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Durability Properties of M60 GradeSelf-Compacting Concrete with Partial Replacement of Cement by GGBS, Lime Powder and Metakaolin

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Abstract: ***In this investigation the Durability Properties of M60 grade Self compacting concrete (SCC) with partial replacement of cement by GGBS, Lime powder, and Metakaolin. Five mixes were prepared at 25% replacement of cement content with different admixture (.i.e.M1, M2, M3, M4&M5) at 0.34 w/c ratio and 1% super plasticizer dosage by cement content for maintaining required workability. Filling and passing ability were found out by slump test, V-funnel, L-box and U-box before casting the specimens. In this investigation M60 grade designed by means of Nansu method by fulfilling EFNARC guidelines for SCC. Durability properties tested under acid environment with H_2SO_4 and HCl and Sulphate environment with $MgSO_4$ and Na_2SO_4 at curing period of 28 days.***

In this investigation the Lime-powder based mixes shows high durability comparatively to Metakaolin as well as addition of GGBS maintained sufficient compressive strengths.

Keywords : SCC, GGBS, Metakaolin and Lime Powder.

I. INTRODUCTION

Day today growth in civilization tends to rapid growth in construction activity such that high rise buildings, hallow shafts, express high ways and massive constructions. For achieving the appropriate requirements such as accomplishing the project on constraint time at optimum budget therefore here comes into picture the Self compacting concrete (SCC) which is compacted by its own weight and fill formwork especially in congested place like beam-column joint and spread into every corner of farm works. Self-compacting concrete (SCC) is non-segregating concrete that can spread into place, fill the formwork and encapsulate the reinforcement without any need of vibration. By this concrete speedy construction is possible and with nice finishing.

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It is a sensitive mix, strongly dependent on the composition and characteristics of its constituents. The use of mineral admixtures not only improves the hardened properties but also durability properties of the concrete. Durability is a general analysis of the service life and the performance of concrete in all aggressive environments.

SCC is the most viable option for site conditions with constrained access and locations of congested reinforcements.

Many investigations undergone testing upon durability properties of SCC by partial replacement of different admixtures, Rizwan A khan concludes that SCC mix containing 20% Fly ash and 10% Metakaolin performs best in compressive strength, initial surface absorption and capillary suction tests [1]. Biswadeep Bharali states that the presence of fly ash in SCC improves workability of fresh concrete and addition of GGBS requires high dosage of super plasticizer to obtain acceptable workability therefore in the combined replacement of FA and GGBS cement shows increase in strength by increase in percentage of replacement [2].

M Jagadeesh describes replacing cement with fly ash reduce the strength of SCC mix when compared with GGBS and Normal SCC mix and also explains that the combined replacement of FA and GGBS withstands all the strength and obtained optimum results [3]. Srihari S and MV Seshagiri Rao explained that the addition of Metakaolin to concrete decreases the workability however can improve by increasing super plasticizer and change in w/b ratio and describes that replacement of cement by Metakaolin forms (C-S-H) gel which improves the compressive strength and makes concrete stronger by blocking existing pores in harden concrete [4].

B H V Pai investigation describes that to obtain acceptable workability requirement of SCC should adopt the mineral admixtures as powder content in concrete mix and states that presences of GGBS improves best results in compressive strength, split tensile strength and flexural strength. The low strength of SF based SCC mix is possible due to the high amount of SF (50.19%) [5]. S A Kristiawan, Sunarmasto and G P Tyas concludes that the degradation of SCC due to sulfuric acid attack as measured by compressive strength loss and diameter change can be reduced with a higher inclusion of fly ash to replace partially cement. The extent of the reduced degradation is more pronounced at a later age. The effect of fly ash content to modify SCC resistance against sulfuric acid could be explained by the combination of lower cement content, pozzolanic reaction and refinement of interparticle spaces [6].

II. MATERIALS USED

1. Cement:

The ordinary Portland cement is used for flexibility in adjusting pozzolanic material content in concrete mixes cement 53 grade of specific gravity 3.14 and normal consistency 28%.

2. Sand (FA):

River sand is used for this investigation with specific gravity of 2.53 and bulk density is about 1765Kg/m^3. Zone-II sand is used for this experimental work with 2.5% water absorption and 0.7% surface water content.

3. Gravel (CA):

Crushed stone aggregate of 10mm is used with specific gravity of 2.6 and bulk density is about 1523 Kg/m^3. These aggregates are more angular with 2% water absorption and 0.5% surface water content.

4. Mineral Admixture:

GGBS: Ground granulated blast furnace slag (GGBS) bought from JSW steel plant Allahabad had a specific gravity of 2.3 with pale yellow colour

Metakaolin: Presence of metakaolin improves durability properties of concrete comparatively. Metakaolin is available at Adhipathi minerals kothapally.

Lime powder: Lime powder is finer than cement collected from local resource.

5. Super plasticizer:

Master ease 3709 is used about 1% of cement content.

III. EXPERIMENTAL STUDIES

Specimens used in this experimental study are 120 cubes of 150X150X150 mm are undergone test i.e. acid attack and sulphate attack of concrete. Usually durability properties of concrete describe residual strength of concrete in mechanism. There are many tests to extract the durability properties such that permeability, sorptivity, water absorption, acid attack, sulphate attack etc. By using Nansu mix design method M60 grade of concrete is designed for this experimental study with fulfilling EFNARC guidelines for SCC. So many trail mixes performed to fix the final mix proportion. After a final proportion are fixed as 1(cement) :1.751(FA) :1.395(CA) for M60 grade of SCC. Mix proportions as shown in table 1. Mix M1 acts as a conventional concrete throughout investigation.

Table 1 Mix proportions

Mix	Proportions
M1	75%C+25%GGBS
M2	75%C+15%GGBS+10%LP
M3	75%C+15%GGBS+10%MK
M4	75%C+10%GGBS+15%LP
M5	75%C+10%GGBS+15%MK

IV. TESTING PROCEDURE

Since the concrete here is SCC need to conduct test on both fresh and harden concrete. To obtain acceptable workability of concrete it should satisfy the passing ability, filling ability and flowing ability. These tests are conducted as per EFNARC guidelines for SCC. After final mix fixed the mix design for mixes as shown in table 2

Table 2 Mix design

Mix	Cement (Kg/m^3)	Pozzalona (Kg/m^3)			FA (Kg/m^3)	CA (Kg/m^3)
		GGBS	*LP*	*MK*		
M1	436	145.5	0	0	1019	812
M2	436	87.3	58.2	0	1019	812
M3	436	87.3	0	58.2	1019	812
M4	436	58.2	87.3	0	1019	812
M5	436	58.2	0	87.3	1019	812

1. Fresh concrete test:

Workability test are conducted on SCC according to EFNARC guidelines for SCC and the fresh properties of SCC mixes with various composition of cementitious materials are tabulated in table 3 as follow.

Table 3 Test results on Fresh concrete

Property	M1	M2	M3	M4	M5
Slump (mm)	650	630	615	590	570
L-box (ratio)	0.9	0.86	0.81	0.75	0.7
V-funnel (sec)	10	11	12.5	14	16
U-box (ratio)	0.8	0.75	0.77	0.8	0.79

2. Harden concrete test:

2.1. Compressive test**:**

Table 4 Compression Test for 28 days

Mix	Proportions	compression test (28 days)			Average (MPa)
		1	*2*	*3*	
M1	75%C+25%GGBS	72.88	71.92	72.5	72.43
M2	75%C+15%GGBS+10%LP	84.2	83.6	83.4	83.73
M3	75%C+15%GGBS+10%MK	63.5	63.9	62	63.13
M4	75%C+10%GGBS+15%LP	71.6	72.8	72.2	72.2
M5	75%C+10%GGBS+15%MK	47.6	47.1	46.4	47.03

2.2. Acid attack:

2.2.1.1. H_2SO_4

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 5

2.2.1.2. HCl

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 6

2.3. Sulphate attack:

2.3.1.1. $MgSO_4$

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 7

2.3.1.2. Na_2SO_4

Percentage weight loss and percentage loss in compressive strengths for all mixes as shown in table 8

Table 5 Compressive strengths after acidic environment (H_2SO_4) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.21	8.33	8.34	8.33	8.34	8.21	8.22	8.26	8.24	8.19	8.31	8.23	8.21	7.96	8.30
After	8.01	8.05	8.18	8.05	8.18	8.19	8.06	8.09	8.04	7.88	8.00	8.11	7.79	7.66	8.00
%Loss of wt	2.38	3.29	1.90	3.29	1.90	0.17	1.86	2.08	2.43	3.73	3.67	1.43	5.12	3.73	3.65
% of loss in wt (Avg)	2.4			1.8			2.1			2.9			4.2		
f_{ck}	72.4			83.7			63.1			72.2			47.0		
f^{l}_{ck}	52.1			59.6			38.8			40.6			38.6		
% of loss in strength	28.06			28.80			38.53			43.79			17.95		

f_{ck} =Average Compressive Strength after 28 days water curing
f^{l}_{ck} = Average Compressive Strength after 28 days curing in Acidic environment

Table 6 Compressive strengths after acidic environment (HCl) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.43	8.18	8.21	8.18	8.20	8.24	8.28	8.14	8.15	8.17	8.33	8.21	8.12	8.00	8.10
After	8.41	8.13	8.19	8.11	8.14	8.12	8.23	8.10	8.11	8.16	8.26	8.19	8.08	7.91	8.00
%Loss of wt	0.31	0.57	0.19	0.89	0.76	1.44	0.59	0.52	0.41	0.17	0.78	0.17	0.39	1.09	1.27
% of loss in wt (Avg)	0.4			1.0			0.5			0.4			0.9		
f_{ck}	72.4			83.7			63.1			72.2			47.0		
f^{l}_{ck}	62.8			58.6			49.8			53.7			41.39		
% of loss in strength	13.29			30.04			21.10			25.67			11.93		

f_{ck} =Average Compressive Strength after 28 days water curing
f^{l}_{ck} = Average Compressive Strength after 28 days curing in Acidic environment

Table 7 Compressive strengths after Sulphate environment (MgSO4) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.40	8.31	8.21	8.29	8.23	8.33	8.29	8.28	8.16	8.44	8.34	8.24	8.09	7.97	8.08
After	8.47	8.38	8.28	8.33	8.29	8.37	8.33	8.32	8.20	8.49	8.39	8.29	8.13	8.01	8.14
%Loss of wt	0.73	0.90	0.86	0.49	0.73	0.48	0.46	0.48	0.49	0.56	0.65	0.61	0.51	0.43	0.74
% of loss in wt (Avg)	0.8			0.6			0.5			0.6			0.6		
f_{ck}	72.4			83.7			63.1			72.2			47.0		

f^{l}_{ck}	73.1	76.6	64.7	66.5	48.6
% of loss in strength	-0.87	8.58	-2.49	7.93	-3.37

f_{ck} =Average Compressive Strength after 28 days water curing
f^{l}_{ck} = Average Compressive Strength after 28 days curing in Sulphate environment

Table 8 Compressive strengths after Sulphate exposure (Na2SO4) at 28days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.42	8.18	8.23	8.39	8.20	8.24	8.19	8.25	8.23	8.39	8.19	8.23	8.14	8.28	8.16
After	8.47	8.23	8.24	8.41	8.24	8.27	8.24	8.28	8.28	8.43	8.23	8.27	8.16	8.30	8.21
%Loss of wt	0.59	0.68	0.06	0.30	0.49	0.36	0.56	0.40	0.56	0.48	0.40	0.46	0.33	0.24	0.61
% of loss in wt (Avg)	0.45			0.38			0.51			0.45			0.40		
f_{ck}	72.43			83.73			63.13			72.20			47.03		
f^{l}_{ck}	65.01			55.11			66.25			66.04			48.95		
% of loss in strength	10.25			34.18			-4.94			8.54			-4.08		

f_{ck} =Average Compressive Strength after 28 days water curing
f^{l}_{ck} = Average Compressive Strength after 28 days curing in Sulphate exposure

V. DISCUSSION AND CONCLUSION

1. The investigation results shows that the compressive strength is high in mix M2 i.e. when 25% of cement content replaced with 10% LP and 15% GGBS.
2. As increasing the percentage of Lime-powder content there is decreasing the compressive strength.
3. The investigation results shows that in acidic environment with H_2SO_4 percentage of loss in compressive strength is observed moderate in mix M2 when compared with other mixes.
4. Percentage of loss in compressive strength for mix M1 is observed moderate in acidic environment with HCL when cement was partially replaced with 25% GGBS.
5. The percentage weight loss and compressive strengths of mixes M3 and M5 were all most zero against Sulphate attacks i.e. $MgSo_4$ and Na_2SO_4

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