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PARTIAL REPLACEMENT OF FINE AGGREGATE AND CEMENT IN CONCRETE PAVEMENT BY PHOSPHOGYPSUM

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Abstract - *Phosphogypsum is a solid by-product material resulting from the production of phosphoric acid, a major constituent of many fertilizers. Depending on the wellspring of shake around 4.5 -5.0 hugs amount of Phosphogypsum are created per ton phosphoric corrosive deliver. Phosphogypsum principally comprises of calcium sulphate, up to 93.9 %. The rest is a mix of polluting influence, for example – Phosphate, fluoride, sand, soluble salts and organic compounds. Crystal of calcium sulphate can exist in at least three (03) unique states viz. de - hydrate (CaSo4 .2H2O), hemi - hydrate (CaSo4 .1/2H2O), an - hydrate (CaSo4). The Phosphate industry creates most Phosphogypsum in de - hydrate structure in 84%. The investigation depends on appropriate use of the waste material of Phosphogypsum as a partial replacement of (a) fine aggregate in cement concrete pavement, (b) cement in cement concrete pavement, (c) both fine aggregate and cement in cement concrete pavement. Phosphogypsum is a gray color, damp, fine grain powder silt and silty sand material with a most extreme size range between 0.5mm (No.40 sieve) and 1.0mm (No.20 sieve) and finer than 0.075 mm (no.200 sieve). Because of this nature it effectively replace the fine aggregate in flexible layer. The investigation includes the material characterization of Phosphogypsum, sieve analysis, specific gravity, moisture content, workability, compressive strength, flexural strength, unit weight, normal consistency, initial and final setting time respectively.*

INTRODUCTION

A large position of industrial waste created as strong squanders by mechanical action which incorporates any material that is rendered incapable amid an assembling procedure, for example that of enterprises, plants, factories and mining activities. Distinctive sorts and wellsprings of strong squanders, for example mechanical waste (inorganic), agro-waste (organic), mineral/mining waste, non perilous and dangerous waste. Out of all these strong squanders, mechanical waste and metropolitan strong squanders are created in tremendous sums. All around the assessed amount of strong waste age was 12 billions tons in the year 2002. Among this sum, 11 billion tons were modern strong squanders and 1.6 billions tons were metropolitan strong squanders [1]. The strong squanders created as side-effects causes major natural issues and additionally involves huge territory of land for their capacity and transfer. Additionally, there is an incredible breadth for setting up these immense amounts of strong side-effects as minerals or assets in the generation of constructional materials. So as to use the strong squanders viably in creating elective development materials, the definite physic-convections, building mineralogical, warm and morphological properties of these squanders must be assessed with great exactness.

Compost ventures are one of the primary driver of age of colossal measure of strong waste amid the generation of manure as nitrogen and phosphorus manure. Phosphorus as phosphate (expressed as P_2O_5) is a supplement for plants and a building obstructs in sustenance generation agriculture zone utilizes enormous measures measure of compound composts to refill and upgrade the supplements that developing plants take up from the dirt. Late serious horticulture helps normal phosphate levels in the dirt through expansion of phosphate composts. Phosphoric corrosive is an essential crude material for the generation of fertilizers (88%), cleansers (6%), and other horticulture items. World assembling comprises of roughly 25 millions tons for each time of phosphoric corrosive. In India, there are 11 number of phosphoric corrosive industrializing unit situated in states to be specific Andhra Pradesh, Gujarat, Rajasthan, Maharashtra, Orissa, Tamil Nadu and west Bengal. The aggregate generation of phosphoric corrosive is about 1.4 million tons amid year 2012-2013. In the year 2015-2016, it scopes to a furthest reaches of 6.5 millions tons for each annum. In Rajasthan the stone phosphate stores are accessible in religions viz. Udaipur, Chittorgarh, Jaisalmer and Jaipur [4]. The present market rate of Phosphogypsum and sand in Rajasthan are 430-600for every ton and 800-850 for every ton individually.

Shake phosphate is the normally happening hotspot for P2O5. The PG basically "calcium sulfate" is created as a loss from the phosphoric corrosive plant by the response of shake phosphate with sulphuric acid [2]. In the events that PG in arranged in open yards, it might make risk the environment, especially amid blustery season if proper measure are not taken. Other then ecological causes, taking care of and vest region required and also the potential for arrival of residue, fluoride and over heavy metal [1-4]. PG produced from phosphoric corrosive plants is by and by stacked and a couple of sums are utilized by different enterprises particularly in bond fabricating as a crude substitute of mineral gypsum and mortar board producing. It can likewise be utilized as channel in bitumen bland. So as to impact sly affect condition; there is requirement for advising the rules for safe dealing with, including transportation, storage room, dumping and legitimate uses of PG.

The material is gathered from J.S. Minerals and Chemical Pvt. Ltd. Lakadwas, girwa, Udaipur, Rajasthan. The plants is arranged 13 kms from Udaipur city. The aggregate creation of PG squander is over 60-70 tons for each day. The rate of PG around there is 400-450 for every ton[5].

Phosphogypsum Stock Piles

Phosphogypsum Stock Piles at J.S. Minerals & chem. Pvt. Ltd

TEST FOR CONCRETE PAVEMENT

- Sieve analysis
- Moisture content
- Specific gravity
- Compaction factor
- Compressive strength
- Flexural strength
- Normal consistency
- Initial setting time
- Final setting time

OBJECTIVE

The principle point of these exploratory investigation is to direct the investigation of PG squanders as a halfway substitution of fine total and bond in solid asphalts. The goal of my work is to put the regular materials of development forms. The utilization of Phosphogypsum squander in fractional sum in solid asphalt development forms. The utilization of Phosphogypsum squanders in frictional sum in solid asphalt;

- Enhances the different properties of concrete viz, compressive strength, flexural strength, water absorption, moisture content, compatibility, surface finish ability and workability.
- Advantageous disposal of industrial waste.
- Solve the problems of environmental pollution.
- As PG is having low value of specific gravity, the density of material is decreased by utilizing Phosphogypsum.

SCOPE

The scope of my study to utilized the PG in partial replacement of fine aggregates and cement, and helps in modification of the different properties of concrete pavements as;

- It improves the compressive strength of the pavements.
- It improves the flexural strength of the pavements.
- Helps in the reduction of thickness or depth of pavement layers.
- Acts as a retarder and helps in increase in the finally setting time of cement.
- Solve the negative environmental impacts.
- Advantageous disposal of industrial waste.

METHODOLOGY

DESIGN MIX OF M-40 GRADE OF CONCRETE-Concrete mix design is a process to find out the mix proportion of cement, fine aggregate (sand), course aggregate, admixture etc.
Stipulations for proportioning:-
Grade designation- M40
Type of cement – 43 grade
Maximum normal size of aggregate – 20 mm
Minimum cement content – 320kg/ m^3
Maximum water cement ratio – 0.45
Workability – 100 mm (slump)
Exposure condition - Severe
Method of concrete placing – Pumping
Design of super vision – Good
Type of aggregate - Crushed angular aggregate
Maximum cement contain – 450kg/m^3
Chemical admixture – super plasticizer
Test data for materials:-
1)Specific gravity of
Cement - 3.15
Course aggregate - 2.74
Fine aggregate - 2.74
2)Water absorption for
Course aggregate - 0.5%
Fine aggregate - 1%

Solution:-

Step -1 Target strength
F'ck = Fck + 1.65S
Hear S is standard deviation from IS 10262 : 2009 for table no. 1
(For M40 S=5)
F'ck = 40 + 1.65 × 5
= 48.25 N/mm^2
Step - 2 Water cement ratio
Maximum water cement ratio – 0.45 (IS 456 : 2000 from table no. 5)
But we adopted water cement ratio – 0.40
0.40 < 0.45 (OK)
Step - 3 Water content
From table no. 2 of IS 10262 : 2009
Maximum water content for 20 mm course aggregate = 186 liter
(for 25 to 50 mm of slump)
We need water content for 100 mm slump
= 186 + 6 /100 ×186
(3% of increase for every 25 mm slump)
= 197 liter
Admixture used so water content reduced to 20% and above
We adopted 29 % of water reduced
Arrived water content = 197 × 0.71 = 140 liter
Step - 4 Cement content
Water cement ratio = 0.40
= 140 / 0.40 = 350 kg/m^3
Step - 5 Volume of course aggregate and fine aggregate
From table no. 3 of IS 10262 : 2009
Volume of course aggregate for 20 mm size of aggregate and fine aggregate
(Zone - I)
Water cement ratio of 0.50 = 0.60
But present water cement ratio = 0.40
Water cement ratio lower by 0.10
For every ± 0.05 change in water cement ratio
The rate of change is -+ 0.01
So we get value of course aggregate for w/c ratio of 0.40 = 0.62
Placing of the concrete by pumping method.
So volume of coarse aggregate reduced by 10 %
Volume of coarse aggregate = 0.62 × 0.90 = 0.56
Volume of fine aggregate = 1 – 0.56 = 0.44

Step – 6 Mix calculation

a) Volume of concrete = 1 m^3
b) Volume of cement = mass of cement / specific gravity of cement × 1000
= 350 / 3.15 × 1000
= 0.111 m^3
c) Volume of water = 140 / 1 × 1000
= 0.140 m^3
d) Volume of admixture = 2 % of by mass of cement content
= 7 / 1.145 × 1000
(2 % of 350 = 7)
= 0.006 m^3
e) Volume of all in aggregate (e) = [a - (b + c + d)]
e = [1 - (0.111 + 0.140 + 0.006)]
e = 0.743 m^3
f) Mass of coarse aggregate =
= e × volume of coarse aggregate × specific gravity of aggregate × 1000
= 0.743 × 0.56 × 2.74 × 1000
= 1140 kg / m^3
g) Mass of fine aggregate =
= e × volume of fine aggregate × specific gravity of aggregate × 1000
= 0.743 × 0.44 × 2.74 × 1000
= 896 kg / m^3

Cement	350 kg / m^3
Water	140 kg / m^3
Fine aggregate	896 kg / m^3
Course aggregate	1140 kg / m^3
Plasticizer	7 kg / m^3
W / C ratio	0.40 kg / m^3

Then ratio of cement, sand and aggregate are –

Cement : Sand : Aggregate
1 : 2.56 : 3.25

RAW MATERIALS

- Cement
- Coarse Aggregates
- Fine Aggregates
- Water
- Phosphogypsum:- A grey colored, soggy, fine grained residue, silt or salty-sand material with a maximum size ranges between 0.5mm(No.40 sieve) and 1.0mm(No.20 sieve).

Phosphogypsum

The material is gathered from J. S. Minerals and Chemical Pvt. Ltd. Lakadwas Girwa Udaipur, Rajasthan. The plant is found 13Kms from Udaipur City. The absolute production of PG around there is 400-450 for every ton[5]. The PG squander created from phosphate industry is accumulated in throw yards, exceptionally minute are utilizing by other manure industrial facilities in that neighboring region, selective of being used in development reasons for various asphalt layers. Fig. demonstrates the examples of PG.

Phosphogypsum (PG) Sample

Natural Sand

The material is gathered from the Banas River(Bani), Tonk, Jaipur, Rajasthan, about 100Kms from the Bani, and made out of finely isolated shake and mineral particles as appeared in fig. 3.2[5].

Natural sand from Bani

MINERAL TESTING

Tests for CC-Pavements

- Grain Size Analysis
- Moisture Content
- Specific Gravity
- Workability Test by Compaction Factor
- Compressive Strength Test by UTM
- Consistency Test
- Initial Setting Time
- Final Setting Time

Sieve Analysis of Phosphogypsum (PG)

This test is executed according to seems to be: 2386 (section 1) 1963 (techniques for test for total for cement) reproduced in august 1997. This test is executed to give the definite thought with respect to degree of the PG[19] .

Sieve analysis of PG by using sieve shaker

Moisture Content of Phosphogypsum (PG)

This test is executed by the oven dry technique. This test is per IS: 2720 (P II) - 1973 in order to the moisture content in the Phosphogypsum [20].

PG sample for moisture content determination

Specific Gravity Test of PG

This test is executed according to seems to be: 2386 (III) 1963in order to find out the particular gravity of the natural sand and Phosphogypsum[21].

Specific Gravity= D/A-(B-C)
Apparent Specific Gravity= D/D-(B-C)

A= weight in g of saturated surface-dry sample,
B= weight in g of pycnometer or gas jar containing sample and filled with distilled water,
C= weight in g of pycnometer or gas jar filled with distilled water,
D= weight in g of oven-dried sample.

Specific gravity determination of PG sample by using Pycnometer

Workability test by Compaction Factor

The test is executed according to IS: 1199(1959) in order to find out the workability of concrete. The test is designed mainly for use in the laboratory, but if conditions permit, it may also be used in the field. It is more accurate and responsive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used & when concrete is to be packed in by vibration, such concrete may consistently fail to slump[22] .

M 40 concrete mix for compaction factor determination

Compressive Strength Test (CST)

This test is executed according to IS: 516-1959 in order to determine the compressive strength of the cubes casted by replacing (a) the natural sand with PG (b) cement with PG (c) Both natural sand & cement with PG, by a variable percentage. This test is executed by compressive testing machine of capacity 2000 KN [23].

Preparation of sample

The mix chosen for the preparation of the cube samples was M-40, designed as per IS: 10262-2009. Cube moulds of size 15cmX15cmXl5cm were made for the analysis. A calculated quantity of the ingredients for making concrete were taken and mixed in a proper manner by weight batching. After mixing the concrete is placed in the cubes and tampered in order to remove the voids[24].The amount of the materials according to blend structured is as follows:

Nominal mix and quantity of for preparation of cube samples

Water Cement Ratio(kg /m3)	Cement(kg /m3)	Fine Aggregates(k g/m3)	Coarse Aggregates(k g/m3)
0.40	1	2.56	3.25
140	350	896	1140

Procedure;

- Initially the entire cube moulds were taken and a layer of the grease or oil is coated on the internal sides of the shapes.
- The cube moulds are filled with concrete and tampered in order to remove the voids.
- The cube moulds are taken on the vibrating table conforming IS: 10262- 2009[24]
- The excessive material is removed with the help of a trowel and the shape moulds are kept as it is for 24 hours.
- After 24 hours the shape moulds are de-moulded and placed in the curing tank for a period of 7days, 14days and 28 days or according to the necessity.

    • After the fulfillment of the restoring time frame the solid shape moulds are evacuated and kept for surface drying.

    • After surface drying these moulds are taken into the compressive testing machine for the determination of compressive strength. In any event the normal estimation of three readings is taken into consideration for the analysis. The compressive strength is determined as:

Compressive strength= Maximum compressive load taken by specimen / Area of specimen.

The unit of compressive strength is taken as N/mm2.

Curing tank containing cube sample

Cube placed in CTM during loading

Flexural Strength Test (FST)

This test is executed according to IS:516-1959 in order to determine the flexural strength of the beams casted by replacing (a) the characteristic sand with PG (b) cement with PG(c) cement & natural sand with PG by a variable rate. This test is executed by universal testing machine of capacity 400 KN [23].

Preparation of sample

The blend picked for the readiness of the solid shape tests was M-40 planned according to IS: 10262-2009. Bar moulds of size 10cmX10cmX50cm were made for the investigation. A determined amount of the ingredients for production of concrete were taken and mixed in a proper way by weight batching. . After mixing the concrete is placed in the beam moulds and tampered in order to remove the voids [24].

Beam sample dimension 10cm x10cm x 50cm

The amount of materials according to blend configuration is according to the following:

Nominal mix and quantity of material for preparation of beam samples

Water Cement Ratio(kg /m3)	Cement(kg /m3)	Fine Aggregates(kg/m3)	Coarse Aggregates(kg/m3)
0.40	1	2.56	3.25
140	350	896	1140

The flexural strength is determined as:

Flexural strength= PL/bd2, if a<11cm

Flexural strength= 3Pa/bd2, if 11cm<a<13.33cm

'a' is the distance between the line of cracks and the nearest support measured on the centre line in cm.
'L' is the range of the bar in cm, 'P' is the applied load, 'b' is the width of pillar in cm &'d' is the profundity of the shaft in cm.

- The unit of flexural strength is taken as N/mm^2. The flexural strength is expressed in the modulus of crack.

Beam placed in UTM during loading

Consistency Test of PG

This test is executed according to be IS: 4031(Part4) 1988 in order to find out the standard consistency of the Phosphogypsum (PG). individual test will be performed at a temperature 27 ± 20°C and the general moistness of research facility ought to be 65 ± 5% (25) . The Standard consistency of sample is calculated as; **Standard Consistency (%) = Weight of Water Added /Weight of PG Sample x 100** Express the amount of water as a percentage by mass of dry sample to the first place of decimal.

Consistency test of PG

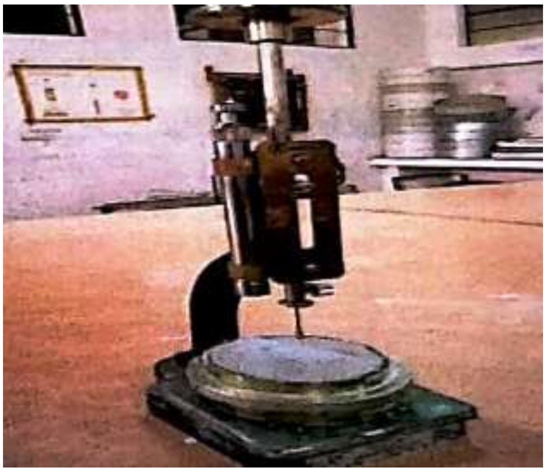
Initial Setting Time of PG

This test is performed as per IS: 4031(Part5) 1988 in order to find out the initial setting time of the Phosphogypsum (PG). Individually specified this test shall be conducted at a temperature of 27 ± 20°C and 65 ± 5% of relative humidity of the laboratory[26].

Vicat apparatus determination of initial setting time

Final Setting Time of PG

This test is performed as per IS: 4031 (Part5) 1988 in order to find out the final setting time of the Phosphogypsum (PG). Individually specified this test shall be conducted at a temperature of 27 ± 20°C and 65±5% of relative humidity of the laboratory (26).



Vicat apparatus determination of final setting time

3.3 TEST SCHEDULE

Sequence of tests

- Grain size analysis
- Moisture content
- Specific gravity
- Compaction factor test
- Compressive strength test
- Flexural strength test
- Normal consistency test
- Initial setting time
- Final setting time

COMPRESSION STRENGTH TEST SCHEDULE OF CURING FOR REPLACEMENT OF NATURAL SAND

Schedule of curing for CST by replacing NS

Name of Test	% of PG	Number of Samples	Duration
Compressive Strength Test	0	3	7
		3	14
		3	28
	5	3	7
		3	14
		3	28
	10	3	7
		3	14
		3	28
	15	3	7
		3	14
		3	28
	20	3	7
		3	14
		3	28
	25	3	7
		3	14
		3	28
	30	3	7
		3	14
		3	28

Schedule of samples for Replacement of NS in CST

Schedule of samples for CST by replacing NS

Name of Test	% of PG	Number of Samples
Compressive Strength Test	0	9
	5	9
	10	9
	15	9
	20	9
	25	9
	30	9

COMPRESSION STRENGTH TEST SCHEDULE OF CURING FOR REPLACEMENT OF CEMENT

Schedule of curing for CST by Replacing Cement

Name of Test	% of PG	Number of Samples	Duration
Compressive Strength Test	0	3	7
		3	14
		3	28
	5	3	7
		3	14
		3	28
	10	3	7
		3	14
		3	28
	15	3	7
		3	14
		3	28
	20	3	7
		3	14
		3	28
	25	3	7
		3	14
		3	28
	30	3	7
		3	14
		3	28

COMPRESSION STRENGTH TEST SCHEDULE OF CURING FOR REPLACEMENT OF BOTH MATERIAL (NS AND CEMENT)

Schedule of curing for CST by Replacing NS & Cement

Name of Test	% of PG	Number of Samples	Duration
Compressive Strength Test	0	3	7
		3	14
		3	28
	5 + 5	3	7
		3	14
		3	28
	10 + 10	3	7
		3	14
		3	28
	15 + 15	3	7
		3	14
		3	28
	20 + 20	3	7
		3	14
		3	28
	25 + 25	3	7
		3	14
		3	28
	30 + 30	3	7
		3	14
		3	28

Schedule of samples for Replacement of Cement in CST

Schedule of samples for CST by replacing Cement

Name of Test	% of PG	Number of Samples
Compressive Strength Test	0	9
	5	9
	10	9
	15	9
	20	9
	25	9
	30	9

Schedule of samples for Replacement of NS & Cement in CST

Schedule of samples for CST by replacing NS & Cement

Name of Test	% of PG	Number of Samples
Compressive Strength Test	0	9
	5 + 5	9
	10 + 10	9
	15 + 15	9
	20 + 20	9
	25 + 25	9
	30 + 30	9

FLEXURAL STRENGTH TEST SCHEDULE OF CURING FOR REPLACEMENT OF NATURAL SAND

Schedule of curing for FST by replacing NS

Name of Test	% of PG	Number of Samples	Duration
Flexural Strength Test	0	3	7
		3	14
		3	28
	5	3	7
		3	14
		3	28
	10	3	7
		3	14
		3	28
	15	3	7
		3	14
		3	28
	20	3	7
		3	14
		3	28
	25	3	7
		3	14
		3	28
	30	3	7
		3	14
		3	28

Schedule of samples for Replacement of NS in FST

Schedule of curing for FST by Replacing NS

Name of Test	% of PG	Number of Samples
Flexural Strength Test	0	9
	5	9
	10	9
	15	9
	20	9
	25	9
	30	9

FLEXURAL TEST SCHEDULE OF CURING FOR REPLACEMENT OF CEMENT

Schedule of curing for FST by Replacing Cement

Name of Test	% of PG	Number of Samples	Duration
Flexural Strength Test	0	3	7
		3	14
		3	28
	5	3	7
		3	14
		3	28
	10	3	7
		3	14
		3	28
	15	3	7
		3	14
		3	28
	20	3	7
		3	14
		3	28
	25	3	7
		3	14
		3	28
	30	3	7
		3	14
		3	28

Schedule of samples for Replacement of Cement in FST

Schedule of samples for FST by Replacing Cement

Name of Test	% of PG	Number of Samples
Flexural Strength Test	0	9
	5	9
	10	9
	15	9
	20	9
	25	9
	30	9

FLEXURAL TEST SCHEDULE OF CURING FOR REPLACEMENT OF BOTH MATERIAL (NS AND CEMENT)

Schedule of curing for FST by Replacing NS& Cement

Name of Test	% of PG	Number of Samples	Duration
Flexural Strength Test	0	3	7
		3	14
		3	28
	5 + 5	3	7
		3	14
		3	28
	10 + 10	3	7
		3	14
		3	28
	15 + 15	3	7
		3	14
		3	28
	20 + 20	3	7
		3	14
		3	28
	25 + 25	3	7
		3	14
		3	28
	30 + 30	3	7
		3	14
		3	28

Schedule of samples for Replacement of NS & Cement in FST

Schedule of samples for FST by Replacing NS & Cement

Name of Test	% of PG	Number of Samples
Flexural Strength Test	0	9
	5 + 5	9
	10 + 10	9
	15 + 15	9
	20 + 20	9
	25 + 25	9
	30 + 30	9

RESULTS AND DISCUSSIONS

RESULTS OF SIEVE SIZE ANALYSIS

Sieve Analysis of Phosphogypsum (PG):
This test is executed according to IS 2386(part I) 1963 (techniques for test for totals for cement) reproduced in august 1997. This test is executed to give the definite thought with respect to graduation of the PG.

The test outcomes saw the test are as follows;

Results of grain size analysis (dry sieve analysis) on PG (Passing 4.75 mm sieve)

IS Sieve Opening, mm,µ	Weight of Dish ,(g)	Weight of Dish + PG Retained(g)	Weight of PG retained(g)	Cumulative wt. Retained(g)	Cumulative % Retained	Cumulative % Finer
4.75	375	375	0	0	0	0
2.36	311	312	01	01	0.5	99.50
1.00	397	403	06	07	3.5	96.50
600	415	424	09	16	8.0	92.00
300	373	386	13	29	14.5	85.80
150	352	372	20	49	24.5	75.50
75	336	398	62	111	55.5	44.50
Pan	327	416	89	200		

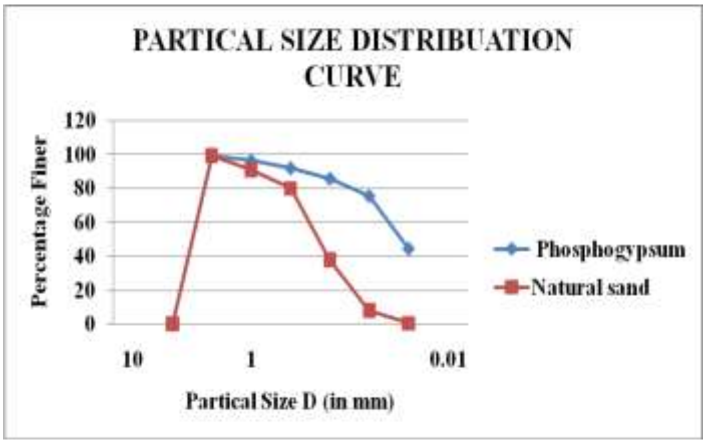
Type of sieve analysis: Dry
Total weight of PG= 200g, Weight of dish= 2886g

Sieve Analysis of Natural Sand (NS):

Results of grain analysis (dry sieve analysis) on NS (Passing 4.75 mm sieve)

IS Sieve Opening, mm, µ	Weight of Dish ,(g)	Weight of Dish + PG Retained(g)	Weight of PG retained(g)	Cumulative wt. Retained(g)	Cumulative % Retained	Cumulative % Finer
4.75	375	375	0	0	0	0
2.36	311	312	01	01	0.5	99.50
1.00	397	414	17	18	9.00	91.00
600	415	438	23	41	20.00	80.00
300	373	456	83	124	62.00	38.00
150	352	412	60	184	92.00	08.00
75	336	351	15	199	99.50	00.50
Pan	327	330	03			

Type of sieve analysis= Dry
Total weight of sand = 200g, Weight of dish= 2886g



Grain size distribution curve between PG and natural sand

Because of the consistency/unconformity in the degree of the particles of the PG, it is inferred that the PG can be used for the incomplete substitution of the natural sand (NS).

RESULTS OF MOISTURE CONTENT (MC)

Moisture content of PG (Oven Dry Technique)

Sample No.	Weight of Empty Container(g)	Wt of Empty Container + Sample. W1(g)	Oven Dry Weight W2 (g)	% Moisture Content (W1-W2)/W2 ×100
W1	44	74	66	12.12
W2	48	78	70	11.43
W3	42	73	64	12.82
Average				12.12

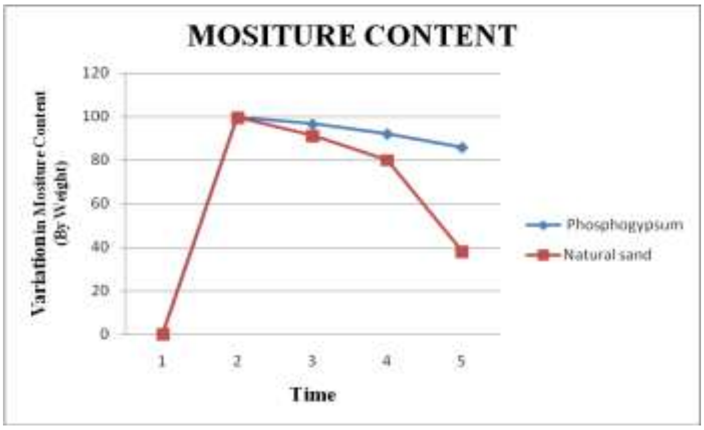
Total weight of sample= 200g

Moisture content of NS:

Moisture content of Natural Sand (Oven Dry Technique)

Sample No.	Weight of Empty Container(g)	Wt of Empty Container + Sample. W1(g)	Oven Dry Weight W2 (g)	% Moisture Content (W1-W2)/W2 ×100
W1	44	74	73	1.36
W2	44	74	73	1.36
W3	43	73	72	1.36
Average				1.36

Total weight of sample= 200g



Moisture content of sand & Phosphogypsum

Amid the time span (hole) of one month the MC of both the PG and natural sand (NS) were determined by an oven dry technique. The dampness substance of PG is more than that of the NS at each examination, which is 11.43, 12.12, 13.97, 13.54 if there should arise an occurrence of PG and 1.36, 1.48, 1.68 and 1.53 for natural sand separately as shown in graph 4.2.Therefore, it is concluded that there is an expansion of dampness substance of PG 0.03-0.07 grams by weight and slight diminishing in the NS by 0.004-0.006 individually.

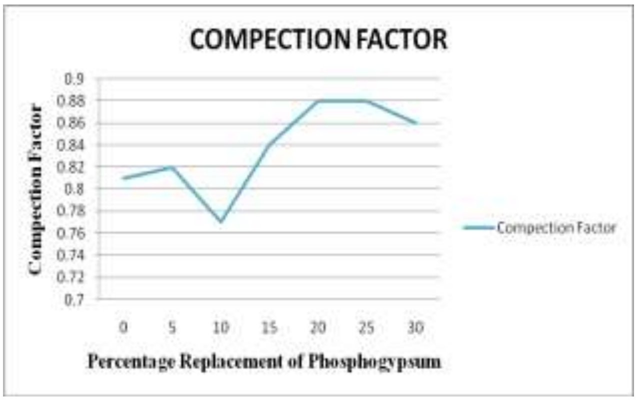
RESULTS OF SPECIFIC GRAVITY TEST (SGT)

This test is executed as per IS: 2386 (III) 1963 in order to discover the specific gravity of the NS and PG. The specific gravity is determined by pycnometer strategy. From the exploratory examination, the specific gravity of NS and PG determined are 2.41 and 2.77 respectively. The specific gravity of PG is somewhat lesser than that of NS therefore, it is reasoned that both the results are comparable.

4.4 RESULTS OF COMPACTION FACTOR TEST (CFT)

Table: 4.5: Results of Compaction Factor Test

S. No.	Percentage(%) of Replacement of PG	w/c Ratio	Compaction Factor
1	0	0.40	0.81
2	5	0.40	0.82
3	10	0.40	0.77
4	15	0.40	0.84
5	20	0.40	0.88
6	25	0.40	0.88
7	30	0.40	0.86



Percentage of Replacement of PG and Compaction Factor

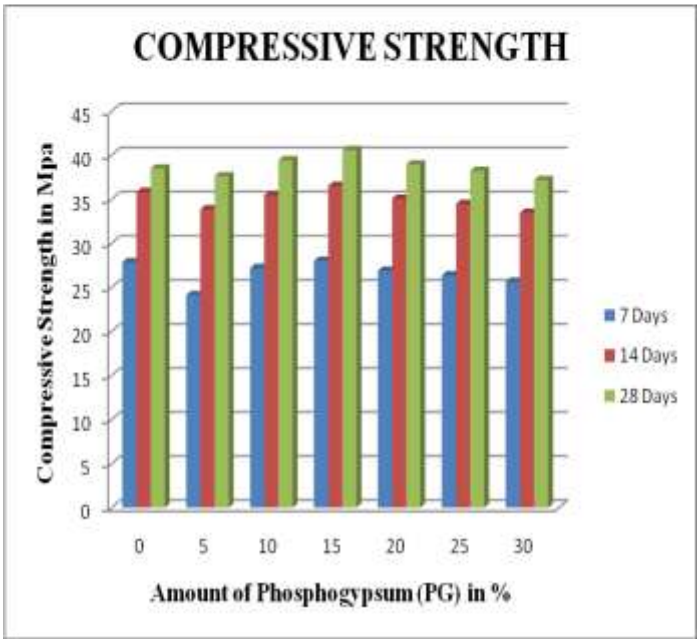
The compaction factor of customary cement (i.e. M-40 mix) comes out to be 0.88 with a w/c proportion of 0.40. After substitution of NS with PG i.e. at the interim of 5% (if there should arise an occurrence of total substitution), the compaction factor turns out to be 0.81, 0.82, 0.77, 0.84, 0.88, 0.86 respectively. Graph 4.3 demonstrates the variety in compaction factor and percentage of replacement of PG.

RESULTS OF COMPRESSIVE STRENGTH TEST (CST)
Rsults of CST for PG as a replacement of NS:

The compressive strength of M-40 mix design at 7, 14, 28 days are 27.87 MPa, 35.84 MPa, 38.50 MPa respectively. In the present analysis of replacement of natural sand by PG, the compressive strength of the cubes samples increment up to the cube samples increases up to the value of 15% replacement of natural sand at 7, 14, 28 days are 28.01 MPa, 36.53 MPa, 40.49 MPa respectively as shown in graph 4.4 Beyond additional (i.e. 15%) replacement of cement by PG the compressive strength decreases with respective to the conventional concrete (M-40 mix). Therefore, it is concluded that up to 15% replacement of NS by PG, the concrete behaves fine with compressive strength and hence can be used in construction of cc-pavements.

Results of CST for Replacement of NS

S. No.	Percentage of PG	Compressive Strength after 7days (MPa)	Compressive Strength after 14 days (MPa)	Compressive Strength after 28 days (MPa)
1	0	26.54	34.59	37.33
		27.38	36.99	39.66
		27.96	35.96	38.52
		27.87	35.84	38.50
2	5	25.48	33.31	37.02
		26.01	34.45	38.24
		25.91	33.86	37.63
		24.13	33.88	37.63
3	10	26.64	34.74	38.61
		26.95	35.16	39.07
		28.02	36.54	40.61
		27.20	35.48	39.43
4	**15**	**27.40**	**35.74**	**39.72**
		28.05	**36.55**	**40.61**
		28.59	**37.29**	**41.44**
		28.01	**36.53**	**40.59**
5	20	26.38	34.40	38.23
		27.20	35.48	39.43
		27.08	35.32	39.25
		26.88	35.07	38.97
6	25	26.15	34.11	37.91
		26.62	34.73	38.59
		26.33	34.34	38.16
		26.36	34.48	38.22
7	30	25.79	33.64	37.38
		25.67	33.48	37.21
		25.51	33.28	36.98
		25.65	33.47	37.19



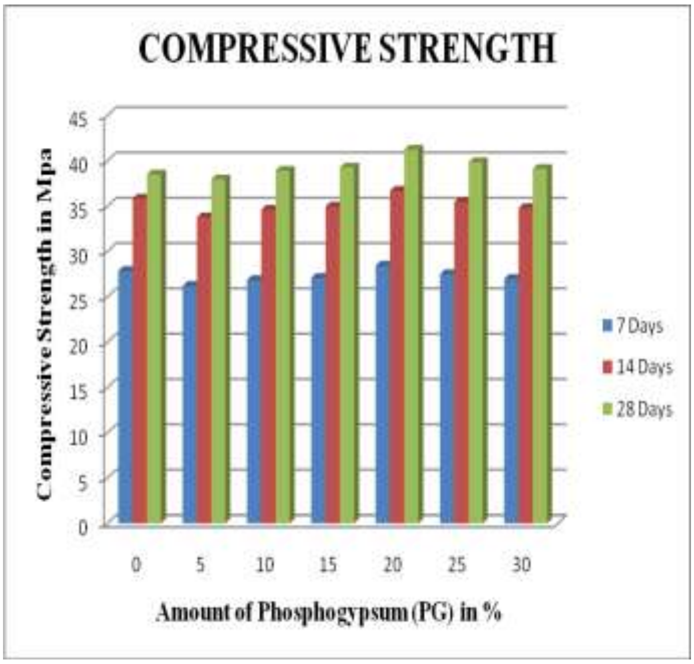
Percentage of PG and added & Compressive Strength by Replacing of NS

Results of CST for PG as a replacement of Cement:

The compressive strength of M-40 mix design at 7, 14, 28 days are 27.87 MPa, 35.84 MPa, 33.50 MPa respectively. In the present analysis of replacement of cement by PG, the compressive strength of the cubes samples increment up to the cube samples increases up to the value of 20% replacement of cement at 7, 14, 28 days are 28.44 MPa, 36.69 MPa, 41.23 MPa respectively as shown in graph 4.5 Beyond additional (i.e. 20%) replacement of cement by PG the compressive strength decreases with respective to the conventional concrete (M-40 mix). Therefore, it is concluded that up to 20% replacement of cement by PG, the concrete behaves fine with compressive strength and hence can be used in construction of cc-pavements. Also, helps in conserving the conventional material like cement and thus overall reduces the cost of construction of cc-pavements

Results of CST for Replacement of Cement

S. No.	Percentage of PG	Compressive Strength after 7days (MPa)	Compressive Strength after 14 days (MPa)	Compressive Strength after 28 days (MPa)
1	0	26.54	34.59	37.33
		27.38	36.99	39.66
		27.96	35.96	38.52
		27.87	35.84	38.50
2	5	26.11	34.59	37.57
		26.28	34.28	38.09
		26.37	34.01	38.22
		26.19	33.78	37.96
3	10	26.89	34.69	38.98
		27.18	35.04	39.38
		26.47	34.14	38.37
		26.84	34.62	38.91
4	15	26.28	33.98	38.10
		26.78	34.54	38.82
		28.21	36.39	40.89
		27.09	34.95	39.27
5	**20**	**28.46**	**36.72**	**41.26**
		29.19	**37.65**	**42.31**
		27.68	**35.70**	**40.12**
		28.44	**36.69**	**41.23**
6	25	27.74	35.78	40.21
		27.71	35.74	40.16
		27.05	34.89	39.21
		27.50	35.47	39.86
7	30	26.86	34.65	38.94
		27.31	35.22	39.58
		26.77	34.54	38.81
		26.98	34.80	39.11



Percentage of PG and added & Compressive Strength by Replacing of Cement

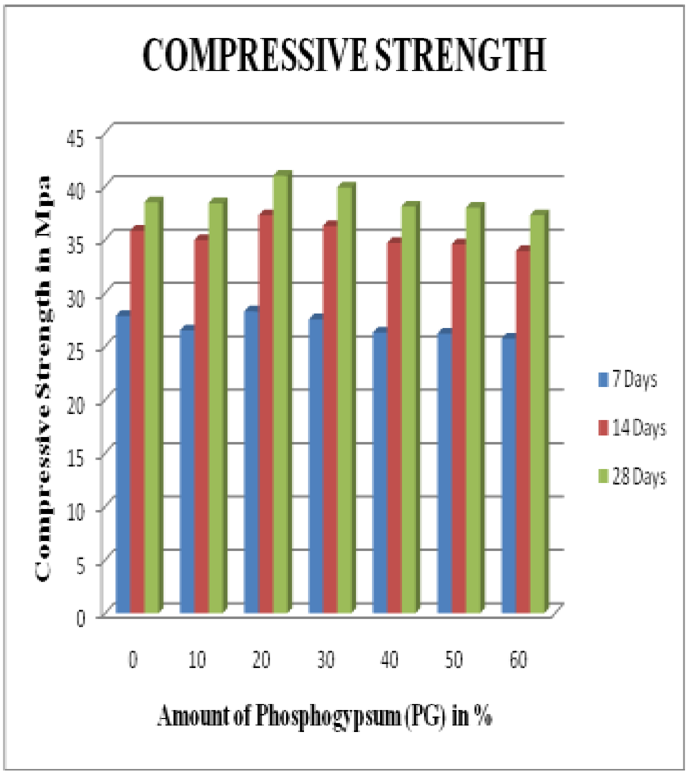
Results of CST for PG as a replacement of NS & Cement:

The compressive strength of M-40 mix design at 7, 14, 28 days are 27.87 MPa, 35.84 MPa, 33.50 MPa respectively. In the present analysis of replacement of both materials (i.e. natural sand and cement) in equal percentages by Phosphogypsum (PG), the compressive strength of the cube samples increases up to the value of 20% replacement of natural sand and cement at 7, 14, 28 days are 28.27 MPa, 37.29 MPa, 40.98 MPa respectively as shown in graph 4.6. Beyond 20% replacement of both the materials (i.e. natural sand and cement), compressive strength decreases with respective to the conventional concrete (M-40 mix). Therefore, it is concluded that up to 20% replacement of both natural sand and cement by PG, the concrete behaves fine with compressive strength and hence can be used in construction of cc-pavements.

Results of CST for Replacement of NS & Cement

S. No.	Percentage of PG	Compressive Strength after 7days (MPa)	Compressive Strength after 14 days (MPa)	Compressive Strength after 28 days (MPa)
1	0	26.54	34.59	37.33
		27.38	36.99	39.66
		27.96	35.96	38.52
		27.87	35.84	38.50
2	5+5	26.37	34.78	38.23
		26.82	35.37	38.87
		26.33	34.72	38.16

		26.50	34.96	38.42
3	**10+10**	**28.26**	**37.27**	**40.96**
		28.11	**37.07**	**40.74**
		28.45	**37.52**	**41.24**
		28.27	**37.29**	**40.98**
4	15+15	28.17	37.15	40.83
		26.89	35.47	38.98
		27.50	36.27	39.86
		27.52	36.29	39.89
5	20+20	26.33	34.72	38.16
		25.90	34.17	37.55
		26.64	35.14	38.62
		26.29	34.68	38.11
6	25+25	25.96	34.24	37.63
		25.91	34.17	37.56
		26.73	35.26	38.75
		26.20	34.56	37.98
7	30+30	25.37	33.46	36.77
		26.27	34.65	38.08
		25.54	33.68	37.02
		25.73	33.93	37.29



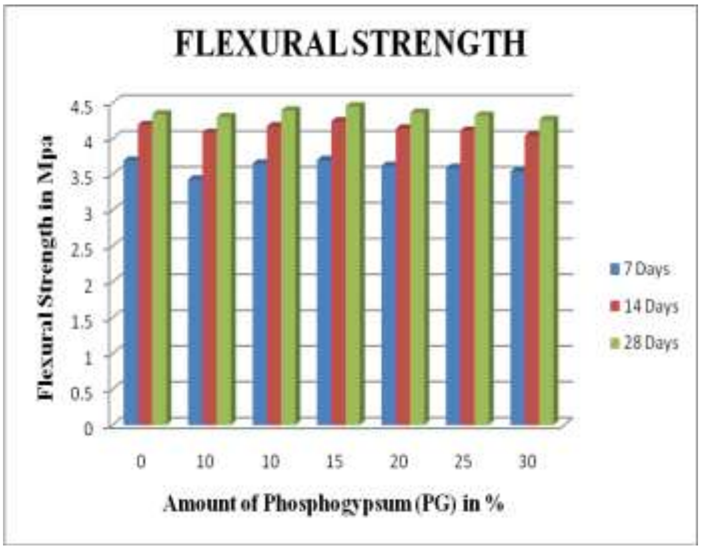
Percentage of PG and added & Compressive Strength by Replacing of NS and Cement

RESULTS OF FLEXURAL STRENGTH TEST (FST)

Results of FST for Replacement of NS

The flexural strength of M-40 mix design at 7, 14, 28 days are 3.23MPa, 3.70 MPa, 3.92MPa respectively. In the present analysis of replacement of natural sand in equal percentages by Phosphogypsum (PG), the flexural strength of the concrete increases after 7, 14, 28 days of curing as 3.70 MPa, 4.24 MPa and 4.45 MPa respectively by 15% replacement as shown in graph 4.7. Beyond 15% replacement of NS, flexural strength decreases endlessly. Therefore, it is concluded that up to 15% replacement of natural sand by PG, the concrete behaves fine with flexural strength and hence can be used in construction of cc-pavements.

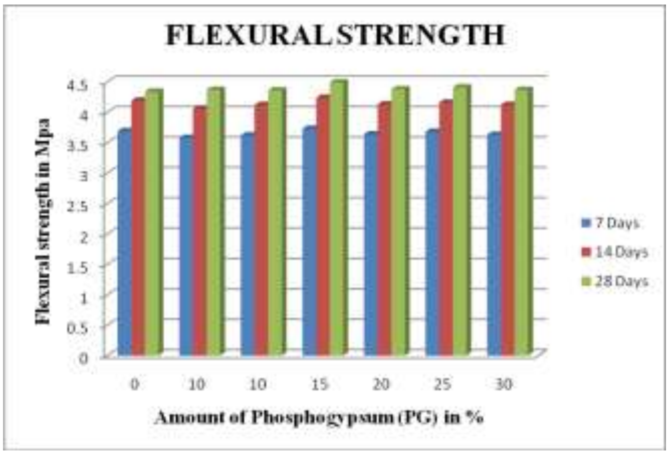
S. No.	Percentage of PG	Flexural Strength after 7days (MPa)	Flexural Strength after 14 days (Mpa)	Flexural Strength after 28 days (Mpa)
1	0	3.60	4.05	4.27
		3.66	4.18	4.40
		3.70	4.12	4.34
		3.69	4.19	4.34
2	5	3.53	4.04	4.25
		3.57	4.10	4.32
		3.56	4.07	4.29
		3.43	4.08	4.30
3	10	3.61	4.12	4.34
		3.63	4.15	4.37
		3.70	4.23	4.46
		3.65	4.17	4.39
4	**15**	**3.66**	**4.18**	**4.41**
		3.70	**4.23**	**4.46**
		3.74	**4.27**	**4.51**
		3.70	**4.24**	**4.45**
5	20	3.59	4.10	4.32
		3.65	4.17	4.39
		3.64	4.16	4.38
		3.62	4.14	4.36
6	25	3.57	4.08	4.30
		3.61	4.12	4.34
		3.59	4.10	4.32
		3.59	4.11	4.32
7	30	3.55	4.06	4.27
		3.54	4.05	4.27
		3.53	4.03	4.25
		3.54	4.04	4.26



Percentage of PG added & Flexural Strength by Replacing of NS

Results of FST for PG as a Replacement of Cement

The flexural strength of M-40 mix design at 7, 14, 28 days are 3.69 MPa, 4.19 MPa, 4.34 MPa respectively. In the present analysis of replacement of cement in by Phosphogypsum (PG), the flexural strength of the concrete increases after 7, 14, 28 days of curing as 3.73 MPa, 4.24 MPa and 4.49 MPa respectively by 15% replacement as shown in graph 4.8. Beyond 15% replacement of Cement, flexural strength decreases endlessly. Therefore, it is concluded that up to 15% replacement of Cement by PG, the concrete behaves fine with flexural strength and hence can be used in construction of cc-pavements.



Percentage of PG added & Flexural Strength by Replacing of Cement

Results of FST for Replacement of Cement

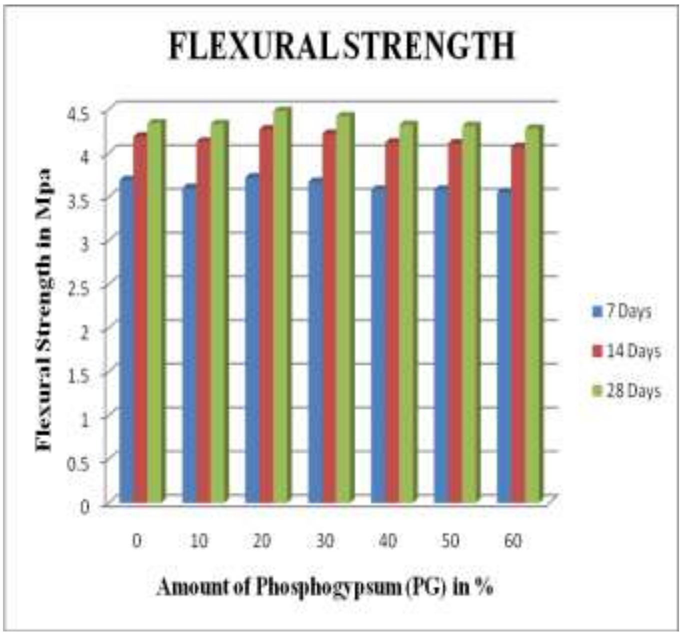
S. No.	Percentage of PG	Flexural Strength after 7days (MPa)	Flexural Strength after 14 days (MPa)	Flexural Strength after 28 days (MPa)
1	0	3.60	4.05	4.27
		3.66	4.18	4.40
		3.70	4.12	4.34
		3.69	4.19	4.34
2	5	3.57	4.11	4.29
		3.59	4.09	4.33
		3.58	4.08	4.31
		3.58	4.06	4.37
3	10	3.62	4.12	4.39
		3.64	4.14	4.35
		3.60	4.09	4.37
		3.62	4.12	4.36
4	**15**	**3.73**	**4.24**	**4.49**
		3.78	**4.29**	**4.55**
		3.68	**4.18**	**4.43**
		3.73	**4.24**	**4.49**
5	20	3.58	4.08	4.32
		3.62	4.11	4.36
		3.71	4.22	4.47
		3.64	4.13	4.38
6	25	3.69	4.18	4.44
		3.68	4.19	4.43
		3.67	4.13	4.38
		3.68	4.16	4.41
7	30	3.62	4.12	4.36
		3.65	4.15	4.40
		3.62	4.11	4.36
		3.63	4.12	4.37

Results of FST for PG as a Replacement of NS & Cement:

Results of FST for Replacement of NS & Cement

S. No.	**Percentage of PG**	**Flexural Strength after 7days (MPa)**	**Flexural Strength after 14 days (MPa)**	**Flexural Strength after 28 days (MPa)**
1	0	3.60	4.05	4.27
		3.66	4.18	4.40
		3.70	4.12	4.34
		3.69	4.19	4.34
2	5+5	3.59	4.12	4.32

		3.62	4.16	4.36
		3.60	4.12	4.32
		3.60	4.13	4.33
3	**10+10**	**3.72**	**4.27**	**4.48**
		3.71	**4.26**	**4.46**
		3.73	**4.28**	**4.49**
		3.72	**4.27**	**4.48**
4	15+15	3.71	4.26	4.47
		3.63	4.16	4.37
		4.67	4.21	4.41
		3.67	4.22	4.42
5	20+20	3.59	4.12	4.32
		3.56	4.09	4.28
		3.61	4.14	4.35
		3.58	4.12	4.32
6	25+25	3.57	4.09	4.29
		3.56	4.08	4.28
		3.61	4.15	4.35
		3.58	4.11	4.31
7	30+30	3.52	4.04	4.31
		3.58	4.12	4.24
		3.60	4.06	4.26
		3.55	4.07	4.28



Percentage of PG added & Flexural Strength by Replacing of NS and Cement

The flexural strength of M-40 mix design at 7, 14, 28 days are 3.69MPa, 4.19 MPa, 4.34 MPa respectively. In the present analysis of replacement of both materials(i.e. NS and cement) by Phosphogypsum (PG), the flexural strength of the concrete increases after 7, 14, 28 days of curing as 3.72 MPa, 4.27 MPa and 4.48 MPa respectively by 20% replacement as shown in graph 4.9.Beyond 20% replacement of both materials (i.e. NS and Cement), flexural strength decreases endlessly. Therefore, it is concluded that up to 20% replacement of both materials (i.e. NS and Cement) by PG, the concrete behaves fine with flexural strength and hence can be used in construction of cc-pavement.

RESULTS OF NORMAL CONSISTENCY (NC)

Consistency physically means that how much percentage of weight of water to be added to sample to make a paste of standard consistency. This test helps to determine the water content required for conducting the tests like initial and final setting time, soundness and compressive strength. The amount of water required for IST and FST is (0.85 P), for compressive strength is (P/4+3%) and for soundness (0.78 P), (where P= Consistency of standard paste). Experimental analysis shows that the normal consistency of PG is 30%, as shown in the table 4.12 above as compared to that of Cement is 25 to 35%.

Results of Normal Consistency

S. No.	Water Cement (%)	Needle Penetration (mm)
1	28	9.5
2	30	6.0

Weight of PG= 300g

RESULTS OF INITIAL SETTING TIME (IST)

Results of Initial Setting Time

S. No.	Time (minutes)	Needle Penetration (mm)
1	0	-
2	10	-
3	20	-
4	30	-
5	40	-
6	50	0.5
7	60	2.5
8	**70**	**7.0**

The initial setting time period is required to delay the process of hardening and hydration or in other words, it is the time from the moment you added water to the building material and even enter in the sample paste vicat needle for a distance of 5mm to 7mm from the bottom of the templates. Test results (table 4.13) shows that the initial setting of

sample (PG) is 70 minutes which is more that the IST of Cement (30min). This concludes that the PG behaves as a retarder to increase the initial
Setting time of the cement in the mix.

RESULTS OF FINAL SETTING TIME (FST)

Results of Final Setting Time (FST)

S. No.	Time (minutes)	Remark
1	0	Clear visible outer ring and dot
2	30	"
3	60	"
4	90	"
5	120	"
6	150	"
7	180	Clear visible outer ring and dot
8	210	"
9	240	"
10	270	"
11	300	"
12	330	"
13	360	"
14	390	"
15	420	"
16	450	"
17	480	Low visible outer ring and clear dot
18	510	"
19	540	"
20	570	"
21	600	"
22	630	"
23	660	"
24	690	"
25	720	"
26	750	"
27	**780**	**Outer ring disappears & only dot is visible**

Final setting time is the period at which the concrete lose its plasticity when placed finally, so that it is least vulnerable to damages from exterior agencies. Test results (table 4.14) show that the FST of PG is 780 minutes (13 hours) which is higher as compared to that of Ordinary Portland Cement and Portland Pozzolana Cement (not more than 10 hours). Therefore, it is concluded that the PG having higher FST can be used with cement, as an admixture (retarder) in the concrete, so as to reduce the FST of cement as well as overall cost of the concrete mix.

CONCLUSIONS

- The gradation of particles in the PG and NS are nearly analogous. Due to the resemblance in the gradation of the particles of the PG, it is concluded that PG, it is concluded that PG can be utilized for the replacement of the natural sand.
- Moisture content of natural sand (NS) is found in the range from 1.36-1.68 and that of PG is in the range from 11.43-12.82. After collection from the plant it is not varying and is in the workable/practicable range.
- The specific gravity calculated for PG and NS are 2.41 and 2.77 respectively. The specific gravity of PG is slightly lesser than that of NS therefore, it is concluded that both the results are comparable.
- The compaction factor of customary cement (i.e. M-40 mix) comes out to be 0.88 with a w/c proportion of 0.40. After substitution of NS with PG i.e. at the interim of 5% (if there should arise an occurrence of total substitution), the compaction factor turns out to be 0.81, 0.82, 0.77, 0.84, 0.88, 0.86 respectively
- The compressive strength of the cube samples increases by replacement of NS up to the value of 15% at 7, 14, 28 days are 24.13 MPa, 36.01 MPa, 40.03 MPa respectively. Beyond 15% replacement of fine aggregate the compressive strength decreases with respective to the conventional concrete (M-40 mix). Therefore, it is concluded that up to 15% replacement of natural sand by PG, the concrete behaves fine with compressive strength and hence can be used in construction of cc-pavements. In second case, the compressive strength of the cube samples increases up to the value of 20% replacement of cement at 7, 14, 28 days are 29.65 MPa, 29.65 MPa, 40.50 MPa respectively. Beyond additional (i.e. 20%) replacement of cement by PG the compressive strength decreases with respective to the conventional concrete (M-40 mix). Therefore, it is concluded that up to 20% replacement of cement by PG, the compressive strength of the cube samples increases up to the value of 20% replacement of NS and cement at 7, 14, 28 days are 27.05 MPa, 36.87 MPa, 40.27 MPa respectively. Beyond 20% replacement of both the materials i.e. (cement and

NS), the compressive strength decreases with respective to the conventional concrete (M-40 mix).

- The flexural strength of the concrete cube samples increases after 7, 14, 28 days of curing as 3.45 MPa, 4.17 MPa and 4.43 MPa respectively by 15% replacement of NS. Ahead of 15% replacement of NS by PG, the flexural strength decreases endlessly. Therefore, it is concluded that up to 15% replacement of NS by PG, the concrete behaves fine with flexural strength and hence can be used in construction of cc-pavements. In second case, the flexural strength of the concrete cube samples increases after 7, 14, 28 days of curing as 3.75 MPa, 4.15 MPa, and 4.15 MPa respectively by 15% replacement of cement. Ahead of 15% replacement of cement by PG, the flexural strength decreases endlessly.
- In third case, the flexural strength of the concrete cube samples increases after 7, 14, 28 days of curing as 3.57 MPa, 4.22 MPa, and 4.43 MPa respectively by 20% replacement of cement. Ahead of 20% replacement of both (natural sand and cement) by PG, the flexural strength decreases endlessly.
- Experimental analysis shows that normal consistency of PG is 30%, as compared to that of cement (OPC) is 25 to 35%. Experimental analysis shows that the initial setting time (IST) of Phosphogypsum is 70 minutes which is more than IST of OPC (30min) and PPC (40min). This concludes that the PG behaves as a retarder to increase the initial setting time of the OPC in the mix.
- Experimental analysis shows that the final setting time (FST) of PG is 780 minutes (13 hour) which is higher as compared to that of OPC and PPC (not more than 10 hours). Therefore, it is concluded that the PG having higher FST can be used with cement, as an admixture (retarder) in the concrete, so as to reduce the FST of cement as well as overall cost of the concrete mix.
- Use of PG helps in conserving the conventional material like sand, cement and thus overall reduces the cost of construction of cc-pavements. The cost of the PG is suitability low as compared to the conventional materials, thus overall cost of the construction of pavement is minimized.
- Utilization of PG in road construction helps us to solve the problems of environmental contamination as well as profitable for disposal of industrial waste.

FUTURE WORK

- Utilization of PG in WBM course.
- Utilization of PG as a filler material in surface courses in flexible payments.
- Utilization of PG in higher grades of concrete.
- Utilization of PG as a stabilizer in various types of soils.

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