Preliminary Study of Cement Paste Admixed with Rice Straw Ash, Microsilica & Rice Straw Ash-Microsilica Composite

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Abstract: The objective of this study was to examine pastes in order to check the possibility of utilizing unprocessed rice straw ash with or without micro silica in Pavement Quality Concrete. Physical (SEM, XRD, Specific Gravity etc.) & chemical properties (XRF) of materials used were analyzed. Different proportions of OPC, RSA & Micro silica were researched for normal consistency, initial and final setting time of paste etc. Different proportion of rice straw ash and microsilica used for part replacement of OPC in the cement paste were 5, 10, 15, 20, 25, 30% and 2.5, 5, 7.5, 10% by weight of OPC respectively. Rice straw ash was also mixed with micro silica to form a composite for replacing OPC in the mix. Mix R1M3 (5% Rice Straw Ash & 7.5% Micro Silica) could achieve highest pozzolanic reaction while mix R2M3 (10% Rice Straw Ash & 7.5% Micro Silica) could achieve maximum economy. In India, Rice Straw is produced in abundance and has extensive geographical coverage. Rice Straw Ash is technically of no use to farmers, and they treat it as a waste product. They tend to burn rice straw in order to clear their field for the next batch of crop. In this paper, rice straw admixed with micro silica is treated as a potential material for pavement construction, and various preliminary tests were done on cement-rice straw ash-micro silica paste to check the possibility of using rice straw ash in pavement quality concrete.

Keywords: Rice Straw Ash; Pastes; Micro silica; Consistency; Initial and Final Setting times.

I. INTRODUCTION

It is highly known that cement plants consume more energy as compared to many and produce a large amount of CO_2. 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] Conventionally, Ordinary Portland Cement (OPC) is used for concrete pavement construction. Production of OPC liberates gases which cause the greenhouse effect. 814-935 kg of CO_2 is liberated into our atmosphere in the production of every 1-ton kg of cement. Cement plants account for 5% of worldwide discharge of CO_2 and are among the fundamental driver of an unnatural weather change. [2] Pavement construction has two options: flexible and rigid. Flexible or bituminous pavements have low initial cost as well as low service life, while rigid or concrete pavements have higher construction cost and higher service life.

El-Sayed et al. (2006) [3] states that rice straw is produced in plenitude on the earth and is viewed as a waste item causing issues with their disposal. As indicated by them, when rice straw is singed, it produces ash which is very pozzolanic. He additionally specifies that rice straw ash fulfils the necessities of ASTM Class N, F, and C pozzolan; and has a specific gravity of 2.25 and specific surface area as 18,460 cm^2/gm. Consistently around 600 million tons of paddy is produced globally. Pathak, Jain and Bhatia (2012) [4] mentions that rice straw is a noteworthy agricultural by-product of Asia where its yearly production adds up to almost 95% of aggregate world production. Ravindranath et al. (2000) [5] mentions that rice straw ranks highest amongst agro-residues at the national level.

Micro silica, generally called silica fume, is an indistinguishable (non-crystalline) polymorph of silicon dioxide, silica. It 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. [6]

Several pozzolans like flyash, rice husk ash, microsilica, wollastonite, GGBS, wheat straw, sugarcane bagasse etc. have been evaluated in the past for this purpose. Most of these were studied for use in general purpose concrete (<M25 grade), except for few like flyash, rice husk ash, microsilica and wollastonite which were studied for Pavement Quality Concrete (PQC).There has been less measure of work done to research the conceivable outcomes of utilizing rice straw ash in PQC and even small number of these research addresses the utilization of natural RSA (RSA that is either not ground to very fine particle sizes and/or that is not produced by an enhanced burning procedure) in PQC. The goal of this investigation was to analyse pastes keeping in mind the end goal to check the practicality of utilizing unprocessed rice straw ash with or without micro silica in PQC.

II. EXPERIMENTAL PROGRAM

A. Raw Materials

The cement utilized was Ordinary Portland Cement (OPC) of 43 grade which was as per IS: 8112-2013. [7] Standard Sand (Ennore Sand) was utilized all through the exploratory work in order to keep the fine aggregate variable consistent. It is accessible at Ennore, Madras.

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920D-grade microsilica was used as a cementitious material. It was gotten from Elkem South Asia Pvt. Ltd. Rice Straw was procured from Agricultural Farm, BHU and was scorched outdoors and afterwards, was sieved through 0.09mm sieve. Consumable water used for blending and curing is in accordance with IS 456:2000. [8] Conplast SP430 super plasticizing admixture was utilized to adjust for

the loss in workability as there is an increase in the surface area. It was obtained from Fosroc Chemicals (India) Pvt Ltd. The chemical composition of OPC, Rice straw ash, and microsilica was investigated by XRF spectrometer. Physical properties, for example, specific gravity, the specific surface of OPC by Blaine's technique and that of RSA and microsilica by Brunauer–Emmett–Teller method, particle shape of materials by SEM, and mineralogical examination of materials by XRD were likewise explored. The above-mentioned tests are just to measure the properties of raw materials.

B. Mixture Proportions

Different mixtures were set up for pastes containing distinctive amounts of rice straw ash and micro silica. Mixtures were prepared by supplanting OPC by weight with Rice straw ash at a normal interval of 5% till 30% and Micro silica at a consistent interval of 2.5% till 10%. Different mixture proportions are shown in table 1.

Table 1 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
R4	80	20	-	0.95
R5	75	25	-	1.20
R6	70	30	-	1.35
R100	-	100	-	-
M100	-	-	100	-
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

C. Chemical Composition

The compound arrangement of OPC, Rice straw ash, and microsilica was examined by X-Ray fluorescence spectrometer.submission.

Cement - XRF result of unhydrated cement is shown below. Table 2 shows that cement has oxide of Silica, Sulphur, Calcium, Aluminium and Magnesium.

Rice Straw Ash - XRF test result of Rice Straw Ash is shown in table 3. This shows Rice Straw Ash mainly contains Silica 79.82 %. [9]

Micro Silica- XRF result of Micro Silica is shown in table 4. This result shows Micro Silica contains mainly Silica 91.3% and Sulphur Oxide 3.13%.

D. Physical Properties

Physical properties, for example, specific gravity, the specific surface of OPC, RSA and micro silica, particle shape of materials by SEM and mineralogical examination of materials were researched.

Table 2 Chemical composition of Cement used

Compound	% by Weight
CaO	42.16
SiO_2	26.34
MgO	14.79
Al_2O_3	6.13
Fe_2O_3	3.7
P_2O_5	2.03
SO_3	1.73
Na_2O	1.33
SrO	0.45
Cl	0.305
TiO_2	0.189

Table 3 Chemical composition of RSA

Compound	% by Weight
SiO_2	79.82
MgO	7.54
Cl	4.06
P_2O_5	3.75
S	1.16
Al_2O_3	1.13
K_2O	1.07
Na_2O	0.501
CaO	0.370
Fe_2O_3	0.245

Table 4 The chemical composition of Silica Fume

Compound	% by Weight
SiO_2	91.3
SO_3	3.13
Fe_2O_3	1.47
MgO	1.29
K_2O	0.653
Al_2O_3	0.616
P	0.38
ZnO	0.244
CaO	0.171
Na_2O	0.082

- *Specific Gravity*

The specific gravity of OPC, RSA, and Micro silica was found according to IS: 2720, Part 3 [10] which turned out to be 3.12, 2.25, and 2.23 respectively.

- *Specific Surface Area*

A couple of tests were done to determine the specific surface area of OPC, RSA & Micro silica. BET test was done by Surface Area Analyser from Smart Instruments Co. Pvt. Ltd. to find the specific surface area of Rice Straw Ash and Micro Silica.

Specific Area of RSA and Micro silica turned out to be 1.846 m^2/gm and 16.14 m^2/gm respectively. Specific surface area of OPC was determined by Blaine's method and it turned out to be 0.3 m^2/gm.

- *Particle Shape of Materials by SEM*

SEM result of OPC, RSA & Micro Silica is shown below. On comparing the SEM images of OPC, RSA & Micro Silica, it can be seen that OPC particle have bigger size as compared to Micro silica & RSA.

Cement - It can be seen unmistakably in the accompanying figure 1 that the particle shape of the OPC is to some degree like that of the aggregates. Around 95% of cement particles are littler than 45 microns with an average size of the particle being 15 microns.

Rice Straw Ash - Microstructural features acquired from Scanning Electron Microscopy (SEM) (Figure 2) demonstrates that RSA particles are nearly more permeable and needle-like structure. [9]

Micro Silica – By SEM analysis of Micro Silica (figure 3), it can be seen clearly that the shape of the particles is round or spherical which increases the flow ability of the mix.

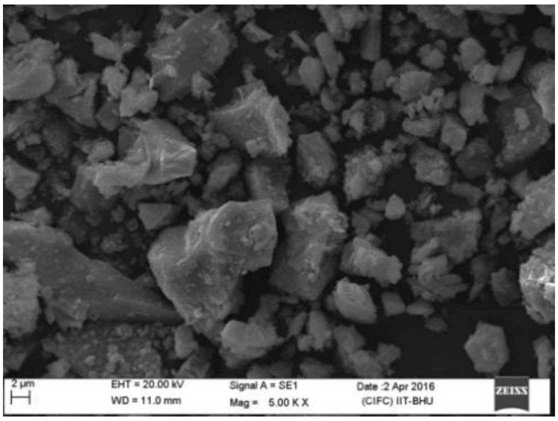

Fig 1 SEM image of unhydrated cement

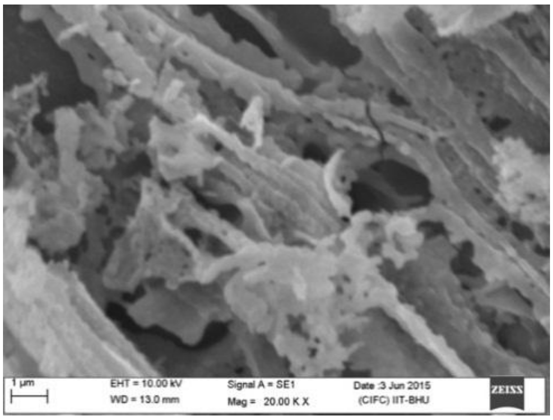

Fig 2 SEM image of Rice Straw Ash

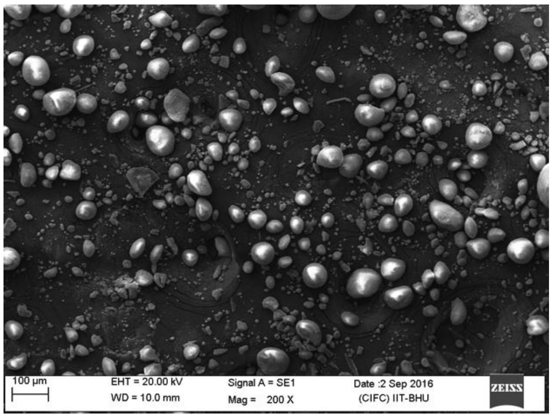

Fig 3 SEM images of Micro Silica

- *Mineralogical Analysis*

XRD Analysis was carried out on OPC, rice straw ash & micro silica using Rigaku Ultima IV X-Ray Diffractometer. Mineral phases present in the materials are known by distinguishing the peaks.

Cement – Figure 4 shows XRD result of unhydrated cement and peaks of Calcium Silica Oxide can be seen.

Rice Straw Ash - Mineral phases present in the rice straw ash are known by identifying the peaks in Figure 5 [9]

Micro Silica - XRD examination of Micro Silica (Figure 6) demonstrates a narrow peak hump which implies Micro Silica contains mineral in the amorphous form. It has peaks of Quartz. This test outcome likewise demonstrates that Micro Silica has exceedingly reactive Silica since it is occurring in the amorphous form.

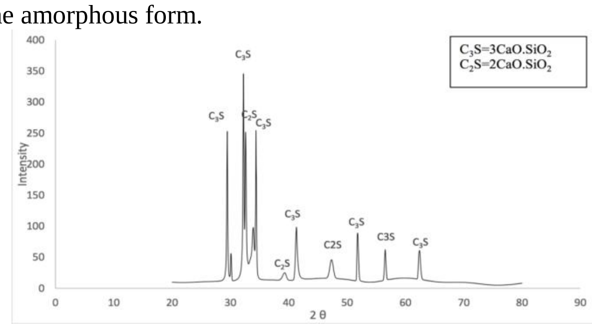

Fig 4 XRD of Unhydrated Cement

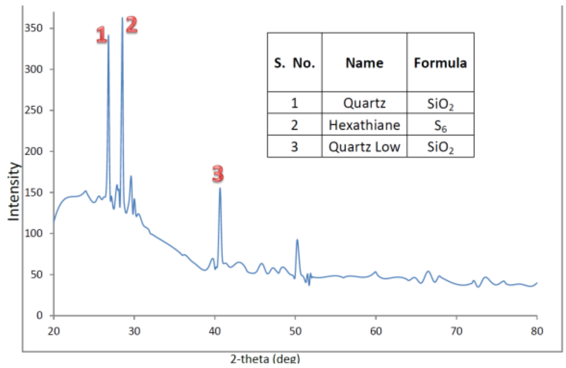

Fig 5 XRD peak distribution for rice straw ash

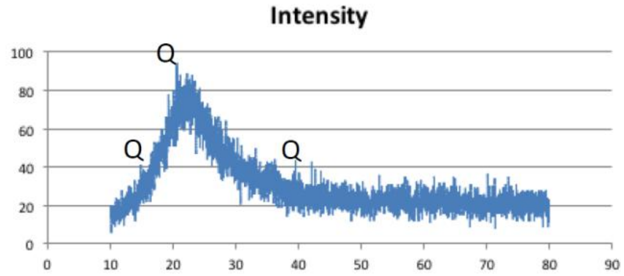

Fig. 6 XRD peak distribution for micro silica

E. Normal Consistency of Pastes

The standard consistency of a cement paste is characterized as that consistency which will allow the Vicat Plunger to enter to a point 5 to 7 mm from the base of the Vicat mould. Table 5 demonstrates the consistency and setting times of control and admixed pastes.

F. Setting Times of Pastes

A test for determining initial and final setting times of control and admixed pastes were done in accordance with IS: 4031-Part 5 [11]. Setting times of control and admixed pastes are shown in Table 5.

Table 5 Normal Consistency, Initial & Final setting times of Pastes

S. No.	Mix	Consistency (%)	Initial Setting Time (min.)	Final Setting Time (min.)
1	R0	32	155	195
2	R1	41	161	220
3	R2	46	175	249
4	R3	53	181	271
5	R4	58	208	303
6	R5	63	241	335
7	R6	67	271	355
8	R100	75	-	-
9	M1	37	160	201
10	M2	40	158	199
11	M3	43	155	198
12	M4	44	154	198
13	M100	73	-	-
14	R1M2	41	145	217
15	R1M3	42.5	139	208
16	R2M2	43.5	155	235
17	R2M3	45	149	223

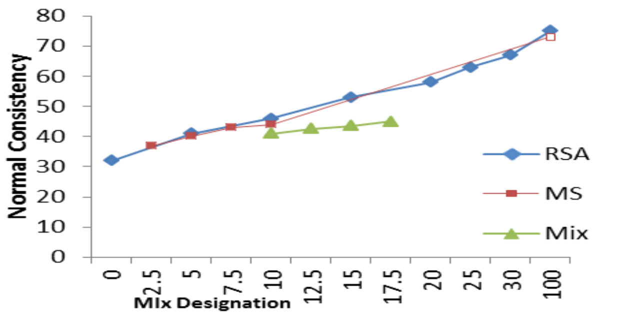

Fig 7 Comparison between normal consistency and replacement ratios of RSA-MS-Cement Paste

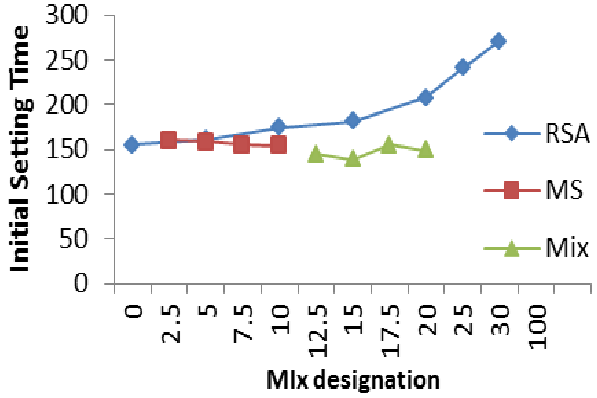

Fig 8 Comparison between Initial Setting Time and replacement ratios of RSA-MS-Cement Paste

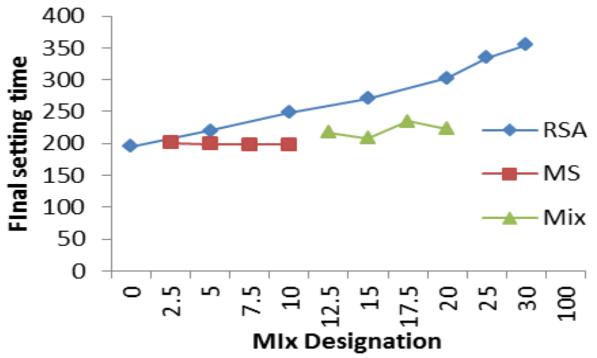

Fig 9 Comparison between Final Setting Time and replacement ratios of RSA-MS-Cement Paste

F. Marsh Cone Test

Flow time of mortar through Marsh cone is a pointer of viscosity which relies on cement super plasticizer compatibility. It is generally used to decide ideal HRWR dose for a particular cement-super plasticizer mix.

W/c proportion of the control mortar (100% OPC) was 0.5 at the desired workability. In this manner, the paste was readied utilizing the regular w/c proportion i.e. 0.5 for all the mix and HRWR (Conplast SP430) was utilized to make up for decreased workability in different mixes.

The dosage of superplasticizer is the point past which there is no huge lessening in the flow time. Saturation point can be taken as the maximum super plasticizer content to be utilized in concrete. HRWR Dosage for various proportions can be seen in table 1.

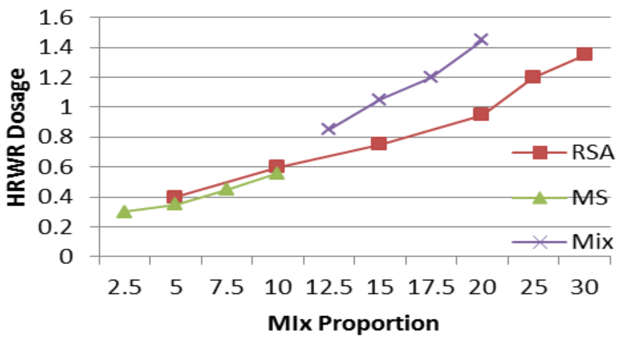

Fig 10 HRWR Dosage for different proportion of RSA-MS-Cement Paste

III. DISCUSSIONS AND CONCLUSIONS

A. Chemical Composition

Table 2, 3 & 4 displays the chemical composition of OPC, Rice straw ash, and Microsilica respectively. According to ASTM C618 [12], rice straw ash may be classified as class N pozzolan as its loss of ignition was nearly 10%. It can be found in the table that measure of SiO_2 exhibit in rice straw ash and micro silica is tremendously more when measured with the amount of CaO present in both the materials, subsequently, they are highly pozzolanic.

B. Physical Properties

Fig. 1, 2 and 3 exhibit the molecule size and state of OPC, rice straw ash and microsilica (MS) utilizing SEM. It was seen that OPC particles were amorphous like aggregates, rice straw ash particles were needle-shaped and micro silica particles were spherical in shape. The particle size of the RSA was smaller when compared with that of the OPC; however, micro silica particles were ultrafine with a smoother surface. In this manner, on blending OPC-RSA-MS, the surface area of the particles of the blend increases causing greater fondness towards the water and therefore reducing workability. As the size of the RSA and Microsilica particles are smaller as compared to OPC particles, their mixture will lead to filling of voids between OPC particles. Thus it may lead to increased strength.

C. Normal Consistency of Pastes

The consistency of control and admixed pastes are shown in Table 5. The normal consistency of R0 (control), R100 (100% RSA) and M100 (100% Microsilica) turned out to be 32, 75, and 73%, sequentially. When compared with the control paste, the normal consistency of OPC-rice straw ash paste had grown in the scale of 41– 67% in mixes R1 to R6. Correspondingly, in OPC-Micro silica paste M1 to M4, the normal consistency of OPC-MS paste had increased in the scale of 37– 44%. In OPC-RSA-MS paste, the normal consistency had increased from 41 to 42.5% in R1M2 and R1M3. It had likewise increased from 43.5 to 45% in R2M2 and R2M3.

As much as 28– 109% of extra water requirement over OPC paste was observed for OPC-rice straw ash paste (R1 to R6). So also, 15.5– 37.5% more water was required for OPC-MS paste (M1 to M4). In OPC-RSA-MS, the extra water requirement over OPC paste was seen to be 28.12% for R1M2, 32.81% for R1M3, 36% for R2M2 and 40.62% for R2M3.

D. Setting Times of Pastes

Initial and final setting times of OPC paste came out to be 155 and 195 min, respectively. For OPC-rice straw ash paste, the initial and final setting times had expanded as rice straw ash has lower CaO content when compared with OPC.

In OPC-rice straw ash-micro silica paste, the initial and final setting times had decreased from blend designation R1M2 to blend designation R1M3, and furthermore from blend designation R2M2 to blend designation R2M3. Among them, the briefest setting times has happened in Mix R1M3 and the longest in Mix R2M2.

E. Marsh Cone Test

The HRWR doses of mortars are shown in Table 1. So also, in expanding the measurement of rice straw ash in OPC-Rice straw ash paste in equal augmentation of 5% up to 30%, the HRWR dose had expanded in the scope of 0.4– 1.35%. In like manner, in expanding the measurements of micro silica in OPC-Micro silica paste in equal augmentation of 2.5% up to 10%, the HRWR dose had expanded in the scope of 0.3– 0.56%. Additionally, admixing of both rice straw ash and MS with OPC, the HRWR measurement has expanded from 0.85% for R1M2 to 1.05% for R1M3. It has likewise expanded from 1.2% for R2M2 to 1.45% for R2M3

F. Conclusions

The aftereffects of this investigations lead to the following conclusions:

- Rice Straw Ash is a Class F pozzolan according to ASTM C618. [12] SEM pictures demonstrate that rice straw ash particles were exceedingly permeable and needle-formed structure. The average size of RSA and Microsilica particles is around 5 and 30 times than that of OPC particles respectively.
- It was seen that OPC particles were amorphous like aggregates, rice straw ash particles were needle-shaped and micro silica particles were spherical in shape.
- As RSA and MS particles are finer than the OPC particles, their affinity towards moisture increases due to increased specific surface area. This was the main reason behind increase in the normal consistency of all the admixed samples as compared to control mix.
- Initial and Final setting times increase because of the blending of rice straw ash (up to 30%) in cement paste. This may be because RSA particles are finer as compared to OPC particles thus requiring more moisture due to increased surface area. Initial setting time decreases because of the blending of micro silica in OPC paste while the final setting time remains to a great extent unaffected. Be that as it may, both the times decreases when rice straw ash and micro silica are combined with OPC with an increment in MS proportion from 5 to 7.5%. Blend designations R1M2 and R2M2 have setting times sensibly near to the ordinary OPC paste. It can be reasoned that R1M3 could accomplish most astounding molecule pressing while R2M3 can accomplish the maximum economy.
- In view of the literature and outcomes, the cementitious material comprising of OPC, rice straw ash and microsilica in different proportions could be utilized in concrete work requiring high compressive strength. Be that as it may, more research is required on concrete and its durability aspects.

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