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An Experimental Investigation of Use of Phosphogypsum and Marble Powder for Making Green Concrete

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ABSTRACT
In this paper, the detailed experimental investigation was done to study the effect of partial replacement of cement by phosphogypsum (PG) and marble powder (MP) in combine proportion started from 5% PG and 25% MP mix together in concrete by replacement of cement with the gradual increase of PG by 5% upto 15% whereas MP is constant at 25%.Last proportion was taken after decreasing PG by 5% and increasing MP by 10%. The tests on hardened concrete were destructive in nature which includes compressive test on cube for size (150 x 150 x 150 mm) at 7, 14 and 28 days of curing as per IS: 516 1959, Flexural strength on beam (150 x 150 x700 mm) at 28 days of curing as per IS: 516 1959 and split tensile strength on cylinder (150 mm ø x 300mm) at 28 days of curing as per IS: 5816 1999. The work presented in this paper reports the effects on the behavior of concrete produced from cement with combination of PG and MP at different proportions on the mechanical properties of concrete such as compressive strength, flexural strength, and split tensile strength. Investigation reported that compressive strength decreases by 16.89% in compared with targeted strength and decreases by 12.78% compared with control concrete at 28 days, flexural strength decreases by 26.46% compared with control concrete at 28 days, split tensile strength increases by 10.833% compared with conventional concrete at 28 days, were obtained at combination of (5% PG and 25% MP). Partial replacement of PG and MP reduces the environmental effects, produces economical and eco-friendly concrete.
Keywords- Phosphogypsum, marble powder, Flexural Strength, Compressive Strength, Split Tensile Strength

I. 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. Various materials are added such as phosphogypsum, marble powder, and admixture to obtain concrete of desired property. The character of the concrete is determined by quality of the paste . The key to achieving a strong, durable concrete rests in the careful proportioning, mixing and compacting of the ingredients.

Phosphogypsum is a by-product in the wet process for Manufacture of phosphoric acid by the action of sulphuric acid on the rock phosphate. It is produced by various process such as dehydrate , hemihydrates or anhydrate 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 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 worldwide to utilise natural waste and by-product as supplementary cementing materials to improve the properties of cement concrete.

A marble powder, obtained as a by-product of marble sawing and shaping, was characterized from a physical and chemical point of view for evaluating the possibility of using it in mortar and concrete production. Marble blocks are cut into smaller blocks in order to give them the desired smooth shape. During the cutting process about 25% the original marble mass is lost in the formimportant impact on environment and humans.

Substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the energy intensive Portland cement.

This research paper deals with the study of effects on the behavior of concrete produced from partial replacement of cement with combination of PG and MP at different proportions. In order to evaluate the effects of Phosphogypsum & Marble Powder on mechanical behaviour, many different mortar mixes were tested.

II. Materials and Methods

The work presented in this paper reports an investigation on the behaviour of concrete produced from partial replacement of cement with MP and PG. The physical and chemical properties of MP, PG and OPC were first investigated. Mixture proportioning was performed to produce high workability concrete with target strength of 31.6 Mpa (M25) for the convetional mix. The effects of MP and PG on concrete properties were studied by means of the mechanical properties of concrete i.e. compressive strength, split tensile strength, and flexural strength.

2.1 Cement

The cement used was Ordinary Portland cement (53 Grade) with a specific gravity of 3.15. Initial setting time of the cement was 48 min,conforming to I.S-8112- 1989.

table 1 chemical properties of cement (opc)

Analysis	**Ordinary Portland cement**
CaO	65.9
SiO2	21.94
Al2O3	4.82
Fe2O3	3.94
MgO	1.65
K2O	0.6
SO3	0.48
Na2O3	0.1

2.2 Marble powder

A marble powder was used, which was obtained as a by-product of marble sawing and shaping. Its specific gravity was 2.55 kg/m3 and the value of Blaine fineness was 1.50 m2/g. It can be observed that the marble powder had a high specific surface area; this could mean that its addition should confer more cohesiveness to mortars and concrete.

2.3 Phosphogypsum

Phosphogypsum was obtained from Panchayat samiti,Bhivapur in Maharashtra State, India. The specific gravity obtained was 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 (PG).

table 2: chemical composition of phosphgypsum

Chemical constituents	Percentage
CaO	31.2
SiO2	3.92
SO3	42.3
R2O3	3.6
MgO	0.49
Phosphate, Fluoride, etc.	18.49

2.4 Aggregate

Good quality river sand was used as a fine aggregate. The fineness modulus and specific gravity are 2.69, 2.65. Coarse aggregate passing through 20mm and retained 10mm sieve was used. Its specific gravity was 2.68.

III. Experimental program

Experimental program comprises of test on cement, fine aggregate,course aggregate , concrete with partial replacement of cement with MP and PG.

3.1 Ordinary Portland Cement

OPC 53 grade cement is used for this whole experimental study. Ordinary Portland cement of 53 grade were tested for different tests and physical test results of OPC were as follows:

1) fineness test=3.96%
2)Normal consistency = 33%
3) Initial Setting time = 48 min.
4) compressive strength of cement on 3,7,28 days was respectively 27.47MPa, 35.09MPa, 54.87MPa.

3.2 fine aggregate

Fine aggregate was tested for different tests and test results as follows:

1) bulking of sand = 4.5%
2) fineness modulus = 2.69
3) Specific Gravity = 2.65

3.**3 course aggregate**

course aggregate was tested for different tests and test results as follows:

1) fineness modulus = 7.74
2) Specific Gravity = 2.68

3.4 Mixture Proportioning

The mix proportion was done as per the IS 10262- 1982. The target mean strength was 31.6 Mpa (M25) for the OPC control mixture, the total binder content was 447.42 kg/m3, fine aggregate was taken700.66 kg/m3 and coarse aggregate was taken 1062.88 kg/m3. The water to binder ratio was kept constant as 0.44. The total mixing time was 5 minutes, the samples were then casted and left for 24 hrs before demoulding. They were then placed in the curing tank until the day of testing. Cement : fine aggregate : coarse aggregate were properly mixed together in ratio 1: 1.56: 2.37 by volume before wa-

ter was added and was properly mixed together to achieve homogenous material. Cube, Beam and Cylinder moulds were used for casting. Compaction of concrete in three layers with 25 strokes of 16 mm rod was carried out for each layer. The concrete was left in the mould and allowed to set for 24 hours before the cubes were demoulded and placed in curing tank. The concrete cubes were cured in the tank for 7, 14,and 28 days for compression test.

table 3: mix proportion for m25 grade concrete for tested material as follows

Material	Quantity	Proportion
Cement	435.45 Kg/ m3	1
Sand	476 Kg/ m3	1.56
Coarse Aggregates	1242.62 Kg/ m3	2.37
Water	191.6 Kg/ m3	0.44
Slump	75-100 mm	--

3.5 Different Proportion Of Cement, Marble Powder And Phosphogypsum For Testing

In this experimentation, cement was partially replaced by combinations ofmarble powder (MP) and Phosphogypsum (PG). Test was started with control concrete of M25 grade. Then, replaced the 30 % cement with MP and PG, by increasing the 5% of PG upto 15% while MP was constant at 25%.Following table shows the percentage variations of cement, phosphogypsum and marble powder .

table 4: proportion of cement,marble powder and phosphogypsum for testing

Sr.no.	% Of cement	% Of phosphogypsum	% Of marble powder
1	100%	0%	0%
2	70%	5%	25%
3	65%	10%	25%
4	60%	15%	25%
5	55%	10%	35%

IV. Experimental Methodology

4.1 Test on Fresh Concrete

Fresh concrete was tested using slump cone test and compaction factor test to find the workability of conventional concrete and concrete of combination of PG and MP with partial replacement of cement.

table 4:test results of workability test

	Type of concrete	**Replacing cement with phospho-gypsum**	**Replacing cement with marble powder**	**Slump (mm)**	**Compaction factor**
1	Conventional concrete	_	_	21	0.81
2	1st combination	5%	25%	50	0.85
3	2nd combination	10%	25%	60	0.87
4	3rd combination	15%	25%	65	0.91
5	4th combination	10%	35%	70	0.92

4.2 Test on Hardened Concrete

Tests were done as per following codes of Bureau of Indian Standards. The test for compressive strength on cubes were measured at 7, 14, 28 days of curing as per IS : 516 1959, test for flexural strength on beam was measured at 28 days of curing as per IS : 516 1959 and test for split tensile strength on cylinder was measured at 28 days of curing as per IS : 5816 1999.

fig.1 moulds for casting

4.3 Compressive Strength Test

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M25 grade of concrete. The moulds were filled with different proportions of cement, marble powder and Phosphogypsum. The top surface of the specimen was leveled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 7,14,28 days. After 7,14,28days curing, these cubes were tested on compression testing machine as per I.S. 516-1959. The failure load was noted. In each cate

gory, three cubes were tested and their average value is reported. The compressive strength was calculated as follows:

Compressive strength (MPa) = failure load / cross sectional area

table 4:test results of compressive strength of concrete

Sr. no.	MIX PROPORTION		COMPRESIVE STRENGTH AFTER NO. OF DAYS OF CURING IN N/MM^2		
	PG by % of cement	MP by % ofcement	7 days	14 days	28 days
1	Conventional mix		14.57	22.36	30.11
2	5%	25%	18.89	23.106	26.26
3	10%	25%	16.86	20.19	22.79
4	15%	25%	10.40	13.9	19.01
5	10%	35%	10.89	12.74	15.46

fig 2 testing of specimen under compression

4.4 Tensile strength test

For tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These specimens were tested under compression testing machine. In each category, three cylinders were tested and their average value was reported. Tensile strength was calculated as follows as split

tensile strength:

Where, P = failure load, D = diameter of cylinder, L = length of cylinder.

table 4:test results of tensile strength of concrete

Sr. no.	MIX PROPORTION		Split tensile STRENGTH AFTER 28 days curing IN N/MM^2
	PG by % of cement	MP by % of cement	
1	Conventional mix		2.40
2	5%	25%	2.66
3	10%	25%	1.88
4	15%	25%	1.51
5	10%	35%	1.35

Fig 3 Testing of specimen under split tension

4.5 Flexural Strength Test

The standard sizes of beam specimen were 15x15x70 cm. The beam moulds conform to IS:10086-1982. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These specimens were tested under universal testing machine(UTM).The specimens shall be tested immediately on removal from the water while they are still in the wet condition. The Flexure test was performed on three point loading system.

table 4:test results of flexural strength of concrete

Sr.no.	MIX PROPORTION		FLEXURAL STRENGTH AFTER 28 days curing IN N/MM^2
	PG by % of cement	MP by % of cement	
1	Conventional mix		2.91
2	5%	25%	2.14
3	10%	25%	1.55
4	15%	25%	1.35
5	10%	35%	1.12

Fig 4 Testing of specimen under Flexure

V. 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. Phosphogypsum in ordinary Portland cement mixes considerably retards setting time but does not contribute to produce unsound cement paste. The degree of workability of concrete mix with increasing percentage of phosphogypsum and marble powder increases as compared to conventional concrete,also improves cohesiveness of the concrete mix and thus reduction in segregation and bleeding.

Based on the results presented above, the following conclusions can be drawn:-

1. When combination of (phosphogypsum+ marble powder) was partially replaced with cement by weight, there is a marked reduction in compressive strength values of mortar mix with increasing (phosphogypsum+ marble powder) content when compared with target strength at each curing age. The maximum 28 days Compressive strength was obtained with combination of(5% phosphogypsum and 25% marble powder) mix in all combinations. Investigation reported that compressive strength decreases by 12.18% in compared with conventional concrete strength at 28 days, flexural strength decreases by 27.58% compared with conventional concrete at 28 days,where as split tensile strength increases by 10.83% compared with conventional concrete at 28 days, were obtained at combination of (5% PG and 25% MP).
2. The maximum 28 days split tensile strength was obtained with combination of(5% phosphogypsum and 25% marble powder) mix in all combinations which was less than control concrete.
3. The maximum 28 days flexural strength was obtained with combination of (5% phosphogypsum and 25% marble powder) mix.
4. The percentage of water cement ratio is reliant on quantity of phosphogypsum used in concrete.
5. The workability of concrete had been found to be increase with increase marble powder and phosphogypsum in concrete .
6. Partial replacement of PG and MP reduces the environmental effects, produces economical and eco-friendly concrete.

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