EXPERIMENTAL INVESTIGATION ON FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAMS CONTAINING COPPER SLAG, FLY-ASH AND STEEL FIBERS

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Abstract - *The main scope of this study focuses on the effect of using copper slag as a partial replacement for sand, fly-ash as a partial replacement for cement in addition of steel fibres in concrete. Fly ash and copper slag is a by-product material obtained in Thermal power station and copper industries. Both the industries are dumping and disposing the materials in nearby area and its generating huge environmental impacts like land, water and air pollutions. In construction industries, huge quantity of sand taken from natural river bed and it affects the ground water table. There is a need of alternate materials for sand in construction activity.*

So in this study, ten concrete mixtures were designed including the conventional mixture by varying the percentage of copper slag from 0% to 40% with 20% increment. 40% of cement was replaced with fly ash in replacement concrete mixtures. Steel fibers were added in some of the replacement mixtures by 1% in volume of concrete. At the end of 28 days, 56 days and 90 days curing period, compressive strength, tensile strength and young's modulus of concrete were measured for all the concrete mixtures. Reinforced concrete beams were casted and their flexural behavior was studied at the end of 28 days curing period. The replacement mixtures show better performance than the conventional concrete. By using the by-product materials in concrete, the environmental pollution caused by them will be reduced.

Key Words: Compressive Strength, Copper slag, concrete

1. INTRODUCTION

Concrete is one of the major construction materials being used around the world. Aggregate, besides cement and water, forms one of the main constituent materials of concrete since it occupies nearly 55%–80% of concrete volume. The aggregate types generally utilized for construction are either coarse or fine aggregate. Aggregates which are being used in concrete for construction are obtained either from natural sources or by crushing large size rocks. Coarse aggregates are bound with cement paste during the hydration process to form cement concrete whereas fine aggregates are employed to fill the gaps between the coarse aggregate particles. The rapid increase in the natural aggregates consumption every year due to the increase in the construction industry worldwide means that the aggregate reserves are being depleted rapidly.

Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. This growth is endangered by the lack of natural resources that are available. Natural resources are reducing worldwide while at the same time the generated wastes from the industry are increasing substantially. This research work is an effort to develop the awareness & importance of industrial waste management & its utilization in beneficial manner in construction industry. The sustainable development for construction involves the use of non-conventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways for conserving the environment.

2. EXPERIMENTAL STUDIES

2.1. Cement:

Cement is a binding material used in concrete which sets, hardens and adheres to fine aggregate and coarse aggregate, binding them together. The commonly used cement is the Ordinary Portland Cement (OPC). OPC confirming to IS: 12269-1987 of 53 Grade was used in this study. The physical properties of cement used in this study are tabulated in Table 1.

Table 1: Physical Properties of cement

TEST DETAILS	RESULTS OBTAINED
Specific Gravity Of cement	3.13
Consistency of cement	33% of water
Initial Setting Time (minutes) of cement	27 mins
Final Setting Time of cement	6hrs 35 mins

2.2. Fly ash:

Fly ash is a residue obtained from the combustion of powdered coal, transferred by the flue gases and claimed together by electrostatic precipitator. In most of the places it is denoted as pulverized fuel ash (PFA). Fly ash is the most commonly used as a pozzolana in various parts of the world. Fly ash is made up of the noncombustible mineral part of coal. They are mostly glassy in texture, spherical in shape like a ball bearing and finer when compared to cement. The sizes of particles range from 0.1µm to 150µm. This pozzolanic material reacts with free lime in the presence of water, forming calcium silicate hydrate (C-S-H) which contributes to the strength and durability of concrete. Fly ash used in this experimental investigation acquired from Ennore Thermal Power Plant is confirming to IS: 3812:2003. This plant is situated near Chennai, Tamil Nadu, India. The specific gravity of fly ash used in this study is 2.18.

2.3. Fine Aggregate (sand):

Fine aggregates can be obtained from natural sources or can be manufactured artificially. Fine aggregates sieved with 4.75mm sieve and the particles retained on 2.36mm sieve were used in this study and they confine to IS: 383-1987. The moisture content and the water absorption of fine aggregates were closely observed. Sand used in this study was procured from Palar River, Vellore, Tamil Nadu.

2.4. Coarse Aggregate:

Aggregate is the major constituent of concrete. They contribute 70-80% of the total volume of concrete, providing a rigid structure, and acting as a cost- effective space fillers. Since at least three fourth of the volume of concrete are engaged by aggregates, it is not astounding that its quality is of significant importance. The properties of aggregate significantly influence the strength of auxiliary execution of concrete. Aggregate was initially seen as an idle material scattered all through the cement glue to a great extent for financial reason.

The Coarse aggregate retained on sieve 12.5mm passing through 20mm sieve size confirming to IS: 383-1987 is used in this project. These aggregates are crushed and angular in shape.

2.5. Copper Slag:

Copper slag is a by-product generated from the process of smelting matte and refining of copper. As the copper settles down in the smelter, it has a higher bulk, impurities stay in the top layer and they are elated to a water basin with a low temperature for solidification process. The end product attained is a solid, hard material that goes to the crusher for further processing. Copper slag used in this project was procured from Sterlite Industries Limited (SIL), Tuticorin, TamilNadu, India. The specific gravity of copper slag was found to be 3.63.

3. Results and Discussion

3.1. Compressive Strength of Concrete

After 7, 14 and 28 days of curing period, three cubes from each mixtures were taken out from the curing tank and surface dried. The value obtained were substituted in equation (1) and the average compressive strength obtained from testing the concrete cubes are presented in Table 2 for comparison of results obtained.

Table 2: Compressive Strength of Concrete (N/mm^2)

Mix ID	7 DAYS	14 DAYS	28 DAYS
C.M	20.91	28.95	32.17
D-1	31.68	43.87	48.75
D-2	33.00	45.69	50.77
D-3	29.78	41.24	45.83
D-4	28.92	40.05	44.50
D-5	27.05	37.47	41.63
D-6	32.14	44.51	49.45
D-7	31.89	44.16	49.07
D-8	28.99	40.14	44.60
D-9	42.44	58.77	65.30

3.2. Splitting Tensile Strength Test

After 28 days of curing period, three cylinders from each mixture of 100mm diameter and 200mm depth were taken out from the curing tank and surface dried. The values obtained were substituted in equation (2) average split tensile strength obtained from testing the concrete cylinders are presented in Table 3 for comparison of the results obtained.

Table 3: Splitting Tensile Strength Test

Mix ID	28 DAYS
C.M	2.87
D-1	2.72
D-2	3.31
D-3	2.63
D-4	3.26
D-5	4.95
D-6	4.17
D-7	4.92
D-8	4.97
D-9	5.67

4. CONCLUSIONS

From the results obtained, the following conclusions were made.

- The addition of fly ash, steel fibers and copper slag in the concrete, results in the increase of concrete's compressive strength and tensile strength.
- All the concrete mixtures have attained the target strength and when compared with the control concrete all the mixtures show improved compressive strength.
- The concrete mixture D-9 containing 40% fly ash, 40% copper slag and 1% steel fibers attains higher compressive strength than other mixtures at all the curing ages.
- The tensile strength of mixtures D-1 and D-3 are slightly less when compared to the control mix they both have 20% copper slag excluding these two mixtures all the other mixtures show improved tensile strength.
- The concrete mixture D-9 containing 40% fly ash, 40% copper slag and 1% steel fibers attains tensile strength than other mixtures at all the curing ages.

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