# NILIM/BRI Joint Field Survey on **the 2011 Off the Pacific coast of Tohoku Earthquake**

(the Great East Japan Earthquake)

National Institute for Land and Infrastructure Management (NILIM)

Building Research Institute (BRI)

## Introduction

- The Great East Japan Earthquake, the magnitude ($M_w$) 9.0 undersea megathrust earthquake off the coast of Japan, occurred at 14:46 JST on Friday, 11th March 2011.
- This magnitude ranked fourth among the earthquakes in the world since 1900. (from U.S. Geological Survey)
- The earthquake triggered extremely destructive tsunami waves.
- In addition to loss of lives and destruction of buildings, the tsunami induced nuclear serious accidents in Fukushima Daiichi Nuclear Power Plant, where the response activity is still in process.

## Introduction

Casualties

| | |
|---|---|
| Deaths | 14,027 |
| Missing | 13,754 |
| Injured | 5,302 |

Damage to buildings

| | |
|---|---|
| Total collapse | 65,347 |
| Partial collapse | 25,200 |

Number of tsunami related damage is included. But the whole number's not been totaled up yet because there are flooded areas where it is very difficult to investigate the status.

*Source: National Police Agency, as of 20 April 2011*

## Introduction

- NILIM and BRI jointly organized field survey teams in the aftermath of the Great East Japan Earthquake to learn lessons from structural damage states and then to reflect them on the future acts for mitigation.
- Total number of man-days for the surveys is more than 150.
- This presentation introduces typical damage to buildings induced by both of seismic and tsunami effects, which is illustrated in the NILIM/BRI quick survey report.

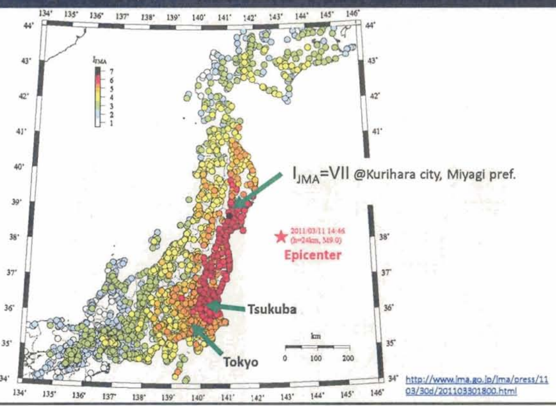
(Japanese web site)
http://www.kenken.go.jp/japanese/contents/topics/20110311/0311quickreport.html

http://www.nilim.go.jp/lab/bbg/saigai/h23tohoku/index.html

## Introduction

Areas investigated

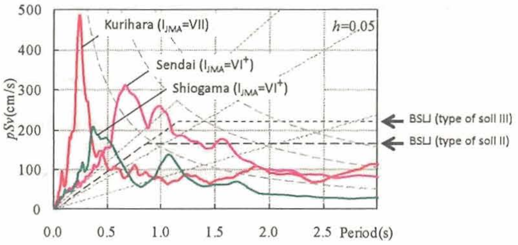

## Seismic Intensity (JMA)




http://www.jma.go.jp/jma/press/1103/30d/201103301800.html

## Seismic Response characteristics (1)

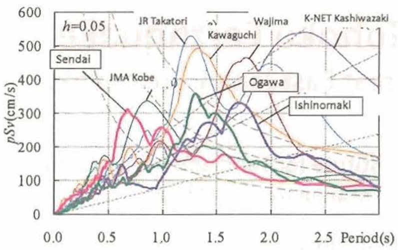
In Kurihara city, where seismic intensity of VII was recorded, predominant spectrum is observed in short period, i.e. less than 0.3s. But the power of spectrum in long period is lower than the limit value regulated in BSLJ (Building Standard Law of Japan) seismic design.




Pseudo-velocity response spectrum at some K-NET observe points where seismic intensity of more than VI was recorded.

## Seismic Response characteristics (2)

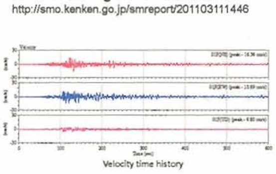
Spectrum characteristics in Sendai is similar to that in JMA Kobe recorded at 1995 Kobe earthquake.
The peak values of the spectrum recorded at several K-NET points is not so larger than those recorded at past great earthquakes.

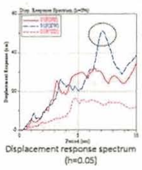



Comparison of pseudo-velocity response spectrum

## Long-period seismic motion on high-rise building

- Long-period seismic motion was recorded at several buildings in "BRI Strong Motion Network".
  http://smo.kenken.go.jp/smreport/201103111446





- In the alluvial plain where Tokyo is located, the effect of long-period seismic motion on high-rise buildings is the important issue.
- MLIT had already requested public comments on the draft of countermeasures against long-period seismic motion on high-rise buildings for two months from last December.

## Typical seismic damage state – RC structure (1)

- It was found that damage degree of buildings designed by the old seismic design method is not so significant compared to the recorded seismic intensity (JMA) on the site.
- However, some suffered from major damage or story collapse mainly because of shear failure of columns.

## Typical seismic damage state – RC structure (2)

- It was observed that some local government buildings designed by the old seismic design suffered from significant structural damage. This kind of damage was mainly because axial load bearing capacity was totally lost following shear failure of short column.
- They had been supposed to keep as much functionality as possible after an emergency like this disaster.

## Typical seismic damage state – RC structure (3)

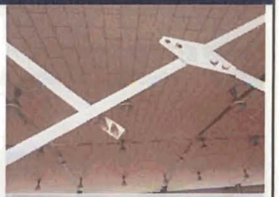
- There were few examples of damage to RC buildings designed by the new seismic design method which is valid after 1981.
- Shear cracks in multi-story walls between openings were observed in some buildings.

## Typical seismic damage state – RC structure (4)

- Damage to non-structural elements such as exterior walls and windows was very common.
- Shear failure of non-structural walls next to the front door were also observed.


## Typical seismic damage state – steel structure (1)

- Fracture of braces or their bolt connections were observed in some gymnasiums.



## Typical seismic damage state – steel structure (2)



Fall of exterior wall panels

Fall of suspended ceilings

## Typical seismic damage state – timber structure (1)

- Earthquake damage of ground caused failure of continuous footing.
- Slope failure of mountain caused total collapse of timber building.


## Typical seismic damage state – timber structure (2)

- Fall of exterior mortar and lath wall
- Large residual deformation

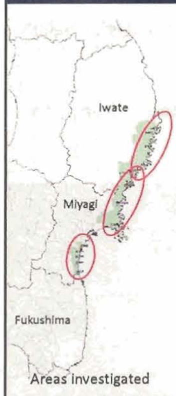

## Typical seismic damage state – soil liquefaction

## Typical seismic damage state – land development area

- Large gap was observed between road and housing site.
- Sliding of filling at housing site caused significant deformation of the house.

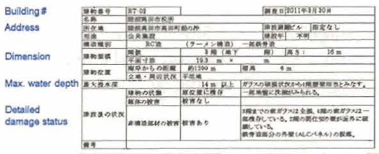
Sendai city

## Field survey of tsunami-induced damage to buildings




- NILIM and BRI have jointly organized 27-person team and carried out damage surveys three times since March 11th to understand the general status of damage to buildings.
  - Team #1 30 March – 2 April
  - Team #2 6 – 9 April
  - Team #3 6 – 8 April
- Data related to water depth and dimension in damaged buildings were also extensively collected. They are supposed to be much informative for the estimation of the effect of tsunami loads and also for the verification of the current design guideline.

## Example of database on tsunami related damage to buildings




## Typical damage state – RC structure (1)

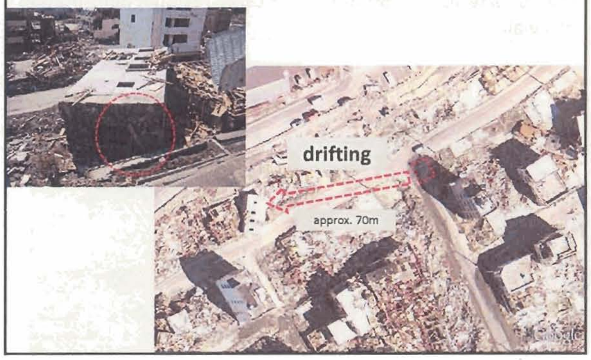
- Total collapse of first story was observed in the two-story RC buildings suffering from tsunami-induced effect.
- When opening area in the second story was not so large, the building was subjected to more tsunami loads on the walls.

## Typical damage state – RC structure (2)

- turnover of an entire building

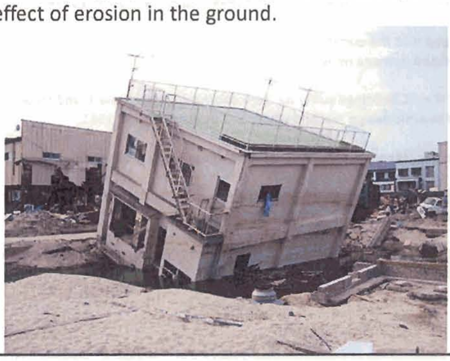
## Typical damage state – RC structure (3)

- turnover and drift of an entire building



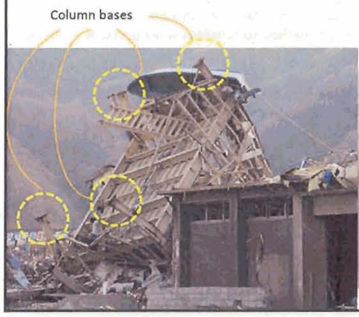
## Typical damage state – RC structure (4)

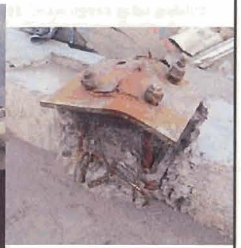
- Entire building suffered from significant sinking following the effect of erosion in the ground.



## Typical damage state – Steel structure (1)

- Turnover and drift of entire building following the fracture of exposed-type column base



## Typical damage state – Steel structure (2)

- Turnover and drift of entire building following the fracture of column capital

This type of damage was observed in the buildings whose columns have concrete encased base or imbedded type base.

## Typical damage state – Steel structure (3)

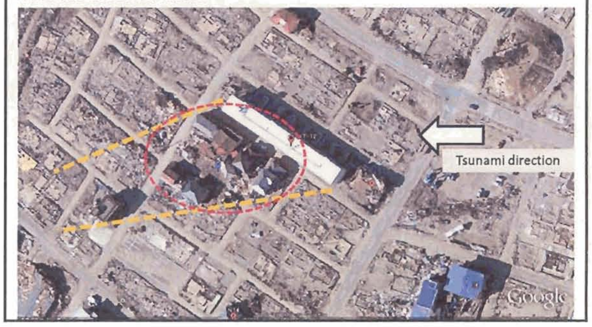
- Main columns and beams in some buildings are almost intact after all the external claddings were swept away. But they have residual deformation in columns.

## Typical damage state – Timber structure (1)

- Entire buildings are swept away.

## Typical damage state – Timber structure (2)

- If timber structures are located just behind a relative large-scale building, they were not swept away because of the decrease of direct tsunami effect on them.



## Guideline on the structural design of buildings for vertical evacuation from tsunamis

- Consideration of the tsunami effect on buildings is not mandatory for the structural design in BSLJ (Building Standard Law of Japan).

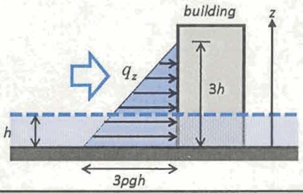
- Cabinet office, government of Japan released official guideline on the structural design of buildings for vertical evacuation from tsunamis in 2005.
- This guideline provides the simplified method to calculate wave pressure affecting a building using design water depth.

- The information obtained from NILIM/BRI field damage survey is reflected on the review and overhaul of this guideline in a rational manner.

*Design wave pressure*

$$q_z = \rho g(3h - z)$$

*Design water depth: h*




## Conclusions

- It was observed that structural damage to buildings was not so significant on the whole even in the areas where seismic intensity of more than VI was recorded.

- This means that the current seismic design in BSLJ is generally appropriate for the seismic-related damage mitigation.

- Most of the RC buildings suffering from seismic damage were found to be designed by the old seismic design method which had been valid until 1981.

- Damage to suspended ceilings in steel gymnasiums was observed.

- The earthquake caused liquefaction of soil more extensively than the recent earthquakes did.

- Typical types of tsunami-induced damage to buildings such as turn-over and swept-away of entire structures were observed.

## Conclusions

- MLIT organizes comprehensive research projects for the development of countermeasures against:

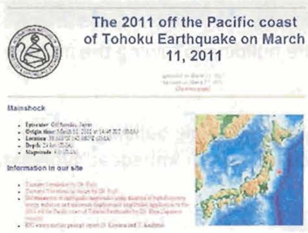
    1) fall of suspended ceilings

    2) liquefaction of soil

    3) long-period seismic action on high rise buildings

    4) tsunami-induced action on buildings in tsunami prone area

- NILIM and BRI support these research projects all the way, providing information obtained from the field surveys.




http://iisee.kenken.go.jp/special2/20110311tohoku.htm


http://smo.kenken.go.jp/smreport/201103111446