Experimental Investigation on Lightweight Concrete with Kegrete Bowling Ball

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1 Introduction

The project's aim is to figure out the physical and mechanical properties of concrete mix, medium-weight concrete, and polypropylene fibre concrete [1]. The lightweight concrete has paved its own way in the civil engineering industry. Many lightweight bridges and decks are being created and constructed with lightweight materials [2, 3]. There are many benefits of using low-density concrete. It assists in the reduction of dead load, the acceleration of construction, and the reduction of haulage and handling costs. The low thermal conductivity of lightweight concrete is another significant feature [4, 5]. It contains fibres of equal length which will increase the structural integrity. For a good fibre-reinforced concrete, the shape, dimensions, and texture of the fibre are important [6]. The usage of fibres in the concrete will reduce the plastic shrinkage cracking and dry shrinkage cracking [7]. These fibres make the concrete low permeable and prevent the bleeding of water. Polypropylene fibres have a good impact and durability properties over the concrete [8, 9].

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2 Material Properties

2.1 Cementitious Material

2.1.1 Cement

Ordinary portland cement is the cement used in general use around the world, used as an essential ingredient of concrete and mortar. When the raw materials' oxides are exposed to high clinkering temperatures, they combine to form four complex compounds.

2.1.2 Fly Ash

Fly ash is a by-product of coal combustion that comes out of the boiler. The constituents of fly vary depending on the coal's composition, including varying concentrations of silicon dioxide, aluminium oxide, and calcium oxide. Nowadays, fly ash is used as a cement replacement in concrete due to its high pozzolanic activity. Since it is a waste from the boilers it can be utilized properly without being polluting the environment by just leaving that as a landfill. It also decreases the amount of cement in the concrete, lowering the amount of carbon dioxide released during cement manufacturing. Fly ash is divided into two classes based on its calcium content: class F and class C.

2.1.3 Silica Fume

Silica fume is produced when high purity quartz is carbothermically reduced with carbonaceous materials such as coal or coke. It is a by-product of silicon and ferrosilicon alloy production. The key production is increased pozzolanic activity in concrete due to the presence of high silica material.

2.1.4 Metakaolin

Thermally activated ordinary clay and kaolinitic clay are natural pozzolans. Metakaolin is a term used to describe these impure materials. Metakaolin has high pozzolanic properties. While it has a lot of pozzolanic properties, it is not very reactive. Different densifications of the cement paste have been observed. This densification provides a boost in strength and a decrease in permeability.

2.2 Aggregate

2.2.1 Cenosphere

Cenospheres are light, inert hollow spheres made primarily of silica and alumina and filled with air or inert gas that are usually created as a by-product of coal combustion at thermal power plants. Thin-walled hollow spheres, or cenospheres, make up a small proportion of the particles of pulverised coal ash. Due to the ultrafine nature of microsphere, this contains low specific gravity. The specific gravity ranges from 0.45 to 0.7. Since they have less specific gravity they can also be replaced as fine aggregate and gives good strength than lightweight materials.

2.3 Admixture

2.3.1 Polycarboxly Ether

High-range water reducers are used as additives in high-strength concrete. Their addition to concrete or mortar allows for a lower water-to-cement ratio without compromising the mixture's workability, allowing for the manufacture of self-consolidating and high-performance concrete. As the water-to-cement ratio decreases, concrete strength decreases.

2.3.2 Air Entraining Agent

This agent is used mainly or added to the structure which has been exposed to potential frost damage. Improves cohesion and workability of concrete mixes. It is used for ready mixed retarded mortar. Improves workability and further enhancing durability. Excellent air bubble stability can be used in a wide range of mixes.

2.3.3 Polypropylene Fibres

Polypropylene fibres were first proposed as a concrete admixture in 1965 by the US Corps of Engineers for the construction of blast-resistant buildings. Since then, the use of these fibres in the construction of buildings has increased dramatically, owing to the fact that the use of these fibres in concrete increases the resilience, flexural strength, tensile strength, and impact strength of concrete, as well as the failure mode of concrete. Cracks play a crucial role because they turn concrete structures into components, exposing them to a high risk of corrosion. The structure would be affected if the crack width widens. As a result, it is critical to reducing the structure's

Table 1 Mix design

Materials	Quantity (kg/m^3)
Cement	300
Cenosphere	385
Silica fume	50
Fly ash	100
Metakaolin	52
Superplasticizer	6
Water	299
Air entrainer	1

crack pattern, which can be accomplished by using polypropylene fibres. The length of the fibres must be determined before they are added to the cement concrete.

3 Mix Design

One of the most critical stages of concrete production is mix design. The mix design provides precise details on the strength and density of the concrete (Table 1). The concepts taught in the concrete laboratory were put into practice. Several trail mixes were made, and the one that produced the best results was chosen for casting the canoe. However, while mixing the chemical admixtures safety precautions were taken, and proper dosage of chemicals as superplasticizer, etc.

4 Mould

As this is a spherical mould, to get better shape and better accuracy, the 3D printing technique was adopted to make the hallow mould. The design of the mould was created in the solid works software. This typically consists of a hallow portion inside the ball and it has an outer portion with a flat strip outside. This flat strip is generally provided to bolt the mould. The mould was designed for two halves, in that one half was containing 100 mm diameter and the other half contained a diameter of 100 mm and these two halves were joined together with M5 bolts and nuts. The modelling and the moulding were carried for one part and it was replicated to the other part. The initial inner to inner diameter was given as 200 mm and clearance was given. The mould was modelled in such a way that to carry a maximum mass of 5.5 kg the accuracy of the mould should also be taken into account to get the exact dimensions of the ball. The thickness of the mould is 3 mm. After the modelling was finalized the solid works file was sliced into different parts so as to determine the number of grams required for printing the mould in the 3D printing machine. After slicing the

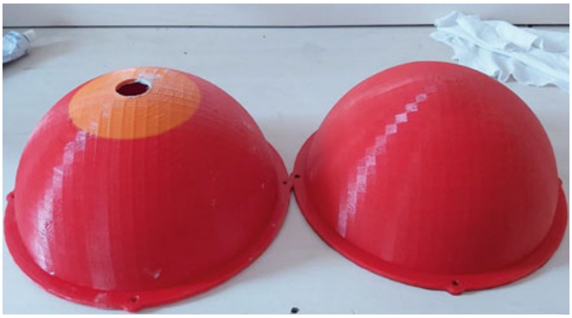

Fig. 1 3D printed mould

model, the 3D printer started to print the mould by heating the polylactic acid which is commonly called PLA (Fig. 1). Once the heating is started the printer automatically prints the mould in the appropriate design which was fended into the printer. After one half was completed another half was started to print.

5 Casting and Demoulding

After printing the mould, the mix was finalized and the bowling ball was ready to get casted. The mould was cleaned properly and with the help of sandpaper the surface was cleaned properly in order to get a smooth finish over the ball. The mix proportions were made already and the mould was applied with shuttering oil in order to get the ball easily out of the mould. The batching was done for the mix proportions (Fig. 2).

The cementitious materials were added first and water was also added to the mix (Fig. 3). The polypropylene fibres were added and after adding water the superplasticizers were added and then the cenosphere was added and the mortar was mixed in the mixer for 2 min. Then it was transferred into the trays and was placed ready to fill up the ball and the cube. The ball and the cube were cast and it was given vibration in order to get even compactness for the materials. Then one rupee coin was embedded on the top of the cube and on the top of the ball. The mould was then bolted tightly

Fig. 2 Batching of materials

Fig. 3 Mixing of materials

in order to make sure that the ball was held in its position firmly. For two days the mortar was allowed to remain in the moulds, then it was demoulded, weighed, and cured for 28 days.

6 Test Results

6.1 Compression Test

The cubes had been cast and cured in water for 28 days. The compression test is performed for 7, 14, and 28 days (Fig. 4). Power was achieved by 60–70% in 7 days and by 95–100% in 28 days as shown in Table 2. After 28 days of curing, the concrete density was 1050 kg/m^3 with a compression strength of 6.3 N/mm^2.

Fig. 4 Compression test

Table 2 Compression test

Material	7 days	14 days	28 days
Mix	4.3 N/mm^2	5.6 N/mm^2	6.3 N/mm^2

Fig. 5 Kegrete bowling ball

7 Conclusion

The fibre-reinforced bowling ball was cast and cured for 28 days and then the weight of the ball was also taken. The fibre-reinforced concrete mixes generally provided an increase in the mechanical properties of the concrete compared to the control mixes. Cylinders were also cast, and they were put through a compression test as well as an impact resistance test. After 28 days of curing, the concrete density was 1050 kg/m^3 with a compression strength of 6.3 N/mm^2. Finally, the specification requirements were applied to the fibre-reinforced kegrete bowling ball (Fig. 5).

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