STRUCTURAL DESIGN OF THE SEISMIC RESPONSE CONTROLLED BUILDINGS WITH ROBUSTNESS

Shinya NISHIMOTO, Yozo SHINOZAKI,
Megumi KAWASAKI, Koji TSUCHIMOTO
Taisei Corporation
Tokyo, Japan

2011 East Japan Earthquake

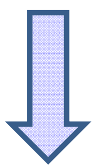
Fukushima Nuclear Power Plant
after hydrogen explosion

The expected height of tsunami in its original design was 6m(20’),
but actual maximum height was about 14m(47’)

Redundancy or Robustness to Disaster

We can't know or imagine unexpected events exactly,
but engineers should speculate all possible events.

Major Earthquake
Stormy Wind
Heavy Rain, Heavy Snow
Tsunami, Flood, High Tide
Volcano Explosion and Falling Ash
Fire or Explosion
.
.
.



Structures should have more redundancy or robustness to such disasters.

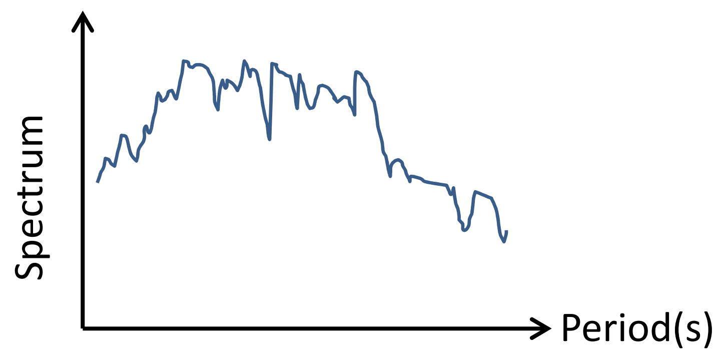
Possible Countermeasures to achieve robustness

Robustness:

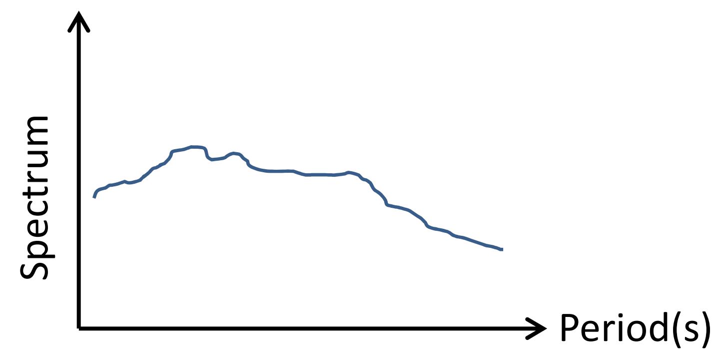
The potential performance of building to deviation or uncertainty of the design loads, building properties and so on.

Uncertainty Factor	Possible Countermeasures
Loading	Giving some allowance or margin to design load
Material Property	Taking the deviation of material properties into account, especially properties of isolators or dampers of seismically isolated structures.
Seismic Force	Giving redundant load factor for seismic input
Seismic Response	Giving enough damping to the building, such as steel-dampers or oil-dampers Giving some allowance or margin to seismic response

Possible Countermeasures to achieve robustness

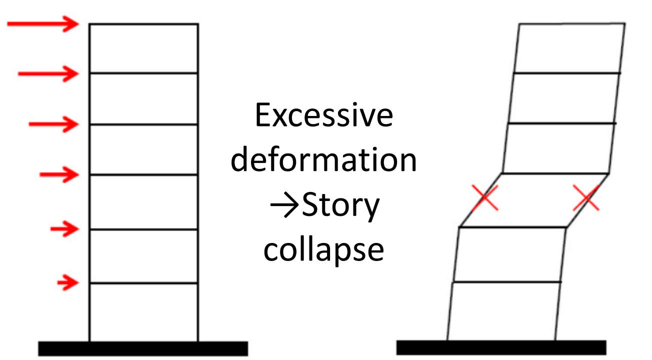


Response spectrum with low damping

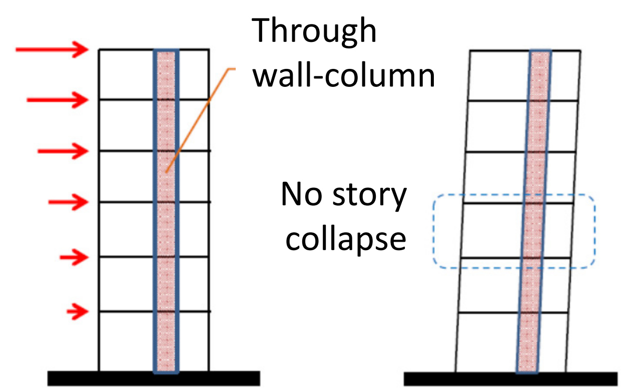


Response spectrum with high damping

Giving enough damping to buildings can make seismic behavior of the building stable



buildings with low stiffness or strength



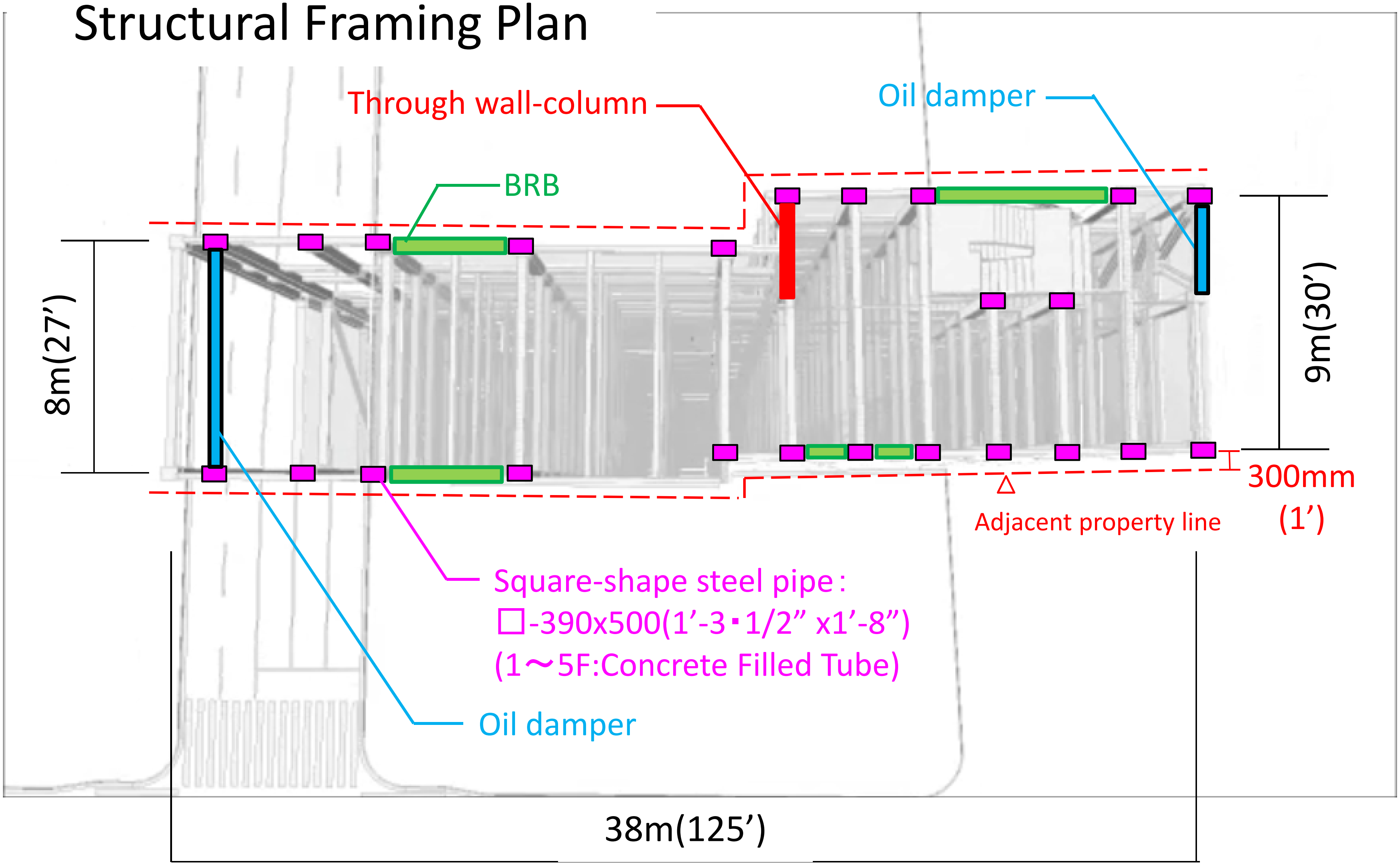
With through wall- column

Installing through wall- columns makes the story drift smaller and prevents story collapse.

Itoya Ginza Building

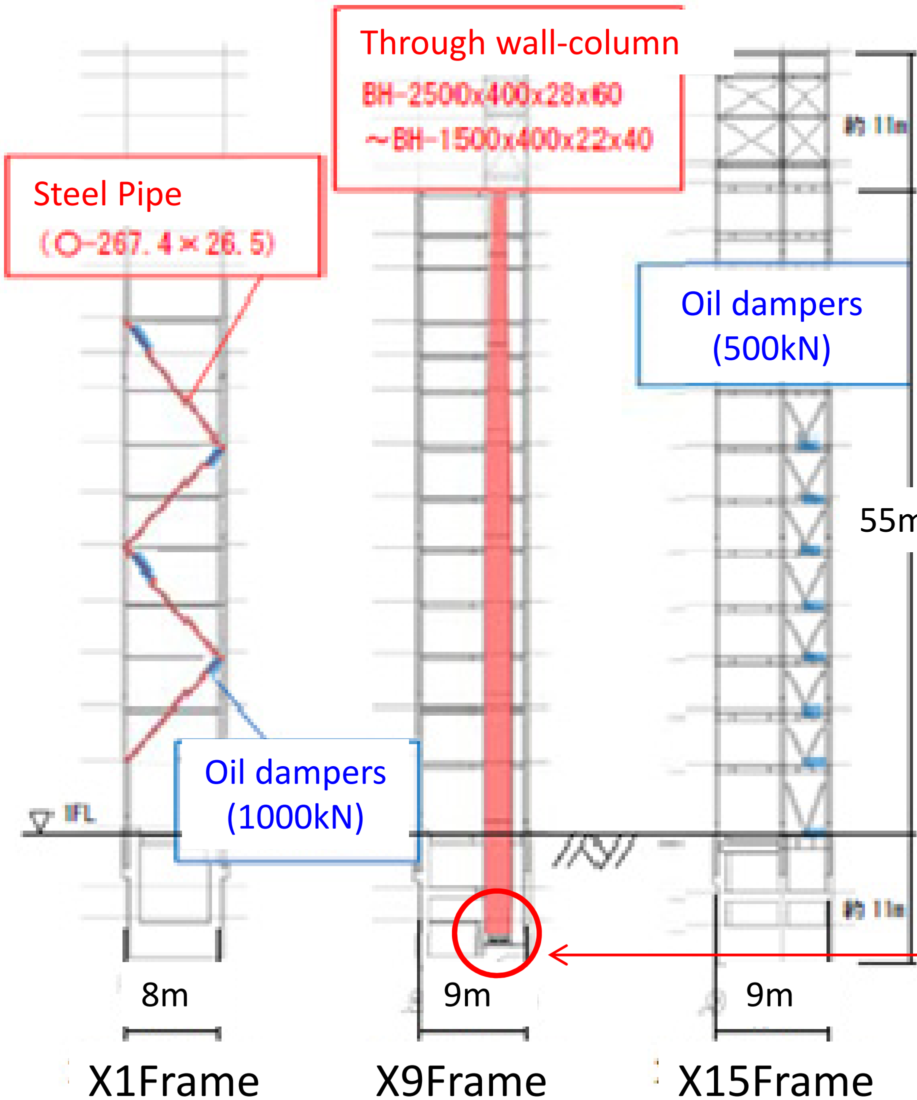
Ginza 2, Chuo-ku, Tokyo, Japan

Structural Framing Plan

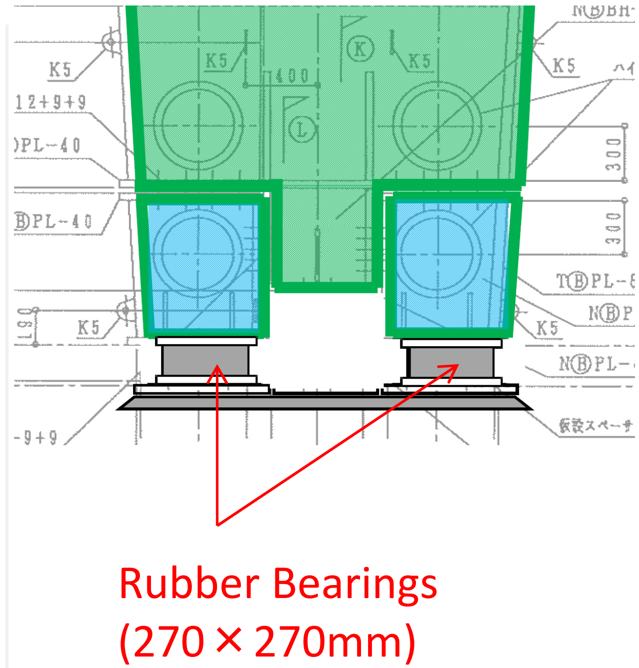


Structural Outline

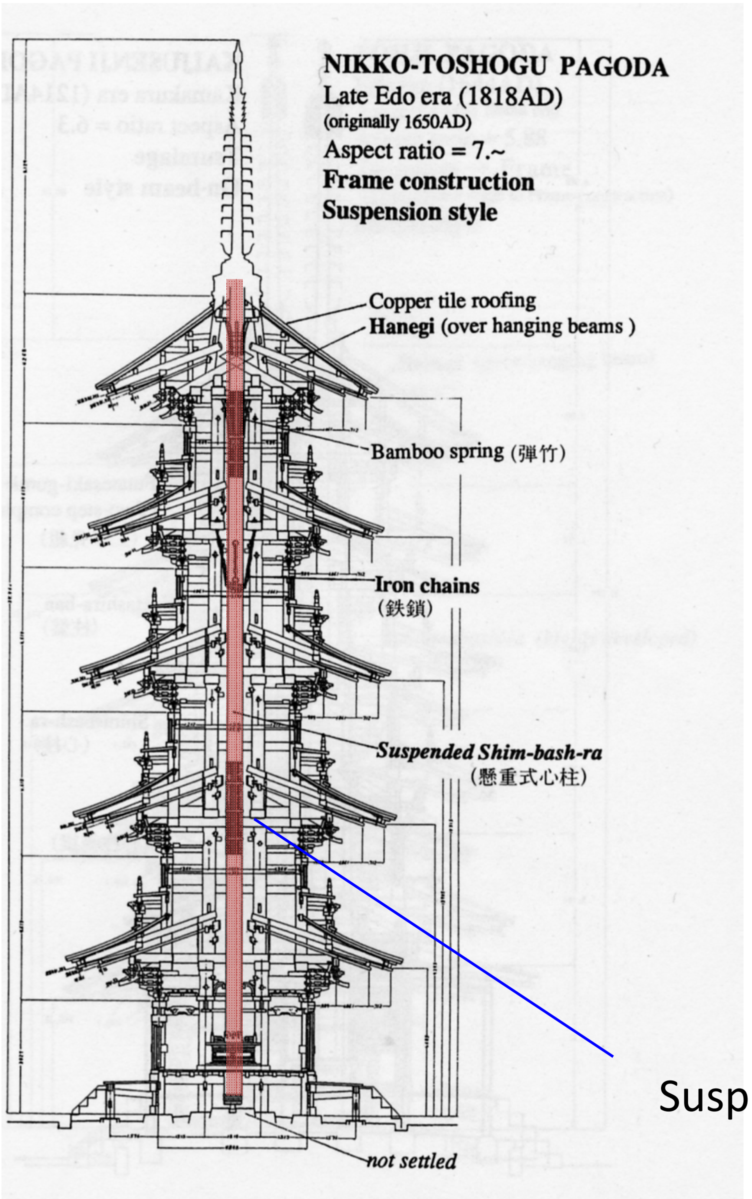
Structural Framing Elevation



Structural Framing Plan



Through column in historical building



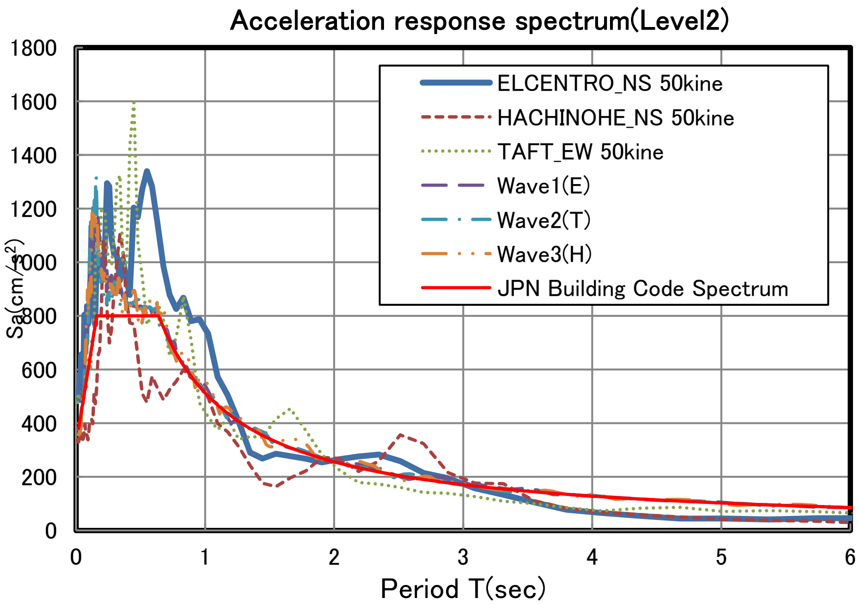
Suspended through column

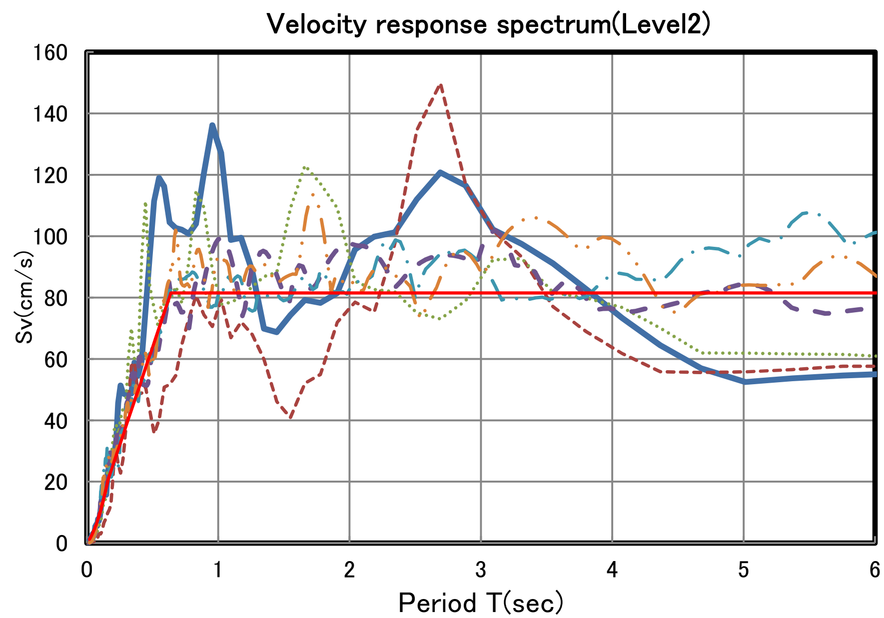
Clearance gap beneath the bottom of suspended column

Trough column is installed at the center of the Japanese traditional 5-storied Pagoda
It is suspended from upper floors, preventing story collapse of the building.

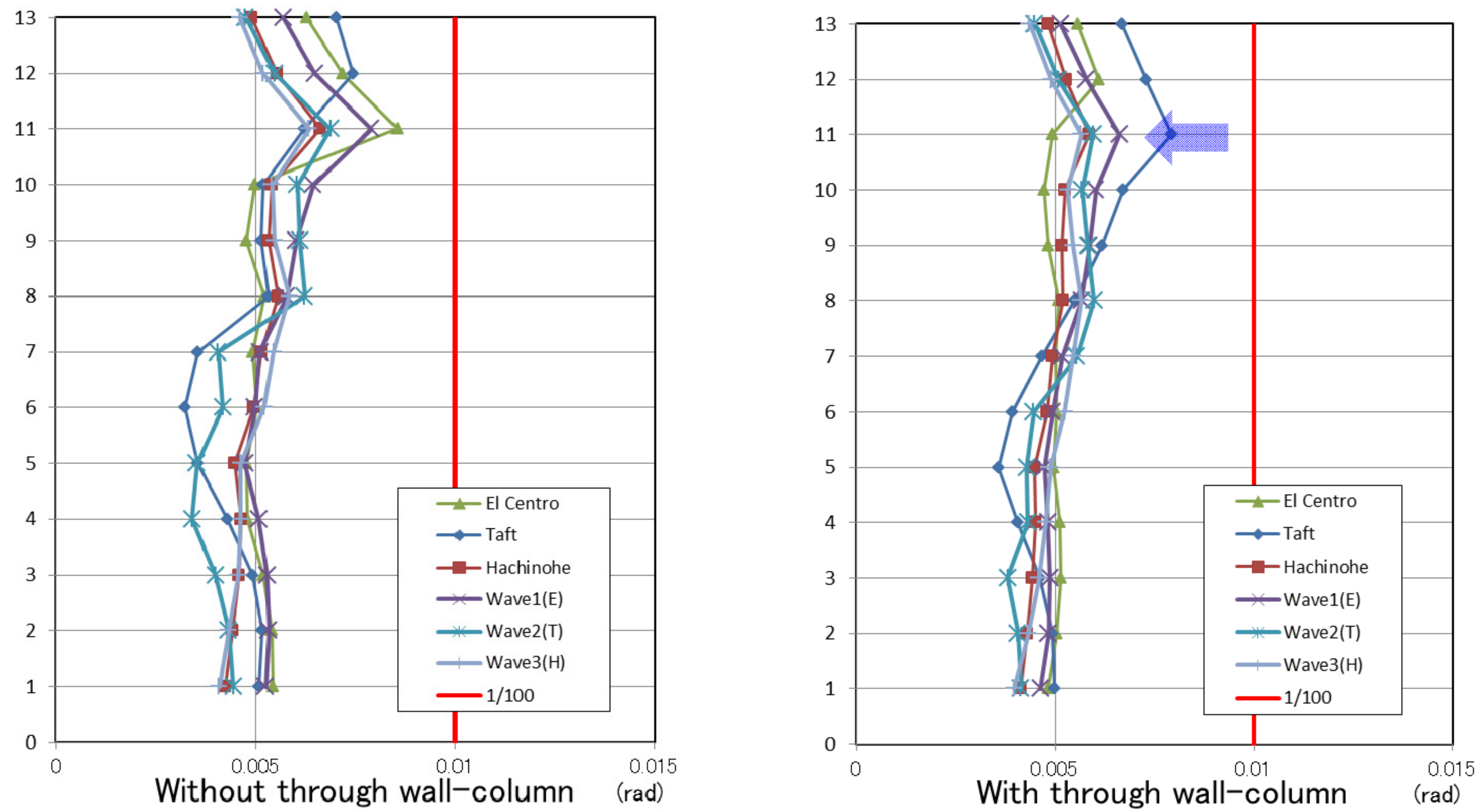
Input Ground Motions

WAVE		Level2 Max.Acc (m/sec^2)	Level2 Max.Vel (m/sec)	Level3 Max.Acc (m/sec^2)	Level3 Max.Vel (m/sec)	Time (s)
Observed seismic motion	El Centro 1940 NS	5.108	0.50	7.662	0.75	53.8
	Taft 1952 EW	4.966	0.50	7.449	0.75	54.4
	Hachinohe 1968 NS	3.333	0.50	5.000	0.75	51.0
Ground motion based on building code supectrum	Wave1(E)	3.623	0.78	5.435	1.17	120.0
	Wave2(T)	3.567	0.44	5.351	0.67	120.0
	Wave3(H)	3.751	0.63	5.626	0.95	120.0



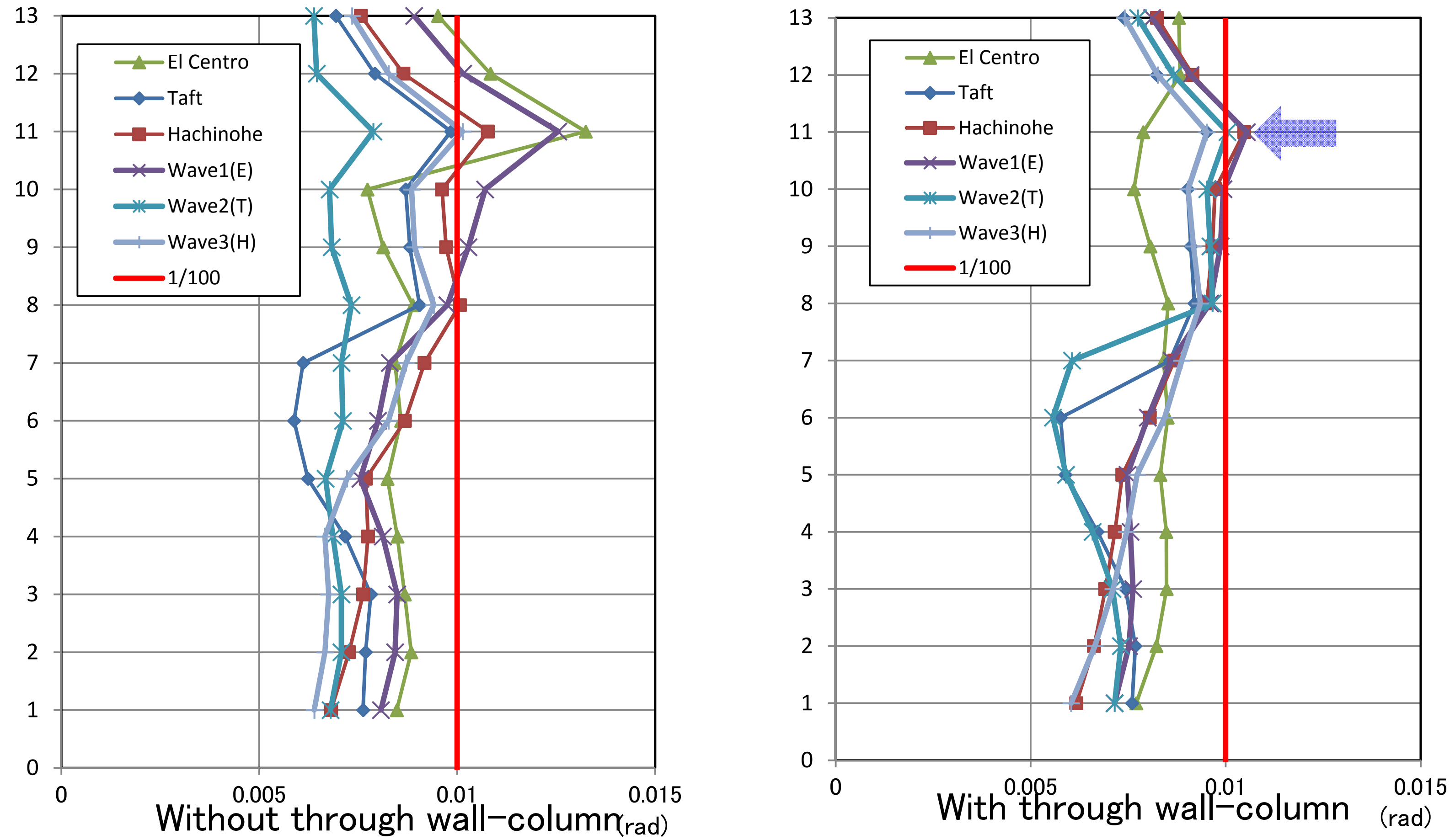


Results of non-linear response history analysis



Response story drift angle to Level2(DBE)

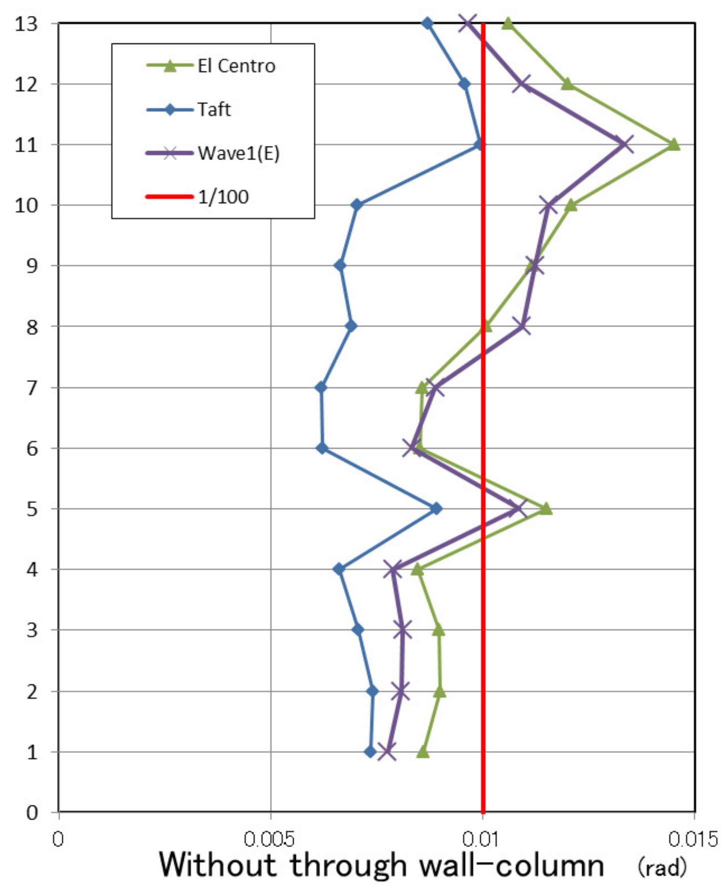
Results of non-linear response history analysis

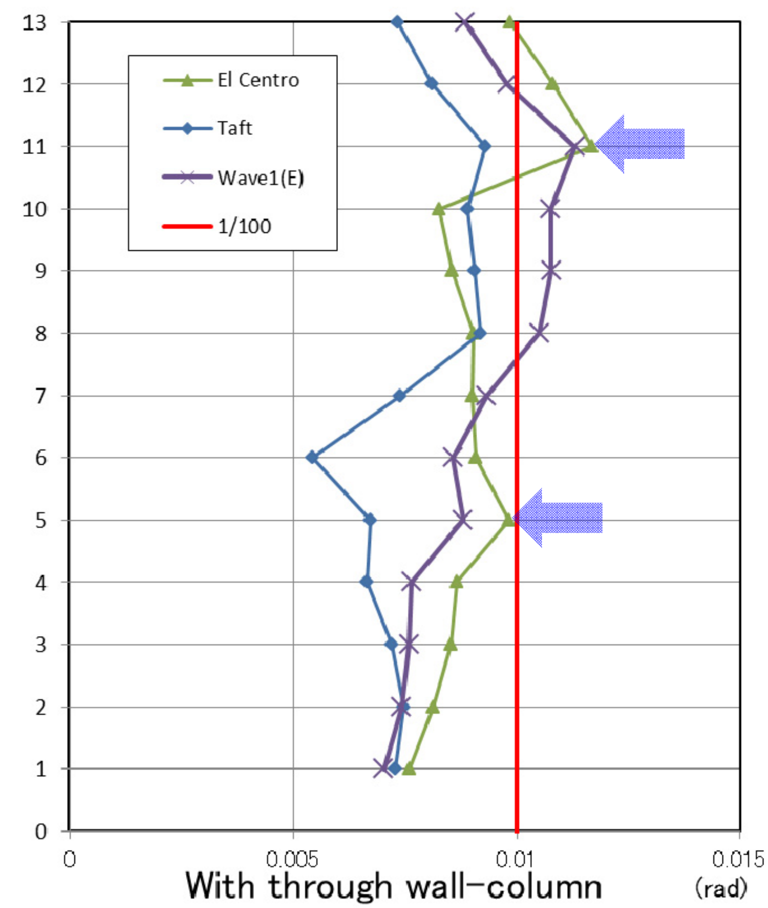


Response story drift angle to Level3(MCE)

Influence of deviations or uncertainties of structural performance

Assuming : Stiffness of the 5th story has half of original one

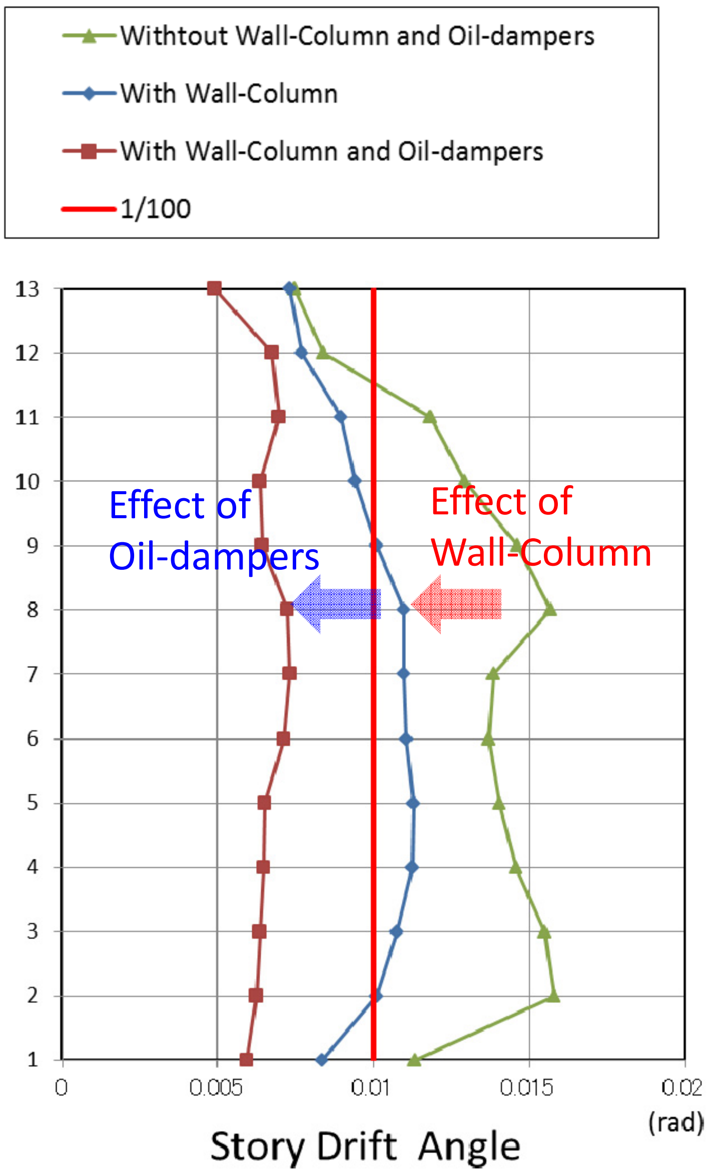


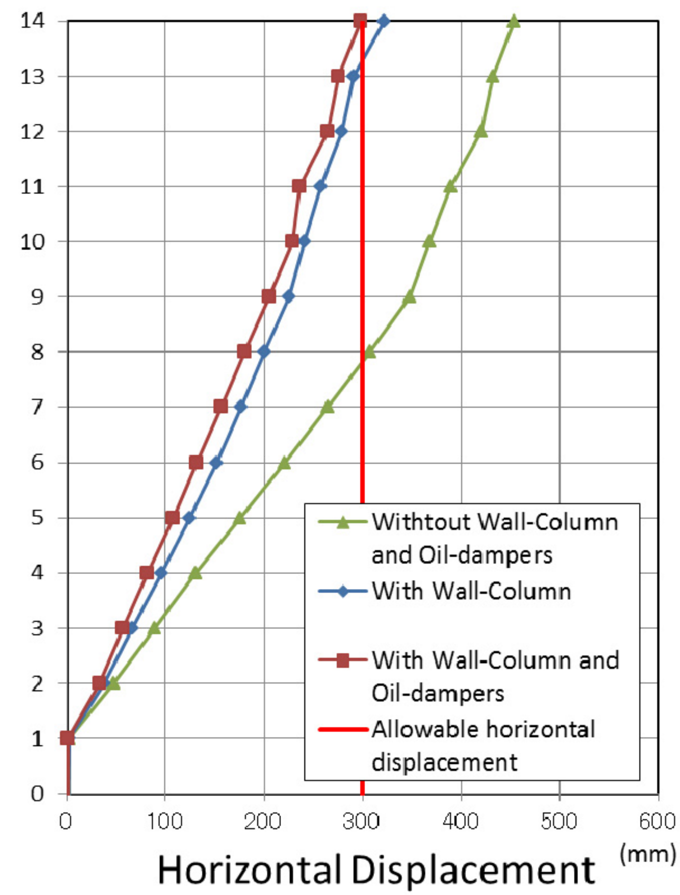


Response story drift angle to Level3(MCE)

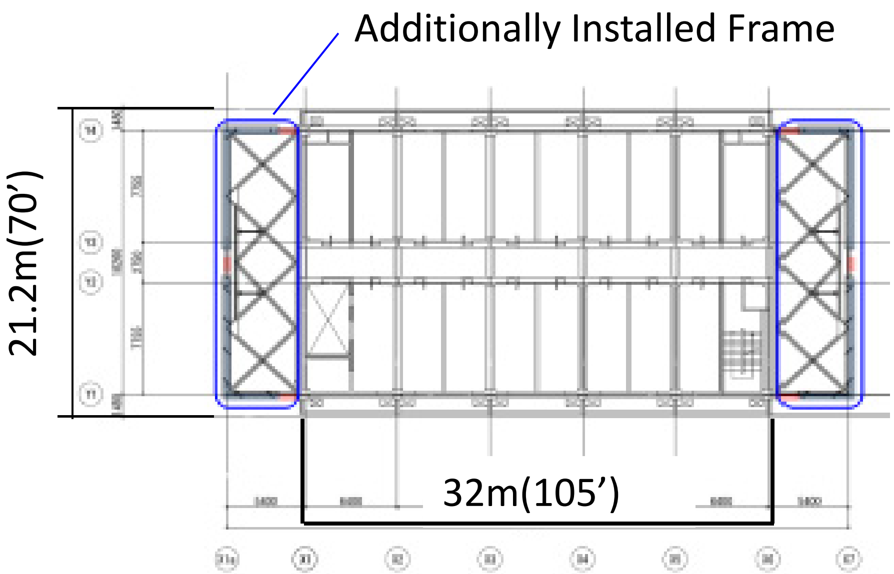
Effect of Through Wall-Column and Oil dampers

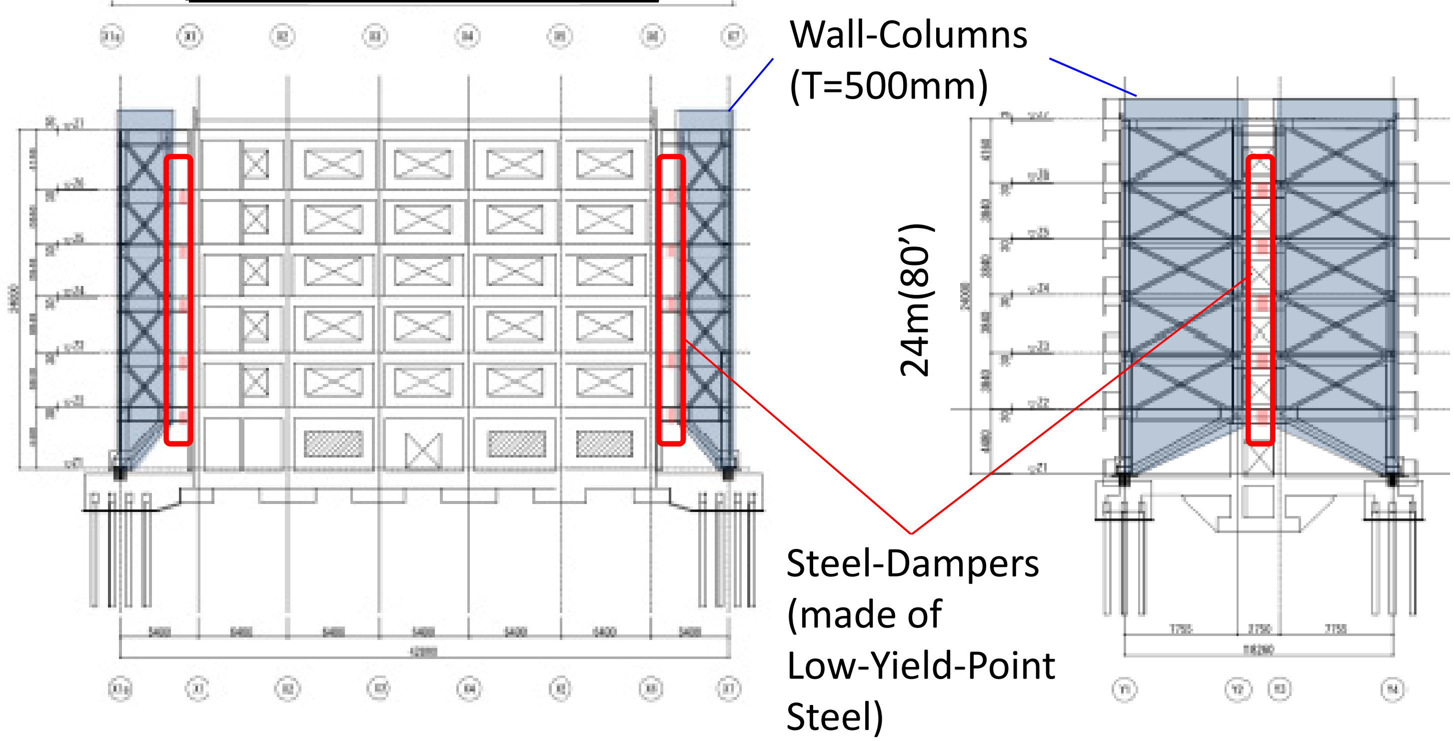
Ground Motion with Building Code Spectrum(Level 2)



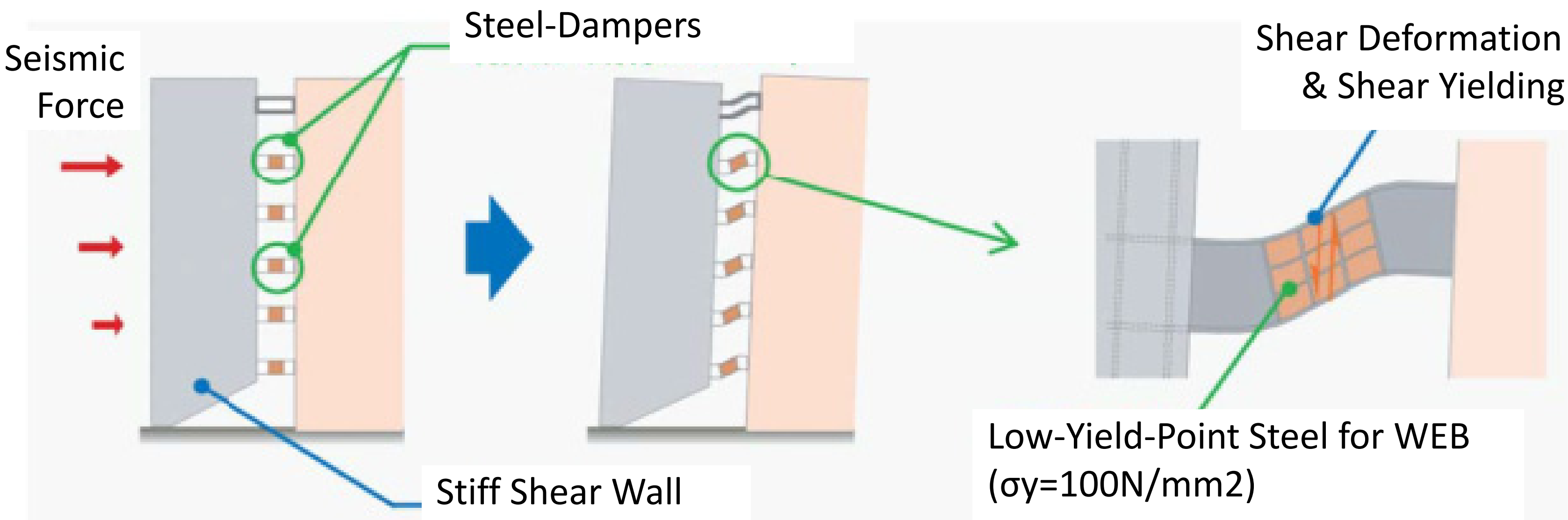


S-Building (seismic retrofit)





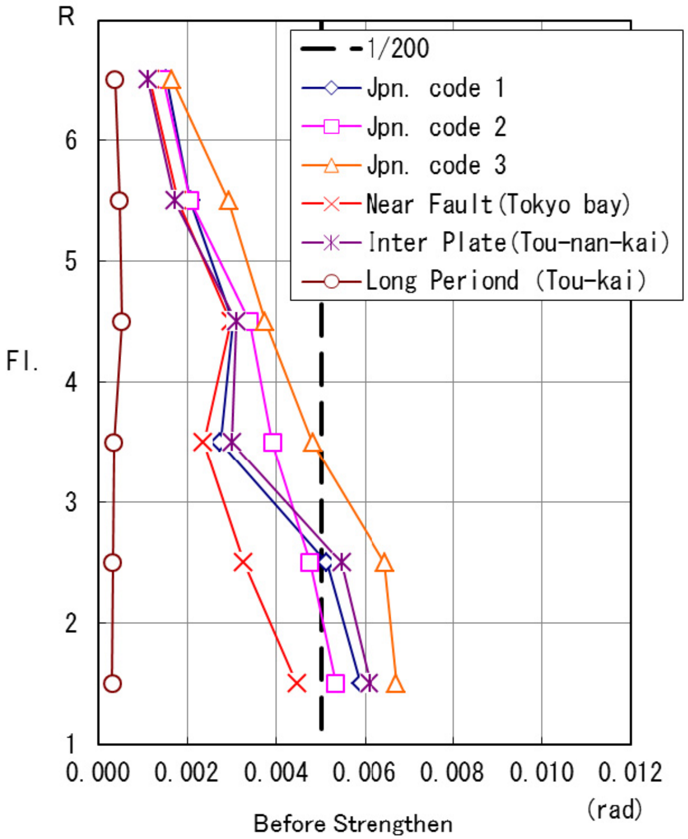
Wall-column for seismic strengthening



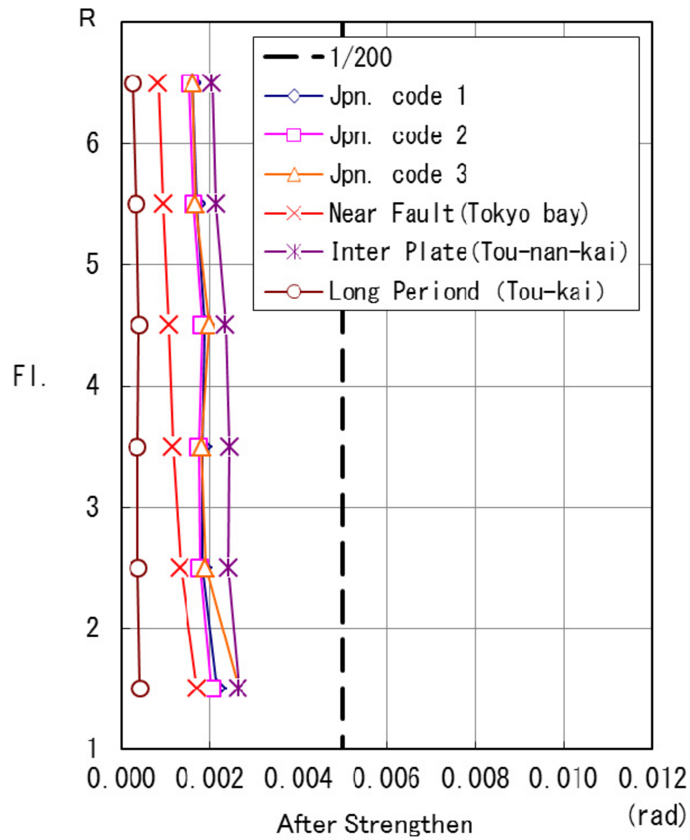
The wall-columns equalize story drift of the building to prevent story collapse.

Steel spandrel beams are installed between building and wall-columns, and between two adjacent wall-columns.

Results of non-linear response history analysis



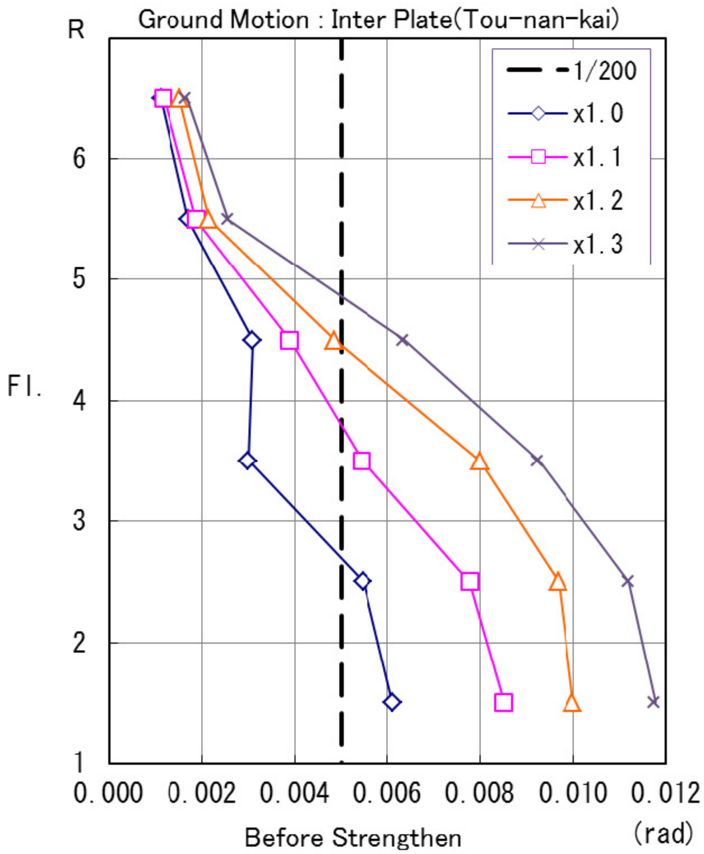
Before Strengthening

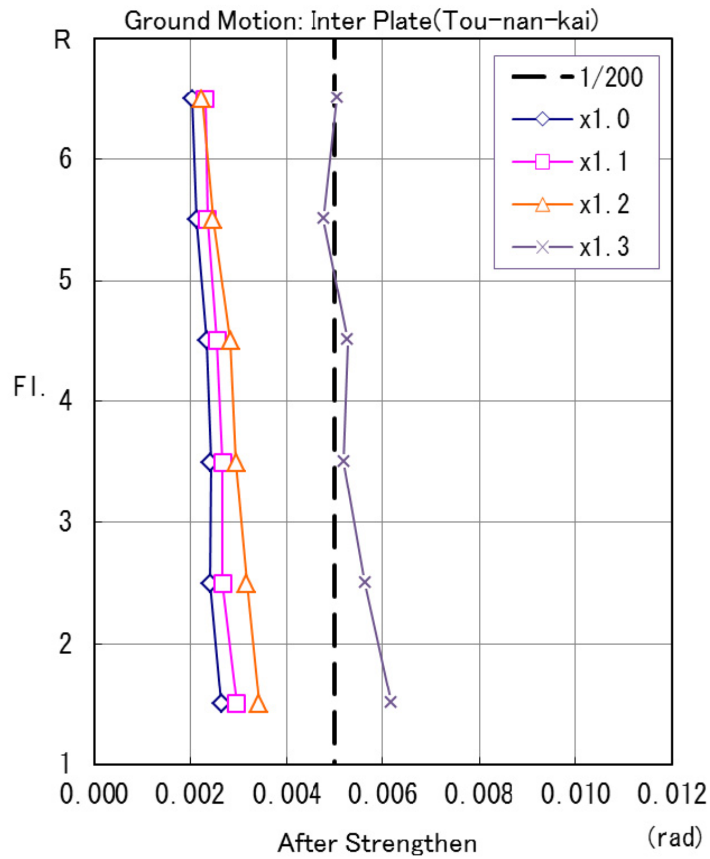


After Strengthening

Response story drift angle to Level2(DBE)

Results of non-linear response history analysis





Before Strengthening

After Strengthening

Response story drift angle to larger seismic input

Summary

・ Through wall-columns with damping devices make it possible to secure good earthquake-resistant performance.

・Such system can provide robustness to the larger seismic input or uncertainties of structural performance.