“EVALUATION AND ANALYSIS OF SOIL STABILIZATION WITH SOME NON-CONVENTIONAL ADDITIVES”

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

In

TRANSPORTATION ENGINEERING

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DECLARATION

I hereby certify that the work presented in this thesis **entitled "EVALUATION AND ANALYSIS OF SOIL STABILIZATION WITH SOME NON-CONVENTIONAL ADDITIVES"** submitted to the Department of Civil Engineering, Babu Banarasi Das University, Lucknow in partial Fulfilment for the award of degree of **Master Of Technology** in **Transportation Engineering** is an authentic record of my own work carried out during the period **from August 2018 –June 2020** under the own guidance and supervision of **Prof. D.S. Ray.** I have not plagiarized or submitted the same work for the award of any other degree of this or any other university. All the tests were performed in the laboratory.

In case this declaration is found incorrect, I accept that my degree may unconditionally be withdrawn.

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(Poonam Tripathi)

ABSTRACT

Largely, a pavement system consists of a relatively thin surface course, a base course, a sub-base course, and 500 mm thick subgrade layer. Thus, design of a pavement crust thickness necessitates the material properties of layers. Yoder and Witczak [1975] point out that adequate preparation of subgrade is essential for the construction of long-lasting, economical pavement performance.

The work presented in this thesis deals with the strength properties of natural and stabilized subgrade. Quality of subgrade layer is assessed by various strength parameters such as bearing capacity/shear strength, modulus of subgrade reaction, Unconfined compressive strength. These parameters play a crucial role in the design of pavement crust thickness and assessment of quality control/quality assurance of the pavement. These parameters are very essential to estimate for pavement construction and rehabilitation and play a crucial role in the design of pavement crust thickness. In this research work, various laboratory tests were performed for the subgrade having diverse physical characteristics.

Clayey soils are considered the weakest subgrade soil from civil engineering point of view under moist condition. These soils attract and absorb water and losses their strength. Because of this reason certain inherent properties of these clayey soils need modification for their bulk use in construction of highways/ runways pavements.

The main objective of this project is to evaluate the effect of Stabilization on the sub base soil by using different additives. In the present study, different percentages of **SILICA FUME, RECRON 3-S FIBRE** and **TERRASIL** are used separately and combination as stabilizer to improve the sub grade characteristics of locally available soil.

In this project, there will be used all these above-mentioned stabilizers, so that their percentage can play crucial role to stabilize the soil. This will help in increasing the stability of soil mechanically. So, California bearing ratio (CBR) and other strength properties tests will have conducted on soil to check whether the CBR of the taken soil is increasing or not therefore, Increment of CBR value is used to reduce the thickness of the pavement and increasing the bearing capacity of soil. Some materials such Silica fume, Recron 3S fibre and Terrasil may use to make the soil to be stable. Some expecting properties to be improved are liquidity index,

plasticity index, bearing capacity, shear strength, CBR value, unconfined compressive strength etc. Mainly we have focused on increasing the CBR of the soil because on increasing the CBR value it helps in reducing the thickness of the pavement and it is also beneficial to us economically.

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SF	Silica Fume
RF	Recron Fibre
T	Terrasil
CBR	California Bearing Ratio
IRC	Indian Road Congress
MoRTH	Ministry of Road Transport & Highways
MSA	Measured Standard Axle
CVPD	Commercial Vehicle Per Day
VDF	Vehicle Damage Factor
LDF	Lane Distribution Factor

CHAPTER-1

INTRODUCTION

1.1 GENERAL

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it become necessary for the engineers to look at means to improve soil other than replacing the poor soil at building site. Soil stabilization was used but due to the use of obsolete methods and due to the absence of proper technique, soil stabilization lost favour.

In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement. One of the common approaches of subgrade stabilization is to remove the soft and replace it with a stronger material of crushed rock. The high cost of replacing has found forced highway agencies to evaluate alternative method for highway construction on soft subgrade. Pavement performance can be largely attributed to the performance of its foundation, which comprises of the subgrade and base layers. Base and subgrade layers must provide enough shear strength, stiffness modulus, resistance to moisture, stability and durability.

In country like India which is rich in monsoons, moisture becomes a huge problem to roads. Admission of water in rainy season weakens the road soil base. The soil of poor shear strength and high swelling and shrinkage, must be treated by some suitable means mostly soil stabilization and reinforcement are employed to improve mechanical behaviour of soil, thus improving the reliability of construction.

Road Infrastructure plays a significance role in the country's economy by providing efficient and cheapest transport facilities in both developed and developing countries. Pavement is the one of primary element and important component in the road infrastructure, which provides firm surface for smooth, safe and efficient movement of vehicular traffic. Subgrade is the integral part of the pavement system, which plays a major role in providing sound durable surface. Subgrade is defined as a compacted layer naturally occurring local soil or stabilized soil from borrow pits just beneath the pavement crust, providing a suitable foundation for the pavement structure. Subgrade layer should be well compacted at all situations to utilize its full strength to economize on the overall pavement thickness. Subgrade layer play an important role in imparting structural stability to the pavement structure as it receives dynamic transient loads imposed upon it by vehicular traffic. These Traffic loads need to be transmitted in a systematic manner in such a way that the subgrade deformation is to be within the elastic limits, and the shear forces developed are to be within the safe limits under adverse climatic and traffic loading conditions.

1.2 PAVEMENT

A structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade.

1.2.1 TYPES OF PAVEMENT

Pavements are generally categorised into two types on the basis of structural behaviour:

- Flexible Pavement
- Rigid Pavement

1.2.1.1 FLEXIBLE PAVEMENT

These pavements have very less flexural strength and are defined by this characteristic.

These types of pavements transmit the load to the lower layer by grain to grain transfer.

A typical flexible pavement consists of four components:

- Soil subgrade
- Sub base course
- Base course
- Surface course

Fig 1.2.1.1: Layers of Flexible Pavement

1.2.1.2 COMPONENTS OF FLEXIBLE PAVEMENT

- **SOIL SUBGRADE**

Subgrade is the bottom most layer which is nothing but natural soil layer compacted up to required depth generally about 150 to 300 mm to receive the loads coming from top layers. This layer is termed as foundation for the pavement system.

The sub-grade should be strong enough to take the stresses and also it is important to keep the stresses coming from top layers should be within the limit of sub-grade capacity. To reduce the amount of stress on soil sub-grade, provide thick layers of base course, Sub-base course and surface course.

Fig 1.2.1.2: Compacting sub-grade

- **SUB BASE COURSE**

The Sub-base course is provided beneath the base course and it also functions as same as base course. If the sub-grade soil is strong and stiff, then there is no need to sub-base course. Granular aggregates are used to construct sub-base course. If sub-grade is weak minimum 100 mm thick sub-base course should be provided.

Fig 1.2.1.3: Laying sub- base course

- **BASE COURSE**

The base course is important layer of pavement structure and it distributes the loads from top layers to the underneath Subbase and sub-grade layers. It provides structural support for the pavement surface. It is constructed with hard and durable aggregates which may either stabilized or granular or both. The thickness of base course must be great enough to reduce the load capacity on sub-grade and Subbase courses. The minimum base course thickness recommended is 100 mm. sub surface drainage system can be provided with in the base course.

Fig 1.2.1.4: Laying of base- course

- **SURFACE COUSE**

Surface course or wearing course is the top most layer of flexible pavement which has direct contact with the vehicular loads. Since it is directly in contact with traffic, good quality aggregates and high dense bitumen or asphalt is recommended for the construction of surface course. The main function of surface course is to provide skid-resistance surface, friction and drainage for the pavement. It should be water tight against surface water infiltration. The thickness of surface course generally provided is 25 to 50 mm.

Fig 1.2.1.5: Binder course

1.3 PERFORMANCE OF SUBGRADE

A subgrade's performance generally depends on two interrelated characteristics:

1. **Load bearing capacity**: Subgrade must have ability to sustain dynamic loads transmitted from the top layers of the pavement structure. This load bearing capacity is often influenced by degree of compaction, moisture content, and soil type. A subgrade that can support a high amount of loading without excessive deformation is considered good.

2. **Volume change:** Most soils undergo certain amount of volumetric changes due to change in moisture contents as well as variations in temperature conditions. Expansive soils shrink and swell depending upon their moisture content variations, while soils with excessive fines may be susceptible to frost heave in cold regions.

Subgrade comprises of unbound earth materials such as gravel, sand, silt and, clay that influence on the structural capacity of the pavement system. The quality of the Pavement depends largely on the strength and shear characteristics of subgrade material. The assessment of physical and strength properties of soil subgrade are vital in design, construction, and maintenance phases of the pavement structure. Therefore, to perform optimistic Pavement design, an accurate and representative material characterization technique is essential; such technique would be more acceptable in developing countries like India if it is simple, rapid and economic.

1.3.1 FACTORS AFFECTING THE DESIGN OF PAVEMENTS:

- Design wheel load
- Subgrade soil
- Climatic factors
- Pavement component materials
- Environmental factors
- Special factors in the design of different types of pavements.

1.4 SOIL

Soil is an important component in any type of civil engineering construction. Developing countries like India need good infrastructure like roadways, railways, buildings, power supplies etc, for their development. India has expansive soils in many parts of the country and it becomes challenging to construct stable structures in such conditions. Thus, it becomes imperative to improve the soil properties to make it suitable for accepting structures. Depending upon the soil type that need to be stabilized and different types of additives are suggested. Soils are complex mixtures of minerals, water, air, organic matter, and countless organisms. Various types of soil available in India like alluvial soils, black cotton soils, laterites soils, mountain soils, desert soils, red soils. Soil is the upper most part of earth and it is cheapest and readily available construction material. Soil is generally categorizing into four basic types (such as): Gravel, Sand, Clay and Silt. Out of them, few possess montmorillonite in high amount resulting in sudden swelling and shrinkage upon contact with water. Such soils are not useful in construction directly but can be made useful after their stabilisation. Soil stabilisation is used for foundation, embankment and highway construction, airport and village roads to highways or expressway. Soil stabilisation improves the bearing capacity, compressibility, strength, and other properties of soil. Soil stabilisation is the popular method of soil improvement. From the beginning of construction work, the necessity of enhancing soil properties has come to the light.

Expansive soils: Expansive soils also known as swelling soils or shrink-swell soils are the terms applied to those soils, which tend to swell and shrink with the variation in moisture content. Because of which significant distress in the soil occurs, causing severe damage to the overlying structure. During monsoon’s, these soils imbibe water, swell, become soft and their capacity to bear water is reduced, while in drier seasons, these soils shrinks and become harder due to evaporation of water. These types of soils are generally found in arid and semiarid regions of the world and are considered as a potential natural hazard, which if not treated well can cause extensive damages to not only to the structures built upon them but also can cause loss of human life. Soils containing the clay minerals montmorillonite generally exhibit these properties. The annual cost of damage to the civil engineering structures caused by these soils are estimated to be ₤ 150 million in the U.K., $ 1,000 million in the U.S. and many billions of dollars worldwide. Expansive soils also called as Black soils or Black cotton soils and Regular soils are mainly found over the Deccan lava tract (Deccan Trap) including Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and in some parts of Odisha, in the Indian sub-continent. Black cotton soils are also found in river valley of Tapi, Krishna, Godavari and Narmada. In the the north -western part of Deccan Plateau and in the upper parts of Krishna and Godavari, the depth of black soil is very large. Basically, these soils are residual soils left at the place of their formation after chemical decomposition of the rocks such as basalt and trap. Also, these types of soils are formed due to the weathering of igneous rocks and the cooling of lava after a volcanic eruption. These soils are rich in lime, iron, magnesia and alumina but lack in the phosphorus, nitrogen and organic matter. 3 Their colour varies from black to chestnut brown, and basically consists of high percentage of clay sized particles. On an average, 20% of the total land area of our country is covered with expansive soils. Because of their moisture retentiveness, these soils are suitable for dry farming and are suitable for growing cottons, cereals, rice, wheat, jowar, oilseeds, citrus fruits and vegetables, tobacco and sugarcane.

1.5 SOIL STABILIZATION

Soil stabilization is a process of treating a soil in such a manner as to maintain, alter or improve the performance of the soil as a road construction material. Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

Fig. 1.5: Soil Stabilization

Stabilization is technique of improving characteristics of native soil or granular material used for construction of pavement layers. Soil Stabilization is required where the road alignment passing through poor soil sub grade does not comply with the engineering properties as per any given standard specification. Stabilization of soil is employed for modifying the properties of soil to improve its engineering performance, both in terms of its strength and durability. Stabilization technique controls the unwanted properties in the sub grade soil such as, excessive compressibility, permeability, frost susceptibility, settlement, volume change, etc.

1.5.1 MECHANISM OF SOIL STABILIZATION

1. Evaluating the properties of given soil

2. Deciding the lacking property of soil and choose effective and economical method of soil stabilization

3. Designing the Stabilized soil mix for intended stability and durability values

Based on the above principles, the various technique of soil Stabilization may be grouped as follows:

1. **Proportioning Technique-**The native material is sieved and blended with other good borrowed material to meet the standard gradation and agency prescribed test values. If the basic test values do not meet the standards, a suitable admixture is added to the graded soil mixture.

2. **Cementing Agents-**Cement, lime and fly ash in combination with cement or lime are used commonly as stabilizing agents. Bituminous emulsions and cutbacks may be used for blinding non-cohesive soil.

3. **Modifying Agents**-If stabilizer added in small proportion could modify the undesirable properties of certain soil i.e. Atterberg's limits making them more useful as construction material, such stabilizer may be called as Modifiers.

4. **Moisture / Water Proofing Agents**-The agents may consist of certain types of bituminous materials including some kinds of resinous materials (such as polyvinyl acetate liquids) which provide stability to the soil mixture including water repelling capability. Membrane blankets such as single or double bituminous surface layer may be placed as the interlayer, above the stabilized base course Membrane treatment is considered as most efficient method of waterproofing, despite its high cost.

5. **Water Repelling Agents**-Almost the same function as water proofing agents may be performed by some water repelling or retarding agents like Vinsol Resin and other resinous materials.

6. **Moisture Retaining Agents**-Calcium chloride, sodium chloride and other chemicals are used mix with soil or granular material to retain certain amount of moisture or absorb moisture from atmosphere as dust palliative.

7. **Heat Treatment**-Thermal Stabilization has different useful aspect with regards to clayey soils. They are desirable for reduction in swelling properties and heat treated soil may be used as a soft aggregate in mechanical soil Stabilization. Comparative Study of Soil Stabilization with Widely used Admixtures Like Lime, Cement, Fly-ash and Bitumen Emulsion

8. **Chemical Stabilization**- Calcium acrylate, sulphite lignin and other applicable chemicals may be suitably explored to use for Stabilization based on their availability nearby at low cost. For example-organic cationic compounds that induce hydrophobic nature to the stabilized soil.

1.5.2 NEEDS AND ADVANTAGES OF SOIL STABILIZATION

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil which makes it easier to predict the load bearing capacity of the soil and even improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids. Thus, it is better to mix different types of soils together to improve the soil strength properties.

1.It improves the strength of the soil, thus, increasing the soil bearing capacity.

2.It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.

3.It is also used to provide more stability to the soil in slopes or other such places.

4.Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.

5.Stabilization is also done for soil water-proofing; this prevents water from entering the soil and hence helps the soil from losing its strength.

6.It helps in reducing the soil volume change due to change in temperature or moisture content.

7.Stabilization improves the workability and the durability of the soil.

1.5.3 METHODS OF SOIL STABILIZATION

There are 3 main methods for soil stabilisation:

1.Mechanical stabilisation

This category consists of physical processes such as compacting or tamping with machineries including rollers or rammers. The mechanical soil stabilisation is also achieved by blending (adding or removing) different soil particles to obtain effective distribution of soil particle. These techniques are usually used for sub-base and base courses.

2. Chemical Stabilisation

As the name suggests, stabilisation of soils depends on the chemical reaction between the chemical/stabiliser used and the soil particle composition. These include, Cement, Lime, Magnesium Chloride, Bitumen Emulsion and Fly Ash among others.

Traditionally and widely practiced type of soil stabilisation techniques include:

1.Bitumen Emulsion

Bitumen emulsion is used as a binding agent both cohesive as well as non-cohesive soils. However, in soils with finer grain sizes, this method may no longer be cost effective as the soil particles require a high dosage of bitumen emulsion in order to provide the same/better level of bonding. Bitumen emulsion is not environmentally friendly and becomes brittle when it dries, which affects the stability of the soil.

ii.Cement/Lime

Cement/Lime is widely used as a soil stabilising agent. Addition of cement to soil improves the strength of the soil. It is used for the sub-base and base courses of all types of pavement. However, due to the consequent wet and dry cycles, there occurs a degradation of the bonding between the cement and soil particles. Also, this is a very costly in terms of financial viability. Lime stabilisation improves the strength of the soil by imparting increased bonding between the lime and soil particles. This method is cost effective as compared to cement stabilisation.

iii. Apart from the above-mentioned stabilising agents, some other alternatives currently in practice include Fly Ash, Cement Kiln Dust (CKD), Tree Resin and Ionic Stabilizers.

3. Polymer Stabilisation

Polymer soil stabilization refers to the addition of polymers to improve the physical & engineering properties of soils (Polymer Soil Stabilisation, 2019). Polymers tend to increase the strength of the soil through their interaction with clayey particles present in the soil. Many polymers currently used, tend to increase the water retention capability and the shear strength of the soil. Polymers used for soil stabilisation can be classified into two main categories viz. Biopolymers and Synthetic Polymers. Biopolymers are eco-friendly as compared to other chemical soil stabilisers.

1.5.4 RESEARCH OBJECTIVES

1. To improve the strength of sub-bases, bases and sometimes surface courses, in case of low cost roads.

2. To bring about economy in the cost of road.

4. To improve certain undesirable properties of soils, such as excessive swelling or shrinkage, high plasticity, difficulty in compacting etc.

5. To facilitate compaction and increase load-bearing capacity

6. To reduce compressibility and thereby settlements.

7. To improve permeability characteristics.

8.To evaluate the effects of additive on preliminary properties (OMC, MDD, CBR, UCS) of soils.

CHAPTER -2

LITERATURE REVIEW

GENERAL

Soil stabilization is a process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest sense, stabilization includes compaction, pre-consolidation, drainage and many other such processes. However, the term stabilization is generally restricted to the processes which alter the soil material itself for improvement of its properties. A cementing material or a chemical is added to a natural soil for the purpose of soil stabilization. The stabilization mechanism may vary widely from the formation of new compounds binding the finer soil particles to coating particle surfaces by the additive to limit the moisture sensitivity. Therefore, a basic understanding of the stabilization mechanisms involved with each additive is required before selecting an effective stabilizer suited for a specific application. Stabilization projects are site specific and require integration of standard test methods, analysis procedures and design steps to develop acceptable solutions. Many variables should be considered in soil treatment, especially if the treatment is performed with the intent of providing a long-term effect on soil properties. Soil-stabilizer interactions vary with soil type and so does the extent of improvement in soil properties. Hence developing a common procedure applicable for all types of stabilizers is not practical (Little and Nair).

Some of these studies have been reported in the following review of literature.

Ekrem Kalkan (2008)[4] studied about the influence of silica fume on the desiccation cracks of compacted clayey soils. The aim of this study is to examine the suitability of silica fume as a stabilization material to reduce the development of desiccation cracks in compacted clayey soils. The amounts of silica fume were selected to be 5%,10%,15%,20%,25%,30% and 50% of the total dry weight of the clay soil–silica fume mixtures. Natural clayey soil and clayey soil–silica fume mixtures were compacted at the optimum moisture content and subjected to laboratory tests. In each sample, it was observed that reduction in the development of desiccation cracks occurred with increasing silica fume content between 0 and 25%. The results show that silica fume decreases the development of desiccation cracks on the surface of compacted samples. It is concluded that silica fume waste material can be successfully used to reduce the development of desiccation cracks in compacted clayey soil.

Muhammad Nawazish Husain et al (2009) studied the Application of Recron 3S Fibre in Improving Silty Subgrade Behaviour. The objective of the present paper is to check the usefulness of Recron 3S fibre in improving soil subgrade strength of local silty soil of Kurukshetra. For this purpose, a series of experiments were conducted which include Modified Proctor Compaction, California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) tests. A total of four samples of soil - fibre mixture were made with fibre content as 0.15%, 0.30%, 0.45% and 0.60% of dry weight of soil. Other tests for index and physical properties like Atterberg's limits, Specific gravity and sieve analysis of parent soil were also carried out. Experimental results revealed that addition of Recron-3S fibre increases the CBR and UCS value of the silty soil. From the results, it is also observed that benefit is more appreciable at lower percentage of Recron 3-S fibre i.e. 0.15% as compared to higher percentage.

Ekrem Kalkan (2011)[5] The basic objectives of this research are to investigate the modification of an expansive clayey soil using a by-product material and to evaluate the effect of drying and wetting cycles on the swelling characteristics of the modified expansive clayey soil. Expensive clay soils contain silicate clay minerals that have the potential for swelling and shrinkage under changing moisture contents. To reduce the effects of cyclic wetting–drying phenomena, it is essential to modify these soils by stabilization techniques. For this purpose, expansive clayey soil samples have been modified using silica fume waste material. The amounts of silica fume were selected to be 10%,20%, 25% and 30% of the total dry weight of the clay soil–silica fume mixtures. and the effects of wetting and drying cycles on swelling behaviour of modified expansive clayey soils have been investigated under laboratory conditions. The results show that silica fume decreases the progressive deformation of modified 0expansive clayey soils subjected to cyclic drying and wetting.

Prof. R.K Sharma (2012) the paper "Subgrade Characteristics of Locally Available Soil Mixed with Fly Ash and Randomly Distributed Fibres" shows the extensive soils cause loads of structural designing structural harm, especially to low-climb structures. Certain inborn properties of these broad soils need alteration for their mass use in the development of expressways/runway asphalts, banks, and so forth. He states the consequences of examination on the conduct of sweeping soil changed with fly fiery remains, and mix of soil, fly powder and Recron 3S fibre of 12mm length. The properties like grain size dissemination, dampness thickness connection and CBR are mulled over for soil mixed with fly slag in the scope of

20-80%. The mixture of soil with 30% fly fiery debris was chosen for further adjustment with fibre content in the scope of 0.5-1.5%. The properties of dampness thickness connection and CBR are assessed.

Ekrem Kalkan (2013)[6] The main objective of this paper is to investigate the use of waste materials such as silica fume and scrap tire rubber fibre in geotechnical applications and to evaluate the effects of scrap tire rubber fibre and scrap tire rubber fibre–silica fume mixture on the unconfined compressive strength (UCS) and swelling pressure of clayey soils. The amount of silica fume was selected 10 and 20%, In the same way, the contents of scrap tire rubber fibre were chosen as 1, 2, 3 and 4% by total weight of mixtures. The results of experimental research indicated that silica fume, fibre and silica fume–fibre mixture modification enhanced both the unconfined compression strength and strength parameters. Consequently, it is concluded that the silica fume–fibre mixture materials can be successfully used for the modifications of clayey soils in the geotechnical applications.

Nandan A. Patel,C. B. Mishra (2013)[19] studied about the Recron-3s Fibre is used as the stabilizers in improving engineering properties soil. This experiment evaluates the effect of the Recron-3s on some basic engineering properties of soil by using varied proportion of Recron- 3s fibre from 0.5% to 2.0%. Four proportion of recron-3s fibre i.e. 0.5%, 1.0%, 1.5% and 2.0% were used to quantify the optimum quantity of Recron-3s on the performance in terms of CBR value and UCS of the soil. the value of CBR of sample increases with increase in addition of Recron-3s up to 1%, and further increase in Recron-3s results in to decrement in CBR value.

Nandan A.Patel, Prof.C. B. Mishra(2015)[20] The examination was completed to focus on soil engineering properties (with and without stabilizer), standard compaction; four days soaked California Bearing Ratio (CBR), permeability test and cyclic loading test according to codal procurement. A concoction named Terrasil was utilized as stabilizer and it was utilized for altered measurement i.e. 0.041% by dry aggregate weight of soil.

Nandan A. Patel, C. B. Mishra (2015)[21] studied on Subgrade Soil Stabilization using Chemical Additives”. It is found that the addition of Terrasil (0.041%) + zycobond (0.020%) to the soil the CBR value increased from 6.64% to 12.15%. This signifies that the quality of subgrade soil is enhanced consequently expanding the load carrying limit of pavement.

Rintu Johnson1, Dr. Kodi Rangaswamy (2015)[24] The soil was collected from Kunnamangalam area of Calicut district in Kerala and the Terrasil Nano-chemical was collected from Zydex, Industries Ltd. for the stabilisation studies. Experimental programme was carried out on both clay and cement treated clay treated with different dosages of Terrasil. Specimens were prepared with 0.05%, 0.07% and 0.09% Terrasil and 1% cement by weight of soil. Results obtained were compared and studied. The CBR strength of soil mixed with optimum dosage of 0.07% terrasil chemical is improved about 6 times the CBR strength of clay soil. The treated soil was found to be impermeable.

P. Sai Venkata Bharath1, K. Jyothi Raju (2016)[23] This paper includes the evaluation of soil properties like compaction and California Bearing Ratio (CBR) test. Detailed experimental study has been undertaken to investigate the characteristics and behaviour of expansive soil mixed with Quarry Dust and Recron-3S fibres with different percentage. From the experimental results, it has been observed that various properties of soil added with these stabilizers at certain percentage show remarkable positive changes as compared to the natural soil. The value of compaction parameters has increased enabling increase California Bearing Ratio which indicates that improved in strength. From these results, it was found that optimum Quarry Dust and Recron-3S fibres 20% and 1.5% respectively gives the maximum increment in the CBR compared with all the other combinations.

Ansu Thomas, R. k. Tripathi (2016)[2] In this study, an attempt has been made to study the improvement in the properties of a soft soil collected from village Arasnara, Durg district of Chhattisgarh, India, stabilized with Terrasil. Various laboratory tests have been conducted on un-stabilized and stabilized soil samples and the results are compared and discussed. Different dosages of Terrasil have been used and evaluated the effect on optimum moisture content, maximum dry density, plasticity index and Unconfined Compressive Strength (UCS). Effect of curing period on UCS has also been studied. Significant improvement in properties of soil is observed.

A.R.Goodarzia, H.R.Akbaria (2016)[3] The present study investigated the potential use and effectiveness of expansive clay stabilization using admixture of cement and silica fume (CSF) as a possibly useful option from environmental, economic, and (or) technical perspectives. In so doing, cement and CSF blend with 10% cement replacement were separately added to a clay sample having high degree of swelling potential. The incorporation of silica fume in to the cement matrix extends the formation of new cementing compounds and provides a much denser micro structure, were found to be very effective in surpassing the problems associated with expansive clays. Adding 10% CSF within 14 days of curing increases the compressive strength of the clay.

Jesna Varghese, Remya.U. R (2016)[17] indicated that reinforced soil with fibre has following properties- The relationship between optimum moisture content and maximum dry density of soil significantly affected by the addition of polypropylene fibre. During the study, MDD increases with decreasing OMC. From unconfined compressive test, it was observed that the unconfined compressive strength value of untreated soil was found to be 15.1 KN/m2 and the strength value increased with increase in addition of polypropylene fibre up to 0.05% and then decreases. There is an increase of strength of about 454.37%. That may be due to increase in interfacial shear strength at 0.05 %. For higher amount of polypropylene fibre.

Kolla Ashwani Chandh et al (2016)[18] studied on the Effect of Fibre on Non-Swelling Sub Grade Layer. In this study, Recron 3s fibre is mixed with soil to investigate the relative strength gain in terms of bearing capacity and compaction. The effect of fibre on the geotechnical characteristics of soil-fibre mixture was investigated by conducting standard Proctor compaction tests, CBR tests and permeability test. The tests were performed as per Indian Standard specifications. The materials were used for preparing the samples are Soil & Fibre. The soil used for these experiments was brought from a site, in our college. The physical properties of the soil were determined as per IS specifications. In this test programme, without additives clay was tested to find the optimum moisture content, CBR value and plasticity index. Fibre is added in varying percentages and that fraction for which maximum strength is obtained was found out. These experiments resulted in decreasing the sub-grade thickness to 50% 0f the actual thickness required, thereby reducing the cost of construction.

Siyyagalla Subbarayudu, S. Rozwana (2017)[28] In this project, we are going to stabilize the soil by using recron-3s, fly-ash and lime. Here we are using recron-3S as (1%,2%,) lime (2%,3%,4%) and fly ash at (10%,12%,15%,20%). With different proportion of soil with additive materials California bearing ratio value will be more compare to conventional materials. And from that thickness of pavement can be minimized to a certain extent. By adding Recron-3s, 1% CBR value of soil increased and further increasing Recron-3s, CBR value decreased.

Tripti Goyal, Er. Rubel Sharma (2018)[30] The research was focused on to improve the strength of soil and to obtain an optimum amount of soil-fly ash-recron-3s mix. The proportions used of fly ash were 10, 15, 20, 30, 40 and 50% and recron-3s was in 0.2, 0.4, 0.6, 0.8 and 1.0% in amount by weight. From the experimental results, it was concluded that recron-3s work as reinforcing the material and provides strength to the soil as well as fly ash worked as cementing material. The preeminent proportion obtained was 84.2% soil – 15% fly ash – 0.8% recron-3s fibre.

CHAPTER-3
MATERIAL USED

3.1 OVERVIEW

In this chapter, we will explain about the materials used to stabilize the soil like Silica-Fume, Recron -3S Fibre and Terrasil. We are also going to check which among the above-mentioned stabilizers is best suited for soil stabilization.

3.2 MATERIALS:

3.2.1 CLAYEY SOIL

To study the behaviour of clayey soil with Silica fume, Recron 3-S fibre and Terrasil. A sample of clayey sub-grade soil is collected from **Krishna Nagar, Lucknow.** According to IS soil classification system, the soil was classified as a medium plastic clay (MI). The index properties of soil are determined as per Indian standard test procedure.

Fig. 3.2.1: Soil Sample

Table 3.2.1: Soil Characteristics

Properties	Description
Liquid limit (%)	30
Plastic limit (%)	21
Plasticity Index (%)	9
Soil Classification	CI
Optimum moisture content (%)	14
Maximum dry density (gm/cc)	1.84
Soaked CBR (%)	5.03

3.2.2 SILICA FUME

Silica fume, also known as Micro Silica, is an ultrafine powder collected as a by-product of silicon metal and ferrosilicon alloy production. It is a pozzolonic material which has a high content of amorphous silicon dioxide and consists of very fine spherical particles. It is available in grey to off-white colours. The particles of SF are 100 to150 times smaller than the cement grains. It is one of the most valuable by-product pozzolonic materials due to its very active and high pozzolonic property. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolana. The current research shows the effective utilization of micro silica fume in the improvement of sub grade characteristics of expansive soil. Micro silica fume improves compressive strength, bond strength and reduce permeability.

Advantages of Using Silica Fume

- High early compressive strength
- High tensile flexural strength
- Very low permeability
- Enhanced durability
- Superior resistance to chemical attack from chlorides, acids, nitrates and sulphates and life-cycle cost efficiencies
- Higher bond strength
- High electrical resistivity and low permeability

Table 3.2.2(a): Physical Properties of Silica fume

Properties	**Description**
Colour	Light to dark grey
Specific gravity	2.2
Particle size	<1mµ
Specific surface	15000-30000m2/kg
Bulk density -Undensified -Densified	 130-430kg/m3 480-720kg/m3

Fig. 3.2.2: Silica fume

Table 3.2.2(b): Chemical composition of Silica fume

Compound	**Value (%)**
SiO_2	85-95
Al_2O_3	1-3
Fe_2O_3	0.5-1
CaO	0.8-1.2
MgO	1-2
Loss on Ignition	0.5-1

Shelf life: Shelf life Minimum 3 years if stored properly in its original bag in dry place.

Storage: Dry, Shaded place

3.2.3 RECRON 3-S FIBRE

Recron-3S is most commonly used synthetic fibre due to its low cost, hydrophobic nature, chemically inert and does not allow reaction with soil moisture. It has a variety of advantageous engineering properties such as resistance to fatigue, physical damage and freezing, as well as being unusually resistant to many chemical solvents, bases and acids. Use of Recron-3S as a reinforcing material is to increase the performance in terms of strength of soil also it enhances flexibility in operation, easy to use and reduces permeability. Recron-3s is also available in different sizes as 6 mm, 12 mm and 24 mm. The fibre used in this study of length 12 mm and it was manufacture by Reliance industries. The recron-3s fibre is made from polymerization of pure Terapthalic acid and Mono Ethylene Glycol using a catalyst. It is a polypropylene fibre which is a stabilizer to improve CBR values. Recron-3S fibres are mixed in soil uniformly to get appropriate strength. Enhanced the unconfined compressive strength (UCS) of the soil and reduced both volumetric shrinkage strains and swell pressures of the clays.Fibres are randomly mixed in soil due to the fact for making a homogeneous mass and maintaining the isotropy in strength.

Table3.2.3: Properties of Recron 3-S fibre

Properties	**Description**
Colour	White
Length	12mm
Unit length	0.91g/cm^3
Tensile strength	4000-6000kg/cm^2
Water absorption	85.22%
Acid resistance	Excellent
Alkali resistance	Good

Fig. 3.2.3: Recron 3-S Fibre

Handling: Normal handling and processing does not require special technical protective measures.

Storage: Store at ambient temperatures. Bags must be stored in line with existing provisions. Existing fire protection provisions must be observed. Do not store near flame, ignition sources, direct sunlight or incompatible materials.

3.2.4 TERRASIL

Terrasil is nanotechnology based product produced by Zydex Industries Ltd., Gujarat. It is defined as an organo-silane compound which reacts with soil particles and converts them (all types of soils) from water loving (Hydrophilic polar) to water hating (Hydrophobic nonpolar) particles. This makes the soil insensitive to water and can be compacted to give better interlocking to the soil particles. It offers or forms a permanent water repellent nano-layer on all types of soils, aggregates etc. Terrasil is water soluble, ultra violet and heat stable, reactive soil modifier. It forms strong covalent bond structure allows the treated material to breathe i.e. It allows free flow of air through its structure and preserves thermal insulation property. It improves the frictional value, reduces water permeability and maintains breathability of the soil layer. Terrasil prevents damage due to capillary rise of water, cracking of soil. Terrasil nano-chemical is environmental friendly. It forms Si-O-Si bonded nano-siliconize surfaces in soil by converting water loving Silanol groups to water repellent Alkyl Siloxane groups.

Terrasil chemical is emerging as a new material for the stabilization of soil. Terrasil is nanotechnology based 100 percent organosilane, water soluble, ultraviolet and heat stable, reactive soil modifier to waterproof soil subgrade. It reacts with water loving silanol groups of sand, silt, clay and aggregates to convert it to highly stable water repellent alkyl Siloxane bonds and forms a breathable in-situ membrane. It resolves the critical sub-surface issues. It is water soluble, chemically reactive and non-leachable and works well with all silicate containing materials. It can be applied to almost all types of soil. Terrasil being a Nano modification keeps the pores open to allow vapours to escape while preventing water to come in. Nano-chemicals can be identified as environmental friendly since they conserve limiting resources like aggregates and bitumen. They also allow the use of in-situ soils minimizing use of fuel for transporting good soils over long distances.

Table 3.2.4(a): Physical properties of Terrasil.

Properties	**Description**
Appearance	Pale yellow liquid
Density	1.01g/ml
Viscosity at 25°C	20-100 Cp
Solubility	Forms water clear solution
Flash Point	>80° C
Freezing Point	5° C

Fig. 3.2.4: Terrasil

Table 3.2.4(b): Chemical composition of Terrasil

Chemical compound	**Value (%)**
Hydroxyalkyl-Alkoxy-Alkylsil	65-70%
Benzyl alcohol	25-27%
Ethylene glycol	3-5%

Benefits:

1. The treated soil has permanent hydrophobic properties.
2. CBR values are increased.
3. Swelling is reduced
4. Improves the Resilient Module.
5. It is possible to reduce the water consumption necessary for compacting the material.

SHELF LIFE: Its shelf life is 48 months

STORAGE: Store Terrasil+ between 41-113 °F (5 – 45 °C) in a shaded, dry area away from sunlight, heat, source of sparks, rain and standing water.

Water

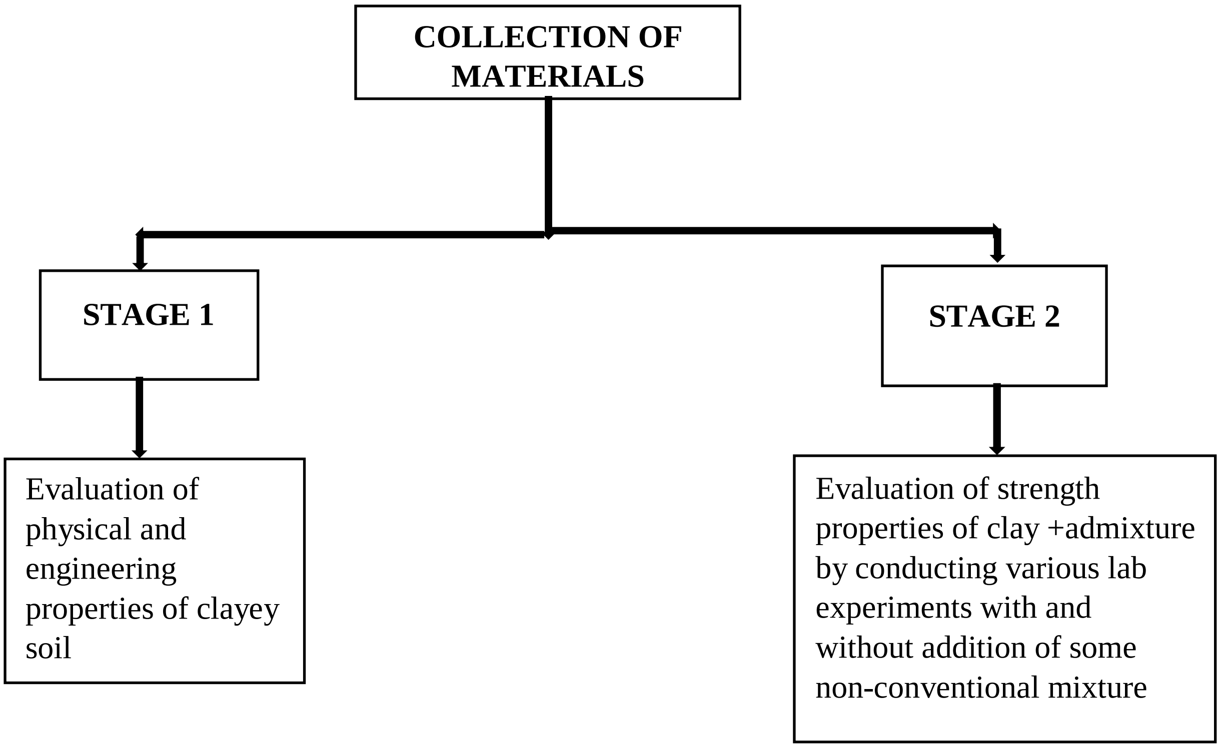
Potable tap water is used for experimental works.

CHAPTER-4

METHODOLOGY

4.1 Overview

The present dissertation work has been carried out in two stages as depicted in Figure and details are discussed below.



4.2 TESTS FOR SOIL

4.2.1 Sieve analysis,

4.2.2 Atterberg limit (Liquid Limit, Plastic Limit),

4.2.3 Standard Proctor Test,

4.2.4 California bearing ratio (CBR) Test.

4.2.1 SIEVE ANALYSIS:

OBJECTIVE: Obtain percentage of soil retained on each sieve.

APPARATUS:

- Stack of test sieves
- Balance (with accuracy to 0.01g)
- Rubber pestle and mortar (for crushing the test material if lumped or conglomerated)
- Sieve shaker
- Oven.

The balance to be used must be sensitive to the extent of 0.1% of total weight of sample taken.

I.S 460-1962 are to used. The sieves for soil tests: 4.75 mm to 75 microns.

Fig. 4.2.1: Sieves

PROCEDURE

The proportion of soil sample retained on 75 microns I.S sieve is weighed and recorded weight of soil sample is as per I.S 2720.

Step 1: Take a representative oven-dried sample that weighs approximately 500g.

Step 2: If particles are lumped or conglomerated, crush the lumps but not the particles using the pestle and mortar.

Step 3: Determine the mass of sample accurately – Weight (g).

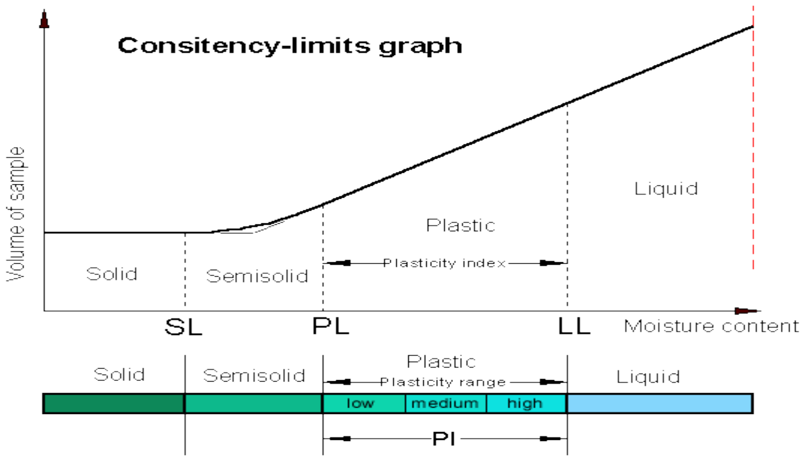
Step 4: Prepare a stack of test sieves. The sieves are stacked in order, with the largest aperture size at the top, and the smallest at the bottom. A receiver is placed under all of the sieves to collect samples.

Step 5: Weigh all the sieves and the pan separately.

Step 6: Pour the samples from step 3 into top of the stack of sieves and put the lid on, place the stack in the sieve shaker and fix the clamps, adjust the timer to between 10 and 15 minutes, and switch on the shaker.

Step 7: Stop the sieve shaker and measure the mass of each sieve and retained soil/material.

4.2.2 ATTERBERG LIMIT: The water contents at which the consistency changes from one state to the other are called **consistency limits** (or **Atterberg limits**).



a) LIQUID LIMIT TEST:

OBJECTIVE: To determine the value of the liquid limit of a soil sample.

DEFINITION: Liquid limit is the water content at which soil changes from liquid to plastic state.

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from liquid state to plastic state.

APPARATUS REQUIRED

- Balance
- Casagrande (Liquid limit device)
- Grooving tool
- Evaporating dish
- Spatula
- Electrical Oven
- Squeeze Bottle

Fig. 4.2.2(a): Liquid Limit Test Device

PROCEDURE

1. Put 250 gm of air-dried soil, passed thorough 425 mm sieve, into an evaporating dish. Add distilled water into the soil and mix it thoroughly to form uniform paste. (The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.)
2. Place a portion of the paste in the cup of Liquid Limit device and spread it with a few strokes of spatula.
3. Trim it to a depth of 1 cm at the point of maximum thickness and return excess of soil to the dish.
4. Using the grooving tool, cut a groove along the centre line of soil pat in the cup, so that clean sharp groove of proper dimension (11 mm wide at top, 2 mm at bottom, and 8 mm deep) is formed.
5. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake meet each other for a length of about 13 mm by flow only, and record the number of blows, N.
6. Take a representative portion of soil from the cup for moisture content determination.
7. Repeat the test with different moisture contents at least four more times for blows between10 and 40.

RESULT:

Plot the relationship between water content (on y-axis) and number of blows (on x-axis) on semi-log graph. The curve obtained is called flow curve. The moisture content corresponding to 25 drops (blows) as read from the represents liquid limit. It is usually expressed to the nearest whole number.

Flow index $I_f = (W_2\text{-}W_1)/\log(N_1/N_2)$

b) PLASTIC LIMIT TEST:

OBJECTIVE: To determine the plastic limit of a given soil sample.

DEFINITION: Plastic limit is the water content at which soil changes from plastic to semi-solid state.

The plastic limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dry soil, at the boundary between the plastic and semi-solid states of consistency.

APPARATUS REQUIRED

- Porcelain dish.
- Squeeze Bottle and Spatula
- Balance of capacity 200gm and sensitive to 0.01gm
- Ground glass plate for rolling the specimen.
- Containers to determine the moisture content.
- Oven thermostatically controlled with interior of non-corroding material to maintain the temperature around 105^0 and 110^0C.

Fig.4.2.2(b): Plastic limit test equipment

Fig. 4.2.2(c): Threads of soil

PROCEDURE

1. Put 20 gm of air-dried soil, passed thorough 425 mm sieve (In accordance with I.S. 2720: part-1), into an evaporating dish. Add distilled water into the soil and mix it thoroughly to form uniform paste (the soil paste should be plastic enough to be easily molded with fingers.)
2. Prepare several ellipsoidal shaped soil masses by squeezing the soil between your fingures. Take one of the soil masses and roll it on the glass plate using your figures. The pressure of rolling should be just enough to make thread of uniform diameter throughout its length. The rate of rolling shall be between 60 to 90 strokes per min.
3. Continue rolling until you get the thread diameter of 3 mm.
4. If the thread does not crumble at a diameter of 3 mm, kneed the soil together to a uniform mass and re-roll.
5. Continue the process until the thread crumbles when the diameter is 3 mm.
6. Collect the pieces of the crumbled thread for moisture content determination.
7. Repeat the test to at least 3 times and take the average of the results calculated to the nearest whole number.

Plasticity Index(Ip) = (LL - PL) =.....

4.2.3 STANDARED PROCTR TEST:

OBJECTIVE: Proctor proposed tests to determine relationship between moisture content, dry density or void ratio of a compacted soil in a standard manner and to determine the OMC for the soil.

Standard Proctor Test covers the determination of the relationship between the moisture content and density of soils compacted in a mould of a given size with a 2.5 kg rammer dropped from a height of 305 mm.

Equipment's for Proctor's Test for Compaction of Soil

- Compaction mould, capacity 1000ml.
- Rammer, mass 2.6 kg
- Detachable base plate
- Collar, 60mm high
- IS sieve, 4.75 mm
- Oven
- Desiccator
- Weighing balance, accuracy 1g
- Large mixing pan
- Straight edge
- Spatula
- Graduated jar
- Mixing tools, spoons, trowels, etc.

Figure 4.2.3: Apparatus of standard proctor test

PROCEDURE

1. Approximately 5 kg of soil passing through 4.75 mm sieve is thoroughly mixed with known water content. For fine soil, 8-10% of water and for coarse soil, 4-5% of water is added.
2. Weight of the mould without base plate and collar is taken. The collar and base plate were fixed.
3. In the mould, the weighed soil is compacted in 3 layers giving 25 blows per layer with the 2.5 kg rammer.
4. Mould and soil, after making soil flush with the mould edges, are weighed.
5. The sample is removed from the mould and sliced vertically to obtain a small sample for water content determination.
6. The remainder of the material is thoroughly broken up.
7. The water content is increased by one or two percentage and the above procedures are repeated for each increment.
8. This series of determination is continued until there is a decrease in the wet unit weight of the compacted soil.

4. 2.4 CALIFORNIA BEARING RATIO TEST (CBR):

OBJECTIVE: The Californian **Bearing Ratio** (**CBR**) **test** is a penetration **test** used to evaluate the subgrade strength of roads and pavements. The results of these **tests** are used with the curves to determine the thickness of pavement and its component layers.

As per IRC recommendation, California Bearing Ratio (CBR) value of subgrade is used for design of flexible pavements. California Bearing Ratio (CBR) value is an important soil parameter for design of flexible pavements and runway of air fields. It can also be used for determination of sub grade reaction of soil by using correlation. It is one of the most important engineering properties of soil for design of sub grade of roads. CBR value of soil may depends on many factors like maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), type of soil, permeability of soil etc. Besides, soaked or unsoaked condition of soil also affects the value.

The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. California bearing ratio is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm / min. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

The significance of the CBR test emerged from the following two facts, for almost all pavement design charts, unbound materials are basically characterized in terms of their CBR values when they are compacted in pavement layers and the CBR value has been correlated with some fundamental properties of soils, such as plasticity indices, grainsize distribution, bearing capacity, modulus of subgrade reaction, modulus of resilience, shear strength, density, and moisture content Because these correlations are currently readily available to the practicing engineers who have gained wide experience with them, the CBR test remains a popular one. Most of the Indian

The values of the load applied are recorded corresponding to the plunger penetration values at 2.5mm and 5.0 mm. The penetration values are indicative of the combined influence of cohesion and internal friction. The CBR is an index of the shearing strength. These recorded test loads are used to calculate the percent ratios with respect to standard loads at 2.5mm and 5mm as 1370kg and 2055kg respectively (IS: 2720(part 16)-1987; 2004). Features of the CBR machine on which we are going to conduct the Test:

EQUIPEMENTS

• Plunger(diameter) = 50mm

• Mould Height = 126mm

• Mould Height with collar = 167.6mm

• Inner diameter of Mould = 100mm

• Weight of Hammer = 2.6kg

• Height of Fall = 310mm

• Number of blows = 56 per Layer

• Number of layer = 3

Fig. 4.2.4: CBR Testing Machine

PROCEDURE

1.Normally 3 specimens each of about 7 kg must be compacted so that their compacted densities range from 95% to 100% generally with 65 blows.

2.Weigh of empty mould

3.Add water to the first specimen (compact it in five layer by giving 10 blows per layer)

4.After compaction, remove the collar and level the surface.

5.Take sample for determination of moisture content.

6.Weight of mould + compacted specimen.

7.Place the mould in the soaking tank for four days (ignore this step-in case of unsoaked CBR.

8.Take other samples and apply different blows and repeat the whole process.

9.After four days, measure the swell reading and find %age swell.

10.Remove the mould from the tank and allow water to drain.

11.Then place the specimen under the penetration piston and place surcharge load of 10lb.

12.Apply the load and note the penetration load values.

13.Draw the graphs between the penetration (in) and penetration load (in) and find the value of **CBR**.

14.Draw the graph between the %age **CBR** and Dry Density, and find **CBR** at required degree of compaction.

CHAPTER-5

EXPERIMENTAL ANALYSIS

Based upon the various methods involved in this research, I conducted following tests in the laboratory with varying percentages of stabilizing agents in soil to get optimum values of stabilizing agents. Since finding the exact percentage of combination is the main key behind this research to different combinations with different percentages were tested, observations, conclusion is drawn from all these which will be discussed in the next chapter.

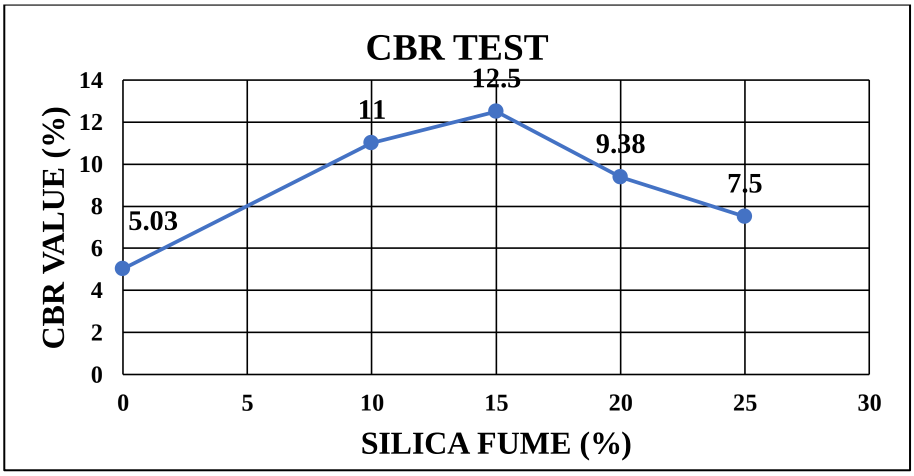
5.1 INDIVIDUAL ADDITION OF STABILIZING AGENTS

5.1.1 STABILIZER: SILICA FUME

Firstly, we take Silica fume as soil stabilizer and mix it with the soil in different percentages (10%,15%,20% and 25%) and perform the test to check the CBR values.

Table 5.1.1: CBR Test Results of Silica fume

S.No.	Silica Fume (%)	CBR Value (%)
1	Soil+0%	5.03
2	Soil+10%	11
3	Soil+15%	12.5
4	Soil+20%	9.38
5	Soil+25%	7.50



Graph 5.1.1: CBR value after adding Silica Fume

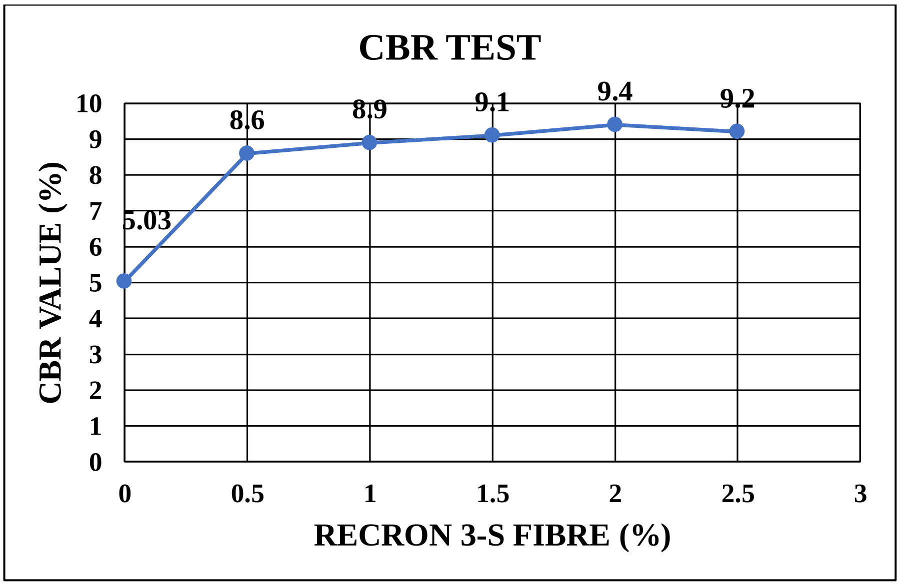
After performing the test and getting the result, we observed that CBR of the soil sample has increased and after adding 15% Silica fume, CBR of the soil is maximum i.e. CBR =12.5%

5.1.2 STABILIZER: RECRON 3-S FIBRE

Next, we take Recron fibre as soil stabilizer and mix it with the soil in different percentages (0.5%,1.0%,1.5%,2.0,2.5%) and perform the test to check the CBR values.

Table 5.1.2: CBR Test Result of Recron 3-S fibre

S.No.	Recron 3-S Fibre (%)	CBR Value (%)
1	Soil+0%	5.03
2	Soil+ 0.5%	8.6
3	Soil+1.0%	8.9
4	Soil+1.5%	9.1
5	Soil+2.0%	9.4
6	Soil+2.5%	9.2



Graph 5.1.2: CBR value after adding Recron 3-S fibre

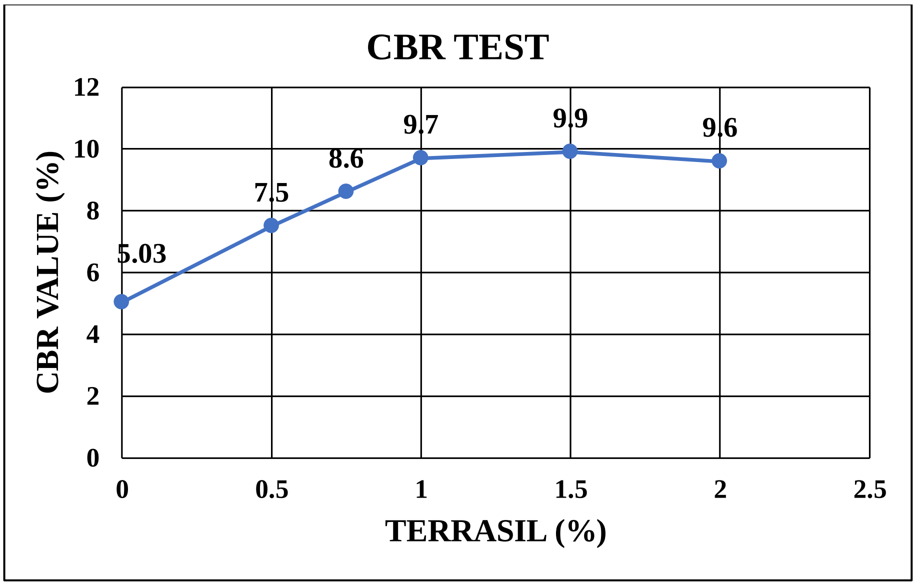
After performing the test getting the result, we observed that CBR of the soil sample taken has increased and after adding 2% Recron fibre, CBR of the soil is maximum i.e. CBR =9.4%

5.1.3 STABILIZER: TERRASIL

Next, we take Terrasil as soil stabilizer and mix it with the soil in different percentages (0.5,0.75,1.0,1.5,2) kg/m^3 and perform the test to check the CBR values.

Table 5.1.3: CBR Test Results of Terrasil

S.No.	Terrasil (kg/m^3)	CBR Value (%)
1	Soil+0	5.03
2	Soil+0.5	7.5
3	Soil+0.75	8.6
4	Soil+1.0	9.7
5	Soil+1.5	9.9
6	Soil+2	9.6



Graph 5.1.3: CBR value after adding Terrasil

After performing the test getting the result, we observed that CBR of the soil sample taken has increased and after adding 1.5% Terrasil, CBR of the soil is maximum i.e. CBR =9.9%

5.2 COMBINATIONS WITH OPTIMUM VALUES OF STABILIZING AGENTS:

After performing test with all individual dosages, now perform the test with combination of optimum dosages of stabilizing agent which show maximum value of CBR. Combination are made after seeing the performance of stabilizing agents.

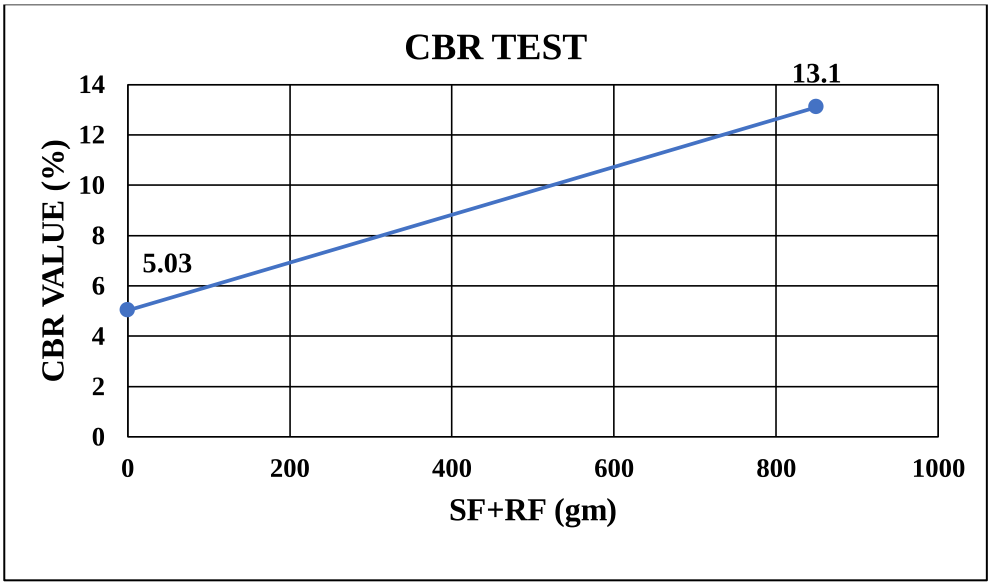
After getting the optimum dose of admixtures, we make combination of admixtures to get effective value of CBR.

5.2.1 STABILIZER: SILICA FUME+ RECRON 3-S FIBRE

First combination is SF+RF, perform the test to check the CBR values.

Table 5.2.1: CBR test results of SF+RF

S.No.	Stabilizer	CBR Value (%)
1	Soil	5.03
2	Soil+ Silica fume (15%)+ Recron 3-S fibre(2%)	13.1



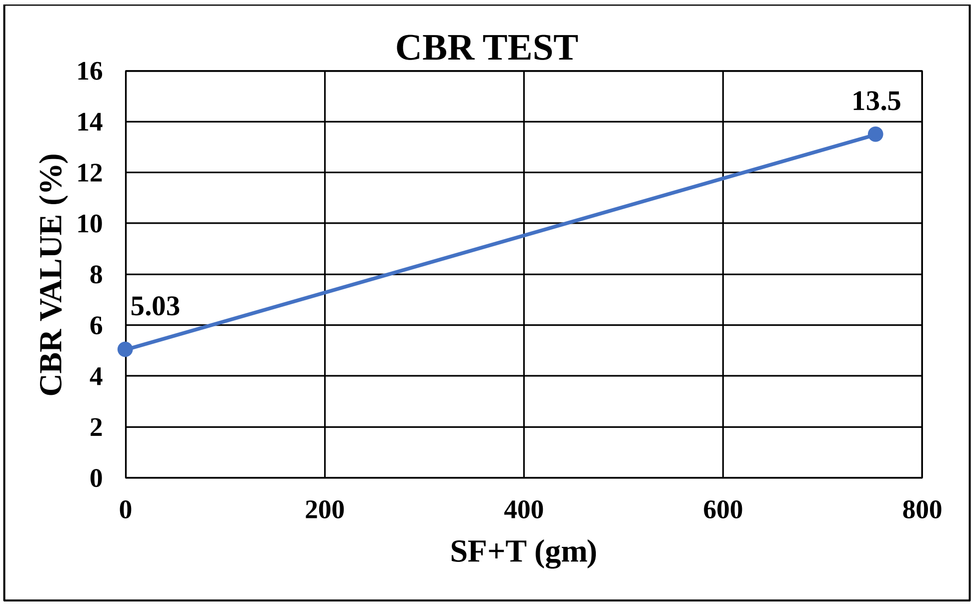
Graph 5.2.1: CBR value after adding Silica fume +Recron 3-S fibre

5.2.2 STABILIZER: SILICA FUME+ TERRASIL

Next combination is SF+T, perform the test to check the CBR values

Table 5.2.2: CBR test results of SF+T

S.No.	Stabilizer	CBR Value (%)
1	Soil	5.03
2	Soil+ Silica fume (15%)+Terrasil (1.5kg/m^3)	13.5



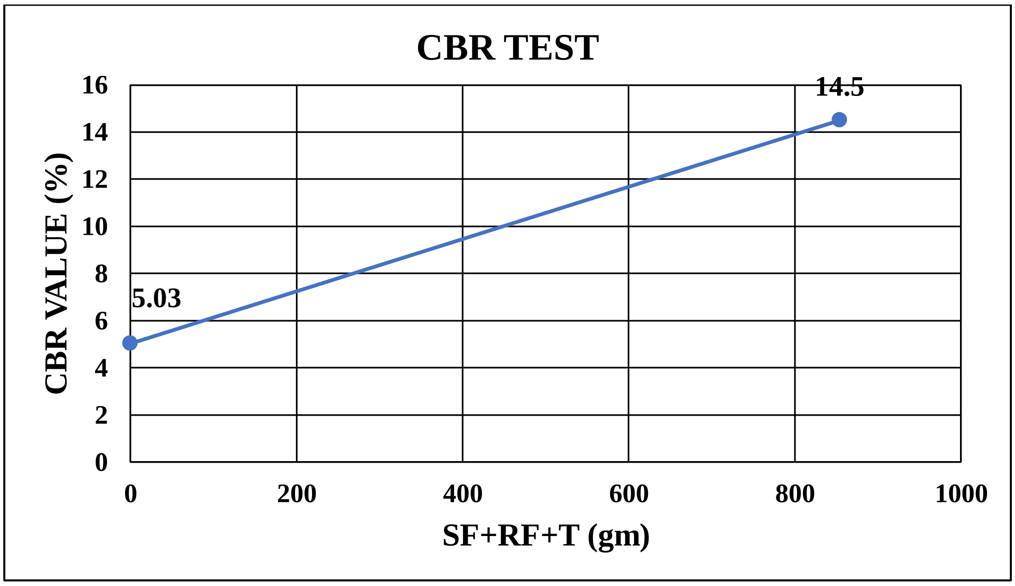
Graph 5.2.2: CBR value after adding Silica fume +Terrasil

5.2.3 STABILIZER: SILICA FUME +RECRON 3-S FIBRE + TERRASIL

Next, combination is SF+RF+T, perform the test to check the CBR values.

Table 5.2.3: CBR test results of SF+RF+T

S.No.	Stabilizer	CBR Value (%)
1	Soil	5.03
2	Soil+ Silica fume (15%)+ Recron 3-S fibre (2%)+Terrasil(1.5kg/m^3)	14.5



Graph 5.2.3: CBR value after adding Silica fume + Recron 3-S fibre +Terrasil

CHAPTER 6

REAULT ANALYSIS AND DISCUSSION

Based on the CBR values obtained the overall crust thickness of the pavement has been calculated. It is seen that required thickness are considerably reduced. Finally, extra cost has to be compared with respect to non-admixture CBR value.

6.1 Calculation of Pavement Thickness: All the calculations are done as per the guidelines of IRC: 37 - 2018

The design traffic, in terms of the cumulative number of standard axles to be carried during the design period of the road is computed from the following formula.

Standard Axle (Ns) = $365[(1+r)^{n} -1]/r *A*F*D$

Ns = cumulative number of standard axles to be catered for during the design in terms of msa

A = initial traffic (commercial vehicles per day) in the year of completion of construction

D = lane distribution factor

F = vehicle damage factor (VDF)

n = design period, in years

r = annual growth rate of commercial vehicles

The traffic in the year of completion of construction may be estimated using below equation

$A = P (1 +r)^{x}$

Where,

P = number of commercial vehicles per day as per last count

x = number of years between the last count and the year of completion of construction

6.1.1 Design Calculation of Pavement Thickness

Available Data:

Growth rate (r) = 5%

Design Period (n) = 15 years

P = 1195

X = 2 year

Traffic (A) = 1317 CVPD (An assumed road)

Vehicle Damage Factor (F) = 3.9

Lane Distribution Factor (D) = 0.5

Standard Axles (Ns)= 20227200.6

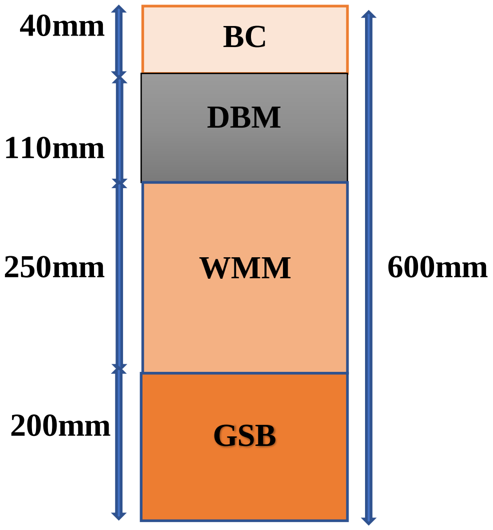
Design Traffic= $N_S/10^6$

N_S **=20.23msa**

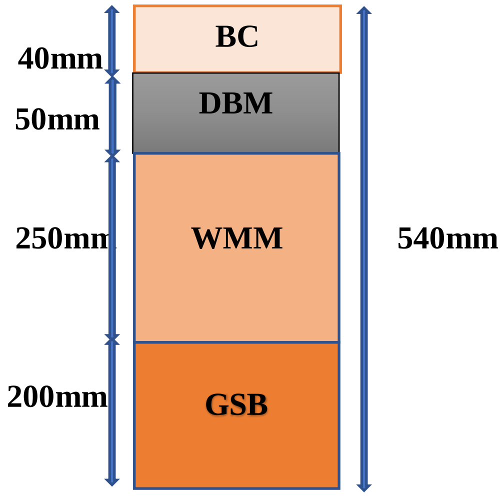
The thickness of crust varies with the change in the value of CBR, below Shown are the crust thickness with different percentages of CBR:

Table 6.1.1: Pavement Thickness

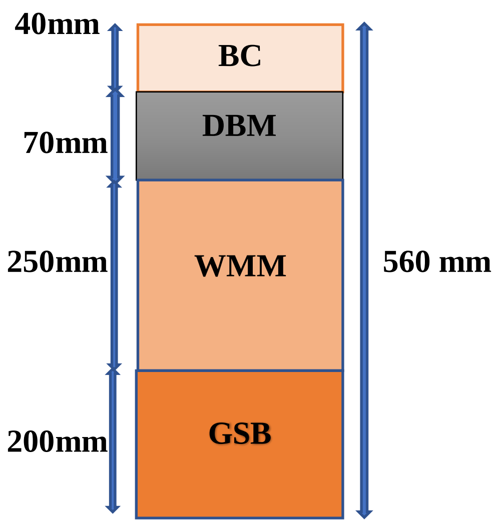
S.No	Admixture	CBR value	Crust Thickness				
			Total crust in mm	Crust Composition			
				Sub base	Base bituminous	Base bituminous	Surface course
				GSB in mm	WMM in mm	DBM in mm	BC in mm
1	**Non Admixture**	5.03	600	200	250	110	40
2	**Silica fume**	12.5	540	200	250	50	40
3	**Recron-3S fibre**	9.4	560	200	250	70	40
4	**Terrasil**	9.9	560	200	250	70	40
5	**SF+RF**	13.1	540	200	250	50	40
6	**SF+T**	13.5	540	200	250	50	40
7	**SF+RF+T**	14.5	530	200	250	50	30



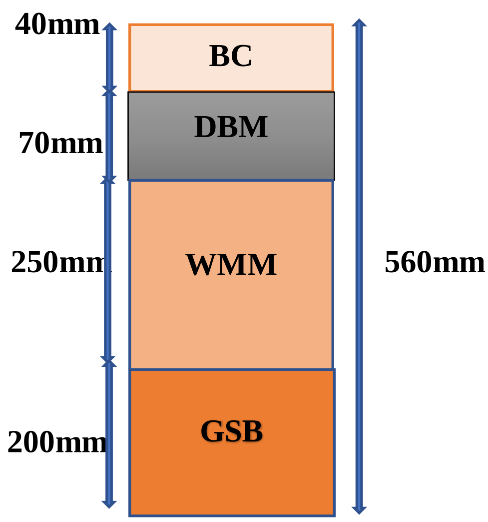
No Admixture added



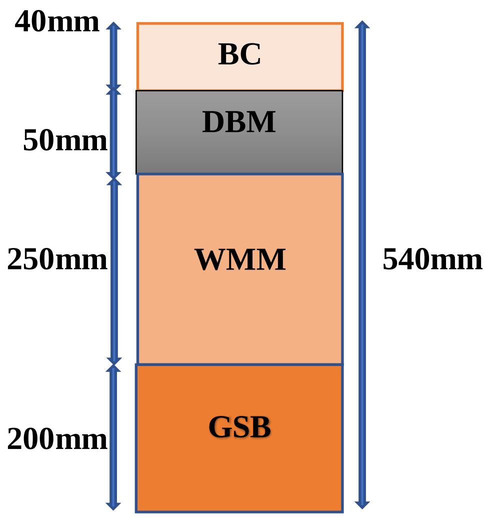
After adding 15% Silica fume



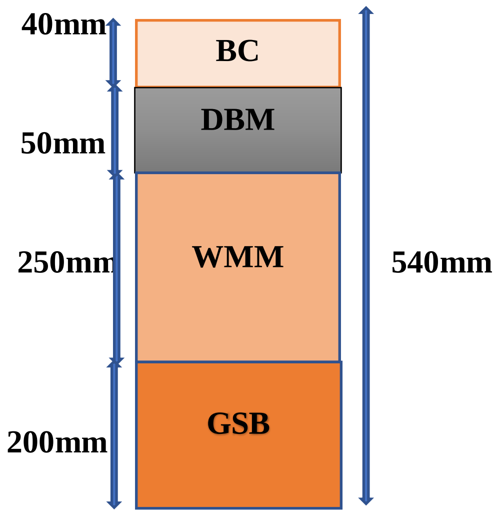
After adding 2% Recron fibre



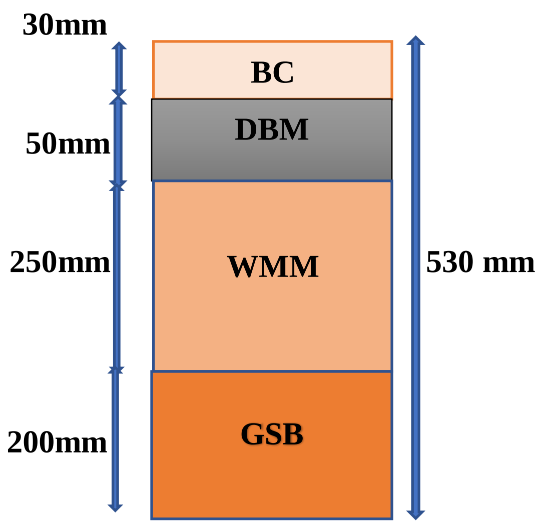
After adding 1.5 kg/m^3 Terrasil



After Adding (15%SF+2% RF)



After adding (15%SF+1.5kg/m^3)



After adding (15%SF+2%RF+1.5kg/m^3 T)

Fig. 6.1.1: Minimum crust thickness as IRC: 37 - 2018

Table 6.1.2: Saving of crust with respect to without adding any admixture soil CBR

S. No.	Admixture		DBM	BC
	Soil	**Crust Thickness**	110	40
		Quantity	770	280
1	**Silica fume**	**Crust Thickness**	60mm	-
		Quantity	420cum	-
2	**Recron 3-S fibre**	**Crust Thickness**	40mm	-
		Quantity	280cum	-
3	**Terrasil**	**Crust Thickness**	40mm	-
		Quantity	280cum	-
4	**SF+RF**	**Crust Thickness**	60mm	-
		Quantity	420cum	-
5	**SF+T**	**Crust Thickness**	60mm	-
		Quantity	420cum	-
6	**SF+RF+T**	**Crust Thickness**	60mm	10mm
		Quantity	420cum	70cum

6.1.2 RATES:

Item rates are calculated as per Data Book of Roads & MORTH. Admixture rates are taken from local market rates.

Admixtures are added in top 500 mm of sub grade as per IRC: 37 – 2018 and procedure has been taken in accordance with Specifications for Road Work: IRC – MORTH.

6.1.3 COST ANALYSIS:

(A) Quantity and cost of soil:

Quantity of Earth to be Stabilized for 1km Length of Road Seven Meters Wide

=1000*12*0.50 =6000 cum

=6000@120/cum

Cost of subgrade =Rs. 720000

GSB =1000*7*0.20=1400cum

=1400@3687.73/cum

Cost of GSB =Rs. 5162822

WMM=1000*7*0.25=1750cum

=1750@4124.20/cum

Cost of WMM =Rs. 7217350

DBM= 1000*7*0.11= 770 cum

=770@8805.27/cum

Cost of DBM =Rs. 6780057.9

BC= 1000*7*0.04=280 cum

=280@9664.85/cum

Cost of BC=Rs. 2706158

Total cost of flexible pavement of 1 km= Rs. 22286387.9

B) Quantity and Cost of Admixture:

1) Silica fume:

Stabilization with silica fume has been done in top 50cm of the sub grade.

Quantity of Earth to be Stabilized for 1km Length of Road Seven Meters Wide

=1000*7*0.50 =3500 cum

Volume of Stabilized Soil = 300cum

Weight of Stabilized Soil =525 Metric Tonne

Density = 525/300 = 1.75 gm/cc

Quantity of Stabilized Soil per km = 3500*1.75 =6125MT

Per Km weight of silica fume at 15% =6125*15/100 = 918.75 MT

Rate of Silica fume per kg =Rs.25

Rate of Silica fume per Quintal =Rs.2500

Cost of Silica fume per Km =918.75*10*2500

= Rs. 22968750

C) Recron 3-S fibre:

Stabilization with Recron 3-S fibre has been done in top 50cm of the sub grade.

Quantity of Earth to be Stabilized for 1km Length of Road Seven Meters Wide

=1000*7*0.50 =3500 cum

Volume of Stabilized Soil = 300cum

Weight of Stabilized Soil =525 Metric Tonne

Density = 525/300 = 1.75 gm/cc

Quantity of Stabilized Soil per km = 3500*1.75 =6125MT

Per Km weight of Recron fibre at 2% =6125*2/100 = 122.5 MT

Rate of Recron fibre per Kg =Rs.250

Rate of Recron fibre per Quintal =Rs.25000

Cost of Recron fibre per Km =122.5*10*25000

=Rs. 30625000

D) Terrasil:

Stabilization with Terrasil has been done in top 50cm of the sub grade.

Quantity of Earth to be Stabilized for 1km Length of Road Seven Meters Wide

=1000*7*0.50 =3500 cum

Volume of Stabilized Soil = 300cum

Weight of Stabilized Soil =525 Metric Tonne

Density = 523/300 = 1.75 gm/cc

Per Km weight of Terrasil/ at 1.5kg/cum =1.5*300=450 kg or 0.45 MT

Rate of Terrasil per Kg =Rs. 550

Rate of Terrasil per Quintal =Rs. 55000

Cost of Terrasil per Km = 0.45*10*55000

=Rs.247500

4)SF+RF:

Cost of (SF+RF) per Km =22968750+30625000

= Rs.53593750

5) SF+T:

Cost of (SF+T) per Km=22968750+247500

=Rs. 23216250

6) SF+RF+T:

Cost of (SF+RF+T) per Km=22968750+30625000+247500

= Rs.53840350

Table 6.1.3: Cost Saving in Construction with respect to Non-Admixture Sub-Grade

COST ANALYSIS PER KM								
S.No.	**Admixture**	**Qty. of DBM**	**RATE per cum**	**Qty. of BC**	**RATE per cum**	**Amount (DBM+BC)**	**Amount in lacs.**	**Net Saving in lacs.**
1	**Non-Admixture**	770	8805.27	280	9664.85	9486216	94.86	**-**
2	**Silica fume**	350	8805.27	280	9664.85	5788003	57.88	**36.98**
3	**Recron-3S fibre**	490	8805.27	280	9664.85	7020740	70.21	**24.65**
4	**Terrasil**	490	8805.27	280	9664.85	7020740	70.21	**24.65**
5	**SF+RF**	350	8805.27	280	9664.85	5788003	57.88	**36.98**
6	**SF+T**	350	8805.27	280	9664.85	5788003	57.88	**36.98**
7	**SF+RF+T**	350	8805.27	210	9664.85	5111463	51.11	**43.75**

After analysing all the data that is collected or generated, it is found that is (SF+RF+T) the best combination of admixture for soil stabilization and most economical as compared to the individual admixtures used for soil stabilization.

CHAPTER-7

CONCLUSION

The objective of this study is to evaluate the potential use of non- conventional additives such as Silica fume, Recron 3-S fibre and Terrasil to check strength of soil subgrade of nature and stabilized soils during and after construction. The study demonstrates the influence of Silica fume, Recron 3-S fibre and Terrasil on local soil of Lucknow.

Now days, the cost of construction of a flexible pavement highway are much higher, finally affect the construction of infrastructure of the country. The bitumen and stone ballast and grit are main constituents of flexible pavement in highway industry. Our country needs huge financial resources to meet out international standard based road infrastructure. To meet out these financial resources, it is now our duty to proceed technological innovation to reduce quantity of material resources and enhance construction quality to ensure this objective with different type of admixture.

A very important parameter, CBR (California Bearing Ratio) is used as tool for determining the improvement of strength of soil in Highway Construction CBR determined with the help of CBR apparatus by adding admixtures (Silica fume, Recron fibre and Terrasil) with various percentages. The Total work is comprised with Zero percentages of admixture in same quality of soil. Each type of admixture with variable percentages show different trend of CBR values. A comparative study is carried out with different % of admixture and data is collected or generated.

The following conclusion have been drawn based on the laboratory investigation carried out in this study:

- It has been observed that CBR value of parent soil increased with the increasing in addition of Silica fume, Recron 3-S fibre and Terrasil.
- It has been observed that Silica fume can tremendously increase the CBR value of local soil more proficiently at 15% as compared to Recron 3-S fibre and Terrasil.
- As per data available:
  It has been observed that when admixtures added to the soil in individually and combination of two admixtures, crust thickness is not more less in comparison to combination of these three(SF+RF+T) three admixtures.

When the combination of admixture (SF+RF+T) is added in soil crust thickness is reduced more as compared to non-admixture soil.

The cost of non-admixture soil is 94.86 lacs. and the cost of combination of these three admixtures (SF+RF+T) is 51.11 lacs. Thus, net saving is 43.75lacs.i.e. huge amount of money is saved here. Which is satisfying the objective of my thesis

- After analysing all the data that is collected or generated, it is found that is (SF+RF+T) the best combination of admixture for soil stabilization and most economical as compared to the individual admixtures used for soil stabilization.
- The thickness of crust varies with the change in the value of CBR with higher value of CBR the crust thickness is less and vice -versa.
- Due to the saving in curst less quantity of material will be applicable so that, huge amount of money can be saved.

SCOPE FOR FUTURE INVESTIGATION

Based on present findings, it is felt that further work should be pursued in the following area:

- Further investigation could be done with other admixtures with different percentages, individual and combinations.
- For advance research, it is recommended that the effect of combining the three additives (Silica fume, Recron 3-S fibre and Terrasil) in the stabilization of locally available soil be investigated to see whether it can better improve the properties of soil than by using an additive alone.
- Future research may be done in this direction to know the exact cause and remedial measures against the low capacity of soil in improving soil subgrade strength.
- Future study should investigate the other stabilizing materials and their respective strength parameters correlation for soaked and unoaked CBR should be checked.

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A Review of Literature on Evaluation and Analysis of Soil Stabilization with Some Non-Conventional Additives

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Abstract:
The aim of this paper is to examine the effect of some non-conventional additives on the properties of soil. In this paper, an attempt has been made to study the compaction and CBR characteristics tests of locally available soil mixing with different percentages (added individually and in combinations)of Silica Fume, Recron-3s Fiber and Terrasil with a view to determine the optimum percentage. The current research shows the effective utilization of micro silica fume, synthetic fiber and terrasil in the improvement of sub grade characteristics of expansive soil. This paper deals with the review of some previous studies that are done to improve properties of weak soil by Micro silica, Synthetic fiber and Terrasil.

Keywords: Soil, Silica Fume, Synthetic fiber and Terrasil, Soil Stabilization, Optimum Moisture Content (OMC), Maximum Dry Density (MDD), California Bearing Ratio (CBR).

I. INTRODUCTION

Geotechnical engineers face various problems while designing the foundations on highly compressible clayey soil due to poor bearing capacity and excessive settlement. Most of the soil available are such that they have good compressive strength adequate shear strength but weak in tension / poor tensile strength. The quality and life of asphalt is enormously influenced by the sort of subgrades. In any case in India the greater parts of the adaptable asphalts must be built over feeble and dangerous subgrade. The California bearing proportion (CBR) of these sub-grades have low, it needs to more thickness of pavement. Lessening in the accessibility of suitable sub base and base materials for asphalt development have prompts a look for financial technique for changing over generally accessible tricky soil to suitable development material Soil stabilization improves the bearing capacity, compressibility, strength, and other properties of soil. In case of road construction, the aim of stabilization of soil is to increase the stability by increasing its bearing capacity and hence increasing its strength and reduction in pavement thickness. Soil stabilization improves the strength of the soil, thus, increasing the soil bearing capacity, used to decrease the permeability and compressibility of the soil mass in the earth structures, more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation, improves the workability and the durability of the soil and maximize the lifecycle costs of projects. Silica Fume is an ultrafine powder collected as a by-product of silicon metal and ferrosilicon alloy production. It is a pozzolonic material which has a high content of amorphous silicon dioxide and consists of very fine spherical particles It is available in grey to off-white colors. The particles of SF are 100 to 150 times smaller than the cement grains It is one of the most valuable by-product pozzolonic materials due to its very active and high pozzolonic property. The current research shows the effective utilization of micro silica fume in the improvement of sub grade characteristics of expansive soil. Recron-3S is most commonly used synthetic fiber due to its low cost, hydrophobic nature, chemically inert and does not allow reaction with soil moisture. It has a variety of advantageous engineering properties such as resistance to fatigue, physical damage and freezing, as well as being unusually resistant to many chemical solvents, bases and acids. Terrasil Nano-chemical is emerging as a new material for the stabilization of soil.It forms Si-O-Si bonded Nano-siliconize surfaces in soil by converting water loving Silanol groups to water repellent Alkyl Siloxane groups.It is nanotechnology based 100 percent organo-silane, water soluble, heat stable and reactive soil modifier to waterproof soil subgrade. Makes the soil insensitive to water and can be compacted to give better interlocking to the soil particles.It prevents damage due to capillary rise of water, cracking of soil.

II. LITERATURE REVIEW

Ekrem Kalkan (2008)[1] studied about the influence of silica fume on the desiccation cracks of compacted clayey soils. The aim of this study is to examine the suitability of silica fume as a stabilization material to reduce the development of desiccation cracks in compacted clayey soils. The amounts of silica fume were selected to be 5%, 10%, 15%, 20%, 25%, 30% and 50% of the total dry weight of the clay soil–silica fume mixtures. Natural clayey soil and clayey soil–silica fume mixtures were compacted at the optimum moisture content and subjected to laboratory tests. In each sample, it was observed that reduction in the development of desiccation cracks occurred with increasing silica fume content between 0 and 25%.The results show that silica fume decreases the development of desiccation cracks on the surface of compacted samples. It is concluded that silica fume waste material can be successfully used to reduce the development of desiccation cracks in compacted clayey soil.

Ekrem Kalkan (2011)) [2] The basic objectives of this research are to investigate the modification of an expansive clayey soil using a by-product material and to evaluate the effect of drying and wetting cycles on the swelling characteristics of the modified expansive clayey soil. Expensive clay soils contain silicate clay minerals that have the potential for swelling and shrinkage under changing moisture contents. To reduce the effects of cyclic wetting–drying phenomena, it is essential to modify these soils by stabilization techniques. For this purpose, expansive clayey soil samples have been modified using silica fume waste material. The amounts of silica fume were selected to be 10%,20%, 25% and 30% of the total dry weight of the clay soil–silica fume mixtures. and the effects of wetting and drying cycles on swelling behaviour of modified expansive clayey soils have been investigated under laboratory conditions. The results show that silica fume decreases the progressive deformation of modified expansive clayey soils subjected to cyclic drying and wetting.

Ekrem Kalkan (2013) [3] The main objective of this paper is to investigate the use of waste materials such as silica fume and scrap tire rubber fiber in geotechnical applications and to evaluate the effects of scrap tire rubber fiber and scrap tire rubber fiber–silica fume mixture on the unconfined compressive strength (UCS) and swelling pressure of clayey soils. The amount of silica fume was selected 10 and 20%, In the same way, the contents of scrap tire rubber fiber were chosen as 1, 2, 3 and 4% by total weight of mixtures. The results of experimental research indicated that silica fume, fiber and silica fume–fiber mixture modification enhanced both the unconfined compression strength and strength parameters. Consequently, it is concluded that the silica fume–fiber mixture materials can be successfully used for the modifications of clayey soils in the geotechnical applications.

Nandan A. Patel, C. B. Mishra (2013)[4] studied about the Recron-3s Fiber is used as the stabilizers in improving engineering properties soil. This experiment evaluates the effect of the Recron-3s on some basic engineering properties of soil by using varied proportion of Recron- 3s fibers from 0.5% to 2.0%. Four proportion of recron-3s fiber i.e. 0.5%, 1.0%, 1.5% and 2.0% were used to quantify the optimum quantity of Recron-3s on the performance in terms of CBR value and UCS of the soil. the value of CBR of sample increases with increase in addition of Recron-3s up to 1%, and further increase in Recron-3s results in to decrement in CBR value.

Nandan A. Patel, Prof. C. B. Mishra(2015)[5]The examination was completed to focus on soil engineering properties (with and without stabilizer), standard compaction; four days soaked California Bearing Ratio (CBR), permeability test and cyclic loading test according to codal procurement. A concoction named Terrasil was utilized as stabilizer and it was utilized for altered measurement i.e. 0.041% by dry aggregate weight of soil.

Nandan A. Patel, C. B. Mishra (2015)[6]studied on Subgrade Soil Stabilization using Chemical Additives". It is found that the addition of Terrasil (0.041%) + zycobond (0.020%) to the soil the CBR value increased from 6.64% to 12.15%. This signifies that the quality of subgrade soil is enhanced consequently expanding the load carrying limit of pavement.

Rintu Johnson1, Dr. Kodi Rangaswamy (2015)[7]The soil was collected from Kunnamangalam area of Calicut district in Kerala and the Terrasil Nano-chemical was collected from Zydex, Industries Ltd. for the stabilisation studies. Experimental programme was carried out on both clay and cement treated clay treated with different dosages of Terrasil. Specimens were prepared with 0.05%, 0.07% and 0.09% Terrasil and 1% cement by weight of soil. Results obtained were compared and studied. The CBR strength of soil mixed with optimum dosage of 0.07% terrasil chemical is improved about 6 times the CBR strength of clay soil. The treated soil was found to be impermeable.

P. Sai Venkata Bharath1, K. Jyothi Raju (2016)[8]This paper includes the evaluation of soil properties like compaction and California Bearing Ratio (CBR) test. Detailed experimental study has been undertaken to investigate the characteristics and behaviour of expansive soil mixed with Quarry Dust and Recron-3S fibres with different percentage. From the experimental results, it has been observed that various properties of soil added with these stabilizers at certain percentage show remarkable positive changes as compared to the natural soil. The value of compaction parameters has increased enabling increase California Bearing Ratio which indicates that improved in strength. From these results, it was found that optimum Quarry Dust and Recron-3S fibres 20% and 1.5% respectively gives the maximum increment in the CBR compared with all the other combinations.

Ansu Thomas, R. k. Tripathi(2016)[9] In this study, an attempt has been made to study the improvement in the properties of a soft soil collected from village Arasnara, Durg district of Chhattisgarh, India, stabilized with Terrasil. Various laboratory tests have been conducted on un-stabilized and stabilized soil samples and the results are compared and discussed. Different dosages of Terrasil have been used and evaluated the effect on optimum moisture content, maximum dry density, plasticity index and Unconfined Compressive Strength (UCS). Effect of curing period on UCS has also been studied. Significant improvement in properties of soil is observed.

A. R. Goodarzia, H. R. Akbaria (2016) [10] The present study investigated the potential use and effectiveness of expansive clay stabilization using admixture of cement and silica fume (CSF) as a possibly useful option from environmental, economic, and (or) technical perspectives. In so doing, cement and CSF blend with 10% cement replacement were separately added to a clay sample having high degree of swelling potential. The incorporation of silica fume in to the cement matrix extends the formation of new cementing compounds and provides a much denser micro structure, were found to be very effective in surpassing the problems associated with expansive clays. Adding 10% CSF within 14 days of curing increases the compressive strength of the clay.

Siyyagalla Subbarayudu, S.Rozwana (2017)[11] In this project, we are going to stabilize the soil by using recron-3s, fly-ash and lime. Here we are using recron-3S as (1%,2%,) lime (2%,3%,4%) and fly ash at (10%,12%,15%,20%).With different proportion of soil with additive materials California bearing ratio value will be more compare to conventional materials. And from that thickness of pavement can be minimized to a certain extent.By adding Recron-3s, 1% CBR value of soil increased and further increasing Recron-3s,CBR value decreased.

Tripti Goyal, Er. Rubel Sharma (2018)[12]The research was focused on to improve the strength of soil and to obtain an optimum amount of soil-fly ash-recron-3s mix. The proportions used of fly ash were 10, 15, 20, 30, 40 and 50% and recron-3s was in 0.2, 0.4, 0.6, 0.8 and 1.0% in amount by weight. From the experimental results, it was concluded that recron-3s work as reinforcing the material and provides strength to the soil as well as fly ash worked as cementing material. The preeminent proportion obtained was 84.2% soil – 15% fly ash – 0.8% recron-3s fibre.

III. CONCLUSION

From the review of literature on soil stabilization with different admixture, the following conclusion can be drawn-

• The liquid limit and plasticity index values decreased with increasing silica fume contents. However, the plastic limit increased with increases in the silica fume contents.

• With the addition of silica fume, the maximum dry unit weight values decreased and the optimum water contents increased under the same compaction effort.

• The swelling pressure and swelling potential values steadily decreased with increasing silica fume content and the low values were finally reached in the stabilized samples with 25% and 30% silica fume contents.

•Silica fume can be used to minimize the development of desiccation cracks and the swelling behaviour of clayey soils. In addition, silica fume waste material can potentially reduce stabilization costs by utilizing wastes in a cost-effective manner.

• UCS values of all modified clayey soil samples increased with increasing silica fume.

• As per the result shown, the value of CBR increases with increase in addition of Recron-3s up to 1%, and further increase in Recron-3s results in to decrement in CBR value.

• Strength of soil can be increased to the certain extent by using additive materials in soil. Especially Recron-3s, when mixed with soil and fly ash mixtures gives a wonderful result.

• By using Recron-3s the thickness of pavement can be reduced which will prove more economical and will also increase load carrying capacity.

• The UCS strength of soil mixed with optimum dosage of 0.07% terrasil chemical is improved about 441% higher than the strength of clay soil.

• The CBR strength of soil mixed with optimum dosage of 0.07% terrasil chemical is improved about 6 times the CBR strength of clay soil.

• The soil treated with terrasil was found to be impermeable.

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Evaluation and Analysis of Soil Stabilization with Some Non- Conventional Additives

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***Abstract*:- The growth of population has created a need for better and economical vehicular operation which requires good highways, proper geometric design and pavement condition maintenance. Road transportation is undoubtedly the lifeline of the nation and its development is crucial concern. The process of soil stabilization helps to achieve the required properties in a soil needed for the pavement construction work. One of the main reason for the failure of pavement is due to lack of strength. Strength can be increased by adding additive materials to the sub-grade in different proportions.**

The work presented in this paper deals with the strength properties of natural and stabilized subgrade. In this research, Silica fume, Recron 3-S fibre and Terrasil are used as stabilizers in improving engineering properties of soil. The aim of this study is to evaluates the effect of different percentages of Silica fume, Recron 3-S fibre and Terrasil are used separately and combination as stabilizers to improve the sub-grade characteristics of locally available soil. Mainly we have focused on increasing the CBR of the soil because on increasing the CBR value it helps in reducing the thickness of the pavement and it is also beneficial to use economically.

Keywords*:- *Soil, Silica fume (SF), Recron 3-S fibre (RF), Terrasil (T), Stabilization, Strength parameters, CBR Test.

1. INTRODUCTION

Due to rapid growth of population, very high utilization of land reserves, fast utilization and some other major civil engineering constructions, availability of good quality of land has been reduced which left less choice to people except to use weak and soft soil surrounding for majority of construction works.

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it become necessary for the engineers to look at means to improve soil other than replacing the poor soil at building site. Soil stabilization was used but due to the use of obsolete methods and due to the absence of proper technique, soil stabilization lost favour.

In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost effective method for soil improvement. One of the common approaches of subgrade stabilization is to remove the soft and replace it with a stronger material of crushed rock. The high cost of replacing has found forced highway agencies to evaluate alternative method for highway construction on soft subgrade. Pavement performance can be largely attributed to the performance of its foundation, which comprises of the subgrade and base layers. Base and subgrade layers must provide enough shear strength, stiffness modulus, resistance to moisture, stability and durability.

In country like India which is rich in monsoons, moisture becomes a huge problem to roads. Admission of water in rainy season weakens the road soil base. The soil of poor shear strength and high swelling and shrinkage, must be treated by some suitable means mostly soil stabilization and reinforcement are employed to improve mechanical behaviour of soil, thus improving the reliability of construction.

Road Infrastructure plays a significance role in the country's economy by providing efficient and cheapest transport facilities in both developed and developing countries. Pavement is the one of primary element and important component in the road infrastructure, which provides firm surface for smooth, safe and efficient movement of vehicular traffic. Subgrade is the integral part of the pavement system, which plays a major role in providing sound durable surface. Subgrade is defined as a compacted layer naturally occurring local soil or stabilized soil from borrow pits just beneath the pavement crust, providing a suitable foundation for the pavement structure. Subgrade layer should be well compacted at all situations to utilize its full strength to economize on the overall pavement thickness. Subgrade layer play an important role in imparting structural stability to the pavement structure as it receives dynamic transient loads imposed upon it by vehicular traffic. These Traffic loads need to be transmitted in a systematic manner in such a way that the subgrade deformation is to be within the elastic limits, and the shear forces developed are to be within the safe limits under adverse climatic and traffic loading conditions.

In case of highways less CBR value soils require higher pavement thickness of design traffic, resulting in costly pavement composition. To overcome this problem associated with soil, many techniques have been developed by different researches in terms of subgrade stabilization.

1.1 SOIL STABILIZATION

Stabilization of soil in a broader sense is the modification of the properties of a soil is improving its engineering performance. Soil stabilization is broadly used about road, pavement and foundation construction. It improves the engineering properties of the soil in terms of volume stability, strength and durability.

In case of road construction, the aim of stabilization of soil to increase the stability by increasing its bearing capacity and hence increasing its strength and reduction in pavement thickness. Soil stabilization improves the strength of the soil,

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thus, increasing the soil bearing capacity, used to decrease permeability and compressibility of the soil mass in the earth structure, more economical both in terms of cost and energy to increase the bearing capacity of soil, improves workability and durability of the soil and maximize the lifecycle costs of projects.

1.2 EFFECTS OF STABILIZATION

Soil stabilization may result in any one or more of the following changes:

1) Increase in stability, change in properties like density or swelling, change in physical characteristics.
2) Change in chemical properties.
3) Retaining and desired strength by water proofing.

2. LITERATURE REVIEW

The following literature review describes important research results regarding use of Silica fume, Recron-3S fibre and Terrasil in soil improvement:

Nandan A. Patel, C. B. Mishra (2015)[13] studied on Subgrade Soil Stabilization using Chemical Additives". It is found that the addition of Terrasil (0.041%) + zycobond (0.020%) to the soil the CBR value increased from 6.64% to 12.15%. This signifies that the quality of subgrade soil is enhanced consequently expanding the load carrying limit of pavement.

Rintu Johnson1, Dr. Kodi Rangaswamy (2015)[15] The soil was collected from Kunnamangalam area of Calicut district in Kerala and the Terrasil Nano-chemical was collected from Zydex, Industries Ltd. for the stabilization studies. Experimental programme was carried out on both clay and cement treated clay treated with different dosages of Terrasil. Specimens were prepared with 0.05%, 0.07% and 0.09% Terrasil and 1% cement by weight of soil. Results obtained were compared and studied. The CBR strength of soil mixed with optimum dosage of 0.07% terrasil chemical is improved about 6 times the CBR strength of clay soil. The treated soil was found to be impermeable.

A.R.Goodarzia, H.R.Akbaria (2016)[3] The present study investigated the potential use and effectiveness of expansive clay stabilization using admixture of cement and silica fume (CSF) as a possibly useful option from environmental, economic, and (or) technical perspectives. In so doing, cement and CSF blend with 10% cement replacement were separately added to a clay sample having high degree of swelling potential. The incorporation of silica fume in to the cement matrix extends the formation of new cementing compounds and provides a much denser. micro structure, were found to be very effective in surpassing the problems associated with expansive clays. Adding 10% CSF within 14 days of curing increases the compressive strength of the clay.

Kolla Ashwani Chandh et al (2016)[12] studied on the Effect of Fibre on Non-Swelling Sub Grade Layer. In this study, Recron 3s fibre is mixed with soil to investigate the relative strength gain in terms of bearing capacity and compaction. The effect of fibre on the geotechnical characteristics of soil-fibre mixture was investigated by conducting standard Proctor compaction tests, CBR tests and permeability test. The tests were performed as per Indian Standard specifications. The materials were used for preparing the samples are Soil & Fibre. The soil used for these experiments was brought from a site, in our college. The physical properties of the soil were determined as per IS specifications. In this test program, without additives clay was tested to find the optimum moisture content, CBR value and plasticity index. Fibre is added in varying percentages and that fraction for which maximum strength is obtained was found out. These experiments resulted in decreasing the sub-grade thickness to 50% 0f the actual thickness required, thereby reducing the cost of construction.

Ansu Thomas, R. k. Tripathi (2016)[1] In this study, an attempt has been made to study the improvement in the properties of a soft soil collected from village Arasnara, Durg district of Chhattisgarh, India, stabilized with Terrasil. Various laboratory tests have been conducted on un-stabilized and stabilized soil samples and the results are compared and discussed. Different dosages of Terrasil have been used and evaluated the effect on optimum moisture content, maximum dry density, plasticity index and Unconfined Compressive Strength (UCS). Effect of curing period on UCS has also been studied. Significant improvement in properties of soil is observed.

P. Sai Venkata Bharath1, K. Jyothi Raju (2016)[14] This paper includes the evaluation of soil properties like compaction and California Bearing Ratio (CBR) test. Detailed experimental study has been undertaken to investigate the characteristics and behaviour of expansive soil mixed with Quarry Dust and Recron-3S fibres with different percentage. From the experimental results, it has been observed that various properties of soil added with these stabilizers at certain percentage show remarkable positive changes as compared to the natural soil. The value of compaction parameters has increased enabling increase California Bearing Ratio which indicates that improved in strength.

Siyyagalla Subbarayudu, S. Rozwana (2017)[16] In this project, we are going to stabilize the soil by using recron-3s, fly-ash and lime. Here we are using recron-3S as (1%,2%,) lime (2%,3%,4%) and fly ash at (10%,12%,15%,20%). With different proportion of soil with additive materials California bearing ratio value will be more compare to conventional materials. And from that thickness of pavement can be minimized to a certain extent.

3. MATERIALS

The materials used for the stabilization of soil are Silica fume, Recron fibre and Terrasil and the properties and availability are mentioned below:

3.1 SOIL: The soil sample used for this study is collected from Krishna Nagar, Lucknow.

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Table 1: Properties of Soil

Properties	Description
Liquid limit (%)	30
Plastic limit (%)	21
Plasticity Index (%)	9
Soil Classification	CI
Optimum moisture content (%)	14
Maximum dry density (gm/cc)	1.84
Soaked CBR (%)	5.03

Fig. 1: Soil Sample

3.2 SILICA FUME: Silica fume, also known as Micro Silica, is an ultrafine powder collected as a by-product of silicon metal. It is a pozzolonic material which has a high content of amorphous silicon dioxide and consists of very fine spherical particles. It is available in grey to off-white colours. The particles of SF are 100 to150 times smaller than the cement grains. It is one of the most valuable by-product pozzolonic materials due to its very active and high pozzolonic property. Micro silica fume improves compressive strength, bond strength and reduce permeability.

Table 2: Physical Properties of Silica fume

Properties	Description
Colour	Light to dark grey
Specific gravity	2.2
Particle size	<1mμ
Specific surface	15000-30000m2/kg
Bulk density -Undensified -Densified	 130-430kg/m3 480-720kg/m3

Table 3: Chemical Composition of Silica fume

Compound	Value (%)
SiO_2	85-95
Al_2O_3	1-3
Fe_2O_3	0.5-1
CaO	0.8-1.2
MgO	1-2
Loss on Ignition	0.5-1

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Fig 2: Silica fume

3.3 RECRON 3-S FIBRE: Recron-3S is most commonly used synthetic fibre due to its low cost, hydrophobic nature, chemically inert and does not allow reaction with soil moisture. Use of Recron-3S as a reinforcing material is to increase the performance in terms of strength of soil also it enhances flexibility in operation, easy to use and reduces permeability. Recron-3s is also available in different sizes as 6 mm, 12 mm and 24 mm. The fibre used in this study of length 12 mm and it was manufacture by Reliance industries.

Table 4: Properties of Recron 3-S fibre

Properties	Description
Colour	White
Length	12mm
Unit length	0.91g/cm^3
Tensile strength	4000-6000kg/cm^2
Water absorption	85.22%
Acid resistance	Excellent
Alkali resistance	Good

Fig 3: Recron 3-S Fibre

3.4 TERRASIL: Terrasil chemical is emerging as a new material for the stabilization of soil. Terrasil is nanotechnology based product produced by Zydex Industries Ltd., Gujarat. It is defined as an organo-silane compound which reacts with soil particles and converts them (all types of soils) from water loving (Hydrophilic polar) to water hating (Hydrophobic nonpolar) particles. This makes the soil insensitive to water and can be compacted to give better interlocking to the soil particles.

Table 5: Physical properties of Terrasil.

Properties	Description
Appearance	Pale yellow liquid
Density	1.01g/ml
Viscosity at 25°C	20-100 Cp
Solubility	Forms water clear solution
Flash Point	>80°C
Freezing Point	5° C

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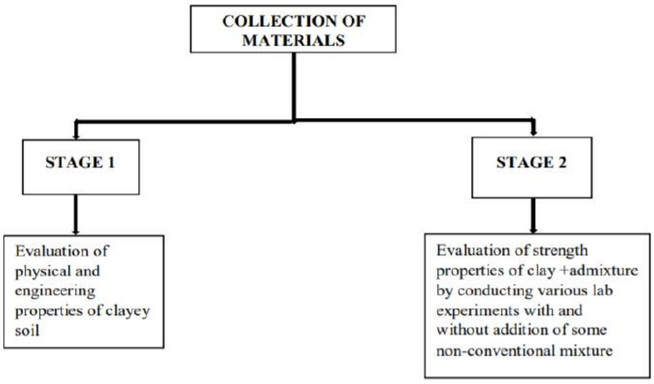
Table 6: Chemical composition of Terrasil

Chemical compound	Value (%)
Hydroxyalkyl-Alkoxy-Alkyls	65-70
Benzyl alcohol	25-27
Ethylene glycol	3-5

Fig 4: Terrasil

4. METHODOLOGY



The common tests that are performed by various researcher on use of Silica fume, Recron 3S fibre and Terrasil to improve soil by adding in different percentages includes following laboratory tests:

- Grain size distribution
- Liquid Limit
- Plastic Limit
- Standard Proctor Test
- California Bearing Ratio Test

5. EXPERIMENTAL INVESTIGATION

The overall testing program is conducted in two phase.

In first phase, soil was blending with various percentages of silica fume, Recron 3 S fibre and Terrasil by weight were used for conducting various tests in laboratory with a view to determine the optimum percentage of SF, RF and Terrasil. The optimum percentage of SF, RF and Terrasil content is obtained from the results of compaction and soaked CBR tests.

In second phase, soil was blending with optimum percentage of SF, RF and Terrasil by weight were used for preparing different samples for compacting and soaked CBR test.

Different samples were prepared for CBR test using soil material mixing with different percentages of Silica fume, Recron-3S Fibre and Terrasil with a view to determine optimum percentages. The CBR tests were conducted in the laboratory for all the samples as per IS Code (IS: 2720 (Part16)-1979) under soaked condition.

Perform the test with combination of optimum dosages of stabilizing agent which show maximum value of CBR.

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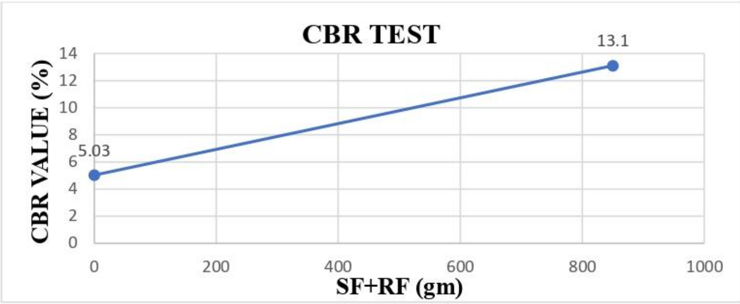
5.1 STABILIZER: SILICA FUME+ RECRON 3-S FIBRE

Table 7: CBR test results of SF+RF

S.No.	Stabilizer	CBR Value (%)
1	Soil	5.03
2	Soil+Silica fume(15%)+Recron 3-S fibre(2%)	13.1

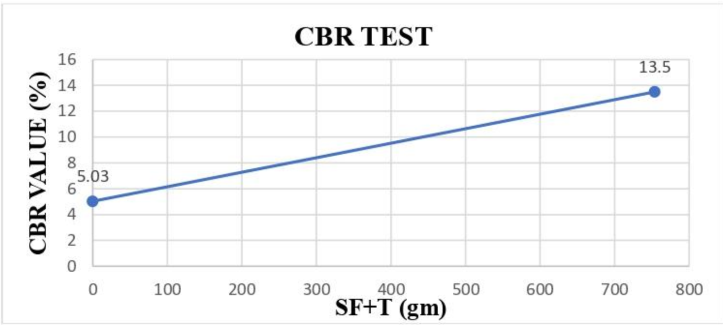


Graph 1: CBR value after adding SF+RF

5.2 STABILIZER: SILICA FUME+ TERRASIL

Table 8: CBR test results of SF+T

S.No.	Stabilizer	CBR Value (%)
1	Soil	5.03
2	Soil+ Silica fume (15%)+Terrasil (1.5kg/m^3)	13.5



Graph 2: CBR value after adding SF+T

5.3 STABILIZER: SILICA FUME +RECRON 3-S FIBRE + TERRASIL

Table 9: CBR test results of SF+RF+T

S.No.	Stabilizer	CBR Value (%)
1	Soil	5.03
2	Soil+ Silica fume(15%)+Recron3Sfibre(2%)+Terrasil(1.5kg/m^3)	14.5

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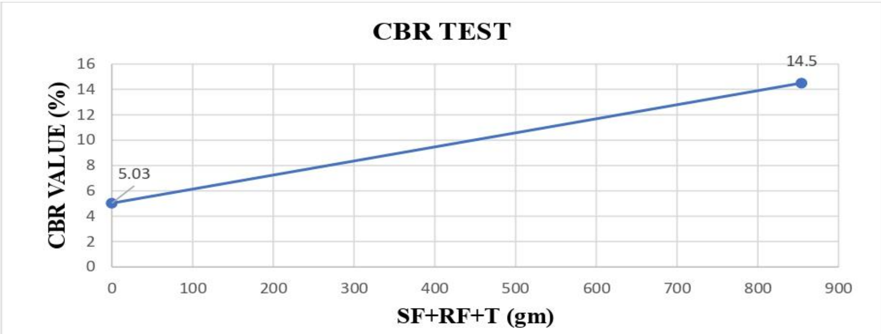

Graph 3: CBR value after adding SF+RF+T

6. TEST RESULTS AND DISCUSSION

Based on the CBR values obtained the overall crust thickness of the pavement has been calculated. It is seen that required thickness are considerably reduced. Finally, extra cost must be compared with respect to non-admixture CBR value.

Stabilized subgrade with higher CBR value reduces the pavement thickness. The thickness of crust varies with the change in the value of CBR, below Shown are the crust thickness with different percentages of CBR:

Table 10: REDUCTION IN PAVEMENT THICKNESS WITH STABILIZED SUBGRADE

S.No	Admixture	CBR value	Crust Thickness				
			Total crust in mm	Crust Composition			
				Sub base	Base bituminous	Base bituminous	Surface course
				GSB in mm	WMM in mm	DBM in mm	BC in mm
1	Non- Admixture	5.03	600	200	250	110	40
2	Silica fume	12.5	540	200	250	50	40
3	Recron-3S Fibre	9.4	560	200	250	70	40
4	Terrasil	9.9	560	200	250	70	40
5	SF+RF	13.1	540	200	250	50	40
6	SF+T	13.5	540	200	250	50	40
7	SF+RF+T	14.5	530	200	250	50	30

Table 11: COST SAVING IN CONSTRUCTION WITH RESPECT TO NON- ADMIXTURE SUB GRADE SOIL

COST ANALYSIS PER KM								
S.No.	Admixture	Qty. of DBM	RATE per cum	Qty. of BC	RATE per cum	Amount (DBM+BC)	Amount in lacs.	Net Saving in lacs.
1	Non- Admixture	770	8805.27	280	9664.85	9486216	94.86	-
2	Silica Fume	350	8805.27	280	9664.85	5788003	57.88	**36.98**
3	Recron 3S Fibre	490	8805.27	280	9664.85	7020740	70.21	**24.65**
4	Terrasil	490	8805.27	280	9664.85	7020740	70.21	**24.65**
5	SF+RF	350	8805.27	280	9664.85	5788003	57.88	**36.98**
6	SF+T	350	8805.27	280	9664.85	5788003	57.88	**36.98**
7	SF+RF+T	350	8805.27	210	9664.85	5111463	51.11	**43.75**

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After analyzing all the data that is collected or generated, it is found that is (SF+RF+T) the best combination of admixture for soil stabilization and most economical as compared to the individual admixtures used for soil stabilization.

7. CONCLUSION

A very important parameter, CBR (California Bearing Ratio) is used as tool for determining the improvement of strength of soil in Highway Construction. CBR determined with the help of CBR apparatus by adding admixtures (Silica fume, Recron fibre and Terrasil) with various percentages. The Total work is comprised with Zero percentage of admixture in same quality of soil. Each type of admixture with variable percentages show different trend of CBR values.

The following conclusion have been drawn based on the laboratory investigation carried out in this study:

- It has been observed that CBR value of parent soil increased with the increasing in addition of Silica fume, Recron fibre and Terrasil.
- It has been observed that Silica fume can tremendously increase the CBR value of local soil more proficiently at 15% as compared to Recron fibre and Terrasil.
- As per data available:
  It has been observed that when admixtures added to the soil in individually and combination of two admixtures, crust thickness is not more less in comparison to combination of these three(SF+RF+T) three admixtures.
  When the combination of admixture (SF+RF+T) is added in soil crust thickness is reduced more as compared to non-admixture soil.
  The cost of non-admixture soil is 94.86 lacs. and the cost of combination of these three admixtures (SF+RF+T) is 51.11 lacs. Thus, net saving is 43.75lacs.i.e. huge amount of money is saved here. Which is satisfying the objective of my thesis.
- After analysing all the data that is collected or generated, it is found that is (SF+RF+T) the best combination of admixture for soil stabilization and most economical as compared to the individual admixtures used for soil stabilization.
- The thickness of crust varies with the change in the value of CBR with higher value of CBR the crust thickness is less and vice -versa.
- Due to the saving in crust less quantity of material will be applicable so that, huge amount of money can be saved.

8. FUTURE SCOPE

Based on present findings, it is felt that further work should be pursued in the following area:

- Further investigation could be done with other admixtures with different percentages, individual and combinations.
- For advance research, it is recommended that the effect of combining the three additives (Silica fume, Recron fibre and Terrasil) in the stabilization of locally available soil be investigated to see whether it can better improve the properties of soil than by using an additive alone.
- Future research may be done in this direction to know the exact cause and remedial measures against the low capacity of soil in improving soil subgrade strength.
- Future study should investigate the other stabilizing materials and their respective strength parameters correlation for soaked and unoaked CBR should be checked.

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