Geo-alteration of clayey soil by adding Phosphogypsum and Recron 3 S fiber

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Abstract- ***Swelling characteristics of expansive clays always poses extensive damages to the overlying structures. So a proper modification method is needed to improve the engineering performance of swelling clays. The use of different additives like cement, lime etc as a stabilizing material is quite common. The use of industrial waste products as an alternative for these conventional binders is gaining more attention in recent times.***

Approximately 85% of the by-product is still discarded into the ocean or river, or stored in ponds or leaps without purification. The disposal causes serious contamination. Reduction in the disposal of this by-product has economic and environmental benefits. Extensive investigations have been carried out to reuse Phosphogypsum in different fields such as soil stabilization amendments, agricultural fertilizers, set controller in cement manufactures and building materials. In this work phosphogypsum is mixed in the soil with recron fiber with proportion varies from 15, 20 and 30 and 0.5 ,1.0 and 1.5 respectively.

The optimum ratio of mix is concluded as 69:30:01 which shows increment in the values of Plasticity Index CBR, UCS, MDD and OMC tests.

Key Words: **Phosphogypsum, swelling clay, Atterberg's limit, Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR).**

INTRODUCTION

As it has been seen that India is a developing country in respect of construction of infrastructures and large amount of soil is expansive in nature due to containing monomorillonite minerals in the soil. The monomorillonite makes the soil compressible at a extent. Due to which, the structures constructed upon such soil can be damaged. The reason of deterioration of structures on soil is swelling and shrinkage behaviour when it comes to contact with high amount of moisture in rainy season and get shrinked over the dry season like summer. The alteration in weather tends to volume change of soil surface and the non uniform settlement of earth takes place and the cracks develops in the structures which is the commencement of failure of structures.

The effect of Phosphogypsum and Portland cement on the soil and found that; the strength performance of cement- Phosphogypsum modified mixtures is strongly influenced by cement content, curing time and compaction energy. Increase in these variables lead to higher values of UCS. The types of cement used has negligible effect on strength development. With increase in the C_3A (Tri-calcium Aluminates) content present in the cement leads to a decrease in the UCS of the mixtures for longer curing periods (A. B. Parreira, 2003).

The effect of phosphogypsum with cement and fly ash on the different samples and found that; treatment with phosphogypsum, fly ash and cement generally reduces the plasticity index. Principally, a reduction in plasticity is an indicator of improvement. The Maximum dry unit weight of phosphogypsum-modified soils increases with an increase in phosphogypsum content. Besides this, flyash decreases the maximum dry unit weight. Generally, the optimum moisture content decreases with the addition of cement, flyash and phosphogypsum. Unconfined compressive strengths of unmodified soils were lower than the modified soils. The cement content has a significantly higher influence than the fly ash content (Nurhayat D, 2005).

The effect of lime-flyash- phosphogypsum on the strength of road base material and found that; the phosphogypsum fastens the reaction between the lime and flyash, so the lime-flyash- phosphogypsum obtains a high early strength.The binder with a phosphogypsum content of 23-46% have the highest 7D (day) strength, while the highest 28D strength is gained when the phosphogypsum content is 18-23%. The lime-flyash- phosphogypsum binder have a much higher early age strength than the flyash and the soils modified with lime or cement (Weiguo Shen, 2005).

The effect of phosphogypsum on clayey soils and found that the plasticity characteristics of soil were improved with the addition of phosphogypsum. The reduction in liquid limit and plasticity index is an indication of diminishing plasticity properties. A small percentage of increase in the value of maximum dry density and decrease in optimum moisture content was observed with the addition of phosphogypsum. The maximum value of unconfined compressive strength was obtained at 6 % addition of phosphogypsum.59 % decrease in free swell index value of clay sample was obtained with the addition of phosphogypsum (Devipriya VP, 2017).

The effect of Recron-3s Fibre with Lime on Expansive Soil and found that; Addition of lime has shown decrement in liquid limit from 84% to 67% and improvement in plastic limit from 55% to 60.5% and plasticity index decrease from 29% to 26.4% when the lime content varies from 0% to 6% mixed in expansive soil as a result of cation from the lime which reduces the volumetric changes.MDD decreased to14.8kN/m^3 from 15.9kN/m^3 due to the agglomerated and flocculated particles of lime mix soil occupy large voids and the OMC increases from 22 % to 26.4 % at 6 % lime due to the action of lime which needed more water for pozzolanic action. Compaction characteristics of treated expansive soil-lime mix at optimum 4% of lime, and OMC increasing from 24.52% to 38.4% and MDD from 24.52kN/m^3to13.4kN/m^3 with the addition of different percentages of fibres due to the reason that as fibre content increases, soil packing becomes loose (P. Sowmya Ratna, 2016).

MATERIALS USED

Clayey Soil

Expansive clay is a clay soil that is prone to large volume changes (swelling and shrinking) that are directly related to changes in water content. Soils with a high content of expansive minerals can form deep cracks in drier seasons or years; such soils are called vertisols. Soils with smectite clay minerals, including monomorillonite and bentonite, have the most dramatic shrink-swell capacity.

The mineral make-up of this type of soil is responsible for the moisture retaining capabilities. All clays consist of mineral sheets packaged into layers and can be classified as either 1:1 or 2:1. These ratios refer to the proportion of tetrahedral sheets to octahedral sheets. Octahedral sheets are sandwiched between two tetrahedral sheets in 2:1 clays, while 1:1 clays have sheets in matched pairs. Expansive clays have an expanding crystal lattice in a 2:1 ratio; however, there are 2:1 non-expansive clays.

Fig. 1 Clayey soil

Table 1 Geotechnical Properties of Swelling Soil Sample

Property	Values
Natural moisture content	33%
Specific gravity	2.41
Grain size analysis Sand Clay Silt	 25% 35% 40%
Atterberg Limits Liquid limit Plastic limit Shrinkage limit	 49.4% 22.9% 11%
Plasticity index	26.5%
Maximum dry density	16.19(KN/m^3)
Optimum moisture content	21%
Unconfined compressive strength	68.8(kPa)

Phosphogypsum

Phosphogypsum (PG) is a by-product from the industry of phosphate fertilizer. Approximately 4-6 tonnes of PG are generated per tonne of phosphoric acid production. The continuous growth in the world population increases food production demand which requires an increase in phosphate fertilizer production resulting in an increase in PG content. Phosphogypsum refers to the calcium sulfate hydrate formed as a by-product of the production of fertilizer from phosphate rock. It is mainly composed of gypsum ($CaSO_4 \cdot 2H_2O$). Although gypsum is a widely used material in the construction industry, phosphogypsum is usually not used, but is stored indefinitely because of its weak radioactivity. The long-range storage is controversial. Somewhere between 100,000,000 and 280,000,000 tons are estimated to be produced annually as a consequence of the processing of phosphate rock for the production of phosphate fertilizers.

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Fig. 2 Phosphogypsum

Table 4 Specifications of Phosphogypsum

Specification	Percentage
Free moisture content	20 %
Total Calcium sulfate	95 % by weight
Total Phosphorus pentoxide(P_2O_5)	1.05 % by weight
Fluorine	0.32

Recron fibre

Fibre is a natural or synthetic substance that is significantly longer than it is width. Fibers are often used in the manufacture of other materials. The strongest engineering materials often incorporate fibers, for example carbon fiber and ultra-high-molecular-weight polyethylene. Synthetic fibers can often be produced very cheaply and in large amounts compared to natural fiber.

Recron 3s- fiber used in this study is the most commonly used synthetic material fiber due to its low cost and hydrophobic and chemically inert nature which does not allow the absorption or reaction with soil moisture or leachate (water that has percolated through a solid and leached out some of the constituents) and it is a polypropylene fiber which is a stabilizer used to improve CBR and UCS values.

Fig. 3 Recron 3S Fiber

Table 2 Properties of Recron 3S Fiber

Property	Values
Colour	White
Specific gravity	1.334
Cut length	12mm
Equivalent diameter	32-55(um)
Water absorption	85.22(%)
Tensile strength	600(MPa)
Acid resistance	Excellent
Melting Point	>250(°C)
Alkali resistance	Good

OBJECTIVE

- To determine the best mix of Phosphogypsum, Recron-3S fibre and clay based on consistency limit tests.
- The maximum dry density and optimum moisture content of the mixes are to be determined.
- Determine UCS value from UCS test at different curing period of 7, 14 and 28 days.
- To study the soaked and unsoaked California bearing ratio value with the different percentages of Phosphogypsum and Recron fibre.

METHODOLOGY

In order to study the effect of phosphogypsum and recron fibre on different geotechnical properties of swelling clay, the clay sample is mixed with different percentages of phosphogypsum and recron fibre (varying from 2 to 8 %) on dry weight basis. The

Atterberg limits, Standard proctor test, unconfined compressive strength test and free swell index are conducted on both treated and untreated samples.

The Atterberg's limits of clay sample with different percentage of phosphogypsum are determined and effect of phosphogypsum in its value was evaluated. The test was conducted as per IS 2720 Part V.

The compaction characteristics of clay sample were determined by conducting standard proctor test as per IS 2720 Part VII. The changes in the values of optimum moisture content and maximum dry density of both treated and untreated samples were evaluated.

The samples for unconfined compressive strength test are prepared with its optimum moisture content and maximum dry density. The sample size used for this test was 38 mm in diameter and 76mm in height. The prepared samples are kept for curing in air tight desiccators by proper wrapping in polyethylene bags. The test was performed on these cured samples after different time intervals and the effect of aging on the strength improvement was evaluated. The test was conducted as per IS 2720 Part X.

The swelling characteristics of clay sample were evaluated by determining the free swell index value of clay sample. The free swell index of different combinations of clay and phosphogypsum was determined. The test was performed as per IS 2720 Part XI.

Fig. 4 Sample for testing CBR values of soil

RESULTS AND DISCUSSION

Sieve Analysis

Table 5 Results of Sieve analysis

IS Sieve Size	Wt. Retained	Percent Retained	Percent Passing
(mm)	(g)	(%)	(%)
4.75	2	1	99
2.36	11.2	6.6	93.4
1.18	18.4	11.3	88.7
0.6	58.4	33.2	66.8
0.3	120.4	65.2	34.8
0.15	179.2	84.6	15.4
0.075	196.8	93.4	6.6

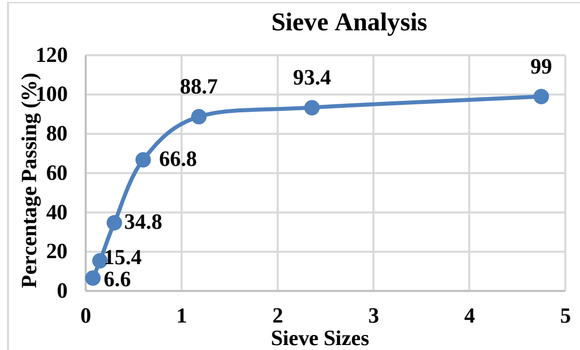

Fig. 5 Graph of Sieve Analysis

The values shown in Table 7.1 and as per the graph shown in Fig. 7.1 it has been clarified that the soil's particles mostly lies in the range silty clayey soil. As from the fig 7.1 it has been cleared that more than 88.7 % of soil easily passed through the sieves of size 1.18mm size which defines its particle size and also the graph shows the variations in the size of particles of soil which means soil is well graded.

Atterberg's Limit Test

Liquid Limit

Phosphogypsum (%)	Recron 3s Fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 PG	51.3	50.8	48.4	44.6
15 PG	52.7	47.5	46.3	45.1
20 PG	53.2	46.6	42.9	45.4
30 PG	55	47.4	40.2	46.2
50 PG	56	49	43.8	45.9

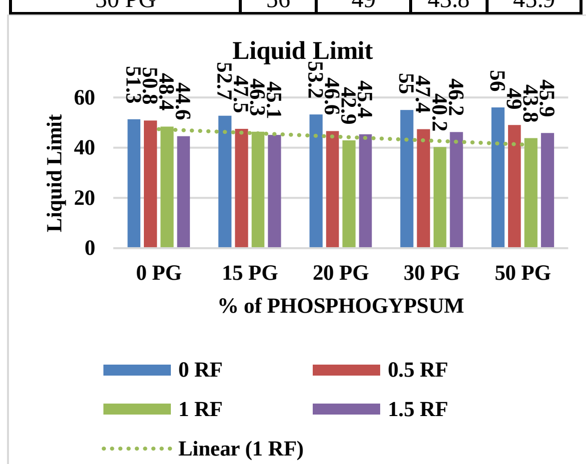

Fig. 6 Liquid Limit of various proportions

The fig. 6 and Table shows the results of liquid limit for pure soil and the soil mixed with admixtures at different proportions of Phosphogypsum and Recron 3S Fiber. Recron 3S fiber helps in improving shear strength of soil at large extent but shows little improvement in decrease of liquid limit but with the help of Phosphogypsum the values of liquid limit get decreased as it contains amount of calcium oxide in it which absorbs the water at large extent.

Plastic Limit

Phosphogypsum (%)	Recron 3s Fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 PG	26	24.5	18.3	16.7
15 PG	27.7	19.9	15.6	17
20 PG	28.6	18.7	11.1	16.7
30 PG	31.2	18.9	7.7	17
50 PG	32.5	19.6	12.6	17.5

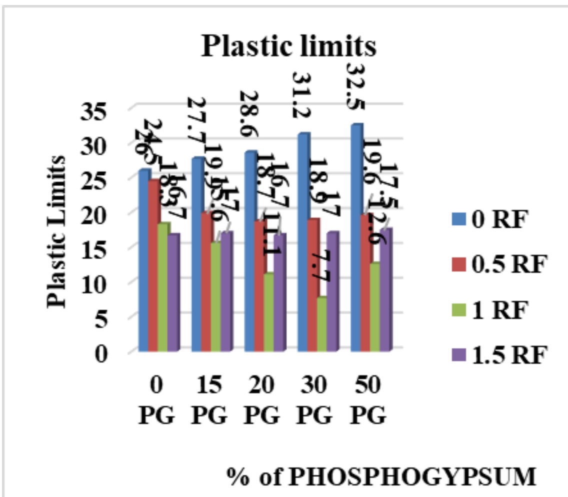

Fig. 7 Plastic Limit of various proportions

As the fig. 7 shows the graph of plastic limits which shows that as the percentage of phosphogypsum and Recron 3S fiber increases upto optimum limit it imparts strength to the soil, but after increasing the percentage of materials more than optimum limit it leads to decrease in the plastic limits which happens due to it absorption of water content upto some limit increases cohesion after that it decreases shear strength of soil due to which the values of plastic limits decreases.

Plasticity Index

Phosphogypsum (%)	Recron 3s Fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 PG	25.3	26.3	30.1	27.9
15 PG	25	28.6	30.7	28.9
20 PG	24.6	28.9	31.8	29.7
30 PG	23.8	29.5	32.5	29.2
50 PG	23.5	29.4	31.2	28.4

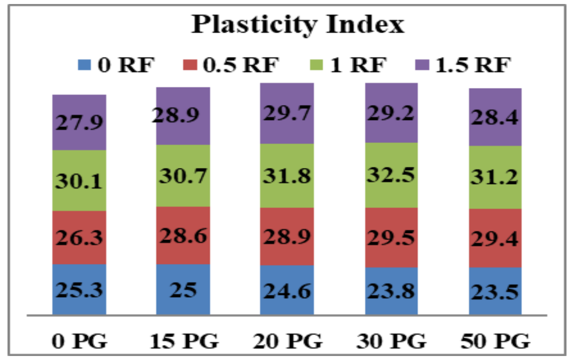

Fig. 8 Plasticity Index of various proportions

To find the consistency of the soil plasticity plays a vital role in it. Consistency of soil shows the nature of soil which decides its behaviour and the behaviour of soil depends upon the water content and soil particle's size. As the fig. 8 shows the graph of plasticity index values of different mixes which is calculated by subtracting the plastic limit from liquid limit. With the help of liquid limit and plasticity index, the compressibility of soil can be defined. The results shows that the compressibility of soil is decreases after increasing the content of phosphogypsum and Recron 3S fiber in soil up to certain limit(optimum limit).

Compaction Test

Maximum Dry Density

Phosphogypsum (%)	Recron 3s Fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 PG	1.32	1.35	1.63	1.58
15 PG	1.3	1.47	1.65	1.62
20 PG	1.28	1.61	1.7	1.64
30 PG	1.26	1.58	1.75	1.69
50 PG	1.25	1.56	1.72	1.7

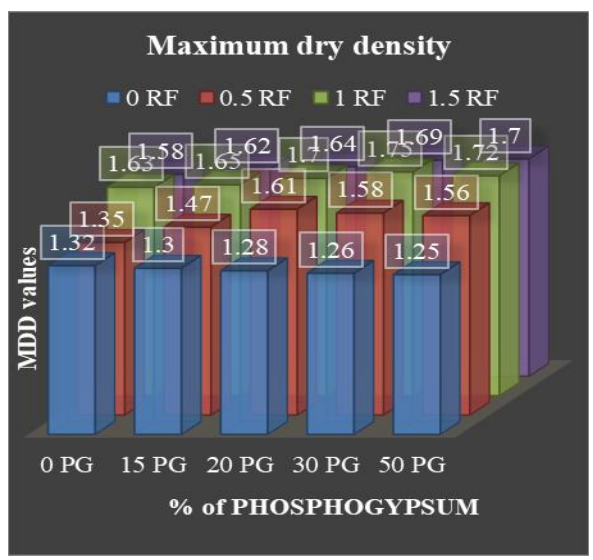

Fig. 9 Maximum Dry Density of different proportion

Figure shows the variation in the values of different mixes goes on increasing up to optimum mix of 30 % of phosphogypsum and 1 % of Recron 3s Fiber. The maximum dry density increases due to the pozzolanic reactions occurs between the different ingredients containing cementitious and siliceous materials when they come in contact with water and form a gel which helps the soil particles to bind up and increases its density, but excess amount of lime delays the time of hardening and make the soil elastic due to which its density get decreases.

Optimum Moisture Content

Phosphogypsum (%)	Recron 3s Fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 PG	28	29	18	15
15 PG	31	27	16	17
20 PG	35	25	14	18
30 PG	33	23	11	19
50 PG	30	20	12	20

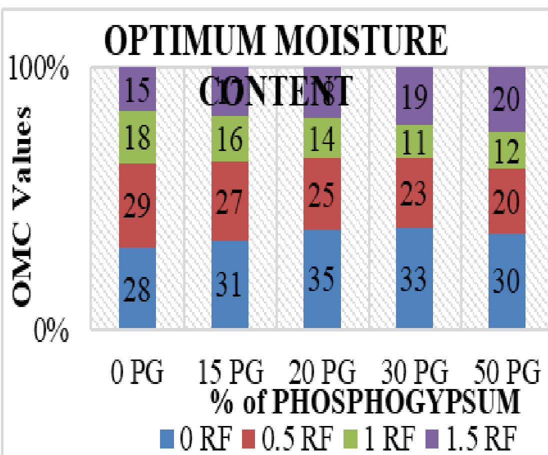

Fig. 10 Optimum Moisture Content of different proportion

Fig. 10 shows the results for optimum moisture content of different mixes of soil, phosphogypsum and Recron 3S fiber. The results shows that phosphogypsum increases the optimum moisture content but Recron 3S fiber reduces the values of it. To improve the geotechnical properties of soil the optimum moisture content must be decreases. The phosphogypsum contains lime content in it at extent so the soil start absorbing more water but when the amount of Recron 3S fiber added to the mixture it stops absorbing water due to which the optimum moisture content decreases.

CONCLUSION

It has been concluded that after stabilization the geotechnical properties of clayey soil are highly improved and the weak and poor soil transformed in strong and compatible soil to work. From the results the following conclusions are derived :

1. The little improvement in decrease of liquid limit but with the help of Phosphogypsum the values of liquid limit get decreased as it contains amount of calcium oxide in it which absorbs the water at large extent.
2. Up to the optimum limit it imparts strength to the soil, but after increasing the percentage of materials more than optimum limit it leads to decrease in the plastic limits which happens due to it absorption of water content upto some limit increases cohesion after that it decreases shear strength of soil due to which the values of plastic limits decrease.
3. The compressibility of soil is decreases after increasing the content of phosphogypsum and Recron 3S fiber in soil up to certain limit (optimum limit).
4. The maximum dry density increases due to the pozzolanic reactions occurs between the different ingredients containing cementitious and siliceous materials when they come in contact with water and form a gel which helps the soil particles to bind up and increases its density, but excess amount of lime delays the time of hardening and make the soil elastic due to which its density get decreases.

FUTURE SCOPE OF WORK

From the result it has been noticed that with the addition of phosphogypsum with Recron 3S Fiber the geotechnical properties have been improved at high extent. As the phosphogypsum contains percentage of lime, it helps to impart compressive strength to the weak soil and the Recron 3S fiber aids to improve tensile strength of soil as the fiber act as reinforcement to the soil which improves its shear strength too and possibly reduces the shear failure among the soil. As observed mostly the improvement in geotechnical properties of weak expansive soil, it has become laborious to construct heavy infrastructures on it at very low cost as the base of the structure has become bearable for high amount of load.

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