Formulation of an Alternate Light Weight Concrete Mix for Concrete Filled Glass Fiber Reinforced Gypsum (GFRG) Panels

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Abstract: ***Glass fiber reinforced gypsum (GFRG) panels are new building materials made essentially of gypsum plaster reinforced with glass fibers. GFRG panels can be unfilled when used as partition walls, but when used as external walls, it is filled with M_{20} grade concrete (reinforced concrete filling) in order to resist the lateral loads. M_{20} 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 aggregates with EPS beads, to formulate a trial mix with optimum percentage which can be used as an alternative to M_{20} 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 M_{20} grade concrete and with the alternative trial mixes. The results of the first stage are presented in this paper.***

Keywords: Prefabricated, Hollow Panels, Light Weight, Phosphogypsum, Expanded Polystyrene (EPS) Beads.

1. 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/m^3 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.

Glass fiber 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 millimeters 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 systems, 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 chloroflurocarbon (CFC) and hydro chloroflurocarbon (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, 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. [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.

2. 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 (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

2.2 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	Specific gravity	2.33
2	Fineness modulus	2.732
3	Effective size	0.18mm
4	Uniformity coefficient	3.83
5	Sand type	Medium

2.3 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

2.4 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.

Table 4: Physical Properties of Phosphogypsum

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

Table 5: Chemical Properties of Phosphogypsum

Sl No	*Chemical Composition 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_2O_5	0.83%
5	Water soluble P_2O_5	0.22%
6	Citrate soluble P_2O_5	0.79%
7	Citrate insoluble P_2O_5	0.32%
8	Acid Insoluble	2.26%
9	Fluorine	0.46%
10	Sodium as Na_2O	0.07%
11	Potassium as K_2O	0.05%
12	Iron as Fe_2O_3	0.01%
13	Aluminium as Al_2O_3	0.04%
14	R_2O_3	0.05%
15	Magnesium as MgO	0.01%
16	Chloride	2ppm

Figure 1: Phosphogypsum

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 6.

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Figure 2: Expanded Polystyrene 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

2.6 Concrete Mixes

Mixes M_{20} and M_{25} 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 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

Table 8: Mix Proportioning

Mix	Cement (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	w/b Ratio
M_{20}	345	183	758	941	0.53
M_{25}	382	183	745	925	0.48

3. Experimental Procedure

3.1 Preparation of Mixes

M_{25} 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	362.9	19.1	745	925
$M_{R\,7.5}$	7.5	353.35	28.65	745	925
$M_{R\,10}$	10	343.8	38.2	745	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
$M_{R\,5.0}$	362.9	19.1	745	0	925
$M_{R\,5.5}$	362.9	19.1	707.75	0.12	925
$M_{R\,5.10}$	362.9	19.1	670.5	0.24	925
$M_{R\,5.15}$	362.9	19.1	633.25	0.36	925
$M_{R\,5.20}$	362.9	19.1	596	0.48	925
$M_{R\,5.25}$	362.9	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 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 5816:1999.

4. 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 11: Compaction Factor of Concrete with Different Percentage Levels of Phosphogypsum

Mix	M_R	$M_{R\,2.5}$	$M_{R\,5}$	$M_{R\,7.5}$	$M_{R\,10}$
Compaction Factor	0.9	0.904	0.91	0.918	0.919

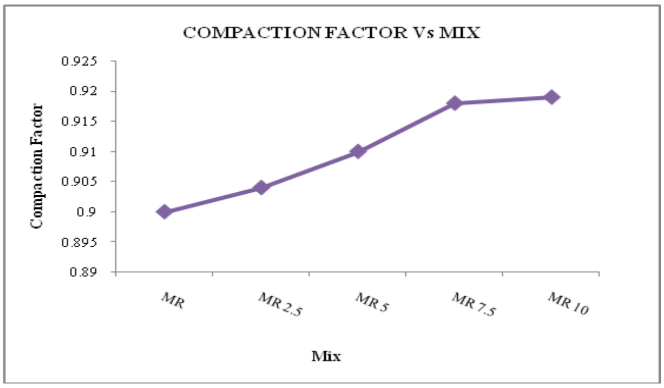

Figure 3: Compaction factor of cement replaced with phosphogypsum Vs mix

Table 12: Compaction Factor of Concrete with 5% Phosphogypsum and different percentage levels of EPS beads

Mix	$M_{R\ 5,0}$	$M_{R\ 5,5}$	$M_{R\ 5,10}$	$M_{R\ 5,15}$	$M_{R\ 5,20}$	$M_{R\ 5,25}$
Compaction Factor	0.91	0.89	0.87	0.86	0.86	0.85

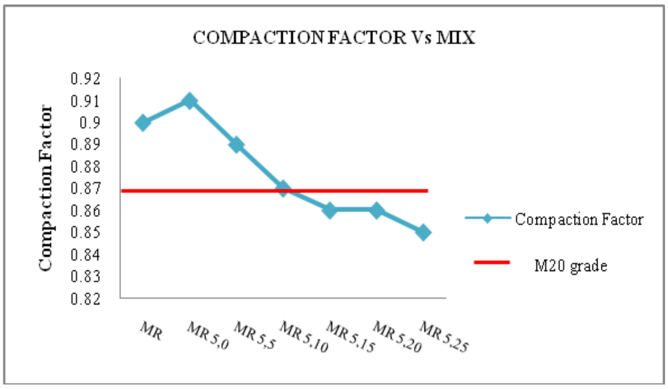

Figure 4: Compaction factor of mix with phosphogypsum and EPS beads

Compaction factor tends to decrease with increase in percentage of EPS beads due to the increase in the volume of voids. Compaction factor of M_{20} grade casted is also shown in the figure.

4.2 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 table 13.

Table 13: Compressive Strength Vs Mix

Mix	*Compressive Strength (N/mm²)*	
	7 days	*28 days*
M_R	23.82	36.44
$M_{R\ 2.5}$	24.43	36.51
$M_{R\ 5}$	24.89	37.2
$M_{R\ 7.5}$	23.32	34.12
$M_{R\ 10}$	21.11	32.34

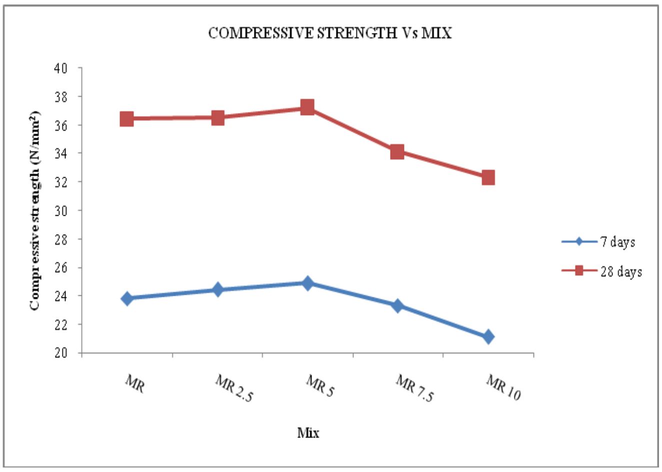

Figure 5: Compressive Strength Vs Mix

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

4.3 Compressive Strength Vs Percentage of EPS Beads

The variation in cube compressive strength for the concrete mix ($M_{R\ 5}$) with various percentages of EPS beads (replacing fine aggregate) is furnished in table 14.

Table 14: Compressive Strength Vs Mix

Mix	*Compressive Strength (N/mm²)*		
	7 days	*28 days*	*56 days*
$M_{R\ 5.0}$	24.89	37.2	42.67
$M_{R\ 5.5}$	22.22	36.6	41.51
$M_{R\ 5.10}$	21.33	35.56	39.78
$M_{R\ 5.15}$	20.28	31.78	35.78
$M_{R\ 5.20}$	18.33	27.78	32.06
$M_{R\ 5.25}$	16.89	23.47	29.84

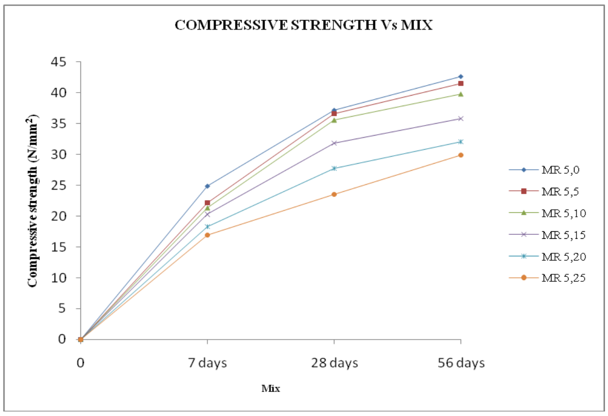

Figure 6: Compressive strength Vs Mix

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

4.4 Density

Density of concrete prepared using various percentages of EPS beads is illustrated in table 15 and fig 7.

Table 15: Density Vs Mix

Mix	*Density (Kg/m^3)*
$M_{R\ 5,0}$	2468.15
$M_{R\ 5,5}$	2420.75
$M_{R\ 5,10}$	2373.33
$M_{R\ 5,15}$	2343.71
$M_{R\ 5,20}$	2296.3
$M_{R\ 5,25}$	1952.59

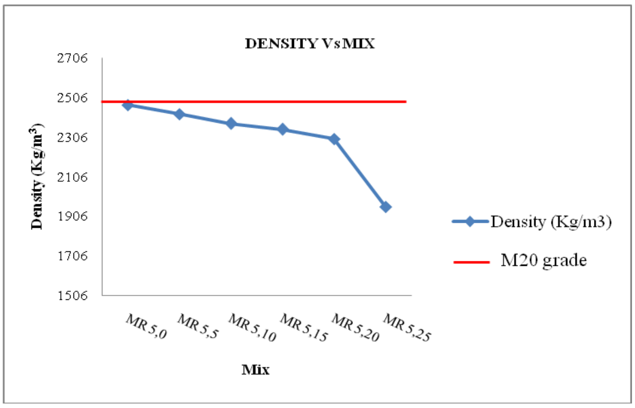

Figure 7: Density Vs Mix

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

4.5 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 table and figures.

Table 16: Split Tensile Strength, Flexural Strength and Modulus of Elasticity of Concrete Vs Mix

Mix	*28 days*		
	Split Tensile Strength (N/mm^2)	*Flexural Strength (N/mm^2)*	*Modulus of Elasticity (N/mm^2)*
$M_{R\ 5,0}$	3.71	3.4	30.495
$M_{R\ 5,5}$	3.51	3.31	30.248
$M_{R\ 5,10}$	3.37	3.25	29.817
$M_{R\ 5,15}$	3.05	3.13	28.187
$M_{R\ 5,20}$	2.41	2.97	26.353
$M_{R\ 5,25}$	1.57	2.84	24.222

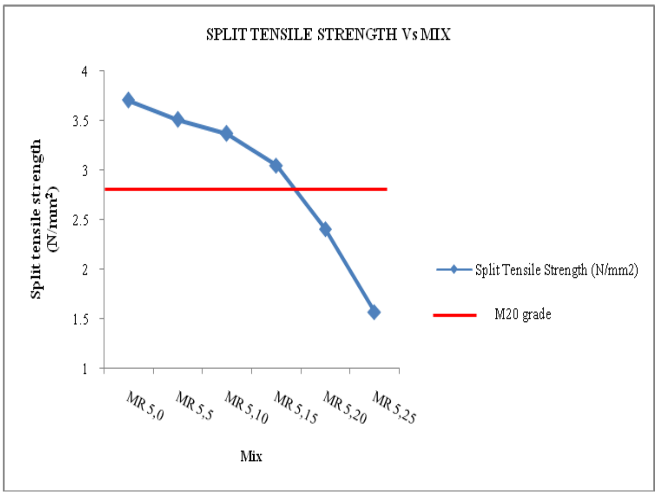

Figure 8: Split tensile strength Vs Mix

Figure 9: Broken surface of concrete cylinder with 10% replacement of EPS beads

Figure 10: Broken surface of concrete cylinder with 20% replacement of EPS beads

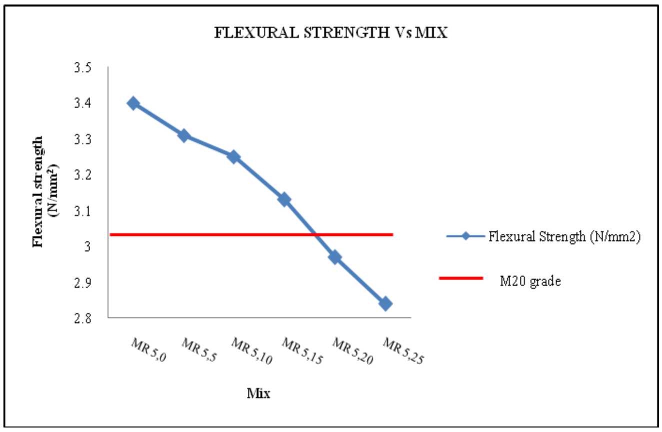

Figure 11: Flexural Strength Vs Mix

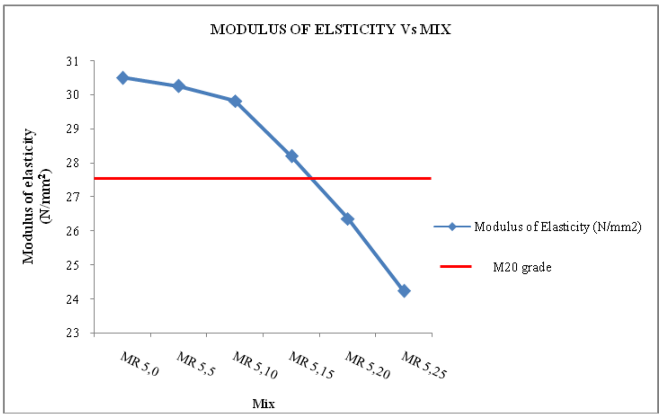

Figure 12: Modulus of Elasticity Vs Mix

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 M_{20} grade concrete upto the addition of 15% of EPS beads.

4.6 Cost comparison

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

Table 17: Cost of materials

Mix No	*Cost (Rs)*
M_{20}	4073.6
M_R	4355.73
$M_{R\ 5,0}$	4208.44
$M_{R\ 5,5}$	4171.75
$M_{R\ 5,10}$	4135.05
$M_{R\ 5,15}$	4098.33
$M_{R\ 5,20}$	4061.65
$M_{R\ 5,25}$	4024.96

5. Conclusions

- 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 M_{20} grade concrete.
- Hence mix with 5% phosphogypsum and 15% EPS beads as partial replacement of cement and fine aggregate can be used as an alternative to M_{20} grade concrete.
- Cost comparison of alternate mix with M_{20} 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 M_{20} grade concrete (5.27%) and as such there will be considerable reduction in the structural loads due to self weight.

References

[1] Cook, D.J. Chapter 2: Expanded polystyrene concrete, in the book of Concrete Technology and Design vol.1, New Concrete, Materials, editor: Swamy, R.N., Surrey University Press, pp 41-68, 1983.
[2] Abraham, M.K., E. John and B. Paul," A Study on the Influence of Mineral Admixtures in Cementitious System Containing Chemical Admixtures", International Journal of Engineering Research and Development, Vol 10, 76-82, 2014.
[3] IS:383–1970,Specification for coarse and fine aggregate from natural sources for concrete, Bureau of Indian Standards, New Delhi.
[4] IS: 456-2000, Plain and Reinforced Concrete- Code of Practice, Bureau of Indian Standards, New Delhi, 2000.
[5] IS: 516-1959, Indian standard code of practice methods of test for strength of concrete, Bureau of Indian Standards, New Delhi, India.
[6] IS: 1199-1959, Indian standard methods of sampling and analysis of concrete, Bureau of Indian Standards, New Delhi, India.
[7] IS: 10262-1982- Recommended guidelines for Concrete Mix Design, Bureau of Indian Standards, New Delhi, 2000.
[8] IS: 12269-1987- Specification for 53 Grade Ordinary Portland cement, Bureau of Indian Standards, New Delhi, 2000.
[9] IS:1727-1967, Indian standard methods of test for pozzolanic materials, Bureau of Indian standards, New Delhi.
[10] Maganti Janardhana,Robin Davis ,S. S. Ravichandran,A. M. Prasad and D. Menon" Calibration of a hysteretic model for Glass Fiber Reinforced Gypsum Wall Panels," Journal of Earthquake Engineering and Engineering Vibration ,vol.13, no.2 ,June, 2014.
[11] Manolia Abed Al-Wahab Ali , "The Possibility Of Produce Self Compacted Polystyrene Concrete", Journal Of Engineering And Development, Vol. 16, No.4, Dec. 2012 ISSN 1813- 7822.
[12] R B Thakare,K G Hiraskar, O P Bhatia, "Utilisation Of Phosphogypsum In Cement Concrete For Strength And Economy" 26th Conference On Our World In Concrete & Structures: 27 - 28 August 2001, Singapore.
[13] Tengku Fitriani L., Subhan, "Lightweight High Strength Concrete With Expanded", "Mektek" Tahun VIII No.1 January 2006.
[14] Tengku Fitriani L. Subhan, "Compressive And Tensile Strength Of Expanded Polystyrene Beads Concrete", "Mektek" Tahun VIII No.1 January 2006.

[15] Yu-Fei Wu and Mike P. Dare, "Axial and Shear Behaviour of Glass Fibre Reinforced Gypsum Wall Panels: Tests", Journal Of Composites For Construction, Vol 10.1061/ (ASCE) 1090-0268 8:6 (569) ,2004.
[16] Yu-Fei Wu, "The effect of longitudinal reinforcement on the cyclic shear behaviour of glass fibre reinforced gypsum wall panels: Tests", Engineering Structures 26, 2004, 1633–1646.
[17] Yu.-Fei. Wu and M. P. Dare, "Flexural and Shear Strength of Composite Lintels in Glass-Fibre-Reinforced Gypsum Wall Constructions, Journal Of Materials In Civil Engineering, Vol 10.1061/ (ASCE) 0899-1561 (2006) 18:3 (415).

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