Mix Design of Self- Compacting Self-Curing Concrete using M-Sand and Cinder Aggregate

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Abstract- Utilizing the industrial wastes in the building construction attracts many researchers and manufacturers these days. In this paper a concrete mix is designed with cinder an industrial waste as coarse aggregate, manufactured sand (M-sand) as fine aggregate and Polyethylene Glycol 400 (PEG 400) as a self- curing compound to assess the characteristics of self-compacting self - curing concrete. Self-compacting concrete is attained by replacing cement with 50 % of mineral admixture Ground Granulated Blast Furnace Slag (GGBFS), super plasticizer at a dosage of 0.8% by weight of cement and reduced water-binder ratio. The self - compacting characteristics such as filling ability, passing ability and segregation resistance of the developed concrete mixes are found and compared with EFNARC standards. The compressive strength of different concrete mixes is determined after 7 and 28 of water and self curing. The integrity of the materials in concrete mixes is also done using Ultrasonic Pulse Velocity (UPV) test. The tests results are compared with the control concrete and found that there is a reduction in density of concrete around 12 %. Usage of admixtures, M-sand instead of river sand for fine aggregate and cinder in place of normal coarse aggregate reduces the consumption of natural resources like water, sand and gravel which further support the sustainable environment.

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Keywords – Mix design; Cinder; M-Sand; Self-compacting; Self-curing

I. INTRODUCTION

Improper compaction and curing of concrete may deteriorate the strength and durability of concrete structures. Repairing and redoing the structure is expensive and time consuming. By using self-compacting concrete the concrete defects can be solved [1, 3, 4, 6, 7, 9, 10, and 14]. Similarly using self-curing compound ensures the strength and durability property of the concrete studied by [2, 5, 8, 11, 15]. When these two characteristics are combined the benefits will be manifold [12, 13, and 17]. Cinder an industrial waste is generally used as a light weight filler material in sunken portions of the slabs. This is porous in nature and available in irregular sizes. By breaking them to uniform sizes of 20 mm or 12 mm it can be used as coarse aggregate in concrete, which decreases the density of the concrete and can be used for structural purposes. By using self-curing compound instead of water curing and M-sand [16] instead of river sand in the concrete conserves the natural resources like water and sand.

II. EXPERIMENTAL WORK

2.1 Materials

The materials used in this study are ordinary Portland cement of 53 grade, river sand, M sand, locally available coarse aggregate of maximum size 12.5 mm, GGBFS, Cinder aggregate, high range water reducing admixture Conplast SP 430, PEG 400, and potable water available in the laboratory. The properties of these materials used in this project are explained below.

Ordinary Portland cement of 53 grade conforming to IS: 8112, 1989 is used for the study. Specific gravity of cement is 3.15 with normal consistency of 34% and initial setting time of 180 minutes. Fineness is 349 m^2/kg. GGBFS a waste from steel industry conforming to BS 6699 is used as partial replacement of cement. The specific gravity is 2.85. Fineness is 390 m^2/kg. The mineralogical composition of the OPC and GGBFS is provided in Table1 and it is observed that the silica content is doubled in GGBFS than in OPC.

Table -1 Mineralogical Composition of OPC and GGBFS in %

Mineral	GGBFS	OPC
CaO	30-50	55-66
SiO_2	28-40	20-24
Al_2O_3	8-24	0-8
MgO	1-18	5

River sand and M-sand (Fig.1) with fraction passing through 4.75 mm sieve is used as fine aggregate and the specific gravity is 2.65.

(a) River sand (b) M-sand

Figure 1. Fine aggregate

Crushed granite and cinder aggregate of size 12.5 mm is used as coarse aggregate. The physical properties of the aggregates are obtained as per IS: 2386 1983and are listed in Table 2. Figure 2 shows the crushed granite and cinder coarse aggregates, respectively.

Table -2 Physical Properties of Coarse Aggregates

No	Aggregate	Water absorption	Impact value	Specific gravity
1	Crushed Granite	0.5%	18.5	2.65
2	Cinder	1.5%.	21.5	2.2

(a) Crushed granite aggregate (b) Cinder aggregate

Figure 2. Coarse aggregate

Conplast SP 430 conforming to IS: 9103-1979 as a high range water reducing admixture is used and its specific gravity is 1.18. Polyethylene Glycol-400 is used as internal curing compound which reduces the rate of evaporation from the surface.

2.2. Mix Design

The mix design for M 25 grade is prepared according to IS: 10262-2009 [19] and EFNARC [18]and the materials required per cubic meter of concrete are arrived at.

Table 3 shows the typical mix design trials of concrete using M-sand, Cinder and 50% replacement of cement with GGBFS by varying the water content by 208 and 200 litres/m^3 of concrete and w/b ratio by 0.5 and 0.48 respectively, to confirm its workability.

Table - 3 Typical Mix design trials using M-sand and Cinder aggregate

Materials (kg/m^3)	MIX 1	MIX 2	MIX 3	MIX 4
w/b ratio	0.5	0.48	0.5	0.48
Water	208	208	200	200
Cement	208	217	200	208
GGBFS-50%	208	217	200	208
Superplastizer-0.8%	3.33	3.47	3.20	3.33
M-Sand	896	888	914	907
Cinder aggregate	687	680	701	695
Remarks	segregation observed	segregation observed	segregation observed	workable

Based on the trial mixes, the mix design details of different water cured (WC) concrete made of natural aggregates and waste aggregates are arrived at and are shown in Table 4.

Table - 4 Mix design details of different WC specimens

Materials (kg/m^3)	Sand & NA	M-sand & NA	Sand & Cinder	M-sand & Cinder
w/b ratio	0.48	0.48	0.48	0.48
Water	200	200	200	200
Cement	208	208	208	208
GGBFS-50%	208	208	208	208
Superplastizer-0.8%	3.33	3.33	3.33	3.33
FA	907	907	907	907
CA	837	837	695	695

In order to get the mix design details of self curing (SC) concrete specimens, the optimum quantity of the internal curing compound PEG 400 is to be obtained. Table 5 shows the typical mix design for self cured concrete which is obtained by varying the percentages of PEG 400 from 0.5 to 2 and reducing the water content to 190 litres/m^3 for workability. It is observed that the concrete with 1% PEG 400 has higher strength (Figure 3) and therefore for the final mix design 1% PEG 400 is used for comparison between water cured and self cured concrete. Table 6 gives the mix design details of self cured concrete specimens using natural and waste aggregates.

Table 5 Typical mix design details using M-sand and Cinder aggregate with varying % of PEG 400

Materials (kg/m^3)	PEG 0	PEG 0.5	PEG 0.5	PEG 0.75	PEG 1	PEG 1.5	PEG 2
w/b ratio	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Water	200	200	190	190	190	190	190
Cement	208	208	198	198	198	198	198
GGBFS-50%	208	208	198	198	198	198	198
Superplastizer-0.8%	3.33	3.33	3.17	3.17	3.17	3.17	3.17
PEG 400	0	2.08	1.98	2.97	3.96	5.94	7.92
M-sand	906	904	928	927	925	923	921
Cinder aggregate (12mm)	695	692	711	710	709	707	705
		segregation observed					

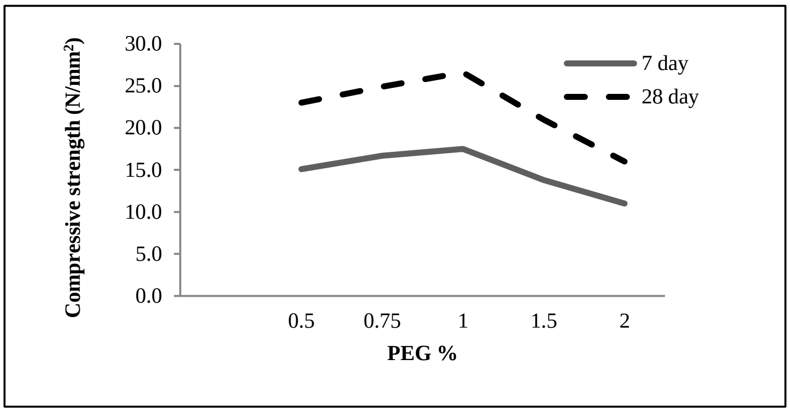

Figure 3. Compressive strength of specimens using M-sand and Cinder aggregate with varying percentage of PEG

Table 6- Mix design details of different SC specimens

Materials (kg/m^3)	Sand & NA	M-sand & NA	Sand & Cinder	M-sand & Cinder
w/b ratio	0.48	0.48	0.48	0.48
Water	190	190	190	190
Cement	198	198	198	198
GGBFS-50%	198	198	198	198
Superplastizer-0.8%	3.17	3.17	3.17	3.17
PEG 1%	3.96	3.96	3.96	3.96
FA	925	925	925	926
CA	854	854	709	709

III. Results and Discussion

3.1 Compressive strength and density of different WC & SC specimens

The 7th day and 28th day compressive strength of WC mixes - Sand & NA, M-Sand & NA, Sand & Cinder and M-sand & Cinder are 23.5, 20.8, 17.6 & 18.5 N/mm^2 and 35.1, 30.4. 27.2 & 28.1 N/mm^2, respectively [20].

The 7th day and 28th day compressive strength of SC mixes - Sand & NA, M-sand& NA, Sand & Cinder and M-sand& Cinder are 19.20, 17.50, 16.80 & 17.10 N/mm^2 and 27.90, 26.60, 25.10 & 25.30 N/mm^2, respectively. It can be seen that the water cured specimens are superior to self-cured specimens. It is also observed that all the self-cured specimens attained the desired strength and this proves the efficiency of PEG 400 in concrete (Figure 4).

Similarly, the density of the mix (Figure 5) M-sand& Cinder is 2160 kg/m^3 for WC specimen and 2148 kg/m^{3}for SC specimens, which is 10 - 12 % lesser to the conventional concrete.

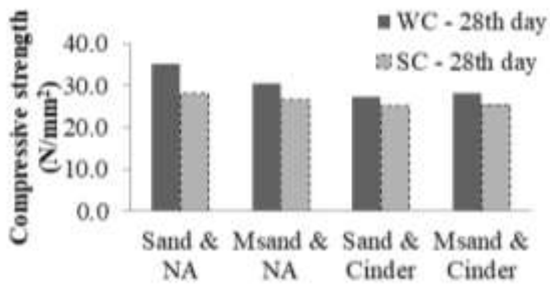

Figure 4. Compressive strength of different WC & SC specimens

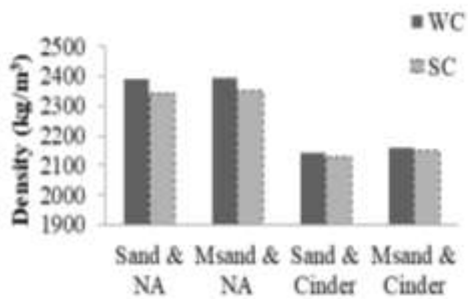

Figure 5. Density of different WC & SC specimens

3.2 Self-compacting Characteristics of M-sand Cinder Concrete

As per European Federation of National Associations Representing for Concrete (EFNARC) the fresh concrete properties such as slump flow test, T50cm slump flow, V-funnel test, U-box test, L-box tests are conducted. The test results and the specific criteria for Self-Compacting Concrete (SCC) are shown in Table 7.The flow ability test results found to be within the range as specified in EFNARC, therefore the concrete with M sand and Cinder aggregates can be used in places where compaction of concrete is difficult.

Table -7 Self-compacting Characteristics of M-sand Cinder Concrete Specimens

No	Tests	Typical range of values (EFNARC)	M-Sand Cinder WC	M-Sand Cinder SC
1	Slump flow (mm)	650 -800	650	670
2	T50 cm Slump flow (s)	2 -5	5	4
3	V – funnel test (s)	6 -12	12	10
4	U – box test (mm)	0 -30	25	20
5	L – box test (h_2/h_1)	0.8 -1	0.8	0.8

3.3 *UPV Tests on Concrete Specimens*

To ascertain the homogeneity and integrity of the specimens, UPV test is carried out and the results are shown in Table 8.The test results show that the WC and SC mixes of M-sand& Cinder is good and is within the range.

Table - 8 UPV Test Results of WC and SC M-sand& cinder Concrete Mixes

Concrete with various % of PEG	Typical range of test value	M-Sand Cinder WC	M-Sand Cinder SC
UPV test result (m/s)	3500-4000 (Good to Very good)	3554	3525

3.4 *Correlation Analysis of Mix Design*

The correlation analysis of mix design is done using R software by assigning value 1 for workability and 0 for segregation (Figure 6). It is inferred that the workability (WK) has inverse correlation with both water content (W) and water binder ratio (WB) by 58% and has direct correlation with M-sand (MS) and cinder (CN) quantity by 33% and 31%, respectively. But has no relationship with Binder quantity (B) and super plasticizer (SP). So we can conclude for this case that workability depend on the aggregate quantity but inversely depend on the water content and water binder ratio and does not depend on binder and super plasticizer quantity.

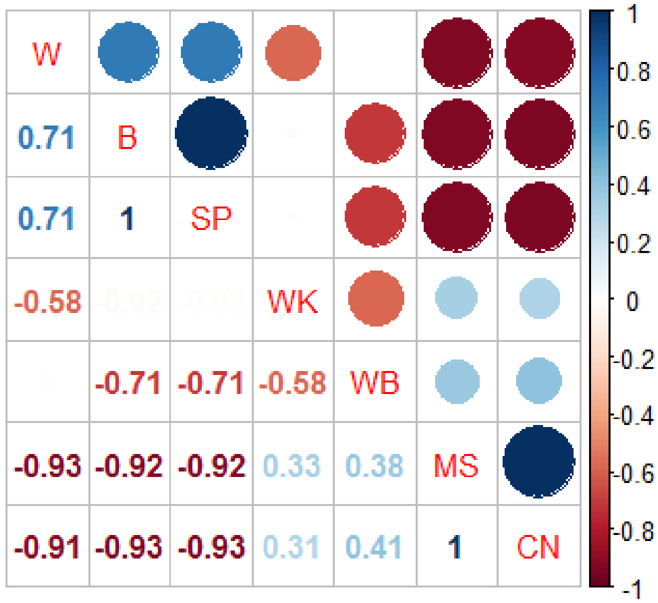

Figure 6. Correlation analysis of mix design

IV.CONCLUSION

In this work an attempt is made to bring out a workable concrete mix design using industrial wastes such as cinder as coarse aggregate and M-sand as fine aggregate. The test results show that the fresh and hardened properties of concrete with these industrial waste materials are well comparable with that of the conventional concrete. Also the developed concrete under water curing and self curing shows similar behavior. Hence fear about curing related issues during the construction of concrete buildings will be minimized.

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