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GEOTECHNICAL CHARACTERIZATION OF SOILS IN THE CENTER OF DIWANIYAH (IRAQ): EXPERIMENTAL EVALUATION OF PHYSICAL AND MECHANICAL PROPERTIES

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Abstract

This paper is a detailed experimental and statistical study on the geotechnical properties of soils collected from more than 15 site locations within the center of Diwaniyah at depths between 1 and 10 m below ground surface. Tests were conducted for grain size distribution, Atterberg limits, compaction characteristics and shear strength parameters in laboratory.

Soils mainly clayey–silty alluvium falls in the CL-CI category. The L.L ranges from 44% to 60% and the plasticity index (PI) varies from 20% to 34%. The results of the statistical analysis show that the mean liquid limit and plasticity index are 51.2% and 27.6%, respectively. The coefficient of variance for both parameters is moderate. The maximum dry density ($\gamma_{d,max}$) is in the range of 16.8 and 18.1 kN/m³; the optimum moisture content (OMC) is in the range of 15 to 21.%

Data on the shear strength parameters showed that c values are between 28 and 62 kPa. Likewise, φ values are from 17° to 27°. The findings show average of shear strength and compressibility. The study presents geotechnical parameters that are statistically backed for foundation design in central Iraq..

Keywords : Geotechnical properties; Statistical analysis; Clayey–silty soil; Shear strength; Compaction; Diwaniyah.

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1. Introduction

Soils are geotechnically characterized for safe and economic design of civil engineering structures. The soil is sensitive to changes in moisture and stress history. It is also a complex material as it is not uniform. As a result, thorough experimental studies are needed to ascertain dependable engineering parameters . In central Iraq, especially in Diwaniyah, the soils are made up mainly of alluvial deposits due to the Euphrates River sedimentation. Usually, the deposits contain a constantly varying mixture of clay, silt and sand. This causes them to behave like a soil of mixed quality which has a low to medium-high compressibility and plasticity. Features can severely impact the performance of a foundation, causing settlement and stability problem .

Earlier investigations of the soils of Iraq have identified critical geotechnical issues including high plasticity and moisture sensitivity, and varying shear strength. Yet, there is no detailed experimental data, supported by statistics, in Diwaniyah's canter. Consequently, this research aims to analyze the soil physical and mechanical properties of this region through laboratory experimentations and the application of statistical techniques.

2. Materials and Methods

2.1 Site Description and Sampling

Soil samples were collected from various sites (more than 15 site) within the center of Diwaniyah with depths ranging from 1 m to 10 m below ground surface. The sites chosen for sampling reflect the ordinary sub soils throughout the study area.

Disturbed and undisturbed samples were obtained according to the standard geotechnical sampling procedures. The index and compaction tests were performed on disturbed samples while undisturbed samples were used for shear strength test.

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2.2 Laboratory Testing Program

The experimental program included the following tests:

- Grain size distribution (ASTM D422)
- Atterberg Limit Test (ASTM D4318)
- Moisture Content of Natural Soil
- The standard proctor compaction test is ASTM D698
- Direct shear exam according to ASTM D3080

Soil classification was performed using the Unified Soil Classification System (USCS).

2.3 Statistical Analysis

To evaluate the variability and reliability of the measured parameters, statistical analysis was performed using:

- Mean value (μ)
- Standard deviation (σ)
- Coefficient of variation (COV)

These statistical indicators provide insight into the consistency and spatial variability of soil properties.

3. Results and Discussion

3.1 Physical Properties and Soil Classification

The outcomes of grain size distributions reflect that the soils are enriched with fine content, clay ranges from about 42% to 50%, and silt varies from 35% to 43% and sand from 10 to 18%.

The liquid limit (LL) is in the range of 47% to 55%, while the plasticity index (PI) is in the range of 25% to 30% shown in figure 1. Which brings it under the CL–CI classification of the Unified Soil Classification System (USCS). As stated by Braja M. Das, soils within this limit are moderately plastic and when wetted and dried will change in volume.

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Statistical analysis shows the mean liquid limit to be about 51% and its standard deviation about 3% which shows relatively low variation. This is shown in figure 2. Therefore, the soil profile is homogenous.

The values of liquid limit (LL) and plasticity index (PI) are relatively low in terms of coefficient of variation (COV), which indicates that the soil deposits are mostly homogeneous over the studied area. Further, low COV (<10%) indicates good consistency of soil properties.

Such homogeneity is common in sediments forming in similar depositional environments.

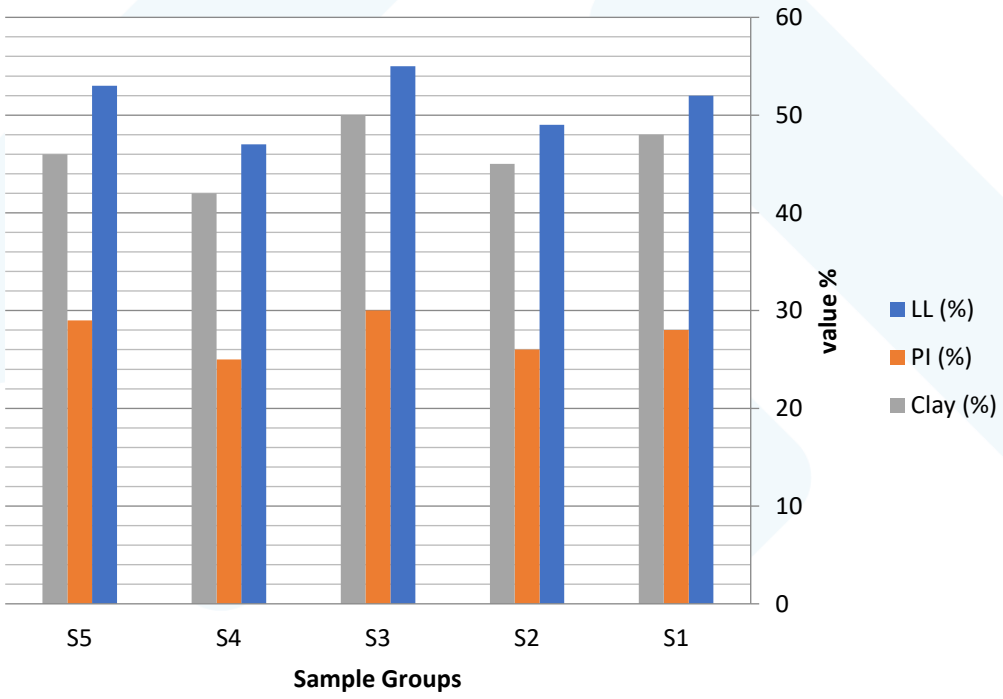

Figure (1): Variation of Atterberg Limits and Clay Content Among Samples

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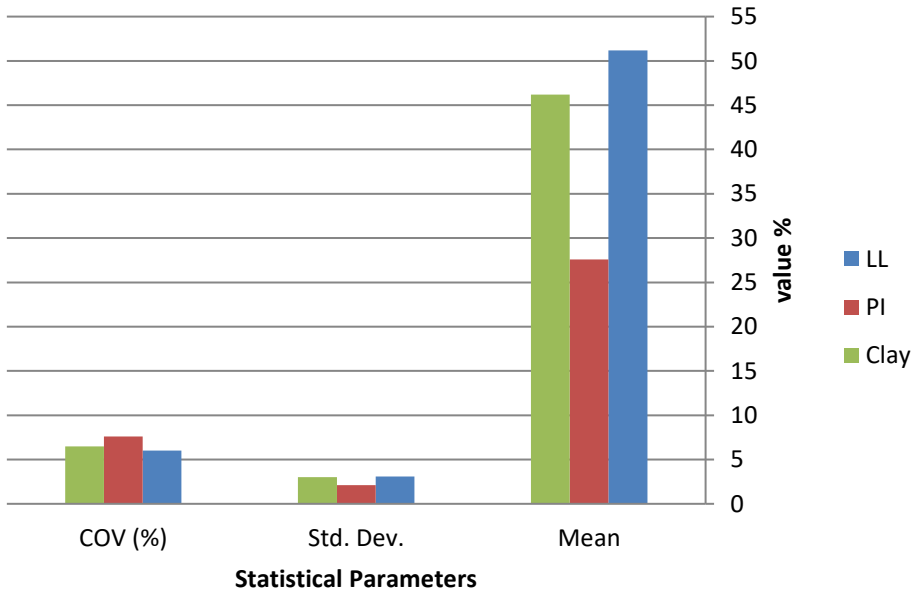

Figure (2) Comparison of Atterberg Limits and Clay Content Statistics

3.2 Compaction Behavior

Findings from the compaction test show that the maximum dry density (γd,max) is approximately 16.9 to 18.1 kN/m³ and optimum moisture content (OMC) from 15.8% to 20.5% shown in figure 3. It is seen that there is an inverse relationship between dry density and moisture content. This is standard soil mechanics behavior. The reason for moderate values is attributed to higher clay content, which restrains the rearrangement of particles during compaction.

According to Karl Terzaghi, fine-grained soils consist of clay particles, which contain thin layers of water and require a greater amount of moisture content to obtain maximum compaction.

Figure 4 depicts the statistical analysis which shows a low standard deviation in γd, max, indicating stable compaction characteristics. The variation of OMC indicates sensitivity to moisture condition subjecting it to field compaction performance.

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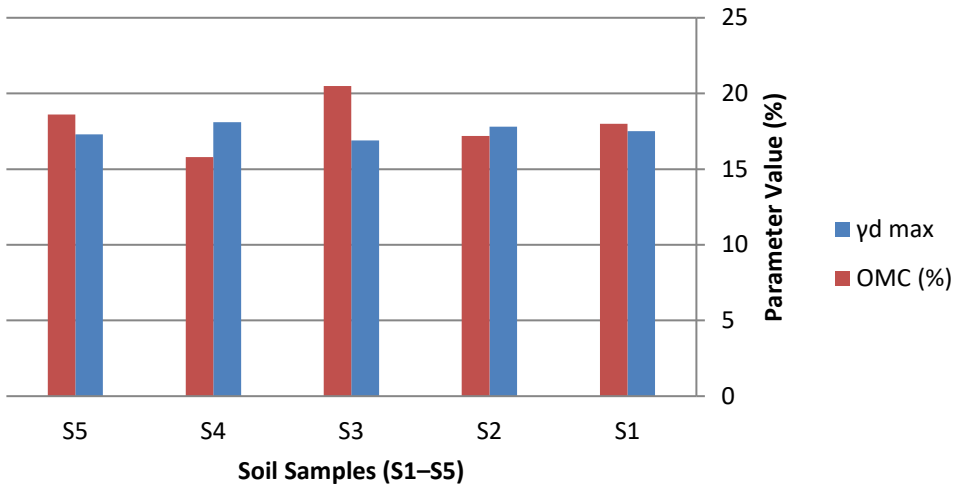

Figure (3) Comparison of Measured Parameter Across Samples (S1–S5)

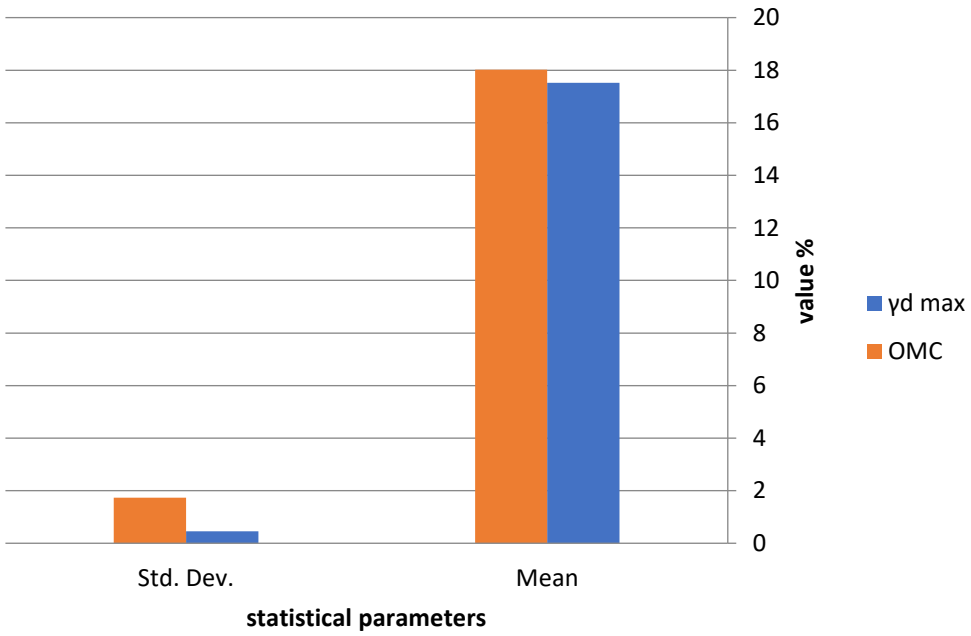

Figure (4): comparison Υ_d max OMC statistics

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3.3 Shear Strength Characteristics

As displayed in figure 5, consolidated-drained tests were conducted to evaluate the stress-strain properties of the soil, which highlighted two significant parameters of soil strength which was internal friction angle (φ) and cohesion (c). The c has range of 28 kPa to 60 kPa and φ with a range of 19° to 27°.

The rather large cohesion values imply that interparticle forces and electrochemical bonding play a major role in soil strength. The fact that the friction angle is moderate indicates limited granules interlocking.

According to figure 6, the cohesion values show much variation as evidenced by its higher coefficient of variation as compared to other parameters. There may be some variation due to.:

- natural soil heterogeneity
- variation in moisture content
- differences in sample structure

This variability is key from an engineering perspective since they influence bearing capacity and slope stability. Consequently, it is recommended to adopt conservative design approaches in saturated conditions where effective stress decreases..

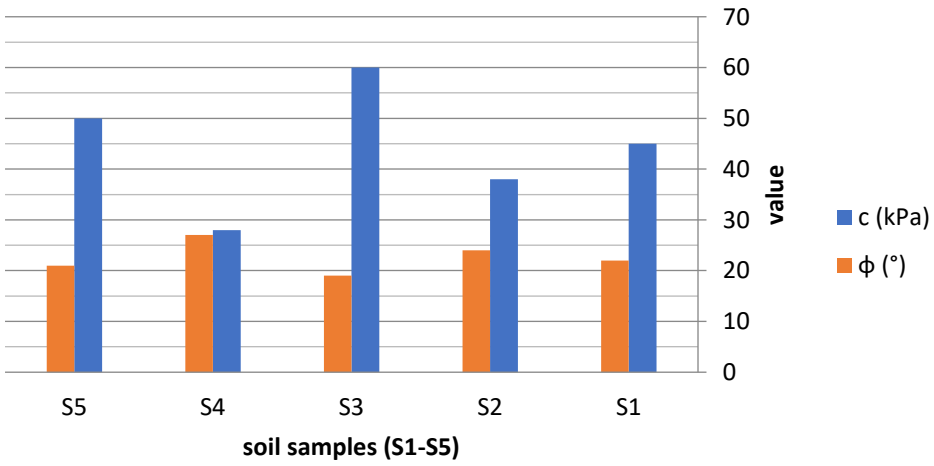

Figure (5): comparison of Measured parameter Across samples (S1-S5)

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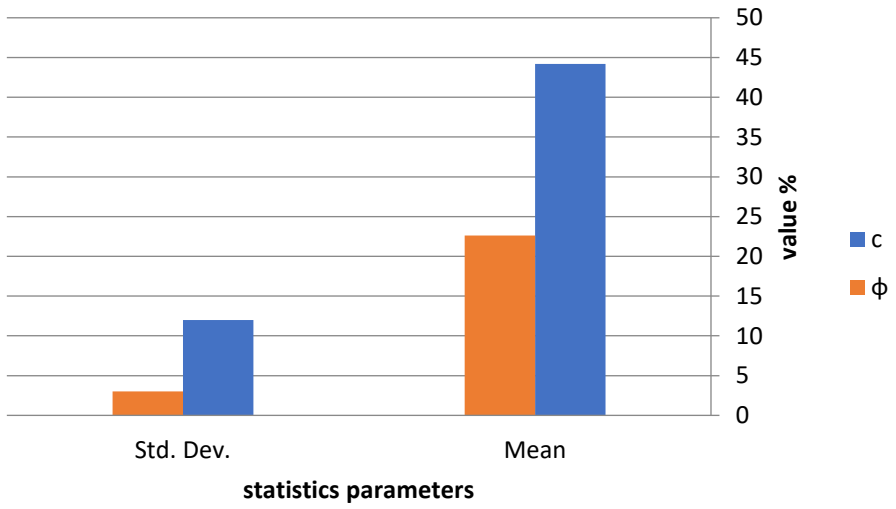

Figure (6) : comparison C, Φ statistics

3.4 Engineering Implications

Soil in the center of Diwaniyah has moderate strength, relatively high plasticity, and noticeable compressibility as per the combined results. Clayey-silty alluvial deposits have these characteristic which must be carefully incorporated in geotechnical design.

Key implications include:

- There might be uneven settling because of a potential shift.
- Moisture variation reduces strength of brick as well as mortar.
- The need for foundation optimization or soil improvement techniques.

3.5 Comparison with Previous Studies

The obtained results are consistent with earlier research on Iraqi soils, which typically report:

- Liquid limits should be in the range of forty to sixty percent.
- The plasticity indices range from twenty to thirty-five percent.

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- Shear Performance Driven by Cohesion.

Such agreement supports the validity of the experimental program and confirms that the soil behavior in the center of Diwaniyah aligns with regional geotechnical characteristics.

4. Conclusions

Based on the experimental and statistical investigation of soils from the center of Diwaniyah, the following conclusions can be drawn:

1. The soil types studied are mostly fine-grained alluvial deposits that mainly consist of clay and silt fractions. Further, the studied soils are classified as CL–CI by the Unified Soil Classification System (USCS).
2. The Atterberg limits suggest moderate to high plasticity and a low coefficient of variation which implies a uniform soil profile in all of the places analyzed.
3. The compaction characteristics of the soil shows that it has moderate maximum dry density and high optimum moisture content due to the presence of clay minerals and water absorption potential of the soil.
4. The soil behavior parameters for shear strength indicate that it is chiefly governed by shear with medium friction angles. Although the cohesion showed more variation than several of the other parameters, it still requires a conservative design interpretation.
5. Statistical analysis indicates that, while index properties have low variability, strength parameters exhibit greater variability: it can have a significant effect on bearing capacity and slope stability.
6. From the perspective of engineering, the soils in the center of Diwaniya hare of moderate strength and considerable compressibility and are sensitive to moisture level changes. As a result, suitable foundation design methodologies and, when needed, soil enhancement techniques should be examined.
7. The findings of this study could provide a reliable geotechnical database for the design of foundations and infrastructure in central Iraq..

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