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\[ \sigma_z = \frac{q}{2\pi} \left( \frac{2x}{a} \alpha - \sin 2\beta \right) = qI_z \]
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\[ \sigma_z = \frac{q}{\pi} \left[ (\alpha_1 + \alpha_2 + \alpha_3) + \frac{b}{a_1} (\alpha_1 + R\alpha_3) + \frac{x}{a_1} (\alpha_1 - R\alpha_3) \right] \]
A 3 m high embankment is to be constructed as shown in Fig. Ex. 6.11. If the unit weight of soil used in the embankment is 19.0 kN/m³, calculate the vertical stress due to the embankment loading at points \( P_1 \), \( P_2 \), and \( P_3 \).

Note: All dimensions are in metres

**Figure Ex. 6.11**  Vertical stresses at \( P_1 \), \( P_2 \) & \( P_3 \)

**Solution**

\[
q = \gamma H = 19 \times 3 = 57 \text{ kN/m}^2, \ z = 3 \text{ m}
\]

The embankment is divided into blocks as shown in Fig. Ex. 6.11 for making use of the graph given in Fig. 6.15. The calculations are arranged as follows:
Solution

\[ q = \gamma H = 19 \times 3 = 57 \text{ kN/m}^2, \ z = 3 \text{ m} \]

The embankment is divided into blocks as shown in Fig. Ex. 6.11 for making use of the graph given in Fig. 6.15. The calculations are arranged as follows:

<table>
<thead>
<tr>
<th>Point</th>
<th>Block</th>
<th>( b ) (m)</th>
<th>( a ) (m)</th>
<th>( b/z )</th>
<th>( a/z )</th>
<th>( l )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_1 )</td>
<td>ACEF</td>
<td>1.5</td>
<td>3</td>
<td>0.5</td>
<td>1</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>EDBF</td>
<td>4.5</td>
<td>3</td>
<td>1.5</td>
<td>1</td>
<td>0.477</td>
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<tr>
<td>( P_2 )</td>
<td>AGH</td>
<td>0</td>
<td>1.5</td>
<td>0</td>
<td>0.5</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>GKDB</td>
<td>7.5</td>
<td>3</td>
<td>2.5</td>
<td>1.0</td>
<td>0.493</td>
</tr>
<tr>
<td></td>
<td>HKC</td>
<td>0</td>
<td>1.5</td>
<td>0</td>
<td>0.5</td>
<td>0.15</td>
</tr>
<tr>
<td>( P_3 )</td>
<td>MLDB</td>
<td>10.5</td>
<td>3.0</td>
<td>3.5</td>
<td>1.0</td>
<td>0.498</td>
</tr>
<tr>
<td></td>
<td>MACL</td>
<td>1.5</td>
<td>3.0</td>
<td>0.5</td>
<td>1.0</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Stress Distribution in Soils due to Surface Loads

Vertical stress \( \sigma_z \)

At point \( P_1 \), \( \sigma_z = (0.39 + 0.477) \times 57 = 49.4 \text{ kN/m}^2 \)

At point \( P_2 \), \( \sigma_z = 0.15 \times (57/2) + 0.493 \times 57 - 0.15 \times (57/2) = 28.1 \text{ kN/m}^2 \)

At point \( P_3 \), \( \sigma_z = (0.498 - 0.39) \times 57 = 6.2 \text{ kN/m}^2 \)
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(a) Significant depth of stressed zone for single footing

\[ D_s \approx 1.5B \]

\[ \sigma_z = 0.2q \]

(b) Effect of closely placed footings

\[ D_s \approx 1.5b \]

Lines of equal vertical pressure or isobars
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21 Pressure isobars based on Boussinesq equation for square and continuous footings
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Pressure isobars based on Westergaard equation for square and continuous footing

23
Pressure isobars based on Boussinesq equation for uniformly loaded circular footings
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- $\sigma_z = \gamma \times h$