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# Design of Flexible Pavements on Expansive Soils

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**ABSTRACT**

*"American roads are good not because America is rich, but America is rich because American roads are good."* **— John F. Kennedy.** India has a road network of over 5,472,144 kilometres (3,400,233 mi) as on 31 March 2015, the second largest road network in the world. Expansive soils are typically clays that demonstrate extensive volume and strength changes at varying moisture content due to their chemical composition. The main causes of premature failures of road pavements is attributed to expansive subgrade soils and poor drainage, leading to severe cracking and heave on road surface. The amount of certain clay minerals that are present, such as montmorillonite and smectite, directly affect the shrink-swell capacity of soil. This ability to drastically change volume can cause damage to existing structures. The aim of this paper is to highlight issues of expansive subgrades & suggest some workable solutions so that highway engineers can improve design and construction methodology of pavement on expansive soils. As per a report, *"Expansive clay soil causes more damage to U.S. commercial and residential property each year than all hurricanes, tornados, earthquakes and floods combined"*.

**Keywords:** Expansive subgrade, soil stabilisation, flexible pavement

Soil is a mixture of minerals, organic matter, gases, liquids, and countless organisms that together support life on Earth. Soil with a high shrink–swell capacity is problematic and is known as expansive soil. As a field study 'Testing of existing Subgrade Soil and its improvement by Stablization using the different additives, was carried out in collaboration with Landmark Material Testing And Research Laboratory Pvt. Ltd., Jaipur. This field study will lead to Modernization of Engineering practice & Business Procedure in PWD" under Rajasthan road sector modernization project funded by world bank. Roads in District Kota were chosen for the said field study/investigation.

## Objectives of the Investigation

In order to use the existing soil to construct the roads, various tests were planned to conduct on existing subgrade soil samples without stabilization and with stabilization using locally available materials like lime, waste of Delhi Cloth Mills (DCM) Fertilizer & combination of waste of DCM Fertilizer with Fly-Ash to achieve the desired parameters suitable for the construction of the road sections.

## Scope of Work

This includes:

- Determination of the engineering properties of original soil to determine its suitability for embankment and sub grade for a road work.
- Determination of the engineering properties of modified soil to make it suitable for the design of embankment and sub grade.
- Design Flexible pavement as per improved CBR of expansive soil (clayey subgrade)

## Laboratory Investigations

Laboratory investigations were conducted on the collected representative samples according to the provisions mentioned in various IS codes (mentioned below) to establish the engineering characteristics of soil Samples. Brief of the tests conducted and the test results obtained are presented herein.

### Physical

Gradation IS: 2720 (Part-IV)

- Atterberg's Limits (IS: 2720 (Part-V))
  - Standard Proctor Test (IS:2720 (Part-VII))
  - California Bearing Ratio, CBR (IS:2720 (Part-XVI))
  - Free Swell Index, (IS:2720 (Part-XL))

### Chemical

- Free Lime content

## District: Kota

This District consist of four different road sections in the Piplada, Ramganj Mandi & Sangod Constituency in Kota District i.e. A/R to Marjhana, Dungrali to Morkhudana, Bhatwada Nayagaon road km 2/100 to Jhamra & Bhonra to Balabhpura. The total lengths of these sections are 13.28 km. This report includes detailed investigation of existing subgrade soil and relevant laboratory tests conducted on representative samples using the Additives i.e. lime, waste of DCM Fertilizer & waste of DCM Fertilizer with Fly-Ash for the improvement of the properties of existing problematic soils using locally available materials.

**Table 1:** Name of the roads in District Kota

| Sl. No. | District | Constituency | Road No. | Road Length (km) | Name of Road |
|---|---|---|---|---|---|
| 1 | Kota | Piplada | 1 | 4.300 | A/R to Marjhana |
| 2 | | Piplada | 2 | 4.430 | Dungrali to Morkhudana |
| 3 | | Ramganj Mandi | 3 | 0.550 | Bhatwara Nayagaon road $km^2/100$ to Jhamra |
| 4 | | Sangod | 4 | 4.000 | Bhonra to Balabhpura |

## Soil Stabilization

In general, soil stabilization is the process of creating or improving certain desired properties in a soil material so as to render it stable and useful for a specific purpose. The improvements in engineering properties due to stabilization include the following:

- Increases in soil strength (shearing resistance), stiffness (resistance to deformation) and durability (wear resistance), reductions in swelling potential or dispersivity (tendency to de-flocculate) of wet clay soils and other desirable characteristics, such as dust proofing and water proofing unsealed roads.
- Stabilization of soil is employed when it is more economical to overcome a deficiency in a readily available material to bring in one that fully complies with the requirements of Specification for the subgrade.

## Lime Stabilization

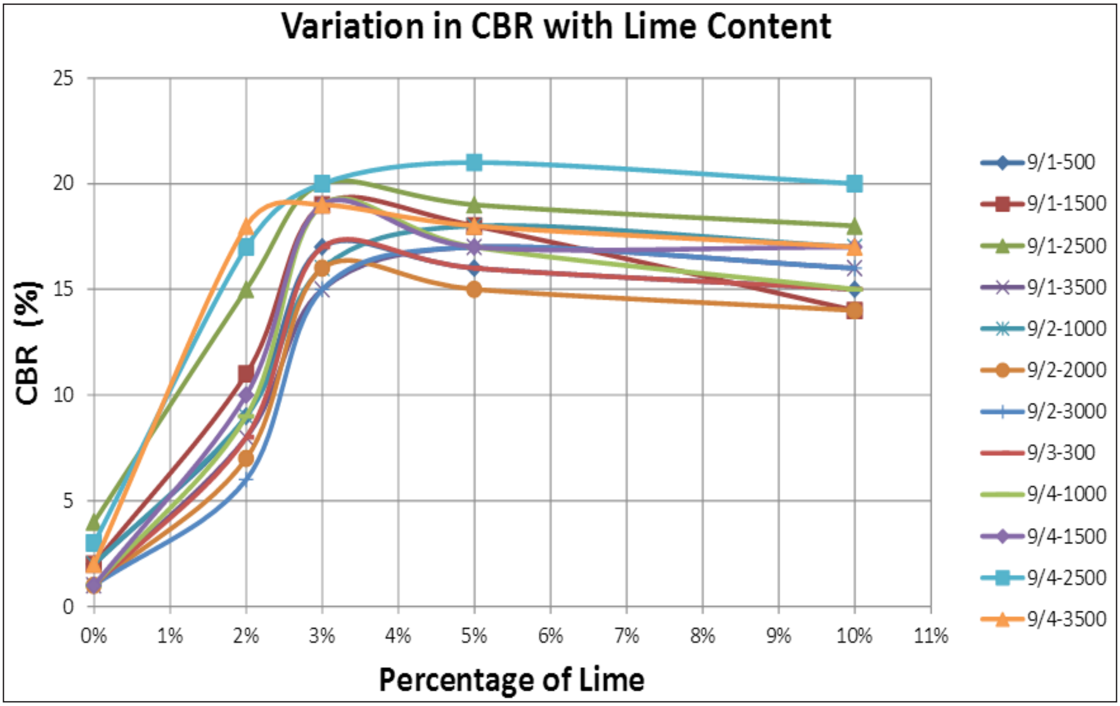
Lime stabilization is one of the oldest processes of improving the engineering properties of Soils and can be used for stabilizing base, sub base & sub grade. The addition of lime to reactive fine-grained soils has beneficial effects on their Engineering properties, including reduction in plasticity and swells potential, improved Workability, increased strength and stiffness, and enhanced durability. It is noticed that 3% Lime gives best results as far as CBR is concerned. Refer Graph 1. Lime can be used to treat soils to varying degrees, depending upon the objective.

- A greater degree of treatment supported by testing, design, and proper construction techniques— produces permanent structural stabilization of soils.
- The determination of the quantity of lime is usually based on an analysis of the effect that different lime percentages have on the reduction of plasticity and the increase in strength of the soil. However, most fine-grained soil can be effectively stabilized with 2%-10% of lime, based on the dry weight of the soil. Lime is used extensively to change the engineering properties of fine-grained soils and the fine-grained fractions of more granular soils. It is most effective in treating plastic clays capable of holding large amounts of water. The particles of such clays have highly negative-charged surfaces that attract free cations (i.e., positive charged ions) and water dipoles.
- The addition of lime to a fine-grained soil in the presence of water initiates several reactions. The two primary reactions, cation exchange and flocculation agglomeration, take place rapidly and produce immediate improvements in soil plasticity, workability, uncured strength, and load-deformation properties.

- The effects of lime treatment can be classified as immediate and long-term. Immediate modification effects are achieved without curing and are of interest primarily during the construction stage. They are attributed to the cation exchange and flocculation–agglomeration reactions that take place when lime is mixed with the soil. Long-term stabilization effects take place during and after curing, and are important from a strength and durability point of view. For lime stabilization to be successful, it is desirable that soil should be lime reactive and to check this 7 days unconfined compressive strength should be more than 3kg/cm$^2$ with lime treatment.

## Stabilization with waste of DCM fertilizer & Flyash

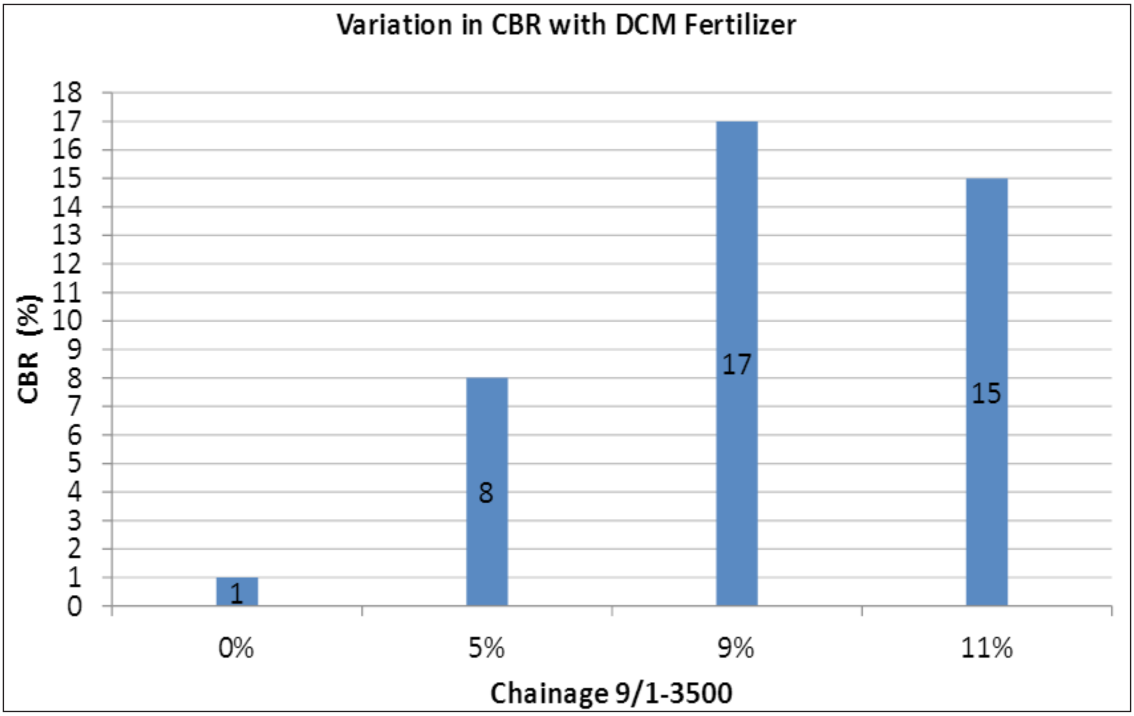
The most fine-grained soil can be effectively stabilized with 5%-11% of waste of DCM fertilizer, based on the dry weight of the soil. Waste of DCM fertilizer is used extensively to improve the engineering properties of fine-grained soils and the fine-grained fractions of more granular soils. The addition of waste of DCM fertilizer to a fine-grained soil in the presence of water initiates several chemical reactions. Some of the soil samples also stabilized with 15% flyash & 5% waste of DCM fertilizer. It improves the properties of soil including CBR. Refer Graph 2.




**Graph 1.**

## Flexible Pavement Design

A flexible, or asphalt pavement typically consists of three or four layers. For a four layer flexible pavement, there is a surface course, base course, and sub-base course constructed over a compacted, natural soil called subgrade. The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed.




**Graph 2.**

Once the CBR is improved by using soil stabilisation, then IRC-37 procedure be followed . Design charts: Based on the fatigue and rutting equations, bituminous pavements can be designed for different subgrade modulus (CBR values).

The amount of volume change that occurs when an expansive soil road bed is exposed to additional moisture depends on the following:

- The dry density of the compacted soil.
- The moisture content.
- Structure of soil and method of compaction.

Therefore extra care should be taken while designing flexible pavements on expansive soils. A proper design incorporating the following measures may considerably minimize the problems associated with expansive soils. Two options are use of Buffer Layer & Blanket course. Computation of effective CBR of sub-grade for pavement design be ensured along with use of rut resistant surface layer and fatigue resistant bottom bituminous layer. Proper selection of surface layer be done to prevent top down cracking. For long life of road, a proper design of drainage layer and system is inescapable requirement.

## CONCLUSION

- For the improvement of properties of clayey soil different combinations of additives which are locally available, were used i.e. Lime, waste of DCM fertilizer & waste of DCM fertilizer combined with flyash.
- In the stabilization of soil with lime, 3% lime content is the optimum quantity at which all the parameters are improved and higher CBR value is achieved. The UCS value of soil after lime treatment is more than 3 $Kg/cm^2$ hence the soil is lime reactive.
- In the stabilization of soil with waste of DCM fertilizer, 9% waste of DCM fertilizer content is the optimum quantity at which desired improvement in the different parameters like CBR value obtained is 17%.
- In the stabilization of soil with combination of 15% Flyash+5% waste of DCM fertilizer, improved soaked CBR value which is obtained is 16%.
- Soils with smectite clay minerals and BC Soil with montmorillonite and bentonite, have the most dramatic shrink-swell capacity with change in moisture content.
- Use of Moorum of low PI as a barrier between subgrade and sub-base has been found effective and does not allow intrusion of soft subgrade soil into the interstices of stone aggregates and ingress of water through it.
- Use of lime-soil stabilization technology has a great potential in expansive soil /subgrades.

## RECOMMENDATIONS

- The existing subgrade soil of all Kota road chainages are having poor soil (Soaked CBR 2%, 2%, 4% & 1%) therefore the soil should be treated with lime.
- Flexible pavement design method involving use of CBR method needs modification due to high swelling characteristics of clayey soil. Rigid pavement construction can be employed to bring out overall economy in expansive soil areas.
- There is a need for providing in detail, the engineering properties/ characteristics of Expansive soil for road construction.
- Some Case studies on expansive subgrade (i.e. in coastal areas with marine clay, black cotton soil etc ) needs to be studied with different traffic, climatic conditions etc. Different methods used in soil stabilisation needs to be tried and performance monitored to arrive at a workable & economical solutions.
- A large number research dedicated to highway engineering on different aspects has been initiated by Central Road Research Institute (CRRI) New Delhi but not much has been done on the adverse affects of expansive soils on life cycle of Flexible Pavement. National Highway Authority of India (NHAI) should also initiate & fund some research projects in collaboration with Indian Institute of Technology (IIT), to find remedial measures to the problem of Expansive soil/ subgrades.

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