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EFFECTS OF PARTIAL REPLACEMENT OF CEMENT WITH PHOSPHOGYPSUM ON STRENGTH CHARACTERISTICS OF CONCRETE

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ABSTRACT

Phosphogypsum is a by-product of phosphate fertilizer plants and chemical industries for manufacture of phosphoric acid by the action of sulphuric acid on the rock phosphate. It can be gainfully utilized in cement and building materials industries. It needs beneficiation before use because of the presence of deleterious constituents like P_2O_5 and fluoride. The disposal of phosphogypsum is a serious environmental problem. This problem along with scarcity of cement, and its increased cost can be solved to some extent by partial replacing the cement in concrete with phosphogypsum. Due to its pozzolonic properties it can be used for partial replacement of cement.

The present paper deals with the experimental investigation on compressive strength, tensile strength, impact strength and durability characteristics of hardened concrete. The study aims to determine the optimum amount of phosphogypsum that can give maximum strength to the concrete. The experiment consists of testing concrete using 0%, 2.5%, 7.5%, 5%, and 10% replacement of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete. It is observed that cement can be replaced with phosphogypsum to develop to good and hardened concrete to achieve economy. From the discussion of results it can be concluded that 7.5% replacement of phosphogypsum in concrete lead to drastic reduction not only in the compressive strength but in the tensile strength and impact strength.

Keywords: Phosphogypsum, Workability, Compressive Strength, Split Tensile Strength, Impact Strength.

INTRODUCTION

Traditionally materials like clay, sand, gravels, cement, stone, brick, block, tiles, paint, timber, and steel are being used as major building components in construction sector. All these materials have been produced from the existing natural resources and will have intrinsic distinctiveness for damaging the environment due to continuous exploration. In India the cost of cement during 1996 was Rs. 1.25/kg and in 2016 the price increased 5 times. In case of bricks the price was Rs. 0.56 per brick in 1996 and the present rate is Rs.7 per brick. Similarly, the price of sand has increased 6 times over a period of 20 years from the year 1996. Due to this find functional substitutes for conventional materials in construction industry.

In India, about 6 MT of waste gypsum such as phosphogypsum, flurogypsum etc., are being generated annually. It is necessary to set a secondary industries and recycling these waste into useful material. In the country produce nearly 4 to 5 MT of phosphogypsum as by-product about 12 fertilizer plants. Major producers are coromandel fertilizers (Andhra Pradesh), Gujarat state fertilizer Co. (Gujarat), Hindustan lever Ltd. (West Bengal), southern petrochemical industries corporation (Tamil Nadu) and Paradeep Phosphates Ltd. (Orissa).

Handling and disposal of phosphogypsum is not only a serious techno-economic problem but creates environmental pollution and requires large area for dumping. So by using phosphogypsum as a substitute for conventional material problem of dumping waste can be solved in eco-friendly manner.

GENERATION OF PHOSPHOGYPSUM

Phosphogypsum generation in India is about 11 Million ton per annum. Nearly 5 tons of phosphogypsum generated per ton of phosphoric acid production. Phosphogypsum is generated from filtration process in phosphoric acid plants. Depending on the source of phosphate rock about 4.5-5 tons of phosphogypsum is generated per ton of phosphoric acid recovered.

The quality and quantum of phosphogypsum generation depends upon the quality of the phosphate rock, process route used to produce phosphoric acid, calcium sulphate generated either in di-hydrate ($CaSO_4.2H_2O$) or the hemi-hydrate ($CaSO_4.1/2H_2O$) form.

The production of phosphoric acid and estimated phosphogypsum scenario in the country as per the information provided by the fertilizer units is compiled and given in table below.

Table1: estimated generation of phosphogypsum

year	Phosphoric acid production*	Estimated Phosphogypsum generation**
2000-01	1042.4	4690.8
2001-02	1134.7	5106.15
2002-03	1085.6	4885.2
2003-04	990.1	4455.45
2004-05	1242.5	5591.25
2005-06	1067.8	4805.1
2006-07	1331.8	5993.1
2007-08	1206.5	5429.25
2008-09	1201.7	5407.65
2009-10	1160	5407.65
2010-11	1544.6	5220
2011-12	1740.4	6950.7
2012-13	1394.7	6276.15

Phosphoric acid is expressed as 100% P2O5 plaster developed from this phosphogypsum has showed improved engineering properties without any harmful effect. Phosphogypsum were recycled for manufacture of Portland cement, masonry cement, sand lime bricks, partition walls, flooring tiles, blocks, gypsum plaster, fibrous gypsum boards and super sulphate cement. Phosphogypsum could also be used as a soil conditioner for calcium and sculpture deficient soils and it also has fertilizer value due to the presence of ammonium sulphate.

Fig 1: Phosphogypsum

MATERIAL PROPERITIES

Concrete is a development material made out of Portland cement, sand, aggregate and water. In addition to its potential for compressive strength and its ability, when poured, to adapt to virtually any form, concrete is fire-resistant and has become one of the most common building materials in the world.

ORDINARY PORTLAND CEMENT

Portland cement is the most common type of cement in general use all around the world. It is used as a basic ingredient of concrete. Several types of port land cement are available in market. The specific gravity of cement is 3.14.

FINE AGGREGATE

Fine aggregate/sand is an aggregation of grains of mineral matter got from the breaking down of rocks. It is recognized from rock just by the measure of the grains or particles. The fine total was

going through 4.75 mm strainer and the evaluating zone of fine total was zone II according to Indian Standard particulars e grains or particles, yet it is unmistakable from dirt's which contain natural materials. Specific Gravity-2.75, Fineness Modulus-2.8

COARSE AGGREGATE

Coarse Aggregates are the pulverized stone is utilized for making concrete. The stone is quarried, pounded and evaluated. Machine smashed rock softened stone precise up shape was utilized as coarse aggregate was 20 mm and Specific Gravity-2.63, Fineness Modulus-7.2

WATER

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

PHOSPHOGYPSUM

Phosphogypsum is a by-product in the wet process for manufacture of phosphoric acid by the action of sulphuric acid on the rock phosphate. Phosphogypsum is produced by various process such as dehydrate, hemihydrates and anhydrite processes. In India the majority of phosphogypsum is produced by the dehydrate process. Dehydrate process is lower maintenance cost and simplicity in operation as compared to the other processes. It is also produced from the hydrofluoric acid and boric acid industries.

The physical properties of the phosphogypsum as follows:

- Color : gray
- Particle size : 0.5 mm (No. 40 sieve) and 1.0 mm (No. 20 sieve) and majority of the particles (50-75%) are finer than 0.075 mm (No. 200 sieve).
- Specific gravity : 2.3 - 2.6
- Dry bulk density : 1470 -1670 kg/m^3
- Moisture content : 25 -30 %

Phosphogypsum was obtained from Rashtriya Chemical and Fertilizers (RCF), Chembur plant in Maharashtra state, India. It was tested according to IS: 12679-1989 and found to satisfy the requirements of IS: 12679-1989. The chemical composition of phosphogypsum is shown in the table below.

Table 2: Chemical Composition of Phoshpogypsum

Chemical constituents	Percentages (%)
CaO	31.2
SiO_2	3.92
SO_2	43.3
Fe_2O_3	1.82
MgO	0.49
Na_2O	0.36
P_2O_5	0.5
Organic matter	0.26

MIX DESIGN

In the present work the IS method has been used to get proportions for M20, M25, and M30 grades of concrete, and mix designs are as follows.

Mix proportion for M_{20} Grade Concrete

Water	cement	Fine aggregate	Coarse aggregate
191.58 lit	383kg	579.50kg	1200kg
0.5	1	1.51	3.13

Mix proportion for M_{25} Grade Concrete

Water	cement	Fine aggregate	Coarse aggregate
197.33 lit	411.11kg	568.47kg	1177.50kg
0.48	1	1.38	2.86

Mix proportion for M_{30} Grade Concrete

Water	cement	Fine aggregate	Coarse aggregate
202.39 lit	449.46kg	555.97kg	1151.41kg
0.45	1	1.23	2.56

EXPERIMENTAL INVESTIGATIONS

The main purpose of this investigation is to determine the optimum amount of phosphogypsum that can be replaced with cement which gives the better strength characteristics. To examine the workability of fresh concrete and compressive strength, tensile strength and impact strength of hardened concrete for M_{20},M_{25} and M_{30} grades of concrete.

CONCRETE MIX PREPARATION

As for mix designs, material proportions were taken and mixes were prepared by replacing the phosphogypsum with cement. The cement is replaced with 0%, 2.5%, 5%, 7.5% and 10% of phosphogypsum.

WORKABILITY OF CONCRETE

Workability of concrete is defined as the amount of useful internal work necessary to produced 100% compaction. It is also defined as the ease with and homogeneity with which a freshly mixed concrete or mortar can be mixed, placed,

compacted and placed. It is the wetness of the concrete of the concrete and measure of fluidity or mobility.

CASTING OF TEST SPECIMENS

After the completion of workability tests, the concrete mix has been put in the standard (150mm x 150mm x 150mm) metal moulds in three layers and compacted about 25 times for each layer. Before putting the solid internal countenances of the mould are covered with the machines oil for simple evacuation of test examples. The solid in the moulds has been vibrated for 30 sec utilizing the table vibrator and the surface of the cubes has been done easily.

CURING PROCEDURE

After the casting of cubes, these are kept at room temperature for one day and the cube examples of moulds are expelled after 24 hours of throwing of solid cube examples Checking has been done on the examples for recognizable proof. To keep up the steady dampness on the surface of the examples, they are set in water tank for curing. Solid examples are cured for 7 days, and 28 days. After cured 7 days and 28 days the examples are removed from water and dried for one day and carried for tests.

TESTS ON HARDENED CONCRETE

COMPRESSIVE STRENGTH TEST

The compression test is most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test carried out on specimens cubical in shape. The cube specimen is of the size 15 cm x 15 cm x 15 cm.

Fig 2: Compressive Strength Test (Left) & Split Tensile Strength Test (Middle & Right)

SPLIT TENSILE STRENGTH TEST

The tensile strength of concrete is one of the basic and important properties of concrete. Split tensile strength test was on concrete cube is a method to determine the tensile strength of concrete. Tensile Strength test was led on the examples at 28days according to IS 5816-1999. The examples of size 150 mm x 150 mm x 150 mm were casted. After 7 days and 28 days of curing, the cubes were tested by using a compressive testing machine.

IMPACT STRENGTH TEST

Each series of freshly mix was placed in the cylindrical moulds of dimensions 15x7.5cm casting the specimens from these cylindrical specimens 18 discs of size 15x7.5cm were cut using a diamond cutter. The discs were than subjected to draw weight test following the guide lines of ACI committee 544.2R89.The test consisted of repeated application of impact load in the form of blows, using 44.5N hammer falling from 457mm height on steel ball of 63.5mm diameter, placed at the center of the top surface of disc Number of blows (N_1) and (N_2) that caused the first split strength of the sample.

The impact test is calculated by using number of blows. Brittle behavior was observed in plain concrete specimens and it was broken into two pieces.

Fig 3: Test Specimens of Impact Strength Test.

EXPERIMENTAL RESULTS & DISCUSSIONS

WORKABILITY

The workability of fresh concrete was found out by conducting slump test as per guidelines of IS: 1199 – 1970. The workability is measured by slump test for fresh concrete.

Table 3: Test results for slump test

S.No	Cement replaced with % of Phosphogypsum	Workability (Slump) ,mm		
		M_{20}	M_{25}	M_{30}
1	0%	76	65	56
2	2.5%	81.32	72.3	63
3	5%	85.45	78.5	68
4	7.5%	83.2	76	65
5	10%	80	73	62

The graph is plotted for workability Vs % of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

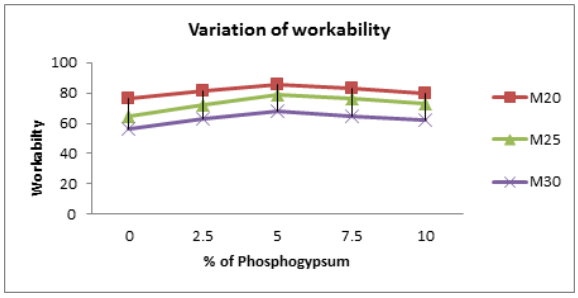

Fig 4: Variation of workability with % replacement of phosphogypsum.

This indicates that the workability increases up to 5% replacement of phosphogypsum, after that replacement of phosphogypsum, the workability gradually decreases. Thus, the optimum amount of phosphogypsum to be added in the concrete is to be 5%.

COMPRESSIVE STRENGTH

In the compressive strength experimental investigation has been carried for the concrete cubes of M_{20} ,M_{25} , and M_{30} grades of concrete by percentages 0%, 2.5%, 5% ,7.5 % and 10% of Phosphogypsum at 7 days and 28 days as depicted in following tables and graphs.

Table 4: Test Results for Compressive Strength Test

S.No	Cement replaced with % of phosphogypsum	Compressive strength , N/mm² ,7 days			Compressive strength , N/mm² ,28 days		
		M_{20}	M_{25}	M_{30}	M_{20}	M_{25}	M_{30}
1	0%	13.75	14.08	19.55	20.05	25.51	28.64
2	2.5%	16.64	18.32	21.32	23.52	27.28	31.59
3	5%	19.08	22.45	25.45	25.45	28.59	33.32
4	7.5%	20.52	25.69	28.64	28.59	30.15	38.48
5	10%	17.38	21.02	22.52	20.35	23.35	32.52

The graph is plotted for Compressive strength Vs % of phosphogypsum at 7 days for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

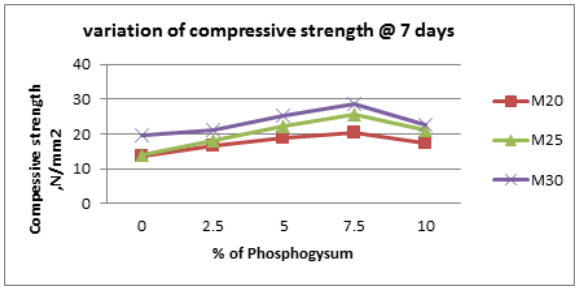

Fig 5: Variation of Compressive strength at 7 days with % replacement of phosphogypsum.

The graph is plotted for Compressive strength Vs % of phosphogypsum at 28 days for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

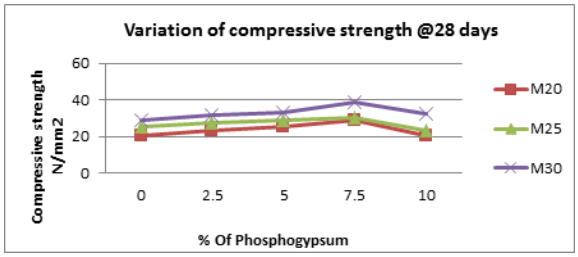

Fig 6: Variation of Compressive strength at 28 days with % replacement of phosphogypsum.

From this results observed that the compressive strengths increases up to the replacement of 7.5% of phosphogypsum and decreases further replacement of phosphogypsum for M_{20}, M_{25} and M_{30} grades of concrete. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

SPLIT TENSILE STRENGTH TEST

In the split tensile strength experimental investigation has been carried for the concrete cubes of M_{20}, M_{25}, and M_{30} grades of concrete by percentages 0%, 2.5%, 5% ,7.5 % and 10% of Phosphogypsum of 7 days and 28 days as depicted in following tables and graphs.

Table 5: Test Results for Split Tensile Strength test.

S.No	Cement replaced with % of phosphogypsum	Tensile strength , N/mm² ,@7 days			Tensile strength , N/mm² ,@28 days		
		M_{20}	M_{25}	M_{30}	M_{20}	M_{25}	M_{30}
1	0%	7.1	5.7	7.6	8.1	8.4	9.2
2	2.5%	5.0	6.4	8.5	8.54	8.8	9.7
3	5%	5.7	7.6	9.1	8.8	9.2	10.1
4	7.5%	6.3	8.4	9.5	9.4	9.7	10.5
5	10%	5.9	7.9	8.8	8.7	9.1	9.3

The graph is plotted for Tensile strength Vs percentages of phosphogypsum @ 7 days for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below. The Tensile strength values are increase from 0% and reduce at 7.5%. Thus, optimum amount of

phosphogypsum to be added in concrete is found to be 7.5%.

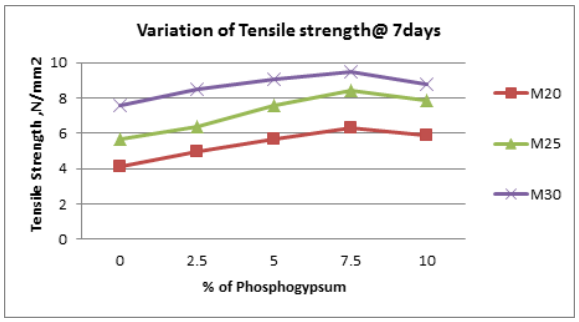

Fig 7: Variation of Tensile strength at 7 days with % replacement of phosphogypsum.

The graph is plotted for Tensile strength Vs percentage of phosphogypsum @28 days for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below

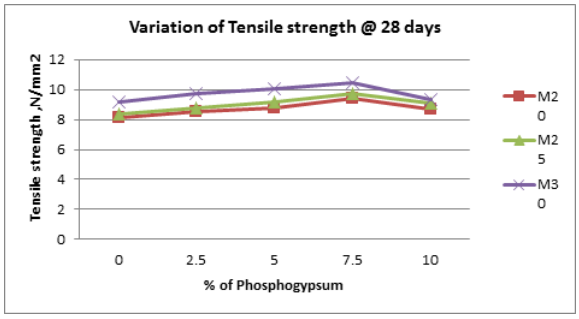

Fig.7: Variation of Tensile strength at 28 days with % replacement of phosphogypsum.

This indicates that the tensile strength increases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, the tensile strength gradually decreases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

IMPACT STRENGTH TEST

In the Impact strength experimental investigation has been carried for the concrete cubes of M_{20} , M_{25} , M_{30} grades of concrete by percentages 0%, 2.5%, 5% ,7.5 %and 10% of Phosphogypsum at 28 days as depicted in following tables and graphs.

Table 6: Test results for Impact Strength test.

S.No	Cement replaced with % of Phosphogypsum	impact strength, N/mm2 ,@28 days		
		M_{20}	M_{25}	M_{30}
1	0%	156	137	170
2	2.5%	170	175	182
3	5%	185	190	196
4	7.5%	143	173	200
5	10%	165	160	175

The graph is plotted for impact strength Vs percentage of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

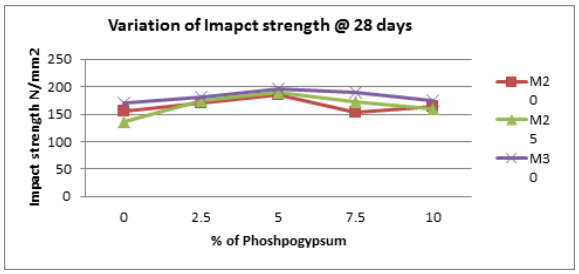

Fig 8 : Variation of impact strength with % replacement of phosphogypsum.

From the results that the impact strengths are increases up to the replacement of 7.5% of phosphogypsum and decreases further replacement of phosphogypsum for M_{20}, M_{25} and M_{30} grades of concrete. Thus, the optimum amount of phosphogypsum to be added in the concrete is found to be 7.5%.

CONCLUSION

An industrial waste phosphogypsum impairs the strength development of calcined product and hence it can be used in construction industry for preparation of concrete to achieve the economy. Addition of Phosphogypsum to concrete affects the strength characteristics of concrete. Based on the experimental investigations conclude as follows:

- The workability increases up to 5% replacement of phosphogypsum, after that replacement of phosphogypsum, the workability gradually decreases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 5%.
- The compressive strengths increases up to the replacement of 7.5% of phosphogypsum and decreases further replacement of phosphogypsum for M_{20}, M_{25} and M_{30} grades of concrete for both at 7 days and 28 days. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.
- The tensile strengths increases up to the replacement of 7.5% of phosphogypsum and decreases further replacement of phosphogypsum for M_{20}, M_{25} and M_{30} grades of concrete for both at 7 days and 28 days. Thus,

optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

- The impact strengths are increases up to the replacement of 7.5% of phosphogypsum and decreases further replacement of phosphogypsum for M_{20}, M_{25} and M_{30} grades of concrete. The optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

Thus, the phosphogypsum is a byproduct of phosphate fertilizer and chemical industries. It can be effectively utilized by replacement of cement in concrete. Utilization of industrial waste such as phosphogpsum not only solves environmental problems but also provides a new resource for construction industry. It is surly a step towards sustainable development and it is an important in engineering, environment and economic point of view.

REFERENCES

[1] Shetty M.S, Concrete Technology Theory and practice, S.Chand & Company Ltd, New Delhi, 2009.

[2] Siva sankar reddy T, D. Rupesh kumar, and H.Suadrsan Rao (2010) "a study on strength characteristics of phosphogypsum concrete", Asian journal of Civil Engineering (Building and Housing) Vol.11.411-420.

[3] Manjit singh, Mridl Garg, Rehsi S.S (1993) "Purifying Phosphogypsum for cement manufacture', Construction and Building Materials Vol.7, pp.3-7.

[4] A.Nanni and W. F.Chang. "Phosphogypsum based roller compacted concrete". Concrete International: Design and Construction Volume 11, Issue 11, (Nov. 1989) 48 -53.

[5] Dr. Manjit Singh "New prospect and new approaches of using waste in building material". Central building research institute CE & CR august 2012.

[6] A. Nanni. "Phosphogypsum as a building material: Strength characteristics and housing application, based roller compacted concrete". Ph. D. thesis, University of Miami, Corel Gables, Florida, (1985).

[7] A. Nanni, and W. F.Chang. "Phosphogypsum based roller compacted concrete". Concrete International: Design and Construction Volume 11, Issue 11, (Nov. 1989) 48 -53.

[8] A. Roy, R. Kalvakaalava, and R. K. Seals. "Micro structural and phase characteristics of phosphogypsum – cement mixtures". ASCE Journal of Materials in Civil Engineering, Volume 8, Number 1, (February 1996) 11 – 18.

[9] M. M. Smadi, R. H. Haddad and A. M. Akour. "Potential use of phosphogypsum in concrete", Cement and Concrete Research, Volume 29, Number 7, (1999) 1419 – 1425.

[10] Nurhayat Degirmenci. "The using of waste phosphogypsum and natural gypsum in adobe stabilization" Construction and Building Materials 22 (2008) 1220–1224.

[11] N. M. Katamine. "Phosphate waste in mixtures to improve their deformation". ASCE Journal of Transportation Engineering, Volume 126, Number 5, (September – October 2000) 382 – 389.