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Enhancement in Properties of Clayey Soil with addition of Calcium Chloride, Brick Kiln Dust and Rubber Fiber

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ABSTRACT- *In today scenario most of land's area is covered by soil which is expansive in nature which is quite risky for the structures constructed over it, as it deteriorate by severely damaged due to expansion and contraction of expansive soil . So, 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.*

Around 85% of the residual product is still dumped into the ocean or stored in ponds or leaps them without purification. This kind of disposals causes harmful contamination. Reduction in the disposal of this by-product has economical and environmental benefits. The present work is carried out to establish the viability of using the combination of Brick Kiln Dust and calcium chloride and Rubber Fiber for stabilizing expansive soils. In experimental evaluation, the observations are made for different mixes like soil-Brick Kiln Dust, soil-Brick Kiln Dust- calcium chloride and Rubber Fiber at different proportions. Calcium Chloride has to kept constant for all mixes to obtain the base line values at 15 % and brick kiln dust percentage mixed in samples varies at 15%, 20%, 30% and 50% has been added to untreated soil with Rubber Fiber at the variation of 0.5%, 1%, 1.5% percentage. Test specimens were subjected under various tests such as unconfined compressive tests at 3, 7, 14 and 28 curing days. Free swell index test and Atterberg's limit test were conducted. It is concluded that mixes with calcium chloride exhibited high strength, low plasticity index and low free swell index.

Key Words: *Soil, Brick Kiln Dust, Calcium chloride, Rubber Fiber, Clayey Soil, Water cement ratio, Dry Density.`*

1.INTRODUCTION

In India, there are several types of soil exists in which one type of soil is clayey soil which is very expansive in nature named as clayey soil, it contains some minerals of montmorillonite in it which makes it swell while contacting with moisture and get shrunk in the hot weather. This swell and shrink properties of soil might be quite dangerous for the structures build upon it as it would be responsible for the non uniform settlement due to which many heavy structures built upon it get collapsed which is the threats to the life of many human beings. These factors makes a lot damages to lightly loaded structures also like foundations, canal beds, canal linings, pavements etc. and this leads to a great problem for civil engineers. So it becomes necessary to enhance the geo-parameters of such problematic soil with the help of stabilization technique. Soil stabilization is the easiest way to enhance the geo-parameters of soil with blending of additives. In the process of stabilization cementitious materials are found to improve the engineering properties of virgin soil. Utilization of industrial waste materials in improving the soil properties is an eco-friendly as well economical method.

The effect of CaCl2, Brick Kiln Dust and Rubber Fiber on the soil and found that; the strength performance of modified mixtures is strongly influenced the weak soil 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**).

Brick Kiln Dust is an industrial waste which imposes many health and environmental hazards. Dumping Brick Kiln Dust in open area is not environmentally suitable measure as it degrades the quality of soil and water nearby the dumping area. Consistent infiltration of Brick Kiln Dust and Calcium chloride in the agricultural fields may infertile the agricultural land. On similar lines, Rubber is also the waste which can be utilized in constructional activities through Rubber Fiber that has been used in many roads' work across the country. (**Rajagopalan Vasudevan, 2018)** Padma Shri awardee pioneered the art of using plastic in road construction works and through this study

and further decided to mix rubber at different percentage in soil during construction of roads.

The waste rubbers is used for the purpose of soil reinforcement because of its tensile strength property. The results are suggestive of the increase in the tensile strength and compressive strength of the mixture. **(Davood Akbarimehr, 2020).**

The effect of the effectively proven CSMs on the engineering, geotechnical, and microstructural properties of expansive soils used in soil stabilization. This study identifies research needs for future including energy perspectives with respect to sustainable local construction and developing a satisfactory protocol explaining the stabilization mechanisms. **(Fazal E. Jalal et al 2020).**

The importance of geotechnical and environmental aspects of utilizing brick kiln dust (a waste product from brick kilns) in stabilizing the sub-grade layer of pavements accompanied with a simultaneous reduction in the associated greenhouse gas emissions. In order to achieve maximum use of this waste, the proposed stabilization was performed on six sub-grade soils of varying plasticity, ranging from the clay of intermediate plasticity to sand with an appreciable amount of silt. **(H. Singh et al., 2019)**

2. MATERIALS USED

2.1 Clayey Soil

Clayey Soil is a soil that has expansive in nature due to which it faces large volume changes like swelling and shrinking due to changes in water content. This soil is having a high content of montmorillonite minerals which leads to formation of deep cracks in drier seasons in some years.. Soils with smectite clay minerals, including monomorillonite and bentonite, have the most dramatic shrink-swell capacity.

The minerals made up this type of soil is mostly responsible for the moisture retaining capabilities. All clays consist of mineral sheets packed into different layers which can be classified as either 1:1 or 2:1. These ratios shows the proportions of conversion 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	25%
Clay	35%
Silt	40%
Atterberg Limits	
Liquid limit	49.4%
Plastic limit	22.9%
Shrinkage limit	11%
Plasticity index	26.5%
Maximum dry density	16.19(KN/m^3)
Optimum moisture content	21%
Unconfined compressive strength	68.8(kPa)

2.2. BRICK KILN DUST

Brick Kiln Dust (BKD) is obtained from Brick Kilns which are usually regarded as waste and dangerous for environment because Brick Kiln Dust, when exposed in open air outside the kiln, is threatful to the environment. Brick Kiln Dust is a residual product material produced from the process of manufacturing bricks, contains large amount of iron oxide and silicate. It has higher density. The end product is in the powder form. It is chemically stable and having physical properties are similar to that of natural sand. The low angularity and friction angle of Brick Kiln Dust contribute to excellent compaction and load bearing capacity.

Fig. 2 Brick Kiln Dust

2.3. CALCIUM CHLORIDE

Calcium chloride is a product with many beneficial properties. For highway work, its main properties are:

1. It absorbs the moisture
2. It dissolves in absorbed moisture.
3. It retains moisture for long duration
4. It decrease the freezing point of the moisture.

The water absorption and retention properties of calcium chloride helps in supplying a damp condition which will give you a smooth riding dust free surface without excessive floater material that is a definite hazard to safe driving.

Fig. 3 Calcium Chloride

2.4. Rubber Fiber

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.

Rubber Fiber does not absorb or respond with soil dampness or leachate. The Rubber Fibers utilized as a part of this examination has physical properties, having specific gravity of 0.91 and a normal measurement and length from 0.06mm to 20mm individually.

Fig. 4 Rubber Fiber

Table2 Properties of Rubber Fiber

Source: https//www.topken.com

S. No.	Properties	Range
1	Fiber type	Single fiber
2	Unit weight	0.91 g/cm3
3	Average diameter	0.04 mm
4	Average length	12mm
5	Breaking tensile strength	350Mpa
6	Modulus of elasticity	3500Mpa
7	Fusion point	160 degree
8	Burning point	590 degree
9	Acid and alkali resistance	Very good
10	Dispersibility	Excellent

Table 3 Chemical composition of rubber fibres (%)

Source: https//www.topken.com

Composition of element	Symbols	Percentage (%)
Carbon	C	87.51
Oxygen	O	9.23
Zinc	Zn	1.76
Sulfur	S	1.08
Silicon	Si	0.20
Magnesium	Mg	0.14
Aluminum	Al	0.08

3. OBJECTIVE

1. To determine the optimum moisture content, maximum dry density for the original sample without additives.

2. Evaluation of soil with Brick Kiln Dust and calcium chloride and Rubber Fiber on the basis of experiments like OMC, Dry density, CBR with different percentage and size of Rubber fiber.

3. Analysis the effect on the geotechnical properties of clayey soil after mixing of BKD, $CaCl_2$ & RF.

4. METHODOLOGY

It becomes necessary from engineering point of view to study the characteristics of the material used in the research work. In the present study three material have been used i.e. soil, Brick Kiln Dust and calcium chloride and rubber fiber for the stabilization purpose. Laboratory test have been conducted to study the engineering properties of soil.

In order to study the effect of Brick Kiln Dust and calcium chloride and rubber fiber on different geotechnical properties of swelling clay, the clay sample is mixed with different percentages of brick kiln dust and rubber fibre (varying from 2 to 8 %) and 15 %of calcium chloride on dry weight basis. The Atterberg's 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 calcium chloride, brick kiln dust and rubber fiber are determined and their effects in its values 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 mixed with 15 % of calcium chloride and 30% of Brick kiln dust and 1% of rubber fiber was determined. The test was performed as per **IS 2720 Part XI.**

Fig. 5 Sample for observing compaction values of soil

5. RESULTS AND DISCUSSION

5.1 SIEVE ANALYSIS

Table 4 Results of Sieve analysis

IS Sieve Size (mm)	Wt. Retained (g)	Percent Retained (%)	Percent Passing (%)
4.75	0	0	100
2.36	0	0	100
1.18	67.8	11.3	88.7
0.6	199.2	33.2	66.8
0.3	391.2	65.2	34.8
0.15	507.6	84.6	15.4
0.075	560.4	93.4	6.6

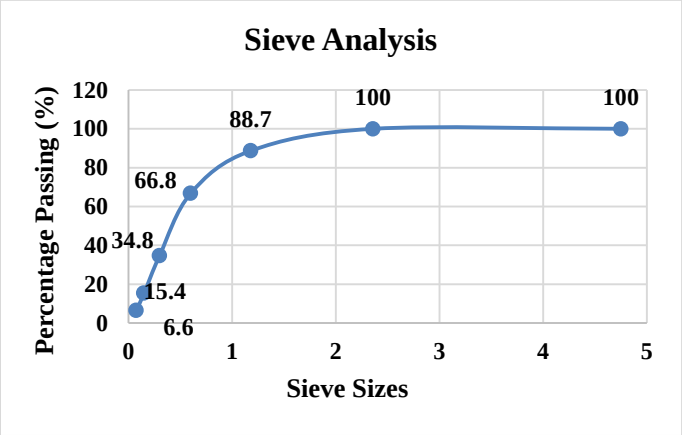

Fig. 6 Graph of Sieve Analysis

The values shown in Table and as per the graph shown in Fig. it has been clarified that the soil's particles mostly lies in the range silty clayey soil. As from the fig 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.

5.2. ATTERBERG'S LIMIT TEST

5.2.1 LIQUID LIMIT

Table 5. Result of Liquid limit

15% of CaCl2 + BKD (%)	Rubber fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 BKD	52.1	51	49.5	48.6
15 BKD	51.9	50.5	48.3	47.1
20 BKD	50.2	49.6	47.9	46.4
30 BKD	49.2	48.4	**45.2**	47.2
50 BKD	48.5	47.2	46.8	45.9

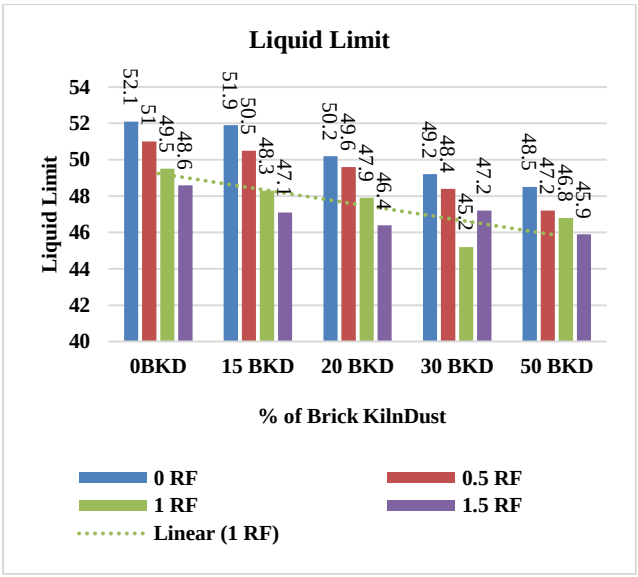

Fig. 7 Liquid Limit of various proportions

The fig. and Table shows the results of liquid limit if pure soil and the soil mixed with admixtures at different proportions of BKD, Rubber fiber with 15% of calcium chloride. Rubber 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 BKD the values of liquid limit get decreased as it contains amount of calcium chloride in it which absorbs the water at large extent.

5.2.2. PLASTIC LIMIT

Table 6 Result of Plastic Limit

15% of CaCl2 + BKD (%)	Rubber Fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 BKD	27.8	28.5	28.9	28.7
15 BKD	28.7	29.9	30.6	30.5
20 BKD	29.6	30.7	31.1	29.7
30 BKD	34.2	35.9	37.7	32.6
50 BKD	35.5	34.6	33.6	29.5

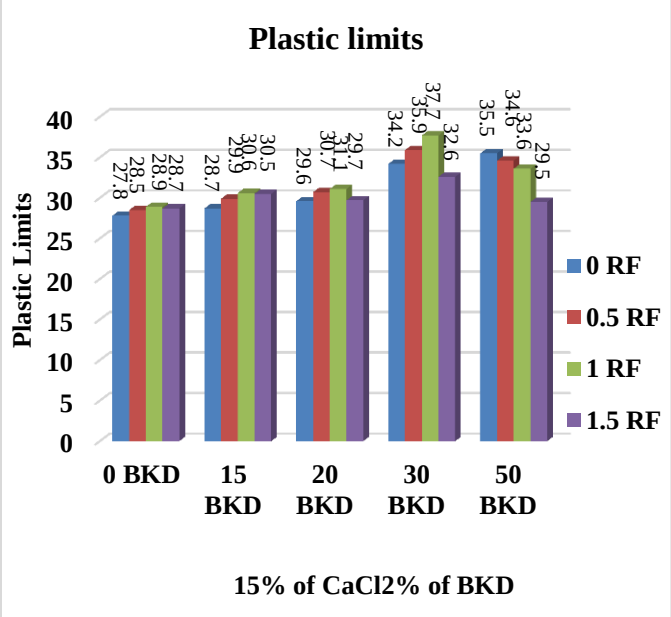

Fig. 8 Plastic Limit of various proportions

The fig. shows the graph of plastic limits which shows that as the percentage of BKD and Rubber fiber with 15% of calcium chloride 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.

5.2.3. PLASTICITY INDEX

Table 7 Result of Plasticity Index

15% of CaCl2 + BKD (%)	Rubber fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 BKD	24.3	22.5	20.6	19.9
15 BKD	23.2	20.6	17.7	16.6
20 BKD	20.6	18.9	16.8	16.7
30 BKD	15	12.5	7.5	14.6
50 BKD	13	12.6	13.2	16.4

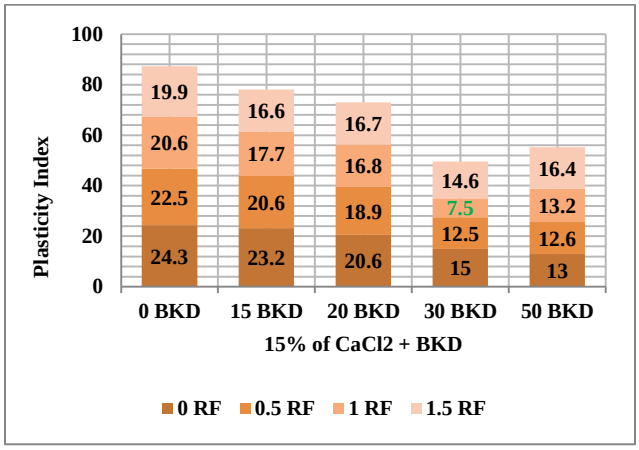

Fig. 9 Plasticity Index of various proportions

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. 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 BKD and Rubber fiber in soil up to certain limit(optimum limit).

5.3. COMPACTION TEST

5.3.1. MAXIMUM DRY DENSITY

Table 8 Result of Maximum Dry Density

15% of CaCl2 + BKD	Rubber fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 BKD	1.42	1.45	1.73	1.68
15 BKD	1.4	1.57	1.75	1.72
20 BKD	1.38	1.71	1.8	1.74
30 BKD	1.36	1.68	**1.85**	1.79
50 BKD	1.35	1.66	1.82	1.8

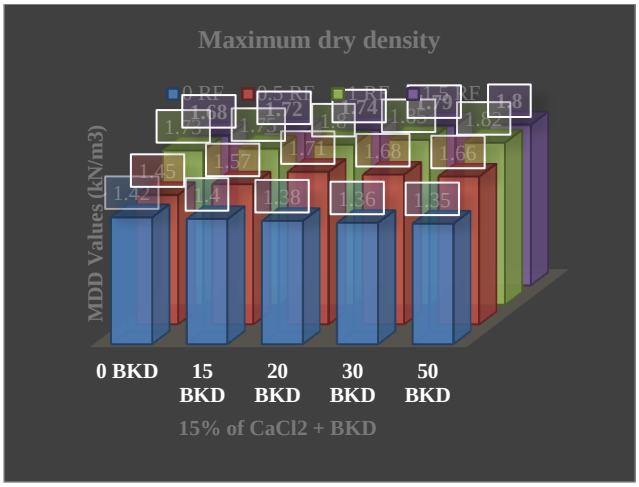

Fig. 10 Maximum Dry Density of different proportion

Fig. shows the variation in the values of different mixes goes on increasing upto optimum mix of 30 % of BKD and 1 % of Rubber 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.

5.3.2. OPTIMUM MOISTURE CONTENT

Table 9. Result of Optimum Moisture Content

15% of CaCl2 + BKD (%)	Rubber fiber (%)			
	0 RF	0.5 RF	1 RF	1.5 RF
0 BKD	29	28	26	25
15 BKD	27	26	24	23
20 BKD	24	23	22	21
30 BKD	21	20	**16**	18
50 BKD	22	21	18	19

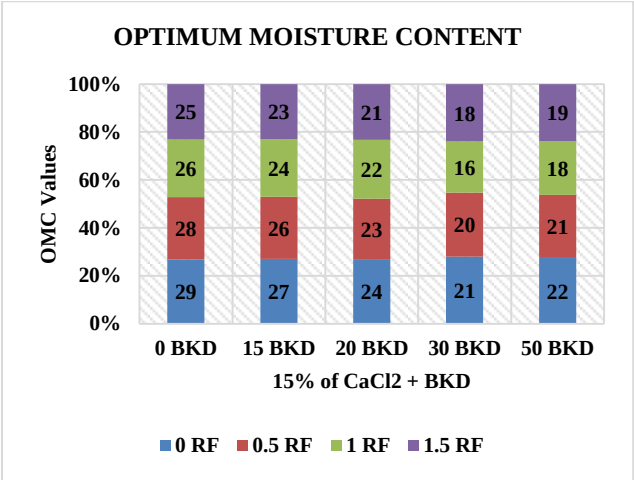

Fig. 11 Optimum Moisture Content of different proportion

Fig. 7.7 shows the results for optimum moisture content of different mixes of soil, BKD and Rubber fiber. The results shows that BKD increases the optimum moisture content but Rubber fiber reduces the values of it. To improve the geotechnical properties of soil the optimum moisture content must be decreases. The BKD contains lime content in it at extent so the soil start absorbing more water but when the amount of Rubber 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 BKD 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 decreases.

3. 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.

4. BKD increases the optimum moisture content but Rubber fiber reduces the values of it. To improve the geotechnical properties of soil the optimum moisture content must be decreases.

FUTURE SCOPE OF WORK

From the result it has been noticed that with the addition of BKD with Rubber fiber the geotechnical properties has been improved at high extent. As the BKD contains percentage of lime, it helps to impart compressive strength to the weak soil and the Rubber 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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