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GREEN HIGH PERFORMANCE CONCRETE USING ECO SAND AND INDUSTRIAL WASTES

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ABSTRACT

This paper aims at making and studying the different properties of green high performance concrete using this silica fume, fly ash and the other ingredients, which is locally available eco sand and coarse aggregates. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to environment-related. The role of Portland cement is replaced by silica fume and fly ash. An experimental investigation was carried out to evaluate the physical and mechanical properties of green high performance concretes containing cementitious materials by the replacement of cement with silica fume (7.5-15%) and fly ash (15-30%) and replacement of sand with eco-sand, a byproduct of cement as filler material. Super plasticizer is added to 1% to improve the workability of concrete. The mechanical properties were assessed from the compressive strength, tensile strength and flexure. While the durability characteristics were investigated in terms of alkalinity and water absorption.

Key words: Eco-sand, Green high performance concrete, Silica fume, Fly ash, durability.

INTRODUCTION

Concrete is a well known composite construction material composed primarily of aggregate, cement and water. There are many formulations, which provide varied properties. The aggregate is generally coarse gravel or crushed rocks such as limestone or granite, along with a fine aggregate such as sand. The cement commonly Portland cement and other cementitious materials such as fly ash and slag cement serve as a binder for the aggregate.

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Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite, which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process called hydration. The water reacts with the cement, which bonds the other components together eventually creating a robust stone-like material. Concrete has relatively high compressive strength, but much lower tensile strength. For this reason, it is usually reinforced with materials that are strong in tension (often steel). Concrete can be damaged by many processes such as the freezing of trapped water.

Main reasons to incorporate eco sand in concrete

Now a days, all over the world, construction activities are taking place on huge scale. Due to this there is great increase in cost of construction. Natural river sand is one of the key ingredients of concrete, is becoming expensive due to excessive cost of transportation from sources. Also large scale depletion of sources creates environmental problems. Unfortunately, production of cement also involves large amount of carbon dioxide gas into the atmosphere, a major contributor for green house effect and the global warming. To overcome these problems there is a need of cost effective, alternative and innovative materials. Industrial by products are those which is coming from different industries other than the main proposed product. It can also call as a sub product of different processes coming in manufacturing. In recent days these products are recycled and reused for other purposes to reduce cost and problems coming from disposal.

These are 50% more cheaply than the original raw materials. In cement manufacturing process, a cement plant consumes 3 to 6 GJ of fuel per ton of clinker produced, depending on the raw materials and the process used. Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications. Selected waste and by-products containing useful minerals such as calcium, silica, alumina, and iron can be used as raw materials in the kiln, replacing raw materials such as clay, shale, and limestone. Because some materials have both useful mineral content and recoverable calorific value, the distinction between alternative fuels and raw materials is not always clear. For example, sewage sludge has a low but significant calorific value, and burns to give ash containing minerals. Eco sand (finely graded silica) is a by-product coming from cement manufacturing process, mainly cement industries those use silica as a raw material is mainly producing eco sand as by-product.

What are called eco sand ?

Eco sand are very fine particles, a bi-product from cement manufacture, which can be used to increases efficiency in concrete. Its micro-filling effect reduces pores in concretes and provides better moisture resistivity and thus durability. It has more consistent grading than many extracted aggregates. Effective use for waste material and thus cost effective and performs as well as naturally occurring sand. The use of eco sand rather than extracted or dredged natural sand will help designers and contractors address issues of sustainability. The present study is checking the compressive strength, tensile strength and flexure of concrete cube using eco sand, cement and super plasticizer. While the durability characteristics were investigated in terms of alkalinity and water absorption. The eco sand has various advantages such as energy efficient, fire resistant, reduction of dead load, environmentally friendly, durable, light weight, low maintenance low construction cost.

EXPERIMENTAL

Effects on addition of eco sand

Eco sand are very fine particles, a bi-product from cement manufacture, which can be used to increases efficiency in concrete. Eco sand is finely powdered crystalline silica, which can replace up to a varying percentage of conventional sand usage in concrete and mortars. Its micro-filling effect reduces pores in concretes and provides better moisture resistivity and thus durability. It has more consistent grading than many extracted aggregates. Effective use for waste material and thus cost effective and performs as well as naturally occurring sand. The use of eco sand rather than extracted or dredged natural sand will help designers and contractors address issues of sustainability. The present study is checking the compressive strength of concrete block using eco sand as fine aggregate. The eco sand has various advantages such as energy efficient, fire resistant, reduction of dead load, environmentally friendly, durable, light weight, low maintenance, and low construction cost.

Materials used

Ordinary Portland cement (OPC) 53 grade cement. Eco sand (chemical composition Sio_2: 58-60%, Al_2O_3: 2-3%, Iron: 1-3%, MgO: 0.4-1% and CaO: 20-25% and natural sand is used as fine aggregate. Silica fume and fly ash is used as cementitious materials for replacing cement in proportions. Conplast SP 430 is used as super plasticizer to improve the workability of concrete.

Properties of materials

Tests were conducted to obtain the specific gravity and fineness modulus and bulk density of fine aggregates and coarse aggregate.

Table 1: Physical properties of materials

Materials	Specific gravity	Fineness modulus	Bulk density (Kg/m^3)
Natural sand	2.65	3.09	1537
Eco sand	2.48	4.33	1500
Coarse aggregate	2.84	5.07	1312
Cement	3.15	-	-
Super plasticizer	1.18	-	-

Methodology

The following flow chart shows the step by step process.

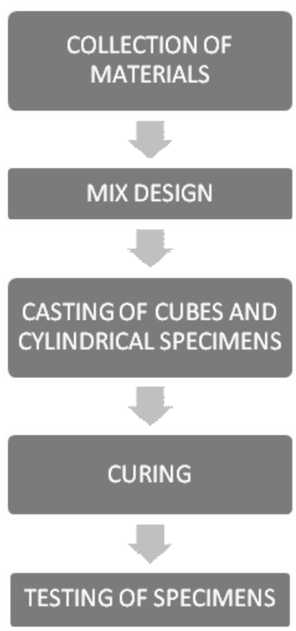

Fig. 1: Schematic diagram of entire work

Mix ratio

The commonly used method of mix design is the American Concrete Institute Method. Various mix ratios were obtained such as M1, M2, M3, M4 and M5.

Table 2: Percentage quantities of raw materials

Mix	Natural sand (%)	Eco sand (%)	Silica fume (% of cement)	Fly ash (% of cement)
M1	Normal mix			
M2	70	30	7.5	15
M3	70	30	10	20
M4	70	30	12.5	25
M5	70	30	15	30

Tests on durability

Saturated water absorption test

Saturated water absorption (SWA) tests were carried out on 100 mm cube specimens at the age of 28 days curing. The specimens were weighed before drying. The drying was carried out in a hot air oven at temperature of 105°C. The drying process was continued, until the difference in mass between two successive measurements at 24 hrs in interval agreed closely. The dried specimens where cooled at room temperature and then immersed in water. The specimens were taken out at regular interval of time, surface dried using a clean cloth and weighed. This process was continued till the weights became constant (Fully saturated). The differences between the measured water saturated mass and oven dried mass gives the SWA. The water absorption was calculated as –

$$\text{Percentage water absorption} = (W_s - W_d) / W_d \times 100$$

Where, W_s = Weight of specimen at fully saturated condition

W_d = Weight of oven dried specimen.

Alkalinity test

The M60 grade of HPC cube specimens were tested for compressive strength after 28 days of curing. The broken pieces of the test specimens were again broken into small pieces using hammer and ball mill and powdered. Each of the powder samples (about 20 g) was put into 100 mL of distilled water. The aqueous solution was allowed to stand for 72 hrs and more and was agitated often, to enable more of free lime of hydrated cement paste to get dissolved in water. The pH of the aqueous solution was measured by pH meter and also by putting the pieces of pH indicating papers into solution. The color of the pH paper in the solution matched with the standard color chart supplied by the manufacturer in order to get the pH of the solution.

Tests on mechanical properties

Fig. 2: Specimens under curing   Compression testing machine

Compressive strength

The compression test is used to determine the hardness of cubical specimens of concrete. The strength of concrete specimen depends on cement, aggregate, w/c ratio, curing temperature, age and size of specimen. Mix design is the major factor that controls the strength of concrete. Cubes of size 100 mm x 100 mm x 100 mm are casted. The specimen should be given sufficient time for hardening approximately 24 hrs and then it should be cured for 28 days. After 28 days the specimen should be loaded in the compression testing machine upto its failure load. Compressive strength is calculated by the following formula,

Compressive strength = Load/cross-sectional area of the cube

Split tensile strength

This is an indirect test to determine the tensile strength of the cylindrical specimens. Split tensile strength tests were carried out on cylindrical specimens of sizes 150 mm diameter and 300 mm height at the age of 28 days curing using compression testing machine.

The load was applied gradually till the specimens split and the readings were noted. The split tensile strength can be calculated using the formula,

$$f_t = \frac{2P}{\pi DL}$$

Where f_t = Split tensile strength of the specimen in N/mm^2

P = Maximum load in N applied to the specimen

D = Diameter of the specimen in mm

L = Length of the specimen in mm

Flexural strength test

Flexural strength tests are carried out on the rectangular beams of size 100 mm x 100 mm x 500 mm at the age of 28 days curing using flexural strength testing machine to determine the flexural strength. The flexural strength of the beam is calculated by using the formula,

$$f_r = \frac{3Pa}{bd^2}$$

Where f_r = Flexural tensile strength of specimen in N/mm^2

P = Maximum load in N

L = Length of the specimen in mm

b = Width of the specimen in mm

d = Depth of the specimen in mm

Fig. 3: Flexural strength testing machine

RESULTS AND DISCUSSION

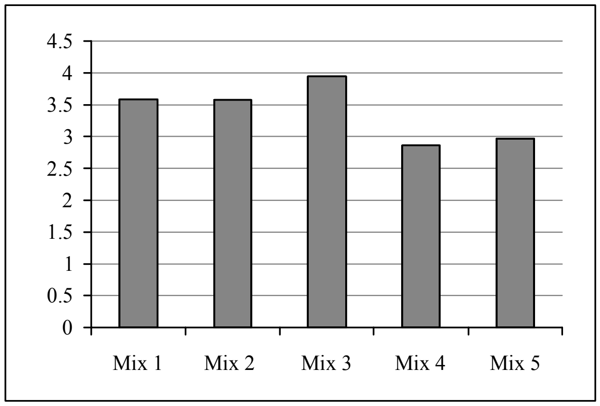

Fig. 4: Graph for SWA test

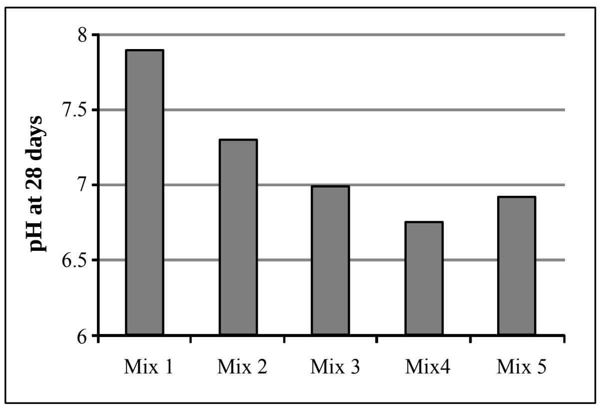

Fig. 5: Graph for alkalinity test

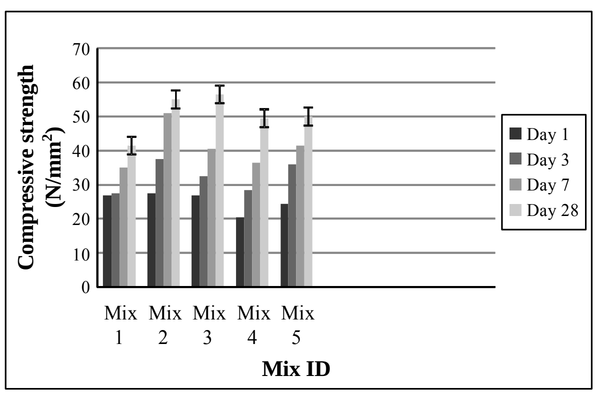

Fig. 6: Graph for compressive strength test on cubes

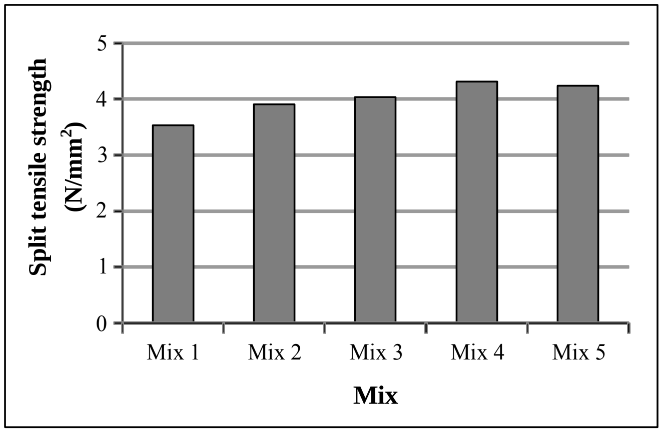

Fig. 7: Graph for split tensile test on cylinders

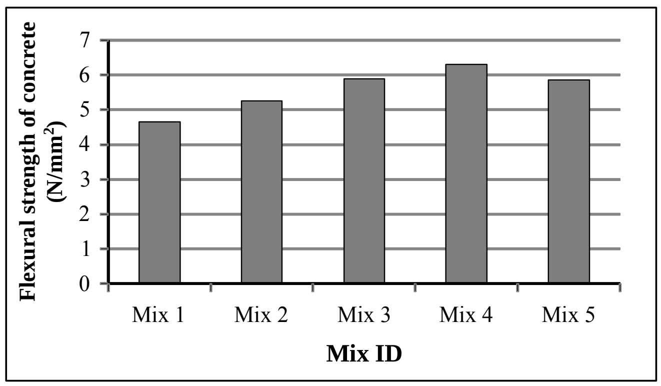

Fig. 8: Graph for flexural strength test on beams

CONCLUSION

On the basis of the results obtained from this research work, the following conclusions have been drawn:

(i) With the water cement ratio of 0.33, the compressive strength increased at all ages due to the use of SF at 10% replacement levels.

(ii) The split tensile strength was increased due to the use of SF at 12.5% and FA at 15%.

(iii) In the 40% replacement of eco sand the flexural strength was achieved more at the age of 28 day due to the use of 25% FA.

(iv) Finally the mix M4 was found to be more effective.

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