Development of self-compacting mortar mixes using agro based waste as a partial replacement to cement

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Concrete is globally used construction material in all categories of civil engineering structures. The rapid increase in construction has caused heavy demand for ingredients of concrete such as cement and sand. These materials are becoming costly and scarce, hence utilization of mineral admixtures in concrete production has got a wide scope in recent years. In the present investigation the Rice-husk ash (RHA) and Bagasse ash (BA) are partially replaced to cement in the production of self-compacting mortar (SCM) which acts as an integral part in studying the properties of self-compacting concrete (SCC). Since the characteristics of SCC depends on the mortar phase in which the aggregates are suspended, hence it is intended to develop SCM. The fresh and hardened properties of SCM developed in the laboratory are studied along with independent and blended replacement levels of RHA and BA.

1.0 INTRODUCTION

Conventional concrete is vibrated to get the good compaction in order to achieve good density, which in turn results in strength and durability. Because of improper workmanship and even excess vibration, poor quality of concrete might be produced. Hence the development of SCC is essential in order to overcome several problems. The concept of SCM is suitable to enumerate the properties of SCC, since the major character of SCC is dependent on mortar phase in which the aggregates are suspended. Apart from this, there is a plenty of agro based waste generated in India every year which can be effectively used in production of sustainable and eco friendly SCM. In the present context RHA and BA are used in order to partially replace it with cement in developing SCM. The RHA and BA are the two waste materials derived from different agricultural products, which contains high silica in its chemical composition which helps in development of secondary CSH gel which intern improves the strength of mortar. Further as the RHA and BA particles are fine in size, it will fill the voids present in cement and increase the density of mortar.

2.0 LITERATURE REVIEW

SCM is used for various purposes like repair works, filling narrow places etc. The major ingredients used are cement which is responsible for considerable amount of carbon dioxide emission to environment. Hence suitable substitute is essential for cement in order to develop a sustainable and eco friendly mortar. RHA is very effective in case of partial replacement to cement to produce high compressive strength concrete and mortar. The RHA is replaced to cement in the range of 10-30% and achieved the strength up to 40MPa. The utilization of RHA and BA as individual and blended replacement to cement in production of concrete has improved the strength and fresh properties.

The strength and porosity of BA based geopolymer mortar is studied and reasonable strength of 11.6-15.8 MPa and porosity of 20.5-23.5% were obtained. The blending of BA and RHA in production of concrete has decreased the chloride penetration and increased compressive strength slightly. The SCM can be effectively developed using RHA and QD. The RHA is replaced to cement in the range

Table 1. Physical properties of OPC

Physical tests		Results obtained	Standard requirements as per IS 8112:1989
Fineness (%)		2.5	Not more than 10%
Normal consistency (%)		30	-
Specific gravity of cement		3.13	3.15
Initial setting time (minutes) Final setting time (minutes)		80 240	Not less than 30 Not more than 600
Compressive strength (MPa)	7-days	33.5	Not less than 33
	28-days	43.0	Not less than 43

of 5-20% in steps of 5% and the maximum compressive strength was observed at 15% replacement. The porosity decreases as the percentage of RHA increases.

3.0 METHODOLOGY

Methodology has been divided into three phases. First Phase covers procurement and testing the basic properties of different agro based by-products used. Second phase reports selection of mix proportion of mortar for different mix cases. Whereas third phase high lights the fresh and the hardened properties of developed SCM mixes in the laboratory.

3.1 Materials

The properties of various materials used are as listed below.

3.1.1 Cement

In the present investigation cement used was OPC. The Physical properties obtained are as shown in Table 1.

Table 2. Test results of fine aggregate

Physical test	Results obtained
Specific gravity	2.6
Fineness modulus	3.0
Water absorption	1.5
Surface moisture content	Nil
Grading zone	Zone- II

Table 3. Physical and chemical characteristics of RHA

Bulk density	0.58gm/cc
LOI	<6%
Physical state	Solid-non hazardous
Appearance	Powder
Color	Grey black
Odour	Odourless
Specific gravity	2.17
SiO_2	88.64
Al_2O_3	1.23
Fe_2O_3	1.19
Carbon	2.33
CaO	1.09
MgO	1.76
K_2O	1.98
Others	1.78
Moisture	1.87

3.1.2 Fine aggregate

These tests were conducted as per BIS Standards. The results obtained are as reported in Table 2.

3.1.3 Rice husk ash (RHA)

In the present investigation RHA from mills in Odisha State, India is procured and used. RHA passed through IS: 90 micron sieve was used for the work. The chemical and physical composition of RHA is shown in Table 3.

3.1.4 Bagasse ash (BA)

In the present work Bagasse ash brought from sugar factory Mandya, Karnataka State is used. This is having grayish black color. Bagasse ash passed through IS: 90 micron sieve was used for the investigation. Specific gravity of Bagasse ash is 1.63. The chemical composition of Bagasse ash is shown in Table 4.

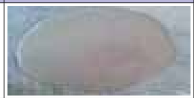
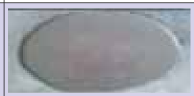
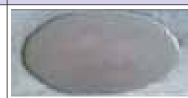
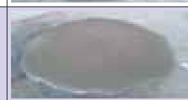
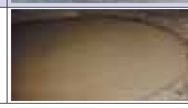
Table 4. Chemical composition of bagasse ash

Element	Mass fraction (%)
Silica	78.34
Alumina	8.55
Ferric oxide	3.61
Calcuim oxide	2.15
Magnesium oxide	1.65

Table 5. Designed mix proportions of SCM

Mix notations	W/B ratio	Proportions	Chemical admixtures (%)
DSCM	0.75	1:1.96	0.50
RHA (5%)	0.81	1:2	0.50
RHA (10%)	0.83	1:2	0.55
RHA (15%)	0.84	1:2	0.56
RHA (20%)	0.86	1:2	0.57
BA (5%)	0.82	1:2	0.55
BA (10%)	0.84	1:2	0.60
BA (15%)	0.85	1:2	0.60
BA (20%)	0.86	1:2	0.60
RHA (2.5%) + BA (2.5%)	0.81	1:2	0.55
RHA (5%) + BA (5%)	0.83	1:2	0.55
RHA (7.5%) + BA (7.5%)	0.84	1:2	0.55
RHA (10%) + BA (10%)	0.85	1:2	0.55

Table 6. Fresh property of self-compacting mortar mixes with RHA

Sl. no.	Figure	Mix proportions	W/b ratio	Slump flow (mm)	V-funnel time (s)
1		DSCM	0.75	245	7
2		RHA (5%)	0.81	240	9
3		RHA (10%)	0.83	243	9.5
4		RHA (15%)	0.84	245	10
5		RHA (20%)	0.86	247	10

3.1.5 Chemical admixtures

In the development of SCM mixes the major or the key thing is the utilization of suitable super plasticizer and viscosity modifying agents which will help in reduction of water content and improve the flow ability of mortar. In the present study the admixtures from a reputed company which are more desired to the development of desired self-compacting mortar (DSCM) having agro based waste as a partial replacement to cement is used. The admixtures used had the property of high range water reducers (HRWR).

3.2 Mix proportions developed

In the present investigation, a fresh and hardened property of DSCM and SCM mixes with the partial replacement of cement by RHA and BA in the range from 5-20% is studied. The design mix proportions of SCM are tabulated in Table 5.

3.2.1 Tests on SCM mixes

The present experimental Programme involves two phases of studies viz: Fresh and hardened properties. The tests are viz: Mini slump cone, Mini V-funnel and compressive strength.

4.0 RESULTS AND DISCUSSION

4.1 Fresh properties of mortar

The test results computed from mini slump cone and mini V-funnel tests are tabulated in Tables 6, 7 and 8. All the mix is designed to satisfy the recommendations given in the EFNARC Guidelines. These results will represent the flow ability and passing ability of mortar without any segregation and bleeding.

Table 7. Fresh property of self-compacting mortar mixes with BA

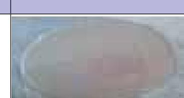
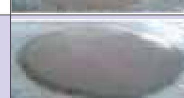
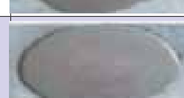
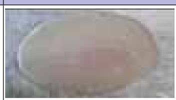
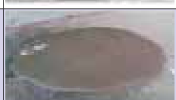
Sl no.	Figure	Mix proportions	W/b ratio	Slump flow(mm)	V-funnel time (s)
1		DSCM	0.75	245	7
2		BA (5%)	0.82	240	9.2
3		BA (10%)	0.84	242	9.5
4		BA (15%)	0.85	245	10
5		BA (20%)	0.86	246	10

Table 8. Fresh properties of self-compacting mortar mixes with RHA and BA

Sl. no.	Figure	Mix proportions	W/b ratio	Slump flow (mm)	V-funnel time (s)
1		DSCM	0.75	245	7
2		(RHA 2.5% + BA 2.5%)	0.81	245	10
3		(RHA 5% + BA 5%)	0.83	240	11
4		(RHA 7.5% + BA7.5%)	0.84	240	11
5		(RHA 10% + BA 10%)	0.85	240	10

The test results shows by using RHA and BA the fresh properties of mortar remain in the designed range as per the guidelines of EFNARC. Further as the RHA percentage increases the mini slump flow increases and the same happened in case of BA along with good passing ability. But in case of blended mixes (RHA+BA) the flow ability and passing ability are almost consistent with the varying percentage of ashes. The figure shown in Table 8 shows flow of mortar mixes in which the segregation and bleeding can be visually examined.

4.2 Compressive strength

The compressive strength of mortar cubes is evaluated for 3, 7, 21, 28, 56, and 90-days in order to know the strength development with respect to age. The mineral admixtures are used in the mortar mixes. However the strength development even after 28 days of curing is due to triggering of pozzolanic reaction at the later ages and hence 90-days cured specimens are tested for compressive strength. The results obtained are reported in Table 9. Further the chemical reaction may be illustrated as follows.

$$Ca(OH)_2 + SiO_2 = CSH_1 + CSH_2$$

Where $CSH_1 = CaO_{0.8\text{-}1.5}\,SiO_2\,(H_2O)_{1.0\text{-}2.5}$ and

$$CSH_{II} = CaO_{1.5\text{-}2.0}\,2(H_2O)$$

From the Table 9, it is observed that the conventional mortar yields higher strength than the desired self compacting mortar (DSCM), where as the DSCM shows the desired strength at the age of 28 days. It is also observed that the compressive strength of DSCM increases gradually with respect to age.

From the above Table 10, it is observed that the compressive strength of RHA added mix keeps on decreasing as the percentage of addition increases i.e. the SCM mixes shows the maximum strength at 5% replacement to cement. It is seen that the compressive strength is about 4.7% higher than the normal mix, but the early age strength is lesser than the normal mix, this is because of the slow hydration process due to presence of RHA. As the age increases the strength keeps on increasing at all percentage replacement levels, because of RHA which triggers the pozzolanic reaction at later ages.

Table 9. Compressive strength of conventional and DSCM mix

Mix proportions	Age (days)	Compressive strength (MPa)
Conventional mix	7	33.50
	28	43.00
DSCM	3	14.80
	7	21.00
	21	29.60
	28	37.90

Table 10. Compressive strength of SCM mixes with RHA

Mix proportion	Compressive strength (MPa)					
	3 days	7 days	21 days	28 days	56 days	90 days
RHA (5%)	10.50	11.5	15.70	27.00	33.50	35.60
RHA (10%)	7.90	9.10	17.00	23.50	26.30	29.50
RHA (15%)	6.90	8.00	14.00	24.00	25.90	26.50
RHA (20%)	6.00	7.90	15.00	20.00	23.00	24.20

Table 11. Compressive strength of SCM mixes with BA

Mix proportions	Compressive strength (MPa)					
	3 days	7 days	21 days	28 days	56 days	90 days
BA (5%)	8.10	12.95	17.90	23.50	31.00	34.50
BA (10%)	10.30	12.60	14.00	16.30	25.90	27.00
BA (15%)	8.50	12.00	12.50	15.00	23.50	25.50
BA (20%)	7.80	11.40	12.00	14.00	20.00	22.60

Table 12. Compressive strength of SCM mixes with RHA and BA

Mix proportions	Compressive strength (MPa)					
	3 days	7 days	21 days	28 days	56 days	90 days
RH (2.5%) +BA(2.5%)	9.80	13.35	18.50	20.50	22.00	24.00
RHA (5%) + BA (5%)	11.10	13.45	19.90	21.50	23.30	25.60
RH (7.5%) + BA (7.5%)	11.00	14.70	20.00	23.00	24.70	29.20
RH (10%) + BA (10%)	10.20	11.90	16.30	18.00	19.60	21.60

From the Table 11, it is observed that the SCM mix with BA will give the optimum strength at 5% replacement level for a period of 90 days age. As the percentage of bagasse ash (BA) increases the strength gradually decreases at all the ages. The initial strength at 28 days is lower than the normal mix, but at later age (ie 90 days) strength developed is almost same as that of normal mixes. The ultimate strength at 90 days is almost same as the normal mix but it is about 1.5% higher than control mix.

From the Table 12, it is observed that, there is a gradual increase in the strength up to mix blended with RHA 7.5% and BA 7.5% replacement levels. Further the compressive strength is slightly higher than the mix with RHA and BA independently at all the ages up to 21 days. The ultimate strength developed at later ages is lower than the normal mixes as well as mix with individual replacement levels of RHA and BA.

5.0 CONCLUSIONS

The present investigation is to make the best use of agro based waste materials like RHA and BA in the development of self compacting mortars. This requires the good concrete knowledge and the laboratory experience, so as to attain the desired self compacting mortar in a short span of time. On the basis of outcome observed, the following conclusions can be drawn.

- The RHA and BA can be used as a better substitute for partial replacement of cement in case of production of self compacting mortars.
- The results obtained represents the compressive strength of SCM is higher at 5% replacement levels of both RHA and BA.
- In case of blended mixes having RHA (7.5%) + BA (7.5%) is the optimum replacement levels, but the strength obtained is lower than the normal mixes.
- The utilization of RHA and BA has improved the fresh properties of SCM, with their quality of particle size and higher specific surface area.
- As the percentage replacement levels of RHA and BA increases the strength increases up to RHA (7.5%) + BA (7.5%) and then decreases.
- The compressive strength at early ages of all the mixes is low, but the strength develops at the later ages because of triggered pozzolanic reaction.
- RHA and BA are the waste materials which are abundantly available in a low cost and hence the economical and eco friendly mortar mixes can be developed.

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