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Full-Scale Tests on Value-Added Performance of 5-Story Building with Various Dampers Commercially Available

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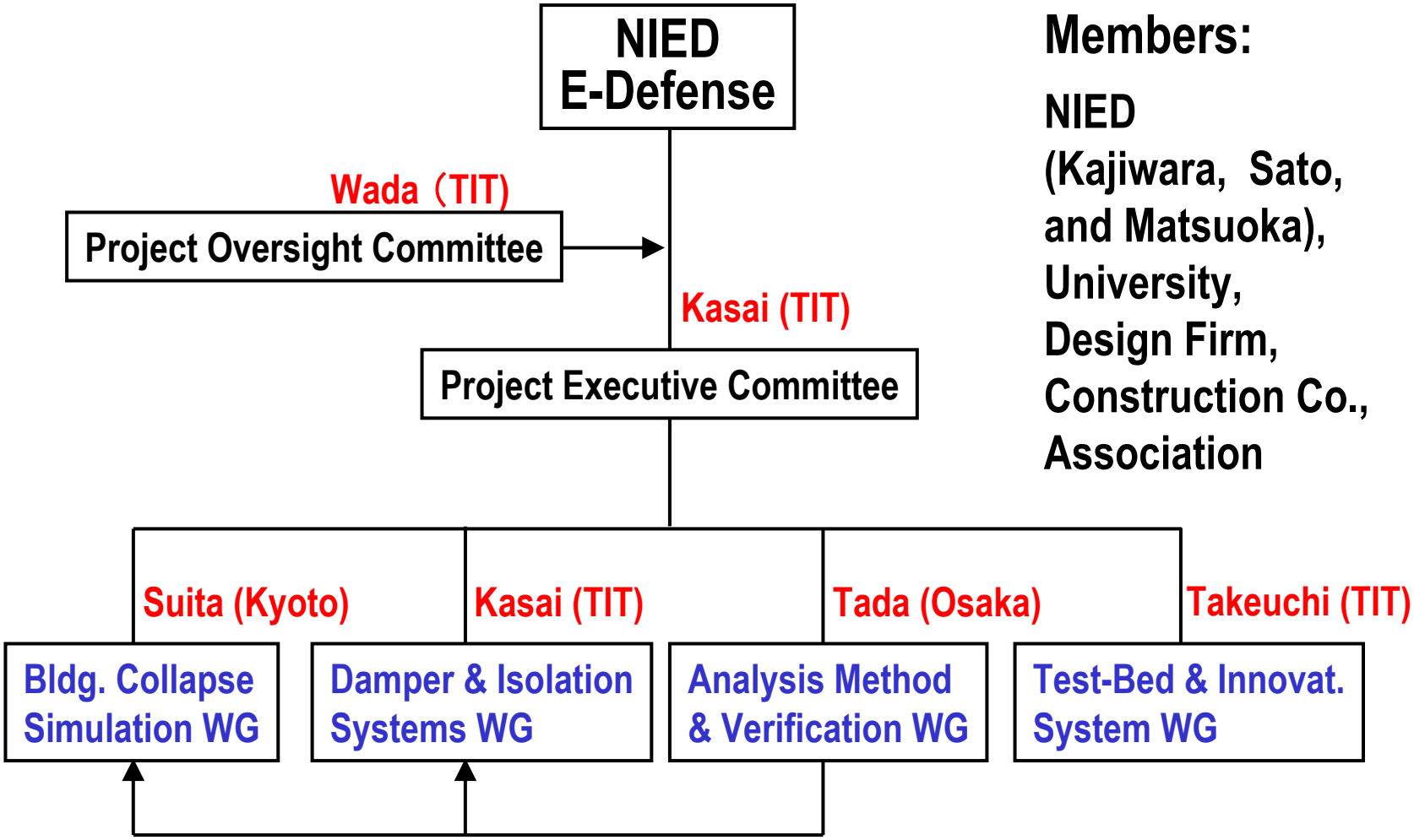


Members:

NIED
(Kajiwara, Sato, and Matsuoka),
University,
Design Firm,
Construction Co.,
Association

Fig. 1 Organizations of E-Defense Steel Projects

Response-Controlled Bldgs.

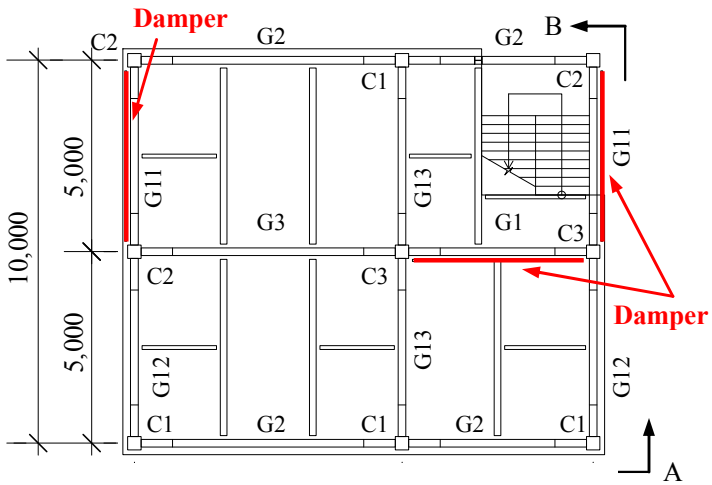
Building with dampers has never experienced moderate to stronger earthquakes. So, conduct realistic tests using full-scale model, and

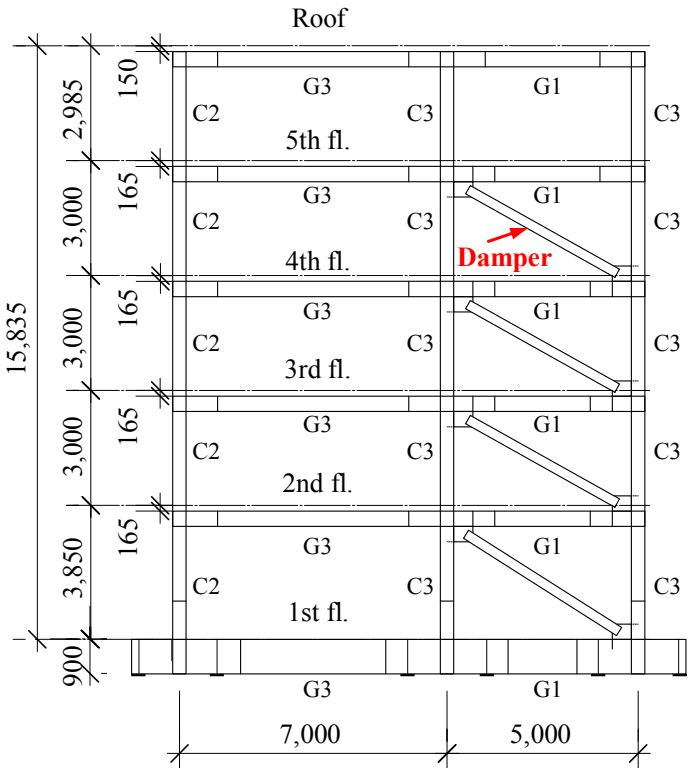
- Verify reliability of different damper types & sizes under in- & out-of-plane dispt.s of small to large magnitudes.
- Measure dynamic properties of the realistic building at various vibration levels (ambient, shaker, & shaking table).
- Confirm improved performance of a typical mid-rise steel office bldg. recognized to vibrate too much. Use minor, major, & catastrophic (Kobe) ground motions.
- Attack unresolved problems on design/analysis by means of challenging data measurement schemes.
- Advance numerical simulation techniques.

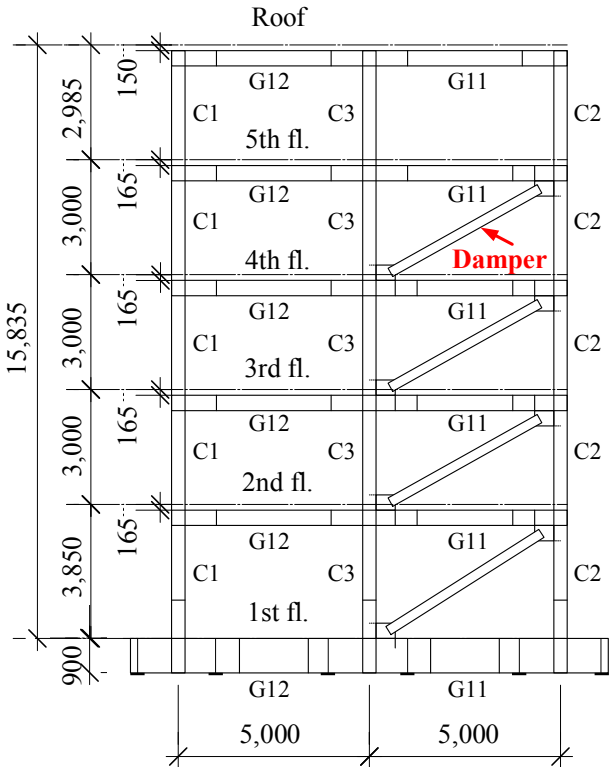
→ Blind analysis contest

Full-Scale 5-Story Building with Dampers

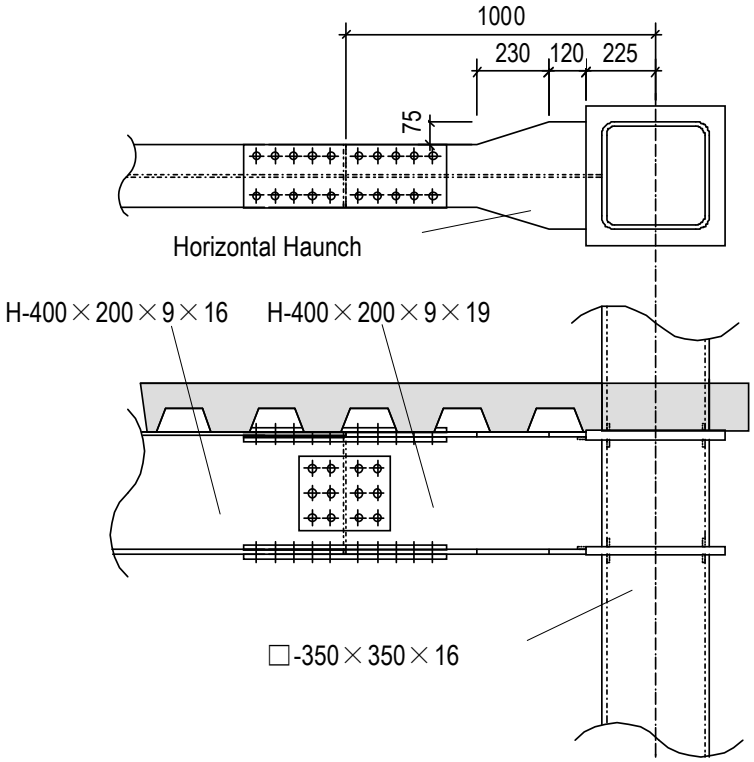
Seismically Active Wt .: 4,734 kN
Frame Period: 0.74s (x), 0.79s(y)
With Elast. Steel Damper: 0.53s (x), 0.56s(y)



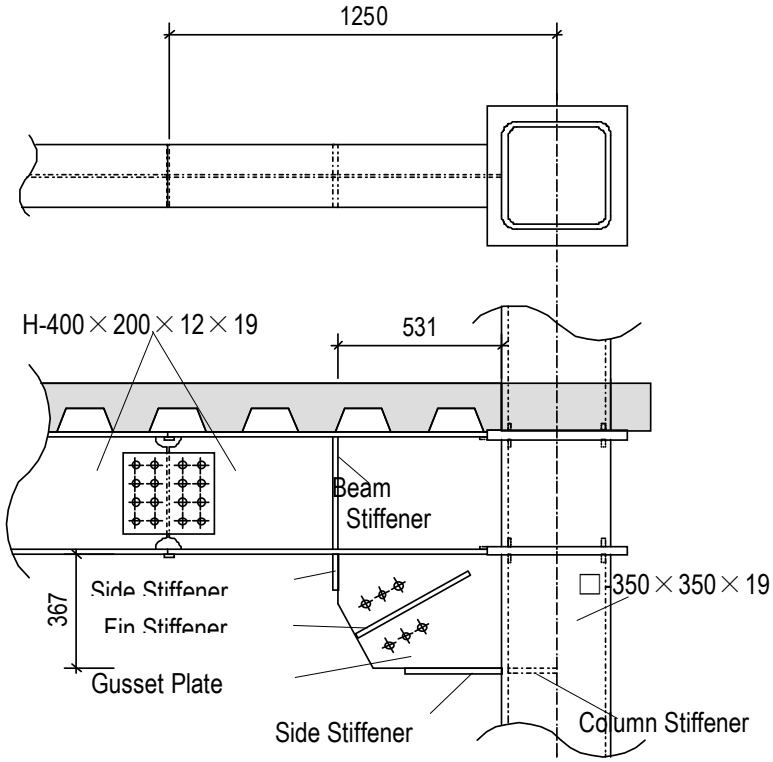




Beam-Column Joints (w.o. & w. Damper)



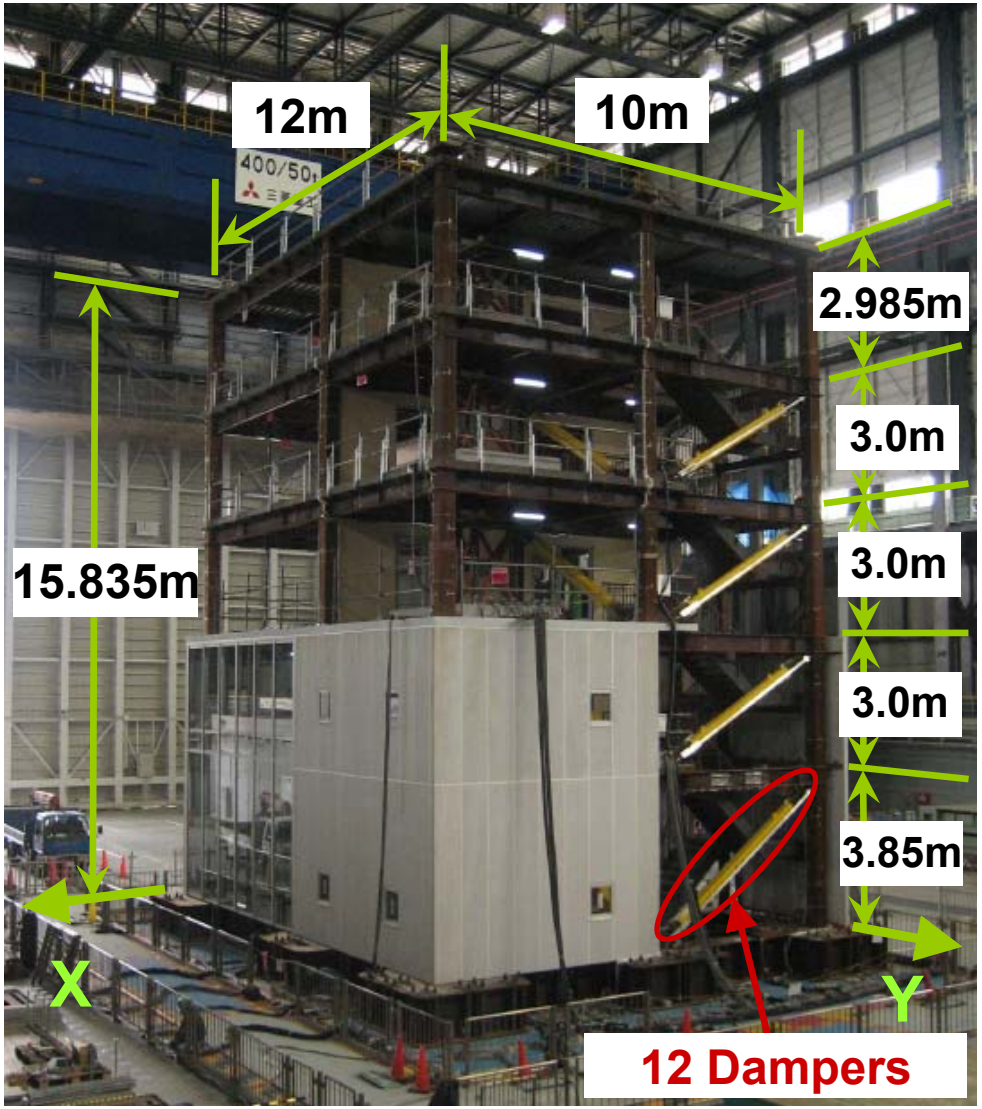
(A) BEAM-COLUMN-GUSSET CONNECTIONS



(B) BEAM-COLUMN CONNECTIONS

Sample for Deformation Measurement (Oil Damper Case)

Full-Scale 5-Story Specimen



Square Section Col.：BCR295
□-350 1F：19,22(FA), 2～3F：16,19(FA), 4～5F：12(FB)

Damper：**Steel, Viscous, Oil, Visco-Elastic**

Beam：SN490B

Undamped Bay（Beam End）

RF	H-400x200x9x12	(FB)
5F	H-400x200x9x16	(FA)
2～4F	H-400x200x9x19	(FA)

Damped Bay（Beam End）

RF	H-400x200x9x12	(FB)
5F	H-400x200x12x16	(FA)
4F	H-400x200x12x16,19	(FA)
3F	H-400x200x12x19,22	(FA)
2F	H-400x200x12x22	(FA)

Total Weight：580t（Including Foundation Beam）

Major Damper Types Used in Japan

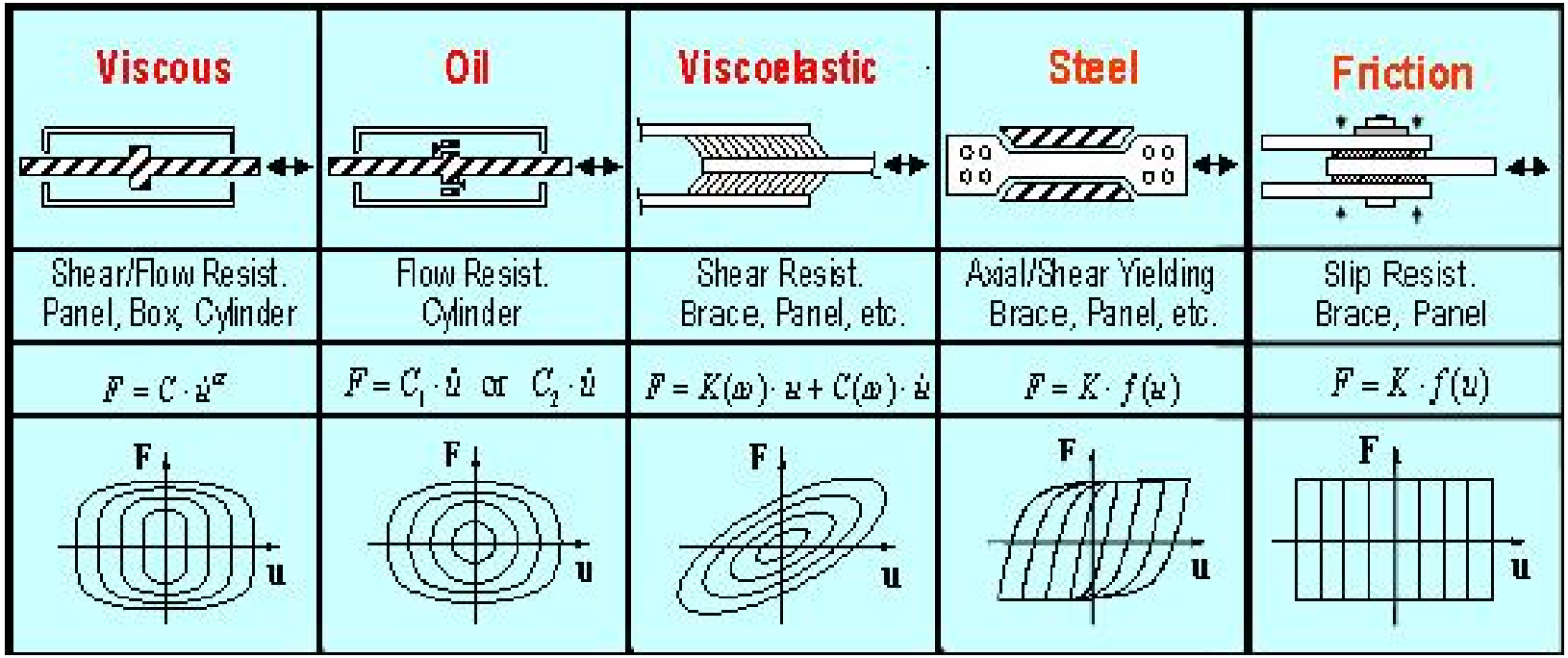
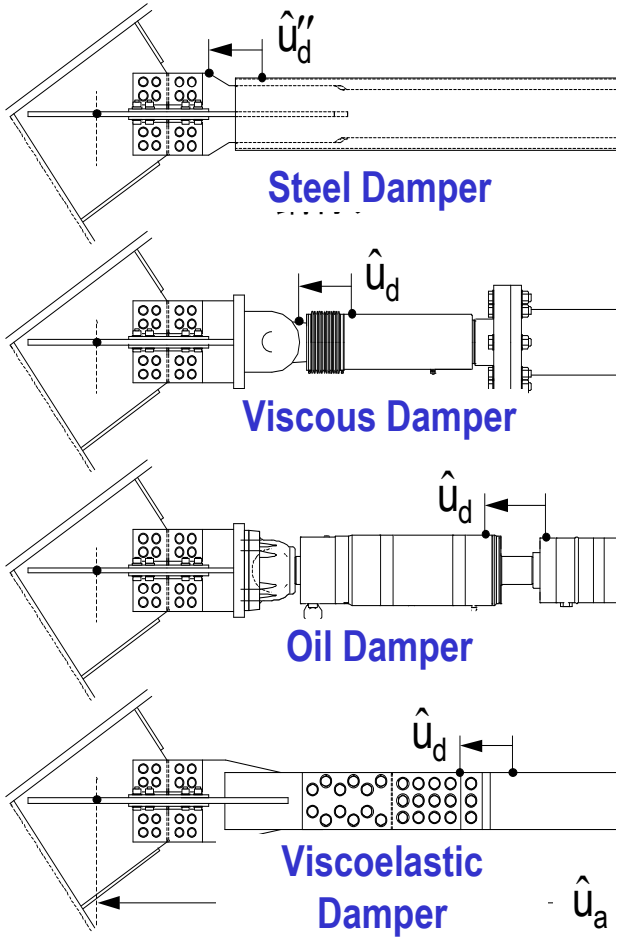
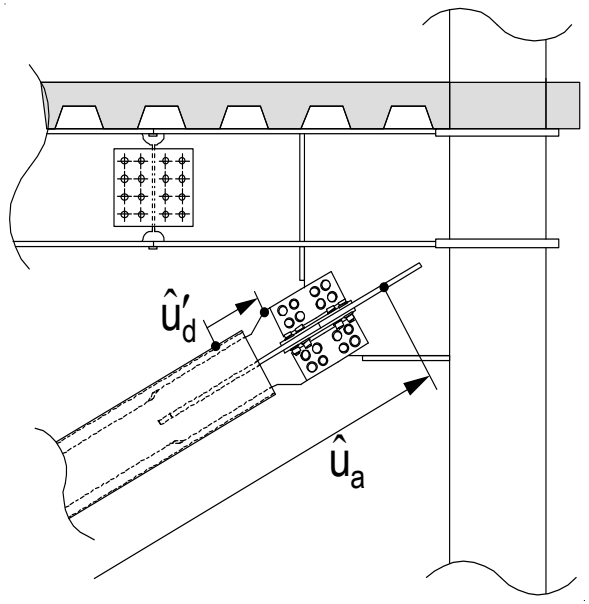


Fig. 4 Five Types of Dampers Considered by JSSI Manual

Manual by JSSI (Japan Society for Seismic Isolation)
1st and 2nd Editions, 2002, 2005, and 2007

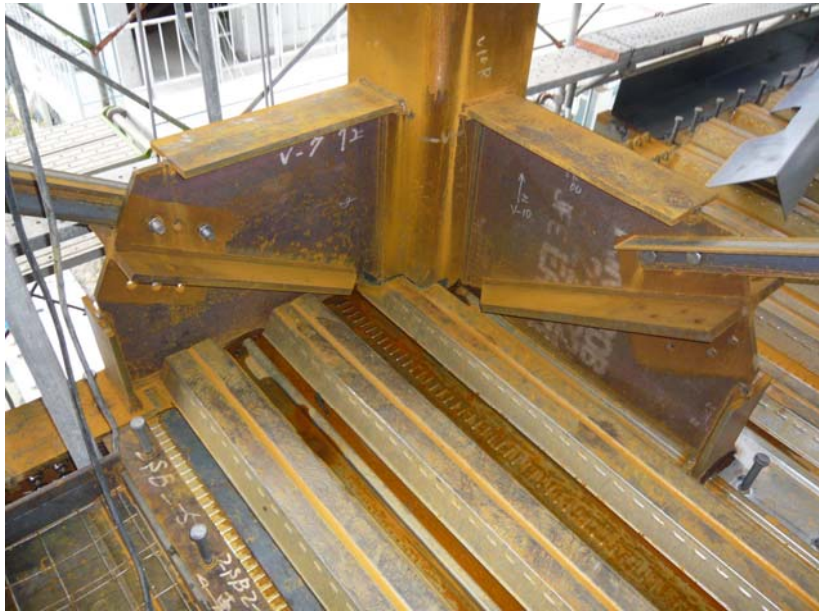
Deformations of Dampers vs. Added Components





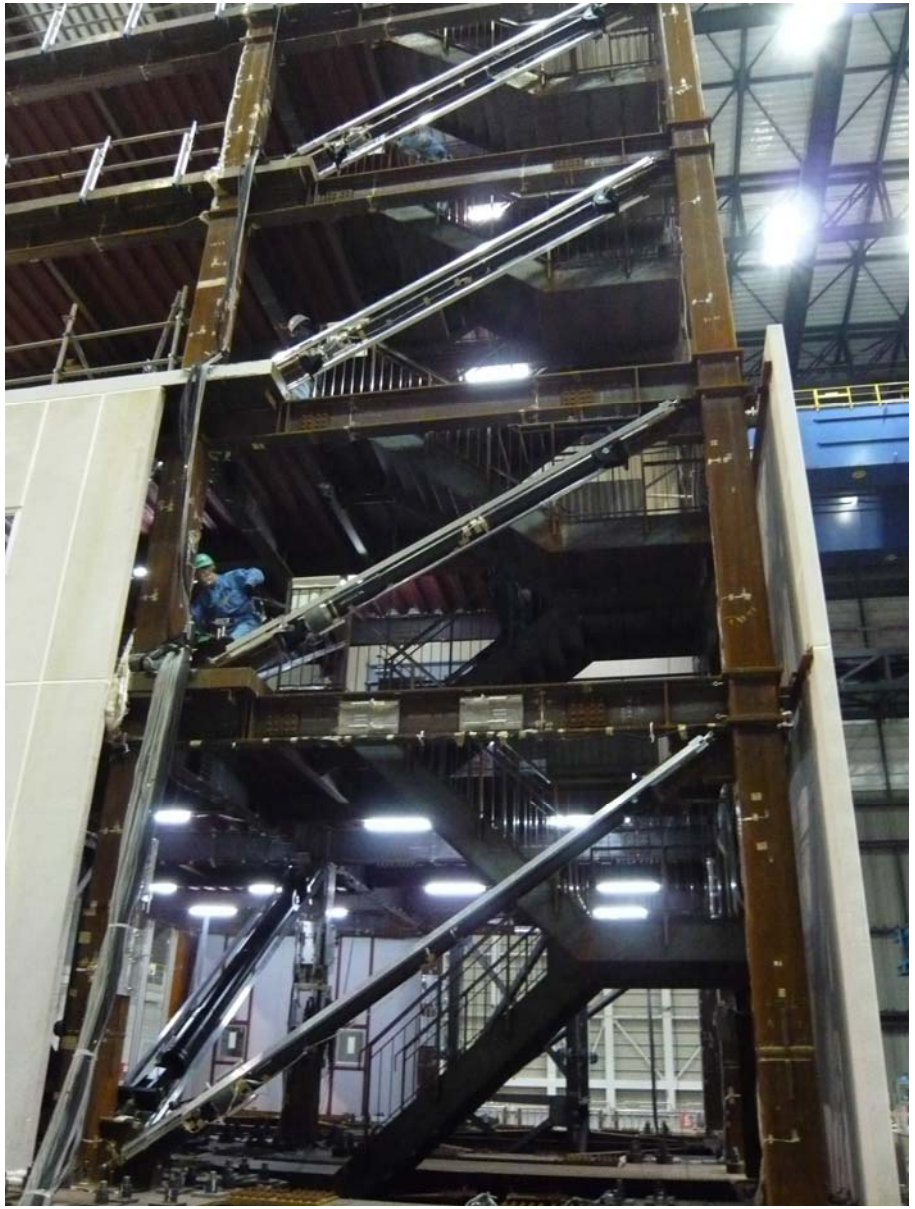
$\hat{u}_d = \hat{u}'_c + \hat{u}''_d$ (sum of deformation at both side

$\hat{u}_a = \hat{u}_c +$ stiffness of supporting member



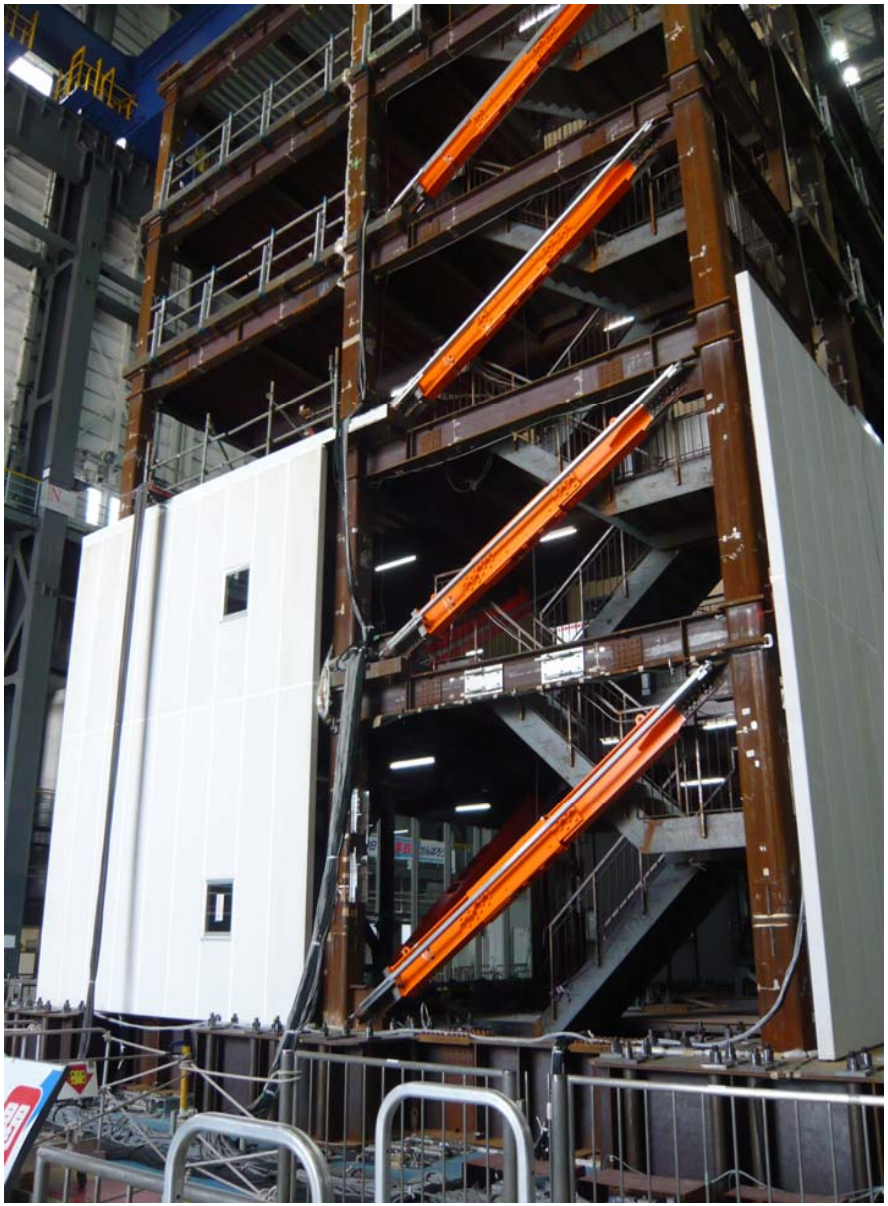
Full-Scale 5-Story Building with Steel Dampers

Steel Dampers

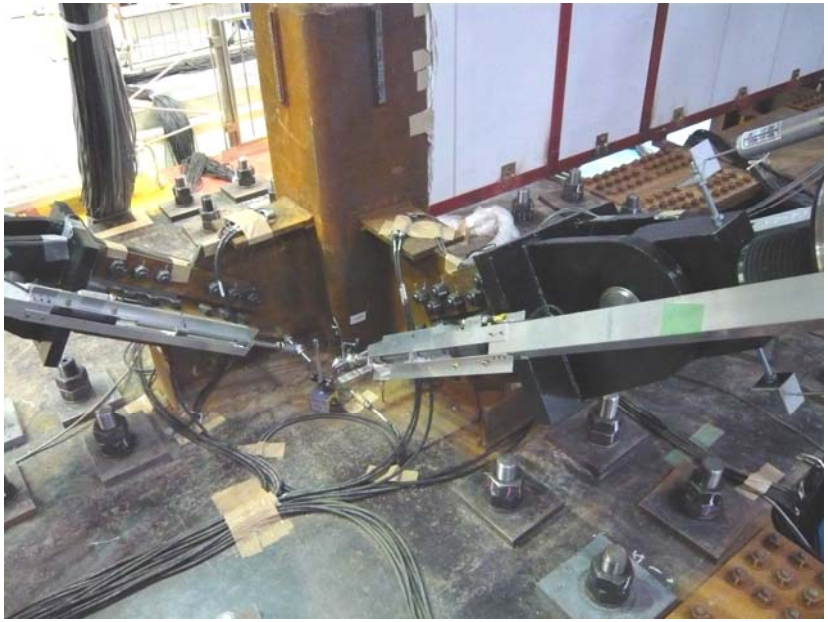


Viscous Dampers

Oil Dampers



Viscoelastic Dampers



Instrumentations（Bldg. w. Dampers)

Strain：1076ch

Col.:360ch，Beam:480ch，Damper:96ch，Anchor:8ch，
Slab Re-bar:84ch，Slab Surface:12ch，ALC Panel Bracket:36ch

Displacement：171ch

Damper:72+12ch，Drift:35ch，Foundation:12ch，ALC Panel:17ch，
Curtain Wall：5ch，Partitions:8ch，Doors:2ch，Stairs:8ch

Accelerations：88ch

Floor:72ch，1F Tower:4ch，ALC Panel:12ch

Sychronization：3ch

Total：1338ch（1447ch After Removing Dampers）

Test Schedule

Date	Damper	Largest Input
2/27（Fri.）	Steel	Preliminary (elastic)
3/2（Mon.）	Steel	JR-Takatori 40%
3/5（Thurs.）	Steel	JR-Takatori 100%
3/11（Wed.）	Viscous	JR-Takatori 40%
3/12（Thurs.）	Viscous	JR-Takatori 100%
3/18（Wed.）	Oil	JR-Takatori 40%
3/19（Thurs.）	Oil	JR-Takatori 100%
3/26（Thurs.）	Viscoelastic	JR-Takatori 40%
3/27（Fri.）	Viscoelastic	JR-Takatori 100%
4/6（Mon.）	No Damper	JR-Takatori 40%
4/7（Tues.）	Np Damper	JR-Takatori 70%

Video Presentation

Full-Scale Passively-Controlled Building:

Vibration Generator Tests

March to April, 2009

Video Presentation

Full-Scale Passively-Controlled Building:

Shake Table Tests

(Steel, Viscous, Oil, and Viscoelastic Dampers)

March to April, 2009


TCR 15:29.36.23

Contrasting Example (1)

Frame without Dampers:

Ceiling Failure

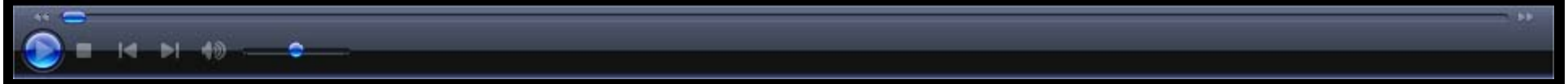
April, 2009

Contrasting Example (2)

Seismic Collapse Test of Full-Scale 4-Story Steel MRF

September 27, 2007

JR-Takatori 100%　(Collapse)



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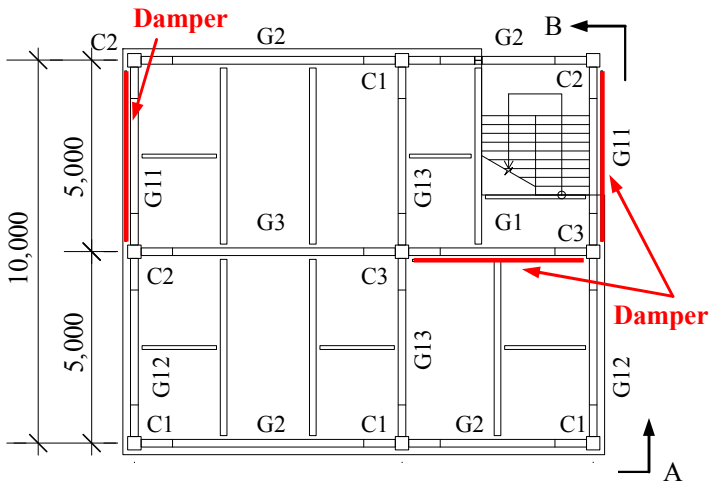
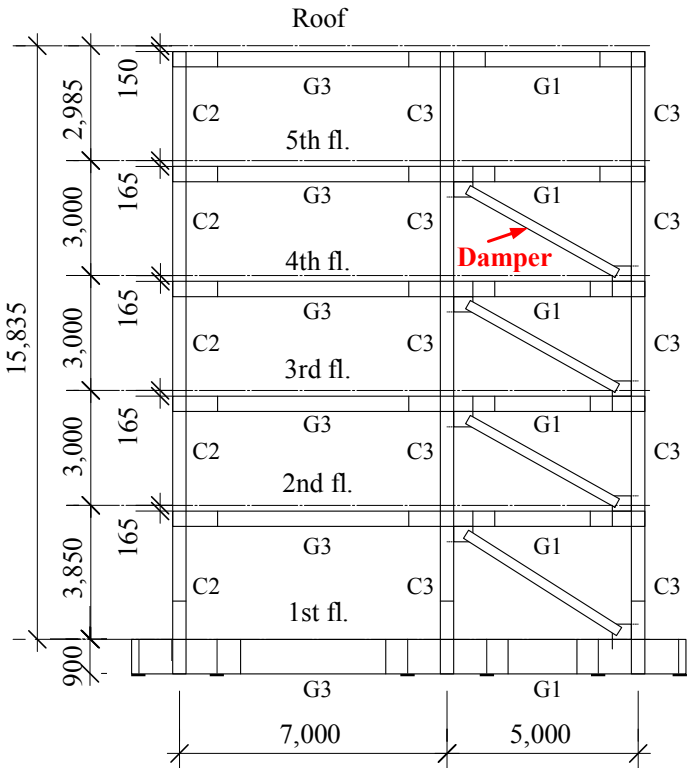
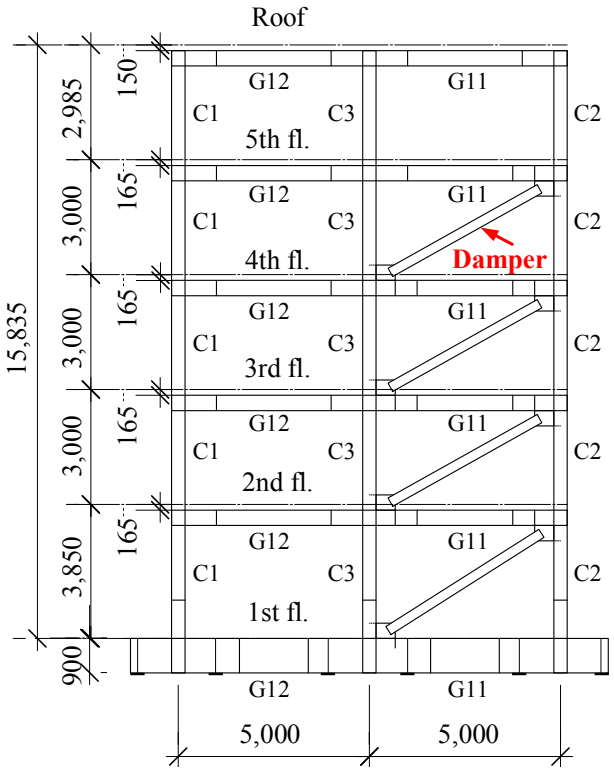
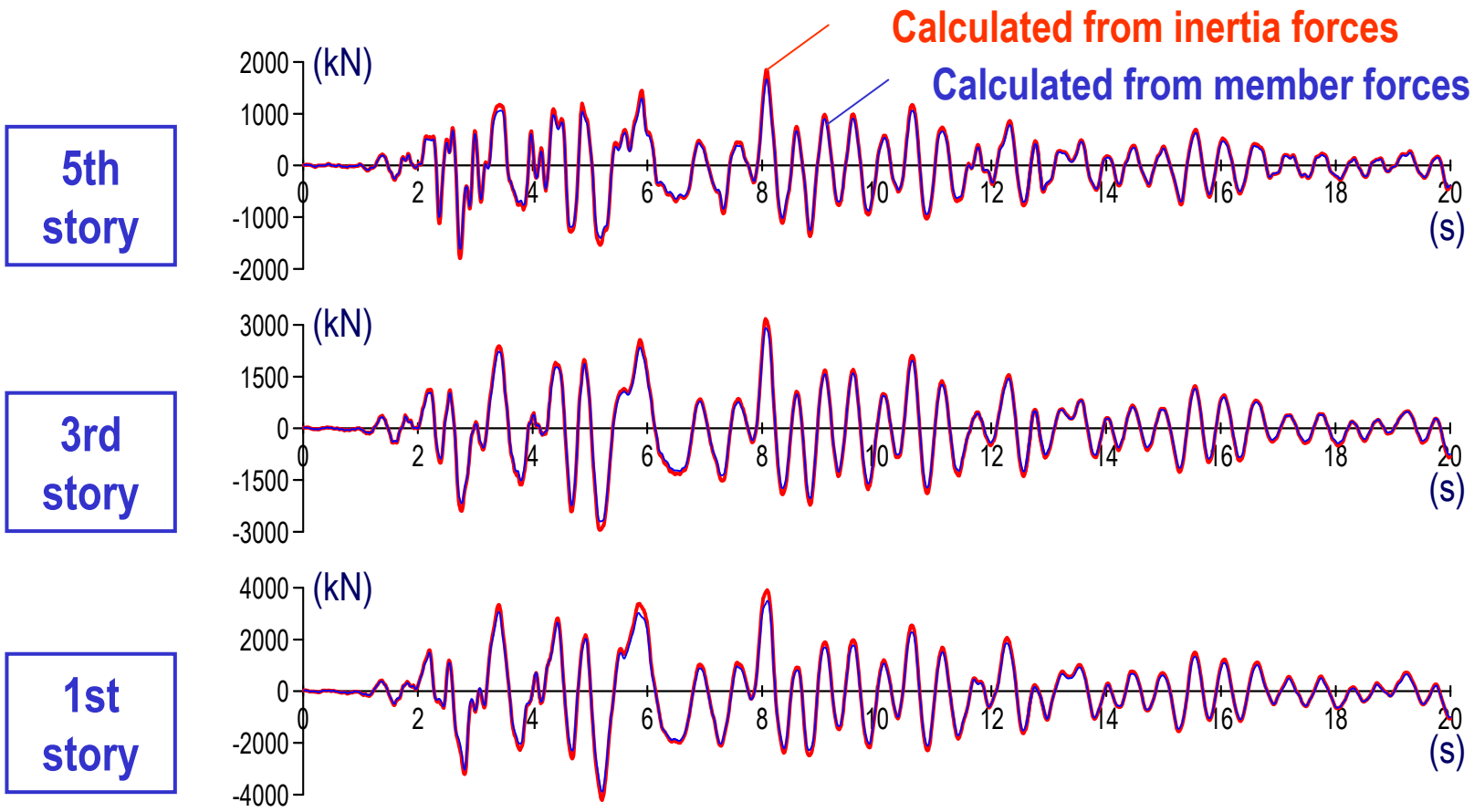


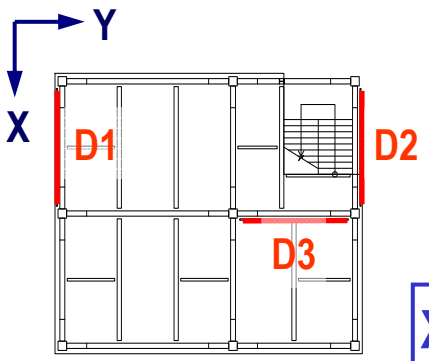


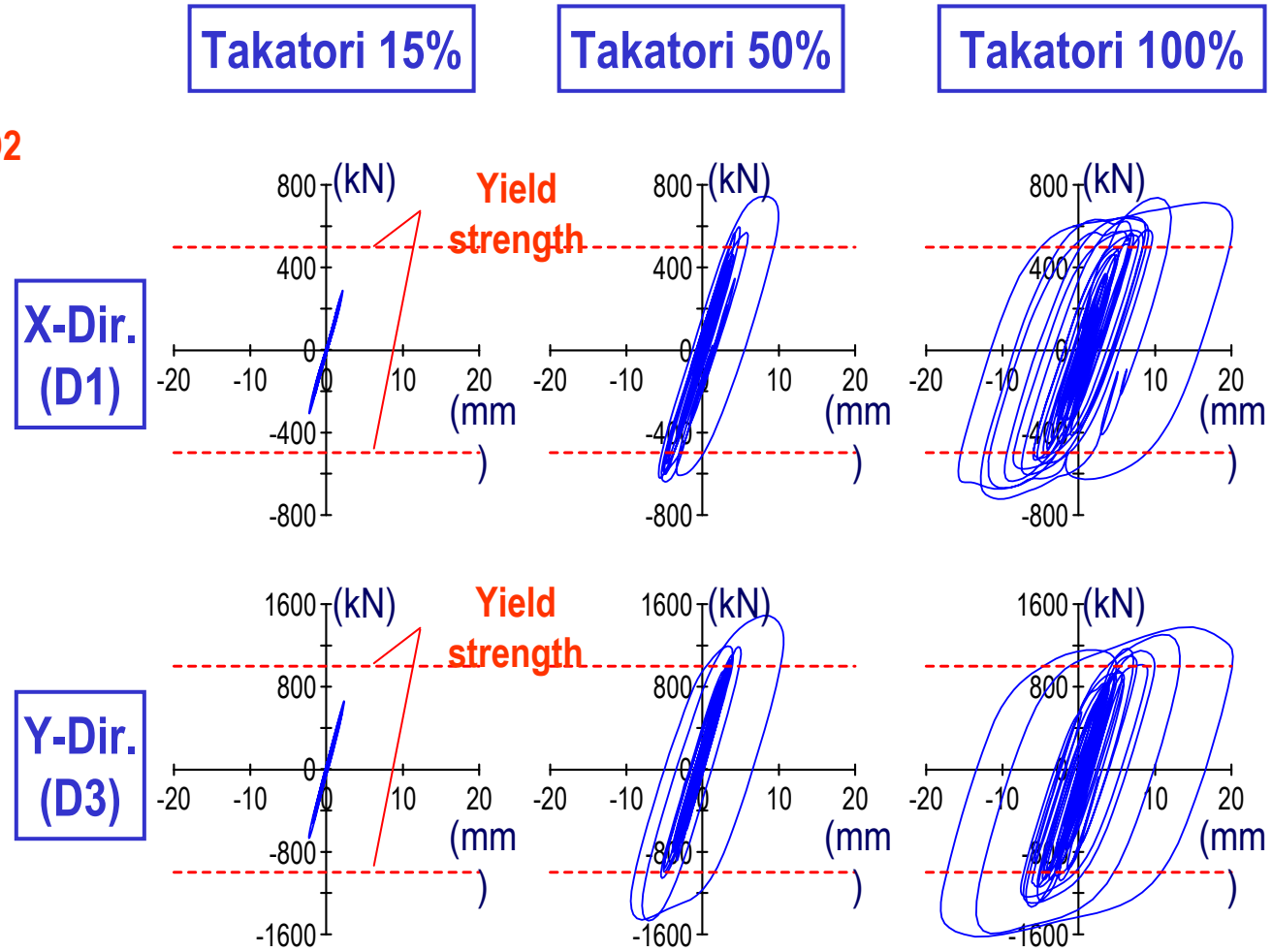


Story Shear (with Seel Dampers, Takatori 100%, X-Dir.)

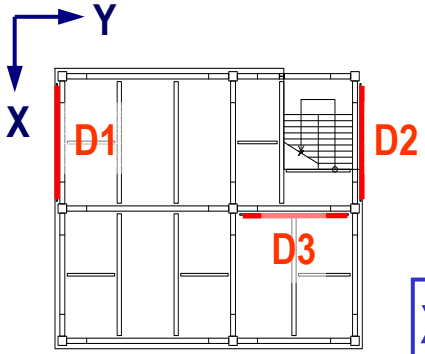


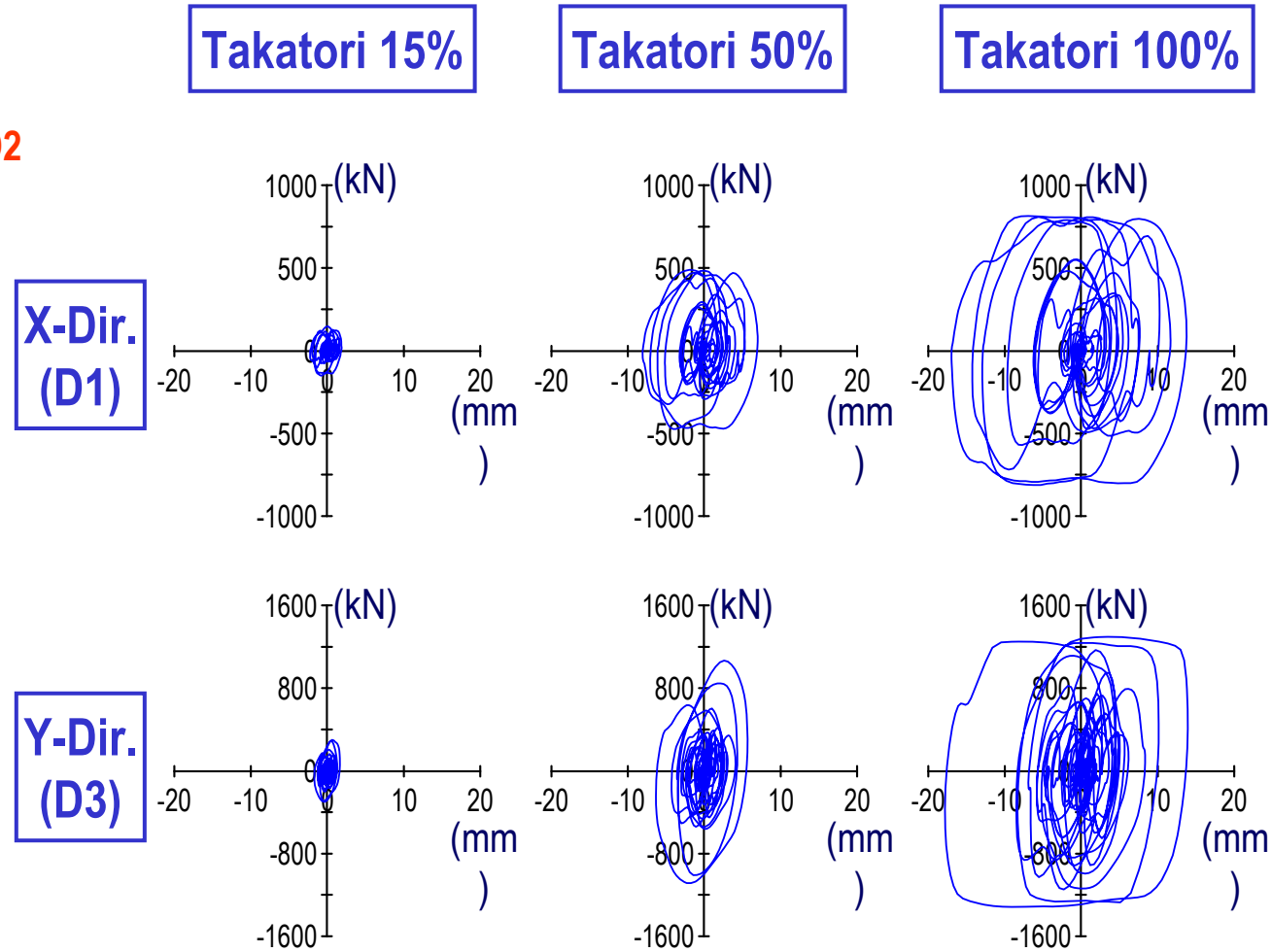
Hysteresis Curves of Dampers (Seel Dampers, 1st Story)



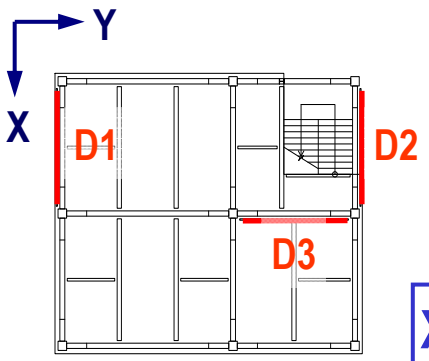


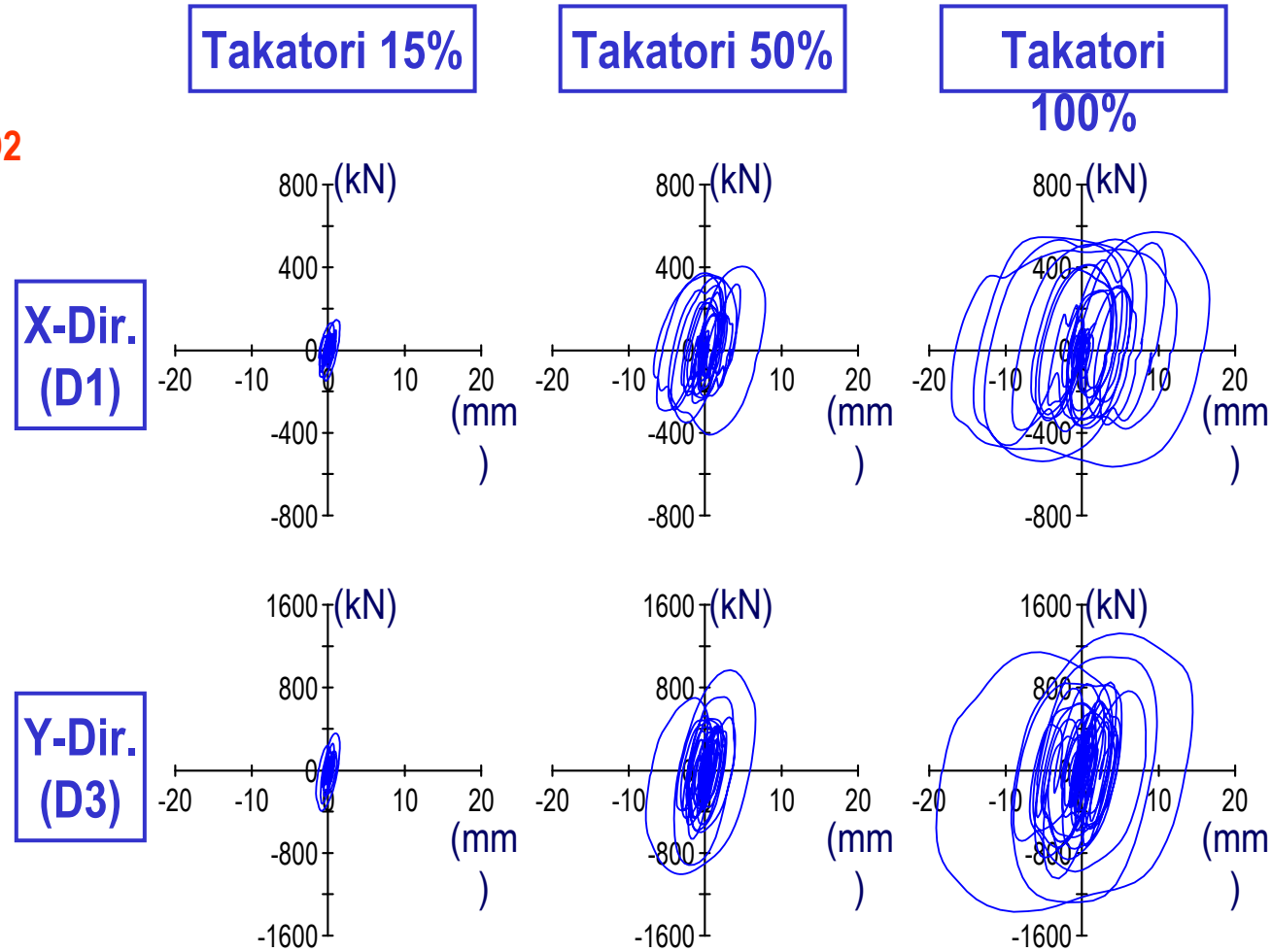
Hysteresis Curves of Dampers (Oil Dampers, 1st Story)



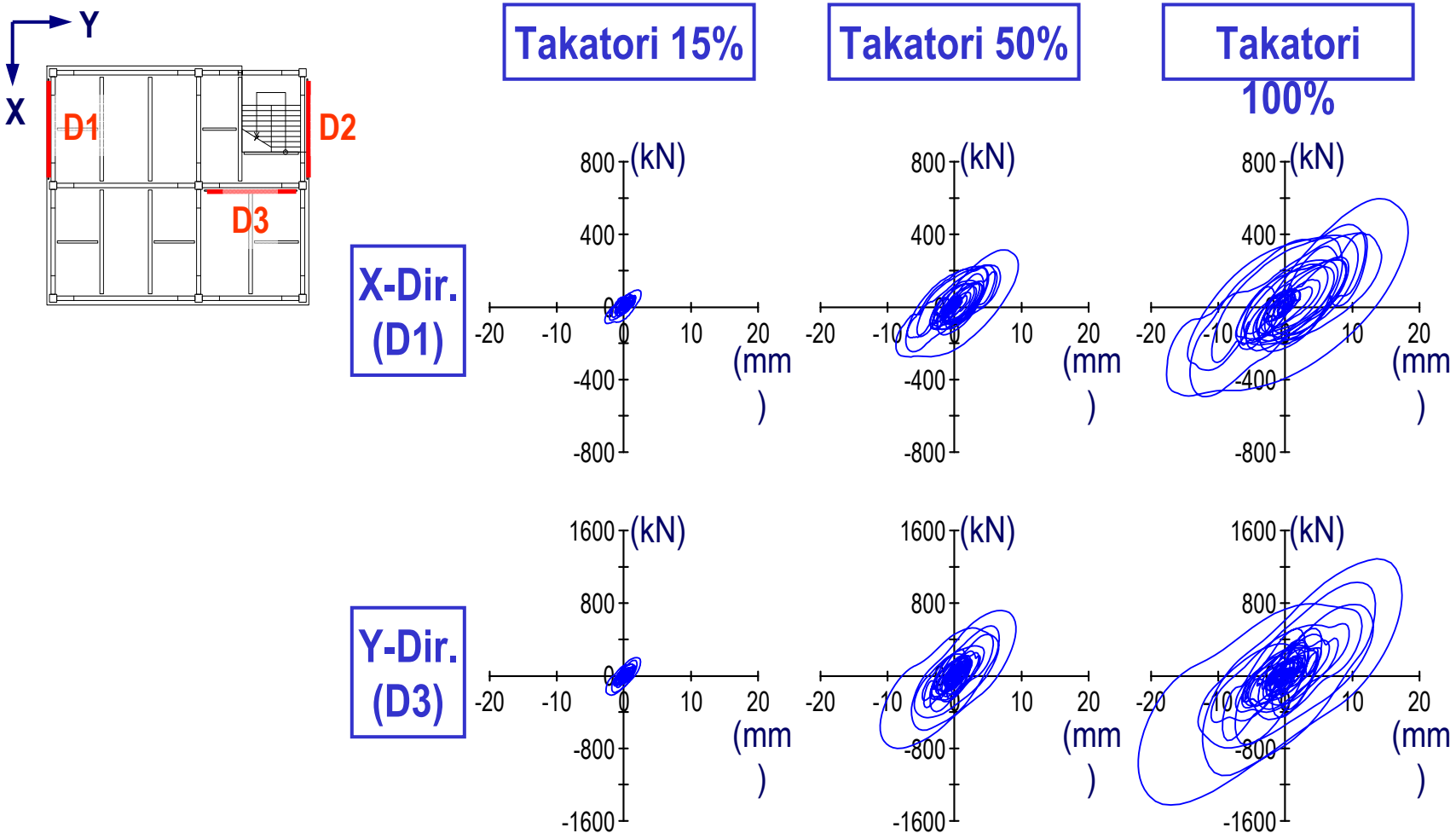


Hysteresis Curve of Dampers (Viscous Dampers, 1st Story)

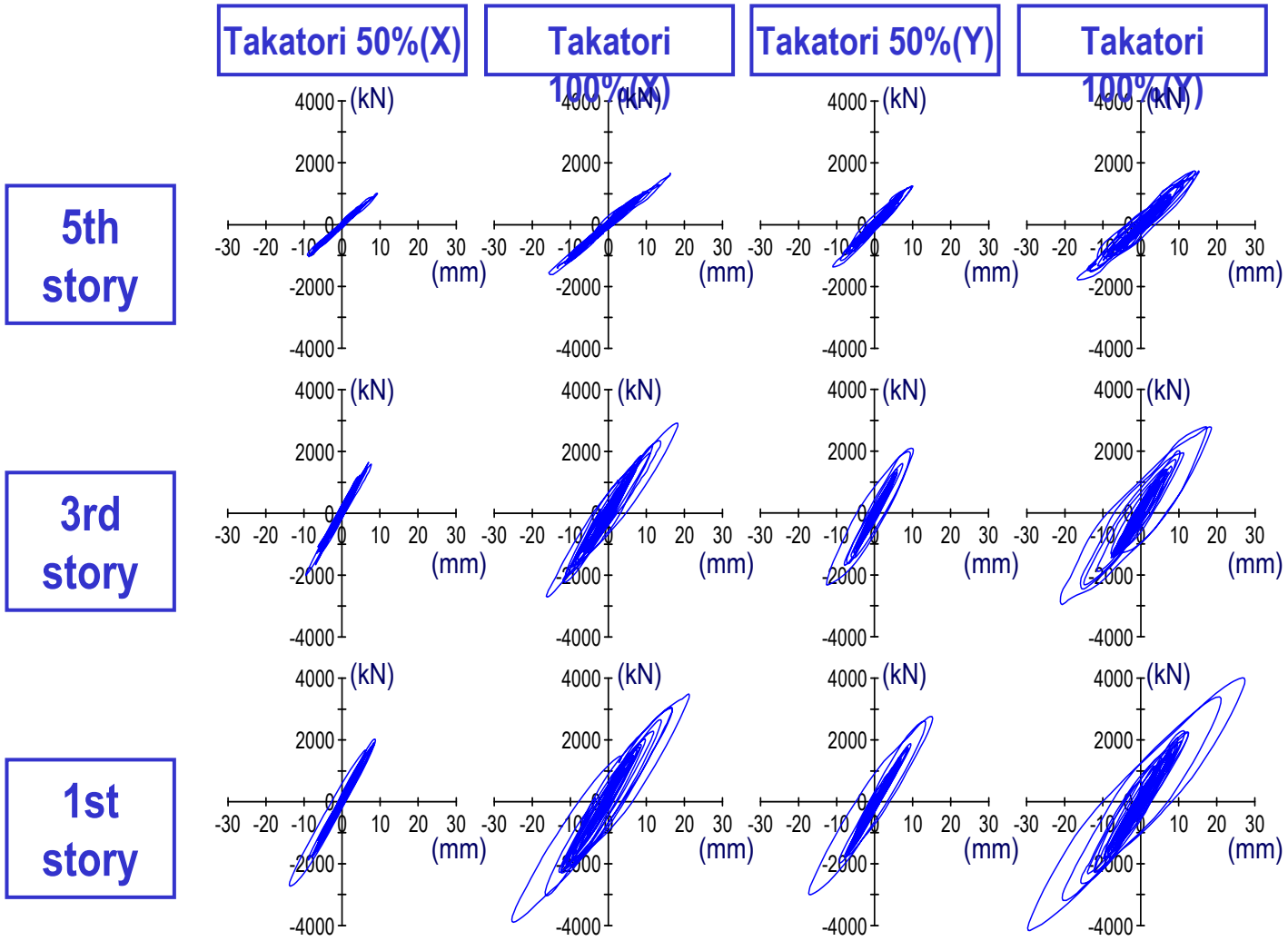




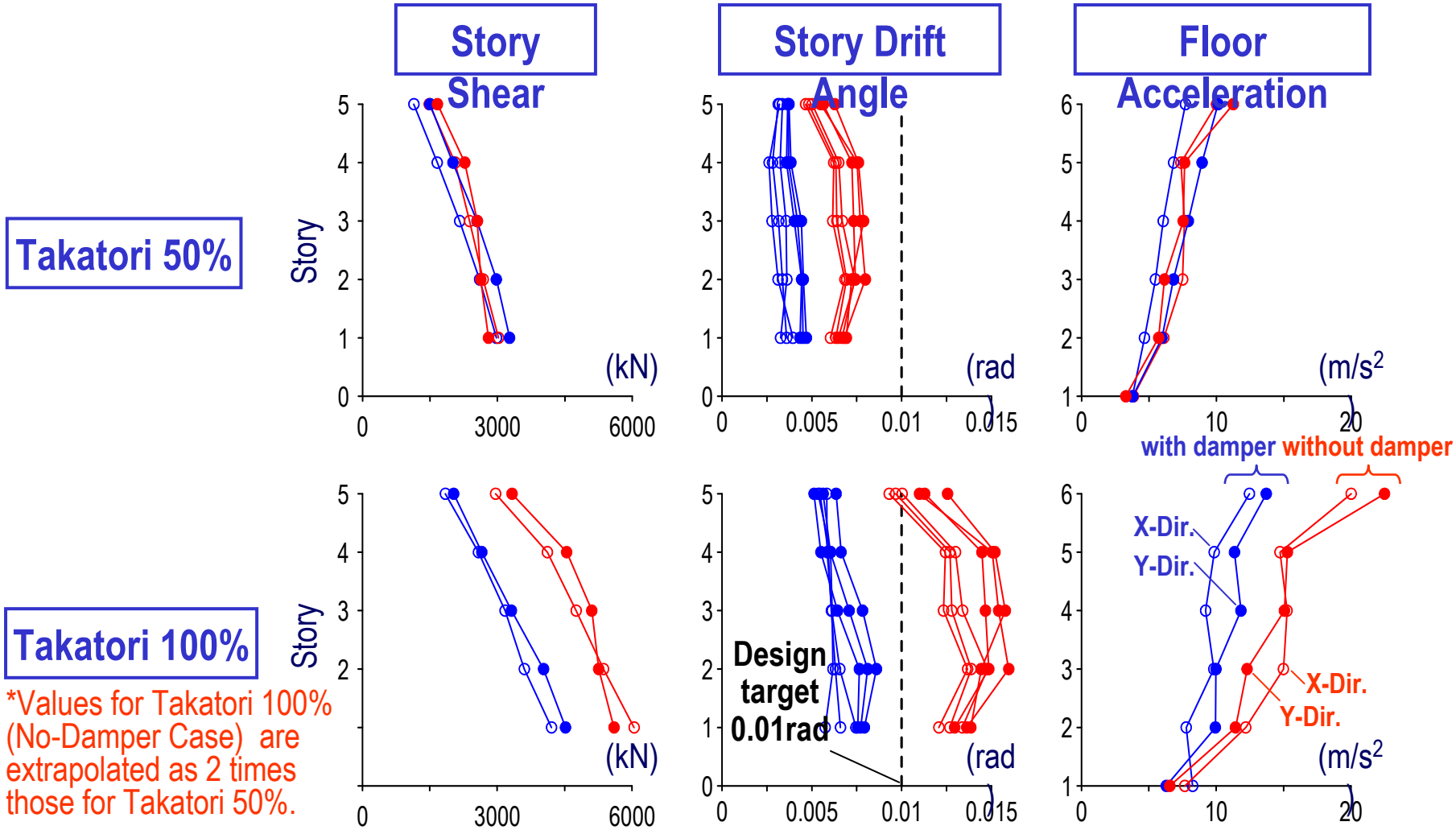
Hysteresis Curves of Dampers (Visco-Elastic Dampers, 1st Story)



Hysteresis Curves of System (with Steel Dampers)

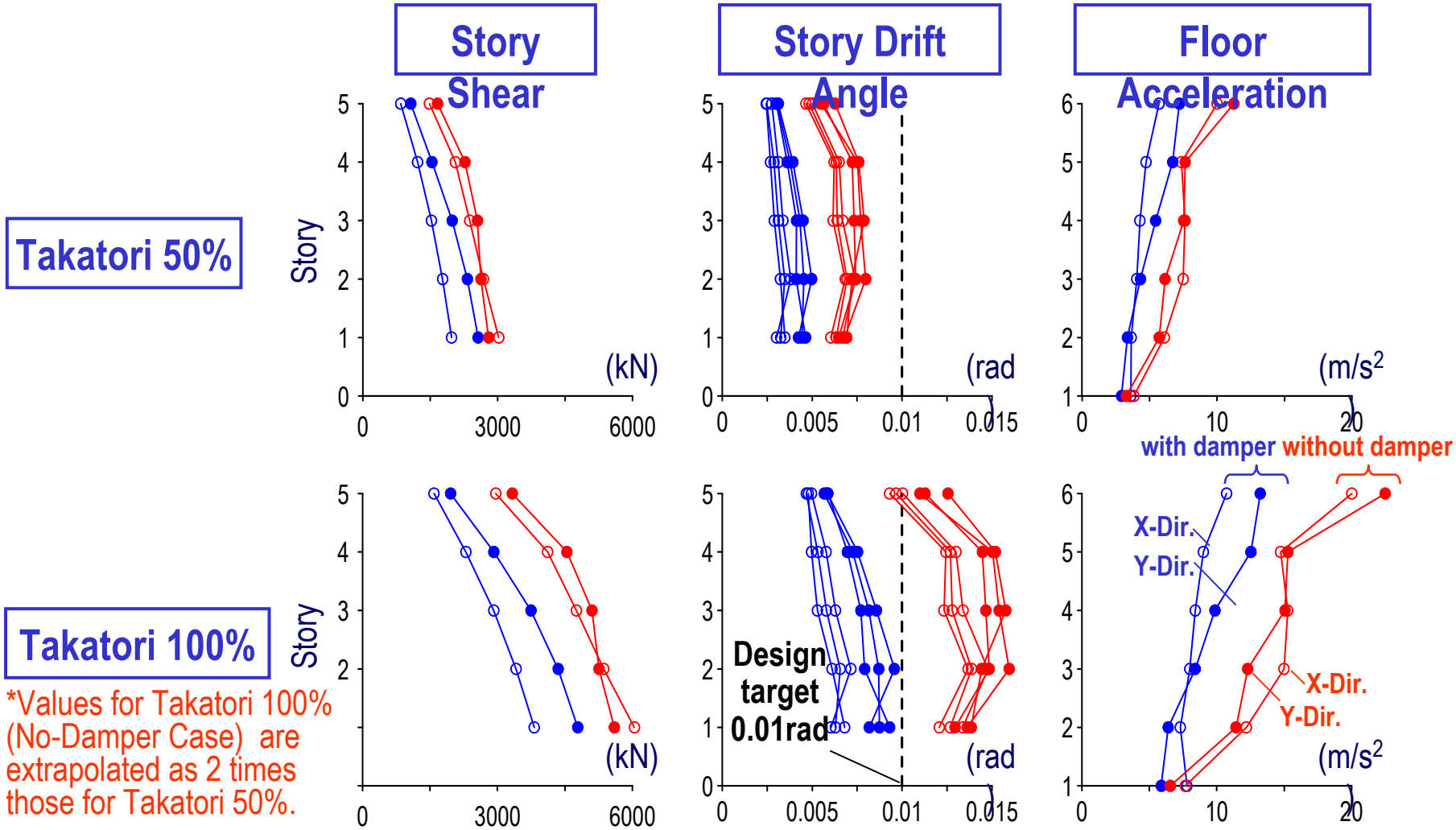


Maximum Reponses (Steel Damper Case vs. No-Damper Case)



*Values for Takatori 100% (No-Damper Case) are extrapolated as 2 times those for Takatori 50%.

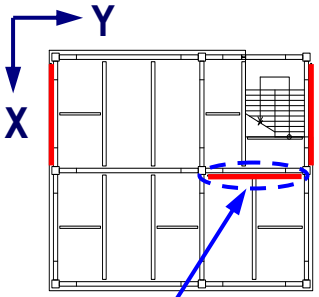
Maximum Reponses (with VE. Damper)



*Values for Takatori 100% (No-Damper Case) are extrapolated as 2 times those for Takatori 50%.

On-Going Blind Analysis Contest for Steel Damper Case and Viscous Damper Case

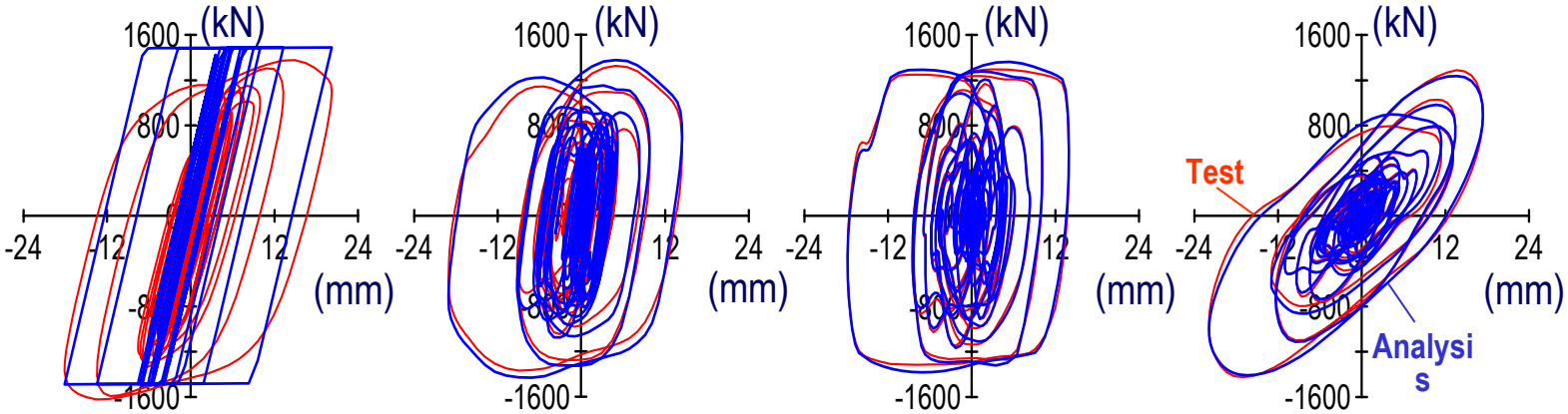
Analysis Results (Damper Force – Damper Stroke)



1st story for Y-Dir.

Steel | Viscous | Oil | Viscoelastic

Takatori 100%



Conclusions and Future Studies

The bldg. with all 4 damper types performed well under design basis & catastrophic earthqs. Since frame members remained mostly elastic and dampers modeled by clear mathematical equations, analysis was more accurate.

Using test data, design & analysis will be verified and improved, including focused studies on the six challanging issues listed earlier in this presentation.

Cases of frame member yielding, and ultimate state must be studied by applying even stronger quakes to the building. The study should be combined with testing of each major components of the building.

END