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AN EXPERIMENTAL STUDY ON HIGH PERFORMANCE CONCRETE BY PARTIAL REPLACED CEMENT BY USING METAKAOLIN AND INDUSTRIAL WASTE

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Abstract - *High Performance Concrete (HPC) is becoming extremely popular now a day in application, which requires substantial improvements in structural capacity and resistance to aggressive environments. Several researchers have tried different mineral admixtures like Fly Ash (FA), Silica Fume (SF) and Ground Blast Furnace Slag (GGBS) in producing HPC. These admixtures are generally by-products of other industries and hence their properties are not identical and it is very difficult to assure the quality. Cement concrete is the most extensively used construction material. High Performance Concrete (HPC) is a concrete, which has far superior strength and durability characteristics as compared to conventional concrete. Maintenance and repair of concrete structures is a growing problems involving significant expenditure. Hence there is an urgent need to ensure durability of search carried out worldwide has well established .*

1. INTRODUCTION

High Performance Concrete (HPC) is becoming extremely popular now a day in application, which requires substantial suitable addition of pozzolanic/ mineral admixtures would lead to improved strength and durability of concrete in aggregate environments. The present study investigates the strength related properties of HPC specimens like compressive strength and flexural strength using cement replacement materials such as Fly ash, lime sludge, rice husk ash and High Reactivity Metakaolin (HRM) with the addition of superplasticiser. HPC is designed for M30 grade concrete. The strength properties of HPC specimens are compared with control (OPC) specimens. The water binder ratio is kept as 0.32. the HPC specimens are cast with replacement of cement with 15% HRM, 30% Fly ash and another set of specimens with 5%, 10%, 15% and 20% replacement with Lime sludge and rice husk ask. The study includes evaluation of modulus of elasticity and modulus of rupture. improvements in structural capacity and resistance to aggressive environments. Several researchers have tried different mineral admixtures like Fly Ash (FA), Silica Fume (SF) and Ground Blast Furnace Slag (GGBS) in producing HPC. These admixtures re generally by-products of other industries and hence their properties are not identical and it is very difficult to assure the quality.

OBJECTIVE AND SCOPE

OBJECTIVE

The objective of this study is to determine the structural behavior of high strength concrete beam grade 30 N/mm2 with replacement of Metakaolin, Rice husk ash, Fly ash, Lime sludge to weight of ordinary Portland cement due to static load. The water binder ratio if fixed at 0.43 and cured in room temperature. Parameters to be investigated include cracking. Deflection, moment resistance and modulus of elasticity due to bending.

- Deflection behaviour
- Initial Crack load and its location
- Location of crack and type of failure
- Actual moment resistance of the beam
- Modulus of elasticity in flexure.

SCOPE OF PRESENT INVESTIGATION

A relatively new minerals admixture called High-Reactive Metakaolin with potential utility in the in the production of High Performance concrete

- Use of rice husk ash as potential partial cement replacement, in different percentages.
- Use of lime sludge as partial cement replacement, in different percentages.
- The optimum percentage of fly ash and metakaolin should be taken from literature review
- Use of all the above materials in various combinations and to find optimum combinations for high performance concrete.

RESULT OF PRELIMINARY INVESTIGATION

MATERIAL PROPERTIES

Fine aggregate

- Specific gravity of fine aggregate – 2.64
- Fineness modulus of fine aggregate – 2.85
- Sand is conforming to zone II

Coarse aggregate

- Specific gravity of coarse aggregate – 2.78
- Fineness modulus of coarse aggregate –7.48

Cement

- Cement used is of OPC 53 grade(Chettinad cement)
- Specific gravity of cement – 3.10

Water

Tap water available in college campus.

METAKAOLIN

The materials used in this study were ordinary Portland cement (OPC), 53 Grade conforming to BIS: 12269-1987 and High - Reactivity Metakaolin (HRM) as mineral admixture in dry densified form conforming to ASTM C 618 class N Pozzolon.

C3S/C2S (Clinker) + H2O --------Calcium silicate Hydrates (C-S-H) + Ca(OH)2

Ca(OH)2 + MK ----------C-S-H pozzolona + Crystalline products(C2ASH8, 4AH13, C3AH6)

Physical properties of High Reactivity Metakaolin

Appearance : Off- White
P^H (10% Solids) : 4.5 to 5.5
Bulk density (Kg/Lit) : 0.4 to 0.5
Specific surface area m^2/g (BET) : 10 to12
Specific gravity : 2.6

FLYASH

Physical Properties of fly Ash

Test	Results
Specific gra..	2.00 to 2.05
Bulk density	750 to 1800 kg/cm^3
Colour	Grey
Physical	Power

Lime sludge samples were collected from the TNPL, Kagithapuram, Karur district. It appears to be paste with high natural water content (over 90% on the gravimetric basis). The physical description of the lime sludge sample.

Physical Properties of Lime Sludge Waste

Phvsical properties	Description
Colour	White to light grey
Odour	None
Hardness	Soft, greasy
Wetness	Wet, natural moisture content 98.4%
Flowability	Non- flowable at natural status
Density	Light
Dry Status	Fine power
Vegetation	No vegetation in lime pond

Chemical Properties of Lime Sludge Waste Parameters Average value

PH 10.88

Conductivity (mS cm- 1)	0.765
Water holding capacity (%)	70.9
Organic carbon (%)	0.14
Total nitrogen (%)	0.03
Available phosphorus (mg/Kg)	0.079
Potassium (meq/Kg)	45.38
Sodium (meq/Kg)	237.0
Calcium (meq/Kg)	752.08
Magnesium (meq/Kg)	188.25
Calcium carbonate (%)	67.43

LIME SLUDGE

RICE HUSK ASH

An extensive literature search has highlighted many uses of RHA. The main uses have been identified, as an insulator in the pozzolan in the cement industry.

Chemical properties of rice husk

Constituents	Average Value
Silica as SiO_2	90.70
Alumina as Al_2O_3	0.40
Iron as Fe_2O_3	0.40
Calcium as CaO	0.40
Potassium as K_2O	2.20
Magnesium as MgO	0.50
Sodium as Na_2O	0.10
Sulphur as SO_3	0.10
Loss On ignition	4.80

TESTING OF SPECIMENS

During mixing slump cone test is to be done for workability criteria and after curing, harden concrete is tested

1. Test on Fresh Concrete
2. Test on Hardened Concrete

COMPACTION FACTOR TEST

Table Compaction factor for Rice Husk Ash:

Grade	% replacement of cement with RHA	Compaction factor
M_{30}	0	0.94
	5	0.92
	10	0.9
	15	0.88
	20	0.86

Table Compaction factor for Lime Sludge:

Grade	% replacement of cement with LS	Compaction factor
M_{30}	0	0.94
	5	0.94
	10	0.92
	15	0.89
	20	0.87

COMPRESSIVE STRENGTH OF THE CONCRETE:

According to Indian Standard specifications (IS: 516 – 1959), the 7 days compressive strength test was conducted on casted specimens prepared as per the trial mix ratio.

Table Compressive strength for Rice Husk Ash

Grade	% replacement of cement with RHA	Compressive Strength (N/mm^2)	
		7th day	28th day
M_{30}	0	25.58	38.75
	5	26.78	40.60
	10	25.14	38.10
	15	24.25	36.75
	20	23.26	35.25

Table Compressive strength for Lime Sludge:

Grade	% replacement of cement with LS	Compressive Strength (N/mm^2)	
		7th day	28th day
M_{30}	0	25.58	38.75
	5	27.27	41.33
	10	27.75	42.05
	15	25.52	38.66
	20	23.92	36.25

SPLIT TENSILE STRENGTH TEST:

Table Split tensile strength for Rice Husk Ash

Grade	% replacement of cement with RHA	Split Tensile Strength (N/mm^2)
M_{30}	0	2.97
	5	2.42
	10	2.66
	15	2.82
	20	3.26

Table Split tensile strength for Lime Sludge:

Grade	% replacement of cement with LS	Split Tensile Strength (N/mm^2)
M_{30}	0	2.97
	5	2.68
	10	2.31
	15	3.69
	20	2.44

Table LOAD (KN)	Load and deflection for M30		
	CC +15% OF MK + 30% OF FA	CC +15% OF MK + 30% OF FA + 5 % of RHA	CC +15% OF MK + 30% OF FA + 10 % of LS
5	0.217	0.202	0.168
10	0.486	0.493	0.400
15	0.858	0.800	0.660
20	1.244	1.11	0.994
25	**1.598(I.C)**	1.604	1.276
30	1.949	**1.898(I.C)**	1.628
35	2.364	2.334	**1.925(I.C)**
40	2.797	2.728	2.194
45	3.228	3.130	2.513
50	3.652	3.503	2.810
55	4.112	3.988	3.128
60	4.629	4.408	3.459
65	5.107	4.806	3.793
70	5.56	5.459	4.245
75 (72)	**7.838**	5.856	4.708
80		6.373	5.053
85 (84)		**7.063**	5.895
90 (87)			**6.835**

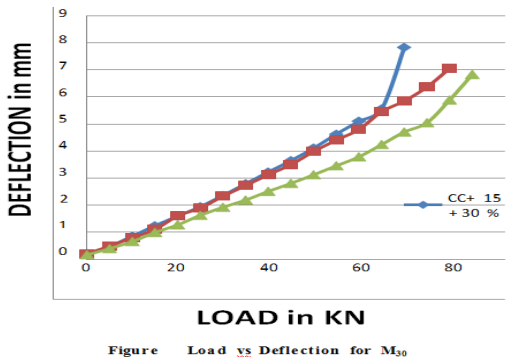


Figure Load vs Deflection for M_{30}

INFERENCE:

Ultimate load carrying capacity for CC +15% OF MK + 30% OF FA + 10 % of LS proportion is high and deflection is less

Table Load and deflection for various proportions

Grade	Proportion	Load		Deflection	
		Initial cracking in KN	Ultimate level in KN	Initial cracking in KN	Ultimate level in KN
M_{30}	CC +15% OF MK + 30% OF FA	25	72	1.598	7.838
	CC +15% OF MK + 5% OF RHA	30	84	1.898	7.063
	CC +15% OF MK + 10% OF LS	35	87	1.925	6.835

INITIAL CRACKING LOAD

Table Initial Cracking load

Grade of concrete	Material proportion	Initial cracking load in KN
M_{30}	CC +15% OF MK + 30% OF FA	25
	CC +15% OF MK + 5% OF RHA	30
	CC +15% OF MK + 10% OF LS	35

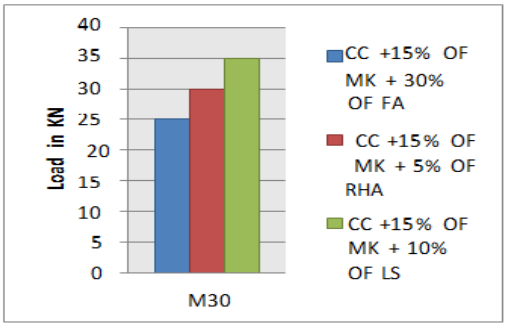


Figure Assessment of cracking load

STIFFNESS

Grade	Material Proportion	Stiffness in N/mm		
		Initial Load	Service Load	Ultimate load
M30	CC +15% OF MK + 30% OF FA	2.42	1.25	1.18
	CC +15% OF MK + 5% OF RHA	2.4	1.4	1.7
	CC +15% OF MK + 10% OF LS	2.4	1.38	1.2

INFERENCE:

Stiffness for CC +15% OF MK + 10% OF LS proportion is less compared to other proportions

9.8 DUCTILITY

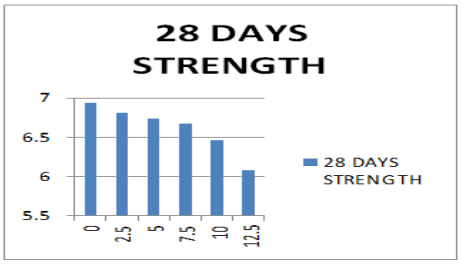
Ductility factor = —

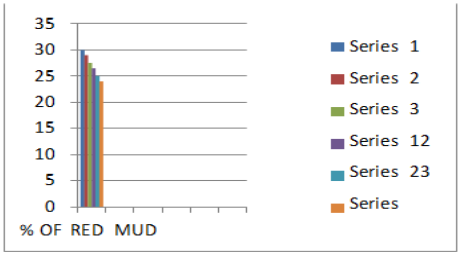
Table Ductility factor

Grade	Material Proportion	Ductility factor
M30	CC +15% OF MK + 30% OF FA	2.74
	CC +15% OF MK + 5% OF RHA	3.3
	CC +15% OF MK +10% OF LS	3.78

INFERENCE:

The CC +15% OF MK + 10% OF LS proportion yield higher ductility





CONCLUSIONS

- The material properties were determined for cement, Fly ash, metakaolin, and lime sludge and risk husk ash. Based on these values the mix design were done for M30 grade of cement cubes and cylinders were casted and cured as per standard procedures, using the above industrial waste materials and metakaolin in different proportions. The compressive strength of concrete cubes and cylinders were tested on 7th and 28th days and found the optimum value of metakaolin, fly ash and lime sludge. The physical and mechanical properties of fly ash, metakaolin, and lime sludge and rice husk ash were found to be favorable for use in cement concrete
- The following structural properties were studied:

  Ultimate load bearing capacity increased by 20.33% while using CC+15% MK+ 30% FA +10% LS proportion of the cement, metakaolin, flyash and Lime sludge in concrete.

  - **Initial Cracking Load** increased by40 %
  - **Deflection** decreased by 12.75 %
  - **Stiffness** decreased by 36.4%
  - **Ductility** increased by 14.54%

  From the analysis of the structural parameters, the proportion (CC+15% MK+ 30% FA +10% LS) has high flexural strength and compressive strength.

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