Experimental Investigation on Ternary Blended Concrete Containing Silica Fume and Phosphogypsum

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***Abstract*—Phosphogypsum is the second largest waste material produced in the World. It contained small quantities of silica, fluorine and phosphate as impurities. These impair the strength development of calcined products. Because of the reason phosphogypsum can be effectively used in cement replacement. 10% Silica fume and 5-15% of phopshogypsum by weight of cement are used for this investigation**

***Keywords*— Calcined products; Phosphogypsum; Silica fume; Ternary blended concrete.**

I. INTRODUCTION

Ordinary concrete has a single cementitious material i.e. cement. Binary blend of concrete includes cement as the binding material and a pozzolanic material being added. Ternary blended concrete marks the inclusion of two different pozzolanic materials to the concrete with cement acting as the primary binding material. Fly ash from coal fired power plants and metakaolin are both important in modern concrete technology. Enlarging the scope of material science to Supplementary Cementious Materials (SCM) viz., fly ash, slag, silica fume, rice husk ash and Metakaolin in the use of concrete, this led to the concept of blended cements and blended concretes. In India, about 6 million tons of waste gypsum such as phosphogypsum, flourogypsum etc., are being generated annually. Phosphogypsum is a by-product in the wet process for manufacture of phosphoric acid (ammonium phosphate fertilizer) by the action of sulphuric acid on the rock phosphate. Current worldwide production of phosphoric acid yields over 100 million tons of phosphogypsum per year. While most of the rest of the world looked at phosphogypsum as a valuable raw material and developed process to utilize it in chemical manufacture and building products.

II. MATERIALS AND METHODS

Materials used are cement, fine aggregate, coarse aggregate, silica fume and phosphor gypsum. All materials are tested as per standard procedures to assess their engineering properties and the results were compared with those in relevant IS codes. Cement used in this investigation is the Ordinary portland cement of 53 grade manufactured by Dalmia with specific gravity 3.125. Table 1 shows the properties of cement. The fine aggregate used was M sand with Fineness modulus 3.714 and fineness modulus of coarse aggregate is 3.871.Table 2 and Table 3 shows the properties of fine aggregate and coarse aggregate respectively. For this study silica fume is collected from Bison shelter system, Edaplly, Kochi. It is having specific gravity of 2.73. Phopspho gypsum is an industrial waste having very fine characteristics. It is collected from FACT, Ambalamedu, Kochi . Specific gravity of phopspho gypsum is obtained as 2.31. Super plasticizer used to improve workability is Master Glenium SKY 8233 (Formerly Glenium B233). The mix design is done as per IS 10262-2009.Fig.1 and Fig.2 shows the sample of silica fume and phosphogypsyum used in the study. Table 4 shows the design mix proportion Table 5 shows the quantity of materials used and Table 6 shows the percentage replacement.

Table 1: Properties of Cement

Fineness	5%
Consistency	35%
Initial setting time	240 minutes
Specific gravity	3.125

Table 2: Properties of Fine aggregate

Specific gravity	2.69
Bulk density	1.2256
Percentage voids	54.53%
Water absorption	1.5%
Fineness modulus	3.714

Table 3: Properties of Coarse aggregate

Specific gravity	2.67
Bulk density	1.324
Percentage voids	50.412%
Water absorption	0.8%
Fineness modulus	3.871

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Fig.1.Silica Fume

Fig.2.Phosphogypsum

Table 4: Design Mix Proportion of M30 Mix

Grade of Concrete	Mix Proportion			
	Cement	*Fine Aggregate*	*Coarse Aggregate*	*Water-Cement Ratio*
M30	1	2.426	3.154	0.45

Table 5:Quantity of Materials Used in Kg/m^3

Mix	Cement Kg/m³	Silica Fume Kg/m³	Phosphogypsum Kg/m³
M30	350.22	0	0
PG0	315.00	30.58	0
PG5	297.50	30.58	13.11
PG7.5	288.75	30.58	19.66
PG10	280.00	30.58	26.21
PG12.5	271.25	30.58	32.76
PG15	262.50	30.58	39.31

Table 6: Mix Designation with Varying Percentage of Phosphogypsum (PG)

Mix Designation	%of Cement	% of Cement Replaced with Silica Fume	% of Cement Replaced with PG
M30	100	0	0
PG0	90	10	0
PG5	85	10	5
PG7.5	82.5	10	7.5
PG10	80	10	10
PG12.5	77.5	10	12.5
PG15	75	10	15

III. COMPRESSIVE STRENGTH TEST

Testing of hardened concrete is important for controlling the quality of concrete. The main purpose of testing hardened concrete is to conform that the concrete has developed required strength. The compressive strength is one of the most important properties of hardened concrete and in general it is the characteristic value for classification of concrete in various codes. Compression test of cubes is the most common test conducted on hardened concrete because it is an easy test to perform and most of the desirable properties of concrete are comparatively related to its compressive strength. The compression test was carried out on cubical specimen of size 150mm×150mm×150mm in a compression testing machine of capacity 2000 kN, at a loading rate of 14N/mm^{2}per minute as per IS 516:1959 specification. The test was done on all the eight mixes for determining the 3rd day, 7th day and 28th day compressive strength. Fig.3 shows compression test on cube.

Fig.3. Compressive strength testing machine

IV. TEST RESULTS

Hardened tests for concrete are conducted on control mix as well as on concrete containing 10% of silica fume and varying percentage of phosphogypsum. Hardened properties of OPC, PG0, PG5, PG7.5, PG10, PG12.5 and PG15 mixes were studied. Silica fume and phosphogypsum used in appropriate amount modifies certain properties of fresh and hardened concrete.

A. Hardened properties of concrete

Hardened properties of concrete made with different percentage of phosphogypsum and 10% silica fume is evaluated by doing compressive strength test. Compressive strength values of M30.PG0, PG5, PG7.5, PG10, PG12.5, PG15 are plotted in Fig.4 to Fig 10. Table 4 shows the different values.

Table 7: Different Values of Strength

Mix Designation	Compressive Strength(N/Mm^2)		
	3 Day	7 Day	28 Day
M30	21.05	27.40	40.90
PG0	21.80	28.30	41.10
PG5	22.00	29.00	42.05
PG7.5	18.10	29.25	43.40
PG10	16.20	29.95	44.10
PG12.5	15.45	28.25	41.20
PG15	13.70	26.55	39.85

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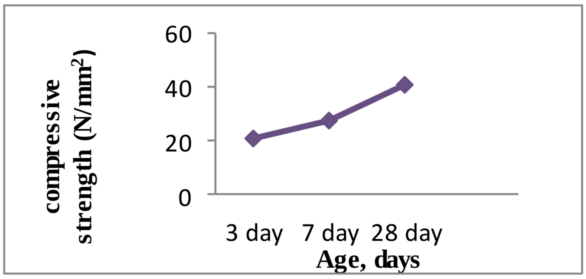


Fig.4.Compressive Strength Values of M30

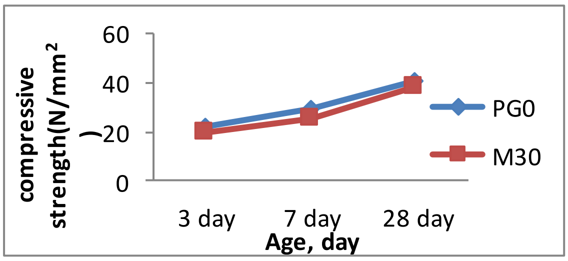


Fig.5.Compressive Strength Values of PG0

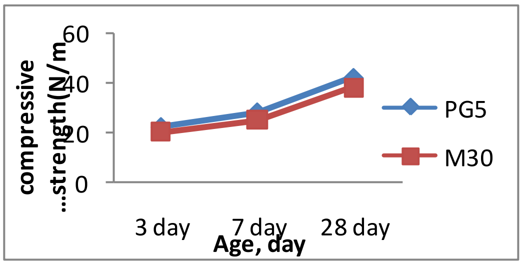


Fig.6.Compressive Strength Values of PG5

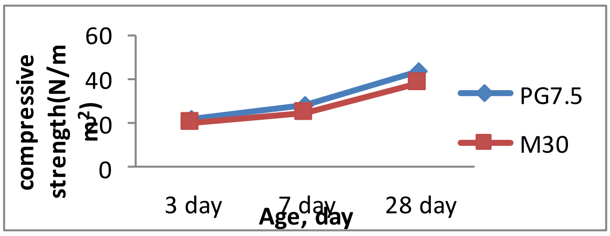


Fig.7.Compressive Strength Values of PG7.5

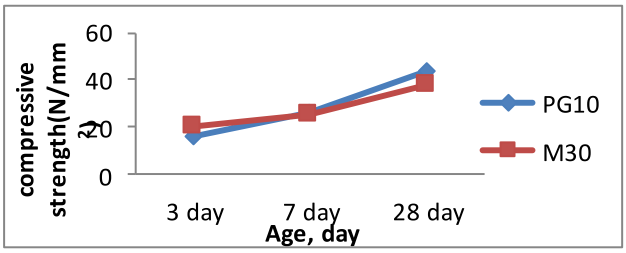


Fig.8.Compressive Strength Values of PG10

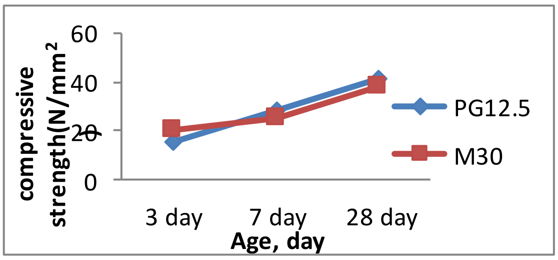


Fig.9.Compressive Strength Values of PG12.5

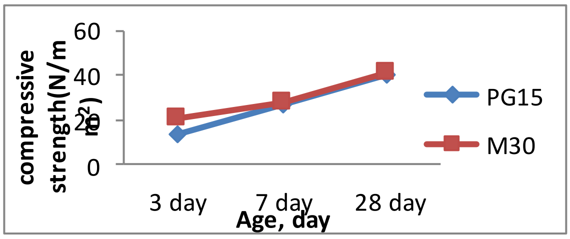
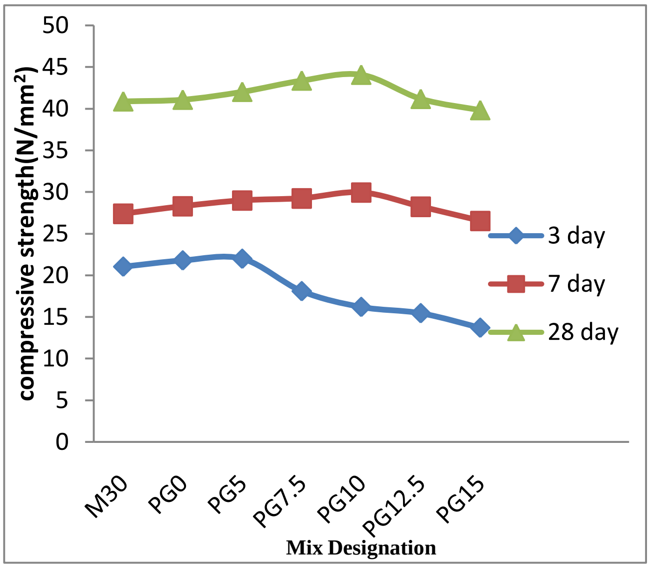


Fig.10.Compressive Strength Values of PG15

Fig.11 shows the variation of compressive strength with age for different type of mixes. 3 day and 7 day compressive strength graph shows a decreasing pattern. But 28 day strength goes on increasing with respect to increasing phosphogypsum percentage. This indicate that phosphor gypsum contribute to the later age strength development.



V. CONCLUSIONS

- The results indicate that use of raw PG is suitable for concreting work. Because of its fine gradation, phosphogypsum provides additional workability, compactability and surface finishability of the mix.
- The incorporation of phopshogypsum in concrete decreases the strength of concrete as the increase in replacement level of phosphogypsum greater than 10% along with 10% silica fume.
- Optimum strength is obtained at 10% replacement of cement with phosphogypsum.

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- Total 20% of cement cane be replaced effectively by using silica fume and phosphogypsum.
- 10% silica fume replacement also give strength greater than control mix. Addition to this 5% phosphogypsum along with 10% silica fume gave higher strength than 10% silica fume alone.
- Ternary blended concrete help in development of later age strength of PG7.5, PG10 etc.
- The replacement of cement results in reduction of density of concrete. This is due to the fact that the specific gravity of phosphogypsum and silica fume is much lower than that of cement.

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