16th CRISP users' group meeting (25th September 2003)
London South Bank University

Modelling integral abutments embedded in granular soil using 3SKH concept

Presented by:

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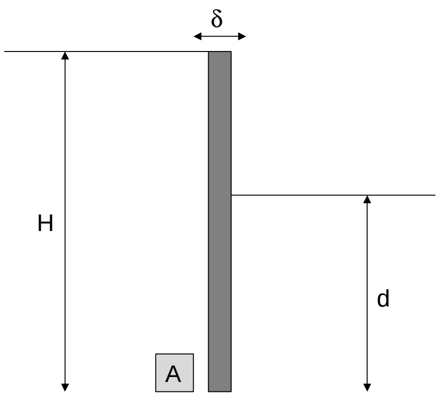
Introduction

- Outline of idealised critical stress/strain paths for modelling integral abutments in plane strain
- Biaxial element simulation of these paths using original 3SKH model
- A fundamental abutment wall situation - FEA to illustrate main drawbacks of current 3SKH model
- A modified 3SKH model is proposed to improve prediction for drained granular soil

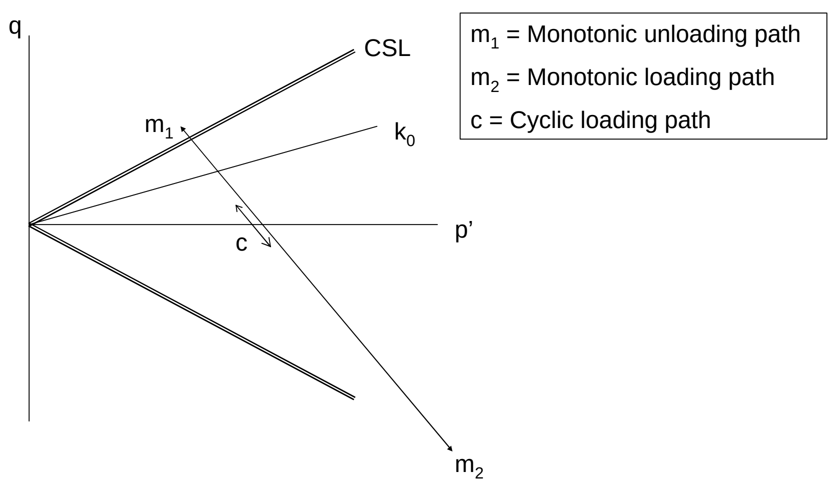
A simple embedded integral abutment illustration



Displacement (δ) at top of wall relates to:

1) initial installation effects and deck shrinkage/creep
2) long-term deck expansion and contraction due to daily and annual temperature change

Idealised stress paths in element A (constant σ and varying ε_h)

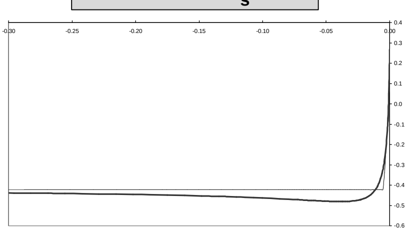


Biaxial element simulation

- Illustrative biaxial simulation for element A with OCR=9 (e_0=0.65)
- ε_h controlled biaxial loading in plane strain
- Results from a NMC model with similar strength parameter (ϕ'=25°) and ψ'=15° plotted for comparison

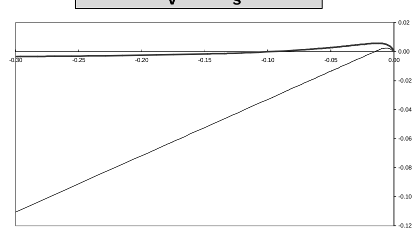
Biaxial compression (OCR=9 & $\delta\varepsilon_h$=-0.30)

t/s' VS e_s



$\phi'_{mob\ (peak)}$ = 29°*

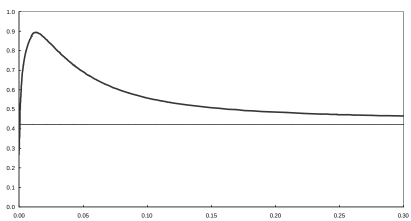
e_v **VS** e_s



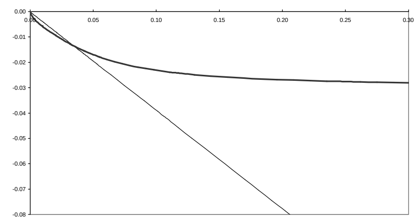
*Note that in plane strain, ϕ'_{mob}= $\sin^{-1}$(t/s')

Biaxial extension
(OCR=9 & $\delta\varepsilon_h$=+0.30)

t/s' VS e_s



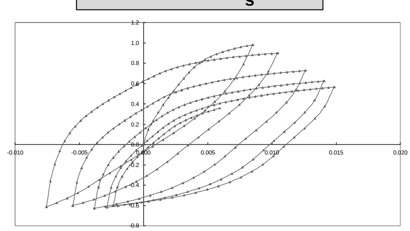
e_v VS e_s



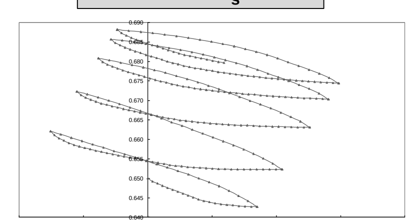
$\phi'_{mob\ (peak)}$ = 63°!

Biaxial cyclic
(OCR=9 & $\delta\varepsilon_s$=±0.01)

t/s' VS e_s



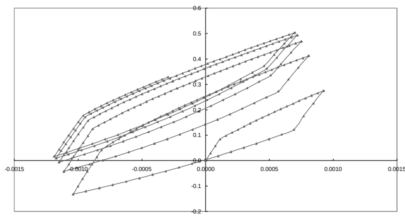
e VS e_s



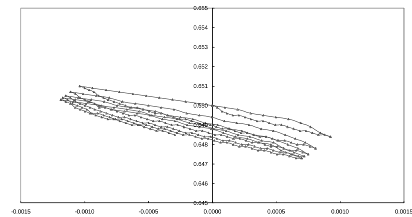
?e = +0.03 after 5 cycles

Biaxial cyclic
(OCR=9 & $\delta\varepsilon_s$=±0.00125)

t/s' VS e_s



e VS e_s

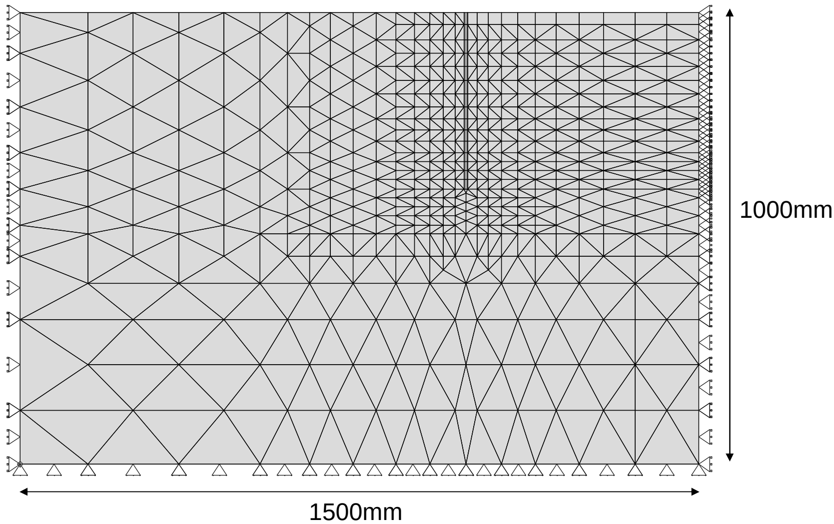


?e = -0.0015 after 5 cycles

Conclusions from biaxial element simulation

- Excellent prediction in monotonic loading path; but excessive mobilised stress ratio as expected in monotonic unloading path
- Cyclic loading of model shows energy dissipation, and collapse or dilation depending on magnitude of cycle
- However, volumetric collapse predicted is much lower compared with experimental data

FEA of excavation supported by a cantilevered wall (model scale wall height=490mm)

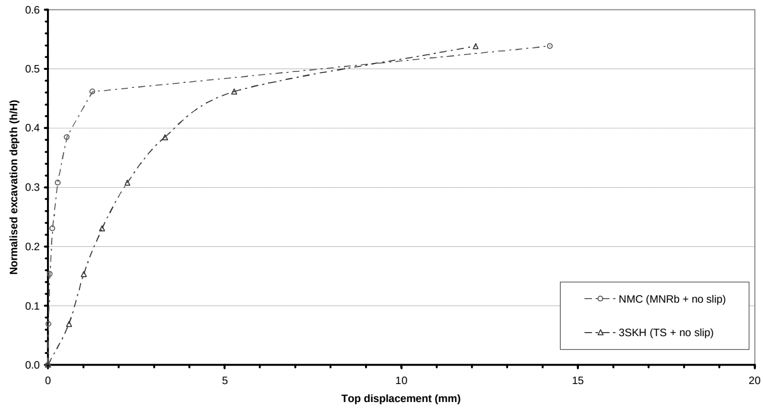


FEA of retaining walls

- Aim is to illustrate the performance of 3SKH model in predicting maximum excavated depth of a cantilevered wall embedded in granular soil
- For comparison, an identical run was performed using a Mohr-Coulomb model of similar material properties (ϕ'=28°)
- Analysis performed using 3SKH has OCR=4 to obtain realistic ϕ'_{mob}
- Surcharge applied at ground level

Predicted maximum depth (cantilevered wall)

Normalised excavation depth VS Top displacement (mm)

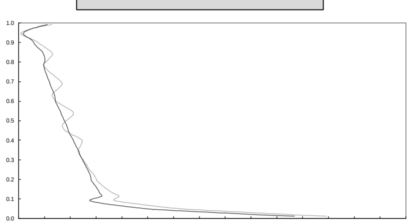


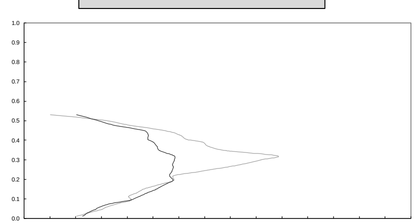
Stress distribution near failure (cantilevered wall)

Retained side

Excavated side

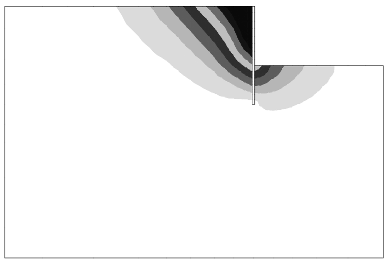
h/H



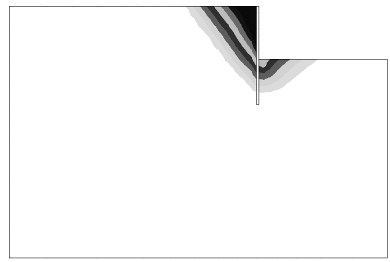


Wall normal stress (kN/m^2)

Horizontal displacement contours, interval=1mm near failure (cantilevered wall)

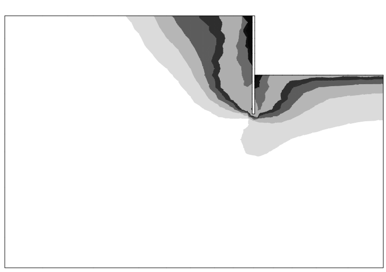


3SKH (TS with 30050 increments)

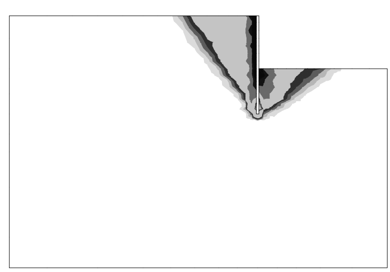


NMC (MNR with 860 increments)

Maximum shear strain contours, interval=0.01 near failure (cantilevered wall)



3SKH (TS with 30050 increments)



NMC (MNR with 860 increments)

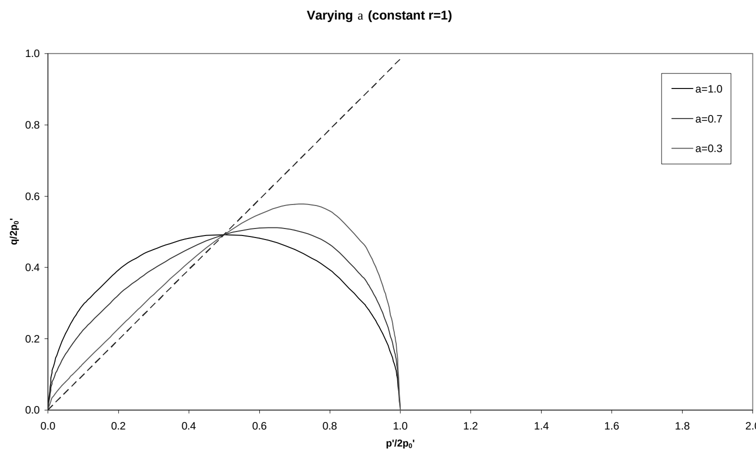
Conclusions from FEA of cantilevered wall

- Excessive strains predicted in excavation (k_0-unloading)
- Tension in the soil easily predicted for OCR > 4
- Very large number of increments necessary using the tangent stiffness scheme to avoid 'drifting' of stress state into 'illegal' locations
- Hence, a modified 3SKH model is proposed to minimise the problems encountered in integral abutment situations

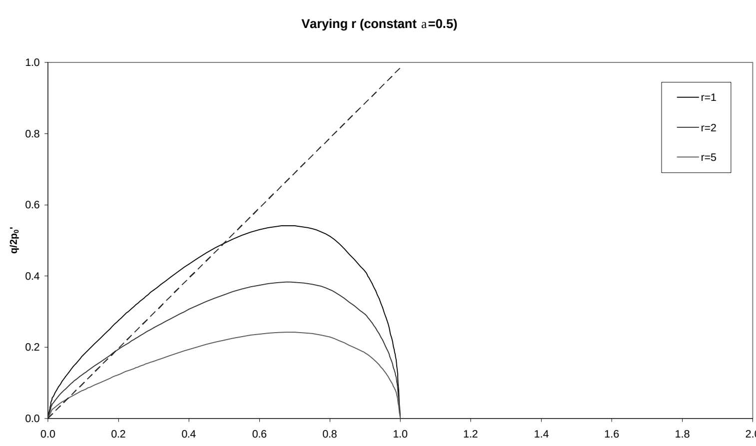
Development of a modified 3SKH

- 3 new parameters, each with its own physical significance:
  - α to modify the shape of the surfaces (Collins, 2002)
  - k to reduce the plastic shear component of the Modified Cam Clay flow rule (McDowell, 2003)
  - r to specify the ratio between M_f and M_g, as adopted by several previous researchers in modelling sand (e.g. Zienkiewicz, 1999)
- The original concept of 3SKH is retained; including the translation rules and modification to the hardening modulus

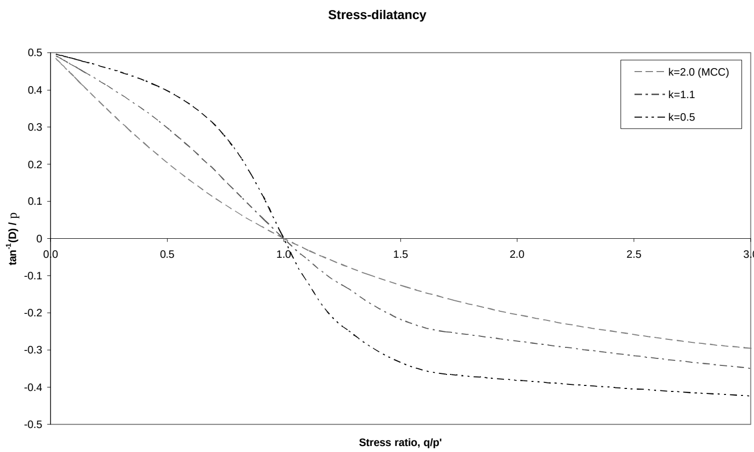
Shapes of bounding surface by varying α



Shapes of bounding surface by varying r

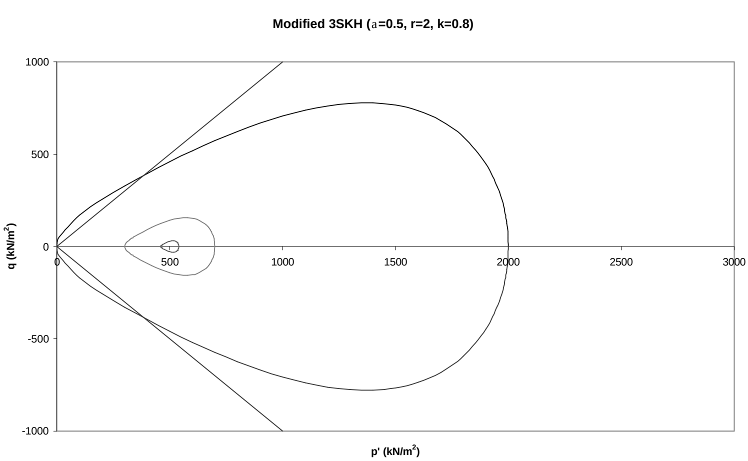


Stress-dilatancy rule by varying parameter k

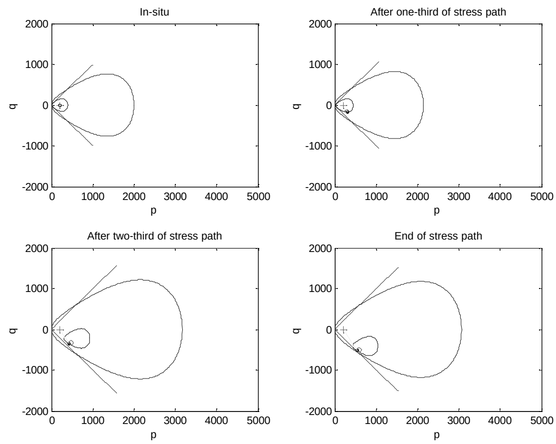


*D=$\delta\varepsilon_p / \delta\varepsilon_q$

A modified 3SKH

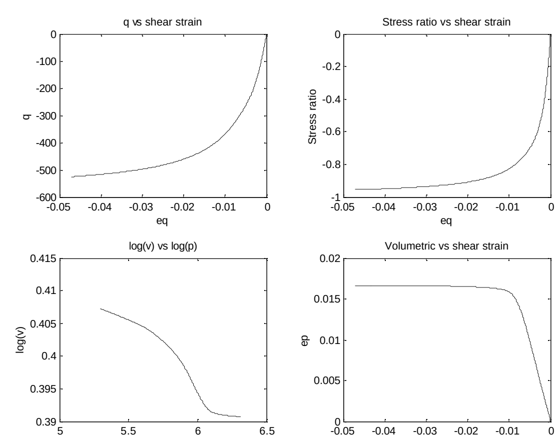


Stress path OCR=10 & *?η=-3/2 (Modified 3SKH)

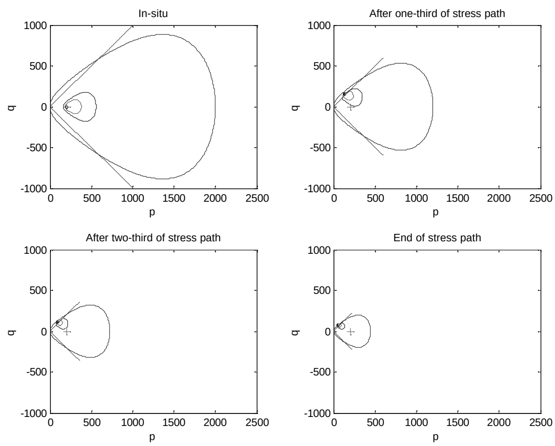


*?=δq/ δp

Stress path OCR=10 & *?η=-3/2 (Modified 3SKH)

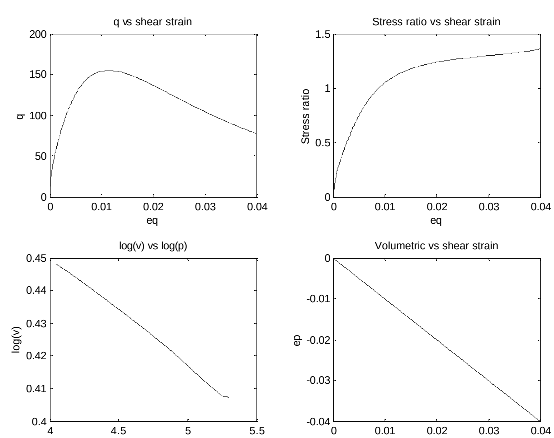


Strain path OCR=10 & ?D*=-1 (Modified 3SKH)



*D=$\delta\varepsilon_p / \delta\varepsilon_q$

Strain path OCR=10 & ?D*=-1 (Modified 3SKH)



Conclusions

- The main problems of using the original 3SKH model to simulate integral abutment in drained granular soil has been outlined
- A modified 3SKH model with 3 extra parameters to enable variation in shape of the surfaces, ratio M_f to M_g and non-associated flow rule has been formulated
- Illustrations of the translation rule, simple hardening stress path, and simple strain path have been performed using Matlab

Conclusions

- To implement into the FE program CRISP, the formulation has to be transferred in a generalised stress-strain space
- A more robust solution scheme such as a MNR method with a suitable integration algorithm would help to reduce the computing time and improve accuracy in using the 3SKH class of models