The 42nd Risk, Hazard & Uncertainty Workshop, Hydra, June 22-25, 2016

Macroelement Modelling of Deep Foundations: Conceptual Elements

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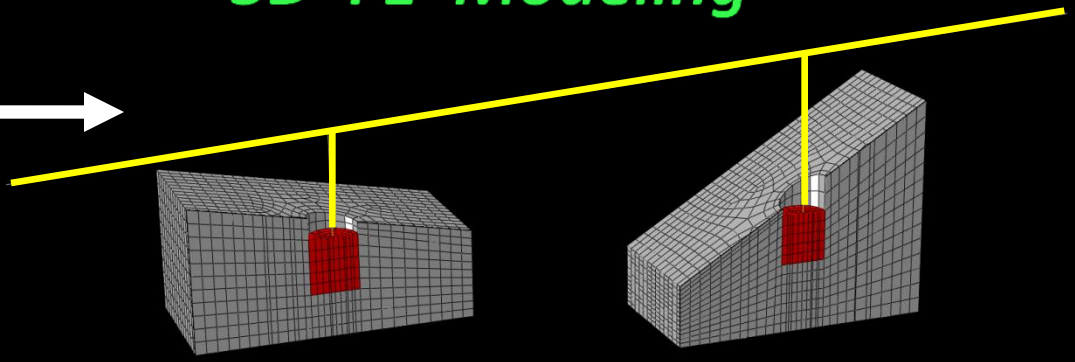
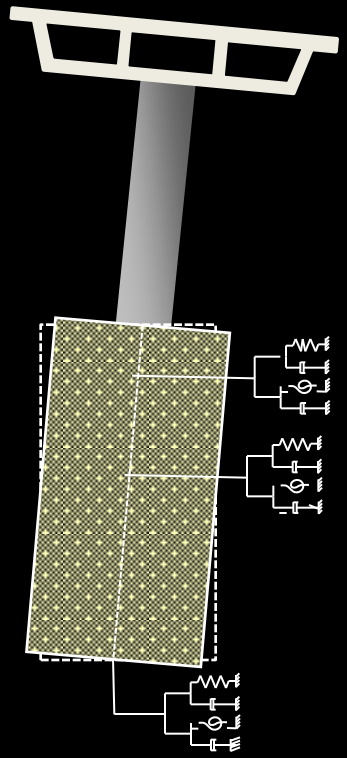
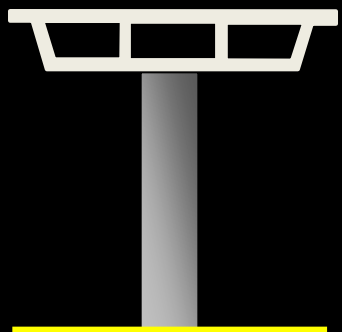
3D FE Modeling





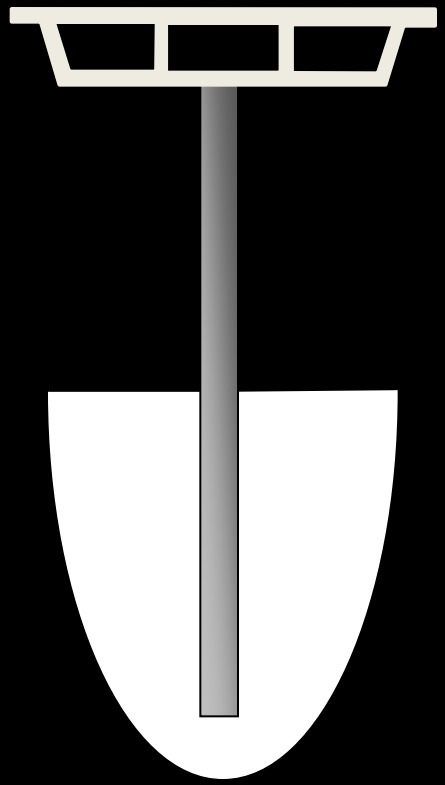
Macro-element Modeling



$$\begin{bmatrix} K^{ep}_{HH} & K^{ep}_{HR} \\ K^{ep}_{RH} & K^{ep}_{RR} \end{bmatrix}$$

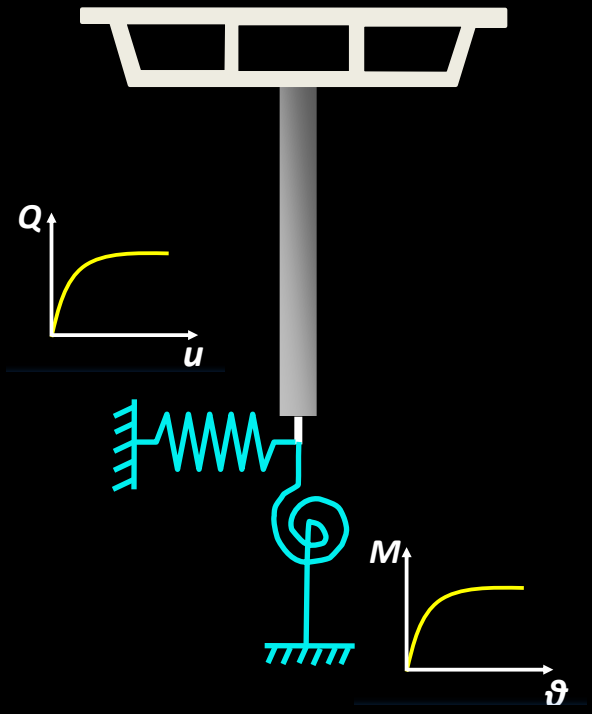
Soil Reaction Level

Foundation Level

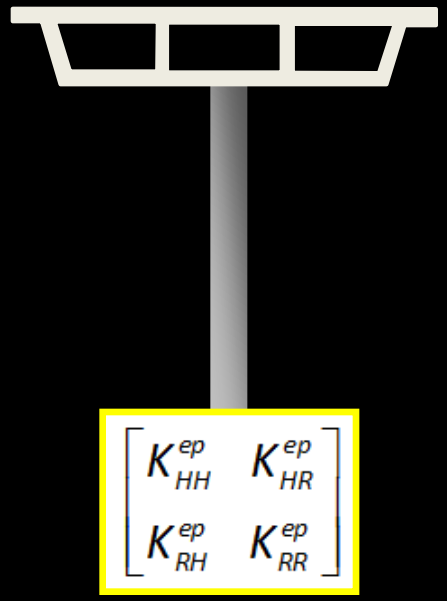


Pier on Extended Column Shaft

Model 1
Uncoupled Springs



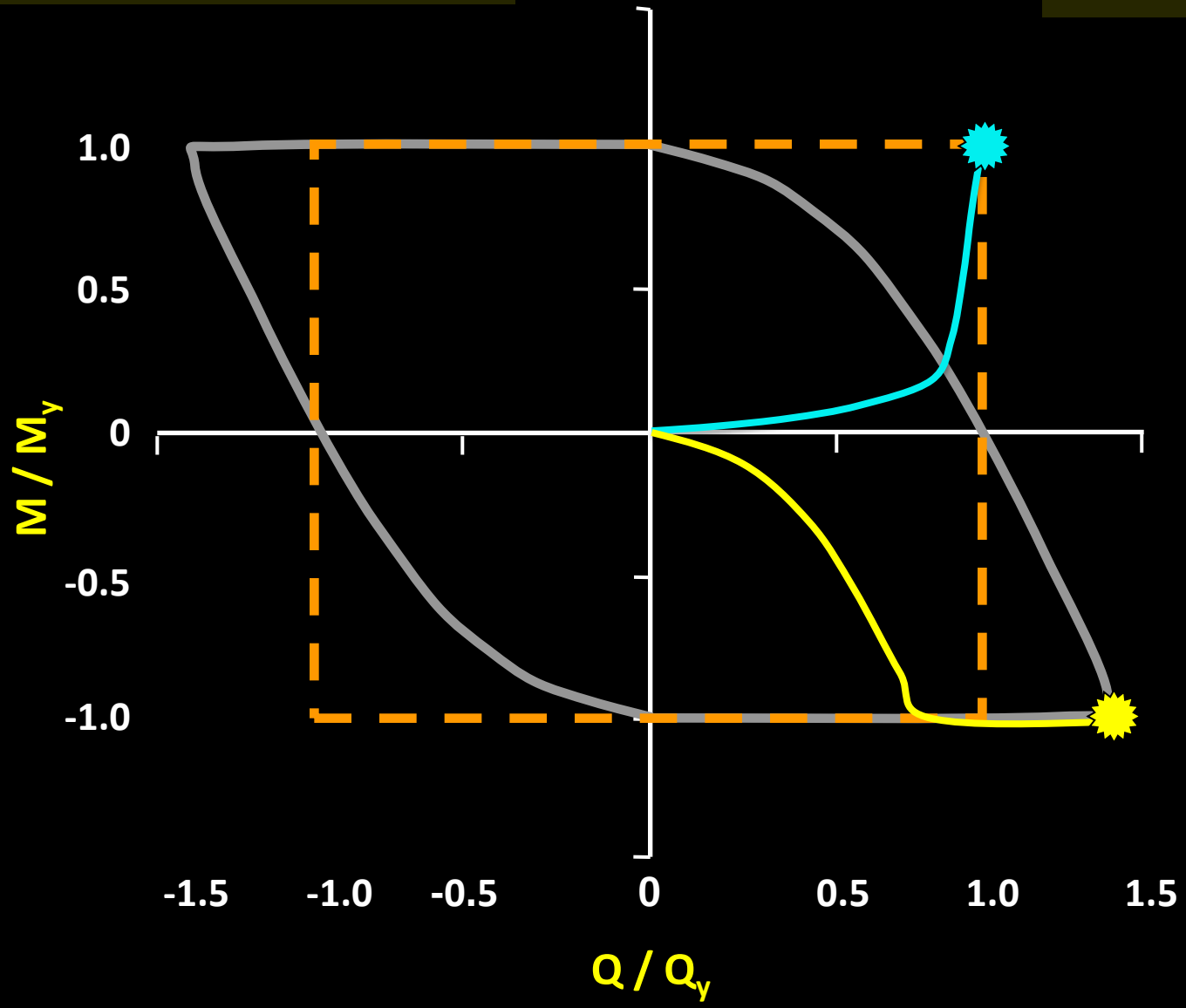
Model 2
Macro-element

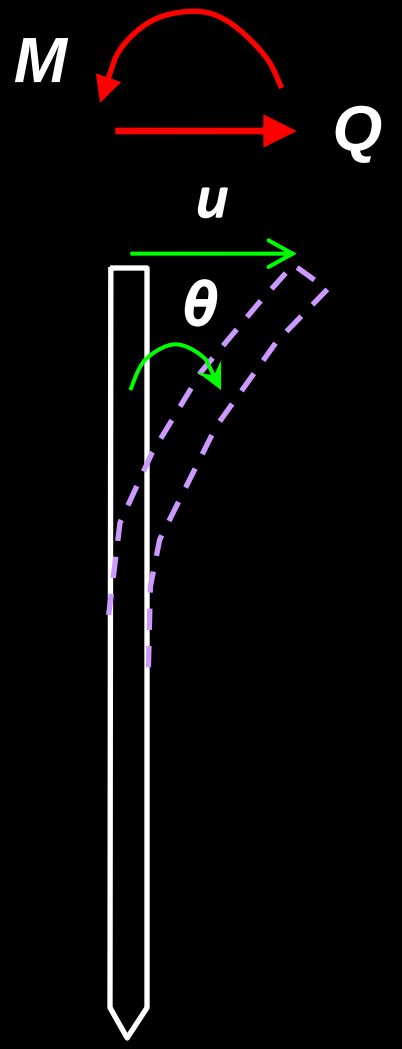


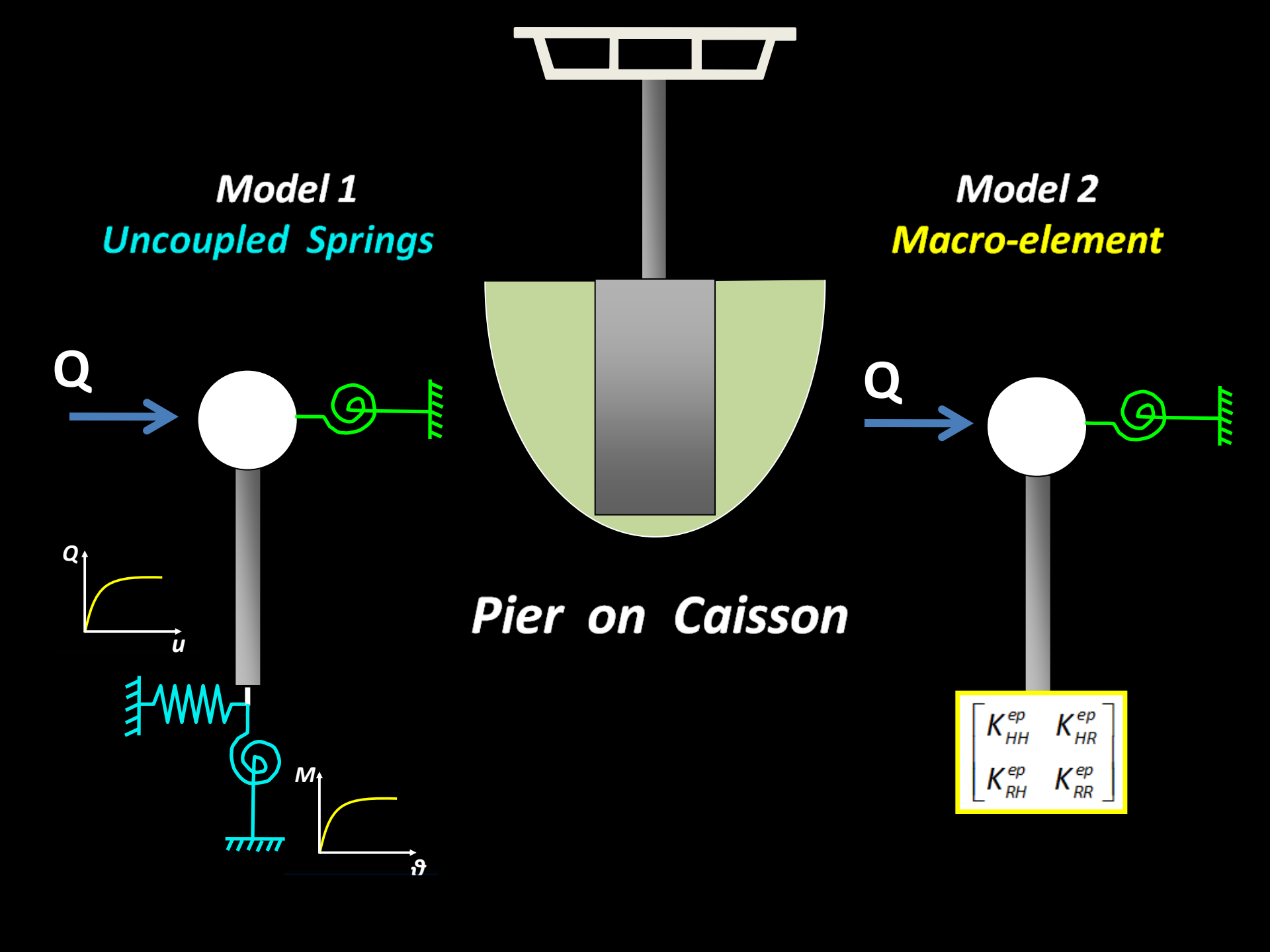
Model 1
Uncoupled Springs

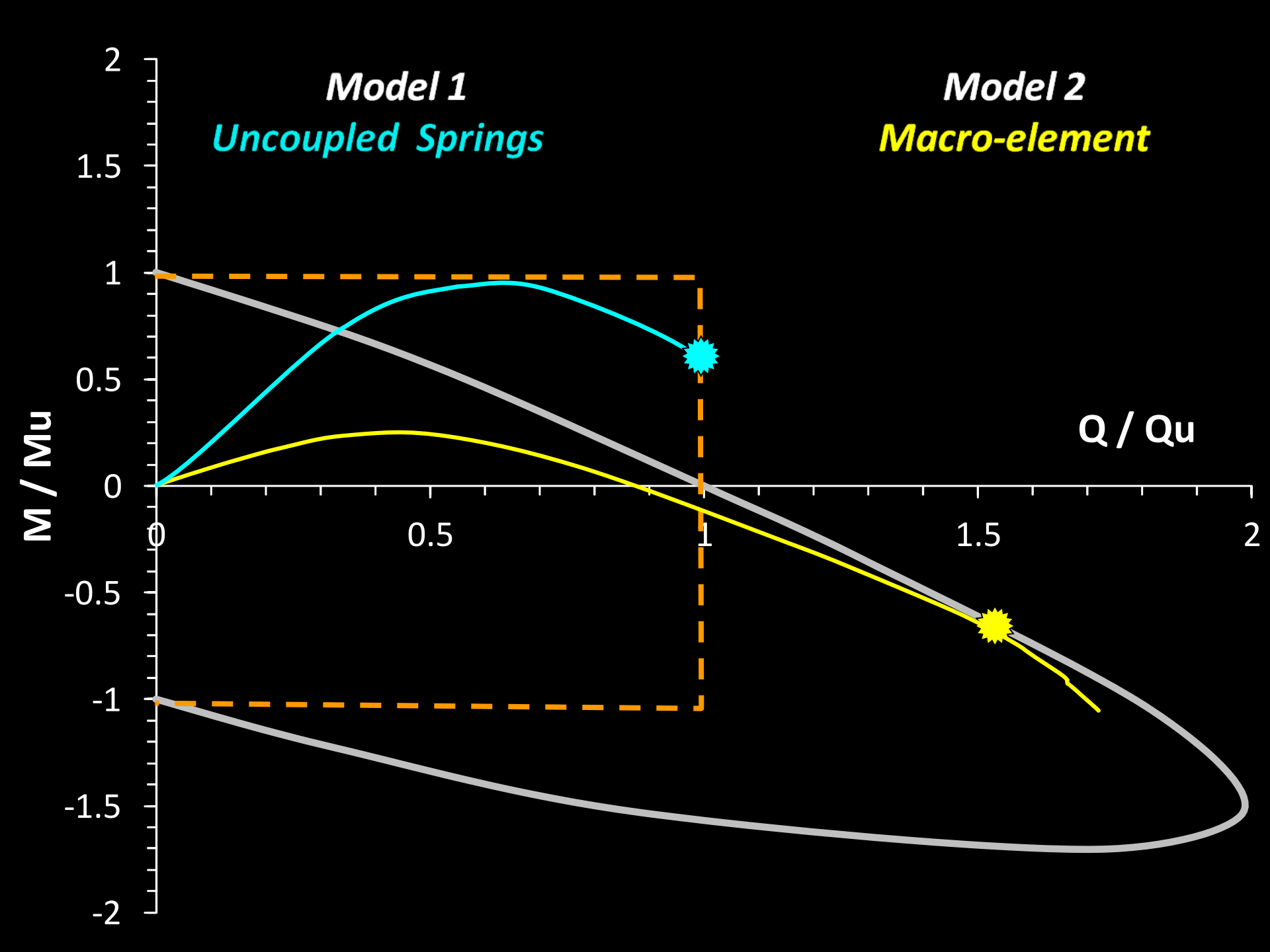
$u / \vartheta = const.,\ u >> \vartheta$

Model 2
Macro-element






Model 1
Uncoupled Springs
Model 2
Macro-element
Q
Q
Q
u
M
ϑ
Pier on Caisson
$\begin{bmatrix} K_{HH}^{ep} & K_{HR}^{ep} \\ K_{RH}^{ep} & K_{RR}^{ep} \end{bmatrix}$


Model 1
Uncoupled Springs
Model 2
Macro-element
M / Mu
Q / Qu
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2

Basic Components of Macroelement

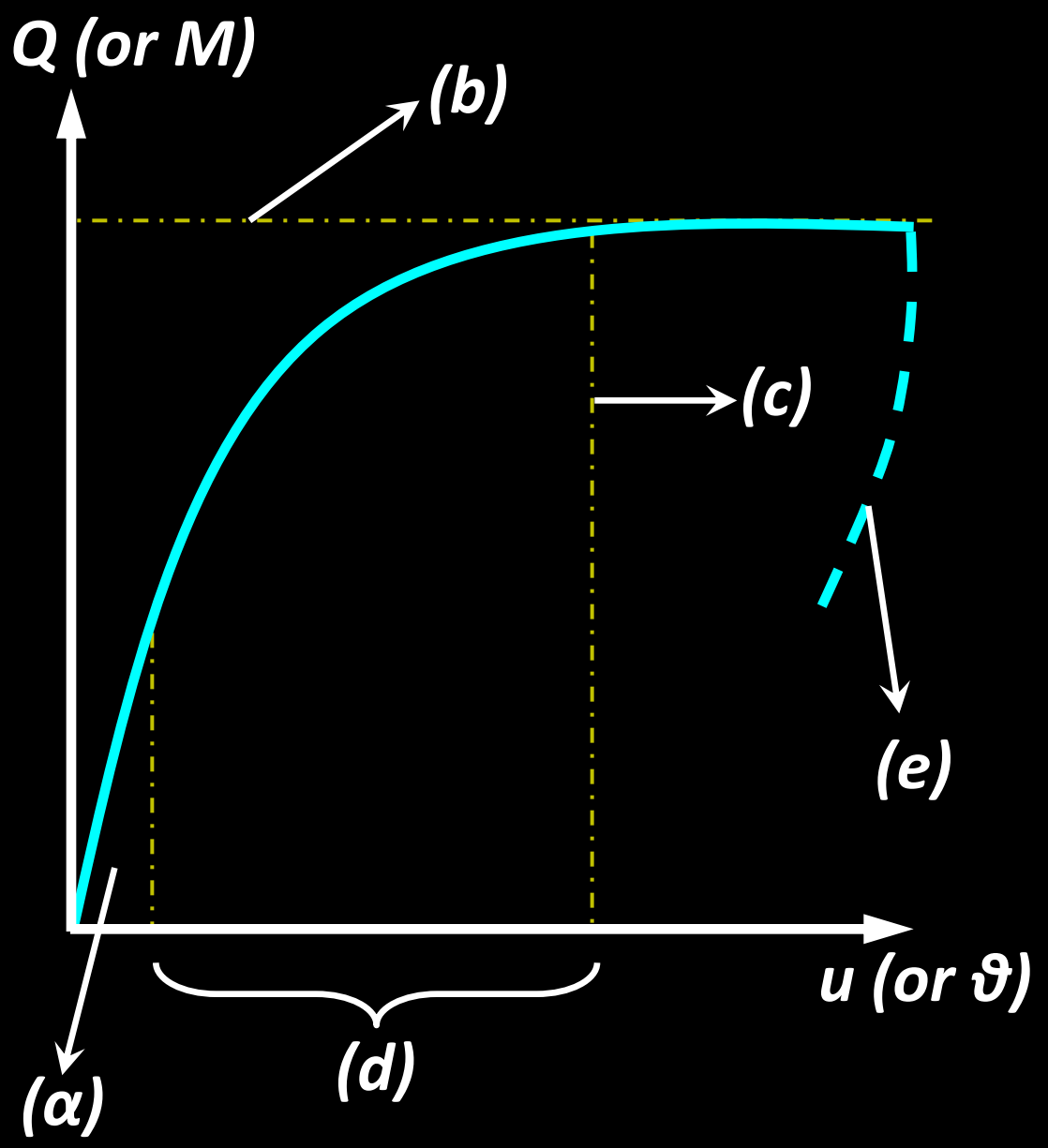
(a) Elastic Behaviour

(b) Failure envelope

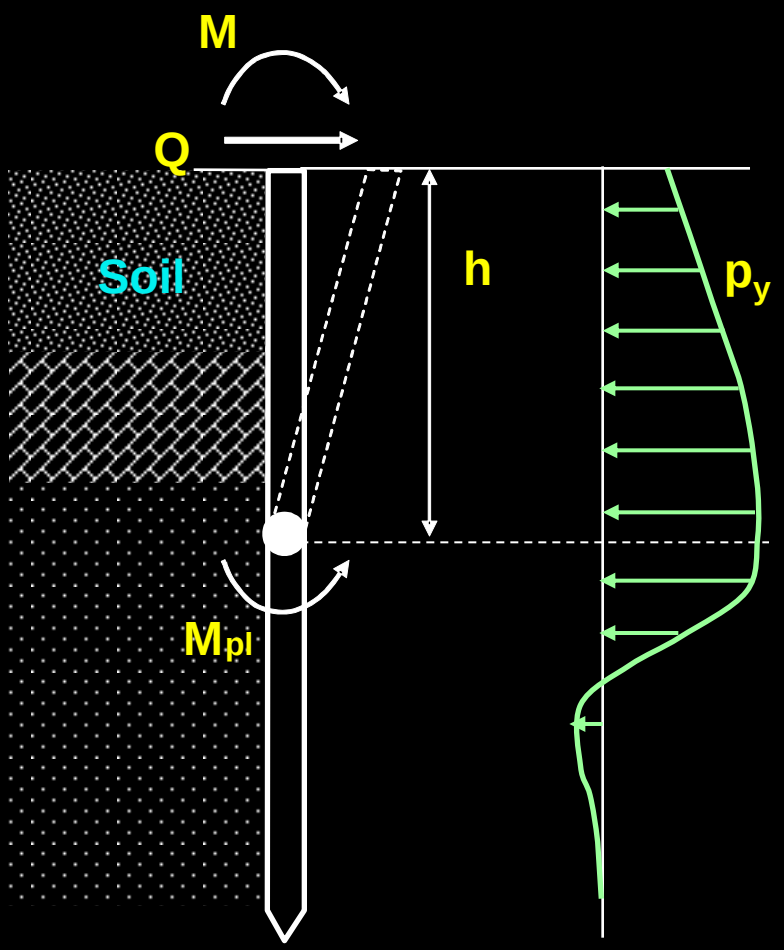
(c) Plastic Flow Rule

(d) Hardening Rule

(e) Unloading – Reloading Rule



Brom's Theory Revisited



General Solution

$$f = \left| \text{sgn}(Q) \left| \frac{Q}{Q_y} \right|^B + A\frac{Q}{Q_y} + \frac{M}{M_y} \right| - 1 = 0$$

$$f = \left| \frac{M}{M_y} \right| - 1 = 0$$

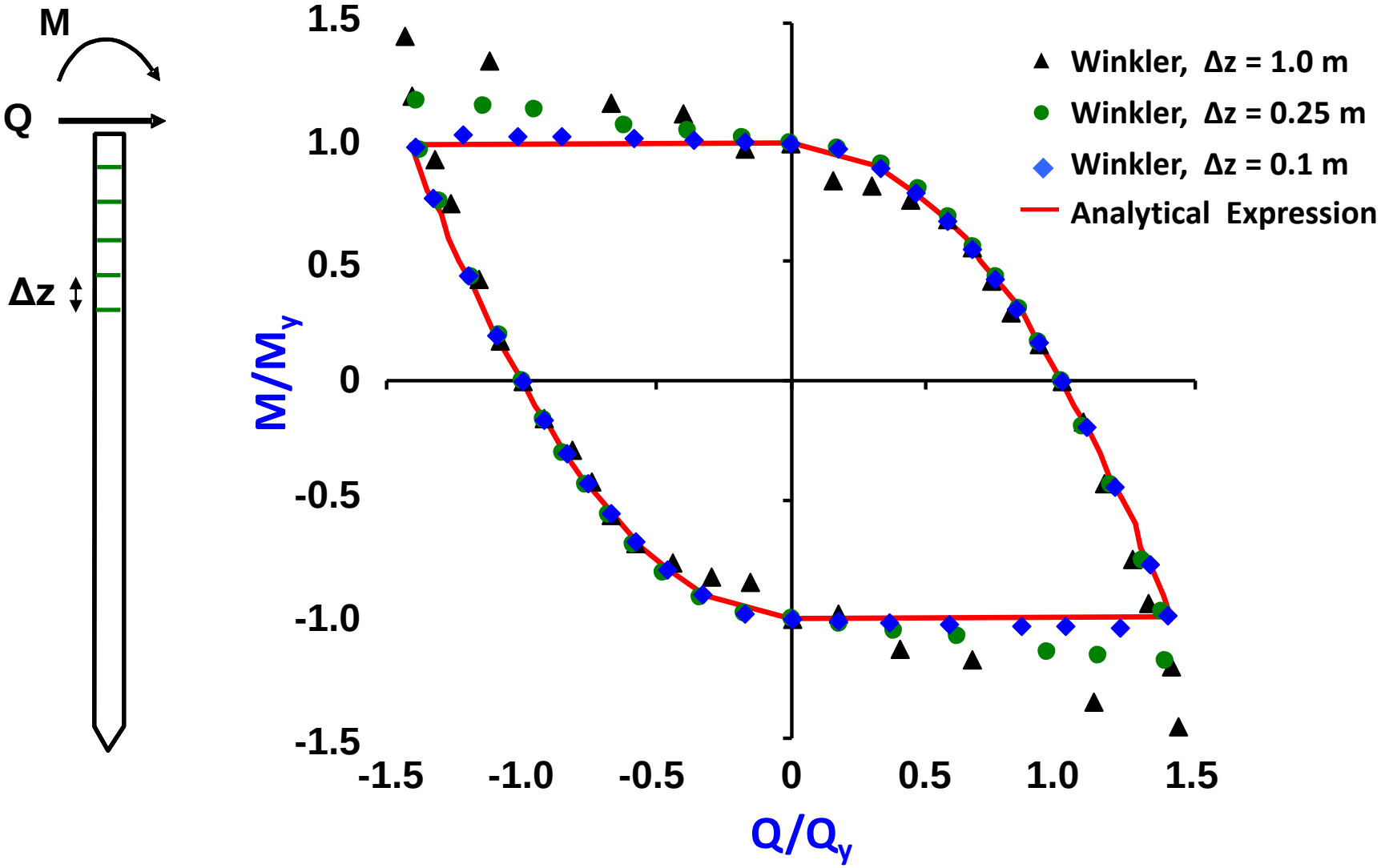
Cohesive Soil + Constant Su

$$B = 2, \quad A = 0$$

$$M_y = M_{pl}, \quad Q_y = \sqrt{2\, M_{pl}\, p_y}$$

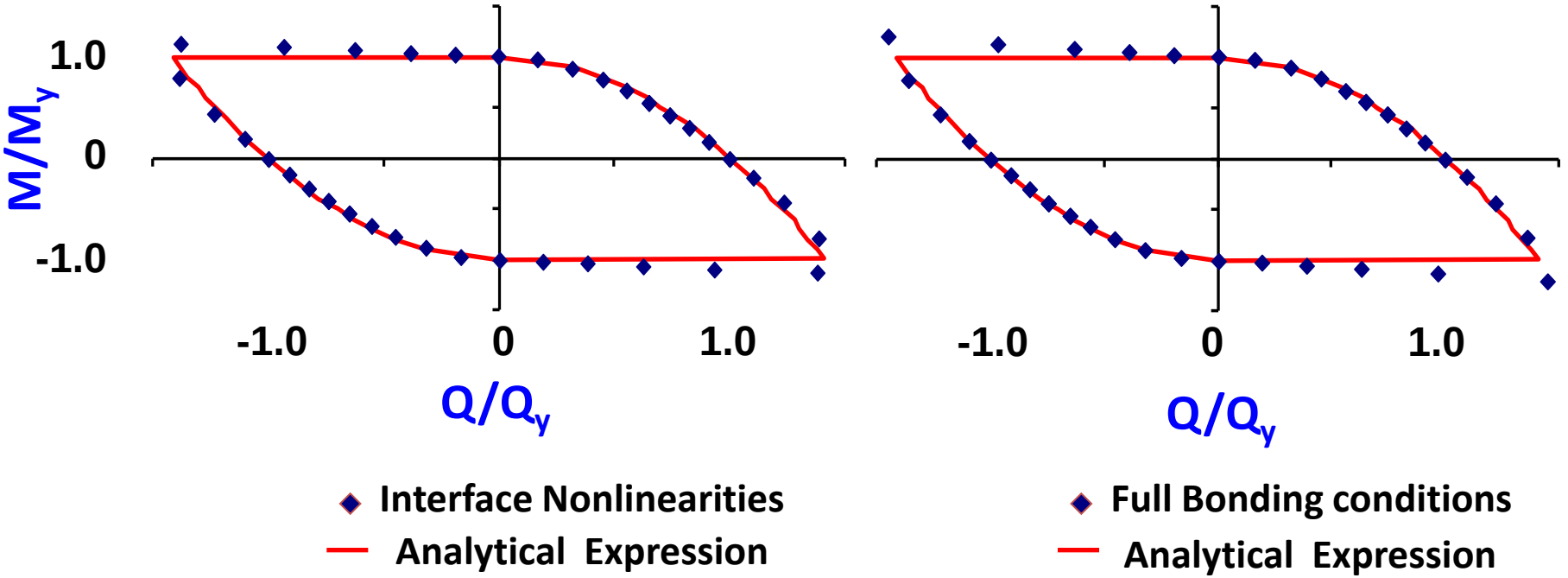
Homogeneous Cohesive Soil

Winkler Modeling ($\Delta z = 0.3$ m)

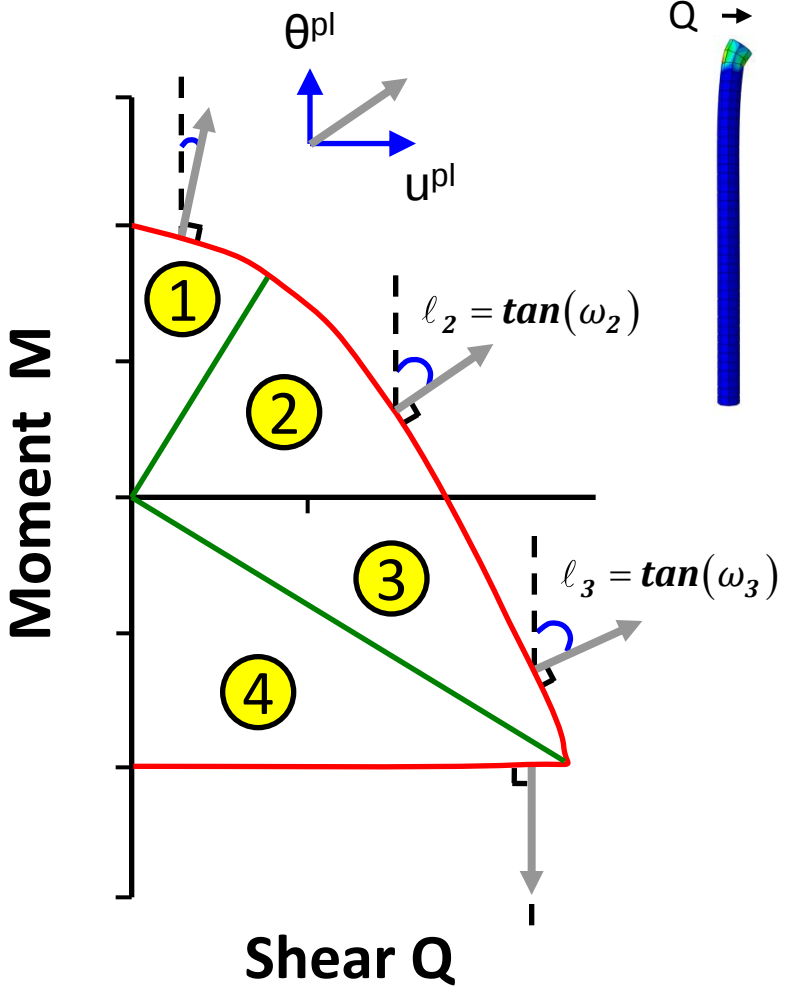


Homogeneous Cohesive Soil

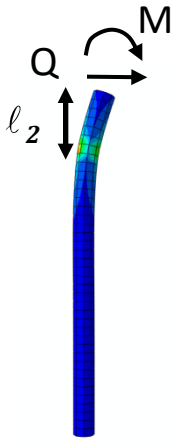
3D FE Modeling ($\Delta z = 0.3$ m)



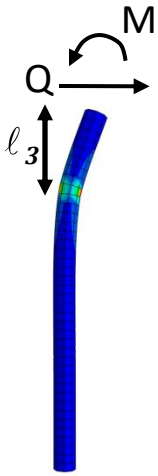
Failure Mechanisms and Plastic Flow Rule



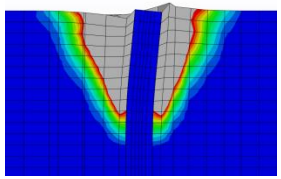
1 ***Small displacement, positive large rotation***

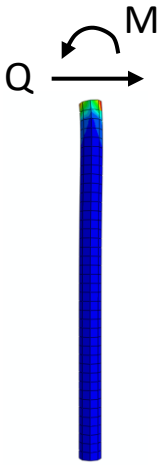


2 ***Large displacement, positive small rotation***



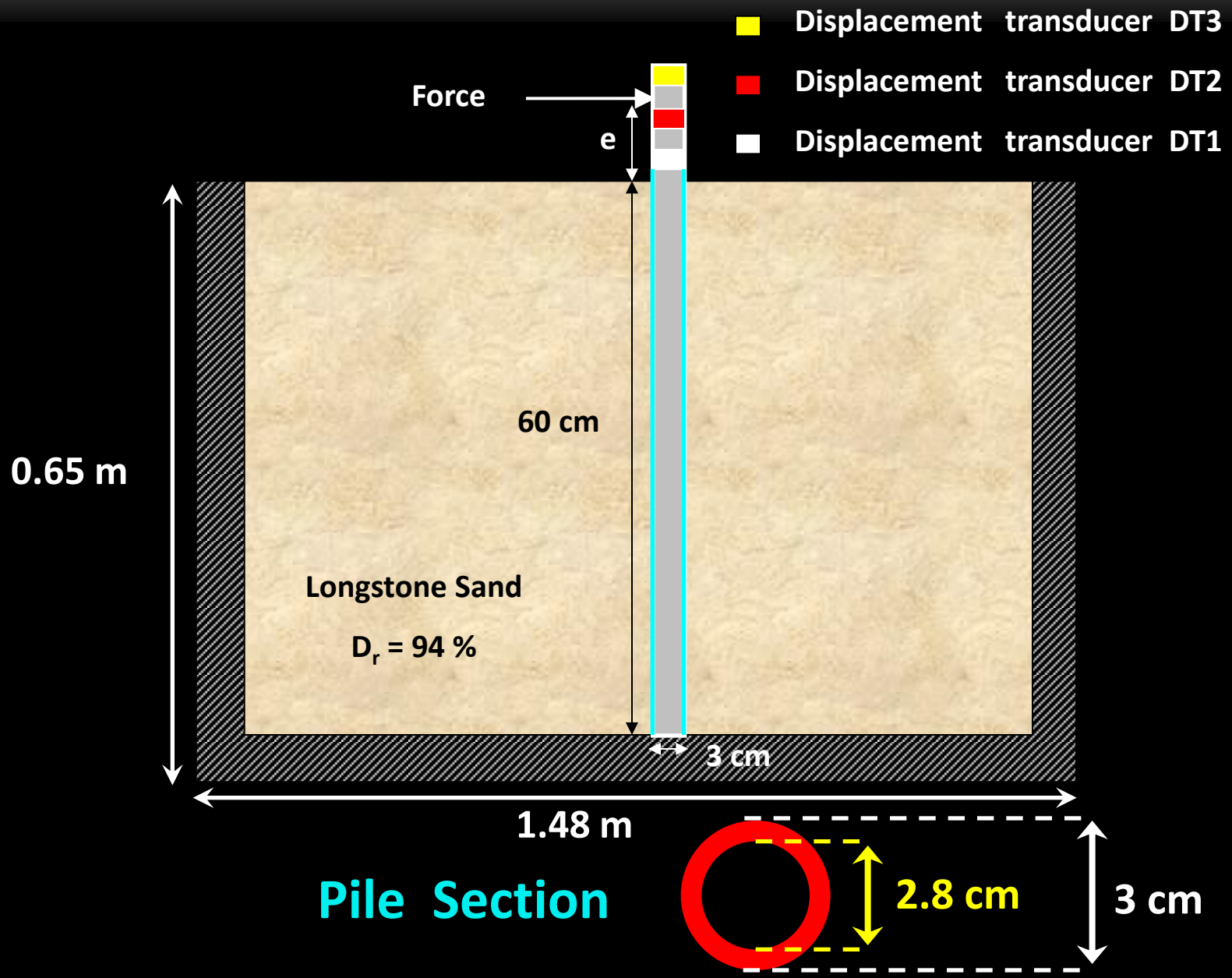
3 ***Large displacement, positive small rotation***



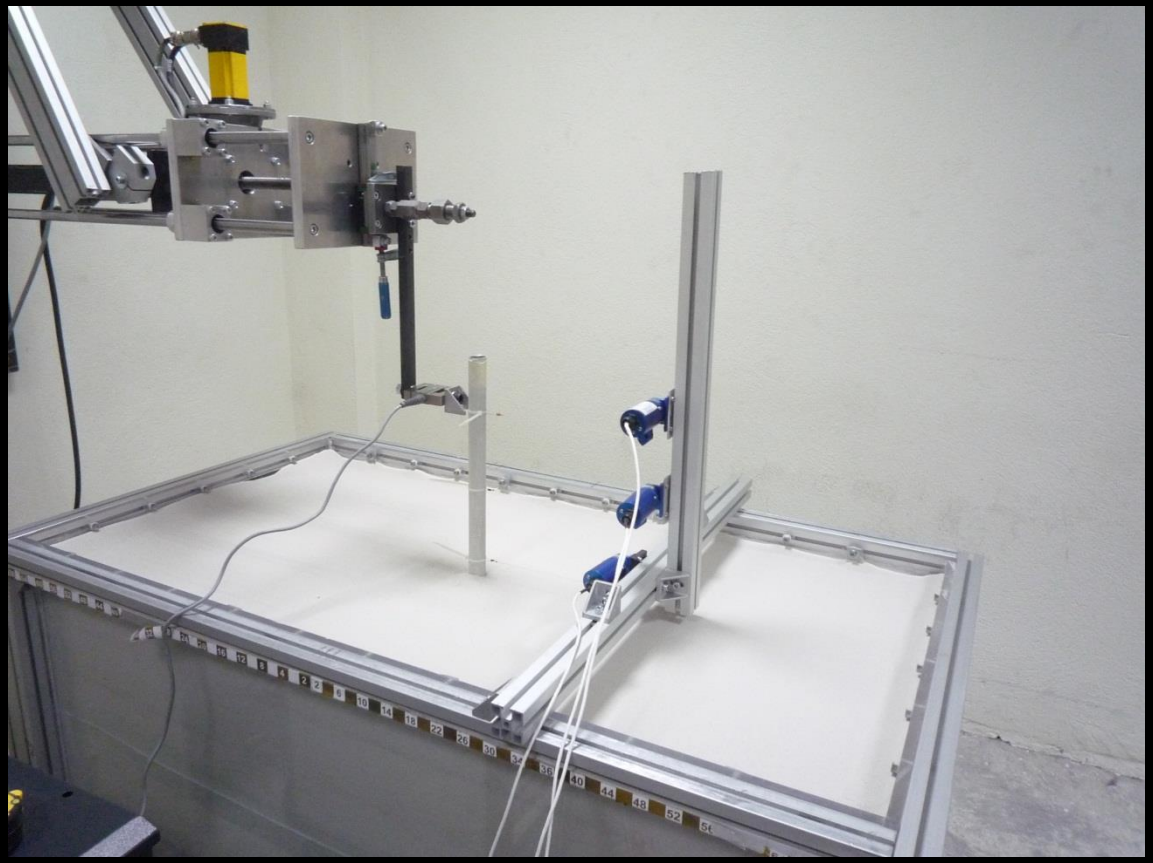


4 ***No displacement, Negative Large rotation***

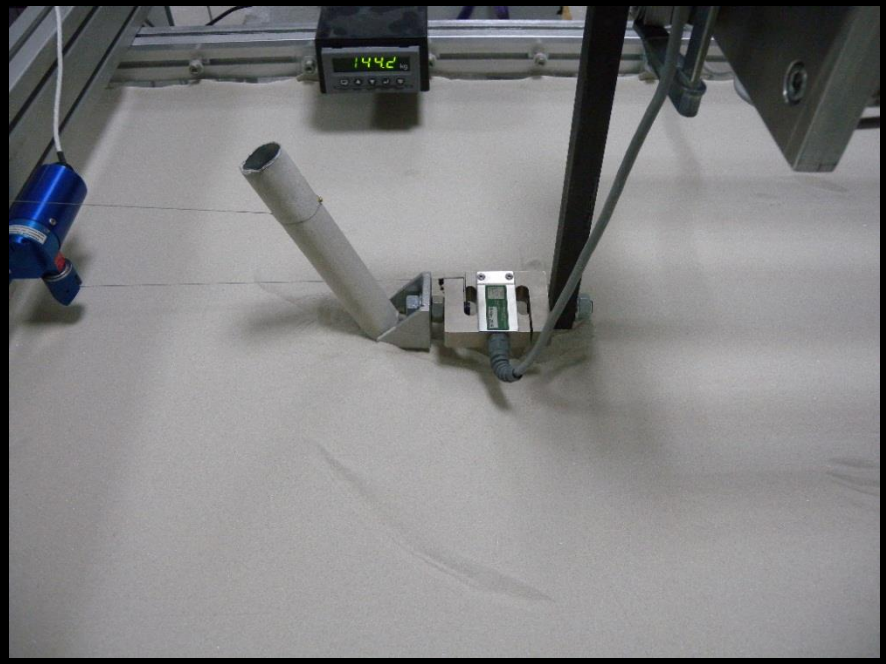
Experimental Setup



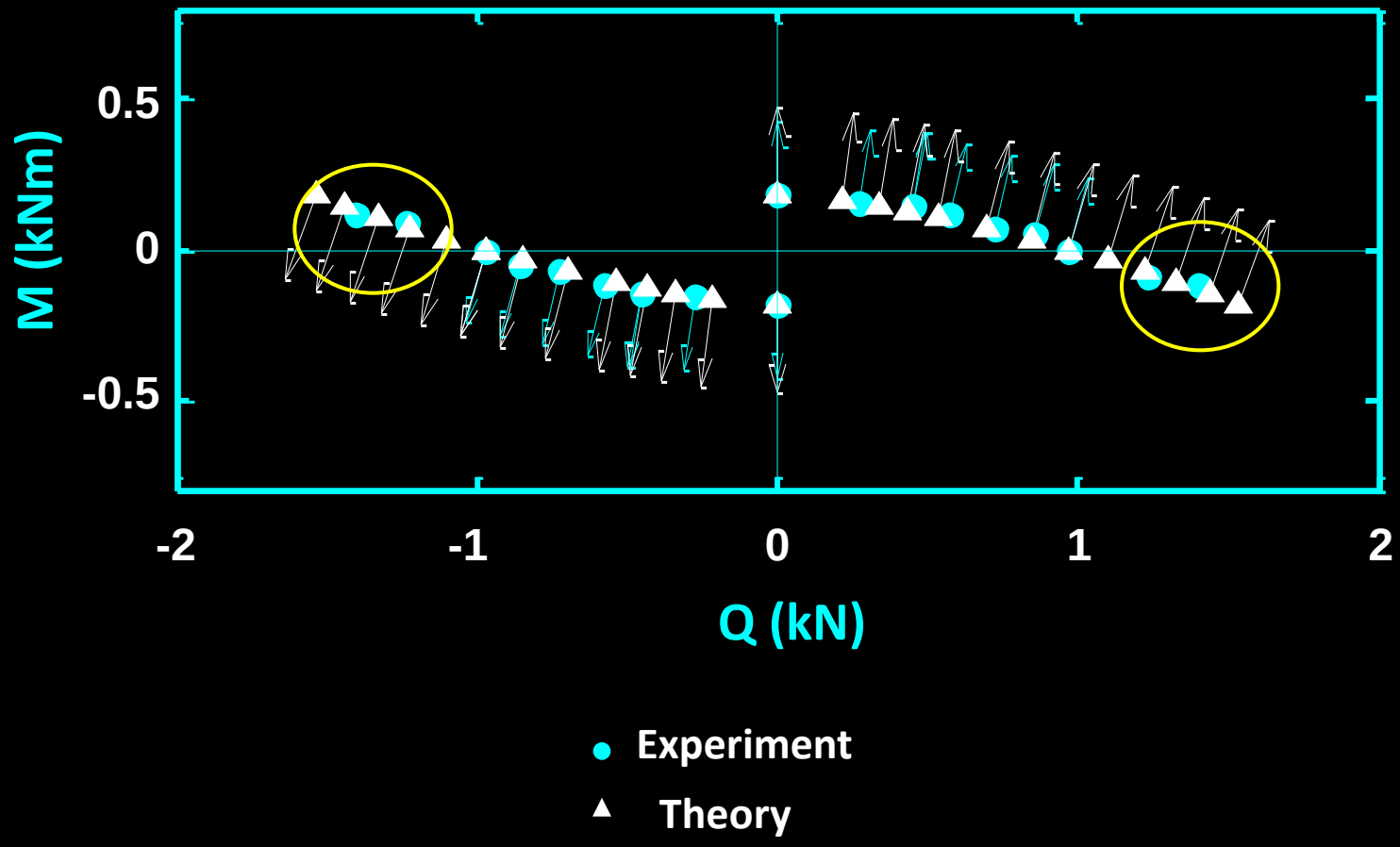
Experimental Setup



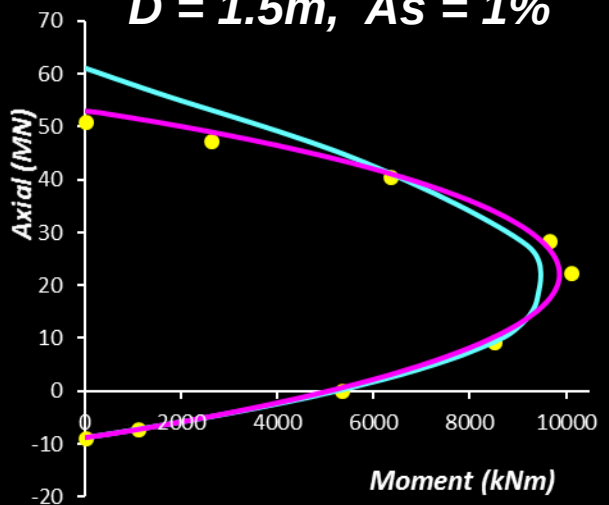
Lateral Push-over Test of a Single Pile

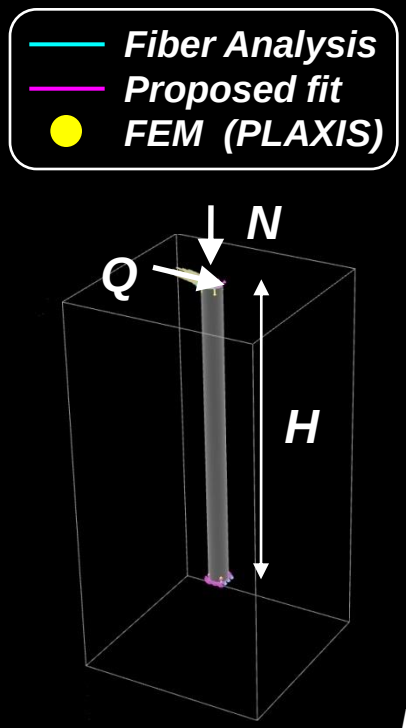


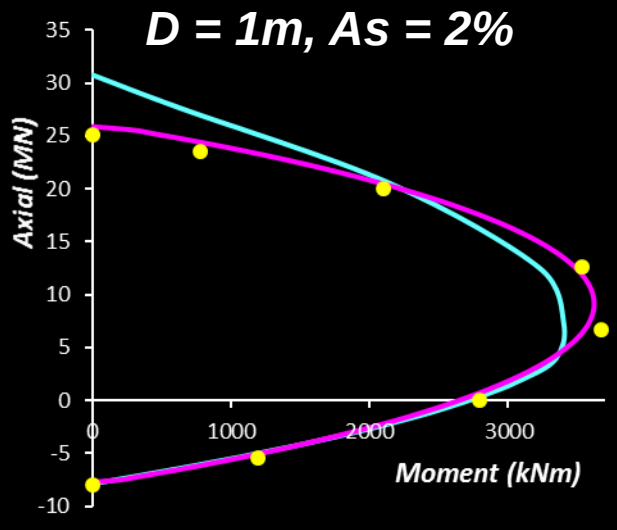
Plastic Flow Rule

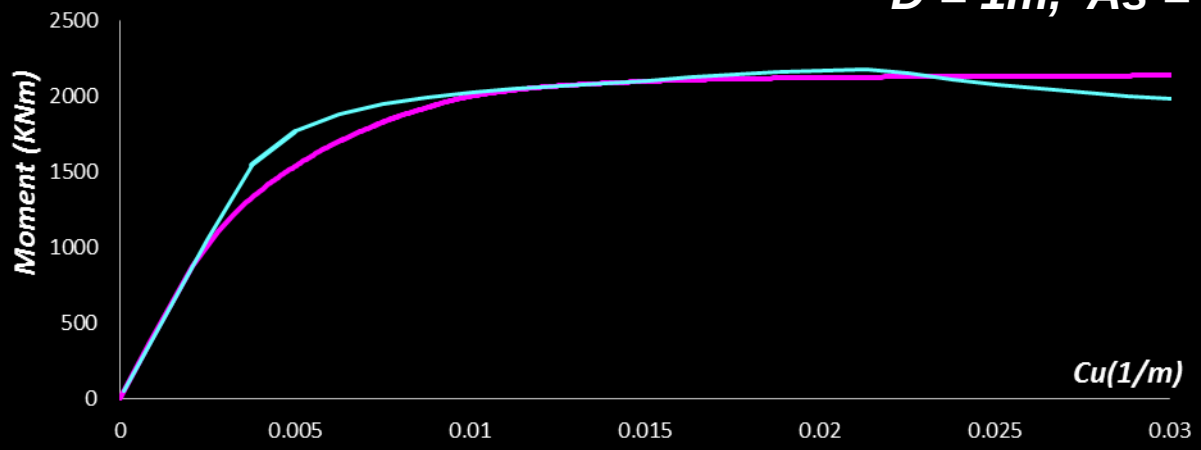


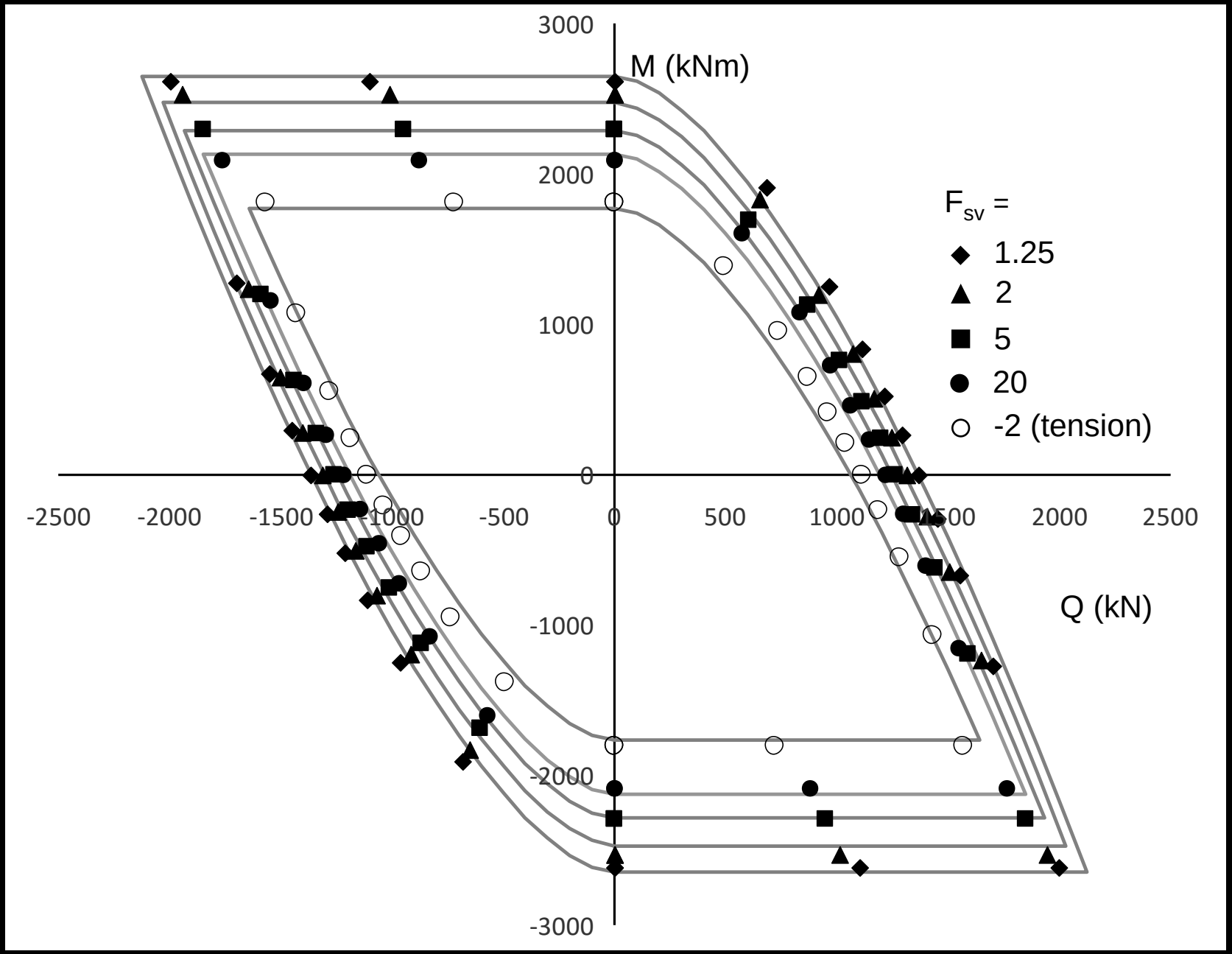
Constitutive Model for M-N Interaction of RC Piles



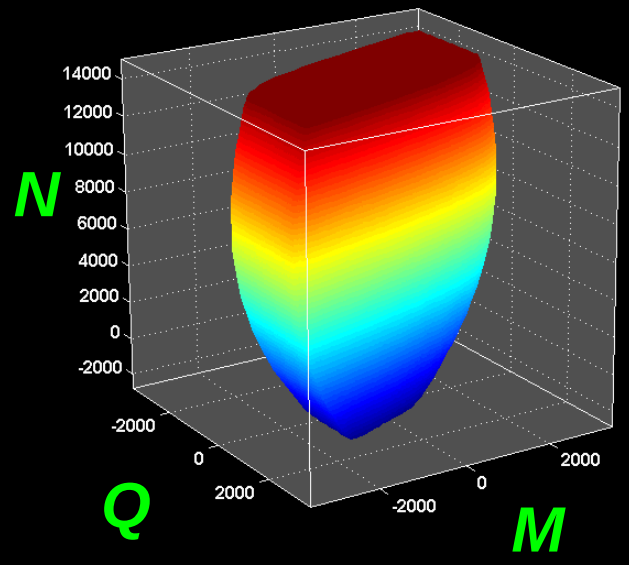


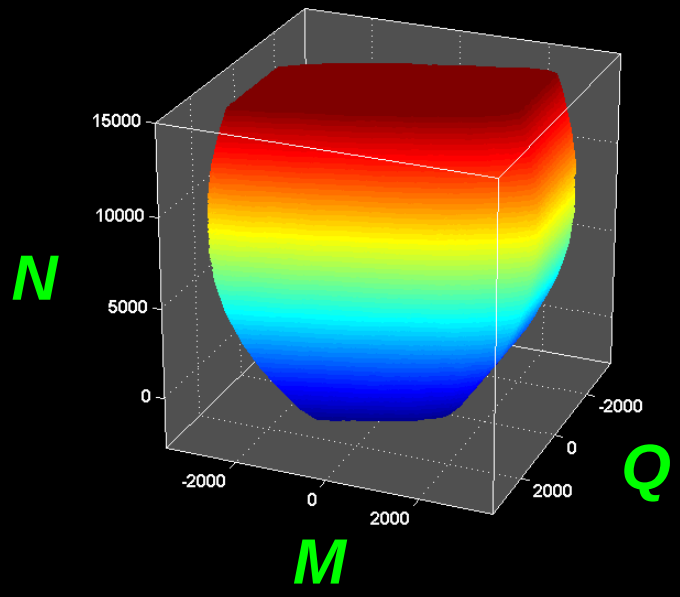


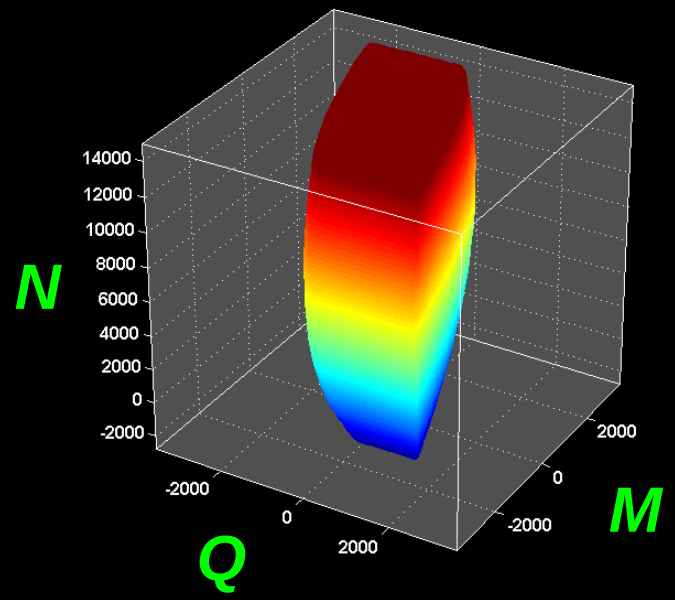


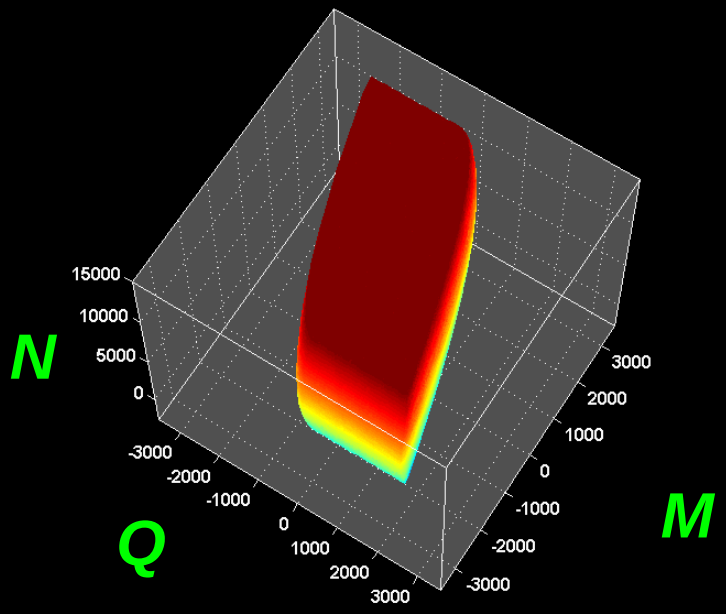

3000
2000
1000
0
-1000
-2000
-3000
M (kNm)
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
Q (kN)
F_{sv} =
1.25
2
5
20
-2 (tension)

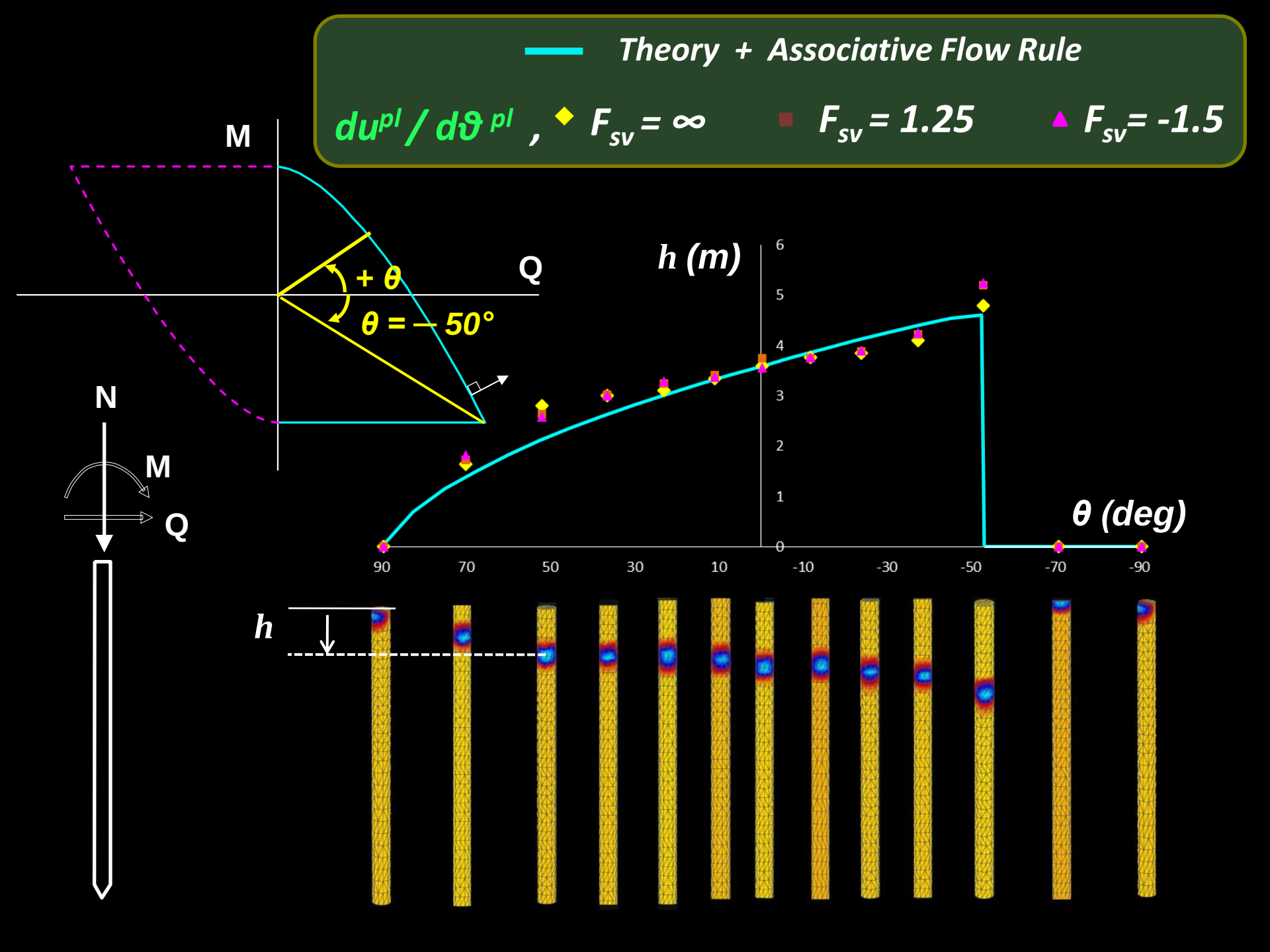
3D Failure Envelope for Single Piles



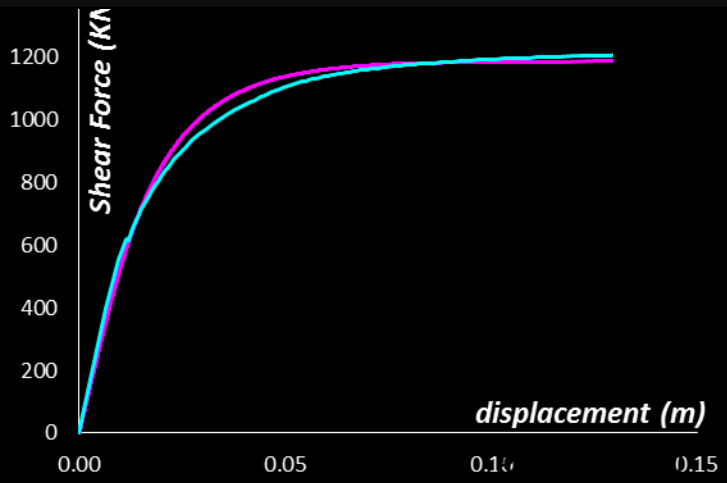




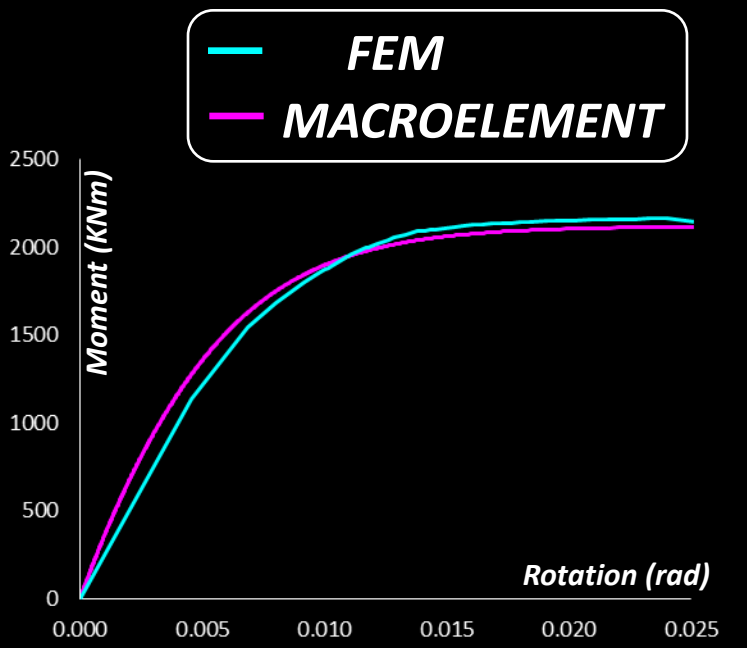



Theory + Associative Flow Rule
$du^{pl} / d\vartheta^{pl}$, $F_{sv} = \infty$
$F_{sv} = 1.25$
$F_{sv} = -1.5$
M
Q
+ θ
θ = – 50°
N
M
Q
h (m)
θ (deg)
6
5
4
3
2
1
0
90
70
50
30
10
-10
-30
-50
-70
-90
h

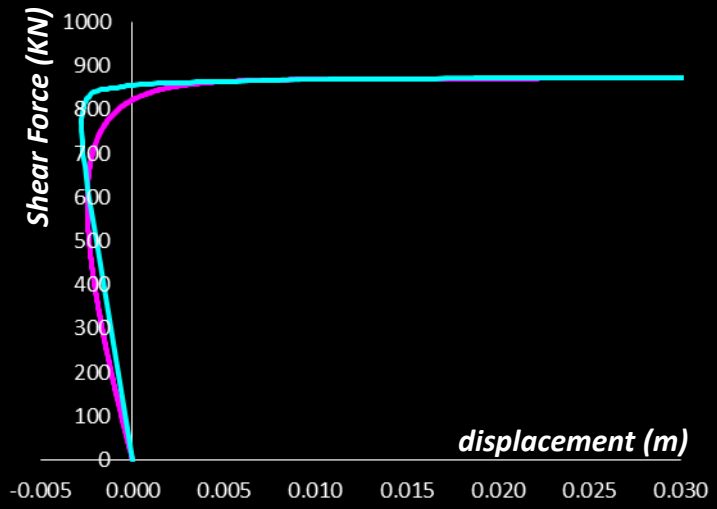
Validation



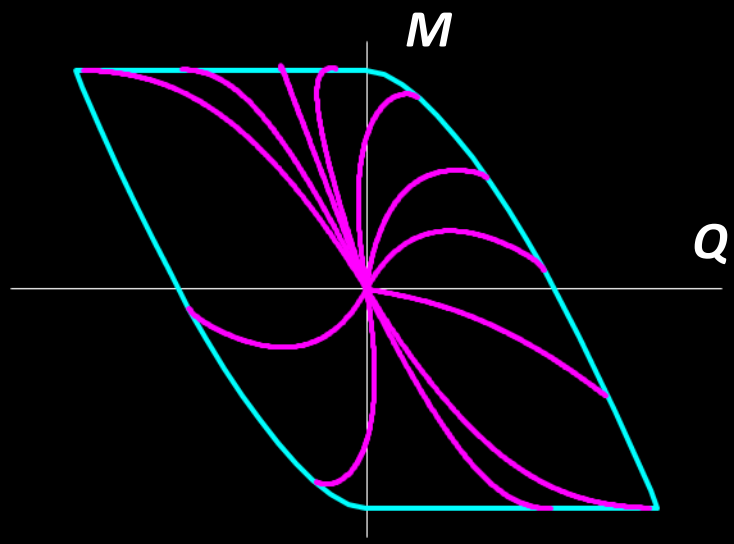
$F_{sv} = \infty$, pure shear force



$F_{sv} = \infty$, pure shear force

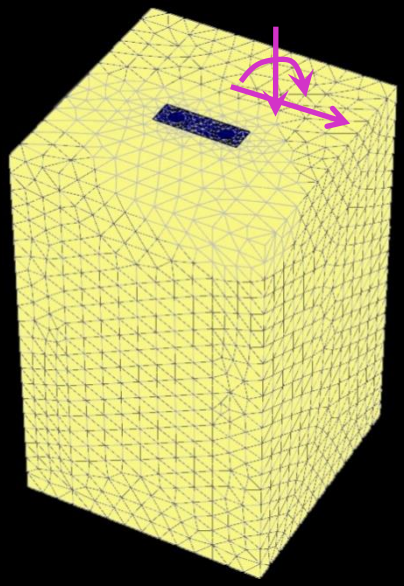


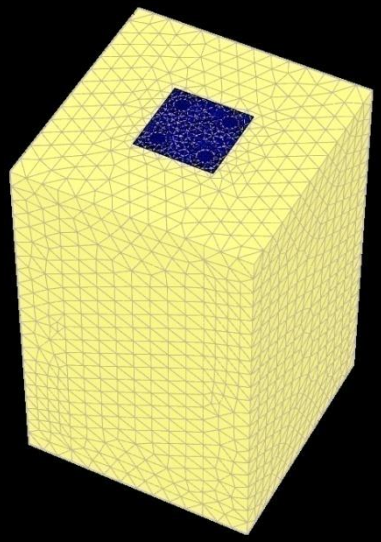
$F_{sv} = \infty \quad \vartheta = -75^{o}$

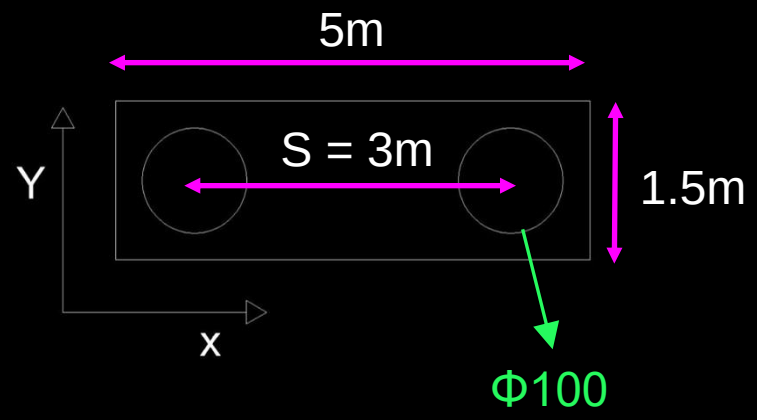


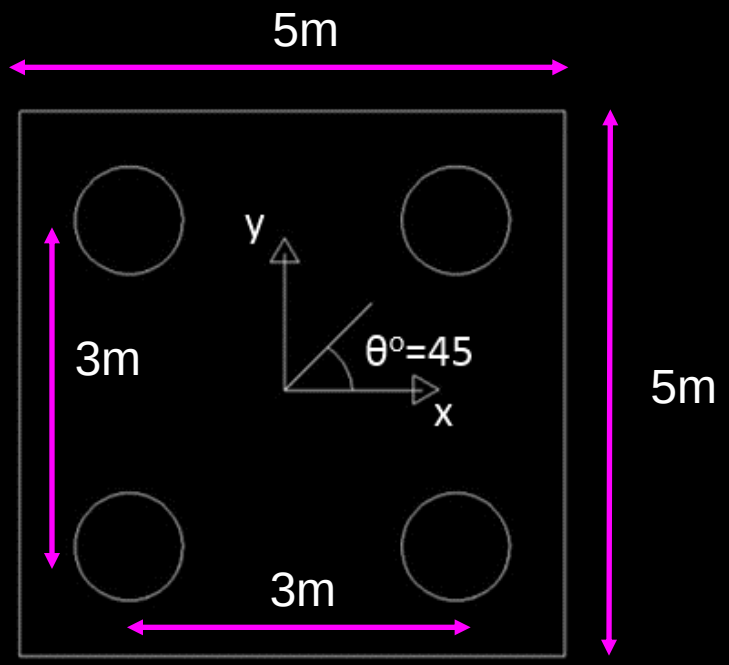
$F_{sv} = -1.25$

Lateral capacity of Pile-Groups : FE Modeling

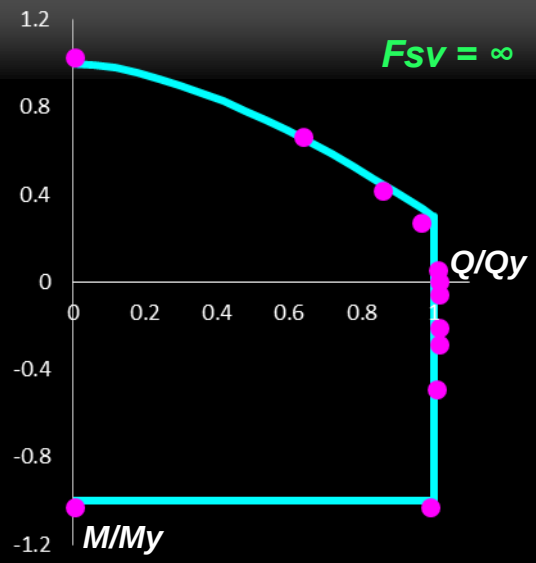


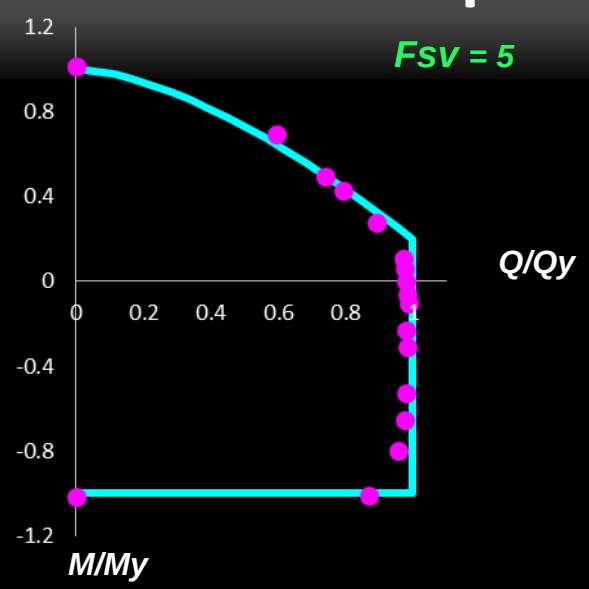


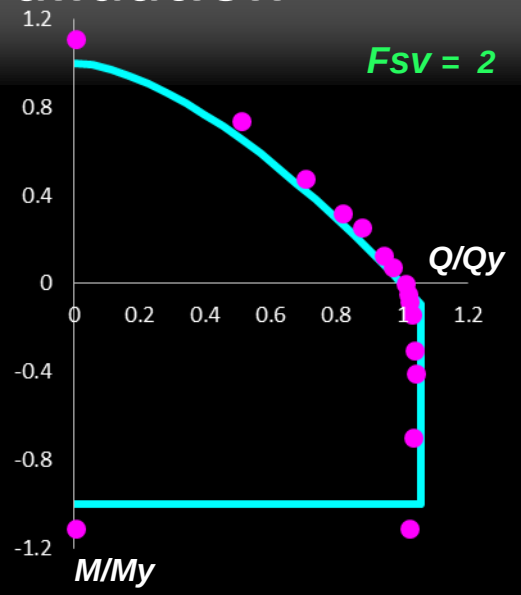


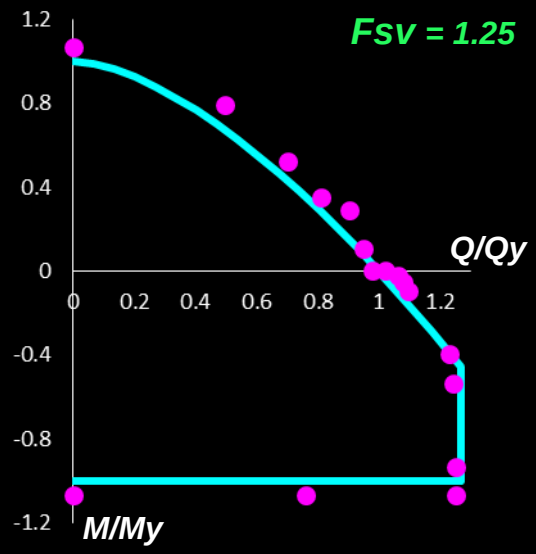


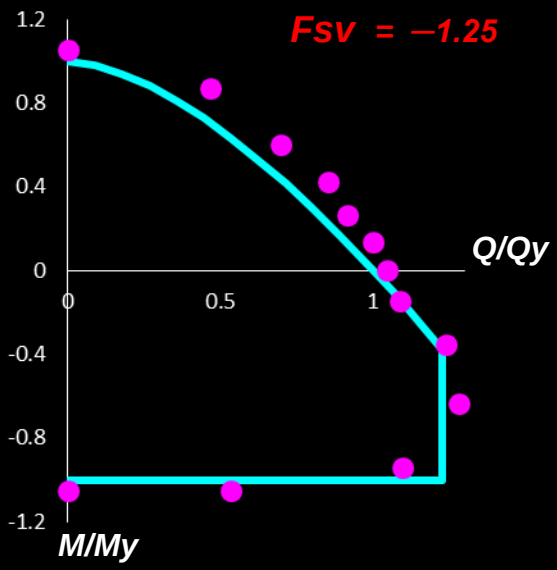
Failure Envelopes for PileGroups: Validation

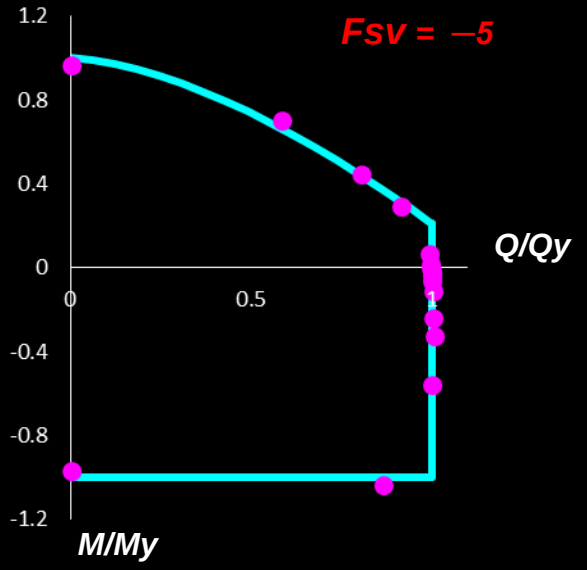






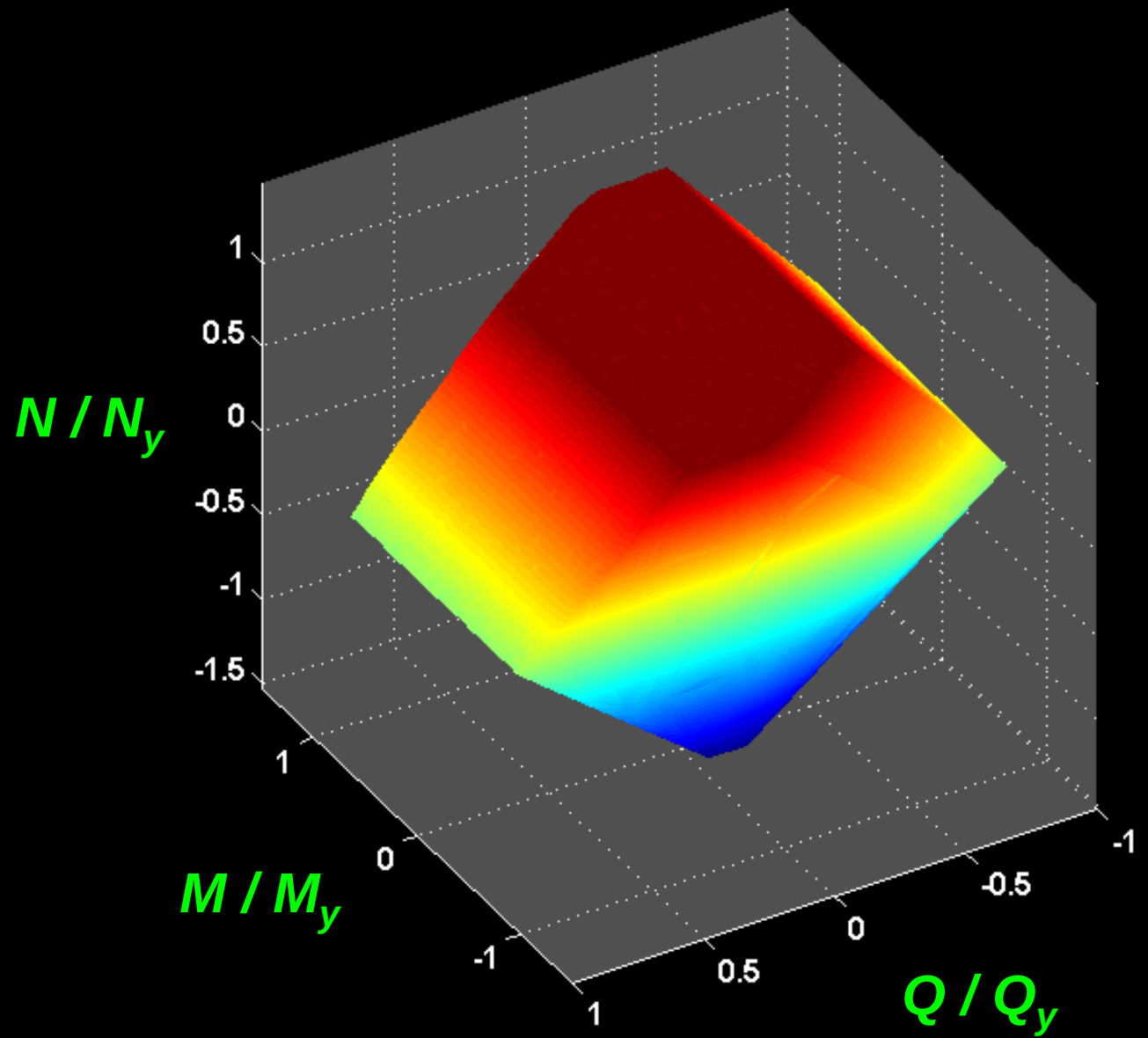






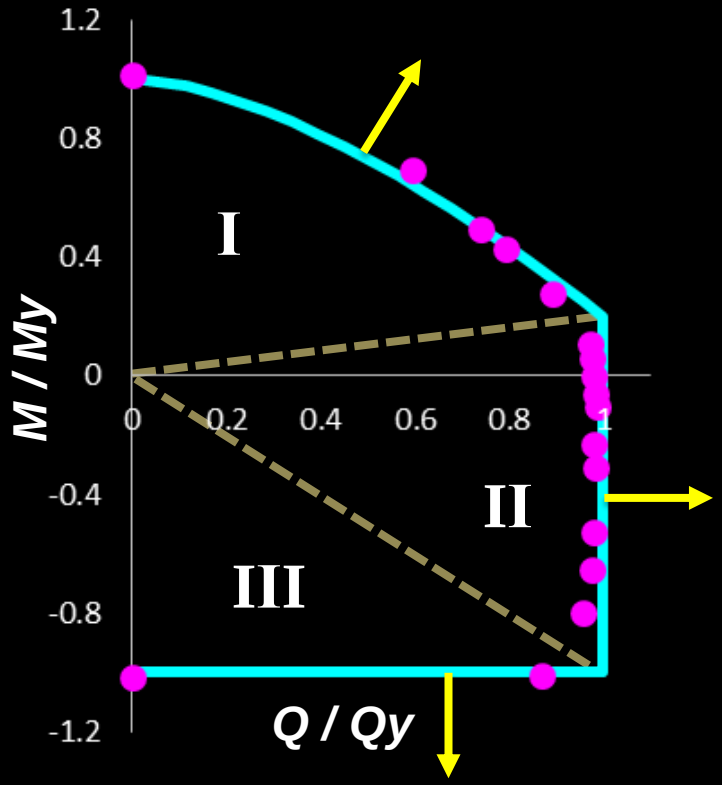
Proposed fit
FEM (PLAXIS)

Failure Envelopes for PileGroups in 3D



Failure Modes of Pilegroups

Below Cap Plastic Hinges +
Bearing Capacity failure



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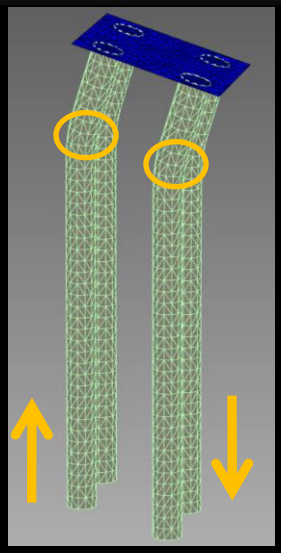
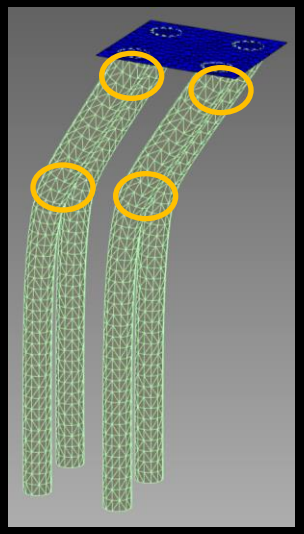


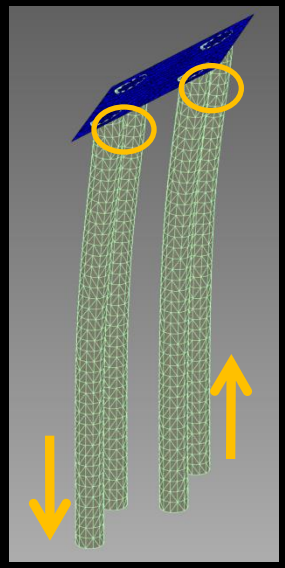
Plastic Hinges

II



Pile-to-Cap Plastic Hinges +
Bearing Capacity failure

III



Thank you