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Effect of Local Materials on Self Compacting Concrete

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***Abstract*— In civil engineering structures, concrete is a main construction material. It's ingredients are cement, fine aggregate (sand) and coarse aggregate. In today's world cost of cement and sand is increasing day by day. Many are unable to purchase because of their economic situation. To provide a solution, in this paper, we partially replaced Rice Husk Ash (RHA) with cement, and Quarry Dust with sand, because they are local and cheap materials. The Advantages of these materials are low cost and easy availability. Actually, Paddy is being cultivated more in India, so we can get large amount of RHA and QD is an industrial waste product. In this paper 5-20% of cement is replaced by RHA and from the above results 40% sand was replaced by QD. Compared the compressive strength of self compacting concrete mix (with RHA and QD) with self-compacting concrete mix (SCM) without the local materials experimentally.**

Keywords*— *Concrete, Rice Husk Ash, Quarry Dust, Compressive Strength, And Self-Compacting Concrete Mix

1. INTRODUCTION

Due to high strength, malleability and durability, concrete is most widely used construction material in civil engineering world. Large amount of concrete is being consumed every year in Indian construction. The main ingredients of concrete are cement, sand and coarse aggregate. For the past 10 years in some constructions local materials like RHA and QD are being replaced partially by cement and sand respectively. In this developing world, we are trying to use solid waste materials as concrete supplementary cementitious materials. By this we can reduce the solid waste disposal problems. One of the advantages of these local material is reduction in cost of concrete and also easy availability. RHA is obtained from Paddy. In India major crop is paddy. So we can get RHA easily. The cost of high quality sand is increasing day by day and also non available compared with QD. In this paper we partially replace cement and sand with RHA and QD respectively (with and without RHA and QD). Super plasticizer (SP) and Viscosity modifying agent (VMA) are used to make concrete self-compacting.

2. PRESENT WORK

2.1 Quarry Dust

Quarry Dust is a by-product in production of concrete aggregate by crushing of rocks. Because of its high fineness nature it is used in concrete in a limited amount. By adding QD to the concrete it increases the water demand and by this cement content will be analyzed for required workability and strength. Advantage of QD is, it is a cost saving product, and it depends on type of material we used as a source. Previous studies shows that by comparing mortar paste and concrete mix with the limestone powder had confirmed that the incorporation of granite fines requires high dosage of super plasticizer for the similar yield stresses and rheological properties. Self compacting concrete requires high powder contents or the addition of suitable viscosity modifying agent (VMA) to increase the segregation.

2.2 Rice husk Ash

Rice Husk Ash is produced after burning of Rice husks, has high reactivity and pozzolanic property. Rice husks is highly available in rice producing countries like India. These are the shells produced during the de-husking of paddy rice. Approximately 1000kg of rice can produce 200kg of husk, which on combustion produces approximately 40kg of ash. But according to Mehta the yearly world production of rice is approximately 500 million tons, which produces approximately 100 million tons of rice husks as a waste product from the milling. Rice husks are used for power generation in industries and as a fuel in boilers. Actually rice husk has ash content varying from 18-20%. RHA used as a supplementary cementing material in developing countries like India because supply of Portland cement is low and cost is high, but rice production is abundant. According to previous studies India produces 18 million tons of rice husks annually and approximately 12 million tons are readily available for the disposal from the rice mills (Bhanumatidas and Kalidas).

RHA may be in black, grey, or pinkish white in color depending on the combustion process. If the percentage of unburnt carbon increases, ash will be in dark color. Higher temperatures and longer durations of controlled burning produce RHA with higher pozzolanic properties. To avoid the formation of inactive crystals from rice husk silica, we have to burn the rice husk at temperature below 800^0c. It is also necessary to burn the rice husk for long enough that all the cellulose burns and leaves a white or grey colored ash. Normally RHA contains silica with small amounts of alkalis and other trace elements. Depending on the temperature range and duration of incineration, crystalline and amorphous forms of silica are obtained. Actually, crystalline and amorphous forms of silica have different properties, so it is important to produce ash with the correct specification of use. Maedeetal designed a furnace for the incineration process of rice husk. To obtain the high quality RHA incineration temperature must be below 550^0c . Duration of incineration must be sufficiently long to burn out fixed carbon in RHA. One of the advantage of RHA is, it has high pozzolanic index (108%) compared to fly ash (class F). Composition of rice husk and the ranges of physical-chemical characteristics of RHA from various sources in the literature are shown in Table 1:

. Table 1: Composition of Rice Husk; Physical and Chemical Characteristics of Rice Husk Ash

Rice Husk		Physical characteristics	Range
Element	Mass fraction	Density(g/cm^3)	2.06-2.15
Carbon	41.44	Average particle size(µm)	5.85-6.86
Hydrogen	3.94	Specific surface area (according to Blaine's air entraining test)(m2/g)	32.4-112.1
Oxygen	37.32	Mineralogy	Noncrystalline
Nitrogen	0.57	Shape and texture	Irregular and cellular
Silicon	14.66	Chemical characteristics	
Potassium	0.59	Silicon dioxide	87-97%
Sodium	0.035	Aluminum oxide	0.2%
Sulfur	0.3	Iron oxide	0.1%
Phosphorous	0.07	Calcium oxide	0.3-2.2%
Calcium	0.06	Magnesium oxide	0.2-0.6%
Iron	0.006	Sodium oxide	0.1-0.8%
Magnesium	0.003	Potassium oxide	0.21-2.3%
		Ignition loss	0.31-4.4%

2.3 *RHA for Cement and Construction*

Current construction industries expect to produce strong and durable building materials to the increasing needs, opposing harmful forces and a polluted environment. For example blended cements are in the forefront of such durable building materials. Blending reactive rice husk ash (rRHA) in cements is almost recommended by all international building codes. When RHA is added to the cement, secondary hydration products will form by combined reaction of calcium hydroxide in cement systems and rRHA. Once this reaction starts calcium hydroxide depletion will occur. By the way permeability of concrete is highly reduced and also resistance to acid attack will be increased considerably. RHA is porous in nature with a very high surface area and average size. That's why RHA increases the water demand. Actually RHA is an active pozzolana, so it has capability of giving high strength at both early and later ages, particularly when water-reducing agents are added. When RHA is added to Portland cement it reacts faster than the flyash with the lime released in Portland cement hydration. It helps to increase the early age strength and formation of calcium hydrate silicate (CSH) gel which forms around the cement particles that is highly dense and porous. This CSH gel alters the microstructure of the concrete with the discontinuous pores. The densification of the pores reduces the permeability of concrete and improves its resistance against the chloride penetration. However physical and chemical characteristics of RHA may vary depending on geographical location and climatic condition.

2.4 *Mechanism for Strength Development*

The significance of pozzolana cements is primarily derived from three features of pozzolanic reaction. First one is, the rate of heat of liberation and strength development are slow because the reaction is slow. Second, the reaction is lime consuming instead of lime producing, due to this phenomenon which increases the durability of hydrated paste by resisting the acid attack. Third the efficiency of filling the capillary spaces is high so that the improvement of strength and impermeability of the system will increase.

Two physical effects result from the chemical reaction between pozzolanic particles and calcium hydroxide. They are pore size refinement and grain size refinement. Both will occur to ensure solid formation of concrete from that more strength and high permeability are achieved. The chemistry of RHA involves the chemical reaction of the amorphous silica in the ash with lime to form calcium silicate hydrates. In a mixture of ordinary Portland cement and RHA, the silica reacts with the extra lime in Portland cement which in some times as high as 60%. According to James and Rao(1986) the silicates formed are of two kinds, CSH_I and CSH_{II} . The reactions are as follows:

$$Ca(OH)2+SiO2=CSHI+CSHII$$

where $CSHI=CaO0.8-1.5SiO2(H2O)1.0-2.5CSHII=CaO1.5-2.0SiO22(H2O)$

2.5 *Characteristics of Materials used*

Here our objective is to study the characteristics of basic materials of mortar i.e, cement, sand, QD, and RHA used as per Indian Standard Specifications. The material properties obtained are presented in Table 2-6

Table 2: Properties of Cement

Tests conducted	Results
Fineness(cm^2/g)	2,280
Specific gravity	3.1
Normal consistency (%)	3.1
Setting time (min)	
Initial	80
Final	210
Compressive strength(MPa)	
3 days	19.40
7 days	34.69
21 days	38.70
28 days	45.00

Table 3: Properties of Sand

Tests conducted	Result
Specific gravity	2.65
Water absorption	0.18%
Fineness modulus	2.44
Gradation	Conforms to Zone II per IS:383-1970

Table 4: Properties of Quarry Dust

Tests conducted	Result
Specific gravity	2.56
Fineness modulus	2.32
Water absorption(%)	9.0
Material finer than 75 µm	16.8
Organic impurities	-
Chloride(% by weight)	0.0085
Sulphate(% by weight)	0.058
p^H	7.65
Soundness(%)	
Sodium sulphate	6.64
Magnesium sulphate	7.48

Table 5: Results of Sieve Analysis of Quarry Dust

	Cumulative percent		Specification per IS: 383-1970 for fine aggregate (percent passing) (Bureau of Indian Standards 1970)			
IS Sieve designation	Retained	Passing	Zone I	Zone II	Zone III	Zone IV
4.75mm	0	100	90-100	90-100	90-100	95-100
2.36mm	0.3	99.7	60-95	75-100	85-100	95-100
1.18mm	20.0	80.0	30-70	55-90	75-90	90-100
600 µm	36.5	63.5	15-34	35-59	60-79	80-100
300 µm	55.0	45.0	5-20	8-30	12-40	15-50
150 µm	71.7	28.3	0-10	0-10	0-10	0-15

The tested sample does not satisfy the requirements of any grading zone of IS: 383-1970

Table 6: Properties of Rice Husk Ash

Tests	Results
Description	Gray powder
Specific surface area(m^2/kg)	448
Specific gravity	2.00
Aluminum oxide(%)	2.17
Iron oxide(%)	0.89
Calcium oxide(%)	11.31
Magnesium oxide(%)	0.23
Silica oxide(%)	54.65
Sodium oxide(%)	0.59
Potassium oxide(%)	1.15
Density(g/cc)	1.9311
Loss on ignition(%)	27.84
Material passing through	
75 µm(%)	98.73
100 µm(%)	99.85

RHA Manufacturing

In this paper RHA used is produced by burning the rice husk from the local rice mills in lime burning kilns shown in fig.1. A local kiln is fully filled with rice husk and covered at the top and sealed, fired using charcoal and firewood for a period of more than 24hours in normal condition and cooled. After that burnt husk ash is collected and finely ground in commercial flour mills. Whatever ash is grounded in flour mills that is now passing through 90 µm sieves. The material passing through 90 µm sieve is used in the self compacting mortar (SCM) mixes. The properties of RHA is used in this paper is shown in Table 6. From that table, whatever RHA obtained from the burning process is with moderate fineness and high loss of ignition. These characteristics would certainly affect the SCM mixes. Actually local burning technology is unsophisticated and cheap. Dimensions of the local burning kilns is as follows:

Top diameter(external): 1.2m; bottom diameter(external): 1.5m; height: 2.0m; wall thickness: 0.23m.

Fig.1: Local lime-burning kilns

Chemical admixtures

Actually admixtures first affect the flow behavior of SCM mixes. The superplasticiser(SP) uses Glenium 51and VMA uses Glenium Stream 2, both are in liquid form. These chemicals are classified as chloride free.

2.6 Normal and Self Compacting mortar mixes

Normal concrete mixes

Normal mortar cubes are cast per Indian standard specification to find the compressive strength of cement mortar cubes with cement and sand in a 1:3 ratio and water content equal to P/4+3% of combined weight of cement and sand. Here P is the normal consistency of cement paste. The cubes are cast and cured as usual and tested for compressive strength in the compression testing machine at different ages: 3,7, 21 and 28 days. The compressive strength results are shown in table 7.

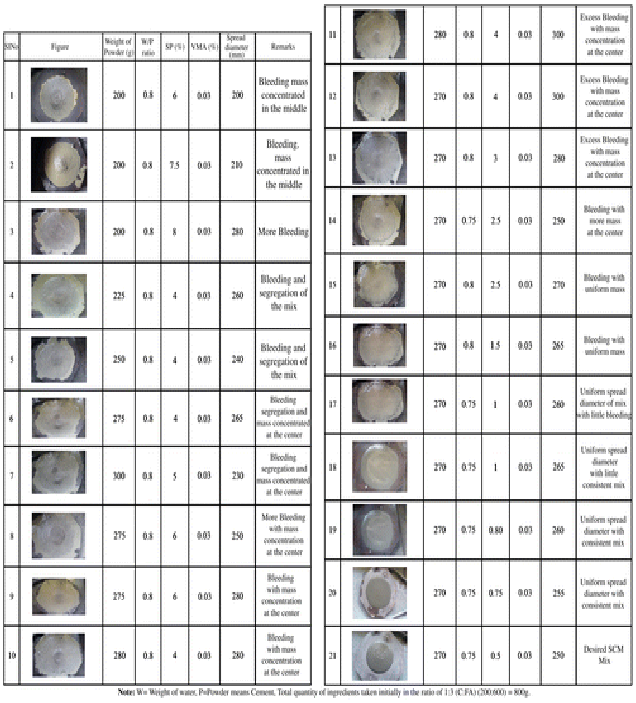
Table 7: Compressive Strength of Normal Mortar Mixes

Normal mortar mix compressive strength(MPa)			
3days	7 days	21 days	28 days
16.20	24.60	33.50	41.50

Self Compacting mortar mixes

The main objective of this paper is to understand the rheological and strength characteristics of the SCM mixes with and without RHA and QD. The rheological properties can be obtained from the results of two simple tests: one is mini slump cone test and second is mini V-funnels test. In fig-2 a number of trail mixes (1-21) with different proportions of cement and sand without RHA and QD, but suitable SP and VMA are prepared and flow properties are estimated. This process is continuous until the trial mix satisfies the desired requirements

Fig.2: Different trials for achieving the desired self-compacting mortar mix



SlNo	Figure	Weight of Powder (g)	W/P ratio	SP (%)	VMA (%)	Spread diameter (mm)	Remarks
1		200	0.8	6	0.03	200	Bleeding mass concentrated in the middle
2		200	0.8	7.5	0.03	210	Bleeding, mass concentrated in the middle
3		200	0.8	8	0.03	280	More Bleeding
4		225	0.8	4	0.03	260	Bleeding and segregation of the mix
5		250	0.8	4	0.03	240	Bleeding and segregation of the mix
6		275	0.8	4	0.03	265	Bleeding segregation and mass concentrated at the center
7		300	0.8	5	0.03	230	Bleeding segregation and mass concentrated at the center
8		275	0.8	6	0.03	250	More Bleeding with mass concentration at the center
9		275	0.8	6	0.03	280	Bleeding with mass concentration at the center
10		280	0.8	4	0.03	280	Bleeding with mass concentration at the center
11		280	0.8	4	0.03	300	Excess Bleeding with mass concentration at the center
12		270	0.8	4	0.03	300	Excess Bleeding with mass concentration at the center
13		270	0.8	3	0.03	280	Excess Bleeding with mass concentration at the center
14		270	0.75	2.5	0.03	250	Bleeding with more mass at the center
15		270	0.8	2.5	0.03	270	Bleeding with uniform mass
16		270	0.8	1.5	0.03	265	Bleeding with uniform mass
17		270	0.75	1	0.03	260	Uniform spread diameter of mix with little bleeding
18		270	0.75	1	0.03	265	Uniform spread diameter with little consistent mix
19		270	0.75	0.80	0.03	260	Uniform spread diameter with consistent mix
20		270	0.75	0.75	0.03	255	Uniform spread diameter with consistent mix
21		270	0.75	0.5	0.03	250	Desired SCM Mix

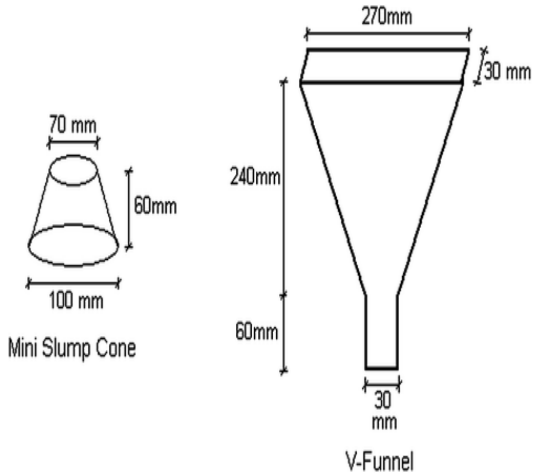
Note: W= Weight of water, P=Powder means Cement, Total quantity of ingredients taken initially in the ratio of 1:3 (C:FA) (200:600) = 800g.

Further to study the characteristics of SCM mix with RHA and QD by partial replacement of sand and cement, i.e, replacement level of sand by QD at 40% and the percentage of RHA are varying in the range of 5-20%. These mixes are tested for their rheological properties and compressive strength at 3, 7, 21 and 28 days.

2.7 Test methods for Developing Self Compacting Mortar Mixes

To know the rheological properties of SCM mixes, there are two tests, mini slump cone and mini V-funnel test and their dimensions are shown in fig-3

Fig.3: Dimensions of the mini slump cone and mini V-funnel apparatuses



Mini Slump Cone Test

The flowability of mortar mix can be known from the results of mortar flow test. Actually ultimate spread diameter is recorded 2 minutes after lifting. The acceptable value of spread diameter is in the range of 240-260mm

Mini V-funnel Test

This test is used to estimate the viscosity of SCM mix. The acceptable value of flow time of SCM mix should be between 7-11 s.

2.8 Developing Self Compacting Mortar Mixes by Trial and Error

The rheological and flow properties of SCM mixes estimated by using mini slump cone and mini v-funnel tests and their values are shown in fig-2 and Table-6. Total quantity of ingredients (cement and sand) maintained as 800g in all mixes, initially in the proportion of 1:3. The results of these tests depending on the water to powder ratio which is in the range between 0.8-0.9.

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Table 8: V-Funnel Test Results of Trial Mixes

SI.No.of mix	V-funnel flow time(s)
1	38
2	34
3	25
4	20
5	19
6	14
7	23
8	21
9	15
10	17
	22
12	19
13	23
14	20
15	14
16	15
17	11
18	10
19	9
20	8
21	8

The slump cone and v-funnel tests comprise many trails, beginning with a mortar ratio of 1:3. The quantities of SP and VMA are changed to obtain the ultimate spread diameter of 240-260mm and V-funnel time of 7-11s. But in initial trails show that bleeding, segregation, and inconsistency and fail to satisfy the desired conditions expected. For desired homogeneous and consistent mix these ingredients are changed simultaneously during each trail: weight of powder, water to powder ratio, SP and VMA. After doing number of trails the SCM mix of 1:2 is stable and consistent without bleeding or segregation. The mix obtained at the 21^{st} trail is the desired mix. The ingredients of desired mix are considered in the present investigation for developing other SCM mix with partial replacement of RHA and QD.

Replacement of sand by QD and cement by RHA were developed at different percentage levels for mix1 to mix4. The rheological properties are known for various replacement levels of RHA and QD to obtain the appropriate quantities of water to powder ratio, SP and VMA. By checking developed mixes which satisfy the rheological properties, then SCM cubes are casted using standard molds. The cubes are de molded after 48h, because setting time required by mortar increases owing to the addition of SP. After that as usual de molded samples are cured in water and tested in laboratory for compressive strength. The cubes are tested at 3, 7, 21, 28, 56 and 90 days. The various replacement levels of cement by RHA and sand by QD is shown in Table-9

Table 9: Replacement Levels of RHA and QD

Cement with RHA	Sand with QD
5%	40%
10%	40%
15%	40%
20%	40%

Table 10: Proportions and Flow Properties of SCM Mixes

Mortar mix designation	Desired SCM mix	Mix 1	Mix 2	Mix 3	Mix 4
Proportions achieved	1:1.96	1:2	1:2	1:2	1:2
Sand replaced by QD (%)	0	40	40	40	40
Quantity of QD (g)	0	212			
Cement replaced by RHA (%)	0	5	10	15	20
Quantity of RHA (g)	0	13.5	27	40.5	54
Water-powder ratio	0.75	0.80	0.81	0.83	0.84
VMA (%) weight of water	0.03	0.03	0.04	0.04	0.05
Superplasticizer (%) weight of cement	0.5	0.5	0.5	0.5	0.5
Quantity of cement (g)	270	256.5	243	229.5	216
Quantity of sand (g)	530	318			
Quantity of water (g)	202.5	385.60	390.42	400.06	404.88
Flow time (s) of mini V-funnel test	8	9	10	9.5	11
Spread diameter (mm) of mini slump cone test	250	240	250	245	255

Table 11: Compressive Strength of SCM Mixes

Mortar mix designation	Compressive strength(MPa)					
	3 days	7 days	21 days	28 days	56 days	90 days
Desired SCM mix	14.00	21.40	31.60	39.00	-	-
Mix 1	10.02	15.40	20.72	32.50	36.60	38.45
Mix 2	7.60	11.40	21.00	30.40	33.50	36.74
Mix 3	6.68	10.70	15.40	19.00	27.40	30.08
Mix 4	4.68	8.68	13.40	15.00	20.72	24.06

2.9 Results and Discussion

From Table-11, the compressive strength of SCM mix with RHA and QD is less than the compressive strength of SCM mix without RHA and QD. From that table later age strengths of SCM mixes with RHA and QD are more comparable to the strengths of the desired SCM mix than the strengths at earlier ages. The rheology of the SCM mix with local materials was not significantly different from desired mix (100% cement and sand) when SP and VMA are added. Compressive strength of SCM mix was decreased by adding RHA, decreasing trend is observed at all ages, but rate of reduction decreased as the age progressed. In 90 days SCM mix with RHA is same as desired mix strength, this is the advantage of RHA i.e, RHA will gain same strength at later ages. Practical problems regarding bleeding and segregation resistance should be studied before selecting the mixes. Mini slump cone and mini v-funnel tests are considered for comparison because they were consistent. This paper shows that adding of RHA to the SCM mix decrease compressive strength occurred at all ages due to coarser property of ash and may not have sufficient pozzolanic index value. However reduction in compressive strength is not very significant when other advantages of RHA considered like durability.

3. CONCLUSION

The main objective of this paper is to show the effect of local materials like RHA and QD in SCM mixes by partial replacement of cement and QD respectively. Actually by adding local materials, compressive strength decreases at early ages than the normal mix. Then at later ages difference in their strength will be less, that's why we use RHA and QD in normal practice. Also they are economical compared to cement and sand. Replacement level of cement by RHA should be between 5-10%, it will give SCM mix with good flow characteristics and comparable compressive strengths. Any way by this experiment we can achieve SCM mix with appropriate flow and strength characteristics by adding RHA and QD.

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