POTENTIAL OF NATURAL BIO-POLYMERS IN STABILIZATION OF SOIL

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Abstract - *As Stabilization of soil improves its engineering properties, Chemical and Polymer Stabilization process are in use. Clay is a very important material in geotechnical engineering, because it is often observed in geotechnical engineering practice. Generally, the clay soil has numerous problems due to its low strength, high compressibility and high level of volumetric changes. Clay needs to be improved before it can be used in road construction, dams, waste landfills and in other construction. In this paper, Bio- polymers (Xanthan gum & Guar gum) are used for stabilization of clay soil.*

Key Words: Stabilization, Biopolymer, Clay, Strength, Xanthan gum, Guar gum, etc

1. INTRODUCTION

Soil stabilization is a general term for any physical, chemical, biological or combined method of changing of a natural soil to meet an engineering purpose. Also, improvements include increasing the bearing capability, tensile strength and overall performance of in-situ soils, sand and other waste materials, in order to strengthened road surface. Some of the renewable technologies are enzymes, surfactants, biopolymers, synthetic polymers and more. Traditionally and widely accepted types of soil stabilization techniques use products such as bitumen emulsions which can be used as binding agents for producing a road base. Tree resin and ionic stabilizers are commonly used stabilizing agents. Other stabilization techniques include using on-site materials including sub-soils, sand, mining waste and crushed construction waste to provide stable, dust free local roads for complete dust control and soil stabilization. Many of the "green" products have essentially the same formula as soap powders, merely lubricating and realigning the soil with no effective binding property. Many of the new approaches rely on large amounts of clay with its inherent binding properties. Bitumen, tar emulsions, asphalt, cement, lime can be used as binding agents for producing a road base. While using such products, issues such as safety, health and the environmental effects must be considered. Utilizing new soil stabilization technology, a process of cross-linking within the polymeric formulation can replace traditional road/house construction methods in an environment friendly and effective way. There is another soil stabilization method called the Deep Mixing method that is non- destructive and effective at improving load bearing capacity of weak or loose soil strata. This method uses a small, penny-sized injection probe and minimizes debris. This method is ideal for re- compaction and consolidation of weak soil strata, increasing and improving load bearing capacity under structures and the remediation of shallow and deep sinkhole problems. This is particularly efficient when there is a need to support deficient public and private infrastructure.

1.1 Soil Stabilization

Polymer, either natural or synthetic is one of the non-traditional stabilizer types of increasing interest. Past studies have described the application of natural biopolymers to stabilize road surfaces and synthetic polymer has also been used to increase the strength and decrease the hydraulic conductivity of sand.

However recent technology has increased the number of traditional additives used for soil stabilization purposes. Polymer soil stabilization refers to the addition of polymers to improve the physical properties of soil, most often for geotechnical engineering. Polymers have been shown to reduce erosion, increase soil strength and support the soil structure.

1.2 Types of Soil Stabilization

Different types of soil stabilization have been performed for thousands of years. The three basic types of soil stabilization are as follows:

- **Mechanical -** The oldest types of soil stabilization are mechanical in nature. Mechanical solutions involve physically changing the properties of the soil, in order to affect its gradation, solidity, and other characteristics. Dynamic compaction is one of the major types of soil stabilization where a heavy weight is dropped repeatedly onto the ground at regular intervals to quite literally pound out deformities and ensure a uniformly packed surface. Vibro compaction is another technique that works on similar principles, though it relies on vibration rather than deformation through kinetic force to achieve its goals.

- **Chemical -** Chemical solutions are another of the major types of soil stabilization. All of these techniques rely on adding an additional material to the soil that will physically interact with it and change its properties. There are a number of different types soil stabilization that rely on chemical additives of one sort or another that frequently encounter compounds that utilize cement, lime, fly ash, or kiln dust. Most of the reactions sought are either cementitious or pozzolanic in nature, depending on the nature of the soil present at the particular site you are investigating.

- **Polymer/Alternative -** Both of the previous types of soil stabilization have been around for hundreds of years, if not more; only in the past several decades, technology opened up new types of soil stabilization for companies to explore. Most of the newer discoveries and techniques developed thus, are polymer based in nature, such as those developed by Global Road Technology. These new polymers and substances have a number of significant advantages over traditional, mechanical and chemical solutions; they are cheaper and more effective in general than mechanical solutions.

1.3 Objective

The objective of the project is to study the geotechnical properties of swelling soil (Clayey soil) and stabilized soil with different proportions of biopolymers.

1.4 Aim

To compare the stabilizing properties of clayey soil before and after adding the stabilizers to the soil with various curing periods.

1.5 Scope

- Biopolymer Stabilization play a major role in fine-grained collapsible soil mechanical properties improvement, resulting in an eco-friendly and sustainable substitute to traditional soil additives.

- The use of biopolymers could increase the fertility in soil and keep it in their own soil tendency.

- Application of biopolymer in mine reclamation is environment friendly in controlling erosion and dust.

2. LITERATURE REVIEW

Works of various authors on the stabilization of soil by using Natural biopolymers have been discussed in brief. A great number of researches have been performed to understand the nature of biopolymers. Various literature studies are performed, which among other things cover the different proportion methods for biopolymer to the soil stabilization.

Kumar & Ganta (2016) explained stabilization of soil improves its engineering properties, chemical and mechanical stabilization processes are in use. In present study of two different soils, expansive soil and dispersive soil are stabilized with geopolymer and biopolymer. It is observed that dispersive soil and pond ash mixed with various percentages of xanthan gum and guar gum are not dispersive and are more durable than ordinary bottom ash and dispersive soil samples guar gum is found to imparts higher unconfined compressive strength and durability than xanthan gum. Based on differential free swell test was observed that with increased biopolymer. Clearly this paper shows guar gum had better strength compared to that of xanthan gum.

Fullen (2016) explained how soil treatment and improvement in properties are commonly performed in the field of geotechnical engineering. Findings from this study demonstrate that biopolymers have strong potential to replace cement as a soil treatment material within the context of environment friendly construction and development. Recent studies have shown that biopolymers can strengthen soil, and they have several advantages in such application, including being environment friendly and lower concentrations.

Kajal Swan (2015) explained that the effectiveness of Biopolymer is studied based on UCS Tests on dispersive soil and pond ash at their moisture content of dispersive soil, Durability Dispersion and DFS tests are also done. It is observed that dispersive soil and pond ash mixed with various percentages of Xanthan gum and Guar gum are not dispersive and are more durable than ordinary bottom ash and dispersive soil samples, guar gum is found to impart higher unconfined compressive strength and durability than Xanthan gum.

Rourkela (2015) studied the mining areas using two Biopolymers, Xanthan gum and Guar gum. Compaction tests were done to obtain the optimum moisture content and maximum dry density and also unconfined compression tests were conducted on samples of pond ash without and with various percentages of Xanthan gum (1%, 2%, 3%) and Guar gum (0.5%, 1%, 2%). It was observed that, an increase of just 1.5 percentage of gum have better strength when sundried. It was observed that pond ash stabilized with guar gum has better strength compared to that of xanthan gum.

Liuhuiguo (2014) explained about the shear strength behavior of expansion soils over a range of amended biopolymer soil addition using western lowa. The shear strength and volume change behavior of specimens stabilized by three different biopolymers at concentrations of 1%, 2% and 4% was tested. The unconfined compressive strength of monomer amended loess was described significantly with in the first 7 days of curing. This paper clearly shows that the unconfined compressive strength of stabilized loess increased faster than that of untreated loss.

Michael (2013) discussed Natural biopolymers as environment friendly and sustainable grouting chemicals. He represents guidelines for selecting potentially useful biopolymers for strengthening cohesion less soil. Depending on the Biopolymer concentration, the unconfined compression strength of sand increased when treated with Agar and Starch. Triaxial compression tests over a range of confining pressures also indicated that the biopolymers effectively increased the strength of soil.

Eire's (2013) explained quite a big part of the country and world's heritage was made using unfired earth constructions. The new earth buildings as well as the conservation of the existing heritage needs scientific knowledge to allow higher durability. This durability is particularly conditioned by erosion caused by water action, especially in countries with high rainfall index. Analyzing the old building techniques, that allow protection on the earth material from water action, it is possible to understand how many earth buildings were preserved, during several centuries, resisting harsh weather conditions. Among these techniques there are specially the incorporation of biopolymers (such as oils or fats), the addition of some minerals and stabilization with lime. The author studied new methods of soil stabilization, with lime and biopolymers, adopting the ancient knowledge to improve the durability, specially related to the water action.

Galan-Marin (2010) objective was to stabilize the soils with natural polymers and fibers to produce a composite, sustainable, non-toxic and locally sourced building material. Tests done showed that the addition of alginate separately increases compression strength from 2.23 to 3.77 MPa and the addition of wool fiber increases compression strength up to 37%. The potential benefit of stabilization was found to depend on the combinations of both stabilizer and wool fiber.

Kavazanjan (2009) explained from the laboratory experiments that spray-applied biopolymer mixtures and biopolymer admixtures for compacted soil may offer cost effective means of mitigating wind-induced soil erosion. Mitigating wind-induced erosion can be a serious geotechnical consideration due to the associated soil loss and air and water quality impacts. Agricultural soil loss is a serious concern worldwide. Air quality problems due to wind-induced erosion of finely grained soil (fugitive dust) from construction sites are common in arid and semi-arid regions. Compaction of soil with a biopolymer Admixture, though more expensive than surface application, can achieve similar results indicate that biopolymers can act as a stabilizing agent against wind-induced erosion.

Orts et al (2007) described about the relatively new application for controlling wind and water erosion using Polyacrylamide copolymers are described that to take advantage of their ability to stabilize and add structure to soil military applications of PAM may not be obvious to the environment but could result in a significant number of critically important soil stabilization applications. Biopolymers alternatives to PAM, which generally degrade more rapidly would likely have marketing advantages due to the public perceptions of the relative safety of natural compounds.

Entry and orts (2005) proved that low concentrations of synthetic or bio-polymers in irrigation water can nearly eliminate sediment, pesticides, micro-organisms, and weed seed from runoff. These environmentally safe polymers are employed in various sensitive uses including food processing, animal feeds, and potable water purification Biopolymers are less effective. Using twice or higher concentrations, existing biopolymers nearly 60% effective as PAM, at 2–3 times the cost. If the supply of cheap natural gas (raw material for PAM synthesis) diminishes, industries may seek alternative polymers. Also, green perceptions and preferences favor biopolymers for certain applications.

3. METHODOLOGY AND MATERIALS

The main objective is to develop a simplified methodology which can be used in an early stage of the collection and preparation of materials. The Methodology is based on characteristics of Materials, Geotechnical Investigations and preparation of UCC samples with different curing.

3.1 Methodology

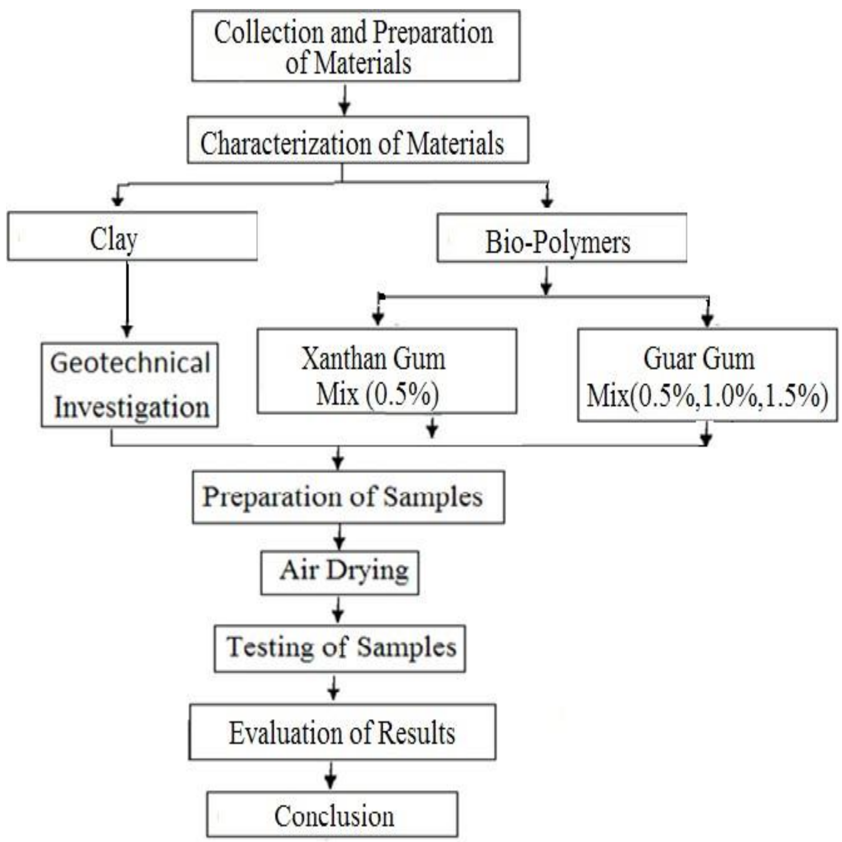

Fig -1: Methodology

3.2 Materials used

Biopolymers are synthesized as a result of biological processes and are often less harmful to the landscape and its biota because of their natural origins of the three types of biopolymers. Polysaccharides have proven more useful soil binders than the polynucleotide or polypeptides.

Biopolymers that have been tested for use in soil stabilization include cellulose, starch, chitosan, xanthan, curdlan and beta glucan. Some biopolymers are sensitive to water and wet solids exhibits weaker biopolymer clay cohesive because of this when wetted gel type biopolymers from hydrogels which have decrease tensile strength but significantly higher compressive strength composed to the original soil. They are more environmentally friendly than many other chemical soil additives and can achieve the same amount of strengthening at much lower concentrations.

3.3 Xanthan gum

Xanthan Gum is a polysaccharide type with a variety of uses. It is used as common food additive. It is one of the powerful thickening agents and also used as stabilizer to prevent ingredients from separating. The chemical formula for Xanthan is $C_{34}H_{49}O_{29}$ (monomer). It can be produced from a range of simple sugar using fermentation process and derived its name from the strain of bacteria used in Xanthomonas. Some of the uses and applications are as follows:

Uses:

- Guar Gum, 1% can produce a significant increase in the Xanthan viscosity of the liquid. It helps to prevent oil separation by stabilizing the emulsion, although it is not an emulsifier.
- Xanthan gum also helps to suspend solid particles. Xanthan gum helps to create desired texture in many ice creams.
- In oil industries, Xanthan gum is used in large quantities to thicken drilling mud. These fluids serve to carry the solids cut by the drilling and hit back the surface. The wide spread use of horizontal drilling and demand for good control of drilled solids has let to its expanded uses.

Applications:

- **Tissue Engineering:** Xanthan gum is used as a joining and creating enzyme in tissue culture of both plants and animals
- **In Baked Food Products:** Xanthan Gum provides less moisture preservation to the dough and retards fat penetration in baked foods.
- **In Dairy Products:** Xanthan Gum improves taste, maintains uniform viscosity, thickening agent and color.
- **In cosmetics:** Xanthan gum keeps the cosmetics fresh and used as a softening agent in traditional cosmetics.

3.4 Amounts used

- The greater the ratio of Xanthan gum added to the liquid, the thicker the liquid becomes. A tea spoon of Xanthan gum weighs about 2.5 grams and brings one cup (250ml) of water to 1% concentration.
- To make foam, 0.2 to 0.8% Xanthan gum is typically used larger amounts results in larger bubbles and denser foams.

3.5 Guar gum

Guar gum also called as a substance made from guar beans which have thickening and stabilizing properties useful in various industries, traditionally the food industries and increasingly the hydraulic fracturing industries. Chemically, guar gum is a polysaccharide composed of sugar galactose and mannose. Guar gum is more soluble than locust bean gum. Guar gum shows a clear low shear plateau on the flow curve and is strongly shear thinning. Some of the uses and applications are as follows:

Uses:

- It is mainly used for natural thickener and emulsifiers.
- Also, Guar Gum acting as bonding agent & stabilizer.
- Guar gum may be considered as natural fiber and Gelling agent.
- Food products in which guar gum powder is used:
  - Ice Cream, soft drinks & concentrates, puddings.
  - Chocolate milk, flavored milk.

Applications:

- **Frozen Food:** Guar Gum reduces crystal formation, acts as a binder & stabilizer to extend shelf life of Ice-cream.
- **In Baked Food Products:** Guar Gum provides unparallel moisture preservation to the dough and retards fat penetration in baked foods.
- **In Dairy Products**: Guar Gum improves texture, maintains uniform viscosity and color.
- **In Sauces & Salad preparations**: Guar gum acts as a water binder in sauces & salad dressings and reduces water & oil separation.
- **In Confections**: Guar gum controls viscosity, bloom, gel creation, glazing & moisture retention to produce the highest graded confectionary.
- **In Beverages**: Guar gum provides outstanding viscosity control and reduces calories value in low calories beverages.

4. EXPERIMENTAL STUDIES

In order to determine the Atterbergs' limits i.e., (plastic limit of soil, liquid limit of soil) tests are carried out and also to check the optimum moisture content of the swelling soil. The samples with different proportions of biopolymer is prepared based on the soil properties. Natural moisture content of the clay sample is found out by Oven drying method. Natural moisture content, W% = 12.4% The soil properties and the test results are tabulated below:

Table -1: Soil Properties

Tests	Results
Liquid limit	64.35%
Plastic limit	37.38%
Shrinkage limit	10.25%
Specific Gravity	2.75

Table -2: Soil Test Results

Tests	Results
Proctor Compaction Test	Optimum Moisture Content = 23.5% Dry density = 1.56 KN/m^3
Hydrometer analysis	Gravel = 0% Fine Sand = 2.31% Coarse Sand = 0.02% Medium Sand = 0.27% Silt = 76.4% Clay = 27.59%
CBR (Unsoaked condition)	4.40%
CBR (Soaked condition)	3.35%

4.1 Unconfined Compression Test

The shearing resistance of finely grained cohesive material is a function of the applied normal pressure, the pre-consolidation load on the soil and drainage conditions and is best studied by conducting triaxial compression tests. Unconfined compression test may be described as triaxial compression test performed at zero lateral pressure.

4.2 Procedure

1. Remove the undisturbed sample from the sampling tube.
2. Carefully trim the sample ends. The trimming process should remove all soil that has been disturbed. Check to see that the trimmed is preferably 2 to 2.5 times high as its lateral dimension (preferably L_0 ratio is 2.25).
3. Weigh the sample and determine its exact dimensions.
4. Place the sample in the testing machine with its vertical axis as near center of the loading plates as possible. Adjust the measuring dials to zero. Note the proving ring details.
5. Record simultaneously load, strain dial gauge readings at frequent intervals to define the stress- strain relationship.
6. Continue the test till cracks and well-defined failure plane have developed or at least 20-22 percent strain has been reached.
7. Remove the specimen, measure the angle between the failure plane and horizontal sketch the shape of the failed specimen.
8. Weigh the sample after oven drying to constant weight at 110^0 C and find is moisture content.

Fig -2: UCC device with sample

4.3 Ratio of Biopolymers used

Xanthan gum: The Compressive strength values treated with xanthan gum leads to lower workability because the viscosity of the soil-xanthan-water increases from 1% of xanthan content in soils. So, Maximum percentage used is 0.5% Hence, soil can be tested only with 0.5% Xanthan gum for different curing days. Here, we tested the sample with 0.5% and 1% to show the decrease in strength in different curing days.

Guar gum: The dry density is increasing from 0% to 1.5% After 1.5%, the dry density trend decreases with increase in percentage of Guar gum. So, Maximum percentage used is 1.5% Hence, soil can be tested with 0.5%,1% & 1.5% of Guar gum for different curing days. Here, we tested the sample with 0.5%, 1%, 1.5% and 2% in order to find the change in strength with respect to the curing days.

Table -3: Tabulation of Unconfined Compression Test

Stabilizers	Amount of Stabilizer used	Duration of Drying	Results
Only Soil	-	1 day	17 KPa
Only Soil	-	7 days	20 KPa
Xanthan gum	0.5%	7 days	17 KPa
Xanthan gum	0.5%	14 days	18 KPa
Xanthan gum	0.5%	28 days	25 KPa
Guar gum	0.5%	7 days	38 KPa
Guar gum	0.5%	14 days	37 KPa
Guar gum	0.5%	28 days	36.4 KPa
Xanthan gum	**1%**	**7 days**	**14 KPa**
Xanthan gum	**1%**	**14 days**	**14 KPa**
Xanthan gum	**1%**	**28 days**	**15 KPa**
Guar gum	1%	7 days	35 KPa
Guar gum	1%	14 days	34 KPa
Guar gum	1%	28 days	32 KPa
Guar gum	1.5%	7 days	27 KPa
Guar gum	1.5%	14 days	25 KPa
Guar gum	1.5%	28 days	23 KPa
Guar gum	**2%**	**7 days**	**13 KPa**
Guar gum	**2%**	**14 days**	**14 KPa**
Guar gum	**2%**	**28 days**	**15 KPa**

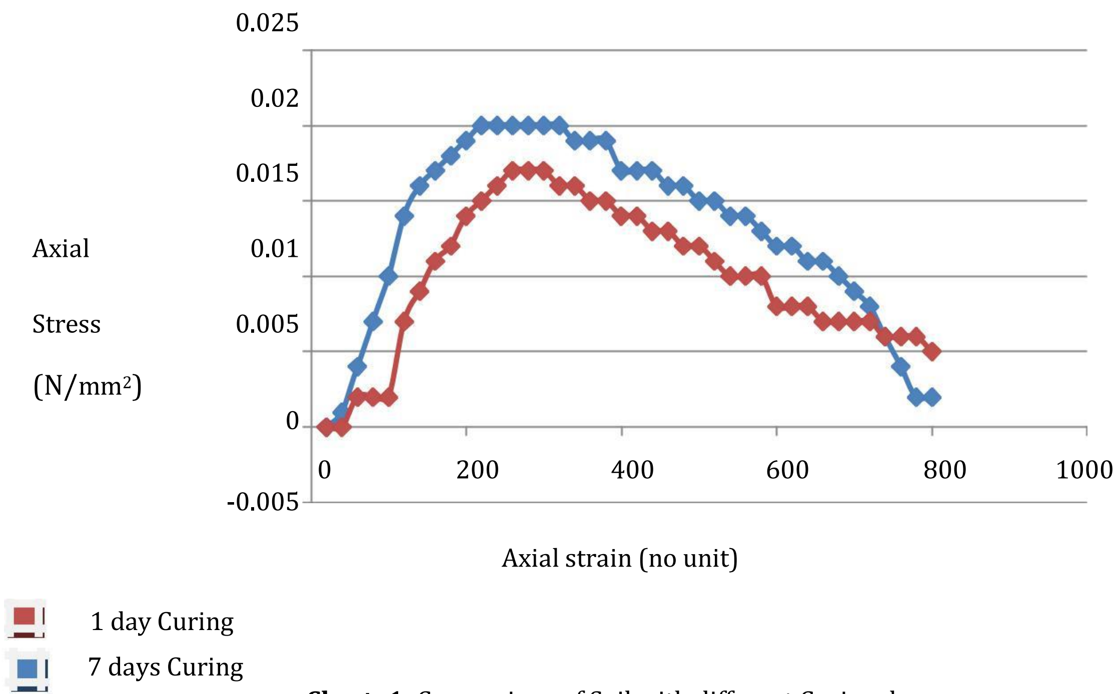

Chart -1: Comparison of Soil with different Curing days

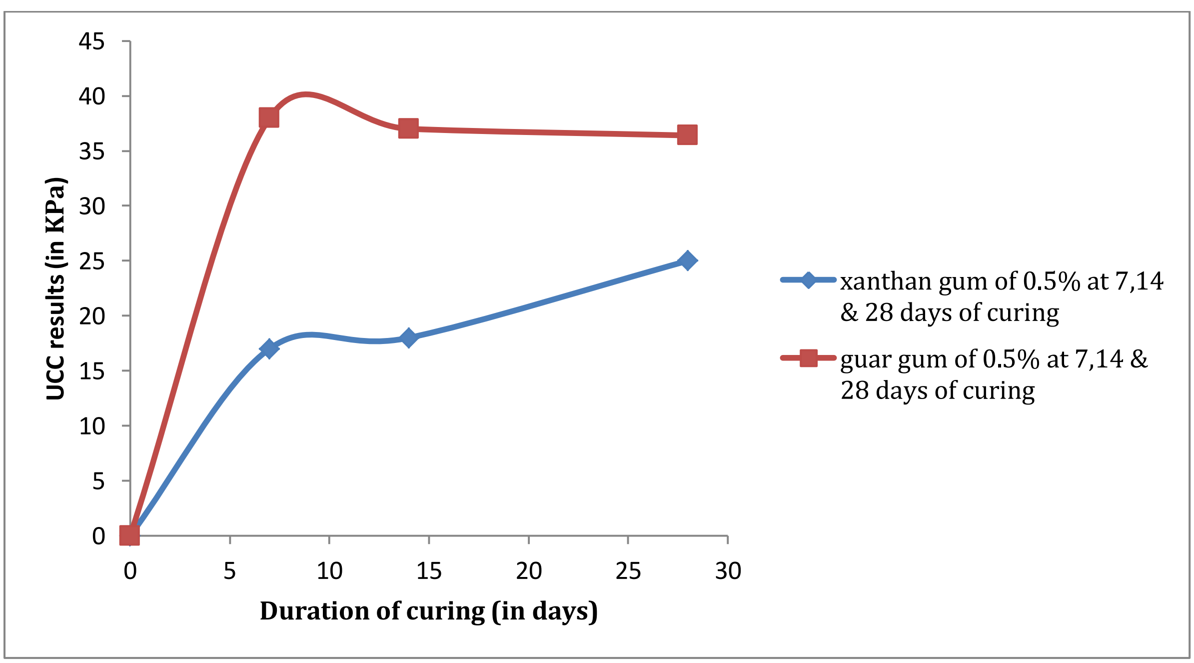

Chart -2: Graph for strength with different percentage of Xanthan gum

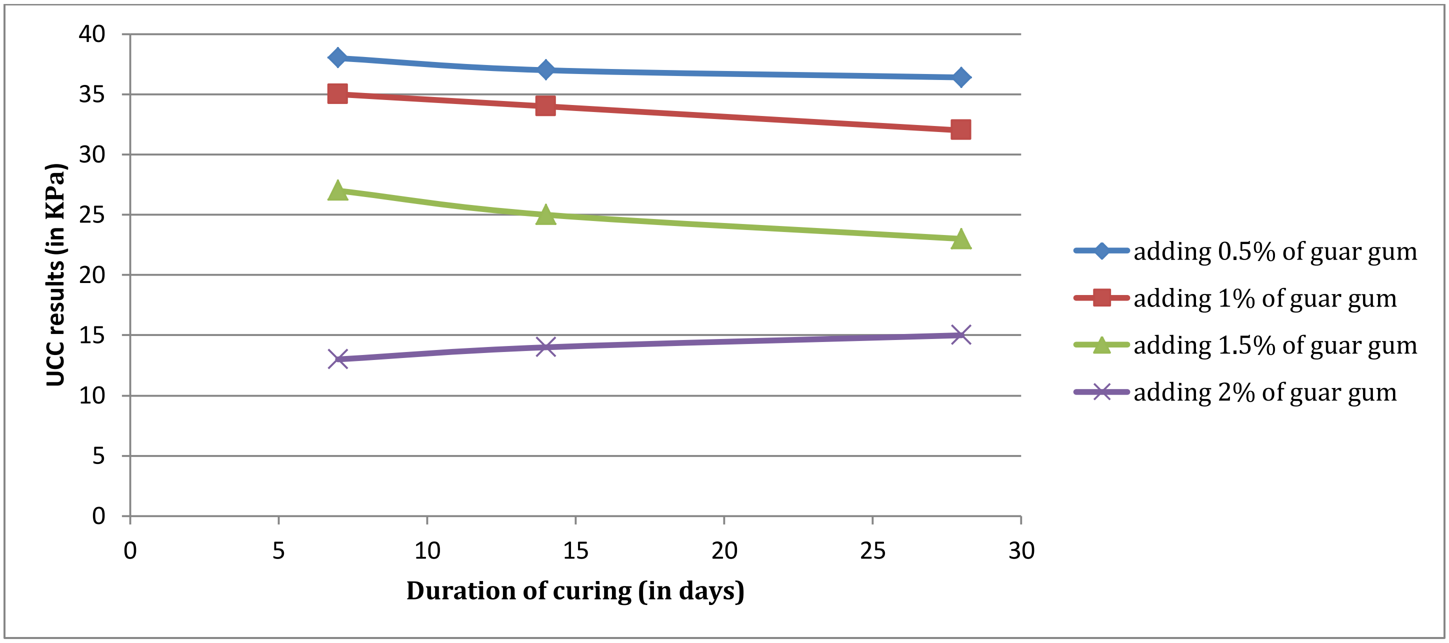

Chart -3: Graph for Strength with different percentage of Guar gum

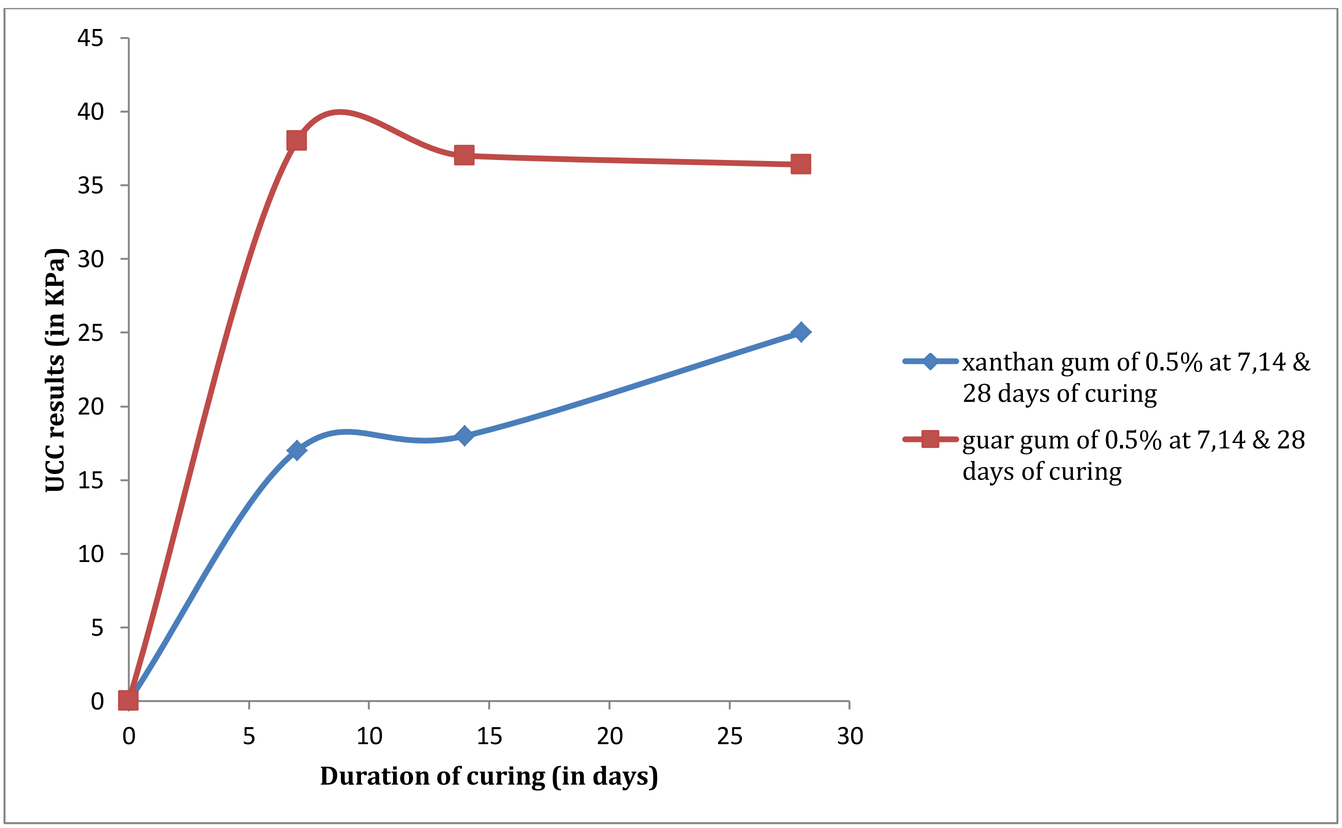

Chart -4: Graph for comparison of Xanthan and Guar gum at 0.5%

5. CONCLUSION

This investigation involved the stabilization of natural biopolymer in stabilization of a clayey soil. The experimental investigation involved the determination of the strength and bearing capacity of biopolymer stabilized soil. Based on the results of the following can be concluded:

- Stabilization of the Clayey Soil using Natural biopolymer resulted in an increase strength in the soil.
- The optimal dosage of biopolymers for maximum strength came out to be 0.5% for both Xanthan gum and Guar gum.
- Guar gum performed 70% more better when compared to Xanthan gum in the stabilized soil.
- The Strength of the stabilized soil after 7 days curing increases to 50% when 0.5% Guar gum is added.
- The bearing capacity of the soil may initially reduce for Xanthan gum but increase for Guar gum.

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