Mechanical Properties of Concrete Containing Phosphogypsum And Expanded Polystyrene Beads

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Abstract- *Investigation have been carried out in order to study the effect of phosphogypsum with partial replacement of cement and EPS beads with partial replacement of fine aggregate. The experimental work carried out, in attempt to formulate a mix design method for producing phosphogypsum cement concrete of greater strength and economy than that of conventional mix. This is an experimental work about light weight concrete by incorporating phosphogypsum and EPS beads. In the first stage, a study has been conducted on normal concrete by replacing cement with phosphogypsum to formulate a trial mix with optimum percentage which can be used as an alternative to M25 grade concrete. Cement is replaced partially by 0%. 7%, 10%, 15% and 20% with phosphogypsum. In the second stage, the optimum trial mix developed in first stage is used for further replacement of fine aggregate by EPS beads with M25 grade concrete. Fine aggregate were replaced partially by 0%, 10%, 20% and 30% with EPS beads.*

Keywords- Phosphogypsum, Expanded Polystyrene (EPS) Beads, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Building materials form the backbone of civil engineering construction. Of all the modern building materials, concrete is one of the oldest and the most versatile building material used in any type of civil engineering structure. The advantages of using concrete include relatively good compressive strength, general availability of its raw materials and adaptability to different environmental conditions. With the advancement of technology and increased field application of concrete and mortars, the density, strength, workability, durability and other characteristics of the ordinary concrete is continually undergoing modifications to make it more suitable for any situation. In order to meet the scarcity of cement and raw materials used in concrete, the use of recycled solid wastes, agricultural wastes and industrial by-products like phosphogypsum, fly ash, blast furnace slag, silica fume, rice husk ash, Expanded polystyrene (EPS) beads etc. came into use. Concrete made with lightweight materials are known as light weight concrete. Light weight concrete with density varying between 1400 to 2100 Kg/m3 has been used for structural purpose for so many years. The benefit of using light weight concrete is that it leads to overall reduction in dead load of a structure. This results in the reduction of final cost and improved economy of structural elements.

Phosphogypsum (PG) is a by-product from processing phosphate rock by the "wet acid" method for phosphoric acid production in fertilizer plants. With the installation of more amount of phosphoric acid plant in India, disposal of phosphogypsum becomes difficult. Phosphogypsum contains free phosphoric acid, phosphates, fluorides and organic matter. This brings about environmental impacts on its disposal sites. Disposal of waste phosphogypsum is one of the most serious problems faced in the phosphate industry. Apart from being used as a fertilizer, building material and soil stabilization agent, about 85% of phosphogypsum is dumped in the vicinity of phosphate factories, requiring large disposal areas. By using phosphogypsum we can reduce the disposal areas required.

Expanded polystyrene (EPS) is a light weight cellular plastic material consisting of fine spherically shaped particles. These beads consist of 98% of polystyrene and 2% of air. It has a closed cellular structure and cannot absorb water. Polystyrene foam is a waste material from packing industry. They are non-biodegradable and produce disposal problems. When these materials are chemically treated, expanded polystyrene beads are produced. They can be effectively used in concrete as partial replacements of aggregates. EPS beads are inert materials and do not contain chlorofluorocarbon (CFC) and hydro chlorofluorocarbon (HCFC).Hence they are environment friendly and do not contribute to the destruction of earth’s ozone layer. They are less resistant to alkalis, methanol, oxidizing and reducing agents. However when these beads are exposed to sunlight, they deteriorate and turn into yellow colour. This is an indication of polymer degradation although it may take years. Since they are embedded in concrete, the deterioration of beads are not of major concern. EPS beads do not carry any loads. They have excellent impact resistance and transfer the load to the surrounding regions.

They help to reduce internal stresses and prevents micro-cracking at lower stress levels. Hence they find applications in prefabricated panels at earthquake prone regions.

II. MATERIALS AND METHODS

Ordinary Portland cement, fine aggregates, coarse aggregates, phosphogypsum, expanded polystyrene beads and water are used for making concrete mixes in this present study. Properties of constituent materials are tested as per the methods prescribed by the relevant IS codes.

2.1 Cement

Ordinary Portland cement (OPC) confirming to IS 12269- 1999 (53 Grade) Brand (BIRLA super Cement) was used for the experimental work.

2.2 Fine Aggregate

River sand was used as fine aggregate. Laboratory tests were conducted on fine aggregate to determine the different physical properties as per IS 2386 (Part III)-1970.The test results are shown in the table 1. Fine aggregate used conforms to IS 383:1970 specification (Zone I).

Table No.1**:** Properties of fine Aggregate

Sr No.	Particulars	Values
1	Specific Gravity	2.56
2	Fineness Modulus	3.56
3	Bulk Density	1972.10(Kg/m³)
4	Water Absorption	3.093%

Figure No. 1: Fine aggregate sample

2.3 Coarse Aggregate

We have used maximum size of coarse aggregate used is 20mm. Laboratory tests were conducted on coarse aggregates to determine the different physical properties as per IS 2386 (Part III)-1970. The test results are shown in the table 2.

Table No 2: Properties of Coarse Aggregate.

Sr No.	Particulars	Values
1	Specific Gravity	2.95
2	Fineness Modulus	3.52
3	Bulk Density	1507.94(Kg/m³)
4	Water Absorption	1.26%

Figure No.2: Coarse aggregate sample

2.4 Phosphogypsum

The phosphogypsum used in this investigation was collected From Gujrat fertilizer manufacturing company Jalgoan.

Figure No. 3: Phosphogypsum sample

2.5 Expanded Polystyrene (EPS) Beads

Polystyrene is a waste material from packing industry. When processed in a special manner, polystyrene can be expanded and used as light weight concrete making material. The properties of EPS beads are shown in table 5.

Table No. 5: Properties of EPS Beads.

SR NO	PROPERTIES	DESCRIPTION
1	Appearance	White emulsion
2	Specific Gravity	0.0075
3	Freeze/Thaw resistance	Excellent
4	Flammability	Non-Flammable
5	Compatibility	Can be used with all types of Portland cement

Figure No. 4: EPS beads sample

2.6 Concrete Mixes

Mix M25 grade concrete were designed as per IS 10262:1982 and IS 10262:2009. Several trail mixes were casted to arrive at the appropriate mix proportion. Table 6 and table 7 show the details of test specimen and mix proportioning of concrete.

Table No. 6: Details of Test Specimens.

Sr No.	Specimen	Size(mm)
1	Cube	150x150x150
2	Cylinder	150x300
3	Beam	150x150x700

Table No. 7: Mix Proportioning.

Mix	Cement (Kg/m³)	Water (Kg/m³)	Fine agg. (Kg/m³)	Coarse Agg. (Kg/m³)	W/C ratio
M25	427	192	569	1331	0.45
M25	384	192	598	1337	0.5

III EXPERIMENTAL PROCEDURE

3.1 Preparation of Mixes

M25 grade concrete mix is taken as the reference mix and designated as MR. The optimum percentage replacement of cement with phosphogypsum was found by preparing samples with various replacement levels of 0%, 7%,10%,15% & 20%.Water cement ratio of the reference mix was kept at 0.45 The optimum percentage of phosphogypsum was found to be 10%. This mix with optimum percentage of phosphogypsum is used further to find the optimum percentage of EPS beads. Fine aggregate is replaced with 0%, 10%, 20% and 30% EPS beads to find the optimum percentage. Phosphogypsum is replaced in terms of its weight and EPS beads in terms of its volume. The details of the mix proportioning for optimum percentage of phosphogypsum and optimum percentage of EPS beads is furnished in table 8 and table 9 respectively.

Table No. 8: Mix Proportion of Various Mixes of Phosphogypsum

Mix	Phospho gypsum (%)	Cement (Kg/m³)	Phospho gypsum (Kg/m³)	Fine Aggregate (Kg/m³)	Coarse Aggregate (Kg/m³)
MR0	0	427	0	569	1331
MR7	7	397.11	29.89	569	1331
MR10	10	384.3	42.7	569	1331
MR15	15	362.95	64.05	569	1331
MR20	20	341.6	85.4	569	1331

Table No. 9: Mix Proportion for Various Mixes of EPS Beads

Mix	Cement (Kg/m³)	Phospho gypsum (Kg/m³)	Fine Aggregate (Kg/m³)	EPS Beads (Kg/m³)	Coarse Aggregate (Kg/m³)
MR 0	427	0	569	0	1331
MR 10-0	384.3	42.7	569	0	1331
MR 10-10	384.3	42.7	512.1	0.2977	1331
MR 10-20	384.3	42.7	455.2	0.5956	1331
MR 10-30	384.3	42.7	398.3	0.8656	1331

Where MR X, Y represents mix with x% replacement of cement with phosphogypsum and y% replacement of fine aggregates with EPS Beads.

Different tests were conducted to study the workability and strength parameters of the concrete. The workability of various mixes was assessed by determining compaction factor as per the IS 1199:1959 specification. Tests for the determination of compressive strength, flexural strength and modulus of elasticity of cement concrete were conducted as per IS 516:1959 and split tensile strength as per IS 516:1999.

IV. RESULTS AND DISCUSSIONS

4.1 Workability Test

The results of workability test for various percentage replacements of cement and fine aggregates with phosphogypsum and EPS beads are as follows

Table No. 10: Slump value of Concrete with Different Percentage Levels of Phosphogypsum

Mix	MR 0	MR 7	MR 10	MR 15	MR 20
Slump(mm)	05	10	12	15	20

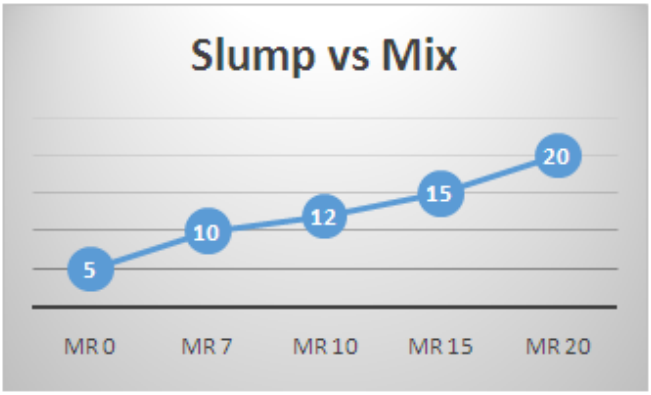

Figure No. 5: Slump value of cement replaced with phosphogypsumVs mix

Table No. 11: Slump value of Concrete with 10% Phosphogypsum and different percentage levels of EPS beads

Mix	MR 10-0	MR 10-10	MR 10-20	MR 10-30
Slump(mm)	12	20	26	35

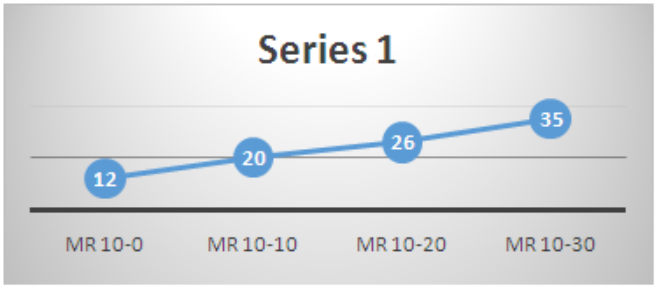

Figure No. 6: Slump value of mix with phosphogypsum and EPS beads

Slump value tends to increase with increase in percentage of EPS beads due to the increase in the volume of voids.

4.2 Compressive Strength Test:

4.2.1 Compressive Strength Vs Percentage of Phosphogypsum

The variation in cube compressive strength for the concrete mix (MR) with various percentages of phosphogypsum (replacing cement) is furnished in table 12

Table No. 12: Compressive Strength Vs Mix

Mix	Compressive Strength (N/mm2)	
	7 days	28 days
MR 0	20	26
MR 7	24	31.2
MR 10	29.77	38.7
MR 15	18.22	23.68
MR 20	14.22	18.48

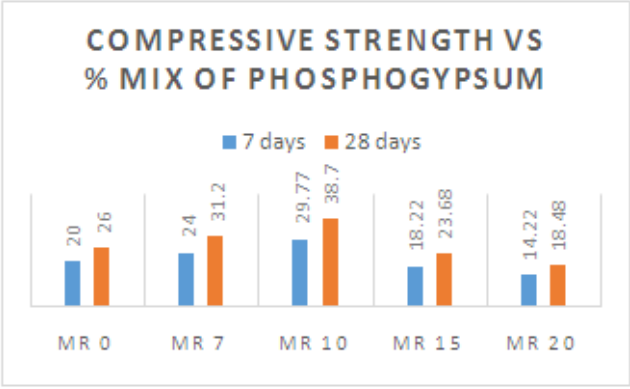

Figure No. 7: Compressive Strength Vs % of phosphogypsum

The optimum percentage replacement of cement with phosphogypsum was found at 10% replacement level.

4.2.2 Compressive Strength Vs Percentage of EPS Beads

The variation in cube compressive strength for the concrete mix (MR 10) with various percentages of EPS beads (replacing fine aggregate) is furnished in table 13

Table No. 13: Compressive Strength Vs Mix

Mix	Compressive Strength (N/mm2)		
	7 days	14 days	28 days
MR 10-0	22.31	28.65	31.55
MR 10-10	22.66	29.33	32.10
MR 10-20	24.89	31.78	37.22
MR 10-30	16.89	20.44	26.33

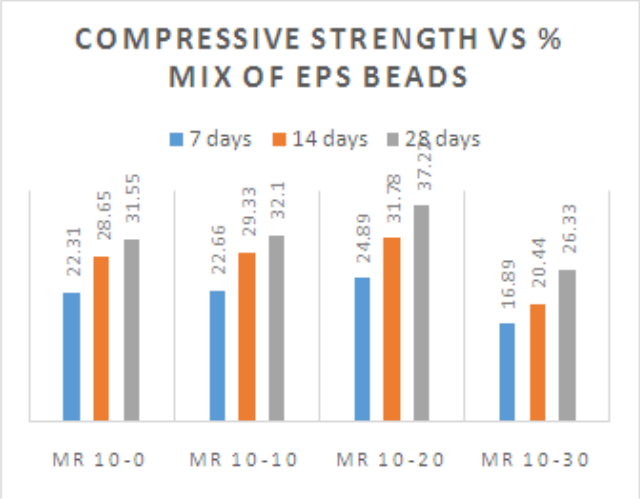

Figure No. 8: Compressive strength Vs Mix of EPS beads at 7 days, 14 days & 28 days

The compressive strength of concrete cubes decreased gradually as the percentage of EPS beads was increased. This is because the density of concrete decreases due to which the compressive strength also decreases. The mean compressive strength of M25 grade concrete is 25MPa and the compressive strength of the specimens with up to 30% replacement exceeded this value. So we can replace fine aggregate up to 30% replacement as alternative for normal concrete.

4.3 Density Test

Density of concrete prepared using various percentages of EPS beads is illustrated in table 14 and fig 9

Table No. 14: Density Vs Mix

Mix	Density (kg/m3)
MR 10-0	2578
MR 10-10	2548
MR 10-20	2518
MR 10-30	2444

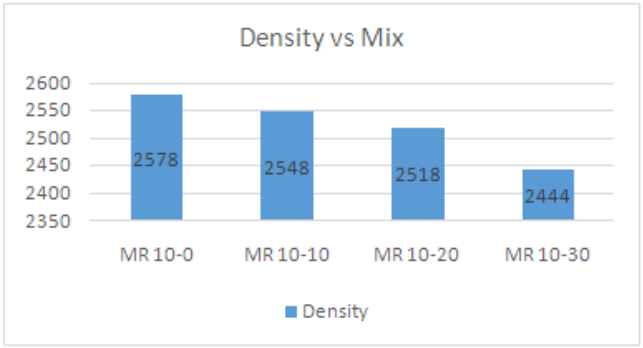

Figure No. 9: Density Vs Mix

Because of increase in voids ratio the density of concrete decreased with the addition of EPS beads since they are lightweight materials having low specific gravity.

4.4 Split Tensile Strength

The split tensile strength of concrete obtained for the concrete specimens prepared using various percentages of EPS beads are represented in the following table 15 and figures.10

Table No. 15: Split Tensile Strength of Concrete Vs Mix

Mix	Split tensile strength (N/mm2)		
	7 days	14 days	28 days
MR 10-0	1.98	2.54	3.04
MR 10-10	1.84	2.12	3.15
MR 10-20	1.90	2.40	3.75
MR 10-30	1.41	1.84	2.40

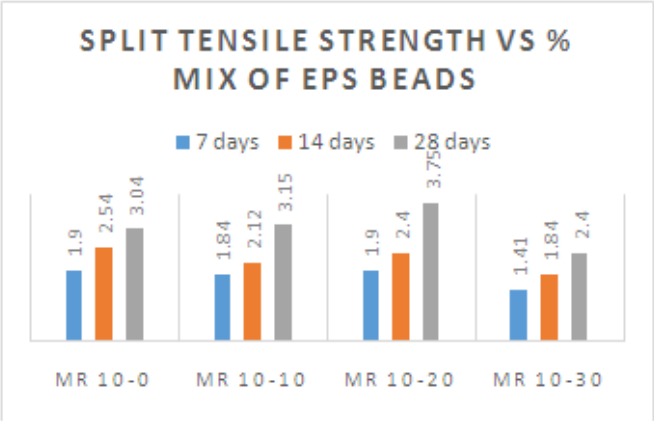

Figure No. 10: Split tensile strength Vs Mix of EPS beads at 7 days, 14 days & 28 days

As there is increase in voids ratio with increase in EPS % the bond between the ingredients in concrete decreases. Hence the split tensile strength of concrete reduced with the addition of EPS beads to the concrete, the values exceeded that of M25 grade concrete up to the addition of 20% of EPS beads.

4.5 Flexural Strength

The flexural strength of concrete obtained for the concrete specimens prepared using various percentages of EPS beads are represented in the following table 16 and figures.11

Table No. 16: Flexural Strength of Concrete Vs Mix

Mix	Flexural strength (N/mm2) at 28 days
MR 10-0	3.55
MR 10-10	3.23
MR 10-20	2.99
MR 10-30	2.70

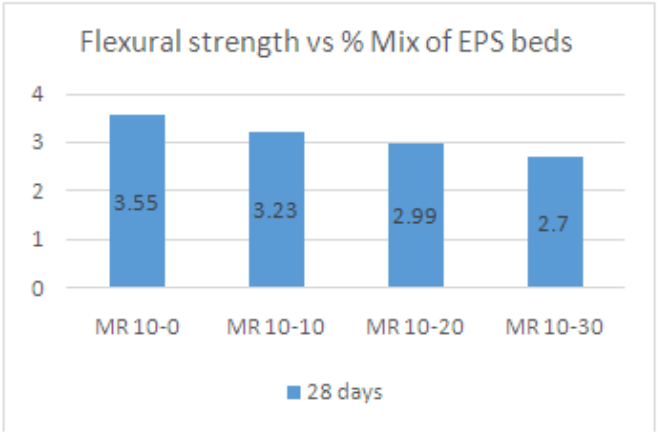

Figure No. 11: Flexural strength Vs Mix of EPS beads at 28 days

Though the flexural strength of concrete reduced with the addition of EPS beads to the concrete, we can replace EPS up to 20% which gives better results as that of normal concrete.

4.6 Cost Comparison

The cost of materials for one cubic meter of concrete for different mixes is given in Table 17

Table 5.8: Cost of materials per 1 meter cube

Mix	Cost (Rs)
MR 0	4142
MR 10-0	4014
MR 10-10	3942
MR 10-20	3866
MR 10-30	3777

V. CONCLUSION

- Replacement of cement with phosphogypsum yielded maximum compressive strength at 10% replacement level.
- Hence mix with 10% phosphogypsum and 20% EPS beads as partial replacement of cement and fine aggregate can be used as an alternative to M25 grade concrete.
- Cost comparison of alternate mix with M25 grade concrete showed as an increase in percentage of phosphogypsum and EPS beads cost per one meter cube of concrete is decreases.
- Compressive strength of EPS beads concrete is increasing as compared to conventional concrete. It is higher at 20%

replacement for M25 grade concrete. At 28 days maximum strength achieve is 37.22MPa for M25.

- It was observed that, increasing vibration duration causes accumulation of beads over the mould.
- Workability increases with increase in EPS beads content.
- The replacement by using EPS has shown a positive application as an alternate material in building non-structural members, and it also serves as a solution for EPS disposal.

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