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An Experimental Research on the Effect of Biopolymers and Nano Materials on Cohesive Soil

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Abstract*: Cohesive soils are extensively distributed worldwide and are a source of great damage to infrastructure and buildings. In order to minimize the undesirable properties and make them suitable for construction purposes, many new approaches are now being developed to improve the strength of cohesive soils. In addition to traditional methods, availability of new materials have promoted the field of soil improvement. Addition of biopolymers and nano materials are the recently developed innovative ideas in the field of soil stabilisation. Microbial induced polymers or biopolymers are introduced in soil stabilisation with the aim of less environmental pollution. Nano technology in geotechnical engineering can be seen in two ways such as, the structure of the soil is seen at nano scale and the manipulation of soil is done at atomic and molecular scale. This study deals with the feasibility of stabilising cohesive soil with biopolymers and nano materials and to analyse the change in geotechnical properties. Guar gum powder and nano magnesium powder is added to soil at varying percentage (0.25%, 0.5%, 0.75% and 1%) and tests were carried out to determine the optimum percentage and strength characteristics of additives.

Key words: Ground improvement, Nano magnesium, Guar gum, Kaolinite clay, UCC, CBR

I. INTRODUCTION

The structures constructed on cohesive soil are always associated with problems of settlement and stability. Construction on soft soils in many civil engineering project has prompted the introduction of many approaches for soil improvement particularly stabilization. The modification or stabilisation of engineering properties of soil is recognised by engineers as an important process for improving the performance of problematic soils and makes marginal soils to perform better as a construction material. A number of modification techniques has been identified in this field. Admixtures such as straw, bitumen, salts are conventional additives to soil, while cement, petrochemicals etc are being increasingly used as an effort to stabilise the soil from mechanical and chemical aspects. In addition to conventional methods, new emerging technologies have been actively developed in the field of stabilization.

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Such reently developed method for soil improvement is the application of biopolymers and nano materials (in the order of 10^9). The use of conventional materials may lead to environmental degradation. As a part of environmental sustainability biological approaches are now being actively introduced in the field of geotechnical engineering with the aim of less environmental pollution. Microbial induced polymers or biopolymers have been introduced as a new innovative idea for soil improvemet. natural biopolymers are environmental friendly and a sustainable grouting chemicals. Nano technology is a rapidly originating technology with a huge potential to create new materials with unique properties and to produce new and improved products for numerous applications. Nano technology in geotechnical engineering dealing with soil can be seen in two ways such as, the structure of the soil is seen at nano scale and soil manipulation is done at atomic and molecular scale.

II. RELATED WORKS

Many researchers have shown that even a small amount of nano material could bring significant change in physical and chemical properties of the soil. This is due to very high specific surface of nano materials, they more actively reacts with other particles in the soil matrix. The main strategy of nano technology in geotechnical engineering is to improve the engineering properties of soil. Application of biopolymers to soil as a stabilising and strengthening agent of aggregates was under consideration in the agricultural engineering from 1940's (Karmi et.al 1997). Biopolymer isustainable carbon neutrality and always classified as a renewable material because it is made from agricultural non-food crops. Therefore, the use of biopolymer in geotechnical engineering would create a sustainable industry(Shipp and Braun, 1997). Experimental results of expansive soil treated with various percentages of guar gum gel for various water content results the improved strength of expansive soil. Biopolymer addition leads to the increase of intercept and CBR values of expansive soils (Gujjula et.al 2018). The idea of nano technology was first introduced in the year 1959 in a lecture delivered by Feynman. Nano particles can influence soil properties more dramatically even present at a small fraction, sometimes as low as few percent (Gouping and Zhang 2007). Raihan Taha et al (2012) conducted a study to investigate the effect of addition of different nano materials including nano CuO, nano MgO and nano clay on the geotechnical properties of soft soil. Addition of each of the nanomaterial decreased the liquid limit, plastic limit and plasticity index of the soil.

The dry density and optimum moisture content increased with increase in nanomaterial percentage. The compressive strength increased with nanomaterial addition. Faizah Kamarudin et al (2014) conducted experimental studies to determine the properties of nano kaolin mixed with kaolin. The presence of nano kaolin improved the kaolin properties even when the small quantity of nano kaolin was used.

Nohani and Ezatolah Alimakan et al (2015) studied the effect of sodium modified montmorillonite nano clay on engineering properties of clay. The results of Atterberg's limits test suggested that plastic and liquid limit can be increased by adding nano clay into the soil. Changizi and Haddad (2016) investigated the effect of adding nano-SiO2 on the strength behaviour of clay soil. The effects of nano-SiO2 on clayey soil were studied on the basis of the results obtained from a series of compaction and direct shear and unconfined compression tests . Hareesh and Vinothkumar (2016) carried out the experimental investigation on assessment of nano materials on geotechnical properties of clayey soils.The effect of Nano materials (nano silica and nano zeolite) on differential free swell, Atterberg's limits, compaction characteristics and unconfined compressive strength were investigated. The results showed the expansive nature of soil got decreased and Atterberg's limits and shear strength characteristics of soils got increased with increase in percentages of nano materials.

Objectives of study: This paper mainly focuses on the engineering properties of cohesive soil before and after the addition of biopolymers and nano materials.

III. MATERIALS AND METHODOLOGY

3.1 Kaolinite clay

Kaolinite is the most common clay with soft consistency and earthy texture. They have low bearing capacities. Kaolinite clay taken from mangalapuram region, Tiruvananthapuram district was selected for the study. The soil was collected, dried and powdered. It was tested as per IS 2720-1985 and the basic soil properties was found out. The basic properties of the clay is found as shown in Table 1.

Fig 1: Kaolinite Clay

Table 1 : Properties of soil sample

PROPERTIES	SAMPLE
Specific gravity	2.64
Liquid limit, W_L (%)	77
Plastic limit, W_p (%)	40
Plasticity Index, I_p (%)	36
Shrinkage limit, W_s (%)	25
Percentage of clay	70
Percentage of silt	30
Optimu moisture content (%)	30
Maximum dry density(g/cc)	1.4
Unconfined compressive strength, q_u (kg/cm^2)	0.12
California bearing ratio(%)	1.7
USCS Classification	CH

3.2 Biopolymers

Biopolymer used for the study is guar gum powder. Guar gum is a galactomannan polysaccharide extracted from guar beans that has thickening ans stabilising property. Guar gum used for the study was collected from Gajanana trading company, Banglore. The properties of guargum powder are shown in Table 2.

Fig 2 : Guar gum powder

Table 2 : Properties of Guar gum

PROPERTIES	SAMPLE
Physical state	Dry, Powder
Particle size	30-50 nm
Molecular weight	24.31 g/mol
Density	1.73 g/cm^3
Melting point	650^{0}c

3.3 Nano materials

Nano material used is nano magnesium powder. Magnesium nano particles are spherical black high surface area particles typically 20-60 nm in size with specific surface area ranging from 30-70m^2/g. They have properties that are totally different from that of bulk materials.

Fig 3 : Nano Magnesium Powder

Table 3 : Properties of nano magnesium

Content	Sample
Physical state	Dry, cream coloured powder
Ash (%)	7 – 12
Nitrogen (%)	0.3 - 0.1
Acetate (%)	1.9 – 6
Pyruvate (%)	1.0 -5.7
Mono valent salt (%)	3.6 - 14.7
Divalent salt (%)	0.085 - 0.17
Viscosity	13.37

3.4 Sample preparation

For the preparation of sample , wet mixing method is used. The nano magnesium powder is first dissolved in water and then mixed into soil matrix. Nano magnesium is added at varying percentages from 0.25%, 0.5%, 0.75% and 1%.

3.5 Experimental work

The soil sample mixed with guar gum powder and nano particles with concentration of 0.25 %, 0.5 %, 0.75% and 1%. Atterberg limits, compaction test, CBR test, UCC test etc were done on the sample prepared with different concentration of biopolymers and nano materials. For performing UCS test water is added at the corresponding liquid limit for sample preparation. CBR specimens are prepared with OMC attained by compaction test.

4. RESULTS AND DISCUSSIONS

The results of the study with guargum powder are discussed below:

With the addition of different dosages, the liquid limit of the sample is seen to be decreasing with the increase in guar gum concentration. The results of liquid limit is tabulated in table 4 and shown graphically in fig 4.

Table 4: Variaton of liquid limit with bio polymer content

BIOPOLYMER CONTENT (%)	LIQUID LIMIT (%)
0	76
0.25	75.8
0.5	75.4
0.75	74.6
1	74.2

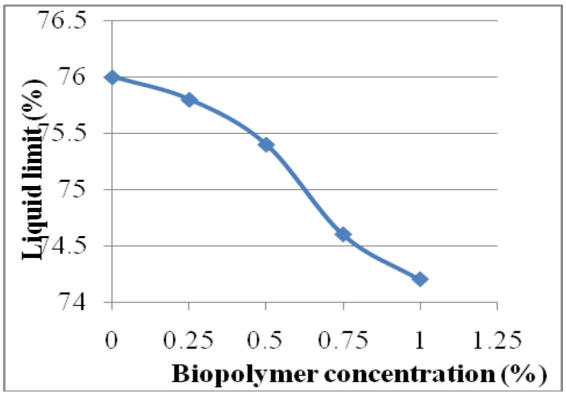

Fig 4 : Variation of Liquid limit with biopolymer

The results of compaction test was found as, maximum drydensity is increasing and also the corresponding OMC content increasing. The MDD is obtained at 0.75 % biopolymer. The results of compaction test is tabulated on table 5 and shown graphically in figure 5.

Table 5: Variation of OMC and MDD for % of Biopolymer

BP CONTENT (%)	OMC (%)	MDD(g/cc)
0	25	1.62
0.25	27	1.82
0.5	29	1.96
0.75	31	2.35
1	35	2.12

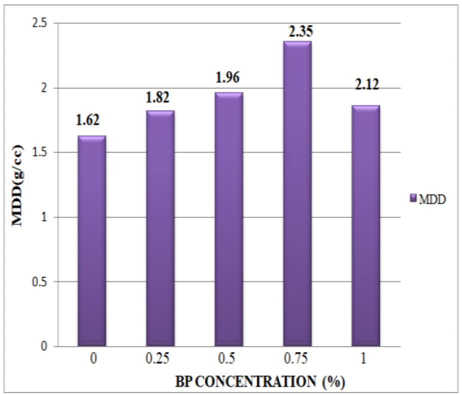

Fig 5: Variation of MDD with BP content

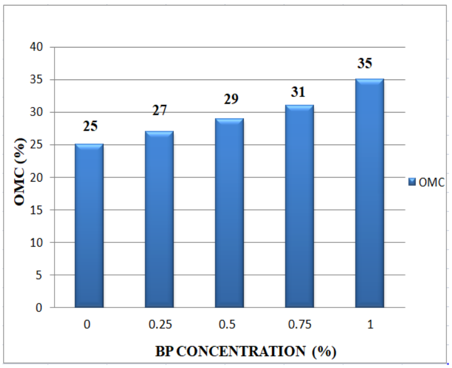

Fig 6: Variation of OMC with BP content

UCC value increases with the increase in biopolymer content upto 0.75 % and decreases on further addition. The results of UCC test is tabulated on table 6 and graphically shown in fig 7.

Table 6: Variation of UCC value with BP content

BP content (%)	UCC Value (kg/cm^2)
0	0.12
0.2	0.13
0.5	0.14
0.75	0.15
1	0.13

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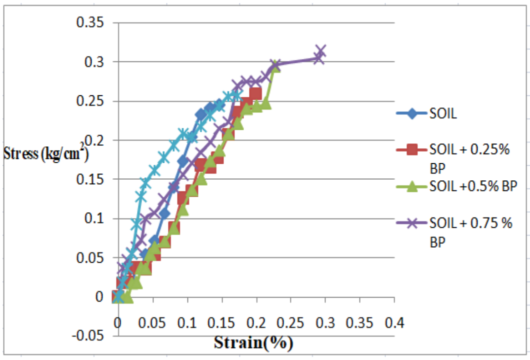

Fig 7 : Stress v/s strain curve

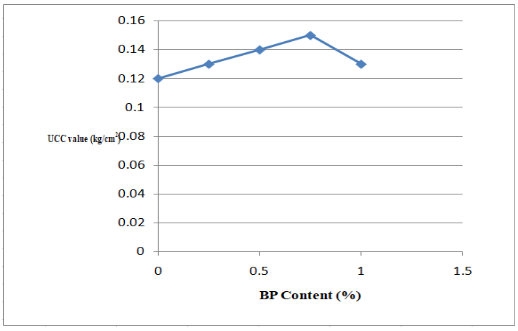

Fig 8: Variation of UCC value with BP content

CBR value increases with increase in BP content upto 0.75 % and then decreases on further addition. The results of CBR test is shown in table 7 and figure 9.

Table 7: Variation of CBR value with BP content

BP CONTENT (%)	CBR VALUE (%)
0	1.9
0.25	2.5
0.5	4.8
0.75	6.9
1	5.6

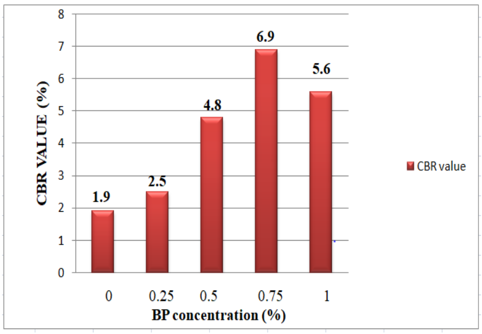

Fig 9: Variation of CBR value with BP

The results of the study with nano magnesium powder are discussed below:

With the addition of different dosages, the liquid limit of the sample is seen to be decreasing with the increase in nano magnesium concentration. The results of liquid limit is tabulated in table 8 and shown graphically in fig 10.

Table 8: Variation in liquid limit

NANOMAGNESIUM CONTENT (%)	LIQUID LIMIT (%)
0.25	74
0.5	70
0.75	65
1	62

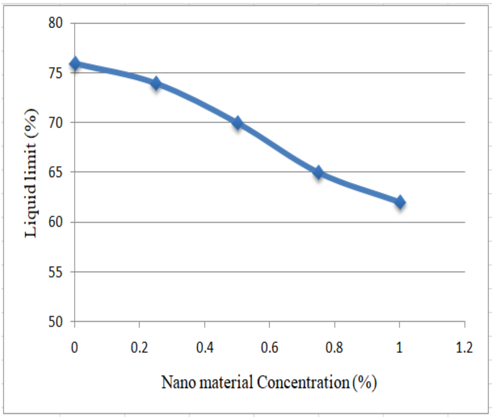

Fig 10:Variation of liquid limit with nano content

The results of compaction test was found as, maximum dry density is increasing and also the corresponding OMC content decreasing. The MDD is obtained at 1% of nano magnesium. The results of compaction test is tabulated on table 9 and shown graphically in figure 11.

Table 9: Compaction Test results

Nano Magnesium content (%)	OMC (%)	MDD(g/cc)
0	30	1.44
0.25	28	1.45
0.5	24	1.5
0.75	24	1.8
1	24	2.25

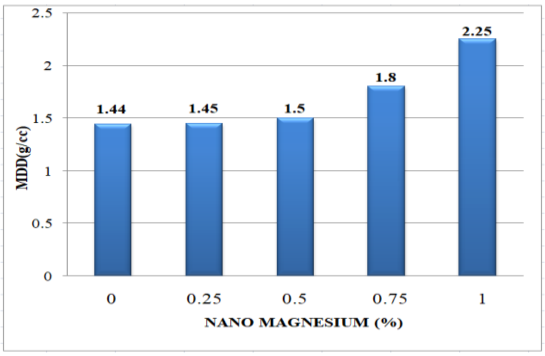

Fig 11: Variation in MDD

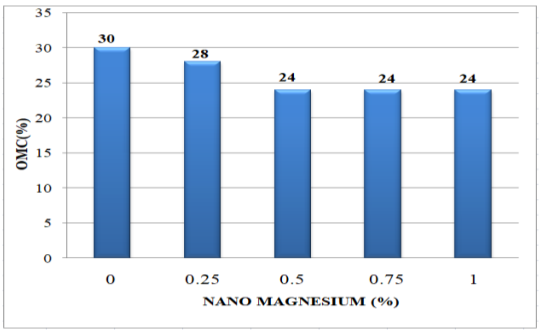

Fig 12: Variation in OMC

UCC value increases with the increase in nano magnesium content and the optimum value is obtained at 1% . The results of UCC test is tabulated on table 10 and graphically shown in fig 12.

Table 10: Variation in UCC value

NANO MAGNESIUM CONTENT (%)	UCC VALUE (Kg/cm^2)
0	0.12
0.25	0.458
0.5	0.716
0.75	0.828
1	1.047

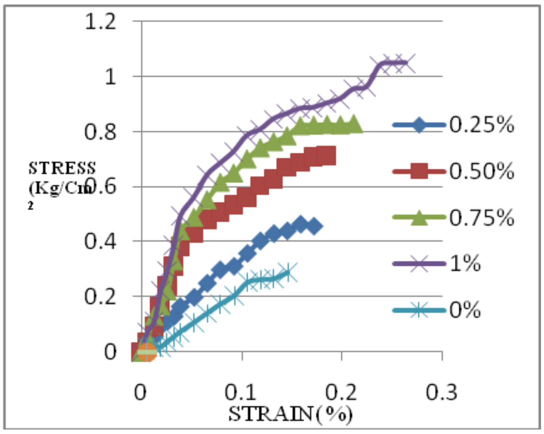

Fig 13: Variation in UCC value

CBR value increases with increase in nano magnesium content . The results of CBR test is shown in table 11 and figure 14.

Table 11 : Variation of CBR value

Nano Magnesium Content (%)	CBR VALUE (%)
0	1.9
0.25	8.8
0.5	9.92
0.75	10.5
1	15.57

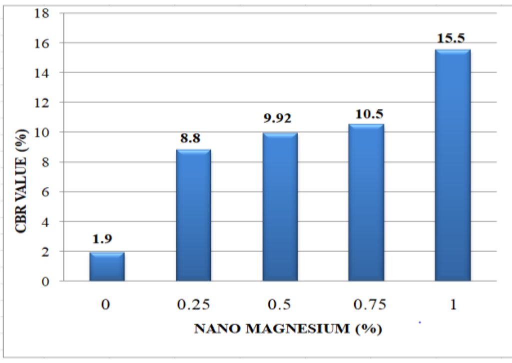

Fig 14 : Variation in CBR value

5. CONCLUSIONS

The addition of guar gum and nano materials improved the properties of selected clay. The CBR and UCC value increased and the liquid limit of the clay is decreased with nano material addition.

- The optimum value of biopolymer content is found to be 0.75%.
- The liquid limit of clay is reduced to 62 % from 76%.
- The MDD of Clay is increased to 2.25g/cc when treated with 1 % of nano magnesium.
- CBR value of the clay is increased to 15.5% from 1.9% with the addition of nano magnesium .Therefore the clay became suitable for pavement construction.
- CBR value of the clay is increased to 6.9% from 1.9% with the addition of guargum. Therefore the clay became suitable for pavement construction.
- The MDD of Clay is increased to 2.35g/cc when treated with 0.75 % of guar gum.

Therefore it can be concluded that guar gum and nano material addition improved the engineering properties and index properties of clay and make it more suitable for different purposes.

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