# Wise Dynamic Testing for Enhanced Understanding of Structures

**Akira Wada**
**Mineo Takayama**
**Satoshi Yamada**

# Large shaking tables

- At the **E-defense**------
- The bed can support 1200 metric tons and 20m tall structures, but we can test only 5 story buildings.

- At the **UCSD shaking table**----
- They can test 10-story buildings but very small floor area.

# Large shaking tables

- Total weight of actual tall building will be heavier over 100,000 metric tons and its height is higher than 300m in Japan and 800m in the world.
- We need new wise ideas for understanding the behaviors of actual large structures due to large earthquakes.

# Intuitions and experiences

- Before Galileo Galilee, we have not any equation for knowing strength of a beam or a column, but humankind is wise and has good intuition.
- They could built very beautiful buildings and architectures such as Pyramids, Parthenon, Pantheon or 5 story pagodas.
- These buildings have very good performance for a long time, but many buildings were also collapsed by many reasons.

# Earthquake disasters

- In some cases, engineers in the ancient time learned better construction technology by observing collapses and failures.
- In $20^{th}$ and $21^{st}$ century, we have had many severe earthquake disasters and we have learned much from these events and understood the structure behavior better under earthquakes.

# Engineers must know what will happen before it happen

# Aims of structural tests 1/3

- Humankind has built many buildings and many big cities.
- But not all we have done are based on our experiences.
- Then we have to know what will happen in the actual building structures in future earthquake event by any possible ways before any troubles happen.
- The static tests and the dynamic tests should give us a lot of important information and important knowledge.

# Aims of structural tests 2/3

- Making safer structures, more economical structures and higher performance structures.
- Structural materials such as concrete, steel and other materials can be changed to increase strength.
- We have to test the structures and to understand new structural systems.

# Aims of structural tests 3/3

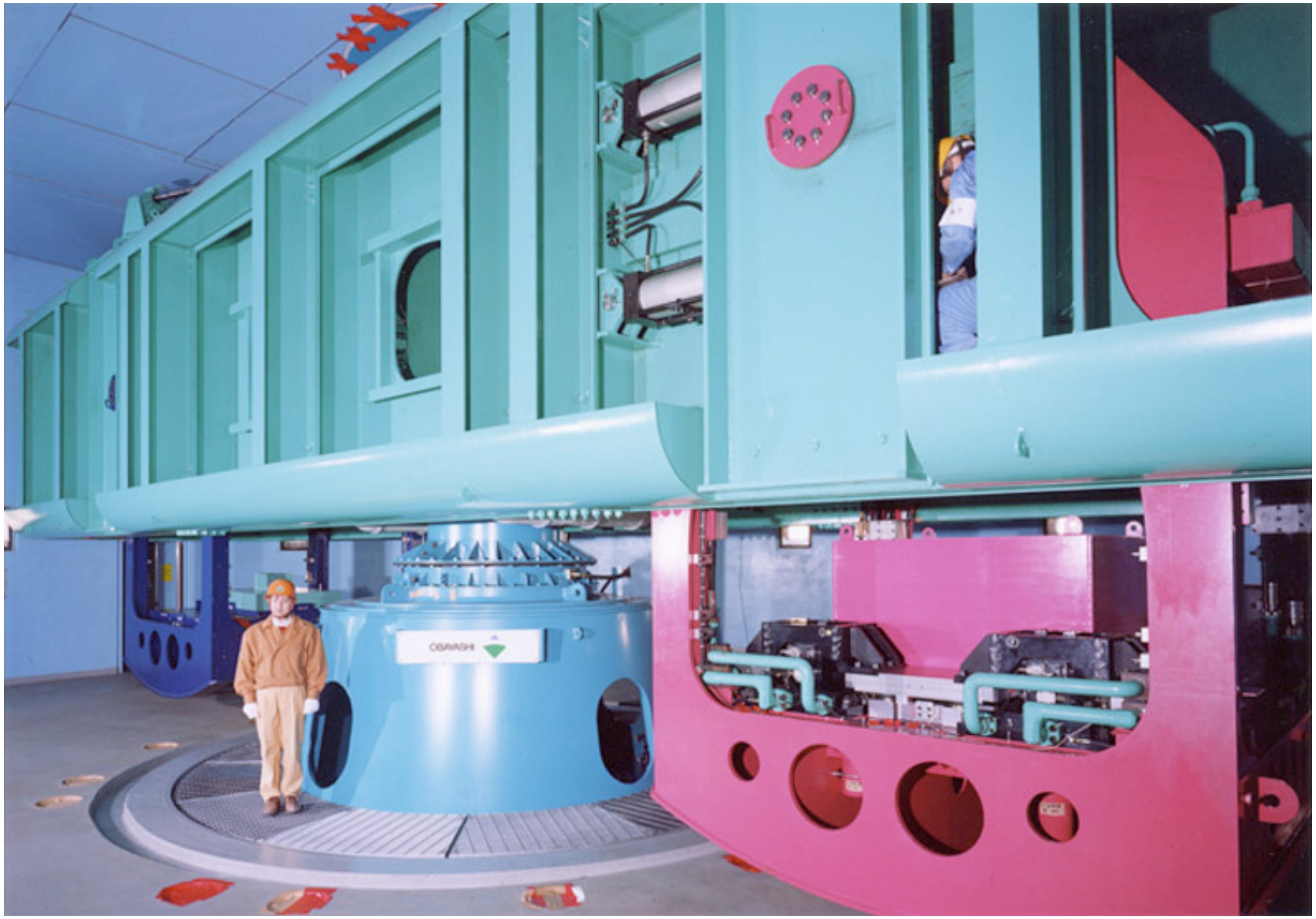
- Making a design guideline, a design standard and a design code.
- Increasing sympathetic friends of engineers and researchers understanding about new ideas and new deign.
- Persuading the building owners about our design and persuading general public about new ideas.

**Realistic dynamic tests are most effective method and they have strong visual persuasive power.**

# Collapse tests of very small steel frames

- When the specimen size is 1/10 of the actual scale of a structure.
- Stress level become 1/10 of actual stress in the structure.
- Nonlinear effect of the structural member cannot be treated correctly in the 1/10 specimen.
- P-delta effect becomes also very small when the specimen's weight is too light.

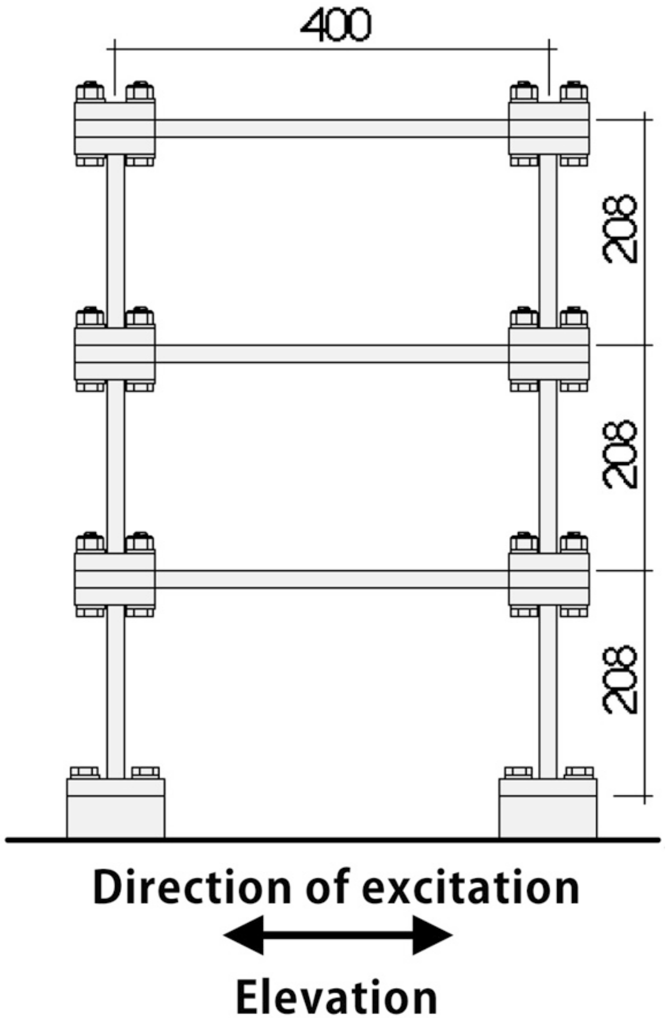
# Centrifuge and container at the Obayashi Research Institute

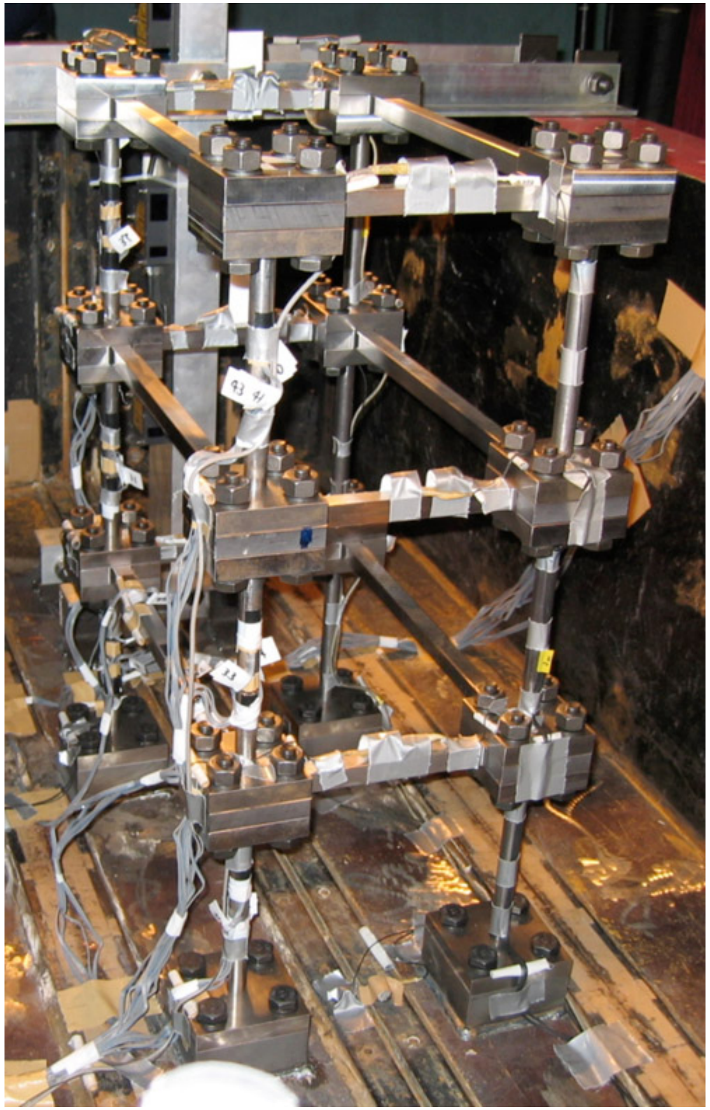


# High gravity in big centrifuge

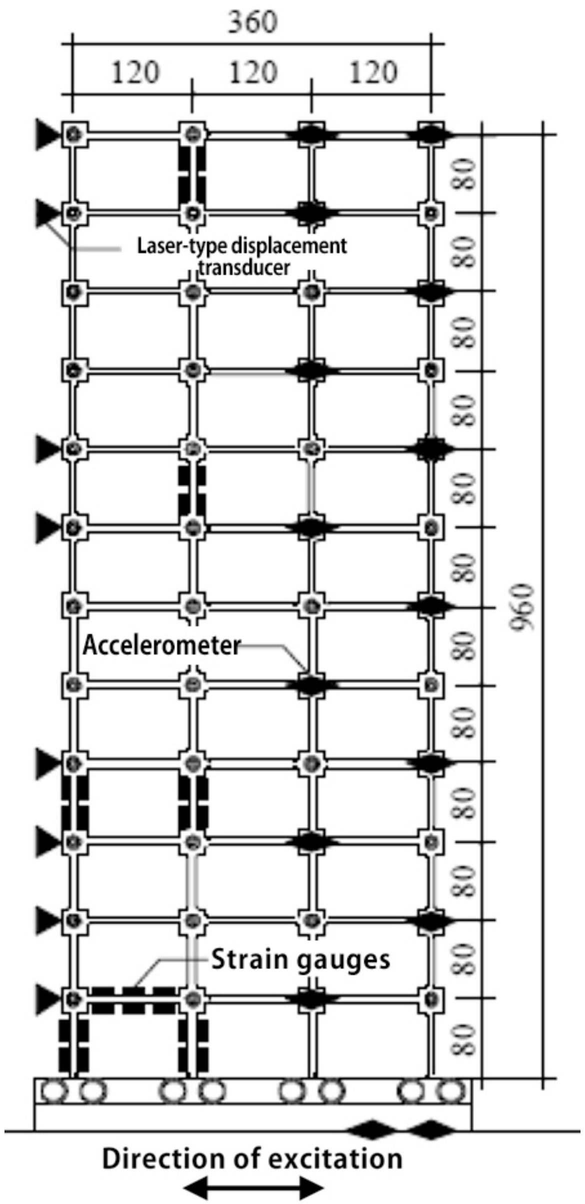
- 3, 12 and 30 story steel frames have tested here.
- The centrifuge could produce 100G gravity and the testing container could have a 2m high specimen.
- We could test 200m tall buildings using this strong machine theoretically.

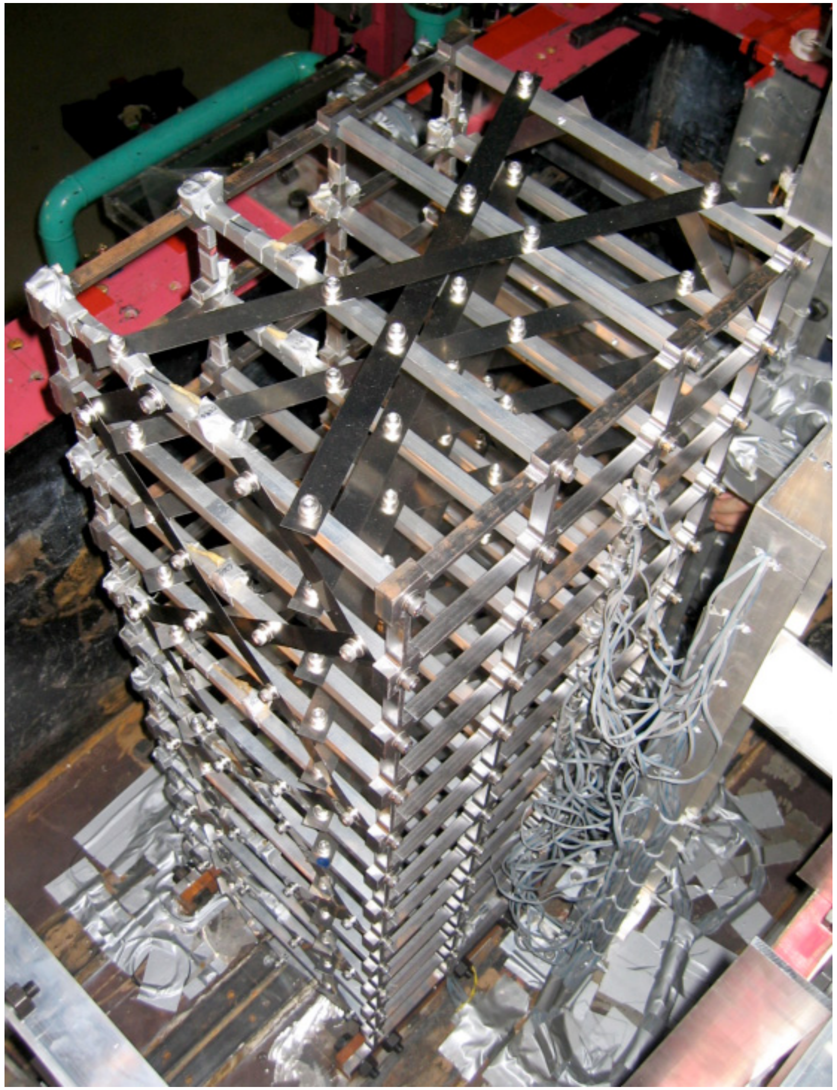
# 3-story weak tube columns and strong beams



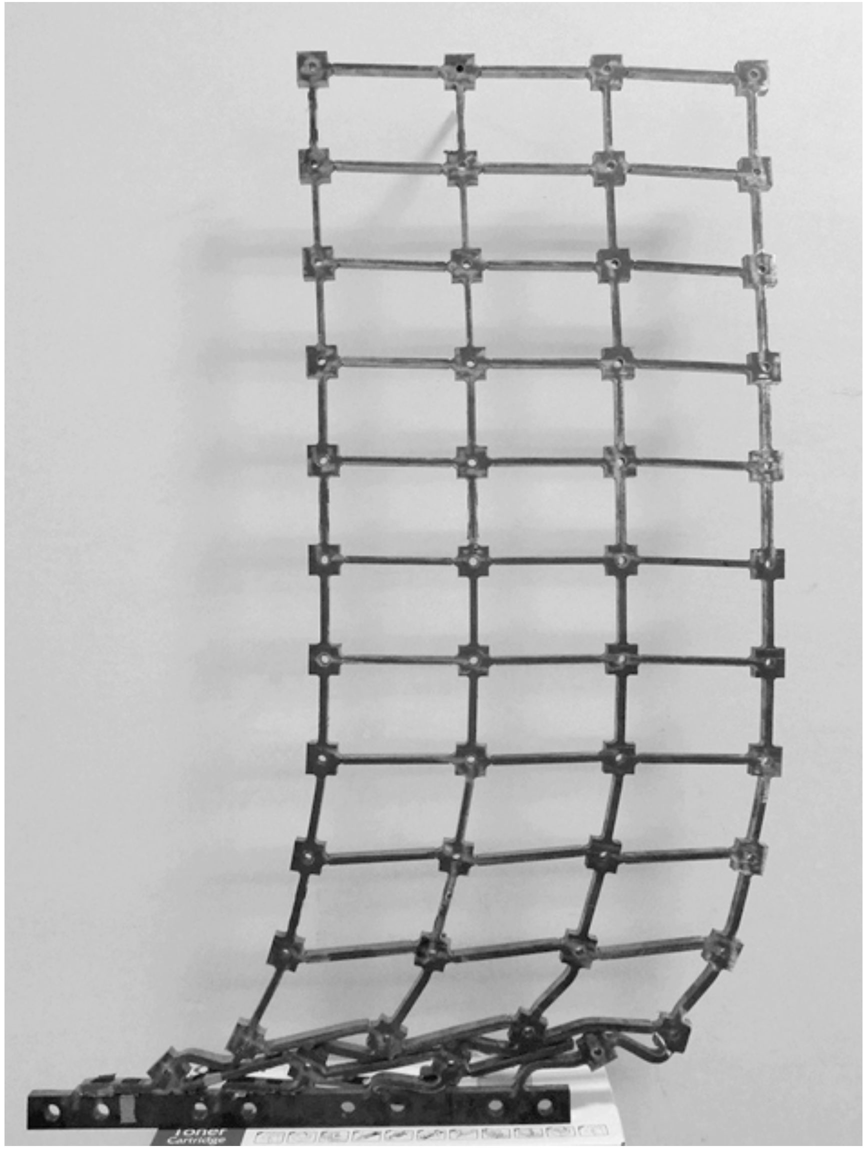



# 12-story strong columns and weak beams

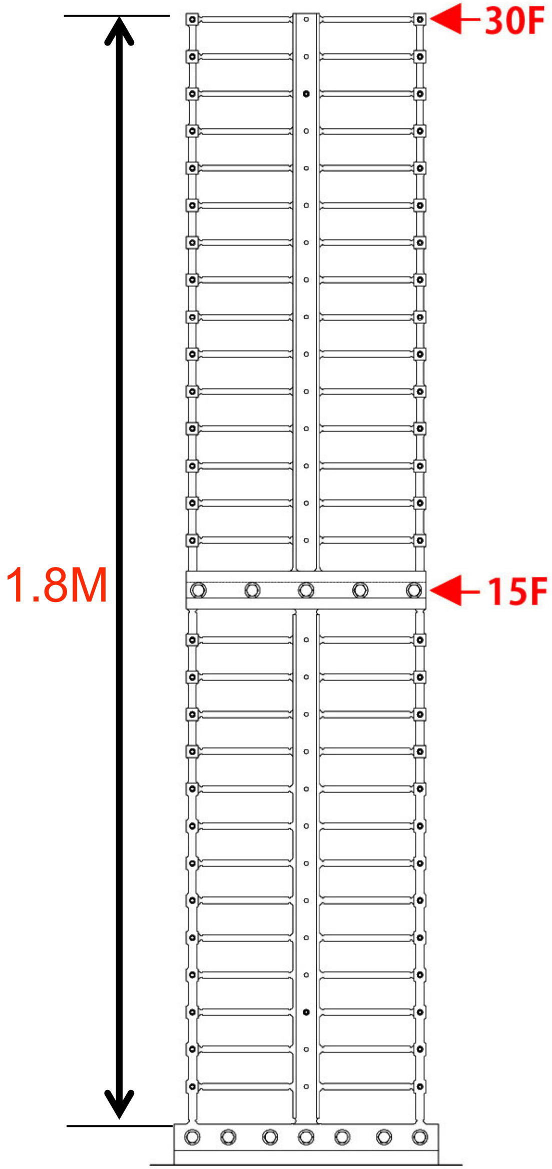


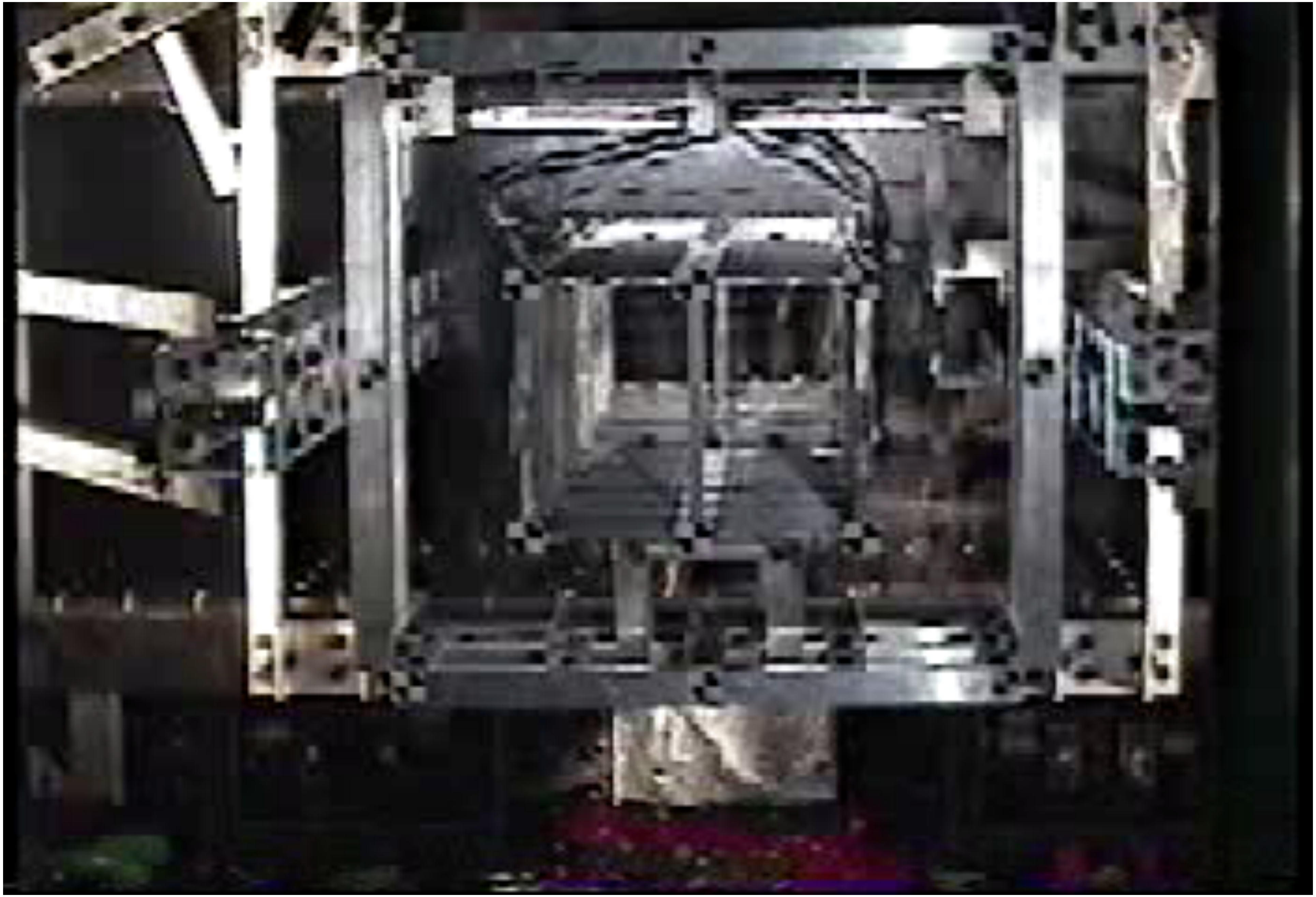



# Final collapse of 12 story frame

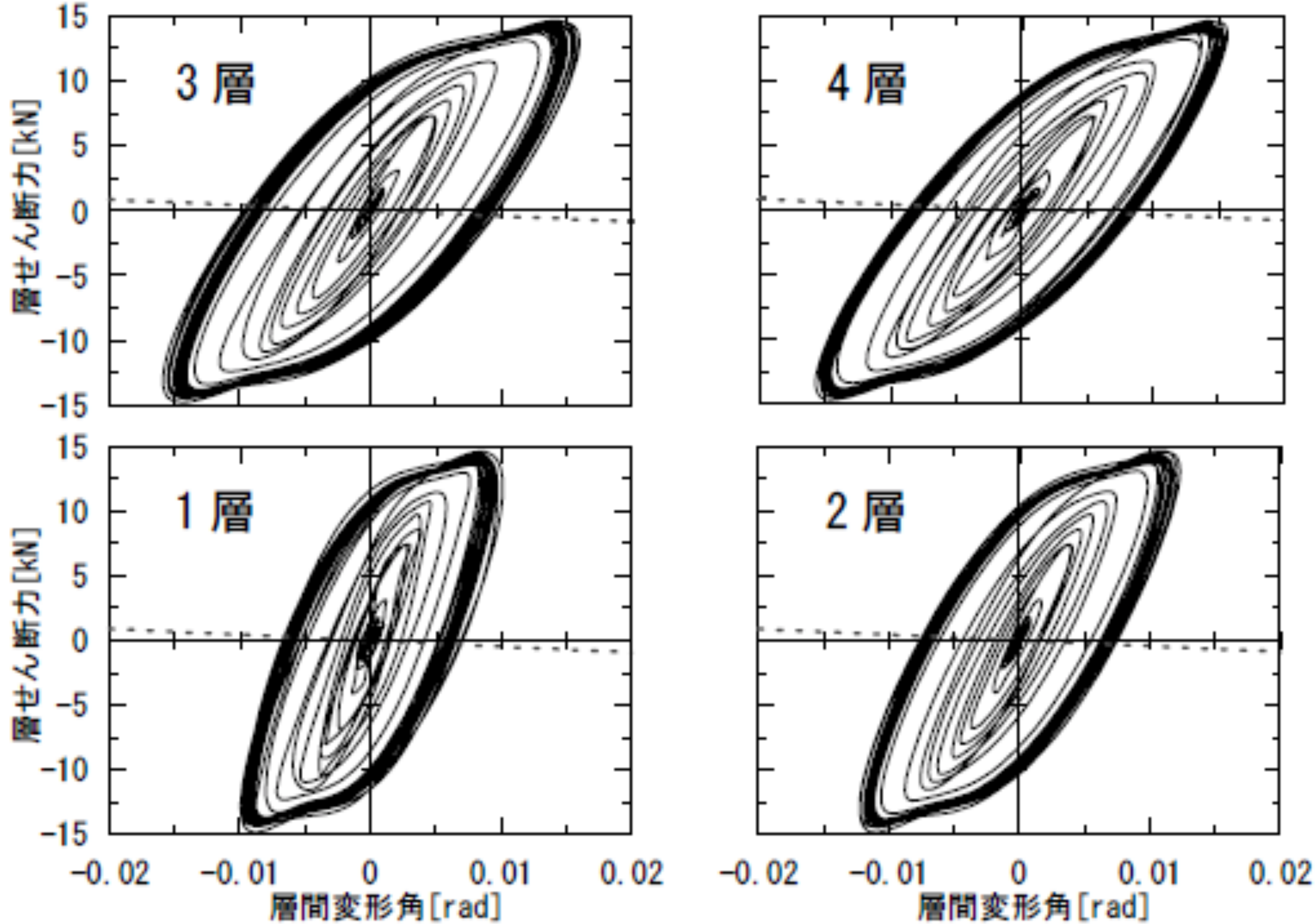


# 30-story shear wall and outrigger

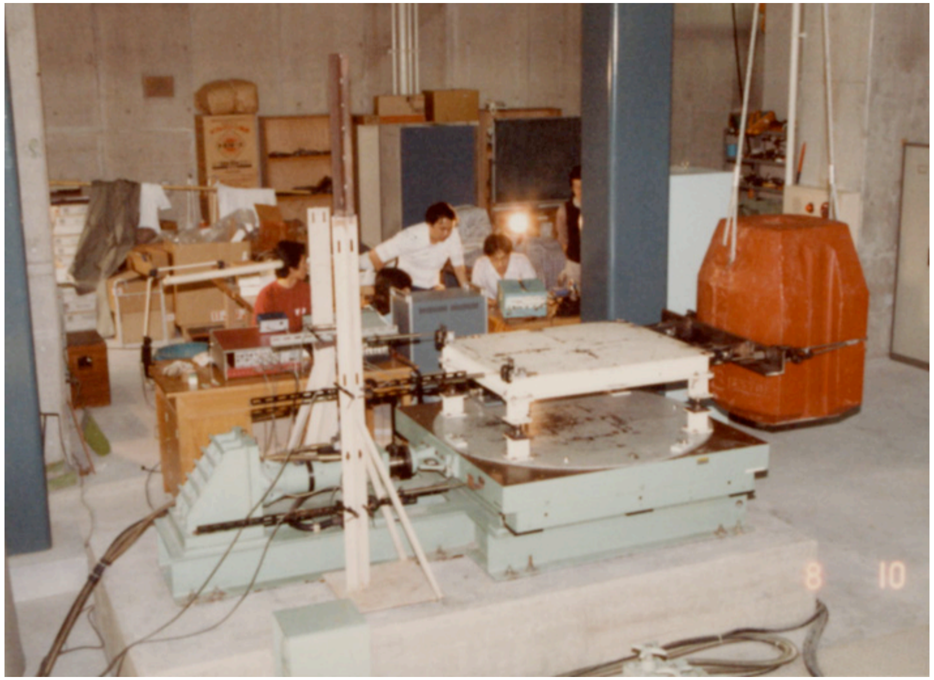


# Story shear & deformation angles



# A tiny seismic isolated structure was tested in 1982

# Homogeneous equation of structural dynamics

$$
\begin{pmatrix} M_x & 0 & 0 \\ 0 & M_y & 0 \\ 0 & 0 & M_z \end{pmatrix}
\begin{pmatrix} \dfrac{d^2x}{dt^2} \\ \dfrac{d^2y}{dt^2} \\ \dfrac{d^2z}{dt^2} \end{pmatrix}
+
\begin{pmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{pmatrix}
\begin{pmatrix} x \\ y \\ z \end{pmatrix}
=
\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}
$$

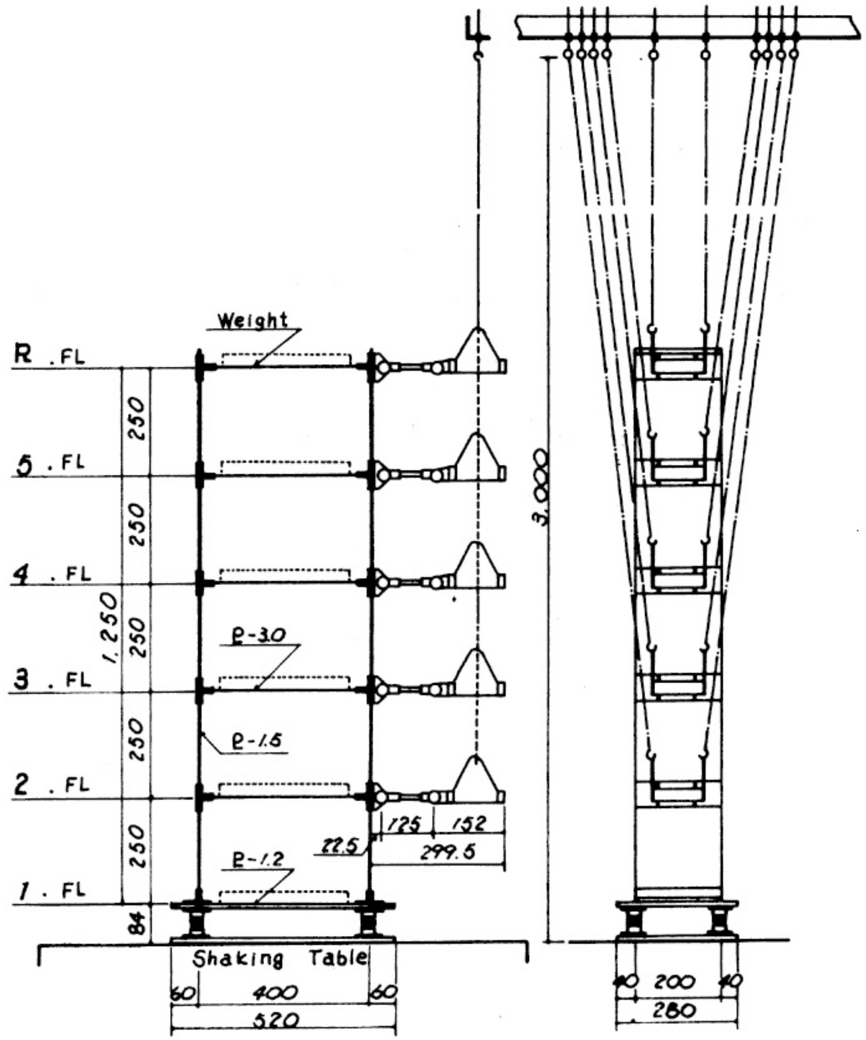
$M_x = M_y = M_z$ **in the actual structures**

# Homogeneous equation of structural dynamics

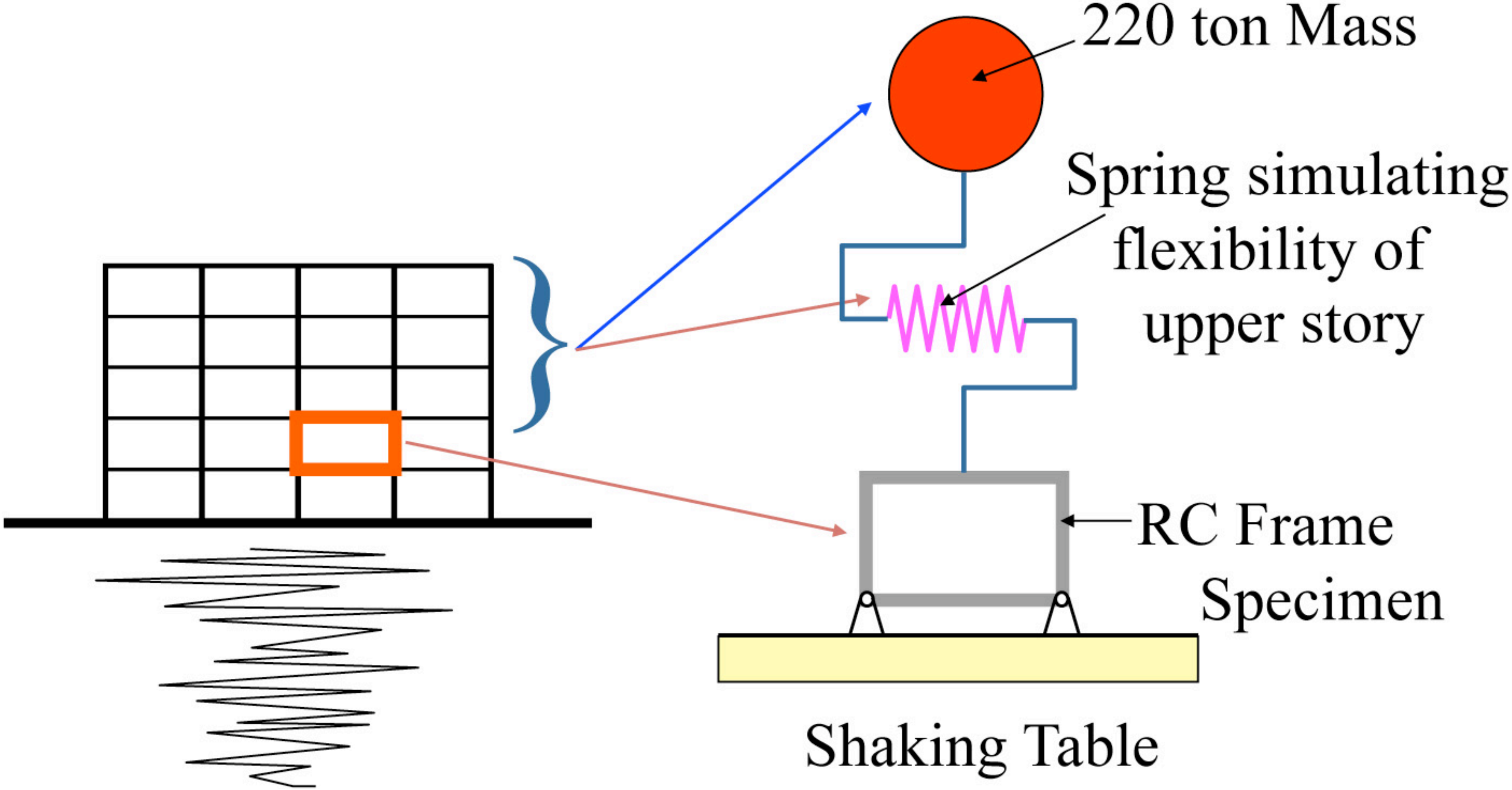
$$\begin{pmatrix} M_x & 0 & 0 \\ 0 & M_y & 0 \\ 0 & 0 & M_z \end{pmatrix} \begin{pmatrix} \dfrac{d^2x}{dt^2} \\ \dfrac{d^2y}{dt^2} \\ \dfrac{d^2z}{dt^2} \end{pmatrix} + \begin{pmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

$M_x \neq M_y \neq M_z$ **in the dynamic tests**

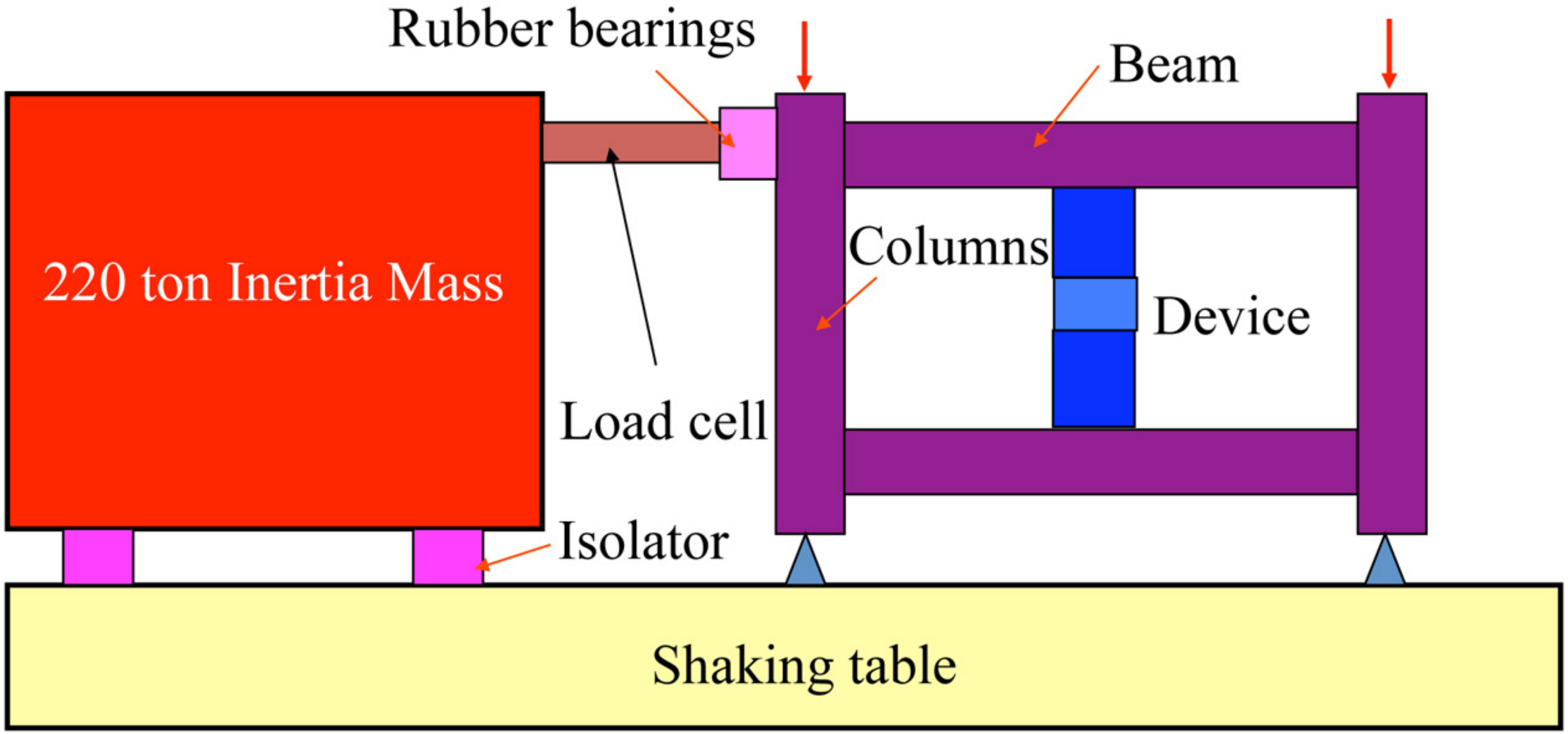
# 5-story seismic isolated structure and 5-horizontal inertia masses



# Old reinforced concrete frames added supplemental dampers

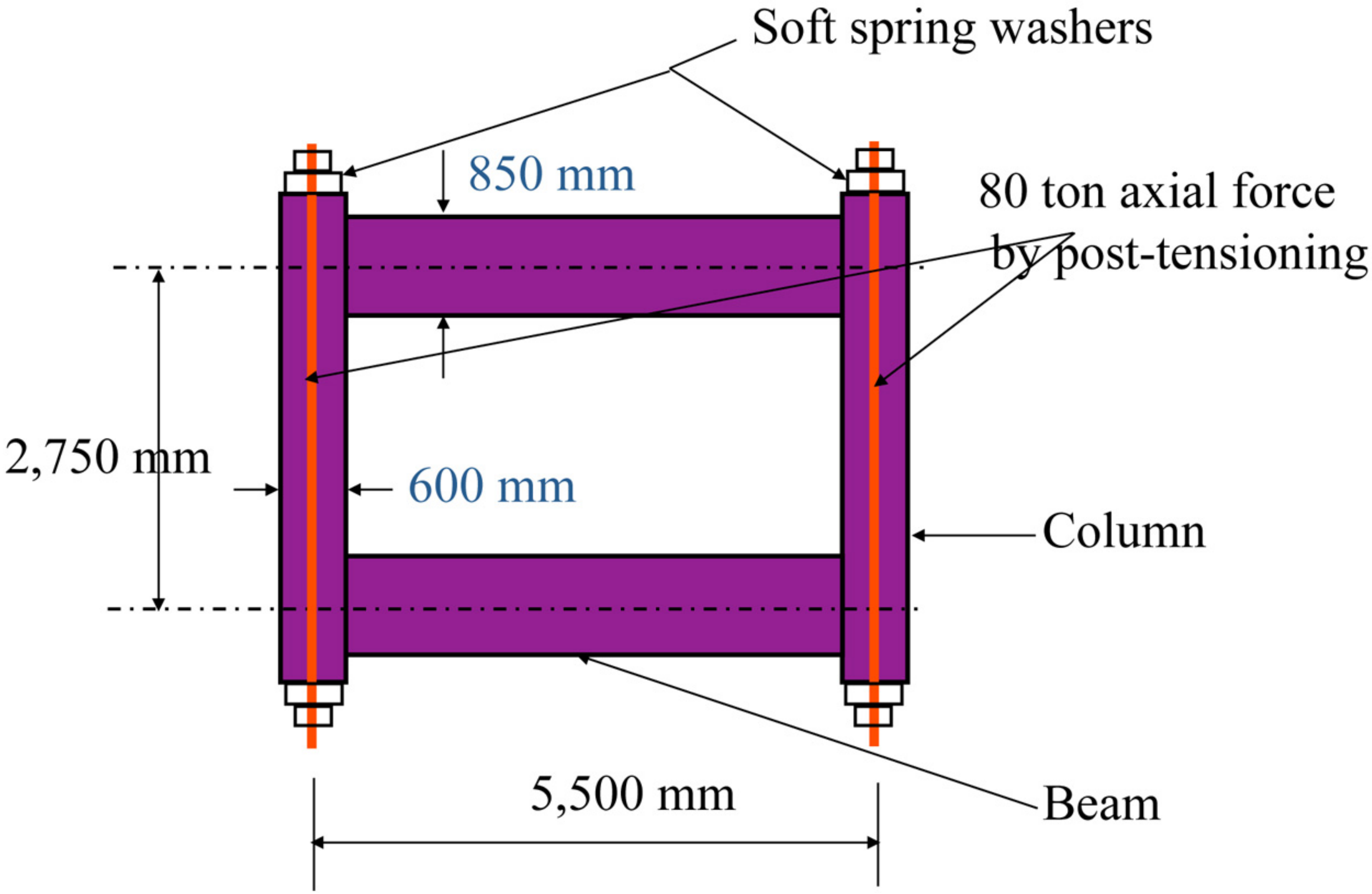


# Elevation view testing system

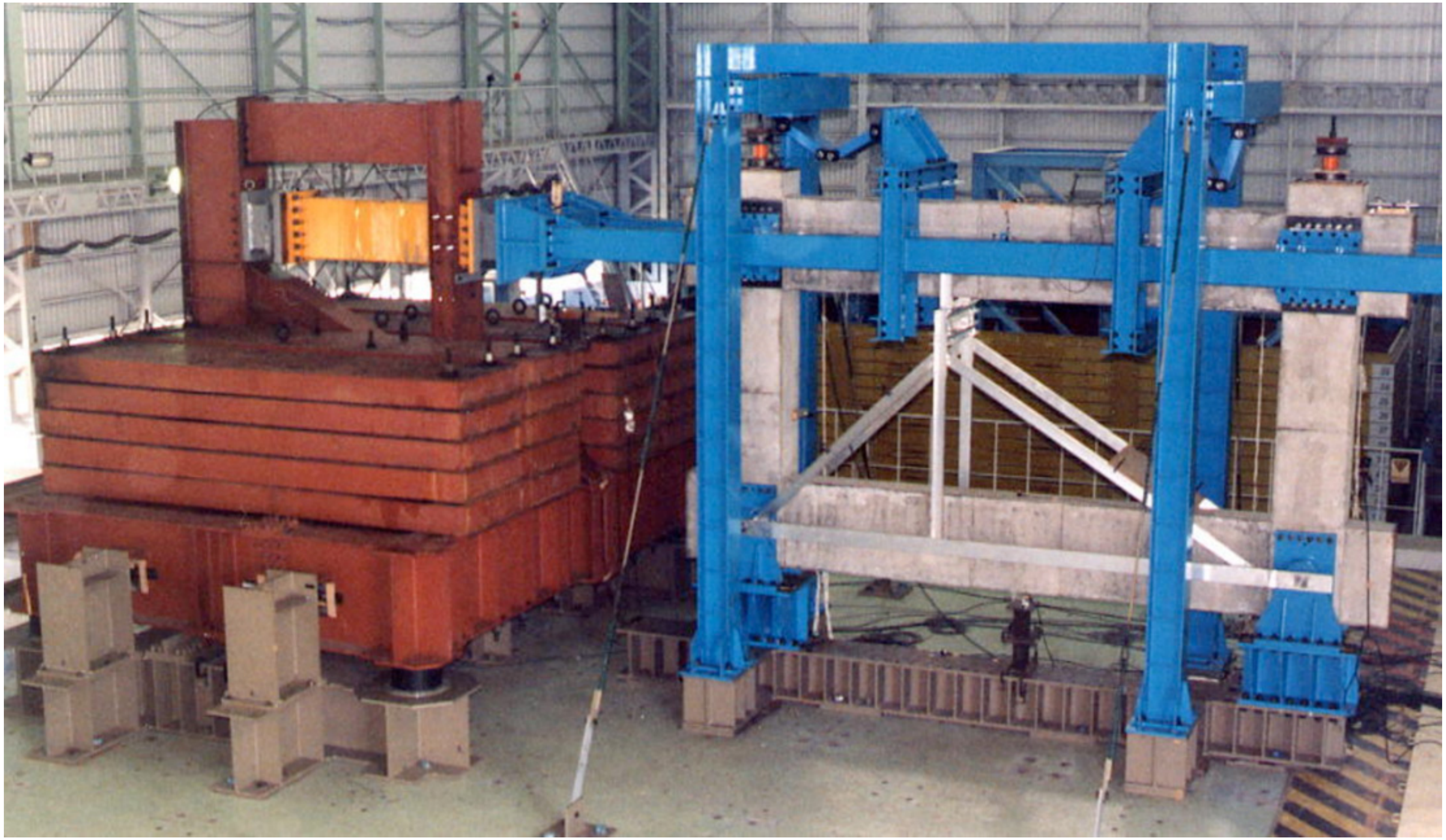



Natural period of the system : $T_1 = 0.6\text{sec}$

# Introduction of column axial forces



# Heavy steel inertia weight and reinforced concrete frame



# Tomorrow’s world by BBC
# August 1998

# Conclusions

- Structural engineers must make safer buildings and safer cities for people.
- We need to do not only the static structural test but also dynamic test.
- But often, the test facilities have some limitation.
- Researchers and engineers have to use these facilities under the combination with deep thinking and innovative ideas.