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Xanthan Gum as Sustainable Biopolymer Additive for Soil Treatment

Ruby Jan , D.Deepa, S Mary Rebekah Sharmila

Abstract: ***Ground improvement procedures give a solid common stage to development exercises and spare time for planning progressively safe structures which would not have been conceivable on powerless and extremely poor soils. Soil treatment in development building plans to improve the dirt properties, for example, total security, quality and disintegration opposition. Customary soil treatment materials have a few inadequacies, particularly from the natural perspective. In this way, there is a requirement for an appropriate eco-accommodating material to supplant the customary materials. In this examination, Xanthan gum is utilized as soil improvement material. Xanthan gum (XG) is a microbial exopolysaccharide created by the action of gram-negative bacterium Xanthitalics Campestris through maturing sucrose, glucose or other sources of sugar. This biopolymer is associated in the sustenance, restorative, pharmaceutical and petrochemical organizations and in various fragments as a thickener, stabilizer, or emulsifier and when united with various gums it can go about as gelling operator. At the point when added to soils, it frames cation connect between the particles, with fine particles it upgrades quality by means of hydrogen holding and goes about as a cementation folio between coarse particles. The fundamental precept of this study is to strengthen the soil by performing California bearing ratio test (CBR) and unconfinedcompression test (UCC) at varying percentages of Xanthangum.***

Keywords : Expansive soil, Xanthan gum, UCC and CBR, FESEM.

I. INTRODUCTION

Soil improvement is one of the basic uses of geotechnical development methods, allowing development on soils by changing or by upgrading their qualities. Conventional materials like bond, lime and petrochemical materials are right now thought about the most mainstream materials for soil improvement. Nonetheless, even with numerous advantages that normal concrete gives, it has similarly a few inadequacies particularly from an ecological perspective. Most by far of these outrageous issues are the oxides of nitrogen (NOx) and CO2 transmissions and particulate air suspensions [9]. Likewise, customary added substance adjustment ordinarily builds the soil pH after treatment in view of the high Ca(OH)2 substance of the stabilizer, which may affect the earth, compromising the nature of the ground water and furthermore on vegetation [11,22]. In this way, the advancement of inexhaustible soil improvement materials with eco-accommodating effect is the required. Biopolymers are feasible, carbon unbiased and constantly inexhaustible materials as a result of the ever-accessibility from agrarian non-nourishment crops. With a definitive objective of limiting the utilization and related natural effect of customary added substances in the present world, a few examinations on non- conventional added substance treated soils have been performed [4,7,22]. Currently Xanthan gum biopolymer, a non-traditional additive, has been used to stabilize fine-grained soils.

The aim of this study is to show the outcomes from an arrangement of macro and micro-scale tests conducted to evaluate the behaviour and strength characteristics of clayey soil stabilized with xanthan gum biopolymer. Macroscale tests conducted to examine the compressibility behaviour of untreated soil and stabilized soil including unconfined compression strength (UCS) tests and California bearing ratio (CBR) test. Microscale tests conducted to evaluate the changes in the microstructure of treated soil include scan electron microscopy(SEM).Tests were conducted on treated specimens at different curing periods to evaluate the changes in engineering properties and strength characteristics of the stabilized specimens over time.

II. MATERIALS AND METHODS

A. Materials

Xanthan gum: XG is a trademark polysaccharide and a basic mechanical biopolymer. It came into existence amid of Fifties. XG is an anionic heteropolysaccharide with a basic shape involving reiterated Penta saccharide gadgets molded through glucose units, two mannose gadgets, and one glucuronic destructive unit, at molar extent 2.8:2.0:2.0 [17]. Its important chain includes b-D-glucose devices related on the 1 and positions. The compound structure of the rule of thumb tie is indistinct to that of cellulose. Trisaccharide aspect chains incorporate a D-glucuronic detrimental unit among D- mannose gadgets associated on the O-3 role of one another glucose improvement within the vital chain, as shown in the Fig.1b. XG exhibits excessive safety beneath a wide extent of temperatures and pH [15]. Additionally, its anionic and water loving surface attributes bolster relationship with cations [16].

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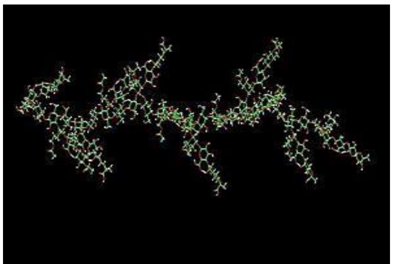
* Correspondence Author
Ruby jan, Department of Civil Engineering SRM institute of science and technology, kattankulathur, Chennai.
Deepa is working as Assistant professor in SASTRA Deemed University, Thanjavur, india. PH- 91- 9842682666. E-mail: deepa@src.sastra.edu.
S. Mary Rebekah Sharmila*, Assistant professor, Department of Civil Engineering SRM institute of science and technology, kattankulathur, Chennai. PH-9003919677. E-mail: rebekahsharmila@gmail.com

The beta-D-glucoses are associated (1->four) to form the backbone like cellulose. Trade glucoses have a short, three-sugar department containing a glucuronic destructive sandwiched between two mannose devices. Along these lines, the general reiterating structure is a Penta saccharide. The terminal mannose will have a pyruvate gather associated and the mannose adjacent the critical chain may additionally have an acetyl general joined to C6. When doubtful, around one department in two has a pyruvate gathering, anyway the extent of pyruvate to acidic corrosive induction adjustments relying upon the substrain of Xanthomonas campestris used and the situations of improvement. The glucuronic and pyruvic destructive social occasions give thickener a significantly negative charge. The nearness of anionic side chains on the XG particles improves hydration and thickener solvent in virus just as heated water. XG is dissolvable in both cold and heated water and is commonly not influenced by changes in pH esteem. The gum will break up in many acids or bases. The thickness of this gum is steady at low pH esteems and at high temperatures for an extensive stretch of time and isn't influenced by the expansion of a lot of salt. It has amazing water restricting limit, thickener arrangements display great stop/defrost security. Thickener definitely expands the consistency (thickness) of any fluid it is added to in exceptionally low fixations. In high fixations, it will shape a mucusy glue that resembles a gel however isn't actually a gel.

Soil : The soil sample was collected near potheri lake from east potheri ,kattankulathur ,Tamil Nadu, from a depth of about 1m.The soil sample was sun-dried and then pulverized. Physical characterization of the soil was

performed as per Bureau of Indian standards (IS:2720) to know the engineering properties, which are given in the table 1. From the test results, the soil being problematic due to its expansive behavior.



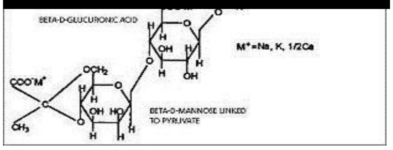


Fig.1(a) Molecular Structure of Xanthan gum

Fig.1(b) Chemical structur of Xanthan gum (Garcia-Ochoa et al.2000)

III. SPECIMEN PREPAPARATION AND TESTING PROGRAM

Soil was sieved through 2-mm sifter to remove any large particles in order to assemble the dealt with soil samples. Using the proctor compaction method as per IS 2720 (Part VII)-1987, both untreated and stabilized soil were compacted and then their ideal humidity (OMC) and most extreme drying unit weight (πdmax) were resolved. In the current investigation, soil specimens were mixed with changing xanthan gum content of 0.5%, 0.75%, 1% and 1.25% by dry soil weight. At their OMC, the treated and untreated soil samples are prepared to assess their engineering properties (characteristics of strength and resistance to penetration).

Unconfined compression(UCC) tests were performed on untreated and treated soil samples as per IS 2720 (Part X)-1973.To prepare homogeneous UCC specimens, the clayey soil samples were mixed (dry mixture) with the stabilizing additive and normal water at their OMC and the respective πdmax developed from the standard proctor compaction test and then prepared the cylindrical specimen (38 mm diameter and 36 mm length). On the same day of their casting, untreated specimens were tested while the treated samples were cured at ambient temperature for (3, 7 and 14 days). Three measures were developed for each additive concentration and for the respective curing periods to ensure the reliability of the result. For UCC research, a strain frequency of 1.25% per minute was used. A mechanized mechanism for the delivery of information was used to document the hub load and critical disfigurement in the experiment, characterizing the failure point for each sample as the deliberate pinnacle hub strain.

The load verses penetration resistance test intended for the assessment of sub-grade strength of flexible pavements. In this study, CBR test of un-treated and treated soil samples were performed as per IS 2720 (Part XVI)-1987. All the CBR soil sample were set up at their OMC and the corresponding **γd**max which were determined from the previously done proctor compaction test. The compaction of the samples in the barrel shaped molds (dia 150mm and tallness 175 mm) is done in five layers giving 25 blows to each layer. An extra charge plate having 2.5 Kg weight was put on the prepared samples before carrying tests and has been continued stand still un-soaked for the respective curing periods (0, 7, 14 days).

The loads were evaluated as an element of entrance up to the absolute infiltration of 12 mm at a strain rate of 1.25% every moment. Burden entrance bends for each case were drawn with required rectifications connected. At that point, CBR esteems got from the heap entrance bends were plotted in the Fig.3a,b,c. CBR esteems detailed are assessed utilizing the stresses at 2.5 mm penetration, as the CBR esteems at penetration 2.5 mm were noticed higher than at 5 mm penetration.

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Table 1: Properties of the virgin soil sample

Description	Values
Free swell index (%)	60
Liquid limit, (w_L) (%)	58.7
Plastic limit (w_P) (%)	31.25
Plasticity index (Ip) (%)	27.45
Shrinkage limit (w_S)(%)	9.7
Specific gravity, GS	2.4
Maximum dry density, γ_{dmax} (g/cc)	1.635
Optimum Moisture content, O.M.C.(%)	19
q_u (kPa)	99.8
CBR	4.61

IV. RESULTS AND DISCUSSION

A. *Effect of variation of Xanthan gum in UCC value of the soil sample*:

Fig. 2 introduces the outcome from UCC tests of both un-treated and treated clayey soil (with varying additive concentrations) at various restoring periods. As appeared, the soil treated with xanthan gum lead to a notable increment in its UCS. It's remarked that the rate of unconfined compressive strength improvement is directly proportionate to the xanthan gum content and restoring period. It implies that UCS values enhanced with increment in xanthan gum concentration and also increase as the restoring time increases. The soil treated with 1.25% xanthan gum would in general induce the most effective gain in quality, with extra xanthan gum past the concentration appearing helpful returns in soil quality improvement. It was seen that the fortifying impact levelled off at higher fixations.

From Fig 3,4,5 the strength characteristics of xanthan gum treated soil at varying percentages with different curing days, it can be seen that there is a significant increment in the unconfined compressive strength with increment in xanthan gum concentration and curing days. It has been observed that clayey soils achieve greater compressive strength of (2540 kPa) than it accomplishes for sandy soil of about (880 kPa) with the treatment of XG [9]. It is normal that, for yonder sustaining, the monomers of gum can be straightforwardly clung to clay particles by methods for cation intersection and hydrogen holding linking the decanedioic acid group (–COOH) and hydroxyl (– OH) gatherings of XG and electrically charged fine surficial particles [2,22].

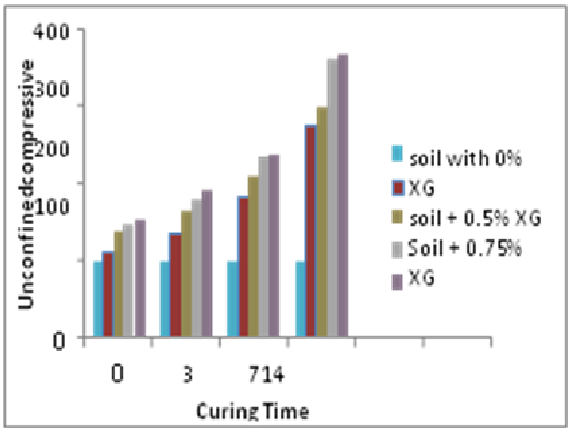

Fig.2 Variation of unconfined compressive strength with varying percentage of Xanthan gum at different curing periods

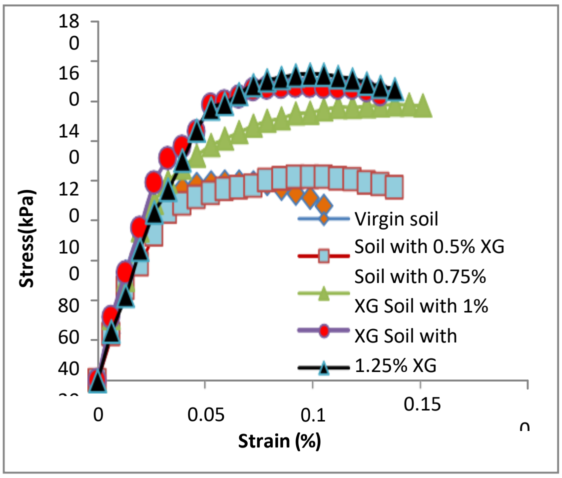

Fig.3 Stress strain curve for xanthan gum treated soil without curing days

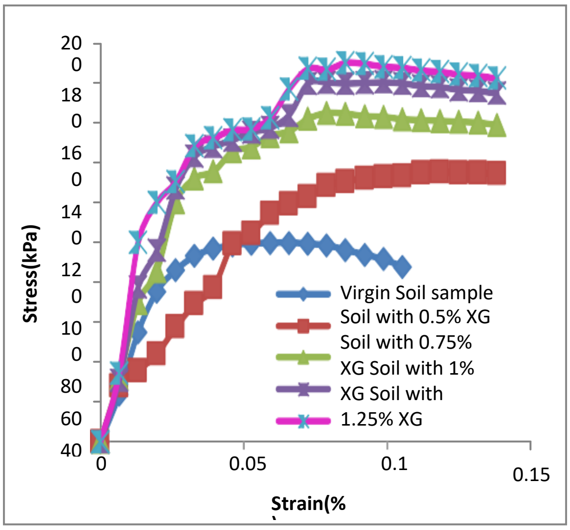

Fig.4 Stress strain curve for xanthan gum treated soil at 3 days of curing.

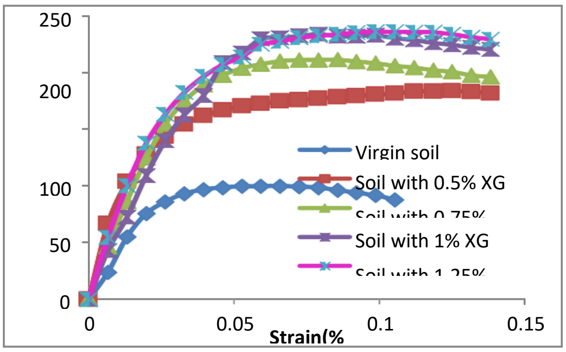

Fig.5 Stress strain curve for xanthan gum treated soil at 7 days of curing.

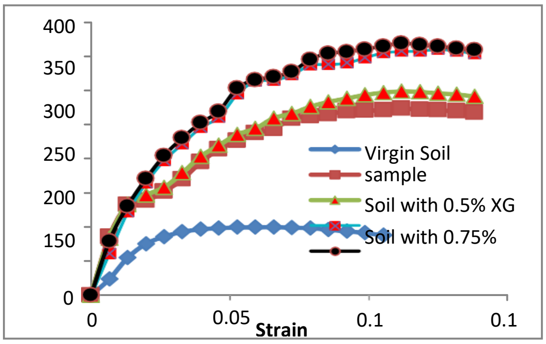

Fig.6 Stress strain curve for xanthan gum treated soil at 14 days of curing.

***B. Effect of variation of Xanthan gum on California Bearing Ratio (CBR) of soil sample*:**

The test results as shown in the fig. 7,8,9. It was observed that there was pretty enhancement in the CBR values after the treatment of the soil with Xanthan gum at varying concentrations. It was also noticed that this increment was directly proportional with the increment in the xanthan gum content and restoring period.

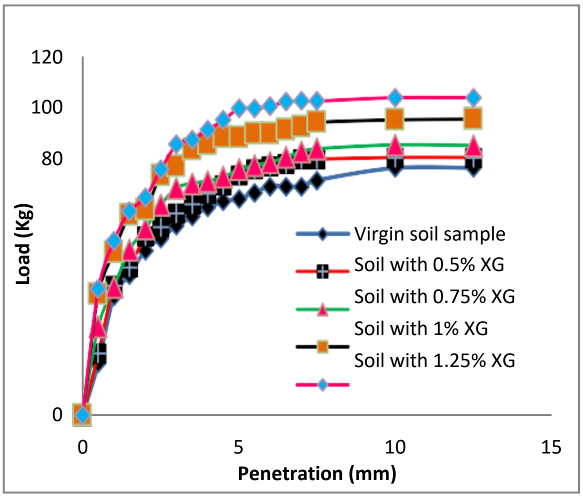

Fig.7 Load vs. Penetration curves of xanthan gum treated soil sample without curing

***C. Microstructural Analysis results*:**

The morphological change in the treated soil was determined using FESEM analysis at 1% content of xanthan gum for the clayey soil. Fig.10,11 shows the micrographs of un-treated and xanthan gum treated soil sample. It can be seen from the image that new binders in the matrix of soil-xanthan gum following 7 days of restoring period and the soil particles were tended to be firmly welded together and immense pore spaces had been filled by these new cementitious binders. Consequently, it can also be seen that the noticeable surficial view of the soil particles appears to be fundamentally altered.

The treated soil sample micrographs demonstrate that because of the electrically charged clay particles, direct associations (hydrogen bond) between fine particles and XG has been developed [3,4,7,9]. Moreover, the direct interaction of xanthan gum fibers forming XG- soil matrices resembling a stiff plastic between distant uncharged soil particles [11, 12]. Therefore, fortifying mechanism regarding XG-stabilized soil is a combination of XG assemblage strength and the hydrogen holding or electrostatic holding (predominant holding) traits among the xanthan-gum and soil debris. These two factors are believed to contribute to the increase in strength and stiffness observed for the xanthan gum stabilized soil [1, 4, 8, 22].

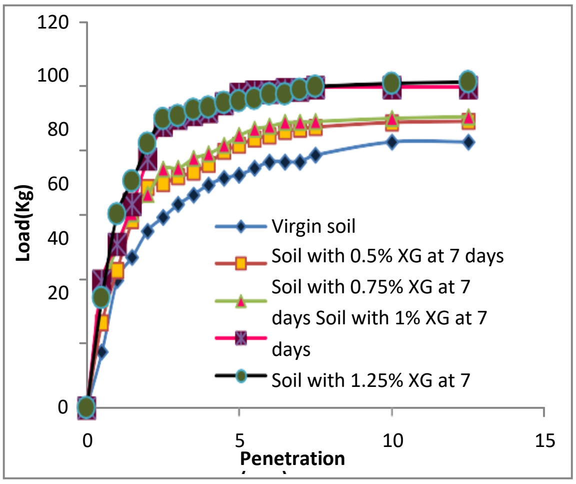

Fig. 8 Load vs. Penetration curves of xanthan gum treated soil at 7 days of curing period

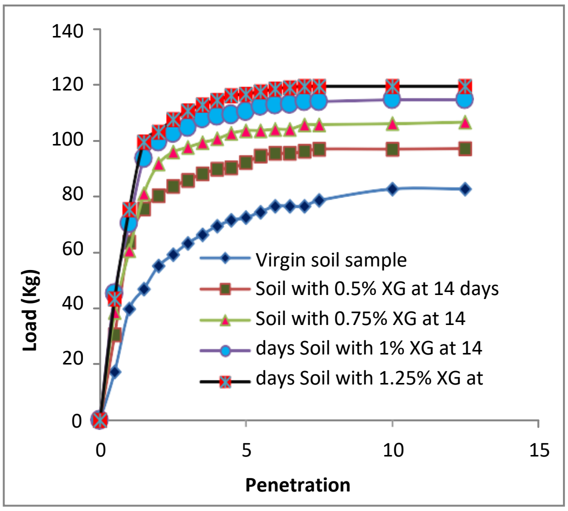

Fig. 9 Load vs. Penetration curves of xanthan gum treated soil at 14 days of curing period

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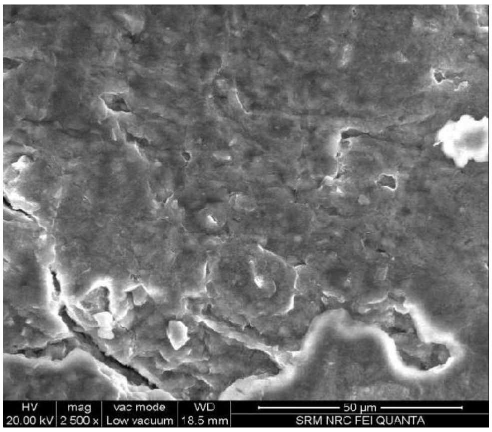

Fig.10 FESEM micrograph of un-treated soil sample

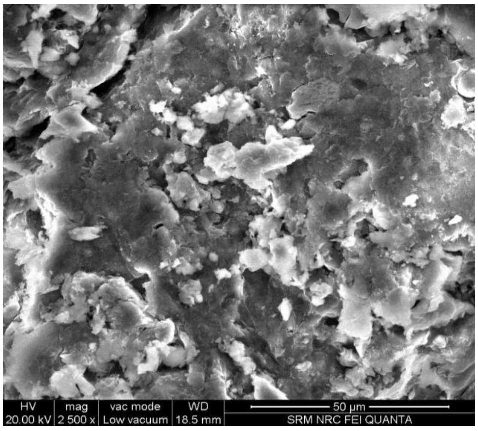

Fig.11 FESEM micrograph of treated soil sample

V. CONCLUSION

XG-thickener is a kind of biopolymer that influences the strength parameter of the soil without causing ecological toxicity. The improvement in unconfined compressive strength of the soil containing xanthan gum tends to be directly dependent on XG concentration and the restoring time. Also, UCC test results signified that 1.25% XG content achieved the optimal stabilization results. Generally, increased additive concentration and curing time yielded in the strength. In addition, CBR value boosted as the XG concentration was increased. This enhancement also enhanced with the expansion of restoring period.

Furthermore, FESEM analysis results indicate the formation of new cementitious products from the chemical interaction which occur between the stabilized soil particles and xanthan gum. The outcomes thus, provide useful insight about the mechanism of stabilization that occurs when the xanthan gum biopolymer is used to treat the fine grained soils. As a result of this investigation, xanthan gum is suggested as an eco-friendly soil stabilizer.

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AUTHORS PROFILE

Ruby Jan P.G Student, Department Of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India.

D. Deepa is working as a Assistant Professor in the department of Civil Engineering at SASTRA University in India.She was awarded PhD in 2016 from Annamalai University, Chidambaram

Mrs. S. Mary Rebekah Sharmila Assistant Professor, Department Of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India.(Corresponding Author)

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