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AN EXPLORATORY STUDY ON ENHANCING STABILITY OF BLACK COTTON SOIL BY BIO-ENZYME: RENOLITH FOR SUBGRADE AND FOUNDATION

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***Abstract*— there is a plethora of subgrade problems especially when the subgrade is on clayey or black cotton soil. This soil shares 15-20% of all Indian soil and covers vast area of construction from roads to heavy building construction. The major reason attributed to the poor behaviour against loading and very low strength is due to presence of huge quantity of montmorillonite mineral, which is responsible for excessive swelling in wet conditions and shrinkage cracks in summer as each of the mineral component can hold 200A of water layer.**
As the performance and economic feasibility are the most important features of any project on soil, thus in this study, we aim to develop such alternative solution for improving locally available clayey soil suitability in terms of its UCS and CBR value at corresponding OMC and MDD values. Also the effect on Atterberg's Limits on soil samples mixed with additive such as Renolith shall also be analysed to observe the change in plasticity characteristics. Renolith is neither corrosive nor combustible polymer product and is fluidic white polymer which is soluble in water used to enhance the bonding with soil and cement by forming Nano rubber bands between particles resulting in forming a strong bond that enhances strength, flexibility and permeability to the stabilized soil.

Keywords*— Soil stabilization, Black cotton soil, Renolith, California Bearing Ratio test, Pavement Subgrade, foundation

I. INTRODUCTION

Infrastructure and transportation becomes a certainly critical component in the socio-economic lifestyle development and overall national development by providing the best access to the lifeline amenities like education, health, employment and sources of residences as well. For roads and infrastructures, we can all agree that as the connectivity and better life values are essential for achieving nation's growth in economic and firmly stable aspects. The present government has set a benchmark of building 23 km of National Highway per day. Besides, thousands of (nearly 19,000 km) of low volume roads under Pradhan Mantri Gram Sadak Yojana (PMGSY) are being constructed per year under Central Government budget scheme 2018-19.
Currently with 5.7 million km of road length, India is the second largest road network in the world with nearly 63% paved road. Due to poorly stabilized sub-surface of roads, problems like surface cracks and potholes develops by the time. It reduces the life of the road surface as well. Nearly 3597 people were died just because of the potholes on under stabilized soils, in which black cotton soil is one of the most dangerous soil as sub-grade. Conventional road construction methods and technologies to such foundation gives unsatisfying results and overspent maintenance costs. This call for introduction of innovative approaches in road sub-grade stabilization for achieving cost effectiveness with quality improvement and safety also. Though so many such new road additives and innovative stabilization techniques were tried world over, they could not become popular in India, due to procedural constraints, lack of awareness and corruption as well.
Black cotton soils, being highly plastic with enormous clay content, exhibits solid problem with regard to sequent performance of the pavement. By varying levels of moistures, it swells when humidity increases in monsoon season and develops shrinkage cracks when loses water. As shrinkage is not uniform with the depth so the crack patterns are also very complex to understand. The softened black cotton soil sub-grade has the susceptibility to up-heaving in the upper layers of the roads, predominantly in cases of soil sub-grade comprises of poorly stabilized layers having voids. By the time, encroachment of saturated black cotton soil with such high shrink and swell property tends to failure of the structural pavement. Pavements constructed over the black cotton soil conjure undulations and unevenness at the surface

if built flexible and end up producing surface failure cracks, heavy depressions and settlements if adopted rigid. Therefore, it is inevitable need to improve the properties of black cotton soil to avoid damage to the structures and pavement.

From last few decades, chemical based stabilization has evolved to a great distinct. Chemical stabilization resides of bonding soil particles with cementing agents which are produced by the chemical reaction within the soil. The primarily additives generally in wide use are lime, salts of cations, fly ash, lignin, polymers as natural ingredients and artificially developed resins, geosynthetics, mesh wires and so many of them. These are mainly traditional mechanical methods and chemical techniques. Many researches have experimented successfully upon lime as admixture manifested to be best among all other considering the economy as well in enhancing the black cotton soil's properties as sub-grade.

Along with the traditional agents there are numerous verities of modern additives appropriable from commercial markets such as emulsion, organic resins, enzymes, various silicates and acids. These modern era additives may be solid, semi-solid or in liquid state and are often suggests to be adopted for stabilizing applications. An immense variety of waste material products from industries and agricultural activities have been used for soil improvement and stabilization.

One of the numerous commercial polymer products which has gained peak eyesight in recent years is RENOLITH. Renolith is whitish viscous liquid polymer additive produced by locally available synthetic chemical products. As per its constituents and information from the patent holder company in Germany, it is non-corrosive, non-toxic, non-combustible, 100 % environmentally safe and eco-friendly. It has great surface activeness which is responsible for altering the hydrophilic characteristic of black cotton soil to hydrophobic (water repelling) nature, maintaining the strength criteria. At this juncture, an attempt is made to bring in Renolith and other such material to exposure of innovative technologies and discuss their positive impacts so as to mark a milestone in effective techniques of black cotton soil improving and stabilizing.

II. LITREATURE REVIEW

A. An Experimental Study on Renolith Treated Black Cotton Soil for Subgrade Pavement.

S Haneefa Jamal, P Suresh Praveen Kumar; "The soil stabilization by modern additives, which has been the subject of numerous research papers, started getting attention in the last few decades. A large number of papers have focused on economic, environmentally safe and effective techniques looking forward to innovative soil stabilization methods. Authors of this study paper tested Renolith treated high clay contained black cotton soil samples for Atterberg's Limits, Specific gravity, FSI Property and most importantly California Bearing Ratio (CBR) Tests for suitability as sub-grade additive material. They mixed Renolith and cement for better binding of soil particles to gain desired strength against heavy shrinkage and swelling. The proportions of Cement in range of 4%, 6%, 8%, and 10% in soil by weight were throughout blended with virgin black cotton soil and 4% to 10% of Bio-enzyme Renolith. They acquired good results in decreasing Liquid Limit and considerable increase in CBR value, which is found to be very effective in Pavement design and sub-grade stabilization"

Table 1: Renolith Properties

Serial Number	Properties	Values
1	Specific Gravity @ 25ºC	1.00-1.02
2	Boiling Point	100ºC
3	Viscosity @ 25ºC	1200-2000 cps
4	pH@ 25ºC	11.00-12.50
5	Solubility in Water	Miscible in water
6	Appearance	Milky White
7	Evaporation Rate	Same as water
8	Melting Point	Liquid
9	Reactivity Data	Stable
10	Materials to Avoid	Caustics and Strong Bases
11	Hazardous Content	None

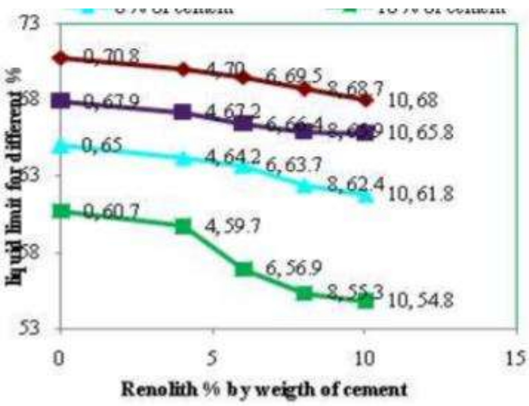

Figure 1: Liquid limit for different contents of of cement and Renolith

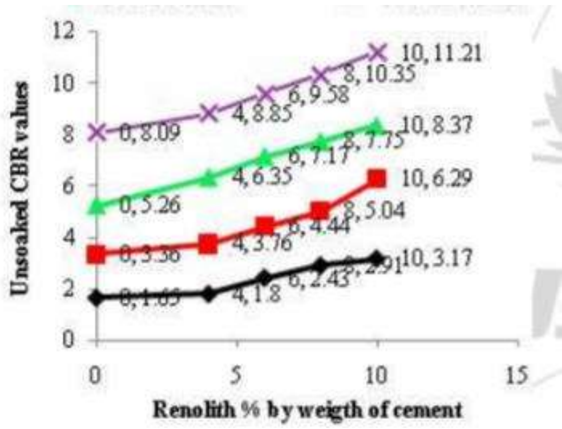

Figure 2: CBR strength for different percentages of cement and Renolith

B. Evaluation of Renolith as a Sub-Grade Stabilizer.

Anoop Singh[1], Prashant Garg[2]; "In this exemplary research work, Anoop[1] and Prashant[2] has done great work in direction of Bio-enzyme application. They have experimented various important tests on virgin soil mixed with Cement from 2% to 10%. They conducted Tests for Specific gravity, Atterberg's limits, Plasticity Index, Standard Proctor Test for determining MDD and OMC, Permeability test, and Soaked and Un-soaked CBR value determined by taking 14 days of curing period. Even the costs incurred in cement stabilization and bio-enzyme are also compared. For that they have designed 1 km of flexible pavement of varying traffic intensity of **2 msa**, **5 msa** and **10 msa**. They concluded 15-28% effective reduction in cost of Flexible Pavement. Proctor test results, CBR results, Permeability and thickness and volume comparison is shown below."

3: Standard Proctor Test Result

Sample + % Cement by wt. of soil	OMC(%)	%increase in OMC	MDD(Kg/m^3)	% increase in MDD
0	17.00	---	1770.25	---
2	16.82	-1.06	1810.35	2.27
4	16.50	-2.94	1845.35	4.24
6	16.45	-3.24	1870.27	5.65
8	16.07	-5.47	1925.06	8.75
10	15.88	-6.59	1980.65	11.89

Figure 4: Comparison between CBR values for 2% Figure Cement with varying Renolith dose with 14 days curing

Renolith dosage by wt.	Unsoaked CBR	Increase in Unsoaked CBR(%)	Soaked CBR	Increase in soaked CBR(%)
0% of cement	17	—	8	—
1% of cement	20	17.65	9	12.50
2% of cement	23	35.29	11	37.50
3% of cement	29	70.59	16	100.00
4% of cement	31	82.35	17	112.50
5% of cement	29	70.59	14	75.00

Figure 5: Comparison between CBR values for 6% cement with varying Renolith dose with 14 Days curing

Renolith dosage by wt. of cement	Unsoaked CBR	Increase in Unsoaked CBR(%)	Soaked CBR	Increase in soaked CBR(%)
0% of cement	39	—	21	—
1% of cement	42	7.69	21	00.00
2% of cement	48	23.08	33	57.14
3% of cement	53	35.90	37	76.19
4% of cement	54	38.46	37	76.19
5% of cement	50	28.20	33	57.14

Figure 6: Comparison between CBR values for 10% cement with varying Renolith dose with 14days curing

Renolith dosage	Unsoaked CBR	Increase in Unsoaked CBR(%)	Soaked CBR	Increase in soaked CBR(%)
0% of cement	43	—	31	—
1% of cement	46	6.98	34	9.68
2% of cement	54	25.58	38	22.58
3% of cement	61	41.86	45	45.16
4% of cement	62	44.19	44	41.93
5% of cement	56	30.23	40	29.03

Figure 7: Results of 2% cement with varying dosage of Renolith

Renolith Dosage by wt. of cement	Co-efficient of Permeability (K)(m/sec)
0%	8.11×10^{-5}
1%	1.44×10^{-5}
2%	5.05×10^{-6}
3%	2.01×10^{-6}
4%	9.51×10^{-7}
5%	6.80×10^{-7}

Figure 8: Permeability Results of 6%cement with varying Renolith dosages

Renolith Dosage by wt. of cement	Co-efficient of Permeability (k)(m/sec)
0%	0.47×10^{-5}
1%	4.72×10^{-6}
2%	1.14×10^{-6}
3%	2.88×10^{-7}
4%	5.74×10^{-7}
5%	0.32×10^{-7}

Figure 9: Results of 10%cement with varying Renolith dosage

Renolith Dosage by wt. of cement	Co-efficient of Permeability (K)(m/sec)
0%	4.08×10^{-7}
1%	4.02×10^{-7}
2%	3.79×10^{-8}
3%	3.22×10^{-9}
4%	2.47×10^{-9}
5%	1.89×10^{-9}

Figure 10: Thickness of layers with varying Traffic intensity

Traffic Intensity (msa)	Layers of pavement	Thickness of layer (mm) for 2% Cement	Thickness of layer (mm) for 2% cement+3% Renolith of cement
2 msa	SDBC	25	25
	DBM	50	40
	G.BASE	225	225
	GSB	175	100
5msa	SDBC	25	25
	DBM	50	40
	G.BASE	250	250
	GSB	210	150
10msa	BC	40	40
	DBM	65	40
	G.BASE	250	250
	GSB	260	200

Figure 11: Volume of layers with varying Traffic intensity

Traffic Intensity (msa)	Layers of pavement	Volume of layer (m^3) for 2% Cement by weight of soil	Volume of layer (m^3) for 2% cement+3% Renolith by weight of cement
2 msa	SDBC	187.5	187.5
	DBM	375	300
	G.BASE	1687.5	1687.5
	GSB	1312.5	750
5msa	SDBC	187.5	187.5
	DBM	375	300
	G.BASE	1875	1875
	GSB	1575	1125
10msa	SDBC	300	300
	DBM	487.5	300
	G.BASE	1875	1875
	GSB	1950	1500

C. An assessment of Renolith on Cement-stabilized Poor Lateritic Soils.

Titilayo Abimbola Owolabi, Aderinola O.S; "This assessment was carried out on materials from different borrow pits. Cement percentage was kept constant (5% and 10% of the dry weight of the soil) and Renolith content varied (i.e. at 2.5%, 5%, 7.5% and 10% of the weight of the cement). Author and her companions carried out various tests like Specific gravity test, Particle Size Distribution, Consistency Limits, Compaction Tests for MDD and OMC determination, Unconfined Compressive Test, Natural Moisture Content, Group Index, AASHTO Classification, USCS Classification, Un-soaked CBR. The ensuing results showed an array of remarkable improvements in soil structure which can be determined by graphs shown below. There was an enormous peak increase in strength of the soil at the 5% of the weight of the cement addition of bio-enzyme Renolith. However, this research paper shows the poorest of the stabilized samples displaying very interesting results from the tests. MDD was observed to be increased about 7% and UN-soaked California Bearing Ratio was hiked up to 1863%. UCS (Unconfined Compressive Strength) was increased by 200% after 28 day of test commencement. They concluded that 5% of Renolith is quite efficient in enhancing Structural properties and Strength of Soil."

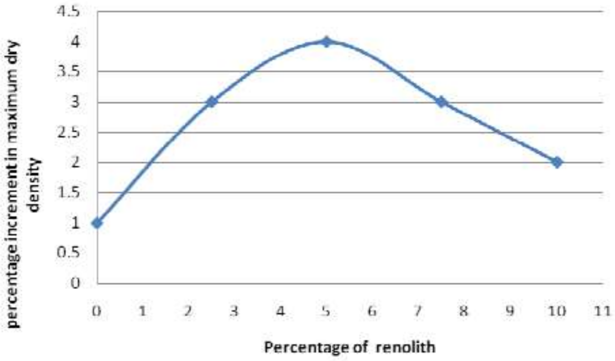

Figure 12: Increment in MDD at 5% Cement

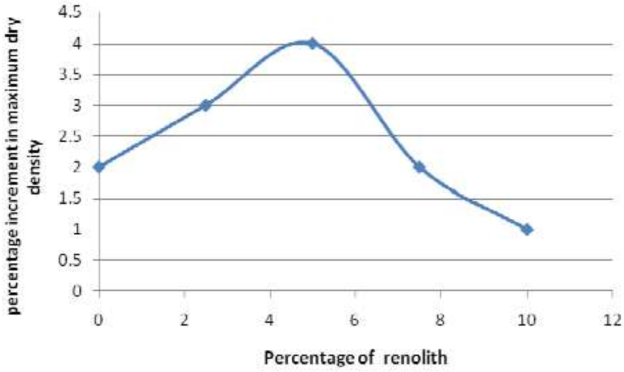

Figure 13: Increment in MDD at 10% Cement

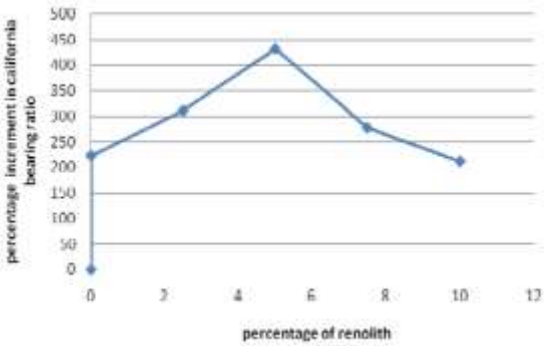

Figure 14: Increment in CBR at 5% cement

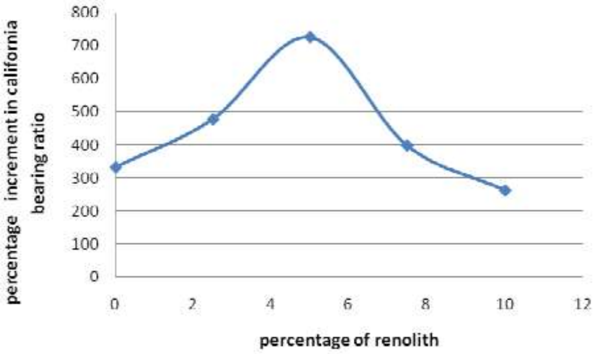

Figure 15: Increment in CBR at 10% cement

D. **Treatment of Soils with the RBI-81 and Renolith Additives.**

Milorad Jovanovski, Spasen Gjorgevski, Jovan Papic and Josif Josifovski; "In this research paper the results from field and laboratory testing on low bearing natural subsoil and coarse grained material for pavement layers, stabilized with RBI-81 and RENOLITH. The effect of improvement of mechanical properties such as CBR, UCS, etc. is analysed for various soil samples. Adequate recommendations about using RBI-81 and RENOLITH are suggested for improving low bearing subsoil as well as for coarse grained material which can be used in pavement. Limitations and favourable considerations are noted as well. The graphs show the regression curves in which added RBI-81 are plotted for CBR as shown below. As from the lab tests CBR increases but for additive RBI-81 it takes some time to attain such peak values."

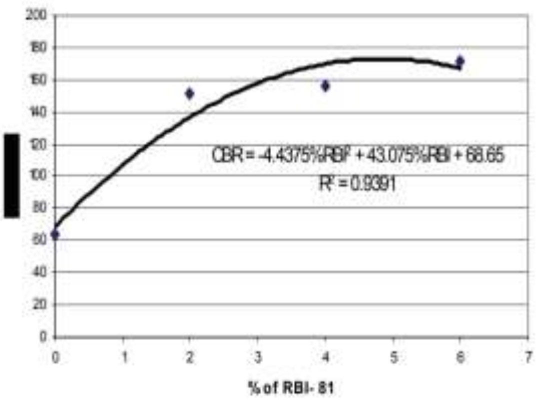

Figure 16: Correlation between %CBR and %RBI-81 for Coarse grained soil,

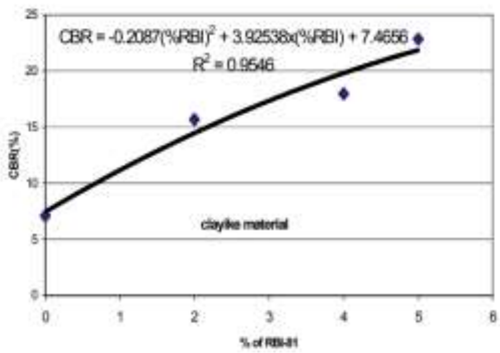

Figure 17: Correlation between %CBR and %RBI-81 for Fine clayey grained soil

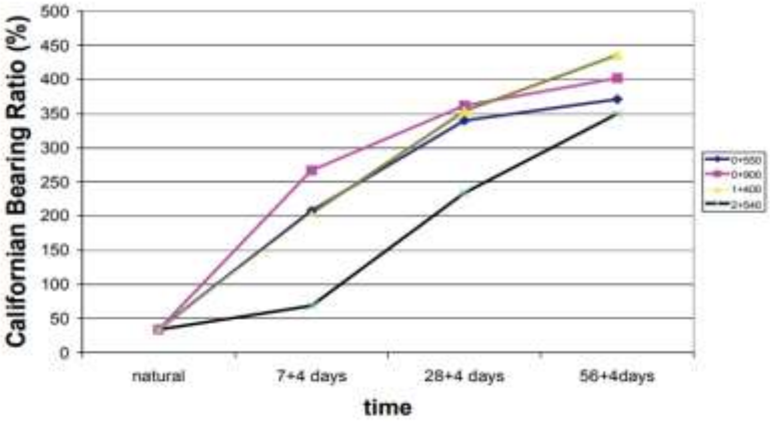

Figure 18: Time dependant improvement effect in value of CBR.

III. CONCLUSION

From the above literature we conclude that

1) By adding Bio-enzyme Renolith in cement stabilized soil, Liquid limit of typical Black cotton soil decreases by 23.36%.
2) For pavements, Renolith is clearly the game changing additive as per the results. We can conclude that maximum increment in CBR found in Black cotton soil was 627.92%, in Silty sand it was found to be 112.50% with 2% cement by weight of soil. In laterite soils increase in CBR was more than 450% with 5% dosage of Renolith and 5% of cement by weight of soil and nearly 1100% for 5% Renolith and 10% cement by weight of soil.
3) From the Standard Proctors test, OMC gradually decreases by 6.59% and MDD increases by 11.89%, which is good for pavement sub-grade stabilization. We can conclude that Renolith additive is essential in enhancing the properties of Black cotton soil as a sub-grade.
4) With increase in Renolith content, there is a drastic decrease in Permeability value (k). which is advisable in water repelling characteristic.
5) With the use of Renolith, about 15 to 28% reduction can be achieved in the cost of Pavement construction.
6) In addition to costs reductions, Renolith also translates to a significant amount of time saving for any project as the material quickly bonds with the soil-cement mixture, as well as the time saving on elimination of some tedious earthworks.
7) We can also conclude that the effect of improvement is evident for all kind of materials, so Renolith can be used in a practice with success for several purposes.

- Important effect on Bearing Capacity.
- Design of Optimal Composition of the Pavement.
- Minimizing earth excavations and minimal transportation expenses.
- Minimal Disturbance to natural media.

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