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COLLEGE OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

DETERMINATION OF SOIL STRENGTH PARAMETERS USING MOHR-COULOMB THEORY AND TRIAXIAL TESTING (RocData Analysis)

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INTRODUCTION

Mohr-Coulomb Failure Criterion

A key soil mechanics principle predicting shear strength and failure. It assumes soil fails when shear stress exceeds resistance from **cohesion** (c) and **friction** (φ).

Formula:

Mathematically, the shear strength (τ) is expressed as: $\tau = c + \sigma \tan(\varphi)$

- **τ**: shear stress at failure
- **σ**: effective normal stress
- **c**: cohesion
- **φ**: internal friction angle

On a Mohr's circle diagram, the straight failure line represents this equation. Cohesive soils (clay) have high *c*; sands have $c \approx 0$ and rely on φ.

Triaxial Soil Testing

Laboratory method to determine *c* and *φ* under controlled stress conditions.
Main types:

1. **CU** – Consolidated, then sheared undrained (quick loading).
2. **CD** – Consolidated, then sheared drained (long-term loading).
3. **UU** – Unconsolidated, undrained (rapid testing).

Procedure:

- Prepare specimen.
- Apply confining pressure (σ_3).
- Consolidate if needed.
- Apply axial load until failure.
- Test at multiple σ_3 to create Mohr's circles and derive *c* and *φ*.

Methodology

In the analysis of soil shear strength parameters using the Mohr-Coulomb failure criterion, RocData software was employed to process laboratory test data and calibrate the model parameters, specifically cohesion (c) and friction angle (φ). This tool facilitates the determination of linear and non-linear strength envelopes from triaxial or direct shear test results, enabling accurate fitting of the Mohr-Coulomb model to empirical data. The methodology focused on triaxial testing for soil, as it simulates three-dimensional stress states relevant to geotechnical applications like foundation design, while direct shear was considered for comparative validation.

Step-by-Step Process for Triaxial Data Analysis

1. Project Initialization: RocData was launched, and a suitable project template (e.g., Rock or Soil) was selected to establish default strength graphs, material models, and an initial failure state. This setup provides a framework for inputting test data and visualizing stress plots.

2. Material Model Definition: A material model was defined via the "Define Material Model" interface, starting with default parameters that would be overwritten post-calibration. This step ensures the model aligns with soil properties.

3. Data Input: Triaxial test data, consisting of confining pressures (σ_3) and corresponding axial failure stresses (σ_1), were entered into the failure state properties. For instance, sample data points were inputted, automatically plotting as points on principal stress graphs and Mohr circles on normal vs. shear stress plots.

4. Model Calibration: The calibration tool was activated to fit the Mohr-Coulomb criterion. Key settings included selecting Mohr-Coulomb as the strength type, applying the Levenberg-Marquardt algorithm for optimization, and using vertical error summation with absolute error type. The software computed the best-fit line, updating parameters like c and φ based on the tangent to the Mohr circles.

5. Results Review and Adjustment: Calibration outputs were reviewed numerically and graphically. The failure envelope range was optionally adjusted for better visualization and comparison with non-linear models if needed.

Results

Data Set 1

Test No.	Confining Pressure (σ3)	Deviator Stress (σ1-σ3)	Major Principal Stress (σ1)
1	100	160	260
2	200	230	430
3	300	300	600
4	400	360	760
5	500	420	920

Data Set 2

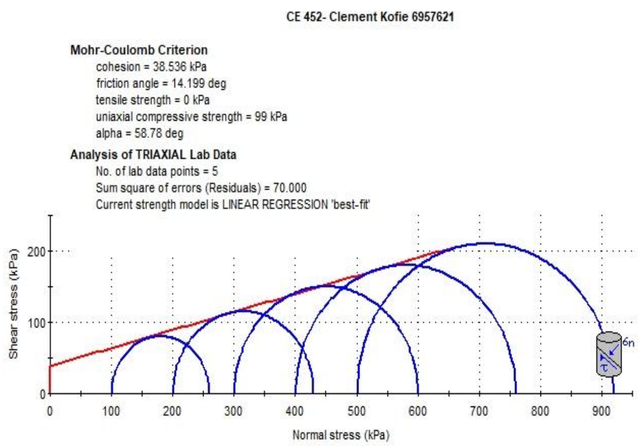
Test No.	Confining Pressure (σ3)	Deviator Stress (σ1-σ3)	Major Principal Stress (σ1)
1	50	100	150
2	100	120	220
3	150	130	280
4	200	140	340
5	500	420	920

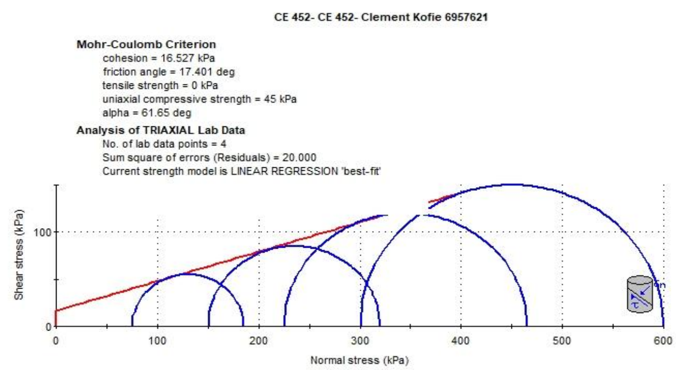
Data Set 3

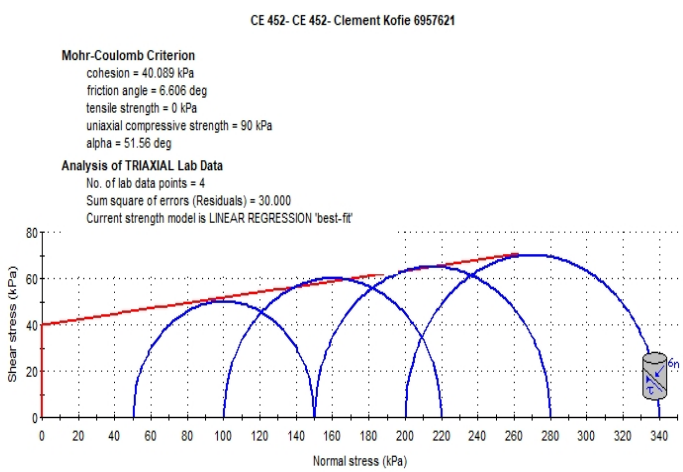
Test No.	Confining Pressure (σ3)	Deviator Stress (σ1-σ3)	Major Principal Stress (σ1)
1	100	250	350
2	200	500	700
3	300	750	1050
4	400	1000	1400

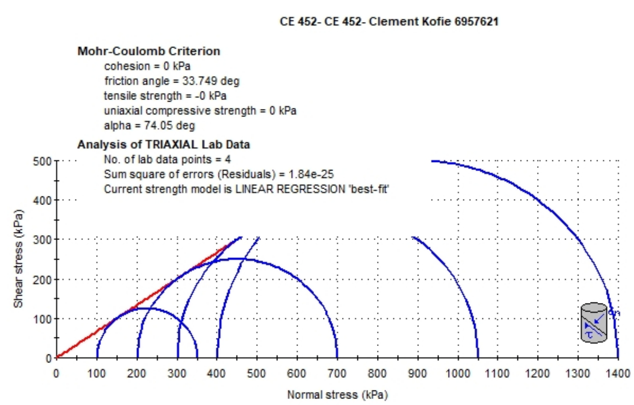
Data Set 4

Test No.	Confining Pressure (σ3)	Deviator Stress (σ1-σ3)	Major Principal Stress (σ1)
1	75	110	185
2	150	170	320
3	225	240	465
4	300	300	600









DATA SET	SOIL TYPE	COHESION (kPa)	FRICTION ANGLE (degrees)
1	Lateritic Soil	38.536	14.199
2	Soft Clay	40.089	6.606
3	Clay Sand	0	33.749
4	Silty Soil	16.527	17.401

Conclusion

The application of the Mohr-Coulomb failure criterion to the triaxial test data for four distinct soil types lateritic soil, soft clay, clay sand, and silty soil—demonstrates its effectiveness in characterizing shear strength parameters through linear regression analysis. The determined cohesion (c) and friction angle (φ) values, derived from the best-fit failure envelopes tangent to Mohr's circles, reveal unique mechanical behaviors tailored to each soil's composition. For instance, the lateritic soil exhibits moderate cohesion (38.536 kPa) and a friction angle of 14.199°, indicative of its weathered, iron-rich nature providing some inherent bonding but limited frictional resistance. Soft clay shows the highest cohesion (40.089 kPa) with a low friction angle (6.606°), highlighting its reliance on interparticle adhesion under low-strain conditions, typical for cohesive fine-grained soils. In contrast, the clay sand is essentially cohesionless ($c = 0$ kPa) with a high friction angle (33.749°), emphasizing granular interlocking as the primary strength mechanism, akin to sandy materials. Silty soil presents an intermediate profile ($c = 16.527$ kPa, $\varphi = 17.401°$), balancing cohesion from finer particles with moderate friction.