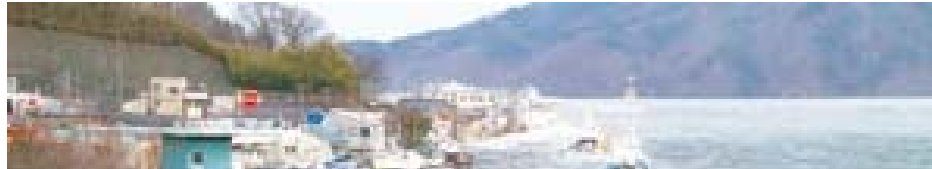
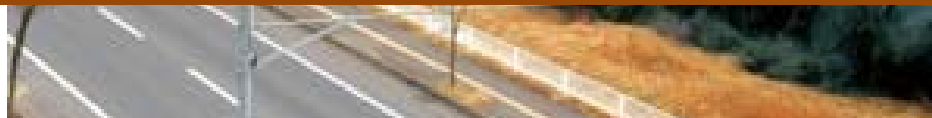


# Categorization of Damage to Buildings Caused by the 3.11 Tsunami



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



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

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# Damage to RC Buildings

# Most of RC buildings survived without any structural damage



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

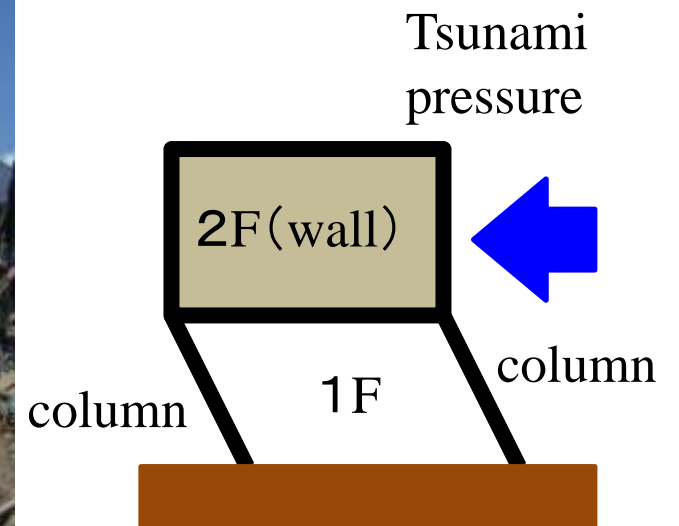
# Damage to RC buildings (1) Total collapse



Natori City, Yuriage district



## Damage to RC buildings (2) Collapse of 1<sup>st</sup> story

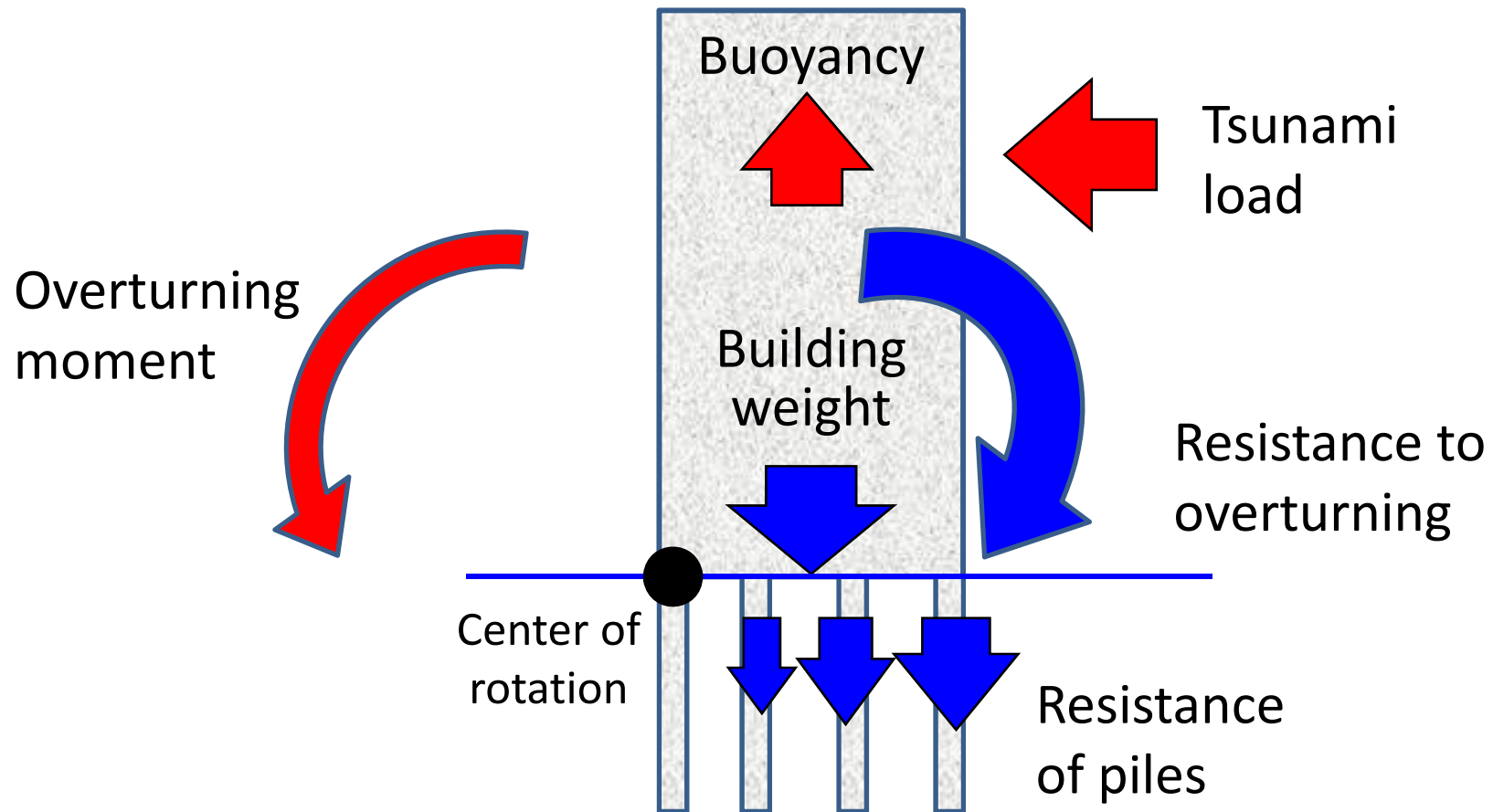


## Damage to RC buildings (3) Overturning



Refrigerated warehouse got over the fence

# Mechanism of overturning





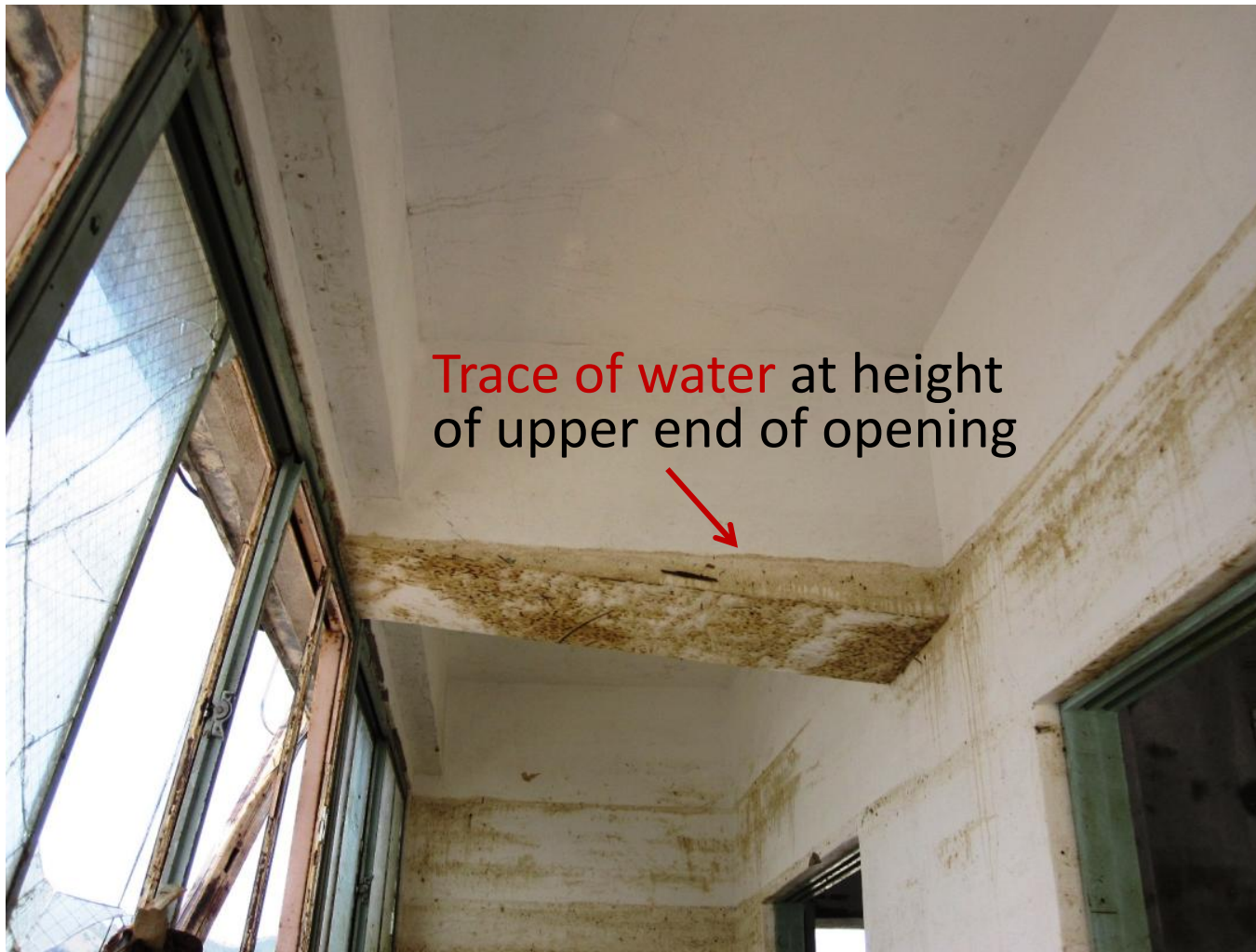
# Damage to RC buildings

## (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



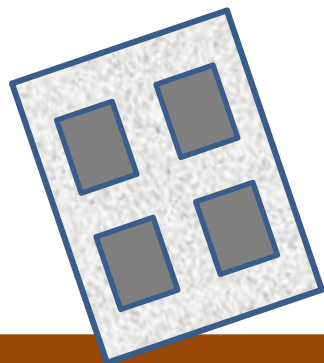
## Damage to RC buildings (5) Scour & Tilting



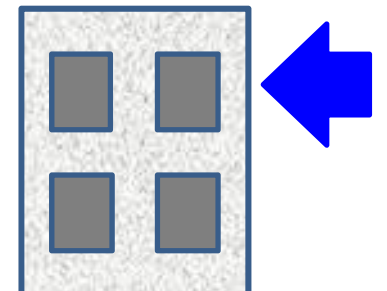
In case of mat foundation

12

# Damage to RC buildings (6) Sliding



Tsunami pressure









# 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<sup>st</sup> 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 1<sup>st</sup> 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 1<sup>st</sup> story
- **Sliding**
- **Washed away**
- **Overturning**
- **Debris impact**
- Tilting due to **scour**
- **Failure** of walls

## < Steel Buildings >

- **Collapse** of 1<sup>st</sup> 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