"EXPERIMENTAL STUDY ON STRENGTH & DURABILITY CHARACTERISTICS OF SPECIAL CONCRETE BY USING PHOSPHOGYPSUM WITH STEEL FIBRE"

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ABSTRACT

Most Concretes produced today contain materials in addition to Portland cement to help achieve the strength or durability performance. These materials include fly ash, silica fume and ground-granulated blast furnace slag used separately or in combination. In this project we used phosphogypsum as admixture to improve the performance of concrete. It is a waste material obtained from fertilizer manufacturing. Also, steel fiber is introduced to increase the tensile strength of concrete. The grade of concrete used is M_{20} & M_{25}. For both the mixes, phosphogypsum is added as 0%,15%, 20% & 25%. The steel fiber is kept constant for all the mixes as 50kg/m^3. The material testing's done to arrive the mix proportion. The fresh concrete properties are studied. Harden concrete properties of concrete like compressive strength, split tensile strength are done and the results are enclosed in this report. It was found that the concrete with 15% phosphogypsum & 50kg/m^3 shown good performance both in fresh and harden state.

1. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable.

In the recent revision of IS: 456-2000, one of the major points discussed is the durability aspects of concrete. So the use of concrete is unavoidable. At the same time the scarcity of aggregates are also greatly increased nowadays. Utilization of industrial solid waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural resources. Cement in general sense of the word, can be described as a material with an adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact mass. This definition encompasses a large variety of cementing material. For constructional purposes the meaning of the term cement is restricted to the bonding materials used with stones, sand, bricks, blocks etc. Cement is the most important material in structural constructions as it is used at different stages of construction in the form of mortar or concrete

World consumption of cement is forecast to continue to increase throughout the next 15 years, taking the annual volume up from the 2250 MT of 2005 to around 3130 MT by 2015 and 3560 MT by 2020, representing overall forward expansion of approximately 56% According to the "GLOBAL CEMENT to 2020", world production and consumption of cement approximated 2250 MT in 2005 this level representing an increase of approximately 5.75% (124 MT) on the previous year and a continuation of the annual underlying expansion which has seen year-on-year growth in almost every year since the 1970‟s.

STUDIES ON PHOSPHOGYPSUM

Now a days the manufacture of cement involves the consumption of valuable natural materials like lime, gypsum etc., in huge quantities. Phosphogypsum is a byproduct of the processing of phosphate ore; mainly in the production of fertilizers..Phosphogypsum refers to the gypsum formed as a by-product of processing phosphate ore into fertilizer with sulfuric acid. Phosphogypsum is produced from the fabrication of phosphoric acid by reacting phosphate ore (apatite) with sulfuric acid according to the following reaction: $Ca5(PO4)3X+5H2SO4 +10H2O \rightarrow 3H3PO4 +5CaSO4 \cdot 2 H2O + HX$ →Eq.No.2.3 where X may include OH, F, Cl, or Br Phosphogypsum has become a material of special attraction, because of its suitability for construction activities. At the same time a lot of Phosphogypsum is produced as an industrial waste and its disposal presents lactic problem to the environment as well as to the industry itself. Any system is more efficient if the out come of the process is effectively consumed and utilized in another process. Here comes the use of Phosphogypsum in the manufacture of concrete instead of cement to an extent of 20 to 40%. Majority of phosphogypsum in India is produced by the dehydrate process due to it's simplicity in operation and lower maintenance as compared to other processes. Approximately, 30 million tons of Phosphorous Pentoxide is currently produced annually worldwide, that is about 120-150 million tons per annum of phosphogypsum is being produced currently. For a country like India, this process has an attraction as it helps in saving the foreign exchange towards the import of Sulphur and thus can solve any shortage of cement in the country.

PROPERTIES AND FIBER TYPES

Generally, carbon fibers are the closest to asbestos in a number of properties. The focus of this section is on Japanese developments in the use of chopped and short carbon fibers in concrete in a form known as carbon fiber cement concrete (CFCC) or carbon fiber reinforced concrete (CFRC).

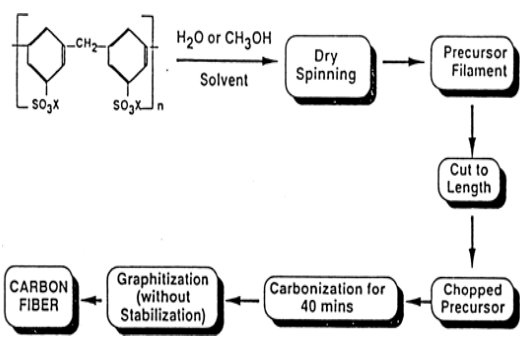
As developed in Japan, CFCC has little resemblance to conventional concrete. It contains no coarse aggregate and typically contains between 3 to 15 percent by volume chopped and short carbon fiber elements. Three types of carbon fiber are used in CFRC in Japan: pitch-based carbon fiber, polyacrlonitrile-based carbon fiber, and Mitsui Mining form.

The first two materials are well known to the composites industry. The last was developed by the Mitsui Mining Co. as a cheaper material form with affinity for concrete slurry. A major concern in the addition of fibers to concrete is the bonding between the two. The production procedure is shown in Figure 1.1. The resulting fiber has a "fuzzy" form with a strong affinity for concrete. The outcome is due to a combination of factors including the surface fuzziness and surface chemistry obtained by skipping the stabilization stage during pyrolysis. Table 1.1

compares the properties of three commercially available carbon fiber varieties.

In its use in polymer concrete, as with fiber reinforced concrete, the optimum form of the fiber may well be different from that used in aerospace applications. Further, the different requirements for civil engineering applications could result in the viability of lower cost fuzzy forms that could not be used previously in composites. Not all production is used in concrete and often special varieties are produced for use in CFCC for chemical stability, bonding issues and economics.

Based on the specific needs for a commercially viable form usable in concrete, Mitsubishi Kasei introduced the DIALEAD chopped fiber form made of pitch some years ago. Due to improved surface characteristics, it can be mixed in a normal top loading mixer without the need for special additive or



a special mixer.

Manufacturer	Trade Name	Strength (GPa)	Modulus (GPa)	Production (tons/year current)
Kureha	Kreca-T	0.5 - 0.8	30 – 35	300
Mitsubishi Chemical	Dialead	1.5 - 1.8	150 -180	Unknown
Osaka Gas	Donacarbo-S	0.65 - 0.80		100

Although the performance levels of the fiber used in concrete are lower, they are at levels sufficient to show significant improvement in the performance of concrete. In addition to the direct improvements in performance in tensile and flexural strengths, the use of chopped carbon fibers in concrete results in other generic advantages, especially in building construction, as shown in Table 1.3.

The following section highlights CFRC application areas drawing on examples of its use in existing structures

ASPECT RATIO

The **aspect ratio** of an image describes the proportional relationship between its width and its height. It is commonly expressed as two numbers separated by a colon, as in 16:9. For an *x*:*y* aspect ratio, no matter how big or small the image is, if the width is divided into *x* units of equal length and the height is measured using this same length unit, the height will be measured to be *y* units. For example,] consider a group of images, all with an aspect ratio of 16:9. One image is 16 inches wide and 9 inches high. Another image is 16 centimeters wide and 9 centimeters high. A third is 8 yards wide and 4.5 yards high.

The most common aspect ratios used today in the presentation of films in movie theaters are **1.85:1** and **2.39:1**.Two common video graphic aspect ratios are **4:3** (1.33:1), the universal video format of the 20th century and **16:9** (1.77:1), universal for high-definition television and European digital television.

TYPES OF FIBER

Steel Fiber

Steel has long been the most common fiber utilized in concrete reinforcement, the first pavement utilizing this technology was installed in a truck weighing station in Ohio. In the last couple of decades, steel fiber reinforced concrete has been used in the building of bridge decks, parking garages, pavements that carry a lot of traffic and industrial floors. Steel fibers are important not only due to the added strength but also since they help reduce cracking during shrinkage and increase "fatigue strength."

2. LITERATURE REVIEW

Adnan Cloak lan (1988) studied the effect of phosphogypsum – Portland cement – natural pozzolan ratios on the physical mechanical and durability properties of gypsum. The results indicate that the setting time of these pastes decrease with the increase of gypsum content in the mixture ranging from 8 to 11 minutes. The addition of super plasticizers increase the setting time from approximately 11 to 35 minutes. This increase is greatly dependent on the plasticizer admixture dosage. These blends show a kinetic of capillary water absorption very similar to that of the Portland cement binder. The gypsum-Portland cement blends themselves possess good water resistance which is further enhanced by the addition of natural pozzolan and super plasticizer. The water cured blends with the composition of 41:41:18 gypsum Portland cement: Natural Pozzolan offers compressive strength of approximately 20 MPa at room temperature. These blends give excellent properties retention after again in water at 20 degree for 95 days.

(Bhattacharyya et al., (2004); Eiichi et al., (2006)). Recently, the effect of phosphatic and fluoride impurities present in waste phosphogypsum on the setting time, strength development and morphology of selenite gypsum plaster have been studied

Kelly Rusch et al. (2002), Phosphogypsum (PG, $CaSO_4 \cdot H_2O$), a solid byproduct of phosphoric acid manufacturing, contains low levels of radium (266Ra), resulting in stackpiling as the only currently allowable disposal/storage method. PG can be stabilized with class C fly ash and lime for potential use in marine environments. An augmented simplex centroid design with pseudo-components was used to select 10 PG: class C fly ash: lime compositions. The 43 cm^3 blocks were fabricated and subjected to a field submergence test and 28 days salt water dynamic leaching study. The dynamic leaching study yielded effective calcium diffusion coefficients (De) ranging from 1.15×10^{-13} to 3.14×10^{-13} m^2 s^{-1} and effective diffusion depths (Xc) ranging from 14.7 to 4.3 mm for 30 years life. The control composites exhibited diametrical expansions ranging from 2.3 to 17.1%, providing evidence of the extent of the rupture development due to ettringite formation. Scanning Electron Microscopy (SEM), microprobe analysis showed that the formation of a $CaCO_3$ on the composite surface could not protect the composites from salt water intrusion because the ruptures developed throughout the composites were too great. When the PG: class C fly ash: lime composites were submerged, saltwater was able to intrude throughout the entire composite and dissolve the PG. The dissolution of the PG increased the concentration of sulfate ions that could react with calcium aluminum oxides in class C fly ash forming additional ettringite that accelerated rupture development. Effective diffusion coefficients and effective diffusion depths alone are not necessarily good indicators of the long-term survivability of PG: class C fly ash: lime composites. Development of the ruptures in the composites must be considered when the composites are used for aquatic applications.

Lopez, Roger (1992) In other attempts, phosphogypsum was recycled for manufacture of fibrous gypsum boards, blocks, gypsum plaster, composite mortars using Portland cement, masonry cement and super sulphate cement

Manjit Singh, (2002) With the advent of 300, 500, 1000 and even 4000-5000 tons per day Phosphorous pentaoxide plants, the Phosphogypsum disposal problem took on new aspects). 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, the country Florida is blessed with abundant low-cost natural gypsum-piled the phosphogypsum rather than bear the additional expense of utilizing it as a raw material. It should be noted that during most of this time period the primary reason for not using phosphogypsum in for construction products in this country was because it contained small quantities of fluorince and Phosphorous pentaoxide as impurities and fuel was required to dry it before it could be processed. It has only been in recent years that the question of radioactivity has been raised and this question now influences every decision relative to its potential use in building products in this country. Phosphogypsum utilization has evolved along three broad use groupings:

1. Chemical raw material
2. Agricultural applications
3. Construction materials

Some attempts have been made to utilize phosphogypsum as a base and fill materials in the form of cement-stabilized phosphogypsum mix) in the construction of highways, railways etc

Marcelo and Alexandre (1982) investigated the properties of cement-stabilized phosphogypsum mixes as potential materials for base and sub-base construction, as well as seeking a non pollutant alternative to discard large quantities of the material. They discussed the physical characterization of phosphogypsum, and the influence of cement content, curing time, and compaction, moisture content on its unconfined compressive strength and initial tangent modulus. The laboratory results indicate that cement-stabilized phosphogypsum mixes have potential applications as road base and sub-base materials.

Mehta and Brany (1977) reported that two secondary roads were constructed, one in Polk Country in central Florida and a second in Columbia, a Country in north Florida. Both were subjected to environmental testing. Testing revealed that the physical strength of the Polk Country roadbed increased with time and use. The road needed fewer repairs than similar roads in the area. Manjit S. (2003)) (. Also, the techno-economic feasibility of beneficiating phosphogypsum has been studied where in the beneficiated phosphogypsum was used for making Portland cement and Portland slag cement, and the results favoured use of phosphogypsum as an additive to cement clinker in place of natural gypsum

3. OBJECTIVES:

SCOPE OF THE STUDY

This project may help to increase the usage of waste product in cement.

By doing such a way, we can reduce the rate of cement.

Rate of the concrete per unit will gets down. This will make a new evolution in construction industry.

The tensile strength of the concrete can also be increased by this in concrete.

People near to the fertilizer industries can utilize the waste in concrete, that now it is being utilized for land fill.

CORROSION

Unlike rebar there is not galvanic cell created in the fibers

No anodic/cathodic reaction

pH level of concert protects steel fibers from corrosion

PROPERTIES

Durability

Made with a high content of cement and low water to cement ratio

When properly compacted and cured, concrete with steel fibers is very durable

Workability

Affects workability

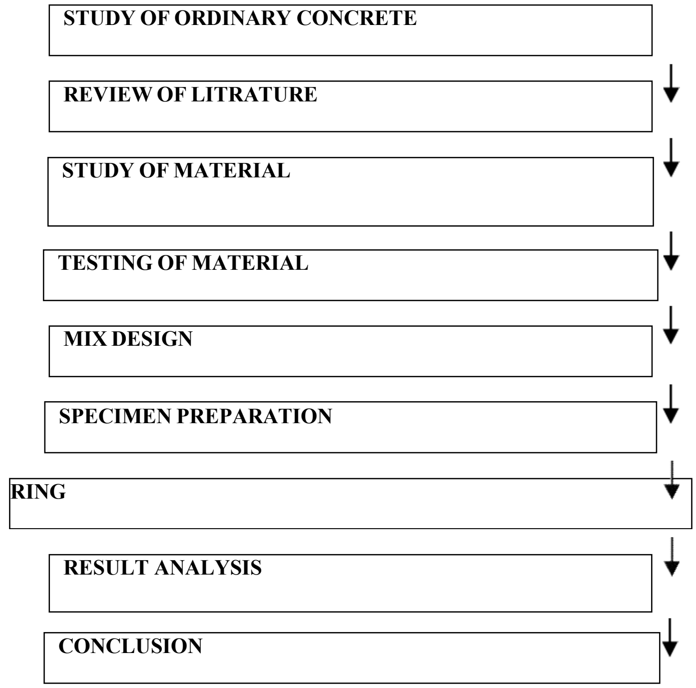
Keeps integrity after failure

Strength slightly enhanced

Tensile behavior

increase tensile strength

METHODOLOGY



4. MATERIALS AND EXPERIMENTATION

The present chapter deals with the properties of materials used in this investigation. The various materials used in this investigation are cement, fine aggregate, phosphogypsum, steel fiber and water. This chapter also highlights the testing of materials used in this investigation.

MATERIALS

The materials used in this experimental investigation include

1. Cement
2. Coarse aggregate
3. Fine aggregate
4. Phosphogypsum
5. Water
6. Steel fiber

Cement

Ordinary Portland cement of 53 grade conforming to ISI standards has been procured. Following tests have been carried out according to IS: 8112 – 1989 on the cement samples.

a) Specific gravity of Cement
b) Normal Consistency of Cement
c) Initial and Final setting time of Cement
d) Compressive Strength of Cement
e) Chemical compositions

Table. The results of cement

S.No	Property	Values
1.	Fineness of Cement	225 m^2/kg
2.	Specific Gravity	3.1
3.	Normal Consistency	29 %
4.	Setting Time i) Initial Setting time ii)Final setting time	 105 mins 350 mins
5.	Compressive Strength i)3 days ii)7 days iii)28 days	 32 N/mm^2 46 N/mm^2 58 N/mm^2

Table. Chemical composition of cement

Lime (CaO)	63.70 %
Silica (SiO_2)	22.00 %
Alumina (Al_2O_3)	4.25 %
Iron Oxide (Fe_2O_3)	3.40 %
Magnesia (MgO)	1.50 %
Sulphur trioxide	1.95 %

Fine aggregate and Coarse aggregate

The locally available river sand conforming to grading zone-II of Table 4 of IS 383-1970 has been used as Fine Aggregate. Following tests have been carried out as per the procedure given in IS 383-1970 and the results are presented in Tables 5.3 & 5.4.

a) Specific Gravity
b) Bulk Density
c) Grading
d) Fineness Modulus of Fine Aggregate

The coarse aggregate of sizes 20mm and 12.5mm have been used. The

Table. Sieve Analysis of Fine aggregate

I.S Sieve Designation	Weight retained gm	Cumulative weight retained	Cumulative percentage retained	Cumulative percentage Passing
10mm	0	0	0	100
4.75mm	0.021	0.021	2.10	97.9
2.36mm	0.039	0.060	6.00	94
1.18mm	0.180	0.240	24.00	76
600	0.316	0.556	55.60	44.4
300	0.355	0.911	91.10	8.9
150	0.075	0.986	98.60	1.4
Pan	0.014	1	--------	-----------

Table: Physical Properties of Fine aggregate

S. No.	Property	Value
1	Specific Gravity	2.69
2	Fineness Modulus	2.77
3	Bulk Density i) Loose ii) Compacted	 14.57 kN/m^3

		16.25 kN/m^3
4	Grading	Zone - II

Fig:View of cement, fine aggregate and coarse aggregate

Properties of Phosphogypsum

Advantages of Waste-Phosphogypsum in Concrete

This technical note summarizes role of industrial waste-phosphogypsum in concrete. Phosphogypsum is a solid byproduct of the production of phosphoric acid, a major constituent of many fertilizers, chemical industry materials. Portland cement can be replaced with phosphogypsum to develop a good and hardened concrete to achieve economy. The traditional methods for producing construction materials are using the valuable natural resources. Besides, the industrial and urban management systems are generating solid wastes, and most often dumping them in open fields. These activities pose serious detrimental effects on the environment. To safeguard the environment, many efforts are being made for the use of different types of solid wastes with a view to utilizing them in the production of concrete. This make highlights on their potentials and possible use in construction area. The alternative for replacing construction materials obtained from industrial with agro-industrial solid wastes.

Advantages of using phosphogypsum as building material radiological aspects

The alternative uses of waste-phophogypsum in the building industry are being considered nowadays in several countries, as its long-term storage and maintenance presents economic as well as potential environmental concerns. Advantages of using both, natural gypsum and phosphogypsum, are discussed in this work over a radiological point of view. The natural radioactivity level in the waste-phosphogypsum could be a restriction for its use as building material, but this drawback could be avoided controlling its percentage in the cement preparation and the natural radioactivity level of the other raw materials used in its production, in addition to the calculation of the Ra-equivalent index in the final by-products. The optimization of waste phosphogysum percentage in the cement production on a pilot scale and its physical and chemical characterization are being studied by CIEMAT-CENIM.

Fig. View of phosphogypsum

The Phosphogypsumused in the investigation was obtained from

Coromandel international Ltd, Ennore, Chennai. The Phosphogypsum passing through 90mm sieve was used throughout the experiment. The specific gravity of Phosphogypsum was found to be 2.34. The properties of PG used in this study are presented in Table 5.8.

Properties of Water

Table. Characteristics of Deionised Water

SI. No.	Parameter	Amount
1	pH	9.7
2	TDS(mg/L)	6.5
3	Alkali	9

	Alkanity(mg/L)	
4	Acidity(mg/L)	2
5	Hardness(mg/L)	1
6	Sulphates(mg/L)	0.3
7	Chlorides(mg/L)	9

Deionised water has been used for mixing as well as curing of concrete in the present investigation. The characteristics of deionised water, to which various chemical substances were spiked to obtain neutral salt, strong alkaline, slightly acidic and acidic water, are presented in the table

The control sample which is prepared with deionised water as mixing water and did not contain any chemical additives was used as the basis of comparison for examining the effects of the chemicals on the properties of HPC.

Properties of Steel Fiber

Materials = Steel

Length = 40mm

Colour = Black

Diameter = 1.5mm

In this project fiber of length 40mm is used

STEEL FIBER

Steel has long been the most common fiber utilized in concrete reinforcement, the first pavement utilizing this technology was installed in a truck weighing station in Ohio.

In the last couple of decades, steel fiber reinforced concrete has been used in the building of bridge decks, parking garages, pavements that carry a lot of traffic and industrial floors.

Steel fibers are important not only due to the added strength but also since they help reduce cracking during shrinkage and increase "fatigue strength."

Steel fibers are adhered together before mixing and separate while mixing to ensure uniform distribution.

Fig view of steel fiber

5. ANALYSING OF CONCRETE PROPERTIES

Concrete specimens are tested to find compressive strength for 7 & 28 days

FRESH CONCRETE PROPERTIES

Some of the tests measure the parameters very close to workability and provide useful information. The following tests are commonly employed to measure workability, Slump cone test

SLUMP CONE TEST

Slump cone test is the most commonly used method of measuring consistency. It doesn't measure all factors contributing to workability. It is used as a control test and gives an indication of uniformity of batches.

Fig. Testing of slump cone

Table 6.1 Slump Cone Test Results

phosphogypsum (%)	Slump in mm
0	68
15	73
20	76
25	81

The slump test results given in Table shows the slump increases as the percentage increase of phosphogypsum.

CASTING OF SPECIMEN

PREPARATION OF MATERIALS

The cement to be used is ordinary Portland cement of 53- grade conforming to IS 12269. The cement should be fresh and of uniform consistency. It should be checked whether there is lumps or any foreign matter in it. The cement should be stored under dry conditions and for as short duration as possible.

The fine aggregate should be clean, hard, strong, and free of organic impurities and deleterious substance. It should be inert with respect to other materials used and of suitable type with regard to strength, density, shrinkage. The fineness of the sand should be such that it passes through 4.85mm sieve.The normal coarse aggregate used should pass through 12 mm sieve and be retained on 10mm sieve.

Water used in the mixing is to be fresh and free from any organic and harmful solutions which will lead to deterioration in the properties of the mortar. Salt water is not to be used. Potable water is fit for use mixing water as well as for curing of cubes.

MIXING

The objective of mixing is that the concrete mass becomes homogeneous and uniform in colour and consistency. All the aggregate particles should have a coat of cement paste and all the ingredients of the concrete should blend into a uniform mass. The mixing is done either by hand or by machine.

Hand Mixing

The concrete batch shall be mixed by using the following procedure:

a) The cement and fine aggregate shall be mixed dry until the mixture is thoroughly blended and is uniform in color.

b) The normal and light weight coarse aggregate shall then be added and mixed with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch

c) The water shall then be added and the entire batch is mixed until the concrete appears to be homogeneous and has the desired consistency.

Machine Mixing

For machine mixing, all the materials of concrete including water are collected in a revolving drum and then the drum is rotated for a certain period. For quality works mixing is carried out by mixer. Mixer can be broadly classified as batch mixers and continuous mixers.

The method which we have adopted is hand mixing.

PREPARATION OF MOULDS

1. Cubes

Before assembling the moulds, make sure that there is no hardened mortar or dirt on the faces of the flange that prevent the sections from fitting together closely. These faces must be thinly coated with mould oil to prevent leakage during filling, and a similar oil film should be provided between the contact surfaces of the bottom of the mould and the base. The inside of the mould must also be oiled to prevent the concrete from sticking to it. The two sections must be bolted firmly together, and the moulds held down firmly on the base plates. The standard size of cube is 150 ×150×150mm.

2. Cylinders

The cylindrical mould shall be of metal which shall be not less than 3 mm thick. Each mould shall be capable of being opened longitudinally to facilitate removal of the specimen and shall be provided with a means of keeping it closed while in use. When assembled ready for use, the mean internal diameter of the mould shall be 15.0cm ± 0.2 mm and in no direction shall the internal diameter be less than 14.95 cm or more than 15.05 cm. The height shall be 30.0 cm ± 0.1 cm. Each mould shall be provided with a metal base plate. The base plate shall support the mould during filling without leakage and shall be rigidly attached to the mould. The mould and base plate shall be coated with a thin film of mould oil before use in order to prevent adhesion of the concrete.

COMPACTION

Compaction of the concrete is the process to get rid of the entrapped air and voids, elimination of segregation occurred and to form a homogeneous dense mass. Compaction of concrete can be carried out either manually or mechanically. When hand compaction is adopted, the consistency of concrete is maintained at a higher level.

Hand Compaction

When compacting by hand, the standard tamping rod shall be used (Tamping rod shall be a steel rod 16 mm in diameter, 0·6 m long and bullet pointed at the lower end) and the strokes of the bar shall he distributed in a uniform manner over the cross-section of the mould. The number of strokes per layer required to produce specified, conditions will vary according to the type of concrete. For cubical specimens, in no case shall the concrete be subjected to less than 35 strokes per layer for 15 cm cubes or 25 strokes per layer for 10 cm cubes. For cylindrical specimens, the number of strokes shall not be less than 30 per layer. The strokes shall penetrate into the underlying layer and the bottom layer shall be rodded throughout its depth. Where voids are left by the tamping rod, the sides of the mould shall be tapped to close the voids.

Machine Compaction

The concrete is compacted mechanically by jets of compressed air or by vibrators.

The method which we have adopted is hand mixing.

FINISHING

After the mould has been filled, the extra concrete found should be struck off using trowel. It must be kept sure that the finished surface is smooth.

Fig. view of finishing cube

CURING

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks which can severely affect durability.

Fig. view of curing

TESTING

COMPRESSIVE STRENGH TEST

Compressive strength test of concrete is used to determine the compressive strength of concrete after curing. The cube mould is used in this test. The size of the mould will be 150×150×150mm.

Fig. view of testing cube

6.5.2 SPLIT TENSILE TEST

Split tensile test of concrete is used to determine the tensile strength of concrete. The cylinder mould is used in this test. The size of the mould will be 150mm diameter and 300 mm height.

Fig. view of testing cylinder

6. RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH TEST FOR CUBES M_{20}

Compressive strength test for conventional concrete

The following table shows the compressive strength test result for conventional concrete in 7 & 28 days.

Table. Compressive strength test for conventional concrete

Conventional concrete	**Average compressive strength after 7 days curing N/mm^2**	**Average compressive strength after 28 days curing N/mm^2**
Specimen 1	17	28
Specimen 2	16.5	28.5
Specimen 3	17.6	27.5
Average	17.03	28

Compressive strength test for 15% replacement of PG

The following table shows the compressive strength test result for 15% replacement of PG in 7,& 28 days.

Table. Compressive strength test for 15% PG

MIX	**Average compressive strength after 7 days curing N/mm^2**	**Average compressive strength after 28 days curing N/mm^2**
Specimen 1	25	32
Specimen 2	24.5	31
Specimen 3	24	32.5
Average	24.5	31.83

Compressive strength test for 20% replacement of PG

The following table shows the compressive strength test result for 20% replacement of PG in 7 & 28 days.

Table. Compressive strength test for 20% PG

MIX	Average compressive strength after 7 days curing N/mm²	Average compressive strength after 28 days curing N/mm²
Specimen1	21	27
Specimen	20.5	26.5
Specimen3	19.6	26
Average	20.36	26.5

Compressive strength test for 25% replacement of PG

The following table shows the compressive strength test result for 25% replacement of PG in 7 &28 days.

Table. Compressive strength test for 25% PG

MIX	Average compressive strength after 7 days curing N/mm²	Average compressive strength after 28 days curing N/mm²
Specimen1	16	21
Specimen2	15.5	22
Specimen3	15	22.16
Average	15.5	21.83

COMPARISON OF COMPRESSIVE STRENGTH TEST RESULTS

Table. Comparison of compressive strength test results

% of PG	Average compressive strength after 7 days curing N/mm²	Average compressive strength after 28 days curing N/mm²
Conventional concrete	16	28
15% PG	24.5	31.83
20% PG	20.36	26.5
25% PG	15.5	21.83

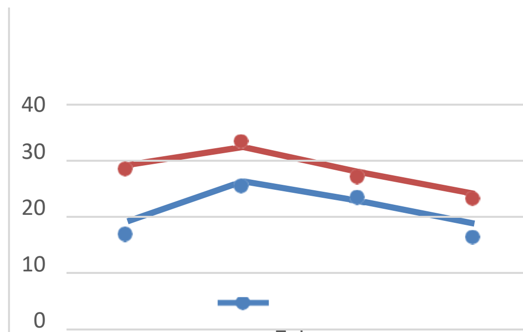


Fig. Comparison of compressive strength test results for M_{20}

SPLIT TENSILE STRENGTH TEST FOR CYLINDER M_{20}

Split tensile strength for conventional concrete

The following table shows the tensile strength test result for conventional concrete in 7 & 28 days.

Table. Tensile strength test for conventional concrete

Conventional Concrete	Average Split tensile strength after 7 days curing N/mm²	Average Split tensile strength after 28 days curing N/mm²
Specimen 1	1.82	2.39
Specimen 2	1.80	2.00
Specimen 3	1.85	2.10
Average	1.82	2.16

Split tensile strength test for 15% replacement of PG

The following table shows the tensile strength test result for 15% replacement of PG in 7, & 28 days.

Table. Tensile strength test for 15% PG

MIX	Average Split tensile strength after 7 days curing N/mm^2	Average Split tensile strength after 28 days curing N/mm^2
Specimen1	1.89	2.9
Specimen2	1.90	2.25
Specimen3	1.92	2.18
Average	1.82	2.44

Split tensile strength test for 20% replacement of PG

The following table shows the tensile strength test result for 20% replacement of PG in 7,& 28 days.

Table. Tensile strength test for 20% PG

MIX	Average Split tensile strength after 7 days curing N/mm^2	Average Split tensile strength after 28 days curing N/mm^2
Specimen1	1.71	2.64
Specimen2	1.80	2.60
Specimen3	1.85	2.62
Average	1.76	2.62

Split tensile strength test for 25% replacement of PG

The following table shows the tensile strength test result for 25% replacement of PG in 7, & 28 days.

Table.Tensile strength test for 25% PG

MIX	Average Split tensile strength after 7 days curing N/mm^2	Average Split tensile strength after 28 days curing N/mm^2
Specimen1	1.31	2.14
Specimen2	1.30	2.10
Specimen3	1.28	2.05
Average	1.29	2.09

COMPARISION OF TENSILE STRENGTH TEST RESULTS

Table Comparison of tensile strength test results

% of PG	Average compressive strength after 7 days curing N/mm^2	Average compressive strength after 28 days curing N/mm^2
Conventional Concrete	1.82	2.16
15% PG	1.90	2.9
20% PG	1.76	2.64
25% PG	1.29	2.09

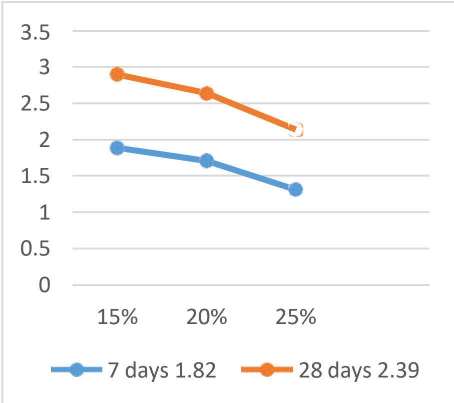


Fig. Comparison of split tensile strength test results for M_{20}

RESULTS FOR COMPRESSION TEST M_{25}

Compressive strength test for conventional concrete

The following table shows the compressive strength test result for conventional concrete in 7 & 28 days.

Table. Compression Test results for specimens with 0% PG

Mix	Average compressive strength after 7 days curing N/mm^2	Average compressive strength after 28 days curing N/mm^2
Specimen 1	28.26	35.78
Specimen 2	28.39	37.86
Specimen 3	27.03	37.04
Average	27.89	36.89

COMPRESSION TEST RESULT FOR SPECIMENS WITH 15% PG

The following table shows the compressive strength test result for 15% replacement of PG in 7 & 28 days.

Table Compression Test results for specimens with 15% PG

Mix	Average compressive strength after 7 days curing N/mm^2	Average compressive strength after 28 days curing N/mm^2
Specimen1	28.44	37.50
Specimen2	27.92	36.80
Specimen3	28.92	38.50
Average	27.92	37.6

COMPRESSION TEST RESULT FOR SPECIMENS WITH 20% PG

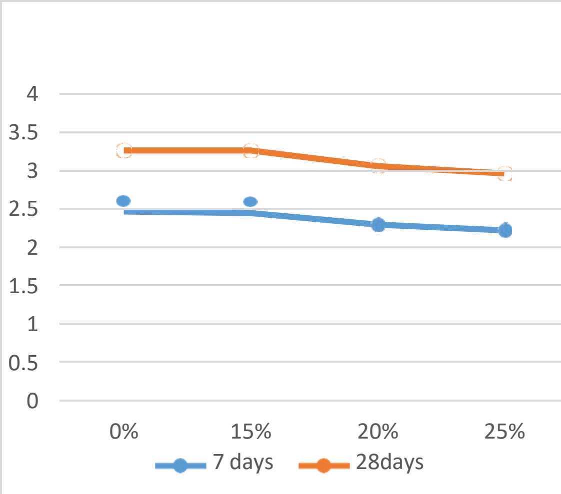
The following table shows the compressive strength test result for 20% replacement of PG in 7 & 28 days.

Table Compression Test results for specimens with 20% PG

Mix	Average compressive strength after 7 days curing N/mm^2	Average compressive strength after 28 days curing N/mm^2
Specimen 1	27.2	36.2
Specimen2	26.82	37.46
Specimen3	26.9	36.5
Average	26.97	36.72

COMPRESSION TEST RESULT FOR SPECIMENS WITH 25% PG

The following table shows the compressive strength test result for 25% replacement of PG in 7 & 28 days.



7. CONCLUSION

The concrete with Phosphogypsum shows better workability.

The effect of replacement of cement by PG has been studied on design mix concrete of grade M_{20} & M_{25}.

The water-cement ratio 0.38 is kept constant for different percentage replacement of cement by neutralized PG.

For the M_{20} Grade of concrete,for 0% replacement of cement with phosphogypsum,the strength was 28 N/mm^2

For 15% replacement of cement with phosphogypsum,the strength was 31N/mm^2

For the M_{25} Grade of concrete,

For 0% replacement of cement with phosphogypsum, the strength was
36.89 N/mm^2

For the 15% replacement of cement with phosphogypsum, the strength was
37.6N/mm^2

For M_{25} concrete mix the optimum replacement is 15 %. Thus it can be concluded, that the PG can be effectively used as cement in concrete.

From economical point of view the conventional concrete costing around
12.7% more than the costing of PG concrete (20 % replacement) with the nominal decrease in the compressive strength of 2.97 % than the actual 7 days compressive strength of M_{25} grade concrete.

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