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An Optimum Content of Ternary Mix Containing Rice Husk Ash and Metakaolin as a Cement Replacement in Self Compacting Concrete

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Abstract—*Self compacting concrete has to be highly flow able yet stable that can spread readily into the congested reinforcement. The SCC is that which gets compacted due to its self weight and is de-aerated (no entrapped air) completely while flowing in the form work. The use of metakaolin (MK) and Rise Husk Ash (RHA) as a recent material in the construction industry proves to be very useful to modify the properties of concrete. In this research material such as coarse aggregates, fine aggregates, cement, MK, RHA have been tested for their physical properties. Mix design of self compacting concrete was based on the EFNARC and BIS method. The workability tests performed in this research were as per EFNARC. The three specimens for each proportion of ternary mix were produced by using matrix form using w/b ratio of 0.45 by incorporating 5%, 10%, 15%, 20% RHA and 5%, 10%, 15%, 20% metakaolin as cement replacement to find the optimum content of ternary mix containing rice husk ash and metakaolin in self compacting and ternary MK-RHA blended self compacting concrete cubes specimens were tested for their compressive strength at 28 days.*

Keywords— *self compacting concrete, rice husk ash, metakaolin, super plasticizer, viscosity modified agent.*

I. INTRODUCTION

Self-compacting concrete (SCC) was first developed in 1988 in Japan due to the gradual reduction of skilled labour in the construction industry. SCC can be achieved without segregation and high deformability in the following three ways, i.e. limiting aggregate content, low water: binder ratio and the use of super plasticiser. Nowadays SCC is gaining popularity throughout the world because of its interesting structural properties.

Self compacting concrete is a revolution in a concrete technology. It is not only easy to place in congested reinforcement structures but also compacts it without noisy vibrations. SCC ensures high durability since air voids and other flaws are likely to be absent in the concrete. SCC is suitable for the placing with pumping and when transported in ready mixed concrete trucks minimize waiting time for transit mixtures and the turnaround times are shorter which will lead to greater productivity per transit mixture. SCC mixes usually contain super plasticizer, high content of fines and/or viscosity modifying additive. While the use of super plasticizer maintains the fluidity, the fine content provides stability of mix resulting into the resistance against bleeding and segregation. It is estimated that SCC may result in up to 40% faster construction speed.

RHA, produced after burning of Rice husks (RH) has high reactivity and pozzolanic property. Indian Standard code of practice for plain and reinforced concrete, IS 456- 2000, recommends use of RHA in concrete but does not specify quantities. Chemical compositions of RHA are affected due to burning process and temperature. Silica content in the ash increases with higher the burning temperature. RHA can be used as an effective and Green supplementary cementing material.

Metakaolin (MK) is an amorphous material that is obtained by dehydrating kaolin at a temperature of about 800°C. The high reactivity of MK with cement, and its ability to accelerate cement hydration, makes it different from other pozzolanic materials. MK accelerates the initial setting time to attain high compressive strength at earlier age, and improves the mechanical and durability properties.

Because it is produced under controlled conditions, its composition (typically 50 to 55% SiO2 and 40 to 45% Al2O3), white appearance, and performance are relatively consistent. Due to its high surface area and high reactivity, produces relatively large increases in strength, impermeability, and durability, while its light colour gives it an aesthetic advantage over other supplementary cementitious material (SCM).MK used in the research was obtained from Shree Ram Micro Minerals, Bhuj, Gujarat.

The main advantage of using ternary-blended concrete is to eliminate the drawbacks of the particular supplementary cementitious materials through combining with other superior quality material. Also the materials used such as Rice Husk Ash is a waste product so it will also contribute in environmental related issues and also provide the option for the dumping of Rice Husk Ash.

Fig:1 Rice Husk Ash

Fig:2 Metakaolin

II. MATERIALS PROPERTIES

A. Cement

In this research ordinary Portland cement manufactured by ultratech cement was used with specific surface 3415cm2/g and specific gravity 3.15gr/cm3 were used. Test results of ordinary cement are reported in Table I.

Table I: OPC Results

Name of test	Result		
Initial setting time	35min > 30 min		
Final setting time	225 < 600 min		
Specific gravity	3.12		
Compressive strength	7 days	14 days	28 days
	28 Mpa	40 Mpa	55 Mpa

B. Rice Husk Ash

The Rice husk ash is obtained from Bharat Rice Mill at Balawa, saland-ahmedabad highway Gujarat, Specific gravity was found 1.96, its chemical composition is given in Table II

Table II: Chemical composition of rice husk ash (Courtesy: Md. Safiuddin 2008)

Typical chemical composition of rice husk ash Component	Mass content (%)
Silicon dioxide (SiO_2)	94.37
Aluminum oxide (Al_2O_3)	0.06
Ferric oxide (Fe_2O_3)	0.04
Calcium oxide (CaO)	0.48
Magnesium oxide (MgO)	0.13
Sodium oxide (Na_2O)	0.08
Potassium oxide (K_2O)	1.97
Phosphorus oxide (P_2O_5)	1.19

Titanium oxide (TiO_2)	0.02
Sulphur trioxide (SO_3)	0.01
Igneous loss	1.18

Fig :3 Le chatelier flask for specific gravity

C. Metakaolin

Metakaolin used in this research was obtained from Shree ram micro minerals, Bhuj, Gujarat.Specific gravity was found 2.3Chemical composition of metakaolin is shown in table III.

Table III: Chemical composition of Metakaolin
(Courtesy: Shree Ram Micro Minerals, Bhuj, Gujarat.)

Chemical composition	% mass content
SiO2	59.90
Al2O3	32.29
Fe2O3	1.28
MgO	0.17
CaO	0.04
Na2O	0.24
K2O	2.83
TiO2	0.36
Loss Of Ignition	2.80

D. Fine Aggregate

The fine aggregates consisted of river sand with maximum size of 4.75 mm, with a modulus of fineness = 2.82; grading zone confirming 2. Specific gravity was 2.50, and absorption value was 1.5%.Also the sieve analyses of fine aggregates are given in Table IV.

Table IV: Result of sieve analysis of fine Aggregates

Sieve size	Wt. Retained gm	% Wt. Retained	% cumulative wt. retained	% cumulative wt. passing
4.75mm	67	6.7	6.7	93.3
2.36mm	67	6.7	13.4	86.6
1.18mm	211	21.1	34.5	65.5
600 micron	143	14.3	48.8	51.2
300micron	320	32.0	80.8	19.2

150 micron	178	17.8	98.6	1.4

E. Coarse Aggregate

Coarse aggregate is from river gravel with a maximum size of 12.5 mm and normal continuous grading. The specific gravity of the coarse aggregates was 2.65, absorption value was 0.68%. Also the sieve analyses of the coarse aggregates 10mm and 20mm are given in Table V and Table VI respectively.

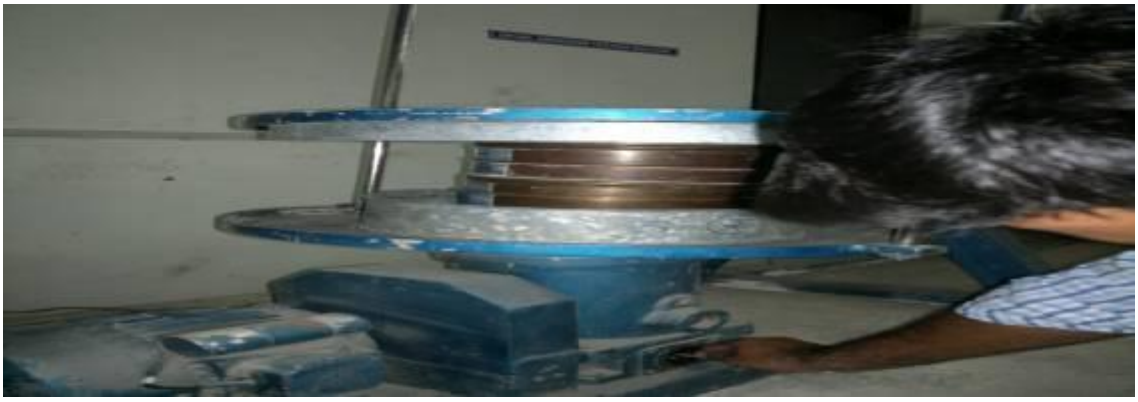

Fig: 4 Mechanically Vibrating Sieves

Table V: Result of sieve analysis of Coarse Aggregates (10mm)

Sieve size Mm	Wt. Retained kg	% Wt. Retained	% cumulative wt. retained	% cumulative wt. passing
20	0	0	0	100
12.5	0.103	2.06	2.06	97.94
10	0.369	7.38	9.44	90.56
4.75	4.351	87.02	96.46	3.54
2.36	0.111	2.22	98.68	1.32
Pan	0.050	1	99.68	0.32
Total			306.32	

Table VI: Result of sieve analysis of Coarse Aggregates (20mm)

Sieve size mm	Wt. Retained kg	% Wt. Retained	% cumulative wt. retained	% cumulative wt. passing
20	0	0	0	100
12.5	0.298	5.96	5.96	94.04
10	4.348	86.96	92.92	7.08
4.75	0.302	6.04	98.96	1.04

2.36	0.040	0.8	99.76	0.24
Pan	0.008	0.16	99.92	0.08
Total			397.52	

F. Admixture

Super Plasticizer (SP)

High-range water reducer, also known as super plasticizer, has made a breakthrough in concrete industry. It is an essential material component that must be used to produce SCC. The HRWRs improve the flowing ability of SCC by their liquefying and dispersing actions. They reduce the yield stress and plastic viscosity of concrete by their liquefying action and thus provide a good flowing ability in SCC. The super plasticizer (BASF glanium sky) is used 1%.

VMA (viscosity modifying agent)

Viscosity-modifying admixture (Stream2) is relatively a new addition to the family of admixtures for cement paste, mortar and concrete. The common application of VMA is to produce non-dispersible underwater concrete and SCC. VMA improves the viscosity and cohesion of fresh concrete, and thus reduces the bleeding.


Fig: 6 Marsh Cone Test **Fig: 5 BASF Super plasticizer** **Fig: 7 Mortar mixture**

III. MIX DESIGN

Self compactability can be largely affected by the characteristics of materials and the mix proportion. A rational Mix-design method for self compacting concrete using a variety of materials is necessary. The coarse and fine aggregate contents are fixed so that self compactability can be achieved easily by adjusting the water powder ratio and super plasticizer dosage only. Mix design was prepared on the basis of Europiun guidelines EFNARC and BIS method. In this investigation, with first by try and error, different mix design of SCC were tested to find out the fresh properties such as value of slump flow, L-box , J ring, T-50 and V-funnel Fresh properties amount are in acceptable limited from European Specifications and Guidelines for Self Compacting Concrete. Coarse aggregates were taken as 60%-10mm and 40%-20mm. Mix design for various mixes are shown in Table VII. Mixes are named as for an example 5M5R meaning 5% Metakaolin and 5% Rice Husk Ash replacement.

Table VII: MIX DESIGN (KG/M3)

MIX	Cement	Water	C.A.	F.A.	R.H.A.	M.K.	S.P.	V.M.A.	W/B ratio
5M5R	416.9	203.2	773.8	882.3	22	22	3.5	1	0.45
5M10R	394.9	203.1	761.7	868.5	44	22	3.5	1	0.45
5M15R	382.4	203.0	749.6	854.7	67	22	3.5	1	0.45
5M20R	359.4	203.0	749.6	854.7	90	22	3.5	1	0.45
10M5R	427.4	203.1	761.7	868.5	22	45	3.5	1	0.45
10M10R	404.4	203.1	761.7	868.5	45	45	3.5	1	0.45

10M15R	382.4	203.0	749.6	854.7	67	45	3.5	1	0.45
10M20R	359.4	203.0	749.6	854.7	90	45	3.5	1	0.45
15M5R	427.4	203.1	761.7	868.5	22	67	3.5	1	0.45
15M10R	404.4	203.1	761.7	868.5	45	67	3.5	1	0.45
15M15R	382.4	203.0	749.6	854.7	67	67	3.5	1	0.45
15M20R	359.4	203.0	749.6	854.7	90	67	3.5	1	0.45
20M5R	427.4	203.1	761.7	868.5	22	90	3.5	1	0.45
20M10R	404.4	203.1	761.7	868.5	45	90	3.5	1	0.45
20M15R	382.4	203.0	749.6	854.7	67	90	3.5	1	0.45
20M20R	359.4	203.0	749.6	854.7	90	90	3.5	1	0.45

IV. RHEOLOGICAL PROPERTIES OF FRESH SCC

Fig: 8 V funnel Test

Fig: 9 J Ring Test

Fig: 10 UBox Test

Fig: 11 L Box Test

Table VIII: Rheological Properties of Fresh SCC

Test / Mix	Slump Flow	50cm Slump flow	V funnel	V Funnel At T-5min	L Box (h1/h2)	U Box(h1-h2)	J Ring
W/B Ratio	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Recomanded value	650-800mm	2-6 sec	6-12 sec	0-+3 sec	0.8-1	0-30 mm	0-10 mm
5M5R	701	5.3	6.3	8.1	1	18	3
5M10R	705	5.5	6.6	7.1	1	15	2
5M15R	709	4.8	6.8	7.9	1	13	5
5M20R	711	4.6	6.5	7.7	1	18	5
10M5R	715	4	6.8	7.2	1	15	3
10M10R	718	3.9	7	9	1	14	4
10M15R	721	3.5	7.2	9.2	1	18	5
10M20R	698	3.8	7.9	9.9	0.9	20	6
15M5R	658	5	8.1	10.1	0.9	22	6
15M10R	663	5.5	8.1	10.2	0.9	25	8
15M15R	666	5.2	8.6	10.7	0.8	26	8
15M20R	670	5.0	8.9	11.1	0.85	26	7
20M5R	688	5.5	9.5	11.7	0.9	25	6
20M10R	678	5.7	9.2	11.6	0.95	27	8
20M15R	684	5.8	9.9	12.1	0.95	25	9
20M20R	654	5.8	9.7	12.6	0.95	27	8

V. EXPERIMENTAL EXAMINATION

In this study, all of concrete specimens were made and covered with plastic sheet for the first 24 hours to prevent moisture loss. After 24 hours, the specimens were demodeled and placed in the water with 22±2 °c for all times of test. Specimen's dimensions were 15 by 15 by 15.

Fig: 12 Cubes filled with SCC

Fig: 13 Cube setting in the compression testing machine

Fig: 14 Cube testing for compression

VI. RESULTS AND DISCUSSIONS

For compressive strength the specimens were tested at 28 days. From the results of compressive test at 28 days it is seen that the replacement level of 10% Metakaolin and 10% Rice Husk Ash gives the best compressive strength then the other mixes. Also the addition of waste material like Rice Husk Ash will prove to be significant in environmental issues. The results are shown in Figure: 15

Table IX: Results of Compressive strength

MIX	Compressive Strength at 28 days
5M5R	38.7 MPa
5M10R	38.9 MPa
5M15R	38.6 MPa
5M20R	40.3 MPa
10M5R	39.6 MPa
10M10R	41.1 MPa
10M15R	40.4 MPa
10M20R	39.6 MPa
15M5R	39.9 MPa
15M10R	40.1 MPa
15M15R	38.8 MPa
15M20R	39.3 MPa

20M5R	39.0 MPa
20M10R	38.8 MPa
20M15R	38.6 MPa
20M20R	37.3 MPa

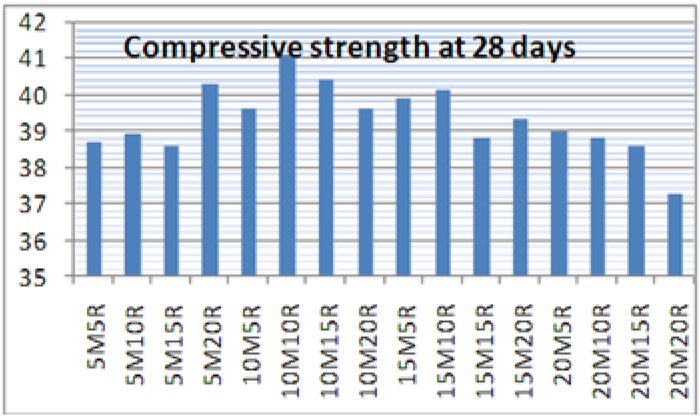

Fig: 15Compressive Test Results

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