

Experimental Investigation on the use of Light Weight Concrete in GFRG Construction Formulation of an Alternate Light Weight Concrete Mix

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Abstract— Glass fibre reinforced gypsum (GFRG) panels are new building materials made essentially of gypsum plaster reinforced with glass fibre. GFRG panels can be unfilled when used as partition walls, but when used as external walls, it is filled with M₂₀ grade concrete (reinforced concrete filling) in order to resist the Lateral loads. M₂₀ grade is adopted in order to satisfy the durability requirements stipulated in the code IS 456:2000 rather than for strength. In the present scenario, the experiment was conducted in two stages: In the first stage, a study was conducted on normal concrete by replacing cement with phosphogypsum and fine aggregate with EPS beads, to formulate a trial mix with optimum percentage which can be used as an alternative to M₂₀ grade concrete (and is lighter than the same). In the second stage, the trial mix developed in first stage is used for a comparative study between GFRG filled with M₂₀ grade concrete and with the alternative trial mix. The results of the first stage are presented in this paper.

Keywords: *Green product, Low cost, Prefabricated, hollow panels, Phosphogypsum, Expanded Polystyrene (EPS) Beads, Light weight.*

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, formability, 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 light weight 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 since they are liable to support lesser amount of dead loads. According to Cook (1983), expanded polystyrene beads are best suited for prefabricated panels, hollow and solid block, light weight sandwich panels and in highway construction as part of sub base where frost is harmful for sub grade stability.

Glass fibre reinforced gypsum (GFRG) panels are machine made in less than one hour. All GFRG panels are 12 meters length and 3 meters height. The panels are cellular in form and are 124 millimetres thick. Construction using GFRG panels is very fast, low in cost and eliminates the need for bricks, blocks, sand, wall framing and plastering. The selection of structural system, analysis and the design should be performed as per the Structural Design Manual prepared by IIT, Madras, India.

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.

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 [1]. 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 quite resistant to alkalis, methanol, oxidising 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. [1]. 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. SCOPE OF WORK

Disposal of phosphogypsum is one of the serious issues faced by the phosphate industry. The effective utilization of this waste material is done by manufacturing of a new construction material known as Glass Fiber Reinforced Gypsum (GFRG) panel, also known in the industry as Rapidwall. These are prefabricated panels used as load bearing and as well as non- load bearing structure. GFRG panels can be unfilled when used as partition walls, but when used as external walls, it is filled with M₂₀ grade concrete (reinforced concrete filling) in order to resist the lateral loads. M₂₀ grade concrete is adopted in order to satisfy the minimum requirements stipulated in IS 456:2000.

In this work, phosphogypsum and expanded polystyrene (EPS) beads are used as partial replacement of cement and fine aggregates by limiting the strength of concrete to that of M₂₀ grade concrete. Tests pertaining to workability, compression, split tensile and flexural were conducted to study the strength characteristics of the mixes.

III. MATERIALS AND METHODS

Ordinary Portland cement, fine aggregate, coarse aggregate, 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.

A. Cement

Ordinary Portland cement (OPC) conforming to IS 12269-1999 (43 Grade) was used for the experimental work. Laboratory tests were conducted on cement to determine standard consistency, initial setting time, final setting time, specific gravity, fineness, and compressive strength as per 4031-1967(reaffirmed 1995). The results are presented in Table 1

TABLE 1. PROPERTIES OF CEMENT

Sl No	Particulars	Values
1	Grade	OPC 43
2	Standard Consistency, %	32.5
3	Initial setting time, min	80
4	Final setting time, min	220
5	Specific gravity	3.16
6	Fineness, %	7
7	3rd day compressive strength, N/mm ²	25
8	7th day compressive strength, N/mm ²	36
9	28th day compressive strength, N/mm ²	47

B. Fine Aggregate

M 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 2. Fine aggregate used conforms to IS 383:1970 specification (Zone II).

TABLE 2. PROPERTIES OF FINE AGGREGATE

Sl No.	Particulars	Values
1	<i>Specific gravity</i>	2.33
2	<i>Fineness modulus</i>	2.732
3	<i>Effective size</i>	0.18mm
4	<i>Uniformity coefficient</i>	3.83
5	<i>Sand type</i>	Medium

C. Coarse Aggregate

In the construction of GFRG panels, maximum size of coarse aggregate used is 12.5mm. 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 3.

TABLE 3. PROPERTIES OF COARSE AGGREGATE

Sl No	Particulars	Values
1	Specific gravity	2.67
2	Void ratio	0.77
3	Bulk Density	1.538
4	Porosity	0.44

D. Phosphogypsum

The phosphogypsum used in this investigation was collected from FACT-RCF building products Ltd, Kochi, Kerala. The physical and chemical properties are presented in Table 4 and Table 5 as obtained from vendor.

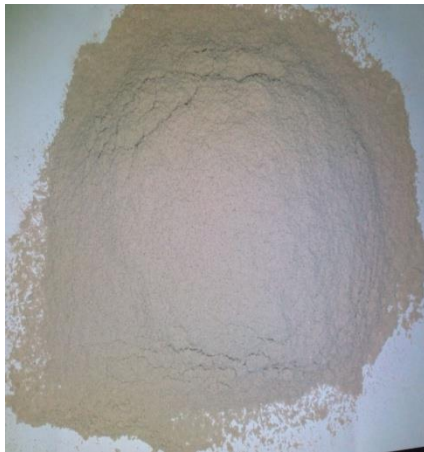


Fig .1. Phoshogypsum

TABLE 4. PHYSICAL PROPERTIES OF PHOSPHOGYPSUM

Sl No	Physical Properties	
1	Moisture at 50°C	8.72%
2	Combined Moisture	17.54%
3	Bulk Density	0.88gm/cc

TABLE 5. CHEMICAL COMPOSITION OF PHOSPHOGYPSUM

Sl No	Chemical composition at dried at 250°C	
1	Calcium as CaO	39.54%
2	Sulphur as SO ₃	56.48%
3	CaSO ₄	95.40%
4	Total P ₂ O ₅	0.83%
5	Water soluble P ₂ O ₅	0.22%
6	Citrate soluble P ₂ O ₅	0.79%
7	Citrate insoluble P ₂ O ₅	0.32%
8	Acid Insoluble	2.26%
9	Fluorine	0.46%
10	Sodium as Na ₂ O	0.07%
11	Potassium as K ₂ O	0.05%
12	Iron as Fe ₂ O ₃	0.01%
13	Aluminium as Al ₂ O ₃	0.04%
14	R ₂ O ₃	0.05%
15	Magnesium as MgO	0.01%
16	Chloride	2ppm

E. 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 6.



Fig 2. EPS Beads

TABLE 6. PROPERTIES OF EPS BEADS

Sl No.	Properties	Description
1	Appearance	White emulsion
2	Specific gravity	0.0075
3	Freeze / thaw resistance	Excellent
5	Flammability	Non – flammable
6	Compatibility	Can be used with all types of Portland cement

F. Concrete Mixes

Mixes M₂₀ and M₂₅ grade concrete were designed as per IS 10262:1982 and IS 10262:2009. Several trial mixes were casted to arrive at the appropriate mix proportion. The Table 7 and Table 8 show the details of test specimen and mix proportioning of concrete.

TABLE 7. DETAILS OF TEST SPECIMEN

Sl No	Specimen	Size (mm)
1	Cube	150x150x150
2	Cylinder	150x300
3	Beam	100x100x500
4	GFRG panel	300x300x124

TABLE 8. MIX PROPORTIONING

Mix	Cement (Kg/m ³)	Water (Kg/m ³)	FA (Kg/m ³)	CA (Kg/m ³)	w/b Ratio
M ₂₀	345	183	758	941	0.53
M ₂₅	382	183	745	925	0.48

IV. EXPERIMENTAL PROCEDURE

A. Preparation Of Mixes

M₂₅ grade concrete mix is taken as the reference mix and designated as M_R. The optimum percentage replacement of cement with phosphogypsum was found by preparing samples with various replacement levels of 0%, 2.5%, 7.5%, and 10%. Water cement ratio of the reference mix was kept at 0.48. The optimum percentage of phosphogypsum was found to be 5%. This mix with optimum percentage of phosphogypsum is used further to find the optimum percentage of EPS beads. Fine aggregate is replaced with 0%, 5%, 10%, 15%, 20% and 25% 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 9 and Table 10 respectively.

TABLE 9. MIX PROPORTIONS FOR VARIOUS PERCENTAGES OF PHOSPHOGYPSUM

Mix	Phosphogypsum (%)	Cement (Kg/m ³)	Phosphogypsum (Kg/m ³)	Fine Aggregate (Kg/m ³)	Coarse Aggregate (Kg/m ³)
M _R	0	382	0	745	925
M _{R 2.5}	2.5	372.45	9.55	745	925
M _{R 5}	5	362.5	19.1	707.75	925
M _{R 7.5}	7.5	353.35	28.65	670.5	925
M _{R 10}	10	343.8	38.2	633.25	925

TABLE 10. MIX PROPORTIONS FOR VARIOUS PERCENTAGES OF EPS BEADS

Mix No	Cement (Kg/m ³)	Phosphogypsum (Kg/m ³)	Fine Aggregate (Kg/m ³)	EPS Beads (Kg/m ³)	Coarse Aggregate (Kg/m ³)
M _R	382	0	745	0	925
M _{R 5,0}	362.5	19.1	745	0	925
M _{R 5,5}	362.5	19.1	707.75	0.12	925
M _{R 5,10}	362.5	19.1	670.5	0.24	925
M _{R 5,15}	362.5	19.1	633.25	0.36	925
M _{R 5,20}	362.5	19.1	596	0.48	925
M _{R 5,25}	362.5	19.1	558.75	0.6	925

Where M_{R 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 compacting 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 5816:1999.

V. RESULTS AND DISCUSSIONS

A. Workability Tests

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

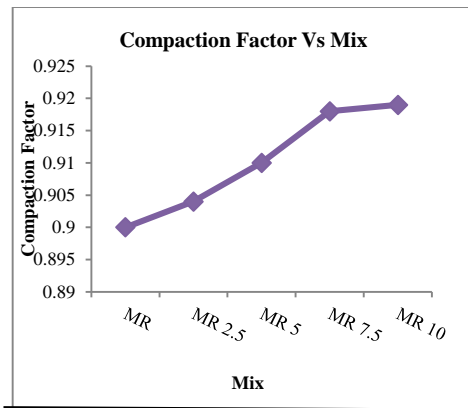


Fig .3. Compaction factor of cement replaced with phophogypsum Vs mix

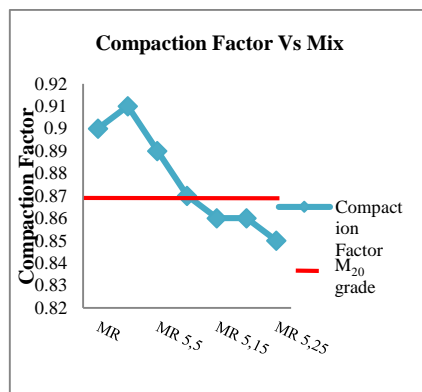


Fig .4. Compaction factor of mix with phosphogypsum and EPS beads

Compaction factor tends to decrease with increase in percentage of EPS beads due to the increase in the volume of voids. Compaction factor of M₂₀ grade casted is also shown in the figure.

B. Compressive strength Vs percentage of phosphogypsum

The variation in cube compressive strength for the concrete mix (M_R) with various percentages of phosphogypsum (replacing cement) is furnished in figure 5.

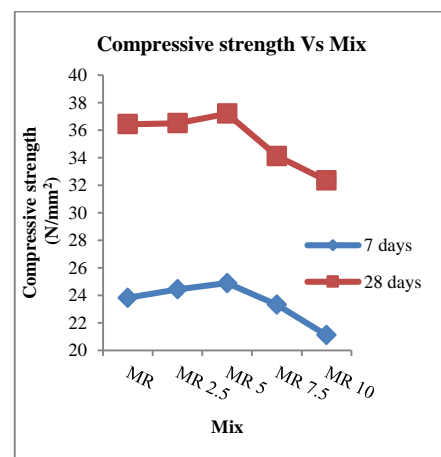


Fig .5. Compressive strength Vs Mix

The optimum percentage replacement of cement with phosphogypsum was found at 5% replacement level.

C. Compressive strength Vs percentage of EPS beads

The variation in cube compressive strength for the concrete mix (M_R) with various percentages of EPS beads (replacing fine aggregate) is furnished in figure 6.

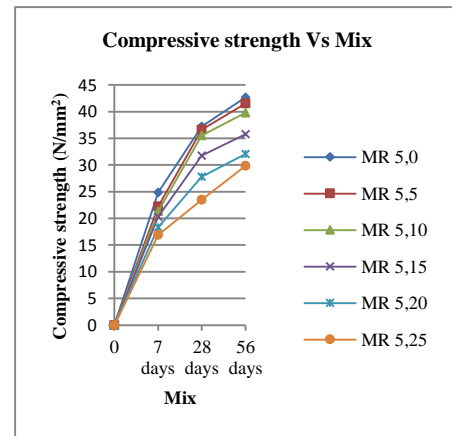


Fig .6. Compressive strength Vs Mix

The compressive strength of concrete cubes decreased gradually as the percentage of EPS beads was increased. The mean target strength of M₂₀ grade concrete is 26.6MPa and the compressive strength of the specimens with upto 20% replacement exceeded this value.

C. Density

Density of concrete prepared using various percentages of EPS beads is illustrated in figure 7.

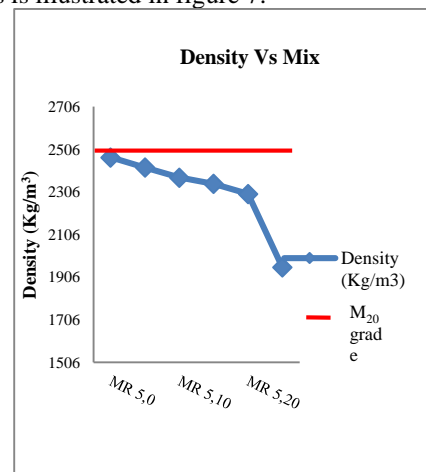


Fig .7. Density Vs Mix

As expected, the density of concrete decreased with the addition of EPS beads since they are light weight materials having low specific gravity.

D. Split tensile strength, Flexural strength and Modulus of elasticity

The split tensile strength, flexural strength and modulus of elasticity of concrete obtained for the concrete specimens prepared using various percentages of EPS beads are represented in the following figures.

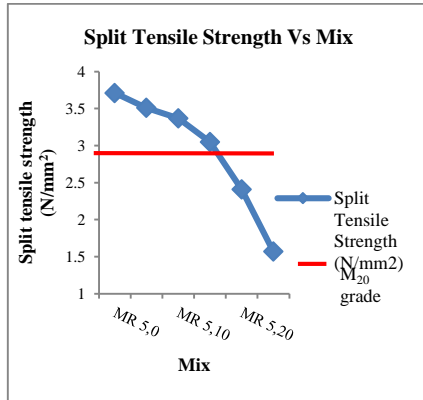


Fig .8. Split tensile strength Vs Mix



Fig .9. Concrete with 10% replacement of EPS beads



Fig .10. Concrete with 20% replacement of EPS beads

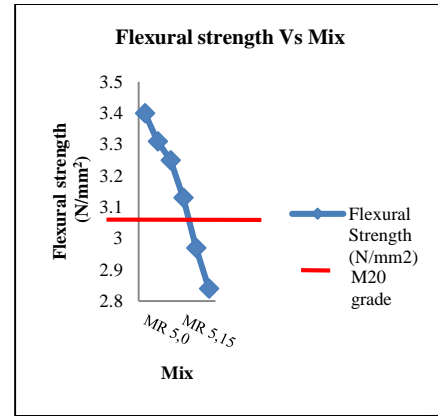


Fig .11. Flexural strength Vs Mix

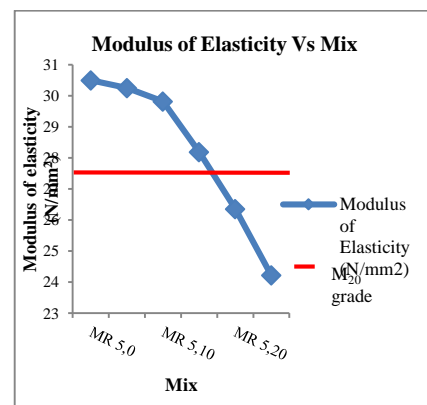


Fig .12. Modulus of elasticity Vs Mix

Though the split tensile strength, flexural strength and modulus of elasticity of concrete reduced with the addition of EPS beads to the concrete, the values exceeded that of M₂₀ grade concrete up to the addition of 15% of EPS beads.

E. Cost comparison

The cost of materials for one cubic meter of concrete for different mixes is given in Table 11.

TABLE 11. COST OF MATERIALS

Mix No	Cement (Kg/m ³)	Phosphogypsum (Kg/m ³)	Fine Aggregate (Kg/m ³)	EPS Beads (Kg/m ³)	Coarse Aggregate (Kg/m ³)	Cost (Rs)
M ₂₀	345	0	758	0	941	4073.6
M _R	382	0	745	0	925	4355.73
M _{R 5,0}	362.5	19.1	745	0	925	4208.44
M _{R 5,5}	362.5	19.1	707.75	0.12	925	4171.75
M _{R 5,10}	362.5	19.1	670.5	0.24	925	4135.05
M _{R 5,15}	362.5	19.1	633.25	0.36	925	4098.33
M _{R 5,20}	362.5	19.1	596	0.48	925	4061.65
M _{R 5,25}	362.5	19.1	558.75	0.6	925	4024.96

Cost of M₂₅ grade concrete is slightly higher than M₂₀ grade concrete. But this difference in cost is compensated by making the concrete light weight as a result of which there is an overall reduction in dead load and optimization of structural elements including the foundation.

VI. CONCLUSION

Replacement of cement with phosphogypsum yielded maximum compressive strength at 5% replacement level. Though workability and strength parameters of the concrete decreased with the addition of EPS beads, the mix with upto 15% replacement of EPS beads yielded better results than that of M₂₀ grade concrete.

Hence mix with 5% phosphogypsum and 15% EPS beads as partial replacement of cement and fine aggregate can be used as a alternative to M₂₀ grade concrete.

Cost comparison of alternate mix with M₂₀ grade concrete showed a marginal increase in cost (0.6%) of concrete per cubic meter which is neutralized by the fact that resultant mix is having lower density than M₂₀ grade concrete (5.27%) and as such there will be considerable reduction in the structural loads due to self weight.

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