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An Experimental Study On The Impact Of Nanomaterials And Biopolymers On Cohesive Soil

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Abstract
All around the world, cohesive soils can seriously damage buildings and infrastructure. Many novel techniques are now being explored to increase the cohesive soils' strength in an effort to reduce their unwanted qualities and make them appropriate for building. Biopolymers, such as plant mucilage and microbial extracellular polymeric substances, are produced in near-surface soils by living organisms and provide improved moisture retention and protection from dry environments. They also lubricate roots to enable root penetration through soil and physically connect soil grains to form soil aggregates. The area of soil improvement has benefited from the availability of novel materials in addition to conventional procedures. The most novel concepts in soil stabilisation that have been developed recently are the addition of nanomaterial and biopolymers. For soil stabilisation, microbially induced polymers, also known as biopolymers, are added with the intention of reducing environmental contamination. Geotechnical engineering uses nanotechnology in two ways: first, it can be used to observe the structure of soil at the Nano scale, and second, it can be used to manipulate soil at the atomic and molecular levels. This study examines the viability of using biopolymers and nanomaterial to stabilise cohesive soil and analyses the resulting change in geotechnical parameters. Tests were conducted to identify the ideal proportion and strength features of additions, which included adding powdered tamarind kernel and nano-silica to soil at different percentages (0, 0.25%, 0.5%, 0.75%, and 1%).
Keywords: *Nanomaterials, Nano-silica, Biopolymers, Cohesive Soil, tamarind kernel*

1. INTRODUCTION

Subsidence and stability problems were a common occurrence for structures constructed on cohesive soil. A number of soil-improvement methods, including stabilisation, have been used as a result of several civil engineering projects using soft soils. One important process for increasing the efficacy of marginal soils as a construction material and improving the effectiveness of problematic soils is the alteration or stabilisation of soil-engineering characteristics, according to engineers [1]. In this field, several approaches for modification have been found. Conventional soil additions include salts, bitumen, and straw; however, in an effort to stabilise the soil from both mechanical and chemical perspectives, cement and other petrochemicals are being employed more frequently [2]. In the subject of stabilisation, new and developing technologies have been actively developed in addition to existing approaches. In engineering practice, slopes and structures that are or will be built in the presence of such soil characteristics are protected against harm by loess soils being treated in a number of methods to lessen compressibility or collapsibility [3]. The collapsibility index, financial factors, and building type are some of the factors that complicate the process of choosing the best strategy. Increasing the mechanical qualities of collapsible soils can be achieved by flooding, piling, a physical method, or chemical stabilisations [4]. With the goal of reducing environmental contamination, biological techniques are currently being aggressively incorporated into the field of geotechnical engineering as part of environmental sustainability [5]. Microbially induced polymers, also known as biopolymers, have emerged as a novel and inventive concept for enhancing soil quality. Natural biopolymers are sustainable grouting materials that are good for the environment. Nanotechnology is an emerging field that is developing quickly and has the potential to provide new and enhanced products for a wide range of applications as well as new materials with special qualities [6]. When it comes to geotechnical engineering, nanotechnology may be viewed in two ways: either at the nanoscale, which shows the structure of the soil, or at the atomic and molecular size, which manipulates the soil. The nanoparticles can work in tandem with conventional additives as well as independently as an additive for soil compaction. Nano-ZnO is added to soil that has been stabilised with lime, increasing its CBR strength 7]. Additionally, it displays a 25% maximum increase at a 1.5% nano-

ZnO concentration. The compactness and structures of soil can be improved because of the nanoparticles' small diameters, aggregation, and modest degrees of granular dispersion. Given its superior engineering qualities and plentiful deposits on Earth, nano-SiO2 is being explored as a potential tool for enhancing the geotechnical soil characteristics [8]. An investigation was conducted into the impact of sodium-modified montmorillonite nano clay on the engineering properties of clay. The results of Atterberg's limits test indicate that adding nanoclay to the soil can improve the liquid and plastic limits. The compactness and structures of soil can be improved because of the nanoparticles' small diameters, aggregation, and modest degrees of granular dispersion. Given its superior engineering qualities and plentiful deposits on Earth, nano-SiO_2 is being explored as a potential tool for enhancing the geotechnical soil characteristics [9]. An investigation was conducted into the impact of sodium-modified montmorillonite nano clay on the engineering properties of clay. The results of Atterberg's limits test indicate that adding nanoclay to the soil can improve the liquid and plastic limits. the soil's chemical composition. This is because nanomaterials have a very high specific surface area, which causes them to interact with other soil matrix particles more actively. Increasing the soil's engineering qualities is geotechnical engineering's primary use of nanotechnology. Since biopolymer is derived from agricultural non-food crops, it is always categorised as a renewable material and has sustained carbon neutrality. Therefore, a sustainable business would be created by the application of biopolymer in geotechnical engineering. A research by Raihan Taha et al. [10] looked at how the geotechnical characteristics of soft soil were affected by the addition of various nanomaterials, such as nano CuO, nano MgO, and nano clay. Each nanomaterial addition resulted in a drop in the soil's plasticity index, liquid limit, and plastic limit. The engineering properties of cohesive soil both before and after the addition of biopolymers and nanomaterials are the focus of this work.

2. MATERIAL AND METHODS

2. Biopolymers

Tamarind kernel powder is the biopolymer that was employed in this investigation. The plant Tamarindus Indica is used to make Tamarind Kernel Powder. Thetamad tree is an evergreen. Tamarind seeds' cotyledon, or section, is regarded as trash. In any case, the component consists of starch and gum that are assembled under top-notch procedures to transform into a powdered form. Amaranth Kernel Powder has excellent qualities for maintaining water and a high consistency. Tamarind seeds are subjected to a number of evaluations before being expertly ground into a powder while retaining their nutritional value (Figure 1).

Figure 1 Tamarind kernel powder

2.2 Kaolinite clay

The most prevalent clay is kaolinite, which has an earthy feel and a soft consistency. Their bearing capabilities are modest. For the investigation, kaolinite clay was selected from the Mangalapuram area in the Tiruvananthapuram district (Figure 2). They gathered, dried, and powdered the earth. Based on IS 2720-1985, it was examined to determine the fundamental qualities of the soil. The fundamental characteristics of the clay are displayed in Table 1.

Table :1 Properties of soil sample

Properties	Sample
Percentage of Clay	**75**
Specific Gravity	2.24
Plastic Limit Wp (%)	46
Shrinkage Limit Ws (%)	20
Liquid limit W_L (%)	73

Figure 2. Kaolinite Clay

2.3 Nano materials

Nano silica is a substance that is distinguished by having a high SiO2 concentration of above 99%. It is sometimes referred to as quartz dust or silica dust. Utilising nanosilica, or crystalline SiO2, completes the aggregate mix grading curve in the zone of the lowest particles while utilising less cement (Figure 3). Its goal is to provide a filler effect, which essentially closes voids and makes the concrete more compact. Because of this, the setting process takes longer and more water or SPs are needed when nanosilica is employed in the production of UHPC (Table 2).

Figure 3.Nano-Silica

Table 2. Physical properties of nano-SiO_2

S.No	Property	Result
1	Type	Silicon oxide (SiO_2)
2	Color	Bright white
3	Purity (%)	99.2
4	Specific gravity	2.39

5	APS (nm)	15-55
6	Bulk density (g/cm^3)	0.16

2.4 Sample preparation

The sample is prepared using the wet mixing technique. After dissolving the micro Silica powder in water, it is combined with the soil matrix. Different amounts of nano silica are added, ranging from 0.25% to 1%.

3. EXPERIMENTAL WORK

The soil sample was combined with nanoparticles and guar gum powder at concentrations of 1%, 0.75%, 0.5%, and 0.25%. Tests such as Atterberg limits, compaction, CBR, UCC, and others were conducted on a sample that was generated with varying concentrations of nanomaterials and biopolymers. Water is added at the appropriate liquid limit to prepare the sample for the UCS test. By using a compaction test, OMC is obtained to prepare CBR specimens. The purpose of the constant temperature evaporation test was to examine the soil that has been fortified with nano-SiO_2 and its ability to evaporate water. The test was carried out in a laboratory using a specially constructed thermostatic box (Figure 4), which can keep the specimen evaporating continuously at the current temperature. A temperature regulator, a weight collecting mechanism, and a heating unit make up the thermostatic box's major components. The specimen was placed in the thermostatic box, which maintained a constant temperature of 50 ◦C. An automated weight loss log was generated every minute. Up until they achieved a constant value, data were recorded. Moreover, the weight loss was equivalent to the water evaporation. The mechanical characteristics of nano-SiO_2-reinforced soil were tested using direct shear tests and unconfined compressive tests (UCS), adhering to the guidelines of ASTM D3080/D3080M-2011 and ASTM D4219-22 [11].

Figure 4. Thermostatic box

4. RESULTS AND DISCUSSION

The following is a discussion of the study's findings using powdered tamarind: The liquid limit of the sample is shown to be diminishing as the concentration of tamarind kernels increases with the addition of various doses. The liquid limit findings are displayed visually in figure. 5 and are reported in table 3.

Table 3: Variation of liquid limit with bio polymer content

Biopolymer Content (%)	Liquid Limit (%)
0	74.3
0.25	73.6
0.50	72.8
0.75	70.1
1.0	70.4

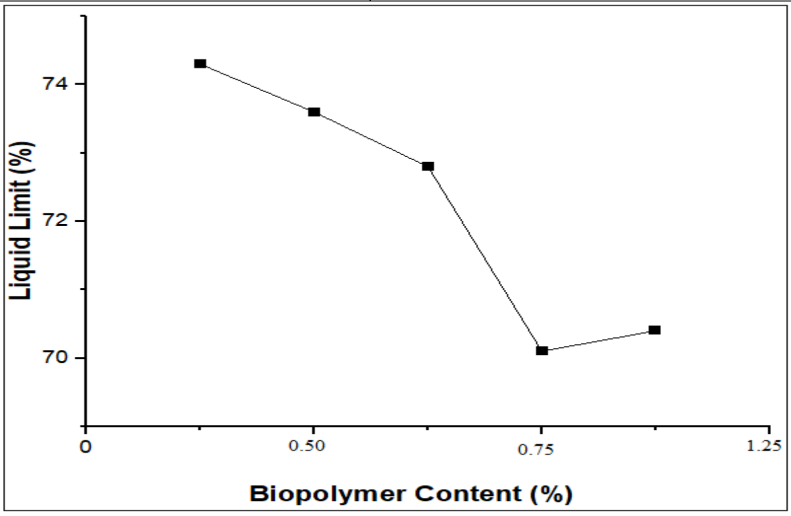


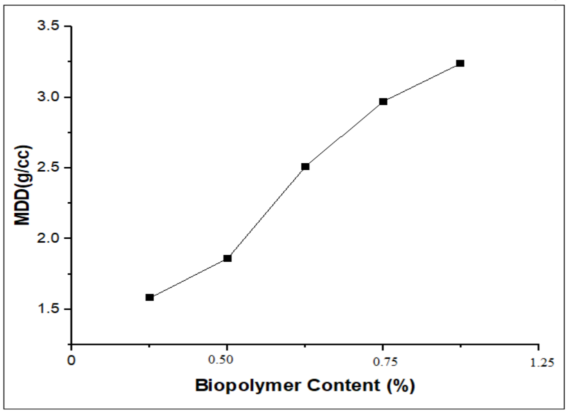
Fig 5 : Variation of Liquid limit with biopolymer

The compaction test findings showed that both the matching OMC content and maximum dry density were rising. A biopolymer of 0.75% yields the MDD (Figure 6 & 7). It displays a visual representation of the compaction test findings, which are summarised in Table 4.

Table 4: Variation of OMC and MDD for % of Biopolymer

Biopolymer Content (%)	MDD(g/cc)	OMC (%)
0	1.58	27.4
0.25	1.86	29.3
0.50	2.51	31.5
0.75	2.97	33.7
1.0	3.24	36.1

Up to 0.75%, the UCC value rises with an increase in biopolymer content and falls with additional addition. Table 5 tabulates the UCC test findings, which are displayed visually in Fig. 8.



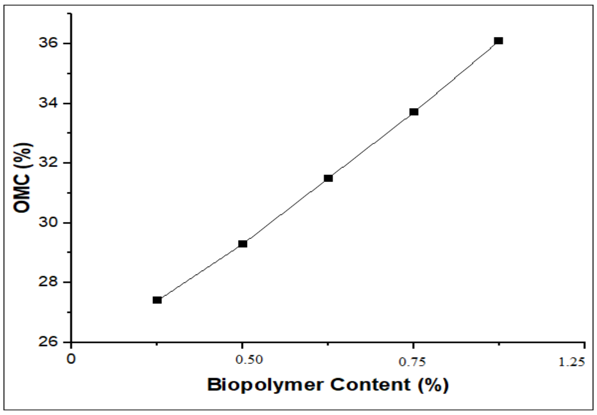


Fig 6: Variation of MDD with BP content Fig 7: Variation of OMC with BP content

Table 5: Variation of UCC value with BP content

Biopolymer Content (%)	**UCC Value** (kg/cm^2)
0	0.11
0.25	0.15
0.50	0.18
0.75	0.25
1.0	0.29

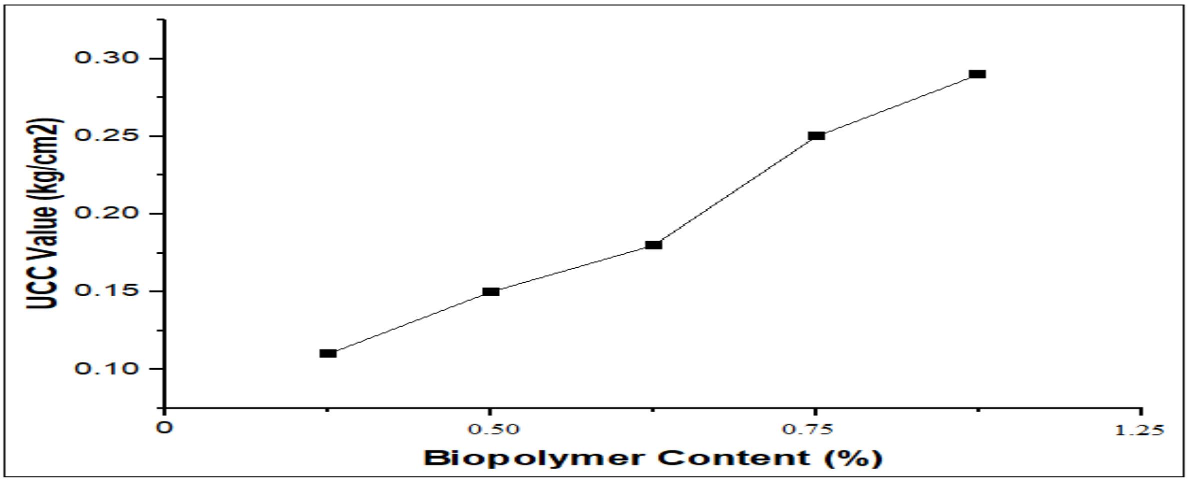


Fig 8: Variation of UCC value with BP content

Up to a 0.75% increase in BP content, the CBR value rises; beyond that, it falls. Table 6 and Figure 9 display the CBR test results.

Table 6. Variation of CBR value with BP content

Biopolymer Content (%)	**CBR Value** (%)
0	2.2
0.25	2.9
0.50	3.4
0.75	4.3
1.0	5.7

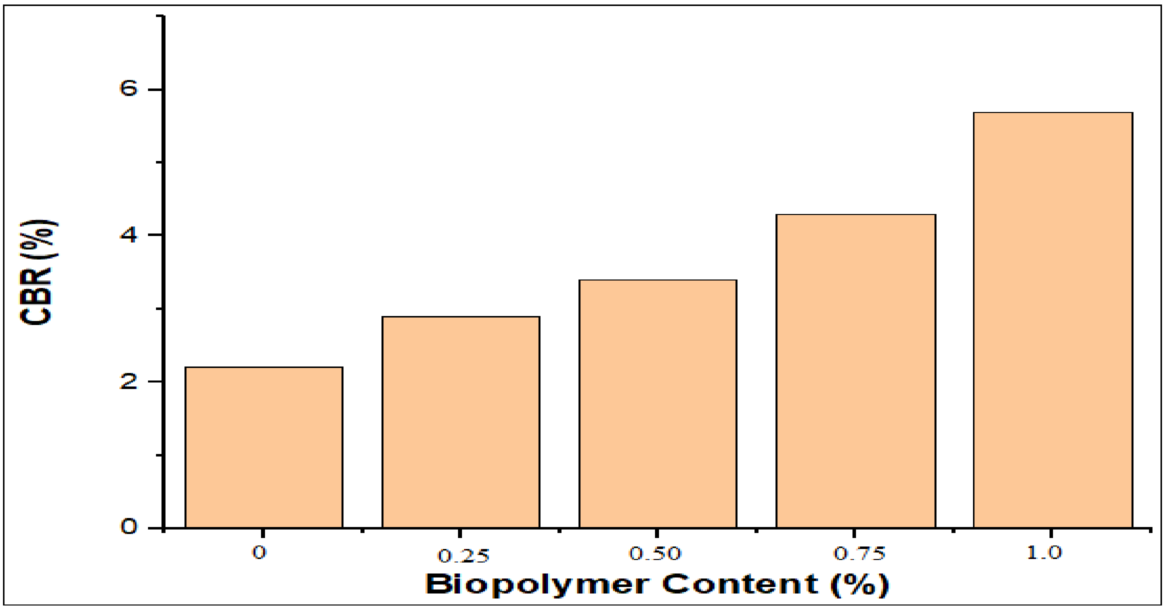


Fig 9: Variation of CBR value with BP

4.1 The following is a discussion of the findings from the study using nano silica powder:

The liquid limit of the sample is shown to be diminishing as the concentration of micro silica increases with the addition of various doses. Table 8 tabulates the results of the liquid limit, and Figure 10 presents the results visually.

The following is a discussion of the findings from the study using nano silica powder: The liquid limit of the sample is shown to be diminishing as the concentration of micro silica increases with the addition of various doses [12]. Table 8 tabulates the liquid limit findings, which are visually shown in Fig. 10.

Table 7. Variation of liquid limit with Nano Silica content

Nano Silica Content (%)	Liquid Limit (%)
0.25	83
0.50	75
0.75	69
1.0	59

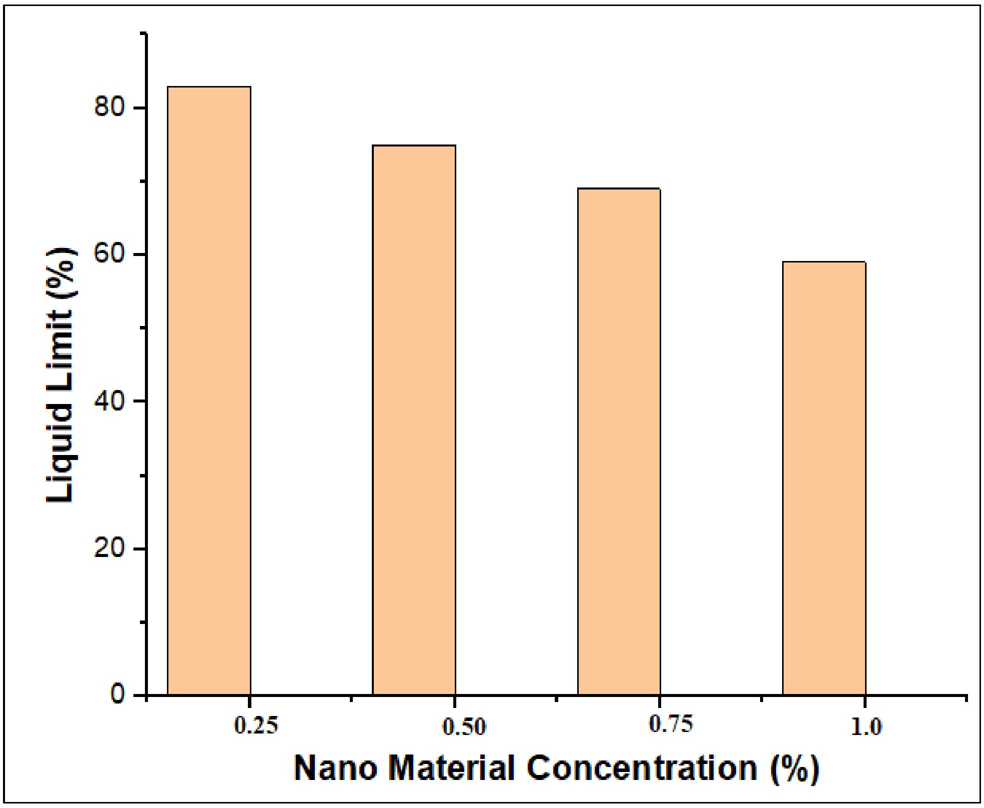


Fig 10:Variation of liquid limit with nano content

The maximum dry density and related OMC content were found to be decreasing in the compaction test findings. A 1% concentration of nano silica yields the MDD. Table 8 tabulates the compaction test findings, which are graphically shown in Figure 11 & 12.

Table 8: Variation of OMC and MDD for % of Nano Silica Content

Nano Silica Content (%)	MDD(g/cc)	OMC (%)
0	1.84	34
0.25	1.68	27
0.50	1.4	22
0.75	2.0	20
1.0	2.7	20

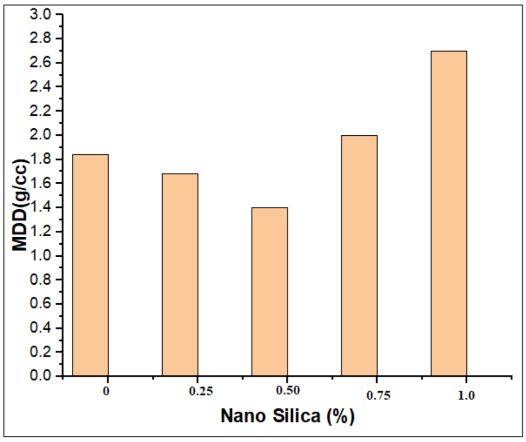


Fig 11: Variation in MDD

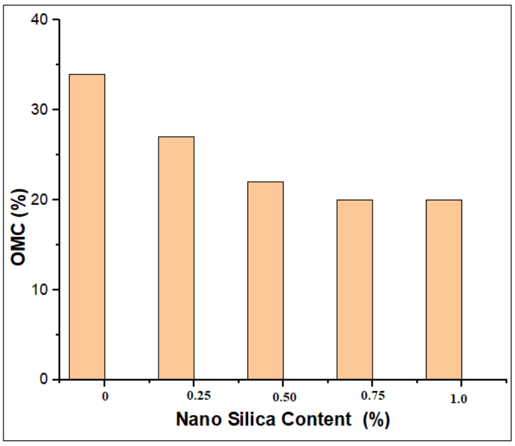


Fig 12: Variation in OMC

The UCC value rises as the amount of nano silica increases, reaching its optimal value at 1%. Table 9 tabulates the UCC test findings, which are displayed visually in Fig. 13.

Table 9: Variation in UCC value with Nano Silica Content (%)

Nano Silica Content (%)	UCC Value (kg/cm^2)
0	0.13
0.25	0.52
0.50	0.83
0.75	0.95
1.0	1.43

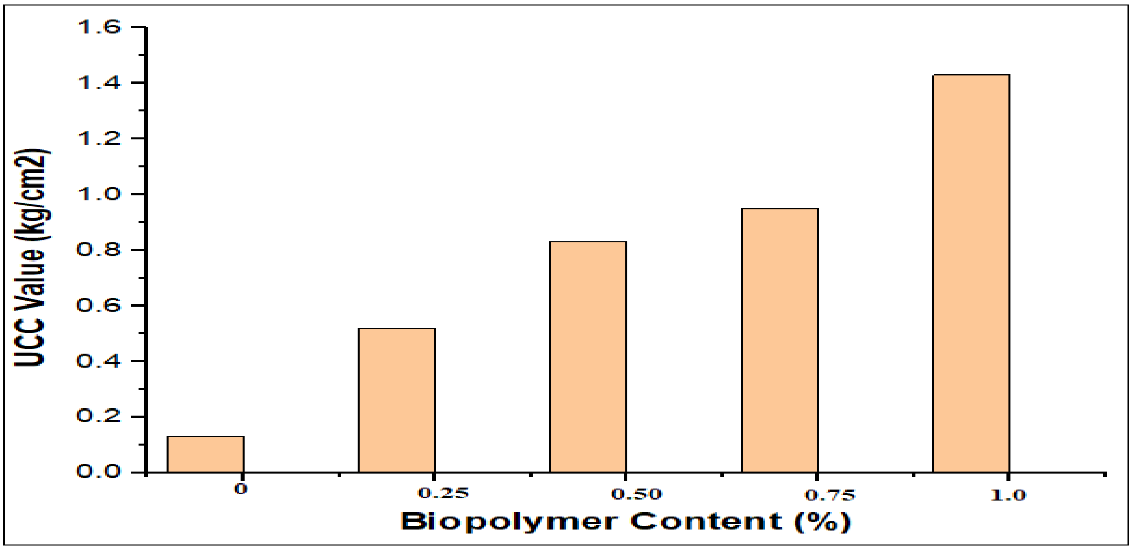


Figure 13.Nano silica with UCC value

As the amount of nano silica grows, so does the CBR value. The CBR test results are displayed in Table 10 and Figure 14. The findings indicate that the most effective combination for stabilising soil is clay with 1% nano silica rather than clay with nano silica. [13–14]

Table 10 : Variation of CBR value

Biopolymer Content (%)	CBR Value (kg/cm^2)
0	2.0
0.25	9.2
0.50	10.5
0.75	12.4
1.0	16.7

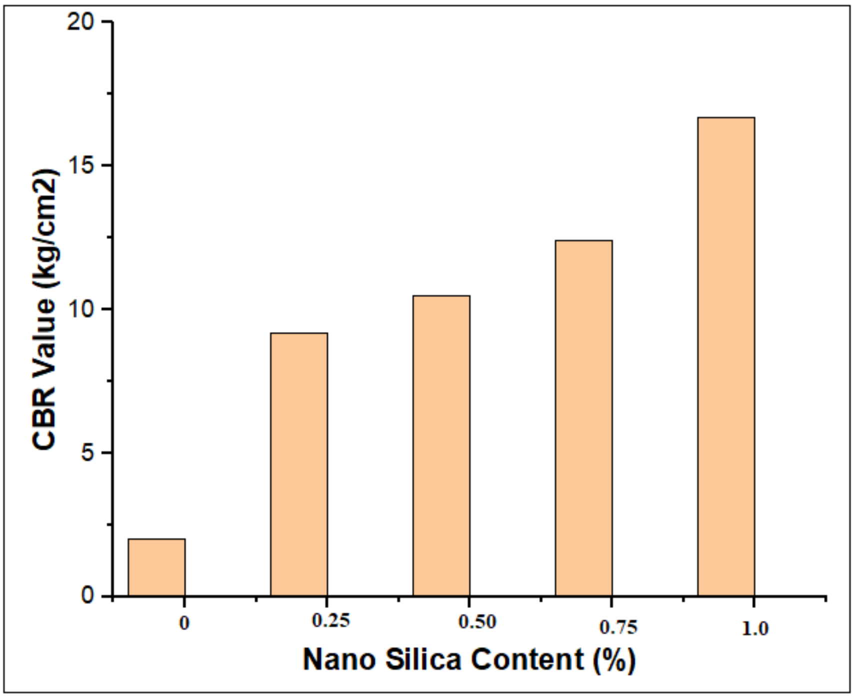


Fig 14 : Variation in CBR value

CONCLUSIONS

The addition of Tamarind kernel and nano materials improved the properties of selected clay. The characteristics of a particular clay were enhanced by the inclusion of nanomaterials and tamarind kernel. With the addition of nanomaterial, the CBR and UCC values rose and the clay's liquid limit fell.

- It is determined that 0.75% is the ideal level of biopolymer content.
- The percentage of clay that is liquid has decreased from 76% to 62%
- After applying 1% of nano silica, the MDD of clay increases to 2.25g/cc.
- The inclusion of nano silica raises the clay's CBR value from 1.9% to 15.5%.As a result, the clay may now be used to make pavement.
- Adding tamarind kernel to the clay raises its CBR value from 1.9% to 6.9%. As a result, the clay might be used to make pavement.
- The addition of 0.75 percent of Tamarind kernel increases the MDD of Clay to 2.35g/cc.

Thus, it can be said that the engineering and index characteristics of clay were enhanced by the inclusion of tamarind kernel and nanomaterials, making it more appropriate for a variety of uses.

REFERENCE

[1] S. Nokande, M.A. Khodabandeh, S.S. Hosseini, S.M. Hosseini, Collapse Potential of Oil-Contaminated Loessial Soil (Case Study: Golestan, Iran), Geotech. Geol. Eng. 38 (2020) 255–264, https://doi.org/10.1007/s10706-019-01014-9.
[2] S. B. Bakhade, P. S. Deshmukh, A. G. Deshmukh, S. R. Saikhede, Effect of Combination of Nano materials on Performance of Black Cotton Soil, International Journal of Engineering Research in Mechanical and Civil Engineering, 3 (2018) 1, 117–12
[3] Nima Lathifi and Muhd Zaimi (2017) "Improvement of Problematic Soils with Biopolymer—An Environmentally Friendly Soil Stabilizer", ASCE journal, Vol.29.
[4] M. Borouni, B. Niroumand, A. Maleki, Synthesis and characterization of an in-situ magnesium-based cast nano composite via nano-SiO2 additions to the melt, Materials and technology, 51 (2017) 6, 945–951, doi:10.17222/mit.2017.036
[5] Reza ziaie Moayed et.al. (2017) " Effect of Nano SiO2 Solution on the strength characteristics of kaolinite", Journal of geotechnical and geoenvironmental engineering
[6] G. Kullayappa, S. Praveenkumar, Study on Strength Characteristics of Soil mixed with Guargum, International Journal of Science and Research, 7 (2018) 6, 302–307
[7] S.B. Bakhade and P.S.Deshmukh (2018) "Effect of Combination of Nano materials on Performance of Black Cotton Soil, International Journal of Engineering Research in Mechanical and Civil Engineering, ISSN (Online) 2456-1290, Vol.3,pg 117-126.
[8] Srinivas Ganta and P.DILIP KUMAR RAO (2016) "Soil stabilization using geopolymer and biopolymer", International Journal for Research and Applied Science, ISSN (Online) :2455-6300, Vol.1,pg 280-289

[9] Chang, I., Im, J., Lee, S.-W., and Cho, G.-C. 2017. Strength durability of gellan gum biopolymer treated Korean sand with cyclic wetting and drying. Construction and Building Materials, 436 143: 210-221. doi:10.1016/j.conbuildmat.2017.02.061

[10] Cabalar, A.F., Awraheem, M.H., and Khalaf, M.M. 2018. Geotechnical Properties of a Low423 Plasticity Clay with Biopolymer. Journal of Materials in Civil Engineering, 30(8). 424 doi:10.1061/(Asce)Mt.1943-5533.0002380.

[11] Zaid Hameed Majeed (2014) "Stabilization of Soft Soil Using Nanomaterials." Research Journal of Applied Sciences, Engineering and Technology, ISSN:2040-7459, pg 503-509

[12[J. Huang, R.B. Kogbara, N. Hariharan, E.A. Masad, D.N. Little, A state-of-the-art review of polymers used in soil stabilization, Constr. Build. Mater. 305 (2021), 124685, https://doi.org/10.1016/j.conbuildmat.2021.124685

[13] J.M. Sarli, F. Hadadi, R.A. Bagheri, Stabilizing Geotechnical Properties of Loess Soil by Mixing Recycled Polyester Fiber and Nano-SiO2, Geotech. Geol. Eng. 38 (2020) 1151–1163, https://doi.org/10.1007/s10706-019-01078-7.

[14] M. Ayeldeen, A. Negm, M. El-Sawwaf, M. Kitazume, Enhancing mechanical behaviors of collapsible soil using two biopolymers, J. Rock Mech. Geotech. Eng. 9 (2017) 329–339, https://doi.org/10.1016/j.jrmge.2016.11.007