Effect of Phosphogypsum and Fly ash on the CBR and UCS of clayey soil

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Abstract* - This paper describes the use of Phosphogypsum and Fly Ash for soil stabilization. Modified proctor test, California bearing ratio test and unconfined compression strength test were carried out. The fraction of Phosphogypsum is used in this paper is 1,3,5 and 7 along with fixed value of fly ash 20%. The different percentage were determined which showed considerable enhancement in the strength of treated soil. The maximum value of C.B.R. is at 5% Phosphogypsum and fly ash 20%. additional increase in ratio of Phosphogypsum the C.B.R. value decreases. The maximum value of U.C.S. is also at 5% Phosphogypsum and fly ash 20%. Experiment results show Phosphogypsum and fly ash enhances the strength properties of soil along with use of economical materials and also solves the environment problem.

Keywords *Fly Ash, Phosphogysum, Modified Proctor Test, UCS, CBR*

I. Introduction

Soil is considered by the engineer as a complex material formed by the weathering of solid rock. It is the only cheapest and easily accessible material for construction purposes besides its behavior reasonably complex. We cannot judge soil behavior suitably in different conditions because soil is naturally obtainable material. The characteristics of soil varies with the variation of topography and its location. Same kind of soil may carry on various in two distinct conditions. Here the work of Geotechnical Engineer winds up noticeably most extreme essential, who needs to confirm whether the current soil can withstand the heap originating from the superstructure or not. In agriculture sector this material is use in large amount as chemical fertilizers to refill and give the extra nutrient to plants take up from the soil. In these days extra use of phosphate fertilizers in agricultural area increases the phosphate levels in soil.

Phosphogypsum is manufactured by filtration process in phosphoric acid industries where insoluble gypsum (and other material) are divided from the product i.e. phosphoric acid as efficiently as possible. Depends on the resource of rock phosphate about 4.5 -5 Tones (dry basis) of Phosphogypsum (by-product Phosphogypsum) is generated per ton of phosphoric acid (as P2O5) recovered.

Thermal Power plants plays a vital role in the development of the nation. The power generation and consumption capacity is increasing day by day. It has been planned to increase to 3,00,000 MW by 2017 by India government in upcoming days.

As there are large quantities of coal present in India, it is used for increasing energy requirements in India in upcoming days . The amount of ash(coal) is higher in percentage i.e. 30-45 % in India. Hence in India large quantities of fly ash is produced. According to the estimates of Fly Ash Utilization Program (FAUP) the production of fly ash is likely to increase to 225 million ton by 2017. Out of huge amount of fly ash produced only 35% use in commercial applications and the remaining part is a waste. So that’s why large areas requires of valuable land for its disposal causing severe health and environmental hazards.

II. Literature review

Divya Krishnan.K , V.Janani , P.T.Ravichandran , R.Annadurai , Manisha Guntur. “Soil Stabilisation Using Phosphogypsum and Flyash”.

In this review, impacts of various settling materials like Phosphogypsum and fly ash have been analyzed in various rates for quality change. This paper depicts a review to dissected the improvements in the properties of soil with Phosphogypsum in various rates (i.e., 2, 4 and 6 %) with settled amount of fly ash 5 %. In this research paper results indicate there is an increase in stress with the adding of different ratios of fly ash and Phosphogypsum. The peak stress is reached at 0.044% strain, while for treated soil sample the peak stress was found at lesser strain of 0.033% and 0.025%.

Weiguo shen, Mingkai Zhou. "study on Lime-Fly Ash-Phosphogypsum binder".

This research paper describes, new type of binder that was prepared for semi unyielding road base material cover in China to enhance the working of lime and fly red hot remains latch. The perfect meaning of the cover was create of 8–12 % changed lime, 18–23 % Phosphogypsum and 65–74 % fly powder. This paper also describes some values of binder when the percentage of modified lime is just below or equal to 10% the strength of binder rises with increasing of percentage of modified lime in binder is 10 % the maximum strength is achieved, when the percentage of modified lime just increases 10 % and 28 days strength of binder is reduces with increases of modified lime percentage.

Nurhayat Degirmenci, "The using of waste phosphogypsum and natural gypsum in adobe stabilization".

This paper shows the consequence of Phosphogypsum with cement and fly ash waste for soil change . This paper additionally demonstrates the aftereffects of concrete adjustment and cement Phosphogypsum adjustment. In this examination paper it can be watched that when versatility of treated soil is decreased, as far as possible esteems raise . Investigation with bond and Phosphogypsum by and large diminishes the versatility of soil. Versatility file was resolved alongside including of 10 % and 15 % of bond in this paper. This exploration paper demonstrates the most ideal measure of bond (2.5-5 %) and Phosphogypsum (2.5-5 %) to diminish the pliancy of soils. At the point when dry unit weight increment and diminishing in ideal water content happened, bond and Phosphogypsum constituents increment for all soils. At the point when dry unit weight of soil expands, it shows change in soil properties.

Hanan Tayibi, Mohamed Choura, Fransico J. Alguacil, (2009), "Environmental impact and management of phosphogypsum".

Arrangement of Phosphoric acid in manufacturing plants from the phosphate rock prompts mechanical waste item known as Phosphogypsum. Rough estimation of waste is 5 tons delivered from per ton of phosphoric corrosive creation and in around the world, it is likely to be around 100–280 Mt for each year. This waste item by and large arranged off without given any treatment, generally by stores into huge stockpiles. PG comprised of gypsum yet it contains a high scope of polluting influences, for example, phosphates, fluorides, sulfates, some radio nuclides, overwhelming metals, and other follow components. The greater part of this number to Negative ecological effect and numerous limitation on its applications. In a world 15 % phosphogypsum is utilized to make building material to control its dangers. In many nations utilization of waste material is prohibited. This paper surveys about different ecological effect related with phosphogypsum dumping and arranged.

III. Materials and Methods

Materials

Phosphogypsum

Phosphogypsum is a waste material of the compost business when the fabricate of sulphuric acid from the chemical response between phosphoric acid and phosphate rock. Phosphogypsum comprises chiefly of calcium sulfate and have a few pollutions. These days Handling and administration of Phosphogypsum is an immense inconvenience in phosphoric corrosive plants as a result of the huge measure of era of Phosphogypsum and substantial range required to deal with this material.

The handling and storage of Phosphogypsum through the vehicles or railways includes loading, unloading and short period storage at yards is likely to cause environment effect during rainy seasons. To minimize this effect on environments there is requirement for including the guidelines for safe handling, utilization and disposal of Phosphogypsum.

Fly ash

At the point when coal is burnt in thermal plants a fine powder material is gotten. Vent gas raised up the fly ash powder and afterward electrostatic precipitators are work into play to separate it from the pipe gas. Fly Ash remains is better material than lime and Portland concrete. The particles size of residue created running between sizes 10 and 100 microns. Fineness is one of the basic part of fly Ash remains weighty in its pozzolanic reactivity.

There are two types of fly ash i.e. Class C (lignite ash) and Class F (bituminous ash). F type of fly ash has lower value of calcium oxide and does not give you an idea about self-cementing properties. The amount of calcium oxide is more than 20% in this ash. So, class C is more beneficial for stabilizing the soil. Most of the fly ash produced in India is class F ash.

Methods of testing

In this research two materials were used Fly ash and Phosphogypsum. Soil was taken from Ludhiana below the top surface with point of getting true sample as the top layer is very regularly affected by human exercises. Once the soil was collected from site, roots of the plants were removed in the wet condition. The wet soil was then dried and pulverized.

The geotechnical properties of the clay sample was found out according to IS code of practice. The laboratory tests carried out on the natural soil include particle size distribution, specific gravity, Atterberg limits, standard proctor compaction, CBR and UCS.

Laboratory tests results on untreated soil is shown in table 1. The modified proctor test was conducted on the soil to attain the maximum dry density as per IS: 2720 (Part-VII). Specimens for Unconfined compression tests and California bearing ratio tests were prepared at the optimum moisture content and maximum dry density.

Fly ash is taken from Ludhiana ACC Cement industry and phosphogypsum is collected from fertilizer industry district Bhilwara Rajasthan are used in this research work. The chemical composition of FA and PG are shown in Table 2. The Fly ash is used in this study is classified as class C type as per the ASTM standard (sum of the oxides of silica, aluminum and ferrous content is greater than 50%).

Table 1. Geotechnical properties of soil

S.NO.	PROPERTIES	RESULTS
1.	Liquid Limit	36 %
2.	Plastic Limit	21.5 %
3.	Plasticity Index	14.5 %
4.	Optimum Moisture	14.06 %
5.	Maximum Dry Density	19.3 kN/m^3
6.	Specific Gravity	2.56
8.	Indian Soil	CI

The combined percent composition of silica, alumina and ferric oxide in stabilizers shows the way for a good pozzolanic reaction that helps in the formation of cementitious compounds in the soils.

In this testing programme, clay samples were mixed with different percentages of Phosphogypsum (1,3,5,7) with Fly Ash of 20% by weight of dry soil and they were moulded at the optimum moisture content to get targeted density. For all the soil-admixtures combinations mentioned above, UCS tests were conducted to observe the changes in strength of clay and CBR tests were conducted on the soil measure the sub-grade strength as compared to a dense graded aggregate.

CBR is an important parameter in pavement design to predict the thickness of the pavement. CBR tests were conducted on untreated soils as well as treated soil as per BIS. CBR samples were initially compacted in the moulds to the corresponding Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) obtained from the Proctor test.

Each soil samples used in the unconfined compressive strength test was statically compacted in the cylindrical mold (38mm in diameter and 76mm high) at the optimum moisture content and maximum dry density. For curing, the samples were closely wrapped and placed in laboratory room where the temperature was maintained around 21°C. The samples cured for 7 days and after curing unconfined compressive strength tests were conducted.

Table 2. Chemical composition of FA and PG

S. No	Name of constituent	FA	PG
1	Silica (SiO_2)	35.2	3.44
2	Alumina (Al_2O_3)	17.6	0.92
3	Iron Oxide (Fe_2O_3)	18.8	0.88
4	Calcium Oxide (CaO)	20.2	32.0
5	Magnesium oxide (MgO)	4.9	0.40

IV. Results and Discussions

Unconfined compression tests were conducted on the normal and treated soil specimen at a constant strain rate of 1.25mm/min. as per IS:2720 (Part - X). The results of UCS tests carried out on the normal and soil samples mixed with different percentage of additives are shown in Table 3.

Figure 1 shows the typical stress versus strain plot fromunconfined compression strength (UCS) tests for normal and treated samples at different stabilizer contents.

Table 3. Unconfined compressive strength of untreated and PG-FA mix of soil samples

Samples (S:P:F)	Days	UCS (kN/m³)
100:0:0	7	84.62
79:1:20	7	180.69
77:3:20	7	215.00
75:5:20	7	247.02
73:7:20	7	233.25

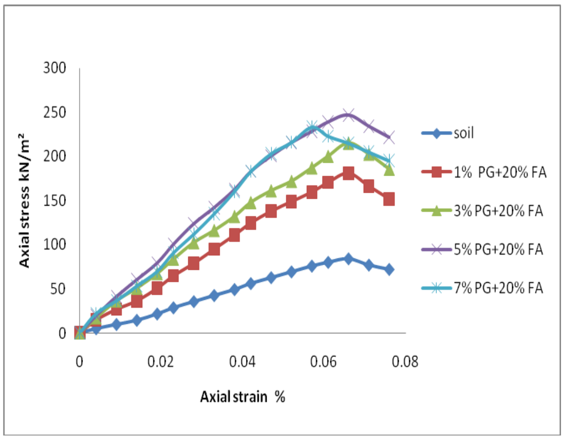

Figure - 1. Stress-strain curves of Unconfined compression strength test for different ratios of PG and 20% of FA.

Sample in the CBR moulds were placed under a surcharge pressure of 2.5 kPa Then it was placed over wetted rice husk base and covered with wet gunny bags to maintaining room temperature in order to avoid moisture loss from the samples prepared.

After curing the samples for desired curing periods, they were soaked for 96 hours. Thereafter, the load was applied on the soil to determine the CBR value of treated and untreated soil.

The results of CBR tests carried out on the normal and soil samples mixed with different percentage of additives are summarized in Table 4. Figure 2 shows the variation in CBR of stabilized soil at varying percentages of the admixtures

Table 4. California bearing ratio of untreated soil and PG-FA mix of soil samples.

Samples (S:P:F)	Curing period Days	CBR (%)
100:0:0	7	3.1
79:1:20	7	4.9
77:3:20	7	5.1
75:5:20	7	5.3
73:7:20	7	5.2

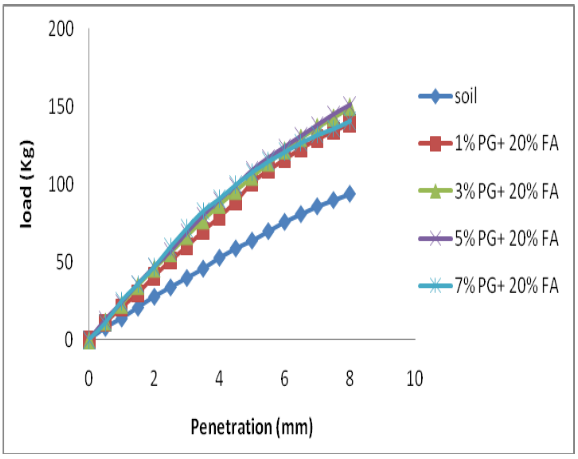

Figure – 2. Load vs. Penetration curves of California bearing ratio test for different ratios of PG and 20% of FA

The UCS value of virgin soil also improves considerably with addition of fly ash 20% and Phosphogypsum 5%. The value increases from 84.62 kN/m² to 247.02 kN/m² with addition of fly ash and Phosphogypsum.

The reason behind of this when fly ash and Phosphogypsum comes in contact with water, pozzolanic reactions takes place during the curing period. With increases the amount of Phosphogypsum, U.C.S. value starts decreasing because of lumps are formed with extra addition of Phosphogypsum. This result in formation of pockets of low density and thus compaction cannot be done properly resulting in decrease in CBR value.

The CBR value of virgin soil is 3.1 and it increase to 1.71 times when fly ash 20% and Phosphogypsum 5% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

The increase in CBR value from 4.9 to 5.3 when fly ash is fixed at 20% and Phosphogypsum added at different ratios i.e. 1,3,5 after that it decreases. As a result of Phosphogypsum is a light material and with increment the amount of Phosphogypsum lumps are formed. This outcome in arrangement of pockets of low thickness and consequently compaction is impossible accurately bringing about diminishing in CBR value.

V. Conclusions

On the basis of experimentations, the following conclusions have been drawn:

1. From this study it is concluded that fly ash and Phosphogypsum are waste products from industries that can be used as stabilizers to clay soil and this would help to solve the conventional problem of disposal of them. .
2. The optimum value of fly ash is used for this work was 20% because of the optimum value of C.B.R. is found at 20% of fly ash when added to soil.
3. The C.B.R value increases with increase of Phosphogypsum along with fixed quantity of Fly ash. It increased 1.71 times from the untreated soil.
4. The optimum value of Phosphogypsum and Fly ash required for soil stabilization is 5% and 20% by weight of soil respectively.
5. Unconfined compressive strength increases with increase of quantity of Phosphogypsum and with fixed quantity of fly ash. The value of Unconfined compressive strength is increased 2.92 times from the untreated soil.

Addition of fly ash and Phosphogypsum stabilizer makes the soil mixes durable, low cost and effective for soil improvement. If these two materials are easily available near to the site.

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