NCREE Tainan Laboratory Grand Opening Forum
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Panel Discussion:

Some Remarks on The Full-Scale Shake Table Test

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Specifications of E-Defense Shaking System

Payload	12MN (1,200tonf)	
Size	20m x 15m	
Driving Type	Accumulator Charge /Electro-Hydraulic Servo Control	
Shaking Direction	XY-Horizontal	Z-Vertical
Maximum Acceleration (at Maximum loading)	>900cm/s^2	>1,500cm/s^2
Maximum Velocity	200cm/s	70cm/s
Maximum Displacement	±100cm	±50cm
Maximum Allowable Moment	Overturning Moment	Yawing Moment
	150MN·m	40MN·m

Full-Scale Shake Table Tests for Realistic & Detailed Studies

4-Story Bldg.
Tested to Collapse

5-Story Bldg.
w/wo Dampers

3-Sory Rocking
Frame w. Dampers

Major Damper Types Used in Japan

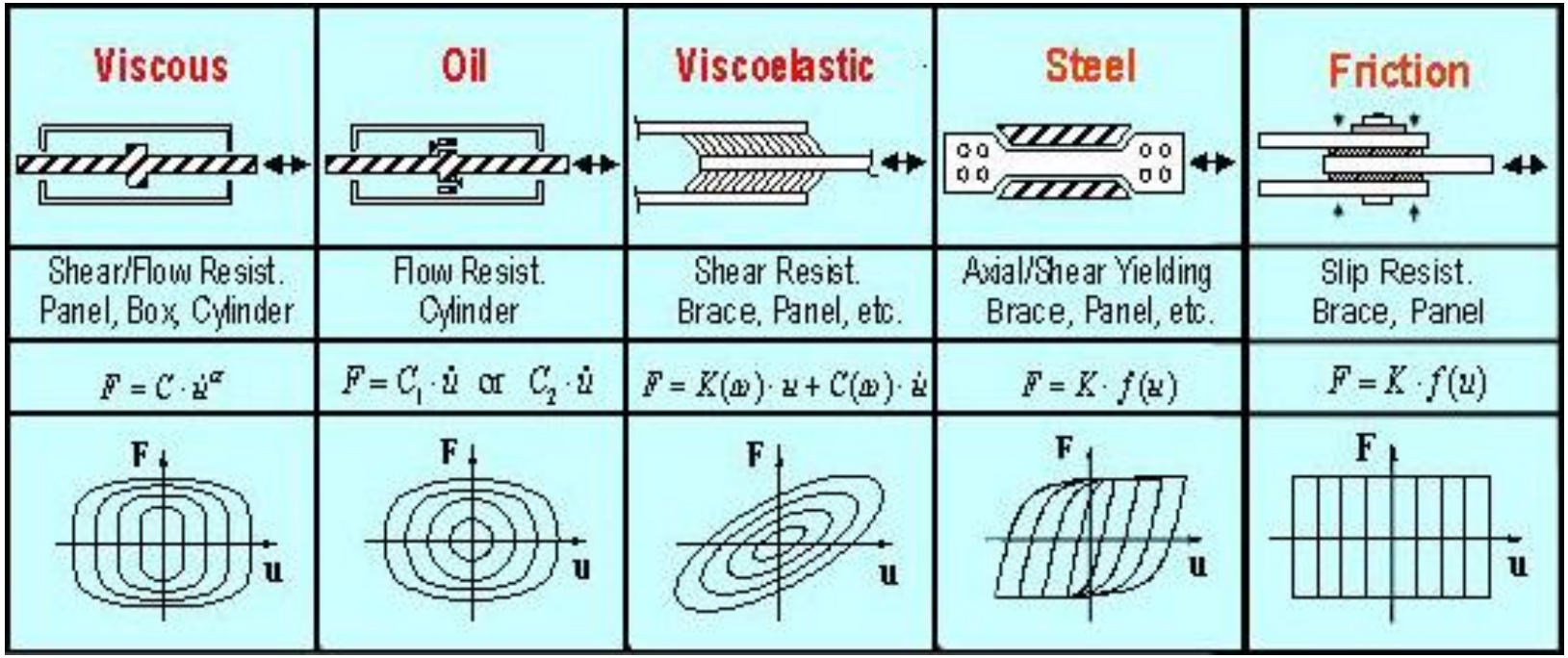
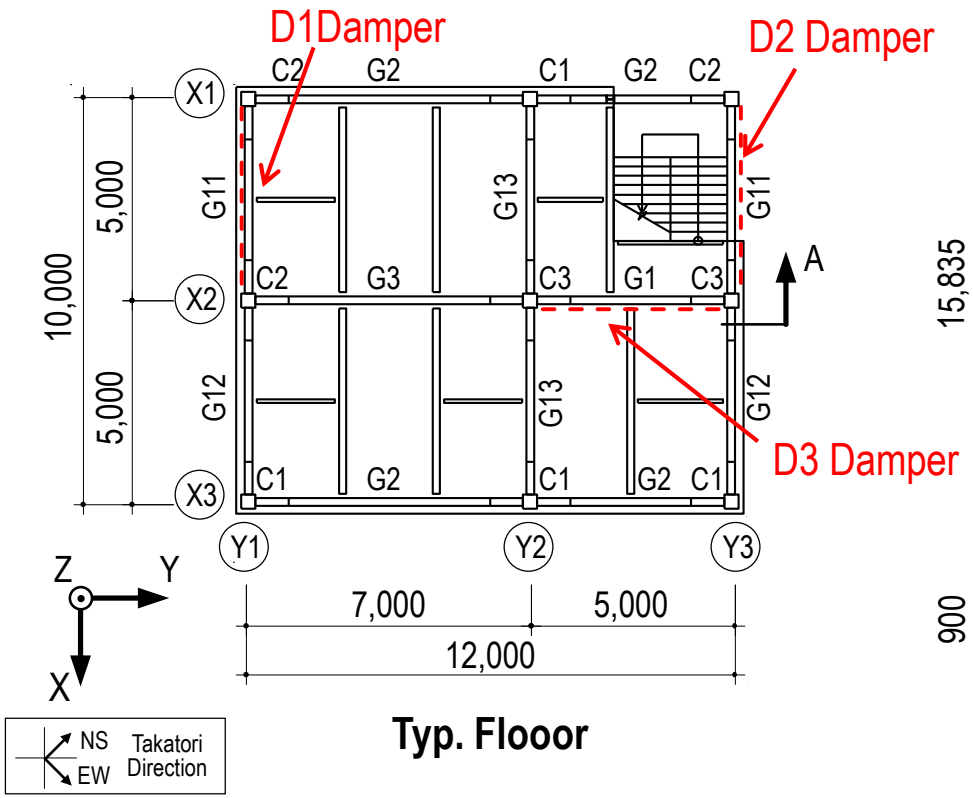


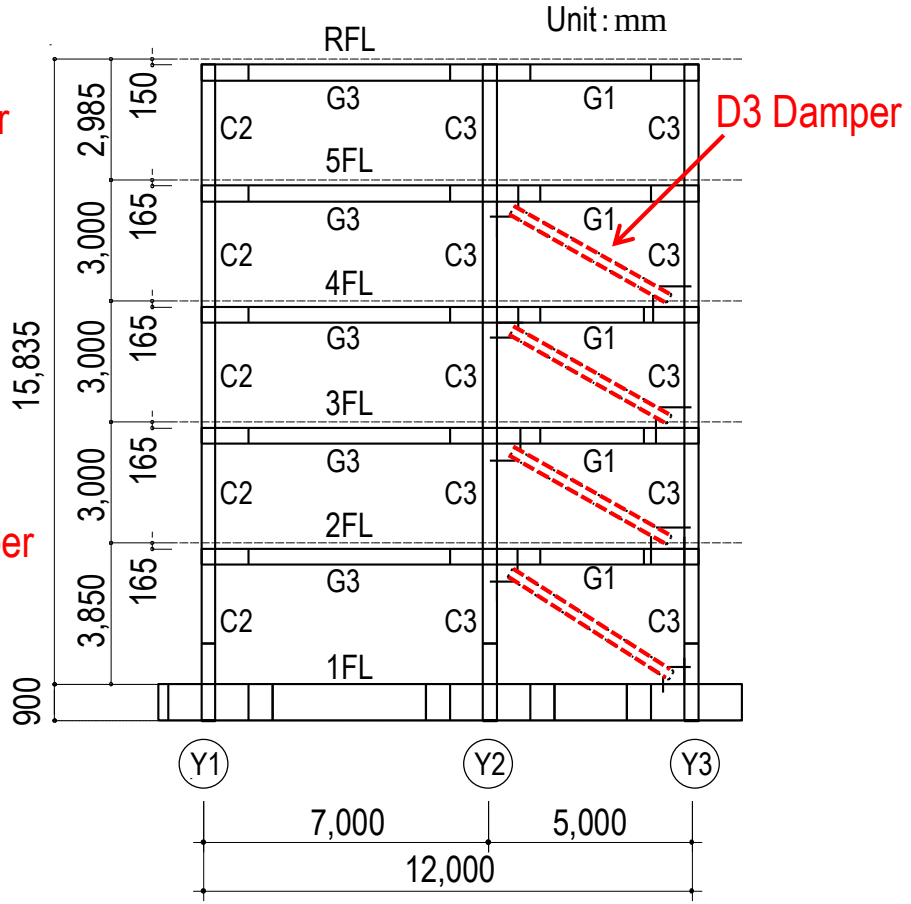
Fig. 4 Five Types of Dampers Considered by JSSI Manual

Manual by JSSI (Japan Society for Seismic Isolation)
1st to 3rd Editions, 2002, 2005, 2007, and 2013

Damped / Undamped 5-Story Frame (Office Bldg.)



Typ. Flooor



Section A-A (frame X2)

Columns : □-350x350x(12～22)

Beams: H or Built-H 400x200x(9～12)x(12～22)

Steel → Viscous → Oil → Viscoelastic → No Dampers

1. Full-Scale 5-story Building with Dampers

- **105 members** ((12 beams + 9 col.s) x 5 story) & **12 dampers.**
  Need **axial force**, **shear force**, and **bending moment** in every element.
- **1,454 sensors**, the largest in E-Defense history.
  (992 strain gages, 209 disp. transducers, 110 accelerometers, etc.)
- **Expensive** ($1,600,000 for construction/testing), very rare specimen.
- **JR Takatori Station ground motion** (1995 Great Hanshin earthquake).

2. Tough Requirements for Specimen & Testing

(2-1) Since only one building specimen was available, its design and test methodology had to be carefully determined for the intended scenario of the building behavior.

- **Negligible damage** against **100% Takatori** 3D motion.
- **Repeated many tests** installing and replacing four damper types.
- Targeted reasonably large **θx , θy ≈ 1/140, 1/100** for useful data.
- Many pre-analyses to select **principle direction** of Takatori motion.
- **Realistic member sizes**, feasible design for low- to mid-rise bldgs.

2. Tough Requirements for Specimen & Testing (Cont'd)

(2-2) Accurate table motion and response measurement were essential for demonstrating the intended scenario of the building behavior and for precisely analyzing/interpreting the results.

- **Table control** was better than the tests of deteriorating structures.
  - Estimates for modal properties were somewhat sensitive to **rocking of the table**, and a new estimation method developed.

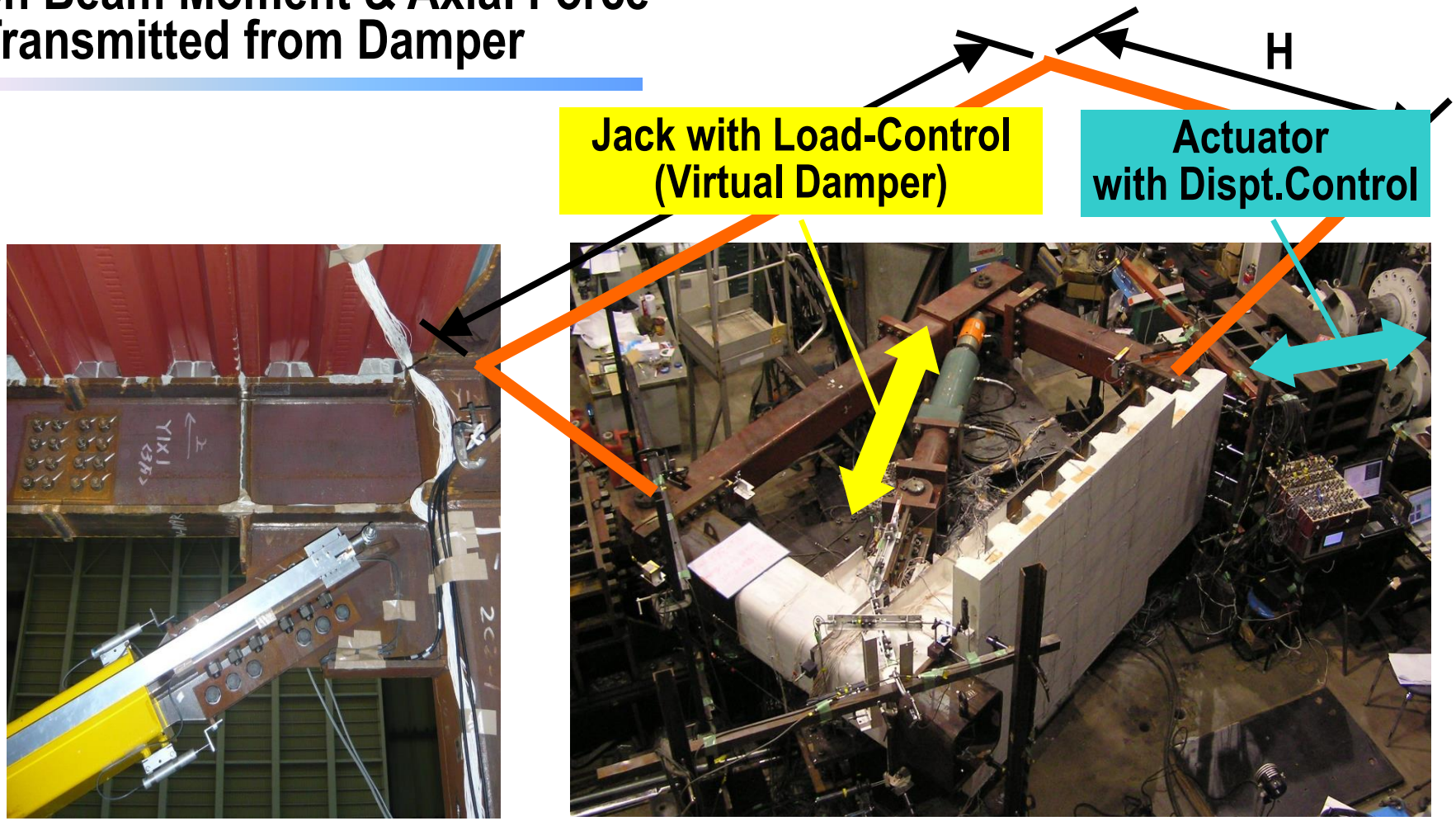
- Validations and quality assurance of **huge data**:
  - **Internal forces** of all 117 members: from strains of beams (w/wo slab), columns, and/or damper braces.
  - **Local equilibrium**: all 45 joints x 3-directions (ΣFz, ΣMx, ΣMy).
  - **Global equilibrium**: all column shear vs. inertia force (accel.)
  - **Displacement**: cumulating measured story drift vs. double integration of accelerations, including torsional response.

2. Tough Requirements for Specimen & Testing (Cont'd)

(2-3) For comprehensiveness, local response measurement requires enormous number of sensors for the large building (dilemma of full-scale building test).

- Used 900 fixed channels of E-Defense and 550 from Tokyo Tech.
  - Almost practical limit, but need more to study local behavior.
- Supplemental tests at Tokyo Tech. for the portion of the building by using as many as 400 channels.
  - More than 20 full-scale beam-column-brace subassemblies (w/wo slab) tested by applying damper force and story drifts.
  - 12 dampers x 4 (steel, viscous, oil, viscoelastic) types tested to confirm the shake table results and to try more general loading.

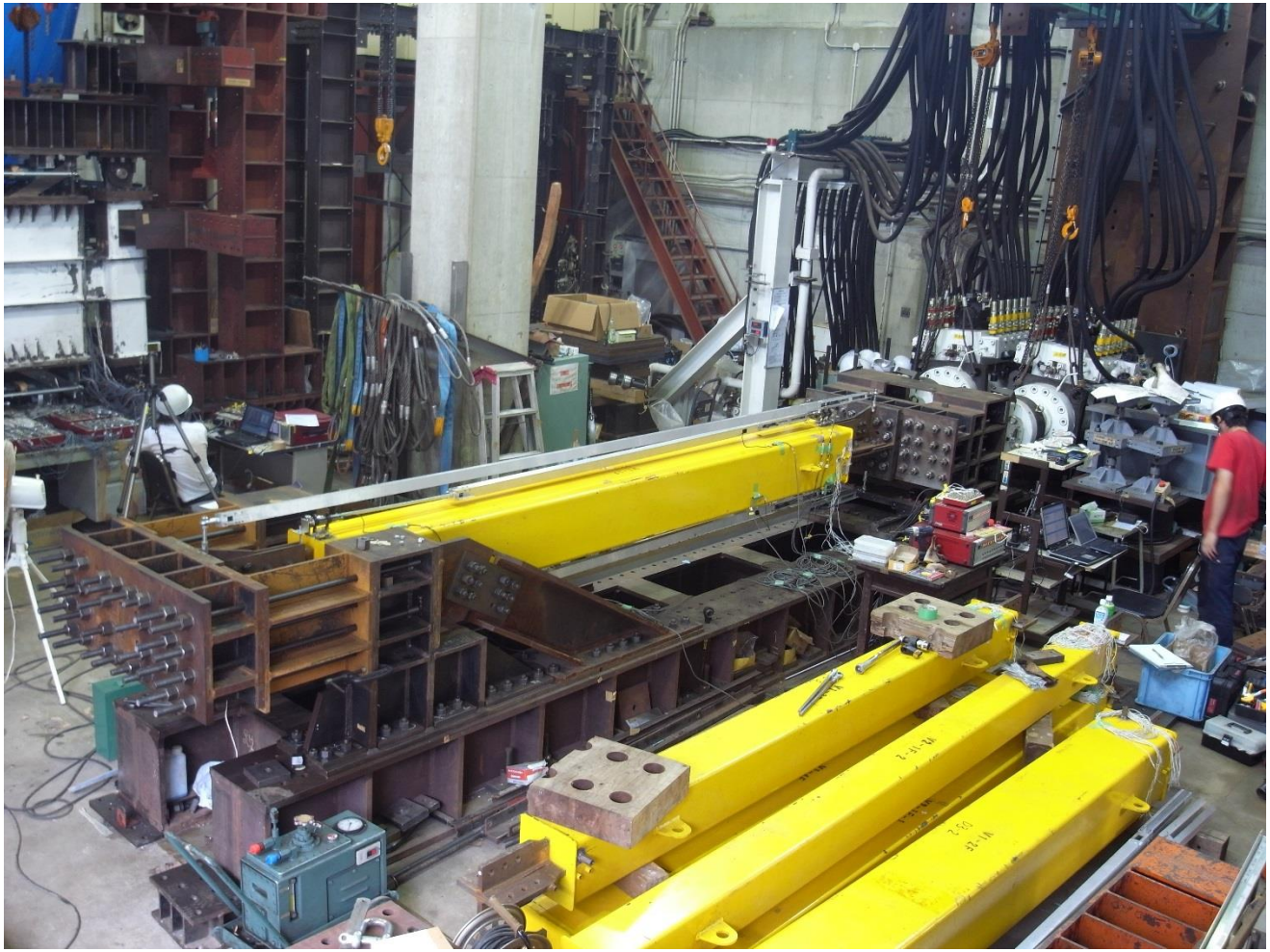
Slab-Girder Interaction Effect on Beam Moment & Axial Force Transmitted from Damper



Full-Scale Building Test
(E-Defense)

Full-Scale Subassembly Test
(Tokyo Tech.)

Re-Testing of Dampers Used for 5-Story Bldg. (Steel Damper, Tokyo Tech.)



2. Tough Requirements for Specimen & Testing (Cont'd)

(2-4) Accident and/or delay was unacceptable, because of high cost of the facility use and tight schedule of subsequent projects.

- **Mistake** can ruin scenario, specimen, and whole schedule.
  - Non-engineered components are unpredictable, and the heavy one failed prematurely, interrupting the test.

- Had **only 40 min. to decide** either stopping or starting the next test. Checking 1,400 sensors one-by-one is impossible.
  - **Immediately plotted integrated results** by the software made. (e.g., story acc. & disp. histories, transfer function from acc., story shear vs. drift, damper force vs. deform., moment diagram when max. disp., etc.)
  - **Quickly detected** bad sensor and measuring method. (e.g., strain gages replaced, disp. transducer added.)

2. Tough Requirements for Specimen & Testing (Cont'd)

(2-5) Because the cost was so high, we needed to get maximum benefit from the test and data.

- Broadcast news, special program, video presentations, effective for **educating both citizens and engineers**.
- True global & local responses, important for evaluating/improving **analysis & design methods**. **Blind analysis contests** showed current status of analytical simulations.
- **Unexpected new & important findings** from the test of this size for the first time. **Extremely valuable** test, if conducted successfully, and if data is enough & correct.