Geosynthetics and Reinforced Soil Structures

Bearing Capacity of Shallow Foundations Supported on Reinforced Soil

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Out Line

- Recap of bearing pressures of shallow foundations
- Reinforcement in the foundation soil
- Experimental data
- Theoretical analysis
What is a shallow foundation?

- Any foundation that has a width larger than the depth of the foundation, e.g. wall footings, isolated column footings, combined footings, etc.

**DESIGN OF FOOTING:**

\[
\text{footing area} = \frac{\text{loads transferred to soil}}{\text{allowable bearing pressure}}
\]
Requirements of a good foundation

• The pressure transferred to soil should not exceed the safe bearing capacity \((q_{ns})\) of the foundation soil.

• The settlements of the structure under the imposed pressure should be within the safe limits, safe bearing pressure \((q_{np})\).

• Allowable bearing pressure \(q_{na}\) is obtained as the minimum of \(q_{ns}\) and \(q_{np}\).
Soil failure due to loading from strip footing

Jumikis 1967
Types of bearing capacity failures

**General shear** failure in case of dense soils, over consolidated clays

**Local shear** failure in case of loose sands, normally consolidated clays

**Punching shear** failure in case of extremely soft soils

After Vesic (1973)
Shallow Foundations

• Provided when competent bearing stratum is available at shallow depths
• Results in good cost economy compared to deep foundation alternatives
• How to use shallow foundations in case of weak/soft surface soils??
• Distribute the applied loads over wider areas
Schematic of Reinforced Soil Foundation

$\frac{b}{B} > 1$
Huang and Tatsuoka (1981)
Schematic of a shallow foundation on geocell reinforced foundation soil
Das, B.M. (1999)
Typical data from tests on strip footings resting on clay soils (BM Das 1999)
Improvement with different geocell mattresses (d/ B=1.2, h/ B=2.75, u/ B=0.1) Dash et al. 2002
Improvement in the performance with different types of reinforcements Dash et al. (2002)
# Summary of Test data from different investigators

<table>
<thead>
<tr>
<th>Series of Tests</th>
<th>Type of Reinforcement</th>
<th>Optimum geometric parameters of reinforcement to get maximum benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binquet and Lee (1975a)</td>
<td>Aluminium foil strips</td>
<td>u/B: 0.333, Δh/B: 0.333, b/B: 20, N: 6</td>
</tr>
<tr>
<td>Fragaszy and Lawton (1984)</td>
<td>Aluminium foil strips</td>
<td>u/B: 0.334, Δh/B: 0.334, b/B: 7, N: 3</td>
</tr>
<tr>
<td>Huang and Tatsuoka (1990)</td>
<td>Metallic strips (sand glued surface)</td>
<td>u/B: 0.3, Δh/B: 0.3, b/B: 6, N: 3</td>
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<tr>
<td>Khing et al. (1993)</td>
<td>PP-HDPE Geogrid</td>
<td>u/B: 0.375, Δh/B: 0.375, b/B: 6, N: 6</td>
</tr>
<tr>
<td>Omar et al. (1993)</td>
<td>PP-HDPE Geogrid</td>
<td>u/B: 0.333, Δh/B: 0.333, b/B: 8, N: 6</td>
</tr>
<tr>
<td>Krishnaswamy and Athavan (1994)</td>
<td>PP Geogrid</td>
<td>u/B: 0.350, Δh/B: 0.350, b/B: 7, N: 6</td>
</tr>
</tbody>
</table>
Non-Dimensional Parameters

- Improvement Factor \( (I_f) = \frac{q}{q_o} \)
- Settlement Ratio \( = \frac{s}{B} \)

Where,
- \( q \) = Footing pressure on reinforced soil at given settlement
- \( q_o \) = Footing pressure on unreinforced soil at the same settlement
- \( s \) = Footing Settlement
- \( B \) = Footing Width
Improvement Factor for different Types of Geogrid
Load-Strain Behaviour of different Geogrids
Improvement Factor for different forms of Reinforcements
Surface Deformation at 2.5B Distance from Footing Center line versus Footing Settlement for different Types of Reinforcement
Improvement Factors for different Relative Densities
(a) $u/B > 2/3$: SHEAR ABOVE REINFORCEMENTS

(b) $u/B < 2/3$ & $N < 2$ OR 3, OR SHORT TIES: TIES PULL OUT

(c) $u/B < 2/3$, LONG TIES & $N > 4$: UPPER TIES BREAK

Binquet and Lee (1975b)
Factors to be considered

- Depth of first layer of reinforcement
- Number of layers of reinforcement
- Length of reinforcement
- Vertical and horizontal spacing between the layers
- Type and material of reinforcement
- Shape and size of footing
POSSIBLE MODES OF FAILURE

• Bearing capacity failure of the soil above the upper reinforcement, which is probably avoided if the first layer is placed at shallow depth
• Insufficient embedment length, which is avoided if the reinforcement extends far enough beyond the potential failure zone to mobilize the required resisting anchorage force.
• Tensile failure of the reinforcement layers due to overstressing. This is the most important design element
SOME GUIDELINES

- Depth of the first layer of the reinforcement, \( u \), is in the range 0.25\( B \) to 0.5 \( B \), where \( B \) is the width of the footing.
- Number of layers of reinforcement is preferably about 3 to 6.
- Length of reinforcement layer is ideally about 7\( B \), more than 7\( B \) is not economical.
- Generally, uniform vertical spacing varies from 0.1\( B \) to 0.4\( B \), depending on the number of layers.
- Reinforcement should have sufficient tensile strength.