EXPERIMENTAL STUDY ON CONCRETE WITH REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG AND STYRENE BUTADIENE

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Abstract – Next to water, concrete is the second most used material in the world. Nowadays, various raw materials of concrete are becoming scare. The various alternative materials for the replacement of raw materials are looked into in order to attain the expected compressive strength of the concrete. This indicates that the replacement of fine aggregate is one of the researches, which is still in process in several parts across the world. This paper mainly focuses on replacing fine aggregate in concrete to improve the strength. An effort has made to replace fine aggregate with copper slag and styrene butadiene in proportions on trial and error basis by keeping water-cement ratio as 0.36 to attain the optimum strength. The study will focus on the optimum content of copper slag and styrene butadiene in the fine aggregate. Strength and performance of concrete will be evaluated in comparison with the conventional concrete.

I. INTRODUCTION

The awareness of using and implementing natural resources in construction industry is increasing rapidly in recent times. This forced the civil engineers to think new strategies. They also concentrated that the strategies should be more economical as well as environment friendly. Various publications repeatedly mentioned the depletion of natural resources and importance of sustainable development, which in turn justified the urge and need for sustainable development. The achievement of sustainable development in construction industry can be implemented by various innovative strategies. These include contemporary techniques/methods for eco efficient activities, choosing appropriate materials, reuse/ recycling of waste materials and so on. The studies (Correia et al., 2006; Anastasiou et al., 2015; Aggarwal and Siddique, 2014; Shettima et al., 2016) also states the reuse of waste materials in concrete will significantly enhance the sustainable construction. The above arguments clearly depicts that the materials used in concrete play a significant role in the construction industry as the material owns merely 75% of its operation cost. This clearly shows that, focusing more on material based sustainability is much better when compared with all other available options. This material based sustainability enhances the whole sustainable development of the construction industry. Even though, there are lots of materials are used in the construction sector, aggregates are considered as the key elements. This is mainly due to the fact that aggregate constitutes significant part (nearly 70%) in concrete mix. In spite of the hiking of scarcity of the natural aggregates, there is also a gradual increase in the consumption of aggregates across the globe. The studies (Tu et al., 2006) confronted with the natural aggregate's rising consumption. The over use of natural aggregates will ultimately lead to the destruction of the environmental in the near future. This concern initiated some studies to come up with several artificial aggregates from the waste generated by the industries as the alternate materials for the natural aggregates in the concrete. Over the last few decades, the increasing industrialization and globalization gives the evidence for the exponential growth of consumerism. This in turn, ultimately resulted in the increase in the generation of waste materials. The recent days statistics also depicts that these waste materials will become a threat to the world, and it also justifies that this is right situation for the effective management of waste. From earlier studies, we can understand that the waste can be eliminated or disposed in two ways, which also includes reducing waste production and effectively recycle/reuse the waste materials for other purposes (Al-Jabri et al., 2009). These strategies are widely followed by civil engineers. They initialed the use of byproducts including coal fly ash, silica fume, blast furnace slag, pulverized fly ash etc., with effective partial replacement of cement used in the construction industry. This method of implementing the byproducts as alternatives, enrich the construction sector. This method now extends the wing to the replacement of aggregate. Therefore, this study considers the construction waste and industrial waste as alternative of coarse and fine aggregates respectively. Providing alternatives with the waste is not new to the literature. But this study considers the use of copper slag and styrene butadiene as the replacement material. The mix is further tested for its mechanical properties. Copper slag is obtained as a byproduct from the copper manufacturing. Mithun and Narasimhan (2016) studied that the annual daily of copper slag is 3t as a byproduct of copper processing. This copper slag mostly ended up as land fill. Some amount of copper slag is used in the abrasive application for removal of rust. The studies show that nearly 75% of aggregate is filled with coarse aggregate. This indicates that equal attention should be given to the course aggregate for the effective management of waste and sustainable development. Mirhosseini et al. (2017) focused mainly on the mechanical properties of concrete along with the investigation of the physical and chemical properties of copper slag. This study concluded that the ratio of copper slag incorporation plays a significant role in providing better mechanical properties. Murari et al. (2015) made a study on the incorporation of copper slag as sustainable material in the construction industry mainly as the replacement for aggregates in the cementitious mix.The improvements in technology also lead to several improvements in concrete industry. These innovations have been entered into the concrete technology in the name of special concretes. The special concretes are nothing but the concretes produced in order to meet different expectations and applications according to their implementation and usage. Some of the special concrete is fluid concrete, structural lightweight concrete, heavyweight concrete and insulating concrete. Some studies (Yazicioglu et al., 2006) depicts the use of synthetic polymers such as polyacrylic ester and polyvinyl acetate in Portland cement mortars and concretes started in 1950s. After that, usage of synthetic polymer latex in polymer modified cement systems showed an increase compared with the usage of natural rubber latex. H. B. Wanger et al., 1965 and E. H. Hwang et al., 2008 studied about the usage of synthetic polymers as styrene butadiene rubber latex in Portland cement systems has gained acceptance in many application. The studies of Van gemerrt et al., 2005 and ohama et al., 1987, clearly concluded that using polymers as regulator in new constructions seems to be a strategy that will develop microstructure and durability of cement mortars and concretes. M. S. Baghini et al., 2014 studied about various polymers. Polymers have an important effect on workability and mechanical properties of aggregate-cement mixtures. In literature, styrene butadiene polymer generally seems to be a more commonly used polymeric substance. The studies (Wang et al., 2006) concluded that Styrene- Butadiene Rubber Latex is used in modified mortars in a significant extent. Previous results have shown that SBR-modified mortars have good impermeability, frost resistance and mechanical properties. According to standards, concretes with strength of more than 50 MPa are called high strength concretes (HSC). Currently, HSC usage is getting widespread. This is because the recently constructed buildings are becoming high-rise buildings and the bridges need to pass longer distances. Besides these, in terms of performance HSC is much more qualified compared to normal strength concrete (NSC). When compared with NSC, it is possible to pass wider distances and use less structural elements with HSC. HSC not only signifies that the strength of concrete is increased but also it signifies that the resistance of the construction against environmental effects and thus its lifetime is increased. Karahan and Atis_ (2007) investigated the effects of Sugözü fly ash, which was used as mineral admixture instead of cement (up to 40% of its amount) in cement mixture, on HSC properties. For 150x150x150 mm cubic samples for which water/binder (cement/ash) ratio in the mixture was taken to 0.35 and hyperplasticiser was used for increasing workability, concrete compressive strength in 7, 28, 90 and 365 days were measured to be 65, 78, 87 and 103 MPa, respectively. O. Karahan et al., 2007 emphasized the usage of fly ash which is produced as a secondary product in thermal plants would be useful for both economic and ecological means. Rossignolo and Agnessini (2002), in their study on the mechanical properties of lightweight concretes modified with polymer, by adding styrene butadiene latex (SBR) to Brazilian lightweight aggregates as polymer, determined that compressive strength of obtained concretes in 7 days were changing between 39.7 and 51.9 MPa as a result of the study they determined that by modifying SBR to Brazilian light aggregates, thin prefabricated component material could be produced. Shafieyzadeh (2013), examined compressive strength of concretes containing SBR and Silica Fume in a study about Styrene Butadiene Copolymer (SBR). In his study, he used aggregate, cement, SBR and plasticiser to adjust the workability. In the study, concrete mixtures prepared by using 0%, 5%, 10%, 15% SBR and 0%, 5%, 7.5% and 10% Silica Fume were studied. In the study, it was specified that when polymer ratio was increased, the compressive strength decreased and the optimum ratio was with 5% SBR admixture. In this study, for high strength concretes produced in C50/C60 designs, Styrene Butadiene Copolymer (SBR) in different ratios by weight (Control (0%), 1%, 3%, 5% and 8%) was used instead of cement and strength properties were investigated.

II Materials

2.1. Cement

For this study, 53 Grade Ordinary Portland Cement (OPC) has been used with the fineness up to 5% with standard consistency 29% along with the specific gravity 3.15. The initial and final setting time was maintained and recorded as 30 min and 10 h respectively.

2.2. Fine aggregate

In addition with the copper slag, river sand was used as a fine aggregate, having the fineness modulus and specific gravity as 2.64 and 2.57 respectively.

2.3. Coarse aggregate

The 12 mm size gravel has been used for this study with the specific gravity as 2.69 and fineness module as 6.87.

2.4. Copper slag

As detailed earlier, existing studies reported the supreme quality of the copper slag and its impacts in concrete, hence this study considered copper slag as one of the partial replacement for fine aggregate. The copper slag used for this study was collected from Sterlite Industries India Limited, Tuticorin, Tamilnadu, India which is having specific gravity and fineness modulus of 4.00 and 3.47 respectively (shown in Fig. 1). For this study, the plain copper slag has been considered without any external induce like NaOH. However, the chemical properties of copper slag were detailed in Table 1.

Table 1 Component % of chemical composition

Component	**Percentage**
Silicon oxide (SiO2)	97.01
Aluminum oxide (Al2O3)	0.095
Iron oxide (Fe2O3)	1.05
Calcium oxide (CaO)	1.064
Magnesium oxide (MgO)	0.118
Potassium oxide (K2O)	0.028
Sulfur trioxide (SO3)	0.008
Sodium oxide (Na2O)	0.118
Titanium oxide (TiO2)	0.120
Manganese oxide (Mn2O3)	0.002
Copper oxide (CuO)	0.183
SulphideSulphur	0.082

2.5. Styrene Butadiene (SB)

It is a type of rubber obtained by emulsion or suspension polymerisation of styrene and butadiene monomers. Butadiene/styrene ratio is generally 75/25. SBR is generally produced as having 250,000–800,000 average molecular weight. Polymerisation type is effective on the properties of SBR. The chemical and physical properties of SBR used in the study are given in Table 2.

Table 2 - Chemical and physical properties of SB.

Appearance	White and powdery/ liquid
Polymer Type	Styrene – Butadiene
Emulsifying system	Anionic/non-ionic
Viscosity	<300 cps
Solid content	% 47.0 ± 1
pH	8.5–9.5
Particle size	ca. 175 nm

III METHODOLOGY

A. Mix proportion

The copper slag is used as the replacement material for fine aggregate. The literature study shows that the replacement of copper slag will yield better compression behavior up to 50%. Beyond 50%, the addition of copper slag reduced the compressive strength. This is mainly due to the excess water content in the concrete mix. The Water content is reduced and the maximum percentage for the replacement of fine aggregate with fine aggregate beyond 50% is obtained. The remaining fine aggregate is replaced with styrene butadiene in order to obtain complete replacement of the fine aggregate.

Specimens Casted

Table 3 Mix Proportion

Specimen	Fine Aggregate	Copper Slag	Styrene Butadiene
S1	50	50	0
S2	40	60	0
S3	30	70	0
S4	20	80	0
S5	25	70	5
S6	20	70	10
S7	15	70	15
S8	10	70	20
S9	5	70	25
S10	0	70	30

B. Compressive strength test

The cube mould of size 150x150x150 mm is taken and it is cleaned. The concrete is mixed by using all the materials in proper proportions and is filled in the mould by three layers with proper tamping. The cube is then demoulded after 1 day and is cured in curing tank for 7 days, 14, days, 21 days and 28 days. Then it is taken out and subjected to compressive strength test in UTM by applying a gradually increasing load. The load at which the concrete fails is noted. This gives the compressive strength of the specimen. For each proportion, three specimens are subjected to compressive strength testing and average is taken as the compressive strength of the corresponding specimen.

C. Split tensile strength

The mix is done for various proportions, and it is casted in to the cylinder mould. It is then placed in the UTM along the diameter.The load is applied gradually, and the load at which it fails is noted. The split tensile strength of the concrete is calculated as per the formula given in the clause 8.1 of IS 5816 : 1999.

D. Flexural test

The beams are casted with the mix satisfying the standards and codal provisions.The beams are then subjected to two point loading as per middle third rule. The gives the effect of beam subjected only to flexure. In this case, the effect of shear force in one direction is counter acted by the shear force in the opposite direction. Hence the effect of shear force is null and the beam is subjected tp pure bending. This gives the effect of beam subjected only to flexure. The load is increased gradually and load at which the beam fails is noted as the capacity of the beam. Thus, the flexural behavior of the beam is evaluated.

IV. RESULTS AND DISCUSSIONS

A. Compressive Strength Test

The compressive strength test is done for three specimens in each and every mix proportion. Initially the fine aggregate is replaced only by copper slag and it is observed that 70% of copper slag incorporation as a replacement for the fine aggregate provided better results. Then the 70% copper slag is kept constant and the remaining 30% fine aggregate is replaced with styrene butadiene in powder form in order to save fine aggregate to the maximum extent.

Table 4 Compressive Strength Test

Specimen	Compressive strength, N/mm^2
S1	43.76
S2	43.92
S3	44.15
S4	42.29
S5	36.97
S6	31.83
S7	25.31
S8	20.62
S9	16.19
S10	10.11

The results show that the addition of copper slag increased the compressive strength of the concrete up to 70% replacement for the fine aggregate. When the remaining 30% fine aggregate is replaced with the styrene butadiene powder, we observe a drastic reduction in compressive strength. The butadiene incorporation as a replacement material for fine aggregate satisfied the codal provisions only up to 10% incorporation. The M25 grade concrete mix satisfied the target mean strength of 31.6 N/mm^2. Thus we can conclude that the proper mix proportion of fine aggregate be 70% Copper slag, 10% Styrene butadiene and 20% sand. This proportion is kept fixed for the further study in flexure.

B. Split Tensile Test

The split tensile test is done for three specimens for each and every mix and the results observed are tabulated as below.

Table 5 Split Tensile Strength Test

Specimen	Split tensile strength, N/mm^2
S1	4.36
S2	4.21
S3	4.40
S4	4.01
S5	3.56
S6	3.08
S7	2.45
S8	2.01
S9	1.46
S10	1.02

The results indicated that the addition of copper slag enhanced the split tensile strength up to certain extent and the addition of styrene butadiene reduced the split tensile strength to a considerable level.

C. Flexural Strength Test

The mix proportion which satisfied the codal provisions with maximum replacement for fine aggregate is chosen and three beams are casted for the mix proportion. These beams are then subjected to flexural test and the results are obtained. Three beams with conventional mix proportion is also casted and subjected to flexural test. The comparison of flexural strength of the conventional beam with the beam with modified mix proportion is done. The flexural strength is studied in the form of deflection to a constant loading. The deflection of the conventional beam is 0.36mm whereas the deflection of beam with modified mix proportion is 0.33mm for the load of 25 ton. This depicts that the deflection of conventional beam is high when compared with the beam with modified mix proportion. This in turn also concludes that the modified mix proportionate beam have high flexural strength than conventional beam as the beam with less deflection has the higher flexural strength.

V. CONCLUSION

The study yields the following conclusions from the tests done

- The optimum mix proportion for fine aggregate is 70% Copper slag, 10% Styrene butadiene and 20% sand.
- The addition of copper slag enhances the compressive and tensile behavior only up to certain extent. Beyond that, there will be reduction in the strength due to the water content.
- The butadiene incorporation results in reduction in strength of the specimen.
- The incorporation of copper slag and styrene butadiene in proper proportion enhanced the flexural behavior of the concrete.

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