A Comparative Cost Analysis Of Soil Stabilization Using Lime, Cement &RBI Grade 81 Stabilizer

[1]MOHD RASHID, [2]NITISH JAUHARI
[1]PG STUDENT, [2]ASSISTANT PROFESSOR,
DEPARTMENT OF CIVIL ENGINEERING,
RAJSHREE INSTITUTE OF MANAGEMENT AND TECNOLOGY, BAREILLY, INDIA.

Abstract : Soil can be considered as very first element of construction industry as no construction work can be done without it. Soil plays an important role in construction industry such as in foundation works, pavement subgrade etc. Soil used in construction industry is first treated and convert into a technically sound which fulfill the criteria of good foundation soil. Soil stabilization is such a process which improves the properties of soil such as strength, stress parameters, Atterberg limit etc.by mixing external agent or compacting it. Hence the requirement of engineering soil can be achieved by such processes.

In this present study, we are comparing the properties of soil by mixing calcium based stabilizers; Cement Lime and RBI Grade 81 at different percent to analysis cost variance and their effects. Cement stabilization and lime stabilization are traditional method whereas the stabilization through RBI Grade 81 stabilizer is the latest research works and is used in construction nowadays. The tests were performed as per IS specifications. RBI Grade 81 stabilization shows effective results over Lime and Cement stabilization techniques.

IndexTerms **-Soil Stabilization, Lime, Cement, RBI Grade 81 Stabilization, CBR Method, Atterberg Limit.**

- **Introduction**

A developing country like India which has a large geographical area and population, demands vast infrastructure i.e. network of roads and buildings. Everywhere land is being utilized for various structures from ordinary house to sky scrapers, bridges to airports and from rural roads to expressways. Almost all the civil engineering structures are located on various soil strata. The long-term performance of any construction project depends on the behavior of soil stratum.

- **Soil Stabilization**

Stabilization is a term being discussed with increasing frequency at every gathering of highway or paving engineers. Soil is the basic foundation for any civil engineering structures which is required to bear the loads without failure. In some cases, soil may be weak which cannot resist the loads, soil stabilization is needed

"*Soil stabilization can be explained as the modification of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil".*

According to writer, "Soil stabilization may be defined as a modification of parent soil into a new soil so as to improve its bearing or load absorbing characteristics. Such an effect may be accomplished by mechanical consolidation (compaction) or by the incorporation within the soil of certain additives which would provide the desired qualities of permanent stability."

Soil stabilization is a major trend in India where the infrastructure is developing at a very fast speed. A large area of our country is covered with expansive soil with their poor engineering properties and is not suitable for construction. Soil stabilization is the process which involves enhancing the physical properties of the soil in order to improve its strength, durability, workability, stiffness, permeability, compressibility, sensitivity etc. by blending or mixing it with additives.

Mainly there are three types of soil stabilization; dewatering, compaction or adding chemicals. This paper was focused on adding chemicals; Lime, Cement and RBI Grade 81 independently in the soil.

- **Objectives of Soil Stabilization**

The main objectives of the soil stabilization are to improvement in the bearing capacity of the soil, its resistance to weathering process and soil permeability. Unstable soils creates significant problems for pavements or structures, therefore soil stabilization techniques are necessary to ensure the good stability of soil so that it can successfully sustain the load of the superstructure particularly in case of soil which are highly active, also it saves a lot of time and millions of money when compared to the method of cutting out and replacing the unstable soil.

- **Necessity of Soil Stabilization:**.

  - Stabilized soil functions as a working platform for the projects.
  - Stabilization improves the soil strength and waterproofs it.
  - Soil volume change due to temperature or moisture has been reduced.
  - Stabilization improves soil workability.
  - Stabilization reduces dust in the work environment.
  - Stabilization improves marginal materials.
  - Stabilization improves durability.
  - Stabilization dries wet soil.
  - Stabilization conserves aggregate materials.
  - Stabilization reduces cost.
  - Stabilization conserves energy.

- **Advantages of Soil Stabilization**

  - If during the construction phase a weak soil stratum is encountered, the usual practice followed is replacing the weak soil with some other good quality soil and can be used successfully as the sub grade material without replacing it.
  - The cost of preparing the sub grade by replacing the weak soil with a good quality soil is higher than that of preparing the sub grade by stabilizing the locally available soil using different stabilization techniques
  - The strength giving parameters of the soil can be effectively increased to a required amount by stabilization, thus increasing the soil bearing capacity.
  - It is more economical both in terms of cost and energy, rather than going for deep foundation or raft foundation for improvement in bearing capacity of soil.
  - Stability to the soil in slopes or other such places can be increased by using stabilization.
  - Soil stabilization is also used to avoid soil erosion or formation of dust, particularly in dry and arid weather.
  - Stabilization is also done for preventing water from entering into the soil and hence helps the soil from losing its strength and making it waterproof.
  - It helps in reduction of soil volume, due to change in temperature or moisture content. However the soil stabilization has disadvantage like increase in cost of construction and difficulty in mixing the fibers with soil.

- **Material used in the Research Work**

  These are calcium based materials that when in contact with water or in the presence of pozzolanic minerals reacts with water to form cementious composite materials. The materials used in this study are;

  - Lime
  - Cement
  - RBI Grade 81

- **Lime and Lime Stabilization**
- **General**

- **Lime Stabilization**

  Addition of lime to soil is termed as Lime Stabilization. When lime reacts with soil there is exchange of cation in the adsorbed water layer and a decrease in the plasticity of the soil occurs. The resultant material is more friable than original clay, and is more suitable as construction material. Lime or Pozzolanic Stabilization of soils improves the strength characteristics and changes the chemical composition of expansive soils.

- **Benefits of Lime Treatment:**

- Drying with lime minimizes weather-related construction delays, extends construction season, and acts quickly-allowing return to work in hours
- Chemically transforms clay soils i.e. friable and easier to handle
- Permanently increases strength
- Eliminates soil expansion
- Creates excellent freeze/ thaw resistance
- Resists cracking
- Reduces thickness of overlying pavement
- Reduces shrinkage and swell characteristics of clay soils.

- **Disadvantages of Lime treatment:**

- Hydrated lime particles are fine in size. Thus, dusting is a problem and this type of application generally unsuitable for populated areas.
- Care must be taken with the use of lime to ensure adequate water addition, mellowing and mixing.
- Quick lime may require more mixing than hydrated lime and also it requires more water to convert in hydrated lime and a significantly evaporation loss due to heat of hydration.

Slurry lime has slower rate of application and not useful in wet soils. Higher cost due to extra equipment requirement and also not practical for drying applications in construction works.

- **Cement and Cement Stabilization**

- **Cement Stabilization:**

Due to it's readily availability, Cement is one of the most popular stabilizer and generally can be applied to a wide range of materials. It is considered to have advanced properties. Soil with some quantity of cement is mixed to form 'Soil-Cement". Increasing the cement content increases the quality of the cement-soil mixtures.

- **Factors affecting cement stabilization:**

The important factors affecting soil cement are nature of soil, cement content, condition of mixing, compaction and curing, and admixtures.

- **Nature of soil –** Granular soils with sufficient fines are ideally suited for cement stabilization. Such soils can be easily pulverized and mixed. They require the least amount of cement, small quantity of silt or clay to sandy soils may aid in cement reaction.
- **Quantity of cement-** The strength of soil cement increases with an increase in the amount of cement added to a soil, and if such an increase in strength does not result, the soil may in general be consider as unsuitable. The amount of cement required, expressed as a percentage by weight of dry soil, and generally varies 2 to 10 %, finer soils requiring more cement.

- **Quantity of water-** The quantity of water used must be sufficient for hydration of cement and silt-clay cement and for making the mix workable.
  Water should be clean and free from hazardous salts, alkalis, acids or organic matter.
- **Mixing, compaction and curing**– Stronger and more durable soil cement will be produced, if the soil-cement water mixture is more intimately mixed. Mixing will, however, result in decreased strength if it is continued long time after the cement hydration has begun.

  It has been observed that better strength and stability develops, if the fined grained soils are compacted wet of optimum water content and the coarse grained soil on the dry side of the OMC. The greater is the compacted density, the stronger and the more durable will be the soil cement. Like concrete, the strength of soil-cement increases with age.

- **Advantages:**

- Decreased cohesiveness (Plasticity)
- Decreased volume expansion or compressibility
- Increased strength (PCA-IS 411, 2003).
- Distribute the loads
- Eliminates Rutting in Base
- Improved constructability of marginal on-site soils and Less susceptible to damaging effect of water
- An all-weather work platform and fast construction techniques.
- Use of on-site soil rather than removal and replacement with expansive select fill material
- Permanent soil modification (does not leach)

- **Disadvantages:**

  - Initial setting time of cement is a major problem during stabilization, as the cement hardens after sometimes when it reacts with water.
  - Dusting is also a problem in soil-cement stabilization as cement particles are fine.
  - Cement reacts with water so rapidly that sometimes due to more humidity in environment, it hardens in its packing bags, hence more cure is to be taken while storing.
  - More percent of cement produces more heat of hydration results in crack development during stabilization.
  - Cement hydration process releases carbon dioxide gas in the atmosphere which is a green house gas, harmful to environment.

- **RBI Grade 81 and Stabilization**

- **General**

It can be termed as "**Road and Building International Grade 81 Stabilizer**". RBI GRADE-81 is calcium driven, inorganic soil stabilizer patented globally used as the additive in soil stabilization without compromising the quality of the result, its specific formulation allows for stabilization of a wide range of materials.

The main components that are used to create RBI GRADE-81 are a series of inorganic hydration activated powders; it is composed of a specific type of cement, a lime, several pozzolonas, rate governing additives, and a unique polypropylene fibers. The specific formulation allows for the uniqueness of the components to contribute to the reaction process and soil stabilization.

The RBI Grade-81 Soil Stabilizer was selected for study which has been certified as cost effective, Eco-friendly, non toxic, non- leaching and suitable for road construction. It reduces pavement thicknesses and reduces aggregate consumption. With the use of RBI Grade-81 technology, not only the above problems are minimized drastically, it is also useful where conventional technologies are not feasible or applicable. The material was tested at IITR (Indian Institute of Toxicology and Research) in Lucknow for toxicity and leach ability and certified as non-toxic and non-leaching.

- **Benefits of RBI Grade-81**

- **Engineering Benefits:**

  - Increases the California Bearing Ratio (CBR) manifolds.
  - Increases Unconfined Compressive Strength (UCS) considerably.
  - Increases Modulus of Elasticity value, which results in decrease of pavements outer layer.
  - Reduces Plasticity Index (PI) value.
  - Reduces Free Swelling Index (FSI) value.

- **General Benefits of RBI Grade-81:**

  - By strengthening the existing soil by 12 to 20 times the initial strength, conventional aggregate layers can be replaced easily with soil stabilized layers, hence saving natural aggregate.
  - Since it modifies any kind of soil and stabilizes it with increased strength, removal and carriage of in-situ soil has been eliminated and replacing it with better soil, suitable for construction works.

- By using treated local soil, transportation of good soil & aggregate reduce by about 40%- 60%, thus reducing the carbon emission from the trucks.
- The treated areas are relatively waterproof, thus preventing damage to the road foundation.
- Due to the reduced construction time, air pollution by heavy suspended particles is reduced noticeably.
- Durability is increased thus the need for maintenance is reduced.
- Requirement of skilled labor is not necessary, as the technology is very simple and easy to apply.
- RBI Grade-81 can also be used for cold recycling of existing pavement layers, thus saving natural resources, as 90% of road material is being reused.
- At an average 19% of construction cost and 40% of construction time can be saved easily by usingRBIGrade81.

III. METHODOLOGY

Sample proportions

S.NO.	MIX PROPORTION
1	LOCAL SOIL
2	Soil+ Lime 2%, Lime 4%, Lime 6%
3	Soil+ Cement 2%, Cement 4%, Cement 6%
4	Soil+ RBI 81 2%, RBI 81 4%,RBI 81 6%

The USCS (Unified Soil Classification System) classifications of the soil strata like black cotton or any other soil are done using suitable technique. To determine the characteristics like Grading by Sieve Analysis, Atterberg's limits i.e. Liquid limit using A. Casagrande Method, Plastic limit by rolling the sample to 3mm diameter thread, Optimum Moisture Content and Maximum Dry Density uses Standard Proctor Test and also California Bearing Ratio by CBR testing machine. The determination of the properties such as liquid limit, plastic limit, optimum moisture content, maximum dry density, CBR value and shear strength for different concentration of admixture with local soil conducting four days soaked CBR Test and Shear using Unconfined Compression Test.

- **Natural Moisture Content [IS 2720 (part II)-1973]**

Moisture Content is defined as the ratio of the mass/weight of water to the mass/weight of soil solids. The methods to determine moisture content in the laboratory are Oven-drying method, Sand bath method, by Pycnometer, Infrared lamp with torsion balance moisture meter, by Alcohol Burning method and by Calcium Carbide method. In laboratory, Oven Dried method is used for determination of moisture

.

- **Wet Sieve Analysis [IS 2720 (Part 4) – 1985]**

The grain size distribution is determined by mechanical sieve analysis. If the percentage fines are more there is a need to conduct wet sieve analysis.

- **Liquid Limit Test [IS 2720 (Part 5) – 1985]**

In order to study the liquid limit of soil, Casagrande test was conducted. Liquid limit is generally determined by the mechanical method using Casagrande's apparatus or the standard liquid limit test apparatus. As per this method the liquid limit is defined as the moisture content at which 25 blows or drops in standard liquid limit apparatus will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specified amount.

- **Plastic Limit Test [IS 2720 (part 5) – 1985]**

In order to study the Atterberg's limit it is important to conduct plastic limit test. Plastic limit (PL) is the water content at which the soil rolled into thread of smallest diameter possible starts crumbling and has a diameter of 3 mm

- **Plasticity Index**

Plasticity Index is a measure of the plasticity of a soil. The plasticity Index is the size of the range of water contents where the soil exhibits plastic properties. It is the difference between the Liquid limit and Plastic limit of soil. Soils with high PI tends to clay, those with low PI of 0 tend to have little or no silt or clay.

- **Specific Gravity Test [IS 2720(part III)-1980]**

Specific Gravity is the ratio of the mass/weight in air of a given volume of dry soil solids to the mass/weight of equal volume of distilled water at 4^0c. It is the important property and is used in calculating void ratio, porosity, degree of saturation. Its value helps upto some extent in identification and classification of soils.

- **California Bearing Ratio (CBR) Test [IS 2720 (Part 16) – 1987]**

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. The CBR determination is a penetration test which measures mainly the resistance of the soil to deformation by shearing. Its principle uses are:

- The design of road pavements with respect to sub grade.
- The prediction of settlements and bearing capacities under embankments and other layers.

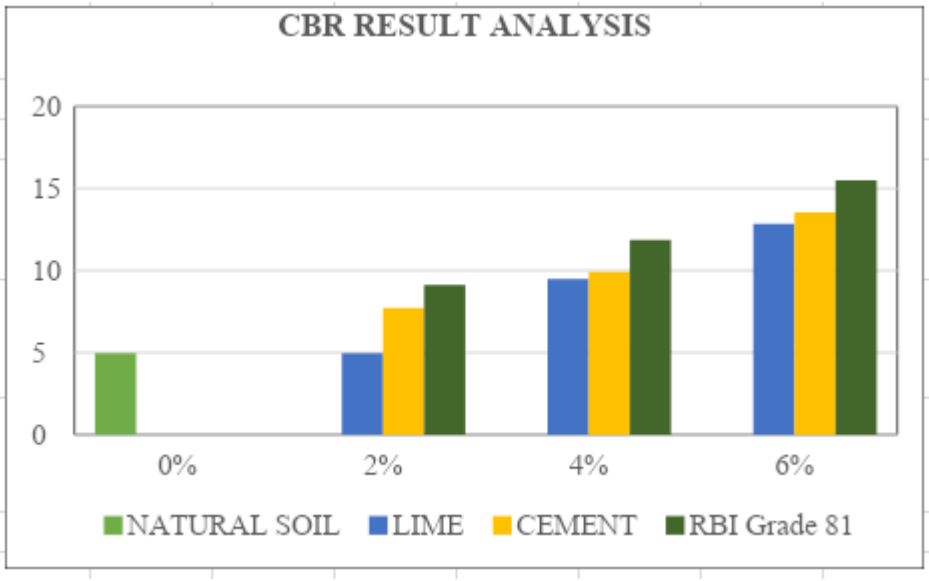
IV.RESULT AND DISCUSSION

On the basis of present experimental study, the following conclusions are drawn,

- Traditional additives like Cement and Lime, can improve soil properties by themselves. Non- traditional additives like RBI Grade 81 can also improve soil properties and are more efficient. Non-traditional additives should be used as soil stabilizer as they provide an economical alternative and also help in less carbon emission.
- RBI Grade 81 is an eco-friendly, cost effective stabilizer which can use with any type of soil whereas cement and lime have their assumptions. No exothermic reaction occurs during stabilization process hence cracks don't occur in the soil.

- **California Bearing Ratio (CBR) Test**

S.NO	**SAMPLE**	**MIX PROPORAYION**			
		0%	**2%**	**4%**	**6%**
1	NATURAL SOIL	4.96			
2	LIME	0	4.96	9.48	12.84
3	CEMENT	0	7.71	9.92	13.55
4	RBI Grade 81	0	9.12	11.87	15.5



➢ COST BENEFIT ANALYSIS

The research aims at assessing the economic viability of using Cement and RBI Grade 81 for subgrade of flexible and rigid pavement in road construction. Lime is not considered in this cost analysis due to its low strength behavior and also it has many disbenefits such as slaking, crack formation etc. For comparison purposes, the optimum quantity of material is taken as 6%, as the highest value of CBR is found when 6% admixture is added in soil. As the high value of CBR shows the higher strength in bearing capacity of soil and also the thickness of pavement is reduced.

➢ Cost analysis of Cement Stabilization

- The approx. cost of Cement Stabilization is found to be Rs. 12,680.
- The approx. cost of Stabilization with RBI Grade 81 is found to be Rs. 11,750.
- Total Saving in cost with respect to cement stabilization (10 m^3) is Rs. 930.
- Percentage of cost reduction in stabilization process = 7.5%
- However, even at this phase, there is considerable lack of knowledge as to what is the most durable and reliable material, and the best technology to be adopted for use for particular soil conditions and related life cycle cost economics. Very limited information is available about soil stabilization, which links up and consolidates theoretical and practical approaches.
- RBI-81 serves to increase the quality of road construction while at the same time eliminating much of the excessive costs associated with this field. RBI Grade-81, through its comprehensive inter-particle matrix due to the complex hydration reactions, irreversibly binds the soil particles into a rigid framework that contributes to the high strength of the stabilised layer. Using RBI Grade-81 decreases the cost of road construction through using in-situ soils at the site of construction, eliminating the requirement to transport masses of soil to the site for use within the road design and decreasing the time required for the project. An RBI Grade-81 stabilised in-situ road eliminates the harmful creation of dust, while producing water resistant all weather surface.

V.CONCLUSIONS

On the basis of experimental study, the following conclusions are found;

- According to the Unified Soil Classification System, the black cotton soil sample has been categorized as OI (Organic clay of medium plasticity)

- There is substantial decrease in Plasticity Index with addition of 2%, 4% and 6% Lime, Cement and RBI Grade 81 by weight. The phenomenon of decreasing liquid limit and increasing plastic limit is seen in Lime and RBI grade 81 whereas in case of Cement both liquid as well as plastic limit decreases.

- The California bearing ratio (CBR) of the soil alone is obtained as 4.96% and it is increased with addition of admixtures, 6% RBI grade 81 has the maximum CBR value when it is cured for 7 days and soaked for 96 hours.

- The percentage increase in CBR value of RBI Grade 81 is, 15.5%, 11.87% and 9.12% with respect to lime whereas 13.55%, 9.92% and 7.71% with respect to cement when added with 2%,4% and 6% respectively.

- From the results, it is concluded that all three admixture (Lime, Cement and RBI Grade 81) has positive impact on soil.

- It is seen that at same dosage, RBI grade 81 is more effective than Lime and cement. It can potentially reduce the ground improvement cost by adopting RBI grade 81 stabilizers.

- It is seen that, at same dosage, RBI Grade 81 is more cost effective than Cement. The cost Benefit Analysis used in this study is an approximate method. Lime is not considered in this cost analysis as lime has low strength behavior than other two admixtures.

REFERENCES

- Dangi. S. Dharmendra, Sharma. Dr. Pramod,(2017) "Laboratory investigation on expansive soil by using RBI Grade 81", IJSRD, Vol. 5, Issue 4.
- Das, Braja M., (2010) "Principles of Geo-Technical Engineering" Cengage Learning, seventh edition.
- Dhakar. Santosh, Jain S.K.,(June, 2016), "Stabilization of Soil using Flyash, Lime and Cement", International Journal of Science and Research, Vol. 5, Issue 6.
- I.S.:2720 part II, (1973) "Indian Standards for methods of test of soil test for determination of water content", Bureau of Indian Standards, New Delhi.
- I.S.:2720 part III, (1980) "Indian Standards for methods of test of soil, test for determination of Specific Gravity", Bureau of Indian Standards, New Delhi.
- I.S.:2720 part IV, (1985) "Indian Standards for methods of test of soil, test for determination of Grain size analysis", Bureau of Indian Standards, New Delhi.
- I.S.:2720 part V, (1985) "Indian Standards for methods of test of soil, test for determination of Atterberg's limit", Bureau of Indian Standards, New Delhi.
- I.S.:2720 part VIII, (1980) "Indian Standards for methods of test of soil, test for determination of Water content/ Dry Density relation using Heavy Compaction", Bureau of Indian Standards, New Delhi.
- I.S.:2720 part XVI, (1987) "Indian Standards for methods of test of soil, test for determination of California Bearing Ratio", Bureau of Indian Standards, New Delhi.
- Jain, P.K., Prakash, Shamsher, (2013)"Engineering Soil testing manual"(2013), Nemchand & Bros publication, Roorkee, Fourth Edition.
- Joe. Adams. M., Rajesh. Maria. A. (2015), " Soil stabilization using industrial waste and Lime" IJSRET, ISSN 2278-0882, Vol. 4, Issue 7.
- K. Kumar P. Shiva, N.K. Darga, (2017), "Effect of RBI Grade 81on strength characteristics of clayey subgrade", International journal of Geo-engineering, Springer publication, Vol. 8, Issue 24.
- Madhurwar K.V., Dahale P.P., Burile A.N.,(2013), " Comparative study of black cotton soil stabilization with RBI Grade 81 and Sodium silicate", IJIRSET, Vol. 2, Issue 2.