AD FALCON API Manual

Consolidation Analysis Assuming Linear Elastic Behavior of Soil

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1.1 File Name

1dTerzagh.txt

1.2 (a) Analytical Solution Using Terzaghi's One-Dimensional Consolidation Equation

Using the analytical solution of Terzaghi's one-dimensional consolidation equation, we analyze the relationship between the degree of consolidation U and the time factor T_v for a cylindrical clay sample.

1.3 Given Data:

- Clay sample dimensions: 4 cm diameter, 3.5 cm height
- Container properties: Impermeable, smooth, rigid cylindrical container
- Applied surcharge: Sudden load of $4\ kg/cm^2$
- Boundary conditions: The top surface becomes open and permeable after applying the load
- Permeability: $k = 6 \times 10^{-6}$ cm/min
- Coefficient of consolidation: $c_v = 0.16135\ cm^2/min$
- Initial void ratio: $e_0 = 1.0$

The time factor T_v is expressed as:

$$T_v = \frac{c_v t}{H^2} \tag{1}$$

where:
- H represents the drainage path length.
- t denotes the time.

The degree of consolidation U is given by:

$$U = 1 - \sum_{n=1}^{\infty} \frac{8}{(2n-1)^2\pi^2} e^{-(2n-1)^2\pi^2 T_v/4} \tag{2}$$

(b) Finite Element Method Solution Using the finite element method (FEM), we solve the same problem under the assumption that the soil behaves as a linear elastic material, characterized by: - Poisson's ratio: $\nu = 0.33$

The FEM approach involves discretizing the clay sample into finite elements and solving for consolidation behavior numerically while incorporating linear elastic soil properties.

1.4 (c) Comparison of Analytical and FEM Results

The following figure compares the degree of consolidation U versus the time factor T_v obtained from Terzaghi's analytical solution and the finite element simulation:

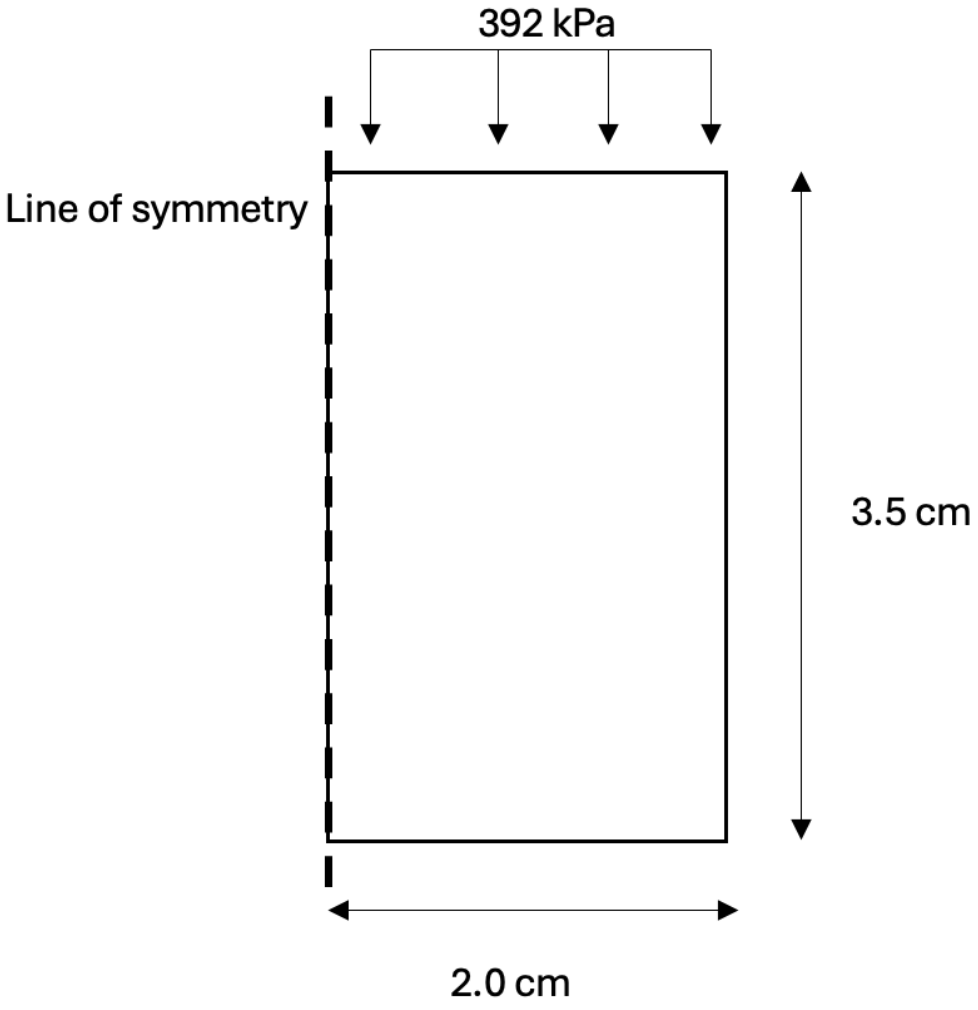

Figure 1: Problem

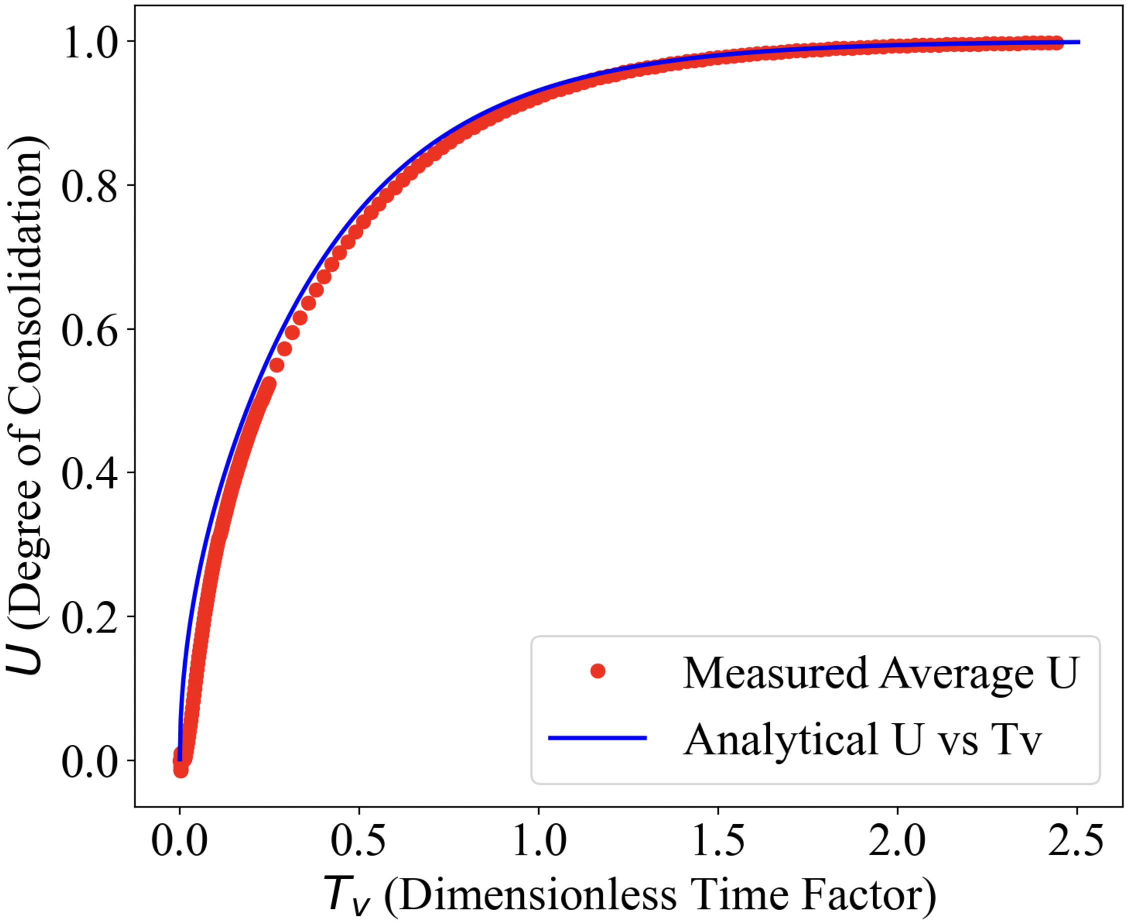

Figure 2: Comparison of analytical and FEM results for degree of consolidation

Figure: Degree of consolidation U versus time factor T_v comparing Terzaghi's analytical solution with the finite element method (FEM) simulation results.

1.5 Python Code for Plotting U vs. T_v

```
import numpy as np
import matplotlib.pyplot as plt

# Set global font properties
plt.rcParams.update({'font.family': 'Times New Roman', 'font.size': 22})

def calculate_U(Tv_values, terms=100):
    """
    Calculate the degree of consolidation (U) using Terzaghi's
one-dimensional consolidation equation.

    Parameters:
    Tv_values: array of time factor values
    terms: number of terms in the infinite series (default: 100)

    Returns:
    U_values: array of degree of consolidation values
    """
    U_values = np.zeros_like(Tv_values)

    for i, Tv in enumerate(Tv_values):
        series_sum = 0
        for n in range(1, terms + 1):
            term = (8 / ((2*n - 1)**2 * np.pi**2)) * np.exp(-((2*n - 1)**2 *
np.pi**2 * Tv) / 4)
            series_sum += term
        U_values[i] = 1 - series_sum

    return U_values

# Define time factor range
Tv = np.logspace(-3, 1, 1000)  # From 0.001 to 10

# Calculate degree of consolidation
U = calculate_U(Tv)

# Create the plot
plt.figure(figsize=(12, 8))
```

```
plt.semilogx(Tv, U, 'b-', linewidth=3, label='Terzaghi\'s Solution')
plt.xlabel('Time Factor, $T_v$')
plt.ylabel('Degree of Consolidation, $U$')
plt.title('Degree of Consolidation vs. Time Factor')
plt.grid(True, alpha=0.3)
plt.legend()
plt.xlim([0.001, 10])
plt.ylim([0, 1])

# Add some key points
key_Tv = [0.008, 0.031, 0.071, 0.126, 0.197, 0.287, 0.403]
key_U = calculate_U(np.array(key_Tv))

for tv, u in zip(key_Tv, key_U):
    plt.plot(tv, u, 'ro', markersize=8)
    plt.annotate(f'({tv:.3f}, {u:.2f})',
                xy=(tv, u), xytext=(10, 10),
                textcoords='offset points', fontsize=16,
                bbox=dict(boxstyle='round,pad=0.3', facecolor='yellow',
alpha=0.7))

plt.tight_layout()
plt.show()

# Print some key values
print("Key Values:")
print("Tv\t\tU")
print("-" * 20)
for tv, u in zip(key_Tv, key_U):
    print(f"{tv:.3f}\t\t{u:.3f}")
```

1.6 File Name

File Name

1dTerzagh_with_drianage_changes.txt

In this analysis, we examine the effect of drainage conditions on consolidation behavior by comparing two steps:

1. **Step 1 (0-50 s)**: Undrained conditions
2. **Step 2 (50-100 s)**: Drained conditions

The analysis demonstrates how changing boundary conditions affect pore pressure dissipation and settlement behavior during consolidation.

1.7 Key Parameters:

- **Material**: Linear elastic with $E = 10^6$ Pa, $\nu = 0.33$
- **Permeability**: $k = 10^{-9}$ m/s

- **Applied load**: 1000 Pa instantaneous

- **Drainage change**: At t = 50s, top boundary switches from undrained to drained

This example illustrates FALCON's capability to handle time-dependent boundary condition changes, which is essential for modeling realistic consolidation scenarios where drainage conditions may change during construction or loading phases.