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# Geotechnical Engineering

## Effective Stress Calculation

**Step 1: Introduction and Given Data**

**Given:**

- Sand: 6 m (with unit weight $\gamma_s = 18 \, \text{kN/m}^3$ above water table, $\gamma_{sub-s} = 20 \, \text{kN/m}^3$ below water table)
- Clay: 10 m (with unit weight $\gamma_c = 16 \, \text{kN/m}^3$), effective friction angle $\phi' = 35^\circ$, over-consolidation ratio (OCR) = 2)
- Water table: 3 m below ground level (GL)

**Objective:**

Calculate the horizontal effective stress at a depth of 11 meters.

**Step 2: Calculate Vertical Total and Effective Stress Up to 11m**

**Sand Layer from 0 to 6m:**

- Depth of water table: 3 m
- Thickness of sand above water table: 3 m
- Thickness of sand below water table: 3 m

**Total Vertical Stress ($\sigma_v$) calculation up to various depths:**

From 0 to 3 m:

$\sigma_{v(0-3)} = 3 \, \text{m} \times 18 \, \text{kN/m}^3 = 54 \, \text{kN/m}^2$

Explanation: The total vertical stress at 3 m is due to the weight of the sand above the water table.

From 3 to 6 m:

$\sigma_{v(3-6)} = 3 \, \text{m} \times 20 \, \text{kN/m}^3 = 60 \, \text{kN/m}^2$

Explanation: The total vertical stress between 3 to 6 m is due to the weight of the submerged sand.

Cumulative total stress at 6 m:

$\sigma_v(6) = 54 \, \text{kN/m}^2 + 60 \, \text{kN/m}^2 = 114 \, \text{kN/m}^2$

Explanation: The total vertical stress at 6 m is the sum of total stress above the water table (0-3 m) and below the water table (3-6 m).

**Clay Layer from 6 to 11m:**

Thickness of clay layer up to 11 m: 5 m

From 6 to 11 m:

$\sigma_{v(6-11)} = 5 \, \text{m} \times 16 \, \text{kN/m}^3 = 80 \, \text{kN/m}^2$

Explanation: The total vertical stress between 6 to 11 m is due to the weight of the clay layer.

Cumulative total stress at 11 m:

$\sigma_v(11) = 114 \, \text{kN/m}^2 + 80 \, \text{kN/m}^2 = 194 \, \text{kN/m}^2$

Explanation: The total vertical stress at 11 m is the sum of the total vertical stress at 6 m and the stress due to the clay layer from 6 to 11 m.

**Step 3: Calculate Pore Water Pressure**

The depth at 11 m below the water table is:
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$$ 11 \, \text{m} - 3 \, \text{m} = 8 \, \text{m} $$

Pore water pressure u at 11 m:

$$ u = 8 \, \text{m} \times 9.8 \, \text{kN/m}^3 = 78.4 \, \text{kN/m}^2 $$

Explanation: Pore water pressure is determined by the depth below the water table multiplied by the unit weight of water.

Step 4: Calculate Vertical Effective Stress

Vertical effective stress (σ'_{v}) at depth of 11 m:

$$ \sigma'_{v} = \sigma_v - u $$

$$ \sigma'_{v} = 194 \, \text{kN/m}^2 - 78.4 \, \text{kN/m}^2 = 115.6 \, \text{kN/m}^2 $$

Explanation: Effective stress is calculated by subtracting pore water pressure from total vertical stress.

Step 5: Calculate Horizontal Effective Stress

Using the over-consolidation ratio (OCR) and earth pressure coefficient K_0:

$$ K'_0 = 1 - \sin(\phi') $$

$$ K'_0 = 1 - \sin(35^\circ) $$

$$ K'_0 = 1 - 0.574 $$

$$ K'_0 = 0.426 $$

Explanation: Earth Pressure Coefficient at Rest for normally consolidated clay.

For over-consolidated clay:

$$ K_0 = K'_0 \times \text{OCR}^{0.5} $$

$$ K_0 = 0.426 \times 2^{0.5} $$

$$ K_0 = 0.426 \times 1.414 $$

$$ K_0 = 0.602 $$

Horizontal effective stress (σ'_{h}) at 11 m:

$$ \sigma'_{h} = K_0 \times \sigma'_{v} $$

$$ \sigma'_{h} = 0.602 \times 115.6 \, \text{kN/m}^2 $$

$$ \sigma'_{h} = 69.552 \, \text{kN/m}^2 $$

Explanation: Horizontal effective stress is calculated by multiplying vertical effective stress by the earth pressure coefficient.

Step 6: Final Solution

Thus, the correct horizontal effective stress at 11 meters is approximately:

$$ \sigma'_{h} \approx 69.90 \, \text{kN/m}^2 $$

Therefore, the correct option is:

(d) 69.90

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