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Light Weight Concrete Using EPS (Expanded Polystyrene) Beads

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A B S T R A C T

With the rise in demand for construction materials, alternative materials are becoming increasingly important for long-term growth. The primary goal of this study is to determine the attributes of lightweight concrete incorporating Expanded Polystyrene (EPS) beads, such as compressive and tensile strengths. Its qualities are compared to those of ordinary concrete, which does not contain EPS beads. Coarse aggregates are partially replaced with EPS beads. The findings revealed that the number of polystyrene beads used in concrete had an impact on the qualities of hardened concrete. In this experiment, half of the coarse aggregate is substituted with EPS (Expanded Polystyrene) beads in M15 grade concrete with a W/C ratio of 0.50 and 0.40. Concrete structure that is light weight, functional, and environmentally beneficial. The low density and low heat conductivity sound insulating properties of light weight concrete are its key advantages. Conventional concrete has a density of 2200 to 2600 kg/m^3. Because of its high self-weight, it will be an uneconomical structural material to some extent. Light concrete has a density ranging from 300 to 1850 kg/m^3. Light concrete has a strength range of 1 to 20 MPa. The weight of light weight concrete is 50-75 percent less than that of regular concrete.

Keywords: Expanded polystyrene beads (EPS); concrete; Water Cement ratio ; Workability; Compressive strength.

1.INTRODUCTION

Since the turn of the century, concrete has been one of the most widely utilized construction materials. It becomes more significant and favored over timber or steel because of its versatility in use. Lightweight concrete has a strength class of 1 to 20 MPa. LWC has a density of 300-1800 kg/m3, while regular concrete has a density of 2200-2600 kg/m3. Lightweight concrete is between 50 and 75 percent lighter than regular concrete. Lightweight concrete has a low viscosity. It has both thermal and acoustic insulation characteristics. Improved thermal characteristics, lower structural loads, and fire resistance are all advantages of lightweight concrete. Because it lowers the cost of shipping, handling, and constructability, reducing concrete density leads to more cost-effective building. The addition of light weight aggregate and an air entraining agent is one way to make concrete lighter. When light weight aggregate and an air entraining agent are used in concrete, dead loads are reduced, building time is reduced, and haulage and handling costs are reduced.

True, the usage of LWC is limited to specific applications when compared to conventional concrete, but the advent of LWC provides more options to the building sector, which is now focused on natural resources. Some light weight aggregates are made from waste materials, such as lytag, which is made from pulverized fuel ash. According to a study, the use of LWC is becoming more popular in Malaysia, where more than 100,000m2 of LWC panel were produced in 1994, and demand is expected to rise in the future year.

2. MATERIALS

2.1 Cement

53 grade Ordinary Portland cement was used for this study program, as this cement is widely used in this country.. The physical and chemical requirementof 53grade Ordinary Portland Cement as per **IS 12269: 1987,** is given in **Table 1.1.**

Table 1.1 Physical and Chemical properties of cement

S.No	Particulars	Typical range	Requirement as per: IS 12269 – 1987
	PHYSICAL PROPERTIES		
1	Brand of cement	Jaypee	-
2	Type of cement	53 Grade OPC	-
3	Fineness (retained on 90 microns sieve)	8%	Not more than 10%
4	Normal consistency	32.00%	-
5	Initial setting time	110	Not less than 30 Minutes
6	Final setting time	600	Not more than 600 Mintues
7	Compressive strength (Mpa)		
	7 Days	49.00	Not less than 37
	28 Days	61.00	Not less than 53
8	Soundness (Le chatelier) mm	1.00	Not more than 10
	CHEMICAL PROPERTIES		
1	Ratio of percentage to alumina to that of Iron oxide	1.20 - 1.40	Not less than 0.66
2	Insoluble residue (%)	1.0 – 1.20	Not more than 3%
3	Magnesium oxide (%)	3.0 – 3.50	Not more than 6%
4	Total loss on ignition (%)	1.0 – 1.20	Not more than4%
5	Sulphuric anhydride (%)	1.80 – 2.00	Not more than 3%

Since, different brands of cement have different strength development characteristics and rheological behavior in the compound compositions and fineness permitted in IS:12269, therefore cement from single supplier of same brand was used.

2.2 Expanded Polystyrene Beads

The rest of EPS, or expanded polystyrene, is made up of microscopic spherical EPS beads, which are comprised entirely of carbon and hydrogen. Expanded polystyrene (EPS) is a closed cell foam that is strong and durable. It's mainly made of pre-expanded polystyrene beads and is white.

It has a high compressibility and can be expected to give little resistance to volume variations in the cement paste as a result of the applied load as well as changes in moisture content. EPS can be employed in a variety of applications due to its technical qualities like as low weight, stiffness, and formability. Its market capitalization is expected to exceed $15 billion by 2020. Polystyrene beads are frequently confused for Styrofoam beads. The initial stage in making EPS (expanded polystyrene) blocks is puffing EPS resin to make puffed polystyrene beads. Aside from making EPS blocks, puffed polystyrene beads are utilized in a variety of applications. Bean bag chair manufacturing and lightweight concrete manufacturing are two of the most frequent.

3.METHODOLOGY:

3.1 Methods of Lightweight Concrete

Lightweight concrete can be made by infusing air into the mix, or by eliminating or substituting the finer aggregate sizes with hollow, cellular, or porous aggregates. Lightweight concrete, in particular, can be divided into three categories:
a) By substituting light weight aggregate for the traditional mineral aggregate (Expanded Polystyrene beads). Expanded polystyrene concrete is what this is called.
b) Adding gas or air bubbles to the mortar. Aerated concrete is the term for this type of concrete.
c) By not including the sand proportion in the aggregate. This is referred to as "no fines concrete."

3.2 Expanded Polystyrene Concrete (Light Weight Concrete)

Expanded polystyrene (EPS) concrete (also known as EPScrete, EPS concrete, or lightweight concrete) is a lightweight concrete constructed from cement and expanded polystyrene (EPS) (Expanded Polystyrene). It's a popular choice for environmentally conscious homeowners. It's been utilized for road bedding, soil or geo-stabilization operations, and railroad trackage sub-grading.

A number of lightweight aggregates can be used to make lightweight aggregate concrete. Lightweight aggregates come from one of two sources:

i. Natural materials, such as pumice from volcanic eruptions.

ii. Leca, which is the thermal treatment of natural raw materials such as clay, slate, or shale.

iii. Lytag is made from industrial by-products such as fly ash.

iv. Industrial by-products, such as FBA or slag, are processed.

The optimal sort of lightweight aggregate to utilize will be determined by the lightweight concrete's desired qualities. If little structural support is required yet significant thermal insulation is required, a light, weak aggregate can be employed. As a result, the concrete will have a low strength. Lightweight aggregate concretes, on the other hand, can be used for structural applications and have the same strength as regular concrete.

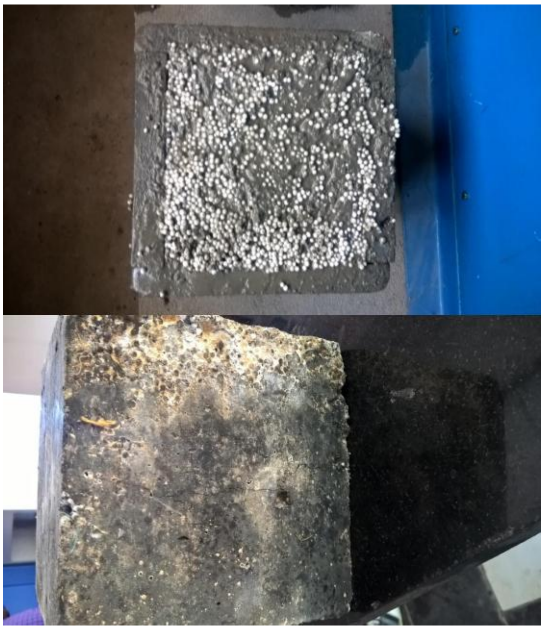

Fig. 3.1. Cube specimens :

According to the findings of this study, the average annual temperature change for the upper 0 mm to 110 mm depth is 2.20C. As a result, the bituminous mix to be chosen should take into account the reported average annual temperature, as well as the testing to be done to determine the modulus of bituminous mix for an average annual temperature of 38.50°C.
Local suitable temperature, freezing, and thawing records can also be provided as boundary conditions for top of surface and bottom of subgrade levels to tie the technique to practical settings.This approach can be used to forecast temperature fluctuations and pick acceptable materials for different layers of pavement based on their material characteristics. Even hypothetically planned pavement sections can be altered to provide a more stable, cost-effective, and ultimately ideal design for specific climatic and soil conditions.The structural models' evaluations of pavement responses, such as

stresses, strains, and deflection, are used as inputs for distress models. Fatigue and rutting criteria are included in the distress models. The calibrated fatigue model and a rutting model were used in this study to estimate fatigue life in terms of a number of standard axles and rutting life in terms of a number of cumulative standard axles, respectively. Both models were used for an 80 percent reliability level as specified in IRC: 37-2012. The computed strains are used as input and are factored into the fatigue and rutting criteria proposed by the Indian Road Congress (IRC: 37-2012) to estimate pavement life under various scenarios. The horizontal tensile strain at the bottom of BL causes fatigue cracking in flexible pavements. The permitted number of load repetitions (Nf) that causes fatigue cracking is related to the tensile strain (Et) at the bottom of BL according to this criterion. Figure 8 shows the fatigue life of a variety of conventional axles on the y-axis versus the thickness of the BL on the x-axis for all trail base materials. For all trail foundation material, Figure 9 shows a graphical representation of the number of cumulative standard axles on the y-axis vs the thickness of the BL on the x-axis.

Design Of Light Weight Concrete

As per IS 10262-2009		
A-1	**Stipulations for Proportioning**	
1	**Grade Designation**	**M15**
2	Type of Cement	OPC 53 grade confirming to IS-12269-1987
3	Maximum Nominal Aggregate Size	20 mm
4	Water Content	186 lit
5	Maximum Water Cement Ratio(MORT&H 1700-3 A)	0.55
6	Workability (MORT&H 1700-4)	30 mm(Slump)
7	Exposure Condition	Moderate
8	Degree of Supervision	Good

A-2	**Test Data for Materials**	
1	Cement Used	Jaypee Cement OPC 53 grade
2	Sp. Gravity of Cement	3.15
3	Sp. Gravity of Water	1.00
5	Sp. Gravity of 20 mm Aggregate	2.50
6	Sp. Gravity of 10 mm Aggregate	2.64
7	Sp. Gravity of Sand	2.64
8	Water Absorption of 20 mmAggregate	0.97%
9	Water Absorption of 10 mmAggregate	0.83%
10	Water Absorption of Sand	1.23%
11	Free (Surface) Moisture of 20 mmAggregate	Nil
12	Free (Surface) Moisture of 10 mmAggregate	Nil
13	Free (Surface) Moisture of Sand	Nil
15	Sp.Gravity of Combined CoarseAggregates	2.882

Step 1: Determination of Target Mean Strength or field strength

Target Mean Strength is determined as follows**:**

$$f_t = f_{ck} + k\ s$$

Where f_t = Target mean compressive strength at 28 days.

Fck = Characteristic compressive strength at 28 days.

K = A statistical value depending upon the accepted proportions of low resultsand the number of tests

S = Assumed standard deviation.

F_t =15+1.65(3.5)

= 20.775 N/mm^2

Step 2: Selection of water content

From Table 2, maximum water content

for 20 mm aggregate = 186 lit (for 25 to 50 mm slump range)

Step 3: Calculation of cement content

Water cement ratio	= 0.55
Water content	= 186 kg/m^3
Cement	= 186/0.55
	= 338.18 kg/m^3

Step 4: Mix proportions for trial number

Mix proportions for M15 grade of concrete is considered as 1:2:4 and calculated as follows in this design

Cement	= 338.18 kg/m^3
Water	= 186 kg/m^3 Coarse aggregate
	= 338.18 X 4 =1352.72 kg/m3
Fine aggregate	= 338.18 X 2
	=676.36 kg/m^{3}Water cement
ratio	= 0.55

Expanded polystyrene beads = 15 kg/m3.

Step 5: Adjustment of the trial mixture proportions

The trial mixture proportions were adjusted according to the following guidelines to achieve targeted slump (as a measure of workability).

(A) Moisture content – as a part of quality control during production of concrete. It is necessary to provide moisture content correction to dry batching. In this project work sand and coarse aggregate are dried in room temperature after sufficient amount of water sprinkled on the aggregate to avoid further absorption of water from the estimated mixing water quantity. The samequality control was maintained for each batch of concrete produced.

(B) Initial slump- If initial slump is not achieved in the desired range, then the mixing water is adjusted so as to maintain water – cement ratio same. With a change in mixing water quantity, sand quantity is also adjusted accordingly.

Step 6: Selection of Optimum mixture proportions

Once trial mixes have adjusted, test specimens i.e. 150 mm cubes are cast from the concrete produced and finally from the strength tests result of the specimens, optimum of proportioning of mixture is suggested.

Calculation

The corresponding strength at 28 days can be found out from the following correlation. (It is however suggested that a new specific correlation should be developed for the specific concrete used at site.)

R28 (Strength at 28 days) = 8.09 + 1.64 Ra Where,

Ra = Accelerated Curing Strength in MPa.

RESULTS

TESTS

STANDARD CONSISTENCY OF CEMENT

Observations and calculations

Weight of cement taken (g) = 400

Initial percentage of water added to cement = 26 Quantity of water added to cement = 104 ml

Table 4.1. Percentage of water added to the depth of penetration of plunge

Sl. No.	Percentage of water added (%)	Quantity of water added (Ml)	Depth of penetration of plunger (mm)
1	2 26	3 104	4 34
2	5 28	6 112	7 18
3	8 30	9 120	10 13

Standard Consistency

= (Quantity of water for 5-7 mm penetration/Weight of cement) X 100

Result

Percentage of water content for standard consistency = **32%**

INITIAL SETTING TIME OF CEMENT (IS 4031, IS 269) RESULT

The initial setting time of the given sample of cement = **110min**

Observations and calculations

Weight of cement taken (g) = **400gms**

Quantity of water added to cement = 0.85 X Quantity of water required for standard consistency = **108.80 ml.**

Table. 4.2. Depth of penetration of needle with respect to time

SL. NO.	Time (min) (Measured from the instant of adding water to cement)	Depth of penetration of needle (mm)
1	0	40
2	50	20
3	110	6

FINAL SETTING TIME OFCEMENT

Result : The final setting time of the given sample of cement = **600min**

SPECIFIC GRAVITY OF CEMENT

Observation and calculations

i. Weight of empty flask (W1) = 30 gms

ii. Weight of flask + cement (W2) = 70 gms

iii. Weight of flask + cement + kerosene (W3) = 100 gms

iv. Weight of flask + kerosene (W4) = 70 gms

v. Specific gravity of kerosene = 0.79

$$\text{Specific gravity of cement} = \frac{(W2-W1)}{(W2-W1)-(W3-W4)} \text{ X } 0.79$$

$$= \frac{(70-30)}{(70-30)-(100-30)} \text{X} 0.79$$

= 3.13

Result

Specific gravity of a sample of cement = 3.13

SPECIFIC GRAVITY OF CORSE AGGREGATES

Calculations

1) Weight of empty container (W1) = 650 gms
2) Weight of container + Coarse Aggregate (W2) = 1286 gms
3) Weight of container + Coarse Aggregate + Water (W3) = 1966 gms
4) Weight of container + water (W4) = 1564 gms

Apparent Specific Gravity = (W2 - W1) / (W4 – W1) – (W3 – W2)

= (1286-650)/ (1564 – 650) – (1966 – 1286)

= 2.71

Result

specific gravity of given coarse aggregate = **2.71**

CONCLUSION

The following conclusions were drawn from the study.

- Increase in the EPS beads content in concrete mixes reduces the compressive of concrete.
- All the EPS concrete without any special bonding agent show good workability and could easily be compacted and finished.
- Workability increases with increase in EPS beads content.
- The replacement by using EPS has shown a positive application as an alternate material in building nonstructural members, and it also serves as a solution for EPS disposal.
- Obtained results suggest that expanded polystyrene concrete has scope for nonstructural applications, like wall panels, partition walls, etc.
- The compressive strength of EPScrete increases with reduction in replacement levels of the Expanded Polystyrene Beads.
- Lightweight concrete using partial replacement of Coarse Aggregates with Expanded Polystyrene Beads can be used for parking lots
- There occurred no indication of segregation of polystyrene beads from the mixture in any of the cases.
- The processes of manufacturing EPScrete is very simple and does not involve any complex machinery, chemical or additives.

The lightweight concrete is different from conventional concrete in certain materials and applications. The features of lightweight concrete are higher strength to weight ratio as compared with conventional concrete, enhanced in thermal and sound insulation, reduced dead load in the structure result reduce structural elements and minimize the steel reinforcement.

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