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PARTIAL REPLACEMENT OF CEMENT BY PHOSPHOGYPSUM IN CONCRETE

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ABSTRACT

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.

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 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.

In this report experimental investigation on compressive and tensile characteristics of partially cement replaced phosphogypsum concrete using 0%, 10%, 20%, 30% and 40% replacement on 20,25and 30 grade of concrete with water-binder ratios of 0.44, 0.47 and 0.50, respectively.. The test program consisted of carrying out compressive strength test on 45 cubes and tensile strength on 45 cylinders.

KEYWORDS: *Compressive strengths. Partial replacement, phosphogypsum, water binder ratio.*

INTRODUCTION

Abundant of research investigations have been conducted to utilized the waste or chemical gypsum, phosphogypsum for various applications. Most of the research investigations were carried out by purifying phosphogypsum for the impurities present in it and then its utilization were suggested. In another research approach phosphogypsum could be utilized without any treatment and therefore it may be entitled as untreated, impure or raw phosphogypsum. Investigations have beencarried out, in order to study the effect of replacement of cement with raw phosphogypsum (PG) in cement, cement mortar, and cement concrete mixes. 0%'10%,20%30%and 40% of cement have been replaced with raw phosphogypsum in cement, cement mortar, cement concrete on equal dry weight basis. The properties of such cement, cement mortar and concrete mixes produced compared with conventional mixes. The conventional

concrete mixes have been modified to accommodate raw phosphogypsum as a part of cement to be suitable for the concrete, for workability and 28 days compressive strength varying from 20 N/ $mm^2$to 30 N/ mm^2.

1.1 GENERAL

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 inclemently. In India, the cost of cement during 1995 was around Rs. 1.25/kg and in 2014 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 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. So we try to focus on the use of phosphogypsum in partial replacement of cement in concrete.

1.2 PHOSPHOGYPSUM

Current worldwide production of phosphoric acid yields over 100 million tons of phosphogypsum per year In India, about 6 million tons of waste gypsum such as phosphogypsum, flourogypsum etc. are being generated annually[2]. **Phosphogypsumis 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.** Itis produced by various processes such as dihydrate, hemihydrate or anhydrite processes. In India the majority of phosphogypsum is produced by the dehydrate process due to its simplicity in operation and lower maintenance as compared to other processes. The other sources of phosphogypsum are by-products of hydrofluoric acid and boric acid industries. . 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 [3, 4]. 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 [5].However, these impurities impair the strength development

of calcined products [6]. 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 [7].

LITERATURE REVIEW

Utilization of phosphogypsum in concrete is not new technique. **Gutt** [10] first proposed it and presented a practical approach to handle phosphogypsum in concrete.

Ghafoori *etal.* [12] studied production of compacted concrete using phosphogypsum, in which they inferred such mixes could achieve excellent compressive strength under compaction. Resembled study reported by Lin and Chang by using 10% cement and 90% phosphogypsum mixture.

Chang [13] investigated the effectiveness of phosphogypsum based concrete in corrosion protection of reinforcement. Test results indicated that pH value increased rapidly when phosphogypsum mix contained small amount of cement. Other effective way of protecting against corrosion was increasing thickness of cover.

Chang *etal.* [15] published a book on engineering presented the primary available data on tests of engineering properties and have presented the state of-the-art on construction applications.

Chang *et al*.[16] have published state of art report on phosphogypsum for secondary road construction. It was concluded phosphogypsum when subjected to compaction could be transformed into a solid of valuable strength. It could be used very properties and construction applications of phosphogypsum with and without other materials (fly ash, slags, epoxy, fibers, etc). The authors have transformed into a solid of valuable strength. It could be used very effectively as binder to stabilized soil, replace shell or clay in secondary road and aggregate and water. A base course was built by spreading 5 inch of loose phosphogypsum on existing soil, over which the concrete was laid.

Nanni *etal.* [17] reported application of phosphogypsum was investigated as an aggregate in construction of various Roller Compacted Concrete (RCC) slabs. Several phosphogypsum-based mixtures were prepared in three different mixing procedures and were compacted using suitable vibrator. A thickness design procedure of this concrete pavement was also suggested. The project indicated that phosphogypsum based RCC was suitable for pavement construction applications. Moreover, phosphogypsum was suitable, as it provide set retardation and drying shrinkage compensation.

Murthy *et al.* [20] carried out studies on basic properties of fly ash-lime-gypsum (FaL-G) cement concrete using phosphogypsum. And it was concluded that phosphogypsum is suitable for producing good quality FaL-G concrete.

EXPERIMENTAL PROGRAM MATERIAL

Cement

The Ordinary Portland Cement, 43 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.

Water

Ordinary tap water was used for mixing and curing operations.

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.

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

Phosphogypsum

Phosphogypsum was tested according to IS: 12679 - 1989 and found to satisfy the requirements of IS: 12679 – 1989 [27]. The chemical composition of phosphogypsum is as shown in Table – 3. The specific gravity obtained was 3.15. The phosphogypsum known to have some of the chemical impurities like phosphates and World – widefor 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 (PG)

Table 1: Physical Properties of fine aggregate

Physical properties	Observed values
Specific gravity	2.56
Bulk density(kg/m^3)	1.3
Fineness modulus	2.43
Water absorption %	0.89

Table 2: Physical Properties of coarse aggregate

Physical properties	Observed values
Colour	Grey
Shape	Angular
Nominal size	20 mm
Specific gravity	2.68 (20mm) 2.74 (10mm)

Table 3: Chemical composition of phosphogypsum

Chemical constituents	Percentage
CaO	31.2
R_2O_3	3.6
MgO	0.49
Phosphate, fluoride, etc	18.49

METHODOLOGY

Experimental investigation on compressive & tensile characteristics of partially cement replaced phosphogypsum concrete using 0%, 10%, 20%, 30% and 40% replacement on 20,25and 30 grade of concrete with water binder ratios of 0.44, 0.47 and 0.50, respectively.. The test program consisted of carrying out compressive strength & tensile strength test on 45 cubes & 45cylinder. Test specimens of size 150 X 150 X 150 mm & 150 X 300 mm were prepared for testing the compressive strength & tensile strength of concrete. The mix type with % replacement of cement, phosphogypsum, is given in Table 4.1.

In this study, to make concrete, cement, phosphogypsum, and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at room temperature for curing. The specimens so cast were tested after 28 days of curing measured from the time water is added to the dry mix. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Average results of three specimens of the compressive strength & tensile strength test on concrete of all five mix including the controlled mix at the age of 28 days are given in the Table 4.2.

Table 4.1: Mix Types

S. No.	Mix Type	% Ingredients	
		Cement	PG
1	A1-M20	100	0
2	C1-M20	90	10
3	C2-M20	80	20
4	C3-M20	70	30
5	C4-M20	60	40
6	A2-M25	100	0
7	C5-M25	90	10
8	C6-M25	80	20
9	C7-M25	70	30
10	C8-M25	60	40
11	A3-M30	100	0
12	C9-M30	90	10
13	C10-M30	80	20
14	C11-M30	70	30
15	C12-M30	60	40

Table 4.2: Mix Design

Mix	W/C	Water Content (kg/m^3)	Cement (kg/m^3)	Fine agg (kg/m^3)	Coarse agg (kg/m^3)	
					I	II
M20	0.5	186	372	676.10	407.35	756.51
M25	0.47	186	395.74	658.72	407.15	756.14
M30	0.44	186	422.73	639.20	405.38	752.84

RESULTS AND DISCUSSION

This result obtained from various tests conducted on concrete specimens cast with four replacement levels of cement by phosphogypsum. The main objective of the research program was to understand the compressive strength, split tensile strength and abrasion resistance aspects of concrete obtained using phosphogypsum as partial replacement for cement. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of phosphogypsum on compressive strength, split tensile strength of concrete. The experimental program consisted of casting, curing and testing of controlled concrete and concrete mix with varying proportions of phosphogypsum at the ages of 28 days.

Table 5.1: Compressive & tensile strength of M20

Mix No.	Compressive strength	Tensile strength
M1	26.72	2.64
M2	26.94	2.62
M3	22.20	2.15
M4	18.15	1.85
M5	11.84	1.36

Fig. 5.1: Compressive strength of M20

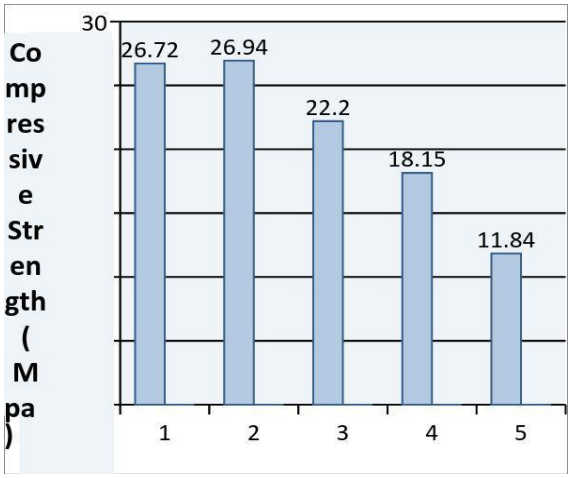


Table 5.2: Compressive & tensile strength of M25

Mix No.	Compressive strength	Tensile strength
M1	32.30	3.10
M2	31.58	3.08
M3	26.04	2.54
M4	21.30	2.17
M5	14.10	1.50

Fig. 5.2: Compressive strength of M25

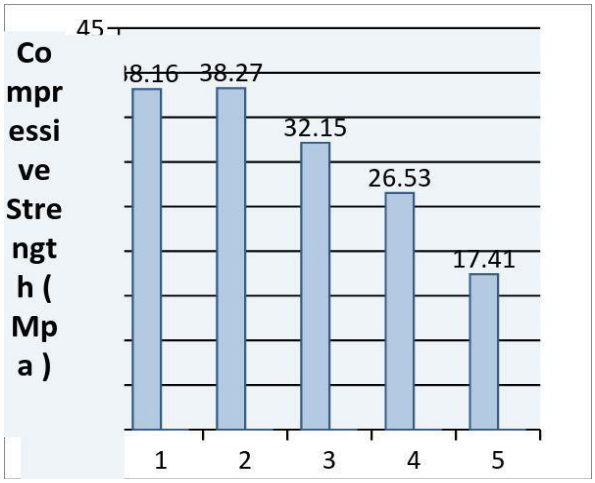


Table 5.3: Compressive & tensile strength of M30

Mix No.	Compressive strength	Tensile strength
M1	38.16	3.81
M2	38.27	3.82
M3	32.15	3.14
M4	26.53	2.69
M5	17.41	1.85

Fig. 5.3: Compressive strength of M30

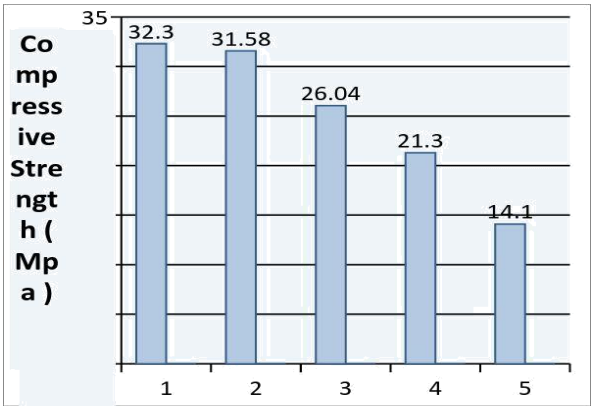
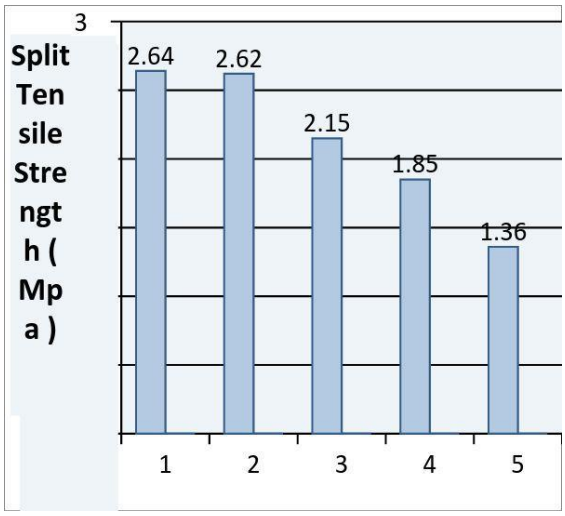


Fig. 5.4: Tensile strength of M20



CONCLUSIONS

Based on the limited experimental investigation conducted and the analysis of test results, the following conclusions are drawn;

1) The mixture in which cement replaced with ten percent phosphogypsum

2) Having almost same standard or normal consistency than that of plain cement and thus water requirement of the cement - phosphogypsum mix minutely affected. But, further replacements of ordinary Portland cement with raw PG seriously affect the consistency.

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

4) Phosphogypsum can be economically used up to ten percent as an ingredient or admixture of cement mortar mix, both for stone and brick masonry work.

4) The compressive strength of phosphogypsum cement concrete (with ten percent PG) is improved indicates that phosphogypsum has immense potential to be utilised in concrete applications especially mass concrete work.

5) 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.

SCOPE FOR FUTURE WORK

Following are the scopes of present study:
a) To provide economical concrete.
b) it should be easily adopted in field
c) Using the wastes in useful manner.
d) To reduce the cost of the construction.
e) To promote the low cost housing to the e.w.s. group people.
f) Find the optimum strength of the partial replacement of concrete.
g) Minimize the maximum demand forcement.
h) Minimize the maximum degradation in environment due to cement and safeguard the ozone layer from green house gases.

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