Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 4 (2025)

Higher Ultimate Strength & Cost Efficient Concrete Using Phospho-Gypsum

Deepak Kandpal[1], Yusufi A Challawala[2] Fatema Lanewala[3]

1. Department Of Civil Engineering, Government Polytechnic Dahod, 389151, Gujarat
2. Department Of Civil Engineering, Government Polytechnic Dahod, 389151, Gujarat
3. Department Of Civil Engineering, Government Polytechnic Dahod, 389151, Gujarat

Corresponding Author: Deepak Kandpal

Email: djkced@gmail.com

Abstract

For a developing country concrete is the most usable and important construction material. There are various studies available that shows that recycled or the waste materials are quite helpful in making the concrete. Materials like Rubber, plastic waste, fiber etc. when replaced in the design mix it imparts their own property in the concrete as well. The motive of the replacement is also important, if we want to reduce the cost, we have to replace the cement which is quite costly as compared to aggregate & sand. The industrial waste may have some chemical properties as well as compared to glass or plastic. Although it is not the cheapest replacement but it helps in saving the cost by replacing the cement component in the design mix. It also Improve the properties of hard concrete & fresh concrete by reducing the W/c ratio or the consistency in the concrete. Gujarat is one the leading state in India for the manufacturing of chemicals & fertilizers and the industrial waste of such industries may harm the environment in different forms. So the study is based on the recycling and the reuse of the industrial waste in the concrete production.

Keywords- PG (Phosphogypsum), Industrial waste, Cost effective concrete, Ultimate Strength

1. **Introduction-** Concrete is the soul of the development of any country as it is one of the most conventional resources for the construction. While the waste material can be reused as an aggregate. Aggregates occupy about 70% of the volume of concrete, thus a large amount of it can be reused [1]. In modern scenario the developing countries as well as the developed countries are restricted with the carbon emission and green house effects to maintain a sustainable environment for living being. By replacing the constituent material with the natural one is the only way to more eco-friendly approach. Arce et.al 2019 [2] suggested that the Phyllite clays can be replaced with the cement in the mortar because of its pozzolanic action as well as the permeability of the concrete may also decreases as compared to the conventional mixture. The Phyllite clays obtain from the metamorphic rock formation and it may be mixed at the varying proportion with the cement by weight would not only save the cost but would also reduce the impact on the environment by lower the temperature of the concrete structure. Sand is of course a cheap as well as a natural resource which plays an undistinguished part in the concrete that need not to be replaced. Few studies also suggested that the industrial waste is also very cost effective and easily available material nearby the construction sites. Glass fiber, Ceramic waste, fly ash, Phophogypsum (PG) can be used in the concrete in this category. There is about 6-million-ton PG is being generated in India every year [3] which can also be used for the plastering purpose this may reduce the adverse impact of PG over the clay soil in India.

If we replace coarse aggregate that we have number of options available that are damaging the environment by different ways like plastic waste, recycled concrete aggregate [4]. RCA is being prepared by the waste concrete material by crushing up to the desired dimensions RCA is a way to recycle waste materials that would otherwise end up in landfills. It's also an environmentally friendly option that can help reduce carbon footprints. The replacement of RCA by 40% impart very less effect whereas higher doses cause reduction in the compressive strength of the Mix [4]. Plastic waste can be used in two form plastic aggregates and plastic fibers. Both forms impart the slump but reduces the compressive strength of the nominal mix of concrete [5].

1.1 Characteristics of Phosphogypsum

PG is obtained after the reaction of sulphuric acid and rock phosphate to obtain phosphoric acid as a product from the industries as a waste by product. Since it contains up to 98 % dehydrated calcium-sulphate it can be used as a retarder in place of gypsum during the cement manufacturing [6]. In construction field it can be used in the plastering as well as the

retarder to increase the workability of the green concrete. The cost of PG is almost negligible if we use it for the replacement of the cement

$$(Ca_5(PO_4)_3X + 5(H_2SO_4) + 2H_2O\ 3H_3PO_4 + 5CaSO_4.2H_2O + HX$$

As a retarder the effect of PG on the setting time of the OPC is being discussed on the table mentioned below which shows the presence of di-calcium silicate in the PG that is responsible for the Ultimate strength of concrete [7]. Hence the Ultimate strength gaining duration may exceed further more from 28 days but due to the presence of the C_2S the Ultimate strength would always be the higher side.

PG %	Initial Setting time	Final Setting time
05	30	490
10	120	595
15	180	866
20	250	942

Table I – Effect of PG on the Setting Time of OPC

1.2 Materials & mix composition-

1.2.1 Cement- Ordinary Portland cement of 53 grade is utilized that was available in the local market. The other properties of the OPC was observed as Normal consistency was 28 % (without PG) with Phophogypsum the consistency increases with the percentage of PG. Specific gravity of the cement is 3.05. The setting time is also varies with the PG percentage but for without any replacement initial setting time was 35 minutes and final setting time is 240 minutes.

1.2.2 Phosphogypsum- In most of the studies it is advisable to treat the PG with the chemicals before replacement to neutralize its chemical effect since it is obtained as a by-product of phosphoric acid production, but in our study we just washed it with water before the replacement. We obtained the industrial waste of PG from the Vadodara Factory.

Fig I - Texture of PG in Lab

1.2.3 Aggregates- Locally available sand of specific gravity 2.7 and fineness modulus 2.9 is being used as a fine aggregates in our study to cast the cubes. For the Coarse aggregates the mixture of 10mm and 20mm size of crushed angular aggregates were being utilized in the same proportion 1.5:1. The fineness modulus of 10 mm aggregates was observed as 7.2 whereas for 20 mm aggregates it was 6.5.

1.2.4 Water- The water was added by considering the w/c ratio as 0.5 as per the code IS 3025-1986 [8], the water as clean and totally free from the organic matters. The w/c ratio is maintain with respect to cement only not from the PG. In reduce the absorption of water in the aggregates, the coarse aggregates were submerged for 24 hour in the water.

1.3 Mixing & Batching –The concrete of the mix design (1:1.67:3.33) is prepared by thoroughly mixing so that the mixture should be homogeneous & uniform. The ingredients in the required proportion of cement, coarse & fine aggregates (by weight)along with the 0%, 5%, 10%,15% & 20% (by weight) replacement of Phosphogypsum in the concrete mix. The constant water cement ratio of 0.5 was used for the design mix of proportion 1:1.67:3.33. Since very low w/c ratio was adopted, the hand vibrators are used to mix properly. Than six cubes of each batch (percentage of Phosphogypsum replacement) were casted in the mold of concrete & cured for forty two days (six weeks). Since the study is mainly focused to improve the ultimate strength of concrete.

1.4 Placing & Curing-As per IS 10086-1982 [9] the concrete is placed in the standard cast iron moulds of size 15cmx15cmx15cm dimensions. The concrete that is already vibrated using hand vibrator is filled in the moulds by a tamping rod. The design mix is cured in water for 42 days for gaining the ultimate strength after gaining the initial hardness in place of 28 days to see the improvement in the "Ultimate strength" due to PG.

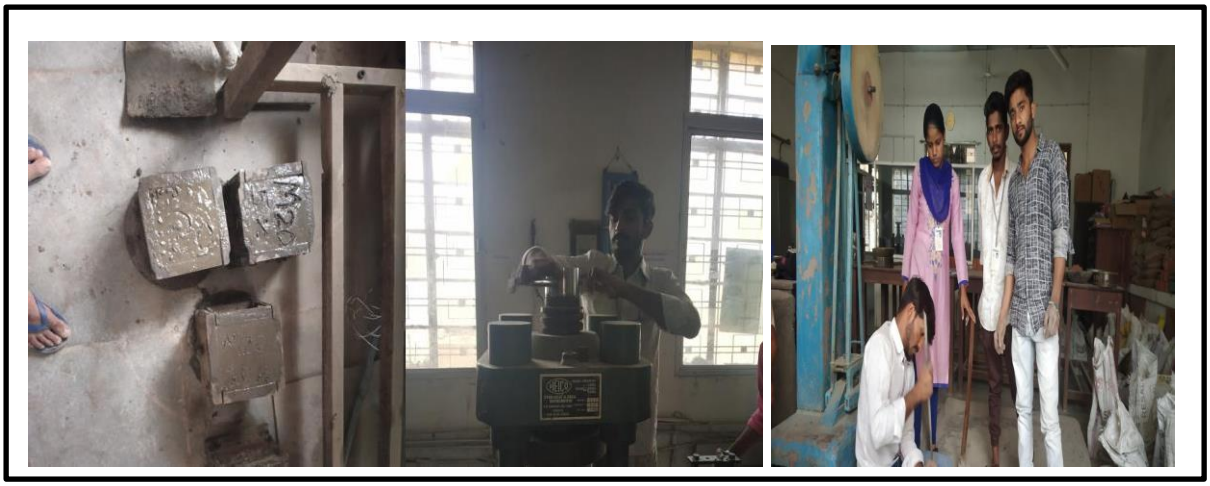

Fig II- Casting of Cubes in Lab

MIX DESIGN (IS 10262-2009)		
1	Design Mix	1:1.67:3.33
2	Type of cement	OPC 53 grade
3	Workability	25mm (slump)
4	W/C ratio	0.5
5	Types of aggregate	crushed angular aggregate
6	Size of aggregates	10mm & 20 mm in 1.5:1
7	Replacement of Phophogypsum	5% ,10% ,15%, 20%
8	Duration of curing	42 days

Table II– Mix Design Composition

1.5 Result & discussion-The design mix was nearly proportionate to M-20 grade of concrete but the design mix gave an extra ordinary results after the compression strength test of the specimens of each batch. As per the IS 10262-2009 [10] the targeted mean strength is near about 30 MP_a and the characteristic compressive strength is 20 MPa but the mix design that we have adopted gave 40 MPa results for 5 % replacement, whereas 37.06 MPa for 10 % replacement that shows the mix design is not only economical but full of strength as well. In 15 % and 20 % of the replacement the ultimate strength was 26.16 MPa & 24.852 MPa respectively that shows at the higher replacement the Ultimate strength may be obtained beyond 42 days.

1.6

PG (%)	Aggregates (kg)		Sand (kg)	Cement (kg)	Water (ml)	PG (kg)	Compressive Strength (kp_a)
	10mm	20mm					
5	3	2	2.5	1.425	713	75	40 (42 days)
10	3	2	2.5	1.350	675	150	37.06

							(42 days)
15	3	2	2.5	1.275	638	225	26.16 (42 days)
20	3	2	2.5	1.200	600	300	24.852 (42 days)

Table III – Quantities & Ultimate Strength of the Design Mix in 42 day

1.6 Conclusion-

a) **Retarder-** Due to the presence of the di-calcium silicate the PG strengthens the concrete mixture retendering the strength gaining duration. Hence such industrial waste can be replace as a retarder.

b) Higher Ultimate Strength- As per the code provisions of IS-456 mostly studies are based on the Ultimate strength of 28 days but in the PG replacement all the test were carried out in 42 days because of its retarding nature. Whereas just in 6 weeks (42 days) the mixture gave an extra ordinary strength. The table mentioned above shows that the test results indicates the Higher Ultimate strength by just Investing two weeks more on the same design-mix.

c) **Curing Period-**Usually the Curing period varies from 16hours to 21 days for the different **type** of vertical and horizontal framework but in case of PG mixture the Curing period may extend by multiplying with the same factor which may be obtain for the duration of Ultimate strength. We can define a "**multiplying factor**" for curing in case of PG as 1.5 (since the curing was extended to 42days in place of 28 days) it may vary for the different type of PG.

d) Cost Effective & Environment friendly- Industrial waste are the causes of the soil and water contamination Engineers always works for the economy which can be obviously obtained by the Industrial waste of PG. if we are getting up to 85 % more strength by just replacing 10 % of cement than it is not only cost effective but also as eco-friendly approach as well. The study may extent for 56 days and 90 days as well.

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