BASIC DESIGN FOR SEISMIC ISOLATION STRUCTURE AND ITS STRUCTURAL CALCULATION

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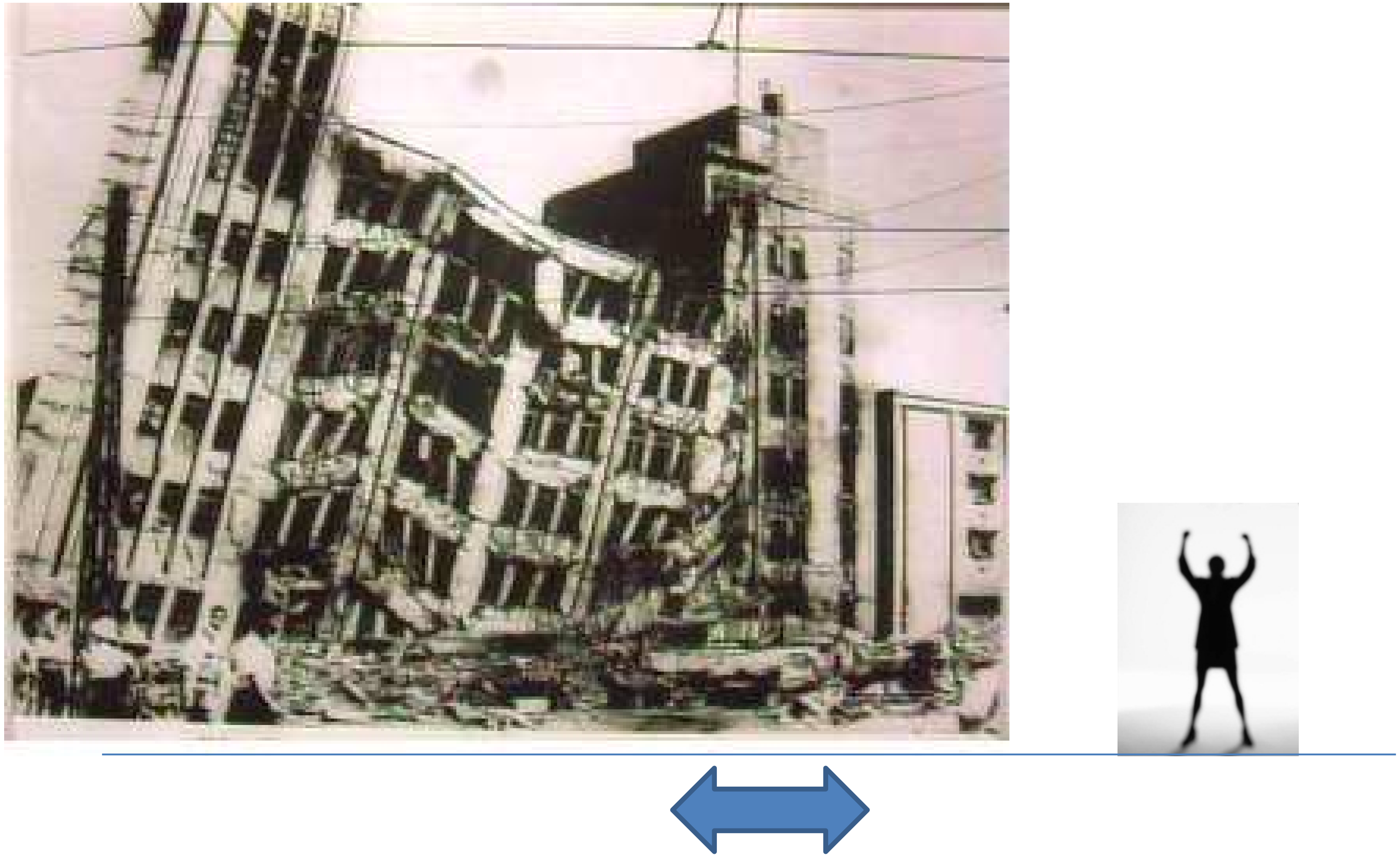
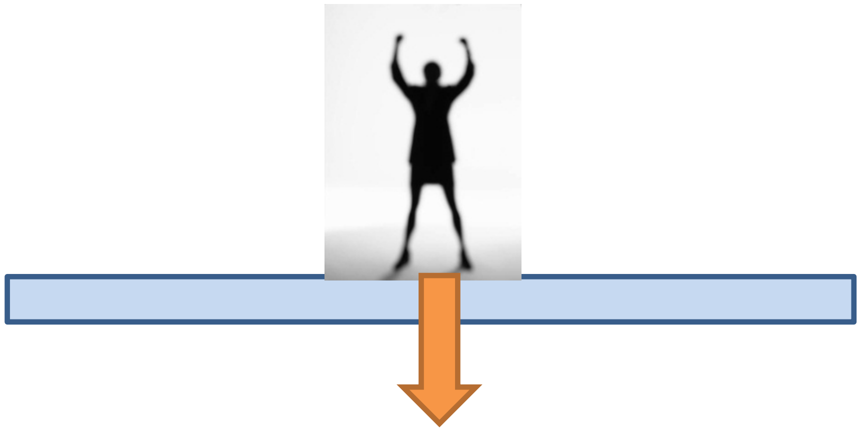
Q1. Why building is weaker than human?



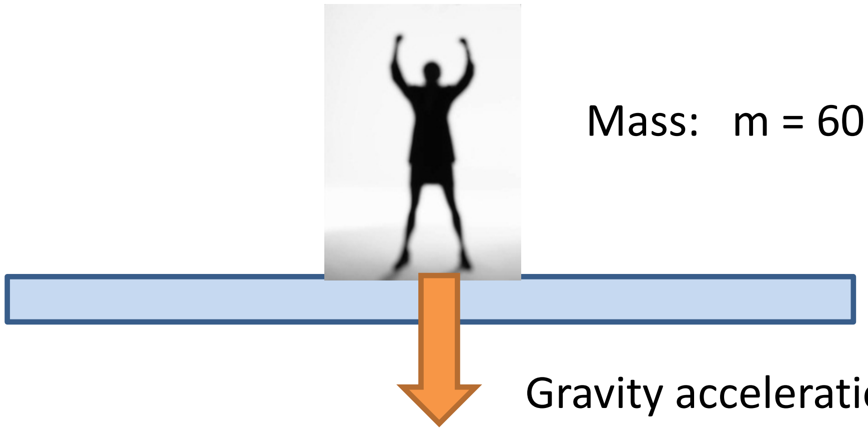
Q1. Why building is weaker than human?

Are you feeling “acceleration”?



Q1. Why building is weaker than human?

Weight = Mass × Acceleration



Mass: $m = 60$ kg

Gravity acceleration: $G = 9.8\ m/s^2$

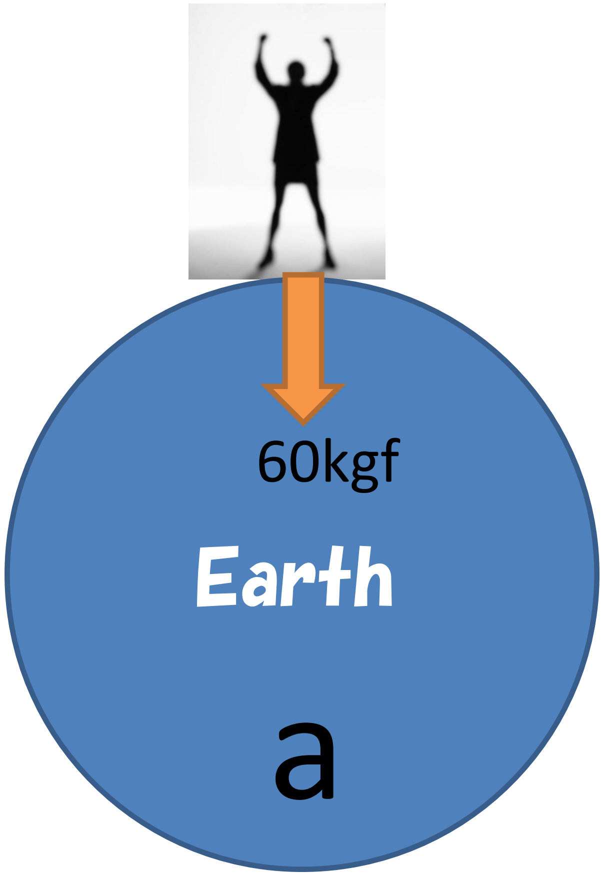
Weight: $F = 60$ kgf

$$F = m \times a\ (=G)$$

Q1. Why building is weaker than human?

Force is different by the acceleration

$$F = m \times \boxed{a}$$

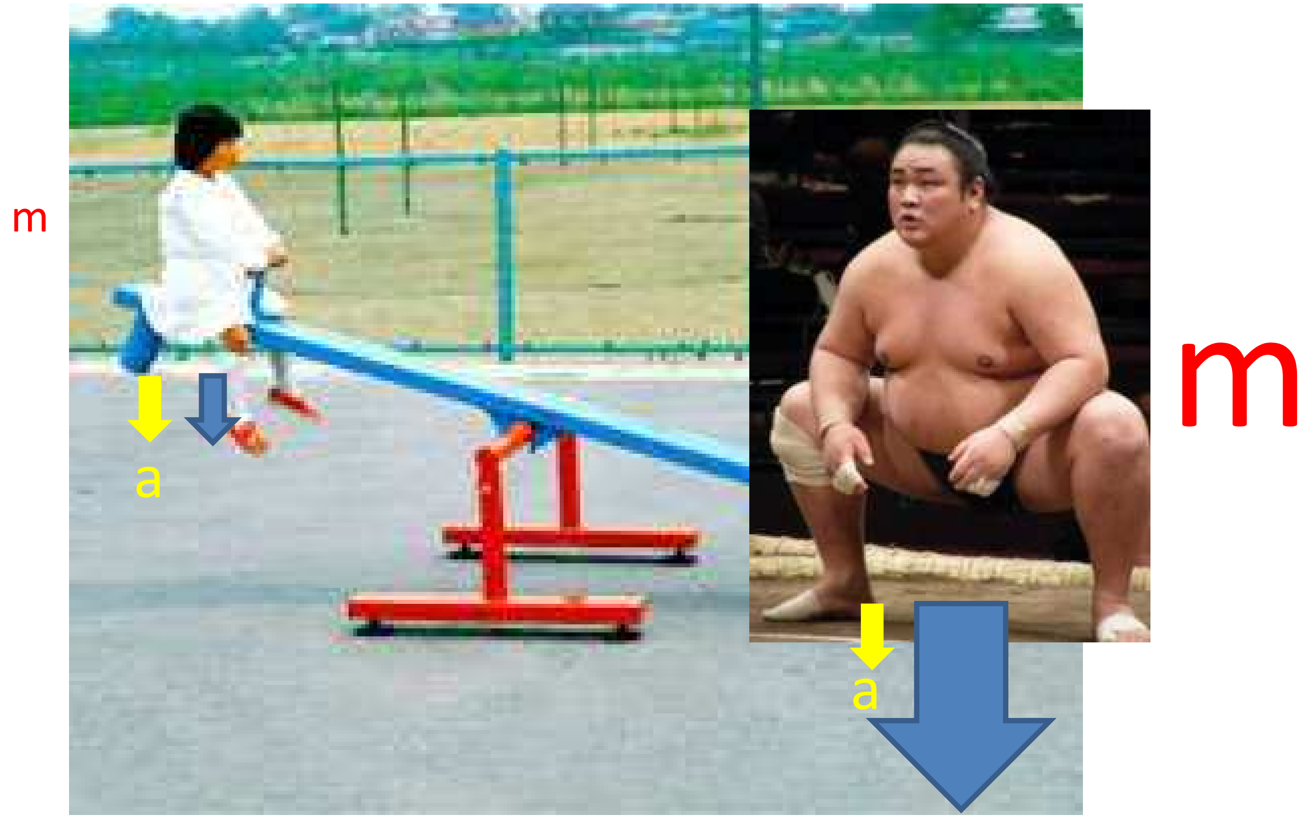


Gravity of Moon is 1/6 G

Q1. Why building is weaker than human?

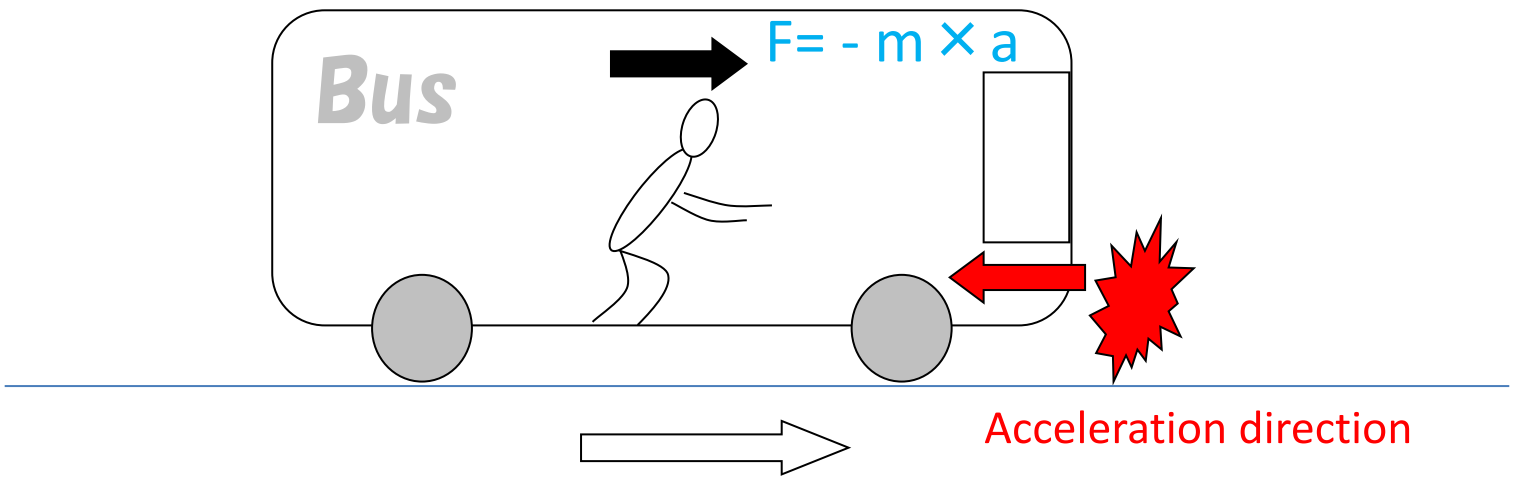
Force is different by the mass

$$F = \boxed{m} \times a$$



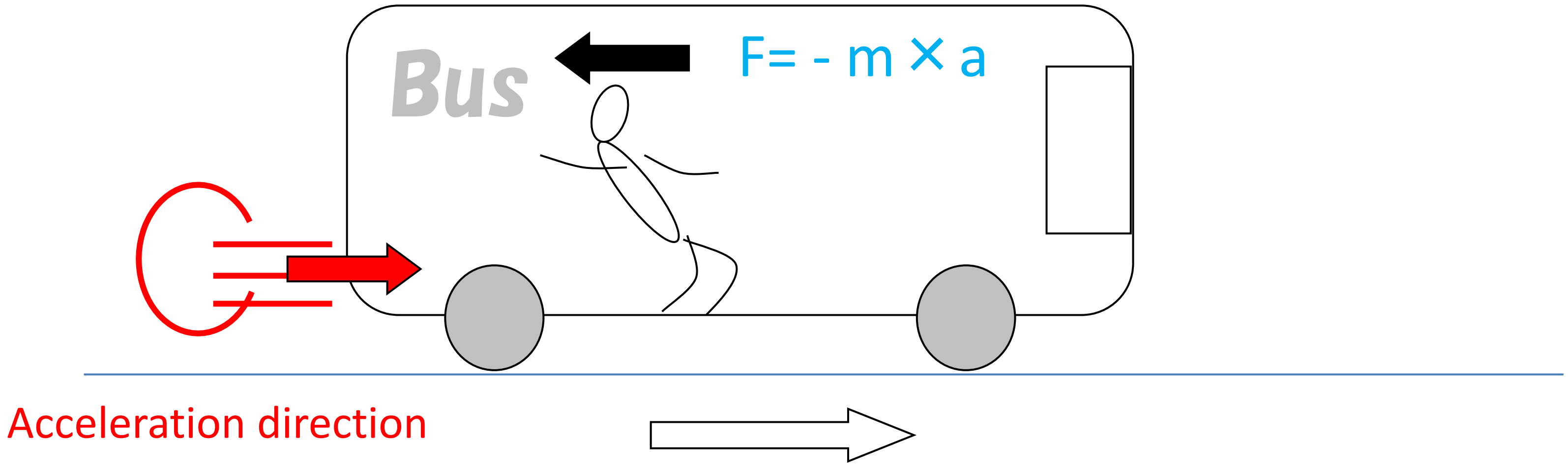
Force from lateral acceleration

Inertia force opposite to acceleration direction



Force from lateral acceleration

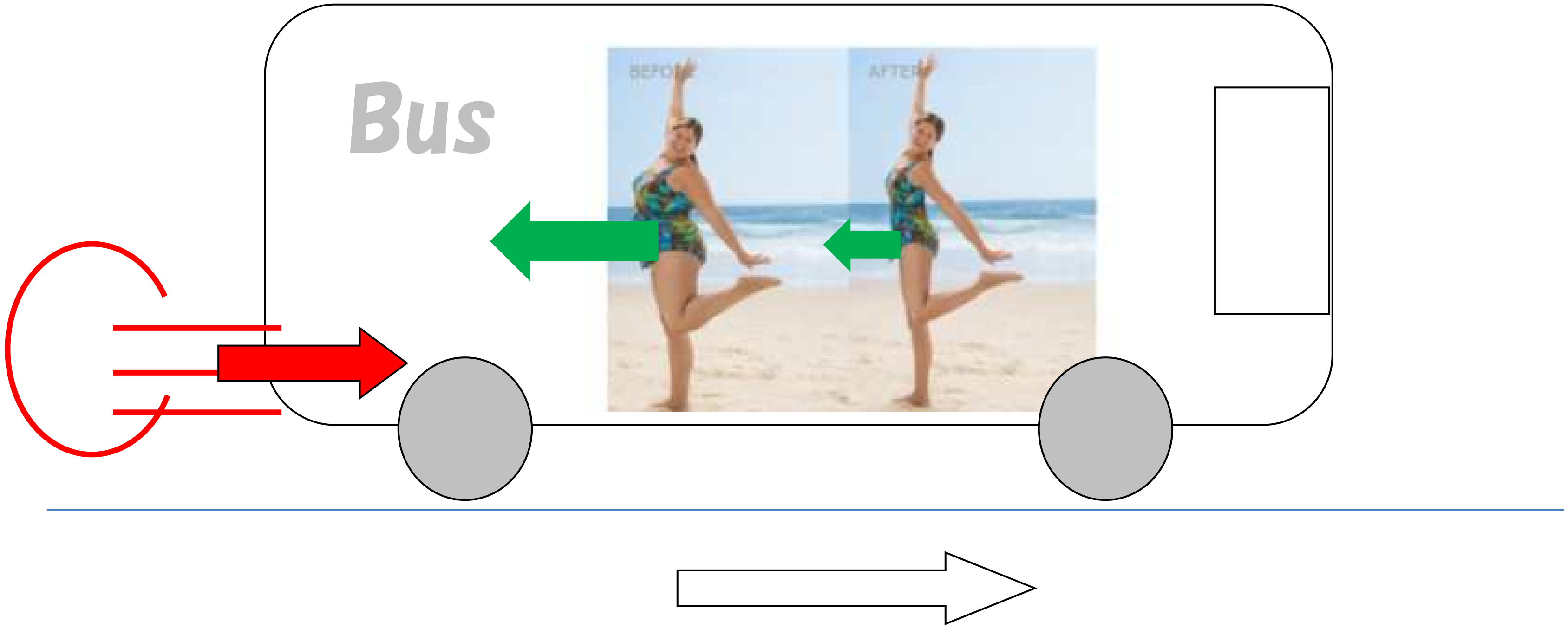
Inertia force opposite to acceleration direction



Q1. Why building is weaker than human?

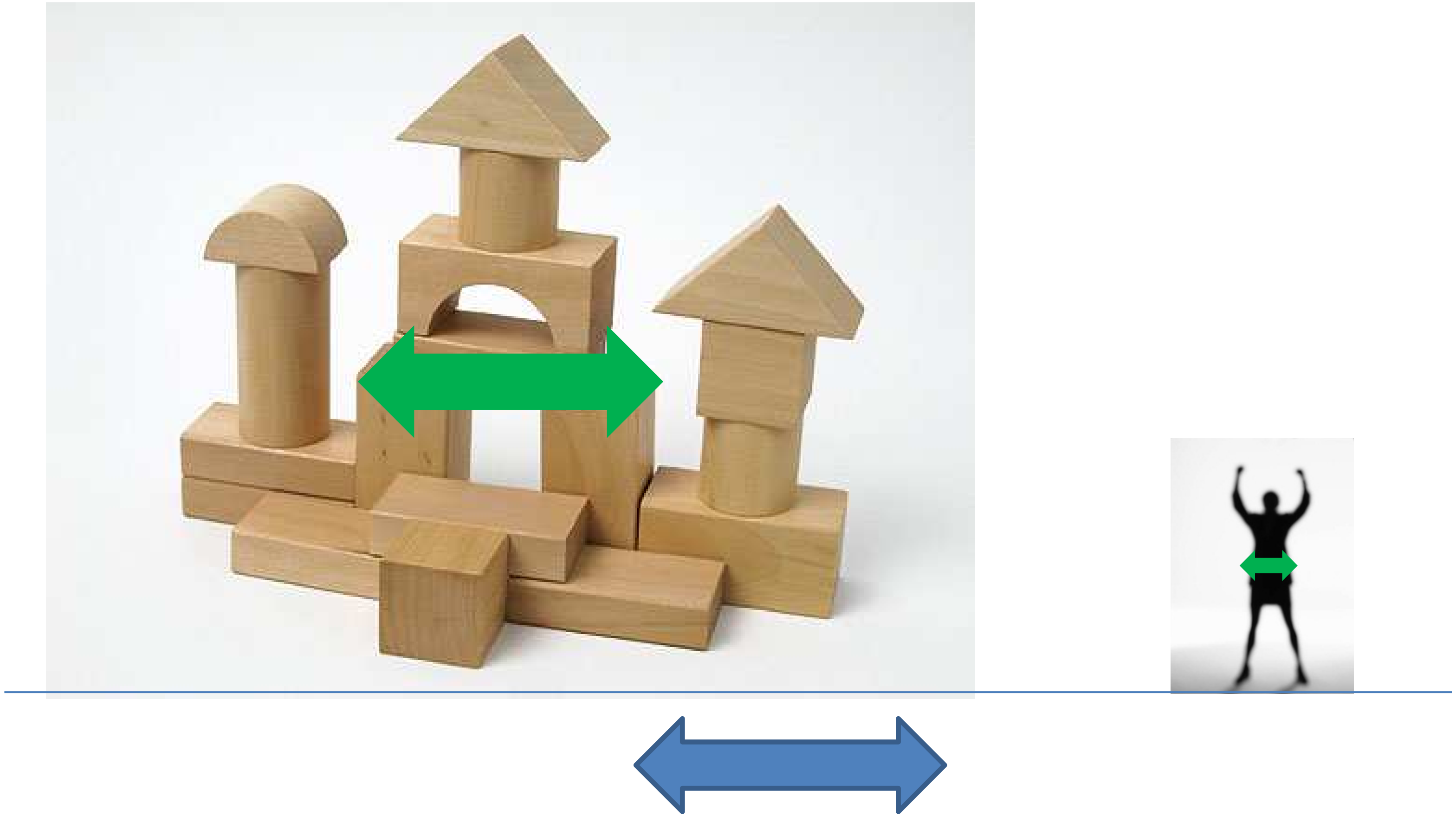
Which inertia force is larger?

$$F = m \times a$$



Q1. Why building is weaker than human?

Which inertia force is larger?



Heavy masonry building is easily destroyed by inertia force

Nepal Earthquake (2015 04/25)

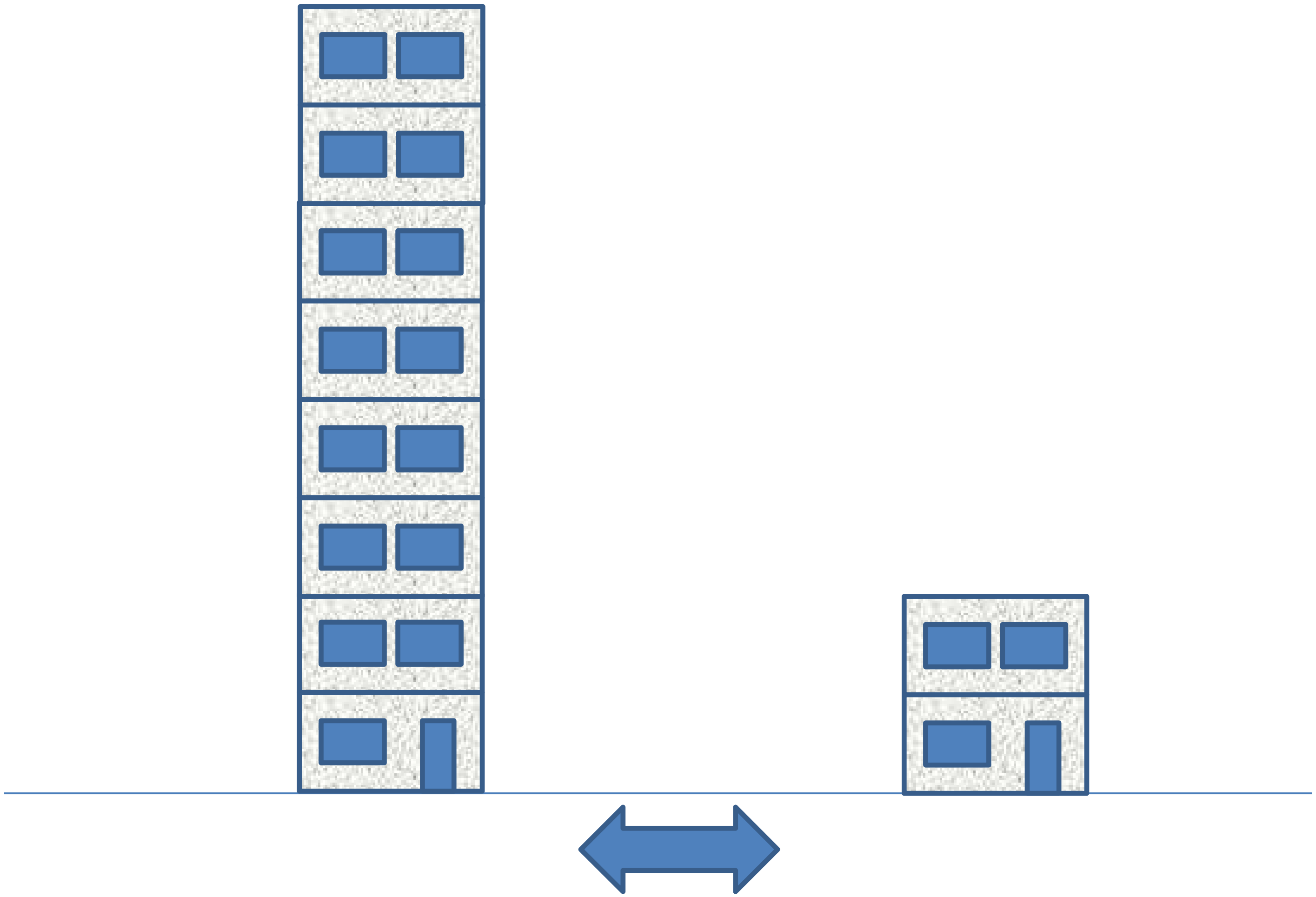
Reducing Inertia Force (simple retrofitting technique)

Demolish 4th floor

4F → 3F

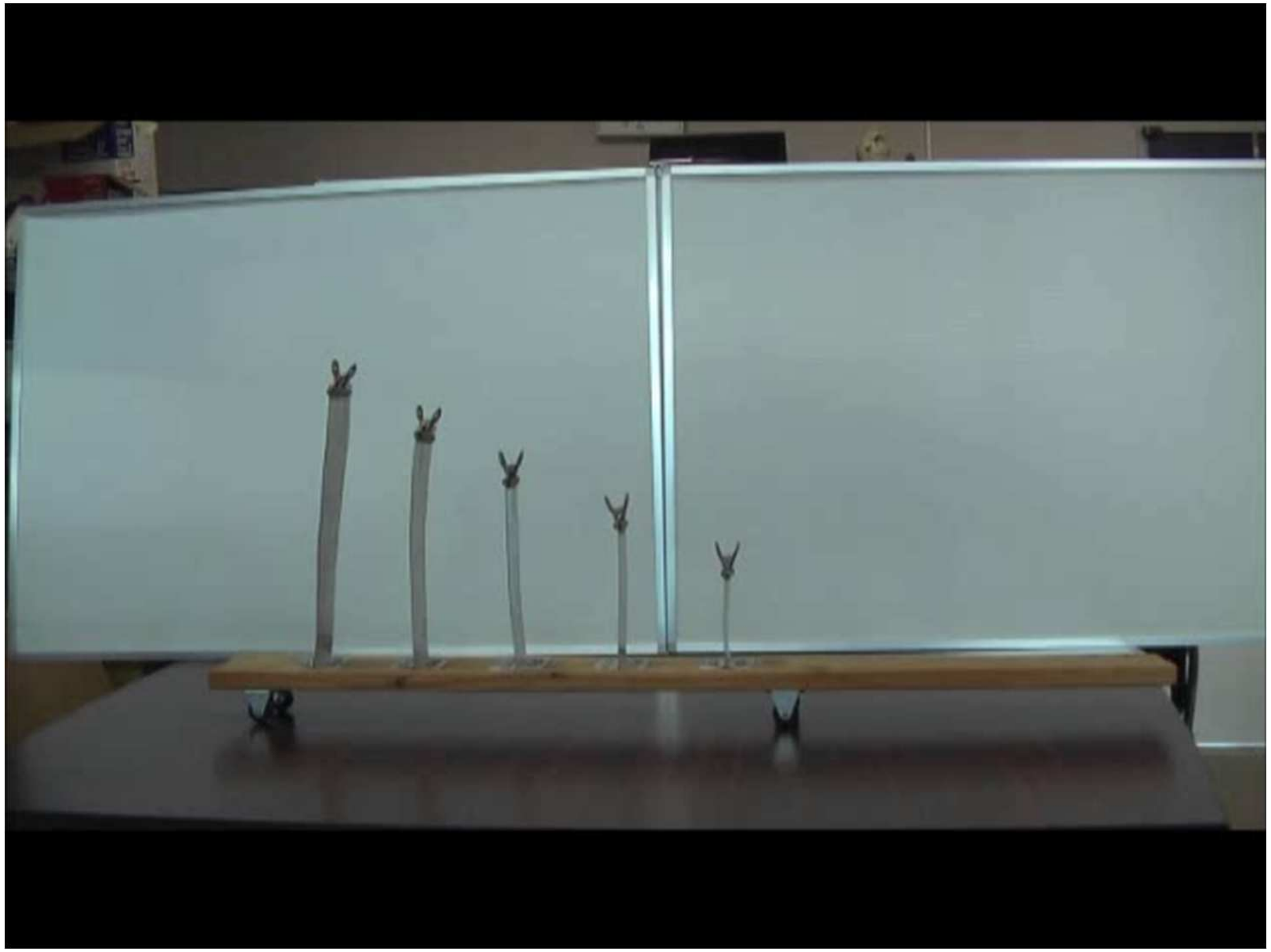
(Junior high-school in Mito city, Japan)

Q2. Which building is safer?



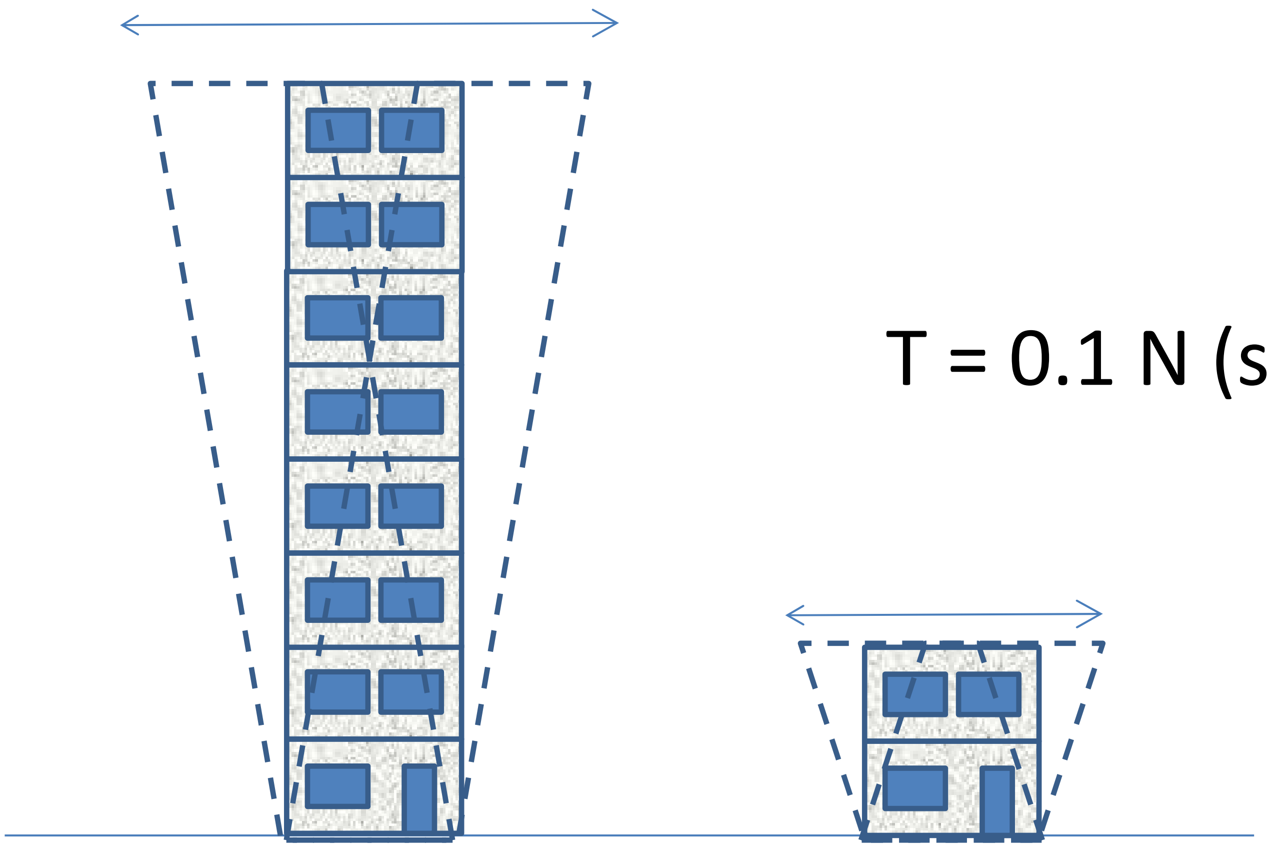
Q2. Which building is safer?

Shake the model



Q2. Which building is safer?

(1^{st}) Natural period of a building



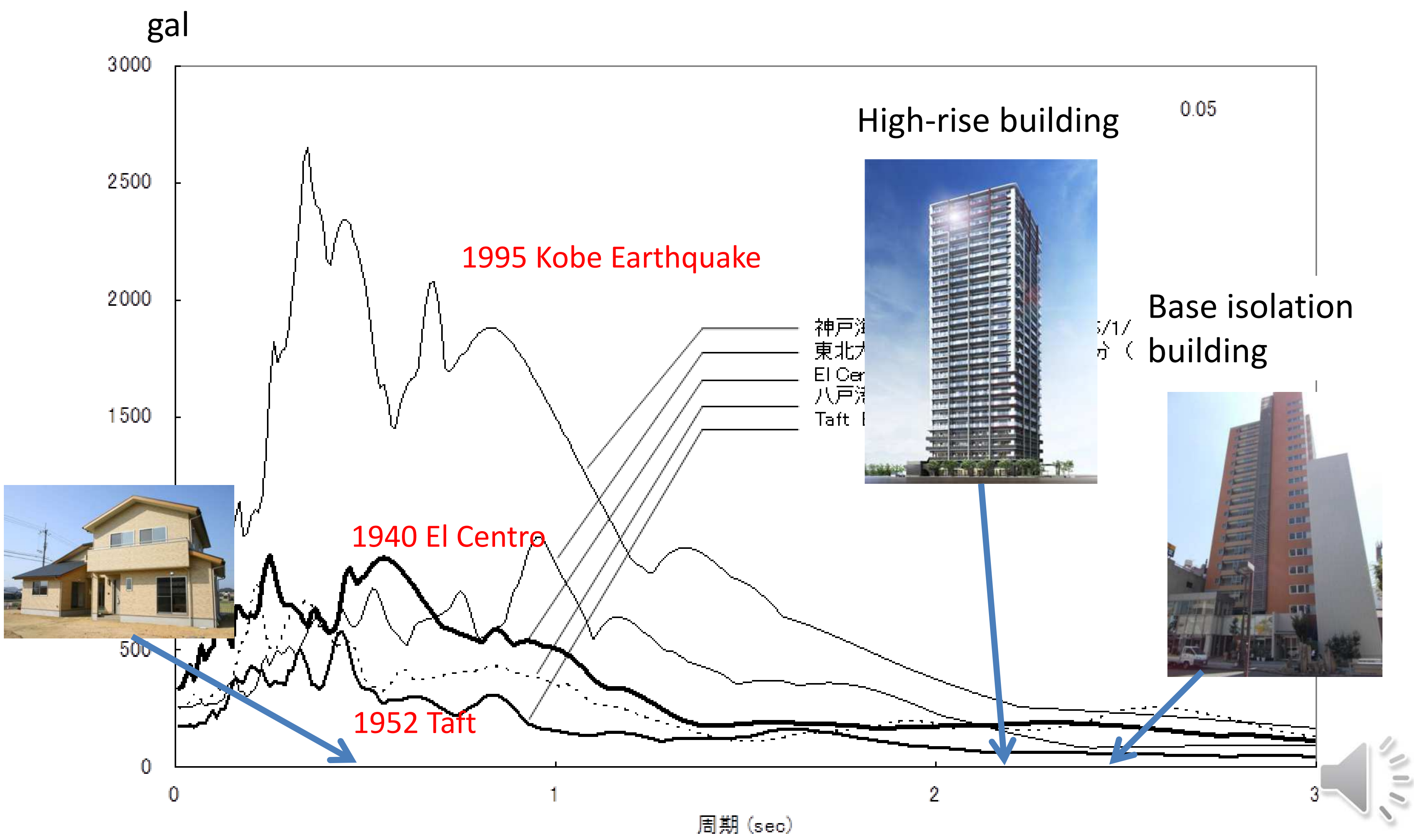
T = 0.1 N (sec)

T = 0.8 sec

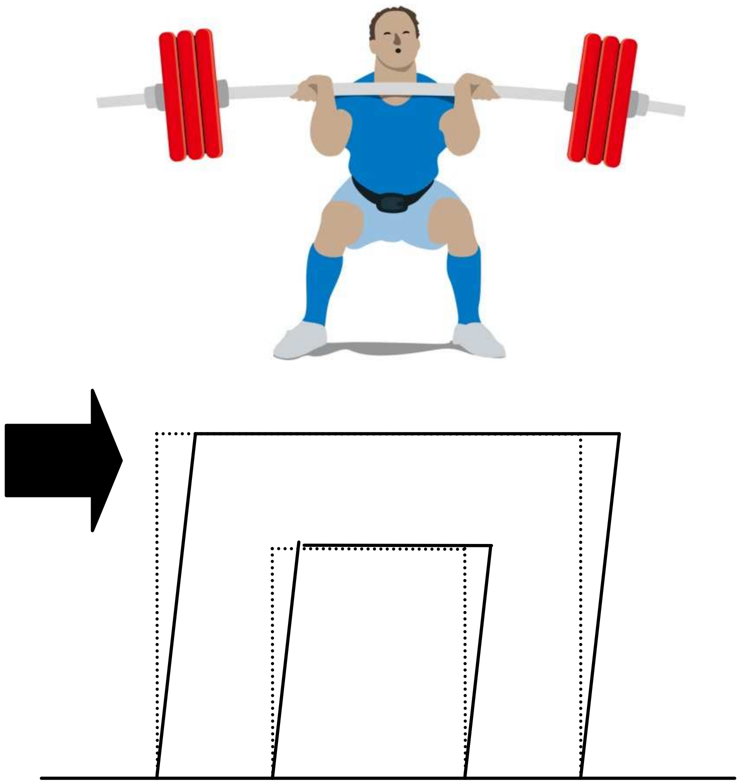
T = 0.2 sec

Q2. Which building is safer?

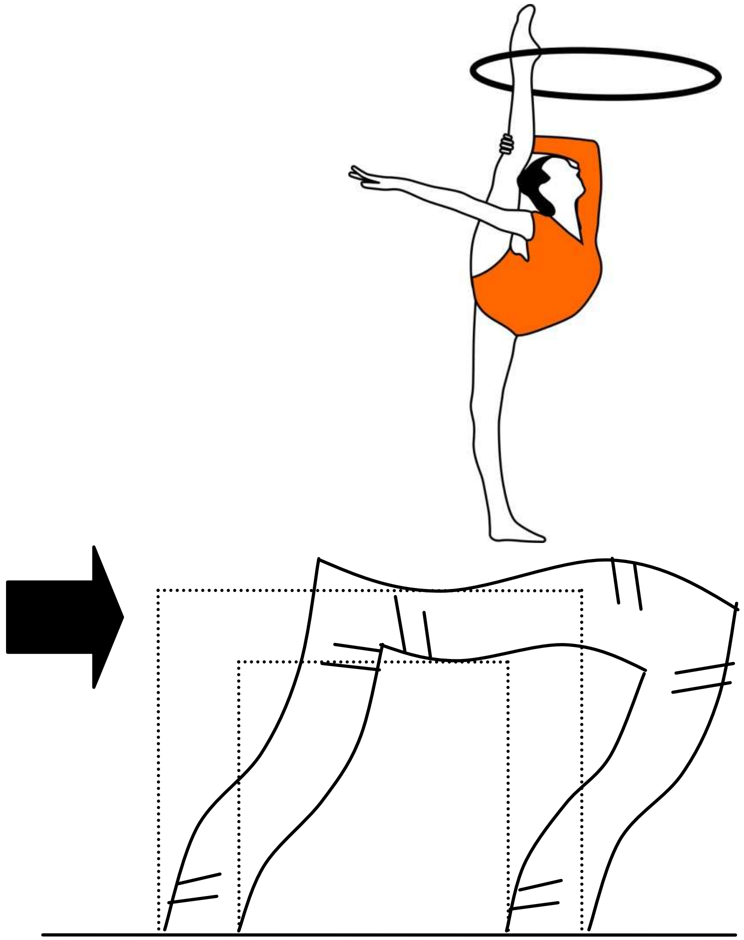
Response spectrum



Q3. Strong or ductile?



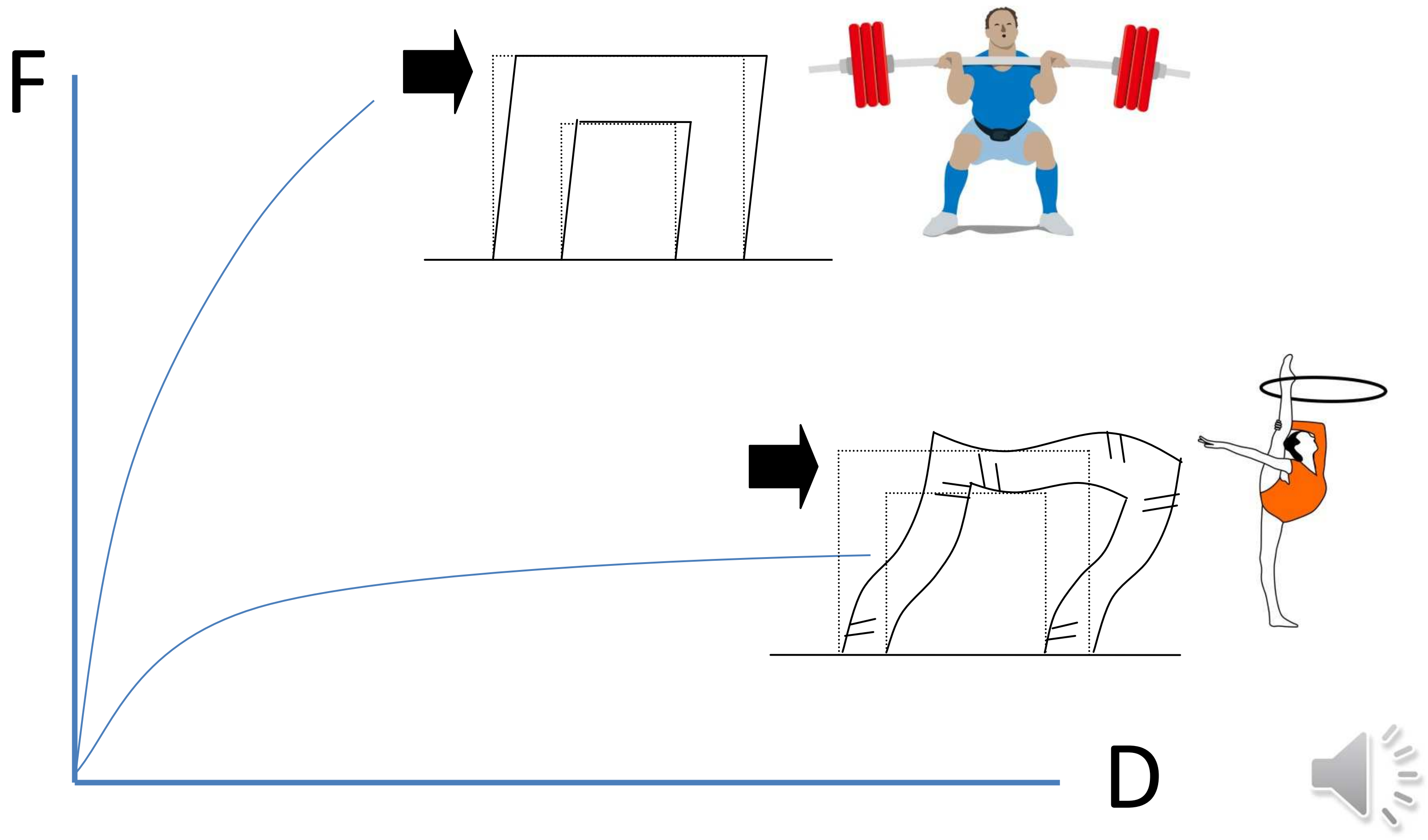
strong



ductile

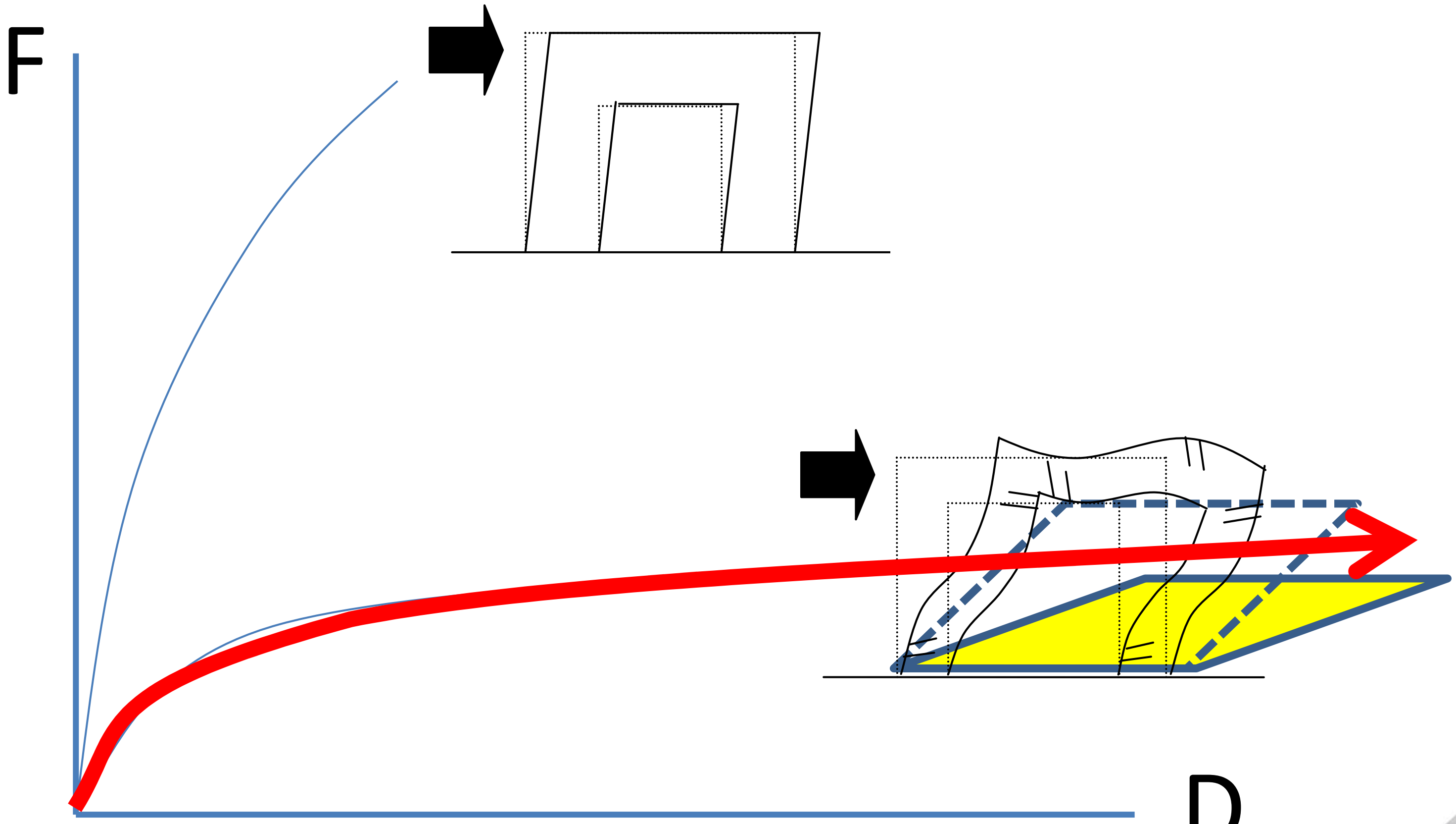
Q3.Strong or ductile?

Force v.s. deformation
(performance curve)

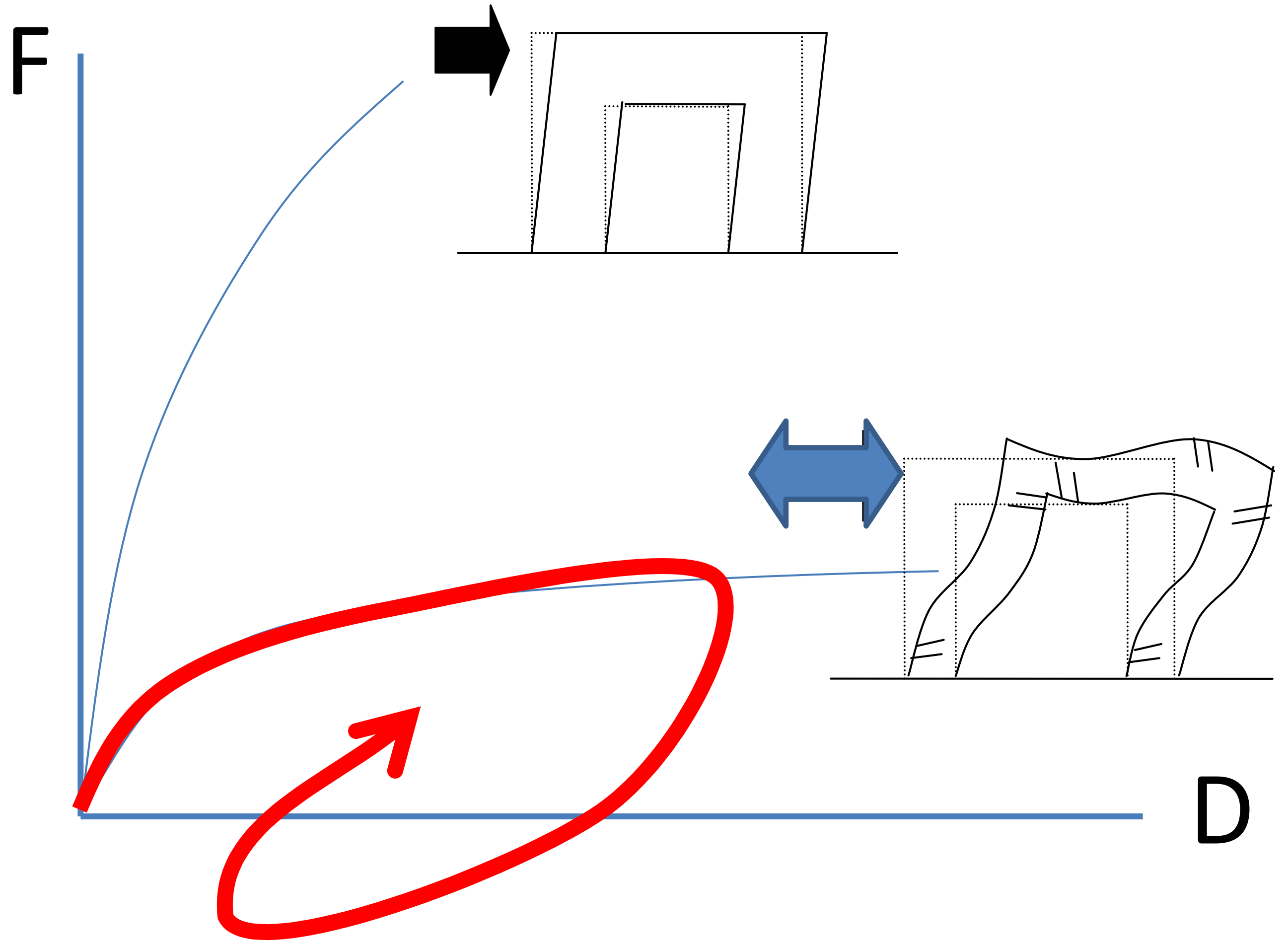


Q3.Strong or ductile?

Static force (monotonic loading)

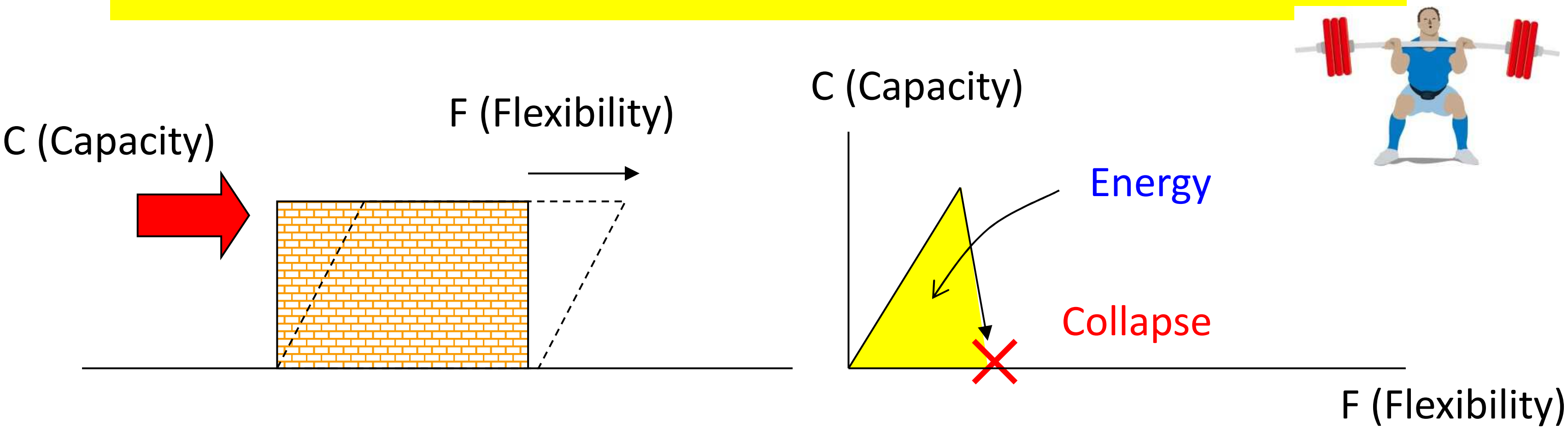


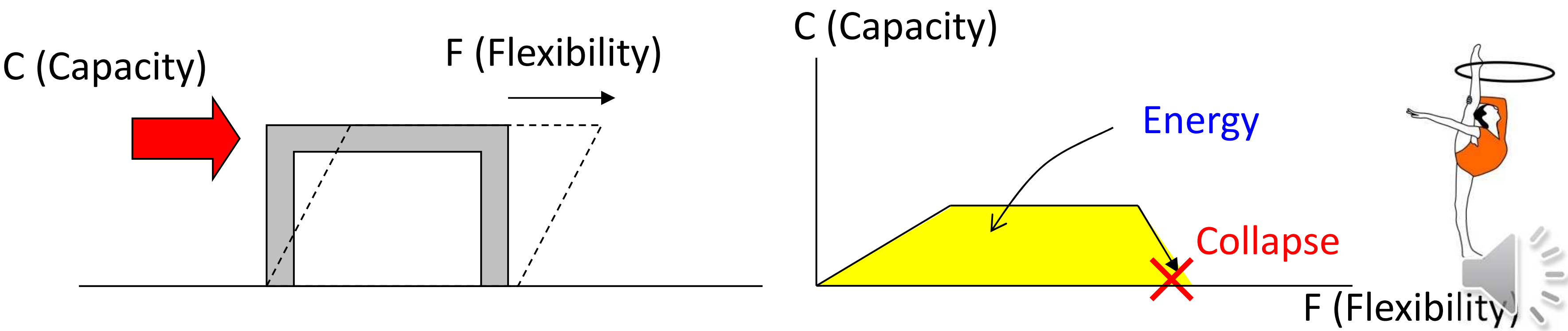
dynamic force (such as earthquake)



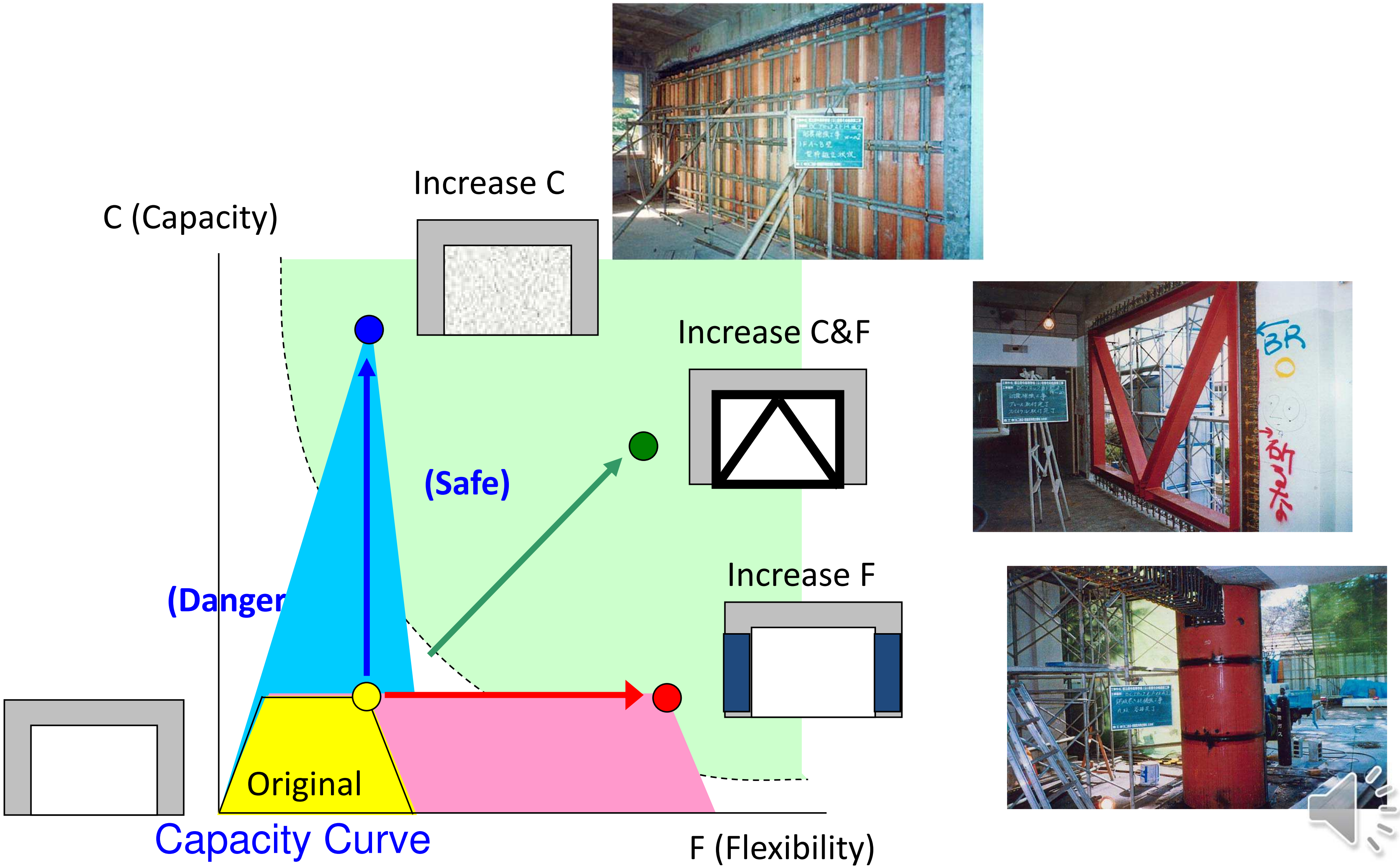
Energy concept

Seismic Resistance = Potential Energy





Retrofitting Techniques (1. Conventional method)

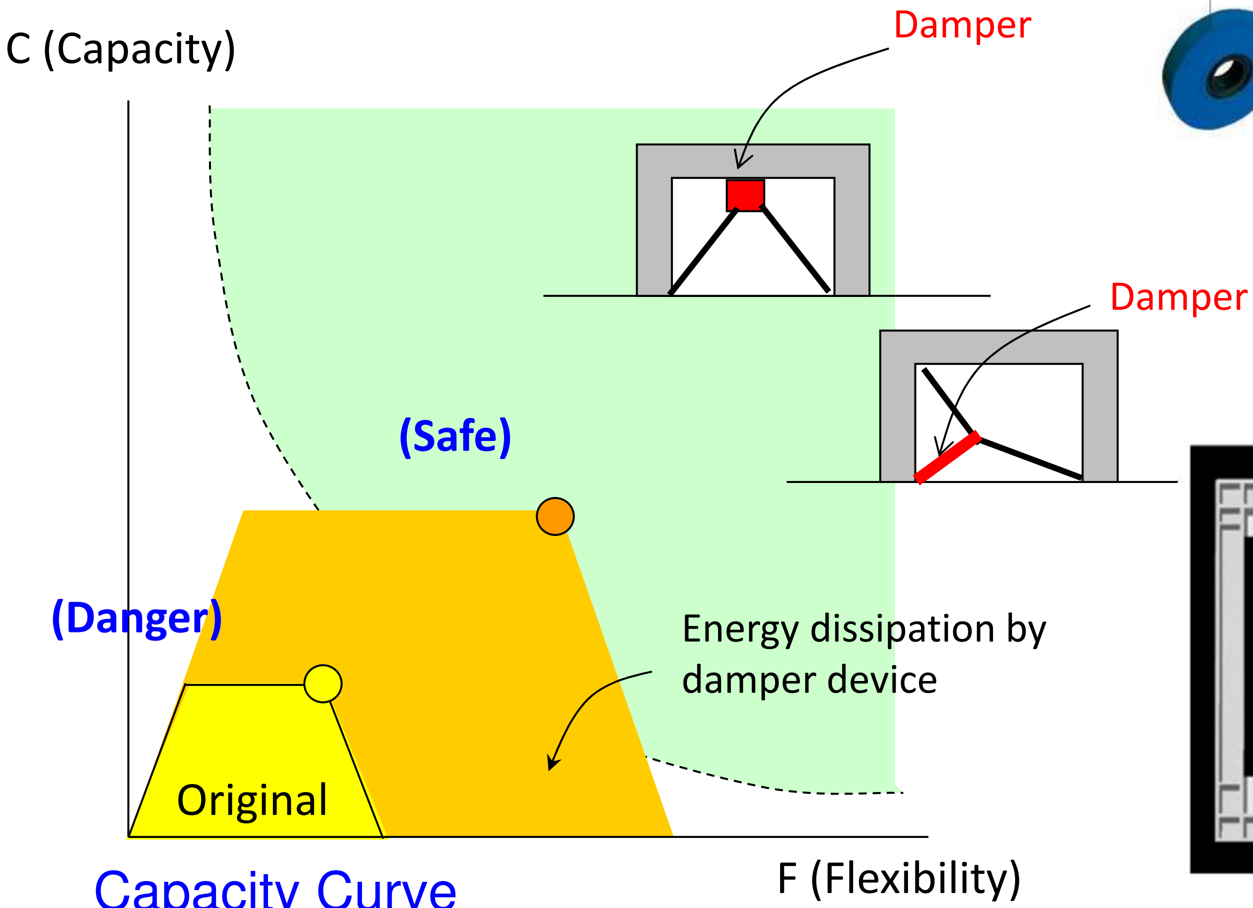


Seismic Retrofitting (Toyohashi University of Technology)

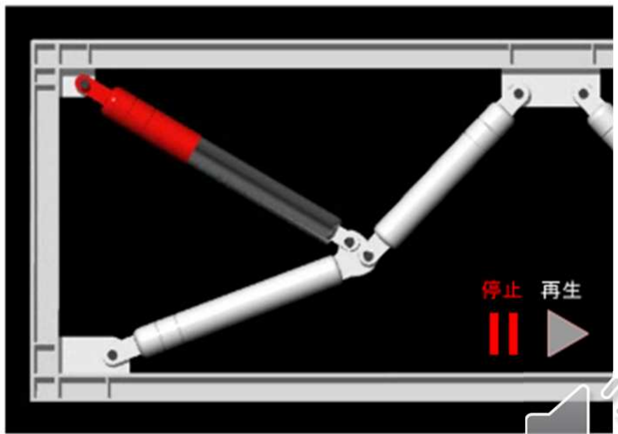
Retrofitting Techniques (2. Response control device)

Oil damper

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

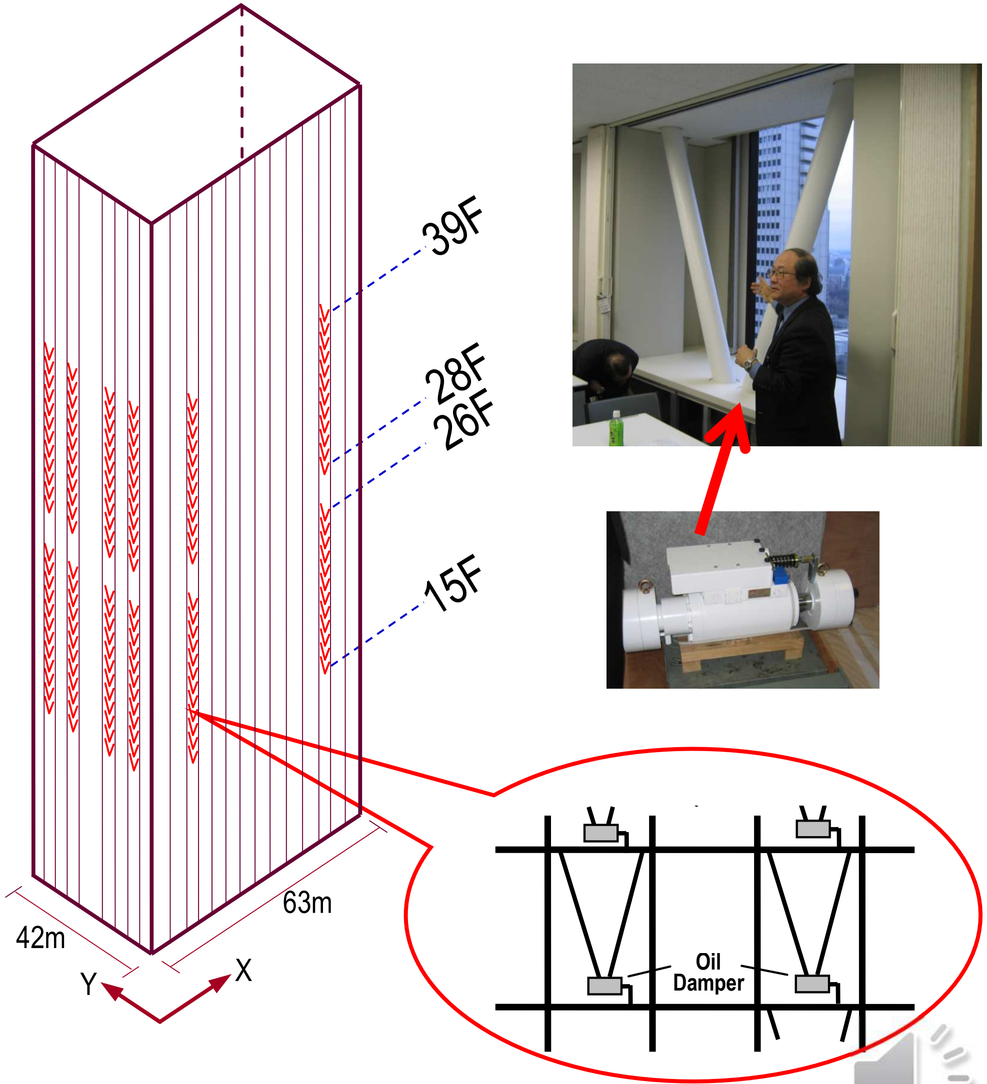


Capacity Curve



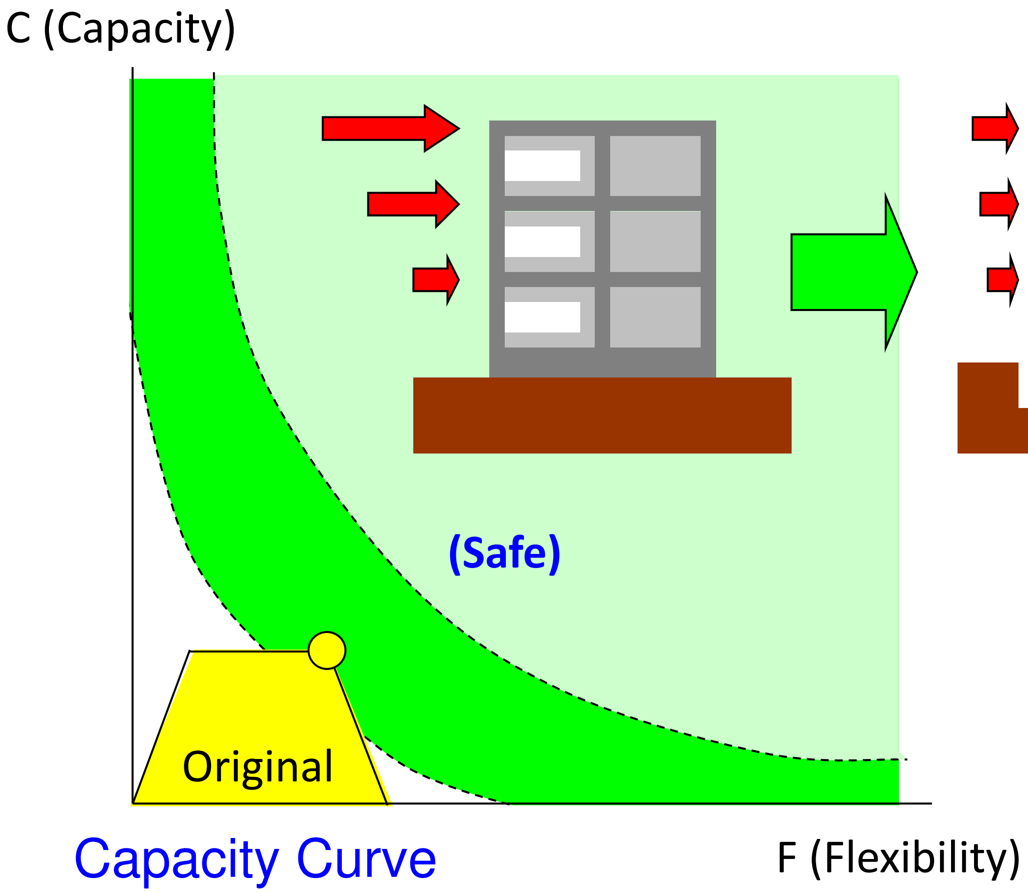
54-Story Bldg. Retrofitted by 288 Oil Dampers.

Constructed in 1979, retrofitted in 2009 using oil dampers



(from K. Kasai)

Retrofitting Techniques (3. Seismic isolation)



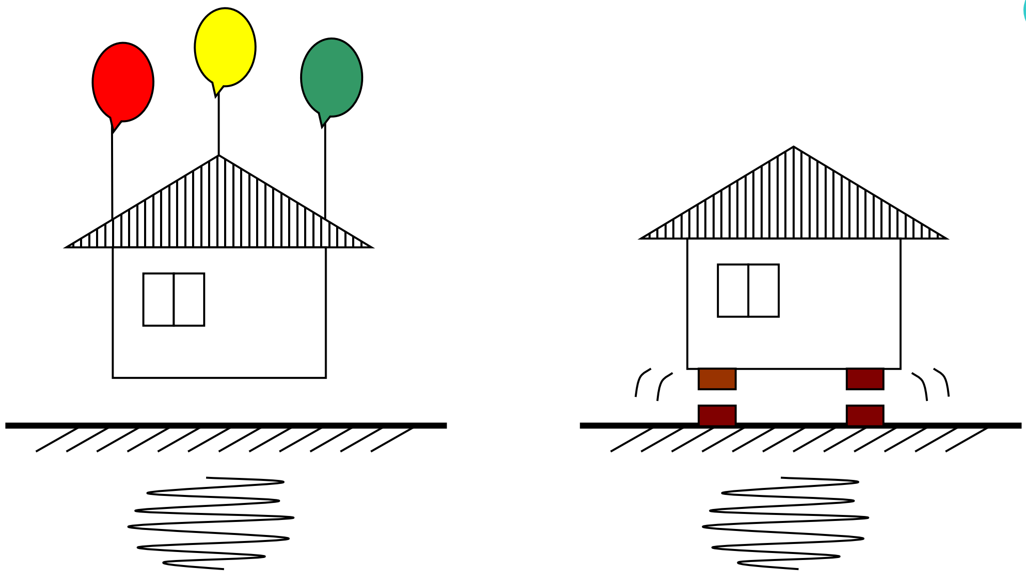
Laminated Rubber bearing

Lead damper

Steel damper

Basic Idea of SI system

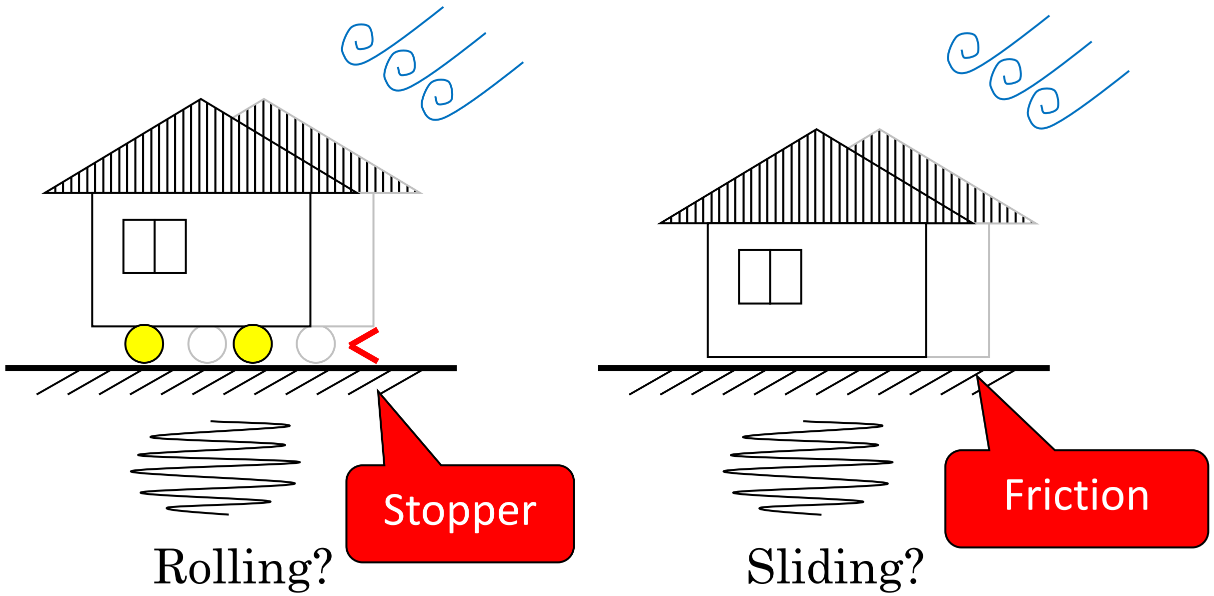
- Isolation from ground



By balloon? By Magnetic force?

How to stop movement against wind?

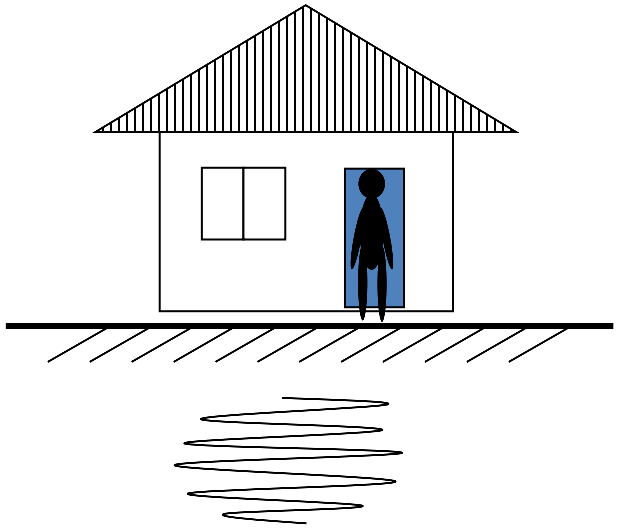
- Seismic Isolation



- Example of sliding system

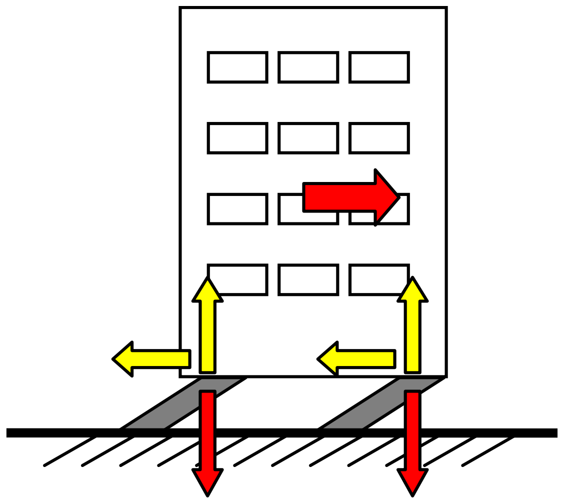
Kamakura statue was rehabilitated in 1960 adopting sliding foundation.

- Restoring position?



Sliding?

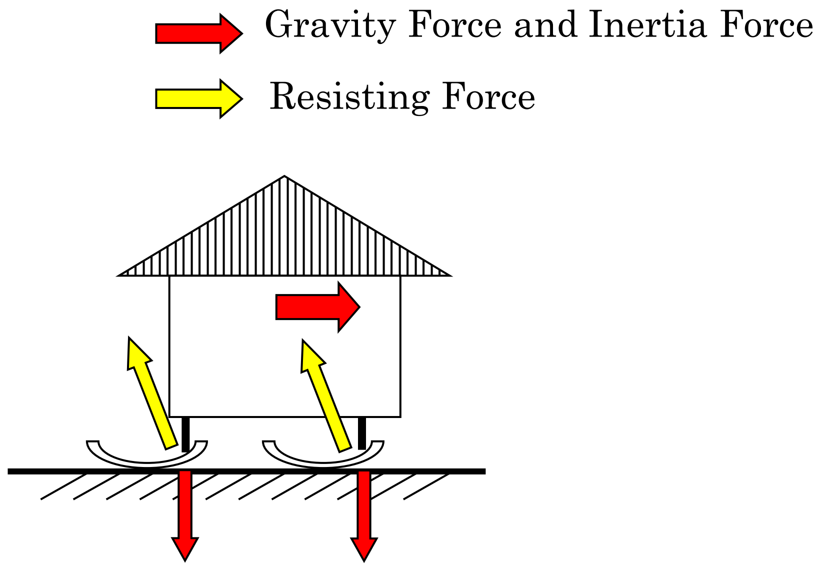
Typical base isolation system



$$T = 2\pi\sqrt{\frac{m}{k}}$$

(m: mass, k: stiffness)
Effective for heavy weight building

Rubber bearing



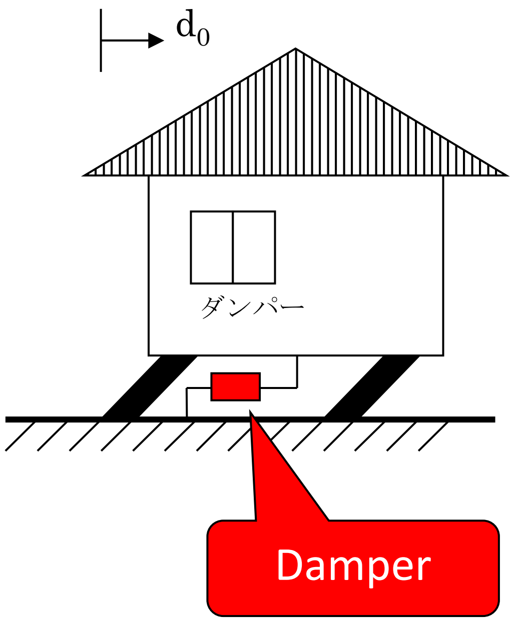
$$T = 2\pi\sqrt{\frac{L}{g}}$$

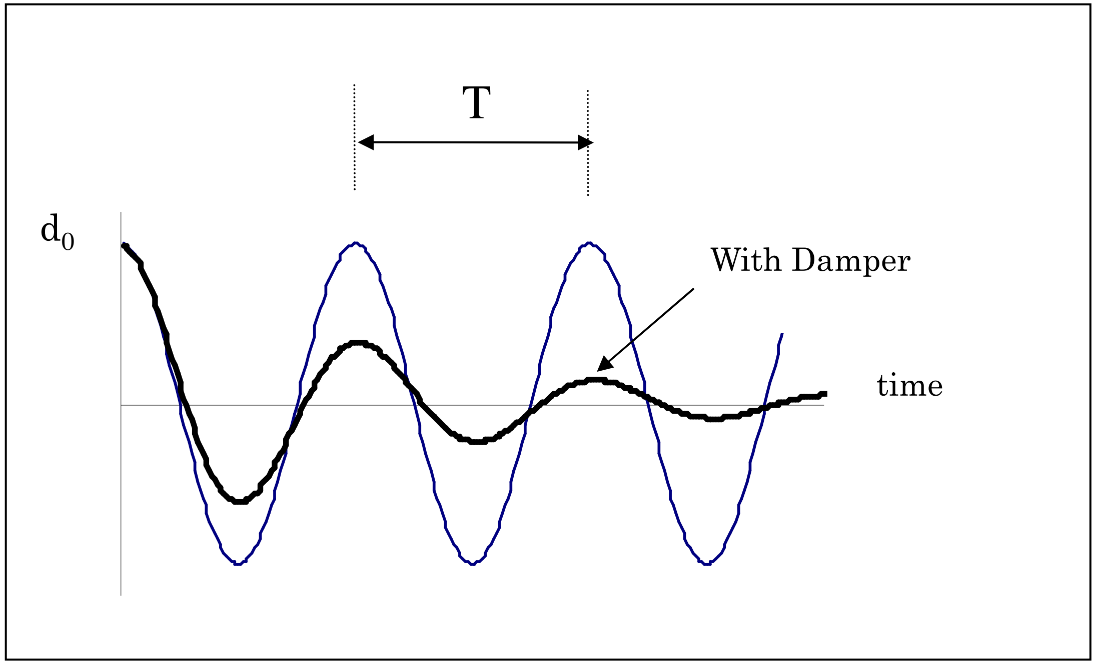
(L: curvature, g: gravity acceleration)
Effective for light weight building

sliding bearing

How to stop vibration?

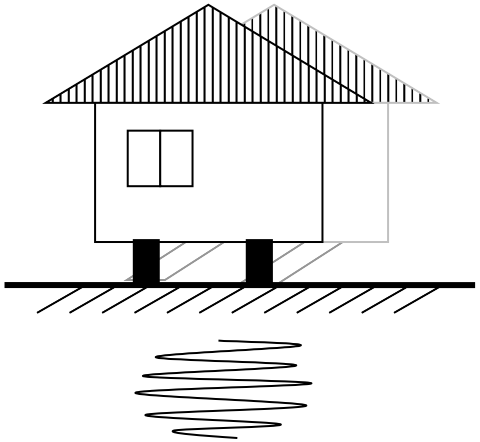
- Damping system

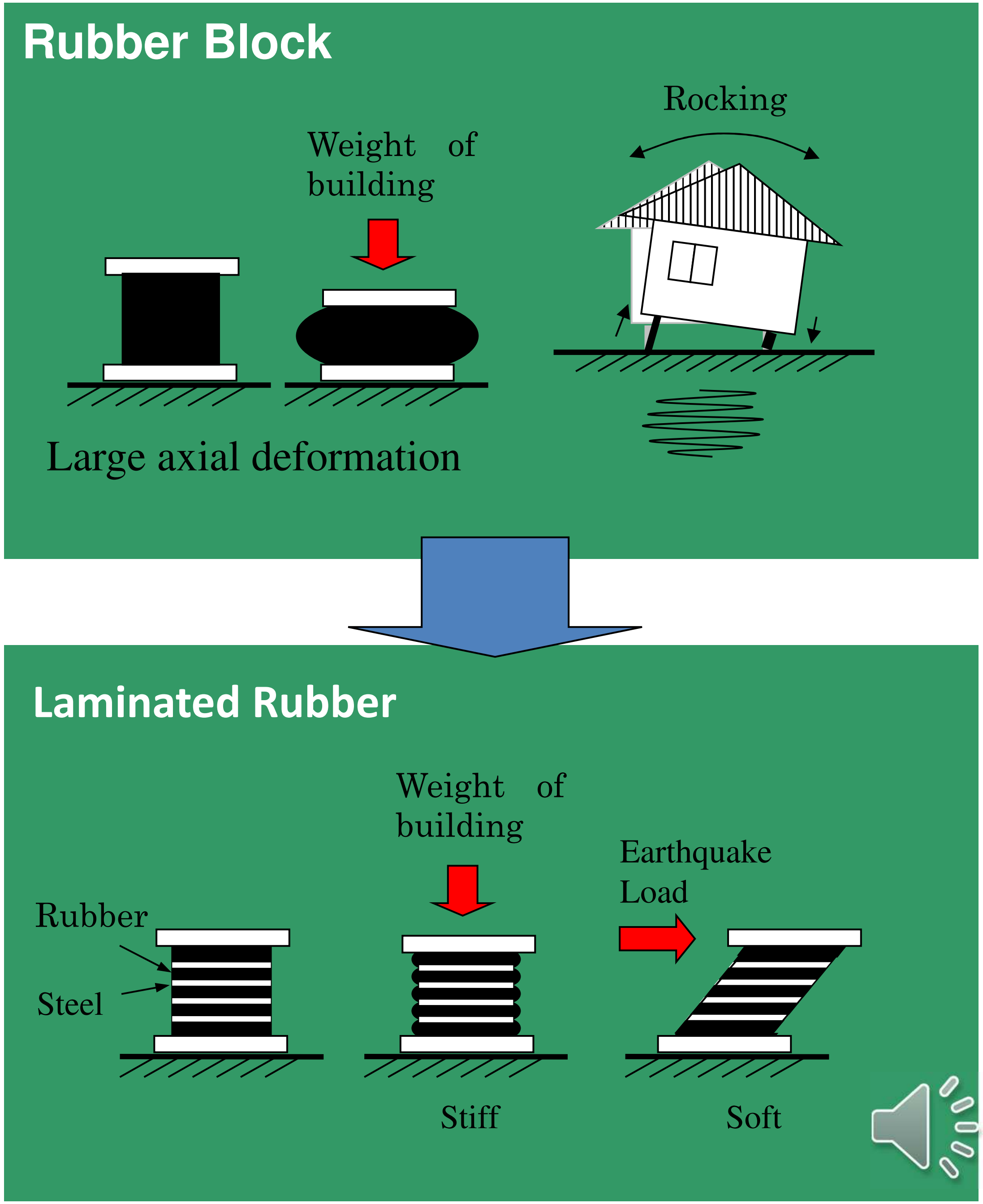




Rubber

Rubber bearing



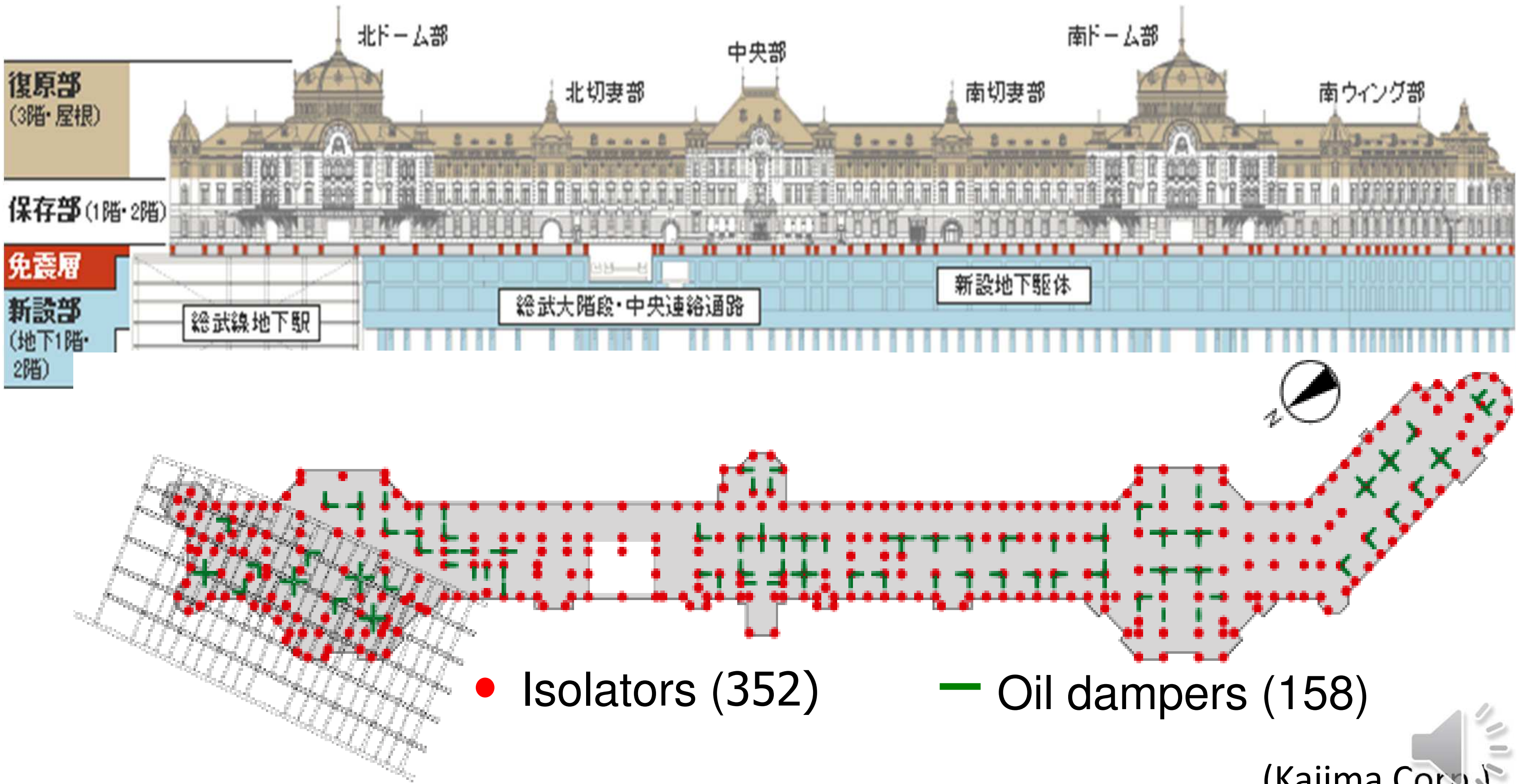


Large deformation of rubber bearing

By Bridgestone Co.

Example

Restoration of Tokyo Station



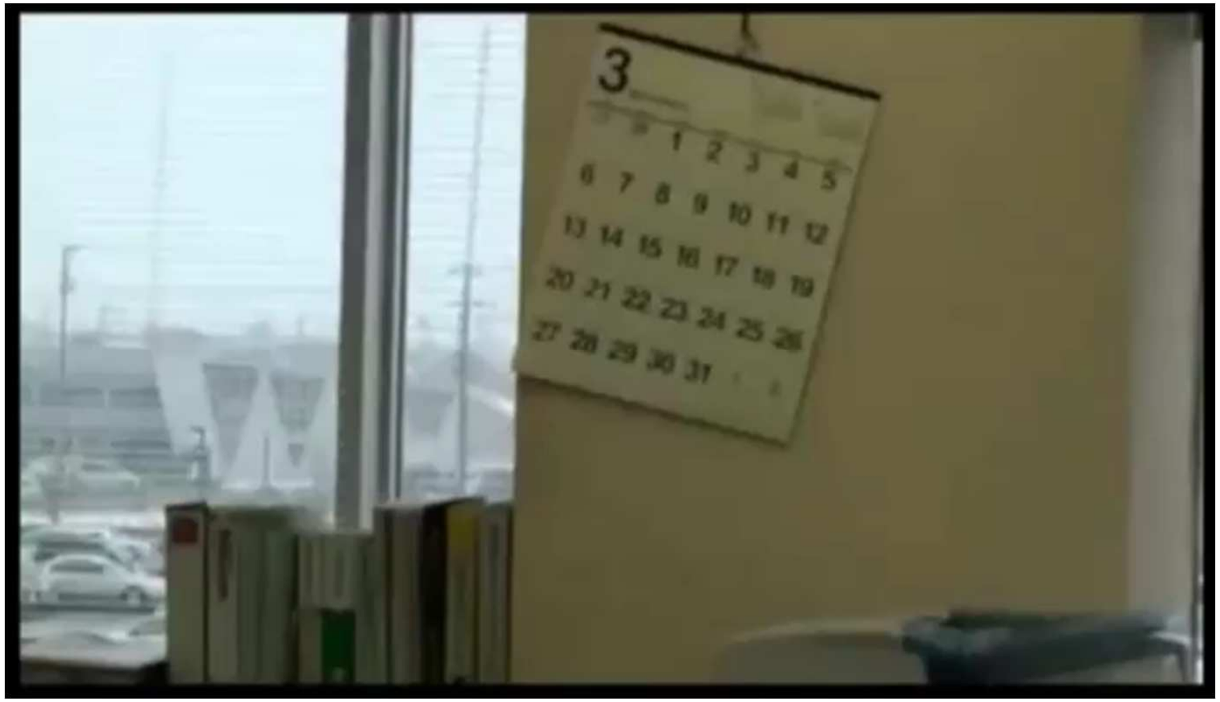
(Kajima Corp.)

Successful case of SI building

Ishinomaki Red-Cross Hospital

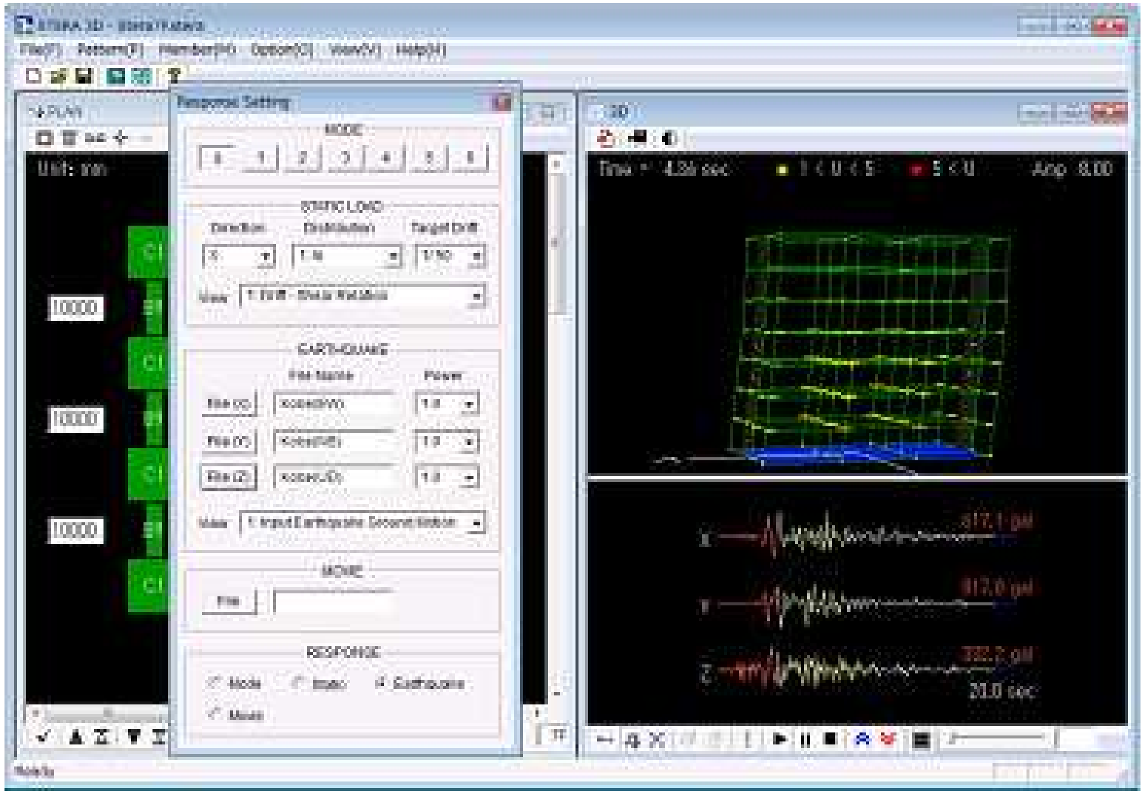
Casualties in Ishinomaki = 3,700 people
by Tsunami at 2011 Great East Japan Earthquake

Resumed medical activities for one hour after the earthquake and accepted 2,800 patients in three days.



STtructural Earthquake Response Analysis
STERA_3D

http://www.rc.ace.tut.ac.jp/saito/software-e.html



- Free download
- Tutorial video on YouTube
- User manual in JP, EN, SP, CN
- Technical manual in EN

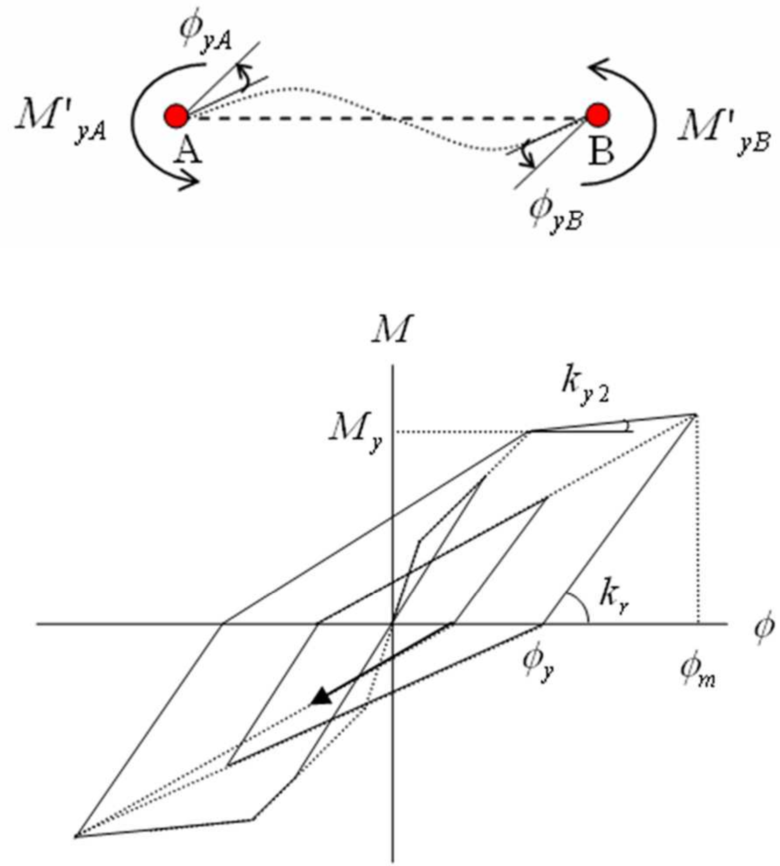
Used widely in JICA training courses for seismic engineering

2019 Education Award from AIJ (Architectural Institute of Japan)

Prof. Akenori Shibata

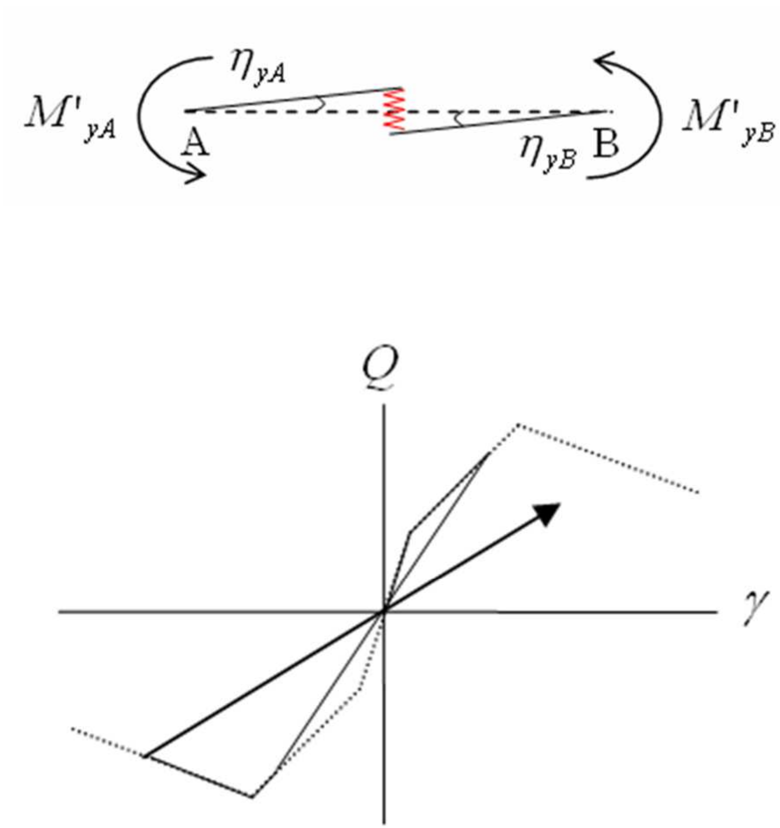
Beam Model

Nonlinear bending spring



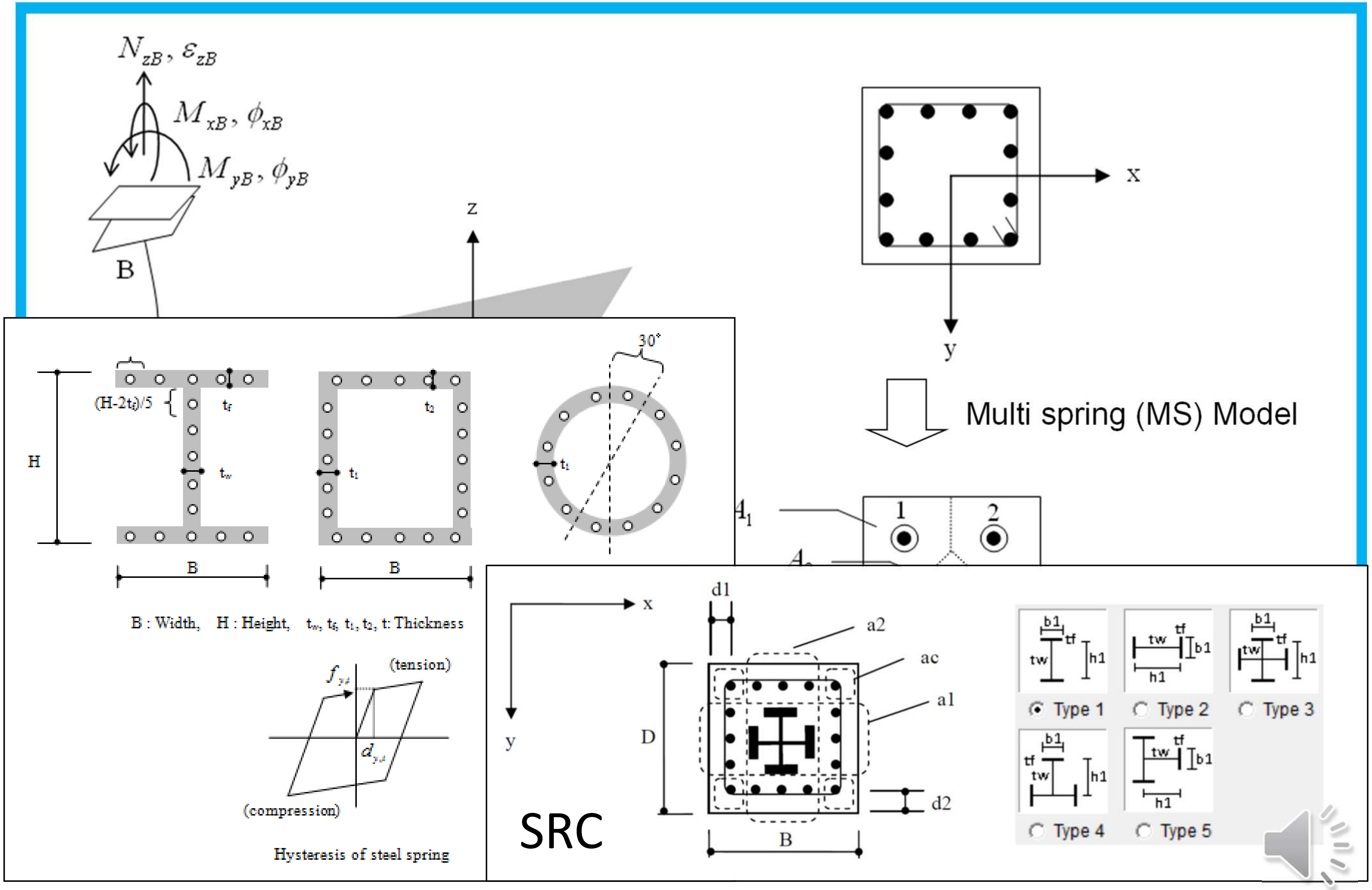
Modified Takeda Model

Nonlinear shear spring

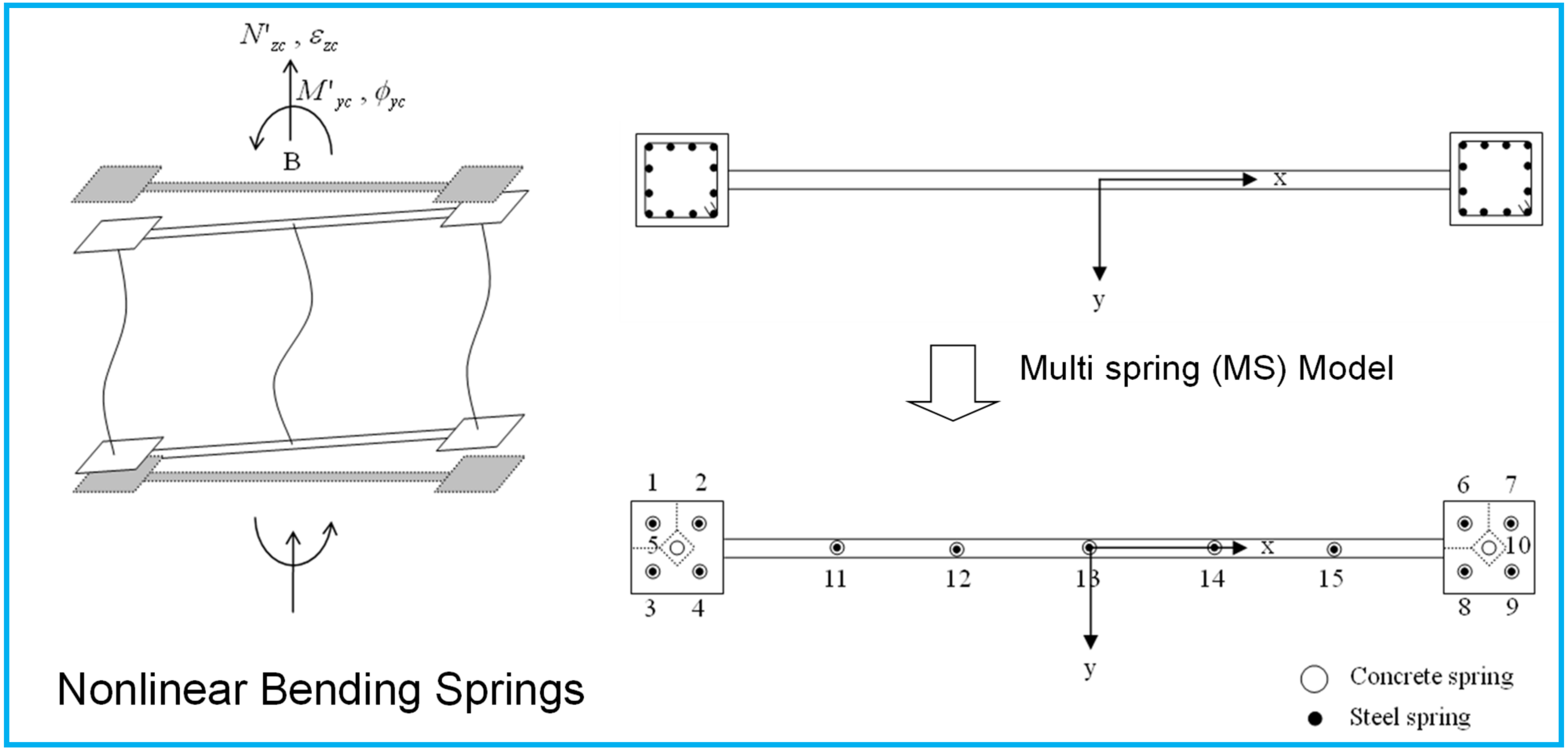


Origin Oriented Model

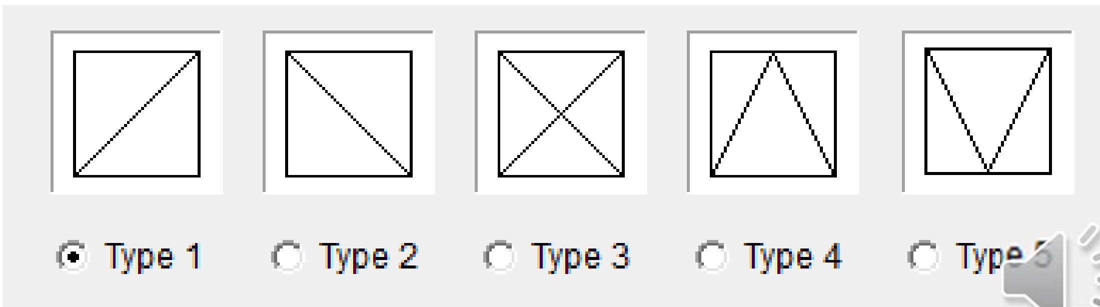
Column Model (MS-model by Otani et.al.)



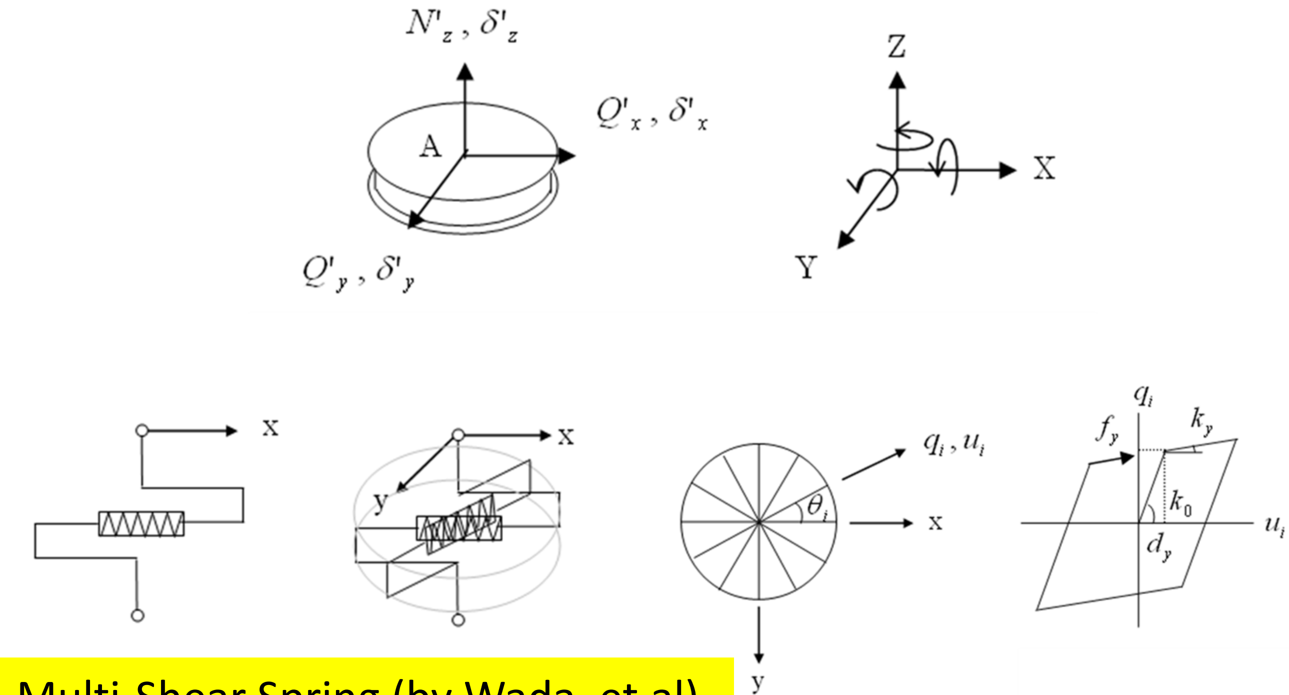
RC Wall model



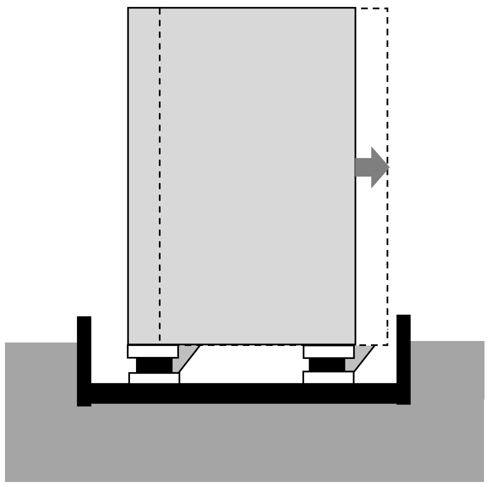
Steel brace

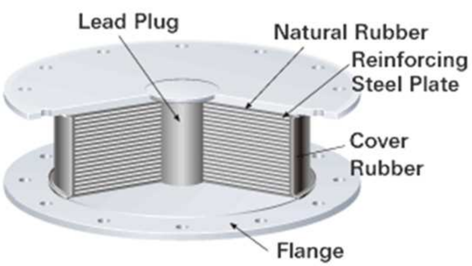


Isolator Model

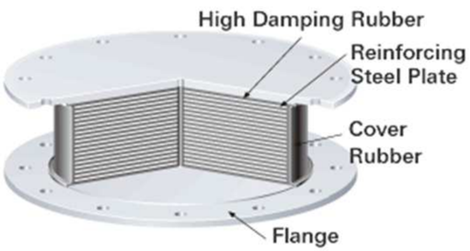


Multi-Shear Spring (by Wada, et.al)

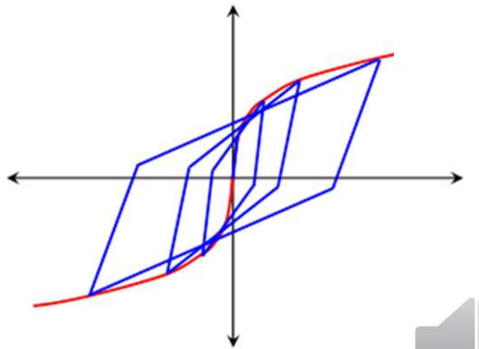




LRB (Lead Rubber Bearing)

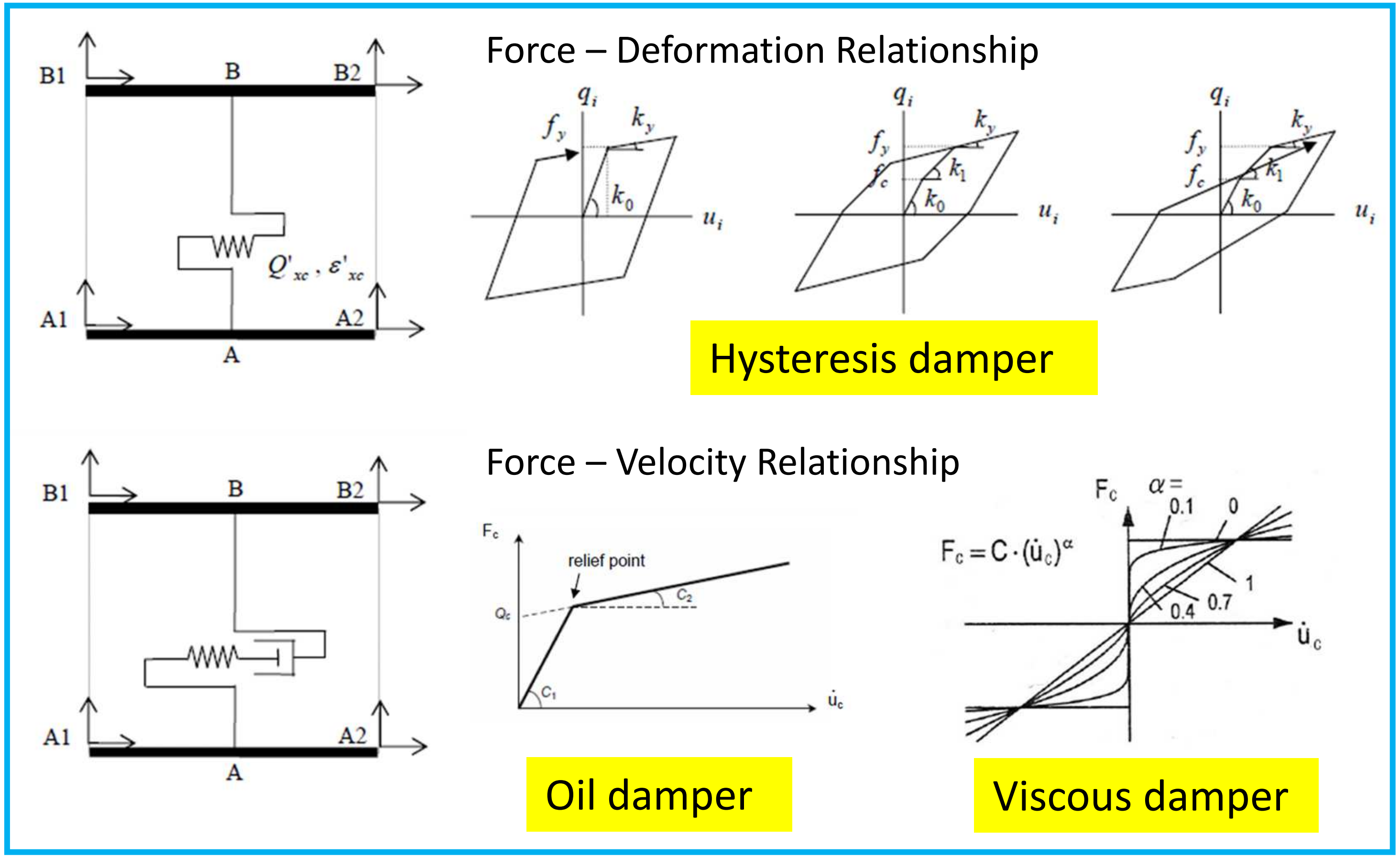


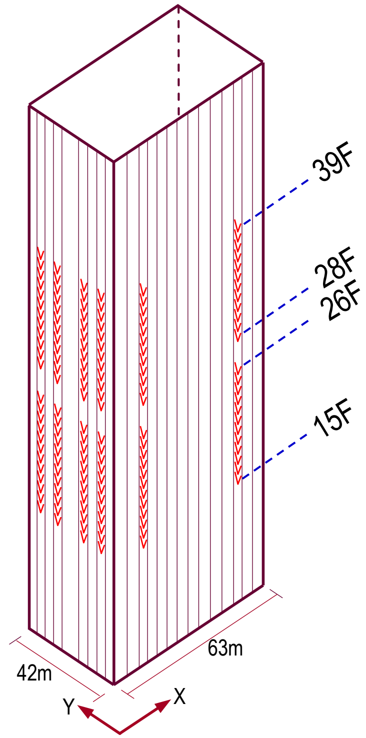
HDRB (High Damping Rubber Bearing)



Modified Bi-linear

Passive Damper Model



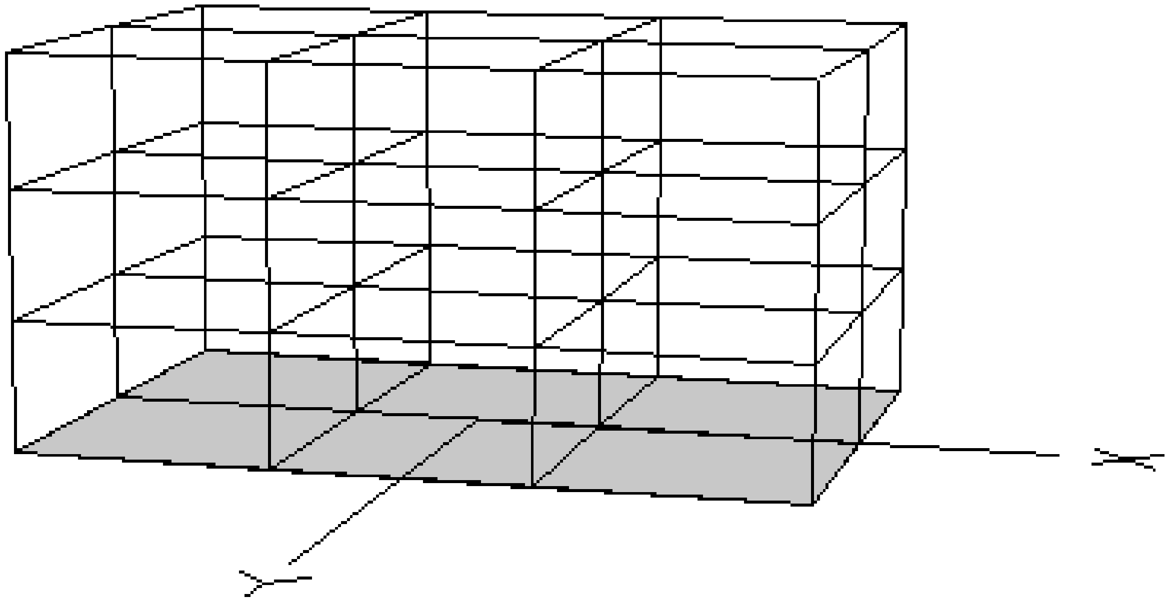


Simple Building Design using STERA_3D

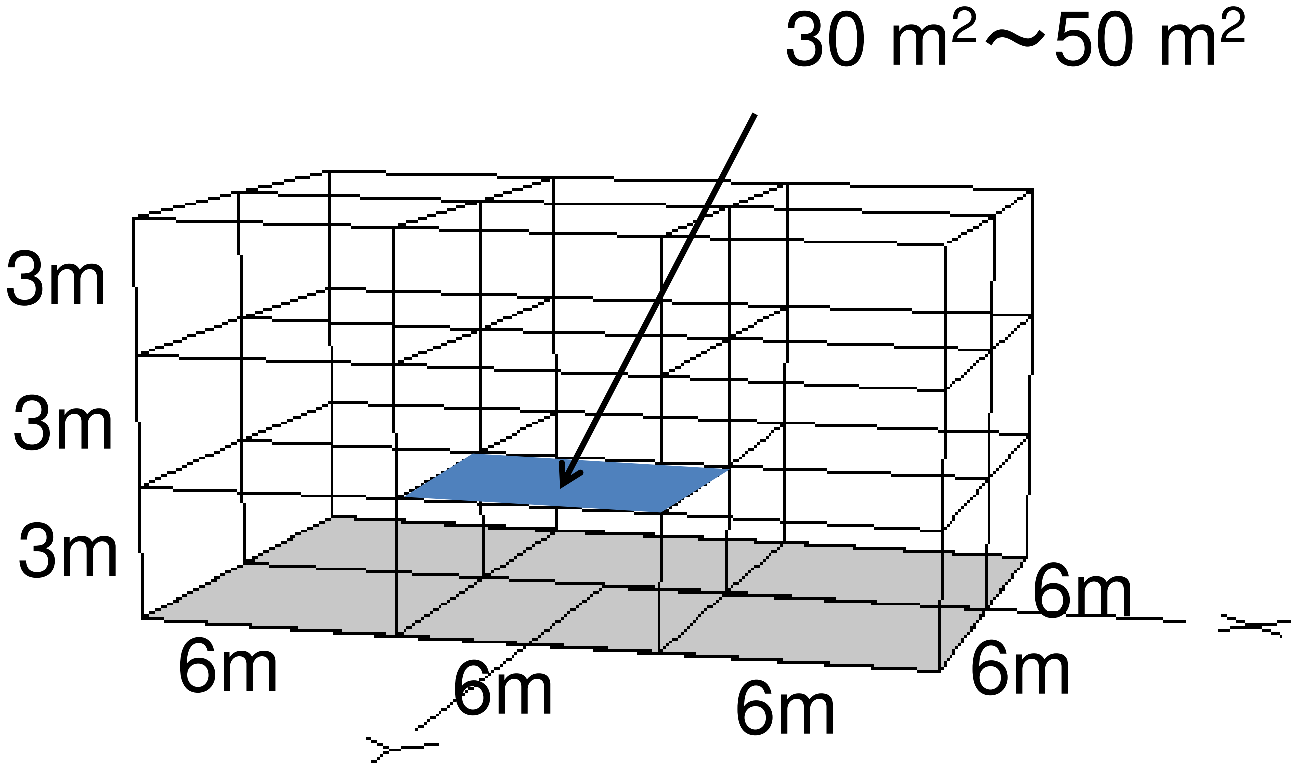
RC (Reinforced Concrete)

3 Story

2×3 Span

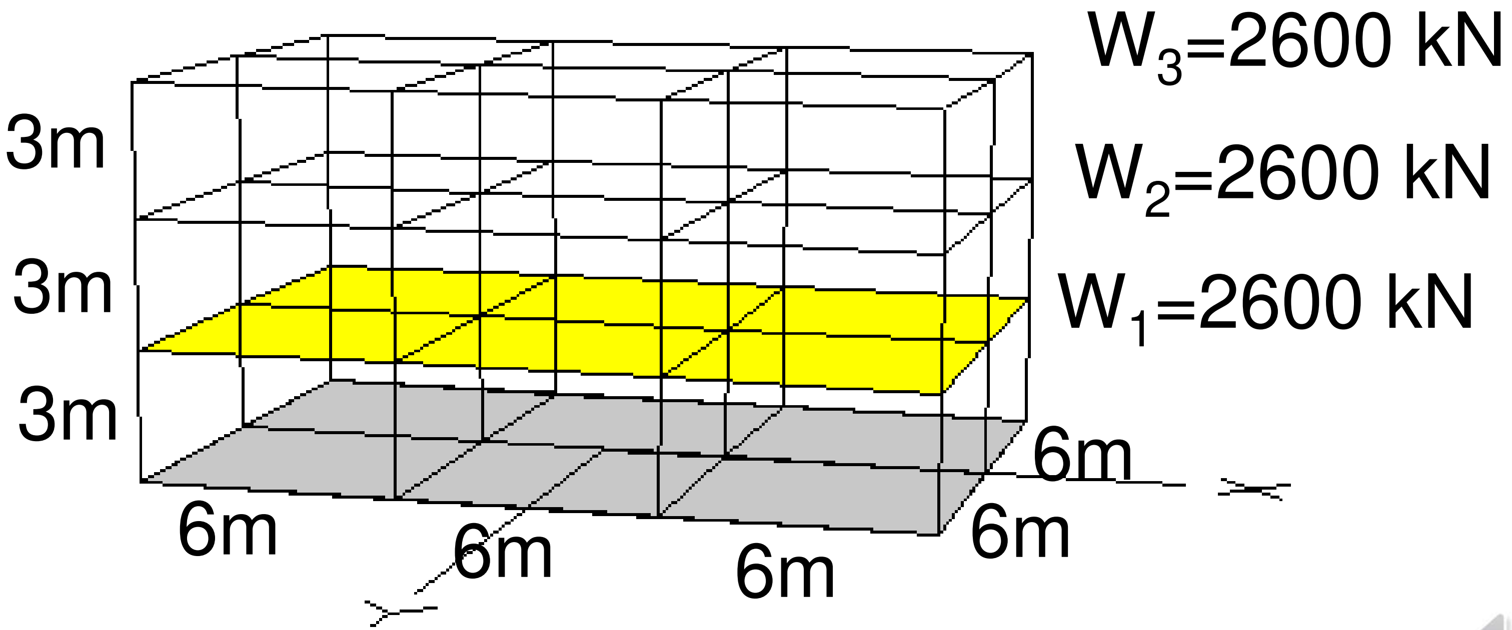


Span



Weight of Building

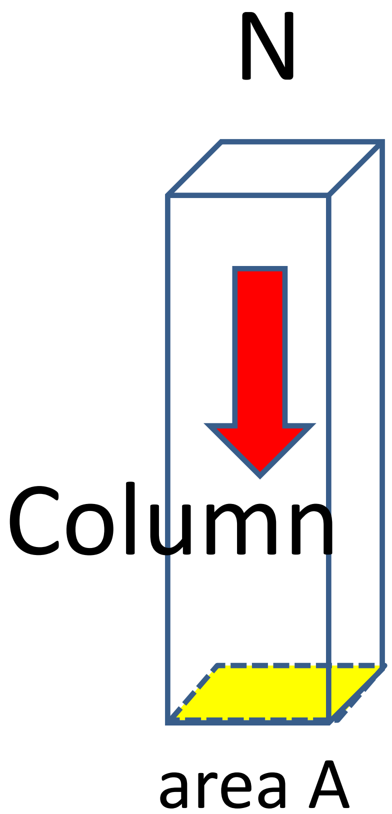
1.2 ton / $m^2 \approx$ 12 kN / m^2



Concrete Strength

$Fc = 240\ (kg/cm^2)$

$= 24\ (MPa,\ N/mm^2)$



Axial Load

$N = 0.2\ Fc \times A$

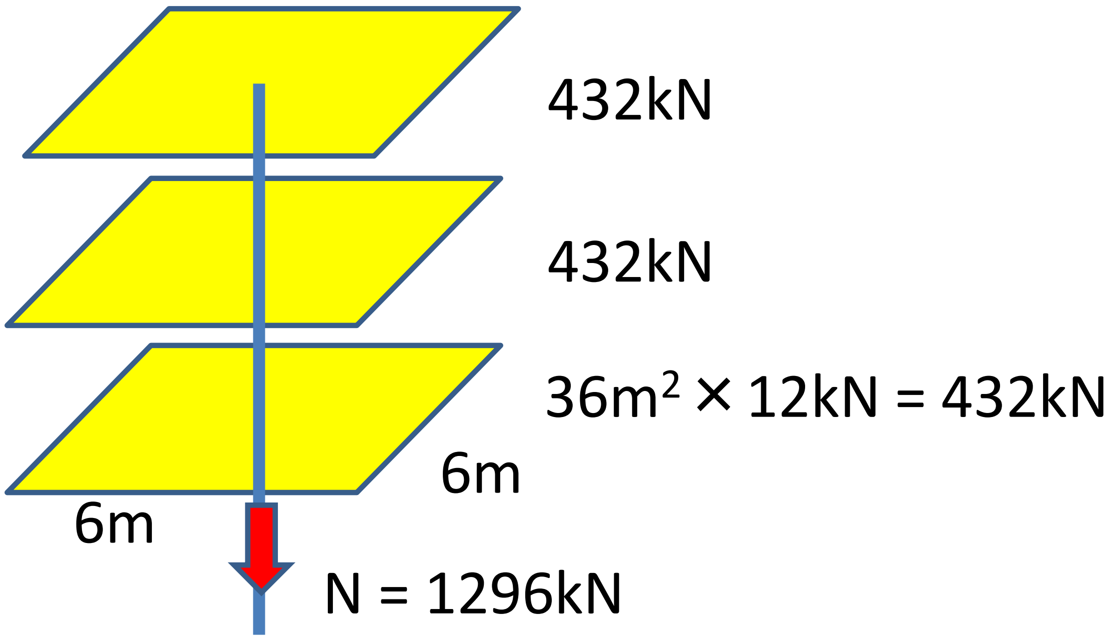
$< (1/3)\ Fc \times A$

Colum Size

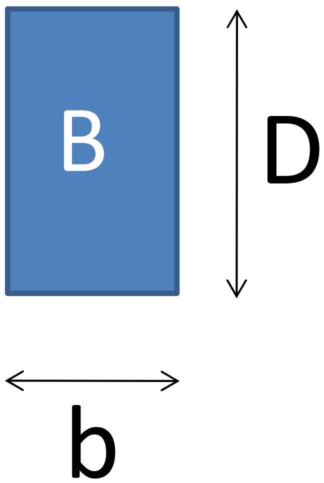
C

$A = N / (0.2Fc) = 1296(kN)/4.8(N/mm^2) = 2700\ (cm^2)$

$\rightarrow$ 60cm × 60cm



Beam Size



$$D \approx (\text{Span}) \times 1/10$$

$$D = 60\ \text{cm}$$

$$b \approx D \times 1/2$$

$$b = 30\ \text{cm}$$

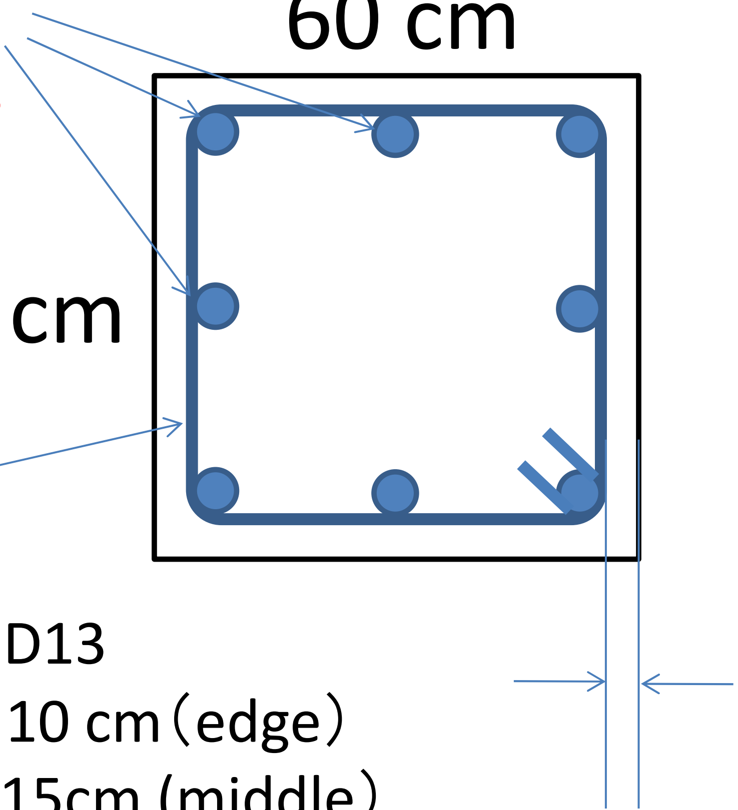
Reinforcement in Column

Main rebars

60 cm

60 cm

Stirrup



D10 or D13

space　10 cm (edge)

15cm (middle)

→ 2-D13@100

Covering Concrete

> 40mm

Minimum rebar ratio = $\dfrac{\text{Total area of rebar}}{\text{Section area}}$

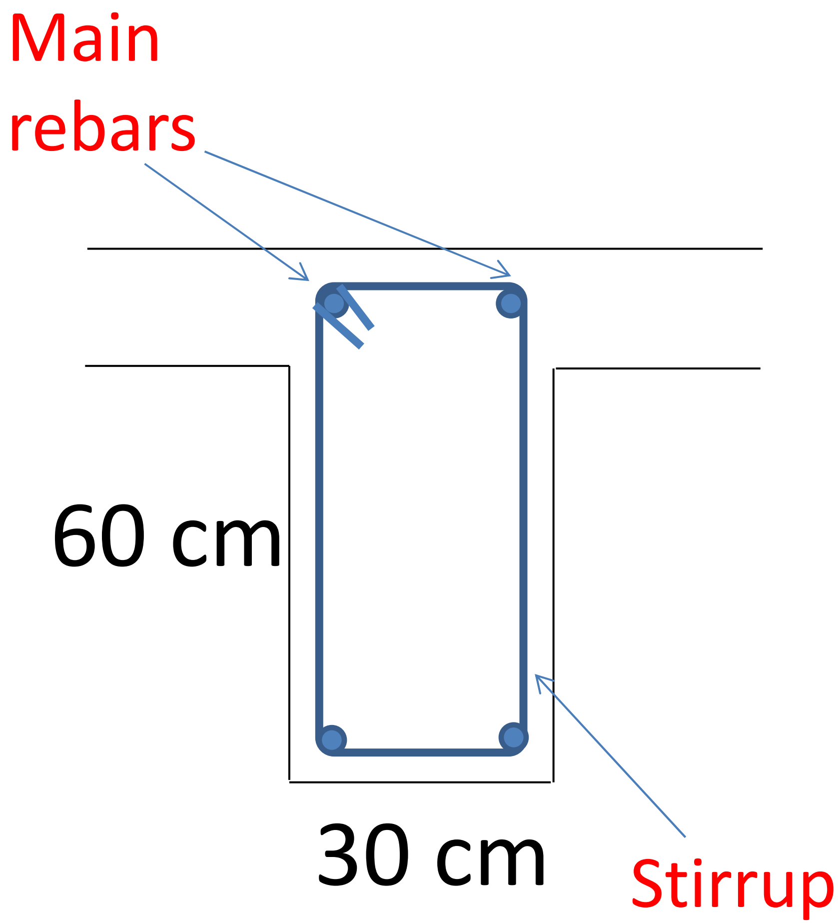
$>$ 0.8 %

Total area of rebar

$= 3600\text{cm}^2 \times 0.008 = 28.8\ \text{cm}^2$

→ D22 (3.87cm^2) × 8

Reinforcement in Beam



$$\text{Minimum rebar ratio} = \frac{\text{Tension side rebar area}}{\text{Section area}} > 0.4\ \%$$

Total area of rebar

$= 1800\text{cm}^2 \times 0.004 = 7.2\ \text{cm}^2$

→ D22 (3.87cm^2) × 2

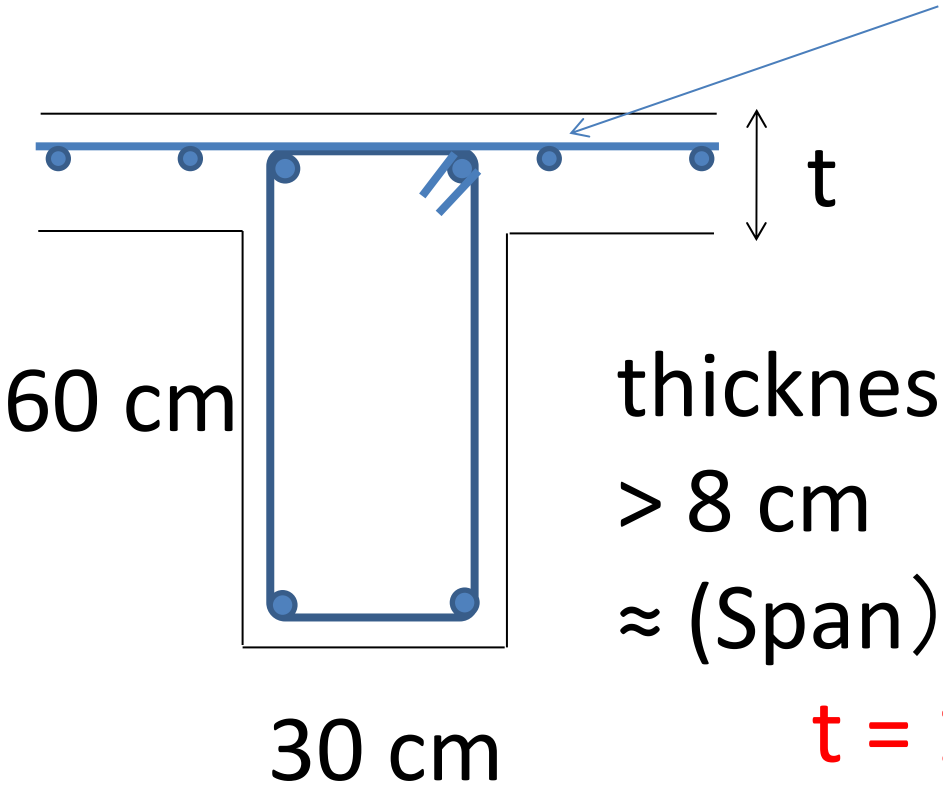
D10 or D13

space 15 cm (edge)

20cm (middle)

→ 2-D13@150

Reinforcement in Slab



D10 or D13

space 20 cm

→ D13 @ 200

thickness: t

> 8 cm

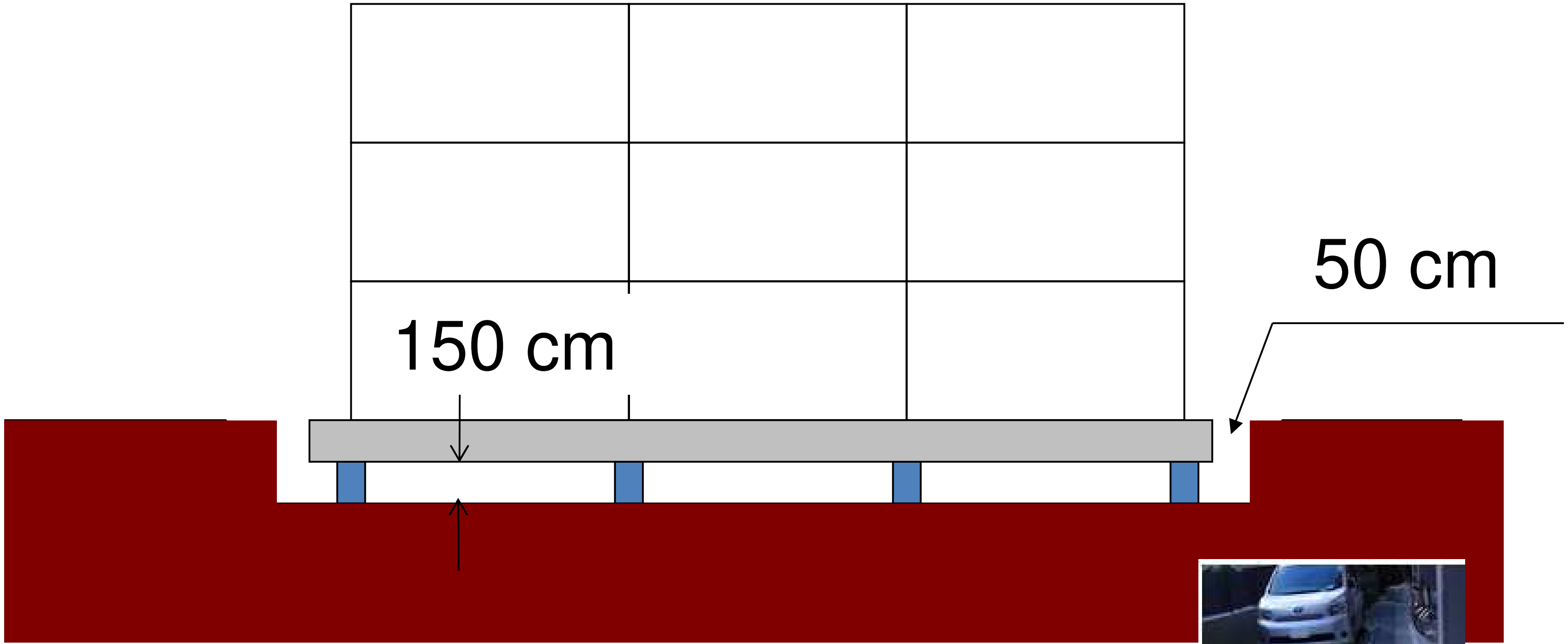
≈ (Span) × 1/40

t = 15 cm

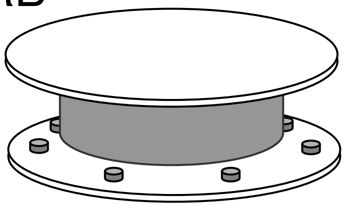
Strength of steel

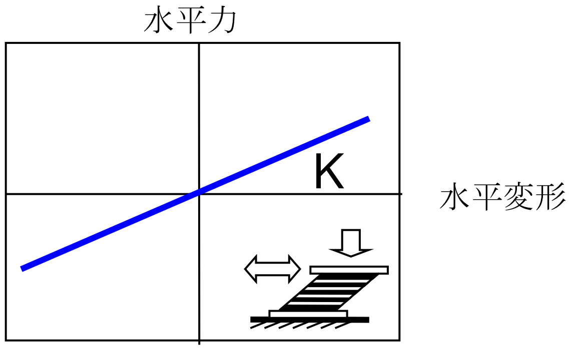
Name	Tensile strength
SD295	3.0 (t/cm^2) = 295 (MPa, N/mm^2)
SD345	3.5 (t/cm^2) = 345 (MPa, N/mm^2)
SD390	4.0 (t/cm^2) = 390 (MPa, N/mm^2)

Design of Base Isolation Layer

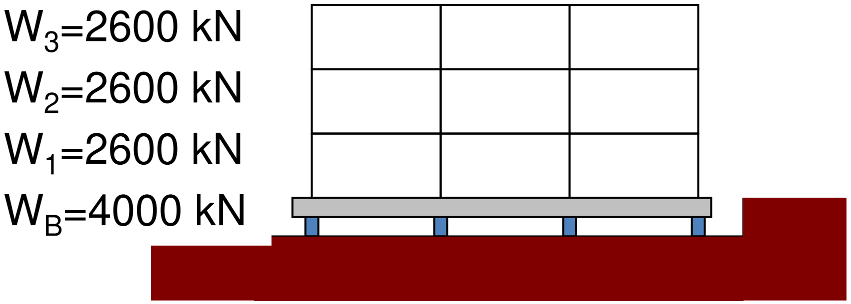


Natural Rubber Bearing
NRB

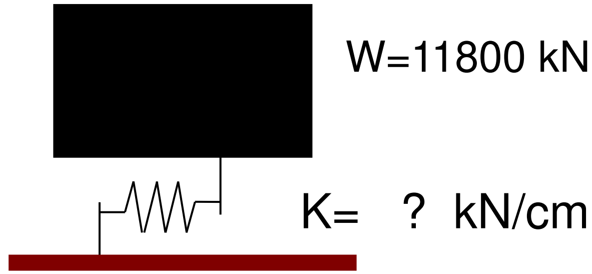




Design of Base Isolation Period



$\approx$



Period Mass Weight

$$T = 2\pi\sqrt{\frac{m}{K}} = 2\pi\sqrt{\frac{W/g}{K}}$$

Gravity acc.

g = 980cm/sec^2

Target Period

T = 4 sec

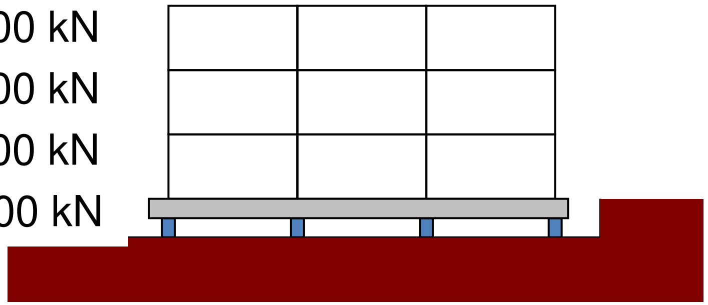
Stiffness

$$\boxed{K = \left(\frac{2\pi}{T}\right)^2 \frac{W}{g}}$$

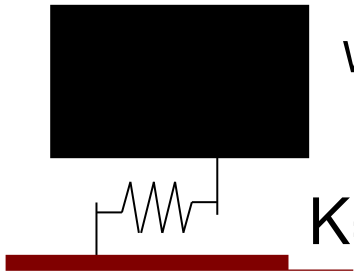
$$K = \left(\frac{2\pi}{4}\right)^2 \frac{11800}{980}$$ = 30 kN/cm

Stiffness of isolator

W_3=2600 kN
W_2=2600 kN
W_1=2600 kN
W_B=4000 kN

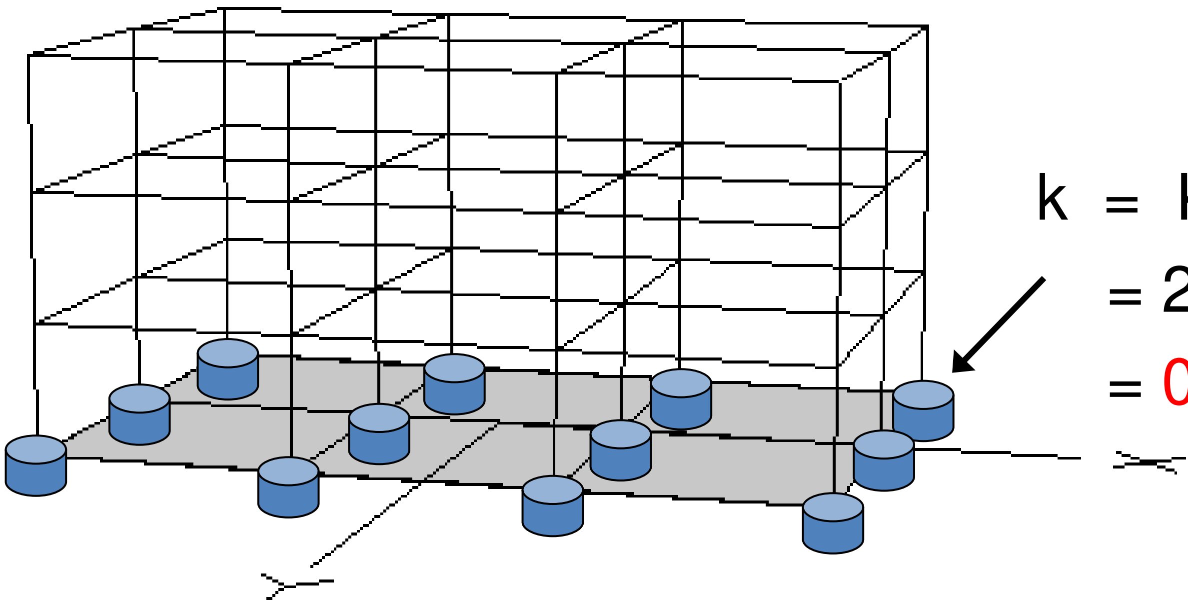


$\approx$



W=11800 kN

K= 30 kN/cm

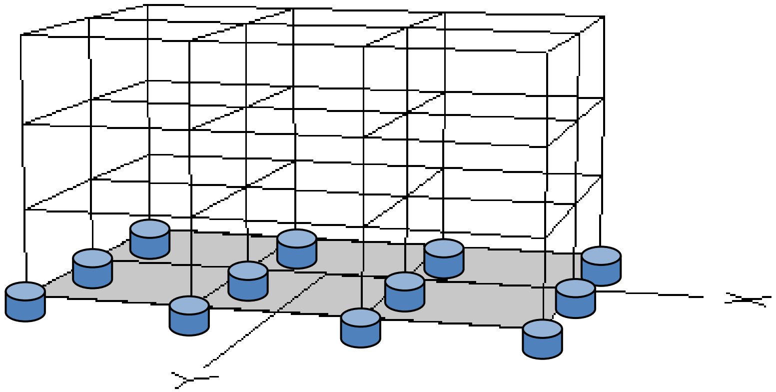


$k = K / 12$

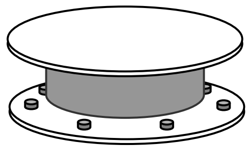
$= 2.5$ kN/cm

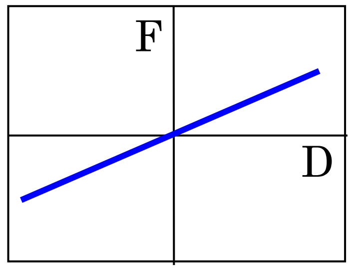
$=$ 0.25 kN/mm

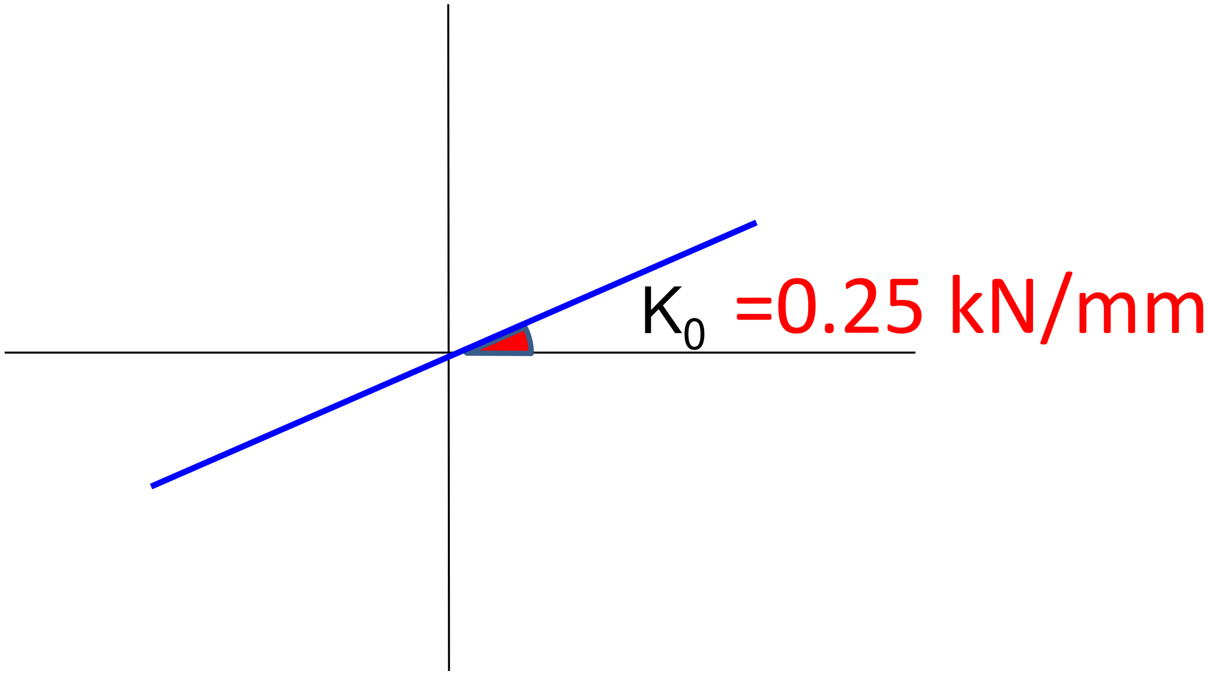
Stiffness of isolator



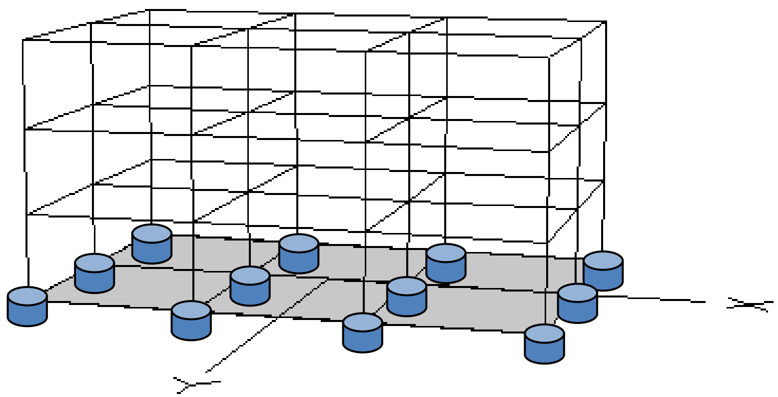
Natural Rubber Bearing (NRB)

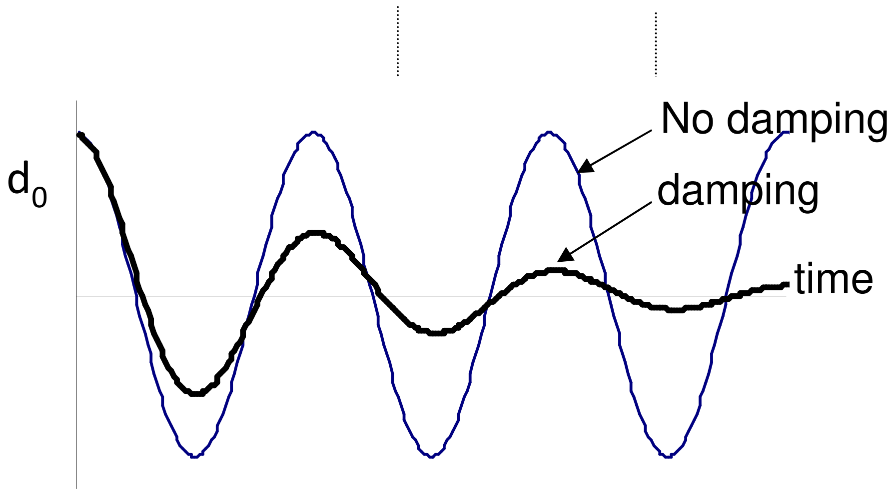


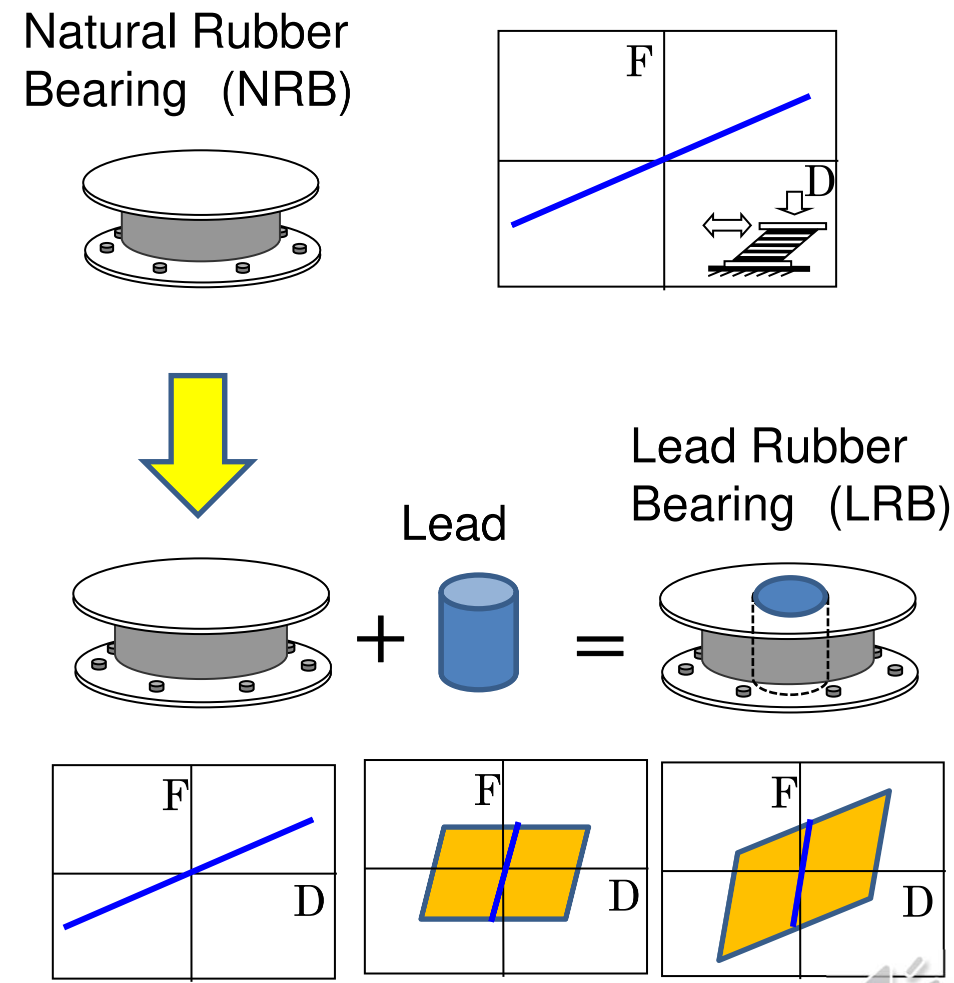




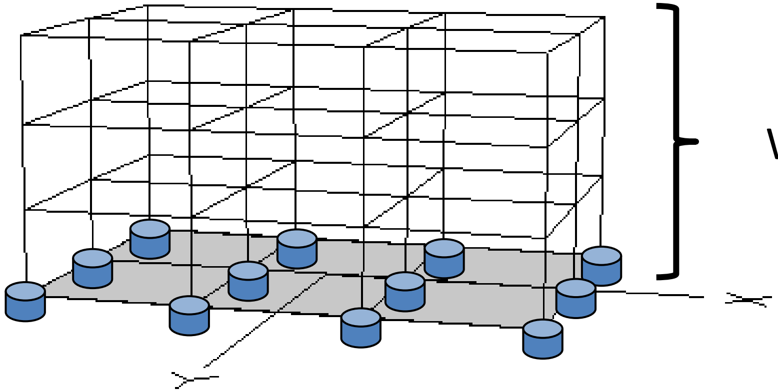
Design of damper



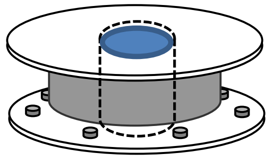




Lead Rubber Bearing



W=11800 kN



$F_y \approx 100$ kN

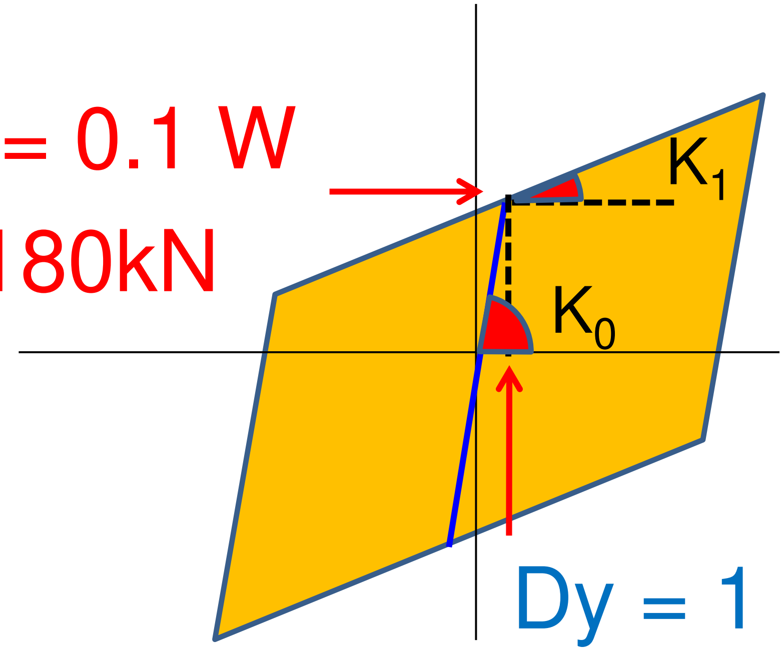
$K_0 \approx 10$ kN/mm

$K_1 / K_0 \approx 0.025$

1/12

$F_y = 0.1\ W$

$=1180$kN



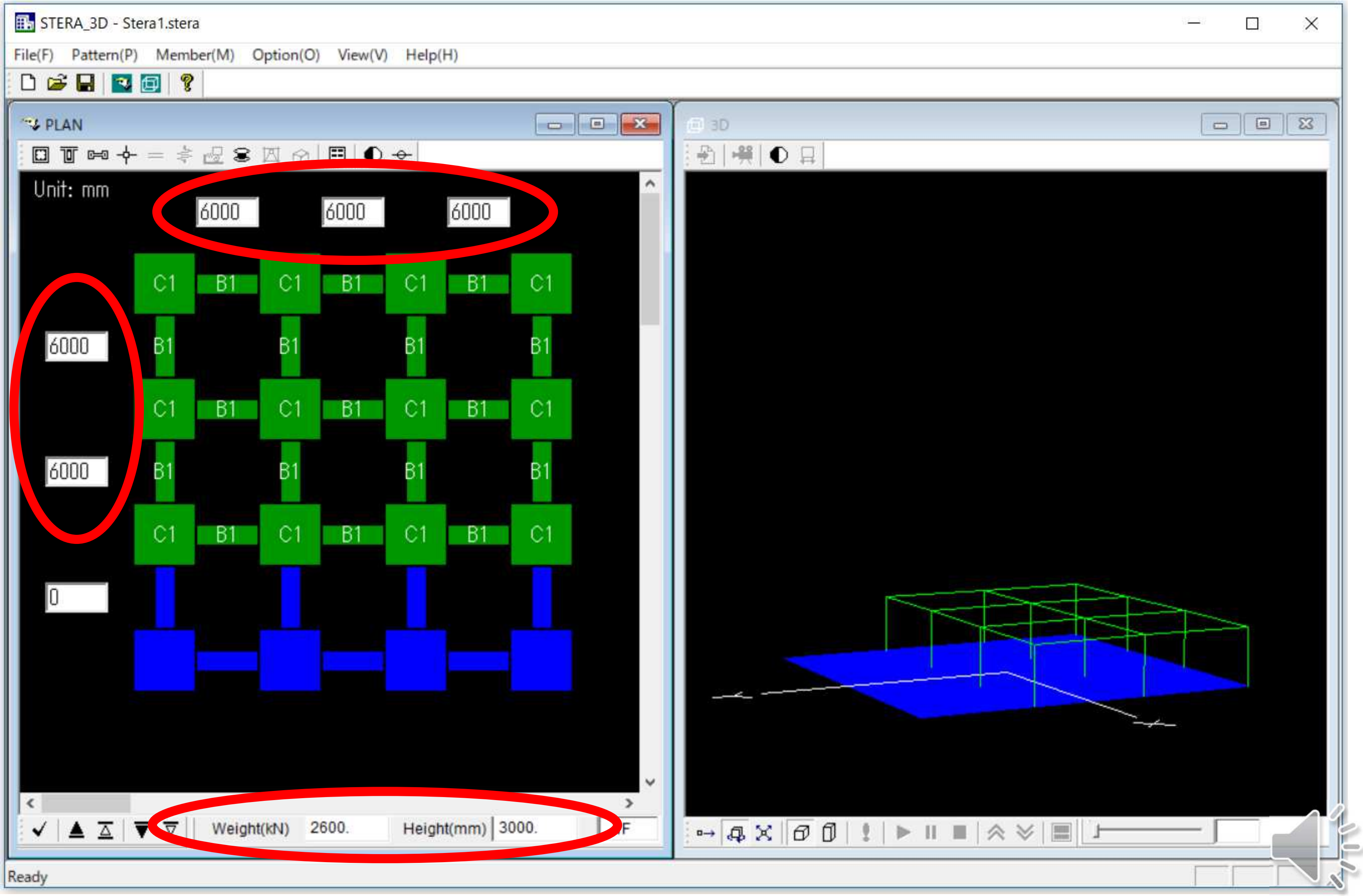
$K_1 = 30$ kN/cm

$K_0 = 1180$ kN/cm

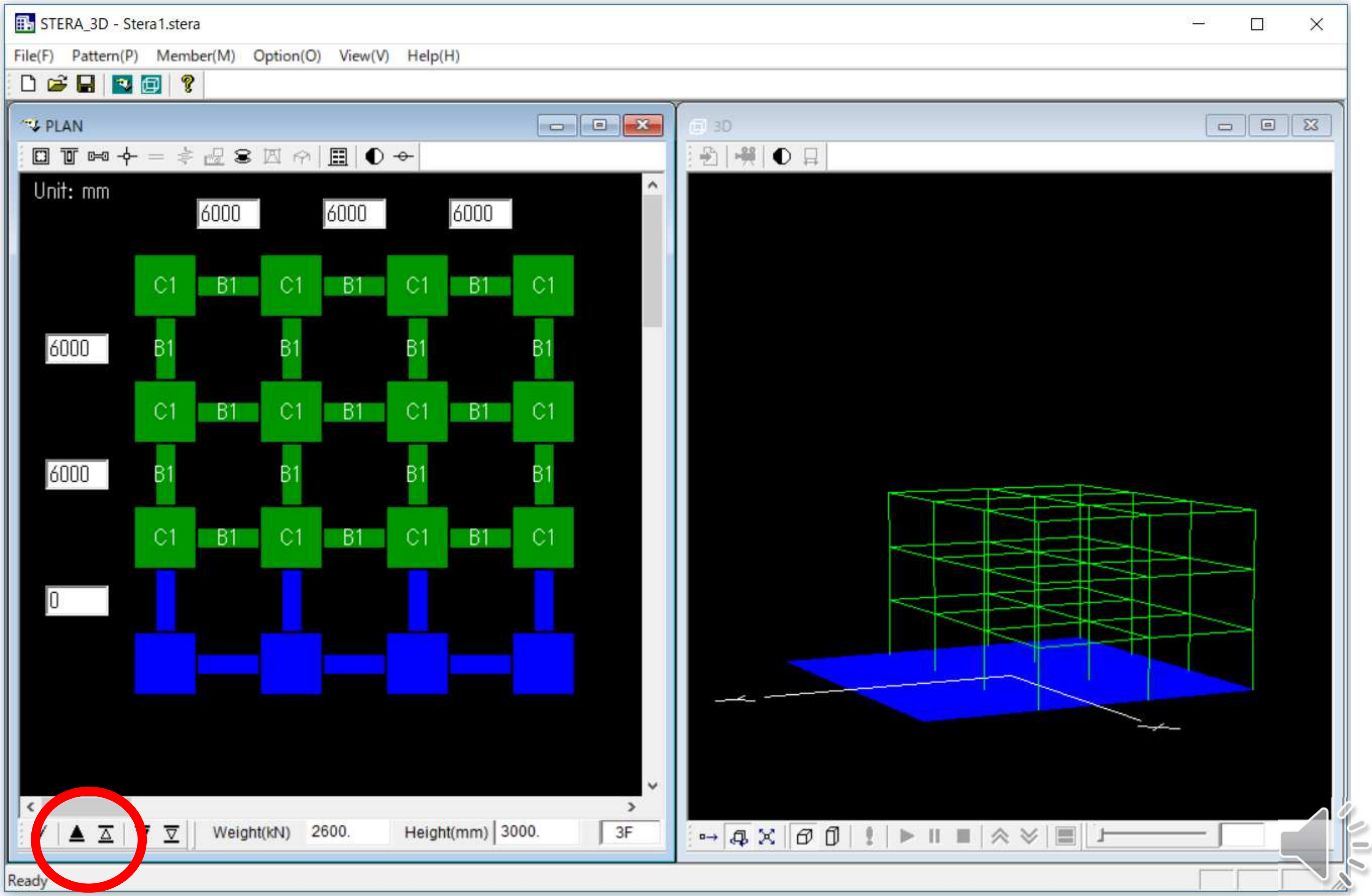
$K_1 / K_0 \approx 0.025$

$D_y = 1$ cm

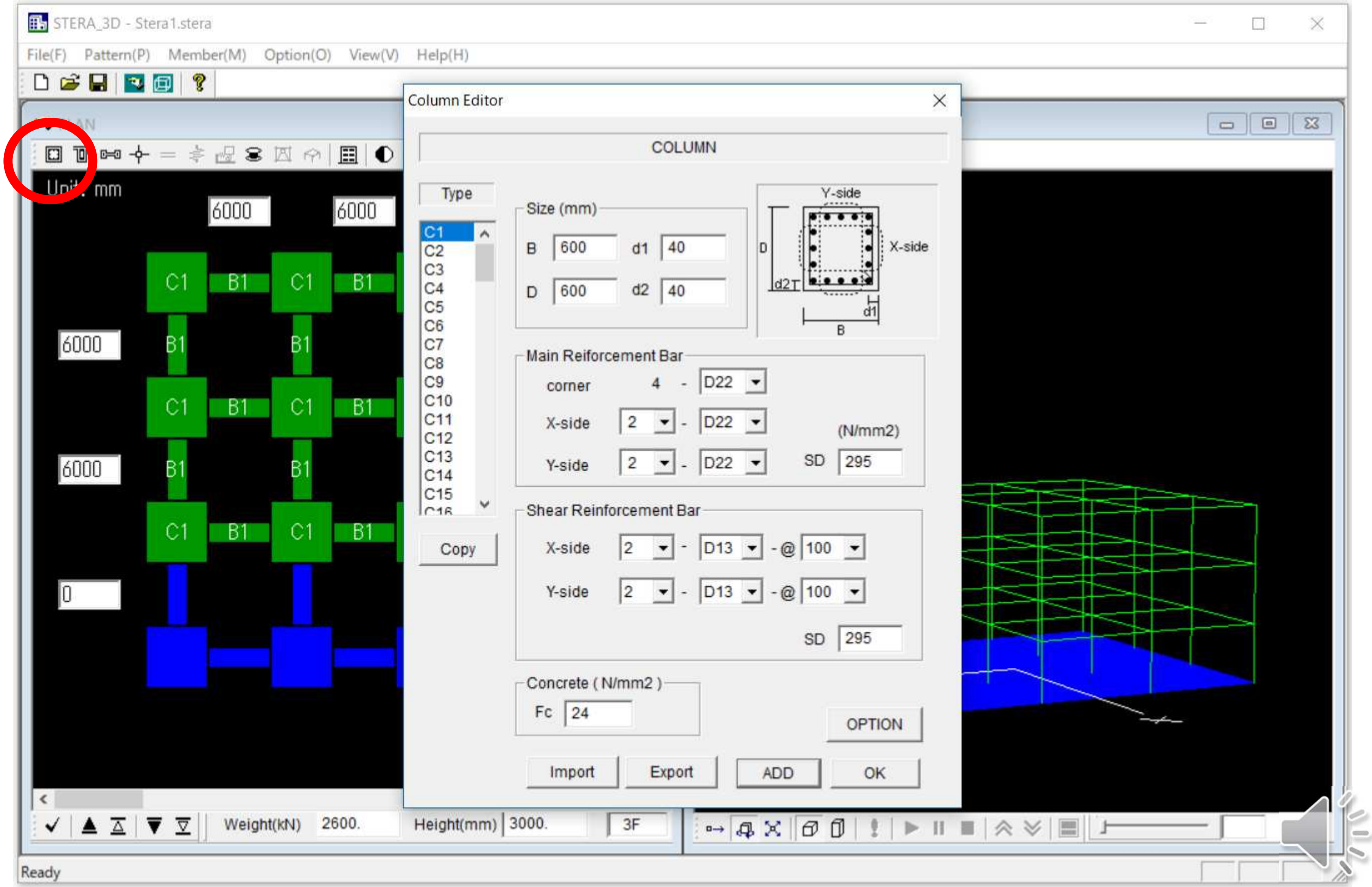
STERA 3D (Input of Size)



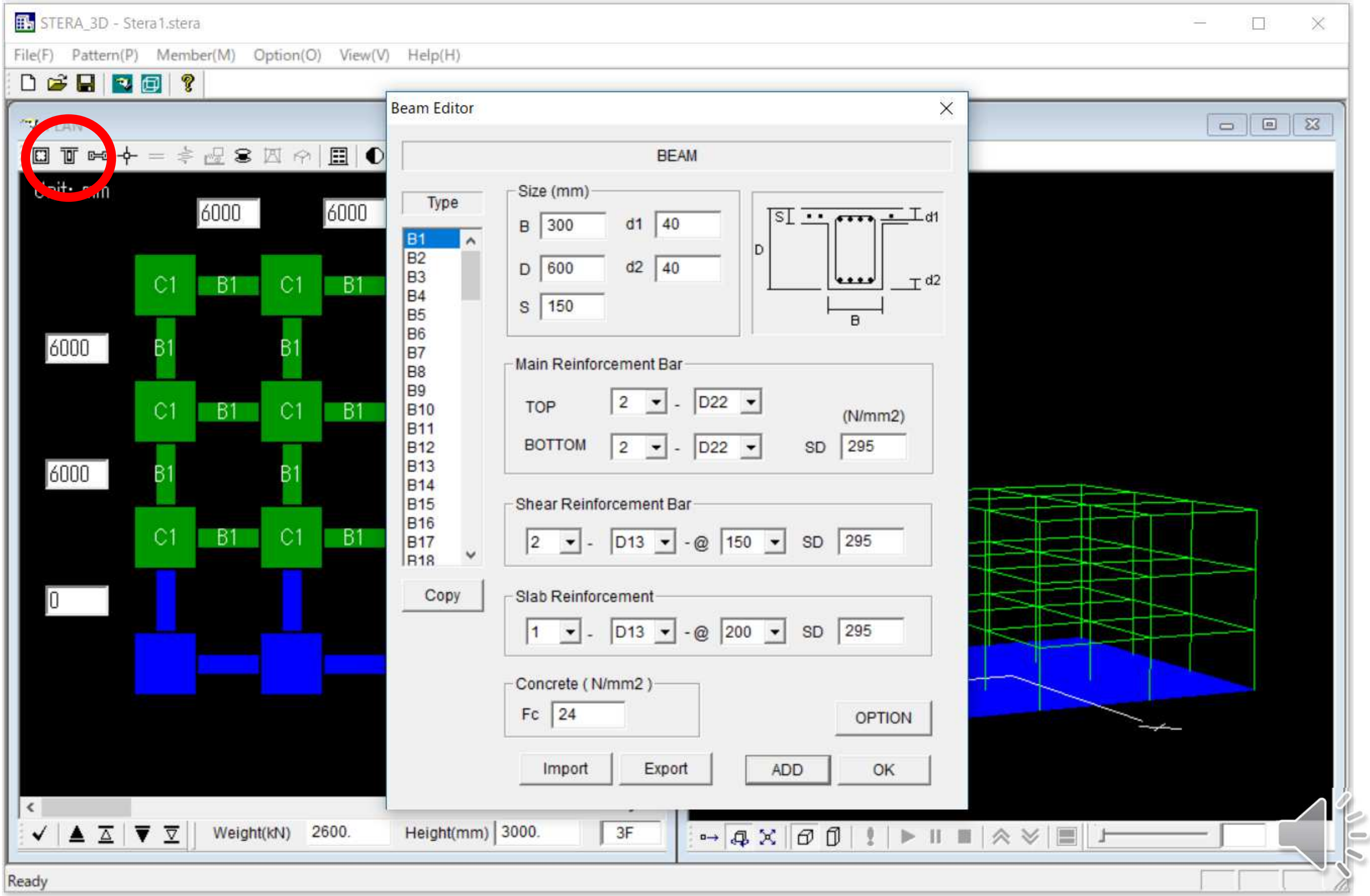
STERA 3D (Upper floor, copy)



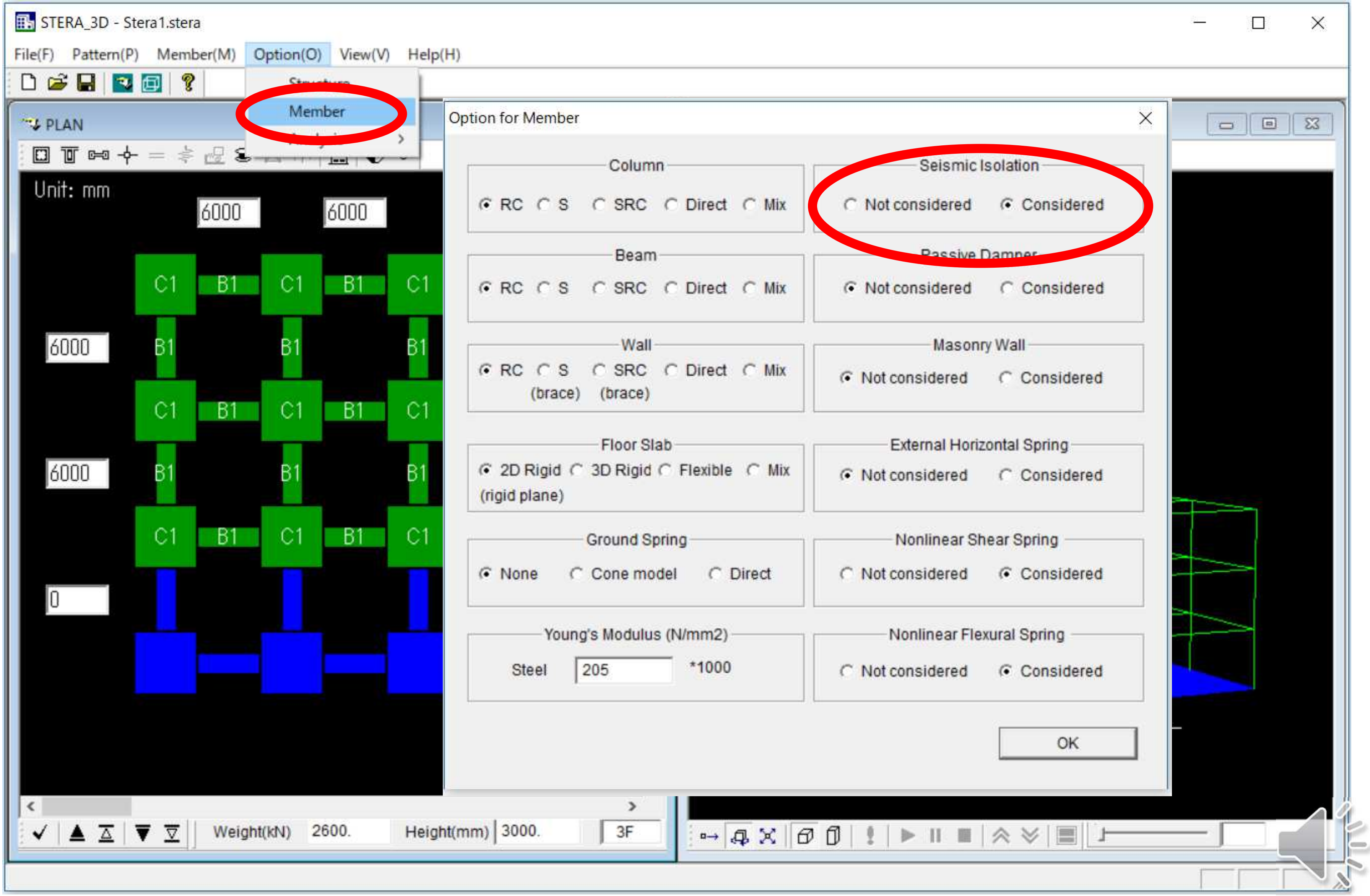
STERA 3D (Column Input)



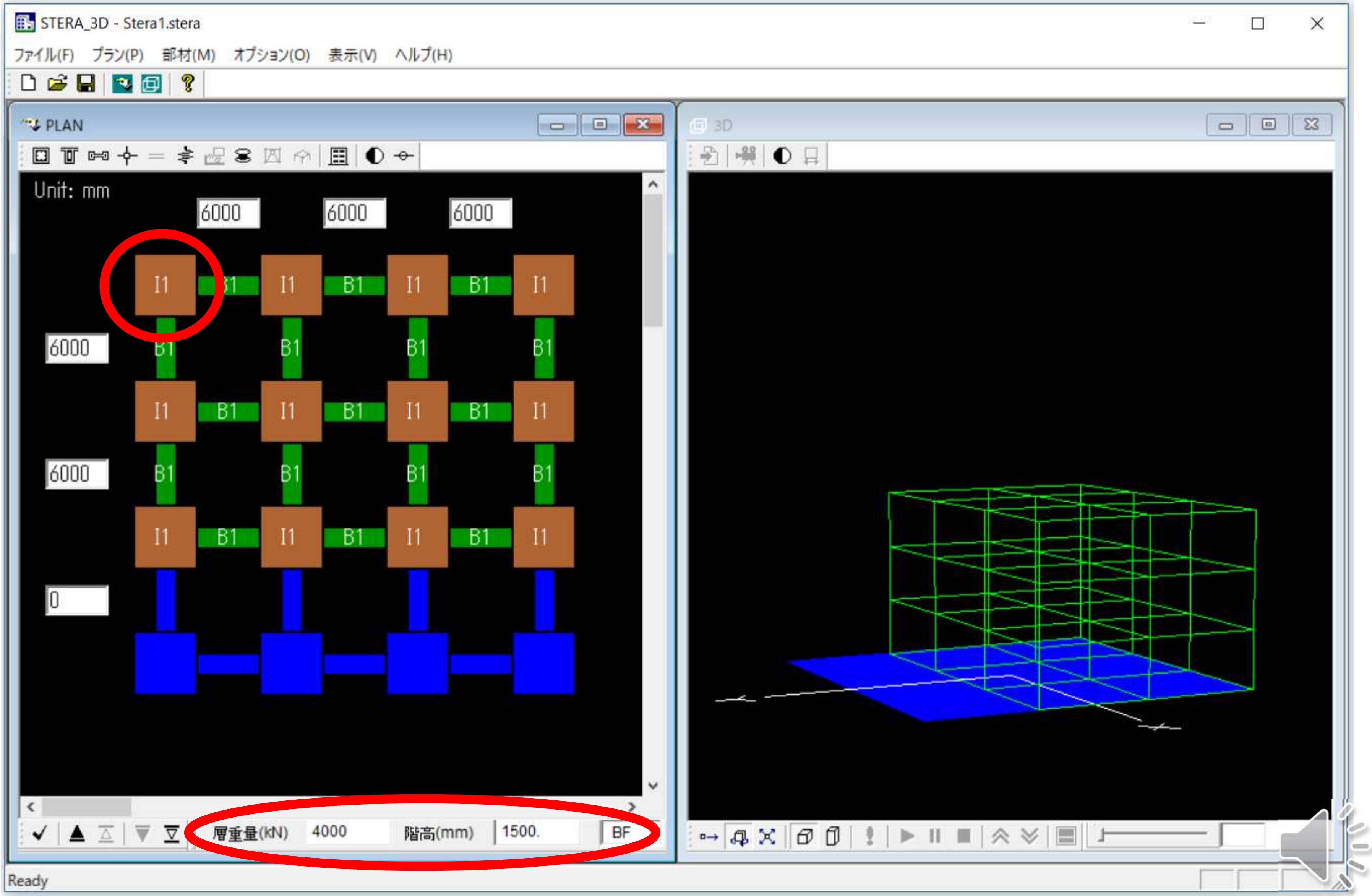
STERA 3D (Beam Input)



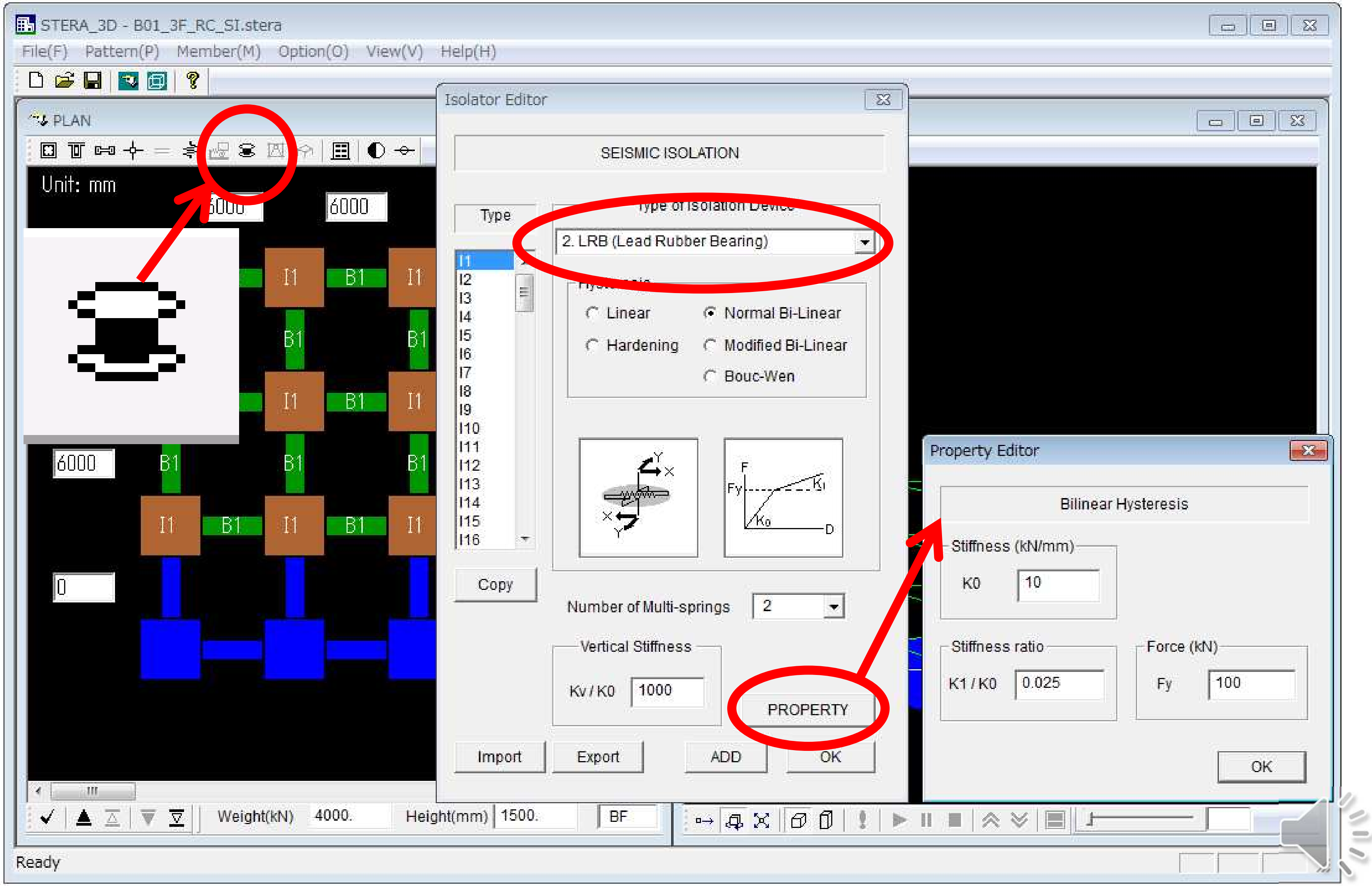
STERA 3D (consider Isolation)



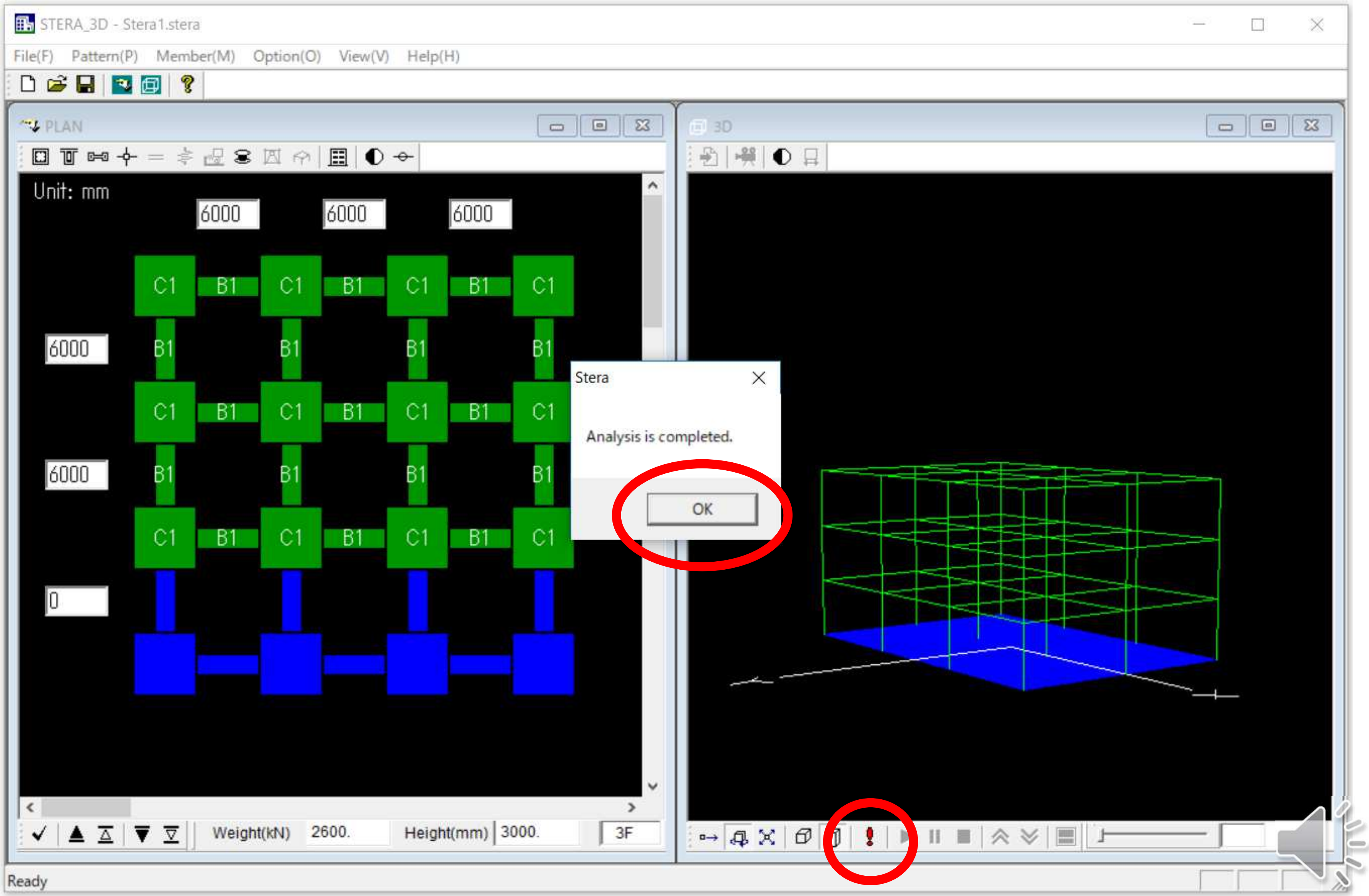
STERA 3D (setting SI member)



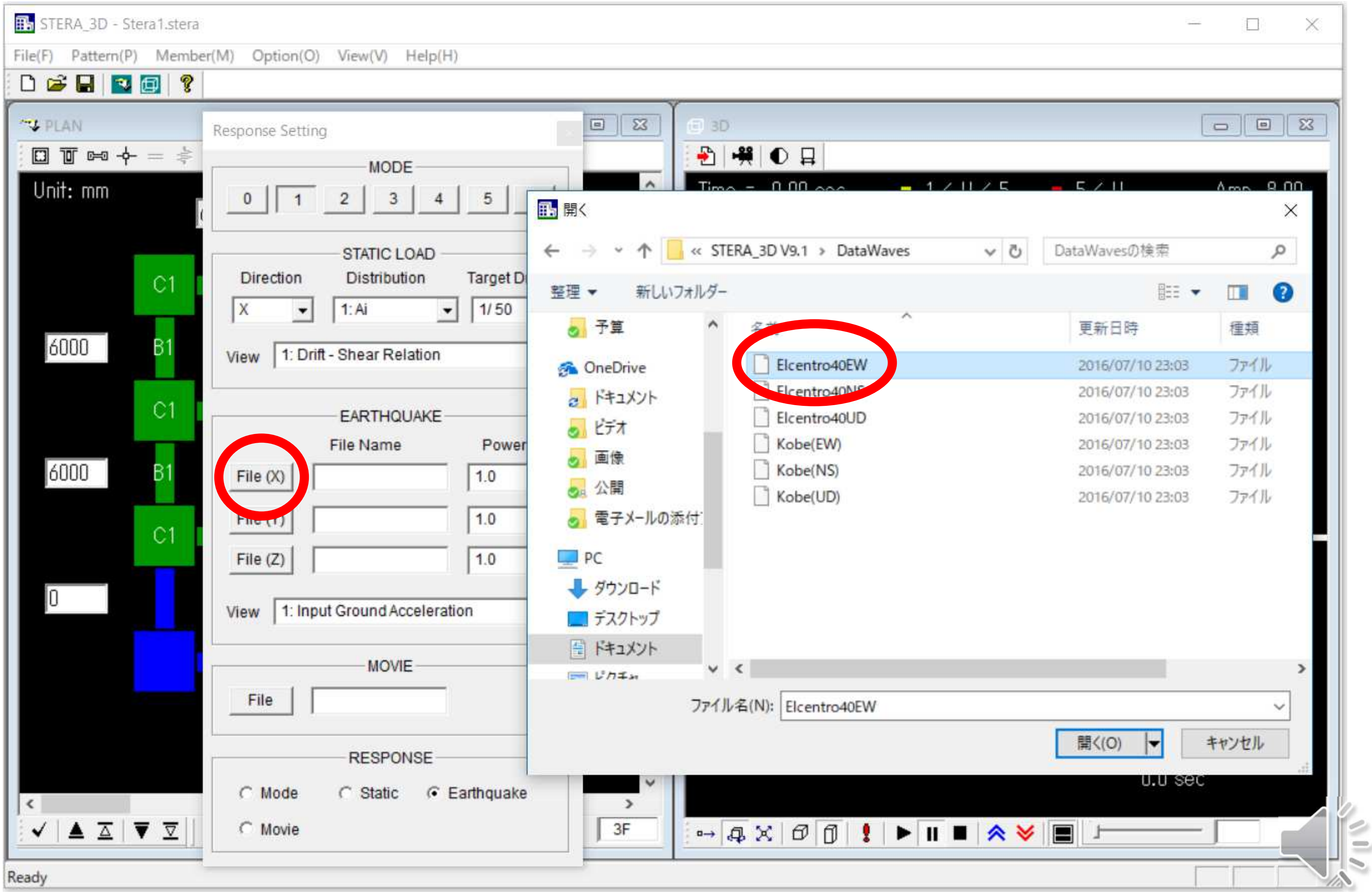
STERA 3D (SI devise)



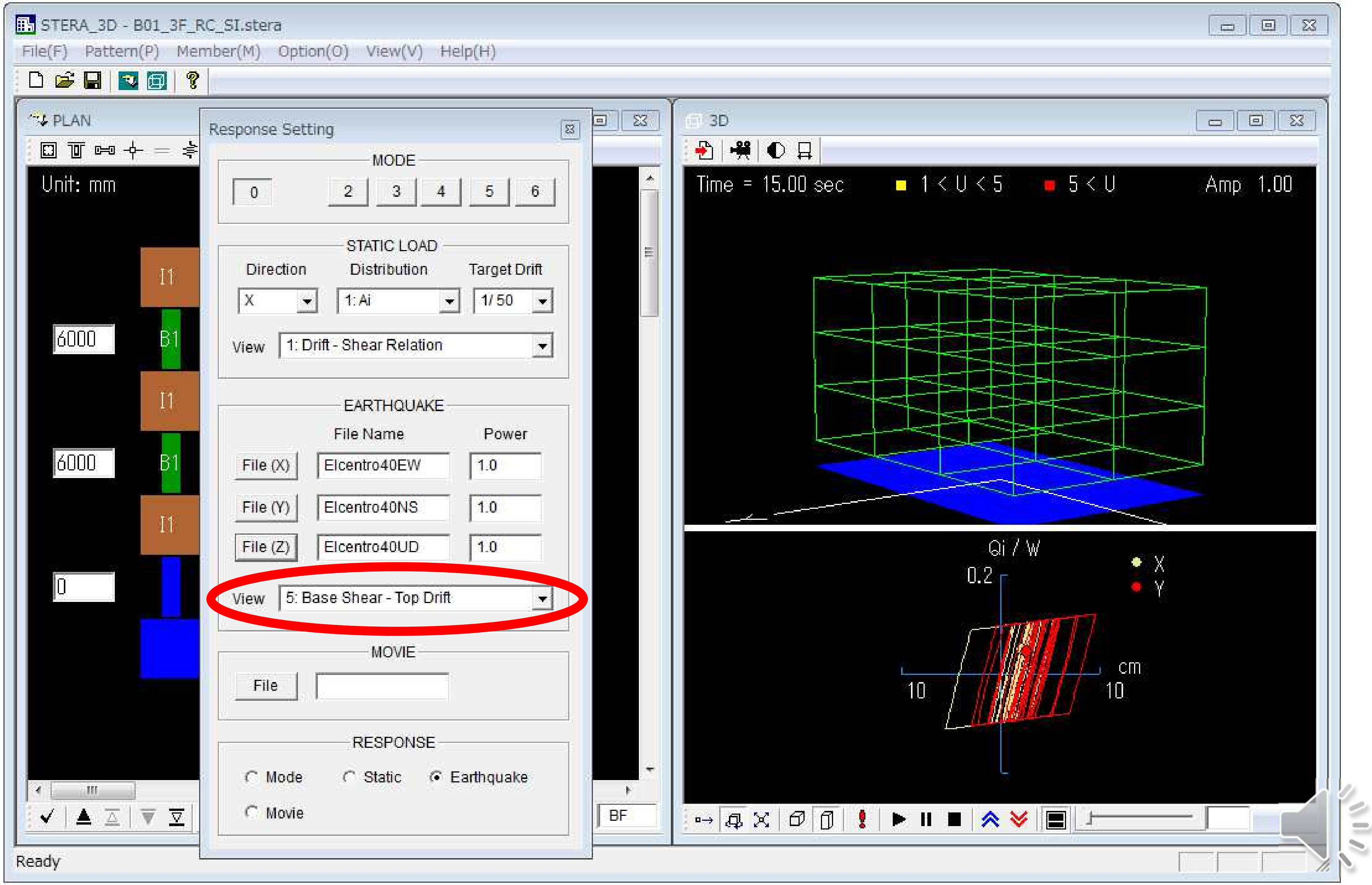
STERA 3D (Analyze)



STERA 3D (Earthquake Response)



STERA 3D (Earthquake Response)



ISO/TC98/SC2/WG13

Bases for design of structures
General Principles of Seismically Isolated Structures

Convener

Taiki Saito
Professor at Toyohashi University of Technology, Japan

ISO/TC98/SC2/WG13

ISO: International Organization for Standardization

TC: Technical Committee

TC98: Bases for design of structures

SC: Sub Committee

SC1: Terminology and symbols

SC2: Reliability of structures

WG: Working Group

WG13: Design Principles of Seismically Isolated Struct

SC3: Loads, forces and other actions

Backgrounds of proposal

- Existing design standards such as Eurocode, ASCE, Japanese Design Guide, etc. are not consistent even in their basic philosophy.
- Further promotion of good quality seismically isolated structures is needed in all earthquake prone countries.

Process of ISO standard to be accepted

1- NP	: New work item Proposal
2- WD	: Working Draft
3- CD	: Committee Draft
4- DIS	: Draft International Standard
5- FDIS	: Final Draft International Standard
6- ISO	: International Standard

WG13 on Nov. 13, 2018
in Prague, Czech Republic

Other meetings

March 5, 2019 in Gangzhou, China

Attendance list:

Convener :

Taiki Saito

China :

Ping Tan, Fulin Zhou,
Jiangang Sun, Lifu Cui,
Xiangyun Huang,
Yangyang Chen, Ying Zhang,
Jianmin Jing, Ying Zhou

Japan :

Katsuhide Murakami,
Hiroki Hamaguchi,
Keiko Morita

Italy :

Paolo Clemente

Russia :

Alexander Bubis

Other meetings

July 3, 2019 in Saint Petersburg, Russia

Attendance list:

Convener: Taiki SAITO

Russia: Victor KOSTAREU, Alexander M. UZDIN, Alexander BUBIS

Japan: Katsuhide MURAKAMI, Hiroki HAMAGUCHI, Keiko MORITA, Demi FENG, Takahiro MORI

India: Manish SHRIKHANDE, Vasant MATSAGAR

China: Ping TANG, Yangyang CHEN

Italy : Paolo CLEMENTE

Turkey: Musutafa ERDIK

WG13 on Nov. 19, 2019
in Denver, U.S.