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Evaluate the Mechanical and Durability Properties of Concrete by Using Phosphogypsum and Fly Ash

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Abstract:

The concrete is the second largest consumed material by human after the water. Cement is the main ingradient in concrete. In the most general sense of the word, cement is a substance which sets and hardens independently, and can bind other materials together. The production of one tonne of OPC consumes about 1.5 tonnes of raw material due to this the cement raw materials are exhausting as quickly as possible. It causes increasing scarity of natural materials and causes environmental problem by emission of co2 and other gases. By replacing pozolanic materials like flyash, silica fume and phosphogypsum etc with cement in concrete it is used as economical, reduces environmental pollution and scarity of cement making raw materials.

Phosphogypsum is 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. And Fly ash is a by-product of the combustion of pulverized coal, usually from coal-fired power plants. The disposal of phosphogypsum and fly ash are serious environmental problems. This problem along with rapid depletion of cement making materials, environmental pollution associated with the manufacture of cement and its increased cost can be solved to some extent by replacing certain quantity

Phosphogypsum generation in the Country is about 11 million tonnes per annum. The RTPP located at muddanur in Kadapa district produces about one million tons of fly ash every year. The main aim of this study is to investigate the influence of phosphogypsum (PG), fly ash (FA) on mechanical properties and durability properties of concrete. The use of partial replacement of opc by wastes favoured concrete production due to their advantages in improving some of the properties of concrete.

The experiment consists of testing partially replaced cement with phosphogypsum in fly ash concrete, Using 0%, 4%, 8% and 10% replacement of cement with phosphogypsum and maintaining fly ash at constant 25% all the mixtures were prepared. Based on the experimental investigation conducted and the subsequent analysis of test plain concrete (PC) is more than 30%. The percentage increase in split tensile strength at 8% phosphogypsum content, when compared with conventional concrete is around 60%. Maximum strength and lowest water penetration of fly ash concrete are achieved at 8% replacement of opc with phosphogypsum.

Introduction:

Scarcity of cement leads to its increased cost, which causes problems in the construction sector. At the same time, reduction in the cement production and usage has environmental benefits also. Thus utilization of phosphogypsum in concrete gives multiple advantages, as it leads to a solution to problems related to waste disposal and reduction in the usage of cement in concrete, thereby reducing its cost. In order to combat the scarcity of cement and the increase in 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. Phosphogypsum is 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. And Fly ash is a by-product of the combustion of pulverized coal, usually from coal-fired power plants1. The disposal of phosphogypsum and fly ash are a serious environmental problem. This problem along with scarcity of cement, environmental pollution associated with the manufacture of cement and its increased cost can be solved to some extent by replacing certain quantity of cement in concrete with phosphogypsum and fly ash. The use of above mentioned 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 and fly ash in partial replacement of cement in concrete shows more application in construction area.

Literature review : Utilisation of phosphogypsum in concrete is not new technique, Gutt first proposed it, he had presented a practical approach to handle phosphogypsum in concrete [1].

Ouyang, Nanni and Chang studied sulphate attack resistance of Portland cement mixture containing phosphogypsum and conventional aggregate. A wide range of SO3 and C3A contents were investigated with respect to linear expansion and compressive strength development for specimen submerged in fresh and seawater. The cement contents were varied between 10% - 30% by weight, whereas phosphogypsum varied from 0 – 50%, lime rock aggregate was used. The results indicated that, the optimum C3A content, which corresponds to minimum expansion, is about 1.1% for Portland cement having C3A content less than 7%. And phosphogypsum contents directly proportional to expansion in cement mixes. Seawater immersion decreases the strength development rate of cylinders and increases linear expansion of bars [2].

Chang it all have 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 so it is economical [3].

Nanni produced bench model phosphogypsum bricks of size 45 X 95 X 203 mm with semi automatic press having a capacity of 1780 kN. The bricks thus produced were handled immediately after fabrication. The bricks were found good in appearance and strength [4].

Chang and Mantell published a book on engineering properties and construction applications of phosphogypsum with and without other materials (fly ash, slags, epoxy, fibres, etc). The authors have presented the primary available data on tests of engineering properties and have presented the stateof-the-art on construction applications [5].

Nanni and Chang 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 [6].

Foxworthy, Ott and Seals utilised phosphogypsum based slag aggregate in Portland cement concrete mixtures. The durability behaviour of such aggregate was explored. The entire preliminary tests on phosphogypsum were performed. The phosphogypsum slag aggregate based concrete mix was prepared and tested for compressive strength, flexural and splitting tensile strength. The result indicated that the slag aggregate performed well as a coarse aggregate in cement concrete and should perform satisfactorily in highway pavement system [7].

Murthy, et. al. 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 [8].

Gutti,, Roy, Metcalf and Seals studied the effect of admixture content, dry density and curing condition on linear expansion of cement-stabilised phosphogypsum (CSPG) over a period of ninety days. The phosphogypsum was stabilized using 8% type I Portland cement, different specimens were prepared and cured for different curing conditions. For soaked specimen, they found ettringite growth was widespread and unusually large as compared to the amount of cement [9].

Smadi, Haddad and Akour studied utilisation of phosphogypsum as cement (OPC and PPC) replacement agents in mortars and found decrease in compressive strength and increase in flexural strength as compared with conventional mix. The incorporation of phosphogypsum in the cement has drastically increased its initial strength. This strength development was attributed to formation of anhydrate at higher temperatures [10].

Konstantin Kovler et alhis experimental results shows on the Testing, interpretation, modeling and prediction of property, and as well as correlation with properties of fresh concrete and durability, effects of special binders, recycled and natural aggregates, fiber reinforcement, mineral and chemical admixtures. Special attention are given to the properties of hardened light weight and self-compacting concrete for improving of strength[11].

Phosphogypsum (treated and untreated) has not yet been studied and utilised in concrete in India. Phosphogypsum obtained from the process plants in India contains greater proportions ofimpurities, radioactivity and pH. These parameters may seriously affect strength and durability ofconcrete if used in high volume. There is, therefore, a strong need to investigate preliminaryproperties of low volume use of unpurified (untreated) phosphogypsum in cement, mortar andconcrete mixes.In the present investigation, apart from cement and mortar mixes, concrete mix design methodhas been tried to produce concrete mixes using phosphogypsum. In case of cement – phosphogypsum mix and mortar all the preliminary properties were studied. Tests have been carried out on phosphogypsumconcrete mixes and the results have been compared with those obtained from conventional concrete.

MATERIALS :

1 53 grade ordinary Portland cement

53 grade ordinary Portland cement manufactured by **ZUARI CEMENT** company with the specific gravity

of 3.10 and fineness of 325 m2/ kg is used in the present study.

2 Fly Ash

Fly ash confirming to the requirements of IS 1727 (1967) obtained from RTPP in Muddanur , kada pa district with specific gravity of 2 . 5 and Fineness of 320 m2/ kg was used as supplementar y cementitious material in concrete mixtures .

3 Phosphogupsum

Phosphogypsum was obtained from Rashtriya Chemical and Fertilizer (RCF), Chembur plant in Maharashtra State, India. Phosphogypsum is a gray coloured, damp, fine grained powder, silt or silty-sand material with a maximum size ranges between 0.5 mm (No. 40 sieve) and 1.0 mm (No. 20 sieve) and the majority of the particles (50-75 %) are finer than 0.075 mm (No. 200 sieve). The specific gravity of phosphogypsum ranges from 2.3 to 2.6. The maximum dry bulk density is likely to range from 1470 to 1670 kg/m3. The gypsum cake, after filtration, usuallyhas free moisture content between 25 and 30%.

Hemihydrate, in the presence of free water will rapidly convert to dihydrate and in the process, if left undisturbed will set into a relatively hard cemented mass and does not cause dust problem unless disturbed.Phosphogypsum consists of primarily of calcium sulphate dihydrate with small amounts of silica, usually as quartz and unreacted phosphate rock, radioactive material (like radium, uranium), heavy metals namely arsenic, cadmium, chromium, mercury and fluoride. The concentration of the metals depends on the composition of the phosphate rock.

Fine aggregate

Naturally available sand from local river bed is used as fine aggregate in the present work. The sieve analysis of sand is shown in table 3.2. As per IS383 the sand falls under zone 2.

5 . Coarse aggregate

20 mm crushed granite aggregate procured from locally available stone crusher unit in Rajampeta, kadapa district is used in present investigation.

QUANTITIES OF MATERIAL: PG= PHOSPHOGYPSUM; FA= FLY ASH; F.A1=FINE AGGREGATE;C.A=COARSE AGGREGATE;

Table:16;quantities of material in mix design

S.NO	MIX DESIGNATION	COMPONENT MATERIALS						
		CEMENTIOUS MATERIAL				F.A1	C.A	W/B
		CEMENT	PG	FA	TOTAL			
1.	S1	350	-	-	350	665.3	1235.6	0.48
2.	S2	248.5	14	87.5	350	653.2	1213.1	0.48
3.	S3	234.5	28	87.5	350	652.9	1212.5	0.48
4.	S4	227.5	35	87.5	350	652.5	1211.8	0.48

TESTS AND RESULTS:

1. Compressive Strength Test:

The specimens were cast with concrete mixes mentioned and cured for 3,7,28 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. Compression test on the cubes is conducted on the digital compression testing machine. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate up to the failure of the specimen and the ultimate load is noted. The cube compressive strength of the concrete mix is then computed. This test has been carried out on cube specimens at 3 days, 7 days, 28 days age.

MIX DESIGNATION	COMPRESIVE STRENGTH(MPa)		
	3 DAYS	7 DAYS	28 DAYS
S_1	16.1	23.9	32.5
S_2	18.1	24.8	34.2
S_3	21.0	28.6	36.4
S_4	24.7	31.8	42.6
S_5	22.6	30.0	39.9

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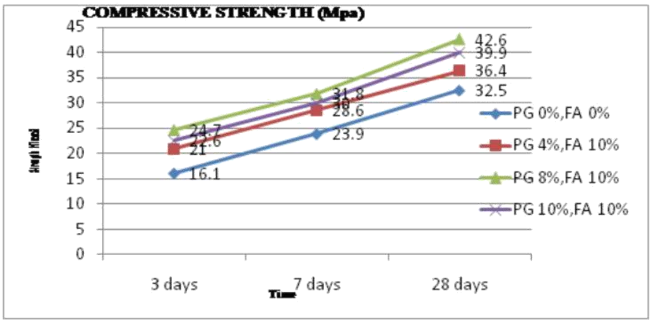


As shown in above graph for 3,7,28 days it is observed that for the compressive strength, we achieved more compressive strength at 8% PG and 25% FA. We observe that approximately 30% more compressive strength achieved at 8% PG and 25% FA when compared to normal concrete.

2. Split tensile strength:

This test is conducted on digital compression testing machine. The cylinders prepared for testing are 150 mm in diameter and 300 mm long. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. The magnitude of this tensile stress is given by the formula (IS: 5816-1970):

Where,

P = Compressive load on the cylinder

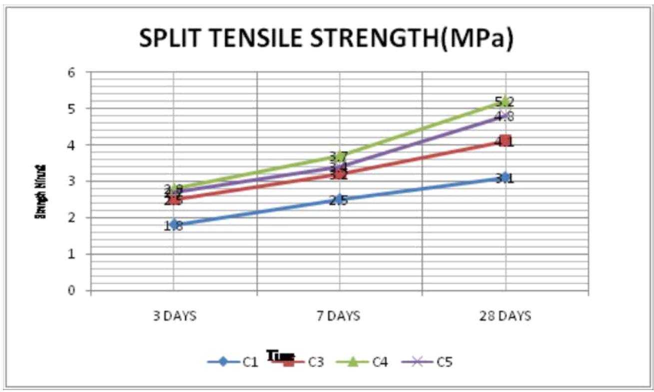
L = length of the cylinder

d = diameter of the cylinder

In the wake of noticing the heaviness of the chamber, polar lines are drawn on the two closures, with the final goal hat they are in the same hub plane. At that point tbarrel is put on the base pressure plate of the testing machine and is adjusted with the end goal that the lines set apart on the closures of the example are vertical. At that point the top pressure plate is brought into contact at the highest point of the chamber. The heap is connected at uniform rate, until the barrel comes up short and the heap is recorded. From this heap, the part elasticity is figured for every example.

In the present work, this test has been led on barrel examples following 3, 7 days, 28 days.

MIX DESIGNATION	SPLIT TENSILE STRENGTH(MPa)		
	3 DAYS	7 DAYS	28 DAYS
C_1	1.8	2.5	3.1
C_2	2.1	2.7	3.4
C_3	2.5	3.2	4.1
C_4	2.8	3.7	5.2
C_5	2.7	3.4	4.8



As shown in above graph for 3,7,28 days it is observed that for the split tensile strength, we achieved more split tensile strength at 8% PG and 25% FA. We observe that approximately 60% more split tensile strength achieved at 8% PG and 25% FA when compared to normal concrete.

3.Water Penetration (WP) :

The water penetration test is most commonly used to evaluate the permeability of concrete, is the one specified by BS EN-12390-8:2000. In this test, water was applied on one face of the 150 mm concrete cube specimen under a pressure of 5 kg/cm^2. This pressure was maintained constant for a period of 72 h. After the completion of the test, the specimens were taken out and split open into two halves. The water penetration profile on the concrete surface was then marked and the maximum depth of water penetration in specimens was recorded and considered as an indicator of the water penetration.

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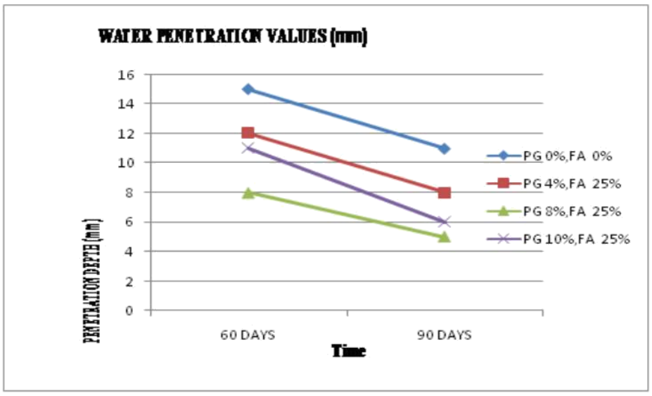
S.no	Trail Proportions	Water penetration in mm	
		60 days	90 days
1.	S_1W	15	11
2.	S_2W	12	08
3.	S_3W	08	05
4.	S_4W	11	06



As shown in above graph for 3,7,28 days it is observed that for the water penetration depth, we achieved less water penetration depth at 8% PG and 25% FA when compared to normal concrete.

ENGINEERING SIGNIFICANCE:

Much research has been done and going on to utilize the constituent material technology for the benefit of human kind. The durability and making concrete more and more ecofriendly are the big challenges even now despite incessant research to mitigate these problems. In developing countries in India, there has been significant growth in industries and the usage of concrete is also significant. The concrete structures which were built 35 to 40 years back are posing so many problems and there is a need to find a permanent solution for these problems. About 5 decades back the cements were of coarse grained whose fineness was very less compared to the present day cement/binding material. As the technology has taken towards fineness material to be used in concrete to make it stronger, durable and eco-friendly, there exigated a need to utilize pozzolanic material in concrete. In the present study an attempt has been made to improve the mechanical properties of concrete by using Phosphogypsum and fly ash and it is observed that the experiments have yielded satisfactory results.

CONCLUSIONS:

In this present study with the stipulated time and laboratory set up an afford has been taken to enlighten the use of so called pozzolanic materials like phosphogypsum, fly ash concrete in accordance to their proficiency. It was concluded that,

1. Phosphogypsum in ordinary Portland cement mixes considerably retards setting time.
2. Phosphogypsum and Fly ash concrete shows less penetration as compared to Ordinary Portland cement concrete.
3. Phosphogypsum and Fly ash concrete is more economical as compared to ordinary Portland cement (OPC).
4. The results obtained from the present study shows that there is great potential for the utilization of best phosphogypsum and fly ash in concrete as replacement of cement.
5. In this study the compressive strength & split tensile strength increased upto 8% of PG and 25% FA after that starts reduction in strength.
6. Concrete with 8% phosphogypsum and 25% fly ash shows lowest water penetration into the concrete as compared to OPC at 90 days.

Future scope:

The research work on pozzolanic materials is still limited. But it promises a great scope for future studies. Following aspects are considered for future study and investigation.

- Percentage and actual fineness of PG require as partial cement replacement for good strength development
- Replacing cement with different percentage of FA & PG to judge the optimum percentage of flyash & phosphogypsum to be used to get better strength result.
- Phosphogypsum did’nt used as nano form yet. If it used as nano form we can get better results than this study.
- It requires a proper mixing propertions for the development of high strength, high performance concrete which may not be

possible manually. So it needs some global optimisation techniques to develop the desire result with greater accuracy and time saving.

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