

Evaluation of Seismic Resistance of Buildings



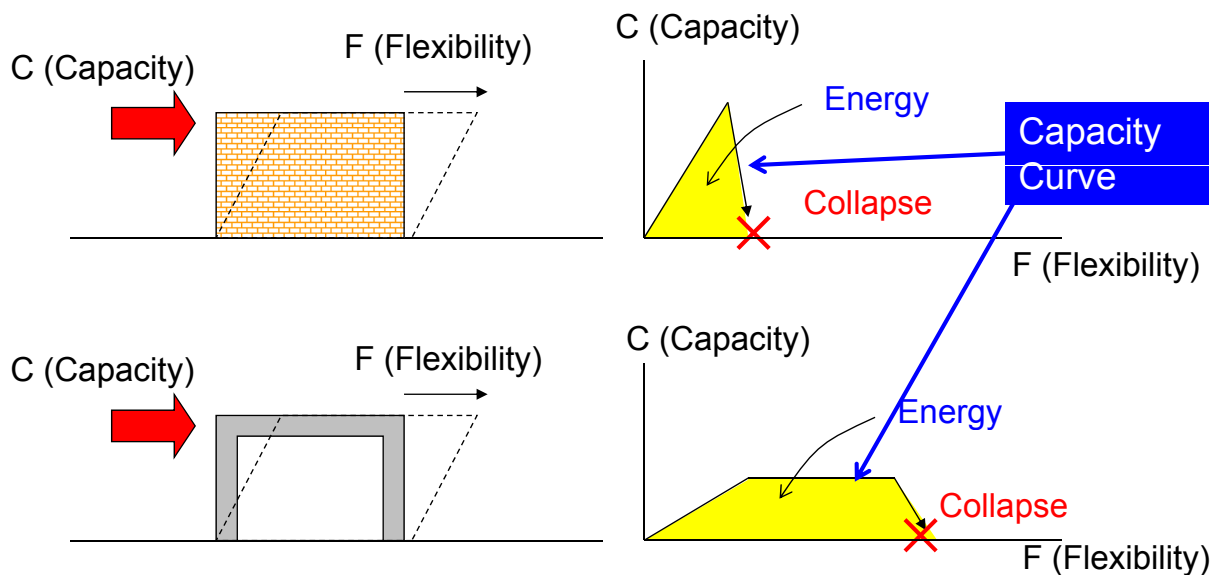
Taiki SAITO

Chief Research Engineer,
International Institute of Seismology and Earthquake Engineering (IISSEE),
Building Research Institute (BRI)

Seismic Resistance of Building



Seismic Resistance = Potential Energy



Seismic Index “Is”

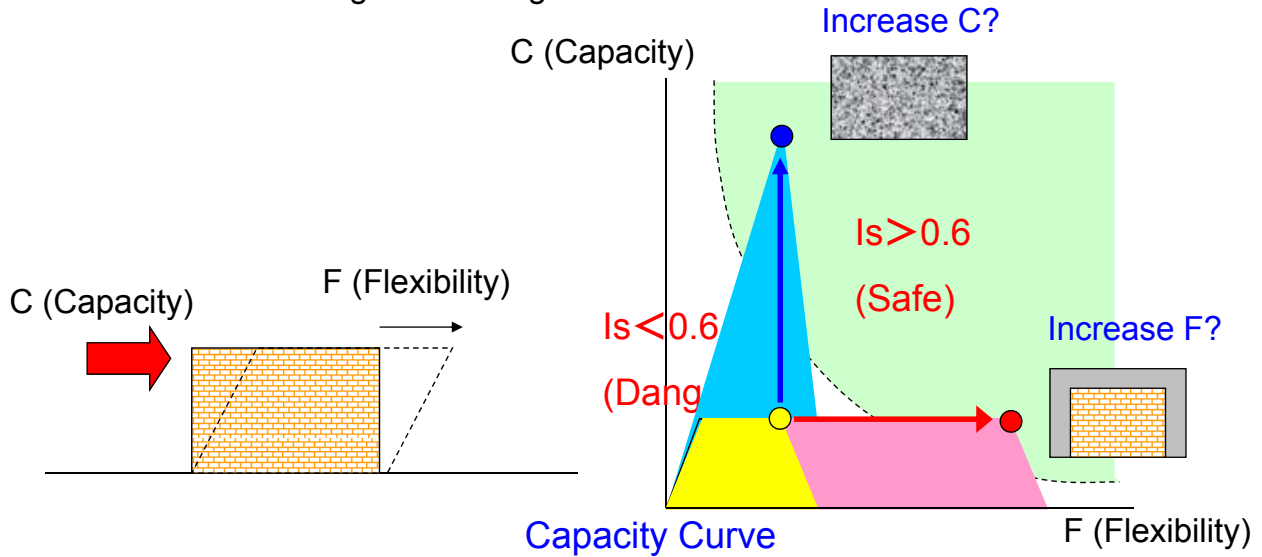


3

$$I_s = (\Phi \times C \times F) \times S_D \times T$$

Φ : factor for number of story
 S_D : factor for shape of building
 T : factor for age of building

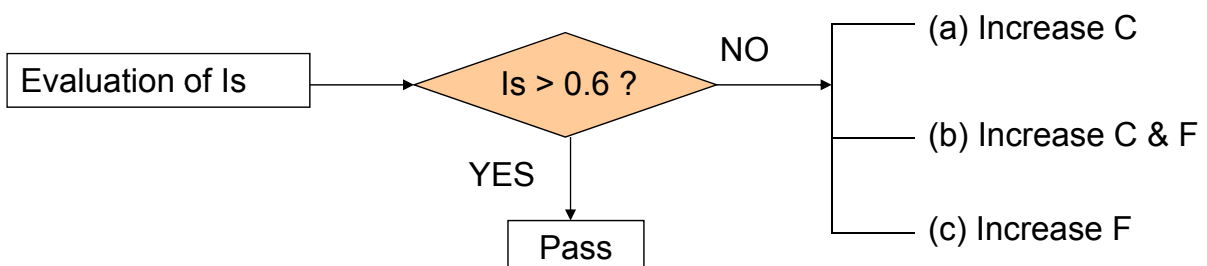
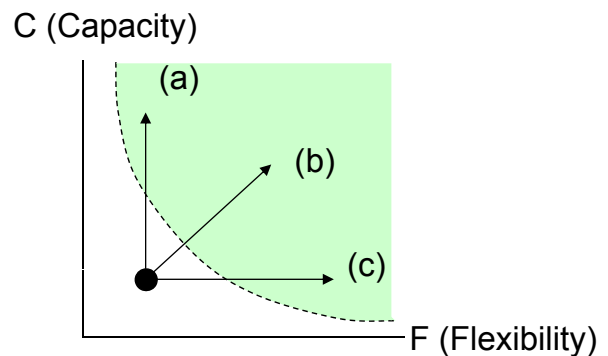
“Design guideline for Seismic Evaluation for RC structures (2001)”



Strategy for Seismic Rehabilitation



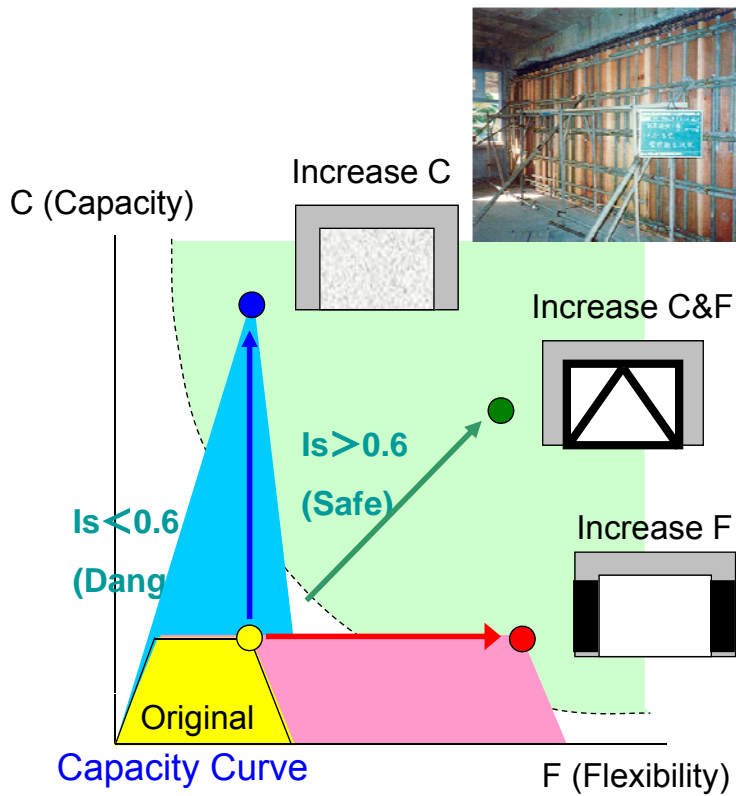
4



Rehabilitation Techniques (1. Conventional method)



5



(Photo from Dr. Fukuyama, BRI)

Example (Increase F)



6

Rehabilitation by Carbon Fiber Sheet

no noise, no dust, no disturbance



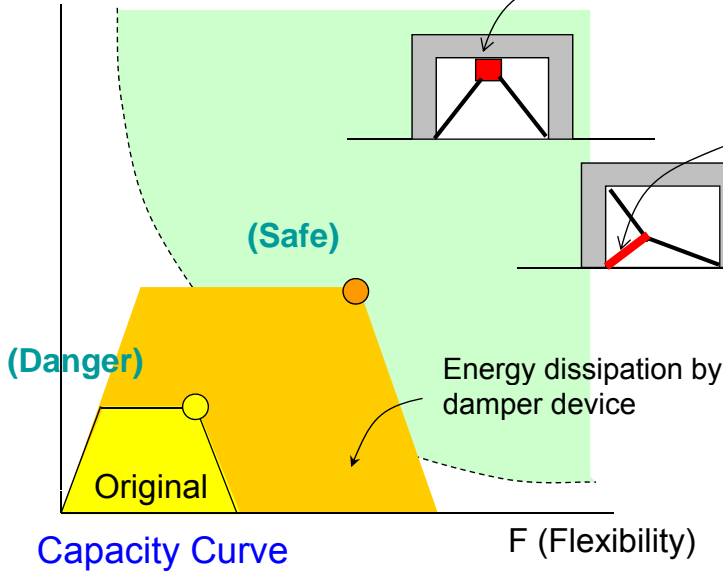
(Photo from Dr. Fukuyama, BRI)

Rehabilitation Techniques (2. Damper device)



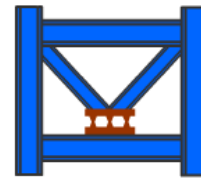
7

C (Capacity)



OILES
<http://www.oiles.co.jp>

Honey-comb damper



KAJIMA
<http://www.kajima.co.jp>

Many other devices

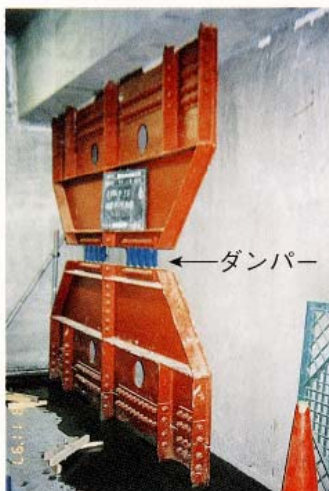
Example (Damper)



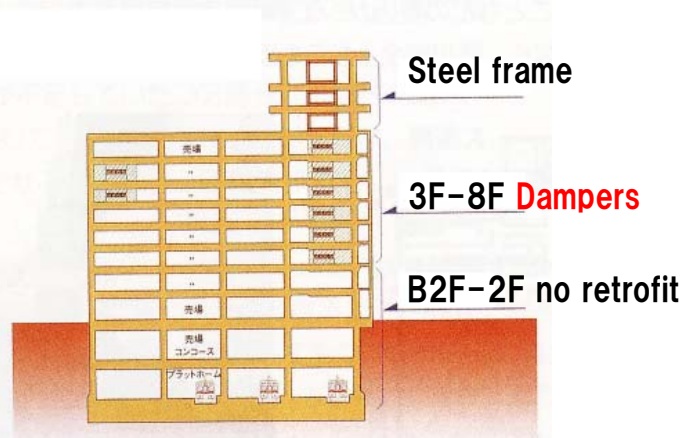
8



Damper wall



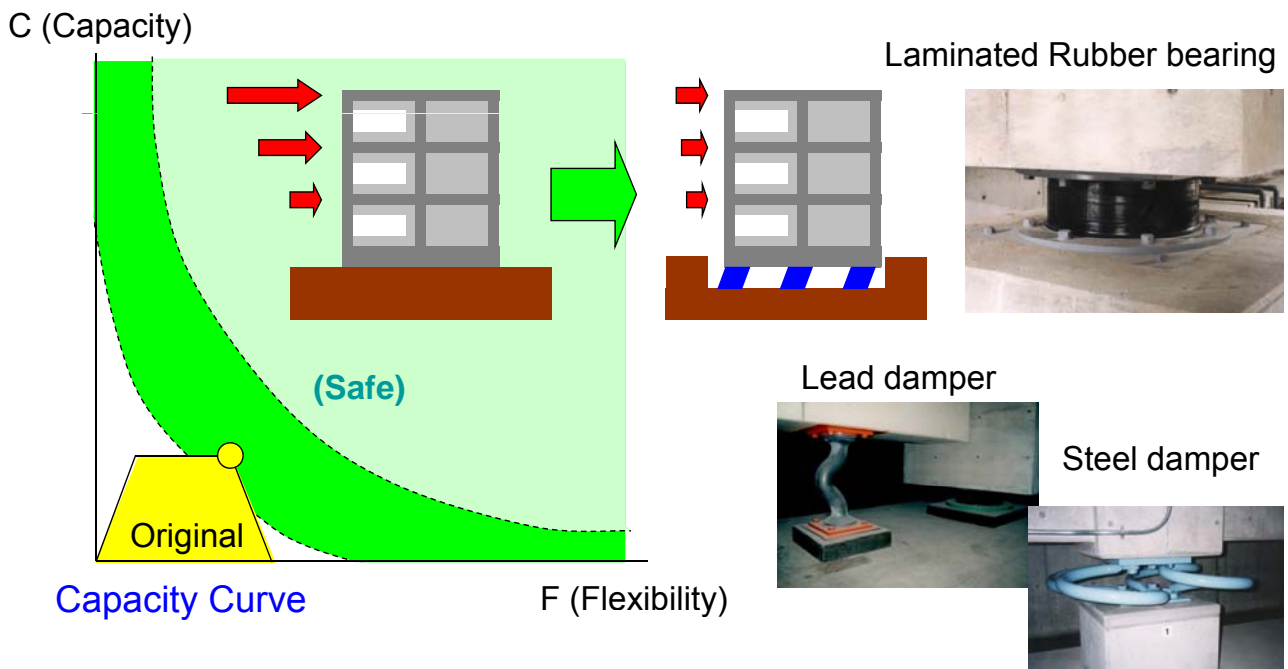
施工中の鋼材ハニカムダンパー



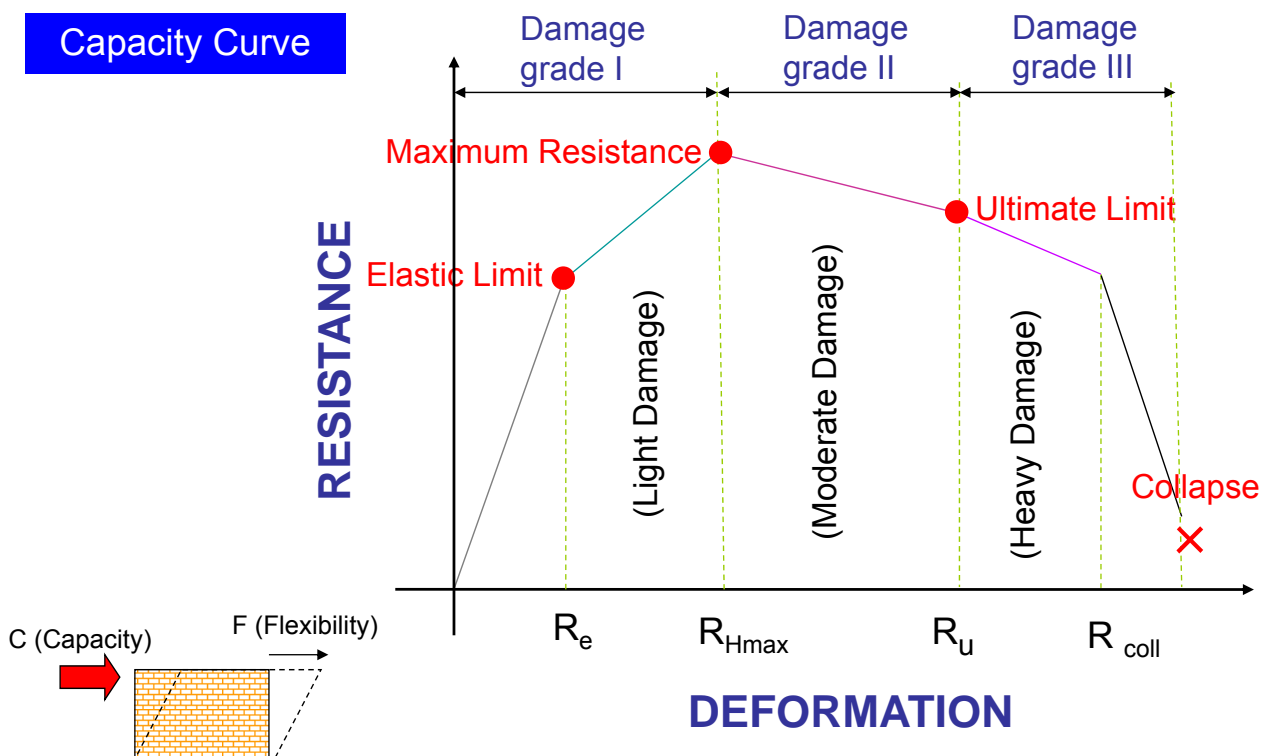
ダンパーおよび鉄骨補強フレームの設置位置

(社)建築・設備維持保全推進協会パンフレットより抜粋

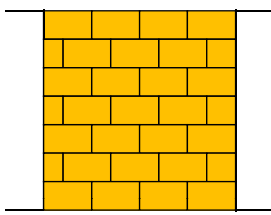
Rehabilitation Techniques (3. Seismic isolation)



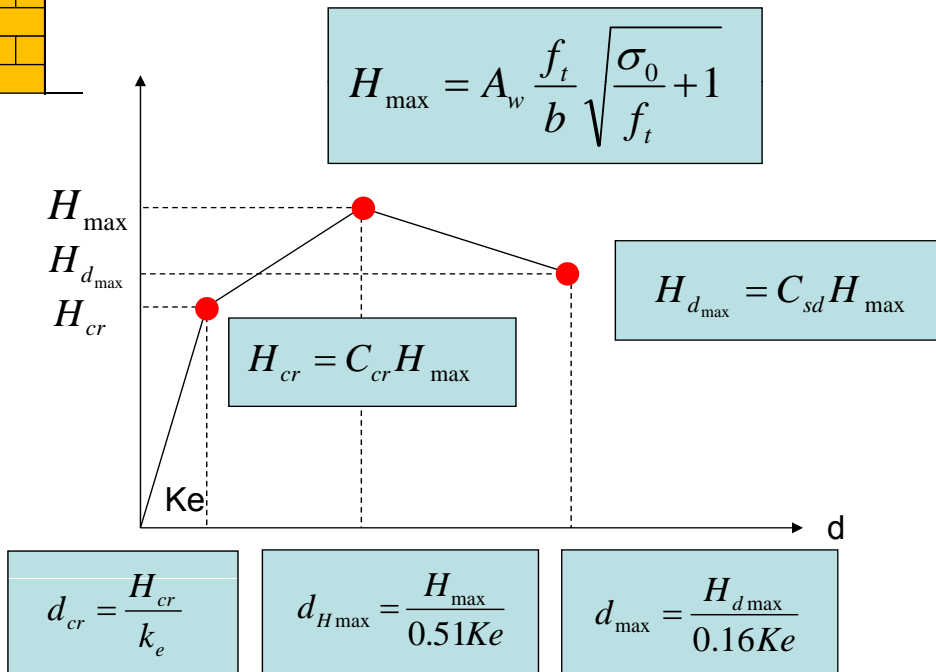
Capacity curve and performance



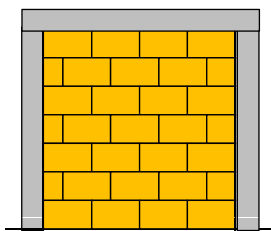
Capacity curve of plain masonry wall



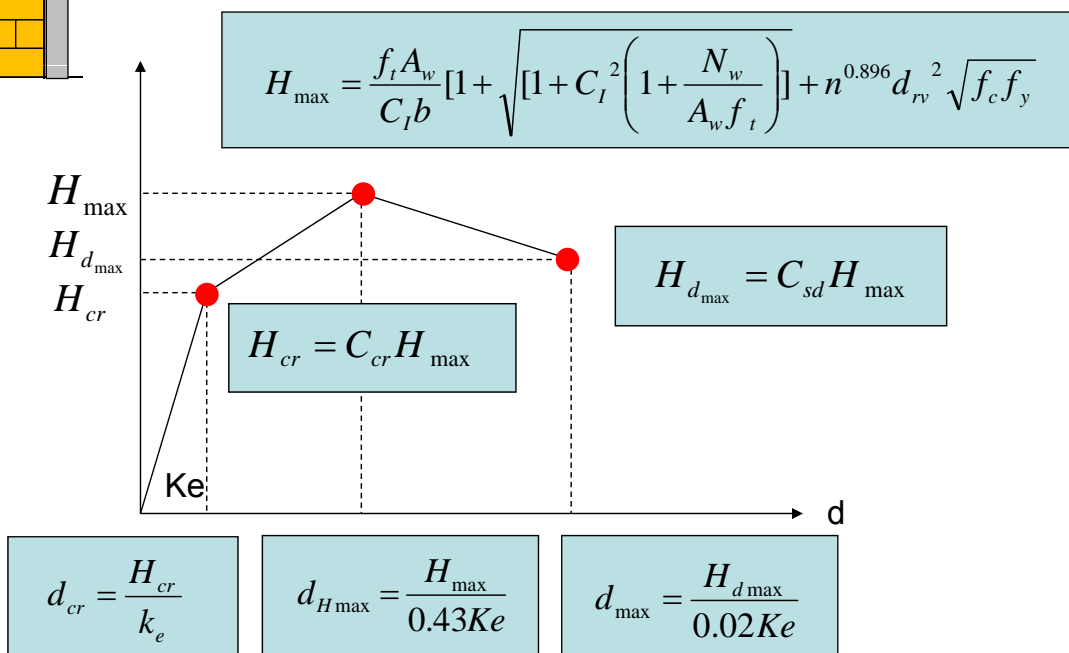
f_t : tension strength of brick
 σ_0 : compression strength of brick



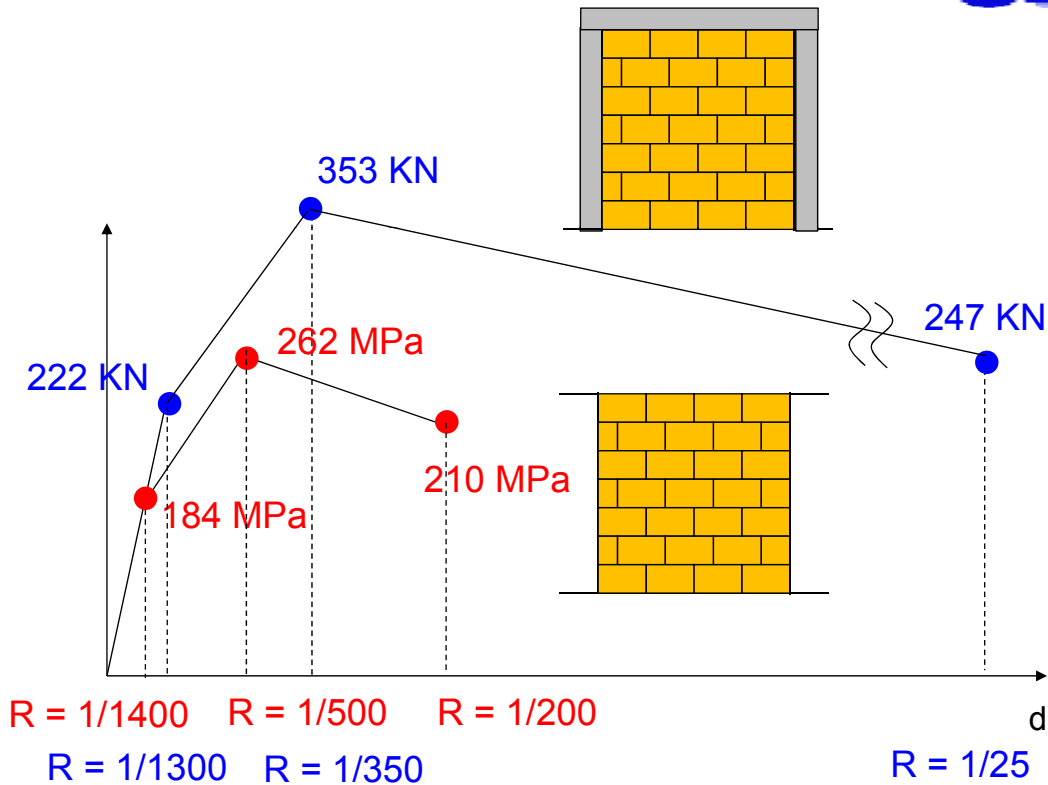
Capacity curve of confined masonry wall



f_y : strength of rebar
 f_c : compression strength of concrete



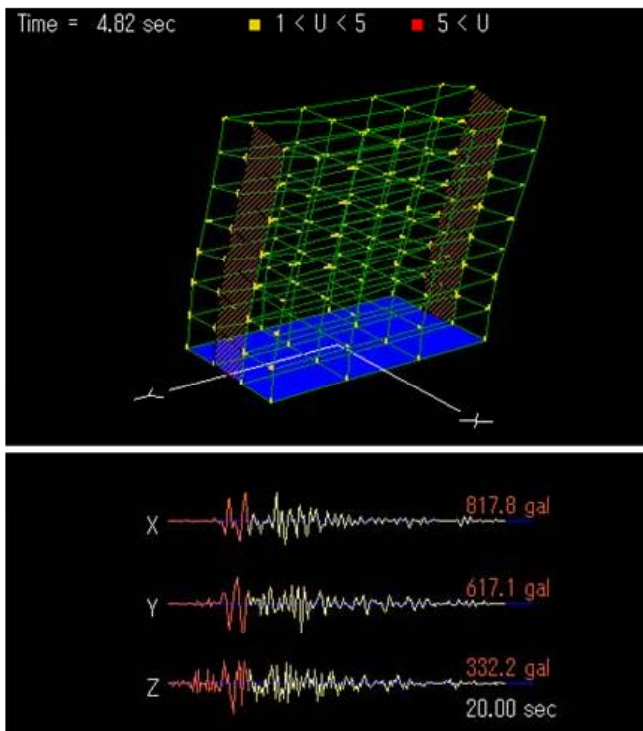
Example



STERA 3D software



STructural E arthquake R esponse A nalysis 3D

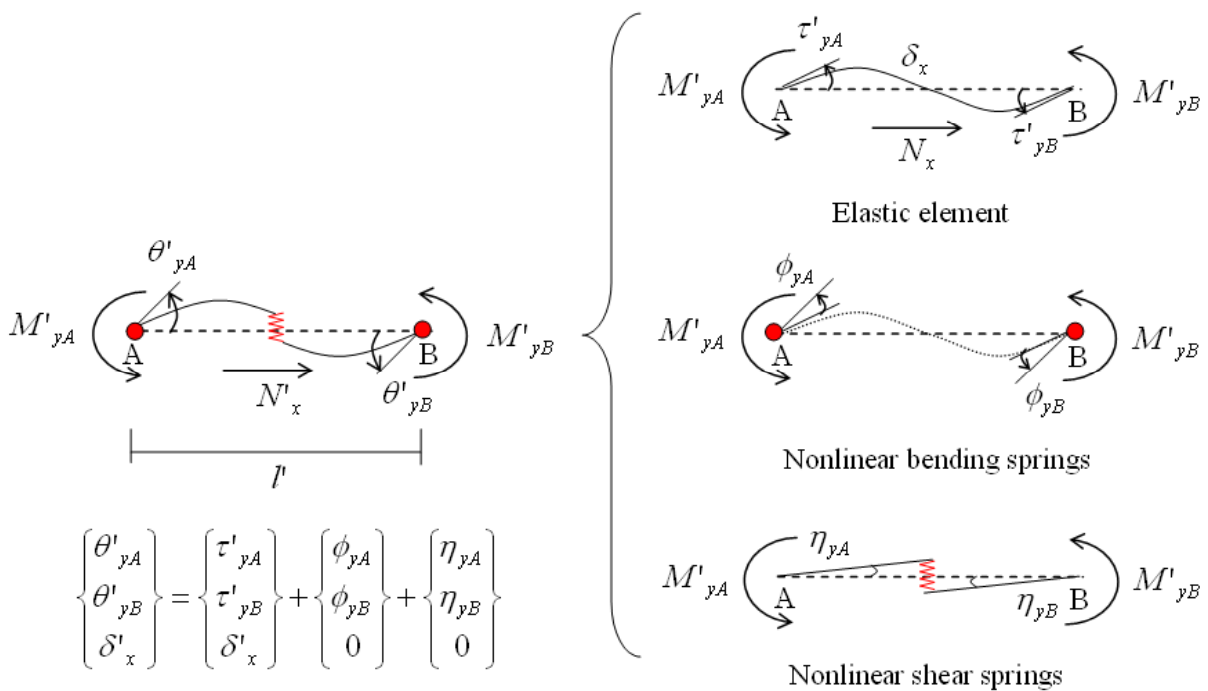


- Seismic analysis of reinforced concrete + masonry buildings
 - 3D elastic modal analysis,
 - 3D nonlinear static push-over and cyclic analysis,
 - 3D nonlinear earthquake response analysis.
- Visual interface
 - Visual interface to create building models and show the results easily and rapidly.
- Free software
 - STERA 3D is distributed for free for the use of research and educational purpose.
- Free download from Web
 - Search “STERA3D”

Element Models

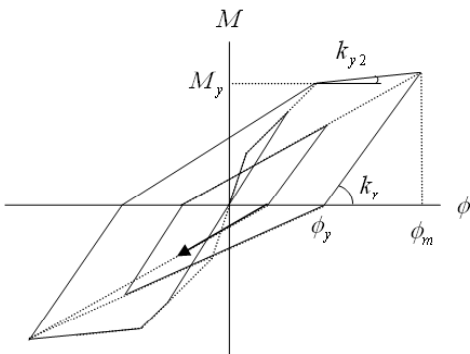
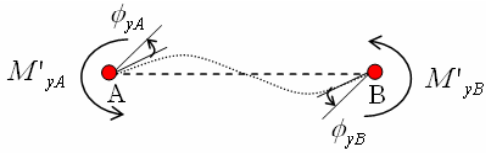
- Beam
- Column
- Wall
- External Springs
- Base Isolation
- Dampers
- Masonry

Beam



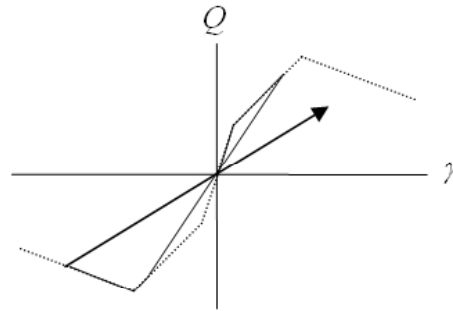
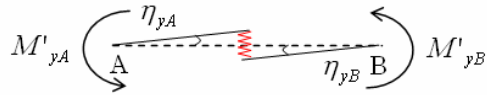
Beam

Nonlinear bending spring



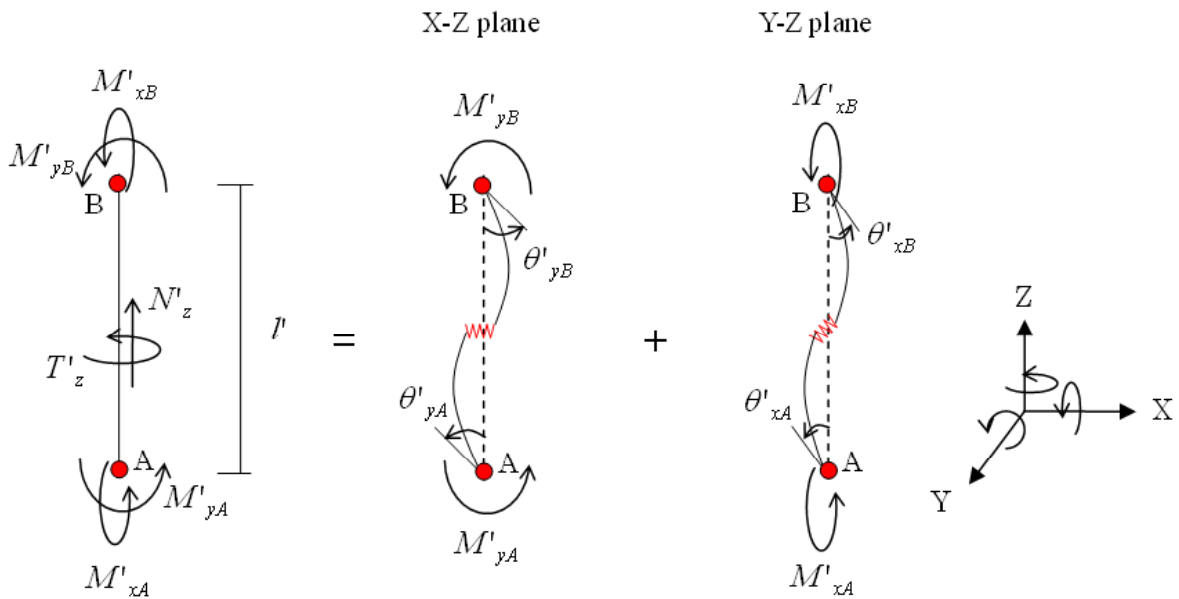
Modified Takeda Model

Nonlinear shear spring

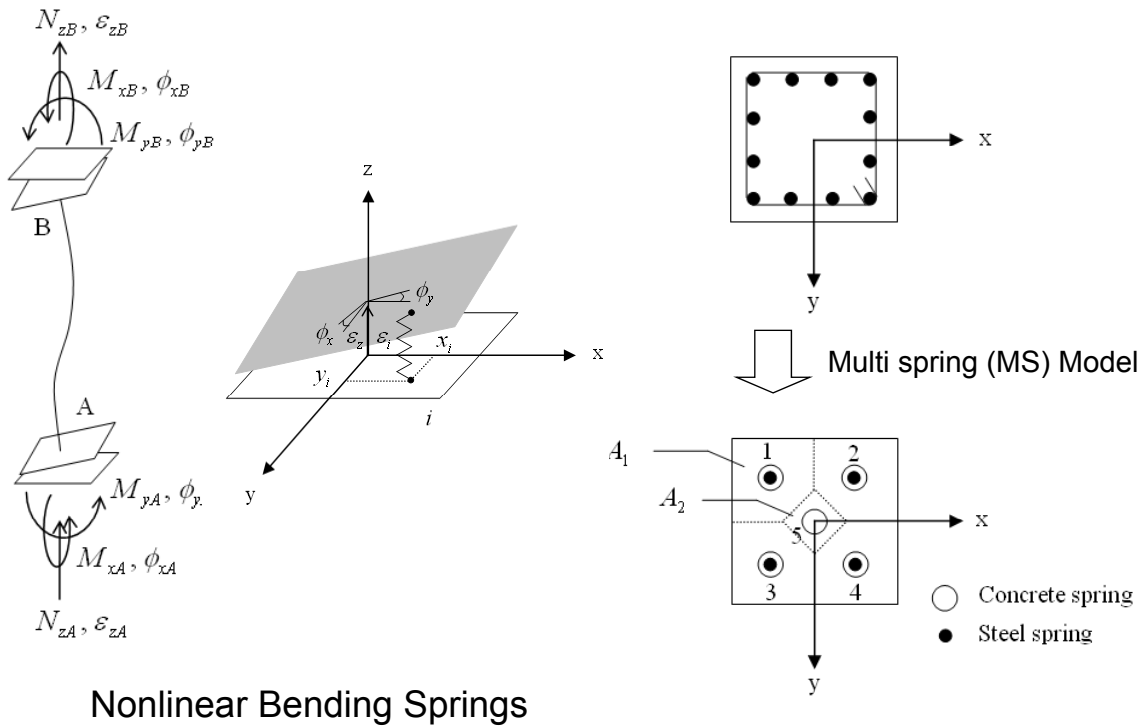


Origin Oriented Model

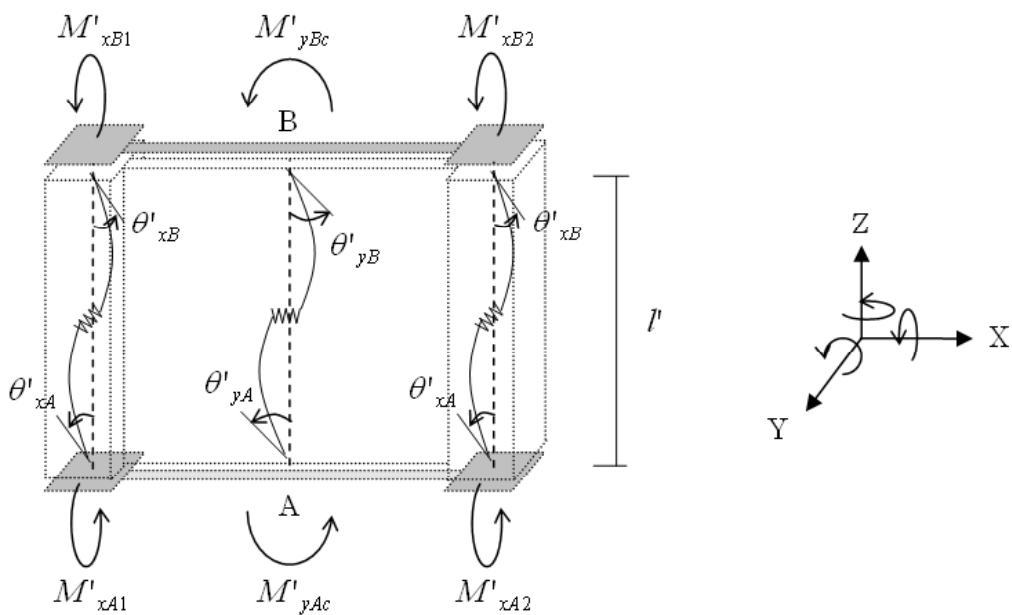
Column



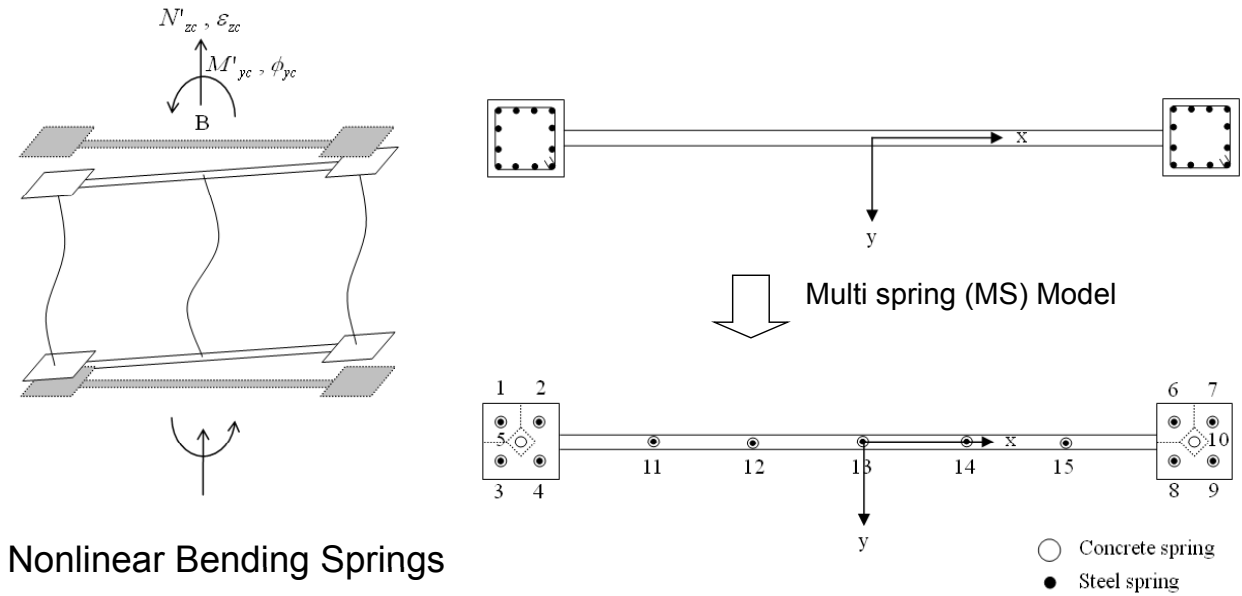
Column



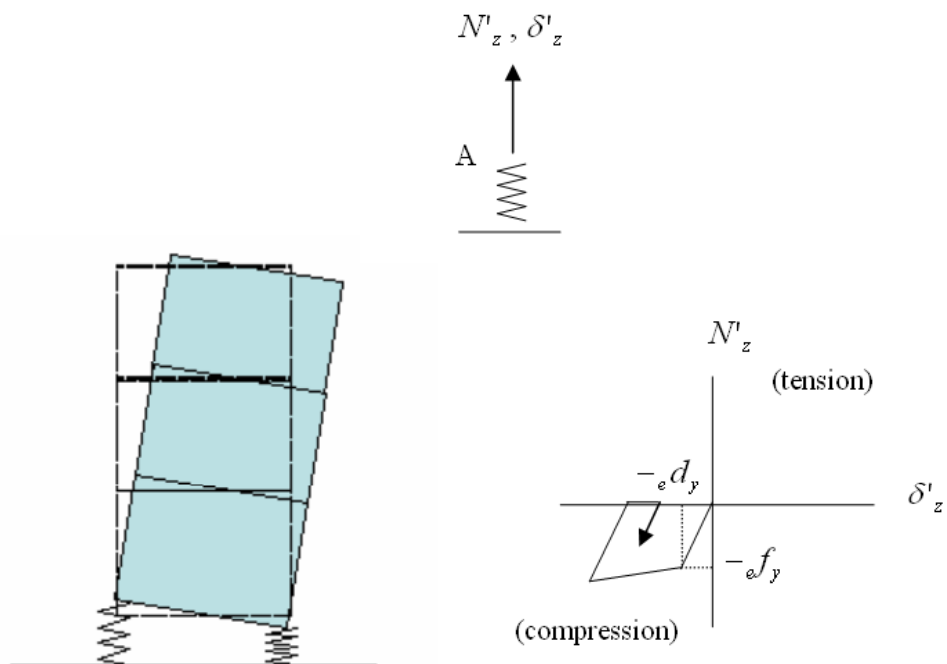
Wall



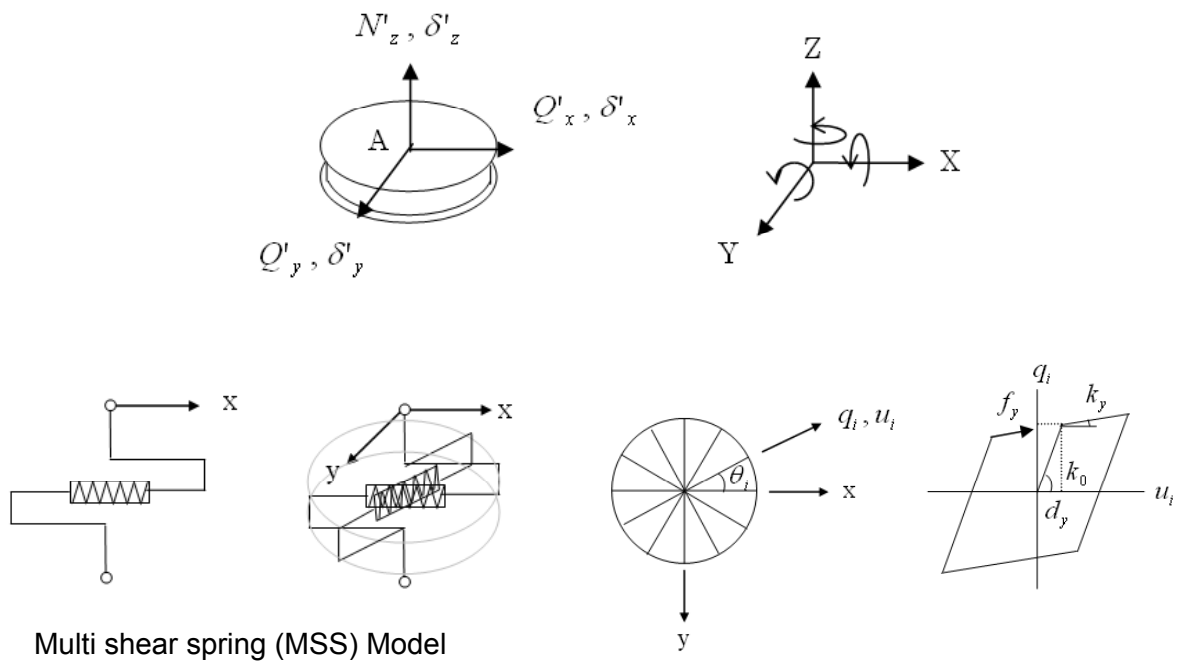
Wall



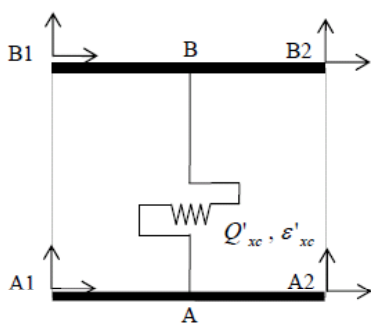
External Spring



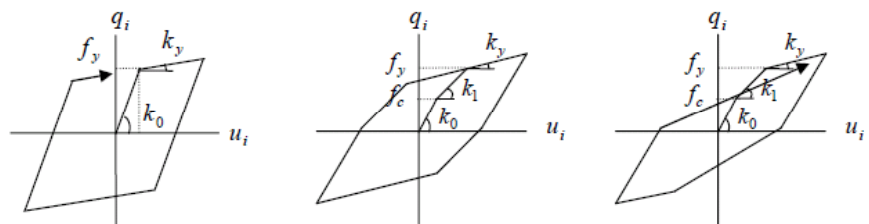
Base Isolation Device



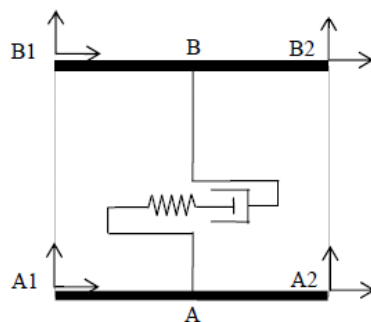
Damper Device



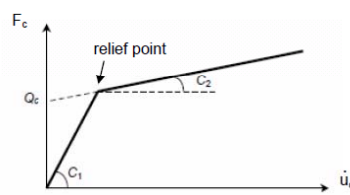
Force – Deformation relationship



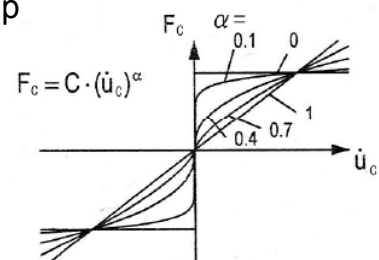
Hysteresis damper



Force – Velocity relationship

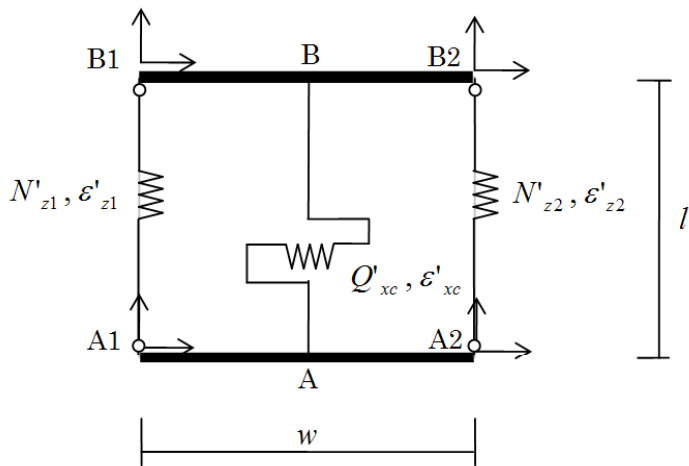


Oil damper

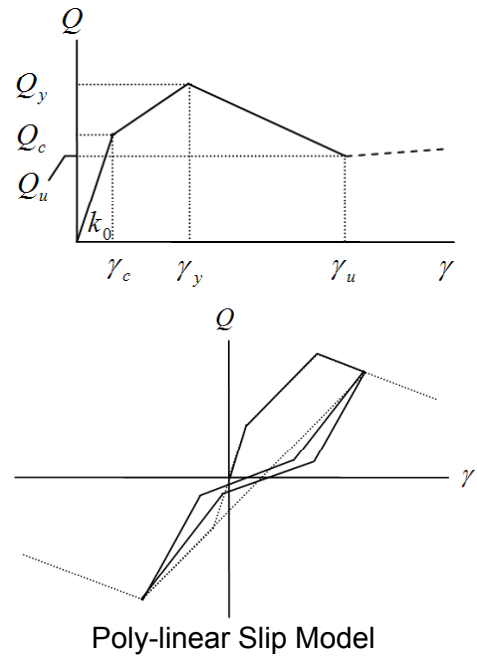


Viscous damper

Masonry Wall



Nonlinear Shear Spring



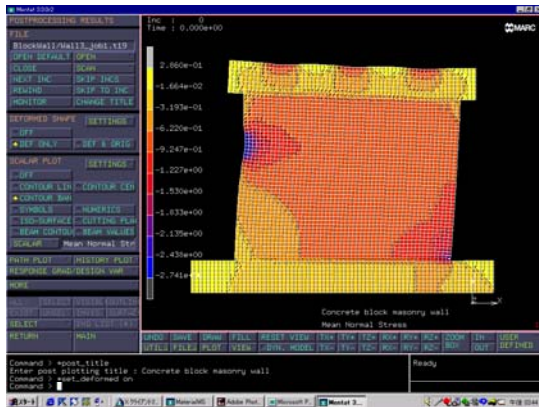
<http://iisee.kenken.go.jp/net/saito/ster3d/index.html>

Frame analysis (STERA 3D Software)

FEM (Finite Element Model) analysis

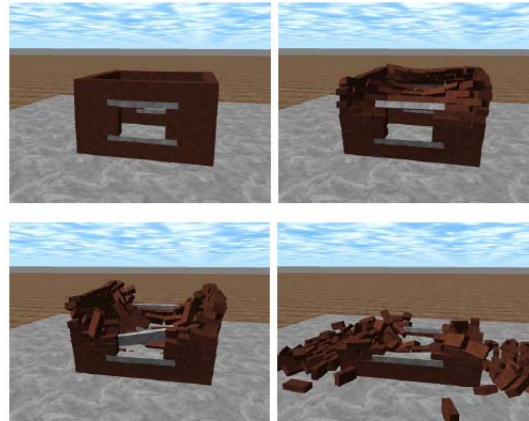
DEM (Discrete Element Model) analysis (STERA Briq Software)

FEM analysis



Stress distribution

DEM analysis



Collapse analysis

Conclusions

- Seismic resistance = potential energy
- Seismic rehabilitation strategy using capacity curve
 - Increase C, F, or C&F
 - Using damper devices
 - Seismic Isolation
- Capacity curve for masonry
 - Plain masonry < Confined masonry
- Tools for seismic analysis
 - STERA3D
 - DEM software (SERABriq)