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An experimental investigation of partial replacement of cement by various percentage of Phosphogypsum in cement concrete.

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ABSTRACT

Phosphogypsum is a by-product of phosphate fertilizer plants and chemical industries. As it is contaminated with the impurities that impair the strength development of calcined products, it can be used as partial replacement of cement. The present paper deals with the experimental investigation on compressive strength characteristics of partially cement replaced phosphogypsum concrete using 0%., 10%, 15% and 20% replacement with water-binder ratio of 0.40. The strength characteristics are studied by casting and testing cube specimens for 7, 14 and 28 days. It is shown that a part of ordinary Portland cement can be replaced with phosphogypsum to develop a good and hardened concrete to achieve economy; above 10% replacement of phosphogypsum in concrete lead to drastic reduction not only in the compressive strength.

Keywords - Compressive strengths. partial replacement, phosphogypsum, water-binder ratio.

1. Introduction

With the advancement of technology and increased field application of concrete and mortars the strength, workability, durability and other characteristics of the ordinary concrete is continually undergoing modifications to make it more suitable for any situation. 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 2005 the price increased approximately three times [1]. In order to combat the scarcity of cement and the increase in cost of concrete under these circumstances the use of recycled 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 abovementioned waste products with concrete in partial amounts replacing cement paved a role for (i) modifying the properties of the concrete, (ii) controlling the concrete production cost, (iii) to overcome the scarcity of cement, and finally (iv) the advantageous disposal of industrial wastes. 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, the literature on the use of phosphogypsum in construction industry is in the budding stage. This paper tries to focus on the use of phosphogypsum in partial replacement of cement in concrete.

2. Cement-Phosphogypsum Mixes

In case of cement phosphogypsum mixes, the materials used were phosphogypsum and ordinary Portland cement.

2.1. Phosphogypsum

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 [2]. The chemical composition of phosphogypsum is shown in the table below.

Table 1- Chemical composition of phosphogypsum

Chemical Constituents	Percentage (%)
CaO	31.2
SiO_2	3.92
SO_3	42.3
R_2O_3	3.6
MgO	0.49
Phosphate, Fluoride	18.49

The specific gravity was obtained as 3.15. The phosphogypsum known to have some of the chemical impurities like phosphates and world-wide for most of the applications as a binder or cements etc. Phosphogypsum supposed to be treated for these impurities; therefore phosphogypsum without treatment referred here as raw or impure phosphogypsum.

2.2. Cement

The Ordinary Portland Cement, 53 grade conforming to IS: 12269-1987 was used [3]. The cement was procured from local markets and in one lot to maintain uniformity throughout the investigation.

2.3. Water

Ordinary tap water was used for mixing and curing operations.

2.4. Fine aggregate

The locally available sand confirming to IS 383:1970 is used as fine aggregate in the present investigation. The sand is free from clay matter, silt and organic impurities. The sand has a specific gravity 2.69 in accordance with IS 2386-1963, and fineness modulus 2.9.

2.5. Coarse Aggregates

Machine crushed 20 mm nominal size angular granite metal from local source confirming to IS 383:1970 is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter, etc. The coarse aggregate has specific gravity 2.72, and fineness modulus 6.90.

3. Cement-Phosphogypsum Mix Test Results

3.1. Normal Consistency

The normal consistency was conducted as per IS: 4031(pt 4)-1988[4]. The normal consistency results are tabulated in the table below. 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 phosphigypsum 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.

Table 2: Normal consistency of cement and cement – phosphogypsum mixes

Percentage replacement of cement	Normal Consistency (%)
0	28.5
5	30.12
10	34.23
15	35.7
20	36.9

3.2. Setting time

The setting time was conducted as per IS: 4031-1988[5]. The water content observed by normal or standard consistency was used for measuring initial setting time. 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(minute)	Final setting time(minute)
0	30	490
5	115	600
10	185	870
15	245	942
20	290	975

3.3. Soundness

The soundness of cement was conducted as per IS: 4031-1988[6]. The raw phosphogypsum is known to have impurities therefore it is very important to measure soundness of paste made with replacing cement. The test results are presented in the table below. The results indicated that even 20% replacement of cement does not contribute to unsound paste.

Table 4: Soundness of cement and cement – phosphogypsum mixes

Percentage replacement of cement	Soundness(mm)
0	1
5	2
10	3
15	5
20	8

4. Cement – Phosphogypsum Mortar Mix

In case of mortar, the materials used were phosphogypsum, cement, sand and ordinary tap water. The details of properties of materials were discussed in previous section. Local river sand was used as fine aggregate. Fine aggregate conforming to IS: 650 – 1966 was used for testing 7]

5. Mortar Mix Proportions

The standard mix proportion of 1:3 by weight was considered for the test. The proportions of phosphogypsum were varied from 5%, 10%, 15%

and 20% of ordinary Portland cement by dry weight. Each time twelve numbers of cubes were cast with the water binder ratio 0.40. The tests were carried out as per IS: 4031-1988[8].

6. Experimental Investigation of Concrete Mixes

The workability of fresh concrete was assessed by conducting Compaction Factor test as per guidelines of IS: 1199 – 1970. The Compaction Factor of concrete without phosphogypsum was found to be 0.935 and concrete with five and ten percent phosphogypsum were 0.89 and 0.91 respectively. It is observed that the further replacement of cement with phosphogypsum it is very difficult to mix in concrete due to inadequate water cement ratio.

6.1 Compressive strength

The specimens were cast with concrete mixes mentioned and cured for 3,7,14 and 28 days in the laboratory. On completion of the curing period the specimens were taken out and tested as per IS code for compressive strength was carried out on order to assess performance of concrete. Below table represent the influence of curing age on the compressive strength of phosphogypsum concrete cubes. Each value represents average value of three tested specimens.

Table 5: Cube compressive strength of cement mortar and cement – phosphogypsum mortar

Design Compressive Strength (N/mm^2) for 25 N/mm^2				
Curing day	% of Phosphogypsum in Concrete			
	0%	5%	10%	15%
3	9.3	12.243	13.31	7.85
7	19.91	22.78	24.11	15.36
14	23.25	25.67	27.59	19.11
28	25.51	28.59	30.15	21.35

7. Conclusions

An industrial waste like phosphogypsum impairs the strength development of calcined products and hence it can be used in construction industry for preparation of concrete replacing some quantity of cement, which is a valuable ingredient of concrete, to achieve economy.

The mixture in which replaced with five percent phosphogypsum having almost same standard or normal consistency than that of plain cement and thus water requirement of the cement – phosphogypsum mix minutely affected.

Phosphogypsum in ordinary Portland cement mixes considerably retards setting time but does not contribute to produce unsound cement paste.

The compressive strength of phosphogypsum cement concrete with five and ten percent are improved indicates that phosphogypsum has immense potential to be utilized in concrete application, especially mass concrete work.

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