EXPERIMENTAL STUDY ON BOND STRENGTH AND FLEXURAL STRENGTH OF CONCRETE USING FLY ASH, COPPER SLAG AND RECYCLED AGGREGATE

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Abstract - *Construction industry is the fastest developing one in the world. But after the life of a structures, it must be demolished which may be a treat to large environmental problem. From time to time, disposal of waste and bi products are a major concern. The concrete waste formed by demolishing has its own physical properties which can recycled into usable constructional goods. Fly ash and copper slag which are bi-products of various process.es which has its own environmental impact. The addition of the following fly ash and copper slag into concrete mass adequately increase the compressive strength, split tensile strength, flexural strength and impact strength of concrete. Research works were started many years before about using the demolished waste in concrete and has revealed positive results in compressive strength. Copper slag can be used in construction industry as partial replacement of fine aggregate. Fly ash, is a coal combustion product. In arrears to its pozzolanic properties, fly ash is used as a replacement for Portland cement in concrete. Coarse aggregate is partially replaced by recycled aggregate at optimum percentage of replacement. The utilization of fly ash for cement, copper slag for fine aggregate, recycled concrete aggregate for coarse aggregate reduces their disposal problems to a great extent. In this experimental investigation, the copper slag, fly ash and recycled aggregate are added in various proportions and their effect on mechanical properties of concrete will be studied.*

***Key Words*: Copper slag, fly ash, recycled coarse aggregate**

1. INTRODUCTION

1.1 General

The construction industry is one of the foundation of any economy. When an economy is beginning to grow, the first industry that grows is construction. Because it "uses" many other types of industries and gives a lot of works. So concrete is the most important element of the most important industries. More than a ton of concrete is produced ever year for each person on the entire planet. Due to that construction projects are executed at very rapid rate. Concrete is a flexible engineering material used in most of the civil engineering structures.

Concrete is combination of various products, essentially consisting of cement, aggregates, water and admixture. Among these, aggregates, such as sand, crushed stone or gravel form the major part. Traditionally aggregates have been easily available at economic price. However, overexploitation and use of aggregates from natural resources has been questioned at an alarming level. This is mainly due to the depletion of quality aggregates and greater awareness of environmental protection. In light of this, the availability of natural resources to future generations has also been analyzed. Since the availability of natural resources of concrete is limited, alternative options which are obtained to industrial by product like copper slag, fly ash etc. Industry produced a large amount of byproduct material during casting process. It also has an environmental issue in disposal of these byproducts since it cannot be used anywhere except the land filling. Copper slag can be used in producing concrete as a partial replacement for sand. Fly ash, is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. . Owing to its pozzolanic properties, fly ash is used as a replacement for Portland cement in concrete. Coarse aggregate can be replace partially by using Recycled cement aggregate (RCA). RCA in structural concrete is to make construction more "green" and environmentally safe. The use of RCA on a large scale may help to reduce the effects of the construction on these factors by reusing waste materials and preventing more natural aggregate from being harvested.

2. LITERATURE REVIEW

A S Alnuaimi & Al-Khoud (2012) conducted studies on the use of copper slag (CS) as a replacement for fine aggregate (FA) in RC slender columns was experimentally investigated in this study. Twenty columns measuring 150 mm x150 mm x 2500 mm were tested for monotonic axial compression load until failure. The percentage of cement, water and coarse aggregate were kept constant within the mixture, while the percentage of CS as a replacement for fine aggregate varied from 0 to 100% .Results showed that replacement of up to 40% of FA with CS caused no major changes in column failure load, EI or concrete strength. Further increasing the ratio of CS or FA reduced the concrete strength and column failure load, and increased concrete slump and lateral and vertical deflections.

Amanda Renee Steele & J Enam(2014)conducted studies to determine the effect of replacing coarse natural aggregates for recycled concrete aggregates (RCA) on the bond strength between deformed mild reinforcing steel and surrounding concrete. Two different RCA replacement levels were considered, 50% and 100%, and were compared to a standard mix design. Analysis of the direct pull-out data indicates that both 50% and 100% RCA mixes preformed comparably or had a slight improvement in bond capacity over the controls.

Binaya Patnaik Å et.al., (2013) found that materials like Stone dust, Copper Slag, Coal Fly Ash, Carbonate Sand etc. having silica composition could be used as a replacement of sand. The Present experimental investigation is carried out forM20 grade of concrete mixes with partial replacement of Fine Aggregate (Sand) with Copper Slag. Compressive Strength at the ages of 7, 28 &90 days for various combinations of Copper Slag and Sand were investigated. Sand was replaced with Copper Slag by 0%, 10%, 20%, 30%, 40% and 50%. Compressive Strength of Copper Slag admixture Concrete, increased due to high toughness of Copper Slag. For longer curing periods (i.e. 90-Days), no detrimental effect (i.e. Strength reversal) was observed, when using Copper Slag. Replacement of Copper Slag as fine aggregate in concrete mixes reduces the cost of concrete production. The utilization of Copper Slag in Concrete production provides additional environmental as well as effective waste management technique for all the related Industries.

D. Brindha and S. Nagan (2010) investigate the potential use of granulated copper slag. The effect of replacing fine aggregate by copper slag on the compressive strength and split tensile strength are attempted in this work. Leaching studies demonstrate that granulated copper slag does not pave way for leaching of harmful elements like copper and iron present in slag. The percentage replacement of sand by granulated copper slag are 0%,5%,10%,15%,20%,30%,40% and 50%. The compressive strength was observed to increase by about 35-40% and split tensile strength by 30-35%. The experimental investigation showed that percentage replacement of sand by copper slag shall be upto40%.

Edwin Fernando et.al., (2013) developed a mix design and its self compactability has been checked. At first the normal concrete is prepared and then further steps 5% - 25% of sand is partially replaced as copper slag, self-compact ability test such as slump flow, V- funnel and J-ring tests have conducted and their results are reported. Also compressive, Split- Tensile strength and have been conducted and the results are compared. The compressive strength was observed to increase by about 35-40% and split tensile strength by 30-35%. The experimental investigation showed that percentage replacement of sand by copper slag shall be upto40%.

Khalifa S. Al-Jabri et.al., (2012)studied the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results obtained for cement mortars revealed that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of the control mixture. Also, there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution in comparison with the control mixture. The results obtained for concrete indicated that there is a slight increase in density of nearly 5% as copper slag content increases, whereas the workability increased significantly as copper slag percentage increased compared with the control mixture.

Mini Soman & Sobha.K(2014) developed a concrete by replacement of Ordinary Portland Cement (OPC) with 50% Fly Ash by mass. The fresh and hardened properties of High Volume Fly Ash Concrete (HVFAC) with 50% replacement of cement and Ordinary Portland Cement Concrete (OPCC) are studied. The study discloses that high volume of Fly Ash in concrete reduces the water demand and improves the workability. Study also reveals that the OPCC and HVFAC exhibits similar hardened properties. Comparison of flexural response of beams made with OPCC and HVFAC with different percentage of reinforcement are also studied. It is observed that HVFAC beams have shown notable improvement in the deflection, cracking behaviour and load carrying capacity.

Mounir M. Kamal et.al., (2015) conduct study on Some of the remnants of construction demolition wastes could be used after recycling as coarse aggregate in concrete industry. Among these wastes are ceramics, shale bricks and hardened concrete. This research was carried out to determine the effect of using such recycled aggregate (RA) as total or partial replacement of the natural dolomite coarse aggregate in concrete mixes on their compressive and bond strength with steel bars. Two types of concrete were investigated in this research which included normal concrete and self-compacted concrete. The main variables taken into consideration wee, the type of concrete, the type and percentage of the recycled aggregate and the age of testing. The consistency of the normal fresh concrete was measured by the slump test. However, the workability and flowability of the self-compacted fresh concrete were measured using slump test, V-funnel test. Out of the experimental test results, equations were predicted which correlated between the concrete compressive strength and bond strength of both the recycled aggregate ordinary concrete and the recycled aggregate self-compacted concrete. These equations were completely different than that of the steel-concrete bond equation of concrete with natural aggregate.

S.C. Kou & C.S. Poon(2009)investigate the fresh and hardened properties of concrete using recycled concrete aggregate as both coarse and fine aggregates were evaluated. Three series of mixtures were prepared with 100% coarse recycled aggregates, and different levels of fine recycled aggregates were used to replace river sand. The cement content was kept constant for all concrete mixtures. The mixtures were prepared with 0, 25, 50, 75 and 100% fine recycled aggregates, the corresponding water-to-binder ratios (W/B) were 0.53 and 0.44 for the mixtures in Series I and II, respectively. The mixtures in Series III were prepared with 100% recycled concrete aggregates (both coarse and fine) but three different W/B ratios of 0.44, 0.40 and 0.35 were used. The compressive and tensile splitting strengths of the RA-SCC mixtures prepared without the addition of fly ash decreased with increasing fine recycled aggregate content. The maximum compressive and tensile splitting strength were achieved by using 25–50% fine recycled aggregates as a replacement of river sand. 4. The resistance to chloride ion penetration of the RA-SCC mixtures increased with an increase in the fine recycled aggregate content.

Wei Wua et.al., (2010)investigate the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate and concluded that less than 40% copper slag as sand substitution can achieve a high strength concrete that comparable or better to the control mix, beyond which however its behaviours decreased significantly. The workability and strength characteristics were assessed through a series of tests on six different mixing proportions at 20% incremental copper slag by weight replacement of sand from 0% to 100%. The results indicated that the strength of the concrete with less than 40% copper slag replacement was higher than or equal to that of the control specimen and the workability even had a dramatic growth. It also suggested that the determination of the copper slag replacement level should consider with the desired compressive strength of concrete.

3. PROPERTIES AND MATERIAL USED

3.1 Coarse aggregate

Table 3.1-Properties of coarse aggregate

Properties	Values
Specific weight	2.7057g/cm^3
Loose unit weight	1.345Kg/m^3
H_2O absorption	1.15%
Compaction unit weight	1.547/m^3

3.2 Fine aggregate

Table 3.2- Properties of Fine Aggregate

Properties	Values
Specific Weight	2.57g/cm^3
Loose unit weight	1.69Kg/cm^3
H_2O absorption	1.83%

3.3 Cement

Table 3.3- Physical properties of cement

Physical Properties	Values
Initial setting time	30 minutes
Final setting time	10 hours
Soundness , expansion	10 mm

Table3.4- Chemical properties of cement

Chemical Properties	Values
Loss on ignition	4%
Insoluble residue	2%
MgO	6%
SO_3	2.5%
CaO	63%

3.4 Recycled Aggregate

Table 3.5- Properties of recycled aggregate

Property	Virgin aggregate	RA
Absorption	1–2.5 %	1–8.5 %
Specific gravity	2.4–2.7	2–4.8
Crushing value	15–20 %	20–35 %

3.5 Copper slag

Composition	% By mass
Fe_2O_3	55-60
Fe_3O_4	<10
SiO_2	27-33
CaO	1-3.5
S	0.2-1.5
Cu	<1
Al_2O_3	<3

Figure 3.1 – Chemical composition

3.6 Fly Ash

Table 3.6-Properties of Fly ash

Chemical components	% by Mass
SiO_2	60.28
Al_2O_3	31.76
Na_2O	2.1
P_2O_5	1.42
SO_3	0.97
FeO_3	0.89
CaO	0.72
K_2O	0.69

4. MIX DESIGN

4.1 Mix proportion-Control mix

Cement	= 394.00 Kg
Fine aggregate	= 725.76 Kg
Coarse aggregate	= 1149.12 Kg
Water cement ratio	= 0.50
Mix proportion in M_{25}	**= 1:1.84:2.92**

5. CONCLUSION

Different views of various authors on bond strength flexural strength of concrete, fly ash, copper slag and recycled aggregate have been discussed. This gives theoretical knowledge about utilization of fly ash, copper slag and recycled aggregate to replace the cement, fine aggregate, course aggregate from the conventional concrete by various ratios. From the literature review, the scope and idea to replace various concrete components can bring several characteristic changes in concrete physical and mechanical properties. The material testing for various materials used in the project are carried out to determine their properties, convenient to obtain required quality and strength. Design of concrete mix had done in this phase for the M25 concrete and the mix proportion for control mix is 1:1.84:2.92.

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