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Comparative Study of Phosphogypsum and Phosphogypsum plus Flyash Mix Concrete

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Abstract : *The growing use of phosphoric acid production by product phosphogypsum increased. Around 6 million tons of phosphogypsum are produced every year in India. Flyash is a byproduct from thermal power station around 165 million tons production in India. To avoid land pollution these byproducts are incorporated in to concrete. The current investigation is based on replacement of cement with phosphogypsum and phosphogypsum plus fly ash. Nine mixes were considered by replacing cement with 4,8,12 and 16% of phosphogypsum with cement and phosphogypsum plus fly ash for M25 grade of standard concrete. Nine cubes were casted to study 7, 28 and 56 days strength of concrete. By incorporating fly ash with phosphogypsum the results of workability and compressive strength were improved. Also the rate of strength gain is higher in phosphogypsum plus fly ash mix concrete*.

Keywords: *Flyash, Phosphogypsum, Strength, Workability*

I. Introduction

The In this modern era, construction work of any kind of structures all over the world either buildings, bridges , roads or any other type of structure are mainly required concreting. Concrete is the backbone of engineering construction and it is one of the oldest and most versatile building materials used in civil engineering construction. The advantages of using concrete include relatively good compressive strength, formability, locally availability of its raw materials and suitability to withstand different environmental condition. With the advancement of technology due to the rapid industrialization, the generation of waste material has increased in last few years, which need to be utilized or disposed safely to save our valuable agricultural lands. Dumping in the vicinity of industries may lead to environmental pollution mainly land pollution. Phosphogypsum and flyash is also industrials by product materials and it is generated in large quantities every years. Also production of one tons of cement produces approximately a ton of carbon dioxide into the environment. In order to reduce the greenhouse gas emission due to production of cement, the use of industrial by products like phosphogypsum, fly ash, blast furnace slag and supplementary cementitious materials (SCM) such as Rice husk, Metakaolin, etc. are replaced partially or fully.In India about 6 MT of phosphogypsum is produced from the phosphoric acid industries annually out of which only 15% phosphogypsum are used in manufacturing of chemical and building products [1]. Fly ash is the byproduct of thermal power plants. The production of flyash is around 169 million tons (MT) in India [2]. These cementation materials contain significant amounts of silica, alumina and calcium, which match with the chemical composition of cement. The use of SCM not only enhance the properties of standard concrete but also reduce the consumption of cement hence the use of phosphogypsum and fly ash in concrete as partial replacement of cement help to minimise the greenhouse gas emission generating during the manufacturing of cement.

II. Literature Review

Thakre et al. (2001) [3] carried out an experimental study on compressive strength and chemical properties of partially mix phosphogypsum mix concrete. The authors work covers the material properties and the mix proportion, and the influence of various parameters on the properties of fresh and hardened concrete. The experimental programmed consist testing of 5, 10, and 15% replaced phosphogypsum mix concrete for M15, M20, M25, and M30 grades of concrete at the age of 28, 35, and 45 days. The chemical analysis of ordinary Portland cement, phosphogypsum and cement plus phosphogypsum was carried out and on the basis of chemical analysis the Bogue's compounds were calculated. The results of chemical analysis indicates cement and 5% phosphogypsum mix produce appropriate quantities of C3S and SO3 which are mainly responsible for production of C-S-H (calcium-silicate-hydrate) and ettringite (Calcium-Sulpho-Alumino hydrate) hydration, strength and durability. And therefore, the concrete produced by this mix must have greater strength and durability than standard mix with further increased in phosphogypsum %, C3S drastically decreased and there is increased in SO3, which result in internal sulphate attack and hence loss of strength and durability. Authors laboratory experiment have shown that all the grades of concrete there is appreciable increased in cube compressive strength for all curing periods when 5% of cement replaced by phosphogypsum. Reddy et al [4] investigated compressive, tensile and flexural strength characteristics of partially cement replaced

phosphogypsum concrete using 0%, 10%, 20%, 30% and 40% replacement with different water-binder ration of 0.40, 0.45, 0.50, 0.55, 0.60 and 0.65.The characteristics strength studied by casting and testing of cube, cylinder and beam specimen for 7, 28 and 90 days, and shown that a part of Portland cement can be replaced with phosphogypsum to develop a good and hardened concrete to achieved economy; above 10% replacement of phosphogypsum in concrete lead to drastic reduction not only in the compressive strength but also in the split tensile strength; the flexure strength decreases as width and number of cracks increases significantly at replacement above 10% of cement with phosphogypsum at different water-binder ratios. Prasad *et al* [5] conducted experimental investigation on flyash based geopolymer concrete made by replacing flyash with GGBS and phosphogypsum in percentages ranging from 0, 2.5, 5, 7.5, and 10%. The study includes assessment of split tensile strength and flexure strength of geopolymer concrete specimens at the age of 28 days and 90 days. As per their test result they conclude that the strength of geopolymer concrete made by blending with GGBS has increased as increased in GGBS percentage and in case of phosphogypsum the strength has increased up to certain limit and decreased with increased in phosphogypsum percentage. It is observed from the previous research that most of researchers conducted investigation only on phosphogypsum at various percentage of replacement with cement such as 5, 10, 15, 20%. At present, there are very few literature available on phosphogypsum blend fly ash by replacing cement. This study is based on by partial replacement of phosphogypsum and phosphogypsum blend fly ash with cement at 4, 8, 12 and 16%.

III. Objectives

The objectives of present work are as follows:

3.1 To study the fresh and hardened state properties of concrete by partially replacing cement with phosphogypsum.

3.2 To study the fresh and hardened state properties of concrete by partially replacing cement with phosphogypsum plus flyash.

3.3 Comparative study on phosphogypsum and phosphogypsum plus flyash concrete mix.

IV. Properties of Materials

In the present experimental work the materials used are such as cement, phosphogypsum, fly ash, river sand as fine aggregate, coarse aggregate and water. The properties of materials and their relative proportions are as follows.

4.1 Cement

Cement use in the work was Ambuja cement 53 Grade Ordinary Portland cement. The properties of cement used are presented in Table 1.

Table 1 Properties of cement

Properties	Result	Permissible limits
Initial setting time (min)	30	IS 4031-PART 5-1988
Final setting time (min)	600	
Specific gravity	3.15	
Consistency (%)	34	IS 4031-PART 11-1988

4.2 Phosphogypsum

Phosphogypsum was obtained from the Rashtriya Chemical and Fertilizers (RCF), chembur plant in Maharashtra state, India. It was tested according to IS: 12679 1989 and found to be satisfy the requirement of IS: 12679-1989. The chemical composition of phosphogypsum is as shown in table 2. The specific gravity obtained was 3.15. The phosphogypsum known to have some of the chemical impurities likes phosphate. Phosphogypsum supposed to be treated for these impurities. Therefore phosphogypsum without treatment referred here as raw or impure phosphogypsum.

Table 2 Chemical composition of phosphogypsum

Chemical constitute	Percentage %
CaO (calcium Oxide)	31.2
SiO2 (Silicon Dioxide)	3.92
SO3 Sulphur trioxide	42.3
R2O3 (3 oxide group)	3.6
MgO (Magnesia)	0.49
Phosphate, Fluoride	18.49

4.3 Fly ash

Fly ash (Pozzocrete P60) produced from Dirk India private limited, Nasik is used in the work. It confirms to IS: 3812 part I fly ash and it is subjected to strict quality control. Physical properties and chemical composition along with IS specification are given below in table 3.

Table 3 Physical properties of fly ash

Sr. no	Properties	Fly Ash (P 60)
1	State or form	Finely divided powder
2	Color	Light grey
3	Specific gravity	2.3
4	Fineness – specific surface by Blaine's air permeability method	320 m^2/kg
5	Compressive strength at 20 days % of plain cement mortar	80%
6	Loss on ignition	< 2.5%

Table 4 Chemical composition of fly ash

Sr. no	Physical properties (% by weight)	Fly ash	IS requirement
1	SiO2+ Fe2O3 + Al2O3	92.45	70 minimum
2	Silica SiO2 as	57.31	35 minimum
3	Magnesium oxide (MgO)	0.46	5 maximum
4	Sulphur as SO3	-	3 maximum

4.4 Aggregates

Locally available Girna river sand was used as fine aggregate and combination of crushed basalt of nominal maximum size of 20 mm is used as coarse aggregate. The properties of coarse and fine aggregates are given in the Table 3 to 5.

Table 5 Properties of Coarse and fine aggregates

Sr. no	Description	Coarse aggregate	Fine aggregate
1	Type	Crushed black trap basalt rock	Natural sand
2	Specific gravity	2.65	2.60
3	Water absorption	SSD	SSD
4	Particle shape	Angular	Rounded

V. Mix Proportioning

The quantity of ingredients M25 grade concrete such cement, water and aggregates are determined by mix design and the quantity of phosphogypsum and fly ash is calculated by the replacing weight of cement. The quantity of ingredients considered for present study is shown in the following table.

Table 6 Quantity of ingredient of concrete per m^3 by mass

		Mix proportion for one cubic meter by mass (kg/ m^3)					
Mix	W/C ratio	Water	Cement	Phospho-gypsum	Fly ash	Fine aggregates	Coarse aggregates
SM	0.5	186	372.00	0	0	688	1144
MP1	0.5	186	357.12	14.88	0	688	1144
MP2	0.5	186	342.24	29.76	0	688	1144
MP3	0.5	186	327.36	44.64	0	688	1144
MP4	0.5	186	312.48	59.52	0	688	1144
MPF1	0.5	186	357.12	7.44	7.44	688	1144
MPF2	0.5	186	342.24	14.88	14.88	688	1144
MPF3	0.5	186	327.36	22.32	22.32	688	1144
MPF4	0.5	186	319.92	26.04	26.04	688	1144

VI. Result and Discussion

This section presents the results on workability and strength of phosphogypsum and phosphogypsum plus fly ash, cement replacement, concrete.

6.1 Results on Workability

The workability was determined by the slump cone method and for every fresh mix the slump cone test was carried out. The mix id and test result on workability using slump as measure of workability are presented in Table 7. The graph is also plotted between phosphogypsum percentages versus slump and phosphogypsum plus fly ash percentages versus slump in Fig 1. It is observed from the figure that the workability of phosphogypsum mix concrete and phosphogypsum plus fly ash mix concrete is continuously fall between 0 to

4% of replacement and almost follows the same pattern of falling but at 4% the workability of phosphogypsum plus fly ash mix concrete is more than phosphogypsum mix concrete. Approximately at 5% workability of both concretes is same but after that it start decreasing gradually. After 8% replacement the workability of phosphogypsum concrete is decreasing more as compared to the phosphogypsum plus fly ash concrete. Phosphogypsum plus fly ash mix concrete has the more workability because of spherical shape particles of fly ash produces the ball bearing effect, thus phosphogypsum plus fly ash concrete has more workable concrete. But in phosphogypsum mix concrete the workability of concrete is low as compared to phosphogypsum plus fly ash concrete because it contains more fine particles and calcium oxide which absorbs the more water and reduces the quantity of water in concrete which decreases the workability of concrete paste. Hence, it is cleared that by addition of fly ash with phosphogypsum the workability of mix comparatively improved.

Table 7 Workability test result by slum cone method

Sr. no	Designation	W/C ration	Percentage of Phosphogypsum	Percentage of fly ash	Workability (slump in mm)
1	SM	0.5	-	-	35
2	MP1	0.5	4	-	19
3	MP2	0.5	8	-	13
4	MP3	0.5	12	-	11
5	MP4	0.5	16	-	5
6	MPF1	0.5	2	2	18
7	MPF2	0.5	4	4	14
8	MPF3	0.5	6	6	13
9	MPF4	0.5	8	8	10

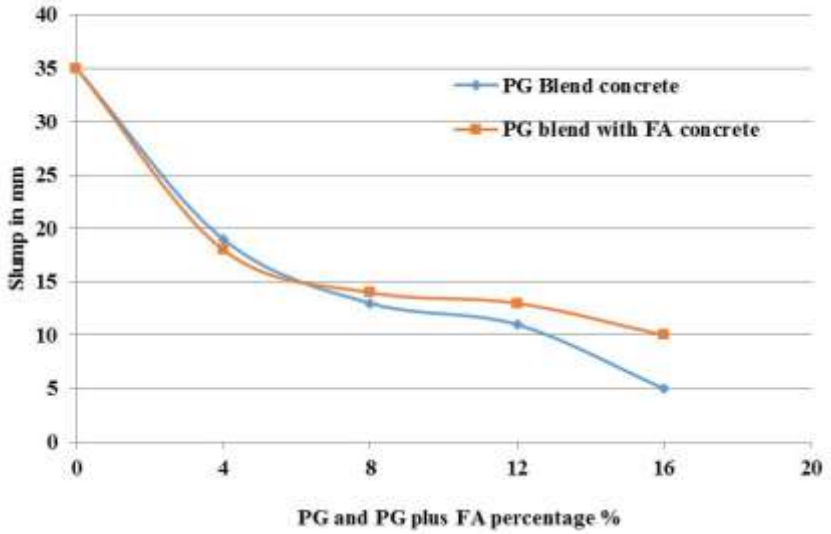

Figure 1 Workability of PG and PG plus FA concrete

6.2 Results on Compressive strength

Nine mixes were considered for compressive strength test at the age of 7, 28, and 56 days. For each mix nine cubes of 150 x 150 x150 mm were casted for curing period 7, 28, 56 days. At the end of each curing period three cubes where tested and average compressive strength was noted as shown in column 5, 6 and 7 in Table 8.

6.2.1 Effect of PG and PG plus FA on compressive strength at 7 Days

It is observed from Fig. 2 the compressive strength of is PG continuously increases up to 8% after that the strength is gradually decreases with increasing in percentage of phosphogypsum but in phosphogypsum plus fly ash concrete the compressive strength is continuously decreases up to 6% after that it start increasing gradually. The compressive strength of phosphogypsum mix concrete and phosphogypsum plus fly ash concrete approximately at 12% is same and furthers both concretes start to decrease but at 16% the compressive strength of phosphogypsum plus fly ash concrete is more as compare to phosphogypsum mix concrete.

Table 8 Compressive strength result

Mix designation	W/C Ratio	Phosphogypsum (%)	Fly ash (%)	Compressive strength (Mpa)		
				7 days	28 days	56 days
(1)	(2)	(3)	(4)	(5)	(6)	(7)
SM	0.5	-	-	19.27	28.76	31.07
MP1	0.5	4	-	20.68	30.89	32.18
MP2	0.5	8	-	21.57	32.21	33.44
MP3	0.5	12	-	19.74	29.09	31.74
MP4	0.5	16	-	16.61	24.82	32.67
MPF1	0.5	2	2	17.61	26.07	33.74
MPF2	0.5	4	4	17.97	26.83	34.97
MPF3	0.5	6	6	20.24	24.04	35.78
MPF4	0.5	8	8	17.61	26.45	38.77

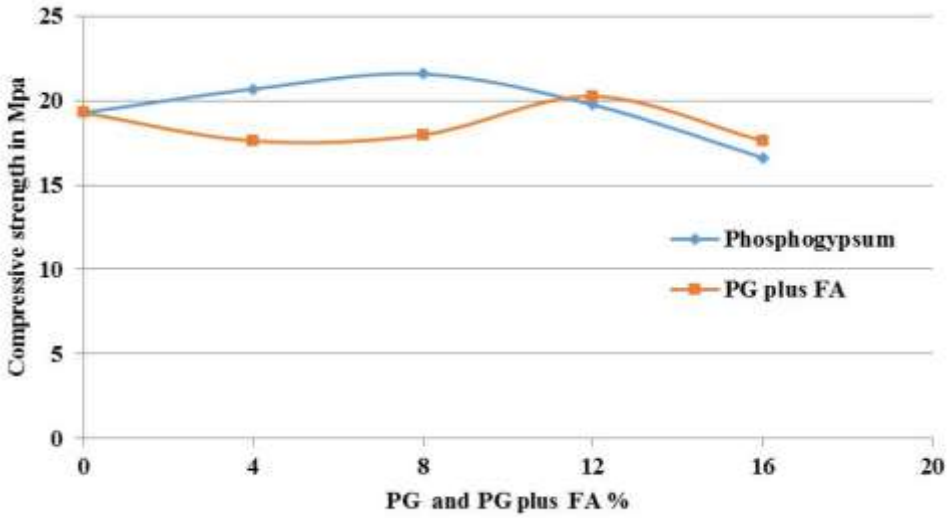

Figure 2 Compressive strength of PG and PG plus FA concrete at 7 days

6.2.2 Effect of phosphogypsum and phosphogypsum plus flyash on compressive strength at 28 Days

The graph is plotted percentage of phosphogypsum and phosphogypsum plus fly ash versus compressive strength. It is observed from Fig. 3, in phosphogypsum mix concrete the rate of gaining strength is more as compare to phosphogypsum plus fly ash concrete. In phosphogypsum mix concrete the strength is increases significantly up to the 12% but after that it starts decreasing. In phosphogypsum plus fly ash concrete the strength is continuously increasing up to 8% and after that it start decreasing up to 12% but after 12% it again start to increasing in strength. Thus the strength is more in phosphogypsum concrete at initial stage while at later stage the strength is more in phosphogypsum plus fly ash concrete as compare to phosphogypsum mix concrete.

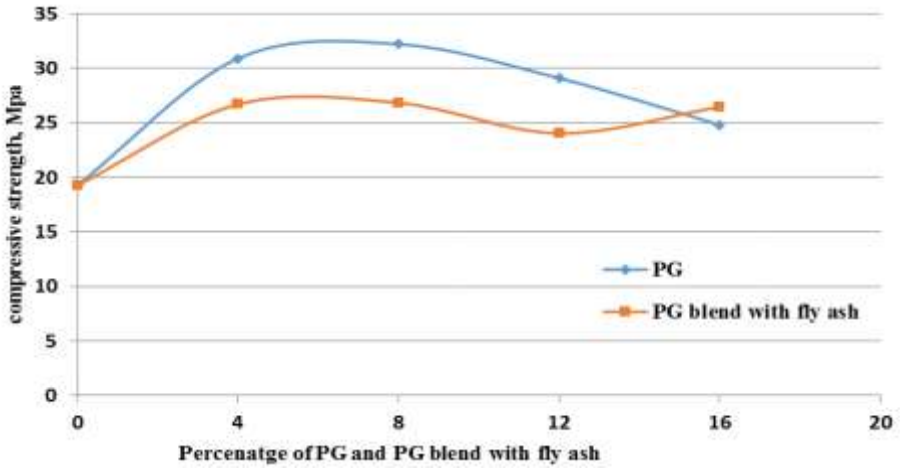

Figure 3 Compressive strength of PG and PG plus FA concrete at 28 days

6.2.3Effect of phosphogypsum and phosphogypsum plus flyash on compressive strength at 56 Days

The graph is plotted for phosphogypsum and phosphogypsum plus fly ash percentage vs. compressive strength at 56 days. The compressive strength in Mpa is plotted on y-axis and the percentage of fly ash and phosphogypsum is plotted on x-axis as shown in Fig. 4. From figure it is observed that compressive strength of phosphogypsum plus fly ash mix concrete is continuously increases with the percentage due the presence of fly ash. Fly ash has the spherical shape which produces the ball bearing effect and makes the concrete dense thus increasing the compressive strength of concrete. The maximum strength of phosphogypsum plus fly ash concrete is obtained at 16%. In phosphogypsum plus fly ash mix concrete the strength is increased with the increased in curing period. The strength in phosphogypsum mix concrete is constantly increases up to 8 % after that it starts decreasing gradually. In phosphogypsum mix concrete the strength is not significantly increases with the time and the maximum strength at 56 days is achieve at 8 % replacement of cement by phosphogypsum.

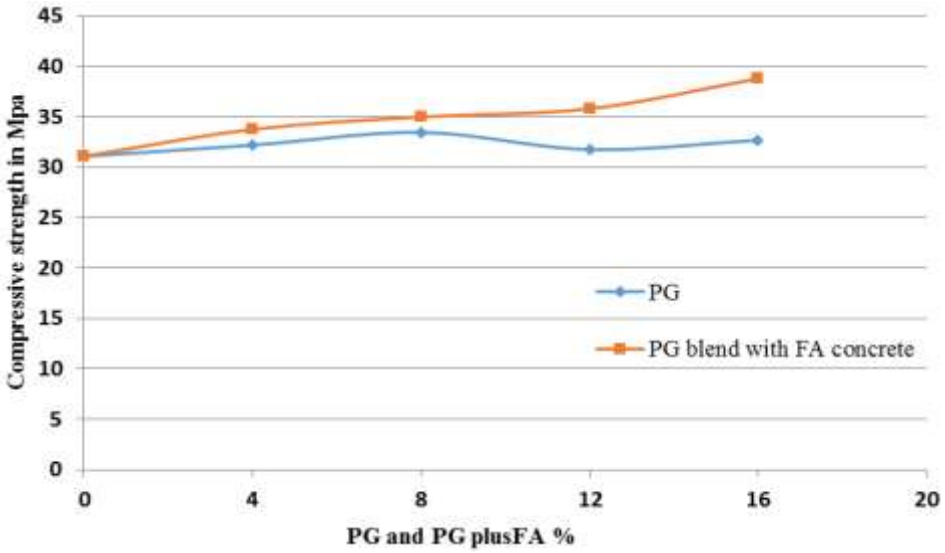

Figure 4 Compressive strength of PG and PG plus FA concrete at 56 days

Table 9 Percentage increment in Compressive strength

Mix	Compressive strength (MPa)			Percentage increment	
	7 days	28 days	56 days	7-28 days (%)	7-56 days (%)
(1)	(2)	(3)	(4)	(5)	(6)
SM	19.27	28.76	31.07	49.25	89.05
MP1	20.68	30.89	32.18	49.37	55.60
MP2	21.57	32.21	33.44	49.32	55.03
MP3	19.74	29.09	31.74	47.36	60.79
MP4	16.61	24.82	32.67	48.42	96.68
MPF1	17.61	26.07	33.74	48.04	91.59
MPF2	17.97	26.83	34.97	49.30	94.60
MPF3	20.24	24.04	35.78	18.77	76.77
MPF4	17.61	26.45	38.77	50.19	120.15

6.2.4 Percentage increment in compressive strength

The compressive strength of phosphogypsum mix and phosphogypsum plus fly ash mix concrete is shown in column no. 2, 3, and 4 of Table 9. The percentage increments in compressive strength are determined between 7-28 days and 7-56 days in column 5 and 6 of Table 9. Percentage increment in 7-28 days of phosphogypsum and phosphogypsum plus fly ash mix concrete is nearly about same i.e. 49% only in MPF3 percentage increment is 18.77. The increment in phosphogypsum concrete of 7-56 days is lower than standard mix and increment in phosphogypsum plus fly ash concrete is more than the standard mix. The increment in phosphogypsum mix concrete lower as compare to phosphogypsum plus fly ash concrete. Thus the percentage increment in compressive strength is higher in phosphogypsum plus fly ash mix concrete.

VII. Conclusions

The conclusions drawn from experimental work as discussed in the previous section are as follows.

1. The workability of phosphogypsum mix concrete decreases with increase in percentage replacement with cement.
2. The workability of phosphogypsum plus fly ash mix concrete is comparatively higher than phosphogypsum mix concrete.
3. The maximum compressive strength of phosphogypsum mix concrete is achieved at 8% replacement of phosphogypsum with cement.
4. The maximum compressive strength of phosphogypsum plus fly ash mix concrete is varying with age of concrete.
5. The later age strength of phosphogypsum plus fly ash mix concrete is high.
6. The early age strength of phosphogypsum mix concrete is high.
7. Percentage increment in compressive strength is higher in phosphogypsum plus fly ash mix concrete.

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