Durability performance of concrete containing copper slag and fly-ash

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ABSTRACT

In this present study an investigation was made on the durability performance of concrete containing fly-ash as partial replacement with cement and copper slag has replacement of fine aggregate in concrete. The concrete mix design was prepared for M30 grade. Six concrete mixes were prepared in which cement is partially replaced by fly-ash about 40% by weight of the total binder content, with 20% increment of copper slag in consecutive mixes ranging from 0-100% replacement on fine aggregate in all the mix proportions. The mixes were evaluated to find out the mechanical properties and durability performance of concrete by conducting various tests like compression test, split tensile test for mechanical properties and carbonation, sorptivity, ultra-sonic pulse velocity, Rapid Chloride Penetration Test (RCPT) for durability performance. Compressive were evaluated for 56 days and sorptivity and split tensile strength are evaluated for 28 days. Carbonation results for all the mixtures were change in purple red color indicate a highly alkaline good concrete. UPSV (Ultra-sonic pulse velocity) results for the mixtures are in the range of above 4; which indicates the quality of concrete good. Sorptivity values goes on increasing while increasing the copper slag percentage. So 40% of copper slag replacement with fine aggregate indicates as comparable to that of control mix. Compressive test result shows that 40% replacement of copper slag with fine aggregate indicates as comparable to that of control mix further amount of increase in copper slag percentage indicates decrease in strength. The maximum strength achieved at 40% replacement of copper slag which shows that the optimum percentage of replacement in concrete.

KEY WORDS: Copper slag, Durability performance, Mechanical properties, Fly-ash.

1. INTRODUCTION

The concrete companies use the natural resources from long decades as raw materials. Due to the continuous usage, the demand will inevitably increase. The increase of demand will continue in the future also. Due to the increment of demand in the natural resource of fine aggregate there will be a need to study about the conventional replacement for the sand and also for the cement. To produce one ton of copper 2.2 tons of slag is generated and every year 24.6 million of copper slag is produced (Khalifa, 2009). Due to the production of such huge quantity of slag the dumping and disposal take large space and it has become an environmental issue. For the last two decades various researchers have shown interest to study the physical, mechanical and chemical properties of copper slag and they have found out that the slag have been utilized for a value added products like cement, ballast, abrasive, cutting tools, aggregate, glass and tiles etc. (Bipra Gorai, 2013). In this research the copper slag is used as a partial replacement for the fine aggregate in concrete. Few researchers have use copper slag as a partial or complete replacement for fine aggregate. Wei Wu (2010), observed that the mechanical properties of high strength concrete with less than 40% replacement of copper slag as a fine aggregate substitution achieve comparable or better compressive strength then the control mix. The addition of copper slag beyond 40% make the concrete to loss the strength in pre-mature level due to the development of void, micro-cracks and capillary channel.

Now a day's large quantity of fly ash is used in concrete to reduce the cost and to enhance the properties of concrete. Fly ash is a waste material generated during combustion of coal (Xiao-Yong Wang, 2015). The compressive strength of fly-ash concrete is less than that of the control mix at higher curing period the 15% and 25% replacement of cement by fly-ash surpasses the compressive strength of control mix whereas the 45% and 55% dose not surpass the control concrete. But when there is a reduction in water to binder ratio the 45% and 55% fly-ash concrete surpass the control mix.

Durability is one of the important parameter in concrete structures; the presence of pores in the concrete will reduce the durability performance. Sorptivity is the main parameter to determine the permeability of hardened concrete.

2. MATERIAL PROPERTIES

Cement: Cement used as a binder material in concrete. The main characteristics of cement in the concrete mix design is developing the compressive strength within period. In this study 53 grade of ordinary Portland cement properties are confirming to codeIS:12269-1987. The specific gravity of cement found in the laboratory is 3.13.

Aggregate: Aggregate which passes through the 20 mm sieve is used as coarse aggregate. Mainly aggregate occupy 70% in concrete; the coarse aggregate will satisfies the requirement specified in the code. The fine aggregate which is having the specific gravity value of 2.6 confirming to Zone-II is used and the properties of fine aggregate is confirming to the requirement specified in the codeIS:383-1970. The specific gravity of the coarse aggregate is found as 2.74.

Copper slag Copper slag is a byproduct material which is generated during the production of copper to produce one ton of copper 2.2 tons of slag is generated and every year 24.6 million of copper slag is produced. The material property of copper slag is similar to the properties of fine aggregate referred to IS:383-1970. The specific gravity of copper slag used in this study is find out as 3.70. The copper slag used in this study is obtained from steerlite industries Tuticorin.

Fly-ash: Fly ash is a byproduct material which is generated during the combustion of coal. The fly-ash is mainly having the advantage in concrete to reduce the voids. It is having the pozzolan properties. The fly- ash used in this study is to confirm the codeIS:3812-2003. The fly-ash obtained a specific gravity of 2.17. The fly-ash used in this study obtained from Ennore Thermal Power Plant, Chennai.

Mix Design: The M30 grade concrete mix proportions were arrived as per the Indian Standard IS: 10262-2009. The cement is partially replaced with 40% of fly-ash with the weight of cement and the fine aggregate is replaced from 0% - 100% with copper slag by an increment of 20% for each mix. The arrived mixture proportions of all mixtures are given in Table 1.

Table.1. Mix proportion

Mix ID	Cement kg/m^3	Fly ash Kg/m^3	W/C ratio	Fine aggregate kg/m^3	Coarse Aggregate kg/m^3	Copper slag kg/m^3
Control Mix (0% of CS)	372	0	0.45	819	1053	0
D-1 (20% of CS)	223	149	0.45	655	1053	229
D-2 (40% of CS)	223	149	0.45	491	1053	457
D-3 (60% of CS)	223	149	0.45	328	1053	665
D-4 (80% of CS)	223	149	0.45	163	1053	914
D-5 (100% of CS)	223	149	0.45	0	1053	1143

Experimental work: The experimental work is carried out in order to find out the mechanical and durability performance of the concrete. The cube of size 100mm × 100mm × 100mm are casted for all the six mixes to find out the compressive strength, Ultra-sonic pulse velocity and Carbonation. The cylinder of 100mm Ø and 50mm deep and 100mm Ø 200mm deep are casted for testing of sorptivity, RCPT and split tensile strength of concrete. The specimens are casted, cured and tested as per IS:516-1987.

3. TEST AND RESULTS

Compressive test: Concrete specimens are taken out from the curing tank and specimens are allowed to dry the surface moisture and specimen was kept in the compression testing machine. The load applied on the specimen until the specimen were failed and found the ultimate load of each specimen. The compressive strength of concrete was calculated and the average of three specimen compressive strength was estimated at different curing age for all the concrete mixtures. By using the result plotted the graph and shown in Fig.1.

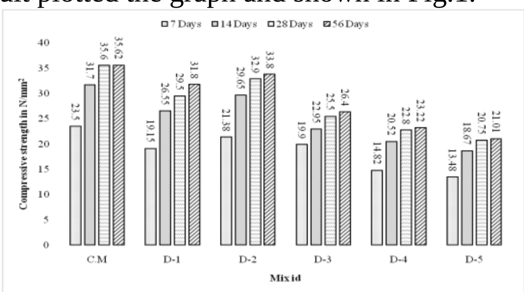

Figure.1. Compressive strength of concrete specimens at various curing ages

From Fig.1, it is observed that, control concrete mixture (C.M) achieved the designed strength at 28 day curing. The replacement of fine aggregate with copper slag (D-2) achieved the strength at 28 days curing but other replacement mixtures gained its strength range from 20.75 N/mm^2 to 29.5 N/mm^2. Increasing the curing age of the specimens shows that the slight increment in compressive strength were observed. The replacement mixtures D-3, D-4 and D-5 mixtures may achieve the design strength in the later age because of the presence of Pozzolana in concrete.

Durability Performance:

Sorptivity test: Sorptivity test is used to measure the capillary rise of the absorption of water in concrete. Cylinder of size 100mm Ø, 50mm depth were casted and kept in curing for 28 days after curing the cylinders were taken out and kept it in the oven for a temperature of 100°C for 24 hours. The experimental procedure was followed as per the ASTM standards ASTM C1585-13. The sorptivity value for all the mixtures was evaluated. The values obtained from the test and plotted the graph show in Fig.2.

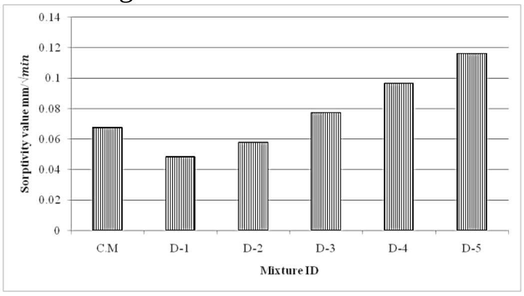

Figure.2. Sorptivity value of concrete mixtures

In Fig.2, observed that when increasing the copper slag percentage there was some increase in sorptivity value which indicates capillary rise of absorption of concrete is more. The sorptivity value of the control concrete shows higher then compare with the concrete made with 20% and 40% of copper slag. Further increment of copper slag in concrete (D-3, D-4 and D-5) mixtures shows very high. The results indicating that the large voids are present in the concrete structure.

Carbonation: The carbonation test is conducted to evaluate the alkalinity (Ph) of concrete. Carbon dioxide from atmosphere reduces the durability performance of reinforced concrete. When calcium hydroxide generated in the cement hydration reacts with atmospheric carbon dioxide which gives precipitation of calcium carbonate, it reduces the alkalinity of concrete. Carbonation test was conducted on concrete surface at 28 days and 56 days of curing by using phenolphthalein indicator solution.

The change in color of concrete indicates a Ph value of about 9. Colorless concrete indicates a carbonated concrete. All the concrete mixes are change in purple red color which indicates the concrete having high alkaline good concrete. The color indication of the concrete is shown in the Fig.3.

Figure.3. Color Indication for the concrete

Ultra sonic pulse velocity (UPV): The quality of the concrete has been determined by using Ultra sonic pulse velocity test. The test is conducted as per the code IS 13311 (part-1) -1992. The test results are obtained after conducted the experiment and graph were plotted and shown in Fig.4.

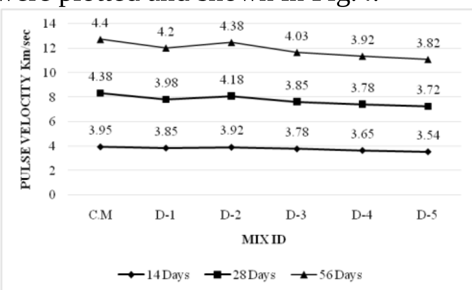

Figure.4. Ultra sonic Pulse Velocity

The Fig.3 shows that 14 days, 28 days & 56 days of ultra-sonic pulse velocity values. The 14 Days value of all the mixes are in the range between 3.5-4.0 Km/Sec which according to the Indian standards the quality of the concrete is good. Whereas in 28 Days & 56 Days value of all the mixes are in the range between 3.5-4.4 Km/sec. from the graph it is observed that, increasing the curing age of the concrete specimens the pores voids are cover by the C-S-H gel and its improved the quality of the concrete.

Rapid chloride Penetration Test (RCPT): The standard concrete specimen of 100mm Ø and 50 mm depth sample were casted for all the mixtures and cured in portable water. At the age of 14 and 28 days curing, specimens were tested as per the ASTM standard ASTM C1202-97. The results were obtained and plotted the graph and it is given in Fig.5. From Fig.5, observed that the mix D-1, D-4, D-5 and D-6 permeability is moderate as the values are in the range of 2000 to 4000 (charge passing in coulombs). D-2 and D-3 the chloride permeability is low. In the 28 days the chloride permeability of the concrete has reduced for all the mixes when compared to 14 days. The value between 1000 to 2000 (charges passing in coulombs). The test results show that there will be low chloride attack for concrete in all the mix proportions.

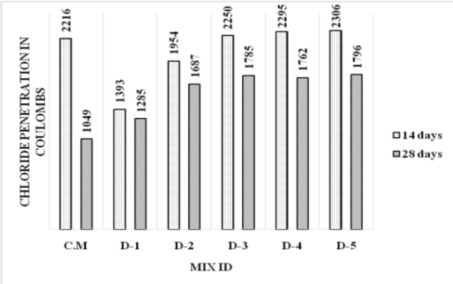

Figure.5. Rapid Chloride Penetration Test

4. CONCLUSION

The below conclusions were made from the experimental results and discussions. The 40% replacement of cement with fly ash and 40% of fine aggregate replacement with copper slag concrete achieved the designed strength at 28 days curing. The slight increment in strength was observed in other replacement mixtures at 56 days curing. Further increasing the curing age, the remaining concrete mixtures will achieve the strength.

The mixtures show that, all concrete mixtures were in alkaline in natures. The mixtures are not turned to acidic due to presence of fly ash and copper slag.

The Rapid chloride permeability and ultrasonic pulse velocity test results are shows that the concrete are in good quality.

The replacement of 40% cement with fly ash and 40% of fine aggregate with copper slag performance is high compared with other mixtures.

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