Estimating Capacity of Offshore Foundations

The McClelland Lecture
A Tribute to Bram
OBJECTIVES

Demonstrate the techniques of plastic limit analysis (PLA) and the advantages of same for estimating foundation capacity
Outline

• Offshore Foundation - A Brief History
• Analysis of Typical Cases Including Individual and Systems of
  ➢ Shallow Foundations
  ➢ Pile Foundations
• Show Similarities and Differences in PLA and Limit Equilibrium Techniques
History- The Early days

Louisiana
September 9, 1947
Ship Shoal Block 32
History- Shallow Water Structures
History- Deep Water Structures
History- Shallow Foundations
IDEALISATION

“...how can mathematics, which is so clear and precise, and in so many ways simple, be applied to the physical world which, although apparently consistent, is many sided and extremely complex? ....”

Calladine, 1969
“The purpose of computing is insight, not numbers.”

Richard Hamming
AN ASIDE

“... this solution was obtained using the analytical tools available to us...”

“... this solution was obtained using the analytical fools available to us...”
SHALLOW FOUNDATIONS

• Conventional Methods

• Plasticity Approach
Conventional Plane Strain Bearing Capacity Solution

\[ \frac{V}{A} = cN_c + qN_q + 0.5\gamma BN_\gamma \]

- Prandtl
- Reissner
- Terzaghi

Mechanism
The Plasticity Approach with Some Words of Caution

“Mathematicians are useful animals who should be kept in golden cages and fed problems judiciously.”

Karl Terzaghi
The Upper Bound Method of Plastic Limit Analysis

• Define an admissible mechanism
• Assume a virtual velocity of the unknown loads
• Set external work rates equal to internal energy dissipation rates
• Solve the resulting equation
• Optimize the mechanism
A Word of Encouragement

Remember --- no one ever really understands anything, we just get used to it.
Example -- Inclined Load Mechanism
Example 1 – Solution

![Graph showing the relationship between $H/S_uB$ and $V/S_uB$. The graph includes two curves: one for BH Uniform Strength and another for BH Increasing Strength. There is also a data point labeled Davis&Booker.](image-url)
Eccentric Load Mechanism

Brinch Hansen Mechanism

Scoop Mechanism
Randolph, et al
Alternative Formulations for Shallow Foundation System

Detailed or Explicit Mechanism

Macro or Implicit Mechanism
Step By Step Procedure for Macro PLA Planar Model (V&H) of System

1. Virtual rotation about $X_o$, $Y_o$
2. Find footing velocities $v$ & $h$
3. Use normality to form ratios of velocities e.g $v/h$
4. Equate these to ratios from mechanism $\Rightarrow$ 2 equations
5. Interaction surface $\Rightarrow$ 3rd equation
6. Solve for V & H
7. Dissipation rate $= Vv + Hh$
8. Set dissipation $= external \ work \ rate$
9. Solve for unknown Force
10. Optimize e.g. wrt $X_o$, $Y_o$
Macro Solutions of Two-Footing System
With Varying Vertical Load
Pile Foundations
AN ASIDE

These piles will have to be driven with considerable batter.

These piles will have to be driven with considerable butter.
Pile Foundations – Lateral Capacity

Deep flow-around of a flat plate
H = 11.42 SuB

Lateral Mechanism for Translation
Pile Foundations – Detailed Rotation Mechanism for Rigid Pile
Pile Foundations – Analysis of a Four Pile Group
Typical Results--Moment vs. Lateral Load Interaction Diagram for a Four Pile Group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>V/Q</td>
<td>0 and 2</td>
</tr>
<tr>
<td>M/QB</td>
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<tr>
<td>RB/Q</td>
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Upper Bound vs. Limit
Equilibrium Concepts
Comparison of Upper Bound vs Limit Equilibrium Analysis
Closing Comments
Acknowledgements