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An Experimental Investigation of Partial Replacement of Cement by Various Percentage of Phosphogypsum In Cement Concrete With Different Water Cement Ratio

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Abstract

This technical paper summarizes role of industrial waste phosphogypsumin concrete. Phosphogypsum is a solid byproduct of the production of phosphoric acid, a major constituent of many fertilizers, chemical industry materials. Portland cement can be replaced with phosphogypsum to develop a good and hardened concrete to achieve economy. The traditional methods for producing construction materials are using the valuable natural resources. Besides, the industrial andurban management systems are generating solid wastes, and most often dumping them in open fields. These activities pose serious detrimental effects on the environment. To safeguard the environment, many efforts are being made for the use of different types of solid wastes with a view to utilizing them in the production of concrete. This make highlights on their potentials and possible use in construction area. The alternative for replacing construction materials obtained from industrial with agro-industrial solid wastes.The present paper deals with the experimental investigation on compressive strength , flexural test,tensile test characteristics of partially cement replaced phosphogypsum concrete using 0%., 5%,10%, 15% and 20%,25% replacement with water-binder ratio of 0.45 and 0.50. The strength characteristics are studied by casting and testing cube specimens for 7, and 28 days, and beam andcylinder for 28 days and find out at what percentage part of ordinary Portland cement can be replaced with phosphogypsum to develop a good and hardened concrete to achieve economy.

Keywords - Phosphogypsum, environment, solid wastes, partial replacement, water-binder ratio.

1. Introduction

Concrete as is well known heterogeneous mix of cement, water and aggregates. The admixtures may be added in concrete in order to enhance some of the properties desired specially. In its simplest form, concrete is a mixture of paste and aggregates. The growth in infrastructure sector led to scarcity of cement because of which the cost of cement increased incrementally. In India, the cost of cement during 1995 was around Rs. 1.25/kg and in now day 2014 the price increased approximately six times and increasing till. Demand of cement is more. Due to this construction cost of the structure is increases. In order to overcome the scarcity of cement and decrease the cost of concrete under these circumstances the use of solid wastes, agricultural wastes, and industrial by-products like fly ash, blast furnace slag, silica fume, rise husk, phosphogypsum, etc. came into use. The use of above mentioned waste products with concrete in partial amounts replacing cement paved a role for

1) Modifying the properties of the concrete,
2) Controlling the concrete production cost,
3) To overcome the scarcity of cement,
4) The advantageous disposal of industrial wastes,
5) Solve the problem of environmental pollution.

The use of particular waste product will be economically advantageous usually at the place of abundant availability and production. Much of the literature is available on the use of fly ash, blast furnace slag, silica fume, rise husk, etc. in manufacture of cement concrete. However, theliterature on the use of phosphogypsum in partial replacement of cement in concrete shows more application in construction area. In this report focus on use of phosphogypsum in partial replacement of cement in concrete.

2. Phosphogypsum

Phosphogypsum is a by-product in the wet process for Manufacture of phosphoric acid by the action of sulphuric acidon the rock phosphate. It is produced by various process such as dehydrate , hemihydrates or anhydrate processes. In India themajority of phosphogypsum is produced by the dehydrate process due to its simplicity in operation and lower maintenance as compared to other processes. The annual production of phosphogypsum from one dozen phosphoric acid and fertilizers plants is of the order of approximately five million tons. Therefore, it is the second largest pollutant in the country after fly ash . At present, in India only about 12% of phosphogypsum is being utilised from the large amount produced . The proper utilisation of phosphogypsum is needed to solve environmental and disposal problems. Considerable efforts are being taken world-wide to utilise natural waste and by-product as supplementary cementing materials to improve the properties of cement concrete.

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Fig.1. Phosphogypsum

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, India blessed with abundant low-cost natural gypsum piled the phosphogypsum up rather than bear the additional expense of utilizing it as a raw material It should be noted that during most of this time period the primary reason phosphogypsum was not used for construction products in India was because it contained small quantities of silica, fluorine and phosphate (P205) as impurities and fuel was required to dry it before it could be processed for some applications as a substitute for natural gypsum, which is a material of higher purity . However, these impurities impair the strength development of calcined products . It has only been in recent years that the question of radioactivity has been raised and this question now influences every decision relative to potential use in building products in this country. The generation of phosphogypsum poses various environmental as well as storage problems. Phosphogypsum is usually deposited in the open areas or dumped into river or sea. The lack of consumption possibility of phosphogypsum causes landfill Problem and environmental pollution.Therefore, it will be worthy if phosphogypsum can be used .

3. Experimental Program

3.1 Cement- The cement used was Birla Cement Ordinary Portland cement (53 grade cement) .The cement was procured from local markets and in one lot to maintain uniformity throughout the investigation.The different properties of cement are: specific gravity-3.15, normal consistency-27.5%, fineness-3%, initial setting time-40minutes, and final setting time- 470 minutes.

3.2 Fine Aggregates- The available sand confirming to IS 383:1970 is used as fine aggregate in the present investigation. The specific gravity was 2.86 in accordance with IS 2386-1963.

3.3 Coarse Aggregate -The coarse aggregate used is locally available. The maximum nominal size of aggregate is 20 mm. Aggregate are the major ingredient of concrete. They contribute about 70-75 % of the total volume, provide a rigid skeleton structure for concrete & act as economical space fillers.Thespecific gravity was 2.80

3.4 Water:-Ordinary tap water was used for mixing and curing operations.

3.5Phosphogypsum-Phosphogypsum was obtained from Hi-Tech agro industries, Pune in Maharashtra State, India. The specific gravity obtained was 3.15. The chemical composition of phosphogypsum is as follows.

Table 1- Chemical composition of phosphogypsum

Chemical Constitution	Percentage
CaO	31.2
SiO_2	3.92
SO_3	42.3
R_2O_3	3.6
MgO	0.49
Phosphate,Fluoride	18.49

4.Cement-Phosphogypsum Mix Test Results

4.1. Normal Consistency-The normal consistency was conducted as per IS: 4031-1988. It was observed that phosphogypsum provides additional stiffness to the paste and therefore it was required to add water for desired penetration of Vicats plunger. However, for five percent replacement of raw phosphogypsum the normal consistency is very close to standard value and for further addition of phosphogypsum the value increased beyond limit specified in IS:12269-1987 i.e. 30% as per Indian standards. The normal consistency results are tabulated in the table below

Table 2: Normal consistency of cement and cement

% replacement of cement	Normal consistancy
0	27.5
5	29.7
10	32.4
15	33.5
20	35.2
25	36.1

4.2. Setting time-The setting time was conducted as per IS: 4031-1988. It was observed that even for five percent replacement of cement with raw of impure phosphogypsum the initial and final time was increased beyond standard value for Ordinary Portland Cement as specified in IS:12269-1987. The initial setting time results are presented in the table below.

Table 3: Setting time of cement and cement - phosphogypsum mixes-

% replacement of cement	Initial setting time (min)	Final setting time(min)
0	35	470
5	112	610
10	190	677
15	244	950
20	288	970
25	290	975

4.3. Soundness Test-The soundness of cement was conducted as per IS: 4031-1988. It is very important to measure soundness of paste made with replacing cement. The test results are presented in the table below. The results

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indicated that even 25% replacement of cement does not contribute to unsound paste.

Table 4: Soundness of cement and cement – phosphogypsum mixes

% replacement of cement	Soundness
0	0.55
5	1
10	3
15	6
20	8.5
25	9

5. Mixture Proportioning

The mix proportion is done as per the IS 10262- 1982. The target mean strength is 31.6 Mpa (M25) for the OPC control mixture, the total binder content is437.77 kg/m^3, fine aggregate is 749.76 kg/m^3 and coarse aggregate 1164.76 kg/m^3 for the water to binder ratio as 0.45. And the total binder content is 394 kg/m^3, fine aggregate is 761.12 kg/m^3 and coarse aggregate 1181.88 kg/m^3 for the water to binder ratio as 0.50. The cement is replaced by phosphogypsum for 5%,10%,15% and 25% for both 0.45 and 0.50 water cement ratios. Cube, Beam and Cylindermoulds use for casting. Compaction of concrete in three layers with 25 strokes of 16 mm rod for each layer. The concrete left in the mould and allow to set for 24 hours before the cubes demould and place in curing tank. The concrete cubes cure in the tank for 7, and 28 days for compression test.And beam and cylinder for 28 days for flexural test and tensile test.

6. Expected Outcomes

Result taken by me till date of materials cement, cement +phosphogypsum and research papers which ,I have taken reference of could give possible outcome conclusion is as follows:

1.Find out at what percentage part of ordinary Portland cement can be replaced with phosphogypsum to develop a good and hardened concrete to achieve economy.

2.Partial replacement cement by phosphogypsum increase setting time, increase standard consistency ,but not effect on soundness property.

3.With 10% replacement of cement with phosphogypsum not only the compressive strength increased marginally/significantly with age but also the split-tensile strength at 28 days increased commendably in case of different water-binder ratios. However, further replacement of cement with phosphogypsum lead to drastic reduction not only in the compressive strength but in the split-tensile strength also.

4. Partial replacement of PG reduces the environmental effects, produces economical and eco-friendly concrete.

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