PARTIAL REPLACEMENT OF CEMENT WITH CENOSPHERE AS POZZOLANIC MATERIAL IN CONCRETE

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Abstract - A Cenosphere is a lightweight, inert, hollow sphere made largely of silica and alumina and filled with air or inert gas, between 10-300 mm in diameter. In an effort to understand the potential for practical use of the Cenosphere as a fine aggregate in concrete, the moisture uptake and loss in Cenosphere and water uptake and loss in Cenosphere concrete composites have been studied. The equilibrium moisture content of Cenosphere is about 18 times higher than that of sand, reflecting the porous nature of Cenosphere (NC). With the reference of various literature that the performance and characteristic of Cenosphere with the replacement of cement are surveyed. Initially tests were carried out on the mix with Cenosphere as replacement at various percentages such as (0%, 5%, 10%, and 15%) by mass of cement. Various tests are conducted to find the property of the Cenosphere concrete materials. The main test such as Compressive Strength for Concrete and Split Tensile Strength for Concrete have been conducted. On comparing the results of Cenosphere Concrete with that of conventional concrete, 5% additionally adding of Cenosphere fiber showed maximum compressive Strength value at 28 days 16.5%, and the Split Tensile Strength value at 28 days 5.07%. During Phase II, Mechanical properties like Flexure Strength and Durability properties will be discussed. Study of microstructure of concrete is also planned.

1. INTRODUCTION

Nowadays, concrete are made with Portland cement is probably the most widely used man made material in the world. At present in the worldwide concrete production is about 12 billion tons annually, consuming approximately 1.6 billion tons of Portland cement, 10 billion tons of sand and rock and 1 billion tons of water. The large quantities of waste materials and by-products are generated from manufacturing processes, service industries and municipal solid wastes, etc. As a result, the solid waste management has become one of the major environmental concerns in the world. With the increasing awareness about the environmental, scarcity of land-fill space and due to its ever increasing cost, waste materials and by-products utilization has become an attractive alternative to disposal. Due to the high consumption of natural sources, high amount production of industrial wastes and environmental pollution require obtaining new solutions for a sustainable development. In recent years there is a growing emphasis on the utilization of waste materials and by-products in construction materials.

As we all know that carbon di-oxide is one of the significant greenhouse gas and it contribute to the environmental pollution is very high. The ordinary Portland cement also consume natural resources like limestone etc., that is why we cannot producing more quantity of cement and there is a need to economize the use of cement. To economize the cement is to replace cement with supplementary cementitious materials. Cement is the key component of concrete that binds the other components together to give the required strength.

A considerable amount of work has been reported in the literature review on how to use waste products of combustion or industrial processes as supplementary cementitious materials. Because of their cementitious or pozzolanic properties, can serve as partial cement replacement. The researchers identify the waste materials with inherent properties that lend themselves to such beneficiation. Further, a few examples shall be mentioned.

A primary goal is to reduce the use of Portland cement, which is easily achieved by partially replacing it with various cementitious materials, preferably those that are byproducts of industrial processes. The best known materials such as fly ash. Fly ash is finely divided residue, resulting in the combustion of powdered coal and transported by the flue gases and collected by Electrostatic Precipitator.

The partial replacement of fly ash in cement and concrete has gained considerable the importance in the requirements of environmental safety and more durability of construction in the future. The usage of fly ash as a partial replacement of cement in mortar and concrete has been extensively investigated in recent years. It is known to be that the fly ash is an effective pozzolan which can contribute the properties of concrete. Fly ash blended concrete can improve the workability of concrete compared to OPC. It will increase the initial and final setting time of cement pastes. Fly ash replacement of cement is effective for improving the resistance of concrete to sulphate attack expansion.

2. LITERATURE REVIEW

Denis Montgomery (1984) explained about the influence of fly ash Cenospheres on the details of cracking in flyash-bearing cement paste. Compact tension specimens were prepared from a cement-flyash paste with an especially-high content of Cenospheres, to permit examination of the details of the influence of Cenospheres on the cracking pattern obtained on loading such specimens in the SEM. Cement-fly ash pastes incorporating Cenospheres develop the usual tortuous and branched crack pattern when loaded in the compact tension device, but show certain specific features peculiar to the intersection of the advancing crack with the Cenospheres.

The increase in crack length and tortuosity induced by the presence of the Cenospheres appears to constitute an energy-dissipating mechanism that should act to decrease the tendency toward fracture of a loaded Cenosphere-containing specimen as compared to one that does not contain such inclusions. Whether such an effect is of any quantitative significance remains to be seen. Observation of Cenosphere surfaces parted from the cement paste matrix, by passage of a crack showed little indication of chemical reaction even after almost two months of room-temperature curing in limewater. However, after ten days of additional curing at 50°C, some evidence of surface etching of the outer glass surface was detected.

F. Blanco et al., (2000) studied the possibility of using Cenospheres as aggregate to manufacture lightweight concrete. Mechanical resistance, thermal conductivity and acoustic absorption were studied. The main advantage presented by Cenospheres in comparison with other competitive filling compounds is their light weight since they are hollow.

According to the granulometric analysis of the Cenospheres obtained from the Narcea coal-burning power plant, the Cenospheres have an average size of 1.80 mm and more than 50% belong to the granulometric fraction between 1.50 and 2.00 mm, there being practically no Cenospheres smaller than 0.20 mm.

The greatest improvements in thermal conductivity were obtained when the percentage of holes not filled with cement paste was increased, though this resulted in a reduction in mechanical resistance. One must therefore look for a compromise between the improvement in conductivity and the loss in resistance to compression.

Comparing the results of the test made with specimens manufactured with gross Cenospheres and with those manufactured with bimodal mixtures, it was proven that mechanical resistances stay constant or even decrease, while thermal conductivity improves 5% in the best of cases. Therefore, the classification in different granulometric fractions of the Cenospheres is not profitable, with only a slight screening being advisable so as to separate the sizes greater than 4.00 mm, which present a high degree of irregularities. The acoustic behavior of the lightweight concrete made with Cenospheres is similar to that presented by lightweight concrete manufactured with expanded clay.

Kolay et al., (2000) studied the physico, chemico and mineralogical behavior of the Cenospheres obtained from an ash lagoon. Cenosphere particle consists of smaller percentages in the pulverized coal ash. They concluded that cenosphere particles are light weight particles and their specific gravity is very low. Cenosphere is thermally stable upto 280°. The cenosphere particles are noticed to be almost uniform in size and their specific surface area is quite low.

Arun Shukla et al., (2002) suggested that Cenospheres are replaced for volume with sand. Various levels of replacement for sand are made. Higher densities of Cenospheres reduced the tensile strength and thus lower densities of Cenospheres are preferred. Cenospheres produced 45% increased compressive strength and reacts to form CSH gel which results in increased strength. These shows the strength of Cenospheres. In this paper they introduced the patented material of silane.

Nikhil Barbare et al., (2003) experimented on the low Specific Gravity (0.67) makes them ideal replacements for fine sand for producing low-density concrete. In an effort to understand the potential for practical use of the Cenospheres as a fine aggregate in concrete, the moisture uptake and loss by Cenospheres and water uptake and loss in Cenosphere-concrete composites have been studied in this paper. The equilibrium moisture content of Cenospheres is about 18 times higher than that of sand, reflecting the porous nature of Cenospheres.

The temporal evolution of water penetration into the Cenosphere–concrete is modeled using Washburn kinetics. The effective pore size using this model is of the order of several nanometers. These results imply a lack of connectivity within the pores, leading to a low permeability. SEM images of the concrete reveal pore sizes of the order of 2–5m. The drying flux for Cenospheres shows a classical behavior. A constant rate followed by a linear falling rate period. Thus, experiments done at these conditions can be used to predict drying times for wet Cenospheres exposed to other environments. The flux of water vapor away from both the Cenosphere–concrete as well as the normal concrete shows a nonlinear change with moisture content throughout the drying cycle, implying that the pore structure within the concrete strongly influences the drying behavior.

Tiwari V. et al., (2004) studied the acoustical properties of cenosphere blended with asphaltic and reinforced cement concrete. The experimental study revealed that noise reduction efficiency can be improved by addition cenosphere up to 40%. Sound absorption property of asphaltic concrete decreases with increase in cenosphere content, and normal acoustic impedance increases with an increase in cenosphere volume fraction.

Michael Thomas et al.,(2006) provides a critical evaluation of the various methods available for testing the efficacy of measures for preventing expansion due to Alkali–Silica Reaction (ASR) in concrete containing deleteriously reactive aggregate. The ideal test method should be rapid, reliable and capable of determining the influence of aggregate reactivity, alkali availability and exposure conditions.

L.Ngu et al., (2007) characterized the fly ash cenosphere obtained from various Australian Power Stations. This research revealed that iron is not the essential constituent of the fly ash from which cenosphere is formed. Cenosphere particle has larger diameter and nearly 70% of cenosphere falls in the range between 45 and 150μm. Both single-ring and network like structure were observed in the spherical sample. Single-ring like structure was the majority percentages than that of network like structures.

The smaller spherical sized particle contains higher value of SiO_2/Al_2O_3 ratio than that of larger sized cenosphere. The wall thickness to diameter of the light weight particle lies in between an upper bound of 10.5% and lower bound of 2.5%. It is revealed that large ash cenosphere has lower SiO_2/Al_2O_3 value. Larger range of spherical particle mainly forms network like structure.

Jun-Yan Wang et al., (2012) Studied the characteristics and stability of Cenospheres used in lightweight cement composites. ASTM C227 and C1260 tests were used to evaluate if Cenospheres are potentially deleterious due to alkali-silica reaction (ASR). The expansion of the mortar specimens tested to ASTM C227 and C1260 seem to be affected by the pozzolanic reactivity of the Cenospheres. The lower expansion of the mortars with the Cenospheres in C1260 test in comparison to that with natural sand might be attributed to the pozzolanic reactivity of the Cenospheres at 80ºC which reduced pH of pore solution and permeability of the mortar.

Diana Bajarea et al., (2013) found that coal combustion bottom ash is replaced in concrete. Price of concrete can be reduced by 10%.CO_2 emission can be reduced by 23%. 20% cement effectively replaced with coal combustion bottom ash results, no change in compressive strength, whereas 40% replacement shows reduction in compressive strength. The research result approves that CCBA has pozzolanic activity.

E.R. Grist et al., (2014) carried out innovative solutions proved elsewhere. The case of a polished lime-pozzolan concrete floor. This case-study show the development of a bespoke lime-pozzolan concrete for an innovative project application and the results of laboratory testing are contextualised by the research programme.

3. PROPERTIES AND MATERIAL USED

3.1 Coarse aggregate

Table 3.1-Properties of coarse aggregate

S. No	Properties	Value	Requirements of IS 383:1970
1	Specific Gravity	2.74	2.5-3.0
2	Fineness Modulus	5.67	3.5-6.5
3	Bulk Density	1507.5 kg/m^3	-
4	Water Absorption	0.80%	0.2%-4%

3.2 Fine aggregate

Table 3.2- Properties of Fine Aggregate

S. No	Properties	Value	Requirements of IS 383:1970
1	Specific Gravity	2.52	2.5-3.0
2	Percentage of voids	24.50%	<40%
3	Fineness Modulus	2.786	2-3.5
4	Bulk Density	1650 kg/m3	-
5	Water Absorption	1.20%	<2%

3.3 Cement

Table 3.3- Physical properties of cement

S. No	Properties	Value	Standard values
1	Specific Gravity	3.17	3.10- 3.20
2	Standard Consistency	28%	25 – 35
3	Initial Setting Time	45 minutes	>30 min
4	Final Setting Time	512 minutes	<600 min

3.4 Cenosphere

Table3.4- Properties of crumb rubber aggregate

Property	Value
Specific gravity	2.83
Initial setting time	45 minutes
Final setting time	10 hours
Fineness modulus	8%

4. MIX DESIGN

4.1 Mix proportion-Control mix

Cement	= 594.3 Kg
Fine aggregate	= 716.56 Kg
Coarse aggregate	= 878.58 Kg
Water cement ratio	= 0.35
Mix proportion in M_{30}	**= 1:1.2:1.5**

5. CONCLUSION

From the literature review, the scope and idea to replace various concrete components can bring several characteristic changes in concrete by physical and mechanical properties. The material testing for various materials used in the project are carried out to determine their properties, required quality and strength. . In this mix proportions for the partial replacement of cement with cenosphere added to the concrete. Design of concrete mix has to be done in this phase for the M30 concrete and the mix proportion for control mix is 1:1.2:1.5.

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