Study on Mechanical Properties of Composite Concrete using Fly Ash, Lime Sludge and Copper Slag

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ABSTRACT
In this paper, a study has been made on the mechanical properties of the composite concrete using fly ash, lime sludge and copper slag. The compressive, flexural and split tensile strengths of the plain or controlled concrete after 28 days and 90 days curing have compared with those of composite concrete made up with partially replacing cement by fly ash and lime sludge, and partially sand by copper slag. Composite concrete with replacement of cement (weight) by lime sludge 20 percent and the sand by copper slag 40 percent is found to be more economical without sacrificing minimum required compressive, flexural and split tensile strength, in general, compared to that of plain concrete. Further this composite concrete helps in solving disposal problem of fly ash and lime sludge, copper slag to the considerable extent.

Keywords--- Composite concrete, Compressive strength, lime sludge, copper slag, split tensile strength

I. INTRODUCTION
In recent times, a rapid development in the production of less energy intensive cements and concretes with high performance in resistance and durability has occurred. This has been accomplished by the use of industrial wastes or by-products like fly ash, slag, silica fume, rice husk etc. with considerable pozzolanic activity.

Paper making Mills generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low-quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings pigments, staples and “stickies” (tape, plastic films, etc.) are also washed off the recycled fibers to join the waste solids. The shiny finish on glossy magazine type paper is produced using a fine kaolin clay coating which also becomes solid waste during recycling. This paper mill sludge consumes a large percentage of local landfill space for each and every year. Worse yet, some of the wastes are land spread on crop land as a disposal technique, raising concerns about trace contaminants building up in soil or running off into area lakes and streams. Some companies burn their sludge in incinerators contributing to our serious air pollution problems. The paper industry is one of the key industrial sectors in India. However the per capita consumption of paper and board in the country is very low at 3–4 kg per annum. Rapid urbanization, increasing literacy rates and industrial development are expected to create a growing demand of paper and paper products at the rate 8 percent per annum. Lime sludge is an waste material from the paper industry.

Fly ash is a waste material obtained from finely ground burnt coal in electricity generating power plants and it is most commonly used pozzolanic material in cement concrete in the world. Physically, it is very fine powdery material, predominantly of silica, with particles almost spherical in shape. In India about 120 million tons of fly ash per annum is generated with land fill covering 200 sq.km and will increase subsequently. The construction industries are yet to reach the target of fly ash utilization. Therefore, there is a need to study the feasibility of using the high calcium fly ash for structural concrete.

Copper slag is an industrial waste from copper producing industry. Its size and appearance almost resembles the fine aggregate. Like fine aggregate i.e. sand, copper slag also an inherent material.

Selvaraj and Bhuvaneshwar[i], studied that conventional building materials are beyond the reach of majority of the world population due to their poor affordability. This is due to escalation of cost of building materials and other reasons. In this paper an attempt is made to utilize waste papers in concrete with and without mineral admixtures like, flyash, kaolin, rice husk ash (RHA), and clay. The characterization study such as cylinder compressive strength, splitting tensile strength, water absorption and dry density were carried out and the behaviour of this new material “paper concrete” is
assessed. It is also found that the incorporation of clay in the mix improves strength properties in paper concrete. It is a lightweight material with large amount of energy absorption characteristics and thus it can be a promising futuristic building material.

Malhotra and Verma [2], studied that several types of industrial/mining byproducts have been attracting worldwide attention these days for the development of building materials. A huge quantity of such byproducts i.e. lime sludge’s, marble dust, dolomite, phosphor-gypsum, granulated blast furnace slag, mine tailings, etc are being produced in the country. Significant efforts have been made in the laboratory for the development of masonry cement from these materials. The paper describes the advantages, development and properties of the masonry cements prepared from these byproducts and strategies of their use taking into consideration of energy and environmental aspects.

Indrajit Patel and Modhera[3], studied on the use of high volume of fly ash (HVFA) concrete fits very well sustainable development. High volume of fly ash concrete mixtures contain lower quantities of cement and higher volume of fly ash (60%). The use of fly ash in concrete at proportion rating from 35 to 60 % of total cementations binder has been studied extensively over the last twenty years and the properties of blended concrete are well documented. The replacement of fly ash as cementations component in concrete depends upon several factors. The design strength & workability of the concrete, water demand and relative cost of fly ash compared to cement. From the literature it is generally found that fly ash concrete in the cementitious material varies from 30-80% for low strength (20MPa) to high strength (100MPa). Though use of high volume of fly ash (HVFA) concrete is very popular in countries like Japan, Canada & other developed nations since last century but to certain limitations of application area the same has been not popularize worldwide. The limitations include slower early strength development, poor resistant to impact and abrasion and contribution to flexural as well.

In this investigation a study has been made on the mechanical properties of the composite concrete developed using industrial waste materials like lime sludge, fly ash and copper slag by partially replacing cement and sand of the conventional concrete. Thereby disposal problems of these industrial waste can also be solved to some extent.

II. MATERIALS USED

Ordinary Portland Cement from Ramco Cement Company was used in this investigation. The grade of cement was 43. The specific property of the cement is 3.06. River fine sand was considered as fine aggregates. From the sieve analysis test it is found that the fine aggregate belongs to zone II of IS code. The specific gravity of the fine aggregate found to be 2.65. Crushed granite aggregates of 20mm and down size were used as coarse aggregate. The specific gravity of the coarse aggregate is 2.69 Lime Sludge from Mysore Paper Mills Limited, Bhadravati Karnataka was used. Fly ash was collected from Raichure thermal power station, Karnataka. Copper slag was procured from Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu, India. The specific gravities of fly ash, lime sludge and copper slag were found to be 2.23, 2.34, and 3.25 respectively.

III. METHODOLOGY

Series of concrete cubes of standard dimensions 150 mm x 150 mm x 150 mm, concrete cylinders of standard dimension 150mm diameter and 300 mm height and concrete prisms of standard dimensions 50mm x 50mm x 500mm were cast with various mix proportions and were cured for 28 days and 90 days. These cured concrete cubes were tested in compression testing machine as per IS: 516-1959[4], concrete cylinders were tested for tensile strength as per IS: 5816-1999[5]. Concrete prisms were tested for flexural strength as per IS: 516-1959.

Specific gravities of cement, fine aggregate and coarse aggregate, fly ash and copper slag were determined in Concrete Lab. Moisture contents and water absorptions of fine aggregate and coarse aggregate and copper slag were also determined in the concrete Lab. The concrete mix design has been carried out for M30 grade concrete as per IS: 10262-2009[6]. Mix proportions used are given in the subsequent section.

IV. TEST RESULTS AND DISCUSSIONS

Concrete cubes, cylinders and prisms were cast and tested for their respective compressive, flexural and splitting tensile strengths of concrete in Concrete and Highway Engineering Lab as per the methodology specified in the previous section. The results are shown in Figures. Comparisons are made between the conventional concrete and composite concrete with respect to their strengths.

Series of concrete cubes of standard dimensions (150 mm x 150mm x 150mm) were cast by replacing cement (weight) by lime sludge 0, 10, 20, 30, 40, and 50 percent. After 28 days and 90 days curing these cubes have been tested using compressive testing machine and results are shown in the Figures 1 and 2 respectively. These results indicate that only 10 percent replacement of cement (weight) by lime sludge increases the compressive strength by 10.9 percent (after 28 days curing) and 16.54 percent (after 90 days curing) compared to strength of conventional (plain) concrete.

And 20 percent replacement of cement by lime sludge will produce the strength of composite concrete almost same, in general, as that of conventional (plain) concrete. Further replacement of cement by lime sludge (more than 20 percent) will reduce the strength of
Concrete beams:
Flexural strength of lime sludge-copper slag based concrete cubes:
Series of concrete cubes of standard dimensions (150 mm x 150mm x 150mm) were cast replacing cement by 20 percent (weight) lime sludge and replacing sand (weight) by copper slag 0, 20, 40, 60, 80, and 100 percent. After 28 days and 90 days curing these cubes have been tested using compression testing machine and results are shown in the Figures 5. These results indicate in general, that the combination where replacement of cement by 20 percent (weight) lime sludge and replacing sand (weight) by copper slag 40 percent produced compressive strength almost equal to that of conventional (plain) concrete.

Compressive strengths of lime sludge-fly ash-copper slag based concrete cubes:
Series of concrete cubes of standard dimensions (150 mm x 150mm x 150mm) were cast replacing cement by 30 percent (weight) lime sludge (10 percent) and fly ash (20 percent), and replacing sand (weight) by copper slag 0, 20, 40, 60, 80, and 100 percent. After 28 days curing these cubes have been tested using compression testing machine and results are shown in the Figures 3 and 4 respectively. These results indicate that, in general, the combination where replacement of cement by 20 percent (weight) lime sludge and 40 percent replacing sand (weight) by copper slag produced compressive strength almost equal to that of conventional (plain) concrete.

Flexural strength of lime sludge-copper slag based concrete beams:
Series of lime sludge-copper slag based concrete beams (prisms) of standard dimensions (50 mm x 50mm x 500mm) were cast by replacing cement (weight) by lime sludge 20 percent and sand content was replaced by copper slag through 0, 20, 40, 60, 80 and 100. After 28 days curing these beams have been tested for flexural strength and results are shown in the Figures 6. These results indicate that 20 percent replacement of cement (weight) by lime sludge and 20 percent replacement of sand by copper slag increases the flexural strength by 11.41 percent (for 28 days curing) compared to flexural strength of conventional (plain) concrete. Also these results indicate that 20 percent replacement of cement (weight) by lime sludge and 40 percent replacement of sand by copper slag increases the flexural strength by 5.9 percent (for 28 days curing) compared to flexural strength of conventional (plain) concrete. Further replacement of sand by copper slag (more than 40 percent) will reduce the flexural strength of concrete below flexural strength of conventional (plain) concrete.

Split tensile strength of lime sludge-copper slag based concrete cylinders:
Series of lime sludge-copper slag based concrete cylinders of 150 mm diameter and 300 mm height have been cast by replacing cement (weight) by lime sludge 20 percent and sand content by copper slag through 0, 20, 40, 60, 80 and 100. After 28 days curing these cylinders have been tested to know split tensile strength and results are shown in the Figures 7. The results indicate that the split tensile strength of lime sludge-copper slag based concrete cylinders are almost same, in general, as split tensile strength of plain concrete.

V. CONCLUSIONS

In this investigation, a study has been made on the mechanical properties of composite concrete using industrial waste materials like lime sludge, fly ash and copper slag. This helps in solving the disposal problem of lime sludge, fly ash and copper slag also.

Series of concrete cubes of standard dimensions (150 mm x 150 mm x 150 mm), concrete cylinders of standard dimension (150 mm diameter and 300 mm height) and concrete prisms of standard dimensions (50mm x 50mm x 500mm) were cast with various mix proportions and were cured for 28 days and 90 days. These cured concrete cubes, concrete cylinders and concrete prisms were tested as per IS: 516-1959, IS: 5816-1999 and IS: 516-1959 respectively for getting compressive strength, split tensile strength and flexural strength of the plain and composite concretes.

The compressive strength, flexural strength and split tensile strength of the plain concrete (without any special or industrial waste materials) have compared with that of compressive strength, flexural strength and split tensile strength of composite concrete made up with industrial waste material lime sludge, fly ash and copper slag.

In this investigation, following conclusions are drawn:

1. The results indicate that only 10 percent replacement of cement (weight) by lime sludge increases the compressive strength by 10.9 percent (after 28 days curing) and 16.54 percent (after 90 days curing) compared to strength of conventional (plain) concrete.

2. And 20 percent replacement of cement by lime sludge will produce the strength of composite concrete almost same, in general, as that of conventional (plain) concrete. Further replacement of cement by lime sludge (more than 20 percent) will reduce the strength of concrete below strength of conventional (plain) concrete. And hence it not advisable to use lime sludge content more than twenty percent of the cement content of the plain concrete.

3. In general, the combination where replacement of cement by 20 percent (weight) lime sludge and replacing sand (weight) by copper slag 40 percent produced compressive strength almost equal to that of conventional (plain) concrete.

4. The results indicate that, in general, the combination where replacement of cement by 30 percent (weight) lime sludge (10 percent) and fly ash (20 percent), and replacing sand...
(weight) by copper slag 80 percent produced compressive strength almost equal to that of conventional (plain) concrete.

5. Composite concrete with 20 percent replacement of cement (weight) by lime sludge and 20 percent replacement of sand by copper slag increases the flexural strength by 11.41 percent (for 28 days curing) compared to flexural strength of conventional (plain) concrete while 20 percent replacement of cement (weight) by lime sludge and 40 percent replacement of sand by copper slag increases the flexural strength by 5.9 percent (for 28 days curing) compared to flexural strength of conventional (plain) concrete. Further replacement of sand by copper slag (more 40 percent) will be resulting in getting reduced flexural strength of concrete.

6. The composite concrete with replacement of cement by lime sludge 10 percent and fly ash 20 percent is resulted in producing almost same split tensile strength as that of plain concrete.

7. The composite concrete where replacement of the cement (weight) by lime sludge 20 percent and sand content by copper slag 40 percent has produced, in general, practically same split tensile strength as that of plain concrete.

8. In general, the strengths of composite concrete with 20 percent replacement of cement (weight) by lime sludge and 40 percent replacement of sand by copper slag are superior compared to strengths of conventional (plain) concrete.

Composite concrete with replacement of cement by lime sludge 20 percent (weight) and the sand by copper slag 40 percent is found be more economical without sacrificing minimum required compressive, flexural and split tensile strength, in general, compared to those of plain concrete. Further this composite concrete helps us in solving disposal problem of lime sludge and copper slag to the considerable extent.

REFERENCES


Figure 1. Compressive strength of cubes at 28 days due to partial replacement of cement with lime sludge.

Figure 2. Compressive strength of cubes at 90 days due to partial replacement of cement with lime sludge.
Figure 3. Compressive strength of cubes at 28 days due to partial replacement of cement with lime sludge and fine aggregate with copper slag

Figure 4. Compressive strength of cubes at 90 days due to partial replacement of cement with lime sludge and fine aggregate with copper slag
Figure 5: Compressive strength of cubes at 28 days due to partial replacement of cement with lime sludge, fly ash and fine aggregate with copper slag.

Figure 6: Flexural strength of beams at 28 days due to partial replacement of cement with lime sludge and fine aggregate with copper slag.
Figure 7. Split tensile strength of cylinders at 28 days due to partial replacement of cement with lime sludge and fine aggregate with copper slag.