Categorization of Damage to Buildings Caused by the 3.11 Tsunami

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

Rikuzentakada City

... 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 1\textsuperscript{st} story

Rikuzentakada City
Damage to RC buildings

(3) Overturning

Refrigerated warehouse got over the fence
Mechanism of overturning

- Overturning moment
- Buoyancy
- Building weight
- Tsunami load
- Resistance to overturning
- Center of rotation
- Resistance of piles

Building Research Institute
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

Tsunami pressure
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 1\textsuperscript{st} 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

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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