iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68629

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Experimental Study on the Influence of Polypropylene Fibres on the Strength and Swelling Behaviour of Lime Stabilized Clayey Soil

Neeti Dwivedi[1], RK Yadav[2]
Jabalpur Engineering College, Jabalpur Madhya Pradesh

Abstract: Black cotton soil is a prevalent soil type in India, known for its significant swelling and shrinking behavior when exposed to changes in moisture content, making it particularly challenging for engineering purposes. This soil is highly clayey, predominantly composed of the Montmorillonite clay mineral. Given its unstable properties, this soil is not ideal for construction at the site. As a solution, the engineer may consider replacing or stabilizing the soil to ensure the stability and integrity of the structure. Soil stabilization is employed to enhance the geotechnical properties of black cotton soil, making it suitable for various engineering applications such as embankment protection, road construction, minor-loaded structures, parking lots, factories etc. In this study the Black cotton soil is treated with lime and reinforced with polypropylene to increase the strength and decrease the expensive behaviour.

This thesis examines various soil properties like optimum moisture content (OMC), dry density, UCS , swelling pressure and shear parameters. Different quantities of lime (3%, 6%, and 9% by weight) are used to significantly decrease the expensive behaviour and plasticity of black cotton soils and polypropylene fibers (0.25%, 0.5%, and 0.75%) were mixed with black cotton soil to enhance its load-bearing capacity and reduce settlement, making it more suitable for construction. A series of experiments were conducted on these mixtures to evaluate their effectiveness in improving the soil's geotechnical properties. The tests conducted include liquid limit, plastic limit, optimum moisture content (OMC), maximum dry density (MDD), bulk density, dry density, and grain size analysis. The goal of this study is to improve the engineering properties of black cotton soil, ensuring that structures built on it can effectively withstand applied loads. The test results revealed that the Liquid limit, Plasticity index, differential free soil index and swelling pressure significantly on addition of lime and on further addition of polypropylene fibers resulted in increased strength of BC soil.

Keywords: Lime, polypropylene, black cotton soil, Swelling and strength etc.

I. INTRODUCTION

Soil improvement is a major concern in construction activities due to the rapid growth of urbanization and industrialization. The term soil improvement is used for techniques that improve the index properties and other engineering characteristics of soil. Soils have high shrinkage and swelling characteristics. The shear strength of the soil is very low. The soil is highly compressible and its bearing capacity is very low. Working with such soils is highly challenging. These soils are residual deposits made up of basalt or trap rocks. These soils are predominantly found in the states like Andhra Pradesh, Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, and Tamilnadu and in some part of Odisha.

A. Problems associated with Black Cotton

Black cotton soils pose significant challenges for engineers worldwide, particularly in tropical regions like India, due to the substantial temperature fluctuations and distinct dry and wet seasons, which result in considerable changes in the soil's moisture content. The following issues are commonly associated with black cotton soil.

1) High Compressibility: Black cotton soils are highly plastic and compressible when saturated. As a result, footings placed on these soils experience significant consolidation settlements.
2) Swelling: A structure built during a dry season, when the natural water content of the soil is low, may experience differential movement in the subsequent wet season. This leads to the soil swelling, causing the structure to lift and crack.
3) Shrinkage: A structure built at the end of the wet season, when the natural water content of the soil is high, may experience settlement and shrinkage cracks during the following dry season.
4) Low Bearing Capacity: Due to their compressible nature, B.C. soils typically have a low bearing capacity, making them unsuitable for supporting heavy loads without proper foundation design or treatment

The aspect of using polypropylene fibers for soil stabilization has aroused interest in the research field. Yang et al. (2022) described in detail an experimental study on the strength of polypropylene fiber reinforced cemented silt soil [15] .

While the strength and deformation of soft soil by polypropylene fibers was studied by Al-Karim et al. (2022). In recent research, many researchers took interest in the field of soil reinforcement using polypropylene fibers [1].

Reshma et al. (2022) investigated the effect of polypropylene fibers and alkofine on soil stabilization,[10]. Tomar et al. (2019) studied a mixture of polypropylene fibers and nanosilica with respect to its durability and strength [11]. Hussain and Ali studied the effect of a mixture of lime and polypropylene fibers on soil properties [3]. On the other hand, Murthi et al. (2020) dealt with the topic of the behavior of mixtures of silica fume and polypropylene [4]. Chen et al. (2015) investigated Shanghai soft clay through an experimental study that dealt with the effect of polypropylene fibers on the composition of cement and fiber-stabilized samples [2]. Two years later, Pekrioglu (2017) studied the mechanical properties of mixtures of polypropylene fibers and marble dust on gypsum-stabilized clay [8]. Patil (1953) described a laboratory method for measuring swelling pressure and an apparatus for testing for reworked or unreworked soil samples [9].

Mogal et al. (2017a) reported the effect of length and dosage of fiber reinforcement on unconfined compressive strength (UCS) values through a non-linear regression equation, based on experimental data measured after 28 and 360 days curing period on expanded clay [5]. Mogal et al. (2017b) proposed two non-linear best fit equations to estimate the California bearing ratio (CBR) of lime treated fiber reinforced expanded clay in terms of quantity and fiber length, relying on laboratory experimental data [6]. Mogal et al. (2015) considered these regression equations and employed the target reliability approach (TRA) to obtain the optimum quantity of fiber reinforcement (for different fiber types) while satisfying the hydraulic conductivity, UCS and CBR behavior of lime mixed expanded clay for the respective applications. Determining the swell index and compression characteristics from one-dimensional oedometer tests takes relatively long time [7].

Tiwari and Ajmera (2011) studied the action of major clay minerals and their mixtures in terms of consolidation and swelling. Void ratio, liquid limit and plasticity index all had a close relationship with compression and swelling index in the initial stages. Using the liquid limit, equations were proposed to estimate the compression and swelling index [12]. Trozine et al. (2012) conducted a study on rubber fibres (extracted from scrap tyres) in mixed clay soil to investigate the swelling behaviour and reported that there was a significant reduction in liquid limit, swelling capacity, swelling pressure and time taken to attain maximum swelling for soil with higher swelling capacity [13].

Tiwari and Satyam (2019) studied the swelling pressure and expansion properties of clay stabilized with silica fume and found a significant effect using polypropylene fibers. Fiber content in the matrix affects swelling pressure and expansion [14].

II. THE OBJECTIVE OF THE PRESENT STUDY

The experimental study was conducted to achieve the following objectives.

1) To examine the plasticity characteristics, such as liquid limit, plastic limit, and plasticity index, upon the addition of lime and polypropylene fibers.
2) To study the swelling behavior of soil when treated with lime and polypropylene.
3) To carry out the ucs test of soil with lime and poylypropylene.
4) To analyze and compare the test results based on the composition of lime and polypropylene.

III. EXPERIMENTAL STUDY

A. *Material*

Black cotton soil: Black cotton soil is collected from village piparia, near khamariya in Madhya Pradesh Jabalpur. The latitude and longitude of the site are 23.213939 and 80.036789. Expansive soil is collected from the respective locality at a depth of about 1-2m depth from the ground level after removing all the vegetation matter. Due to the high initial moisture content,The soil was first oven-dried at 110°C, then broken into small pieces, and subsequently sieved in the laboratory for sample preparation.The basic properties of the soils are presented in the Table No. 1

Table No.1 basic Properties of Black cotton soil

Test	Value obtained
Liquid limit	52%
Plastic limit	24
Plasticity index	28
OMC & MDD	25.33 & 1.41
Specific gravity	2.69
Passing 75 micron sieve	79.121 %
Free swell index	45.8 %

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Polypropylene fiber:
In this study, waste synthetic plastic files, which are commonly available in institutions, offices, hospitals, and other places in bulk, were utilized. These types of fibres are low-cost, chemically inert, and do not absorb water or react with soil. The plastic files were manually cut into small pieces, each approximately 12 mm in length. For the experimental process, various ratios of plastic fibers were mixed with black cotton soil, as shown in **Figure 1.**
Lime: Lime is a white, caustic alkaline substance made up of calcium oxide. It is produced by heating limestone and reacts with water, releasing a significant amount of heat during the process. Commercially available quicklime was sourced from the local market, processed to eliminate lumps, and used in its powdered form to prepare the samples

Fig1 Manually cut Polypropylene fibreFig-2 quicklime

IV. TESTING METHODOLOGY

The Various test conducted in the geotechnical laboratory to assess the influence of polypropylene fiber on the swelling behavior and strength of lime stabilized clayey soil. The following tests were performed in the laboratory as per the relevant IS codes:
1) Atterberg limit test (IS 2720 PART-V)
2) Proctor test (IS 2720 PART-VII)
3) Free swell index (IS 2720 PART-40)
4) Unconfined Compressive strength test (IS 2720 PART-X)
5) Swelling Pressure Test (IS 2720 PART- 41

Fig 3. Testing samples

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

V. RESULT AND DISCUSSION

Various tests were conducted in the geotechnical laboratory to reduce the swelling behavior of the soil and increase its strength. In this study, lime and polypropylene fiber were mixed with the soil. The different proportions of lime and polypropylene are detailed below, and the variation of test results (LL, PL, OMD, MDD, UCS, and swelling pressure) is summarized in Table 2 based on the experimental work.

Table 2 Summary of the variation of lime and PP on geotechnical properties of expansive soil

Composition	LiquidLimit(LL)	PlasticLimit(PL)	PlasticityIndex(PI)	MDD	OMC	UCS kpa	Swelling pressure kpa
PlainSoil	52	26	26	1.41	25.23	116	67.21
3%Lime	45	24	21	1.51	23.23	121.23	46.32
6%Lime	38	25	13	1.64	20.29	125.37	35.23
9%Lime	33	26	7	1.71	18.22	130.35	15.32
3%Lime+0.25%PP	43	23	18	1.50	23.21	138.43	45.6
3%Lime+0.5% PP	42	26	16	1.51	23.02	148.65	44.32
3%Lime+0.75% PP	41	26	14	1.53	22.98	157.51	41.34
6%Lime+0.25%PP	38	26.5	11.5	1.63	20.2	146.48	29.45
6%Lime+0.5% PP	36	27	9	1.685	19.93	159.34	25.32
6%Lime+0.75% PP	35	28	7	1.695	19.00	167.72	20.21
9%Lime+0.25%PP	30	25	5	1.726	18.09	151.23	10.21
9%Lime+0.5% PP	29	26	4	1.734	17.98	171.21	9.21
9%Lime+0.75% PP	29	26	3	1.75	17.40	180.49	9.1

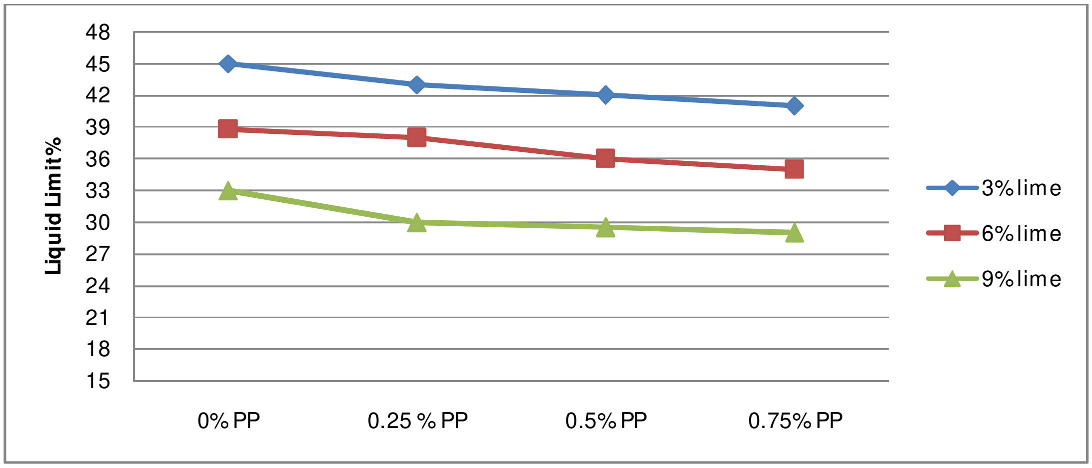
- Black cotton soil
- Black cotton soil+3% lime
- Black cotton soil+6% lime
- Black cotton soil+9% lime
- Black cotton soil+3% lime +0.25% PP
- Black cotton soil+3% lime +0.5% PP
- Black cotton soil+3% lime +0.75% PP
- Black cotton soil+6% lime +0.25% PP
- Black cotton soil+6% lime +0.5% PP
- Black cotton soil+6% lime +0.75% PP
- Black cotton soil+9% lime +0.25% PP
- Black cotton soil+9% lime +0.5% PP
- Black cotton soil+3% lime +0.75% PP

1) *Discussion:* The experimental results show the considerable improvement in the soil properties with the addition of lime and polypropylene discussed as below with the comparison graph.
2) *Atterberge limit test:*

a) *Liquid Limit:* based on the graph shown a variation with the addition of lime and polypropylene.

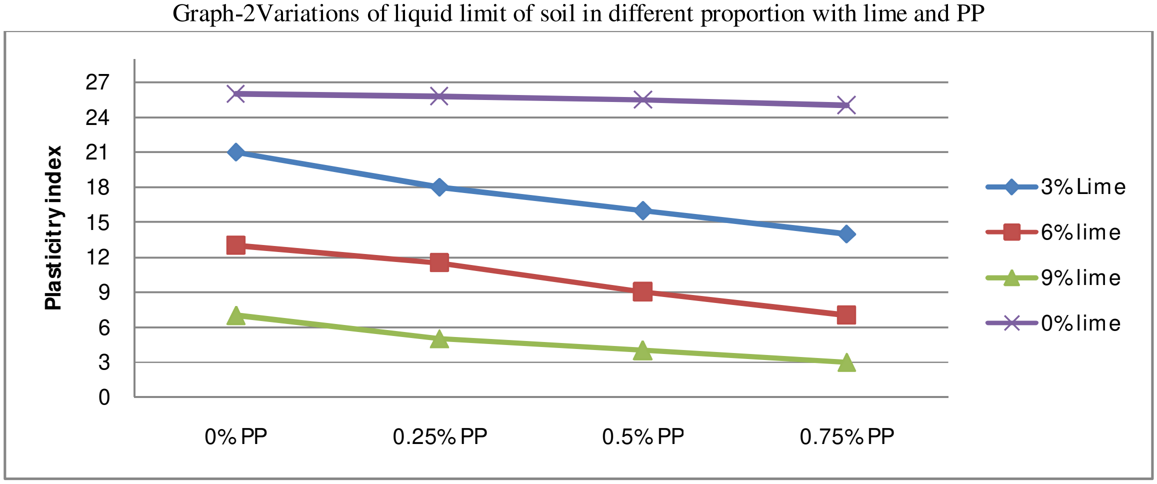
International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Graph-1 Variations of liquid limit of soil in different proportion with lime and PP



b) *Plasticity Index:* The Plasticity index decreases, with the addition of lime and Polypropylene and indicating soil changes in to slight or non-expansive behavior

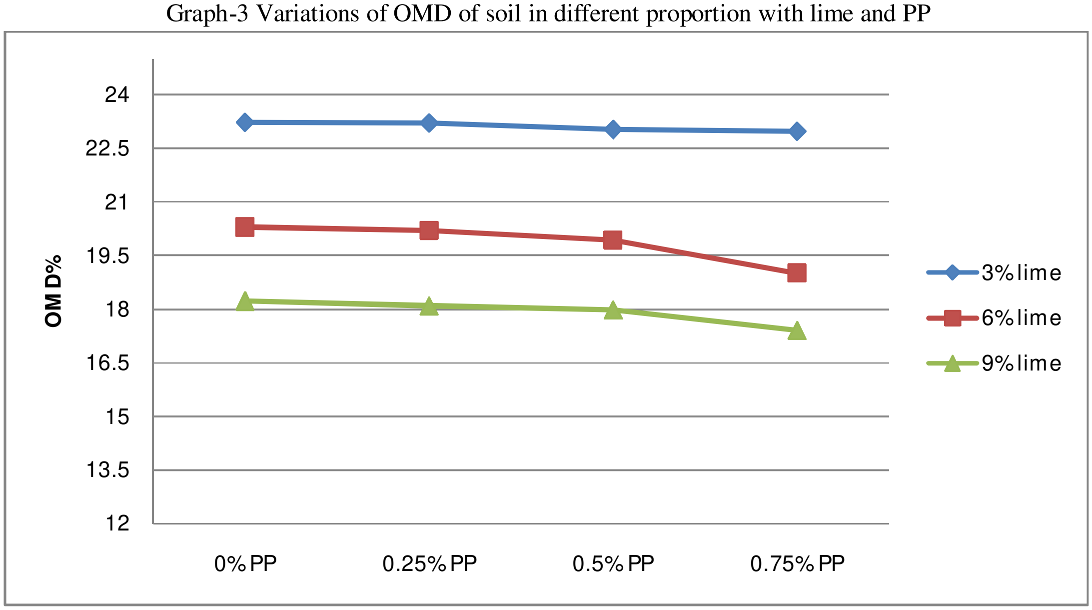
Graph-2Variations of liquid limit of soil in different proportion with lime and PP



3) *Proctor Test:*

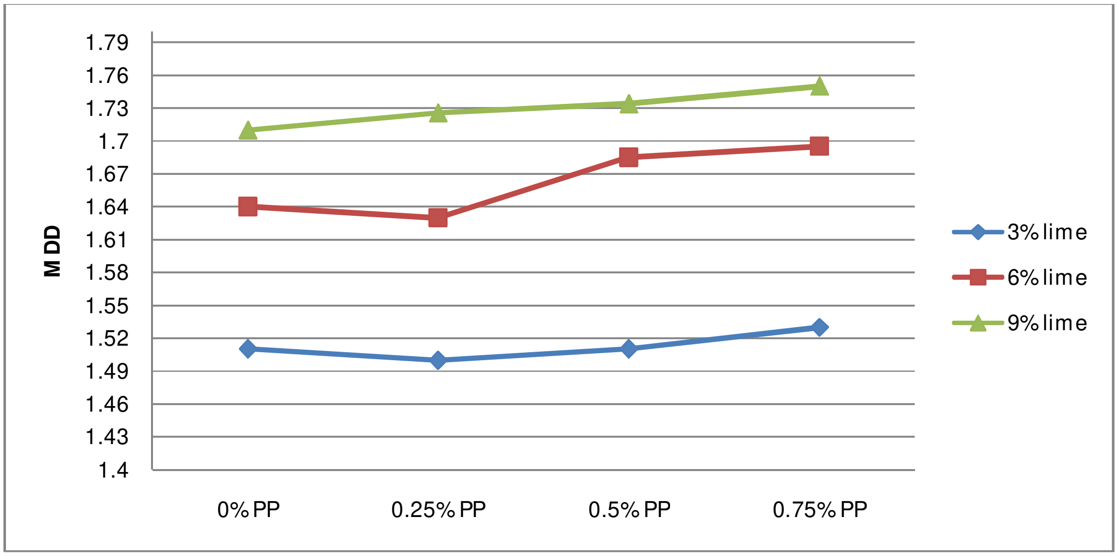
a) Optimum moisture content: The OMC is reduced slightly with the addition of lime and polypropylene.

Graph-3 Variations of OMD of soil in different proportion with lime and PP



b) Maximum Dry density: Due to addition of lime and polypropylene MDD value are slightly increased and variations are shown with the graph.

Graph-4 Variations of MDD of soil in different proportion with lime and PP



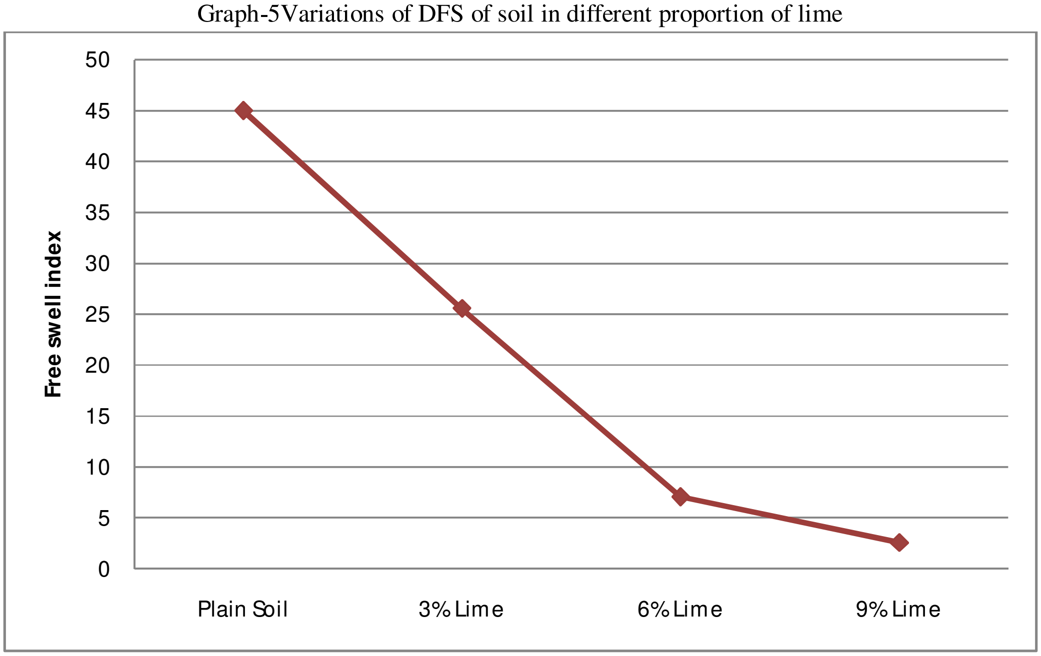
4) Differential Free Swell Index Test Results

The DFS test measures the swelling potential of the soil. The results are summarized and analyzed below:

Table No 3

Composition	Free Swell Index (FSI)
Plain Soil	45.0 %
3% Lime	25.6%
6% Lime	7.1 %
9% Lime	2.5 %

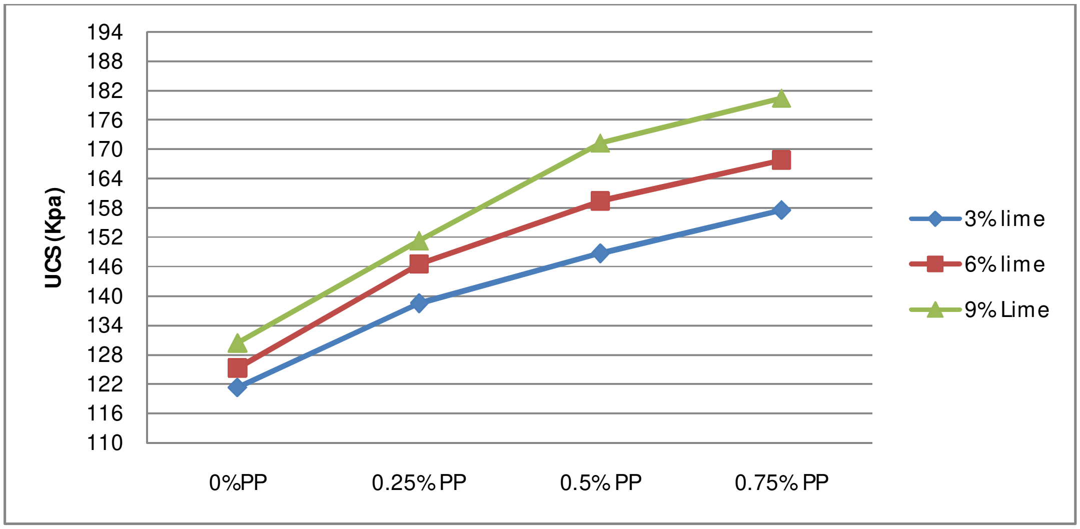
Graph-5Variations of DFS of soil in different proportion of lime



5) Unconfined Compressive Strength (UCS) Test Results

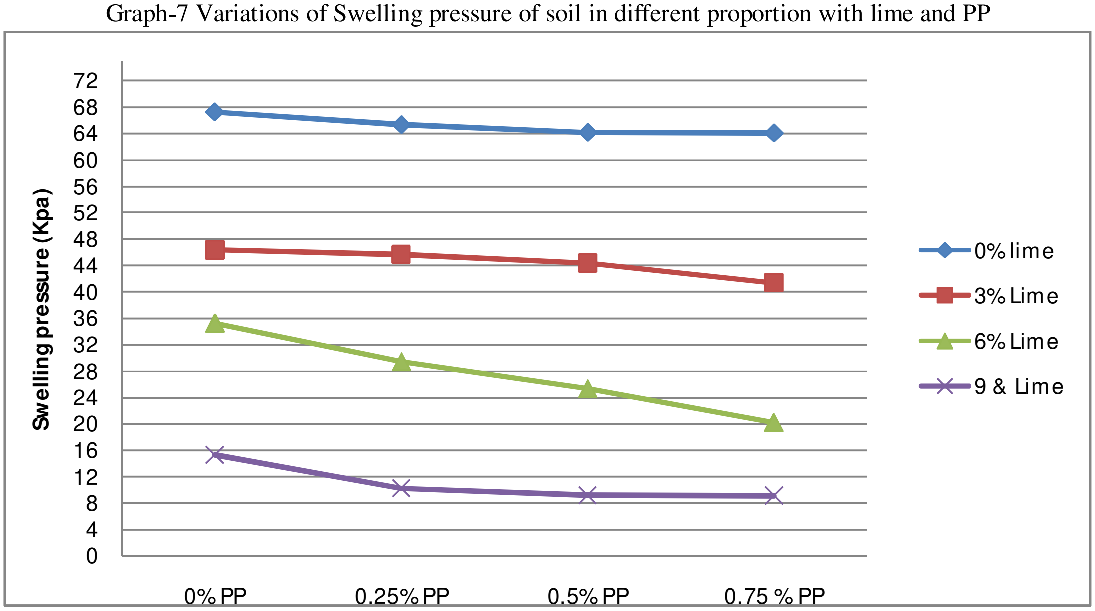
The UCS test evaluates the strength of the stabilized soil. The results are summarized and analyzed below:

Graph-6 VariationsofUCS of soil in different proportion with lime and PP



6) *Swelling Pressure:* Swelling pressure of black cotton soil is decease, addition of lime and also mixing the polypropylene which is increase the tensile strength of loose soil.

Graph-7 Variations of Swelling pressure of soil in different proportion with lime and PP



VI. CONCLUSIONS

The experimental study clearly demonstrates that the addition of lime and polypropylene fibers significantly improves the mechanical and swelling behaviour of clayey soil. The incorporation of lime (3%, 6%, 9%) reduces the plasticity index and swelling pressure of the clayey soil, while increasing the plastic limit and lowering engineering properties such as the liquid limit. The addition of polypropylene fibers (0.25%, 0.5%, and 0.25%) to lime-treated clayey soil enhances its strength. The optimal combination of 6% lime and 0.5% polypropylene fiber results in a reduction of swelling pressure and an increase in soil strength. These proportions were found to improve soil strength, reduce swelling, and enhance stability under varying moisture conditions.

Overall, it can be concluded that lime treated fiber-reinforced soil is an effective ground improvement technique, particularly in engineering projects involving weak soils, as it enhances strength and reduces swelling behavior.

REFERENCES

[1] Al-Kaream, K. W. A., Fattah, M. Y., & Hameedi, M. K. (2022). Compressibility and Strength Development of Soft Soil by Polypropylene Fiber. International Journal of GEOMATE, 22(93), 91–97. doi:10.21660/2022.93.3206.

[2] Chen, M., Shen, S. L., Arulrajah, A., Wu, H. N., Hou, D. W., & Xu, Y. S. (2015). Laboratory evaluation on the effectiveness of polypropylene fibers on the strength of fiber-reinforced and cement-stabilized Shanghai soft clay. Geotextiles and Geomembranes, 43(6), 515–523. doi:10.1016/j.geotexmem.2015.05.004.

[3] Hussein, S. A., & Ali, H. A. A.-R. (2019). Stabilization of Expansive Soils Using Polypropylene Fiber. Civil Engineering Journal, 5(3), 624. doi:10.28991/cej-2019-03091274.

[4] Murthi, P., Saravanan, R., & Poongodi, K. (2020). Studies on the impact of polypropylene and silica fume blended combination on the material behaviour of black cotton soil. Materials Today: Proceedings, 39, 621–626. doi:10.1016/j.matpr.2020.09.004.

[5] Moghal, A.A.B., Chittoori, B., Basha, B.M., & Al-Shamrani, M.A. (2017a). "Target reliability approach to study the effect of fiber reinforcement on UCS behavior of lime treated semi-arid soil." Journal of Materials in Civil Engineering (In press DOI: 10.1061/(ASCE)MT.1943-5533.0001835).

[6] Moghal, A. A. B., Chittoori, B., & Basha, B.M (2017b). "Effect of fibre reinforcement on CBR behavior of lime blended expansive soils: reliability approach." Road Materials and Pavement Design (In press, DOI: 10.1080/14680629.2016.1272479).

[7] Moghal, A.A.B., Dafalla, M.A., Elkady, T.Y., & Al-Shamrani, M.A. (2015). "Lime leachability studies on treated expansive semi-arid soil." International Journal of Geomate, 9(2), 1467-1471.

[8] Pekrioglu Balkis, A. (2017). The effects of waste marble dust and polypropylene fiber contents on mechanical properties of gypsum stabilized earthen. Construction and Building Materials, 134, 556–562. doi:10.1016/j.conbuildmat.2016.12.172.

[9] Patil, R.M. " Determination of swelling pressure of black cotton soil-A method" In proceedings of 3rd international conferenceon soil mechanics and foundation engineering, 1, (1953): 170-172.

[10] Reshma, T. V., Patnaikuni, C. K., Manjunatha, M., Bharath, A., & Tangadagi, R. B. (2022). Influence of alccofine and polypropylene fibers on stabilization of soil – An investigational study. International Journal of Advanced Technology and Engineering Exploration, 9(89), 551–562. doi:10.19101/IJATEE.2021.874996.

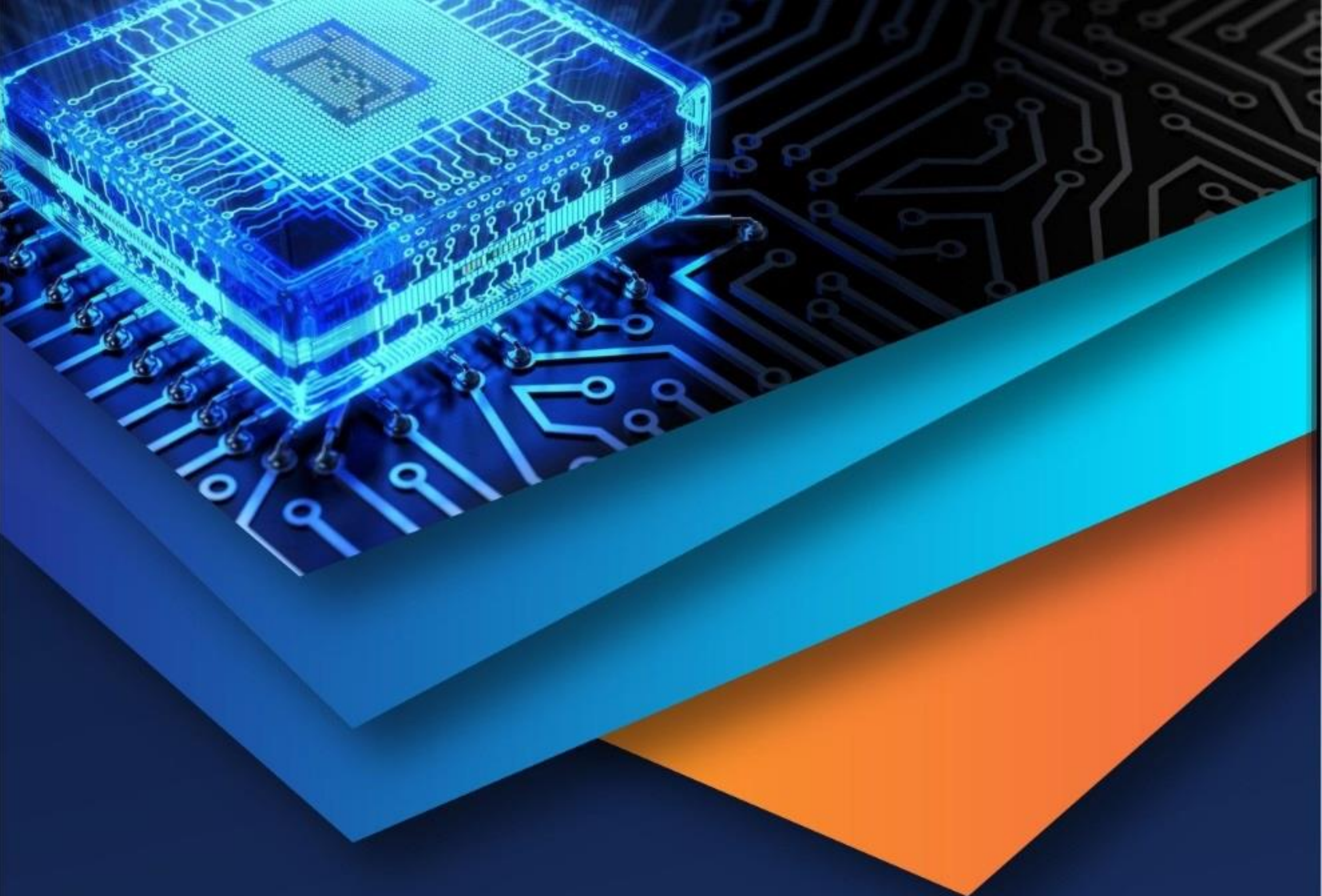
[11] Tomar, A., Sharma, T., & Singh, S. (2019). Strength properties and durability of clay soil treated with mixture of nano silica and Polypropylene fiber. Materials Today: Proceedings, 26, 3449–3457. doi:10.1016/j.matpr.2019.12.239.

[12] Tiwari, Binod, and Beena Ajmera. "Consolidation and Swelling Behavior of Major Clay Minerals and Their Mixtures." Applied Clay Science 54, no. 3–4 (December 2011): 264–273. doi:10.1016/j.clay.2011.10.001.

[13] Trouzine, H., M. Bekhiti, and A. Asroun. "Effects of Scrap Tyre Rubber Fibre on Swelling Behaviour of Two Clayey Soils in Algeria." Geosynthetics International 19, no. 2 (April 2012): 124 132. doi:10.1680/gein.2012.19.2.124.

[14] Tiwari, Nitin, and Neelima Satyam. "Experimental Study on the Influence of Polypropylene Fiberon the Swelling Pressure Expansion Attributes of Silica Fume Stabilized Clayey Soil." Geosciences 9, no. 9 (August 29, 2019): 377. doi:10.3390/geosciences9090377.

[15] Yang, X., Liang, S., Hou, Z., Feng, D., Xiao, Y., & Zhou, S. (2022). Experimental Study on Strength of Polypropylene Fiber Reinforced Cemented Silt Soil. Applied Sciences (Switzerland), 12(16). doi:10.3390/app12168318.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY