Aseismic Design of Shallow (rocking) Foundations

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UACEER

MJP starting point 1

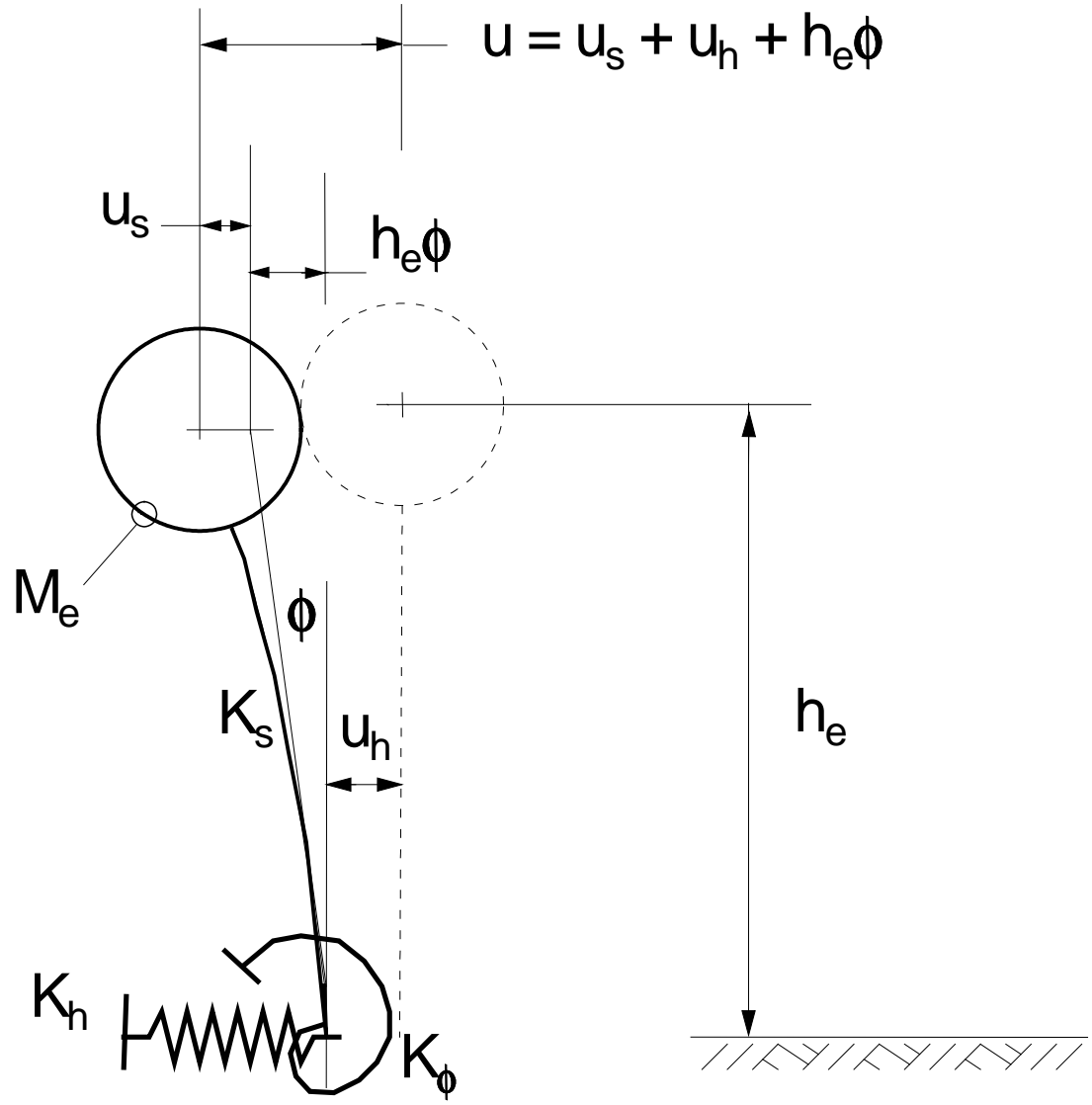❑ **Structure and foundation form a single entity**

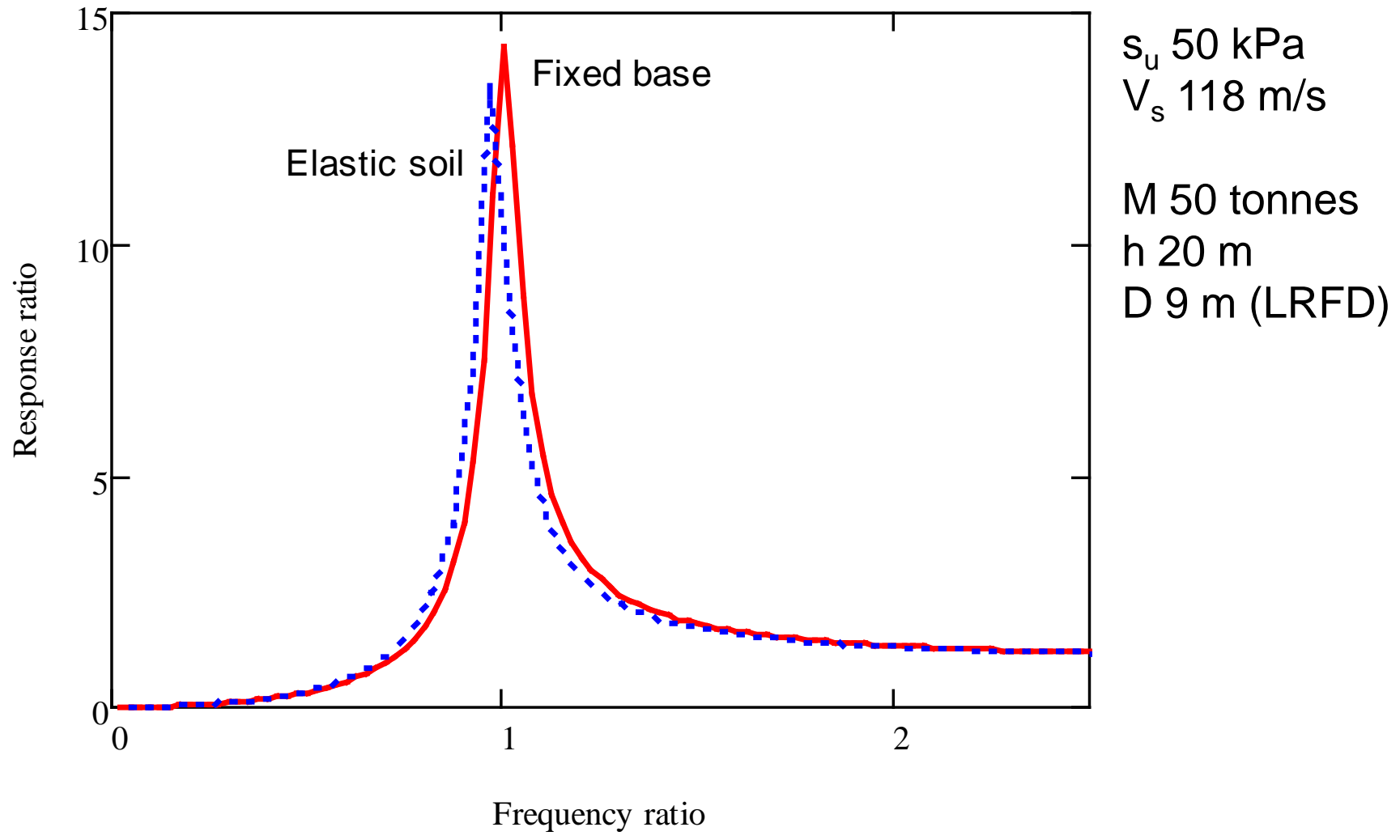# MJP starting point 2

❑ **Foundation behaviour is nonlinear**

MJP starting point 3

❑ **Elastic soil-structure interaction doesn't work**

    ❑ **hence the terminology SFSI (*soil-foundation-structure-interaction*)**

Elastic SSI diagram

$u = u_s + u_h + h_e\phi$

u_s

$h_e\phi$

M_e

ϕ

K_s

u_h

h_e

K_h

K_ϕ

Elastic SSI for a water tower

s$_u$ 50 kPa
V$_s$ 118 m/s

M 50 tonnes
h 20 m
D 9 m (LRFD)

MJP starting point 4

- ❑ **Priestley et al 2007:** *Displacement-based seismic design of structures*
  - ❑ use of replacement structure
- ❑ **Paper by Trevor Kelly in Bull. NZSEE 2009**
  - ❑ many buildings not heavy enough to prevent rocking
  - ❑ need better understanding of soil response
- ❑ **Paper by Priestley, Evison & Carr Bull. NZSEE 1978**
  - ❑ related NZS4203 (1976)
  - ❑ based on Housner BSSA 1963 (a famous paper)
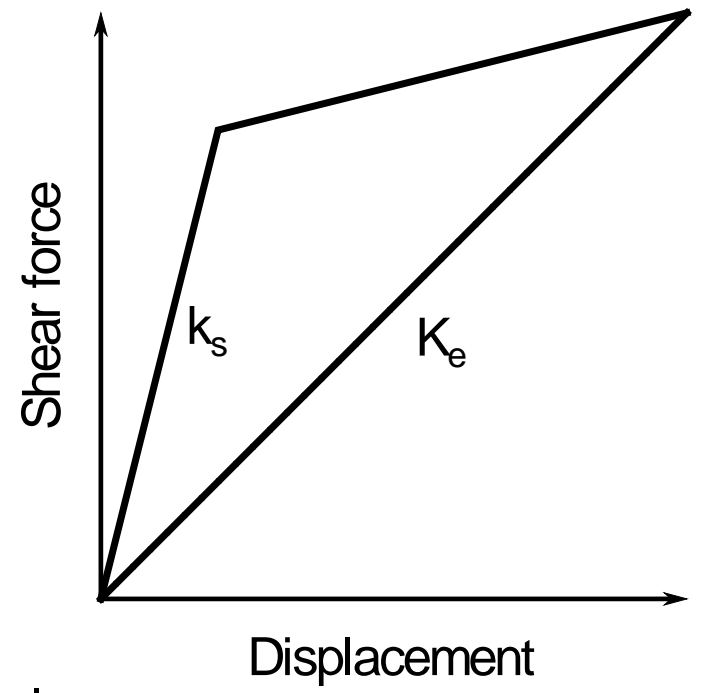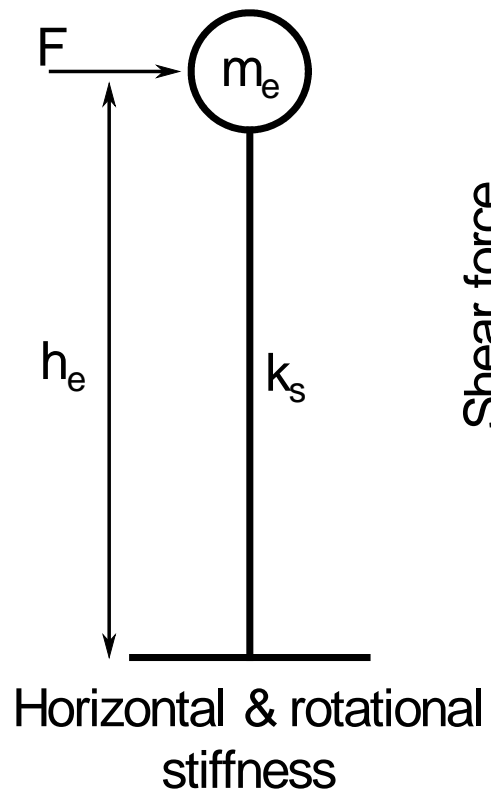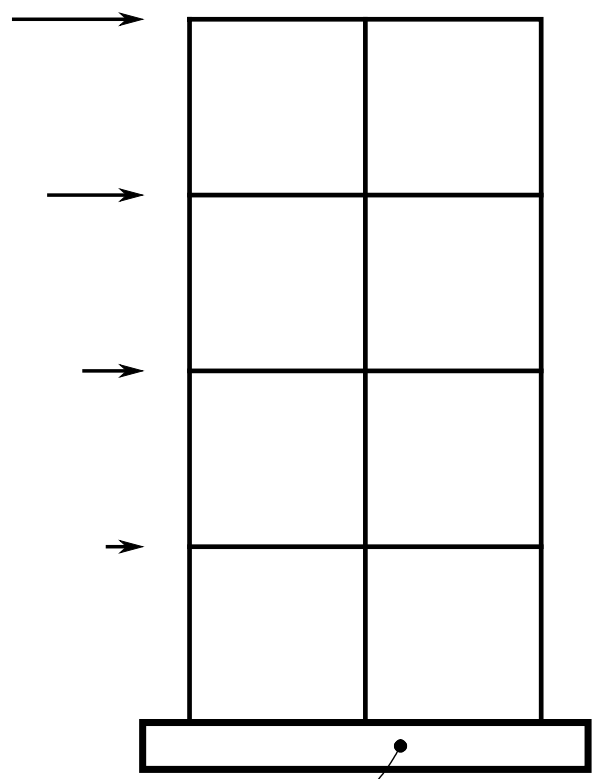
Nonlinear SFSI

❑ **Need a "design" method for modelling foundation moment-rotation curves**

❑ **hands-on approach – quick check on software output or a peer-review tool**

Shibata and Sozen - 1976

M - θ uncracked section

M - θ cracked section

M - θ for substitute (ductile) structure
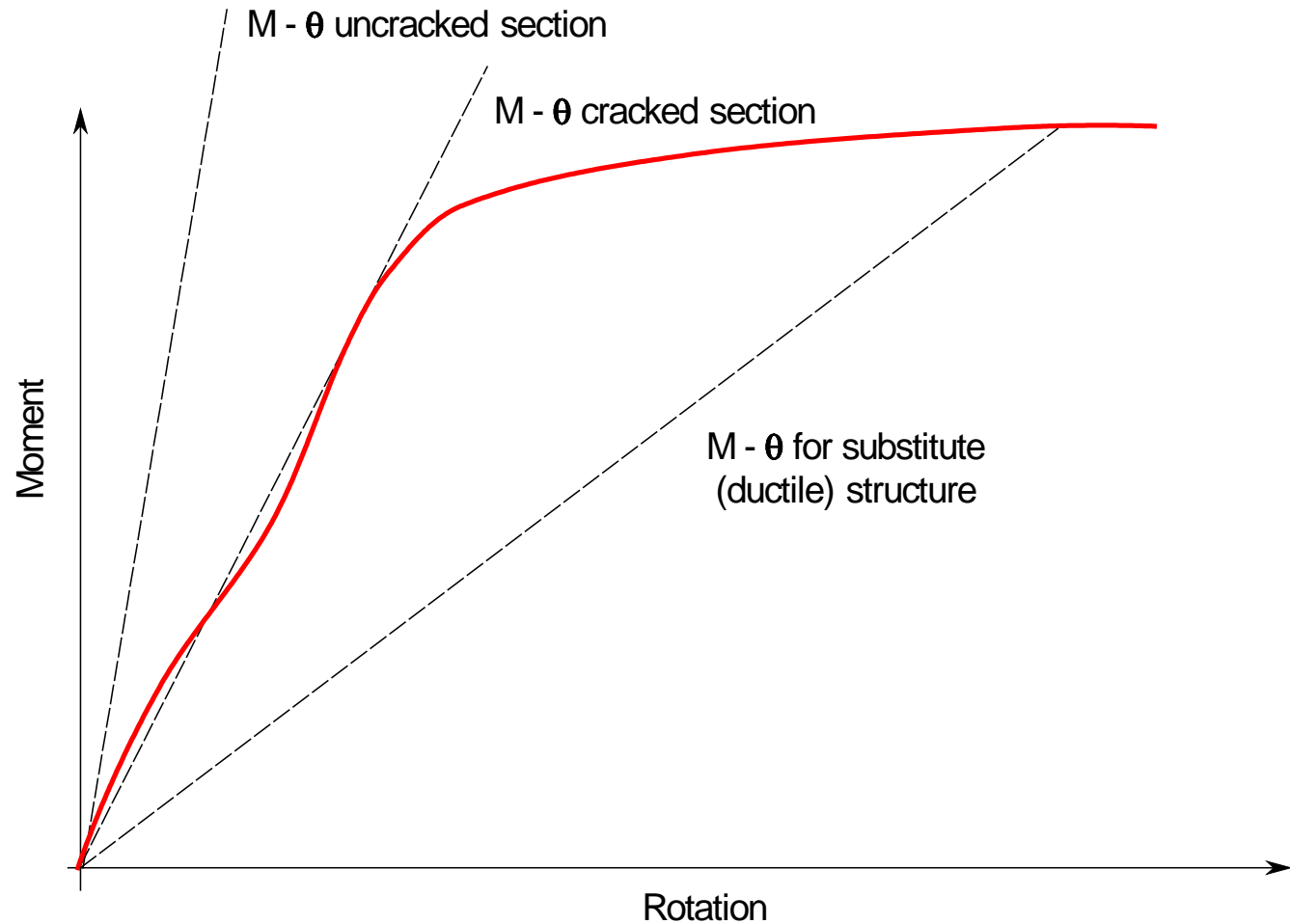
Moment

Rotation

For a structural component – beam or column

Priestley replacement structure

F

m_e

h_e

k_s

Horizontal & rotational
stiffness

Foundation: shallow or pile   SDOF simulation

Shear force

k_s

K_e

Displacement

MJP starting point 5

❑ **Nonlinear foundation moment-rotation relation**
    ❑ **neglect horizontal deformation at foundation level**
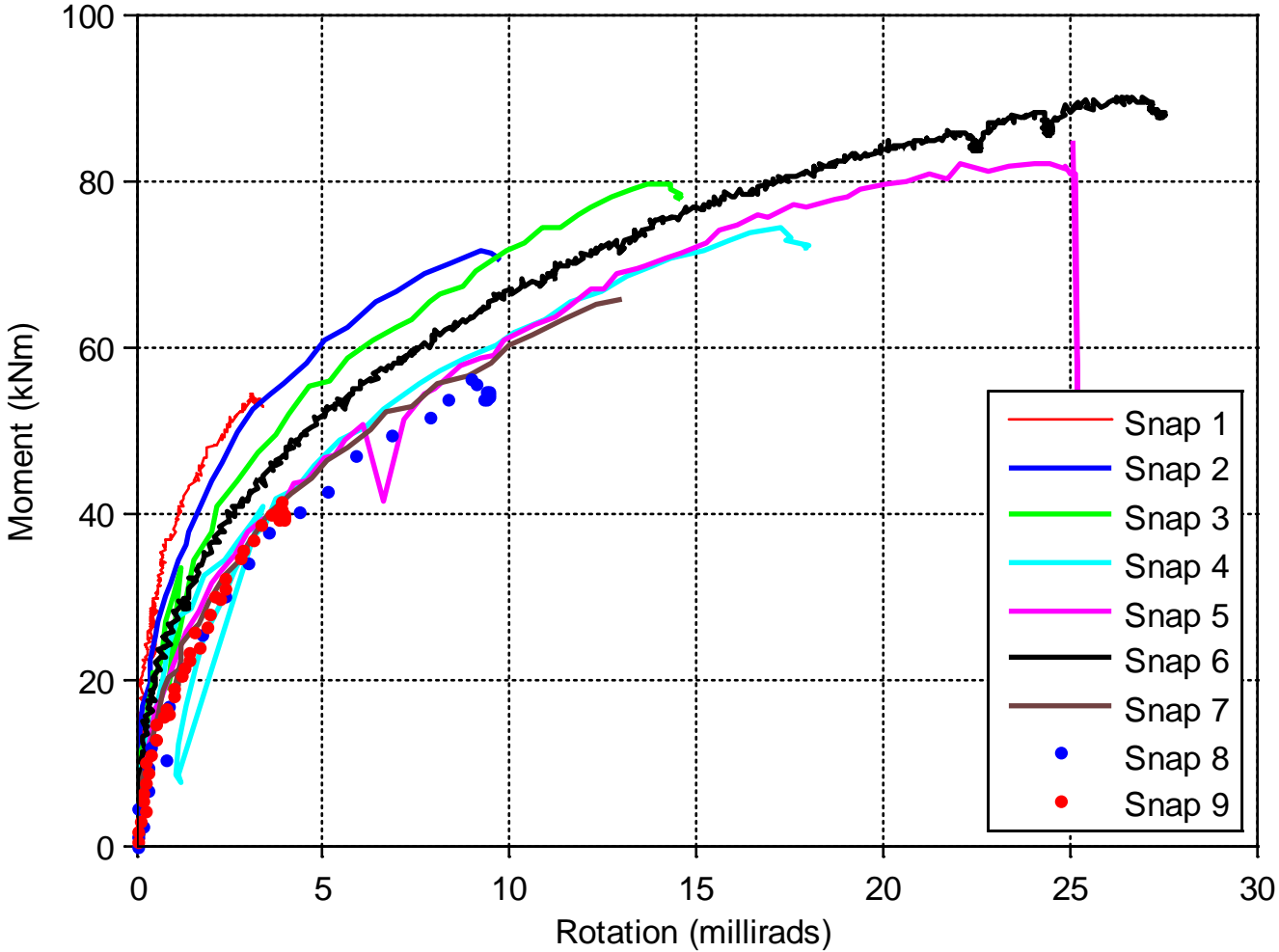❑ **linear structural behaviour**

Nonlinear foundation response
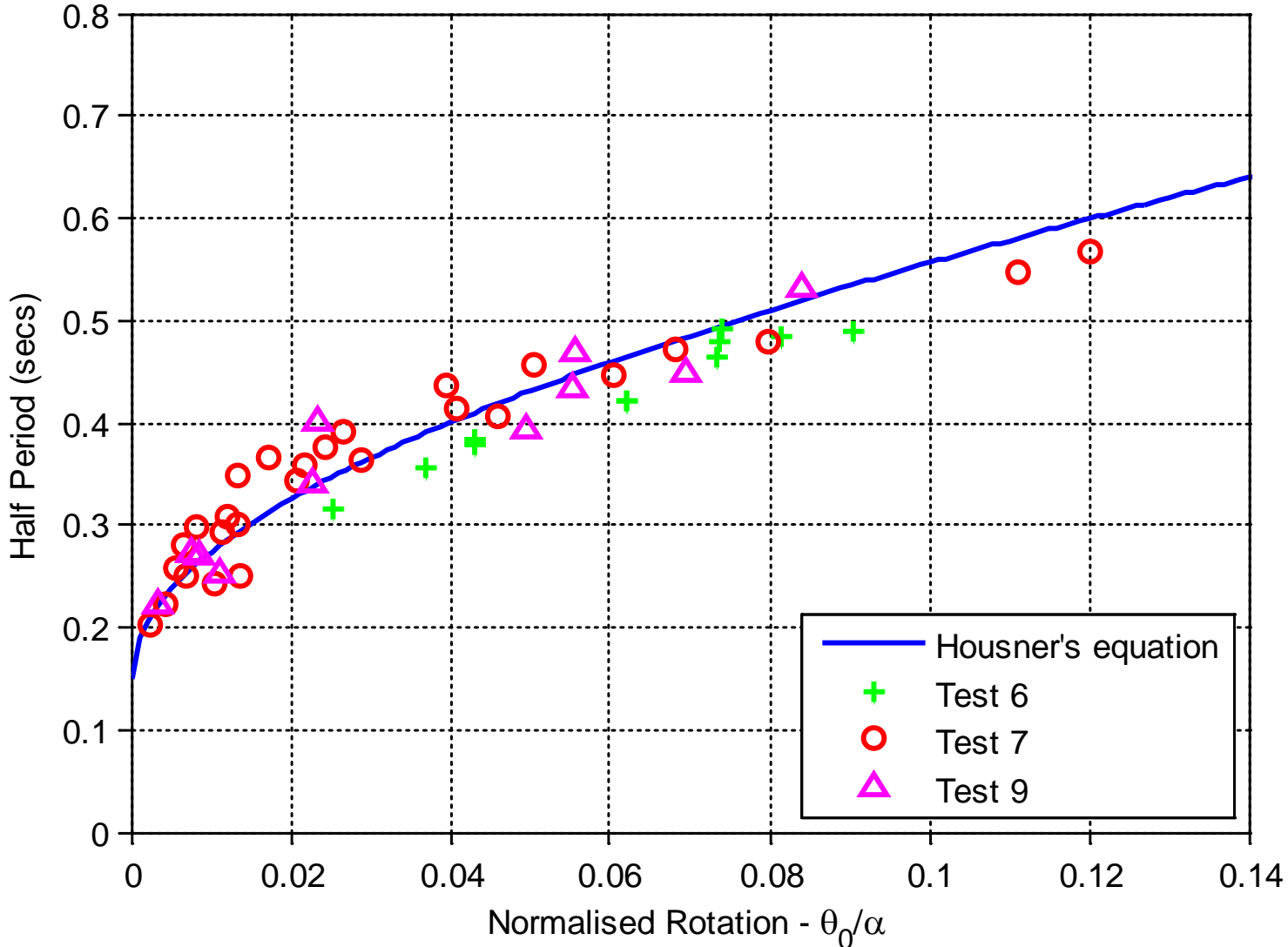
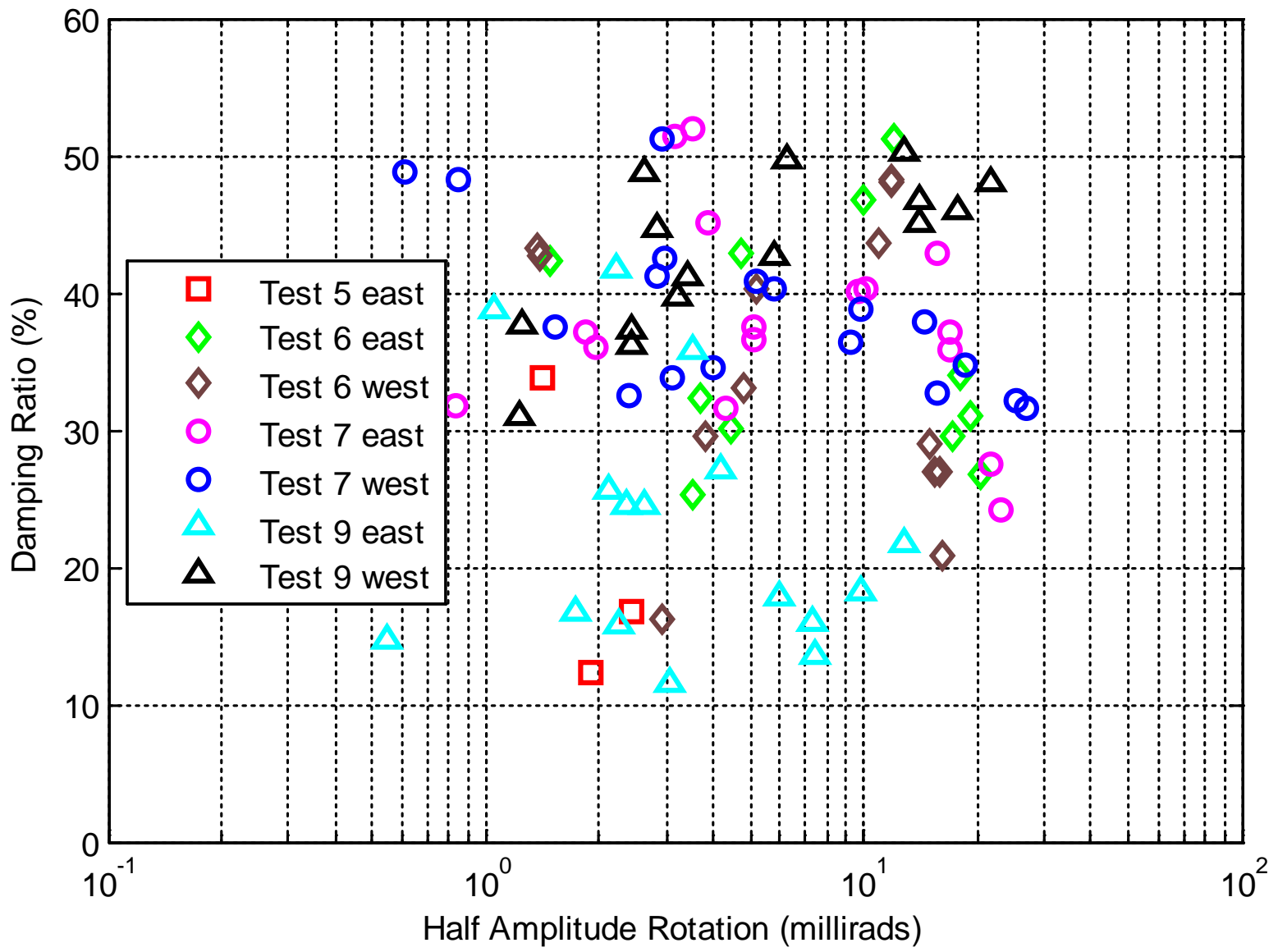❑ **Experimental data – Tom Algie's PhD thesis**

Shallow foundation pull-back

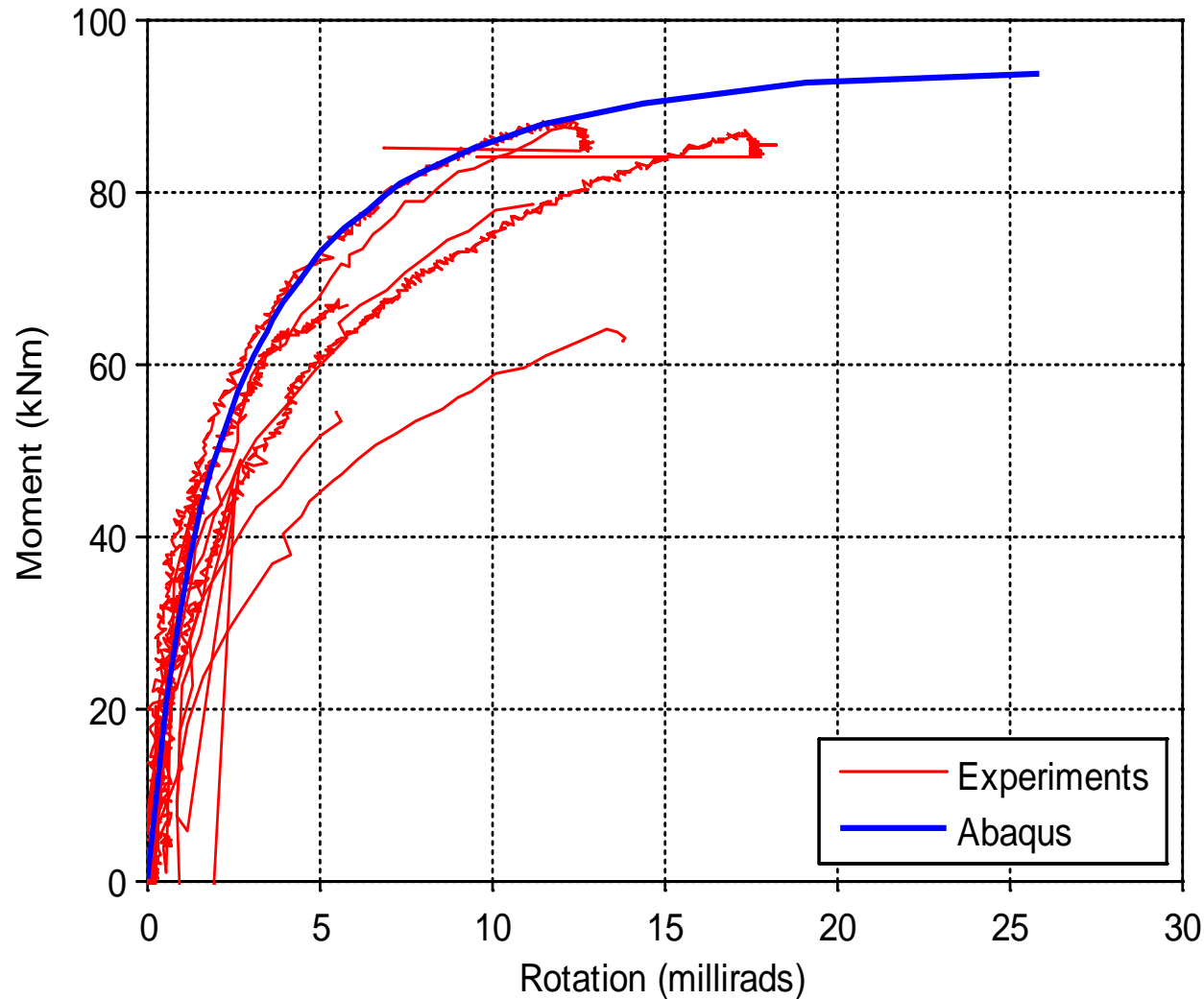# Shallow foundation pull-back

Shallow foundation snap-back

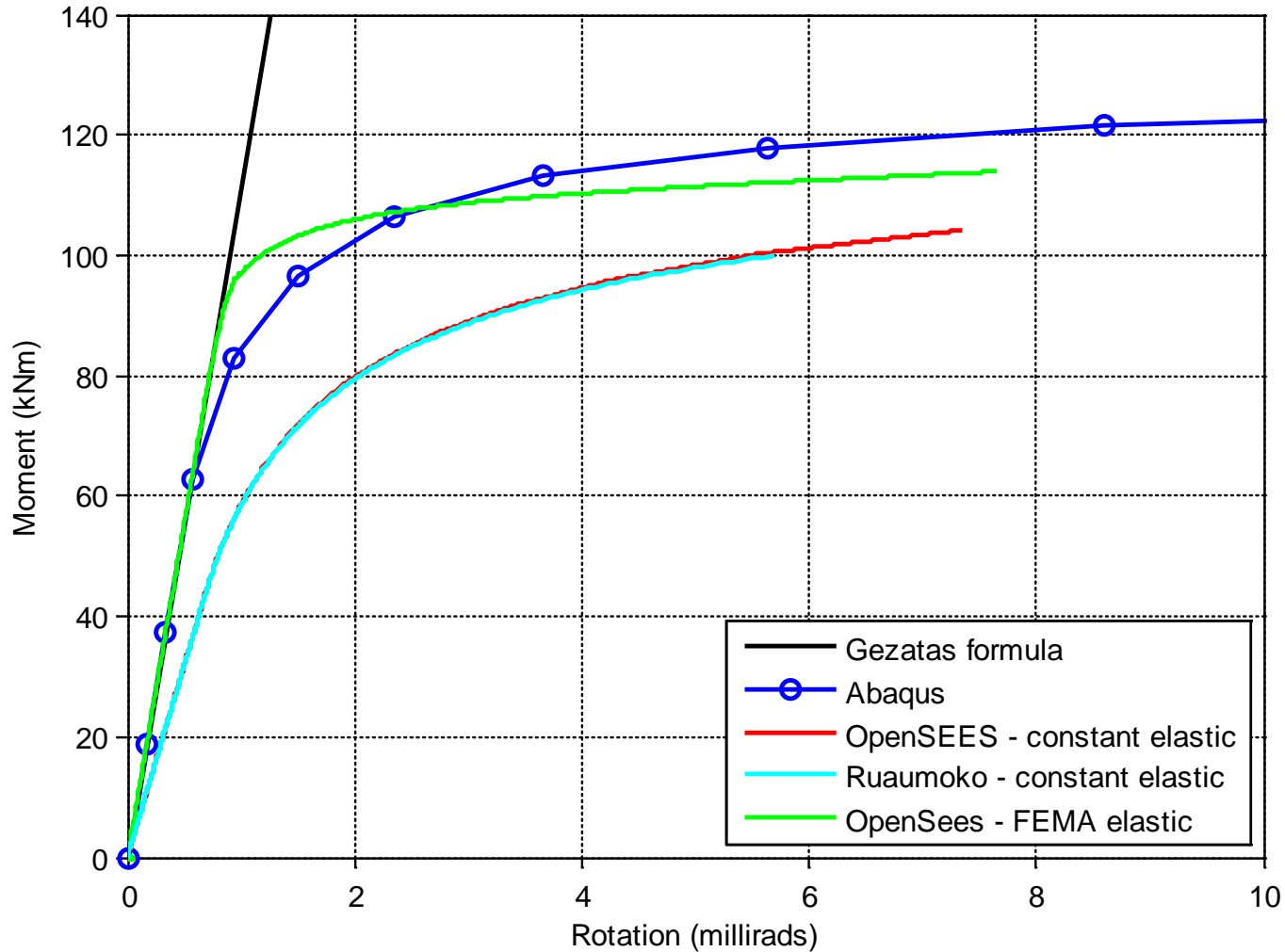# Shallow foundation snap-back
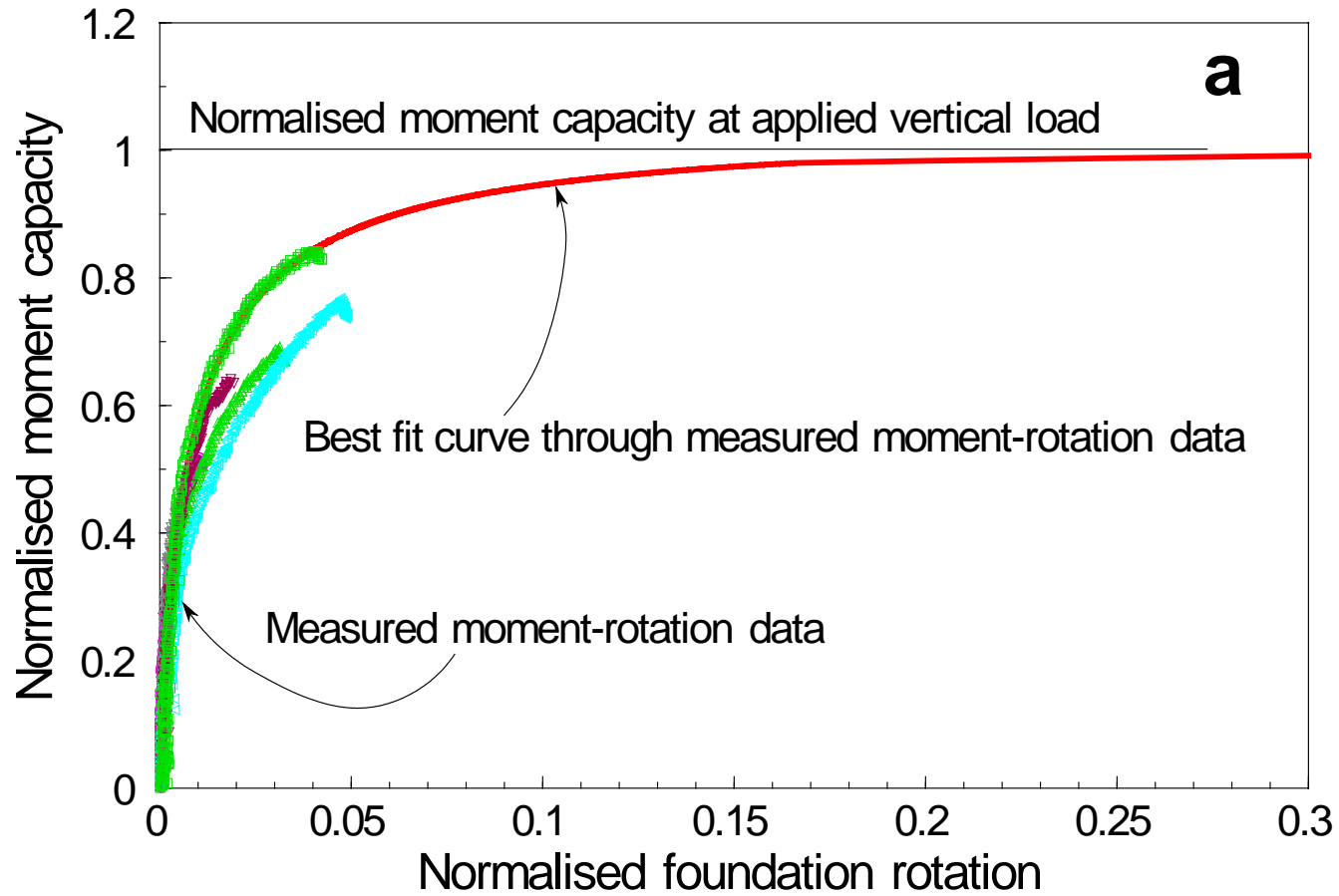
Tom's Abaqus modelling

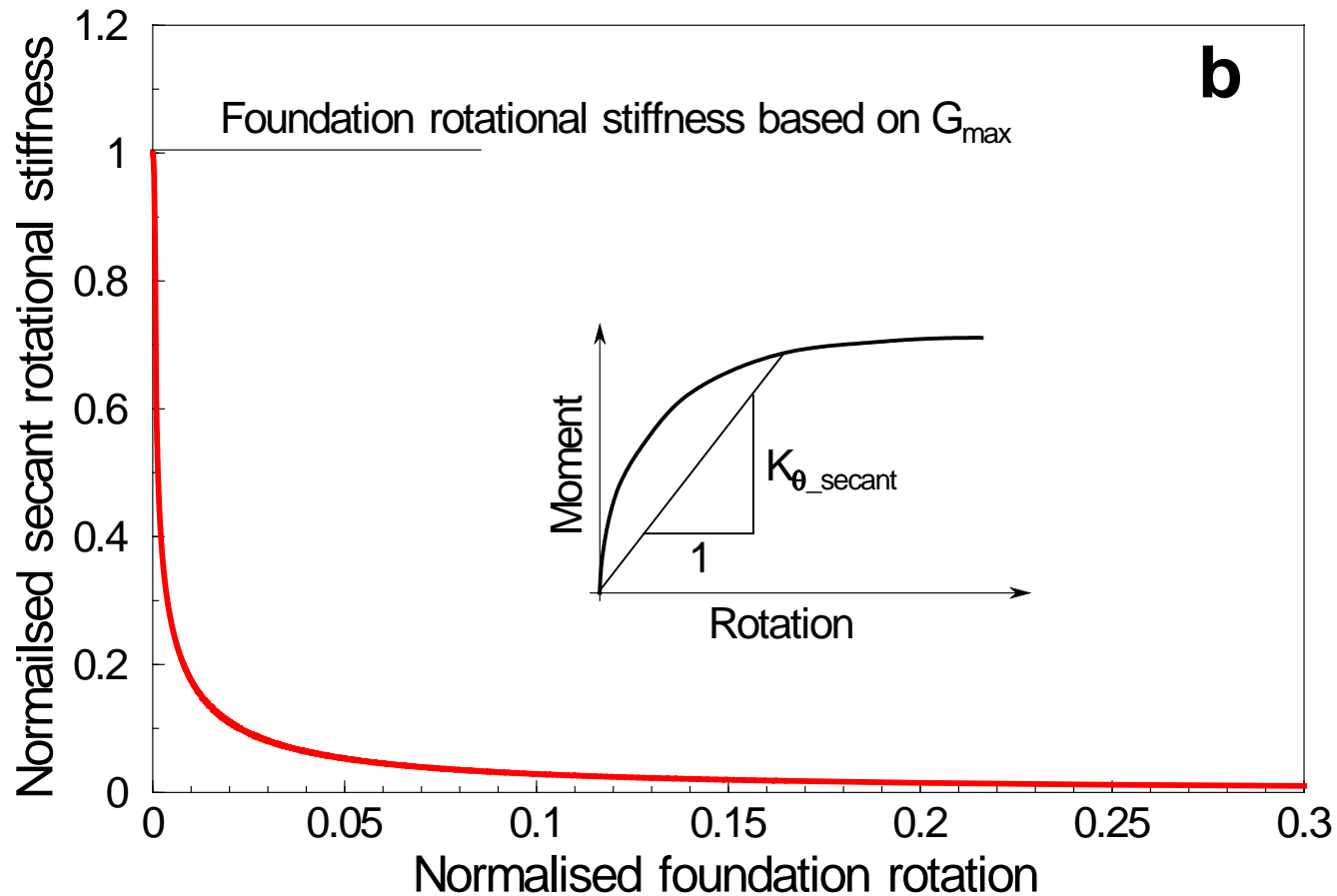(Hence not dependent on spring bed modelling.)
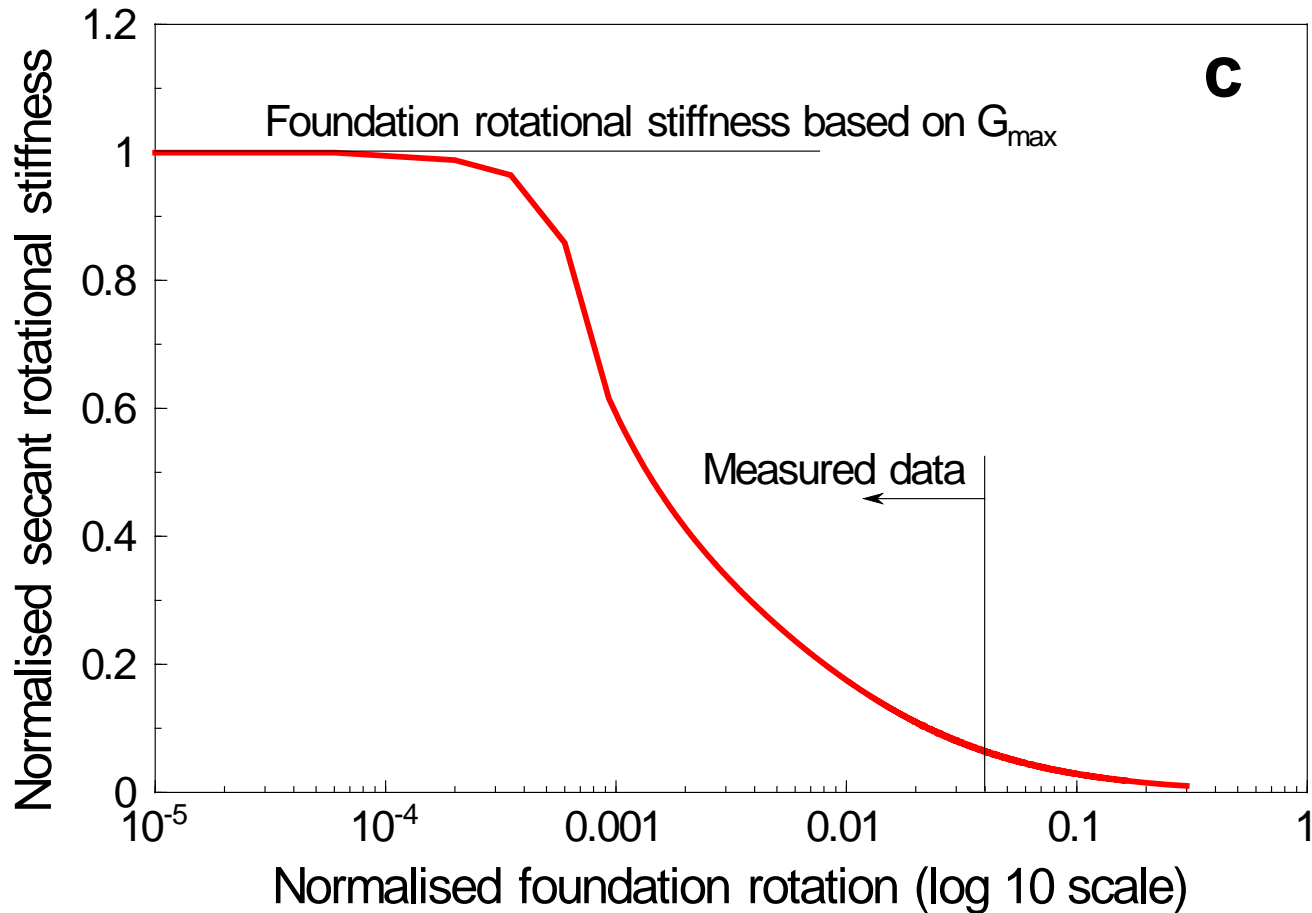
Tom Algie's finite element work

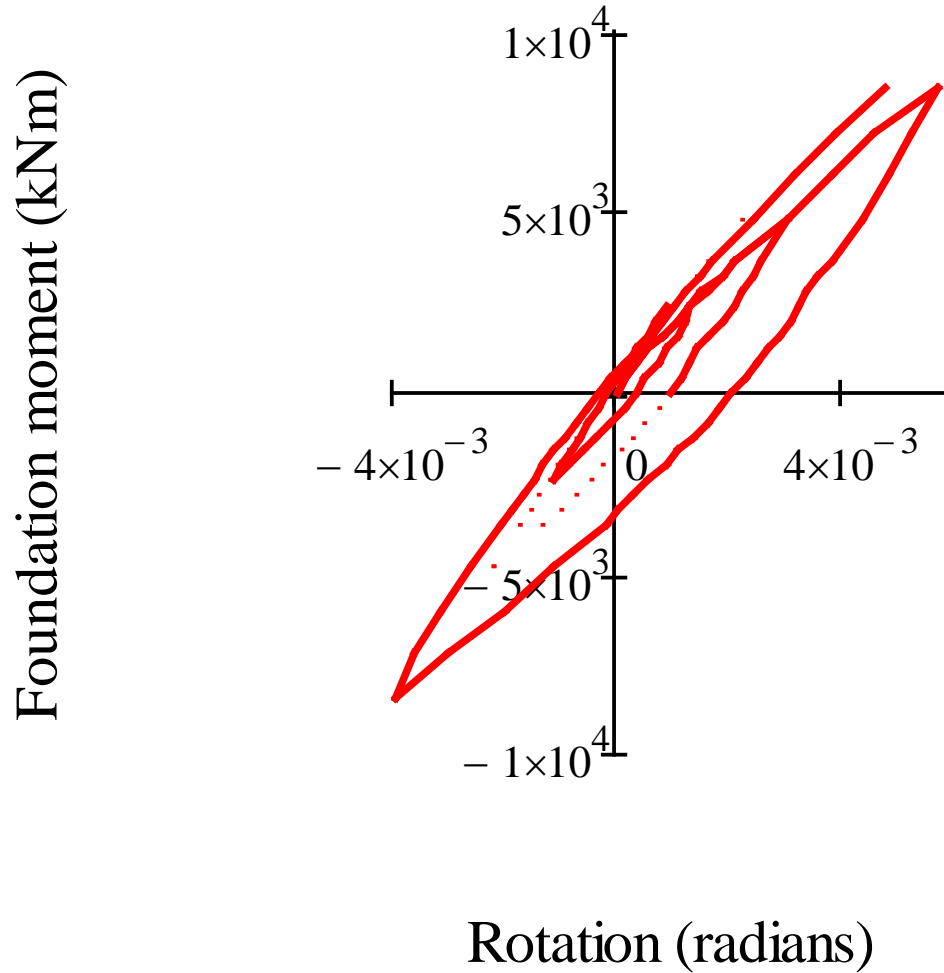# Hyperbolic M-θ curve fit

Hyperbolic curve as a secant modulus

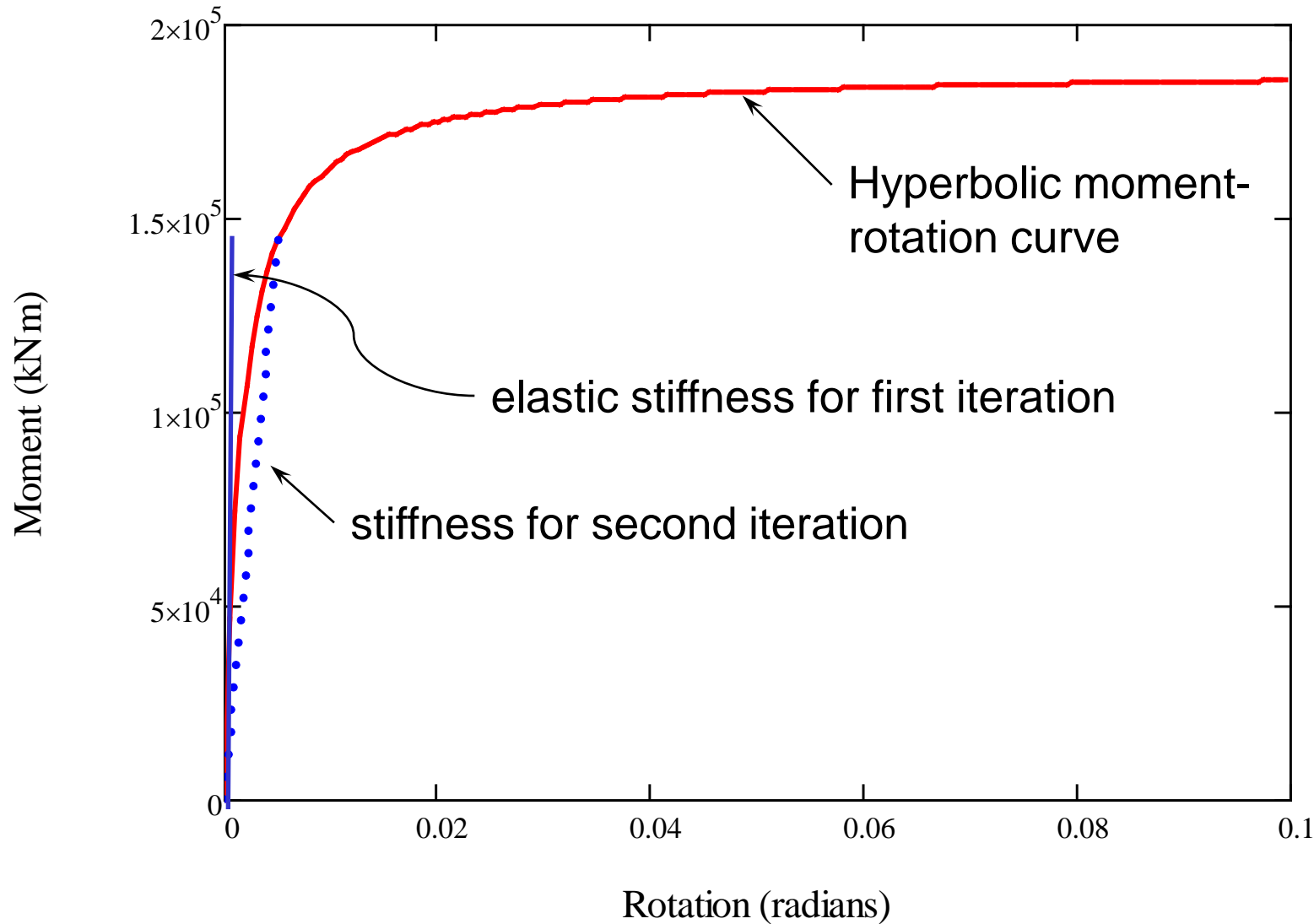# Secant modulus on a log rotation scale

What about damping?

❑ **Important for forced-based and displacement-based design**

❑ **hysteretic damping rather than radiation**
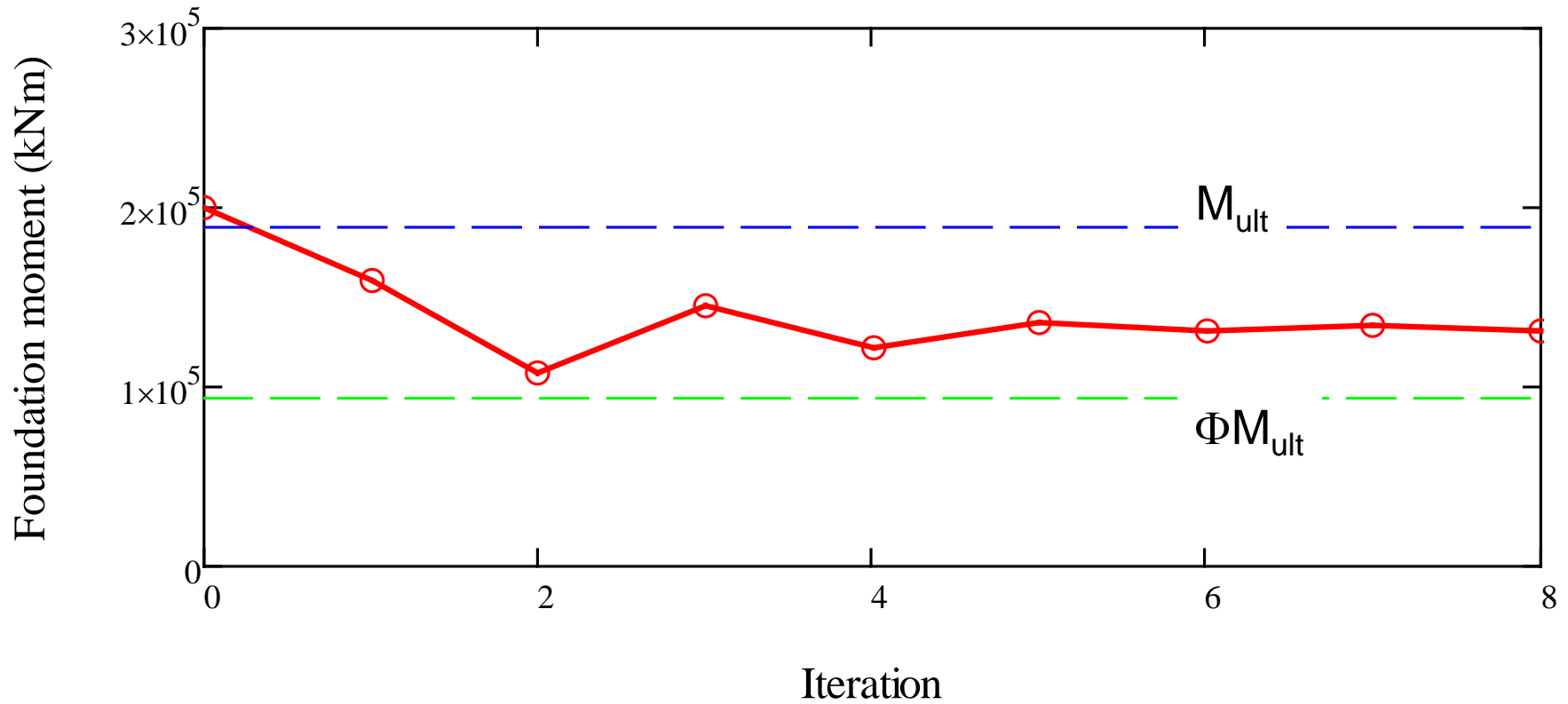
  ❑ **not frequency dependent**

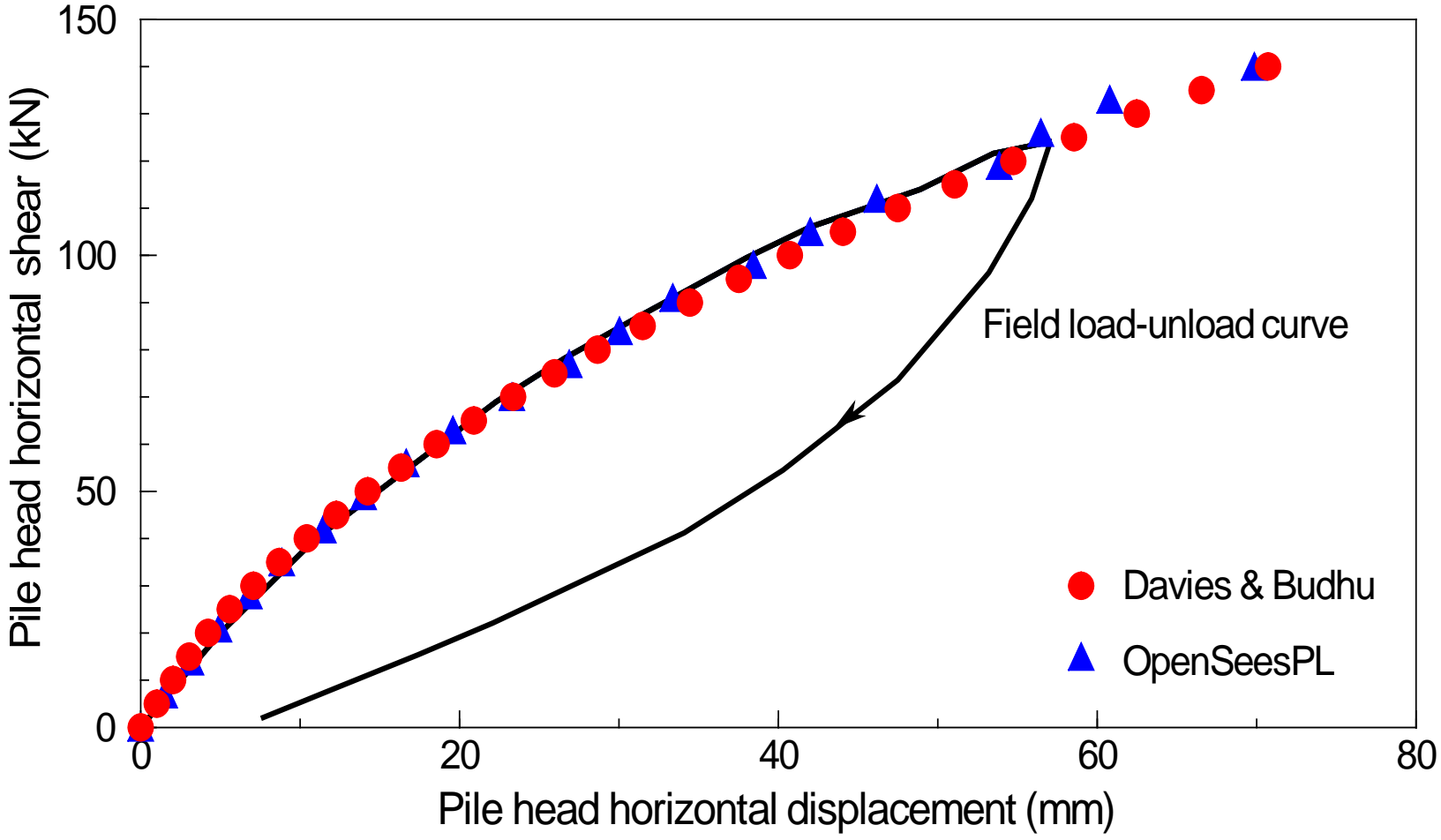# Nonlinear finite element damping using PLAXIS 3D

Shallow foundation example

Shallow foundation iteration

Pile foundation nonlinear

Conclusions

❑ **An approach to incorporating nonlinear foundation moment-rotation curves into modelling the rocking of shallow foundations**

❑ **reduced foundation actions when compared with classical SSI**

  ❑ **nonlinearity at the "middle" of the moment-rotation curve important**

❑ **based on field test data and 3D nonlinear finite element modelling with foundation loss of contact**

  ❑ **not dependent on spring-bed modelling**

❑ **relatively simple hands-on calculation as a design aid or peer review tool.**