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# Experimental Study of Soil Bearing Capacity and Unconfined Compressive Strength Value on Dry-Wet Scenario

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**Abstract:** Structure deterioration is a process in which damage to structure begins to develop due to a combined impact of loads and environmental conditions around the location of the structure. In general, researchers seek to analyze the extent to which changes in the mechanical behavior of soil under a structure when hampered by a dry and wet cycle. This research was conducted in order to analyze changes in CBR and the unconfined compressive strength of soft soil due to the dry-wet scenario. Laboratory investigation results showed that due to the dry-wet cycle, the CBR and UCS values had decreased, particularly during the initial cycle, when the CBR and UCS values dropped dramatically by 77 and 87%. Moreover, by increasing cycles, the CBR and UCS value decreases. This relatively large decrease is influenced by changes in the formation of soil microstructure particles, the binding particles of which become tenuous due to the presence of water. At the saturated condition, CBR and UCS value might decrease by 90%. This result can be considered in the implementation of road construction in tropical climate zones where the wet-dry and the dry-wet cycle is a very important factor in the behavior of the road layers. One of the measures to be taken to solve this problem is to use chemical stabilization to increase the mechanical index of water content modification or using impermeable protection.

**Key words:** CBR, dry-wet cycle, unconfined compressive strength, wet-dry cycle, mechanical

## INTRODUCTION

Fine-grained soils are extremely vulnerable to changes in moisture content. When the moisture content rises above its optimum moisture content, the soil's consistency turned to the liquid phase. This condition leads to decreasing cohesion and weakens its engineering properties such as the CBR value and the unconfined compressive strength. Changes in the moisture content of fine-grained soil will also change its volume. It can cause settlement and uplifting of a structure which is extremely considered as a critical failure of a structure whether it's a building or road pavement.

In tropical-climate countries, moisture content of soil fluctuating throughout the year in the rain and summer season. Especially, in an archipelago with large lowland areas. It's soil mostly fine-grained. Difficulties in reaching the bedrock layer in certain areas leaving engineers have no choices but to build a structure on it. This condition encourages the authors to conduct this research. In this research, the effect of dry-wet and wet-dry cycle to CBR and UCS value of soft soil will be observed.

**Literature review:** Soils may be separated into three very broad categories: cohesionless, cohesive and organic soils. Cohesive soils are characterized by very small particle size where surface chemical effects predominate. The particles do tend to stick together the result of water-particle interaction and attractive forces between particles. Cohesive soils are therefore both sticky and plastic. Cohesive soils (mostly clays but also silty clays and clay-sand mixtures with clay being predominant) exhibit generally undesirable engineering properties compared with those of granular soils. Clayey soils cannot be separated by sieve analysis into size categories because no practical sieve can be made with openings so small; instead, particle sizes may be determined by observing settling velocities of the particles in a water mixture (Coduto, 1999).

Compressibility, strength and permeability are extremely important properties and are the main aspects to consider in the design of embankments built with fine soils. The knowledge of water retention properties is also important to solve transient flow problems. Settlement prediction and long-term behavior, in particular, require the knowledge of the swelling properties of the soil as water is exchanged with the atmosphere even if water percolation is not predicted inside the earth structure.

Concerning the swell potential of the clayey soil, this property is related to the nature of the clayey minerals as

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well as specific surface, cation exchange capacity, ion exchange nature, organic material content and the presence of cementation agent between particles (Mitchell and Kenichi, 2005).

Clayey soils tend to have low shear strengths and to lose shear strength further upon wetting or other physical disturbances. They can be plastic and compressible and they expand when wetted and shrink when dried. Some types expand and shrink greatly upon wetting and drying. Cohesive soils can creep (deform plastically) overtime under constant load, especially when the shear stress is approaching its shear strength, making them prone to landslides. They develop large lateral pressures and have low permeability (Coduto, 1999).

The properties of clay soil depend on the mineral composition of the particles, their shape and size, the type, and strength of structural bonds, the structure, texture and interaction with water (Das, 2006). To construct on such soils, either pre-treatment or specially, designed foundations can be used for low-cost construction to build houses and road infrastructures (Chan and Ibrahim, 2008).

Construction of highways and runways over soft soils is one of the most common civil engineering problems in many parts of the world since soft soils generally show low strength and high compressibility. Subgrades having California Bearing Ratio (CBR) values smaller than 8 and Unconfined Compressive Strength (UCS) values smaller than 48 kPa are considered as soft soil and need to be stabilized especially in pavement applications (Das, 1997).

Expansive soils owe their characteristics to the presence of swelling clay minerals. As they get wet, the clay minerals absorb water molecules and expand; conversely as it dries they shrink, leaving large voids in the soil. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5% by weight. Soils with smectite clay minerals such as montmorillonite, exhibit the most profound swelling properties.

Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity, generally those with liquid limits exceeding 50% and plasticity index over 30, usually have a high inherent swelling capacity. Expansion of soils can also be measured in the lab directly by immersing a remolded soil sample and measuring its volume change (Rogers *et al*., 1993).

However, the magnitude of the deformation decreases with the increase in the drying wetting cycle, failing to restore the initial state which confirmed an irreversible influence of the drying-wetting cycle on the deformation properties of the soils (Ye *et al*., 2018). On the other hand, the soils with high water content would shrink when their moisture content is decreased (Ikizler *et al*., 2014). Expansive soil is a kind of special cohesive soil, the kind of soil can significantly become to soften after it absorbs water and it also can become to contract after its losses water (Wang and Liang, 2014).

## MATERIALS AND METHODS

The research method to be performed can be classified as a form of experimental research in a laboratory that can be defined as a scientific and systematic approach in which the researcher manipulates one or more variables and controls and measures each variable of other variables.

The research was designed by making objects and laboratory test models to examine, process, observe, study and finally, summarize in a research conclusion on the phenomena and objectives to be achieved.

In order to classify the material used in this experimental study, a laboratory investigation program was carried out to evaluate the basic properties and mechanical properties of the soil.

Unconfined compression test and california bearing ratio specimen was remolded according to standard method ASTM D 1883-07 and ASTM D 2166 with 6 inches in diameter and 7 inches high for CBR and 2 inches diameter with 4 inches high for UCT.

The dry-wet scenario was then applied and changes in CBR and UCS values are observed for each cycle. The dry-wet cycle consists of 3 dry cycles and 3 wet cycles.

## RESULTS AND DISCUSSION

Based on the results of the laboratory tests, the soil used in this study is classified as high plasticity clay/CH based on the unified soil classification system. The results of the test are detailed in Table 1.

According to AASHTO, the soil used in this research is classified in category A-7-6, clayey soil. Overall, the test results show that the soil used is classified as soft soil.

In Fig. 1, it is shown that the CBR value of the soil decreases each cycle. In the first wet phase, the CBR value dropped critically 72% compared to the initial condition. After the first wet phase and entering the first dry phase, the CBR value recovered a bit, yet it still decreased by 38% compared to the initial condition. This shows us that the damage done by water was permanent and irreversible. The cycles go on and in the second wet phase, the CBR value dropped even worse than the first cycle by 89% compared to the initial condition. At the dry phase of the second cycle, the CBR value recovered a bit, yet, it dropped already by 69% compared to the initial condition. In the third cycle, the CBR value decreases 90% at the wet phase and 72% at the dry phase compared to the initial condition. The CBR values are shown in Table 2.

Table 1: Recapitulation of basic properties and mechanical properties of soft soil

| Basic properties | |
|---|---|
| Index | Results/Units |
| **Sieve analysis** | |
| Gravel fraction | 13.4 (%) |
| Sand fraction | 23.2 (%) |
| Clay and silt fraction | 63.4 (%) |
| **Atterberg limits** | |
| Liquid Limit (LL) | 61.19 (%) |
| Plastic Limit (PL) | 28.37 (%) |
| Shrinkage Limit (SL) | 13.21 (%) |
| Plasticity Index (IP) | 32.82 (%) |
| Activity (A) | 0.52 (-) |
| Specific gravity | 2.62 (-) |
| **Standard proctor** | |
| Optimum moisture content | 30.76 |
| (%)Max dry density | 1.41 (gcm$^{-3}$) |
| Mechanical properties | |
| CBR | 6.96 (%) |
| Unconfined compressive strength | 0.187 (gcm$^{-2}$) |
| **Classification** | |
| AASHTO | A-7-6 |
| USCS | Clay-high plasticity |

Table 2: Changes in CBR value due to dry-wet cycle

| CBR (%) | | | | | | |
|---|---|---|---|---|---|---|
| 0 | Wet 1 | Dry 1 | Wet 2 | Dry 2 | Wet 3 | Dry 3 |
| 6.97 | 1.56 | 4.31 | 0.75 | 2.24 | 0.67 | 1.94 |

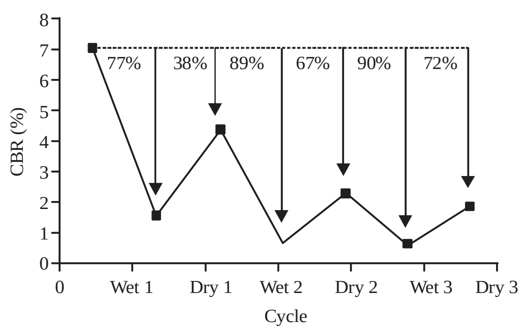


Fig. 1: Changes in CBR value due to dry-wet cycles

In Fig. 2, it is shown that the UCS value of the soil decreases each cycle. In the first wet phase, the UCS value dropped by 87% compared to the initial condition. After the first wet phase and entering the first dry phase, the UCS value recovered a bit, yet, it still decreased by 21% compared to the initial condition. In the second wet phase, the UCS value dropped even worse than the first cycle by 92% compared to the initial condition. At the dry phase of the second cycle, the UCS value recovered a bit, yet, it dropped already by 46% compared to the initial condition. In the third cycle, UCS value decreases 94% at the wet phase and 58% at the dry phase compared to the initial condition. The UCS values are shown in Table 3.

The patterns of the changes in UCS and CBR value show that the worst condition occurs at the wet phase.

Table 3: Changes in UCS value due to dry-wet cycle

| USC (kgcm$^{-2}$) | | | | | | |
|---|---|---|---|---|---|---|
| 0 | Wet 1 | Dry 1 | Wet 2 | Dry 2 | Wet 3 | Dry 3 |
| 0.187 | 0.023 | 0.148 | 0.014 | 0.101 | 0.010 | 0.078 |

Table 4: Changes in CBR and UCS value due to dry-wet cycle

| CBR (%) | | | | | | |
|---|---|---|---|---|---|---|
| 0 | Wet 1 | Dry 1 | Wet 2 | Dry 2 | Wet 3 | Dry 3 |
| 6.97 | 1.56 | 4.31 | 0.75 | 2.24 | 0.67 | 1.94 |
| **USC (kgcm$^{-2}$)** | | | | | | |
| 0.187 | 0.023 | 0.148 | 0.014 | 0.101 | 0.010 | 0.078 |

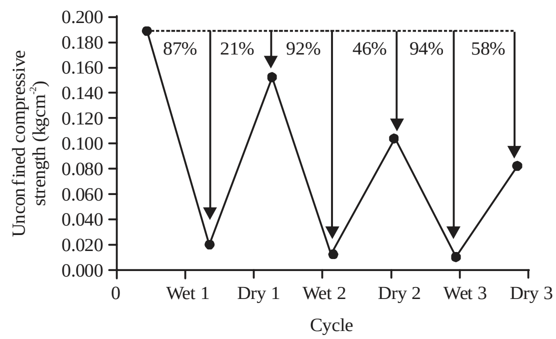


Fig. 2: Changes in UCS value due to dry-wet cycles

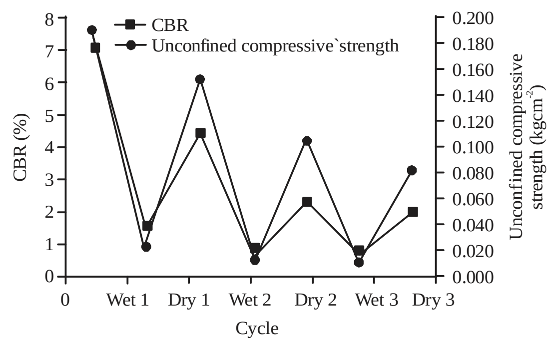


Fig. 3: Changes in CBR and UCS value due to dry-wet scenario

This may occur due to the behavior of soil bodies in saturated conditions lead the soil to enter the liquid phase and loses its cohesion, thus, decreasing its mechanical properties.

Although, Fig. 3 and Table 4 when entering the dry phase the mechanical value recovered, yet, the damage done by water infiltrating the soil bodies was irreversible and permanent.

Based on the overall test results, UCS and CBR value decreases linearly with increasing cycles. This result shows us that in tropical climate areas when the rainy season comes, it is possible for the compacted soil to lose its capacity by 90%. It is highly recommended for engineers to conduct soil stabilization to reduce soil's permeability and strengthen its cohesion to prevent structure deterioration. Protection using impermeable geotextile always be a wise option too. It is hoped that the results of this analysis, this research should serve as a reference for considering the implementation construction, especially in areas with a tropical climate.

## CONCLUSION

The wet-dry cycle results in a decreasing CBR and UCS value, especially, during the wet cycle where CBR and UCS value drop significantly 90%. UCS and CBR value decreases linearly with increasing cycles due to the damage done by water infiltrating the soil bodies was irreversible and permanent. Thus, saturated soil will never gain its mechanical properties back without recompacting.

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