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EFFECT OF FLY ASH AND COPPER SLAG ON MECHANICAL PROPERTIES OF CONCRETE

RUPINDER KAUR[1], DR SARITA SINGLA[2]
[1]*Department of Structural Engineering, PEC, Chandigarh (Deemed to be University), India*
[2]*Department of Civil Engineering, PEC, Chandigarh, India*

Abstract: ***The present study aims at developing the concrete mixes incorporating fly ash and copper slag as a partial replacement of cement and fine aggregates respectively. The aim is to study the mechanical properties of modified concrete with fly ash and copper slag and to compare it with reference mix i.e without any supplementary material. Cement was partially replaced by fly ash with 20%, 30%, 40% replacement, fine aggregate was partially replaced by copper slag with 30%, 40%, 50% replacement. The design mix was worked out as per Indian standard guidelines and various trials were performed to obtain the mix of grade M-25 at 28 days. In this study, the compressive strength, split tensile strength and flexural strength of concrete mixes for different percentage of replacement of cement and fine aggregate are obtained at 7 days and 28 days. After analysis of test results, it was found that performance of binary mix with fly ash was less than that of reference mix whereas performance of binary mix with copper slag was higher than that of reference mix. Results of ternary mix with both fly ash and copper slag was found to better than that of reference mix. Cube compressive strength of mixes showed up to 27% increase in strength, split tensile strength showed up to 50% increase in strength, flexural strength showed up to 20 % increase in strength. Maximum increase in compressive strength, split tensile strength and flexural strength was found for the M10 mix i.e. mix with 30% fly ash and 40% copper slag.***

Keywords: mechanical properties of concrete, fly ash and copper slag.

1. INTRODUCTION

Concrete is most widely used construction material in the world due to its ability to get cast in any form and shape it also replaces old construction materials such as brick and stone masonry. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suitable for a wide range of application. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. Concrete's use in the modern world has become a important agenda. Concrete is also the basis of a large commercial industry. Given the size of the concrete industry, and the fundamental way concrete is used to shape the infrastructure of the modern world, it is difficult to overstate the role this material plays today. On the other hand, recycling waste solid materials is one of the most challenging problems worldwide with the unprecedented growth of the world population and in order to combat the scarcity of cement and the increase in cost of concrete under these circumstances the use of recycled solid wastes, agricultural wastes, and industrial by products like used copper slag, fly ash, blast furnace slag, silica, rise husk, came into use.

Coal based thermal power stations account for as much as 60% of installed power generating capacity in India. The same trend is expected to continue in foreseeable future, considering availability of vast reserve of coal in India. The high percentage of fly ash content in the Indian coal has resulted in huge production of fly ash at these coal-based stations. But at the same time quality of fly ash produced is superior because of low Sulphur and unburnt carbon content.

In last four decades, cement concrete technologies have shown evolutional changes and apart from the strength consideration, durability and economy have become important factors for deciding the concrete quality. The concept of higher cement content means greater strength and thus durability has not proved in true sense for the structures exposed to different climatic conditions. To make cement concrete strong and durable at lower cost, use of supplementary cementitious material i.e. fly ash started in practice and is now a proven technology World over. Thus, today cement concrete has 4 essential ingredients-cement, aggregates (coarse & fine), water and fly ash in place of traditionally 3 ingredients cement, aggregates and water. In India, though various Indian Standards published by Bureau of Indian Standard (BIS) specifies use of fly ash as part replacement of cement in concrete, in actual practice it is in nascent stage.

Indian Copper companies - Sterlite Industries, Hindalco, and Hindustan have contributed to the production of major quantities of copper. Copper slag is a by-product obtained from the smelting and refining of copper. Production of one ton of copper generates approximately 2.2 - 3.0 tones copper slag.

Copper slag is used in the concrete as one of the alternative materials. It is the waste product of copper from Sterlite Industries India Ltd, Tuticorin. The safe disposal of this waste is a lack, costly and causes environmental pollution. The construction industry is the only area where the safe use of waste material (copper slag) is possible. When it is introduced in concrete as a replacement material, it reduces the environmental pollution, space problem and also reduces the cost of concrete.

2. EXPERIMENTAL PROGRAMME

The experimental program was planned to investigate the compressive strength, split tensile strength and flexural strength of partial replacing cement with fly ash and fine aggregating with copper slag. It also discusses the various test conducted on copper slag and fly ash modified concrete in its hardened state It includes tests conducted on various constituent's materials such as coarse aggregates, fine aggregates and cement. Physical properties of cement which were studied includes fineness, specific gravity, consistency, initial and final setting, soundness and compressive strength. The physical properties of fine and coarse aggregates which were studied includes specific gravity, grading, water absorption, sieve analysis and bulk density. Control mix of M-25was designed as per the guidelines of IS 10262: 2009 In this study, the influence of combination of Fly Ash and Copper Slag on the mechanical properties of concrete are presented. Concrete mixes were made with 0%,20%, 30% and 40% replacement of cement with fly ash and fine aggregate is replaced by Copper Slag with 0%,30%,40%,50% replacement keeping same water binder ratio. Further ternary mix containing fly ash and copper slag were prepared in varying percentages. On the hardened concrete various strength tests such as compressive strength (7, 28 days), split tensile strength (7,28 days) and flexural strength (7,28 days) were determined. Aim of this experiment is to compare the properties of concrete mixed with and without fly ash and copper slag used as a replacement of cement and fine aggregate respectively.

Table 1 Mix proportions of ternary mixcontaining fly ash and copper slag

Mix designation	% replacement of	% replacement of	Cement	Fly ash (kg)	Water	Fine aggregate (kg)	Coarse aggregate (kg)	Copper slag (kg)
M0	0	0	360	0	172.8	660	1265	0
M1	20	30	288	72	172.8	462	1265	198
M2	30	30	252	108	172.8	462	1265	198
M3	40	30	216	144	172.8	462	1265	198
M4	20	40	288	72	172.8	396	1265	264
M5	30	40	252	108	172.8	396	1265	264
M6	40	40	216	144	172.8	396	1265	264
M7	20	50	288	72	172.8	330	1265	330
M8	30	50	252	108	172.8	330	1265	330
M9	40	50	216	144	172.8	330	1265	330

3. MIXING, BATCHING, CASTING and CURING OF SPECIMENS

The material was weighted in batches in required proportions and was put into the mixer. The required quantity of water was added slowly to get a uniform mix. All the moulds were cleaned and were applied with oil on the inner faces well before concreting operation for casting of specimen so that oil may not affect concrete ingredients. These were securely tightened to correct dimensions before casting. Care.The complete procedures were adopted in the making and casting operations. The quantities of cement, coarse aggregates, fine aggregate, copper slag, fly ash and water for each batch was weighed accurately.

The aggregates and copper slag were put into the mixer and over that cement and fly ash were added, mixer started to rotate to mix the dry ingredients. Then water was added carefully and mixer was started to rotate, until the concrete appeared to be homogenous and of the desired consistency. The prepared concrete was then out from rotating drum into M.S. Plate. Then concrete was filled into the previously prepared moulds in three layers. Electric vibrator was used for compaction of concrete. Vibrations were stopped as soon as cement slurry appeared on the top surface of the mould. The surface of the concrete was finished level with the top of the mould using a trowel and marked properly to indicate the mix proportions date of casting. The finished specimens were left to harden. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank filled with the potable tap water in the laboratory for curing. For plain cement concrete specimens, no fly ash and copper slag were added to the mix and all the specimens for a particular testing age were cast in one batch. The specimens for fly ash concrete replacing cement by fly ash and incorporating copper slag with varying percentages of fly ash and copper slag were cast in separate batches. This procedure was adopted to ensure uniform properties of the specimens in each batch

4. ANALYSES OF RESULTS

Table 2 Test results of compressive strength, split tensile strength and flexural strength

Mix designation	Compressive strength		Split tensile strength		Flexural strength	
	7 days	28 days	7 days	28 days	7 days	28 days
M0	21.02	33.48	2.05	3.36	4.7	5.2
M1	21.29	33.48	2.21	2.97	4.6	5.3
M2	20.8	33.9	2.42	3.5	4.4	5.30
M3	20.02	34.1	2.32	3.3	4.2	5.0
M4	23.82	38.44	2.70	4.03	4.9	5.7
M5	22.14	40.11	3.08	4.1	5.1	6.0
M6	21.28	39.44	3.01	3.9	4.6	5.6
M7	22.02	36.9	2.33	3.94	4.7	5.5
M8	21.2	35.36	2.21	3.75	4.9	5.4
M9	19.11	32.78	1.95	3.35	4.5	5.4

4.1 Compressive strength

The ternary mixes were prepared using fly ash and copper slagand their Compressive strength testswere conducted at 7 and 28 days curing periods for all mix proportions by using Compression testing machine. It can be seen from Table 2 that at 7 days compressive strength of ternary mixes containing fly ash and copper slag were more than that of the reference mix. The compressive strength has increased with increase in dosage of copper slag also depending on dosage of fly ash.The compressive strength at 28 days of ternary mixes was also more than that of reference mix. The overall variation of compressive strength for all mix proportions at 7 days and 28 days are shown in Fig 1 and Fig 2 respectively.From these figures it can be seen that the use of copper slag with fly ash enhances the strength of fly ash mix concrete. This is because Combination of both industrial wastes fly ash and copper slag reacts with cement and produce binding properties to the concrete hence; it has not affected the strength at early age to later age

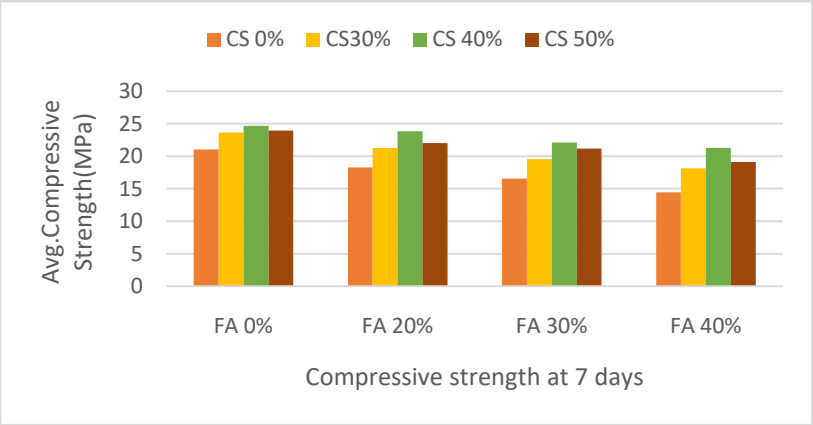

Fig 1 variation of compressive strength at 7 days

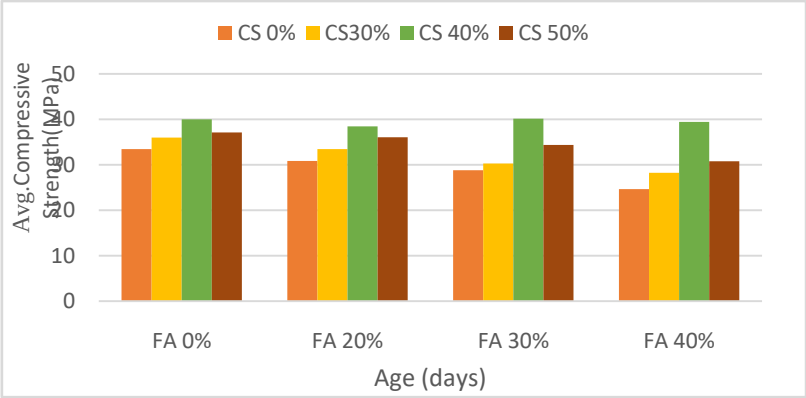

Fig 2 variation of compressive strength at 28 days

4.2 Split tensile strength

The ternary mixes were prepared using fly ash and copper slagand their Split Tensile strength testswere conducted at 7 and 28 days curing periods for all mix proportions by using Compression testing machine.It can be seen from Tables 2 that at 7 days compressive strength of ternary mixes containing fly ash and copper slag were more than that of the reference mix without fly ash and copper slag for all replacement levels. The split tensile strength has increased with increase in dosage of copper slag also depending on dosage of fly ash.The split tensilestrength at 28 days of ternary mixes was also more than that of reference mix and binary mixes with fly ash for all replacement levels. The overall variation of split tensile strength for all mix proportions at 7 days and 28 days are shown in Fig3 and Fig 4 respectively.

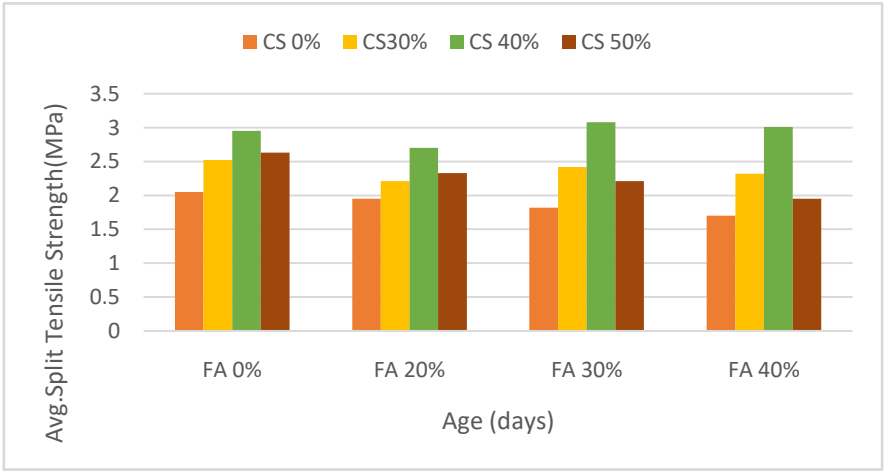

Fig 3 variation of split tensile strength at 7 days

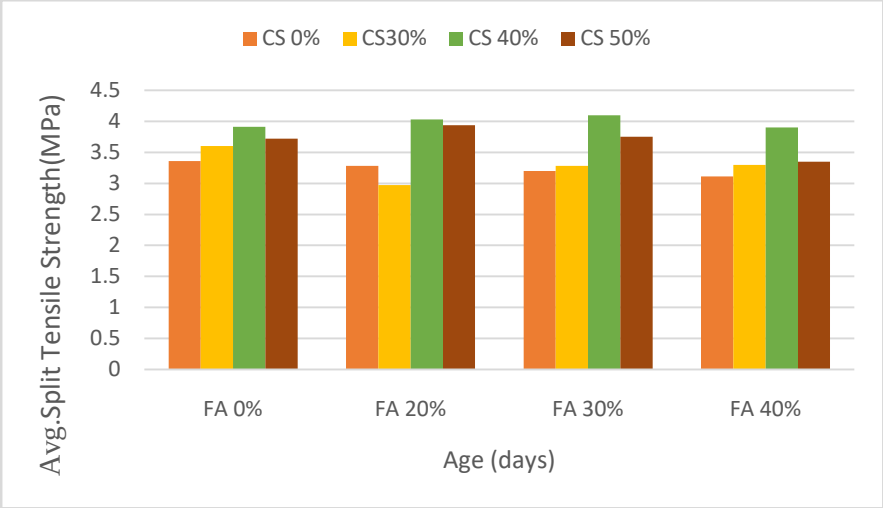

Fig 4 variation of split tensile strength at 28 days

4.3 Flexural strength

The ternary mixes were prepared using fly ash and copper slagand their Flexural strength testswere conducted at 7 and 28 days curing periods for all mix proportions. It can be seen from above tables and figures that at 7 days flexural strength of ternary mixes containing fly ash and copper slag were more than that of the reference mix. The Flexural strength has increased with increase in dosage of copper slag also depending on dosage of fly ash.The flexural strength at 28 days of ternary mixes was also more than that of reference mix and binary mixes with fly ash for all replacement levels. The overall variation of flexural strength for all mix proportions at 7 days and 28 days are shown in Fig 5 and Fig 6 respectively. It can be seen that the use of copper slag with fly ash enhances the strength of fly ash mix concrete.The increase in strength is observed because of combination of both industrial wastes copper slag and fly ash reacts with cement and produce binding properties to the concrete hence; it has not affected the strength at early age to later age. From this study, it is concluded that flexural strength of concrete with fly ash and copper slagwas always higher than control concrete. It is also suggested that, concrete with 30% fly ash replacement for cement and 40% copper slag replacement for fine aggregate is suitable for concrete structures.

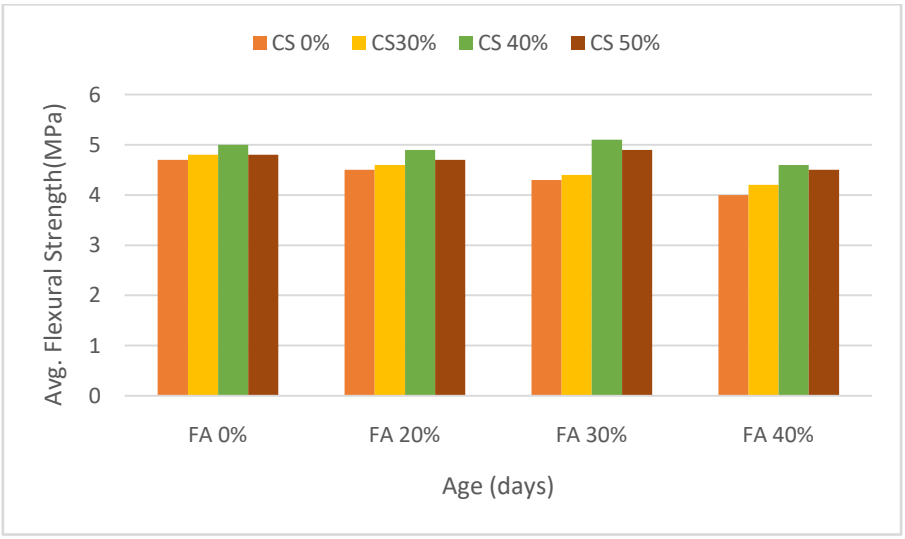

Fig 5 variation of Flexural strength at 7 days

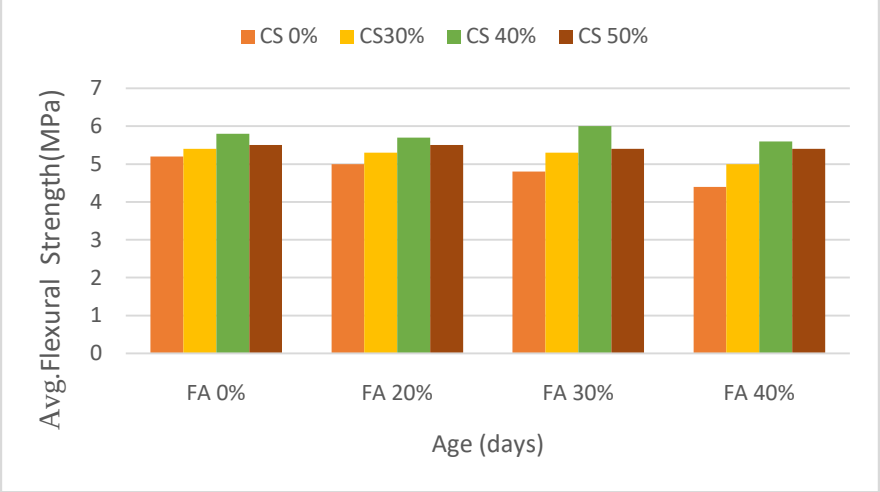

Fig 6 variation of Flexural strength at 28 days

5. CONCLUSIONS

The present study was undertaken to investigate the influence of fly ash and copper slag on Compressive strength, Split Tensile strength, Flexural strength

The effect of fly ash and copper slag on mechanical properties of concrete proportioned with cement replacement (20%, 30%, 40%) with fly ash and fine aggregate replacement (30%, 40%, 50%) with copper slag were studied. The reference mix of M-25 grade was prepared without addition of fly ash and copper slag and the results were compared with them. Different specimens of cube, cylinder and beam were tested for compressive strength, split tensile strength and flexural strength at the age of 7 days and 28 days. Based on the results and within the scope of research the following conclusions can be drawn:

1. The ternary mix containing both fly ash and copper slag exhibited higher compressive strength as compared to binary and reference mix. At 7 days, compressive strength of mix with 20% fly ash and 40% copper slag was found to be highest. However, the mix with 30% fly ash and 40% copper slag shows a maximum increase in compressive strength at 28 days.
2. The ternary mix containing both fly ash and copper slag exhibited higher Split tensile strength as compared to binary and reference mix. The Split tensile strength of mix with 30% fly ash and 40% copper slag found to be highest both at 7 days and 28 days.
3. The ternary mix containing both fly ash and copper slag exhibited higher flexural strength as compared to binary mixes and reference mix. The split tensile strength of mix with 30% fly ash and 40% copper slag found to be highest both at 7 days and 28 days. But the rate of increase is less as compared to split and compressive strength.
4. The mix which showed strength gain in all mechanical properties was mix M5.

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