IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

# Experimental Study On Shear Strength Of Soil Subgrade Using Cement At Different Percentages As Stablizing Agent

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***Abstract**:* The construction of any civil engineering structural project (whether house, bridge, dam or road, etc.) is carried out on or below the surface of the earth. The main aim of any structure is to transfer the load to the ground below, so that the soil below can be strong enough to support the coming loads without any loss. The building of any structure on a weak soil is very difficult and dangerous as land undergoes unequal settlements due to high compressibility and low shear strength. It is therefore of the utmost importance for us to test the engineering properties of the soil prior to construction.The current research focuses on improving the shear strength of the soil (which is one of the most technological properties of the soil) by using cement as an additive to minimize subgrade failure. Thus, the present study offers an idea for improving the geotechnical engineering properties of the soil used for subgrade pavement by using an additive that has been blended into the soil to achieve the desired result to fulfil the strength criteria. Similar standards may be extended to roads and airfields with a far stable surface layer. This can be done by combining the sandy soil and the Ordinary Portland Cement with the water and compacting the mixture to produce a stronger composite content.The present investigation therefore defines the behavioural dimension of soils mixed with 0 per cent, 5 per cent, 10 per cent and 15 per cent cement by soil volume to increase soil load bearing capacity. The shear strength and index properties, such as water content, MDD, OMC, Liquid Limit, Specific Gravity, etc., have been calculated and evaluated for the improvement of the pavement subgrade.

***Index Terms*** - :- Cement, Shear Strength, Atterber's Limits(liquid limit),Water Content, MDD, OMC, Specific gravity

## I. INTRODUCTION

Soil stabilization is the process of altering certain soil properties by various means, either mechanical or chemical, in order to create an enhanced soil substance with all the necessary engineering properties. Soils are usually stabilized to improve their strength and resilience or to avoid soil erosion and dust formation. The main goal is to establish a soil material or system that can be sustained under the conditions of use of the design and for the planned life of the engineering project. The soil properties vary greatly at different locations or, in some cases, only at one location; the effectiveness of soil stabilization depends on soil testing. Various methods are used to stabilize the soil and the method should be verified in the soil material laboratory before it is applied to the field. The main objective of soil stabilization is to enhance the CBR of in-situ soils by 4 to 6 times. The other key goal of soil stabilization is to strengthen on-site materials in order to establish a stable and strong sub-surface and base courses. For some regions of the world, usually developing countries, and also more frequently for developed countries, land stabilization is being used to build the entire road.

In the past, soil stabilization has been accomplished by using the binding properties of clay soils, cement-based products such as soil cement using the 'rammed earth' method (compaction) and lime. Traditionally and generally accepted forms of soil stabilization techniques use products such as bitumen emulsions that can be used as binding agents for the creation of a road foundation. However, bitumen is not environmentally friendly and can become brittle as it dries out. Portland cement was used as an alternative to soil stabilization. This can also be expensive, however, and is not a very good "climate" option.

For some regions of the world, usually developing countries, and also more frequently for developed countries, land stabilization is being used to build the entire road. Originally, soil stabilization was accomplished by the use of the binding properties of clay soils, cement-based products such as soil cement, and/or the use of soil compaction (soil compaction) and lime techniques. Many of the green technologies include: enzymes, surfactants, biopolymers, organic polymers, co-polymer based materials, cross-linking styrene acrylic polymers, tree resins, ionic stabilizers, fiber reinforcement, calcium chloride, calcite, sodium chloride, magnesium chloride and more. Many of these modern stabilizing methods are producing hydrophobic surfaces and the mass that prevents road failure from entering water or heavy frosts by inhibiting the ingress of water into the treated layer.

Recent research has, however, increased the number of conventional additives used for soil stabilization purposes. These non-traditional stabilizers include: polymer-based products ( e.g. cross-linking water-based styrene acrylic polymers that greatly increase the load-bearing ability and tensile strength of treated soils), copolymer-based products, fiber reinforcement, calcium chloride, and sodium chloride. Portland cement was used as an alternative to soil stabilization.

# 1.1Techniques of Stabilization

i. Mechanical Soil Stabilization
ii. Soil Cement Stabilization
iii. Soil Lime Stabilization
iv. Soil Bitumen Stabilization

## I. Mechanical Soil Stabilization

This type of stabilization involves the process of enhancing the properties of the soil by changing its gradation (correctly proportioned materials that is aggregates and soils). Two or more types of soils are mixed to obtain a composite material that has the superior quality than that of its components. Then these types mixed soils are compacted properly by mechanical means to obtain a stable layer. This type of method is known as Mechanical or Granular Stabilization.

The two basic principles in this stabilization are (proportioning and compaction). If a granular soil containing fines in a smaller quantity is mixed up with certain proportion of soil cement (binder) then it is possible to increase the stability of this type of soil. Similarly the stability of the fine grained soils can be improved by materials in a suitable gradation.

Mechanical Stabilization is achieved by blending the particles so as to obtain a desired gradation. This is done by compaction of soil, high dense and well graded mass of soil offers higher resistance to lateral displacement under a vertical load. The mechanical strength of the soil is achieved due to the internal friction (is provided by coarser particles i.e. gravels, sand and slit) and cohesion (cohesion is provided by clay) of particles.

## II. SOIL CEMENT STABILIZATION

Soil cement Stabilization is done by mixing soil and Portland cement with water and then compacting the resulting material to form a strong base course. The material obtained by mixing the soil and cement in proportions is known as soil cement. The cement mixed with the soil imparts strength and modifies the properties of soil.

In granular soils the stabilization is developed due to bond formed by the hydrated cement and the compacted soil particles that are in contact. In fine grained soils the stabilization is due to reduction is plasticity and formation of structure enclosing small clay lumps. Degree of stabilization depends upon the nature of soil proportion of cement and dry density of mixed components by increase in the percentage of cement there is an increase in strength and durability, while as decrease in volume change, moisture, movement and plasticity.

### III. Lime Cement Stabilization

This type of stabilization is done by adding lime to soil. This type of stabilization is useful for clayey soils. When lime reacts with soil, there takes place exchange of cations in the adsorbed water layer and decrease in plasticity occurs. Thus the resulting material is more suitable as subgrades. Soil lime has been widely used as a modifier for clayey soil or as a binder. Lime also imparts some binding actions in the granular soils.

The maximum dry density of soil lime is decreased by 2 to 3 percent than the original soils. However decrease in dry density with the addition of small quantity of lime doesn't cause reduction in strength. Soil lime is quite suitable in warm regions but not suitable under freezing temperatures.

### IV. Soil Bitumen Stabilization

Bitumen are non-aqueous systems of hydrocarbons that are soluble in carbon di-sulphide. The basic principle of the bitumen stabilization is water proofing and bonding. Water proofing inherits the strength properties and retains the other properties of soil. In case of cohesion less soils both binding and water proofing is provided by the bitumen to soil.

In granular soils the coarse grained soils may be individually coated and adhered by a thin film of bitumenious material. While in case of fine grained soils bitumenious material fills up the voids between soil particles, thus making the compacted soil-bitumen a water proofing surface. Most commonly used materials are cutback bitumen and bitumen emulsions. Heating of large quantities of soil and bitumen may not be possible, so a suitable grade of cutback must be chosen depending upon the weather conditions and mixing problems of soil and bitumen. While as the emulsions may be used while there is a scarcity of water for the use of construction. Soil bitumen (cut back or emulsion) is compacted in the required layers and is cured by the water for the period of time up to which volatile compounds evaporates and the resulting mixture hardens and provides the stiffened sub grade. According to the High Research Board of USA there are mainly four types of soil bitumen:

- Soil bitumen. This is the water proof and is used for the cohesive soil system. The percentage of bitumen varies from 4% to 7% of dry weight.
- Sand bitumen. This is used for the cohesion less soil system. The sand should be free from all types of impurities and the amount of bitumen varies from 4% to 10%.
- Water proofed clay concrete. This type is used for water proofing the different gradations of soil that are mixed together. Generally three different gradations are recommended. The amount of bitumen varies from 1% to 3% .
- Oiled earth. This type is used for water proofing the soil surface consisting of slit clay constituents. Slow or medium curing bitumen or emulsions are used. The surface is made water proof by the spraying of bitumen in two or three coatings. The amount of bitumen required is 5 litres/ sq m of the surface.

## 2. Literature Survey

Geotechnical engineers often face problems of constructing road bases on the soils or with the soils that do not have sufficient strength to support the wheel loads during the construction process or during the entire life of the pavement. So it is necessary to treat these soils or to enhance wheel load carrying capacity of these soils. The treatment results in less time and energy that is to be required for the production handling placement of road sub grades, and therefore takes less time in completing the construction process and thus resulting in a less traffic delay and disruption. This treatment is generally called as modification of soil or stabilization of soil.

**ManikantMandal and Dr, MayajitMazumdar (1995),** This study was made on lateritic soil stabilization with the addition of cement and lime. Particularly, the strength and fatigue behavior, under repeated flexure, of the stabilized latertic soil treated with the different types of additives, has not been studied in our country till now.

**Abu siddique and Bipradasrajbongshi (2002),** A study of Mechanical properties of a cement stabilized coastal soil for use in road construction, this paper present the soil cement stabilization with different percentages of cement fulfills the criterion of road sub-base and base subjected to light traffic. Analysis using CIRCLY computer program were conducted to estimate the thickness of soil-cement for paved and unpaved rural road maximum width 2.5m and subjected to anticipated design traffic loading of light cross country vehicle (LCCV), i.e, jeep. Virender Kumar (2002).

**Costas A.Anagno– stopoulos (2004),**In this study, a laboratory test programme was carried out to find out the effect of addition of cement and acrylic resin on physical and engineering behaviour of a soft clay. A series of tests were conducted with the addition different percentages of cement contents and acrylic resin of 5% . From this it is concluded that the development of strength and stiffness for a short curing time (7 days) is delayed significantly because of A.R addition while for long curing time (28 days) the engineering parameters are increased considerably.

The change in chemical composition of the soil is be noticed by decrease in the MDD and increase in the OMC of the soil-stabilized

**Umesha et al. (2009)** find out even more different results than theinvestigated byother researchers by use of lime on soil with plasticity limit of 42 % and plasticity index of 18 %. They found that the maximum dry density increased while the optimum moisture content decreased with the addition of lime/cement as compared to those of the raw soil.

**Bhattacharja and Bhatty (2003)** compared the results of lime and cement on three different types of soils in Texas with PI of different plasticity limits, and found that for all soils, better performance was observed from cement stabilizer. However, there was great decrease in the strength (by more than 50%) of the cement treated soils with delay compaction of 24 hour.

**Similarly, Parson et al. (2004)** performed durability tests on the four different types of soils (CH, CL, ML and SM) stabilized with lime, cement, fly ash, and enzymes. Durability test includes swelling, freeze and thaw, wet and dry, and leaching test of the stabilized soil samples. Swelling of all soils treated with all stabilizers was almost reduced, except for a soil with small amount of sulfate content (0.41%). The order of soil loss after freeze and thaw was cement < fly ash < lime. However, they found higher strength and lower PI in lime and cement treated soils than in those treated with fly ash after leaching. The result showed that the clayey soils were vulnerable to wet and dry cycles; however different stabilizer performed differently depending upon the type of the soil.

**Mohammad and Saadeh (2008)** conducted resilient modulus and permanent deformation tests on base and sub-base materials treated with lime/cement, and observed an increase in the resilient modulus by 1000 to 1500 percentage for cement treated soils and 225 to 325% for lime treated soil under identical conditions of 6 psi confining stress. The base materials in these tests were crushed limestone, Blended Calcium sulfate (BCS), BCS stabilized with slag (BCS-slag). The subbase materials were lime-treated and cement-treated soils over A-4 subgrade soil. Furthermore, they also observed considerable decrease in permanent deformation of the treated layers.

**Similarly, Achampong et al. (1997)** This study shows improvement in the resilient modulus of the cohesive soil with the increase in cement and/or lime; however instead of using real soil they blended two commercially available chemicals to obtain lean clay (LL = 48% and PI = 20%) and heavy clay (LL = 70, and PI = 44). They concluded that for a given stabilizer content and type, the resilient modulus is higher for lean clays as compared to heavy clays; while cement was less effective in heavy clays. The cement stabilized soils were cured for 7 days and 28 days; however the curing period for the lime treated soil was only 7 days. Furthermore, lime treated soils were compacted in three different moisture contents (OMC and OMC± 2%), but optimum moisture content was selected as a compaction moisture of cement-treated soils.

# 3. Methodology

The experimental work provides the details of the laboratory investigation program which was performed to find out the mechanical properties of the untreated soil sample and stabilized soil sample with cement. The soil is stabilized by the different cement contents by weight of soil. The tests carried out are as follows:

1. Water content by oven-Dry Method.
2. Specific gravity of soil by pycnometer method.
3. Soil properties (Atterberg's limits)

4. Liquid limit by Casagrande's apparatus
5. Particle size distribution by sieve analysis
6. Maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test.
7. Shear strength by Direct shear test (DST).

# RESULT AND DISCUSSION

**5.1 Water Content by Oven-Dry method**

**Result:** The average water content of the soil sample is found to be **12.76%.** From the Oven Dry Method test, we found out that sample 1 has the highest 22.73 % and the sample 3 has lowest 5.55% water content among all the three samples respectively. Moisture content of a soil has a direct effect on its strength and stability. Therefore, sample 3 with the lowest water content will be more stiff and stable and possess higher strength comparing to the other samples.The water content may range from low quantity to that of maximum to saturate the soil or fill all the voids in it. The natural moisture content is used for investigating the bearing capacity and settlement failures of soil. The study of moisture content is necessary in soil compaction control, and determining consistency limits of soils and for the calculation of stability of all kinds of foundation problems. The natural moisture content will also give an idea of the properties of soil in the field. From all this we conclude that Soil moisture content mainly depends on the type of soil. A coarse grained soil and sandy soil holds 1ess amount of water than silt clay. As sand particles do not bind with water drains out of the sand due to gravity action up to which field capacity is reached. For the above reasons, sandy soil may be preferred over clayey soil. As clayey soil has maximum capacity of holding water than sandy.

**5.2 Specific Gravity by Pycnometer Method**

**Result:** The specific gravity of the soil sample 1(without cement) is found to be 2.85 and the specific gravity of soil with cement (as additive) comes out 2.44. The Specific gravity by pycnometer method shows that all the soil samples have their specific gravity in the range of required soil i.e 2.65 to 2.80 for clayey and sandy soils. The specific gravity of soil sample is higher than the sample with cement.

**5.3 Soil Properties by Atterberg's limits**

**Result:** The liquid limit for sample 1 is **23.1%**, for sample 2 with 5% addition of cement is **19%**, for sample 3 with 10 % addition of cement is **18.2%** and for sample 4 at 15 % cement is **12%** from the graphs. The liquid limit of the soil indicates the compressibility parameter of the soil. Soils having a liquid limit above 45% are compressible in nature. With the addition of cement the liquid limit reduces and soil becomes less compressible as shown by the results. Cement sets and hardens independently and can bind the other constituent materials together. It gains high compressive strength with the addition of cement, reduces plasticity and volume changes, with the maximum increase in shear strength..

**5.4 Grain size distribution by sieve analysis**

**Result:** From the graph we get value of $D_{60}$= 0.02, D30 = 0.01, D10= 0.005

:. $Cc= \frac{D30^2}{D10 \times D60} = \frac{(0.01)^2}{(0.005)x(0.02)} = 1$

Also $Cu= \frac{D60}{D10} = 4$

The most basic classification of soil is whether it is fine-grained (cohesive) or coarse-grained soil (non-cohesive). From the sieve analysis test, we found out that the soil samples are sandy soil, consisting of sandy particles and the soil type can be classified as sand with some fines (silt and clay).

The uniformity coefficient (Cu) is a parameter which indicates the range of distribution of grain size in a given soil sample. For well-graded soils Cu is large and poorly graded soils have Cu nearly equal to 1, which means that the soil particles are approximately equal in size.

**5.5 Maximum Dry Density and optimum moisture content by S.P.T.**

**Result& Discussion:** The tests have been performed with the addition of different percentages of cement, the max dry density and the optimum moisture content for these samples are in table below.

**Table 5.1 Max dry density vs optimum moisture content**

| Result | Sample 1 (soil) | Sample 2 (soil+cement) at 5% | Sample 3 (soil+cement)at 10% | Sample 4 (soil+cement)at 15% |
|---|---|---|---|---|
| Max.Dry Density | 1.69 g/cc | 1.72 g/cc | 1.74 g/cc | 1.34 g/cc |
| Optimum Moisture Content | 16.4% | 17% | 14.6% | 18.4% |

Of these soil samples which are tested for the maximum dry density and the optimum moisture content. The sample 4 has shown the highest optimum moisture content but least maximum dry density and Samples 3 (soil +cement) has shown high maximum dry density but low moisture content.

The bearing capacity of any soil usually increases with increase in dry density and decrease in water content. Higher dry density assures higher shear strength and greater impermeability. When a soil is in submerged condition, its effective density and bearing capacity gets reduced. So we conclude from this, the OMC should always be less than the shrinkage limit. Otherwise on exposure to sun, cracks will develop in such soil and such soils are not suitable for the embankments, roads, etc.

**5.6 Shear strength parameters by Direct Shear Test**

**Result:** The shear strength parameters, angle of internal friction ($\phi$) and cohesion (C) of the soil samples are determined. We found that all the samples are cohesion less, but the angle of internal friction increases from 35° to 40.3° by adding 5% and 10 % of cement to sample-1 and sample-2 then the angle of internal friction decreases due to shrinkage after further increase in addition of cement to the soil. As the angle of friction increases the shear strength also increases. We can observe the change in volume characteristics of soil sample upon the action of shear load at two different loading, it can be seen that first, the soil gets expanded (volume increases) and at attaining highest loosest state, it gets compacted with decrease in volume.

## Conclusion

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

1. Based on the oven dry method of water content we found that the sample 1 had the highest 22.73 % and sample 3 had the lowest 5.55 % water content respectively of all the three samples. A soil's moisture content has direct effect on resistance and stability. Test 3 with the lowest moisture content would be more stable and stiff and has higher strength than other samples.
2. Based on the Casagrand's apparatus liquid limit test, we found that the soil sample 1 had the liquid limit of 23% relative to the other three samples. When adding 5%, 10% and 15% of the cement to the soil, the water content decreases as the drying rate rises with an increase in the cement content, therefore decrease in water content increases its strength.(Fig 3.4) shows the decrement in Liquid limit at varying cement content.
3. From the graphical representation of the Sieve analysis (Fig. 3.8) the coefficient of curvature (Cc) is 1 and the coefficient of uniformity (Cu) is 4. On the basis of Cc and Cu, we can infer that soil samples are sandy soil, consisting of sandy particles and some gravel.
4. Among the four soil samples evaluated for maximum dry density and optimum moisture content, (Fig. 3.20) and (Fig. 3.13) indicate that the dry density and optimum moisture content of the soil first increases with the addition of 5 % and 10% of cement, then decreases with the addition of 15% of cement to the soil due to shrinkage. The capacity of any soil usually increases with increasing dry density and decreasing moisture content. High density provides high shear strength and higher impermeability.
5. From the graphical study of the direct shear test in (Fig. 3.29), we found that the angle of internal friction increased from 35 ° to 40.3 ° by adding 5 percent and 10 percent of cement to sample-2 and sample-3, and then decreased to 9.4 percent by adding 15 percent of cement to the soil due to shrinkage.The increase in shear strength is respectively found to be 13.75%, 19.19% and 9.4% at 5%, and 10% then it decreases with the further addition of 15% cement content .

6. Overall, we can conclude that soil stabilization for subgrade pavement using cement as an additive is a good ground improvement technique, especially in engineering projects on weak soils.

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