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An Experimental Study on Renolith Treated Black Cotton Soil for Subgrade Pavements

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Abstract: ***There are many sub-grade problems especially when the sub-grade is of clayey soils. The main reason is due to the presence of enormous quantity of montmorillonite mineral. Thus in the present study an attempt has been made to bring an alternative solution to enhance the properties of clayey soil available locally by conducting laboratory experiments on the soil samples treated with polymer chemical Renolith. Renolith is one Renolith is a polymer chemical which is a water soluble white milky viscous liquid. It is non toxic and eco friendly polymer chemical which when mixed with soil, cement and road construction material forms a sturdy polymer surface that facilitates additional strength, flexibility and permeability to the pavement. The polymer chemical is used along with cement to enhance its efficiency with the clay particles of the soil. The soil is treated with different quantities of Renolith and cement. The various laboratory tests such as Liquid Limit, Differential Free Swell Index, Standard Proctor Compaction test and California Bearing Ratio test are conducted to examine the improvement in the properties of the soil.***

Keywords: Black Cotton Soil, Cement, California Bearing Ratio test, Liquid limit, Pavement Subgrade, Polymer chemical.

1. Introduction

Black-cotton soils are highly plastic soils with high clay content. It is very strenuous that the clods cannot effortlessly be pulverized for treatment to be used in pavement works. This tends to pose solid problem with regard to sequent performance of the pavement. In addition to this, the softened soil sub-grade has the propensity to up heaving in the upper layers of the road, predominantly when the soil sub-grade comprises of stone soling with numerous voids. Step by step encroachment of saturated black-cotton soil or any other expansive soil with high plasticity invariantly tends to failure of the structural pavement.

The pavements constructed over the black-cotton soil generate undulations at the surface of the pavement structure because of reduction in strength of the soil sub-grade due to softening in monsoon. It is identified that due to drying, the black cotton soil generates very deep cracks. As a result of drying and wetting, vertical movement develops in the soil mass. These movements results in the failure of pavement structure, in the form of heavy depressions, unevenness, cracking and settlements.

Chemical stabilisation consists of bonding of soil particles with cementing agent that is produced by the chemical reaction within the soil. The primary additive is a chemical in the process. The reaction does not necessarily include the soil particles, although the bonding does involve molecular force of the soil. The use of chemical as secondary additive to increase the effectiveness of cement, lime and bitumen (asphalt) is in light. The primary additives generally in wide use are lime, salt, lignin and polymers. Many researchers have experimented upon lime as admixtures proven to be best among all other considering the economy as well in enhancing the expansive soil properties.

Along with the traditional agents there are numerous varieties of modern additives acquirable from commercial markets such as polymer emulsion, lignin, tree resin, enzymes, silicates and acids. These modern or non-traditional additives may be solid, semi-solid or liquid state and are often tipster to be implemented for almost soils. These modern additives are easy for application with different ratios in different soil categories.

In the past decade water soluble polymers were recognized as highly efficient erosion preventing and infiltration improving polymers. Polymer chemicals tend to be recognised by their commercial brands. This makes it difficult to identify the similarities among various polymer additives due to the reason that the chemical phenomenon of each additive is generally hidden by the brands. The brands often become not consistent due to variation of names as per different marketing plans appealed by the brands.

One of the numerous polymer chemical compounds which have gained peak recognition in the recent years is Renolith. Renolith is the liquid polymer additive produced from by blending of locally produced synthetic chemical products. As per the manufacturer the polymer is a non combustible, non poisonous, non toxic, non corrosive, environmentally safe and eco friendly. The polymer chemical is a synthetic product with a property of surface activeness which as the capability of changing hydrophilic nature (water absorption) of the fine grained soils to hydrophobic nature (water retention) maintaining the strength criteria. Main advantage of the polymer chemical stabilisation is that very small volume of the polymer additive is enough and the cost of ground improvement is less when compared to the other geotechnical processes. Compaction has been shown to affect the soil structure, strength, permeability and compressibility characteristics and stress-strain characteristics (leonard, 1962).

2. Literature Review

Unlike the standard stabilizers such as Portland cement, lime and bitumen, non-standard stabilizers have no laboratory tests that can be used to predict their field performance.

Some of the experimental studies of soil with polymer additives are presented here.

Polymer additives of soil have grown interest in the past decade as an effective way for enhancing the strength and permeability properties of poor graded soils. Large number of natural and synthetic polymers like lignosulfonates and lignins are available in the market. The polymers contain chains of hydrocarbons and these chains get entwined with the particles of soil, thus making it a solidified mass. There by polymer additive acts as a sticky substance like glue binding the soil particles altogether which results in reduction of dust and stabilizing the entire soil mass (Brown et al., 2004).

Vedenskaya et al. (1971) experimented using copolymers to consolidate clays, silts and sands. They were guanidine acrylate (GA), ethylene dimethacrylamide(EDMA), methylene bisacrylamide (MBAM). The polymer formula was 24:1 ratio of vinyl monomer to diene. The assemblage of EDMA and GA reacted best in loams and sands followed by GA and MBAM. They reported an increment in the values of unconfined compressive strength for 5% mixture of an additive in sand. Vedenskaya et al. (1971) stated that the organisation of the polymer soil structure in soil consolidation was finished in less than 10 days. They recommended the quantity of additive to be taken must be in ranges of 5 and 10 percent.

Oldham et al. (1977) evolved a synthesis of potential stabilising agents determined by the corps of engineers and contract researchers from 1946 to 1977. Their reports determined acids, resins, cement, asphalt, lime, silicates, salts and other products as potential stabilising agents with varying degree of success. The results of their research demonstrated the performance differed for different variety of soil type. They also observed that some stabilising agents such as salts used for stabilising mechanism are suited only for particular environment and climatic conditions only. For sand sample the unconfined strength provided by the polymer emulsion/ resin is the highest increment.

Gopal et al. (1983) conducted comparative research studies on dune sand using urea-formaldehyde (UF) and its copolymers to stabilise the sand sample. The specimen samples were set up with different proportions of UF, pH and acidic catalysts. All the samples were kept for 6hrs curing at a temperature of 60ºC. The reduction in pH of mixture of stabilising agents using phosphoric acid catalysts increased the relative strength in the soil specimen. The optimum UF for their test sampling was 1:2.25 by weight. Gopal et al. (1983) recommended the usage of 9% and 0.3% resin and acid catalyst respectively for stabilising dune sands.

Methuku Anvesh Reddy (2012) conducted studies on the polymer based chemical treated clayey soils to find the effect on the geotechnical properties of the soil and determined the soil characteristics, California bearing ratio and unconfined compressive strength corresponding to the optimum moisture content. He reported that the addition of polymer chemical Renolith to the clayey soils along with the cement increase the strength of soil as long as the concentrations of Renolith and cement increases in California bearing ratio and unconfined compressive strength.

3. Materials

3.1 Soil Sample

The soil that is utilized in the current research study has been attained from Kopparthy village, Kadapa. The soil obtained is of Black cotton soil which was of dark black in colour. The soil was originally collected in the form of lumps excavated from an approximate depth of 2.0m from ground level. The collected soil was naturally air dried and then the soil cleaned is by separating from roots, gravel, pebbles and any other inappropriate materials. The cleaned soil lumps are then pulverized or disintegrated manually into small sizes and screened to collect required size of the soil particles by passing through desired sieve size. Finally collecting a homogeneous soil required for the laboratory experimentation.

3.2 Renolith-Polymer Chemical

The polymer chemical Renolith used in the study was obtained from the Khopoli polymer product which is a local chemical manufacturing unit in Mumbai. Renolith is said to be the by-product obtained by blending locally produced synthetic chemical products. It generally referred as the polymer additive used for improvement of soil properties. The quantity of Renolith varies in proportion for different soils. Commonly Renolith is used along with cement. It can be said the soil-cement properties increases due to the addition of Renolith. The properties of Renolith are summarized in the table 1.

The soil specimens are also treated with cement along with polymer chemical Renolith. The cement that to be used along with Renolith for this intent in the work is Portland Pozzolona Cement (PPC) which is conveniently available in the market and in the study it is brought from a local cement dealer of Bharathi cement brand. The properties of the cement are cited in the table 2.

Table 1: Properties of Renolith **(**As per Manufacturer**)**

S.No	*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: Renolith-Polymer Chemical With Measuring Cylinder.

Table 2: Properties of Cement

S. No	Experiment	Experimental Values
Cement Used-Portland Pozzolona Cement		
1	Average Specific Gravity	3.10
2	Initial setting time	27 min
3	Final setting time	558 min
4	Fineness Modulus (Passing 90µ Sieve)	99.5%

The properties of the natural black cotton soil obtained from field which is used in the investigation work are given in table 3.

Table 3: Properties of Original Black Cotton Soil

S.No	Experiments	Tested Results
1	Specific Gravity	2.29
2	Differential Free Swell Index (%)	110
3	**Grain Size Analysis** Gravel (%) Sand (%) Silt (%) Clay (%)	 0.2 15.11 51.61 33.08
4	**Atterberg Limits** Liquid Limit (%) Plastic Limit (%) Shrinkage Limit (%) Plasticity index (%)	 71.50 41.75 19.00 29.75
5	**Standard Proctor Test** Optimum Moisture Content (%) Maximum Dry Density (g/cc)	 31 1.353
6	Unconfined Compression Test (kg/cm^2)	1.185
7	California Bearing Ratio (%)	1.54
8	Indian Classification Of Soil	MH

4. Tests Conducted

The tests on the untreated black cotton soil are specific gravity, differential free swell index and Atterberg limits from index properties while engineering properties such standard proctor test, unconfined compression test and California bearing ratio are conducted. The tests on the untreated black cotton soil conclude that the type of the soil in the present study is of MH that is inorganic clays as per IS classification of soil.

The treated black cotton soil comprises of varied proportions of cement and Renolith. The amount of cement in the soil specimen ranges from 4% to 10% by weight of dry soil with 2% intervals and there is variation in concentration of Renolith for every proportion of cement taken in the specimen from 4% to 10 % by weight of cement alone. The soil is treated with cement alone to determine the increases in strength variation when compared with soil-cement-Renolith mix. By this way the overall soil specimens treated are counted to be 20 samples.

As Renolith is mainly used for pavement sub-grades the major concentration in experimental study is given to the California bearing ratio test. The California bearing ratio test is done to determine the penetration resistance of the sub-grade. Thus tests conducted on black cotton soil treated with Renolith-Cement are liquid limit and California bearing ratio test.

4.1 Liquid Limit

Liquid limit test for the soil sample treated with Renolith is done after mixing the specified quantity of Renolith to the soil-cement and leaving the sample for 24 hours. The liquid limit of the untreated soil is 71.5%. The results of the soil samples tested with different compositions of Renolith are given in the table below.

The experimental results show that there is a decrease in liquid limit value with every increase in the percentage of Renolith for specified concentration of cement percentage. The decrement in the value of liquid limit for each respective percentage of Renolith and cement are shown in the graph below.

Table 4: Liquid Limit for various percentages of cement and Renolith

Renolith %	Cement %			
	4	6	8	10
0	70.8	67.9	65	60.7
4	70	67.2	64.2	59.7
6	69.5	66.4	63.7	56.9
8	68.7	65.9	62.4	55.3
10	68	65.8	61.8	54.8

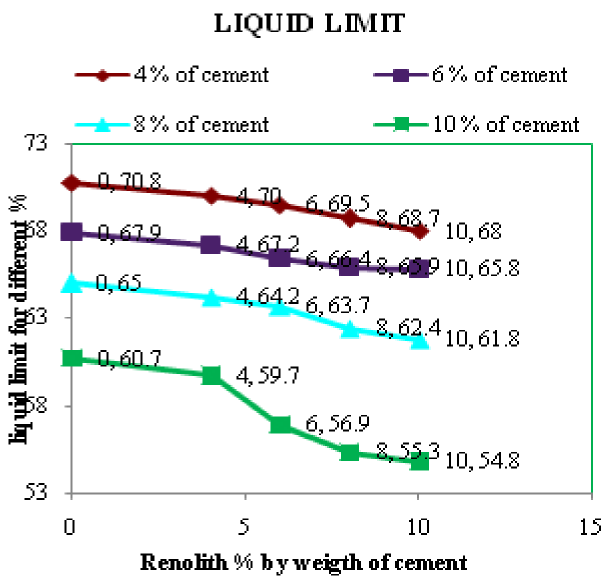

Figure 2: Liquid Limit for different contents of cement and Renolith

4.2 CBR Test

The CBR experiments are conducted for the soil samples treated with various percentages of cement and Renolith. The CBR values of untreated black cotton soil and the soil samples treated with cement and Renolith percentages are shown in the tables below. The value of CBR is 1.54 at 5mm penetration. The CBR values are generated from the load Vs penetration curve. The CBR values of all the samples treated with cement and Renolith are represented in the figures given below.

Table 5: CBR strength for various percentages of cement and Renolith

Renolith %	Cement %			
	4	6	8	10
0	1.65	3.36	5.26	8.09
4	1.80	3.76	6.35	8.85
6	2.43	4.44	7.17	9.58
8	2.91	5.04	7.75	10.35
10	3.17	6.29	8.37	11.21

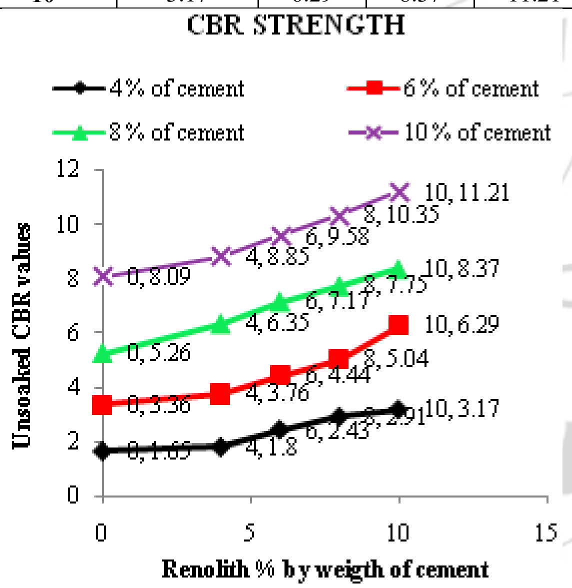

Figure 3: CBR strength for different percentages of cement and Renolith

As observed from the test results the CBR values of CBR are lesser for the untreated soil whereas the CBR values of soil treated with Renolith and cement are significantly high.

5. Conclusions

5.1 Conclusions

The inculcation of polymer chemical Renolith have shown considerable effect on the enhancement of soil properties. The liquid limit of the soil treated with cement and Renolith reduces significantly with the increase in their respective proportions.

1) The liquid limit of the soil follows a decrement of 23.36% with addition of cement and Renolith.
2) The CBR test done for original black cotton soil is observed to be very less when compared to the CBR values resulted for the soils samples treated with cement and Renolith.
3) For every increase in percentage of cement there is a considerable increment in the both liquid limit and CBR values of the soils.
4) It is notified that for every increase in Renolith percent for a specific percentage of cement there is a significant rise of CBR values of the respective soil samples.
5) The maximum increase in the CBR value is 627.92% when compared to the untreated soil sample.

Finally, from the study it can be concluded that there is a scope of utilizing the polymer chemical Renolith with cement for the enhancement of pavement subgrade strength.

5.2 Further Study

Further the polymer chemical can be used with lime instead of cement while the soil is of very high plasticity as we know that lime readily react with cohesive soils when compared cement.

For evaluation of strength criteria of the soil to be used for structural constructions such as buildings, bridges, etc in addition to the present work further research investigation and laboratory experimental have to be carried out.

The study may be applied at the site of work with desirable proportions of cement and Renolith as per strength requirements.

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