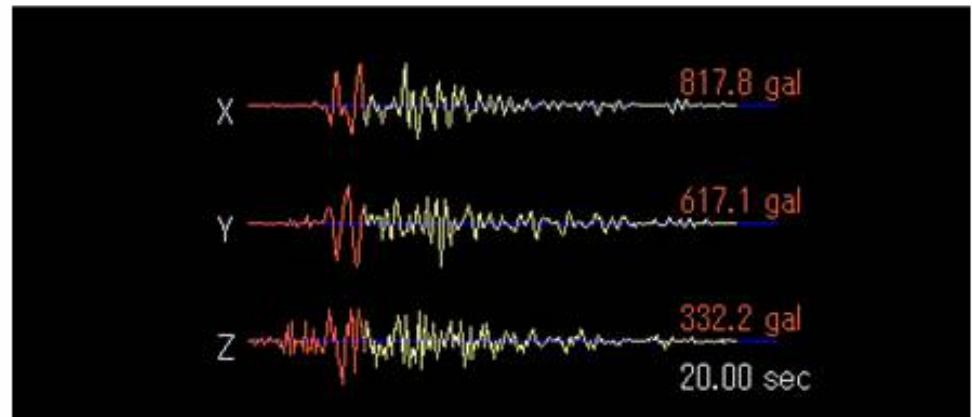
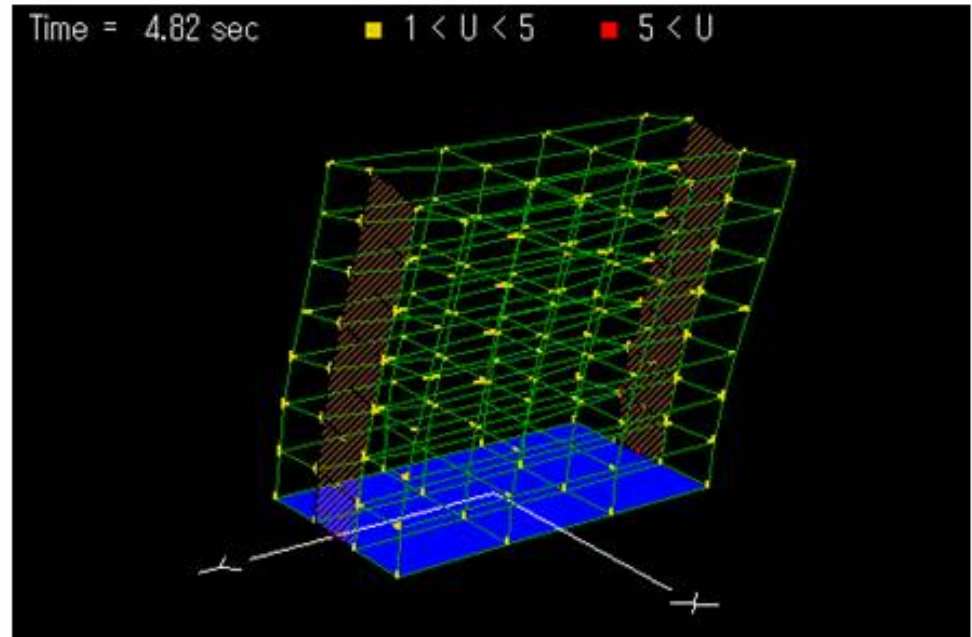


Frame Analysis Program

STERA 3D

ST_ructural Earthquake Response Analysis 3D



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Chief Research Engineer,
IISEE,
Building Research Institute,
Tsukuba, Japan



About “STERA 3D”

- **Seismic analysis of reinforced concrete buildings**
 - 3D elastic modal analysis,
 - 3D nonlinear static push-over and cyclic analysis,
 - 3D nonlinear earthquake response analysis.
- **Visual interface**
 - STERA_3D has a visual interface to create building models and show the results easily and rapidly.
- **Free software for research purpose**
 - STERA_3D is distributed for free for the use of research and educational purpose.

- **Free download from**

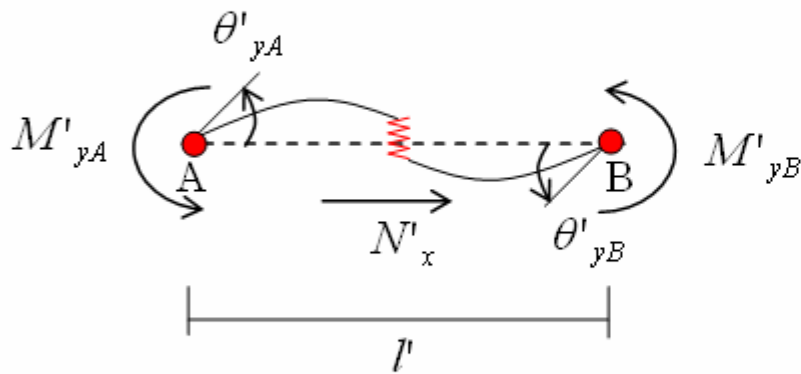
<http://iisee.kenken.go.jp/net/saito/stera3d/index.html>



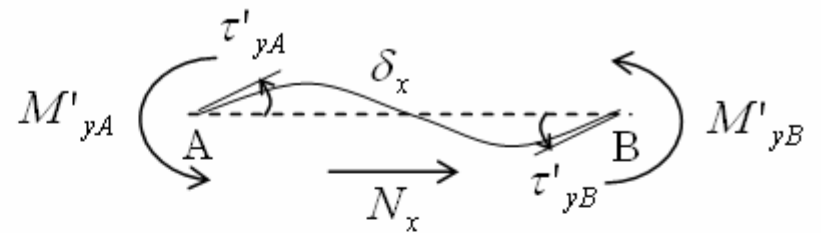
Element Models

- Beam
- Column
- Wall
- External Springs
- Base Isolation
- Nonstructural Wall → Masonry

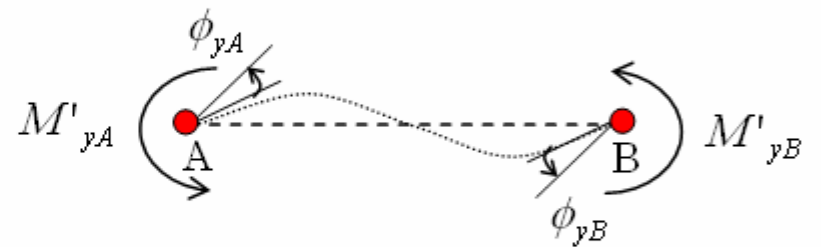
Beam



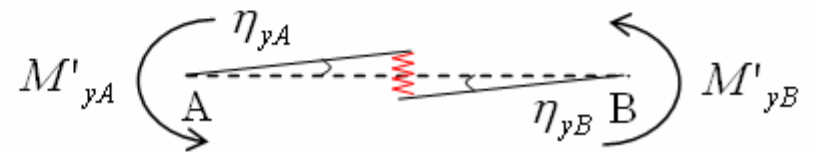
$$\begin{Bmatrix} \theta'_{yA} \\ \theta'_{yB} \\ \delta'_x \end{Bmatrix} = \begin{Bmatrix} \tau'_{yA} \\ \tau'_{yB} \\ \delta'_x \end{Bmatrix} + \begin{Bmatrix} \phi_{yA} \\ \phi_{yB} \\ 0 \end{Bmatrix} + \begin{Bmatrix} \eta_{yA} \\ \eta_{yB} \\ 0 \end{Bmatrix}$$



Elastic element



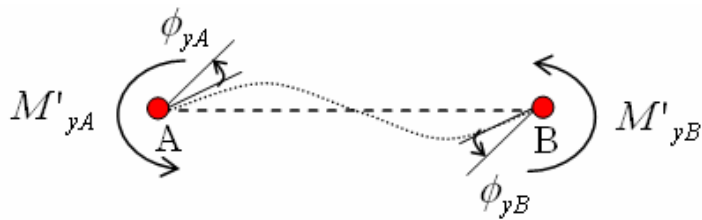
Nonlinear bending springs



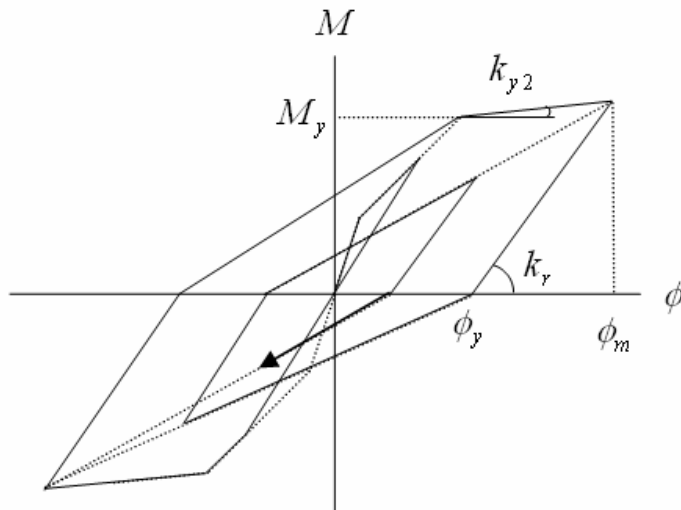
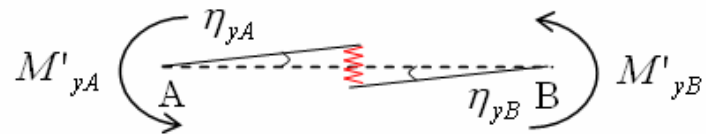
Nonlinear shear springs

Beam

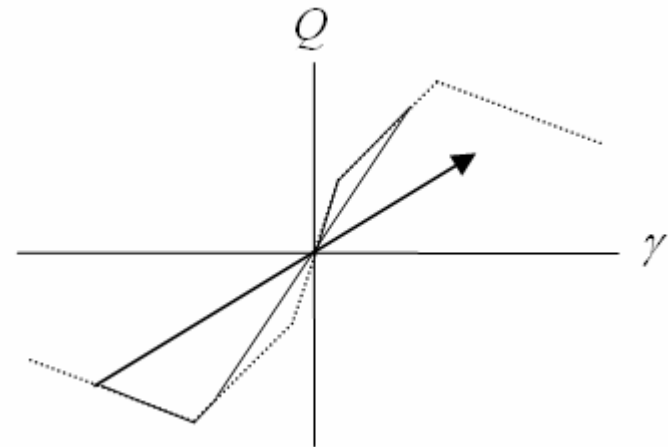
Nonlinear bending spring



Nonlinear shear spring

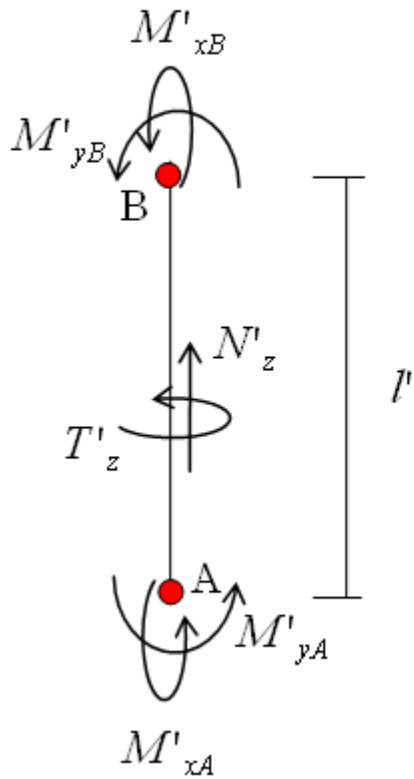


Modified Takeda Model

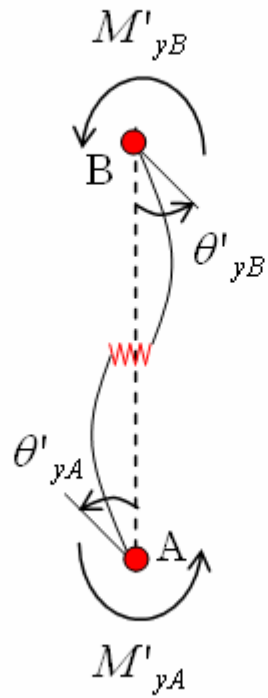


Origin Oriented Model

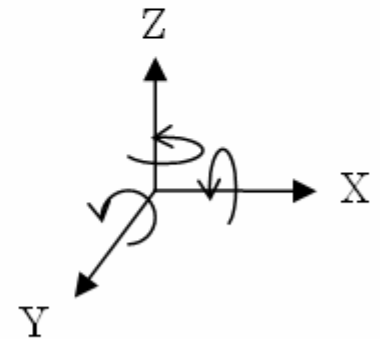
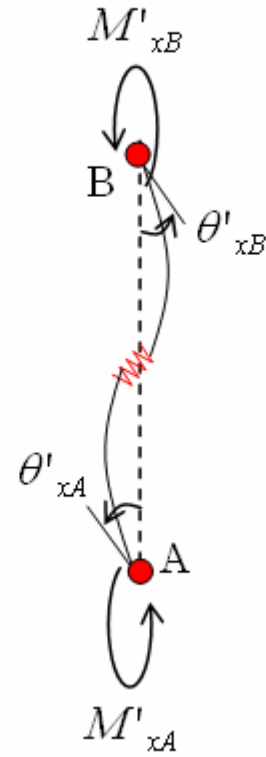
Column



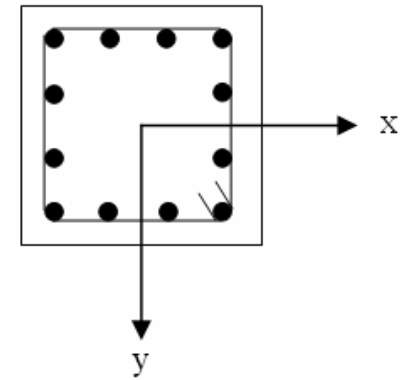
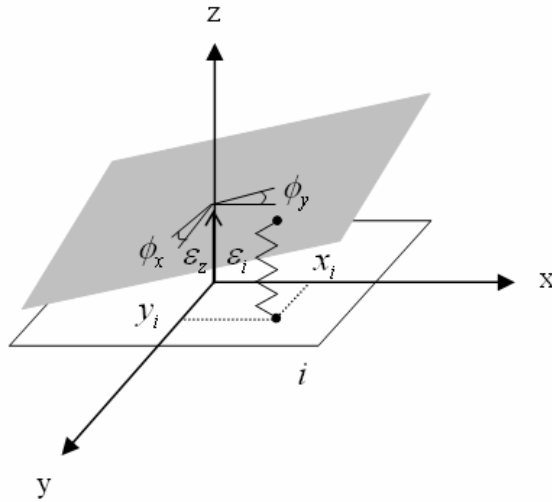
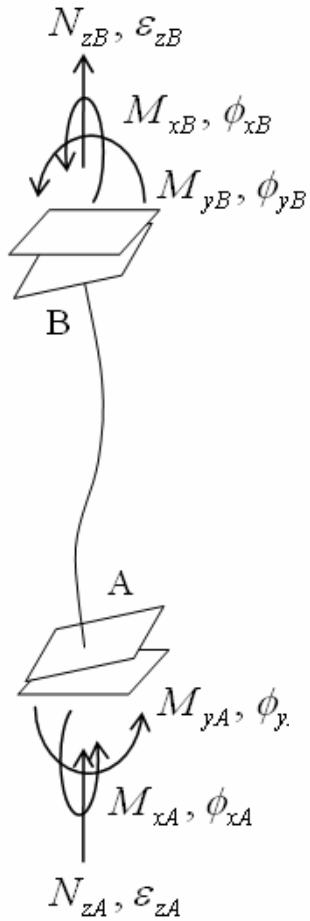
X-Z plane



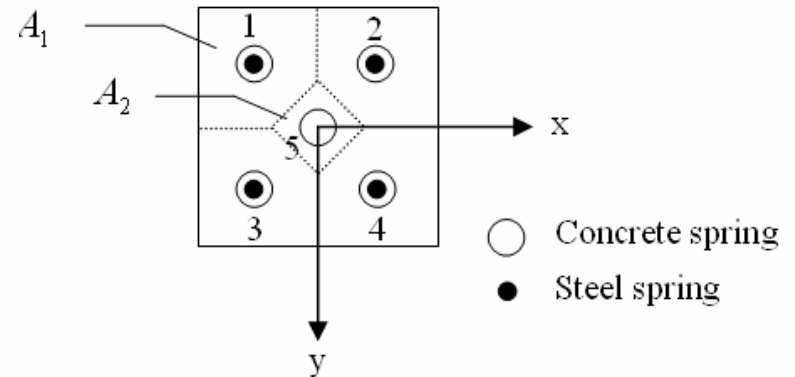
Y-Z plane



Column

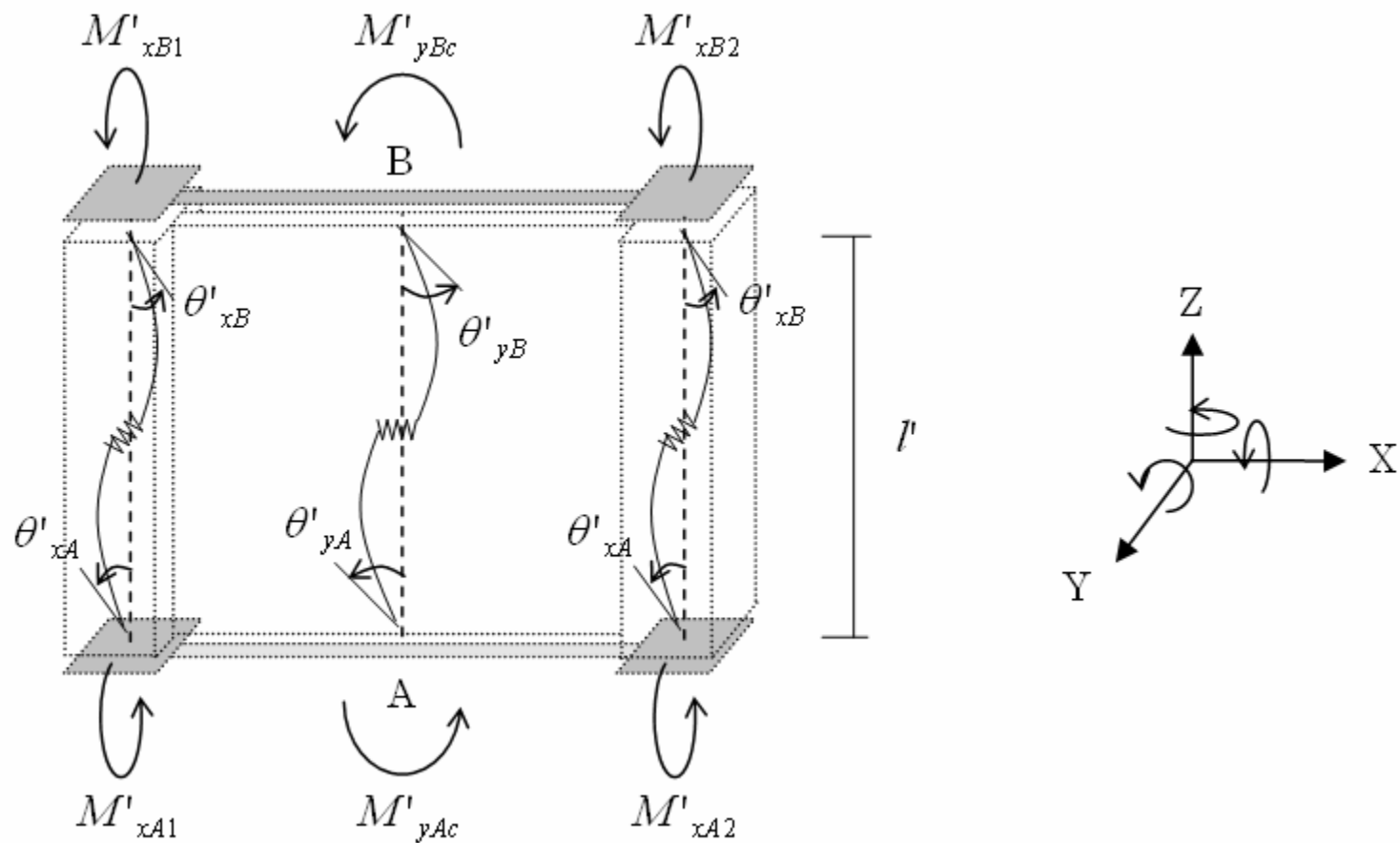


Multi spring (MS) Model

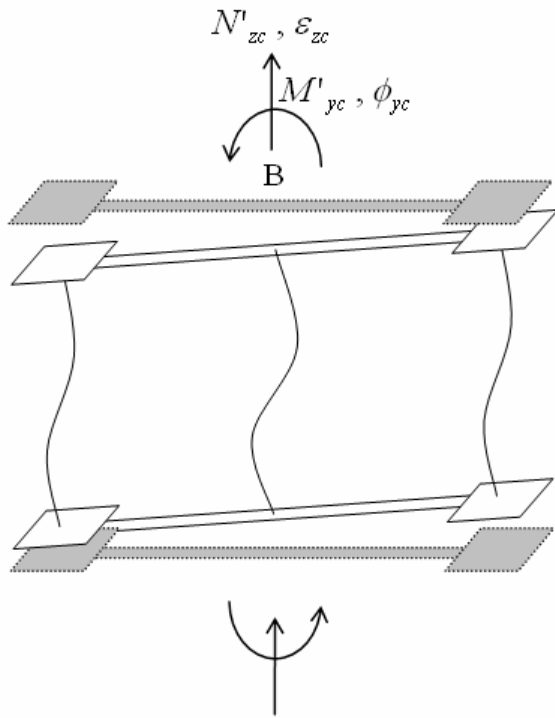


Nonlinear Bending Springs

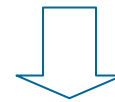
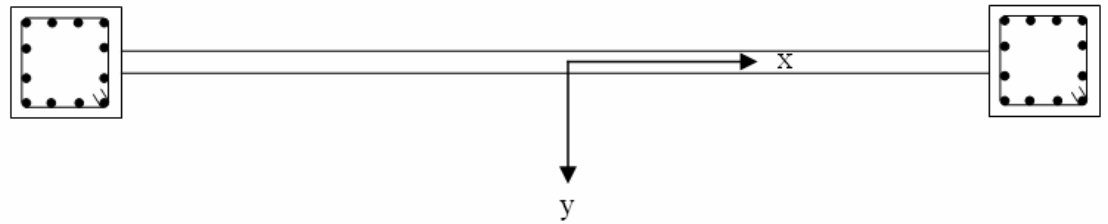
Wall



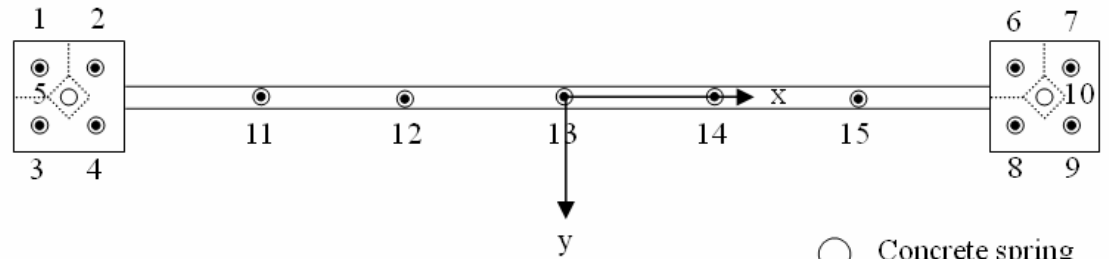
Wall



Nonlinear Bending Springs

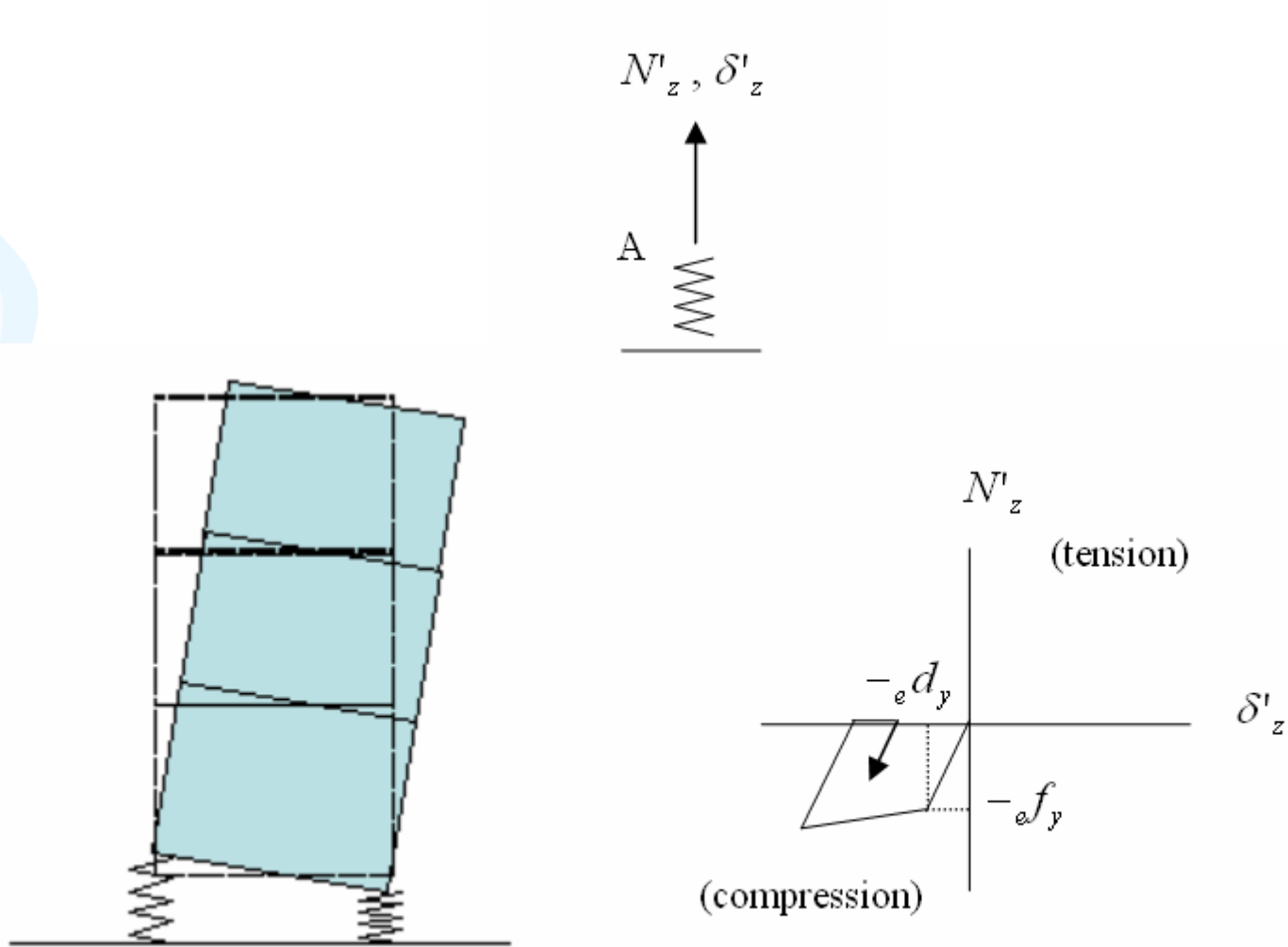


Multi spring (MS) Model

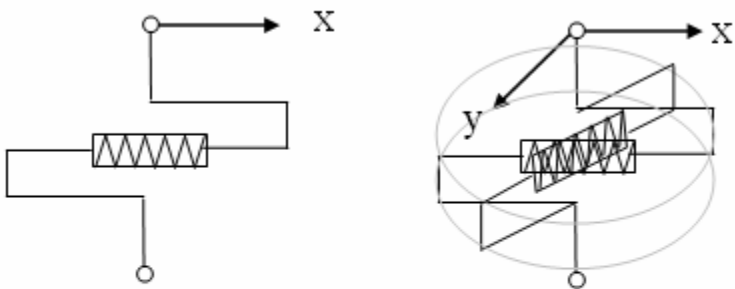
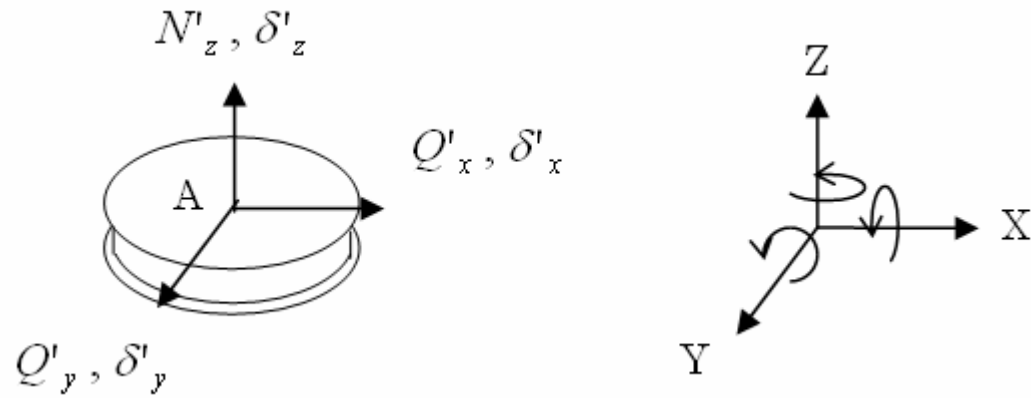


- Concrete spring
- Steel spring

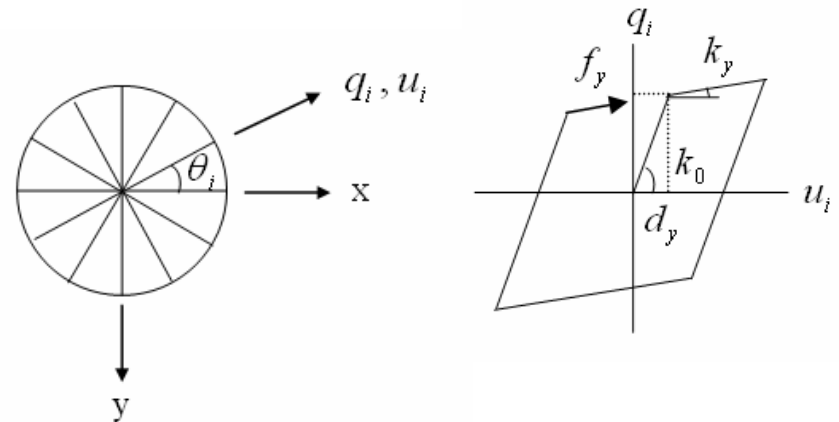
External Spring



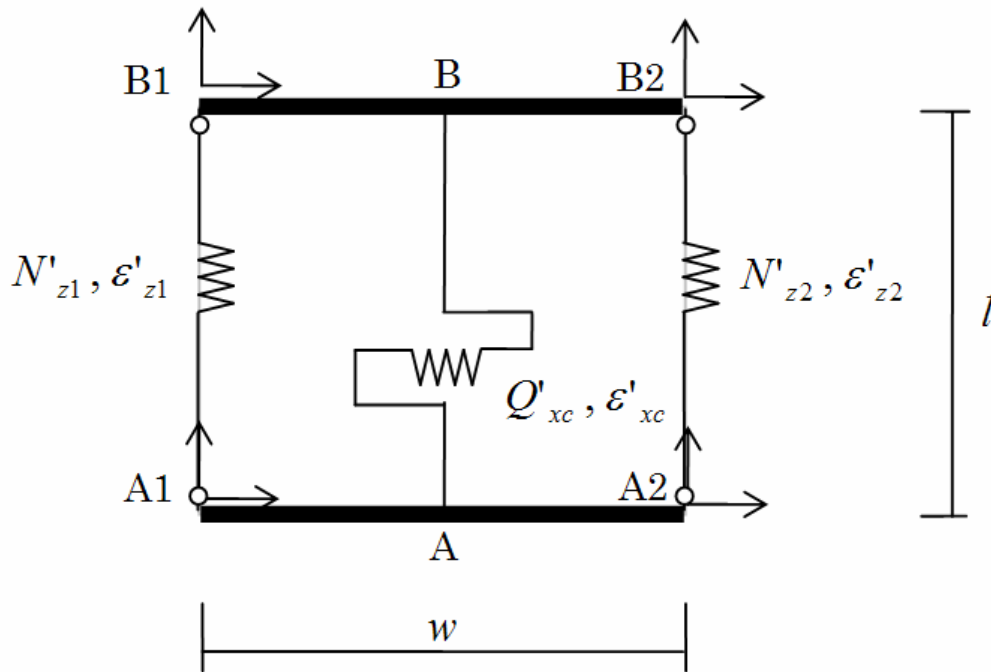
Base Isolator



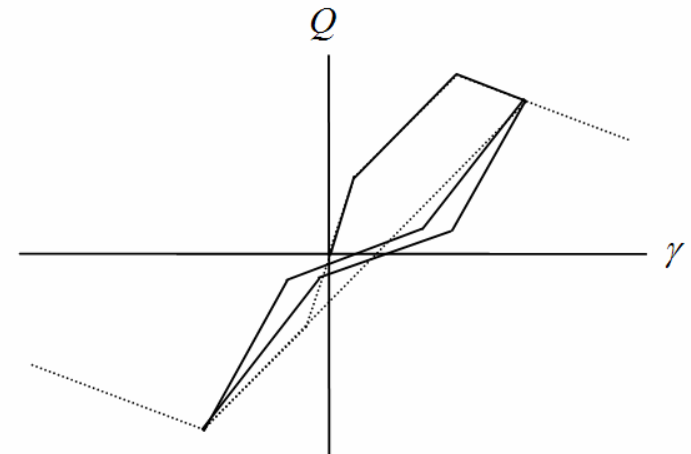
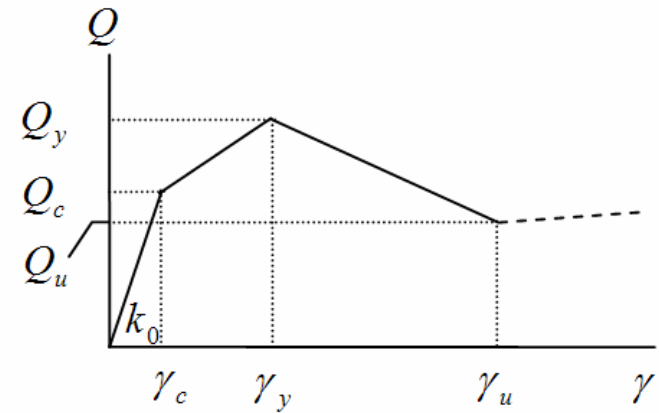
Multi shear spring (MSS) Model



Nonstructural Wall



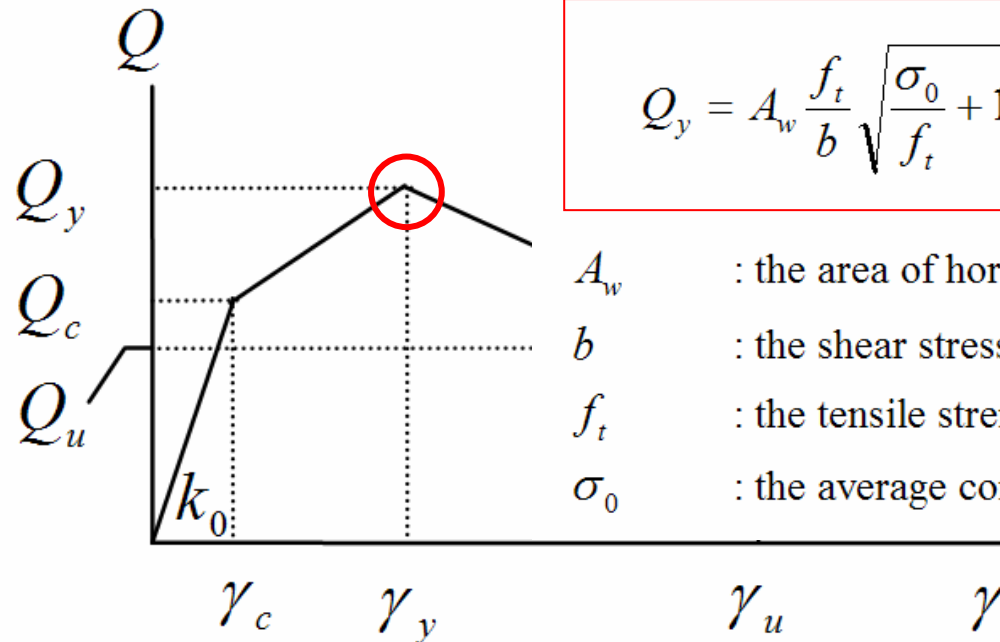
Nonlinear Shear Spring



Poly-linear Slip Model

Resistance envelope for plain masonry walls

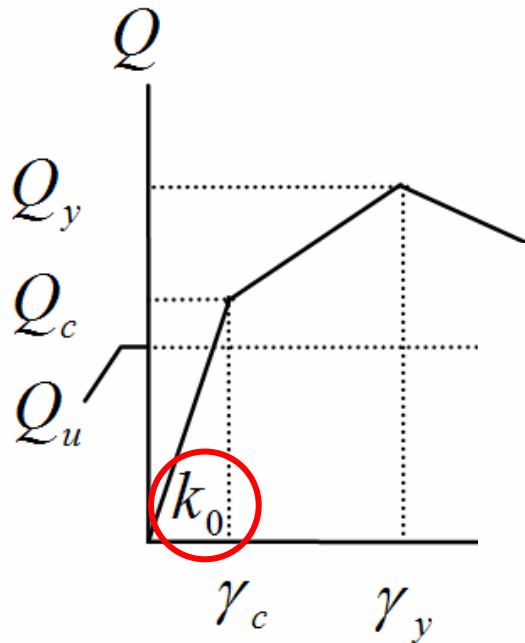
Maximum shear resistance



$$Q_y = A_w \frac{f_t}{b} \sqrt{\frac{\sigma_0}{f_t} + 1}$$

- A_w : the area of horizontal cross-section of the wall
- b : the shear stress distribution factor ($=h/l$)
- f_t : the tensile strength of masonry
- σ_0 : the average compression stress due to vertical load

Resistance envelope for plain masonry walls



Effective elastic stiffness

$$k_0 = \frac{GA_w}{1.2h \left[1 + \alpha' \frac{G}{E} \left(\frac{h}{l} \right)^2 \right]}$$

h : the height of the wall

l : the width of the wall

A_w : the area of horizontal cross-section of the wall

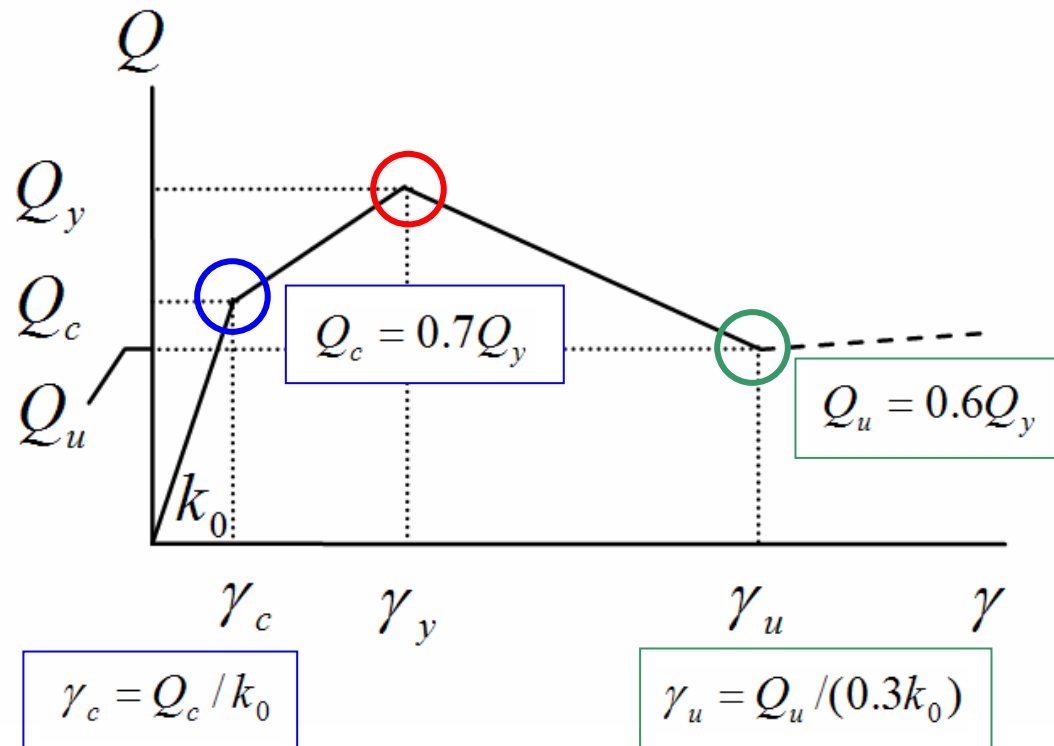
G : shear modulus of masonry

E : modulus of elasticity of masonry

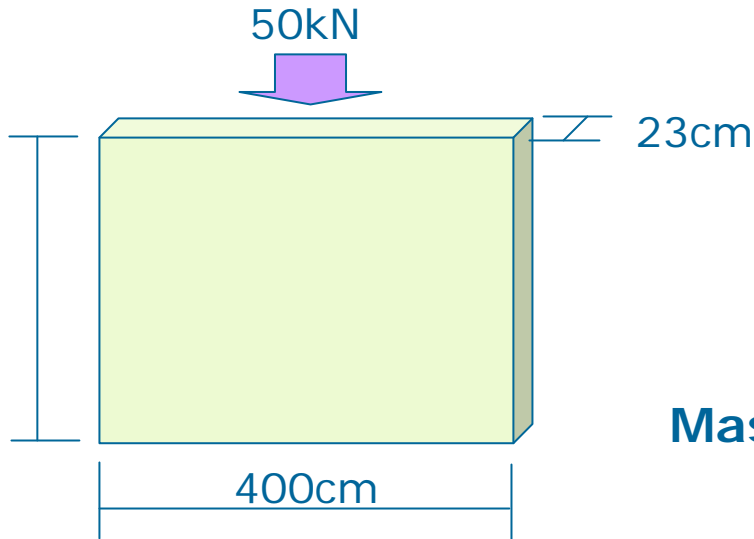
α' : =0.83 for a fixed-ended, =3.33 for a cantilever wall

Resistance envelope for plain masonry walls

Resistance envelope for plain masonry walls*

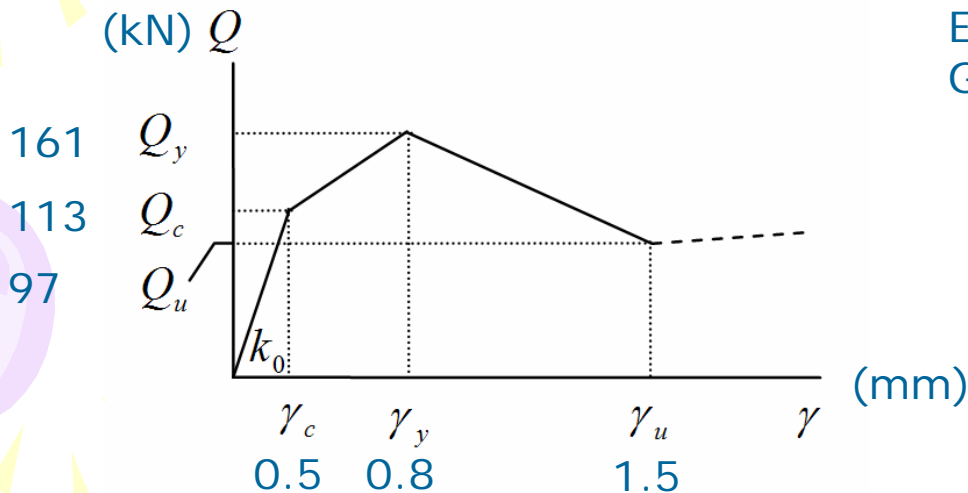


Example of calculation



Masonry property

Compression strength $f_k = 3.0\text{MPa}$
Tensile strength $f_t = 0.15\text{MPa}$
 $E = 3000\text{MPa}$
 $G = 1200\text{MPa}$





Study Plan using “STERA 3D”

- Mathematical model of resistance envelope of masonry walls
 - plain, confined, reinforced masonry walls
 - masonry wall with openings
 - out-of-plane behavior
- Comparison with experiments
 - static test
 - shaking table test
- Analysis of typical masonry buildings