International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Sustainable Solution for Disposal of Industrial Waste Product

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Abstract - *Waste materials have become a threat to the environment. These materials should be reused and treated before they are disposed off. Phosphogypsum, one such waste by-product of fertilizers industries possess huge landfill problems all over the world. India produces approximately 25 million phosphogypsum per annum, only a small quantity of which is utilized by famers or cement industries. This research focuses on the maximum use of raw phosphogypsum in cement concrete mixes and analyses the futuristic scope of phosphogypsum in construction industry. Untreated phosphogypsum was used in the preparation of concrete mixes by partially replacing it with cement in 0%, 5%, 10%, 15%, 20% and 25% by weight and finding its compressive strength. The results have been evaluated and it was found that raw phosphogypsum gave unsatisfactory results in compression and thus needs treatment before using them in concrete. The future scope of phosphogypsum in construction industries is huge if the waste is treated and used effectively.*

Key Words: **Phosphogypsum, Cement concrete, Compressive strength, Waste product, Phosphoric acid**

1. INTRODUCTION

Waste Materials are a major threat to the environment when not disposed of properly. It is important to reuse and treat such materials which possess certain characteristics and then dispose them off. One of the methods is incorporating wastes in the construction industries by finding their potential strength and utilizing them. This will reduce the burden on nation's land filling.

Phosphogypsum is one such waste by-product obtained from Fertilizer Industries which is then dumped on lands and in seas. Approximately 4.5-5 tons of phosphogypsum is generated per ton of phosphoric acid production (P_2O_5) using wet process [1]. In India, approximately 4.9 million tons of phosphoric acid was produced in the year 2018-19 which accounts for 24.5 million tons of phosphogypsum produced per annum. Commercially, Phosphoric Acid is produced by two methods namely 'The Wet Process' and 'The Thermal Process'. In India, Wet Process is mostly used for the production of phosphoric acid for making phosphatic fertilizers [2].

The phosphogypsum is mainly calcium sulphate in dihydrate form which also contains impurities such as fluorides, hydroxides, heavy metals, carbonic acids, etc. The general reaction showing production of phosphoric acid and phosphogypsum by wet process is as follows [3].

$$Ca_5F(PO_4)_3 + 5H_2SO_4 + 10H_2O \longrightarrow 3H_3PO_4 + 5CaSO_4.2H_2O + HF \quad (1)$$

The weathered phosphogypsum can be used as a retarder in place of natural phosphogypsum for Portland cements [4]. Up to 75% of waste phosphogypsum is simply prepared into non fired bricks only with small quantities of river sand which is a cost effective way to recycle the waste [5]. The influence of phosphogypsum impurities is studied and its effect on setting time and compressive strength of mortar and concrete are presented along with various methods to beneficiate the PG has been postulated [6]. Phosphogypsum based slag aggregate was substituted for coarse aggregate in Portland cement and was tested for compressive, splitting tensile and flexural strength by using in concrete. The results indicated that slag aggregate performed well as a coarse aggregate in Portland cement concrete and should perform satisfactorily in highway pavement system [7].

This research mainly investigated the effect on compressive strength of the concrete in presence of waste phosphogypsum when added with different percent by weight of cement. Only raw phosphogypsum was used to find the maximum percentage of the phosphogypsum that can be used in cement concrete and thus possess less risk on landfills. The concrete samples were designed for 20 MPa and 40 MPa of compressive strength and the calculated quantity of cement was replaced by phosphogypsum at 0%, 5%, 10%, 15%, 20%, and 25% in terms of weight.

2. PROPERTIES OF PHOSPHOGYPSUM

2.1 Physical Properties of Phosphogypsum

Phosphogypsum is a grey coloured, damped, fine grained powder with a maximum size range between 0.5

mm to 1 mm [2]. Phosphogypsum has properties similar to natural gypsum. The density of particles ranges from 2.27 to 2.40 g cm^{-3}. The free water content of phosphogypsum mainly depends on nature of rock, draining time of the stack and local meteorological conditions [8]. Usually free moisture content between 25-30% exists in the gypsum cake after drying [1].

Fig -1: Raw phosphogypsum

2.2 Chemical Properties of Phosphogypsum

The concentration of the metals in phosphogypsum depends on the composition of the phosphate rock [2]. Calcium and SO_4^{2-} are major constituents of phosphogypsum. Phosphogypsum is acidic in nature due to presence of various residual acids such as Phosphoric, Sulphuric and Fluoride acids [8]. Primary phosphogypsum may consist of calcium sulphate dihydrate with small amounts of silica, usually as quartz and unreacted phosphate rock, radioactive material (like radium, uranium), heavy metals namely arsenic, cadmium, chromium, mercury and fluoride.

3. MATERIALS AND PREPARATION OF SPECIMEN

Ordinary Portland cement, raw phosphogypsum, crushed stone (fine and coarse) was used to prepare concrete specimens in this research. The fineness modulus of sand and coarse aggregate was 2.9 and 6.9 respectively. The aggregate was washed and dried to remove any dust, clay or organic materials. Potable water was used for mixing of concrete.

The phosphogypsum sample was collected from Paradeep Phosphates Ltd, Paradeep, Odisha. The industry is one of the huge producers of Phosphatic fertilizers in India and eventually of phosphogypsum. Cement concrete blocks of strength 20 MPa and 40 MPa were prepared to check the effects of phosphogypsum on compressive strength of concrete.

The quantities of ingredients for concrete mix was calculated as per IS 10262:2009 (Guidelines for Concrete Mix Design Proportioning) and IS 456:2000 (Workability, Durability and Concrete Mix Proportioning). The specimens are tested for compressive strength (in MPa) according to IS 516:1959.

4. RESULTS AND DISCUSSION

4.1 Compressive Strength of Concrete (20 MPa)

The test results of 7 days and 28 days compressive strength for 20 MPa are presented in Charts 1 & 2 respectively. The result shows that the compressive strength obtained does not decrease below 50% of the expected value when the percentage of phosphogypsum is kept between 5-15%. Adding more than 15% of phosphogypsum reduces the strength of concrete significantly. In any case the compressive strength does not seem to increase with the addition of waste phosphogypsum when added directly into the concrete.

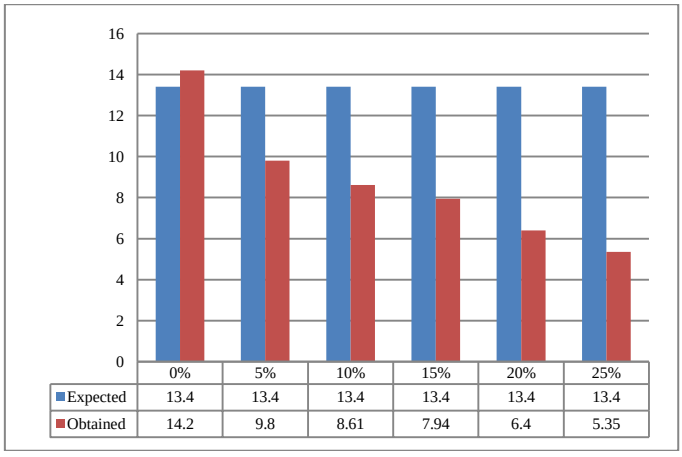


Chart -1: Compressive Strength of Concrete at 7 days

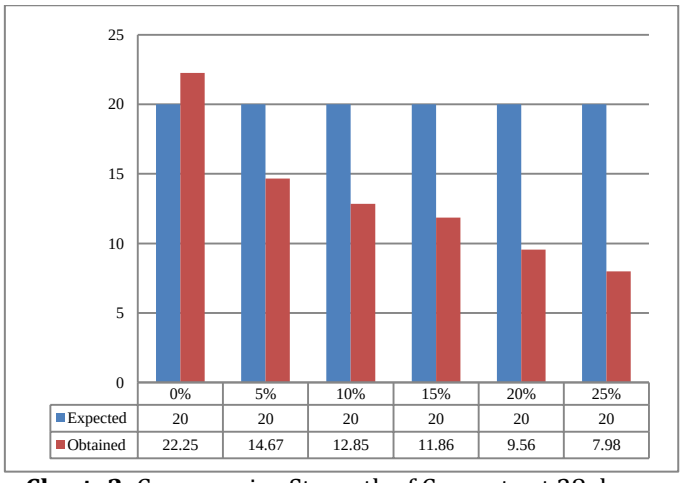
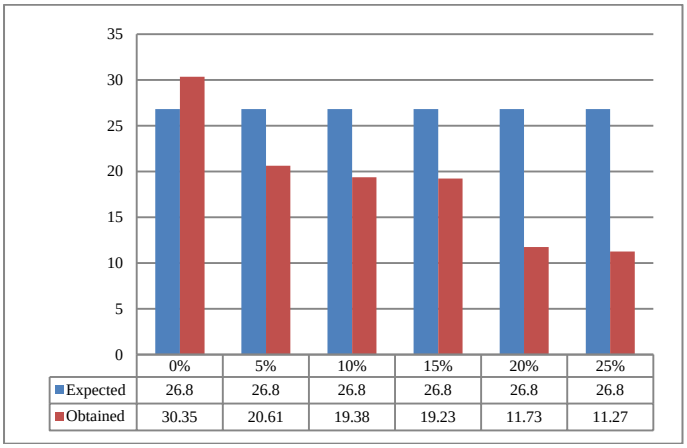


Chart -2: Compressive Strength of Concrete at 28 days

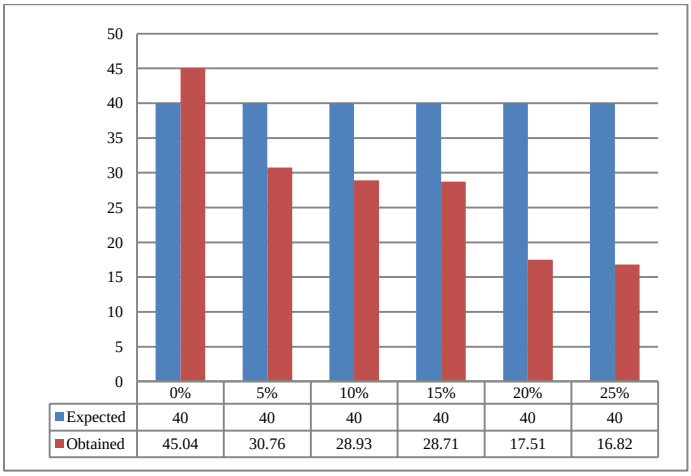
4.2 Compressive Strength of Concrete (40 MPa)

The test results of 7 days and 28 days compressive strength for 40 MPa are presented in Charts 3 & 4 respectively. The result of M20 and M40 gives almost similar interpretations. The strength of concrete decreases with addition of waste phosphogypsum but the results are more drastic when percentage exceeds 15%.



	0%	5%	10%	15%	20%	25%
Expected	26.8	26.8	26.8	26.8	26.8	26.8
Obtained	30.35	20.61	19.38	19.23	11.73	11.27

Chart -3: Compressive Strength of Concrete at 7 days



	0%	5%	10%	15%	20%	25%
Expected	40	40	40	40	40	40
Obtained	45.04	30.76	28.93	28.71	17.51	16.82

Chart -4: Compressive Strength of concrete at 14 days

5. SCOPE OF PHOSPHOGYPSUM IN CONSTRUCTION INDUSTRY

The Concrete paving blocks are also the ideal materials on the footpaths for easy laying, better look and finish. Within a span of 3 years these block become unserviceable due to rapid deterioration occurred on new pavers [9].

The paving blocks can become a potential source of utilizing the waste phosphogypsum in its manufacturing. The minimum strength requirement of paving blocks are 30 MPa, which can be obtained if the phosphogypsum based concrete is designed for strength of 40 MPa. The waste gets utilized and the cement content is reduced which makes it an economical product, hence posing less burden on landfills.

6. CONCLUSIONS

PPL at Odisha is one of the leading sources of phosphogypsum production in India. The industry occasionally sells the waste product at low prices to the local farmers who use it in soil amendment techniques. However, the waste phosphogypsum which is in the form of slurry is mainly stored in surge tanks as per the guidelines of Central Pollution Control Board, India. The addition of 5-15% of raw phosphogypsum in concrete is an acceptable approach if the concrete is used in manufacturing of paver blocks, bricks, etc. To obtain better results, phosphogypsum needs to be treated chemically and use it as a substitute of cement in concrete works. A lot of research work has been carried on the use of phosphogypsum and from this research, it can be concluded that raw phosphogypsum should be treated before it is used as a replacement of cement. Phosphogypsum when used effectively provides an economical approach to the construction industry while carrying the benefit of sustainable utilization of industrial waste product.

ACKNOWLEDGEMENT

The laboratory support provided by Pimpri Chinchwad College of Engineering & Research, Pune and Dr. Sameer Sawarkar, H.O.D. of Department of Civil Engineering, PCCOE&R are gratefully acknowledged. We are grateful to Dr. Harish U. Tiwari, Principal, PCCOE&R for giving us the opportunity to work for this project. Thanks also extended to the authorities of Paradeep Phosphates Ltd, Odisha for providing the material support.

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