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***Research Article***

# Effect of Cement Amount on CBR Values of Different Soil

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**Abstract**

Due to continued growth and rapid development of road construction, identification and recognition of type of soil and soil behaviour in different condition help us to select soil according to specification and engineering characteristic, also if necessary sometimes stabilize the soil and treat undesirable properties of soils by adding materials such as bitumen, lime, cement and etc. If the soil under pavement is not done according to the standards, construction will need more cost and construction time. In this case, a large part of soil should be removed, transported and sometimes deposited. Then purchased sand and gravel is transported to the site and full depth filled and compacted. Stabilization by cement or other treats gives an opportunity to use the existing soil as a base material instead of removing it and purchasing and transporting stabilized materials. In this study soil classification and the relation between soil classification and stabilization method is discussed, cement stabilization with different percentages have been selected for soil treatment based on National Cooperative Highway Research Program (NCHRP). In this study California Bearing Ratio (CBR) will be used to define the subgrade strength. Because for flexible pavements, the subgrade is considered an ideal layer to withstand wheel load, and the CBR value is considered a force measuring parameter. 0%, 3%, 7% and 10% cement were added to different soil types to evaluate its effect on CBR values and plasticity properties of treated soil. Results showed that cement addition increased CBR values of different soil types by the rate of 22-69%.

**Keywords:** Cement stabilization, California Bearing Ratio, Clayey soil, Silty soil

# Çimento Miktarının Farklı Toprakların CBR Değerlerine Etkisi

**Öz**

Yol yapımının sürekli ve hızlı gelişmesi nedeniyle, farklı koşullarda toprak tipinin ve toprak davranışının tanımlanması ve tanınması, şartnamelere ve mühendislik özelliklerine göre toprağı seçmemize, gerektiğinde toprağı iyileştirmeye ve toprakların istenmeyen özelliklerini işlemesine yardımcı olur. Yol kaplaması altındaki toprak standartlara göre yapılmazsa, yapılaşma daha fazla maliyet ve inşaat süresine ihtiyaç duyacaktır. Sağlam toprağın eksikliği bölgedeki toprağın kaldırılmasını taşınmasını ve bazen de depolanmasını gerektirmektedir. Daha sağlam dolgu malzemesinin sahaya taşınması ve arazide sıkıştırılması ek maliyet gerektirmektedir. Çimento veya diğer mineral katkılarla zeminin iyileştirilmesi, mevcut malzemenin yerinde kullanımı açısından destek sağlamaktadır. Bu çalışmada, farklı toprak sınıflandırmasına göre Ulusal Kooperatif Karayolu Araştırma Programına (NCHRP) dayanarak toprak işlemesi için farklı oranlarda çimento stabilizasyonu seçilmiştir. Bu çalışmada, alt temel dayanımını tanımlamak için Kaliforniya Taşıma Oranı (CBR) kullanılacaktır. Çünkü esnek yol yabakası için gerekli olan alt katman, tekerlek yüküne dayanacak ideal bir katman ve CBR değeri, bir kuvvet ölçüm parametresi olarak kabul edilir. Çimentonun toprağın CBR değerleri ve plastisite özellikleri üzerindeki etkisini değerlendirmek için farklı toprak türlerine % 0, % 3, % 7 ve % 10 çimento eklenmiştir. Sonuçlar çimento ilavesinin farklı toprak tiplerinde CBR değerlerini % 22-69 oranında arttırdığını göstermiştir.

**Anahtar Kelimeler:** Çimento stabilizasyonu, California taşıma oranı, Killi toprak, Siltli toprak

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# 1. Introduction

Soil stabilization a general term for any physical, chemical, mechanical, biological or combined method of changing a natural soil to meet an engineering purpose. Improvements include increasing the weight bearing capabilities, tensile strength, and overall performance of in-situ subsoils, sands, and waste materials in order to strengthen road pavements. Stabilization can be divided into two groups, mechanical stabilization and admixture stabilization. Mechanical stabilization performed by mixing gradation portion into soil on-site or quarry plant to changing gradation and sieve analysis of soil to reach required specifications. Spreading, mixing and compaction is done to achieve required density. The most important objectives of soil stabilization are providing one or more of the following:

- Modify the soft soils and low resistivity
- Increases soil stability
- Increased soil bearing resistance
- Lower permeability
- Reduce the swelling and contraction of the soil
- Reduce soil moisture
- Reduction of soil plasticity range
- Prevent soil erosion
- Reduce the thickness of pavement layers
- Create the basis capable of bearing base layers and more
- Reconstruction of old pavements using materials available
- Preparation area for easier implementation of construction operations
- Dust Reduction
- Saving energy
- Accelerate the operation
- Enhance quality and reduce layer thickness [1,2]

The most important reason for soil stabilization in road construction can be regarded as follows:

- Moisture Control
- Dust control
- Modify of poor soil
- Construction the appropriate sub-grade with excellent quality
- Reconstruction of roads
- Reduce the cost and implementation time
- Modify inappropriate properties of soil under the base and sub-base

This study discusses how much effective cement will be to improve soil properties (CBR) when used as additive.

# 2. Cement Stabilization

Strength gain in soils using cement stabilization occurs through the same type of using lime stabilization. Cement contain the calcium required for the pozzolanic reactions to occur; however, the origin of the silica required for the pozzolanic reactions to occur differs. With cement stabilization, the cement already contains the silica without needing to break down the clay mineral. Thus, cement stabilization is fairly independent of the soil properties; the only requirement is that the soil contains some water for the hydration process to begin. [3]

Soil material that has been treated with a proportion of Portland cement (5 to 14%) to modify undesirable properties of soils or sub standard materials so that suitable soil may be used as road sub-layers' construction.

Cement percentage that will be used to stabilize in-situ soils depends on the level of modification required, plastic behavior of soil or other criteria. Cement stabilization is used to improve the engineering properties and construction characteristics of silt and clay soils by reducing its plasticity and increase the compaction and strength of the treated soil. Silt and clay soils, especially when are wet, can create compaction and construction problems. These soils can be soft, plastic, and difficult to compact. Good compaction and cement stabilization of soil help to strength and durability of pavement. Cement stabilization may not be suitable for all types of soil such as organic soil, acid soil, sulfate soil and uniform sand.

Singh et al. mentioned in their study that the CBR value of gravel soil stabilized with cement increased significantly with increase in cement content. 6 % cement content increased CBR value from 30 to90 % for 96 hours soaking [3].

Okunkwo et al. stated in their experimental research that for soil type A-2-6 subgroup of A-2 group (generally consisting of silty or clayey sand), the addition of 5.36% and 6.48% of cement help the soil meet the CBR requirement for sub-base and base course respectively [4].

Mousavi et al. emphasized on that as for the CBR value, it was found that the CBR value of stabilized clay increased drastically in comparison with the CBR of untreated soil specimen [5].

In Udo's study, for river sand, increase in cement content from 2-10 % caused increase in CBR from 26% to 127% [6].

Literature review shows there are difference between the results which is due to the nature of the soils with different properties.

## 3. Soil Tests

To classify soil, two system have been used (USCS-Unified Soil Classification System and AASHTO-American Association of State Highway and Transportation Officials). To determine particle size distribution, sieve analysis and hydrometer tests have been performed. Also for consistency property, Atterberg limits (plastic limit and liquid limit) tests have been performed. Figure 1 and Table 1 shows flowchart for fine soil classification according to USCS and AASHTO, respectively.

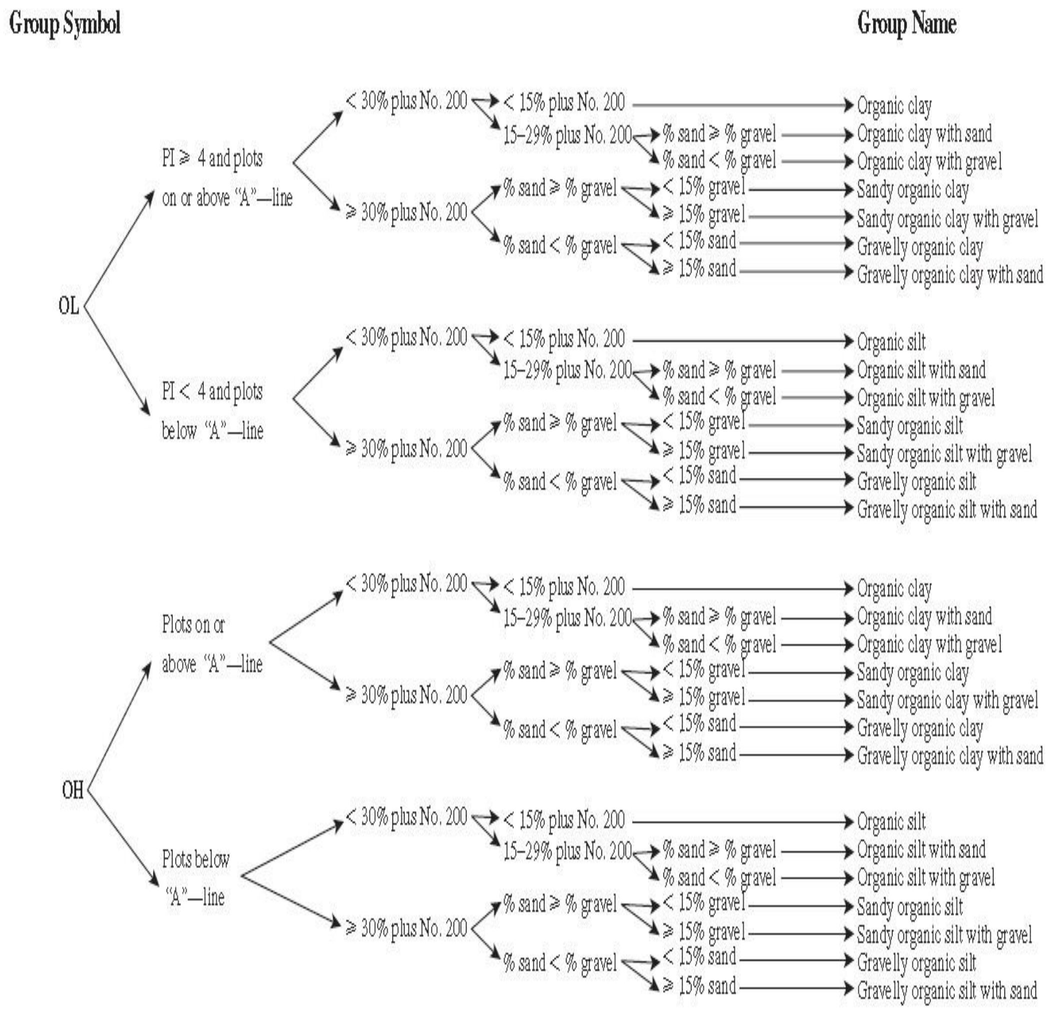


Figure 1. Fine Soil Classification according to USCS [7]

Table 1. Classification of Silty-Clay with respect to AASHTO [8]

| **General Classification** | **Silt-Clay Materials (>35% passing the 0.075 mm sieve)** | | | |
|---|---|---|---|---|
| Group Classification | A-4 | A-5 | A-6 | A-7<br>A-7-5 A-7-6 |
| Sieve Analysis, % passing | | | | |
| 2.00 mm (No. 10) | … | … | … | … |
| 0.425 (No. 40) | … | … | … | … |
| 0.075 (No. 200) | 36 min | 36 min | 36 min | 36 min |
| Characteristics of fraction passing 0.425 mm (No. 40) | | | | |
| Liquid Limit | 40 max | 41 min | 40 max | 41 min |
| Plasticity Index | 10 max | 10 max | 11 min | 11 min |
| Usual types of significant constituent materials | silty soils | | clayey soils | |
| General rating as a subgrade | fair to poor | | | |

After soil classification, laboratory compaction tests have been performed on soil samples to obtain moisture-density relationship according to ASTM-D1557, 2007 [9]. Then according to specifications, amount of cement content as additive has been determined and CBR testing done on un-stabilized and stabilized soil samples.

## 3.1. Soil Types

Table 2 gives four different soil type with their MDD (maximum dry density), OMC (optimum moisture content) and Atterberg limits (LL-Liquid Limit, PL-Plastic Limit and PI-Plasticity index) that have been classified according to USCS and AASHTO.

Table 2. Test results for all samples

| **Soil Classification systems** | | **MDD** | **OMC** | **LL** | **PL** | **PI** |
|---|---|---|---|---|---|---|
| USCS | AASHTO | (g/cm$^3$) | % | % | % | % |
| GC-GM(Silty-clay gravel with sand) | A-2-4,(0) | 1.955 | 9.7 | 27 | 22 | 5 |
| CL-(Sandy Lean Clay) | A-4,(0) | 1.852 | 12.3 | 30 | 20 | 10 |
| ML-(Sandy Silt) | A-4,(0) | 1.841 | 13.3 | 34 | 24 | 10 |
| CL-ML-(Sandy Silty Clay) | A-4,(0) | 2.034 | 10.3 | 25 | 18 | 7 |

### 3.2. California Bearing Ratio Tests and Results

CBR or strength is one indication for of the degree of reaction in the (soil, cement, and water). California Bearing Ratio is directly related to density, it is affected by the degree of compaction and water content in cement stabilized soil. Compressive strength tests were performed 4-hour after sample preparation according to (ASTM-D1633, 2000). CBR test have been performed according to (ASTM-D1883, 2007). Table 3 gives CBR values of four different soil types with addition of 0, 3, 7 and 10% cement additions. Figure 2. shows the effect of cement addition on different soil types.

Table 3. CBR values for all samples

| **Soil Class** | | **Added Cement%** | **CBR%** |
|---|---|---|---|
| **USCS** | **AASHTO System** | | |
| GC-GM(Silty-clay gravel with sand) | A-2-4,(0) | 0 | 30.4 |
| | | 3 | 63.1 |
| | | 7 | 155.8 |
| | | 10 | 211.9 |
| CL-(Sandy Lean Clay) | A-4,(0) | 0 | 4.2 |
| | | 3 | 47.6 |
| | | 7 | 70.4 |
| | | 10 | 116.1 |
| ML-(Sandy Silt) | A-4,(0) | 0 | 2.1 |
| | | 3 | 47.6 |
| | | 7 | 78.6 |
| | | 10 | 141 |
| CL-ML-(Sandy Silty Clay) | A-4,(0) | 0 | 5.6 |
| | | 3 | 64.2 |
| | | 7 | 120.5 |
| | | 10 | 136.3 |

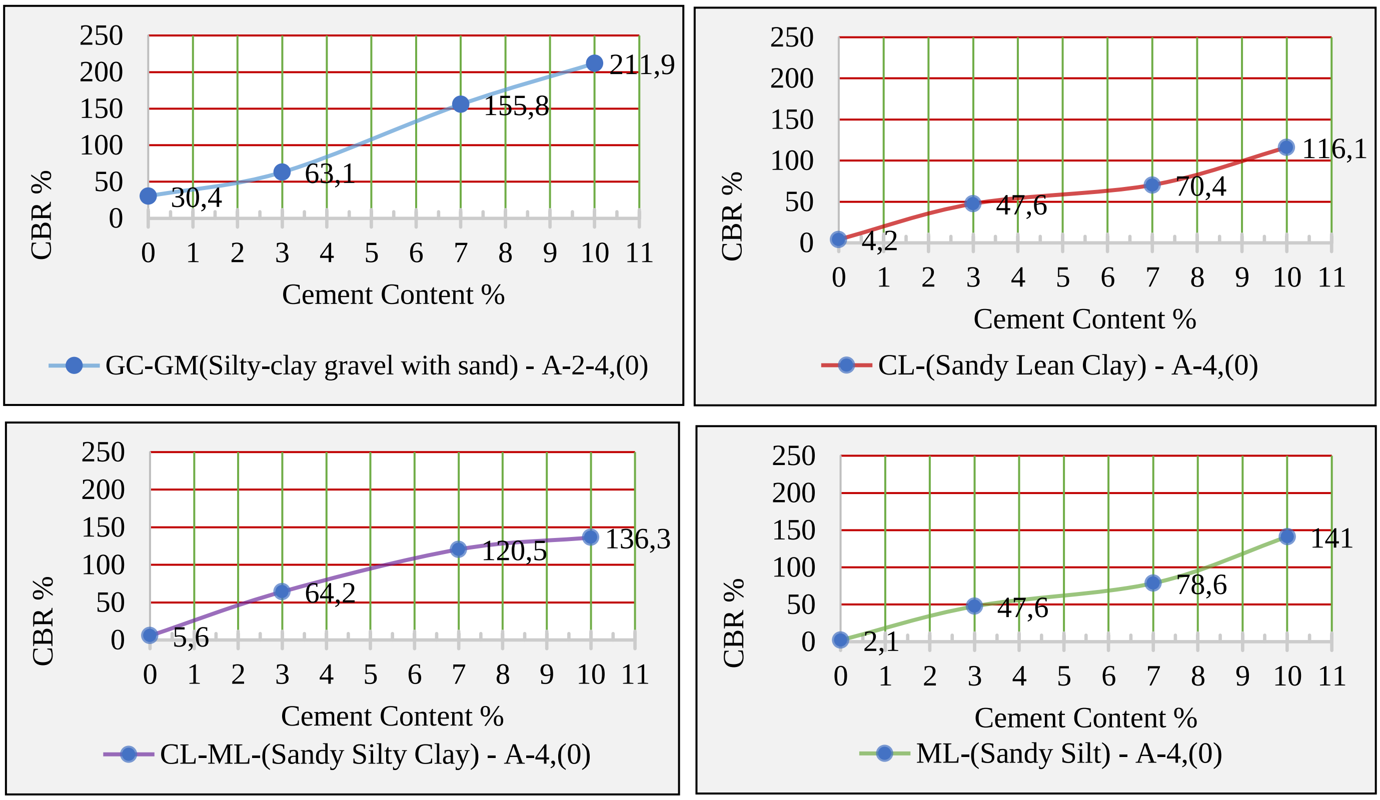


Figure 2. Effect of cement addition on CBR values of treated soils

As it can be seen from Figure 2, as the amount of cement increased, CBR values of all soil types increased. Maximum increase in CBR is obtained for ML soil. Adding cement to the soil reduces plastic properties of soil and improves the bond between soil particles. This property increases the load resistance of cement-stabilized soils. Fine-grained soils and clayey soils that have plastic properties in moist condition can more successfully stabilized with cement**.** Clayey soil when wet are soft and their strength decreases extremely. Soil stabilization with cement increase CBR especially in clayey soils in saturated or wet conditions because cement creates strong bonding between soil particles and improves plasticity behavior. Usually immediately after adding cement to the soil, there is an increase in the soil strength. The immediate increased resistance facilitates construction machinery on soil layer and the pavement ready for implementation. The results of the tests and perceives studies shown cement has high impact in clayey soil strength. Implementation of stabilization process by different cement content help to engineers to select an economic cement amount for the stabilization process according to project specification and characteristics.

## 4. Conclusions and Recommendations

Cement stabilization improves strength and plasticity of soil. Cement stabilization is useful epecially for fine-grained soils. By adding 3,7 and 10 % cement content in samples, CBR increase for, No. 1: 32.7, 125.4 and 181.5, No. 2: 43.4, 66.2, 11.9, No. 3: 45.5, 7.5, 138.9 and No. 4: 58.6, 114.6 and 130.7 respectively. Cement addition increases CBR values of different soil types by the range of 22-69%. The use of stabilizing agent which is cement in this study, for sub-grade with weak soil, improves strength parameter, such as cohesion and improvement in cohesion leads to strengthening of subgrades. This will ultimately lower down the road construction cost. Imporevment in CBR is directly related to the improvement in compressive strength. Cementation decreases the plastic behaviour of soil.

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