Performance Evaluation of Polysachharide based Biomaterials for Sand Stabilization

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ABSTRACT:

Recent research on soil improvement have showed that the use of biopolymers can significantly enhance the various engineering properties of the soil. Soil improvement using biopolymers has attracted considerable attention in recent years, with the aim to reduce the harmful environmental effects of traditional materials. This report aims to provide a review on the environmental assessment of biopolymers as binders in soil improvement, biopolymer-treated with soil characteristics, as well as the most important factors affecting the behavior of the treated soil. Various geotechnical properties are evaluated and compared, including the unconfined compressive strength, and durability of biopolymer-treated soils. The usage of biopolymers has positive effects on the soil in the form of enhanced strength, However, a thorough understanding of the geotechnical qualities is required in order to completely apply the biopolymer technology to the fields. Biopolymer kinds, soil types, biopolymer contents, curing times, thermal treatment, and mixing techniques all play a significant role in how effective biopolymers are at improving the ground. In this part of study, the pycnometer method, sieve analysis, standard proctor compaction tests, unconfined compression test, durability, gel plug tests, pH test, and FTIR test, were used to understand and analyze the pectin-treated sand.

Keywords: *Pectin,Geotechnical Engineering,Bio Polymer- Treated soil*

INTRODUCTION:

Environmental issues have become more praised in our world in recent years. New sustainable technologies have so been the subject of numerous studies. For various construction reasons, a soil binder is required in the field of geotechnical engineering. However, the most popular materials are those that are not environmentally friendly. New materials, such as biopolymers, have been studied for their potential to improve the soil. They typically comprise monomeric units that are linked together in bigger forms and have applications in a variety of industrial sectors, including food production, agriculture, cosmetics, medical treatment, and pharmaceuticals. Utilizing biological components to efficiently enhance the engineering qualities of soils is a new strategy. It is appropriate to evaluate if advances in biology might have the ability to lead academics to a deeper understanding and new approaches in geotechnical engineering given the explosion of new biological information over the past several years. When faced with a challenge, a geotechnical engineer would work to develop the most efficient method of treating the soil, taking into account the types of the underlying soil, treatment depth, locations that needed to be treated, desired level of improvement, environmental friendliness of the method. These design considerations are the most useful in choosing the best treatment strategy. Many different materials are utilized nowadays to remediate soil. Among the most worrisome recent phenomena are those of global warming and climate change. Regarding materials applied to civil applications The possible impact of biopolymer binders in geotechnical engineering is the effect on improving a number of marginal soil behavior characteristics. Recent studies have examined the advantages and positive effects of biopolymers from a variety of angles. Understanding the behavior of biopolymer-treated soil under various loadings and environmental factors. Additionally, it's important to comprehend how many variables, particularly curing conditions and environmental circumstances, may affect how biopolymers interact with soil particles prior to, during, and after mixing. Biopolymers can be classified based on different terms including biodegradability (biodegradable and non-biodegradable) and the source of raw materials. Three groups can be considered when classifying biopolymers based on their source of origin: plant-based biopolymers, animal-based biopolymers, and biopolymers produced by microorganisms. Below is a list of biopolymers, which are mostly utilized for soil improvement purposes, based on the source of production.

Common biopolymers used for soil improvement based on their source of production.

Plant based: Guar lignin agar Beta Alginate Carrageenan.

Microorganism based: Dextran Xanthan E- polysine gellan. Animal based: Chitosan casein.

PECTIN

Pectin, a biopolymer is complex plant polysaccharide present in primary cell wall, is a form of soluble fiber. Pectin has important role in plant growth, morphology, development, cell adhesion and plant defense and also works as an emulsifier, gelling and stabilizing agent in diverse food and specialty products and also reveals defense mechanisms against plant pathogens and wounding. Scientific research has revealed a number of health benefits and multiple biomedical uses of pectin. Pectin is a macromolecule which is composed by a number of distinct polysaccharides such as homogalacturonans (HG), rhamnogalacturonans (RG), xylogalacturonans (XGs), arabinans and arabinogalactans. Pectin has gelling ability, which makes it a useful additive in the production of jams and jellies.

2.LITERATURE SURVEY:

2.1 Journal of petroleum science and Engineering 38(1-2): 13-1

The impact of xanthan gum content was the significant factor among the specimens tested. The results of this study may have implications on both modelling treated sands in the laboratory and on ground improvement The xanthan gum-treated sand behaves differently according to the xanthan gum hydrogel phase variation. In the initial condition, the xanthan gum hydrogel forms a uniformly dissolved matrix by hydrogen bonding. When the xanthan gum is thinner in the hydrogel, the inter-particle reaction is dominant in contrast to that of the shearing band which is formed by the hydrogel. In contrast, the shearing band force is superior in the case of the xanthan gum being dense. As a result, the xanthan gum loosely dissolved sand—2.5% and 5.0%—shows peak behavior although residual behavior in the highly dense xanthan gum-treated sand—10.0%. As the xanthan gum hydrogel is highly concentrated, the peak cohesion increases, though the peak friction angle shows little difference. It reveals that the xanthan gum-treated sand in the initial state, which is tested immediately after mixing, is influenced not by its interlocking but by its viscosity, especially when the xanthan gum concentration is larger than 2.5%. Furthermore, the xanthan gum hydrogel forms a continuous matrix by hydrogen bonding. When the shearing force is applied, the gel is crushed into crumbs and ionic bonding is caused by van der Waals interaction between the hydrogel crumbs. Therefore, the cohesion is increased although the friction angle is unchanged, as the xanthan gum is denser.

2.2 Journal of construction and building materials

His study addressed the strengthening behavior of thermos gelation biopolymers to facilitate their use as a construction material for soil improvement. Agar gum and gellan gum were used as thermo-gelation biopolymers, and clayey soil and sandy soil were used to represent fine-type soil (CL) and coarse type soil (SP–SM), respectively. Through a series of experimental and analytical studies, the factors influencing the strengthening behavior of thermo-gelation biopolymer-treated soils were discussed and the main findings are summarized as follows: Thermo-gelation biopolymer soil treatment has significant impacts, enhancing soil strength and soil durability. Thermal treatment induces higher strength as well as structural stiffness. Moreover, thermally treated specimens showed high structural durability under immersion, which is a remarkable characteristic

2.3 Journal of geotechnical and geo environmental engineering

Biopolymer shows to modify and engineer soil behavior to have specific strength and deformation characteristics in terms of level of stiffness or ductility. The sustainability and Eco friendliness of biopolymers also add to their attractiveness for use in engineering applications**.** Biopolymers can effectively improve the strength characteristics of sand without causing environmental toxicity. The improvement in performance of sand treated with agar and modified starch was found to be directly dependent on the concentration of agar as the main component and starch as the additive. The addition of Starpol 600 and 136 at the same agar concentration was observed to significantly increase the value of cohesion intercept and also to enhance stiffness. In conclusion, biopolymer treatment shows promise as a tool to modify and engineer soil behavior to have specific strength and deformation characteristics in terms of level of stiffness or ductility. The sustainability and Eco friendliness of biopolymers also add to their attractiveness for use in engineering applications.

3.EXPERIMENTAL METHODOLOGY:

3.1 SPECIFIC GRAVITY

The specific gravity of soil is determined using the relation:

$$G = (M_2 – M_1)/ [(M_2 – M_1) – (M_3 – M_4)]$$

Where M_1=mass of empty Pycnometer, M_2= mass of the Pycnometer with dry soil M_3= mass of the Pycnometer and soil and water, M_4 = mass of Pycnometer filled with water only. G= Specific gravity of soil

3.2 SIEVE ANALYSIS

The grain size analysis test is performed to determine the percentage of each size of grain that is contained within a soil sample, and the results of the test can be used to produce the grain size distribution curve. This information is used to classify the soil and to predict its behavior. The two methods generally used to find the grain size distribution are:

Sieve analysis which is used for particle sizes larger than 0.075 mm in diameter.Sieve analysis is a method that is used to determine the grain size distribution of soils that are greater than 0.075 mm in diameter. It is usually performed for sand and gravel but cannot be used as the sole method for determining the grain size distribution of finer soil. The sieves used in this method are made of woven wires with square openings.

The values of C_u and C_c are used to classify whether the soil is well-graded or not. Sand is considered well-graded, if C_u is greater than 6 and C_c is between 1 and 3. For gravel to be considered as well-graded,

C_u should be greater than 4 and C_c should be between 1 and 3.

Uniformity Coefficient (C_u):

The uniformity coefficient (C_u) is defined as the ratio of D_{60} to D_{10}. A value of Cu greater than 4 to 6 classifies the soil as well graded. When Cu is less than 4, it is classified as poorly graded or uniformly graded soil.

$$C_u = D_{60}/D_{10}$$

Uniformly graded soil has identical particles with C_u value approximately equal to 1. A uniformity coefficient value of 2 or 3 classifies the soil as poorly graded. Beach sand comes under this category. A higher value of C_u indicates that the soil mass consists of soil particles with different size ranges.

Coefficient of Curvature (C_c)

The coefficient of curvature is given by the formula:

$$C_c = (D_{30})^2 / (D_{60} * D_{10})$$

3.3 STANDARD PROCTOR TEST (SPT)

Compaction is a type of mechanical stabilization where the soil mass is densified with the application of mechanical energy also known as compaction effort. The mechanical energy may be produced by the dynamic load, static load, vibration, or tamping. During compaction, the soil particles are relocated, and the air volume is reduced. It may also involve a modification of the moisture content, and in the saturated coarse-grained soil, the moisture content may be pressed out during the process of compaction. Compaction should not be confused with consolidation; where the density of saturated soils is increased due to a reduction in the volume of voids brought about by the expulsion of water under the application of static load

For a given type of soil and compaction effort, the dry density of a soil mass varies with moisture content. At low moisture content, the internal friction and adhesion between the particles contribute to the resistance to compaction. As the moisture content increases the particles develop moisture films around them, which help in lubricating the particles, thus increasing the workability of the soil mass. It does not increase any further when the moisture content is increased beyond a certain particular value of the moisture content; as the water at this stage starts replacing the soil particles and as the unit weight of water is less than that of soil particles the density starts decreasing. The particular value of moisture content at which the maximum dry density of a soil mass is attained for a given compaction effort is known as the optimum moisture content (OMC).

3.4 UNCONFINED COMPRESSION SHEAR TEST (UCS)

The unconfined compression test is the most popular method of soil shear testing because it is one of the fastest and least expensive methods of measuring shear strength. It is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The test is not applicable to cohesionless or coarse-grained soils. The unconfined compression test is strain-controlled, and when the soil sample is loaded rapidly, the pore pressures (water within the soil) undergo changes that do not have enough time to dissipate. Hence it is representative of soils in construction sites where the rate of construction is very fast and the pore waters do not have time to dissipate.

3.5 GEL PLUG TEST

In this experiment, water was sprinkled on top of pectin powder in a 50-ml test tube. A 1.24 g of pectin powder (almost the same average amount of powder added to the soil samples in chapter 6) was poured first into the dry test tube then we sprinkled water inside the tube slowly till the level of water reached the 50 ml mark. The powder started to hydrate slowly forming a fluffy surface bio-film plug in the bottom of the tube. The height of the bio-film increased slightly and slowly with time. No trace of powder was noticed suspended in the water column on top of the powder. To examine the dehydration potential of the pectin, another experiment was performed. In that experiment, we added pectin powder to the water in a test tube and sealed the tube. We then shook the tube to ensure complete mixing.

3.6 pH TEST

The Bureau of Indian Standards has developed Indian Standard methods of test for soils (IS: 2720), which have been published in sections, with the goal of providing uniform producers for the assessment of various soil parameters as well as making it easier to compare the results. This section discusses how to determine pH value.

3.7 FOURIER TRANSFORM INFRARED SPECTROSCOPY TEST (FTIR)

Fourier Transform Infrared (FTIR) Spectroscopy is commonly referred to as FTIR Analysis or FTIR Spectroscopy. This infrared spectroscopy method is used to identify organic, polymeric, and in some cases, inorganic materials. The FTIR test relies on infrared light to scan samples and observe bond properties. FTIR analysis services can identify compounds and the general type of material being analyzed when there are unknowns. This technique is used to assess the purity of some inorganic samples and is highly reliable for identifying polymer composition. Before FTIR analysis begins, the sample is prepared for testing using either the attenuated total reflectance (ATR), Nujol, or other technique. Enough sample is required to obtain an absorption spectrum. The FTIR Spectrometer generates a graph in the form of an absorbance spectrum, which shows the unique chemical bonds and the molecular structure of the sample material. This absorption spectrum will have peaks representing components present. These absorbance peaks indicate functional groups (e.g., alkanes, ketones, acid chlorides). Different types of bonds, and thus different functional groups, absorb infrared radiation of different wavelengths.

RESULTS AND DISCUSSIONS:

4.1 SPECIFIC GRAVITY

The specific gravity of tested soil at room temperature is 2.66

4.2 SIEVE ANALYSIS

S. No.	Particle size (mm)	Particle size (mm)	Weight retained (g)	Percentage retained (%)	Cumulative percentage retained (%)	Percentage finer
1	4.75	4.75	18	1.8	1.8	100
2	2.36	2.36	32	3.2	5	95
3	1.18	1.18	254	25.4	30.4	69.6
4	0.6	0.6	506	50.6	81	19
5	0.425	0.425	166	16.6	97.6	2.4
6	0.3	0.3	16	1.6	99.2	0.8
7	0.15	0.15	6	0.6	99.8	0.2
8	pan	0	2	0.2	100	0

$$\text{Percent retained} = \frac{\text{Weight of material retained on the sieve}}{\text{Total sample weight}} * 100$$

Percent passing =100%-Cumulative percent retained

For the soil to be well graded, the value of C_c must range between 1 and 3.

For any single sized soil mass, the value of both C_u and C_c is 1.

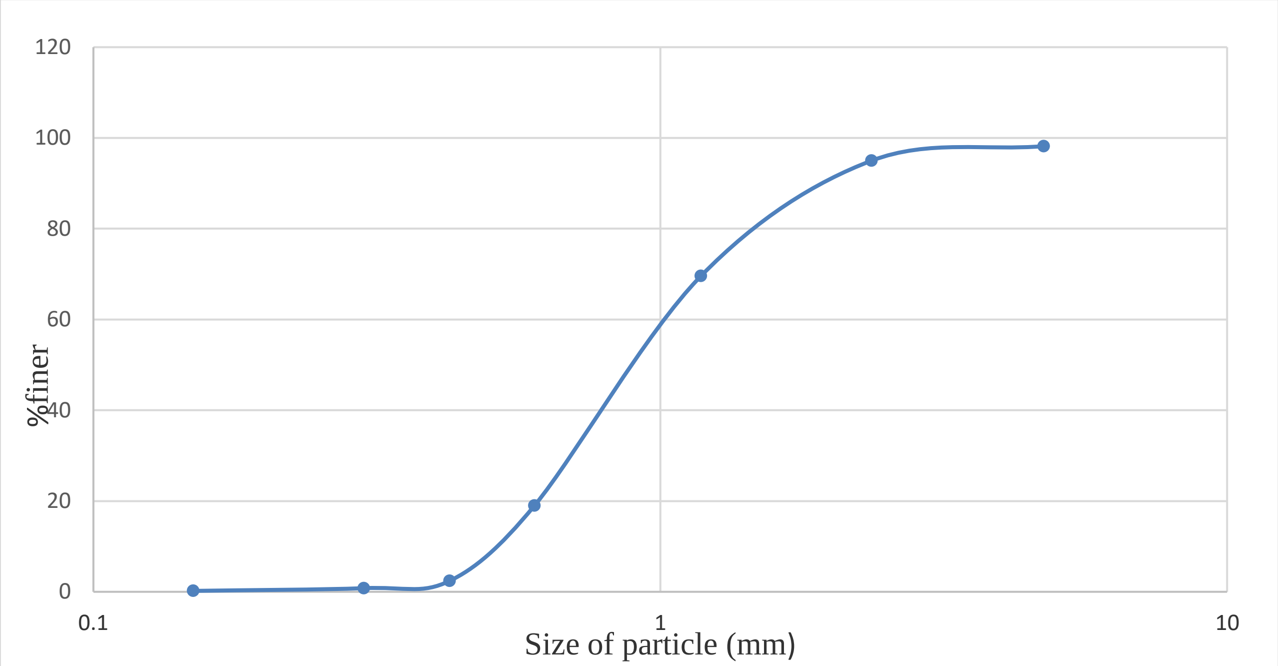

Fig 4.2 particle size distribution curve.

In our case, C_u= 2.75, C_c = 0.64

Hence, soil is classified as poorly graded sand.

4.3 STANDARD PROCTOR TEST

Description	Optimum Moisture Content (%)	Maximum Dry Unit Weight (kN/m^3)
Soil	6	16.157
Soil +0.5% pectin	7	16.12
soil +1% pectin	8	16.09
soil +1.5% pectin	11	15.77
soil + 2% pectin	14	15.46

Table 4.3

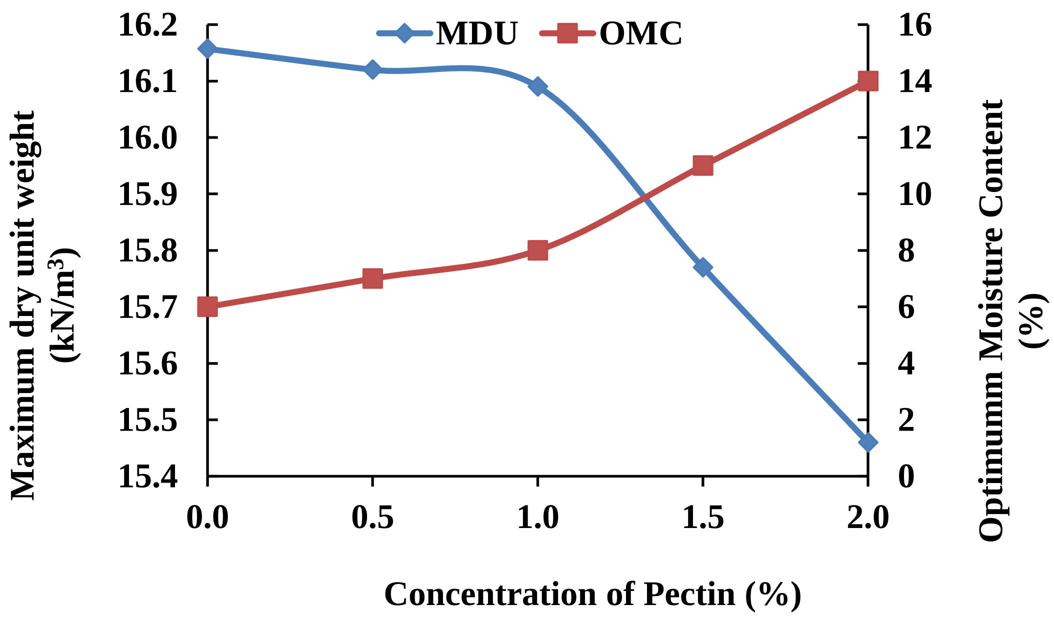

Fig 4.3

Initially, sand without treating with biomaterial (pectin) having optimum moisture content was 6 percent. After treating with pectin by increasing the percentage from 0.5%, 1%, 1.5% and 2%, their corresponding optimum moisture content were 7%, 8%, 11%, and 14% respectively. It is observed that as the percentage of pectin increases, their optimum moisture content also. Maximum dry unit weight was decreased with increasing the percentage of pectin content.

4.4 THERMAL CURING

Fig 4.4 cylindrical specimens.

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4.5 GEL PLUG TEST

Pectin powder which was added to water, slowly forming a fluffy surface bio-film plug in the top of the test tube.

4.6 UNCONFINED COMPRESSION STRENGTH

Tests are done after one day, from the preparation of sample.

Sample	Cohesion (kN/m^2)
Sand + 0.5% of pectin	30
Sand + 1% of pectin	34
Sand + 1.5 % of pectin	41
Sand + 2% of pectin	75

Table 4.61

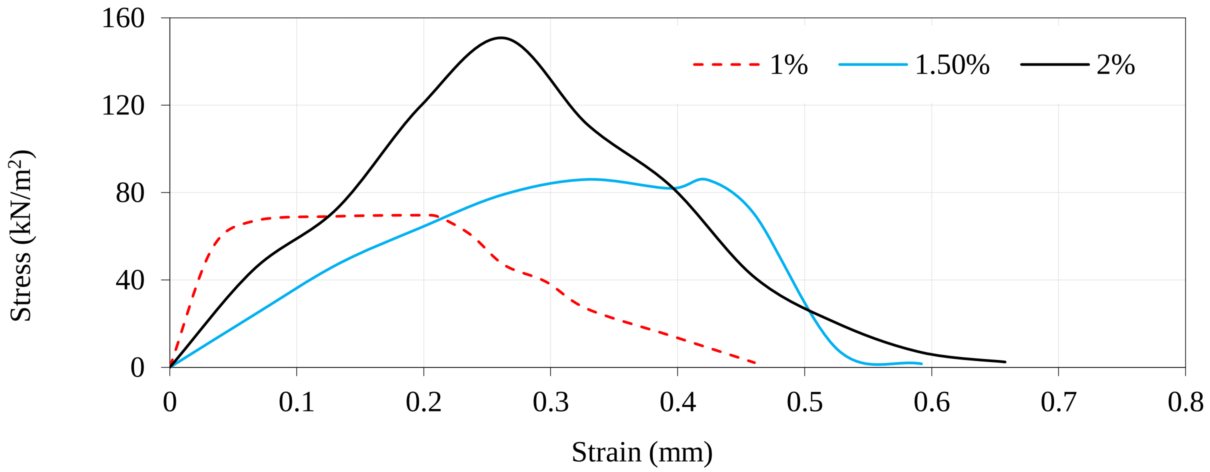

Fig 4.61 after 24 hours.

After 7 days from the preparation of the sample.

Sample	Cohesion (kN/m^2)
Sand +0.5% of pectin	30
Sand +1% of pectin	36
Sand + 1.5 % 0f pectin	45
Sand + 2% of pectin	104

Table 4.62

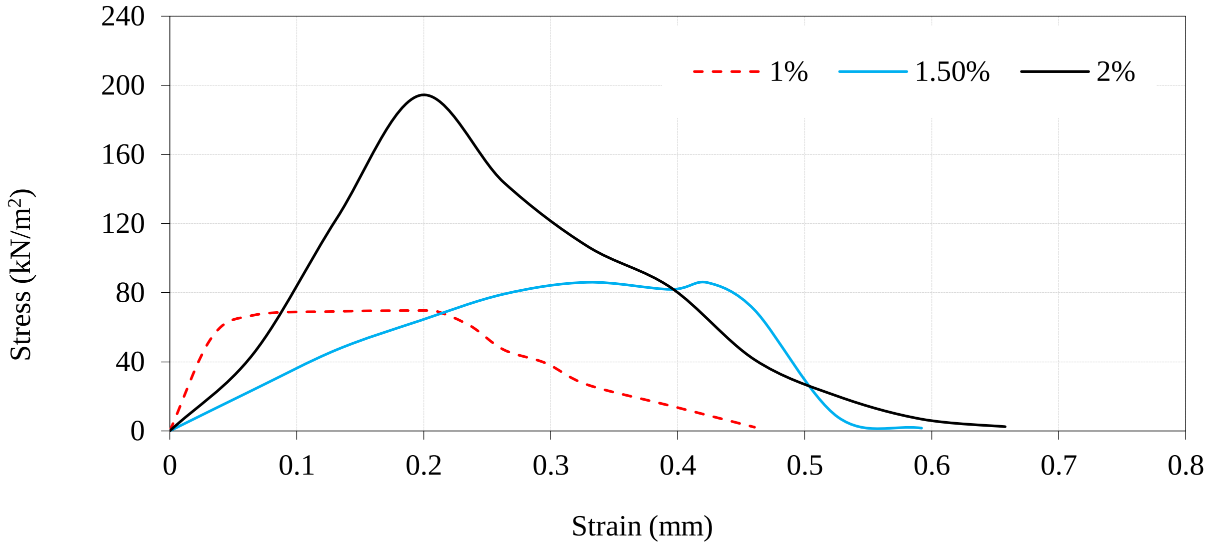

Fig 4.62 after 7 days

Unconfined compression tests were performed on the dry sand and sand that had been treated with solutions containing 1%, 1.5% and 2% of pectin by weight. The data indicated that higher pectin concentrations produced higher compressive strength and stiffness for the treated sand (Figure 4.61and Figure 4.62).

Fig 4.63

Fig 4.64

The test specimens failed in by forming a rough shear plane or an intermediate state for sand treated with 0.5 %, 1.0%, 1.5%, and 2.0% pectin solution, respectively (Figure 4.63 & 4.64). Also, the specimen treated with 1.5% and 2% pectin sheared along a distinct failure plane at a slightly lower axial strain.

4.7 pH TEST

Sample	pH
Sand + 0.5% pectin	9
Sand +1% of pectin	9.2
Sand + 1.5 % 0f pectin	9.6
Sand + 2% of pectin	10
Sand	8.8
Pectin	11

Table 4.7

It is clear that the pH of pectin treated sand is in the range of 8 to 10.

4.8 FOURIER TRANSFORM INFRARED SPECTROSCOPY TEST (FTIR)

FTIR curves yielded minimal changes for the untreated and the treated soils. Peaks of pectin treated sand in the absorbance spectrum were observed at 1687.13 (cm^{-1}) suggesting the presence of pectin in the treated sand.

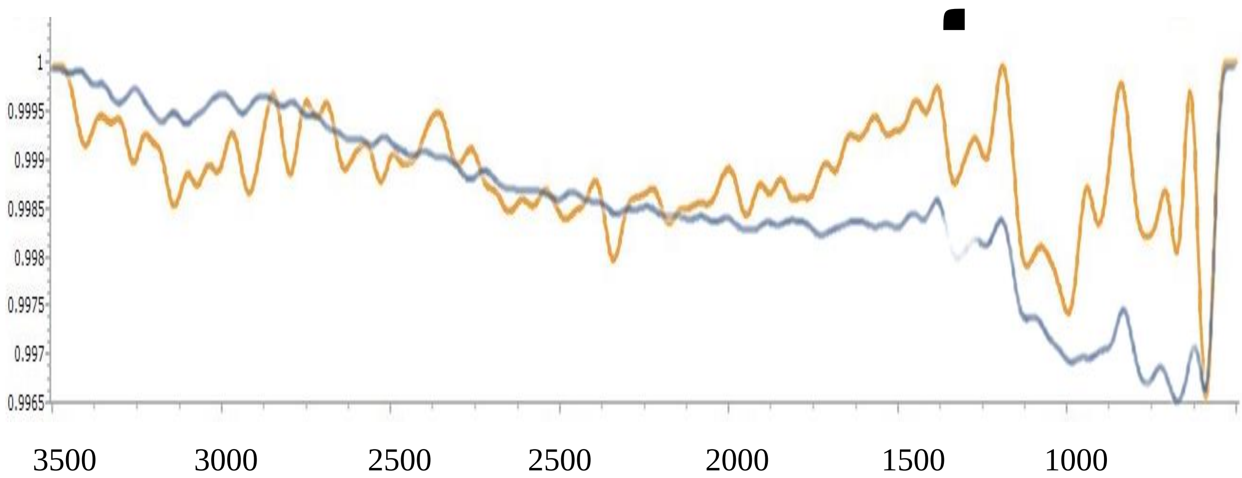

Fig.4.8 X axis-wavenumber (cm^{-1})

Y axis-transmittance (%)

The point denotes the peak value of FTIR test.

CONCLUSION

The pectin-treated sand behaves differently according to the pectin concentration. Pectin content had a substantial impact. The findings of this research could impact both modelings of the treated sands in both the lab and on the ground improvement. These outcomes might appear a completely new age of research combining biology with geotechnical engineering and also taking into account of static deformation characteristics. It is quite clear that more additional research requires. Biopolymer treatment has the potential to control soil behavior and has particular strengths and deformation properties. Biopolymers are more appealing for usage in engineering applications because they are environmentally friendly and sustainable. After treatment with pectin, Sand which were used for conducting tests was a uniformly graded soil, by increasing the concentrations of 0.5, 1, 1.5 and 2 percentages of pectin respectively. Their corresponding cohesion values after 14 days from the preparation of the samples are 30, 36, 45, and 104 kN/m2, Optimum Moisture Content (OMC) of the treated sand with 0.5, 1, 1.5, and 2 percent of pectin are 16.12, 16.09, 15.77 and 15.46 kN/m^3 respectively. Treating sand with pectin, with an appropriate concentration makes sand durable.

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