An Experimental Investigation on Strength Characteristic of High Density Concrete Incorporating Hematite

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Abstract

Concrete has an extensive role to play both in construction and improvement of our civil engineering and infrastructure. It's great strength, durability and versatility are properties that are utilized in the construction of roads, bridges, airport, railways, tunnels, ports and harbors and many other major infrastructure projects. To call the concrete, as high density concrete, it must have unit weight ranging from 3360 kg/m^3 to 3840 kg/m^3. They can, however be produced with the densities up to about 5280 kg/m^3 High density concrete offers reliable, cost-efficient radiation shielding and can be used alongside other shielding materials to maximize protection in the available space. High density aggregates are the key ingredient in High density concrete. The more common aggregates used to achieve the required densities are Hematite, Ilmenite, Magnetite and Steel aggregate. The concrete was studied using Hematite (iron ore) having a density varies from 3400-3600 Kg/m^3. Several properties of concretes with design mix of M30 grade were also studied that include the compression, The high density concrete was also compared with normal weight concrete of the same strength grade with respect to the above parameters. Based on the experimental investigations carried on the conventional concrete, high density Concrete has more Compressive strength, Split tensile strength, flexural strength values are found out.

Keywords: Infrastructure, High Density Concrete, Hematite, Conventional Concrete

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I. INTRODUCTION

High Density concrete (HDC) or Heavy Weight concrete (M30) is a concrete type specially introduced for arresting ionization radiation in accordance with the limited space availability in Nuclear power plants, in hospitals and other Radiation zones. The concrete is ideal for radiation shielding in a variety of environments using less space than traditional concrete construction. HDC used for shielding applications generally has a density in the range of 3500 Kg/m^3 to 5000 Kg/m^3. Since concrete contains more than 70% aggregate, the only way to make it highly dense is to choose suitable high density aggregates. The high density aggregates employed here were obtained from the TANMAC region of Tamilnadu.

Density of normal concrete is in the order of about 2400 kg. Per cubic meter. Normal density concrete lacks required strength and durability which are used for concrete structures such as high rise buildings, bridges and structures under severe exposure condition. The advent of the nuclear energy industry presents a considerable demand on the concrete technologists. Large scale production of penetrating radiation and radioactive materials, as a result of the use of nuclear reactors, particle accelerator, industrial radiography, and, X-ray, gamma-ray therapy, require the need of shielding material for the protection of operating personnel against the biological hazards of such radiation. Concrete, both normal and high density is effective and economic construction materials for permanent shielding purposes.

II. METHODOLOGY AND EXPERIMENTAL PROGRAMME

The main objectives of this paper are as below:
- To study the physical properties of High density concrete materials(sand, coarse aggregate, hematite aggregate)
- To find out Concrete mix design based on Indian Standard Recommended Guidelines IS10262:2009
- To examine the workability of High density concrete incorporating hematite aggregate.
- To investigate the performance of these concrete terms of its compressive strength, split tensile strength and flexural strength.
- To compare the results of High density concrete incorporating hematite aggregate with conventional concrete

III. MATERIAL COLLECTION FOR EXPERIMENTAL INVESTIGATION

A. Cement
Good quality of Ordinary Portland cement (53 Grade) is used for this research. The most important uses of cement are as a component in the production of mortar in masonry, and of concrete, a combination of cement and an aggregate to form a strong building material. The bulk density of cement was 1300 kg/m^3.

B. River Sand
The size of aggregates which are lesser than 4.75mm are considered as fine aggregate. The most commonly used fine aggregate is the river sand. It passes through 4.75mm sieve. The bulk density of river sand was 1860 kg/m^3.

C. Coarse Aggregate:
The aggregates of size greater than 4.75mm are generally termed as coarse aggregates .in this research the nominal size of aggregate (20 mm) was used. The bulk density of river sand was 1560 kg/m^3.

D. Hematite:
Hematite is the mineral form of iron (III) oxide (Fe_2O_3), one of several iron oxides. Hematite is a mineral, colored black to steel or silver-gray, brown to reddish brown, or red. It is mined as the main ore of iron.

Fig. 3.1: Hematite

Table – 1
Physical Properties of Cement

Sl. No	*Description*	*Test Results*
1	*Standard consistency*	*33 %*
2	*Initial setting time*	*45 minutes*
3	*Fineness (by sieve analysis)*	*1 %*
4	*Specific gravity*	*3.15*

Table – 2
Physical Properties of fine Aggregate

Sl. No	*Description*	*Test Results*
1	*Gradation*	*Zone-II*
2	*Fineness modulus*	*3.2%*
3	*Specific gravity*	*2.78*

Table – 3
Physical Properties of Coarse Aggregate

Sl. No	*Description*	*Test Results*
1	*Total water absorption*	*Nil*
2	*Impact value*	*12.62 %*
3	*Specific gravity*	*2.79*

Table – 4
Physical Properties of Hematite Aggregate

Sl. No	*Description*	*Test Results*
1	*Maximum size*	*20 mm*
2	*Specific gravity*	*3.33*

E. Concrete Mix Proportions:

Table – 5
Mix Design for M30 Grade –Conventional Concrete

Water (Kg/m^3)	Cement(Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate(Kg/m^3)	Chemical admixture(Kg/m^3)
183.42	394	711.79	1216.33	7
0.45	1	1.8	3.09	0.018

Table – 6
Mix Design for M30 Grade –High density Concrete

Water (Kg/m^3)	Cement(Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate(Kg/m^3)	Chemical admixture(Kg/m^3)
213.65	394	1072.81	1451.75	7
0.45	1	2.72	3.68	0.018

F. Experimental Study on Fresh Concrete:

Slump test is the most commonly used method of measuring the consistency of concrete which can be employed either in the laboratory or site work. It is not a suitable method for very wet or very dry concrete. Type of collapse: shear slump Slump value: 78 mm from top.

Another one workability method is compaction factor test, this test works on the principle of determining the degree of compaction achieved by the standard amount of work done by allowing the concrete to fall through a certain height. Compaction factor test is adopted to determine the workability of concrete, where the nominal maximum size of aggregate does not exceed 40mm and is primarily used in laboratory. Compaction factor value = 0.91

G. Specimen Specifications

The cube size	150 mm x 150 mm x 150 mm.
The cylinder size	150 mm diameters. 300 mm Height
The Beam size	1200 mm x 150 mm x 100 mm.
The Reinforcement details	2No's 10 mm Dia at bottom of beam. 2 No's 10 mm Dia at top of beam. 8 mm Dia stirrups.

IV. EXPERIMENTAL STUDY ON HARDENED CONCRETE

A. Compressive Strength Test

The values of compressive strength of concrete at the end of different curing period (7, 14 and 28 days) are given in Table 7. This shows the variation of compressive strength at different curing ages respectively. From the a test results it is observed that Sample II (High density Concrete) has more compressive strength value when compare to Sample I (Normal concrete)

Fig. 4.1: Compressive Strength Test

Table – 7
Compressive Strength of Concrete

Sample	Compressive strength in N/mm^2		
	7th Days	14th Days	28th Days
I	27.76	35.46	39.53
II	29.80	36.91	42.29

B. Spilt tensile Strength Test

The test is carried out by placing a cylindrical specimens (150mm diameter and 300mm long) horizontally between the loading surfaced of a compression testing and the load is applied until failure of the cylinder, along the vertical diameter. Table 8 shows the Split Tensile Strength values.

Fig. 4.2: Split Tensile Strength Test

Table – 8
Split tensile Strength of Concrete

Sample	Compressive strength in N/mm^2		
	7th Days	14th Days	28th Days
I	2.36	3.47	4.37
II	2.43	3.54	5.00

C. Flexural Strength Test

For this study, experimental work involves casting of concrete beam of size 1200 mm x 150 mm x 100 mm for determination of flexural strength for 14 days and 28 days curing. The beam was subjected to one point loading to expose the behavior of the beam. The failure pattern of RCC beam is shown in Fig As the load increases the crack width is also increased and extended towards the top of the beam.

Fig. 4.3: Flexural Strength Test

Table – 9
Flexural strength of HDC concrete beams

Sample	Flexural strength(Mpa)	
	14th Days	28th Days
I	4.02	4.38
II	5.9	6.7

D. Weight Density Test

It is important to evaluate the unit weight for Normal & High Density Concrete. Weight density is the weight of a material in a given volume. It is expressed in Kg/m^3. The following are the steps carried out in weight density test.

The weight of the specimen is found out

- The volume of the specimen is calculated
- The weight density is equal to the weight of specimen to its volume
- The weight density is calculated using the formula (ρ=W/V)

P = Weight Density (kg/m^3)
W= Weight of the specimen (kg)
V = Volume of the specimen (m3)

Table – 10
Physical Properties of Hematite Aggregate

Sl. No	*Fresh Density (kg/m3)*	*Hardened Density (kg/m 3)*
1	*2577*	*2459*
2	*3614*	*3467*

V. RESULTS AND DISCUSSION

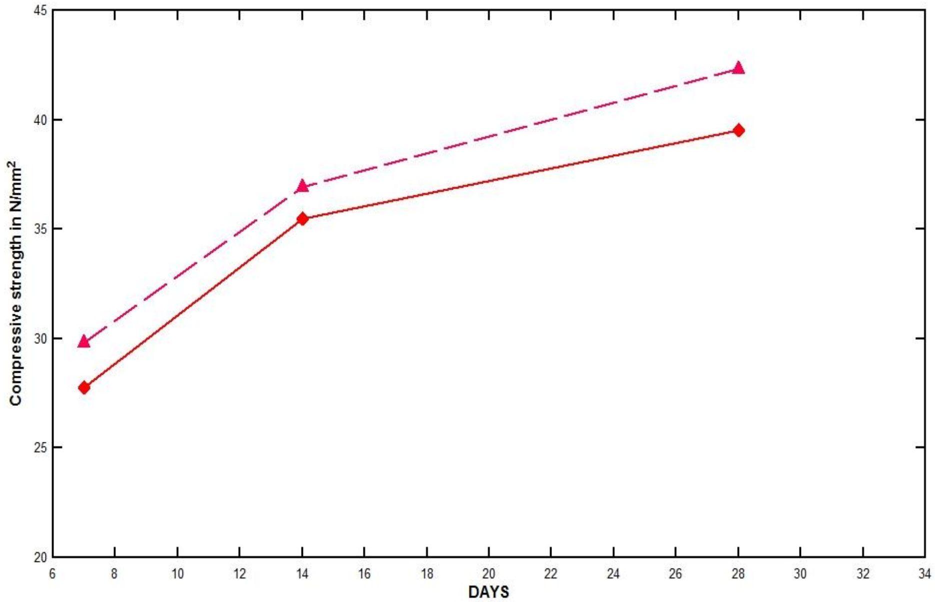

Fig. 5.1: Graphical representation of compressive strength values

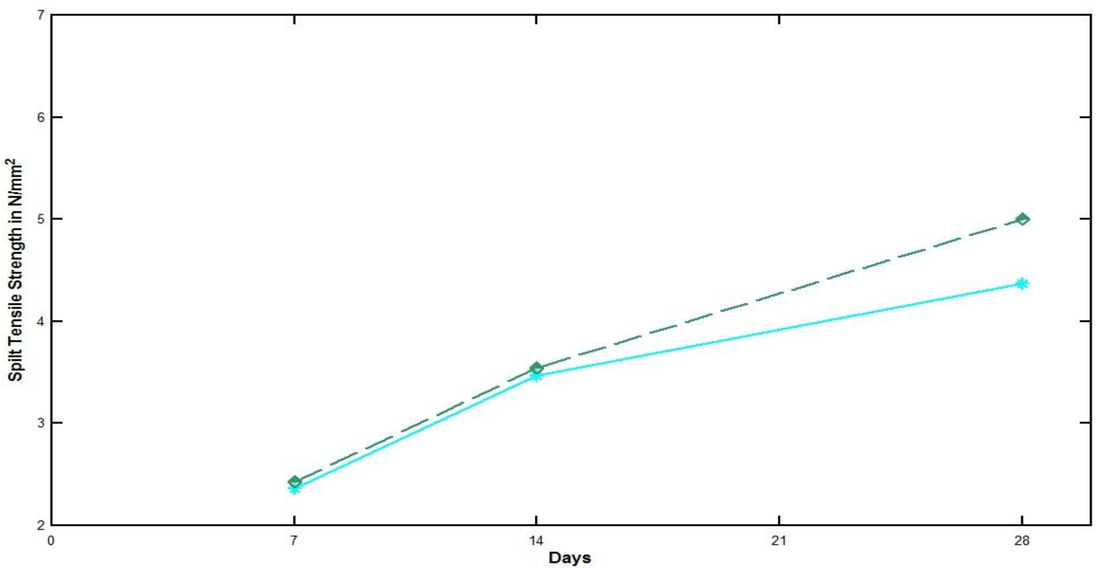

Fig. 5.2: Graphical representation of split tensile strength values

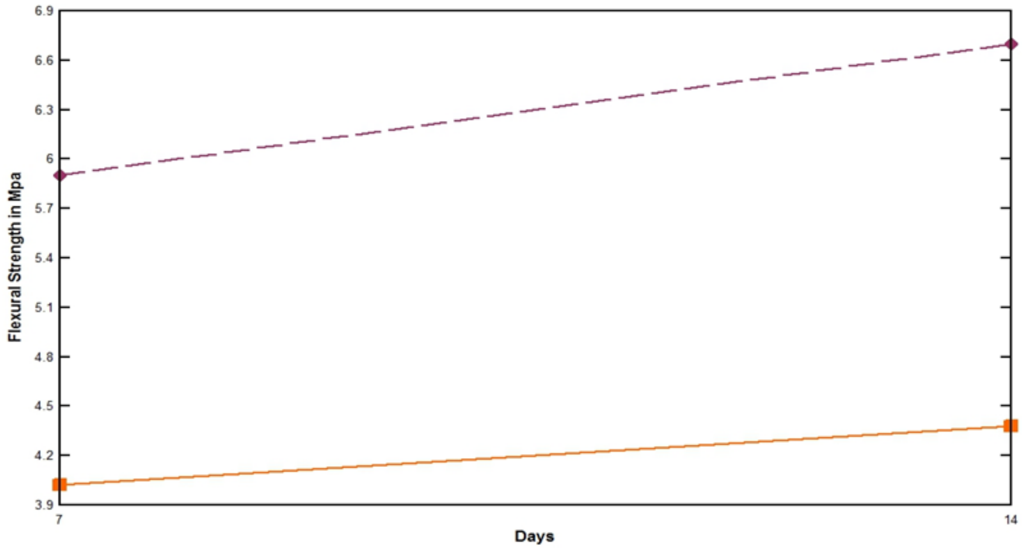

Fig. 5.3: Graphical representation of flexural strength values

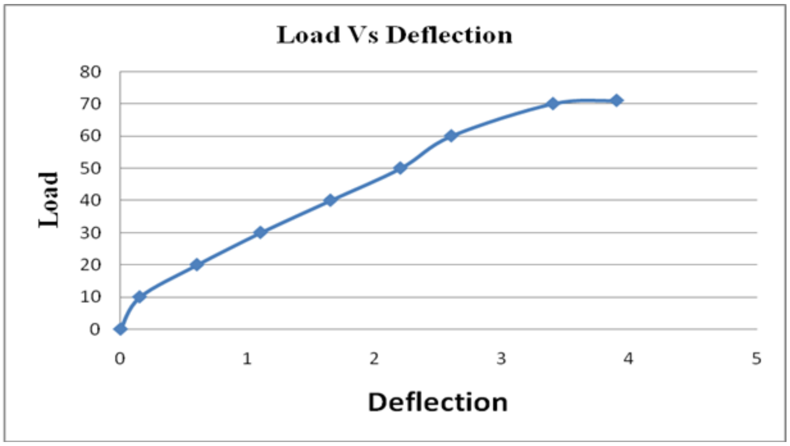

Fig. 5.4: Load Deflection Behavior of Beams.

VI. Conclusion

- In this project we find suitable High strength concrete for nuclear power plant shielding. in this research we use sustainable material (Hematite) to presence the environment usage hematite as an alternate material in the place of granite aggregate is gate prevalent widely across the globe. Based on the experimental investigations carried on the high density concrete, the following points are concluded
- The above experimental procedure by replacing the hematite aggregates instead of granite aggregates, density of concrete was achieved as 3467 kg/m3.
- A High Density Concrete has more Compressive strength and Split tensile strength values compared to normal concrete sample.
- In our experimental study High density Concrete (ie, Sample-II) is effective in shielding the Gamma rays by about 40% more when compared to the conventional concrete. By increasing the density over 3500 kg/m3 and thickness of the concrete (above 150mm), shielding can be more effective when compared to the Sample HDC specimen.

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