Review on Road Sub grade Improvement with Phospho-gypsum

Upadhyay Lohit[1], Ajay K Duggal[2]

[1]*ME Student, Department of Civil Engineering, NITTTR, Chandigarh, India.*
[2]*Associate Professor, Department of Civil Engineering, NITTTR, Chandigarh,, India.*

Abstract – *The purpose of this research is to determine as how phosphor-gypsum affects the stabilization of sub grade soil (black cotton soils). Soil stabilization refers to the use of proportioning different sizes, or the use of suitable admixtures or stabilizers with controlled compaction, to improve the strength or California Bearing Ratio of sub grade soil. Phospho-gypsum is a suitable substance for stabilizing cohesive soil. When phosphor-gypsum is mixed with soil samples, there is a need for a full understanding of the results of numerous engineering studies. Phospho-gypsum's ability to improve soil characteristics has piqued the interest of only a few researchers. Phospho-gypsum in soil stabilization can be a long-term solution for waste disposal. The use of phosphor-gypsum for stabilization is a cost-effective and environmentally friendly solution to the challenges associated with its disposal.*

Key Words: Phospho-gypsum, California Bearing Ratio, sub grade soil, mechanically stabilizing, cohesive soil etc.

1. INTRODUCTION

In a construction project such as a highway project for the construction of a paved road there is a requirement of raw materials such as good soil. At many places the availability of it at construction site is limited, which may lead to increased project costs due to transportation. It is always preferred that the available in-situ soil be used; however, it is not feasible every time. In case of poor soil, it is therefore necessary to replace these raw materials with waste from nearby area such as steel slag, ground granulate blast furnace slag, fly ash and Phospho-gypsum. These are industrial waste byproducts produced at power plant, steel plant, and disposal of this waste poses an environmental problem and therefore proper use of this material can reduce the environmental problem and can preserve the traditional raw materials to some extent. Numerous studies have been conducted to find a combination of different materials such as steel slag, fly ash, sand, coarse aggregate and fine aggregate with cement for sub grade, base course and sub base course of pavement. The aim of this study to check behavior of sub grade soil when it is stabilized with Phospho-gypsum

2. SOLID WASTE PRODUCTION AROUND THE WORLD AND IN INDIA

In the current situation, industrial waste use has already begun and is growing at an exponential rate. Bricks, aggregates, plaster boards, blocks, pavers, and mortars have all been known to be made from industrial waste. However, with more and more industrial wastes being explored for their efficacy in changing sub grade soil properties and serving as mechanical and chemical stabilizers, their application in sub grade soil stabilization has recently received universal acceptance.

We now see massive amounts of industrial garbage being created all over the planet. Cities are predicted to generate 1.3 billion tonnes of solid trash per year. These volumes of garbage are growing at an exponential rate, with the World Bank estimating that by 2025, the total will be 2.2 billion tonnes. The amount of coal combustion products (CCP) produced is projected to be around 780 million tonnes (2010 data). China produces 395 million tonnes of CCP, while North America produces 118 million tonnes, India produces 105 million tonnes, Europe produces 52.6 million tonnes, and Africa produces 31.1 million tonnes.

3. PHOSPHO-GYPSUM PRODUCTION IN INDIA

Phospho-gypsum is an industrial product produced by the phosphorus fertilizer industry and thermal power plants, respectively. About eleven million tons of Phosphogypsum are produced annually in India; these waste products are dumped in landfills, rivers and lakes. Phosphogypsum contains mainly calcium sulphate and contains certain impurities, such as phosphate, fluorides, organic matter and alkalis.

Phospho-gypsum is a fine-grained silt or silty sand substance that is moist and grey in colour. The maximum particle size of phosphor-gypsum is between 0.5 and 1.0 mm, with the majority of particles (about 50-75%) being finer than 0.075 mm. Based on standard proctor compaction, phospho-gypsum has a specific gravity of 2.3 to 2.6 and a maximum dry bulk density of 1470 to 1670 kg/m^3. After filtration, the gypsum cake normally has free moisture content of between 25% and 30%.

Phospho-gypsum is type of waste called Calcium Sulphate produced by fertilizer plants during the production of phosphoric acid, which is a major component of many fertilizers. Phospho-gypsum contains a variety of pollutants that can pollute the soil and groundwater. This item has never been used in the housing industry to detect pollution leading to large warehouses around the world.

Of the many phosphoric acid production processes, the wet process is the most widely used. In the wet phase, fine powder phosphate rock, $Ca_{10}F_2 (PO_4)_6$, is dissolved in phosphoric acid to form a monocalcium phosphate solution (see Equation 1 below). Sulphuric acid, added to the slurry, reacts with monocalcium phosphate to produce hydrated calcium sulphate which can be separated from phosphoric acid by filtration (see Equation 2):

$Ca_{10}F_2 (PO_4)_6 + 14H_3 PO_4 \rightarrow 10Ca (H_2PO_4)_2 + 2HF$ --- (1)

$Ca (H_2PO_4)_2 + H_2SO_4{*}H_2O \rightarrow CaSO_4{*}H_2O + 2H_3PO_4$ --- (2)

An emerging filter cake that contains hydrated calcium sulphate is called phosphor-gypsum. Usually, slurry of filter cake and wash solution are piped to large warehouses where they are allowed to disperse.

The amount and quality of phosphor-gypsum produced is determined by the phosphoric acid production method, the amount of calcium sulphate produced, and the phosphate rock quality. Based on the premise that 5 tonnes of phosphor-gypsum are produced for every tonne of phosphoric acid produced, phospho-gypsum output in the country is estimated to be around 11 million tonnes per year.

4. ENVIRONMENTAL IMPACTS ASSOCIATED WITH PHOSPHOGYPSUM DUMPING YARDS

Due to residual phosphoric acid, hydrofluoric acid, and sulphuric acid inside the porous structure, phosphor-gypsum is acidic in nature. sulphates, fluorides, organics, residual acids, trace metals, and naturally occurring radionuclides are examples of contaminants that may be kept in a potentially mobile condition (i.e. leachable form) due to the acidic nature of fresh phosphor-gypsum. Environmental problems about phospho-gypsum stacks are are listed below:

- Fluoride uptake,
- Ground water pollution if located nearby
- Surface water pollution if located nearby

Water and wind erosion, infiltration, leaching into surface and ground water, and airborne emissions of gaseous and radioactive elements are all major contributors to their movement in the environment. Fine phosphor-gypsum particles can be scooped up and carried into nearby locations by wind and motor movement on stacks. Fluoride-containing dust particles are a hazard for both active and non-operational stacks.

Fluoride levels have been observed to be high in the soil and vegetation near the stacks.

5. QUALITY IMPROVEMENT DUE TO STABILIZATION

Stabilization results in improved soil gradation, increased durability, increased strength, lower plasticity index, and lower swelling potential. Stabilization enhances the characteristics of sub-grade soil and provides the following benefits: (IRC: SP:89-2010).

- A significant percentage of their strength is retained after saturation with water.
- Erosion resistance.
- The amount of surface deflection is lowered.
- Layers created above the stabilized layer have higher elastic moduli.
- The application of admixture to lessen the thickness of the road pavement can increase the stiffness and strength of a soil layer.

6. POSSIBLE PROBLEMS DUE TO STABILIZATION:

The following issues arise as a result of soil stabilization (IRC: SP:89-2010).

- The stabilized layer may crack because to heat and shrinkage cracks.
- Water can infiltrate the pavement through cracks that reflect through the surfacing.
- The stabilizing reaction is reversible if CO_2 has access to the material, and the layer's strength can be reduced.
- The construction process necessitates greater competence than the use of unstable materials.

7. LITERATURE REVIEW

Nurhayaat Degirmenci and Arzu Okucu :(2007) they had done study describing the application of phosphor-gypsum with cement and fly ash for soil stabilization. Atterberg limits, standard Proctor compaction and unconfined compressive strength tests were carried out on cement, fly ash and phosphor-gypsum stabilized soil samples. Treatment with cement, fly ash and phosphor-gypsum generally reduces the plasticity index. The maximum dry unit weights increase as cement and phosphor-gypsum contents increase, but decrease as fly ash content increases. Generally optimum moisture contents of the stabilized soil samples decrease with addition of cement, fly ash and phosphor-gypsum. Unconfined compressive strengths of untreated soils were in all cases lower than that for treated soils. The cement content has a significantly higher influence than the fly ash content. The use of two waste by-products, phosphor-gypsum and fly ash may provide an inexpensive and advantageous construction product.

Raviteja.A and Kumar Vinay BS (2015) found that expansive soils have been a tough task for Civil Engineers in the design and construction of infrastructure projects. The major problems with clays, including low strength and high compressibility, can cause severe damage to Civil Engineering structures and can lead to very serious economic loss and environmental hazards. Therefore, these soils must be treated before commencing the construction operation to achieve desired properties. This has led to the development of soil stabilization techniques. Since ancient times, a number of stabilization methods are being used to improve soil properties. Various studies have been carried out on expansive soil after stabilization with additives such as cement, lime, cement kiln dust etc. which shown promising results. However, in recent past, soil stabilization using industrial waste materials has been widely recommended for developing countries for the construction of various elements of pavements. In the past few years, many researches were focused on utilization of industrial solid wastes. Rapid industrialization also causes production of huge amounts of solid waste materials whose disposal creating lot of environmental problems. Utilization of these waste materials in soil stabilization is one of the alternative methods where high-volume consumption is possible. It gives solution for proper disposal of wastes and also provides good material for construction activities. Thus, in this work, an attempt was made to utilize an abundantly available powder like Phospho-gypsum, industrial residue resulting from the production of phosphoric acid used in many agricultural fertilizers, along with lime to improve the properties of black cotton soil. Strength properties are analyzed with the help of unconfined compressive strength test and California bearing ratio test, to evaluate the effectiveness of stabilization. From the experimental investigations, it was found that soil treated with the binder mix containing lime and Phospho-gypsum (4:4) has better strength characteristics and can be used for stabilizing Black cotton soils for pavement sub grades.

Divya Krishnan.K, Janani.V, Ravi Chandran. P.T, Annadurai.R, Manisha Gunturi: (2014). The results of the laboratory studies undertaken to investigate the effect of Phospho-Gypsum (PG) with Fly Ash (FA) on geotechnical properties of clayey soils for soil stabilization purpose are being presented in this paper. The test results on clayey soil treated with different dosages of stabilizer shows that the increase in PG with FA content increases the volume stability as well as the strength of the soil. Observations are made for the changes in the properties of the soils such as Unconfined Compressive Strength (UCS) test and microstructural analysis using SEM and EDS results. The study on feasibility of PG and FA for increasing the strength and microstructural development of clayey soils is being carried out thereby proposing an effective solution for the conventional problem of waste management.

Ghosh, A: (2010). This paper presents the laboratory test results of a Class F Pond ash alone and stabilized with varying percentages of lime (4, 6, and 10%) and phosphor-gypsum (0.5, and 1.0), to study the suitability of stabilized pond ash for road base and subbase construction. Standard and modified Proctor compaction tests have been conducted to reveal the compaction characteristics of the stabilized pond ash. Bearing ratio tests have been conducted on specimens, compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests, cured for 7, 28, and 45 days. Both unsoaked and soaked bearing ratio tests have been conducted. This paper highlights the influence of lime content, PG content, and curing period on the bearing ratio of stabilized pond ash. The empirical model has been developed to estimate the bearing ratio for the stabilized mixes through multiple regression analysis. Linear empirical relationship has been presented herein to estimate soaked bearing ratio from unsoaked bearing ratio of stabilized pond ash. The experimental results indicate that pond ash-lime-PG mixes have potential for applications as road base and subbase materials.

Jijo James and Prof. Pandian.P. K: (2014) The use of phosphor-gypsum as an additive to lime, to enhance its performance in soil stabilization, is analyzed in this paper. Phospho-gypsum is a by-product of the phosphate rock processing during production of phosphoric acid. Expansive soil samples used in this paper were stabilized using three different lime proportions: initial lime consumption, optimum lime content, and less than initial lime consumption. The results reveal that the addition of phospho-gypsum to lime led to improvement of both the early and late strength of stabilized soil.

8. LITERATURE SUMMARY

The following conclusions can be drawn from the review.

- This study demonstrates that soil stabilization is beneficial in stabilizing weak soils. Most waste materials, such as fly ash, rice husk, and egg shale, are employed, which is one of the waste utilisation and also serves as a stabilizing agent, resulting in improved outcomes.

- Industrial solid wastes should be encouraged to be used as stabilizers instead of costly chemical stabilization and cement or lime stabilization.

- It may also be concluded from the foregoing review that phosphogypsum and other similar industrial wastes can be successfully disposed of by employing them as a soil stabilizer; however, it should be noted that these wastes do not impair soil productivity and should not pollute subsurface water.

- The use of phosphogypsum as a soil stabilizer could alleviate the region's negative environmental impact as well as eliminate the need to store massive amounts of phosphor-gypsum produced by the phosphoric acid plant.

9. REFERENCES

[1] Alaa M. Rashad "Phosphogypsum as a construction material" Journal of Cleaner Production Volume 166, November 2017.

[2] Ameta. N. K, Purohit. D. G. M, Wayal A. S, Dangda Sandeep (2007), "Economics of Stabilizing Bentonite Soil with Lime-Gypsum", Electronic Journal of Geotechnical Engineering, Vol.12(E), 1-8.

[3] Ankit Singh Negi, Mohammed Faizan, Devashish Pandey Siddharth, Rehanjot singh (2013), "Soil stabilization using lime", International Journal of Innovative Research in Science, Engineering and Technology.

[4] B. Mishra, "A study on engineering behaviour of black cotton soil and its stabilization by use of lime," International Journal of Science and Research, vol. 4, no. 11, pp. 290–294, 2015.

[5] Chang WF. "A demonstration project: roller compacted concrete utilizing phosphogypsum" Publication no. 01-068-072, Florida Institute for Phosphate Research Bartow, FL.

[6] DivyaKrishnan.K, Janani.V, Ravi Chandran. P.T, Annadurai.R, Manisha Gunturi(2014), "Effect of Fly Ash and PhosphoGypsum on Properties of Expansive Soils", International Journal of Scientific Engineering and Technology.

[7] Ghosh, A. (2010), "Compaction Characteristics and Bearing Ratio of Pond Ash Stabilized with Lime and Phosphogypsum", Journal of Materials in Civil Engineering, Vol. 22(4), 343-351.

[8] Jijo James and Prof. Pandian.P. K "Effect of phosphogypsum on strength of lime stabilised expansive soil" Gradevinar Journal, December 2014, Chennai.

[9] Lilian Ribeiro de Rezende and Tallyta da Silva Curado "Laboratory study of phosphogypsum, stabilizers and tropical soil mixtures" ASCE journal, 2015, Brazil

[10] Louis C. Murray, Jr. and Barbara-Ann G. Lewis (1985), "Phosphogypsum waste anion removal by soil minerals", Journal of Environmental Engineering, Vol. 111(5), 681-698.