Torsional Loading of Subsea Shallow Foundations

Final year research project

Ben Holland

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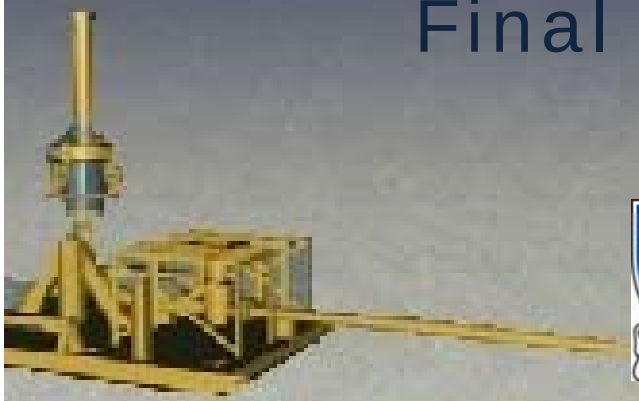
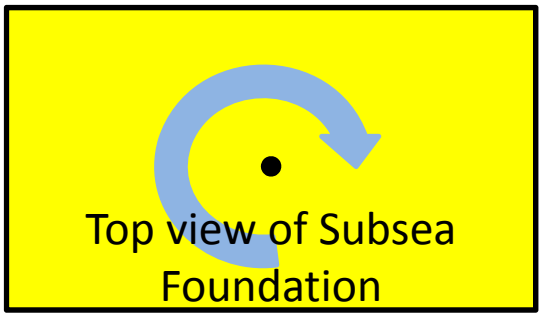
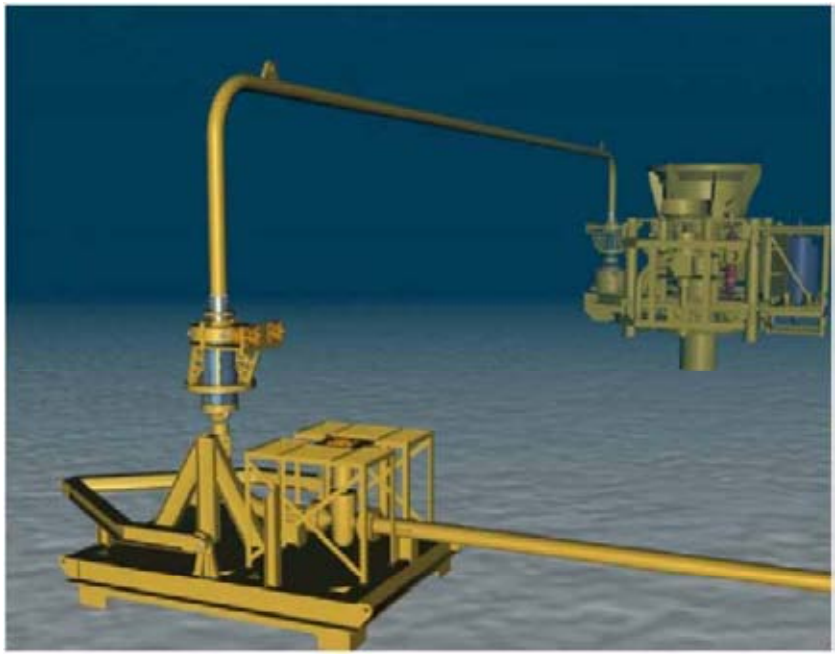


What is torsion loading?

- Twisting of the foundation about vertical axis





- Torsional loading has been shown to significantly reduce foundation capacity

Project Objectives

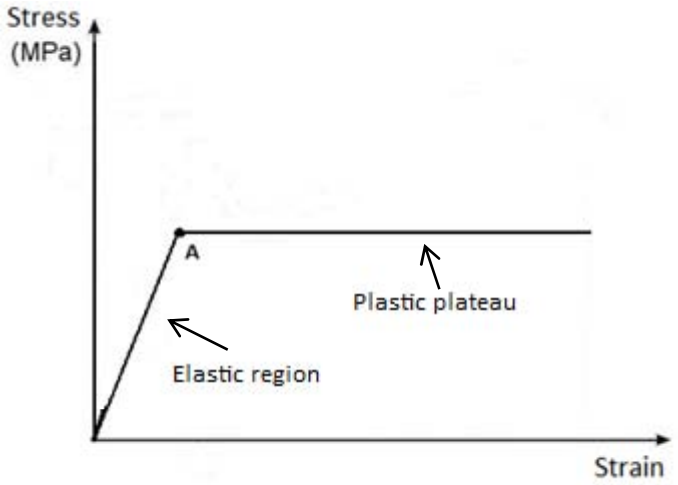
1. Define the effect of torsional loading on lateral capacity of shallow foundations.

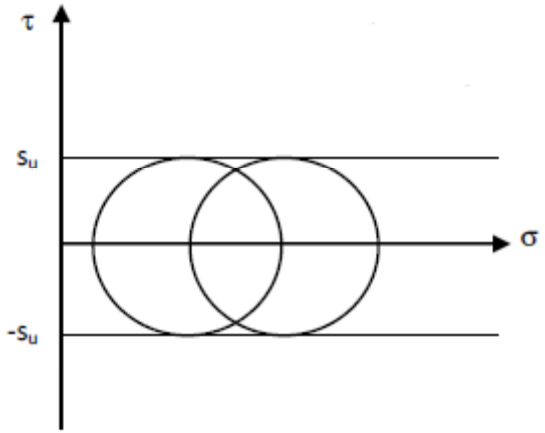
2. Develop a suitable design technique for combined VHT loading

3. Note the effect of foundation embedment, aspect ratio and soil strength profile

Study technique

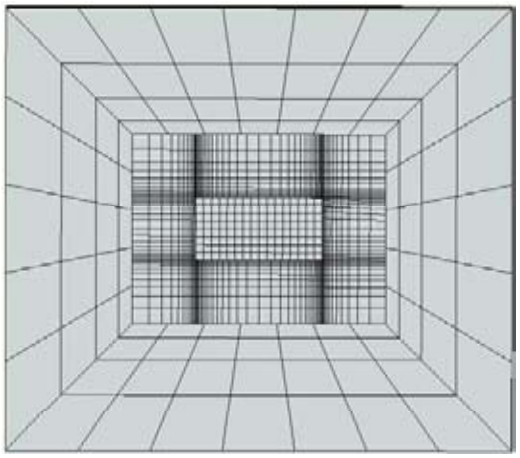
- Analysis conducted using Abaqus FEA software
- Rigid foundation – constant reference point
- Linear elastic perfectly plastic soil
  - Undrained, conforming to Tresca Criterion

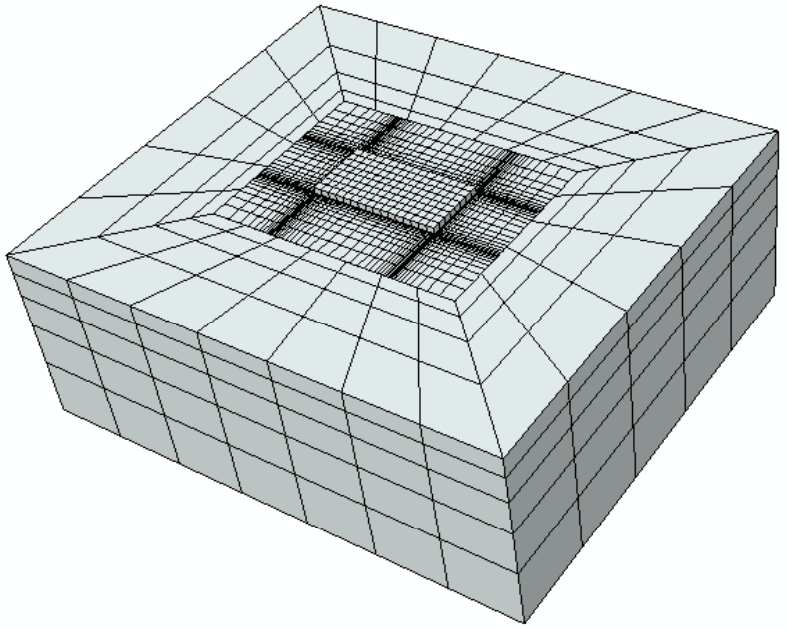




Models

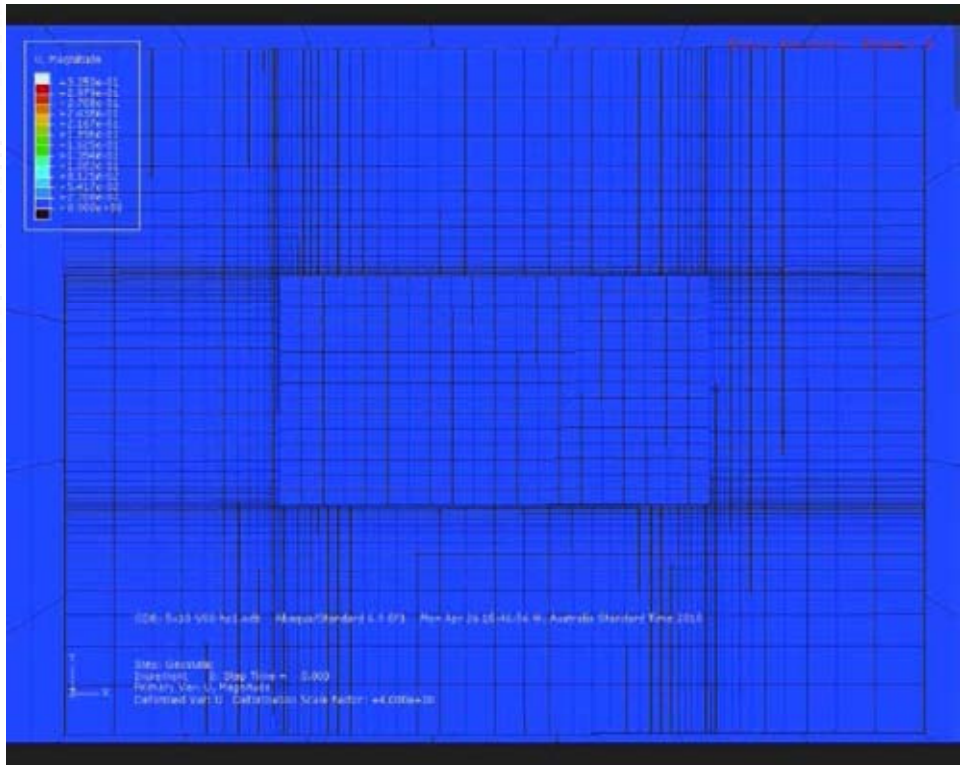
- 3 aspect ratios
  - B/L = 0.5, 1, 2
- 2 embedment ratios
  - Surface and embedded
- 2 soils strength profiles
  - Uniform and highly heterogeneous

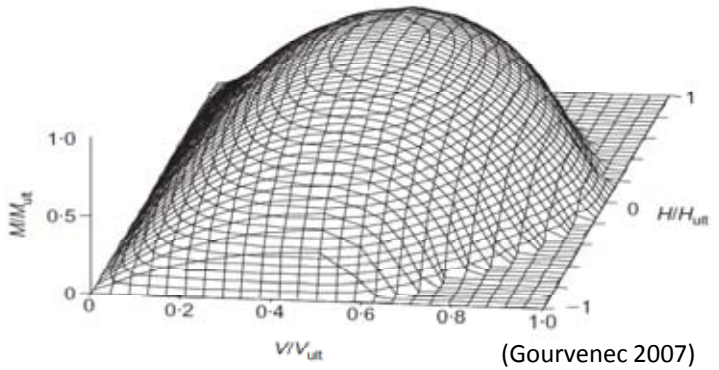




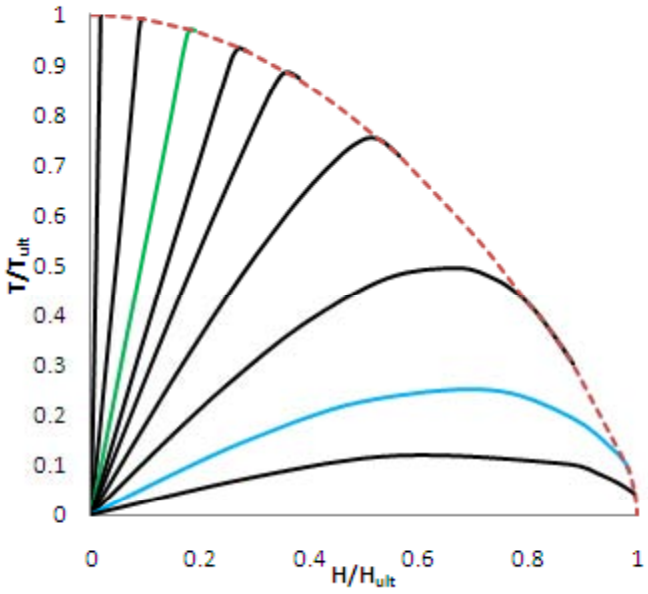
Failure envelopes

- Failure envelopes are the best way to depict the interaction
  - Normalised loads





(Gourvenec 2007)



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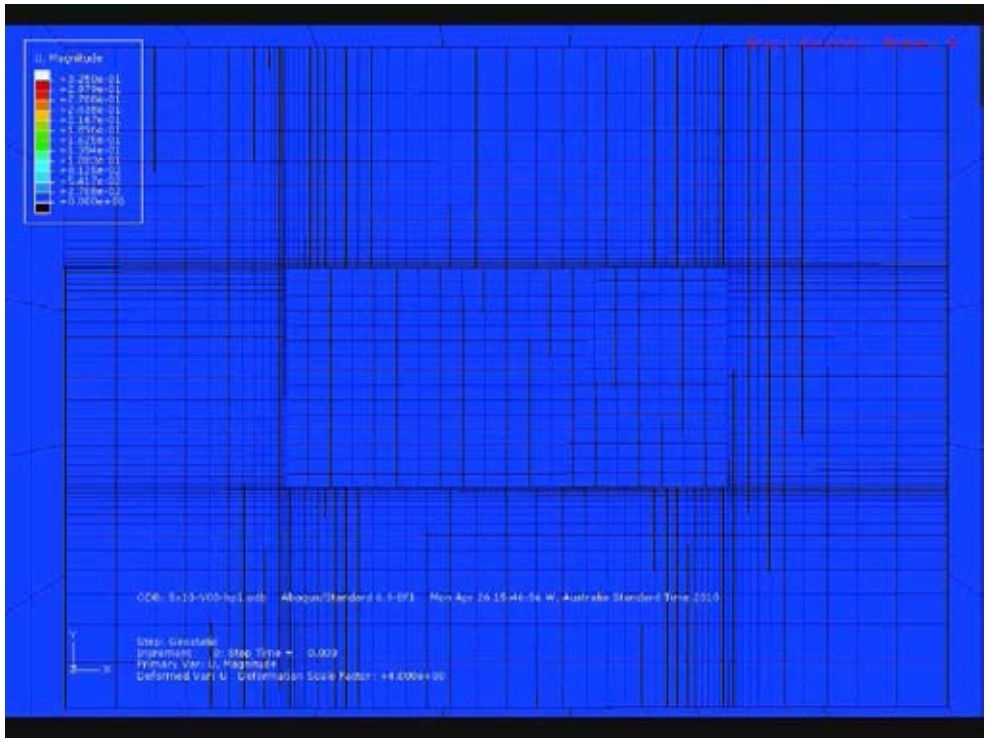

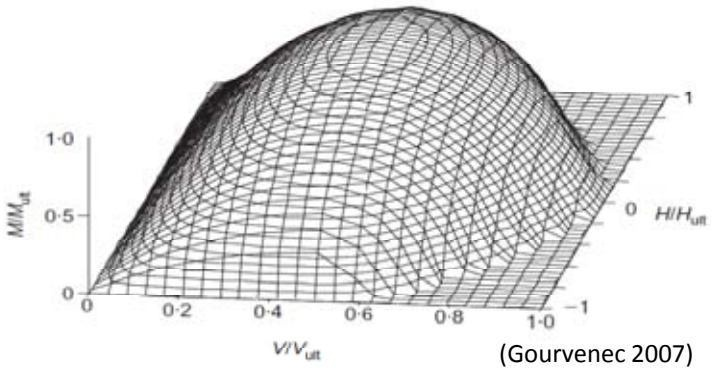

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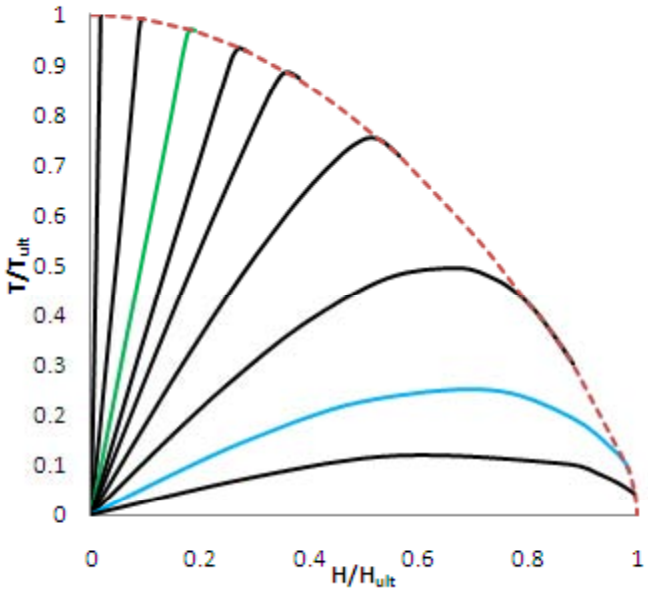
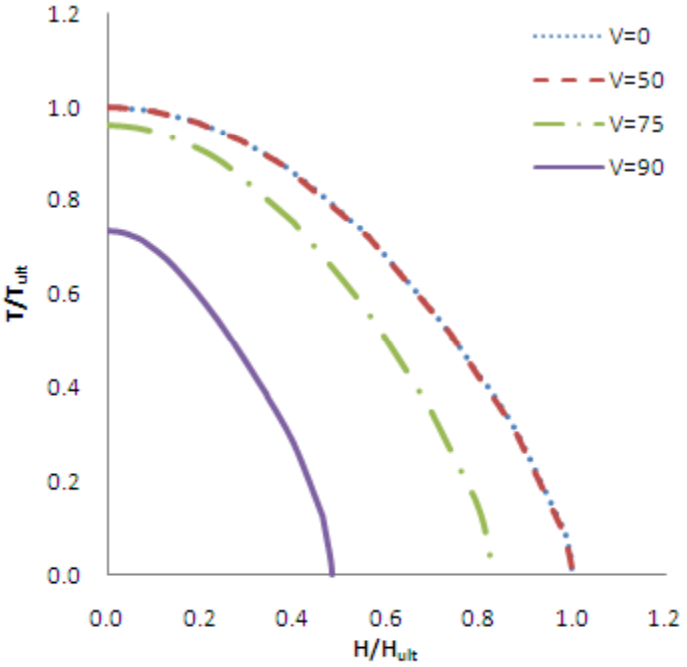
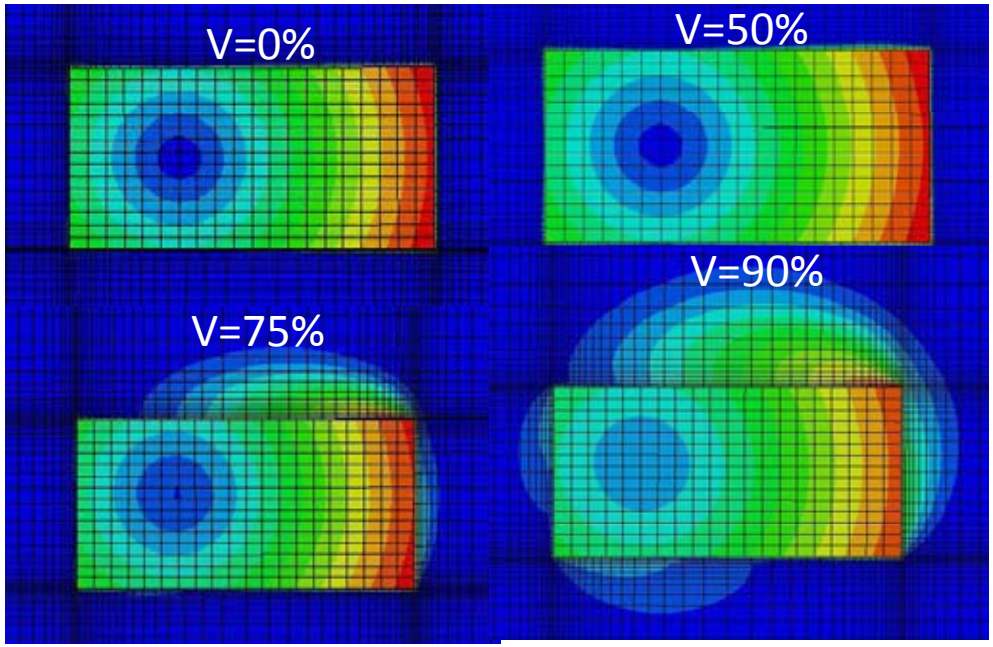


Effect of Vertical load

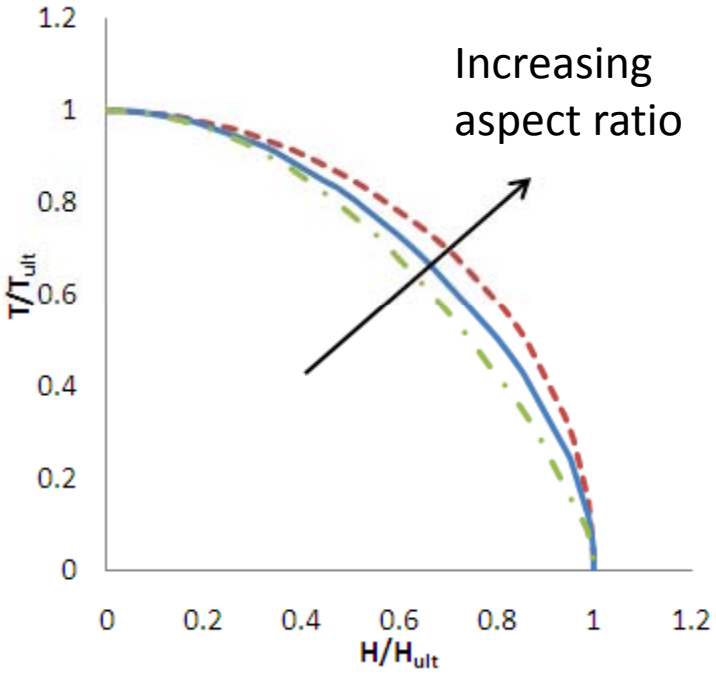
- Vertical load reduces the horizontal and torsional capacity

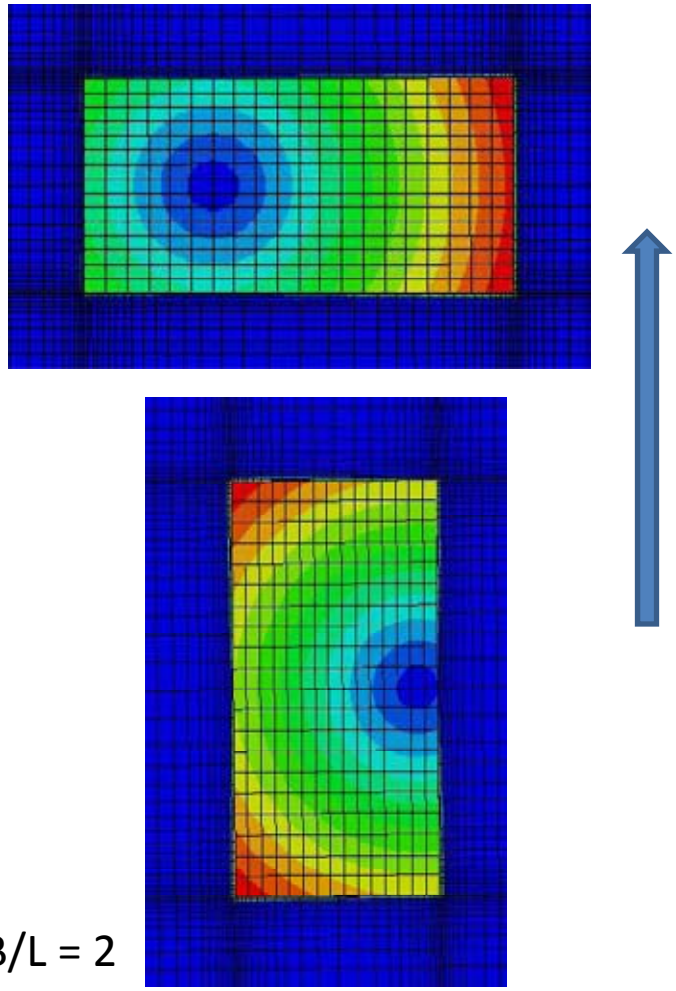




Foundation aspect ratio

- Increased normalised HT capacity with increasing aspect ratio





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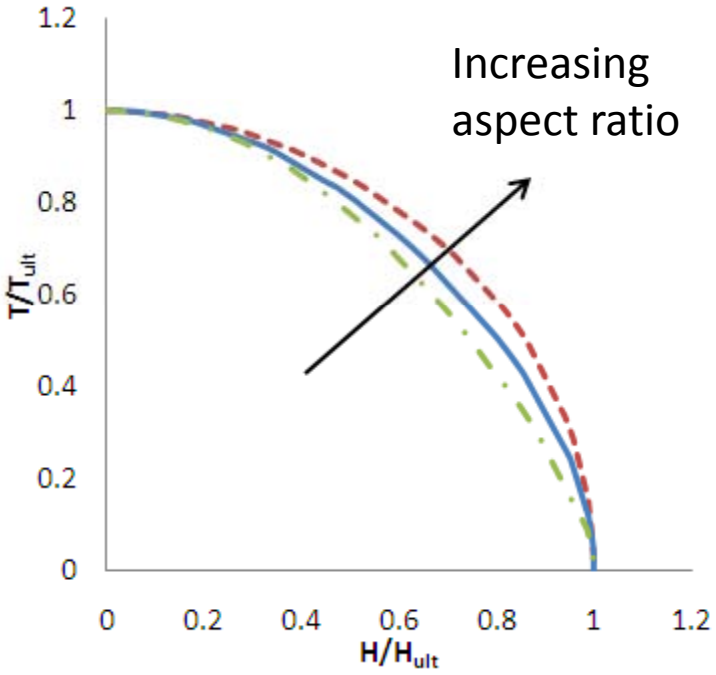

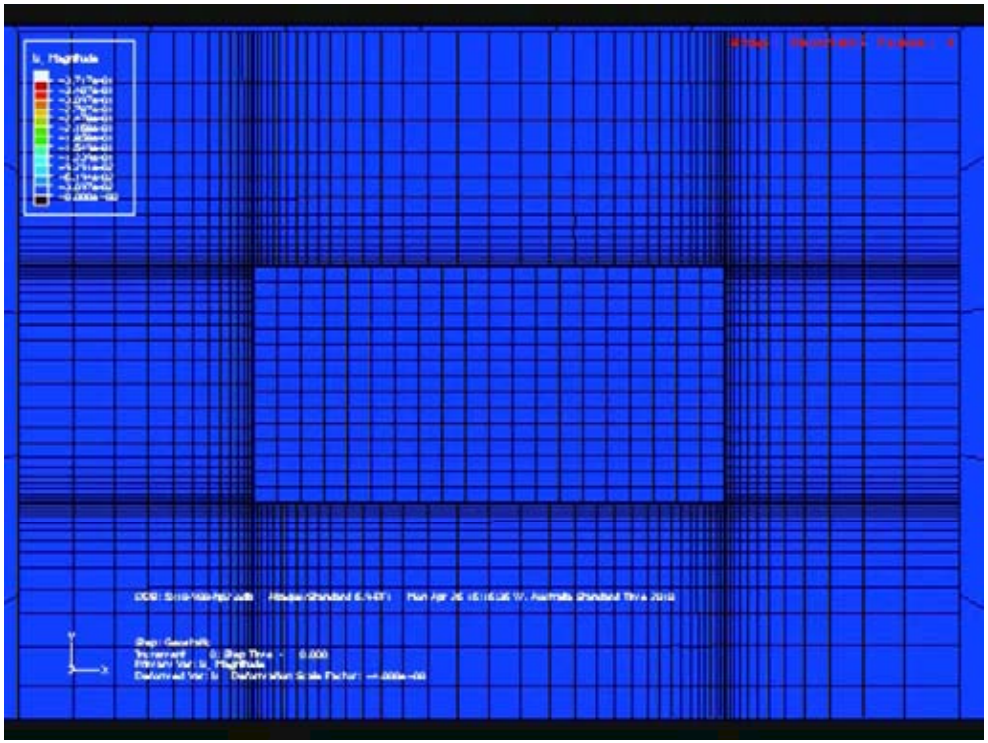

Foundation embedment

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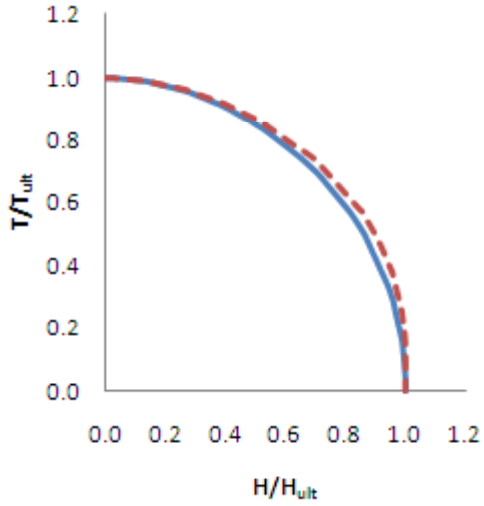
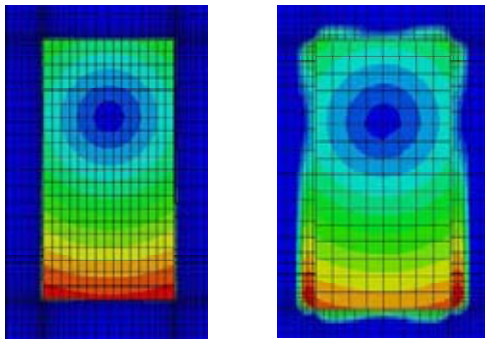
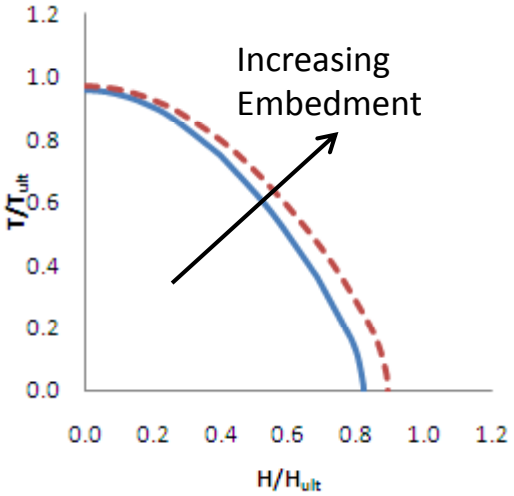
V ≤ 50%

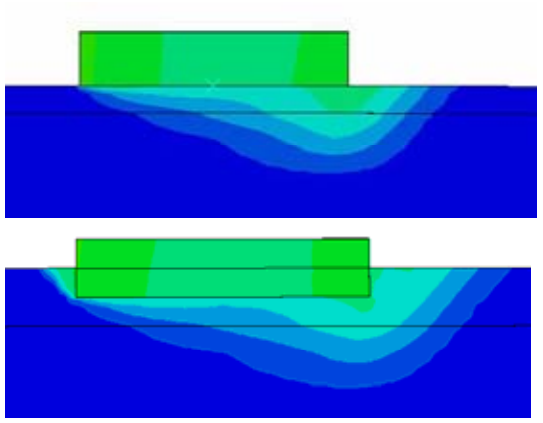


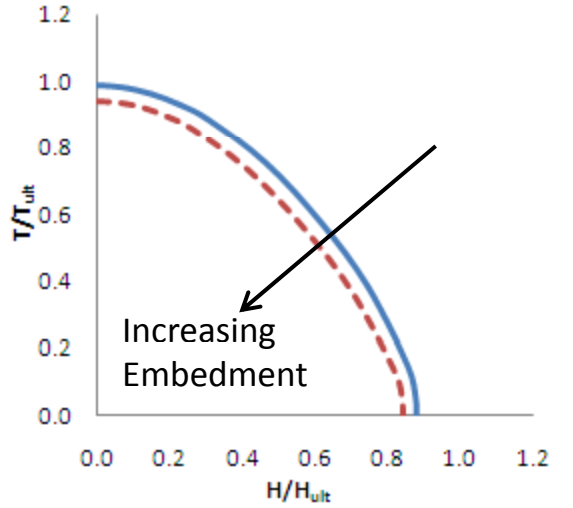


V = 75%

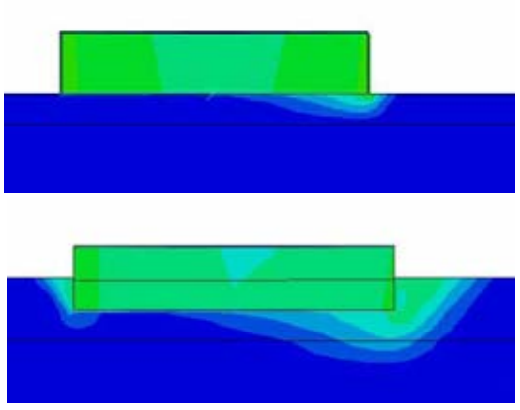


Uniform soil





Non-uniform soil



Soil strength profile

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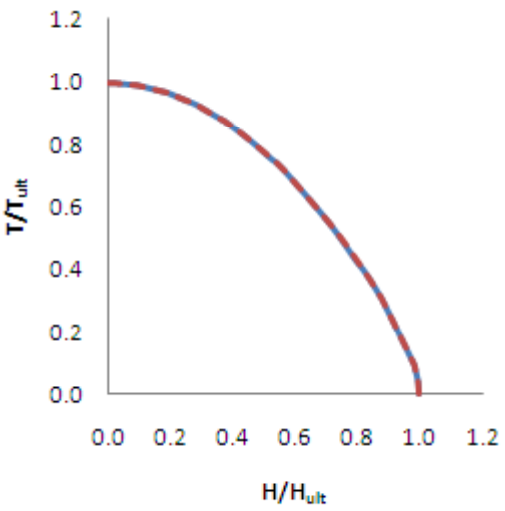
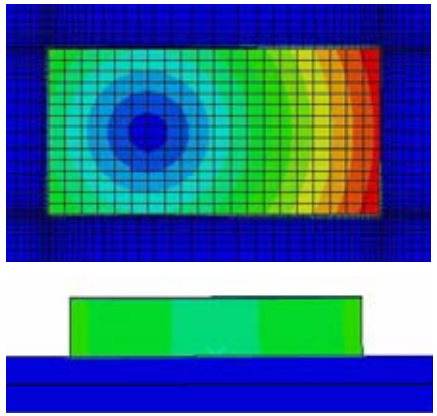
V ≤ 50%





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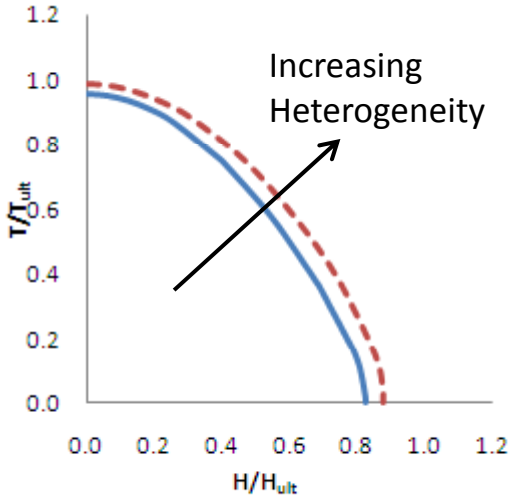
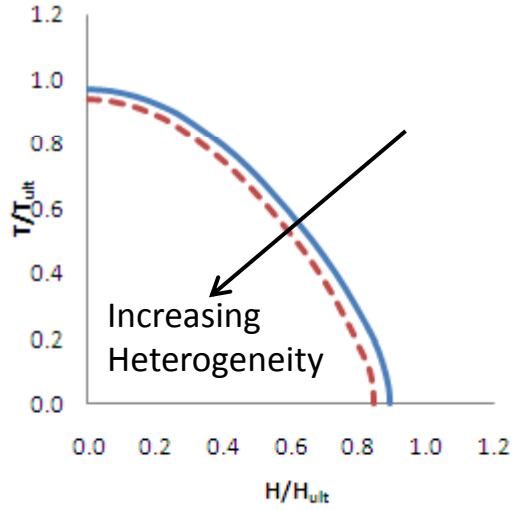
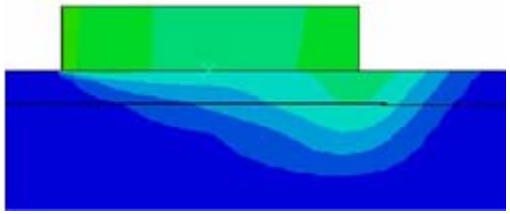
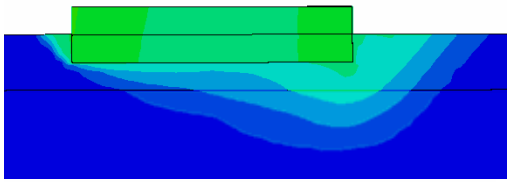


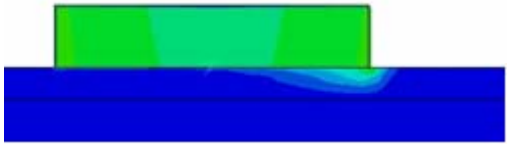


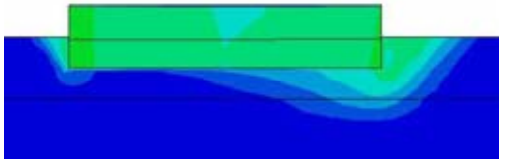
Surface foundation

Embedded foundation









Closed form solution

- Allows simple and accurate modelling of combined VHT loading

$$\left(\frac{h}{h^*}\right)^a + \left(\frac{t}{t^*}\right)^b - 1 = 0$$

  - h = normalised horizontal loading
  - t = normalised torsional loading

  - h* = available normalised horizontal capacity
  - t* = available normalised torsional capacity

  - ‘a’ and ‘b’ are constants
    - $1.4 \leq a \leq 1.8$
    - $1.3 \leq b \leq 2.5$

Conclusions

- Improvement to current design techniques
  - Classical Bearing capacity theory insufficient for offshore applications
  - VHT interaction curves provide better understanding
- When V ≤ 50%, embedment and heterogeneity can be ignored
- Closed form solutions
  - Allow for easy use in design

Thankyou

- Thankyou to Professor Susan Gourvenec for her excellent supervision this year
- Thankyou to Ian Finnie from Advanced Geomechanics for his assistance with current design codes

- **Questions?**

Closed form solution

- Surface foundation with B/L= 2 on uniform soil body
- Take loads as: h = 0.7, t = 0.6, v < 0.5
- For these conditions
  - a = 1.7, b = 2.1
- When v ≤ 0.5 → h* = 1 and t* = 1

$$\left(\frac{0.7}{1}\right)^{1.7} + \left(\frac{0.6}{1}\right)^{2.1} - 1 = -0.11$$

- Result below zero, inside failure envelope

Closed form solution

- Take vertical load as increased to v = 0.75, other factors the same → a = 1.7, b = 2

$$h^* = 1 \times \sqrt{1 - 1.6(0.75)^7 + 0.6(0.75)^{10}} = 0.906$$

$$t^* = 1.21 \times \left(0.75 - 1.6(0.75)^3 + 0.6(0.75)^{12}\right)^{1/4} = 0.956$$

$$\left(\frac{0.7}{0.906}\right)^{1.7} + \left(\frac{0.6}{0.956}\right)^{2} - 1 = 0.039$$