

Cenosphere Based No. Aggregate Floating Concrete

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Abstract

Concrete is an excellent building material, used widely around the world, but the only disadvantage of concrete is that it has self-weight. This self-weight does not allow concrete to be used in light weight structures. In this work, mix design is prepared in such a manner that density of concrete is less than that of water and hence concrete can float on water and therefore it is termed as floating concrete. This type of concrete can be helpful in making canoe, boats and other marine structures which are subjected to excessive corrosive actions due to constant contact with sea water, structure being subjected to tidal forces and alternate drying and wetting actions. To achieve this, instead of normal aggregates cenospheres are used which are light in weight. Results show that compressive strength is lower but that can be enhanced and it is possible to produce light-weight concrete.

Keywords: Cenospheres, cement, fly ash, floating concrete

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INTRODUCTION

Concrete is one of the most used materials in the field of construction. It is second most widely used material after water. Concrete is extensively used today as it has ability to be molded into any shape and size, has very good compressive strength and has excellent durability property. To cater to different needs at different times, numbers of varieties of concrete are produced. Normally density of concrete is 2400 kg/m^3 . Therefore, this is quite heavy and induces lot of self-weight. To reduce this weight, one such growing trend is of lightweight and floating concrete. Various possibilities are considered for producing such type of concrete. One such innovation is the use of “cenospheres”, a lightweight, waterproof, insulative material obtained from the processing of the residues left in coal powered power plants.

Cenospheres based concrete is a very lightweight concrete which can be made floating on a little higher replacements of cements with cenospheres. It is lower in strength compared to normal concrete. Concrete produced using cenospheres is also waterproof and insulative in nature. Being high on density reduction, this concrete can be used for construction of floating structures where the density of the structure needs to be reduced

drastically (less than density of water). The present study is done with an aim of producing lightweight floating concrete without using any aggregates to be used in the construction of canoe with moderate strength requirements to be able to bear the self-weight and the rowers sitting in the canoe. The present study produced a concrete having lowest density of 961 kg/m^3 without using any type of aggregates (course aggregates or fine aggregates).

The present study only uses cement, cenospheres, fly ash (to further reduce weight), latex (to reduce water cement ratio) and water to produce concrete. The study incorporates use of different proportions of cenospheres to attain a mix design that allows concrete to float. Alongside design, compression, split-tensile and flexure strength test of various specimens was performed. The results thus obtained were compared to control concrete.

LITERATURE REVIEW

Various mix design were referred before and during the course of our research. These mix design helped us deciding on the material of research and subsequently to work on it. ASCE organizes the National Concrete Canoe Competition (NCCC) every year. Various Universities across the United States participate in this competition of Canoe designing. We referred to the mix design of various

universities who participated and won this competition (the details about the mix design is available on the website by Concrete Canoe Team UW Madison [1]). Canoe competition was won by University of Wisconsin-Madison in 2006 [1]. Their primary materials were Glass Microspheres and a combination of glass beads of various sizes (0.25 mm, 0.5 mm and 1.0 mm) apart from Ordinary Portland Cement (OPC). Using Microspheres and glass beads was not viable as it is difficult and costly to avail. University of California-Berkeley, in 2009 won the competition. The primary elements in their mix design were K1 Glass Microspheres and 0.25 mm recycled glass apart from OPC. The same problem arrived with these materials- cost and availability [2]. While in 2010, University of Alabama-Huntsville stood third in the competition [3]. The primary elements in their mix design were a combination of Cenospheres and Poraver apart from OPC. Poraver is costly to obtain but, Cenospheres is one such material which had the advantage of easy availability and feasibility in cost.

Not only the above mentioned but a lot of other mix designs were referred and finally after seeing the cost and availability as the two major factors for deciding our material of research, cenospheres was decided as the most appropriate material which can be used. Not only is the cost and availability, but also the efficient properties of cenospheres (which are described in detail in the paper) makes it most suited material to be used for construction of floating concrete.

EXPERIMENTAL WORK

Materials and Mix Proportions

In light weight concrete, cement and fly ash are used as binding material. While cenospheres are used as aggregate, admixture is latex based which gives binding property. The physical and chemical properties of ingredients are given in Tables 1–3 respectively. Properties of cenospheres are given in Table 4.

Cement

Ordinary Portland cement (of grade 53) was used for preparing concrete mixes. Its physical properties are as given in Table 1.

Table 1: Physical Properties of Portland Cement (IS: 12269-1989) [4]

Physical Properties	Results Obtained	Specifications
Fineness (retained on 90 um sieve)	1%	<10%
Standard Consistency	30%	-
Initial setting time (min)	65	30 minimum
Final setting time (min)	215	600 maximum
Compressive strength 3 days (MPa)	23.6	22 minimum
Compressive strength 7 days (MPa)	35.4	33 minimum
Compressive strength 28 days (MPa)	43.0	44.3
Specific gravity	3.12	3.15
Soundness (mm)	2.50	10 maximum

Table 2: Physical Properties of Fly Ash. (IS: 3812-2003) [5]

Sr. No.	Physical Properties	Test Results
1.	Colors	Blackish Grey
2.	Specific gravity	2.13
3.	Lime reactivity-average compressive strength after 28 days of mixture	4.90 MPa

Table 3: Chemical Properties of Fly Ash (IS: 3812-2003) [5]

Sr. No.	Constituents	Percent by Weight
1.	Loss on ignition	4.17
2.	Silica (SiO ₂)	58.55
3.	Iron Oxide (Fe ₂ O ₃)	3.44
4.	Alumina (Al ₂ O ₃)	28.20
5.	Calcium oxide (CaO)	2.23
6.	Magnesium oxide (MgO)	0.32
7.	Total Sulphur (S ₀₃)	0.07
8.	Insoluble Residue Alkalies	-
9.	Sodium oxide (Na ₂ O)	0.58
10.	Potassium Oxide (K ₂ O)	1.26

Table 4: Chemical Properties of Cenosphere.

Sr. no.	Constituents	MA 50	MA 30 (MA 80)	MA 15
1.	Particle Size	>425	>300	>150
2.	Mesh Size ASTM E 11	40#	50#	100#
3.	Silica(SiO ₂)	50-63%	50-63%	50-63%
4.	Alumina(Al ₂ O ₃)	25-38%	25-38%	25-38%
5.	Iron(Fe ₂ O ₃)	1-5%	1-5%	1-5%
6.	TiO ₂	-	-	-
7.	CaO	0-2.0%	0-2.0%	0-2.0%
8.	MgO	0-2.0%	0-2.0%	0-2.0%
9.	K ₂ O	-	-	-
10.	Na ₂ O	-	-	-

Admixture

Latex-Rhoplex MC-76 is a white colored, milky liquid having odor slightly ammonical

and mildly acrylic with a pH of 9.5–10 at 25°C and a specific gravity of 1.059.

Production of Cenospheres based Concrete

The various constituents of the concrete were mixed in a pan mixer with a capacity of 20 l. First, dry mixing of cement, cenospheres and fly-ash of required quantities was done. Then the specified amount of water and latex were mixed together in the measuring cylinder. After the completion of the dry mixing, the latex mixed water was added slowly in the mixer and all the constituents were mixed until a uniform mix was obtained. Various proportions of cement, fly ash and cenospheres were tried to obtain concrete with density lower than 1000 kg/m³. Table 5 gives final floating concrete mix design.

Casting, Curing and Testing of Specimens

Various sizes of test specimens were casted to measure the compressive, split-tensile and flexure strengths. The casted specimens were cured in a water tank for 7, 14 and 28 days to attain the required strength. These obtained strengths were compared with the strength of control concrete. A cube of 150 mm was casted

to measure compressive strength, a cylinder of 150 mm diameter and height of 300 mm was casted to measure the split-tensile strength, and a beam of 100 mm*100 mm*500 mm was casted to measure the flexural strength. All the specimen sizes conform to IS: 10086-1982. Table 6 gives the results obtained for the mix.

Steel Fibers

Steel fibers having length of 40 mm and aspect ratio of 40 were used.

Mix Proportion

Two concrete mixes were made, first mix contains cenosphere (size-20 μ) and second mix contains cenosphere (size-20 μ) along with 2% of steel fiber. Their mix proportions are given in Table 5. Figure 1 shows the graph of compressive strength for Mix 1 and Mix 2 for 7, 14 and 28 days.

Test Results

Table 6 gives compressive strength, split tensile strength and flexure strength results of light weight concrete. Modes of failure are shown in various photographs (Figures 2–5).

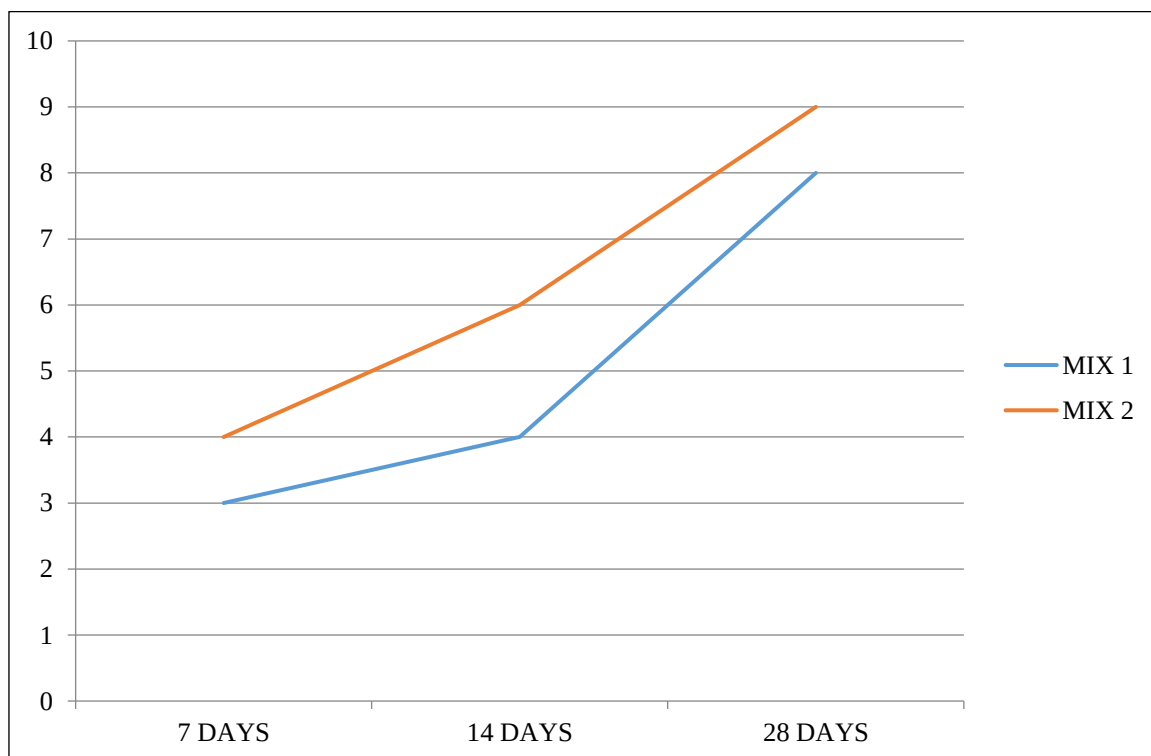


Fig. 1: Compressive Strength versus Days of Curing.

**Fig. 2:** Split Tensile Test.**Fig. 3:** Compressive Test.**Fig. 4:** Floating Cube.**Fig. 5:** Flexure Test.**Table 5:** Details of Cenosphere Concrete Mix.

Mix	Cement (kg/m ³)	Fly Ash (kg/m ³)	Water (kg/m ³)	Cenosphere (kg/m ³)	Steel Fibre (kg/m ³)	Latex (kg/m ³)	Theoretical Density (kg/m ³)
Mix I	378	67	255	403	-	64	1167
Mix 2	378	67	255	403	7.6	64	1174.6

Table 6: Strength and Density of Concrete Mix.

Mix	Actual Density (Kg/m ³)	Compressive Strength (MPa)			Split Tensile strength (MPa) 28 Days	Flexure strength (MPa) 28 Days
		7 Days	14 Days	28 Days		
Mix I	961	3	4	8	2.26	4
Mix 2	983	2	6	9	2.83	5

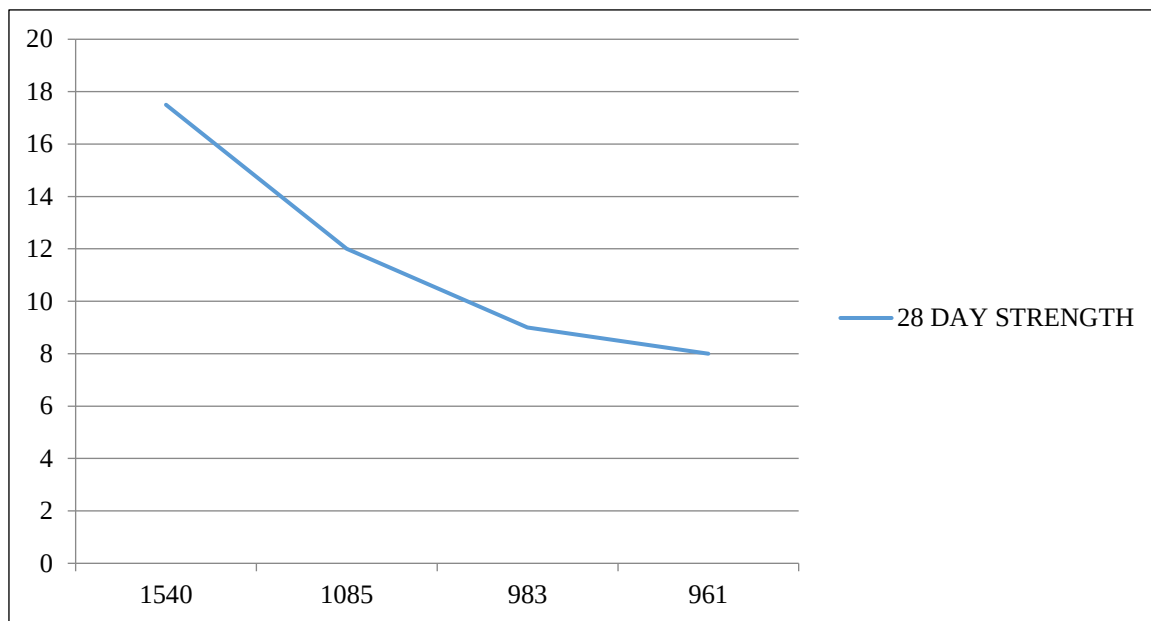


Fig. 6: Density of Specimen versus 28 Day Strength.

RESULTS AND DISCUSSION

A summary of the different proportions, strength obtained and density achieved is presented in the Table 6. Figure 1 to 3 shows different failure patterns in compression, split tension and flexure while Figure 4 shows floating concrete.

Compressive Strength

Effect of Age

From the Figure 1, it can be observed that as the age of concrete grew the compressive strength also increased. The strength obtained by a curing of 28 days was more than the strength after days curing. There were no substantial effects of addition of steels fibres on compressive strength.

Effect of Density

By differing the proportions of cenospheres in concrete, different densities were obtained. From Figure 6, it can be seen that with substantial decrease in the density of concrete, there is a certain decrease in the compressive strength of concrete. So, with increasing proportions of cenospheres in concrete, a decreasing pattern of strength is observed.

Split-Tensile Strength

Effect of Steel Fibers

From Table 6, it can be observed that when steel fibers (about 2%) were included in the design, a very small increase in the tensile

strength was observed. Though no substantial effects on tensile strength is seen, it helped improving the shrinkage characteristics of concrete.

After Testing Observations

Failure Pattern

It is observed that as the proportion of cenospheres increased, the strength reduced and a shear failure was observed. The specimens when tested under compressive loads did not show any sign of failure up to a certain load, and after that it failed suddenly. The similar patterns were observed in tensile and flexure strength testing also. But when steel fibres are introduced the failure pattern is gradual in nature. The concrete showed signs of failures with cracks development before complete failure.

Specimen Study after Failure

After the complete failure the specimens under loads they were observed for the reason of shear failure. It is seen that the even after 28 days of curing, the concrete did not gain proper bonding from inside.

CONCLUSIONS

1. Decreasing density resulted in substantial decrease in strength.
2. With larger replacements of cement with cenospheres, volume instability is observed.

3. Cenospheres is a competent material to drastically reduce the density.
4. With addition of latex, water cement ratio decreased and strength improved.
5. With use of air entraining agents in concrete, there may be an increase in the floatability of the concrete which may help in reduction of cenospheres proportion in design and a strength increment may be observed.

Concluding Remark

Cenospheres is a very versatile material and can be effectively used to produce lightweight floating concrete. Cenospheres based concrete have wide applications especially in structures where drastic reduction in density is required. This concrete is slightly lower on strength criteria but this can be improved with certain methodologies like addition of additives or any other.

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