Experimental Study on Mechanical and Durability of Properties and Expanded Polystyrene Concrete Using Silica Fume

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Abstract— The Lightweight materials include expanded polystyrene (EPS) light weight concrete have been employed in engineering applications. The Expanded polystyrene beads are the material which replaced in the place of fine aggregate. These factors will lead the concrete to become lighter and have a lower density. In this investigation the concrete density is reduced by adding polystyrene beads to the silica-fume concrete. Silica-fume was added for enhancing the concrete strength and balances the loss in concrete strength due to the inclusion of polystyrene beads. It has good thermal insulation properties with stiffness and compression strength. It is used in sound and vibration damping, settlement reduction beneath embankments, and related applications. The expanded polystyrene beads are used in varying proportions such as (EPS0, EPS1 and EPS2) for replacing fine aggregate also cement is replaced with silica fume as 10% of total bender content as it shown similar pozzolani property as that of cement. The water-cement ratio was 0.41 and the sand-cement ratio was chosen. The tested for mechanical properties, durability properties and Non destructive tests.

Index Terms- EPS beads, silica fume, Mechanical properties, durability properties, Lightweight concrete, Construction materials, Low density concrete etc…

I. INTRODUCTION

This Concrete is the second largest material utilized by human beings after food and water as per WHO. It is obtained by mixing cement, fine aggregate, coarse aggregate and water in required proportion. When mixture is placed in forms and allowed to cure become hard like stone. The hardening is caused by chemical action between water and cement due to which concrete grows stronger with age. The strength, durability and other characteristics of concrete depends upon the properties of the ingredients, the proportion of the mix, the method of compaction and other controls during placing compaction and curing. In India, there is a great demand for aggregates mainly from civil engineering industry for road and concrete constructions. But nowadays it is a very difficult problem for available of fine aggregates. So, researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Expanded polystyrene beads are used as a replacement of fine aggregate. Due to these the concrete will become light and the density of the concrete will be less. The expanded polystyrene beads are used in varying proportions of 2% & 3% Silica fume is replaced with cement in 10% it has good binding property and increases compressive strength and split tensile strength. Hence, the objectives of this paper is to investigate the durability indicators of different concrete grades by studying the water absorption, volume of voids (VPV) and the sorptivity capacities to introduce performance-based durability indicator before any real structure can be constructed on ground.

OBJECTIVE

The main objective of the study is to investigate the replacement of the expanded polystyrene beads in concrete as a replacement of fine aggregate. This study also includes the performance of the concrete using silica fume and EPS beads.

- To study the compression strength and splitting tensile strength.

- To study the water absorption behavior of expanded polystyrene concrete.
- To perform durability test of sorptivity on expanded polystyrene & silica fume concrete.

II. DESIGN MIX MATERIALS

a) CEMENT

Ordinary Portland Cement (OPC) is by far the most important type of cement. The OPC was classified into three grades, namely 33grade, 43grade and 53grade depending upon the strength of the cement at 28 days. The tests were conducted on cement; specific gravity.

b) COARSE AGGREGATE:

The aggregates of size greater than 4.75mm are called coarse aggregates. They generally range between 10 mm to 20 mm. Aggregates are used in concrete for very specific purposes. The use of coarse and fine aggregates in concrete provides significant economic benefits for the final cost of concrete in place. Aggregates typically make up about 60 to 75 percent of the volume of a concrete mixture, and as they are the least expensive of the materials used in concrete, the economic impact is measurable. In addition, the use of aggregates provides volume stability to the hardened concrete.

c) Expanded Polystyrene Beads:

Polystyrene is a synthetic aromatic polymer made from the monomer styrene. Polystyrene can be solid or foamed. General-purpose polystyrene is clear, hard, and rather brittle. It is an inexpensive resin per unit weight. It is a rather poor barrier to oxygen and water vapor and has a relatively low melting point. Polystyrene is one of the most widely used plastics, the scale of its production being several million tonnes per year. Polystyrene can be naturally transparent, but can be colored with colorants. Uses include protective packaging containers lids, bottles, trays, tumblers, and disposable cutlery. The figure 5 shows the expanded polystyrene beads.

- The specific gravity of expanded polystyrene beads is 0.00358
- The bulk density of EPS beads is 3.59 Kg/m3.

d) FINE AGGREGATE:

Aggregates of size less than 4.75mm are considered as fine aggregates. The commonly used fine aggregate is River Sand. The sand particles should be free from any clay or inorganic materials. The tests were conducted on fine aggregate; specific gravity, sieve analysis, fines modules.

e) SILICA FUME:

Silica fume, also known as micro silica, is an amorphous (non crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a byproduct of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Silica fume is generally used in concrete to increase the bonding property in the concrete.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compression strength, bond strength and abrasion resistance.

f) Water:

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.41 for M30 concretes.

Mechanical properties	
Le-Chatelier's apparatus (cement)	Specific Gravity of cement G = 2.9
Le-Chatelier's apparatus (silica fume)	Specific Gravity of Silica Fume G = 2.1
Pycnometer	Specific Gravity of Cement G = 2.65
Sieve analysis	Fineness Modulus = 2.6
Specific gravity on Baskets	Specific Gravity of Coarse aggregate G = 2.7

TABLE 1: MATERIAL OF PROPERTIES

III. DESIGN MIX METHODOLOGY

A) DESIGN MIX

The concrete is mixed in concrete mixer of capacity 70kg. The concrete is manufacture in different proportions of EPS as 0%, 2%, 3% replacement of fine aggregate with expanded polystyrene beads and a partial replacement of cement with 10% of silica fume with weight.

Mixture proportions	
Cement	408.29Kg/m^3
Silica Fume (10%)	45.37 Kg/m^3
Coarse aggregate	1151.44Kg/m^3
Fine aggregate	598.15 Kg/m^3
EPS beads (fine aggregate)	3.59 Kg/m^3
Water	186 Kg/m^3
w/c	0.41

Table 2: Concrete Design Mix Proportions

Fig 1: Mixing of EPS beads concrete

b) Workability Test

The workability of the fresh mixture was calculated with the help of slump test as per IS 1199-1959. The slump for silica fume mixture from 60mm while that of EPS mixture from 68mm. The slump tests of mix design containing Type EPS (3%) beads gave good results as compared to the mix designs having Type EPS (2%) beads. The Slump for Type EPS (2%) beads ranged from 65mm while the slump for Type EPS (3%) beads ranged from 68mm. The linear equation formed by y=4x+56.33 from (R^2 = 0.979).

Concrete mix	EPS (0%)	EPS (2%)	EPS (3%)
Slump value	60	65	68

Table 3: slump value for EPS beads concrete

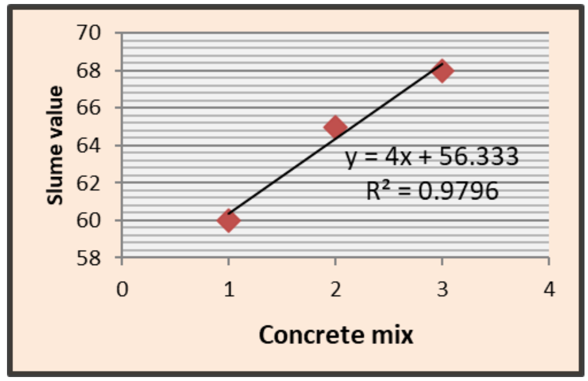

Fig 2: Relation for slump values

c) Compression Strength Test

The compression strength of concrete is one of the most important and useful properties of concrete. In most structural applications Concrete is used primarily to resist compression stress. In those cases where strength in tension or in shear is of primarily importance, the compression strength is frequently used as a measure of these properties.

The compression strength of the concrete is conducted on the of the cube of standard dimensions of (150 x 150 x 150) mm the compression strength is conducted at the age of 7, 14 & 28 days.

Fig 4: compressive test on cube

d) Split Tensile Strength

Splitting tensile strength test on concrete cylinder The tensile strength of concrete is one of the basic and important properties. is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack .The split tensile strength is conducted on concrete is conducted at 28 days. The fig shows the split tensile strength of the concrete.

e) Rebound hammer

Rebound hammer consist of spring control hammer, a plunger. The plunger is pushed towards the surface of the specimen, the mass is being rebound from plunger and it withdraws against the compel of spring. The hammer impacts against the concrete and spring control mass rebounds, the rider is taken by hammer with it along guide scale the rider is kept in place by clicking the button and rebound number is observed.

f) ULTRASONIC PULSE VELOCITY TEST

This test is done to get the nature of cement by UPVT strategy according to IS: 13311 (Part 1) – 1992. It is likewise non-ruinous test. This technique helps to calculating the time of ultrasonic pulse velocity going to the concrete. Relatively higher speed is recorded if the concrete quality is great such as, consistency, homogeneity and so on.

Fig 5: Ultrasonic pulse velocity test of EPS beads concrete

g) Water absorption test

One of the most important properties of a good quality concrete is low permeability, especially one resistant to freezing and thawing. A concrete with low permeability resists ingress of water and is not as susceptible to freezing and thawing. Water enters pores in the concrete paste and even in the aggregate. In this work three full size blocks shall be completely immersed in clean water at room temperature for 24 hours. The blocks shall be then removed from the water and allowed to drain for one minute by placing them in air, visible surface water being removed with a damp cloth; the saturated and surface dry blocks are immediately weighed. After weighing all blocks shall be dried at room temperature for not less than 2 days and then the blocks are weighed.

% water absorption = [(W2– W1) / W1] x 100

Where

- W1 = Oven dry weight of cube in grams
- W2 = after 3.5 hours wet weight of cube in grams.

Fig 6: Water absorption test of EPS beads concrete

h) Volume of Permeable Pore Voids (VPV)

Water has been filled in suitable container and boiled for 1 hour. In boiled water, 24 hours oven dried specimens at 110 0C (A) were used. The specimens are immersed and boiled for 5 hours continuously. After boiling, specimens were allowed to cool at room temperature 220 – 250 C for 14 hours and the mass of each specimen is noted as (B). Samples are tied with copper wire and is immersed in water using spring gauge as shown in Figure. This weight was denoted as (C). The percentage of volume of voids were calculated by using Equation

Water absorption % = [(B - A) / (B - C)] X 100

Fig 7: Volume of permeable pore voids test of EPS beads concrete

i) SORPTIVITY TEST

Water ingress into a non-saturated concrete structure is due to sorption, driven by capillary forces. If the water is on top of the concrete surface, gravity also will play a role in the water penetration. Therefore, it is necessary to use the method more appropriate for the application of the concrete structure to be evaluated. Because of the difficulties associated with the absorption tests, on the one hand, and, on the other, because permeability tests measure the response of concrete to pressure, which is rarely the driving force of fluids entering concrete, there is a need for another type of test. Such a test measure the rate of absorption of water by capillary suction of unsaturated concrete placed in contact with water; no head of water exists. Essentially, the sorptivity test determines the rate of capillary–rise absorption by a concrete prism which rests on small supports in a manner such that only the lowest 30 mm of the prism is submerged. The increase in the water level of the prism with time is recorded.

Sorptivity test on cube specimen

Where,

S = Sorptivity in cm/min0.5.

i = Depth of water level increased by capillary action, expressed in mm.

t = Time measured in minutes at which the depth determined.

Fig 8: Sorptivity test of EPS beads concrete

IV. EXPERIMENTAL RESULTS

The experimental investigation on Table-3,4,5,6,7 and 8 gives the compressive strength, spilt tensile strength, rebound hammer, ultrasonic plus velocity, water absorption, volume of permeable voids and Sorptivity test results of % replacement of silica fume in concrete for 28 days curing. The % replacement vs % water absorption, volume of permeable voids and Sorptivity results are graphically shown in figure 7 and 8.

EPS	7^{th} day	14^{th} day	28^{th} day
EPS 0	16.19	24.45	26.45
EPS 1	18	26.5	29
EPS 2	19.55	26.3	28.15

Table 4: Compressive strength of cubes at different ages N/mm2

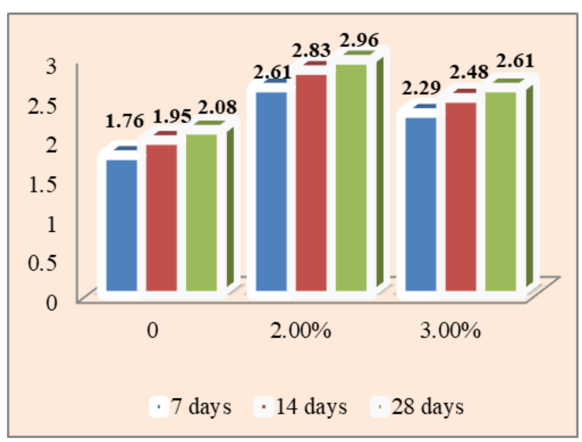

Fig 9: Compressive strength of cubes – Graph

Table 5: split tensile strength at 7-, 14- & 28-days N/mm2

EPS	7th day	14th day	28th day
EPS 0	1.76	1.95	2.08
EPS 1	2.61	2.83	2.96
EPS 2	2.29	2.48	2.61

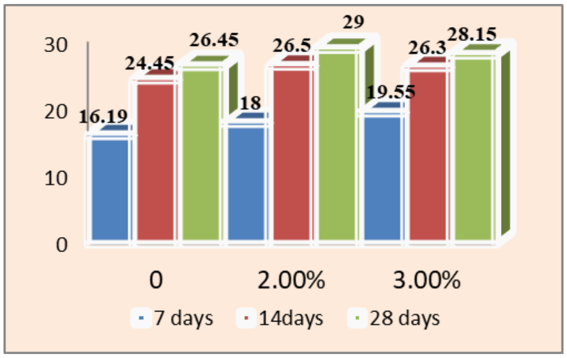

Fig 10: split tensile strength of cylinder

Mix	Rebound values	Compressive strength value	Destructive test (fc)
EPS 0	34	29	36.5
EPS 1	29	28.15	31.0
EPS 2	18	26.45	20.2

TABLE 6: REBOUND HAMMER VALUES OF EPS CONCRETE N/MM2

Table 7: UPV test of Travel path on EPS beads concrete

Mix	Method of probing	Travel path (L) IN Km	Time in (T) sec	Pulse velocity cross probing v=(L/T) Km/sec
EPS 0	Direct	150	31.29	3.79
	Indirect	105	22.66	3.63
EPS 1	Direct	150	35.75	2.28
	Indirect	105	24.39	2.34
EPS 2	Direct	149	40.2	1.53
	Indirect	105	31.11	1.37

Specimen designation	Initial weight (W_1) gram	Finial weight (W_2) gram	Water absorption (%)
EPS_0	2500	2540	1.67
EPS_1	1950	2020	3.34
EPS_2	1670	1729	3.42

Table 8: Water absorption test of EPS beads concrete

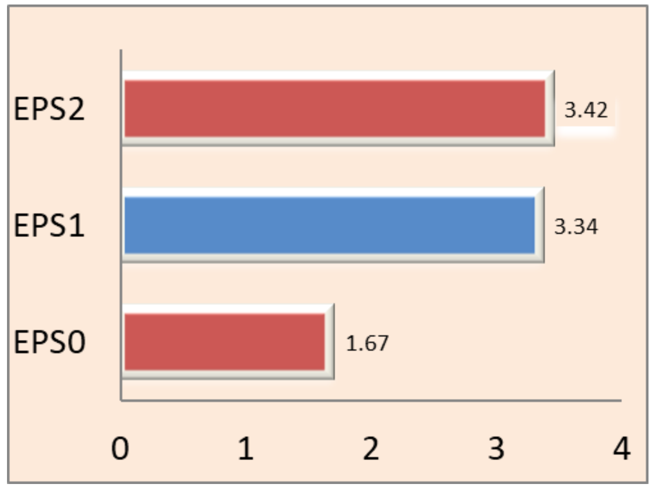

Fig 11: Water absorption test of EPS beads concrete

Table 9: Volume of permeable pore voids test of EPS beads concrete

Specimen designation	Curing age	Absorption after immersion (%)	Absorption after immersion boiling (%)	Volume permeable voids (%)
EPS_0	24 hours	2.18	2.66	7.17
	28 days	0.89	1.32	3.33
EPS_1	24 hours	3.42	4.02	8.98
	28 days	1.84	2.12	4.73
EPS_2	24 hours	4.56	4.69	11.2
	28 days	2.01	2.14	5.19

Fig 12: Volume of permeable pore voids test of EPS beads concrete

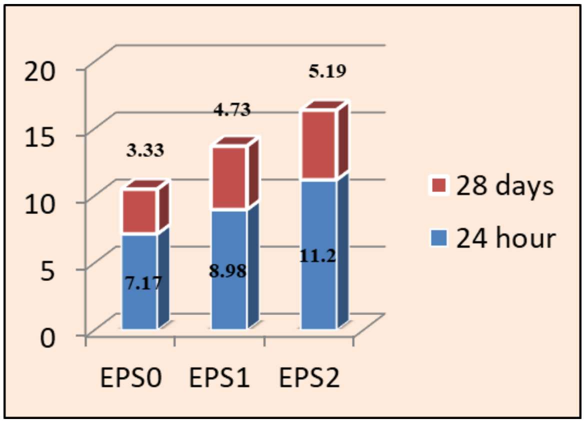

Fig 13: correlation graph for Volume of permeable pore voids

Mix	Cumulative Volume of water absorbed / surface area of exposure (cm)				Sorptivity x10^{-3}
	30 min	60 min	90 min	120 min	Cm/min$^{0.5}$
EPS_0	0.04	0.06	0.07	0.07	4.4
EPS_1	0.07	0.08	0.09	0.11	5.2
EPS_2	0.08	0.1	0.11	0.12	5.8

Table 10: Sorptivity test of EPS beads concrete

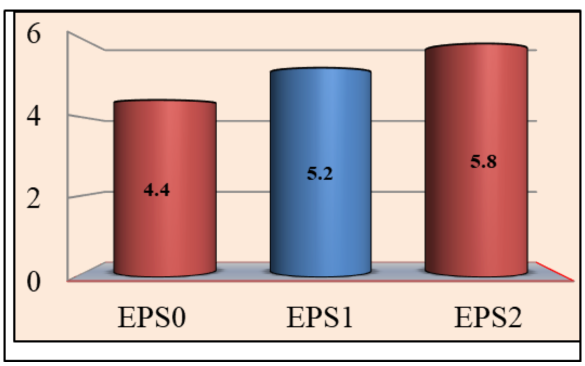

Fig 14: Sorptivity test of EPS beads concrete

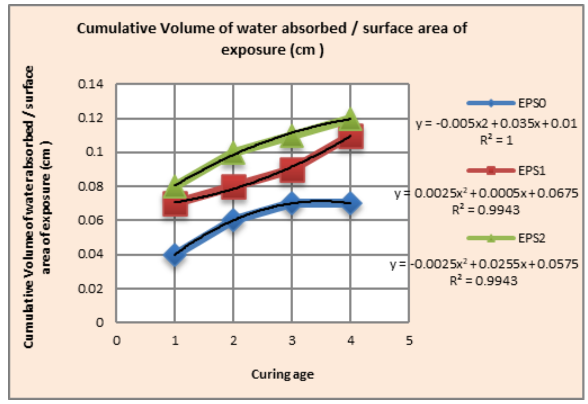

Fig 15: correlation graph for Sorptivity test

CONCLUSION

Inclusion of silica fume to the concrete improves its strength for both normal concrete and concrete of EPS beads.

1) The EPS beads tests an mechanical & durability testing As per 7, 14 & 28 days test results

2) The replacement of fine aggregate by expanded polystyrene beads, increased when silica fume add the strength of concrete and weight has reduced.
3) 3) The 2% replacement of fine aggregate with EPS beads gave strength nearly conventional concrete.
4) At 3% replacement the compressive strength of concrete was found to be reduced as compared to the conventional mix
5) From the above experimental results, it is proved that silica fume can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction.
6) As the density of concrete decreasing, the dead weight of structure also decreasing by replacing the polystyrene we can achieve light weight concrete
7) The water absorption and sorptivity of silica fume concrete shown lower. water absorption and sorptivity at replacement level of 10% with silica fume M30 grade concrete.

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