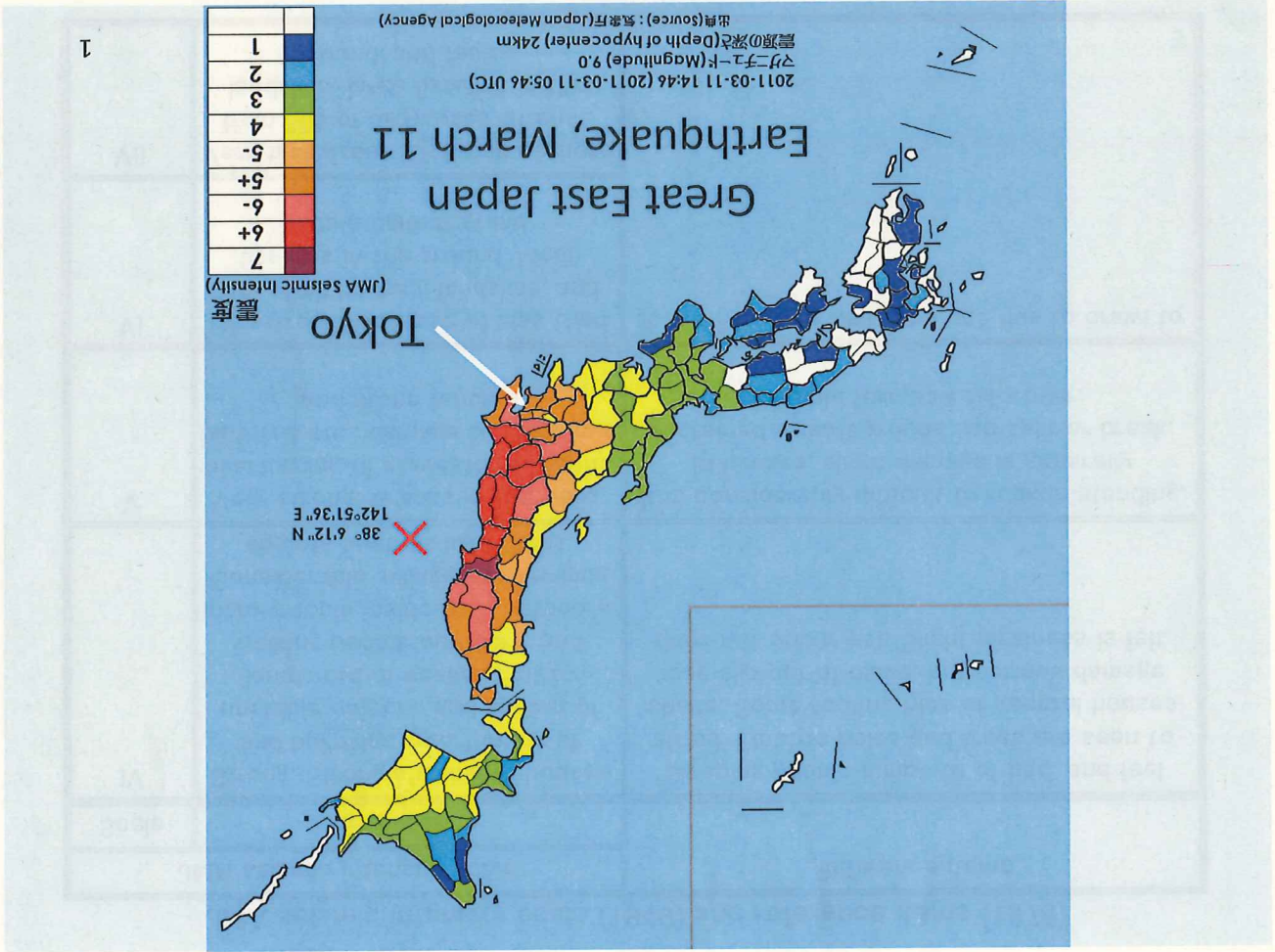


Earthquake and Concert Hall

Takayuki Hidaka
Takenaka R&D Institute

Toronto, Canada
International Symposium on Room Acoustics
2013 June 9-11



Damages of ceiling fall

2

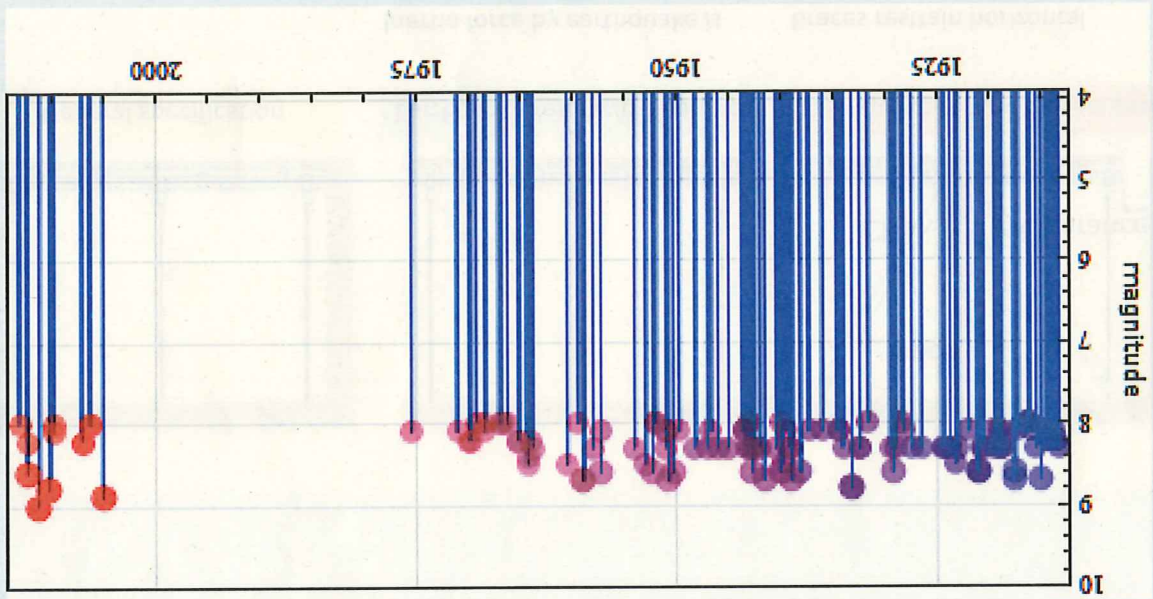


JMA seismic intensity scale (1949) and reference items (1978)

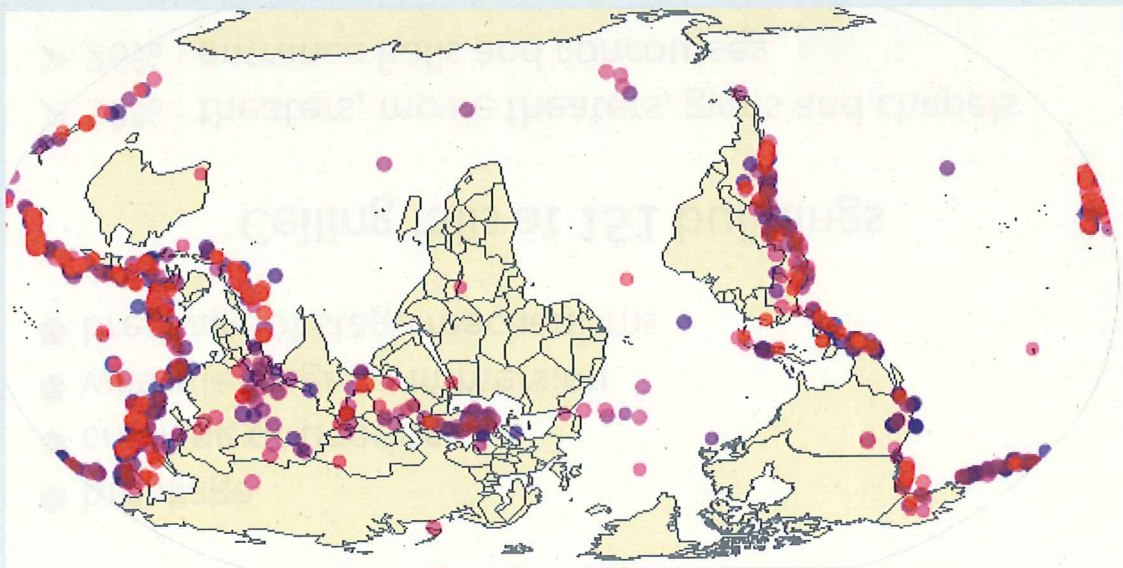
JMA seismic intensity scale		Scale
Explanation		
Reference items	IV	Strong. Strong shaking of houses and buildings, overturning of unstable objects, and spilling of liquids out of vessel. Felt by walking people outdoors, and many people inside rush outdoors. Considerable swinging of hanging objects such as light bulbs.
	V	Very strong. Cracks in the walls, overturning of gravestones, stone lanterns etc., damage to chimneys and stone fences.
3	VI	Disastrous. Collapse of less than 30% of all houses, landslide, and fissures in the ground. Most people cannot stand.
	VII	Very disastrous. Collapse of more than 30% of all houses, intense landslide, large fissures in the ground, and faults.

It is difficult to walk, and one has to crawl to move.
 Unstable furniture falls over.
 In houses, slight damage is generally sustained. A soft ground can split or break.
 It is considerably difficult to remain standing.

Timeline of earthquakes with M 8.0 and above past 100 years.



Earthquake center of M 7.0 and above past 100 years.



Cases of damage to halls and theaters

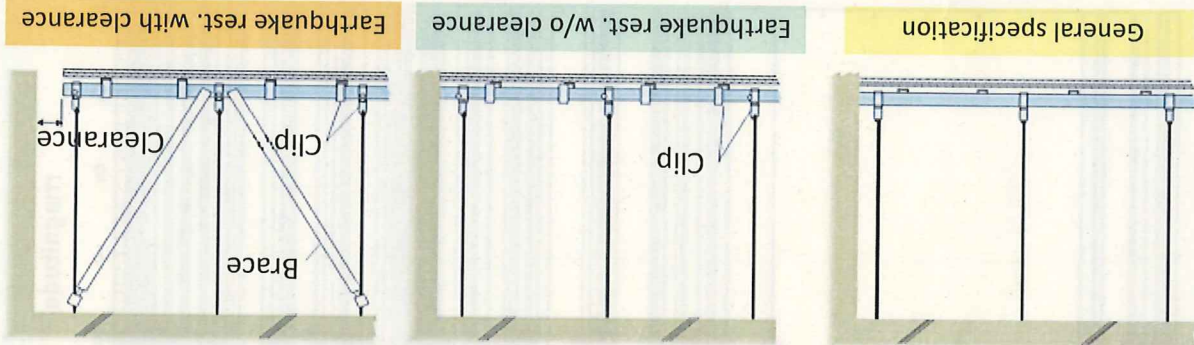
- breakage
- cracking or peering
- water leakage or immersion
- breakage of stage mechanisms

Ceiling falls at 151 buildings

- 50% : theaters, movie theaters, gyms and chapels
- 26% : entrance halls and concourses

➤ 70% of damages cases : "Suspended ceiling system"

Suspended ceiling system



General specification

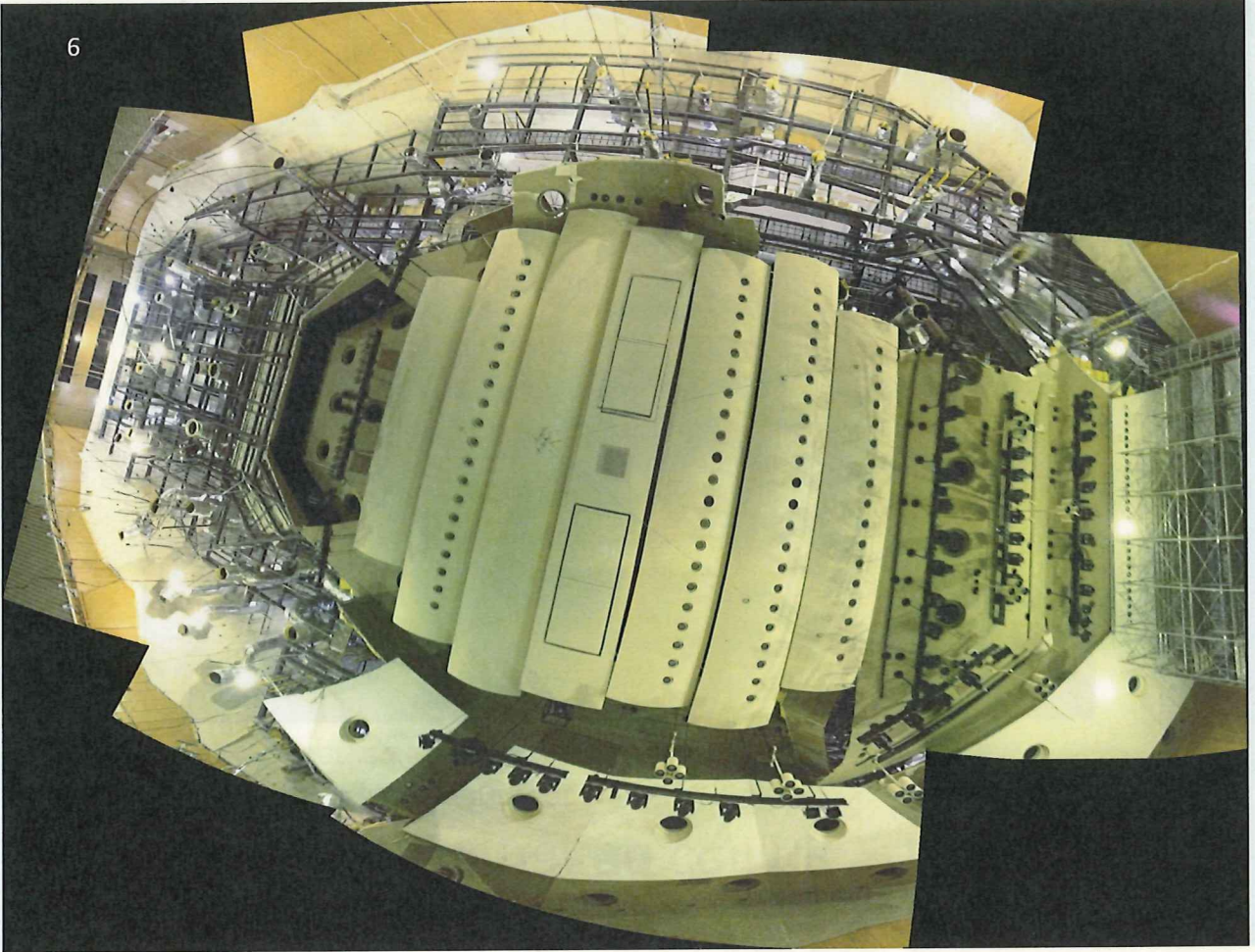
Earthquake rest. w/o clearance

Earthquake rest. with clearance

Inertia force by earthquake is absorbed by wall.

Braces restrain horizontal displacement, and clearance protects wall from being touched.

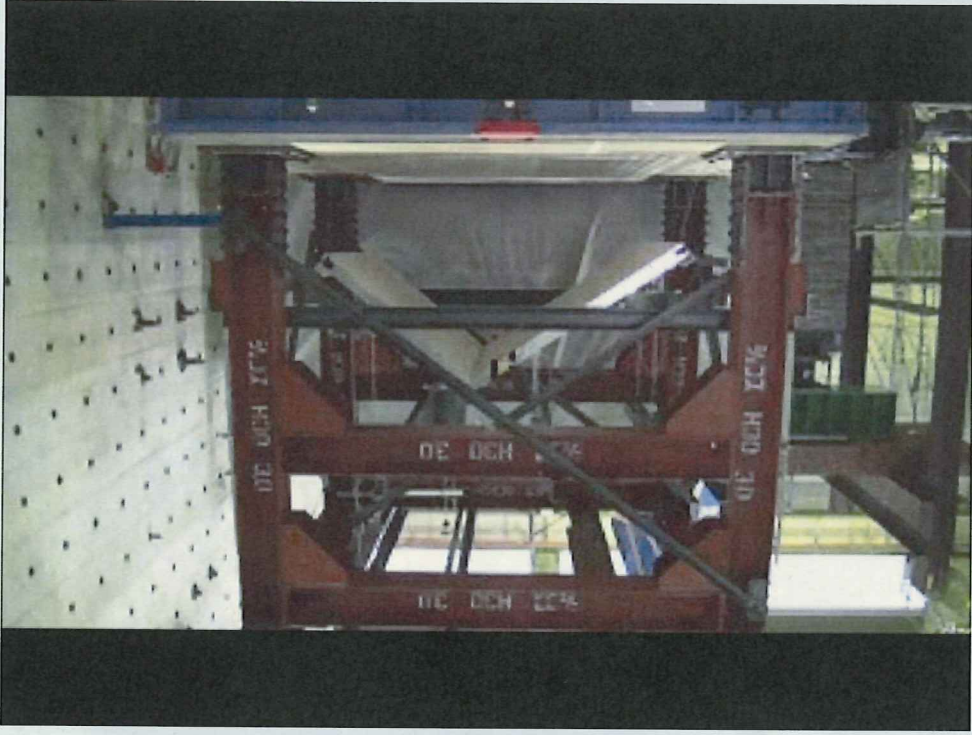
6



8



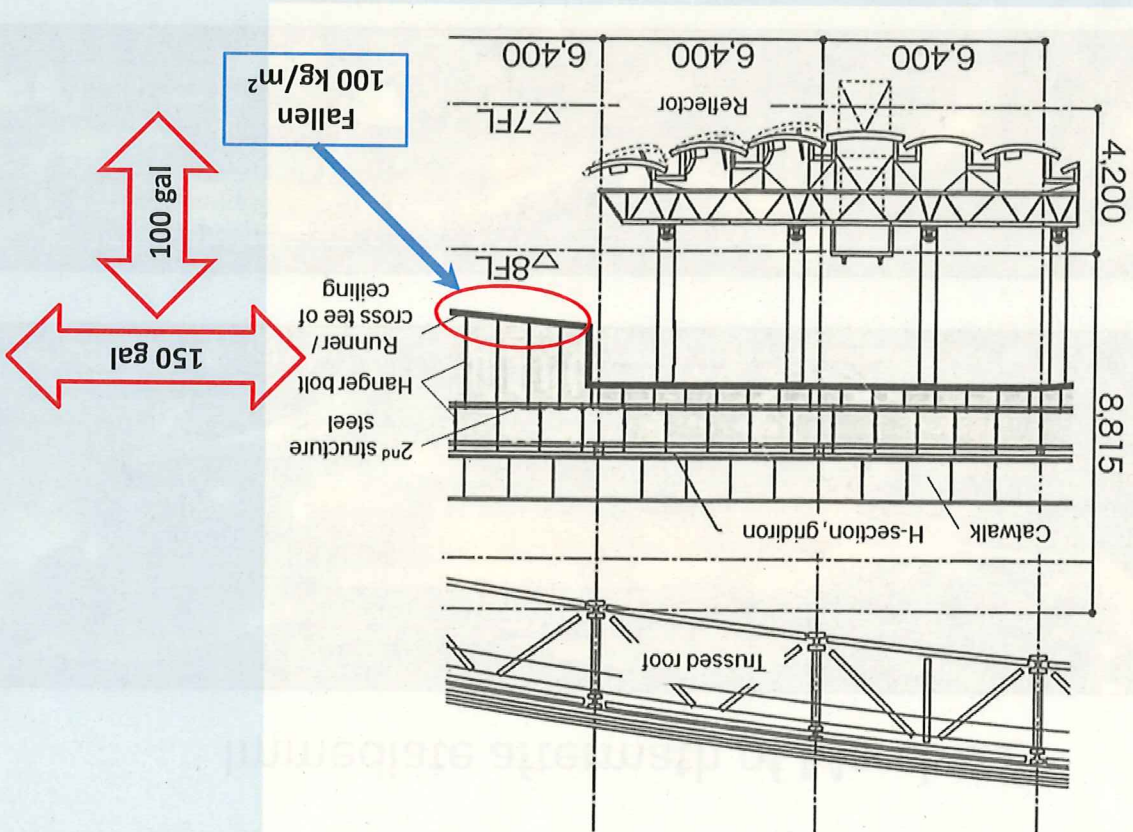
Immediate aftermath of March 11

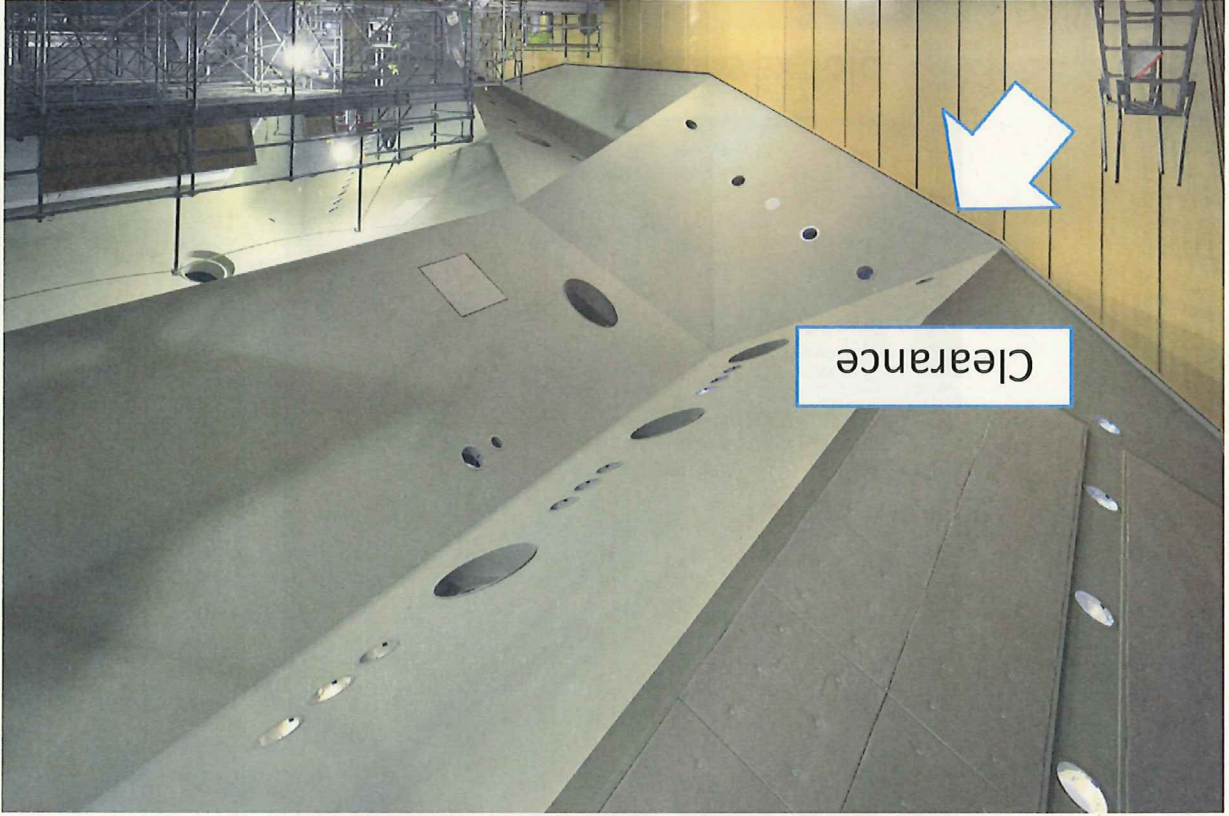


- Real scale experiment
- Observed earthquake near the cite: S.I. = 5 or more

Damaged ceiling

Section of the damaged ceiling.

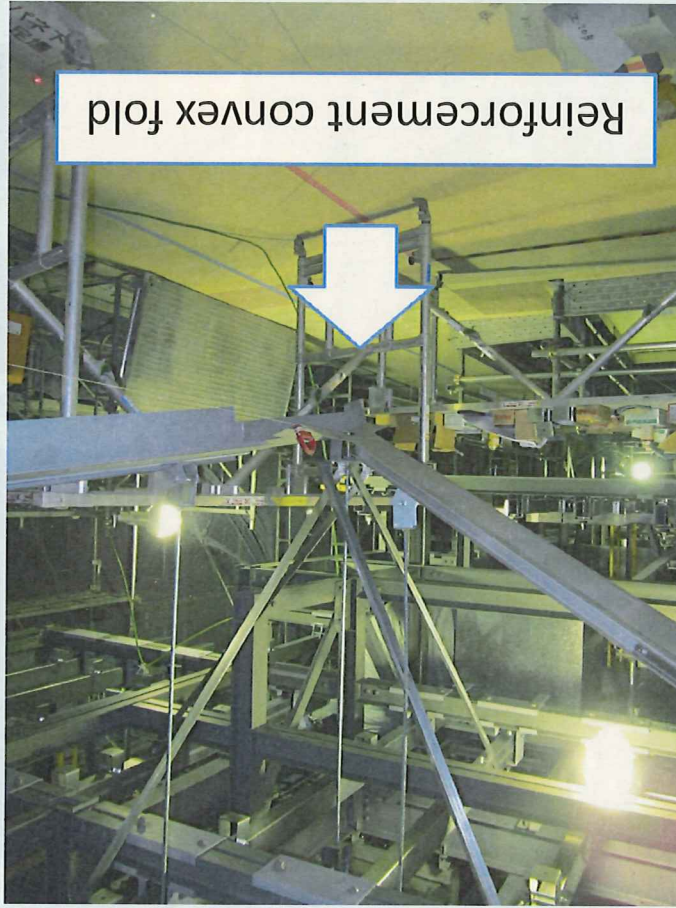


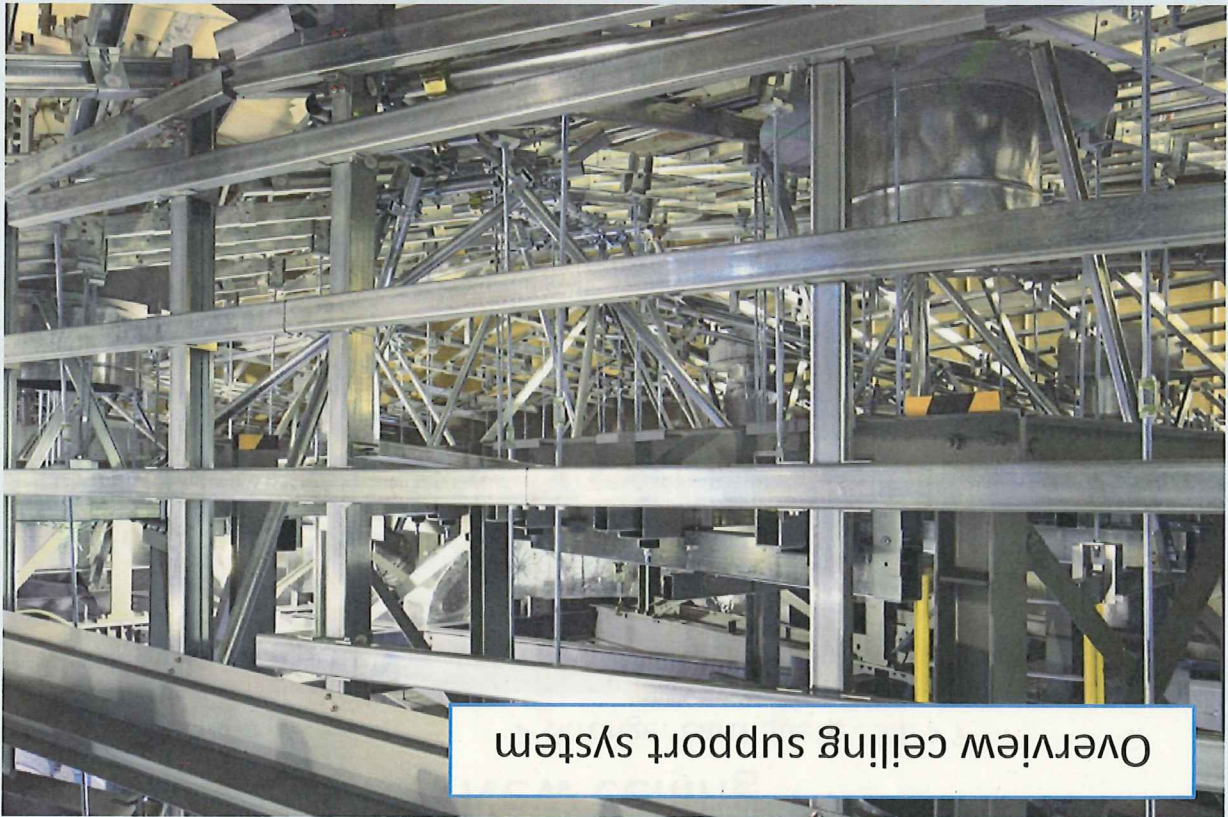


1. Clearance between ceiling and wall
2. Reinforcement of ceiling support members
3. Reinforcement of convex folds, board joint, etc.
4. Prevention of concentrated loading
5. Same length of hang bolts
6. Prevention of shear disp. of vibration isolator

Design Objective: S.I. 7.0

Solution

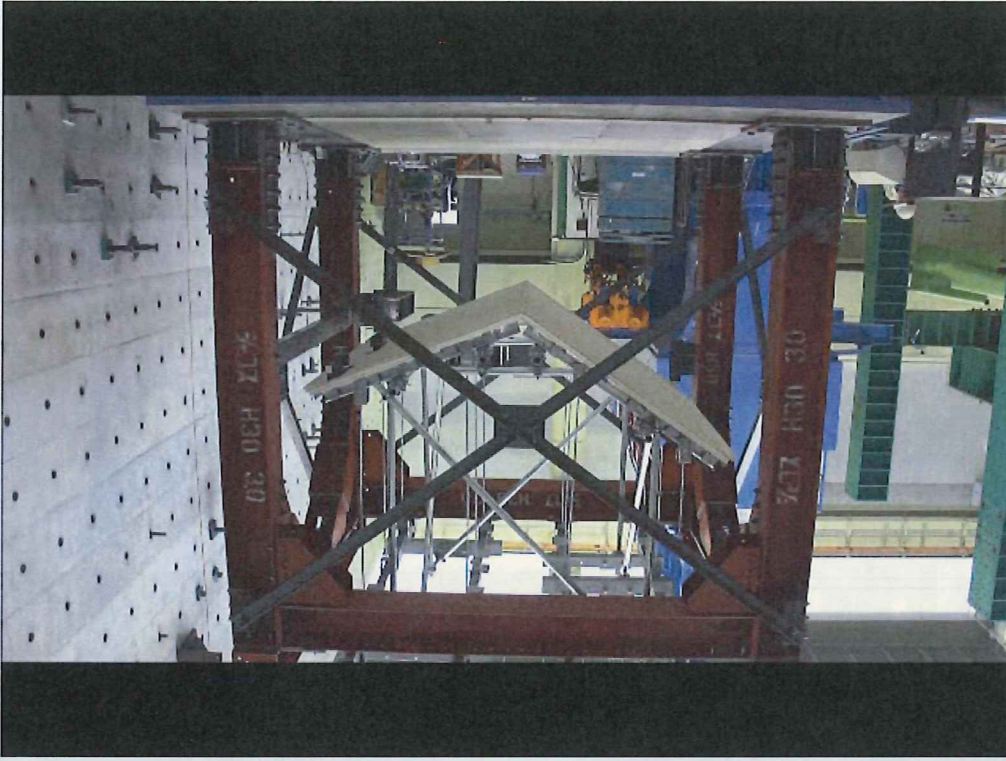




Overview ceiling support system



Same bolt length, reinforcement

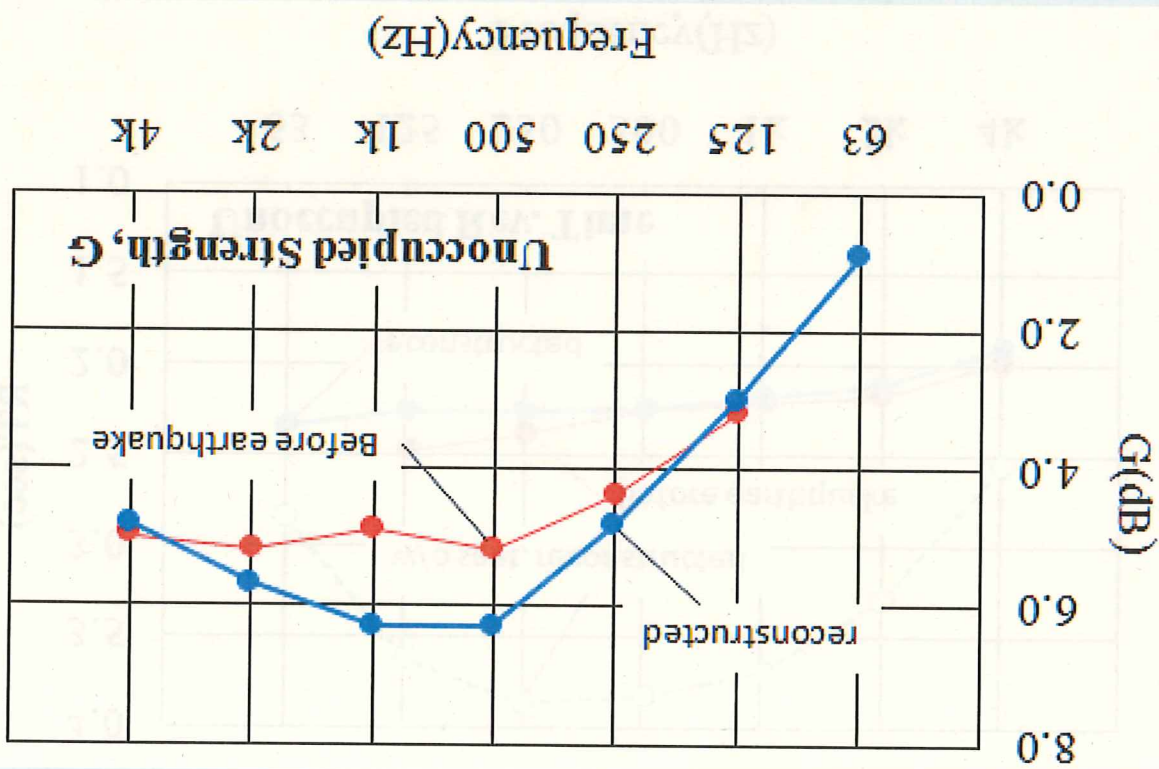
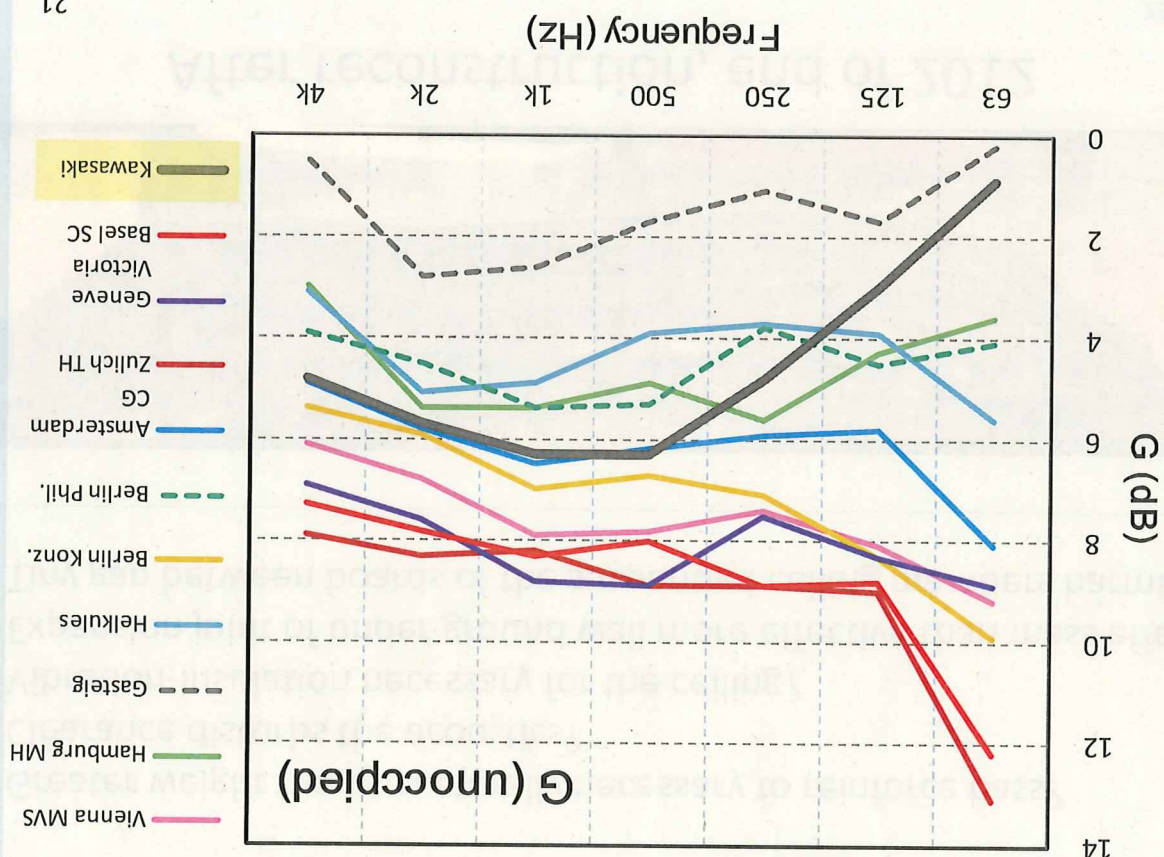


➤ Stronger earthquake : S.I. = 7

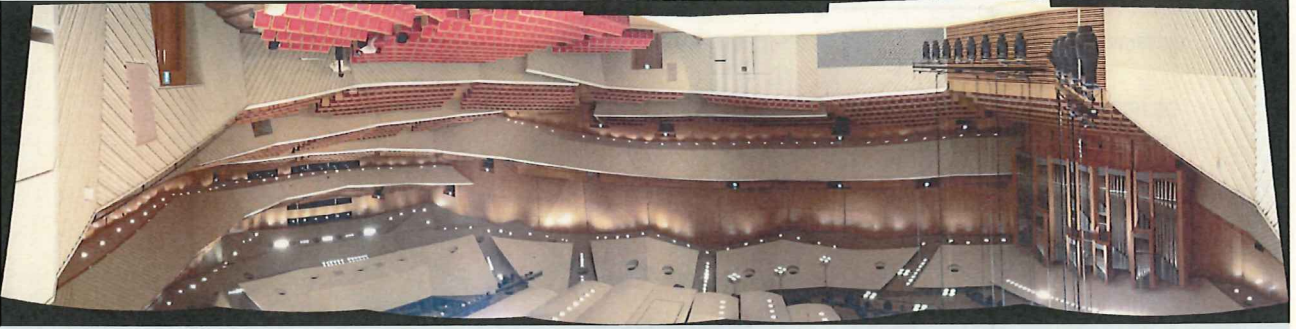
New ceiling



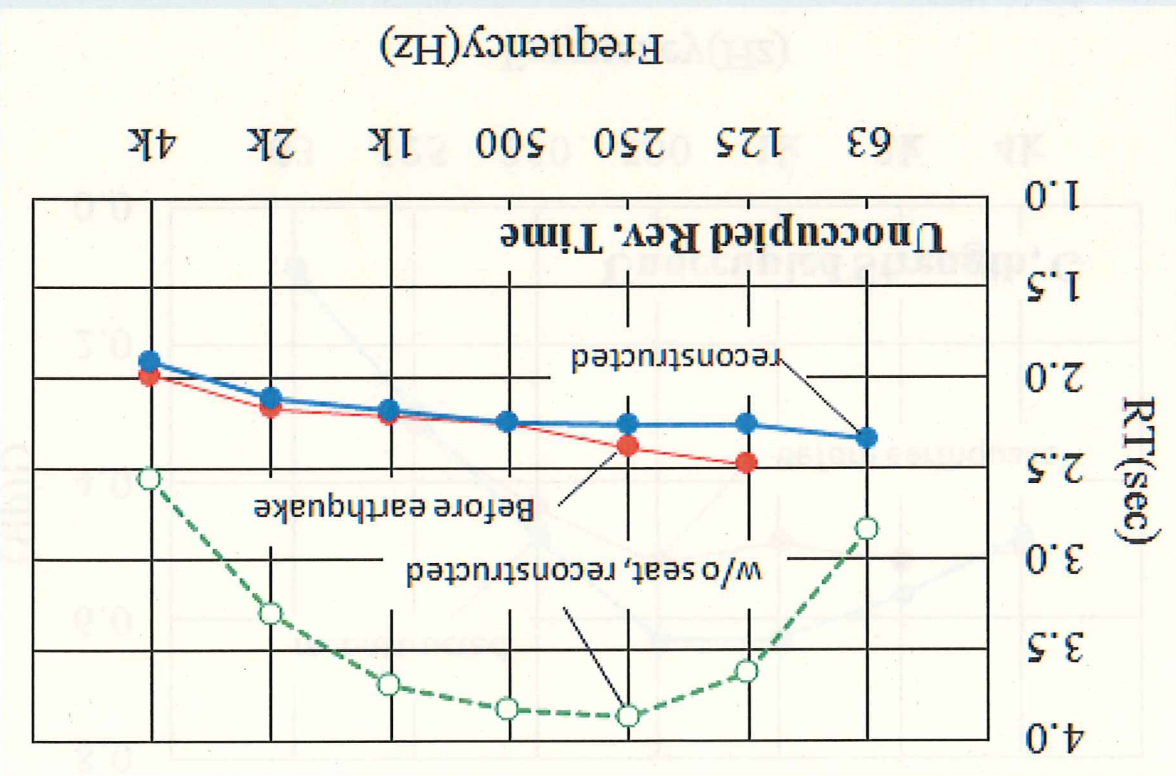
Overview ceiling support system



After reconstruction, end of 2012



- Greater weight than structurally necessary to reinforce bass?
- Clearance disturbs the acoustics?
- Vibration-insulation necessary for the ceiling?
- Expansion joint of under ground wall more effective than mass effect?
- Tiny gap between boards of the suspended ceiling members harmful?





Thank you for your attention.

THANK YOU FOR YOUR ATTENTION