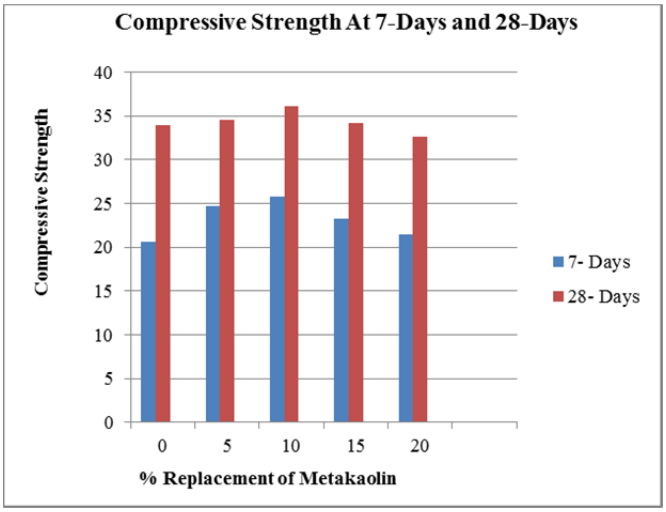

Fig. 1: Compressive Strength at 7- Days and 28- Days

Table 4: Split Tensile Strength at 7-days and 28 - days

S.NO	Mix Designation	% Of MK	Split tensile Strength at 7-days (N/mm2)	Split tensile Strength at 28-days (N/mm2)
1	Control Mix (M)	CM	2.7	3.34
2	0% MK (M1)	0	2.86	3.42
3	5% MK (M2)	5	2.97	3.61
4	10% MK (M3)	10	3.11	3.98
5	15% MK (M4)	15	3.02	3.52
6	20% MK (M5)	20	2.94	3.36

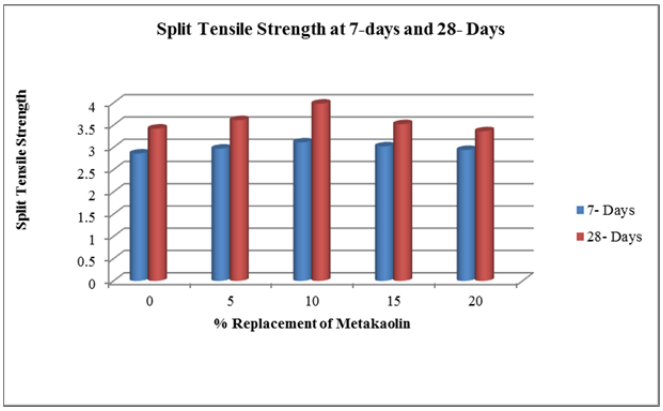

Fig. 2: Split Tensile Strength at 7-days and 28-days

Table 5: Flexural Strength at 7-days and 28 - days

S.NO	Mix Designation	% Of MK	Flexural Strength at 7-days (N/mm2)	Flexural Strength at 28-days (N/mm2)
1	Control Mix (M)	CM	1.12	1.47
2	0% MK (M1)	0	1.07	1.41
3	5% MK (M2)	5	1.14	1.55
4	10% MK (M3)	10	1.21	1.65
5	15% MK (M4)	15	1.05	1.48
6	20% MK (M5)	20	0.98	1.33

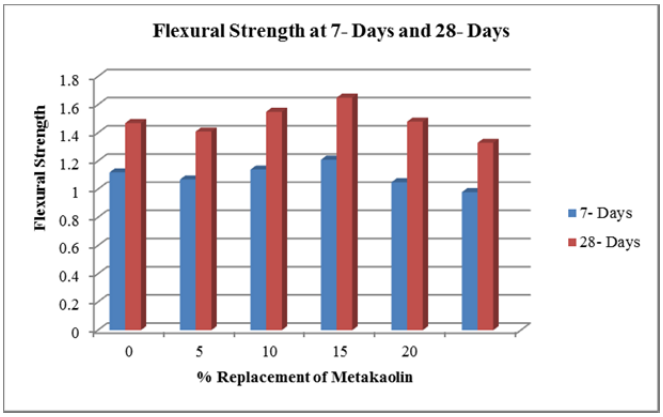

Fig. 3: Flexural Strength at 7-days and 28-days

5. CONCLUSION

From the above study we concluded that replacement of cement with Metakaolin and Natural Sand with ROBO sand give better results for strength. The Compressive strength, Split tensile Strength and Flexural Strength of concrete is gradually increased up to addition of 10% Metakaolin and 50% replacement of Natural sand with ROBO sand as compared to conventional concrete. The gain in strength is improved by replacement level of OPC by Metakaolin and Natural sand with ROBO sand. Use of Metakaolin and ROBO sand give GREEN Concrete because during production of Metakaolin no emission of CO_2.

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