A Study on the Influence of Natural Bio-Polymers on Geotechnical Properties of Soil

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Abstract: **The hold of traditional soil stabilization method on the soil is now a crucial concern for all the researchers. While taking into consideration the sustainability -there have been ample number of options for stabilization of soils. However, all the sustainable materials are not scrutinized as eco-friendly and delivers a negative effect on the soil. To control these ill effects, bio products are acquainted into the soil which has an encouraging future in the field of sustainable soil geotechnics. The use of bio-polymers for stabilizing pavement subgrades has gained increasing attention in recent years due to their eco-friendliness and effectiveness in improving subgrade strength and stability. An overview of the idea of stabilizing the pavement subgrades using bio-polymers is presented in this research work, the centre of attraction is biopolymer, an eco-friendly material which is extracted from sources like plants, animals and microorganisms. There are variety of materials which are extracted from the living world, a very few of them are commonly used in the field of soil engineering. Though biopolymers, such as Xanthan gum, guar gum and corn starch were used & have shown immense increase in the strength of soil when added in different proportions. In contrast to traditional material with biopolymer, a very small amount is required to achieve the comparable strength. Biopolymer have itself shown beyond doubt to be versatile in the strength property but was found to be lacking behind when put forward with water. Biopolymers for stabilization are fit for cohesive and non-cohesive soils with elevated strength, which makes it ideal in place of traditional technique.**

Keywords: **Soil Stabilization, Sustainability, Subgrade, Biopolymer, Strength, Xanthan gum, Guar gum, Corn starch, etc**

INTRODUCTION

A natural resource known as soil is generated over a long period of time by the disintegration and decomposition of rocks, minerals, and organic material. Soil is a combined mixture of minerals, water, air, organic matter, and living things that supports the growth of plants, maintains the good physical condition of ecosystems, and serves as a habitat for a diversity of creatures [2]. Yet not all soils are created equal, and some soils might not be appropriate for particular kinds of construction or development. For example, gigantic structures or enormous traffic may not be able to be supported by soils with deficient bearing capacity or high compressibility, whereas soils with high water content may be prone to erosion, decay or instability. Soil stabilization is the method of enhancement of the physical and mechanical properties of soil to make it more fit for specific uses, such as construction, infrastructure development, or agriculture [2]. The aim of soil stabilization is to increase the soil's strength, durability, and resistance to deformation and degradation, and to reduce the potential for settlement, erosion, or other types of soil failures. Some of the renewable technologies are enzymes, surfactants, biopolymers, synthetic polymers and more. Bitumen, tar emulsions, asphalt, cement, lime can also be adopted as binding agents for producing a road base. [1]

While using such products, concern on safety, health and the environmental effects must be considered. So, using biopolymers in soil stabilization is an alternate method to minimize the environment effects. Biopolymers are a type of natural polymer that are derived from renewable resources, such as plants, animals, and microorganisms. They have gained significant attention in recent years due to their environmentally-friendly and sustainable nature. One potential application of bio-polymers is in the stabilization of pavement subgrades. Bio-polymers, on the other hand, offer a natural and sustainable alternative for subgrade stabilization. They can be used in two ways: as a soil additive or as a soil binder. As a soil additive, bio-polymers can improve the engineering properties of subgrade soil, such as its strength and stiffness. As a soil binder, bio-polymers can be used to stabilize loose or sandy soils by binding the soil particles together and creating a more stable subgrade [3].

OBJECTIVES OF THE PROJECT

- To compare the stabilizing properties of Alluvial Soil & laterite soil before and after adding different proportions of biopolymers.
- To Draw a conclusion about the optimum percentage of the biopolymer suitable for the stabilization of a particular soil. Also, to identify which biopolymer exhibits a pronounced effect on stabilizing characteristics of soils.

MATERIALS USED

Xanthan gum: Xanthan gum is a high molecular weight polysaccharide that is produced by the fermentation of carbohydrates by the bacterium Xanthomonas campestris. It is commonly used as a food additive, particularly as a thickening and stabilizing agent in a wide variety of food products, such as sauces, dressings, and baked goods. Xanthan gum is an effective thickening agent because it forms a gel-like substance when mixed with water, and it has the ability to suspend particles in liquids. This makes it useful in a range of food products where a stable texture and appearance are important [2].

Guar gum: Guar gum (Cyamopsis tetragonolobus) is a high molecular weight polysaccharide group biopolymer which are deracinated from endosperm of guar seed. And it is a better stabilizer, it also enhances viscosity. Guar gum has exceptional binding property and chemical bond, this enables a strong cohesive gel formation. This binding and gelling properties are utilized for modifying the soil properties [4].

Corn-Starch: Cornflour, corn-starch, maize starch, or corn starch is the starch derived from corn (maize) grain. The starch is obtained from the endosperm of the kernel. Corn starch is a common food ingredient, often used to thicken sauces or soups, and to make corn syrup and other sugars. Corn starch is versatile, easily modified, and finds many uses in industry such as adhesives, in paper products, as an anti-sticking agent, and textile manufacturing

Laterite soil & Alluvial soil: Laterite is a soil type rich in iron and aluminium and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. Alluvial soils are soils deposited by surface water. You'll find them along rivers, in floodplains and deltas, stream terraces, and areas called alluvial fans.

Bio-polymers like Xanthan gum, Guar gum & corn starch of required quantity were purchased through online from Amazon. Both the soil samples were collected from the local surroundings. It was extracted from a depth of 1.5m below the ground level to avoid the top soil, organic matter & non-representative aggregates. The initial properties of both the soils were investigated & presented in the below listed table.

METHODOLOGY ADOPTED

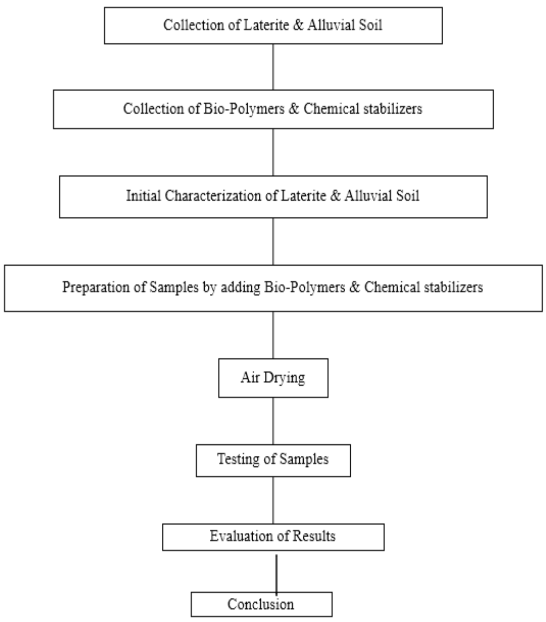

Fig 01 Sequences of operations followed for experimentation

Sample Preparation:

The soil samples were oven dried at 110˚C for 24 hours. The biopolymer treated soils were prepared by adopting the wet mixing procedure. Initially the bio-polymer in powder form (0.25,0.5, 0.75 & 1%) by the weight of soil is mixed with water to form a viscous gel. (Note: for e.g.: a teaspoon of biopolymer powder weighs about 2.5g and brings one cup nearly 250ml of water to 1% concentration) [1]. Upon initial mixing of biopolymer with water, the galactose & mannose present in the biopolymer hydrate at a faster rate by absorbing the water rapidly & to avoid this moisture loss from the soil, the biopolymer gel is allowed to hydrate completely for 24 hours before mixing it with soil (Evangelin et al... 2019). It is covered with a cling wrap to avoid air entrainment.

Air entrainment can cause oxidation & accelerate the rate of biopolymer degradation. After 24 hrs, the soil is spread over a large tray and the gel is poured uniformly over the soil & then both the soil & the gel are mixed thoroughly in such that each of the soil particle is perfectly coated with the biopolymer. The mixing is continued until the homogeneity is achieved. The mixture is then transferred to airtight bags & allowed to rest for 24 hours to attain an equilibrium moisture content. The soil biopolymer mixture is prepared for unconfined compression test, CBR, MDD & OMC tests at a water content closer to the liquid limit.

Experimental Investigations:

This study investigates the effects of various biopolymer treated soils on compaction characteristics, unconfined compression strength & CBR. The experimental investigations were carried out in accordance with the procedures outlined in IS 2720.

Initial characteristics of soils:

Laterite & Alluvial soil samples immediately after collection were tested for the following properties and the results are as tabulated below:

Table 01 – Initial test results for Soil

Sl. No	Properties	Alluvial soil	Laterite Soil
1	Specific gravity	2.11	2.00
2	Natural moisture content	15.16%	19.33%
3	Liquid limit	12%	16%
4	Plastic limit	8.67%	5.25%
5	Compaction test	dry density - 1.99 g/cc OMC - 10.3%	dry density - 1.785 g/cc OMC - 10.34 %
6	CBR	10.41	8.99
7	UCS in Kg/Cm^2	1.25	1.06

RESULTS & DISCUSSIONS

Using Xanthan gum (XG)

Table 02 – Test results on variation in % of XG

Properties	Alluvial soil			
	0.25 % XG	0.5% XG	0.75% XG	1% XG
Specific gravity	2.21	2.07	2.046	1.42
Liquid limit	58%	34%	45%	43%
Compaction test	MDD - 1.82 g/cc OMC - 5.40 %	MDD - 1.65 g/cc OMC - 5.26 %	MDD - 1.88 g/cc OMC - 4.44 %	MDD - 1.73 g/cc OMC - 3.12 %
CBR	13.48	13.54	12.9	12.67
UCS in kg/cm^2	1.34	1.37	1.39	2.54

Table 03 – Test results on variation in % of XG

Properties	Laterite soil			
	0.25 % XG	0.5% XG	0.75% XG	1% XG
Specific gravity	1.14	2.1	1.45	2.13
Liquid limit	40%	35%	70%	57%
Compaction test	MDD - 1.64 g/cc OMC - 14.28 %	MD D- 1.56 g/cc OMC - 13.63 %	MDD -1.51 g/cc OMC - 23.07 %	MDD - 1.54 g/cc OMC - 15 %
CBR	9.7	12.99	13.69	13.25
UCS in kg/cm^2	1.19	1.26	1.29	2.13

Using Guar gum (GG)

Table 04 – Test results on variation in % of GG

Properties	Alluvial soil			
	0.25 % GG	0.5% GG	0.75% GG	1% GG
Specific gravity	2.26	2.04	2.2	2.45
Liquid limit	44%	42%	47%	60%

Compaction test	MDD -1.91 g/cc OMC -2.32 %	MDD -1.425 g/cc OMC - 20 %	MDD - 1.3 g/cc OMC - 40 %	MDD- 1.70 g/cc OMC - 15.38%
CBR	12.49	13.83	13.59	12.9
UCS in kg/cm^2	2.54	2.67	2.83	2.87

Table 05 – Test results on variation in % of GG

Properties	Laterite soil			
	0.25 % GG	0.5% GG	0.75% GG	1% GG
Specific gravity	2.23	1.72	2.2	1.73
Liquid limit	26%	58%	44%	20%
Compaction test	MDD - 1.70 g/cc OMC - 8.69 %	MDD - 1.15 g/cc OMC -27.7 %	MDD- 1.58 g/cc OMC - 3.7%	MDD - 1.56 g/cc OMC - 17.6%
CBR	9.66	11.13	12.79	10.04
UCS in kg/cm^2	1.41	1.62	1.95	2.21

Using Corn Starch (CS)

Table 06 – Test results on variation in % of CS

Properties	Alluvial soil			
	0.25 % CS	0.5% CS	0.75% CS	1% CS
Specific gravity	2.13	2.76	2.08	2.44
Liquid limit	36%	23%	38%	10%
Compaction test	MDD- 1.78 g/cc OMC -11.11 %	MDD-1.69 g/cc OMC - 5.12%	MDD- 1.73 g/cc OMC -13.04 %	MDD- 1.82 g/cc OMC -8.51 %
CBR	4.97	7.97	8.21	6.89
UCS in kg/cm^2	2.32	2.36	2.59	2.82

Table 07 – Test results on variation in % of CS

Properties	Laterite soil			
	0.25 % CS	0.5% CS	0.75% CS	1% CS
Specific gravity	1.84	2.22	2.28	1.55
Liquid limit	22%	46%	27%	54%
Compaction test	MDD - 1.96 g/cc OMC - 2.77%	MDD - 1.84 g/cc OMC - 8 %	MDD - 1.68 g/cc OMC - 16.66%	MDD- 1.67 g/cc OMC -5.88 %
CBR	9.34	8.16	8.79	6.83
UCS in kg/cm^2	1.36	1.24	1.21	1.16

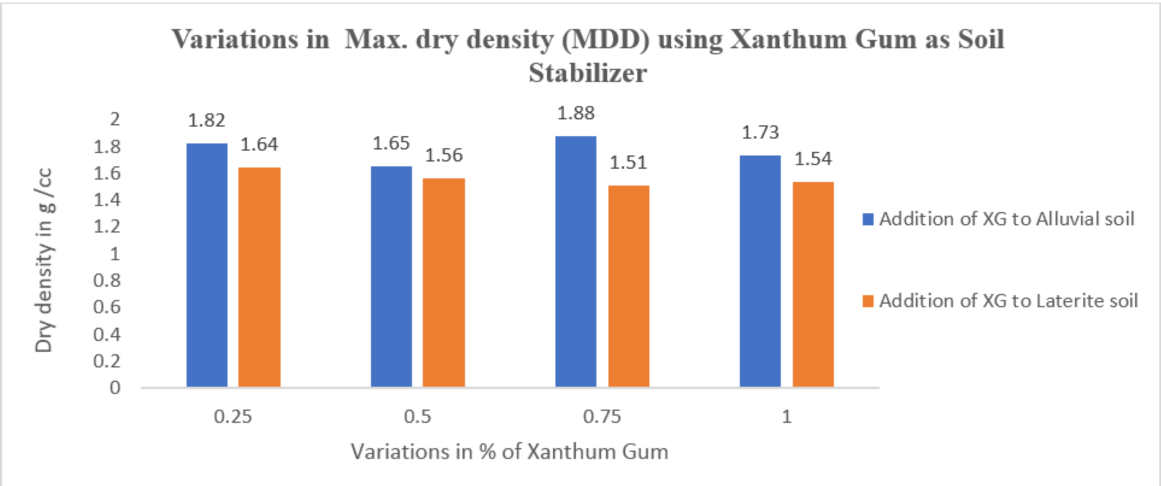

Fig 02 – Graphical results for variation in % of XG for MDD

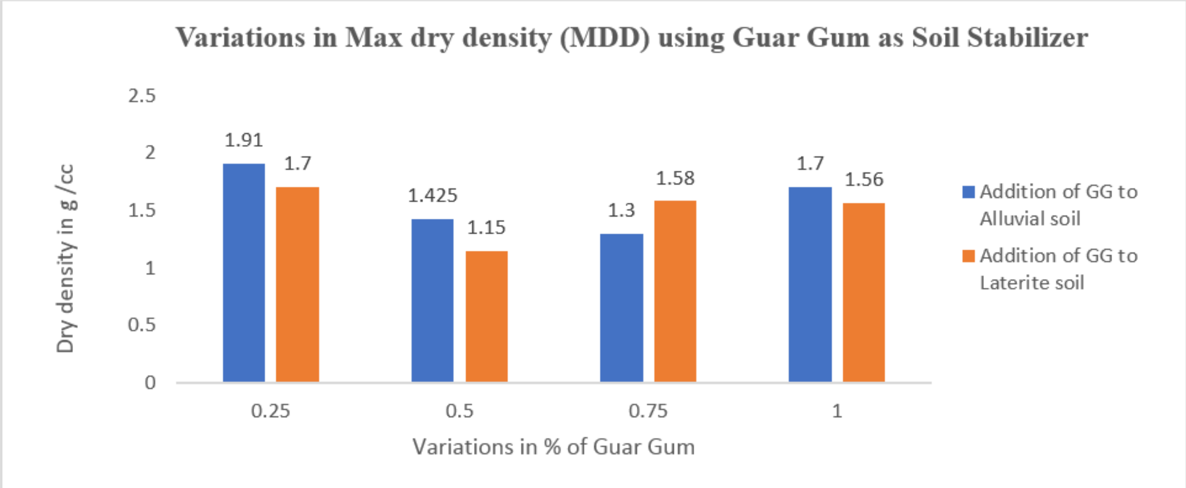

Fig 03 – Graphical results for variation in % of GG for MDD

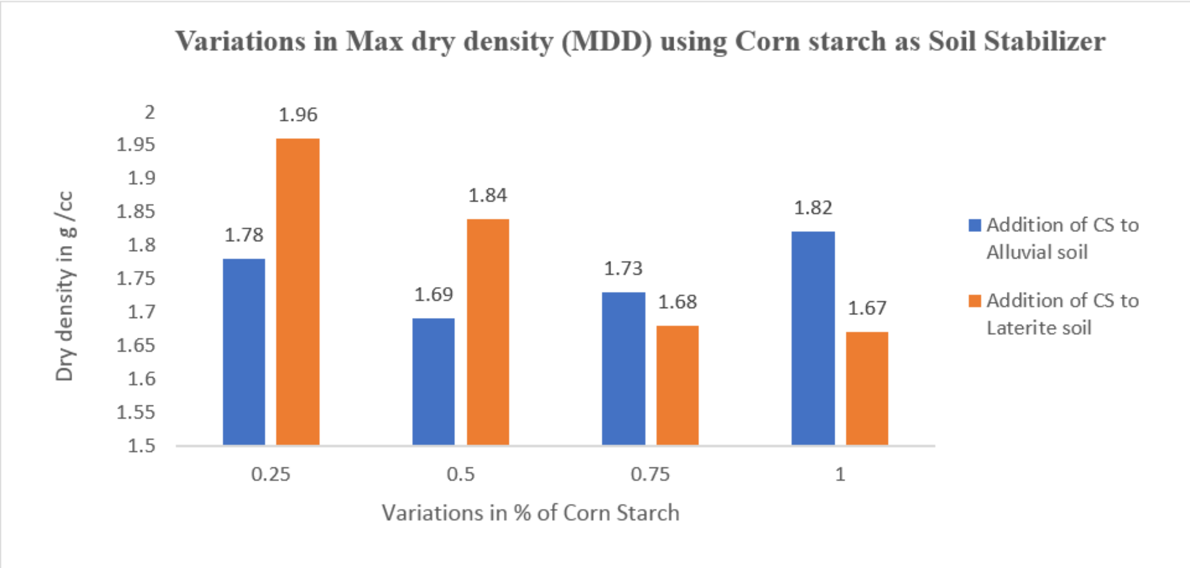

Fig 04 – Graphical results for variation in % of CS for MDD

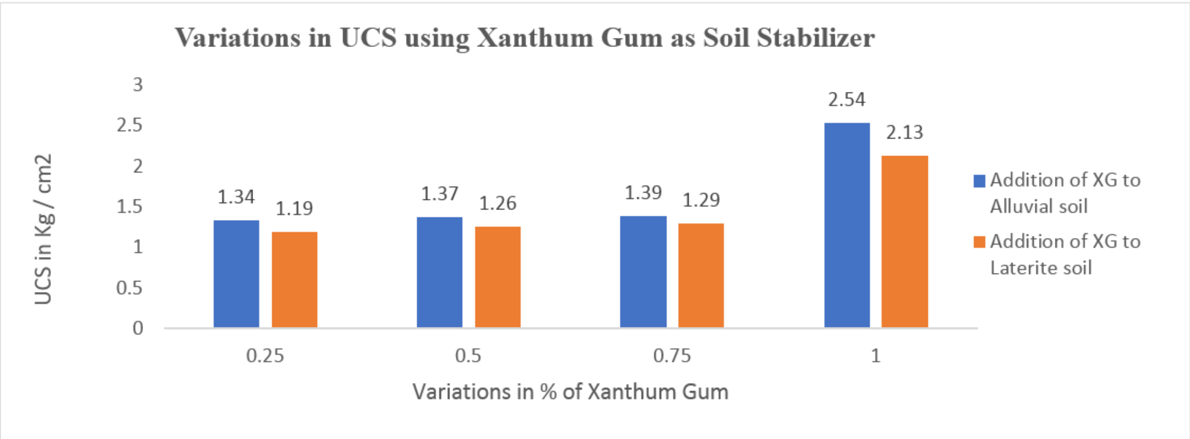

Fig 05 – Graphical results for variation in % of XG for UCS

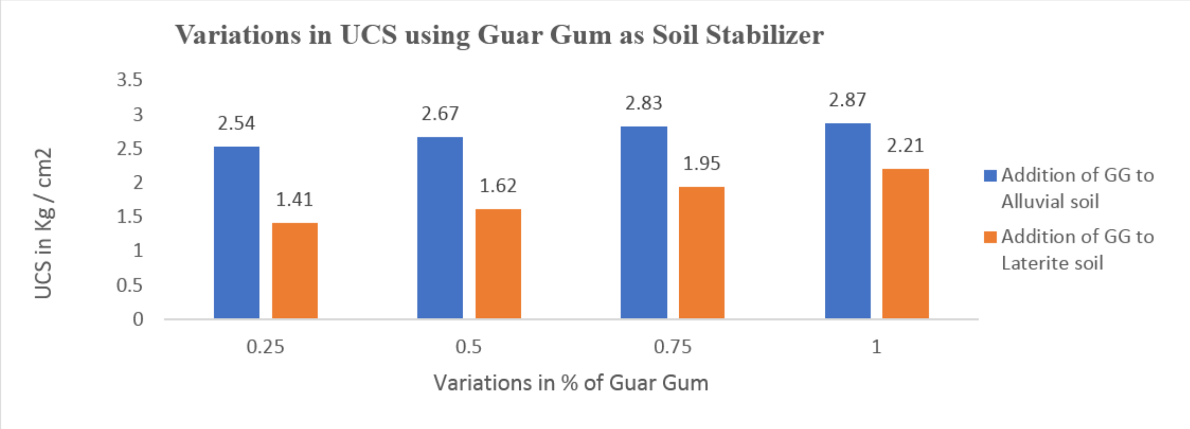

Fig 06 – Graphical results for variation in % of GG for UCS

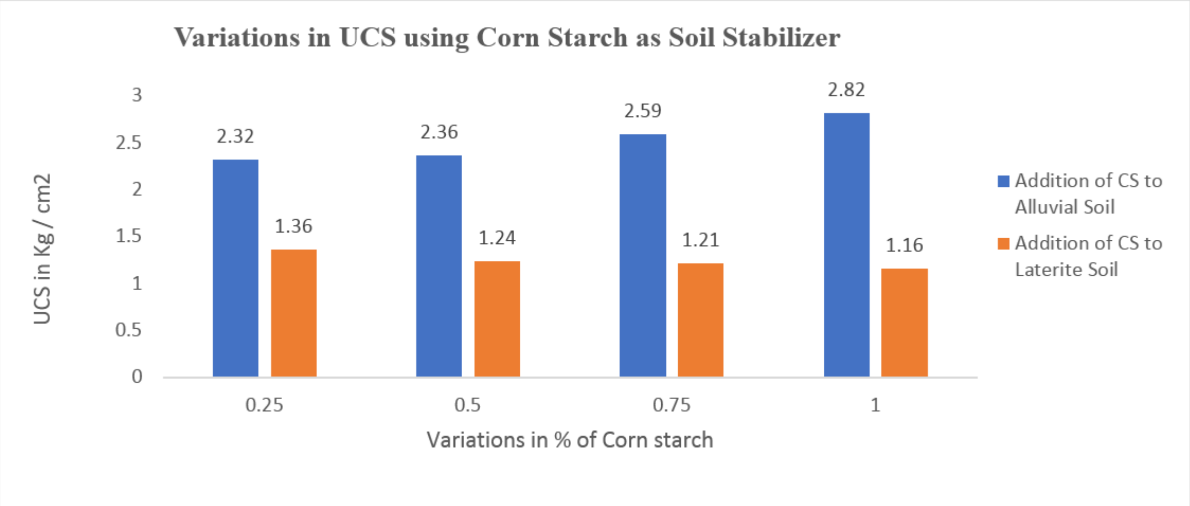

Fig 07 – Graphical results for variation in % of CS for UCS

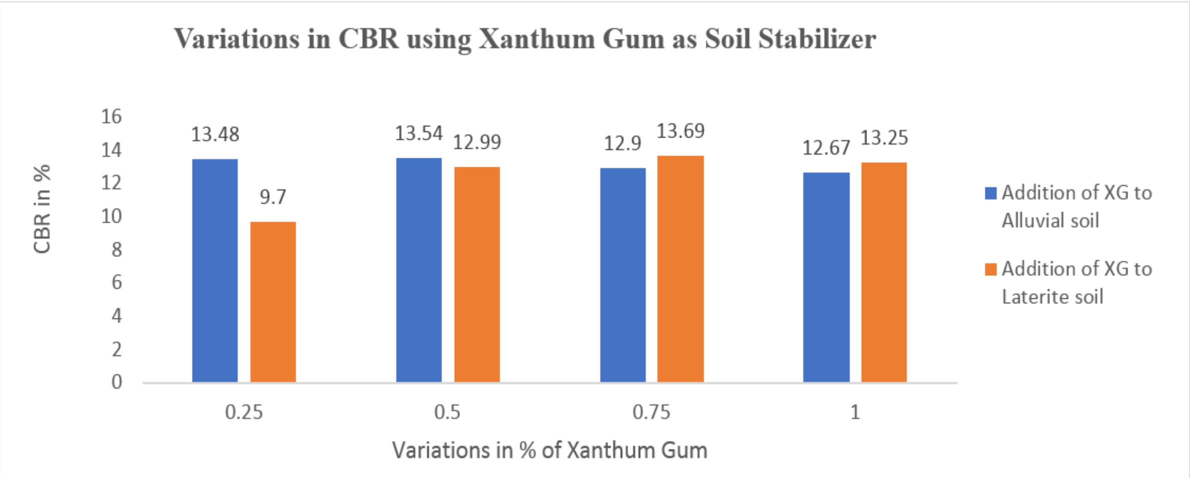

Fig 08 – Graphical results for variation in % of XG for CBR

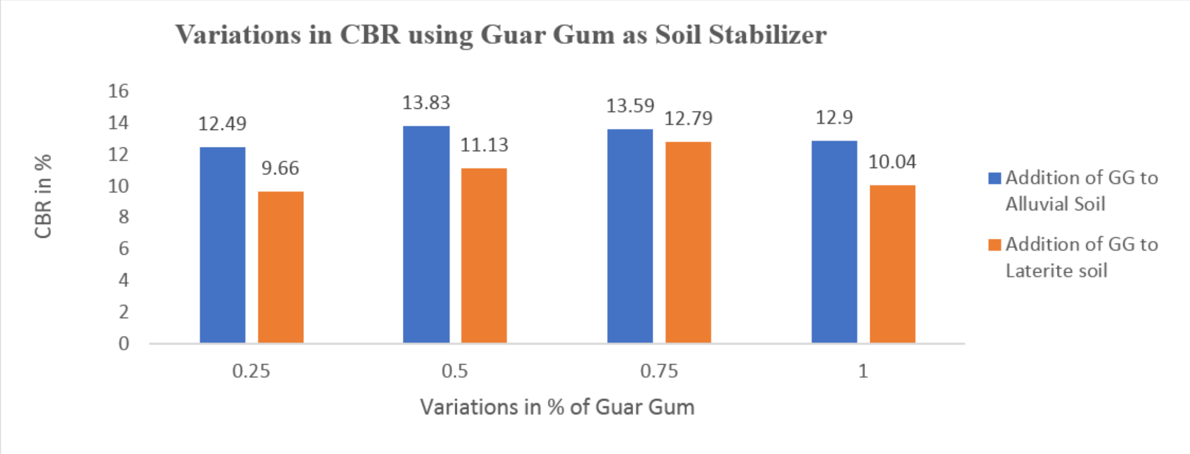

Fig 09 – Graphical results for variation in % of GG for CBR

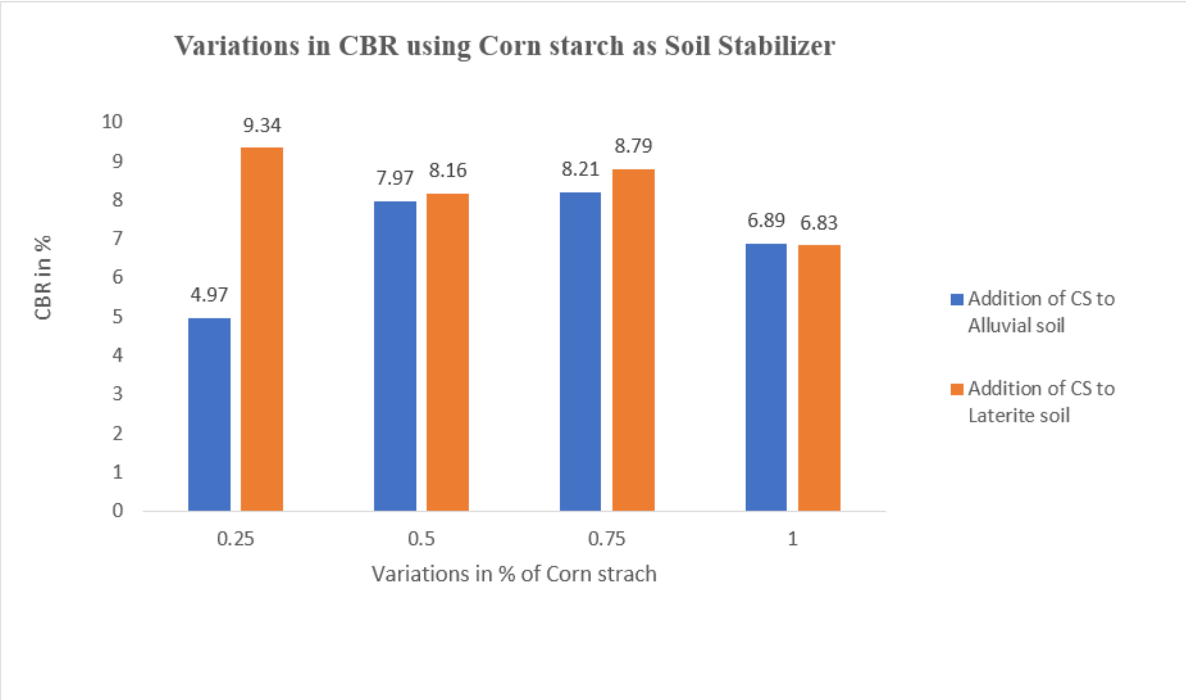

Fig 10 – Graphical results for variation in % of CS for CBR

CONCLUSIONS

The pioneering effect of using biopolymers for soil stabilization has overruled the past methodologies. The biopolymers which are available naturally & abundantly play a crucial role in eco-friendly options available for stabilization of soils. A significant improvement in soil stabilization has been observed through the use of biopolymers because of their exceptional bonding properties as they form highly structured cohesive gels by way of hydrogen bonding. These gels interact to accumulate & collect the soil particles. The geotechnical properties of the soils are improved without changing their mineral compositions. Based on the experimental investigations involved, the following conclusions were drawn:

- Stabilization of both alluvial & laterite soil using natural biopolymers resulted in an increase in the strength of soil.
- The results indicate that maximum modification of the geotechnical properties can be observed at 0.25% of addition of corn starch.
- Corn starch performed 70% more better when compared to Xanthan & Guar gum.
- The optimum dosage of biopolymers required for maximum improvement in geotechnical properties of soil from the tests carried out came out to be 0.25%

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