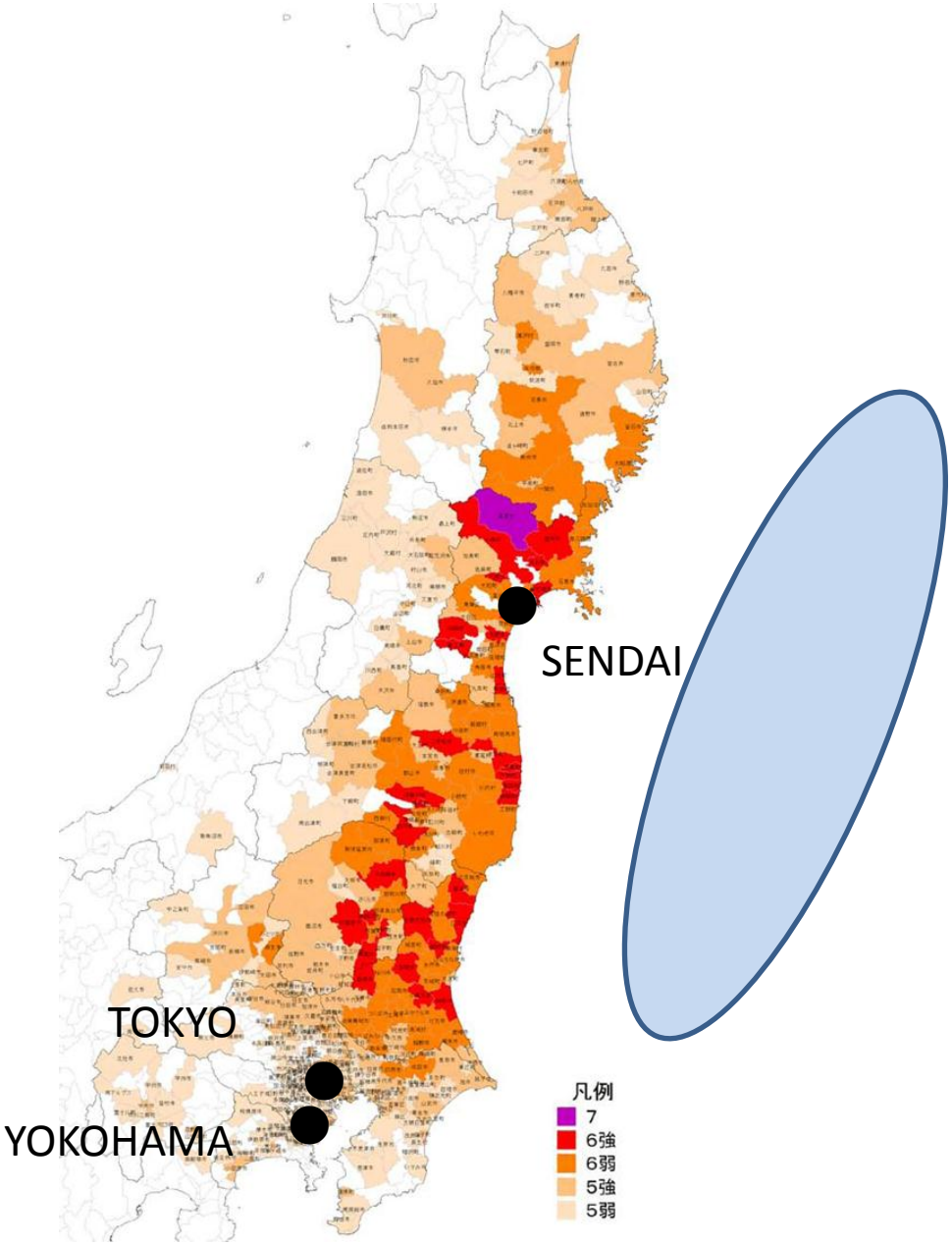
14th US-Japan Workshop

Performance of Base-Isolated Buildings Under the 2011 East Japan Earthquake

Yoshikazu FUKASAWA

Mitsubishi Jisho Sekkei Inc. Japan Society of Seismic Isolation

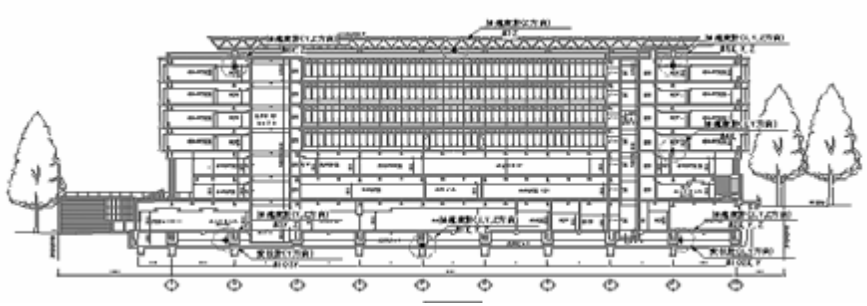

SENDAI
TOKYO
YOKOHAMA
凡例
7
6強
6弱
5強
5弱

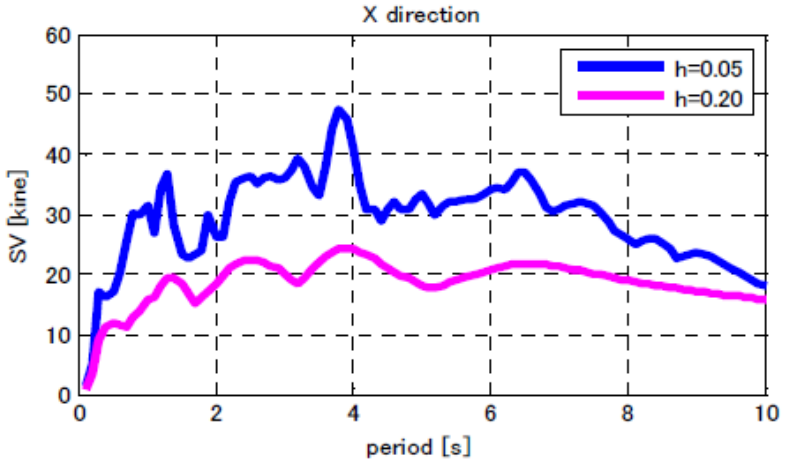
1. The Behaviors of Two Base-Isolated Buildings
   - Building A in Yokohama
   - Building B in Sendai

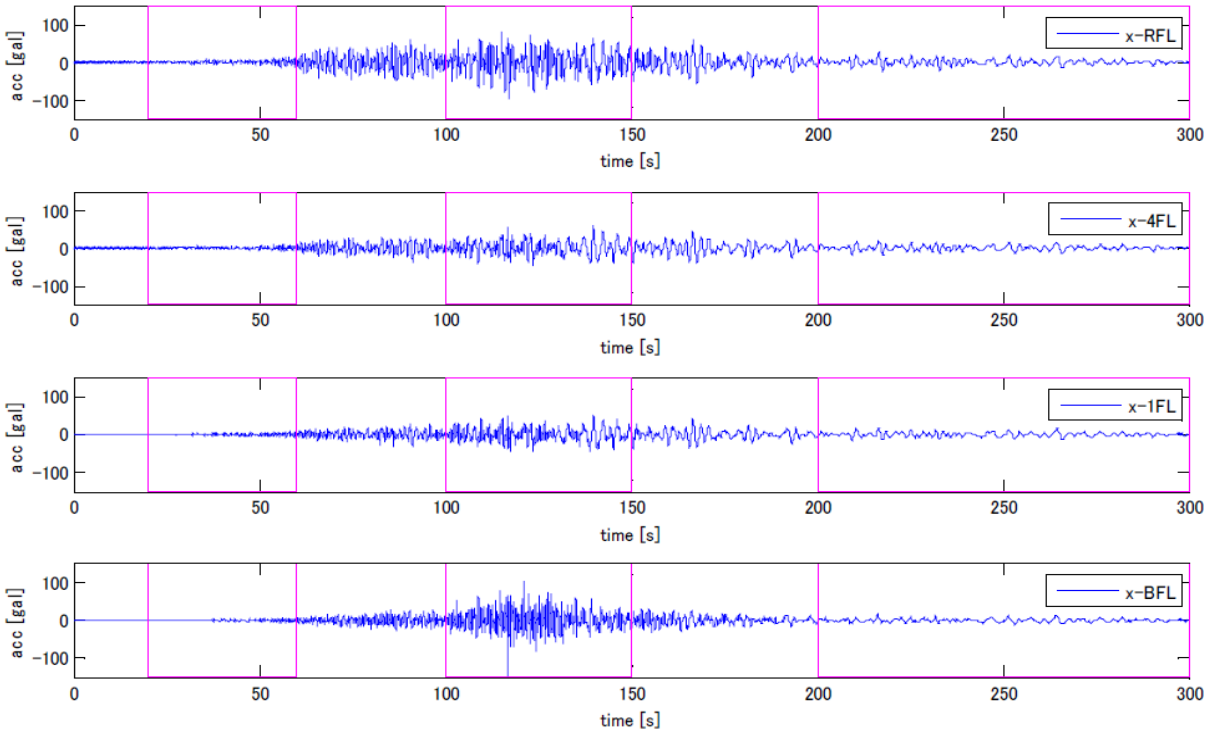
2. Damages of finishing material to the Expansion Joints
   - Causes of damage
   - Measures against Damage

3. Damages of Damper
   - Crack of Lead Dampers
   - Damages of Bolt Fastener of Steel Damper

Building A in Yokohama







	最大加速度[gal]		
	X	Y	Z
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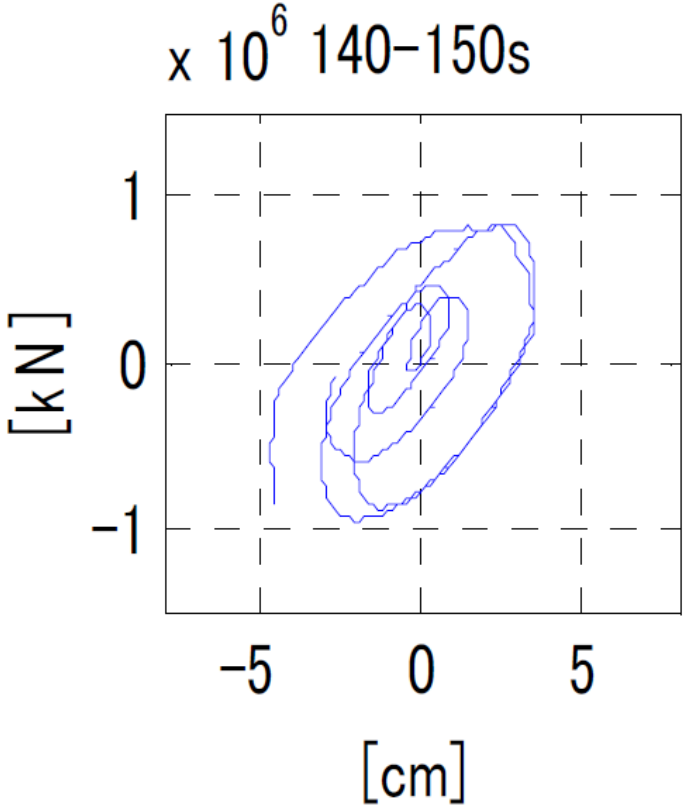
x 10^6 140-150s
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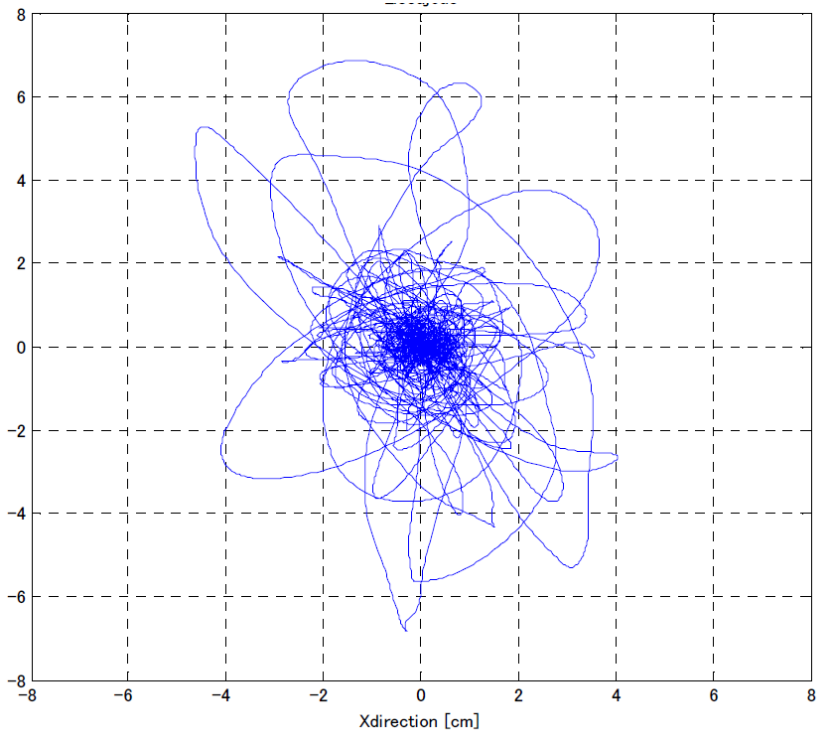
−1
[kN]
−5
0
5
[cm]


8
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−4
−2
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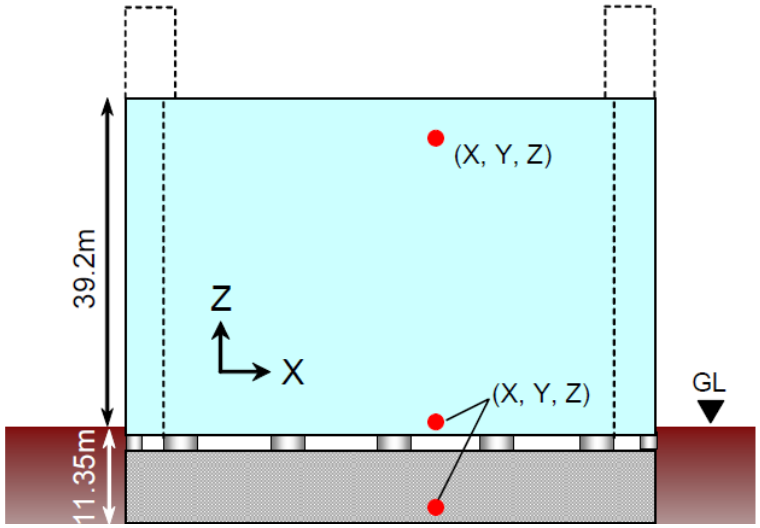
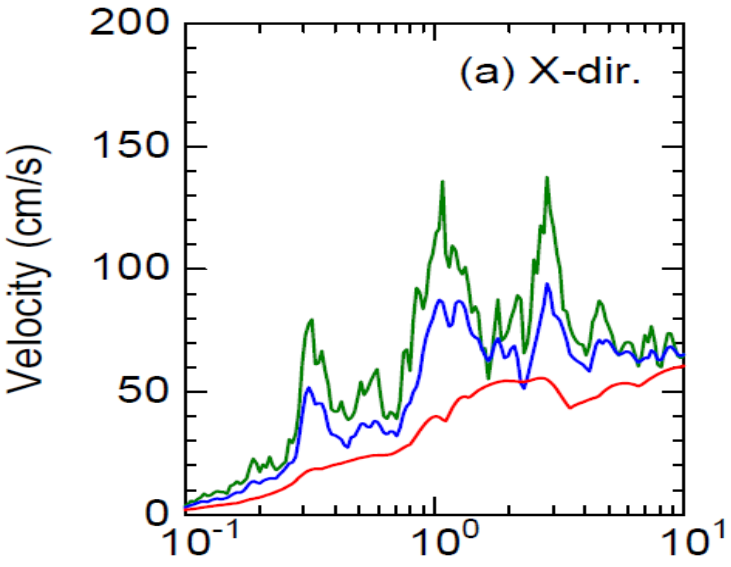
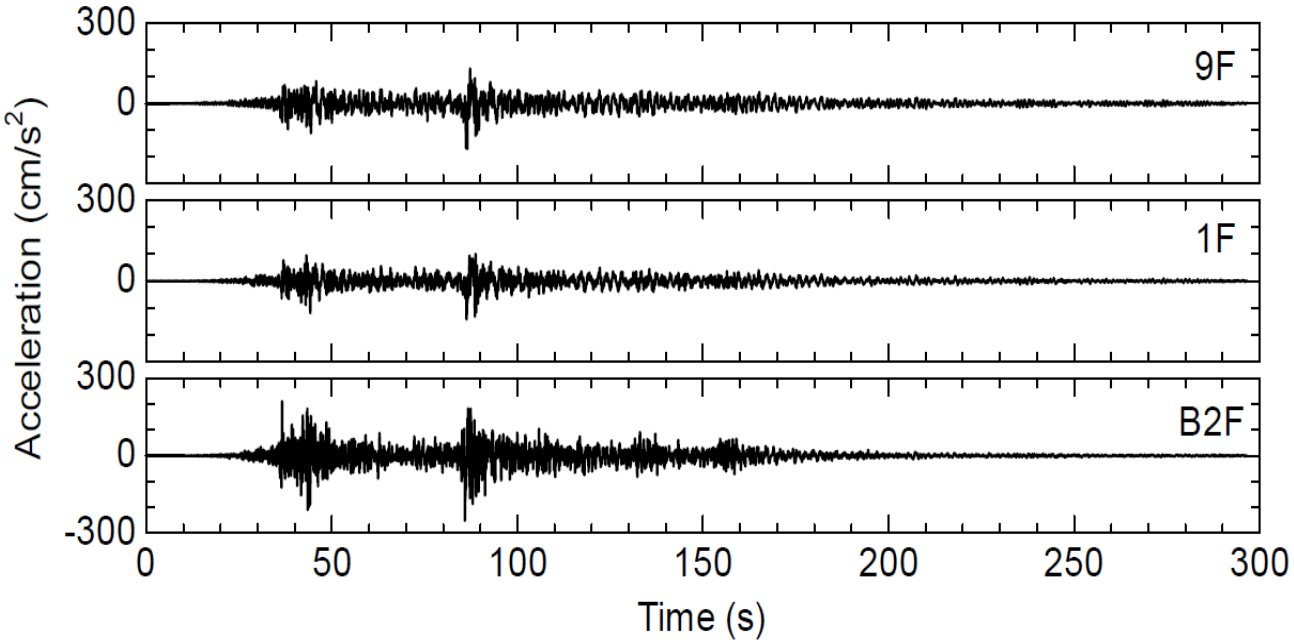
2
4
6
8
Xdirection [cm]

Building B in Sendai







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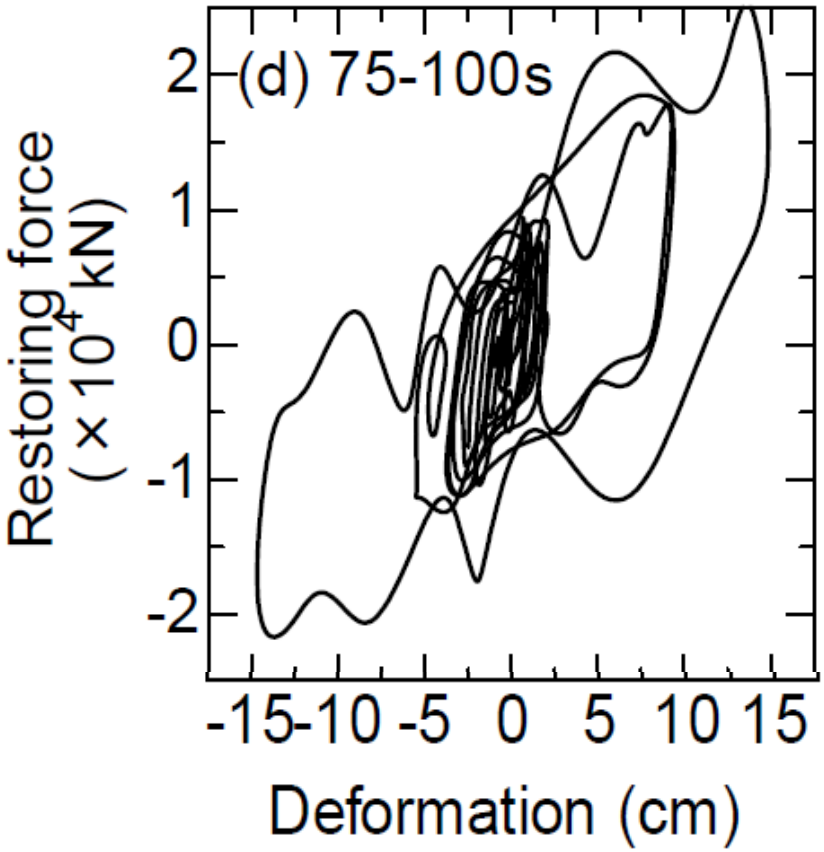
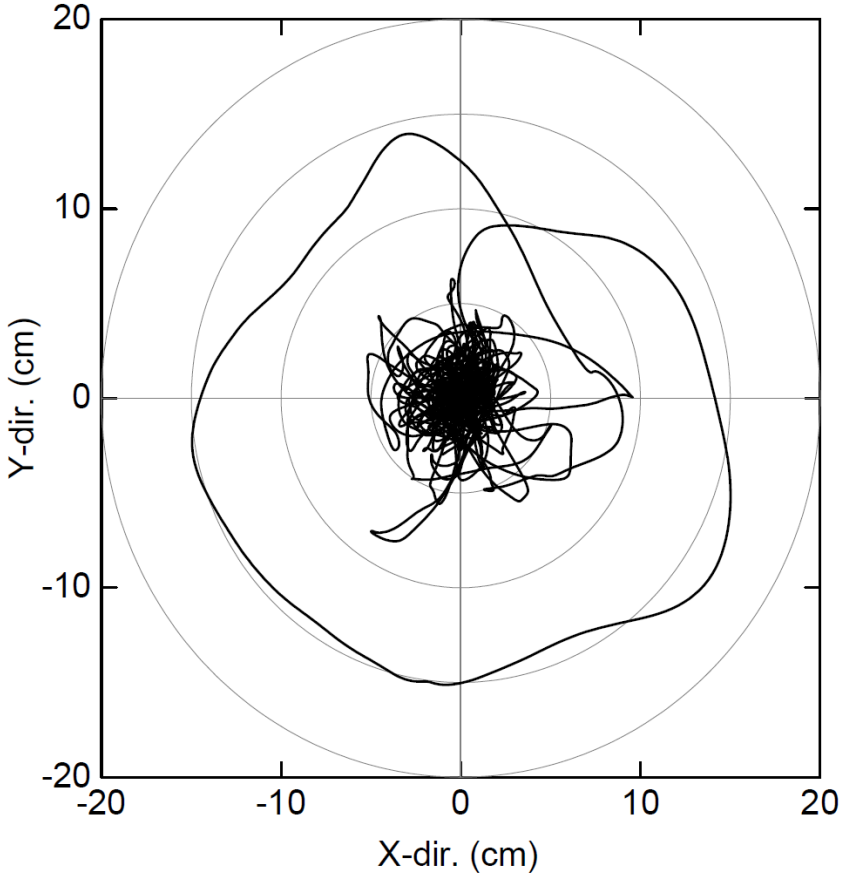
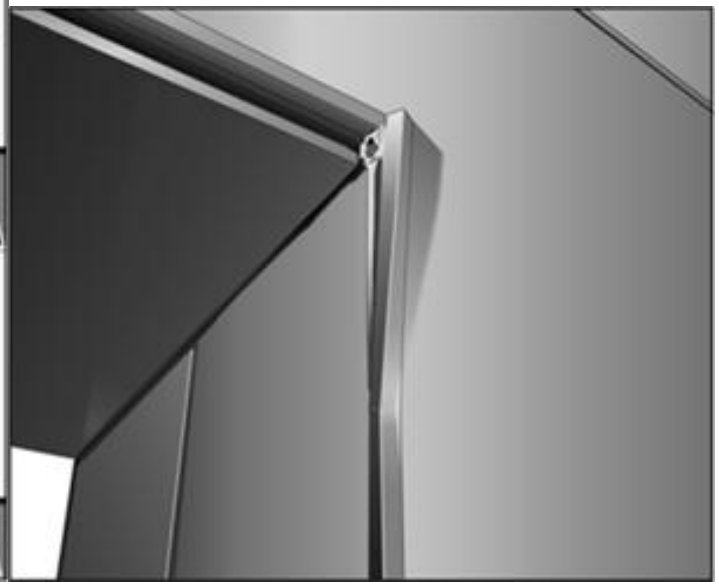

(d) 75-100s
Restoring force
(×10^4 kN)
2
1
0
-1
-2
-15 -10 -5 0 5 10 15
Deformation (cm)


20
10
0
-10
-20
Y-dir. (cm)
-20 -10 0 10 20
X-dir. (cm)

Damages of finishing material to the Expansion Joints



Causes of Damages to the Expansion Joints

1. Insufficient consideration of dynamic and cyclic behavior.
2. Unintended contact with other elements.
3. Lack of strength and deformation capacity.
4. Neglecting unique considerations required for joints during construction.
5. Misunderstandings the required deformation capacity to one direction only.

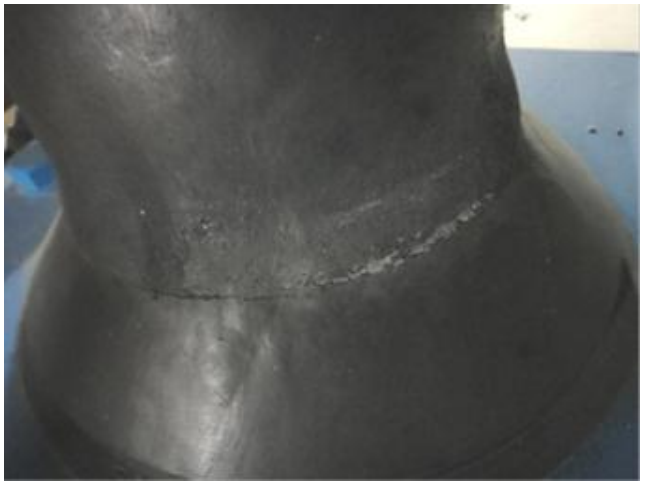
Target Performance of Finishing Material

1. Fatal damage must be prevented.
   Even if the maximum displacement occurs,
   1) People must not be injured.
   2) There must not be any serious trouble in the case of refuge or help is needed.
   3) Continuous use of building must be possible.

2. Allowable damage should be considered and confirmed.
   A damage of finishing material to expansion joint may be allowable unless it is not a fatal damage. However, if damage occurs, it has to be repaired, hence cost performance should also be considered. In order to study cost performance, allowable damage in each part has to be set up.

Crack of Lead Dampers

(cracked depth) 30mm



(cracked depth) 7mm.

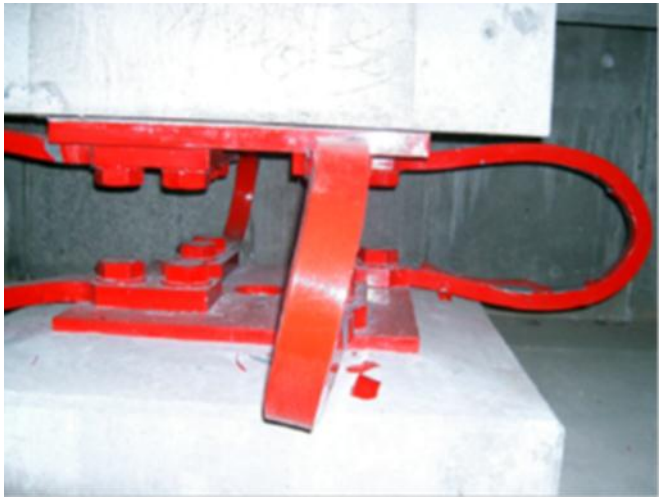
a=1-p/r

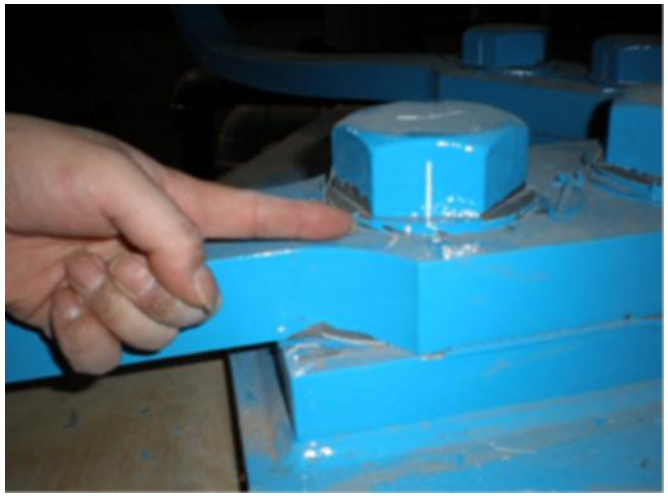
a : residual energy ratio to initial energy

p : cracked depth

r : radius of lead dumper

Damages of Bolt Fasteners of Steel Dampers





Conclusion

1. All base-isolated buildings showed good performance in both extremely shaken area and strongly shaken area. Superstructures were not damaged and nonstructural components were mostly protected.
2. Some damages of finishing material to expansion joints were observed at about 30 % of the base-isolated buildings
3. Cracks of lead damper were observed at a few buildings. Also looseness of bolt fasteners of steel dampers was observed at a few buildings.

Categorization of Damage to Buildings Caused by the 3.11 Tsunami

Miyako City URL
http://www.city.miyako.iwate.jp/cb/hpc/Article-6834.html

Damage to RC Buildings and Steel Buildings is discussed in order to develop structural design methods for Tsunami Evacuation Buildings

Hiroshi FUKUYAMA

Director, Dept. of Structural Engineering,
Building Research Institute (BRI), JAPAN

Damage to RC Buildings

Most of RC buildings survived without any structural damage

・・・ However, severe damage were observed in a part of RC Buildings

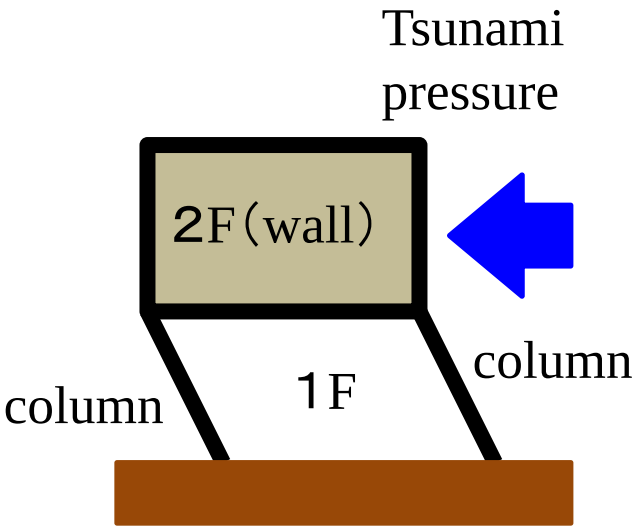
Damage to RC buildings

(1) Total collapse

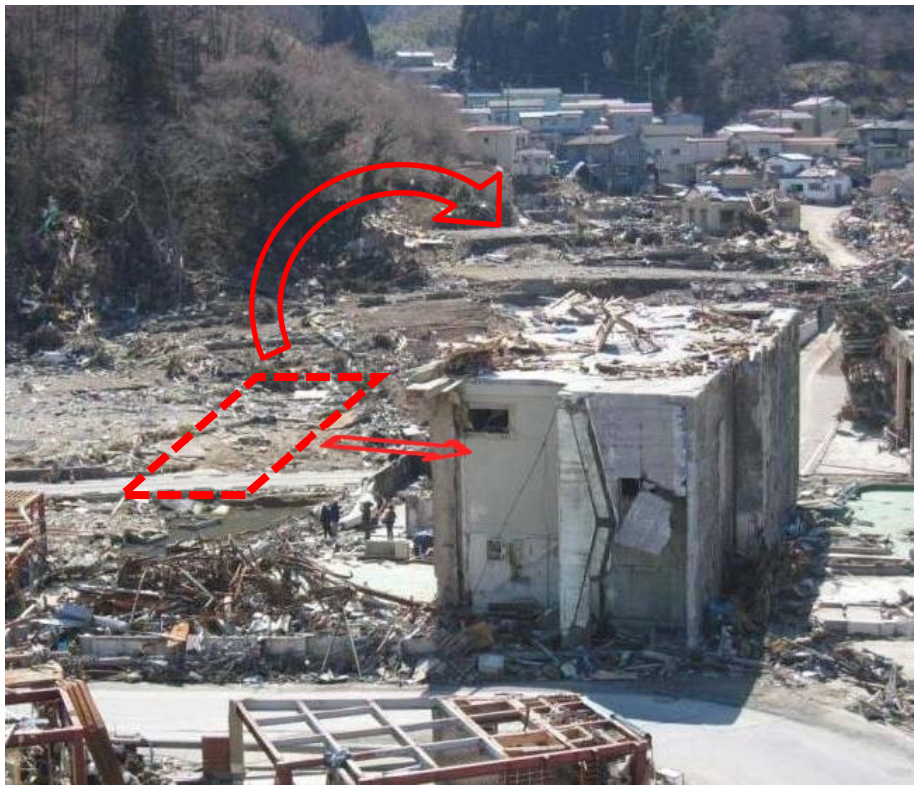
Natori City, Yuriage district

Damage to RC buildings

(2) Collapse of 1st story

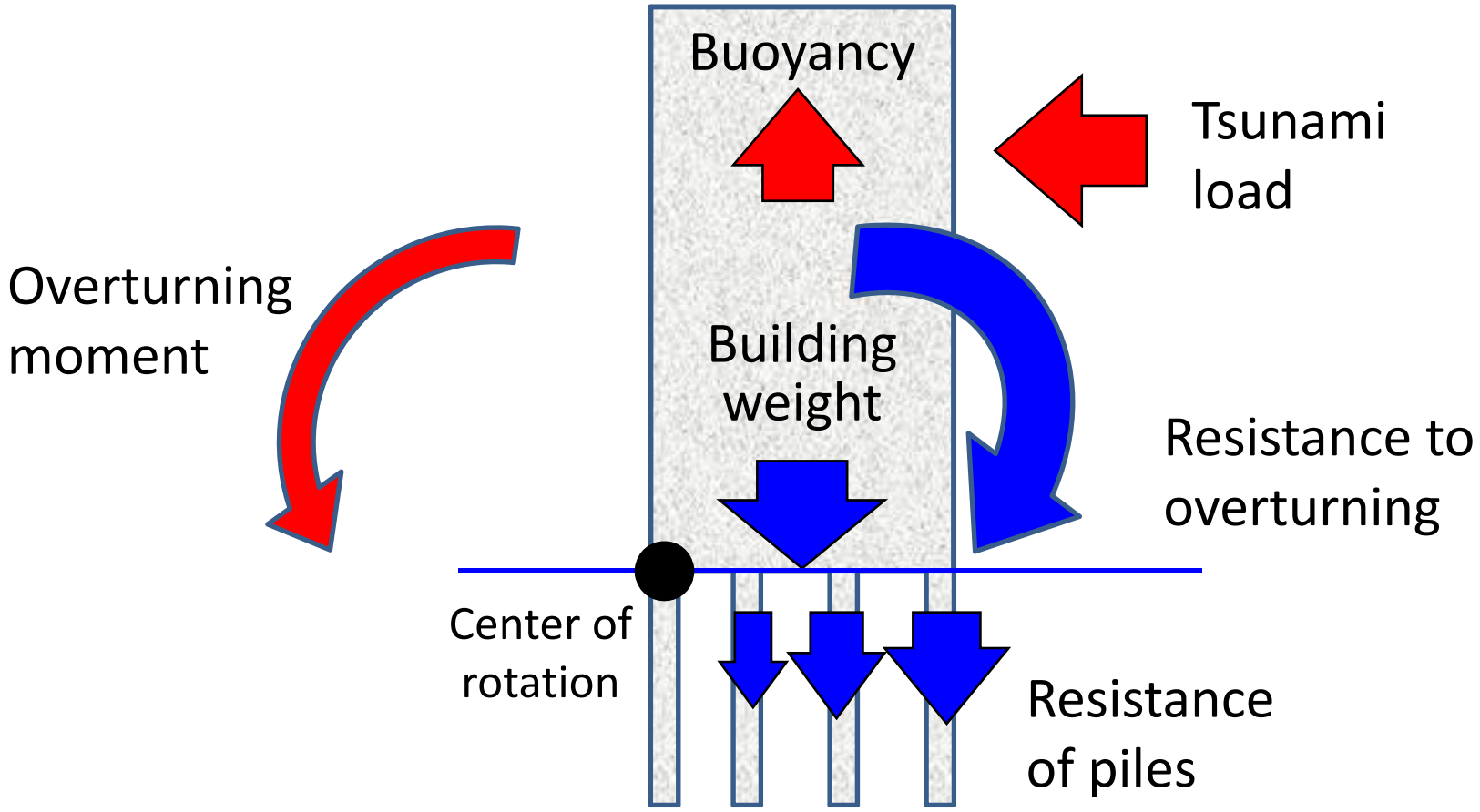


Damage to RC buildings
(3) Overturning



Refrigerated warehouse got over the fence

Mechanism of overturning



Damage to RC buildings

(3) Overturning

Trapped air below floor slab caused buoyant force

The building was submerged completely

Damage to RC buildings

(4) Failure of walls

A filtration plant

Damage to RC buildings

(5) Scour

Very strong stream was generated around the corner of the building, resulted in large holes on the ground

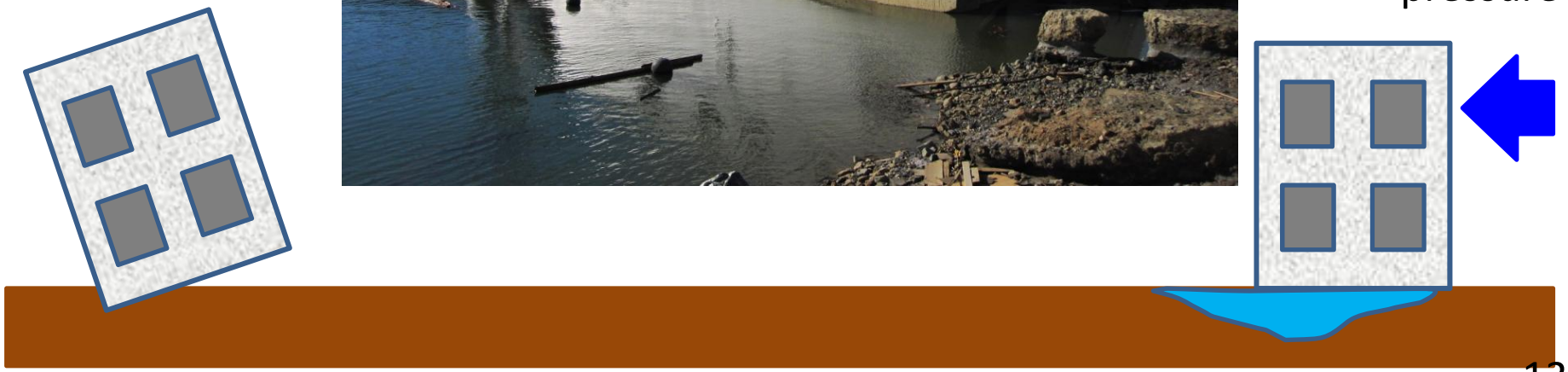
Damage to RC buildings

(5) Scour & Tilting

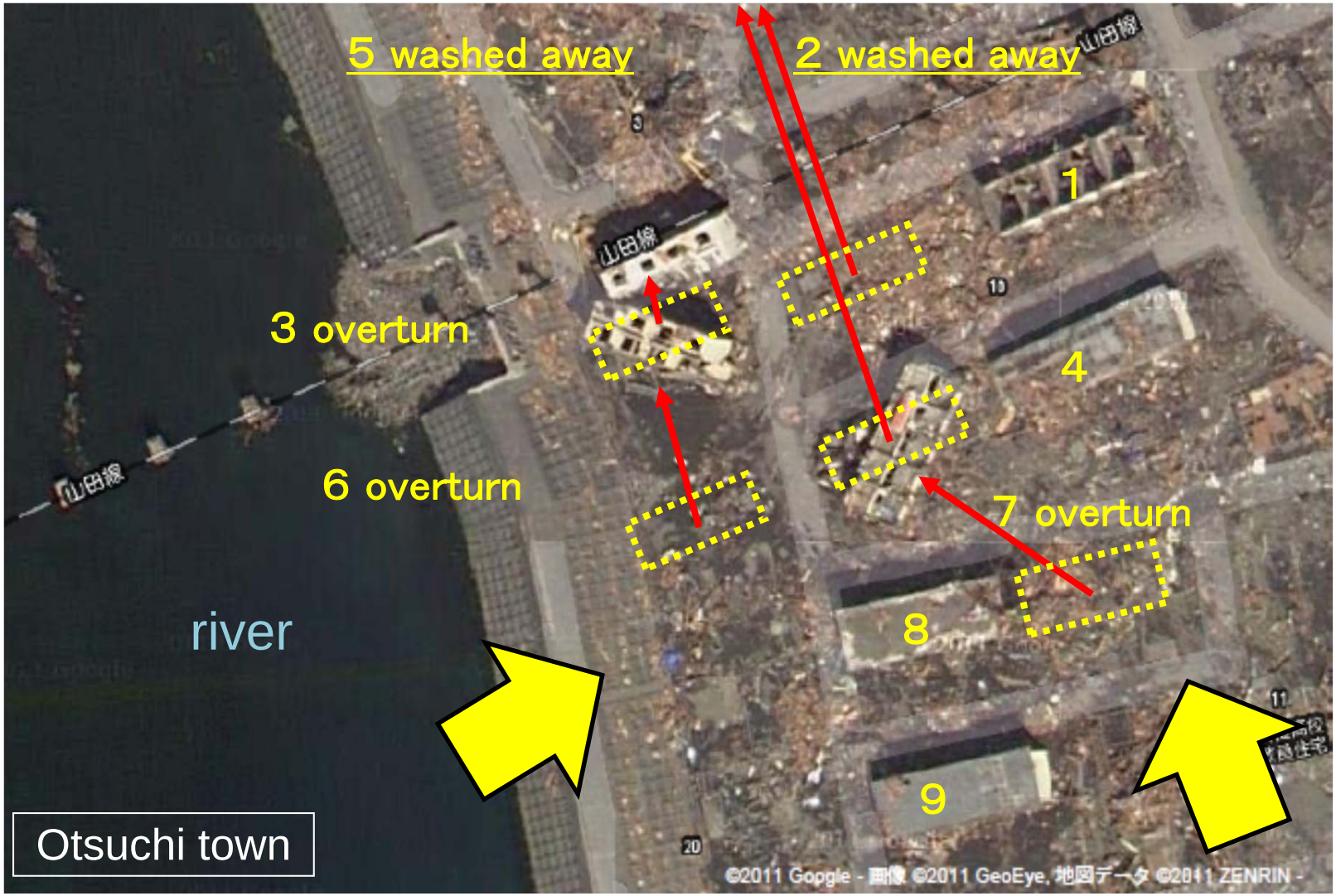
In case of mat foundation

Damage to RC buildings

(6) Sliding



Overturning, Sliding & Washing away



Overturning, Sliding & Washing away

Survived

Partially damaged

Overturned

Overturned (upset)

Damage to RC buildings

(7) Debris impact

Damage to Steel Buildings

Damage to Steel buildings

(1) Failure of exposed column

Rupture of anchor bolt, base-plate or welding part between column and base-plate

Damage to Steel buildings

(2) Failure of column top connection

Damage to Steel buildings

(3) Overturning

Exterior finishing was survived
Then large tsunami load and buoyancy happened

Overturning due to rupture of anchor bolt and buckling of 1st story columns

Damage to Steel buildings

(4) Washed away of finishing

Damage to Steel buildings

(5) Large residual deflection

Damage to Steel buildings

(6) Collapse of 1st story

Damage to Steel buildings
(7) Deformation of columns due to tsunami pressure and/or debris impact

Summary

Damage pattern to buildings are categorized

< RC Buildings >

- Total collapse
- Collapse of 1st story
- Sliding
- Washed away
- Overturning
- Debris impact
- Tilting due to scour
- Failure of walls

< Steel Buildings >

- Collapse of 1st story
- Failure of column base
- Failure of column top connection
- Washed away of finishing
- Overturning
- Debris impact
- Large residual deflection

Based on the categorization, structural design methods of tsunami evacuation buildings were discussed

Design target

1) Not to collapse:
Tsunami load on each floor will never be higher than the lateral capacity

2）Not to overturn:
Overturning moment by tsunami load will never be higher than the resistance moment considering buoyancy

3) Not to slide:
Lateral force will never be higher than the friction of the foundation or the lateral capacity of the piles

Design items

- Design for preventing failure of exterior elements (walls & columns)
- Design for debris impact
- Design for scour

Thank you
for your attention


Otsuchi town

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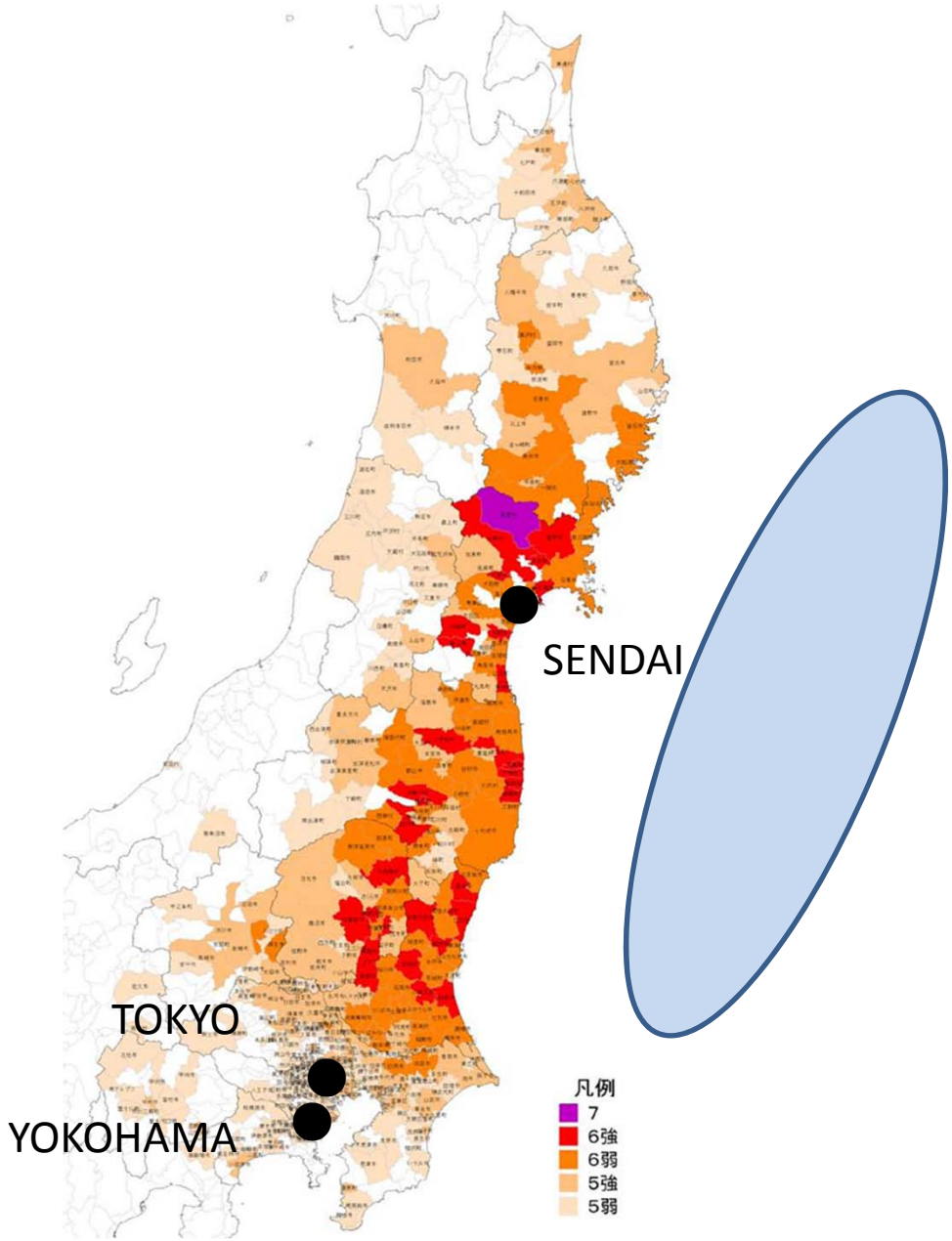
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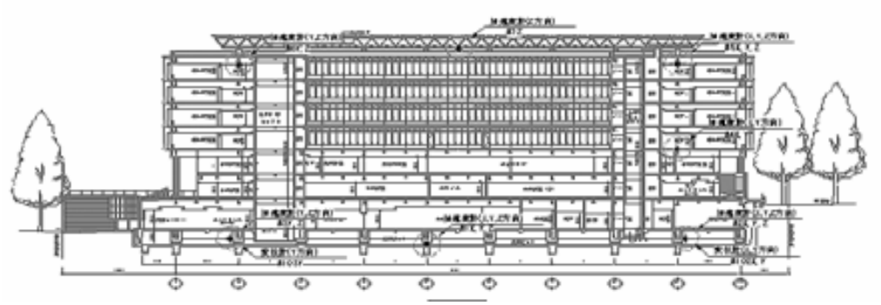

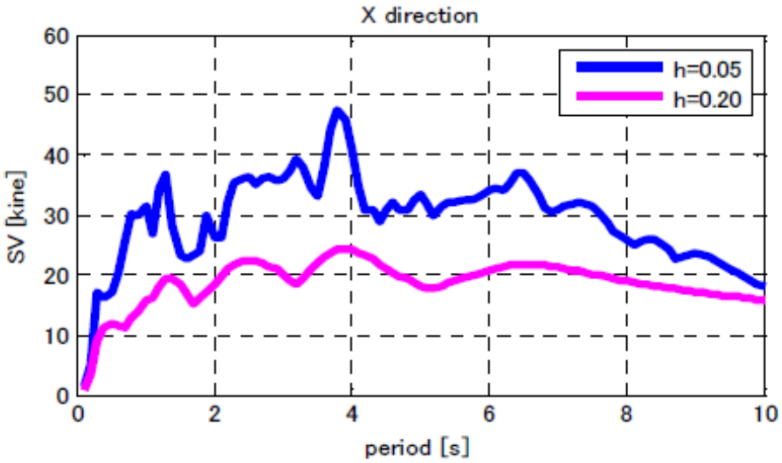

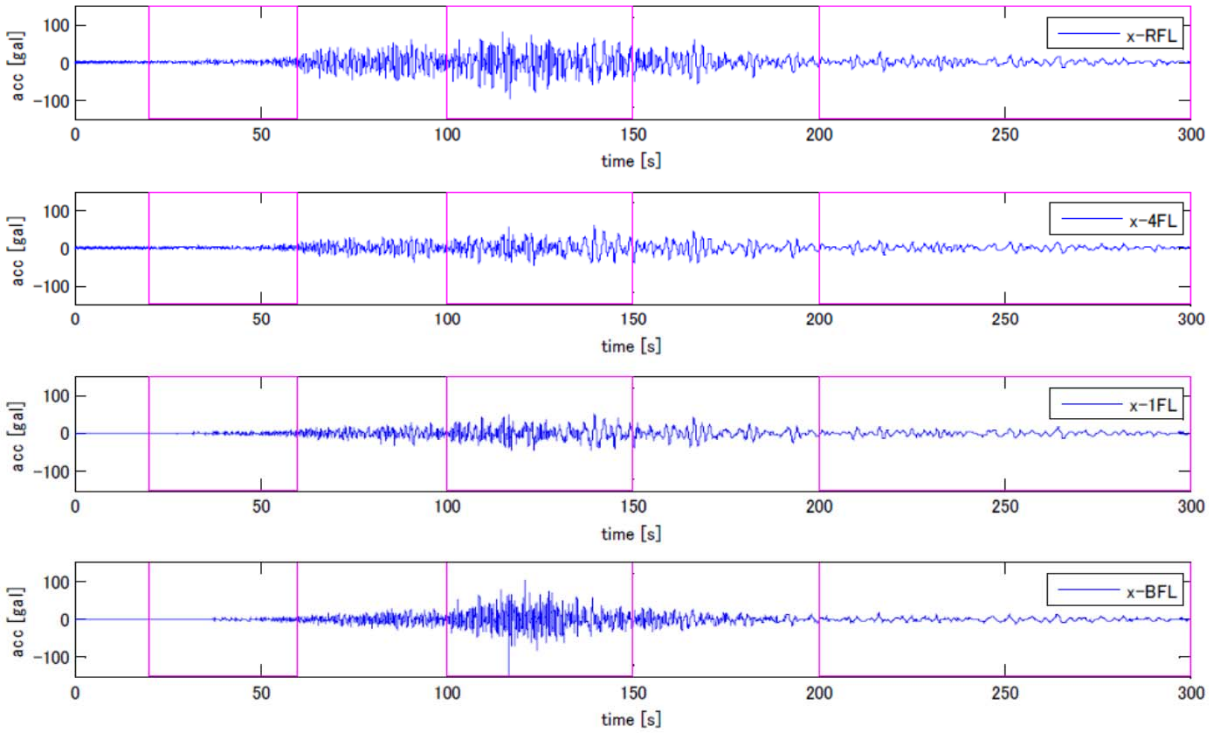

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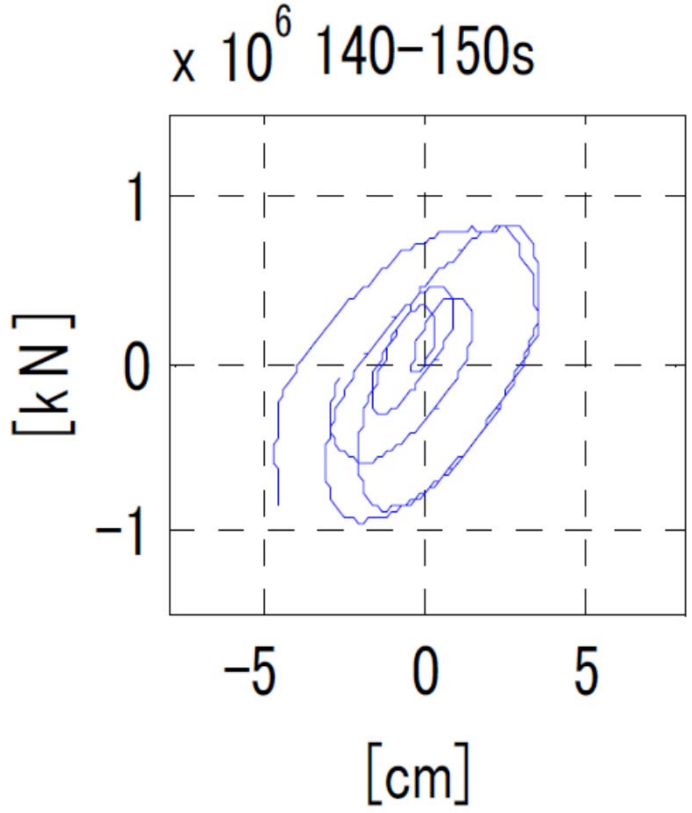
x 10^6 140-150s
1
0
-1
[kN]
-5
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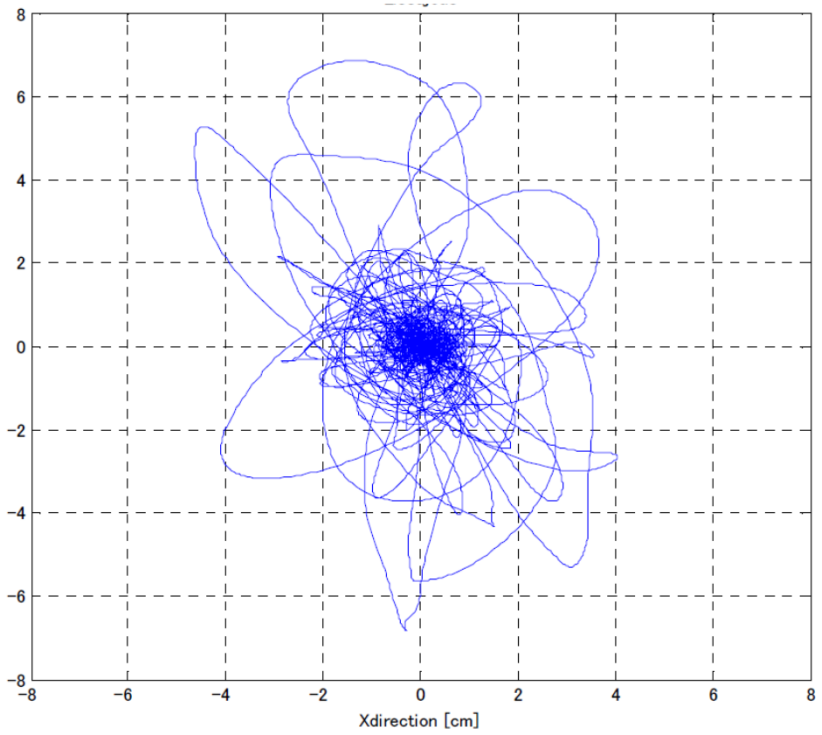
[cm]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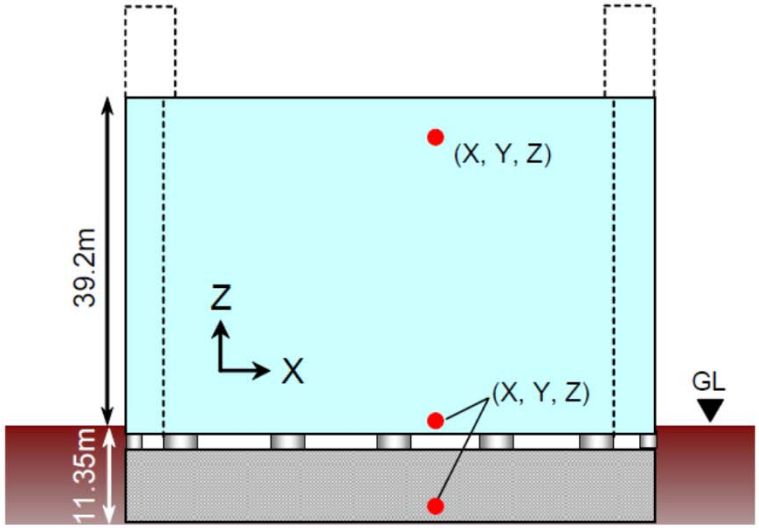
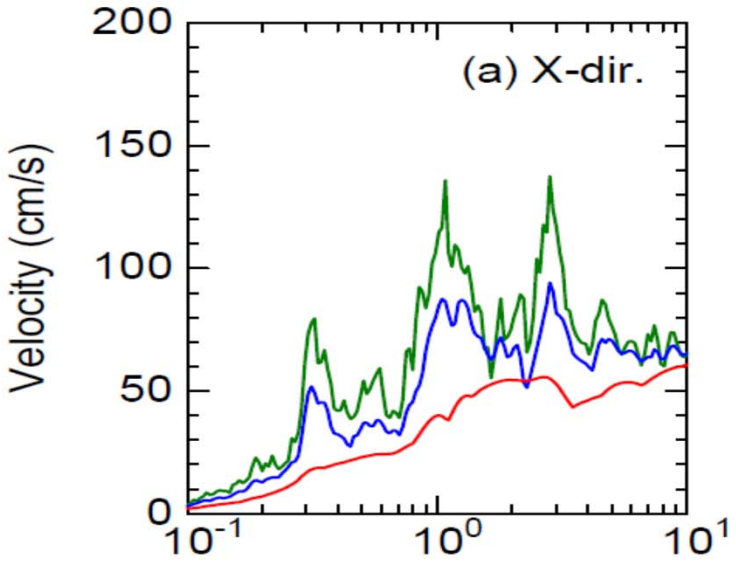
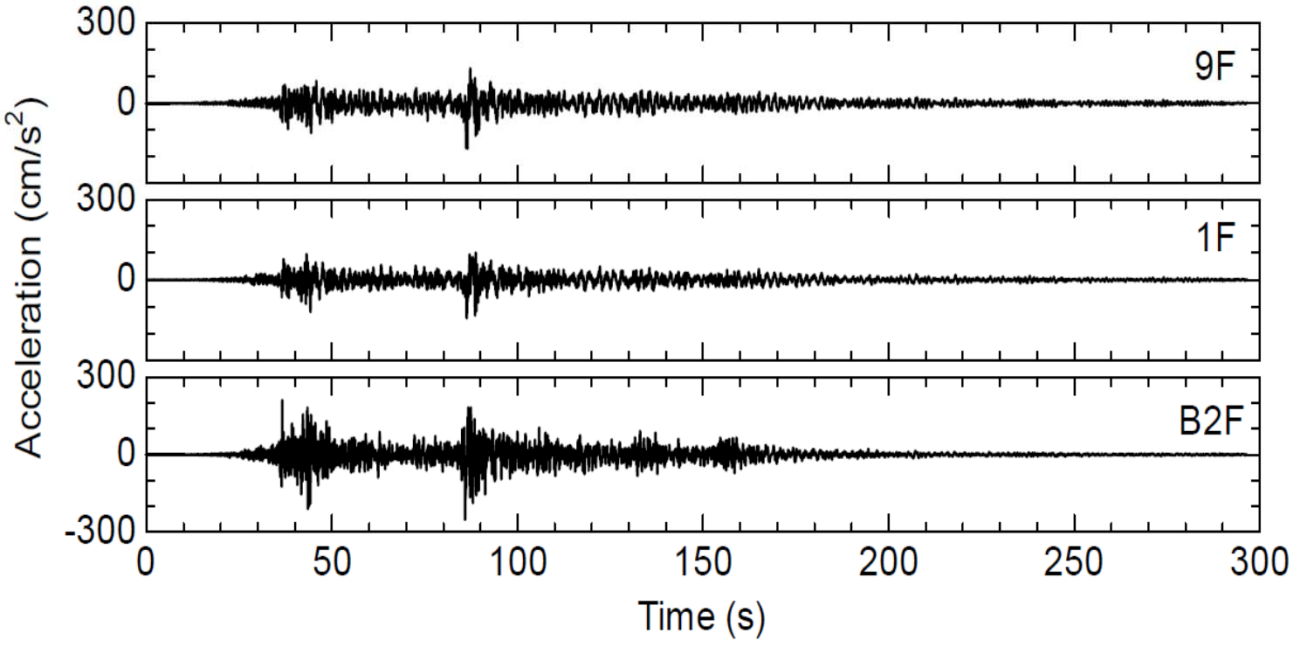
Xdirection [cm]

Building B in Sendai







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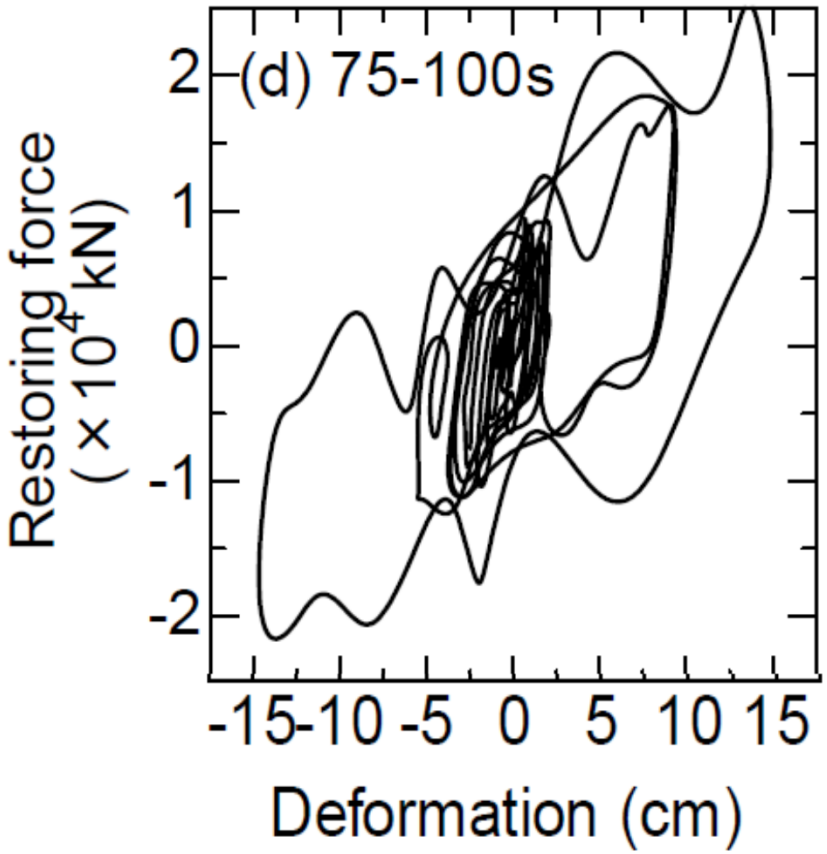
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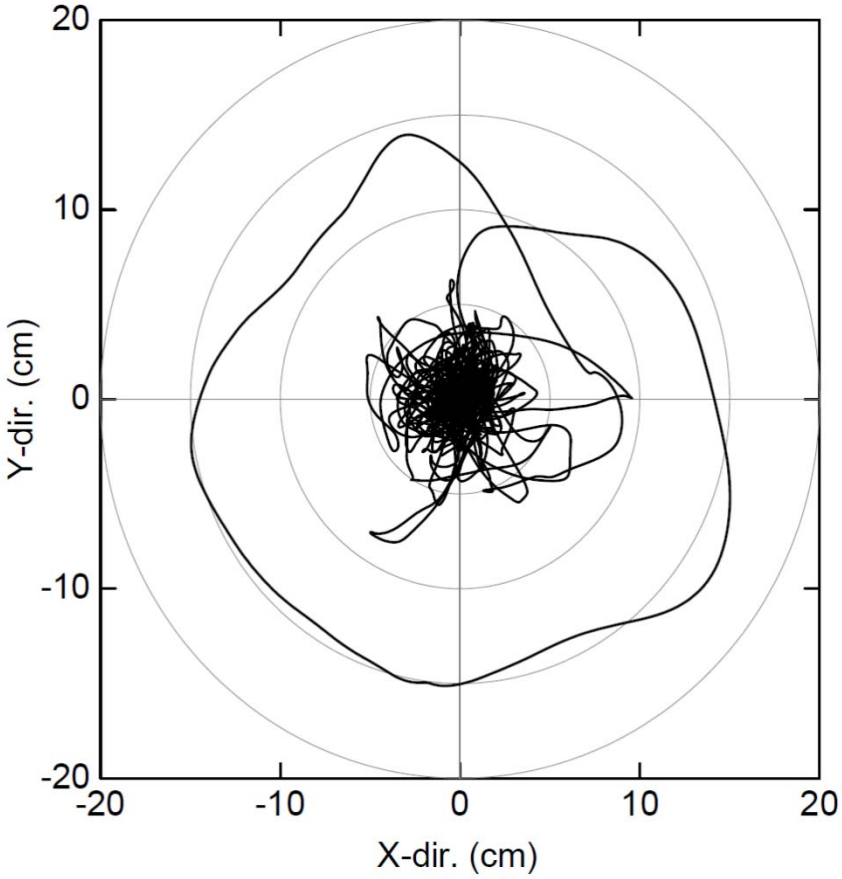
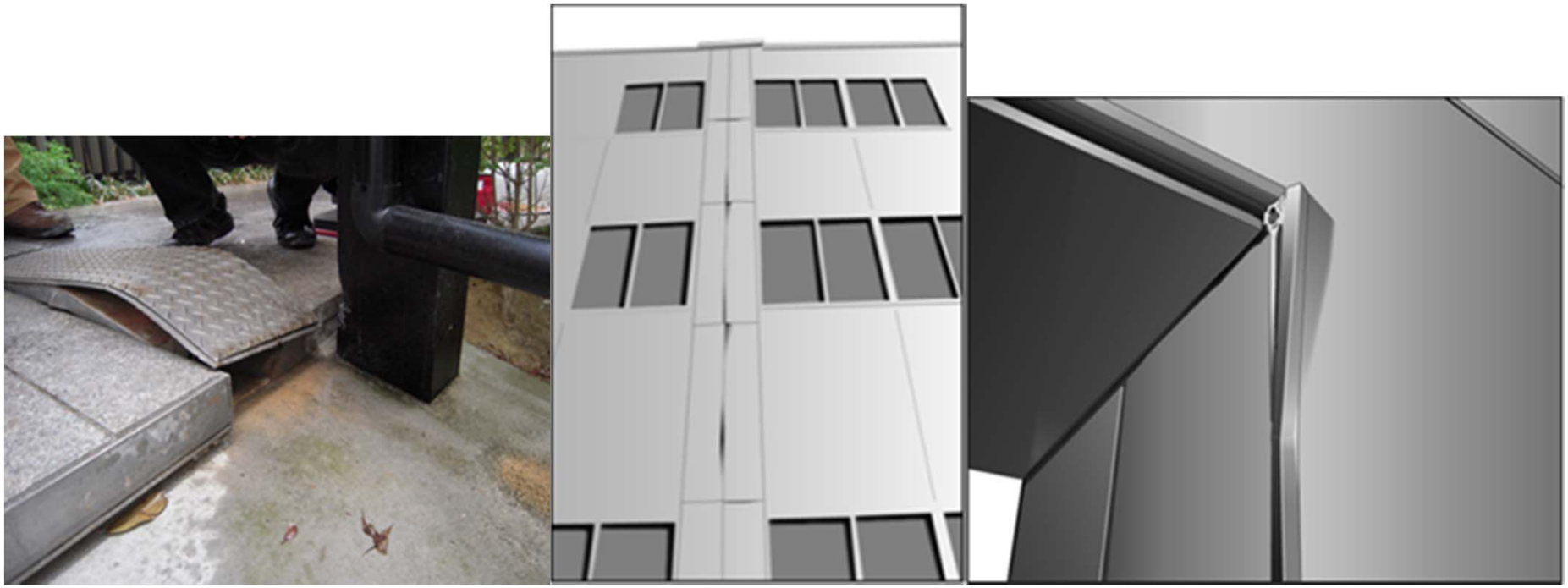
Restoring force
(× 10^4 kN)
2
1
0
-1
-2
-15 -10 -5 0 5 10 15
Deformation (cm)


20
10
0
-10
-20
Y-dir. (cm)
-20 -10 0 10 20
X-dir. (cm)

Damages of finishing material to the Expansion Joints



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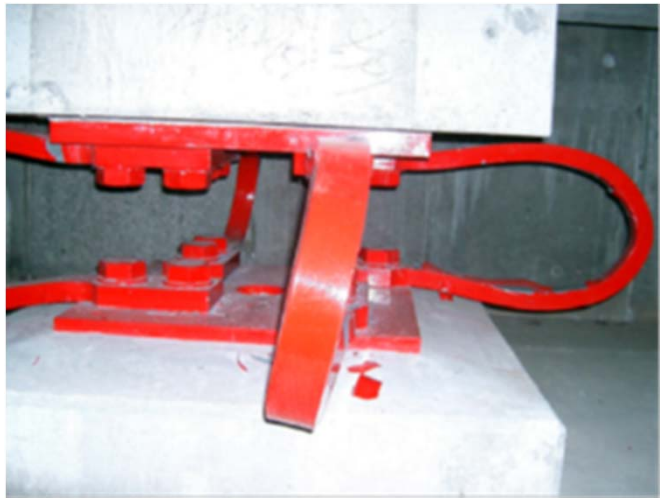
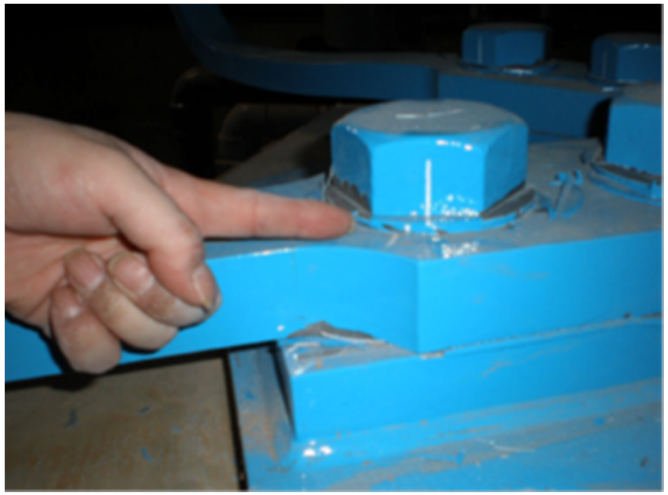
Damages of Bolt Fasteners of Steel Dampers





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