Aalto University

Replication of fall cone test on marine clay with material point method

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Penetration tests

- **Penetration tests are often used for estimation of soil parameters**

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Fall Cone Test

© Mulukula et al., 2011

Free Fall Cone Test

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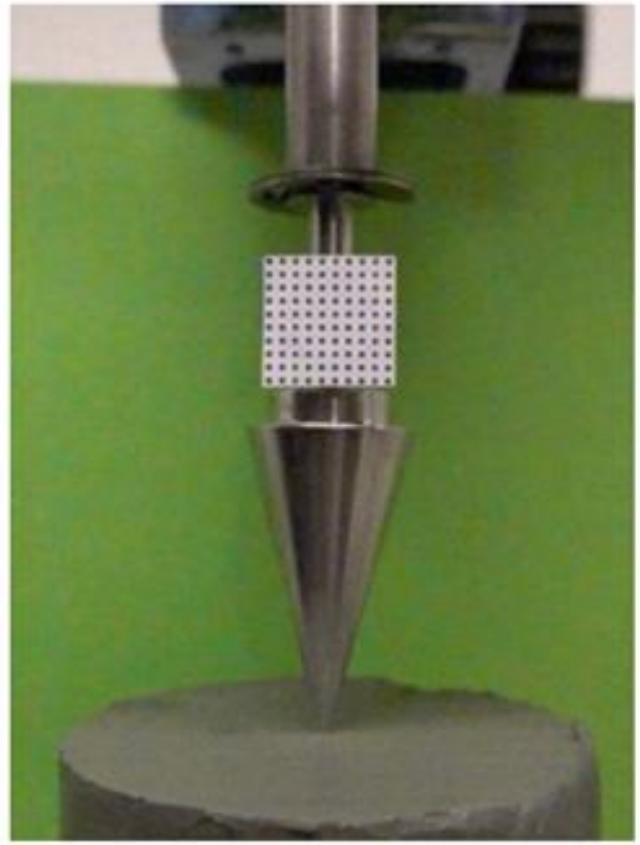
Cone Penetration Test

Experimental investigation of fall cone test

- **Study area: The neighbourhood of Inkoo town, Finland in the Baltic sea**
- **Fall cone tests at Aalto laboratory using 30° 100g cone**
- **Recorded using high speed camera (1000 frames/sec)**
- **A MATLAB script analyses the data and gives the cone displacement, velocity, acceleration and reaction force during the penetration process**

Inkoo,
Northen Baltic sea



30° 100g test set up used to track the cone

Developed MATLAB algorithm to track the cone

1- Convert the video files to frames

2-Automatic selection of featured points

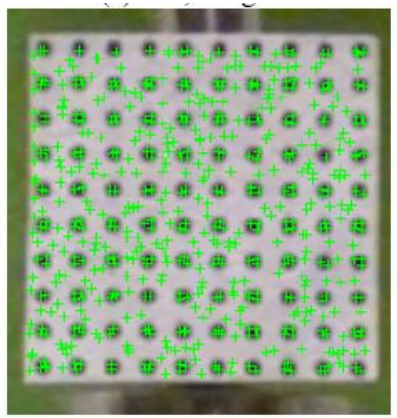
3- Track the featured points using the Kanade-Lucas-Tomasi (KLT) Algorithm and remove unsucessful tracked points

4- Convert image space to object space to get displacement curve

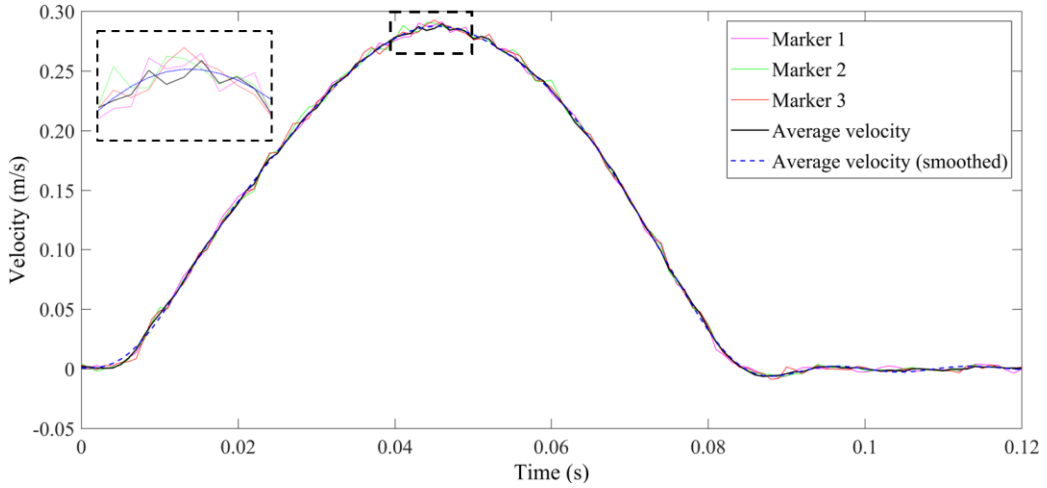
5- Numerical differentiation: velocity curve

6- smoothen velocity by reducing noise

7- Numerical differentiation: Acceleration and reaction force

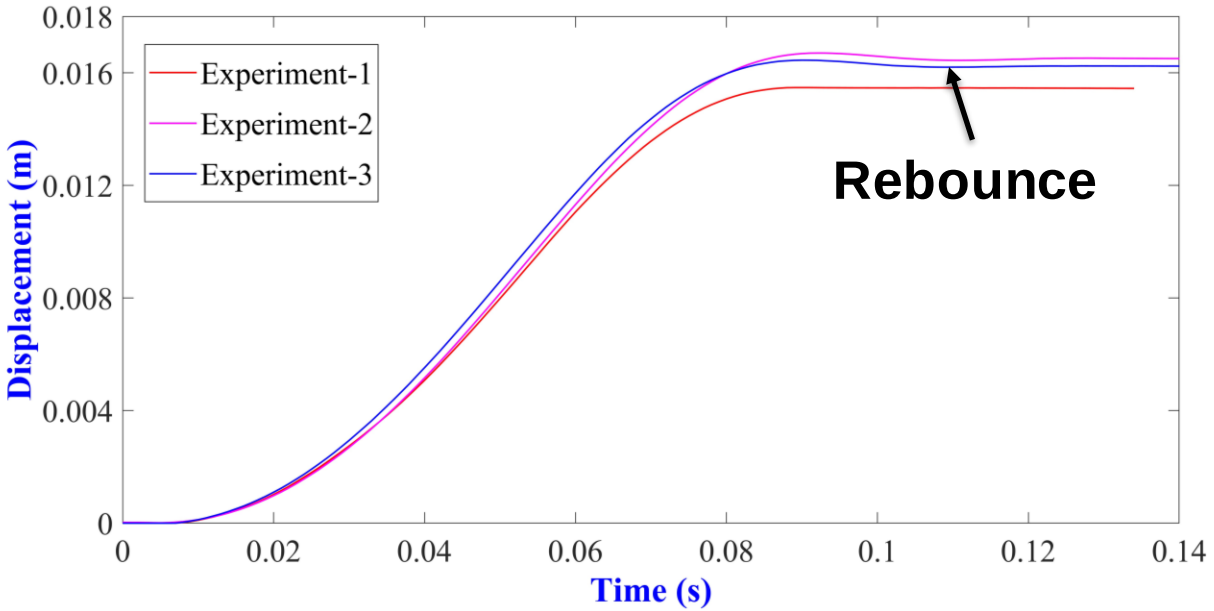


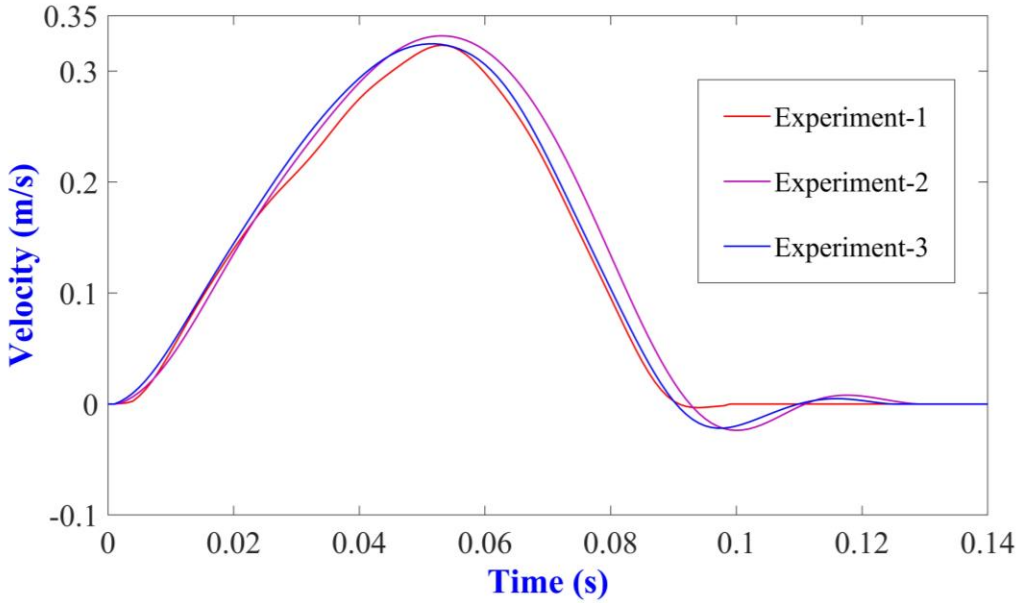
Automatically selected featured points on the tracker

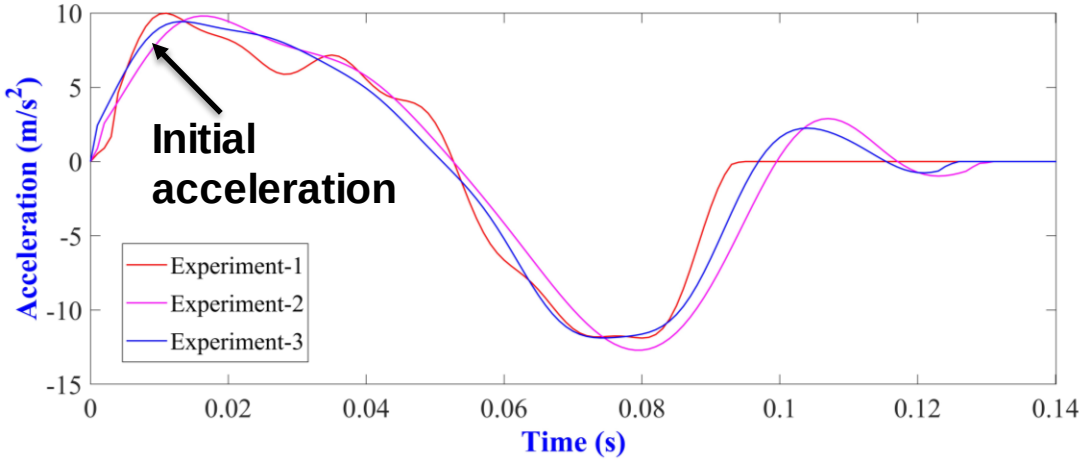


Smoothed cone velocity

Experimental results





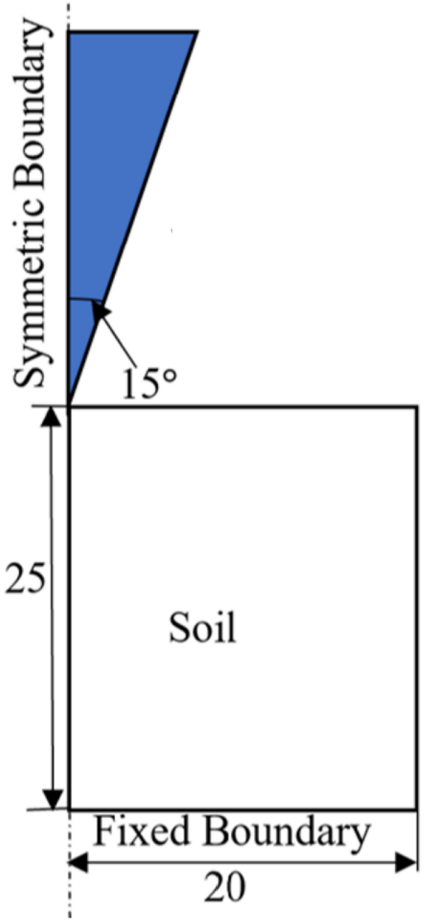


Final Penetration depth(d_p) in mm

	Expt - 1	Expt - 2	Expt-3
Experiment	15	16.4	16.0
Image Analysis	15.1	16.5	16.2

Numerical modelling of fall cone test

- **The present analysis uses Explicit MPM as it is well-suited to solve dynamic large deformation problems.**
- **To avoid numerical instabilities and cell crossing errors associated with original MPM , the Generalized interpolation MPM (GIMP) is used.**
- **We have used GIMP as encoded in Uintah software (developed by University of Utah) for simulations of the fall cone test.**
- **We have used extended Tresca material model to consider the strain rate and strain softening effects**

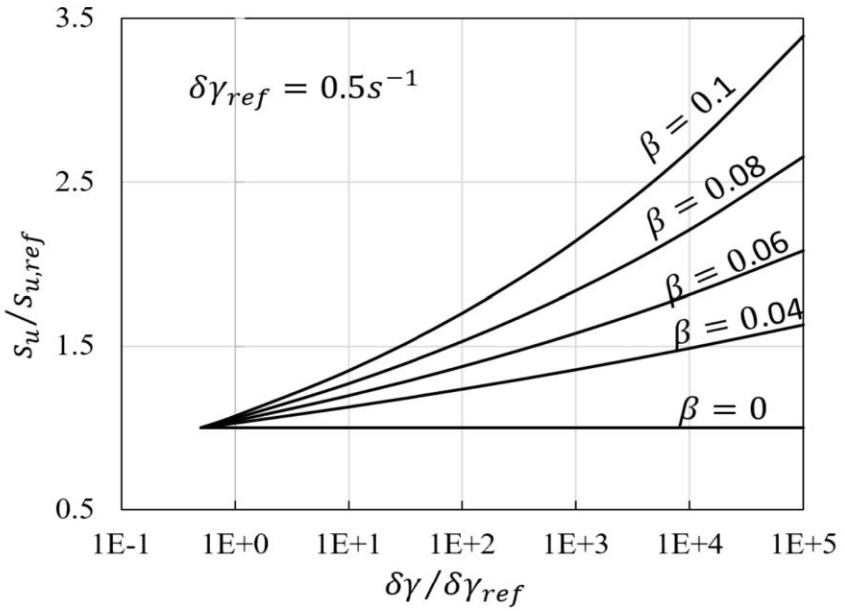


Axisymmetric model used for MPM Analysis

Effect of strain rate and strain softening

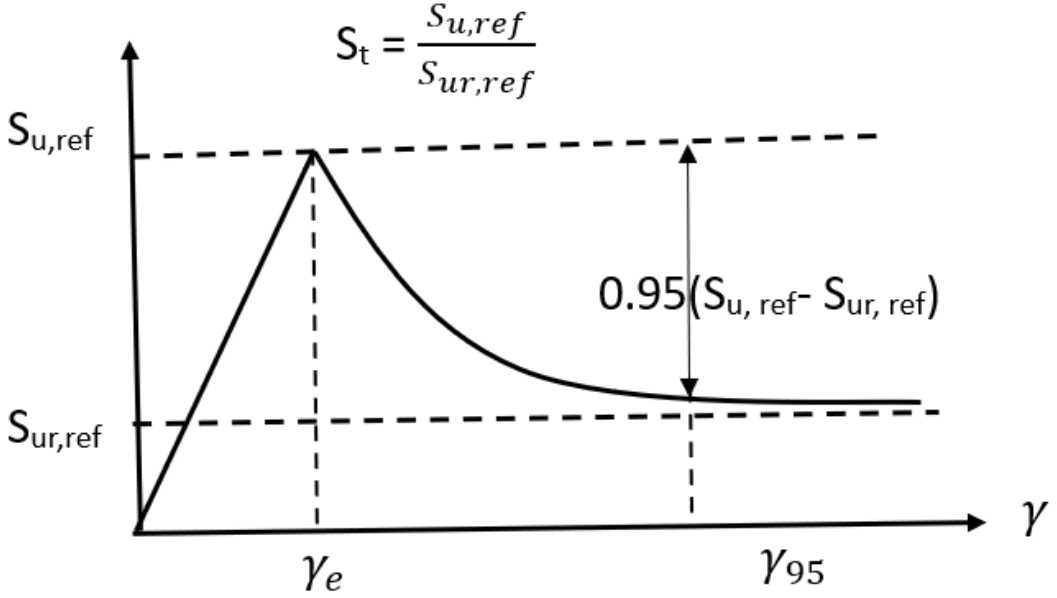
Effect of strain rate

$$s_u(\delta\gamma) = s_{u,ref} \left(\frac{\delta\gamma}{\delta\gamma_{ref}}\right)^{\beta}$$



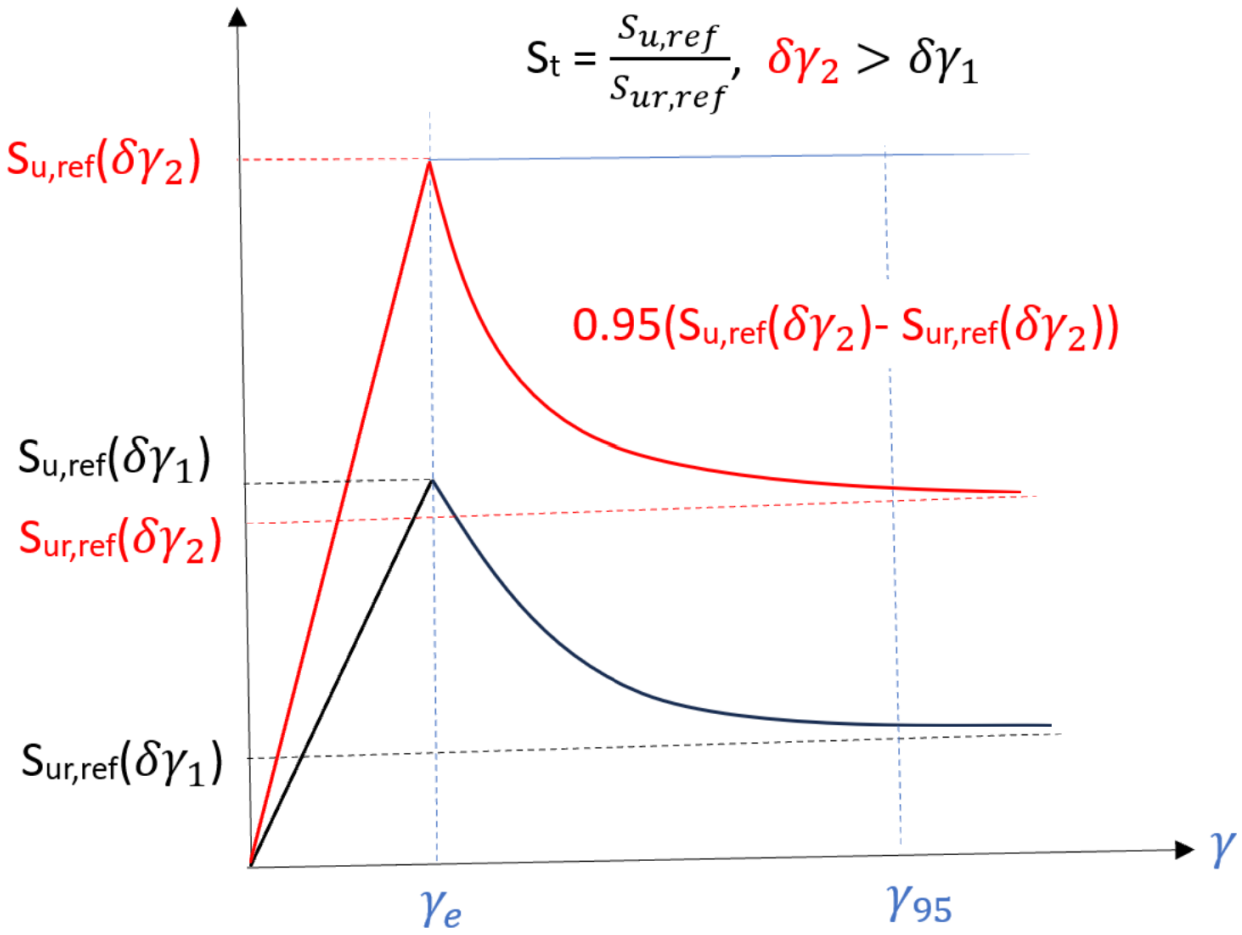
Effect of strain softening

$$s_u(\gamma, S_t) = s_{u,ref} \left[\frac{1}{S_t} + \left(1 - \frac{1}{S_t}\right) e^{\frac{-3\gamma}{\gamma_{95}}}\right]$$



Constitutive model

$$s_u(\delta\gamma, \beta, \gamma, S_t) = s_{u,ref} \underbrace{\left(\frac{\delta\gamma}{\delta\gamma_{ref}}\right)^{\beta}}_{\text{Strain rate effect}} \underbrace{\left[\frac{1}{S_t} + \left(1 - \frac{1}{S_t}\right) e^{\frac{-3\gamma}{\gamma_{95}}}\right]}_{\text{strain softening effect}}$$



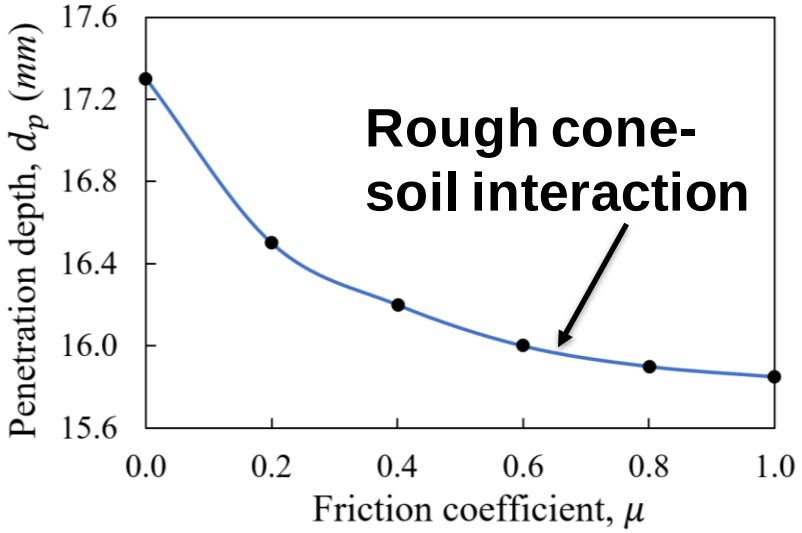
Constitutive model considering strain rate and strain softening effect

Selection of material parameters

Material parameters	value
$s_{u,ref}$(kPa)	3.95
$G_{u,ref}$(kPa)	$167s_u$
ν_u	0.495
μ	0.65
$\delta\gamma_{ref}(s^{-1})$	0.5
β	0.06
s_t	10
$\gamma_{95}(s^{-1})$	25

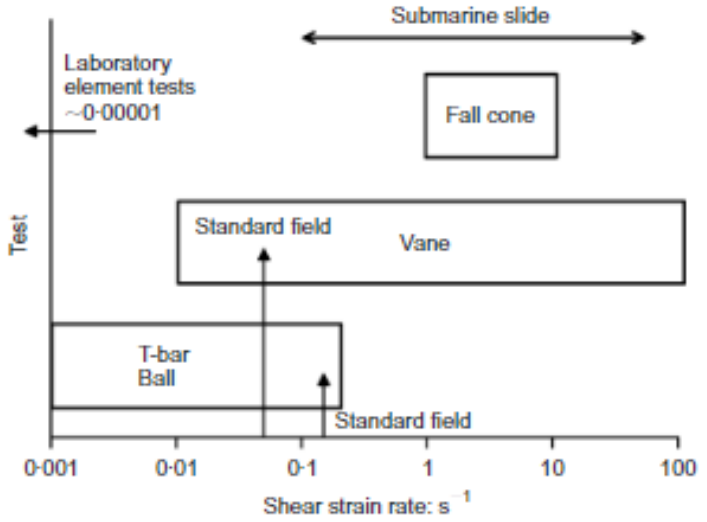
Influence of friction coefficient on Penetration depth

- **Rough cone-soil interaction condition is enforced**



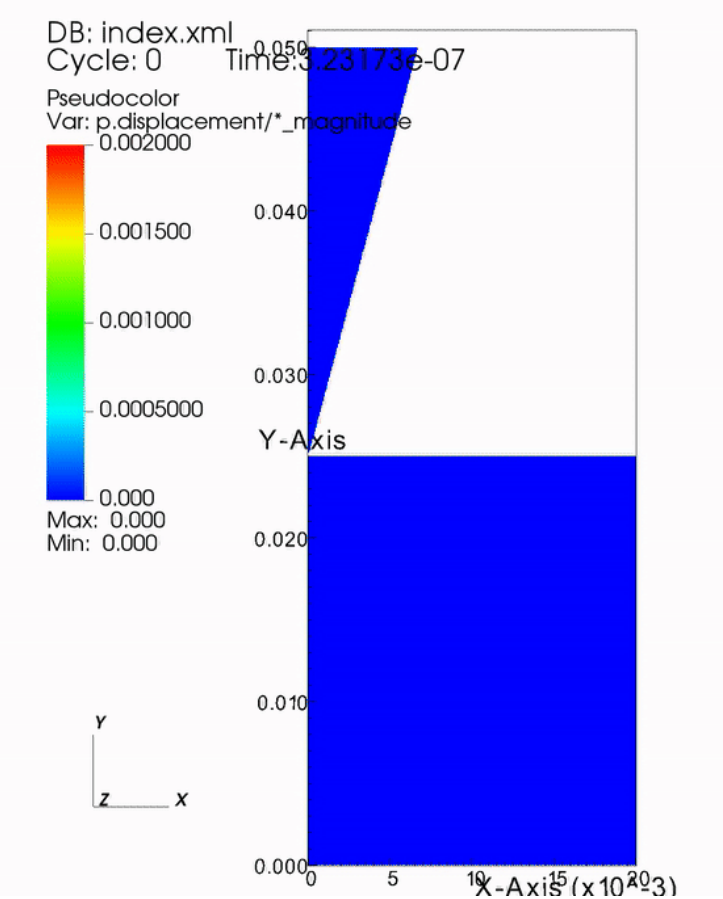
Strain rate range for different tests

- **For fall cone test : 1-10s^{-1}**

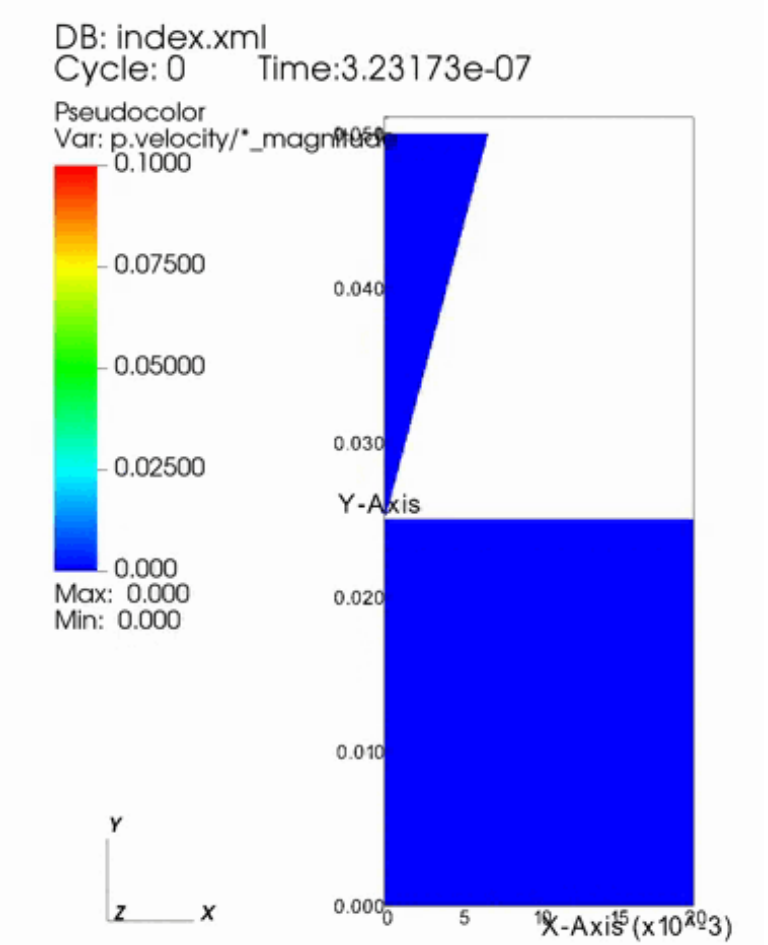


Numerical cone penetration process

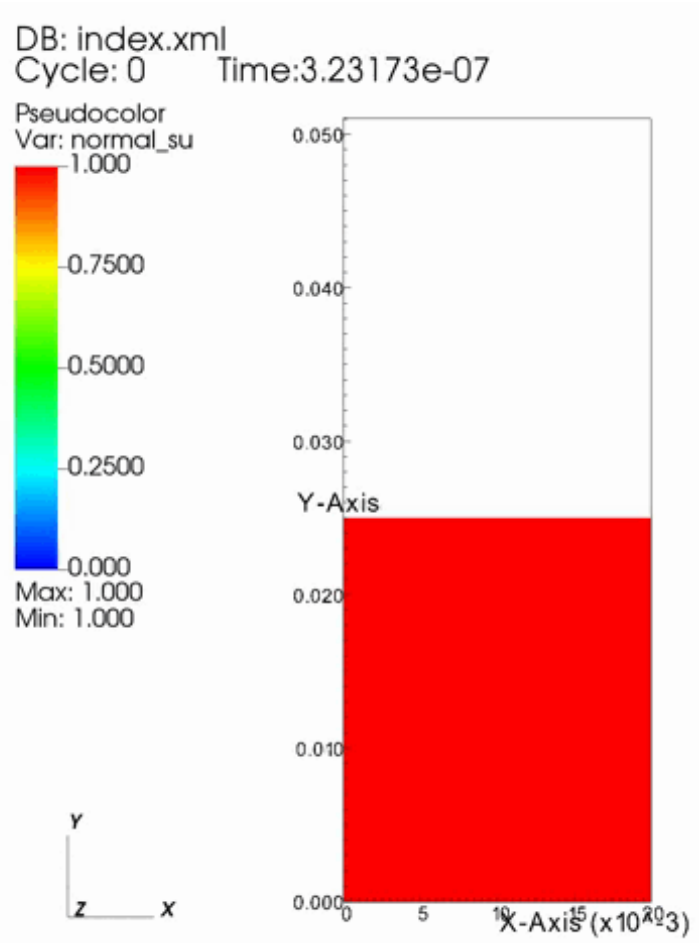
Displacement



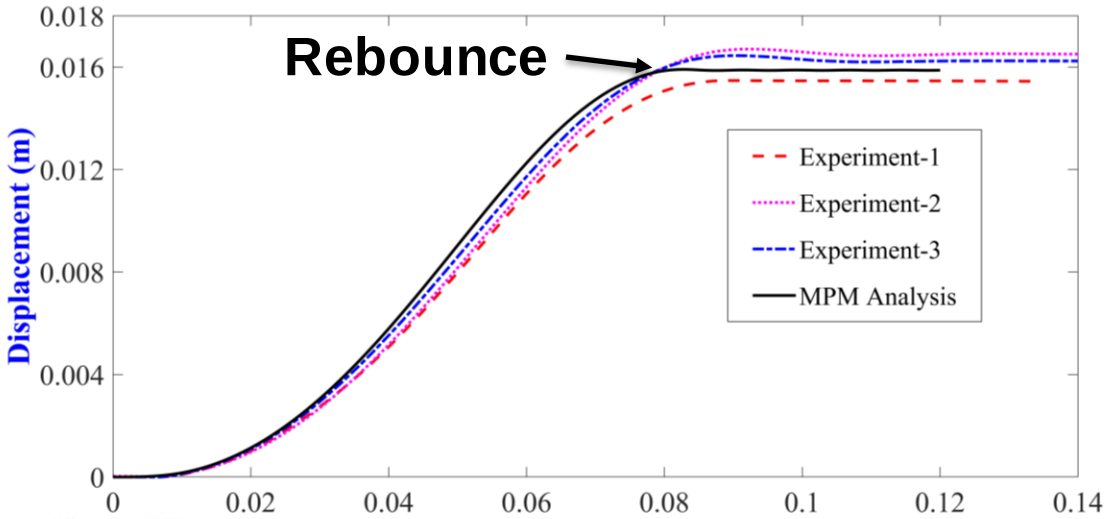
Velocity

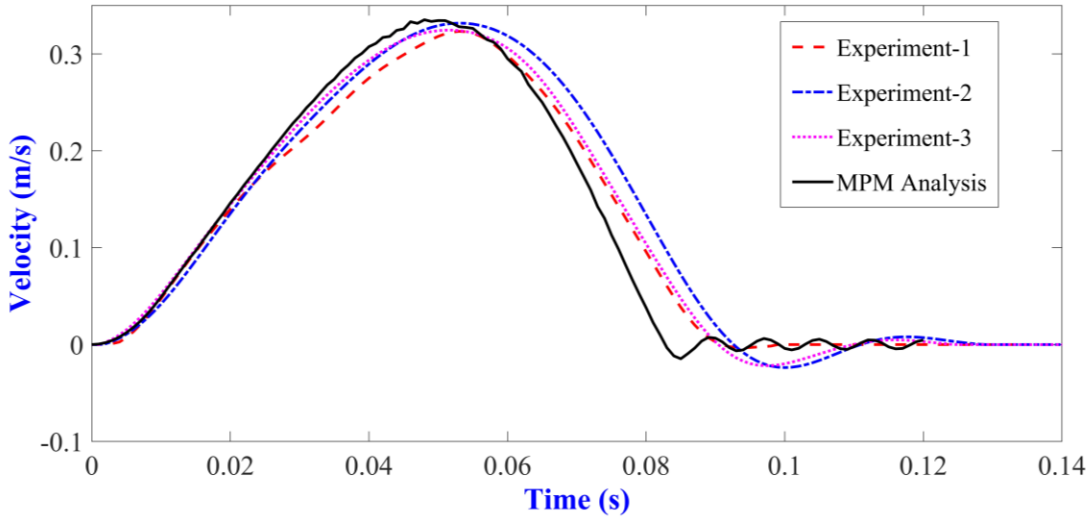


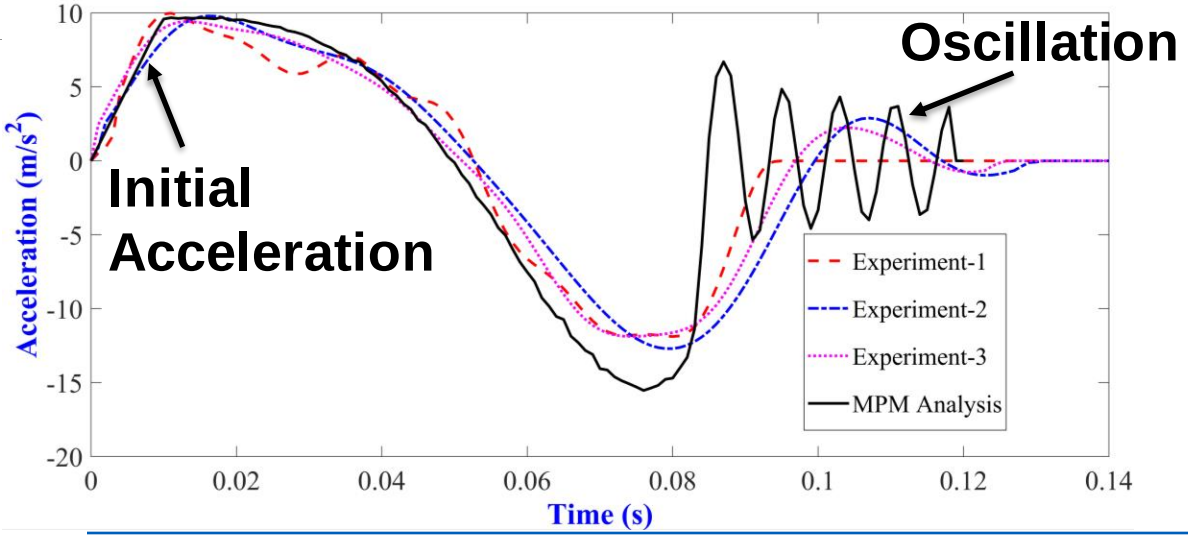
$s_u/s_{u,ref}$

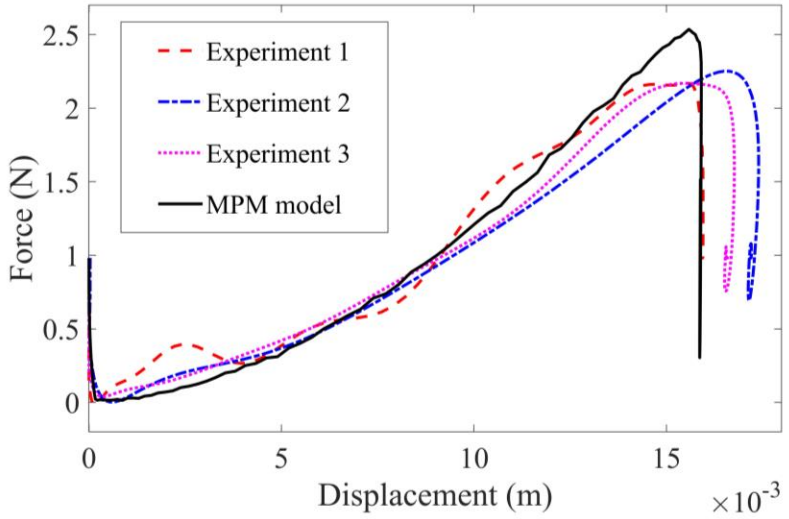


Numerical replication of fall cone test



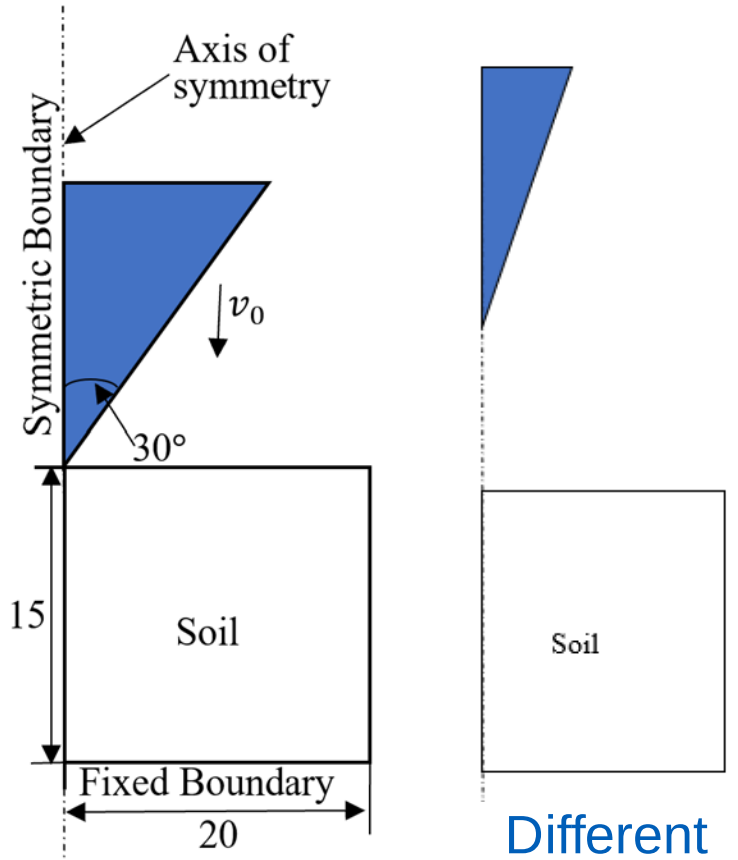






Conclusion and outlook for future

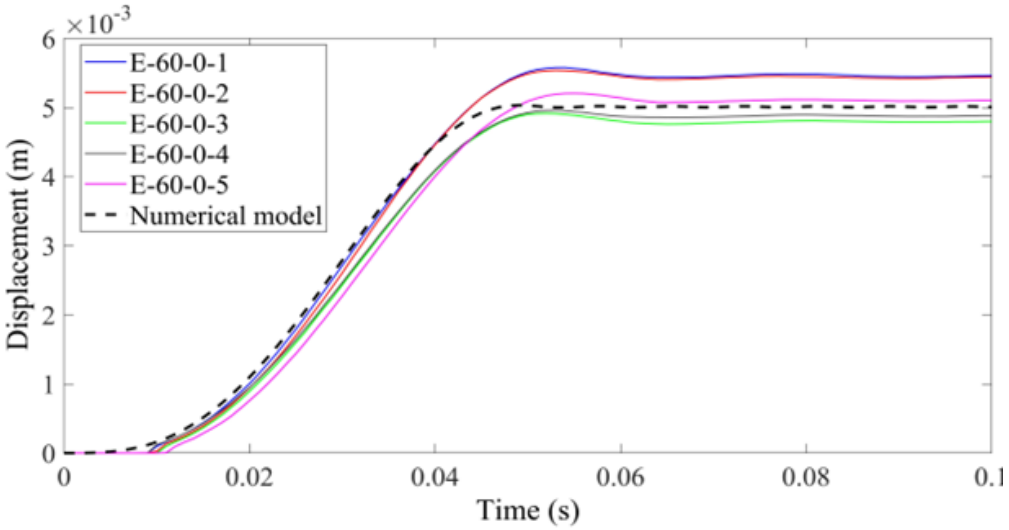
- **A MATLAB script reliably analyses video to get displacement, acceleration and velocity**
- **It seems that the used material model captures the most important aspects of the soil behaviour: destructuration and associated softening and strain rate dependency**
- **Good replication of data, same material parameters for a number of different tests**
- **The future research aim is to replicate free fall cone experiment numerically and investigate correlation between the data and soil properties**



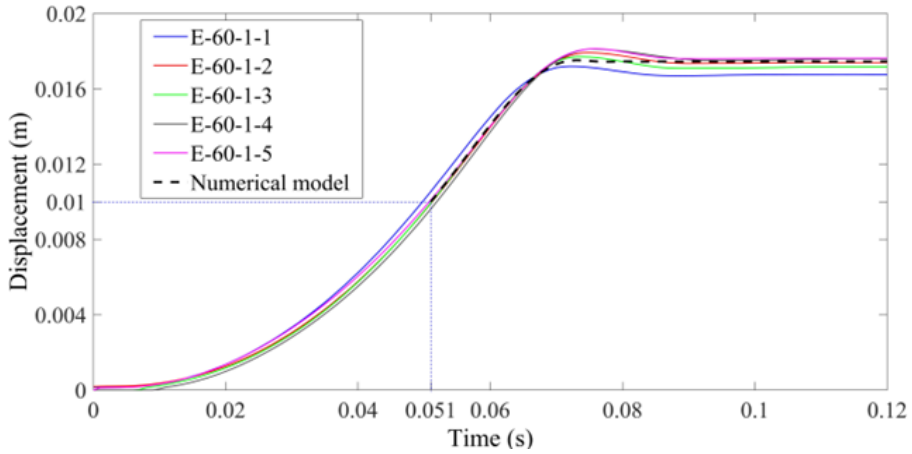
Different cone angles

Different drop heights

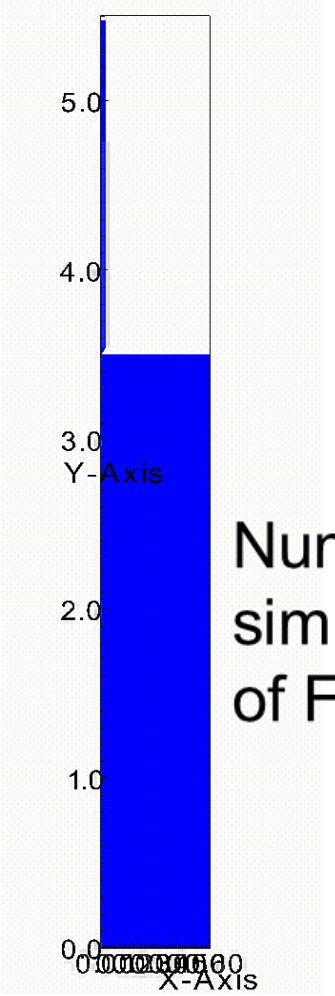
Replication of fall cone test of different cone angles and drop heights



60° 60g cone, drop height =0



60° 60g cone, drop height =10mm



Numerical simulation of FF-CPT

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Thank You !!!