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Comparative Study on Durability Properties of Self-Compacting Concrete Produced Using Different Pozzolanas

Rachael Challagalli[1] & G.S.Hiremath[2]
[1]PG student BEC Bagalkot
[2] Asst. Professor BEC Bagalkot

***Abstract**:. Self- Compacting Concrete is a special type of concrete that is able to flow and compact under its own weight and can occupy all the spaces in the form without any vibration and at the same time it is cohesive enough to be handled without bleeding or segregation. In recent years, self-compacting concrete has been gaining wide range of application for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, the fresh concrete must possess high fluidity and good cohesiveness. The use of additive materials such as industrial wastes as mineral admixtures can ensure the required concrete properties. The initial experimental study aims at producing and evaluating SCC for ternary and quaternary blends incorporating fly ash, GGBS, sugarcane bagasse ash and alccofine as partial replacement of cement. Twelve number of SCC mixes were investigated in this study. The self-compacting mixes have cement replacement with different percentages of mineral admixtures while keeping cement quantity fixed for 360kg/m^3.Further durability tests such as alkaline attack and sulphate attack tests were conducted on both ternary and quaternary mixes*

1. Introduction

Self compacting concrete is a type of concrete which does not need any type of external compaction, as it is designed in a way that it gets compacted by its own weight. The property of the self compacting concrete is such that it enables the flow of concrete through congested reinforcement and also fills every corner of the formwork undergoing compaction on its own. Self compacting concrete is also known as super workable concrete because of its high flowability and self leveling property

2. Materials used

The mix mainly consists of ordinary Portland cement, mineral admixtures together called as binder or cementitious material. Chemical admixture, fine and coarse aggregates are being used.

2.1. Ordinary portland cement

Type of cement and its choice depends on required strength. However it is essential that the cement used should be compatible with the super plasticizer used. Cement used in this present study is OPC , ordinary Portland cement of 43 grade.

2.2. Class F fly ash

It is obtained from burning bituminous coal. It is called as low calcium fly ash as the lime content i.e calcium oxide is less than 6%. Class F fly ash exhibits better pozollanic properties. The cementitious compounds are formed only when agents like cement/quick lime is treated with water.

2.3. Ground granulated blast furnace slag (GGBS)

GGBS is an industrial waste obtained from rapid quenching or chilling of the molten ash from the furnace. It meets the requirement of IS 12089:1987 as the slag is fragmented which turns into granules, further the slag is ground to desired fineness to obtain GGBS. GGBS reduces heat of hydration, increases durability, it is also better at resistance to acid attacks such as sulphate and chloride attack comparative to other pozzolanas.

2.4. Alccofine

Alccofine 1203 is a calcium silicate based additive for cement. It has unique particle size distribution due to controlled granulation process. Alccofine has a very good hydration process due to latent hydraulic property and also its pozzolanic reactivity. Alccofine when added in concrete improves the packing density in paste, however, it results in lower water demand and dosage of admixture therefore improving the strength and durability of concrete. Its specific gravity range is 2.86 + 0.02.

2.5. Sugacane bagasse ash

Sugarcane bagasse ash is the by product from sugar factory, it is obtained when the sugar cane bagasse is burnt , where as sugarcane bagasse is formed after the extraction of sugar from sugarcane. Environment problems are caused due to large amount of waste material dumped around the sugar factories, hence this by product can be burnt at a temperature of 700°C for about 1 hour which then transforms the silica of the ash into amorphous. The product so obtained is ground to required fineness which can be used as a mineral admixture.

2.6. Fine aggregates

Sand is one of the important materials in concrete which plays major role in SCC. It is used in filling the voids that are preseent between aggregates and the powder content. It is important for the fine aggregate to be well graded in terms of particle size. The particle size of about 150 micron helps in increasing cohesion also resistance to segregation. In the present study locally available sand is used.

2.7. Coarse aggregates

SCC can be obtained from aggregates used in conventional concrete. Aggregates give dimensional stability to the concrete. The most important property of aggregates to produce SCC is its shape and gradation. For better flowability it is essential to choose rounded aggregates which also produce better blocking potential. Use of flaky and elongated aggregates cause blocking in confined areas. In the present investigation, coarse aggregates passing through 12.5mm and 4.75mm retained and conforming to IS383:1970 have been used.

2.8. Chemical admixture

A newly developed super plasticizer Poly Carboxylated Ether (PCE) is found out to be very effective on SCC. They help in avoiding potential problems such as unwanted retardation, excess air entrainment and provide high workability. In these present research high performance super plasticizers PCE (polycarboxylic eather) is used for self compacting concrete i.e. Master Glenium SKY8233.

3. Experimental investigaton

Mix design method adopted was absolute volume method. Where volume of paste was fixed to 0.4 and water cement ratio to 0.45. Further SCC mix were prepared for cement replacement by fixing the cement content to 360kg/m^3 which is the minimum cement content for M40 grade concrete. The remaining cement content was replaced with fly ash, bagasse ash , alccofine and GGBS. Fine aggregates used was 864.6kg/m^3 and coarse aggregates used was 764.1 kg/m^3, with 0.5% of super plasticizer

A total of 12 mix were designed as listed in table below. 5 mixes were designed for ternary blends and 7 mixes were designed for quaternary blends. The last 3 mixes of quaternary blends had one of its admixture replaced with 50% of the total replacement of cement. Cubes of 150mm×150mm were cast and tested after 28 days of curing.

Table 1. List of mixes designed

Mix no.	Type of mix	Admixture used
MIX 1	Ternary blend	Cement + GGBS +fly ash
MIX 2	Ternary blend	Cement + fly ash+ alccofine
MIX 3	Ternary blend	Cement +fly ash+ sugarcane bagasse ash
MIX 4	Ternary blend	Cement + GGBS + alccofine
MIX 5	Ternary blend	Cement + GGBS + sugarcane bagasse ash
MIX 6	Quaternary blend	Cement + GGBS + fly ash + alccofine
MIX 7	Quaternary blend	Cement + GGBS + fly ash + sugarcane bagasse ash
MIX 8	Quaternary blend	Cement + GGBS + alccofine + sugarcane bagasse ash
MIX 9	Quaternary blend	Cement + fly ash + alccofine+ sugarcane bagasse ash
MIX10	Quaternary blend	Cement + 50% flyash+ GGBS+ alccofine
MIX11	Quaternary blend	Cement + 50% GGBS+ alccofine +flyash
MIX12	Quaternary blend	Cement +50% alccofine+ flyash+ GGBS

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Mix No.	V_p	W/C	Cement content kg/m^3	Fly ash kg/m^3	GGBS kg/m^3	Alccofine kg/m^3	Sugarcane Baggase ash kg/m^3
MIX 1				74.25	79.75		
MIX 2				74.25		81.4	
MIX 3			360	74.25			54.9
MIX 4	0.4	0.45			79.75	81.4	
MIX 5					79.75		54.9
MIX 6				49.4	53.07	54.16	
MIX 7				49.4	53.07		39.6

MIX 8					53.07	54.16	39.6
MIX 9				49.4		54.16	39.6
MIX 10				74.25	39.8	40.7	
MIX 11				37.12	79.75	40.7	
MIX 12				37.12	39.8	81.4	

4. Alkaline attack test

This test was done on the 150×150×150 mm Solid cube. concrete cubes are cast and demoulded following 24 hours and at the finishes of 28 days of typical curing period The cubes were taken out from the curing tank and initial weight was taken. 5% of sodium hydroxide by weight of water was included with water according to prior examiners. The centralization of the arrangement was kept up all through this period by changing the arrangement occasionally. The cubes were taken out from the solution following 28 days of soaking. The surface of the Cube were cleaned, weighed and at that point tested in the compression testing machine under the uniform rate of stacking of 120 kg/cm^2/min. The changes in quality of the cube were computed according to IS codes

5. Sulphate attack test

In this test the cubes are immersed in a solution containing 5% of the sodium sulphate (Na_2SO_4)and 5% of the magnesium sulphate ($MgSO_4$) by the weight of the water. Concrete cubes of 150mm are then tested after 28days of immersion and then the weight loss is determined. The compressive strength of the cubes are also determined as prescribed in the code IS: 516-1959

6. Durability test results and discussion

6.1. Sulphate attack test

Table 3. Sulphate attack on ternary blends

Mix No.	Initial weight (kg)	Weight after 28 days (kg)	Percentage change in weight(%)	Strength of concrete (MPa)	Percentage loss in strength(%)
1	8.36	8.20	1.91	52.1	6.33
2	8.23	8.09	2.20	51.4	6.22
3	8.21	8.05	2.80	43.6	6.69
4	8.28	8.23	2.60	53.1	6.11
5	8.32	8.08	2.78	48.5	6.58

Table 4. Sulphate attack on quaternary blends

Mix . No.	Initial weight (kg)	Weight after 28 days (kg)	Percentage change in weight(%)	Strength of concrete (MPa)	Percentage loss in trength(%)
6	8.38	8.21	2.1	54.7	6.2
7	8.41	8.21	2.3	45.2	6.8
8	8.39	8.17	2.5	47.5	7.1
9	8.51	8.29	2.7	46.1	7.5
10	8.48	8.26	2.6	54.1	6.2
11	8.32	8.16	1.9	51.3	5.3
12	8.33	8.15	2.2	54.2	5.7

Table 3 represent the results obtained from sulphate attack after 28 days. In the percentage change of weight after 28 days, the MIX 3 and MIX 5 had highest loss of weight with 2.8%. From the percentage change in strength in which it can be inferred that MIX 3 had highest loss in strength of 6.69% .

The Table 4 represent the results from suphate attack test on quaternary blends. From which it can be seen that the percentage loss in weight of SCC mixes with quaternary blends, MIX 9 has highest loss of weight for 28days of 2.7% and the percentage loss in strength is highest for MIX 9 with 7.5% loss.

6.2. Alkaline attack test

Table 5 . Alkaline attack on ternary blends

Mix No.	Initial weight (kg)	Weight after 28 days (kg)	Percentage change in weight(%)	Strength of concrete (MPa)	Percentage loss in strength(%)
1	8.29	8.13	1.9	50.1	8.8
2	8.44	8.38	1.86	49.6	9.1
3	8.34	8.17	1.98	45.6	9.8
4	8.26	8.13	1.96	50.7	9.7
5	8.28	8.11	2.08	46.9	9.75

Table 6. Alkaline attack on quaternary blends

Mix . No.	Initial weight (kg)	Weight after 28 days (kg)	Percentage change in weight(%)	Strength of concrete (MPa)	Percentage loss in trength(%)
6	8.47	8.35	1.42	52.8	8.7
7	8.34	8.18	2.18	43.8	10.13
8	8.42	8.24	2.03	48.3	9.7
9	8.40	8.23	2.2	45.8	9.8
10	8.31	8.12	1.96	49.3	9.1
11	8.38	8.22	1.9	52.7	8.8

12	8.32	8.2	1.44	53.9	9.0

The table 5 represent results from alkali attack test carried out on ternary blend mixes in which the percentage loss of weight after 28 days in SCC mixes had highest loss of weight for MIX with 2.08% and the percentage loss of strength was maximum for MIX 3 and MIX 5 which had similar loss in strength of about 9.8% and 9.75% respectively.

Table 6 represents the results from alkali test on quaternary blend mixes in which percentage change in weight for MIX 7 had highest loss of weight and the percentage loss in strength of quaternary blends was maximum for MIX 7.

7. Conclusion

From the results obtained it can be concluded that particle packing of GGBS and alccofine is better than bagasse ash thus GGBS, fly ash and alccofine provides better resistance to alkali attack when compared to bagasse ash. The alkali attack is more effective when bagasse ash is used because of the particle size, there is no dense packing thus increasing permeability and leading to the increase in alkali attack on concrete.

GGBS due to its high alumina and silica content , produces more complex hydrates, which further helps in blocking of pores which helps in high strength and low permeability. The disintegration of hydrated compounds and leaching that takes place in presence of acids increases the effect of sulphate attack on concrete. Hence GGBS and alccofine provides better sulphate resistance when compared to fly ash and bagasse ash.

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