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Investigating the Performance of Cement Mortar containing Rice Straw Ash, Microsilica and Their Composite by Compressive Strength

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***Abstract**: The primary objective of this research was to compare the effect of partial replacement of OPC with Rice straw ash, microsilica and their composite on the compressive strength of cement mortar. High range water reducer (HRWR) was also used to compensate for the decreased workability due to an increase in the overall surface area of the cementitious material. Its dosage for the different mix was decided by the Marsh Cone Test. Different proportion of rice straw ash and microsilica used for part replacement of OPC in the mortar were 5, 10, 15, 20, 25% and 2.5, 5, 7.5, 10% by weight of OPC respectively. The compressive strength of the mortar cubes of various proportions was determined after 3, 7, 28, 60, 90 and 365 days of curing in water. It was observed that the highest pozzolanic reaction could be achieved by mix R1M3 thus leading to increased compressive strength while the mix R2M3 could achieve both economy and relatively increased compressive strength.*

***Keywords: Rice Straw Ash; Mortar; Micro silica; Compressive Strength; Marsh Cone**.*

I. INTRODUCTION

The rapid growth of the construction industry is known to all thus causing an increase in demand and consumption of cement. As production of cement is associated with liberation of CO_2, it creates a greenhouse effect which is the main reason behind global warming. Therefore, Mineral Admixtures can be considered as a feasible option which can meet the ever-increasing demand for cement and in turn will reduce energy consumption & CO_2 emission [1]. Cement plants cause 5% of the overall release of CO_2 and are among the crucial factor of an unnatural climate change [2]. Micro silica and Rice straw ash can be used as a mineral admixture which can enhance the properties and reduce the adverse environmental effects. According to El-Sayed et al. (2006) [3], when rice straw is burnt, the ash produced is highly pozzolanic. Arunabh et al. [4] suggest that rice straw has high silica content and it fulfills the necessities of ASTM Class N, F, and C pozzolan. Microsilica is an ultrafine powder gathered as a by-product of the silicon and ferrosilicon composite production and comprises spherical particles with an average particle diameter of 150 nm [5].
The goal of this investigation was to compare the effect of rice straw ash and microsilica on admixing with OPC on the compressive strength of cement mortar.

II. MATERIALS USED

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The cement utilized was Ordinary Portland Cement (OPC) of 43 grade which was as per IS: 8112-2013 [6]. Specific gravity as per IS 2720 (III) [7] and specific surface area by Blaine's
Method of OPC was found out. 920D-grade microsilica was used which was acquired from Elkem South Asia Pvt. Ltd. Rice Straw was procured from Agricultural Farm, BHU and was scorched outdoors and afterward, was sieved through 0.09mm sieve. Specific gravity as per IS 2720 (III) [7] and specific surface area by BET test of micro silica and rice straw ash was found out. Specific Surface Area, Specific Gravity and chemical composition of Grade 43 OPC, micro silica and rice straw ash are shown in table 1 and table 2 respectively [8]. Figure 1 shows the graphical comparison between the chemical composition of grade 43 OPC, rice straw ash and micro silica [8]. Consumable water used for blending and curing is by IS 456:2000 [9]. Conplast SP430 super plasticizing admixture was utilized to compensate for the loss in workability as there is an increase in the surface area. It was obtained from Fosroc Chemicals (India) Pvt Ltd. Standard Sand (Ennore Sand) was used throughout the experimental work on the mortar. It was acquired from Ennore, Madras.

Table 1. Specific Gravity and Specific Surface Area of OPC, RSA and Microsilica

	OPC	RSA	Microsilica
Specific Gravity	3.2	2.25	2.23
Specific Surface Area (m^2/g)	0.3	1.846	16.14

Table 2. Chemical Composition of OPC, RSA and Microsilica

Compound	Percentage by Weight		
	OPC	Rice Straw Ash	Microsilica
CaO	42.16	0.370	0.171
SiO_2	26.34	79.82	91.3
MgO	14.79	7.54	1.29
Al_2O_3	6.13	1.13	0.616
Fe_2O_3	3.7	0.245	1.47
P_2O_5	2.03	3.75	-
SO_3	1.73	-	3.13

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Na_2O	1.33	0.501	0.082
SrO	0.45	-	-
Cl	0.305	4.06	-
TiO_2	0.189	-	-

S	-	1.16	-
K_2O	-	1.07	0.653
P	-	-	0.38
ZnO	-	-	0.244

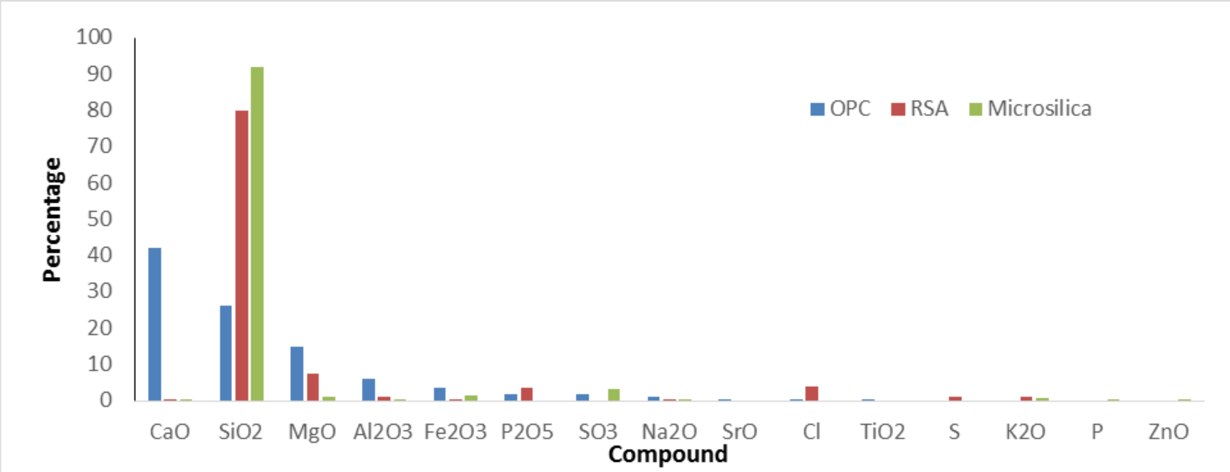

Fig 1. Graph showing comparison between chemical composition of OPC, RSA and Microsilica

III. EXPERIMENTAL PROGRAM

A. Mixture Proportion

Different mixtures were set up for cement mortar containing distinctive amounts of rice straw ash and micro silica. Mixtures were prepared by supplanting OPC by weight with Rice straw ash at a regular interval of 5% to 25% and Micro silica at a consistent interval of 2.5% to 10%. Mixtures were also prepared by replacing OPC by weight with the composite of Rice straw ash and microsilica. Different mixture proportions are shown in table 3.

B. Sample Preparation

W/c proportion of the control mortar (R0) was 0.5 at the desired workability. In this manner, the mortar was readied utilizing the regular w/c proportion, i.e., 0.5 for all the mix and HRWR (Conplast SP430) was used to make up for decreased workability in different combinations. The dosage of HRWR for different mixes was found by Marsh Cone test and is shown in table 3.

The ratio between the binder material and sand was kept fixed at 1:3 for all mixes. Mortar cubes of size 70.7mm X 70.7mm X 70.7mm were cast confirming to IS 10080-1982 [10]. For each mix proportion, 18 cubes were cast. Total no. of mortar cubes were 252 for all mix proportions. After 24 hours of casting, the samples were removed from the mould and put in the curing tank for 3, 7, 28, 60, 90 and 365 days of wet curing.

C. Compressive Strength

After completion of 3, 7, 28, 60, 90 and 365 days of wet curing, samples were taken out of the curing tank and tested for their compressive strength as per IS: 4031-1982 (Part 6) [11]. 3 samples of each mix were tested for each duration of wet curing, and their average value was reported.

IV. RESULTS AND DISCUSSIONS

A. Results

The compressive strength of mortar cubes with a part replacement of OPC by rice straw ash, microsilica and rice straw ash-microsilica composite are shown in table 4. Figure 2, Figure 3 and Figure 4 show the comparison between the compressive strength of control mix and mix containing rice straw ash, microsilica, and rice straw ash-microsilica composite respectively in 3, 7, 28, 60, 90, 365 days. Table 5 shows the percentage increase in compressive strength of mix containing rice straw ash, microsilica, and their composite respectively w.r.t. Control mix in 3, 7, 28, 60, 90, 365 days.

B. Discussions

As can be seen in table 4, the compressive strength of almost all the mix of different proportion has increased for all the ages of curing. It can be understood that up to 10% part replacement of OPC, with rice straw ash, was possible in mortar cubes without any loss of compressive strength.

The relative compressive strength of rice straw ash admixed mortar, as compared to the control mix, ranges from 100.5 to 105.6% for mix R1 and R2. Upon replacing OPC with rice straw ash for more than 10%, there is a huge decrease in the compressive strength as can be seen in figure 2 ranging from 15.13% to 36.73% (table 5). As the particle size of the rice straw ash is almost five times smaller than that of the OPC particles (table 1), it fills the voids between the OPC particles leading to a dense mix.

Table 3. Mix Proportions of Cementitious Materials

Mix	Mix Proportion (by weight)			
	OPC	**RSA**	**Microsilica**	**HRWR Dosage (% by wt.)**
R0 or Control	100	-	-	-
R1	95	5	-	0.4
R2	90	10	-	0.6
R3	85	15	-	0.75

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R4	80	20	-	0.95
R5	75	25	-	1.20
M1	97.5	-	2.5	0.3
M2	95	-	5	0.35
M3	92.5	-	7.5	0.45
M4	90	-	10	0.56
R1M2	90	5	5	0.85
R1M3	87.5	5	7.5	1.05
R2M2	85	10	5	1.20
R2M3	82.5	10	7.5	1.45

Table 4. Compressive Strength of Mortar Cubes of Various Mix Proportion

Mix	Compressive Strength					
	3 days	7 days	28 days	60 days	90 days	365 days
R0	23.67	34.17	43.33	47.33	48	49
R1	25	34.67	45.33	48	49.33	50
R2	24.33	34.33	43.67	47.67	48.33	49.33
R3	19.33	29	35.83	38.33	39	40
R4	18	25	30.67	32	33	33.67
R5	17	24	29.33	30	30.67	31
M1	27.33	35.33	49.67	52.33	53	53.67
M2	32.33	37.17	51.17	54.33	55	55.33
M3	33.33	38.67	52.67	56.33	57.67	58
M4	23.5	34	47.67	51.17	52.17	53.33
R1M2	26	35.11	47	51	52	53
R1M3	29	36.67	50.67	53	53.67	54.33
R2M2	25	35	46	50	51.33	52
R2M3	25.67	35.33	46.67	50.5	51.67	52.33

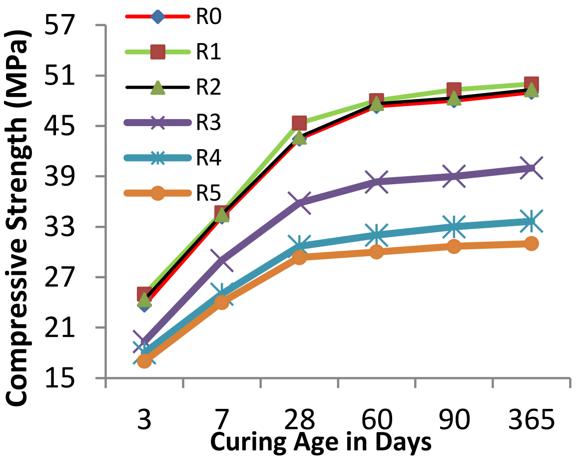

Fig 2. Compressive Strength of Rice Straw Ash admixed mortar

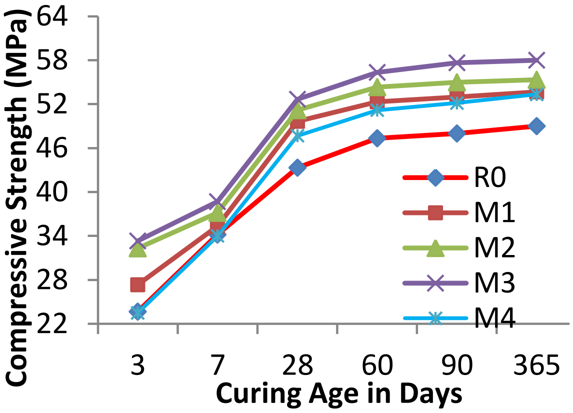

Fig 3. Compressive Strength of Microsilica admixed mortar

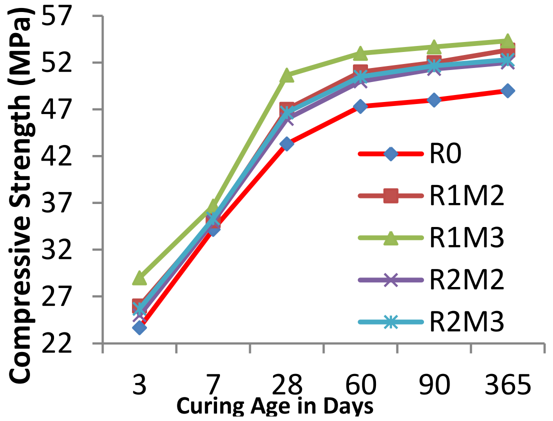

Fig 4. Compressive Strength of Rice Straw Ash-Microsilica admixed mortar

Table 5. % Increase in Compressive strength of RSA, MS and RSA-MS admixed mortars wrt control mix (R0)

Mix Proportion	% Increase in Compressive Strength w.r.t. R0					
	Days of Curing					
	3	7	28	60	90	365
R1	5.62	1.46	4.62	1.42	2.77	2.0
R2	2.79	0.47	0.78	0.72	0.69	0.6
R3	-18.3	-15.1	-17.3	-19	-18.7	-18
R4	-23.9	-26.8	-29.2	-32.4	-31.2	-31
R5	-28.2	-29.8	-32.3	-36.6	-36.1	-36
M1	15.4	3.39	14.6	10.5	10.4	9.5
M2	36.5	8.78	18	14.7	14.5	12
M3	40.8	13.1	21.5	19.0	20.1	18
M4	-0.72	-0.50	10	8.11	8.69	8.8
R1M2	9.84	2.75	8.47	7.75	8.33	8.1
R1M3	22.5	7.32	16.9	11.9	11.8	10.
R2M2	5.62	2.43	6.16	5.64	6.94	6.1
R2M3	8.45	3.39	7.71	6.70	7.65	6.8

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This leads to an increase in the compressive strength as compared to a control mix.

As the ratio of rice straw ash particles is increased (mix R3, R4, R5) in the mix, amount of unburnt carbon (due to uncontrolled burning) present in the mix increases thus leading to high water demand which decreases the compressive strength. As the Chloride content in RSA is higher, part replacement of OPC with RSA leads to a decrease in compressive strength of the mortars containing RSA.

In the case of OPC-MS mix, it was observed that the maximum compressive strength is obtained at 7.5% replacement (table 4). Relative compressive strength of micro silica admixed mortar, as compared to the control mix, ranges from 99.3 to 140% for mix M1, M2, M3, M4 (table 5). The resultant high compressive strength of micro silica admixed mortar is mainly due to the size of its particles which is almost 30 times smaller (table 1) than that of the OPC particles and its high silica content (table 2). There is 0.72% and 0.50% reduction in 3 days and 7 days compressive strength respectively (table 5) of mix M4 as compared to the control mix. But at 28 days, the compressive strength of mix M4 increases as compared to that of control mix R0. As percentage replacement of the OPC in the mix by micro silica increases amount of SO_3 present in micro silica (table 2) also increases in the mix. As more amounts of SO_3 are present in mix M4, it leads to a decrease in the contents of alite and aluminate and an increase in belite materials. Therefore compressive strength reduces at early stages due to the reduction in the amount of alite and increases in longer stages as the formation of belite takes place [12].

In the case of OPC-RSA-MS mix, it was observed that the maximum compressive strength is obtained for mix R1M3 which has 5% rice straw ash and 7.5% microsilica (table 4). The relative compressive strength of rice straw ash-microsilica admixed mortar, as compared to the control mix, ranges from 103 to 122% (table 5). The resultant high compressive strength of RSA-MS admixed mortar is mainly due to the size of its particles which are comparatively smaller (table 1) than that of the OPC particles and its high silica content (table 2). It can be seen in figure 4 that when the quantity of micro silica is increased from 5 to 7.5% keeping the amount of RSA constant (5% and then 10%) in the mix, the compressive strength increases (R1M2, R1M3 & R2M2, R2M3). This is because microsilica has the most amount of Silicon Dioxide (SiO_2) % which may contain more reactive silica as compared to rice straw ash. It may lead to secondary CSH formation. The total amount of Magnesium Oxide (MgO) is more in rice straw ash as compared to micro silica and is higher than the prescribed limit which may lead to decrease in strength and increase in setting time [13].

V. CONCLUSION

It can be seen that micro silica increases the strength of the cement mortar. As it is a costly material, it will increase the construction cost. Therefore a material is needed that is economical and also does not compromise with the strength of the cement mortar e.g. rice straw ash.

Adding rice straw ash up to 10% can increase the compressive strength of the mortar, and it is very cheap also which will reduce the construction cost.

Composite of rice straw ash-microsilica can also be used to replace OPC as the results show. An advantage of using the RSA-MS composite as an OPC replacement is that they give sufficient strength to the mix without compromising with the cost. Though their compressive strength is much lower as compared to a mix containing micro silica but they are comparatively very cheap. It is known to everybody that cement plants contribute significantly towards global warming, using RSA-MS composite as replacement of OPC can dramatically reduce the production of cement thus reducing pollution. Therefore on this basis and the basis of compressive strength and economic consideration, mix R1M3 and R2M3 can be elected as the two best possible combinations. It can be said that R1M3 will provide more compressive strength and will be comparatively costly while R2M3 will provide lesser compressive strength between the two but will be cheaper than R1M3.

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