International Platform for Reducing Earthquake Disasters (IPRED)
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Lessons Learnt from the Recent Off the Pacific Coast of Tohoku Earthquake in Japan

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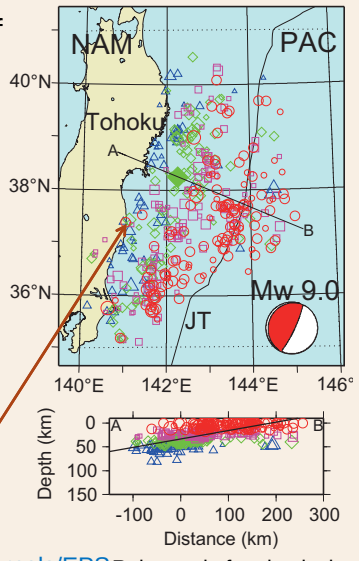
Introduction

- The M_w 9.0 earthquake occurred off the Pacific coast of Tohoku, Japan at 14:46 JST on 11th March 2011.
- This magnitude ranked fourth among the earthquakes in the world since 1900.
- The earthquake caused extremely destructive tsunami.

- In addition to loss of lives and destruction of buildings, the tsunami induced nuclear serious accidents in Fukushima Daiichi Nuclear Power Plants, where the response activity is still in process.



http://www.terrapub.co.jp/journals/EPS/pdf/free/inpress/201105027.pdf

Relocated aftershocks by Hurukawa (2011 EPS)

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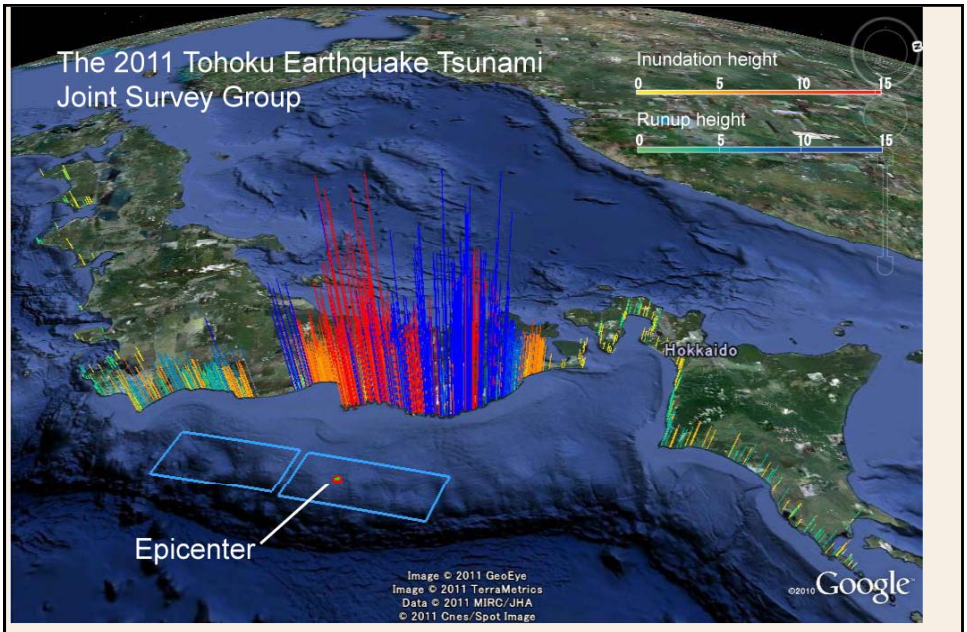

I'll present "The Tohoku Earthquake and its Tsunami Simulation" by Hurukawa and Fujii this afternoon.

The 2011 Tohoku Earthquake Tsunami Joint Survey Group
http://www.coastal.jp/tsunami2011/

Introduction

Casualties

Deaths	**15,562**
Missing	**5,306**
Injured	**5,690**

Damage to buildings

Total collapse	**108,557**
Partial collapse	**120,186**

Source: National Police Agency, as of 15 July 2011

1. **Strong motion observations for building structures**
2. **Field Surveys of damage to buildings**
   1) Outline
   2) Damage to buildings caused by Seismic motion
   3) Damage to buildings caused by Tsunami
   4) Damage to buildings caused by Fire
3. **Technical support to the Ministry of Land, Infrastructure, Transport and Tourism**
4. **Information uploads**
5. **Activities on going**

＊Many research activities and field survey were carried out jointly by National Institute for Land and Infrastructure Management (NILIM) and Building Research Institute (BRI).

I'll introduce results obtained by staff members of NILIM and BRI.

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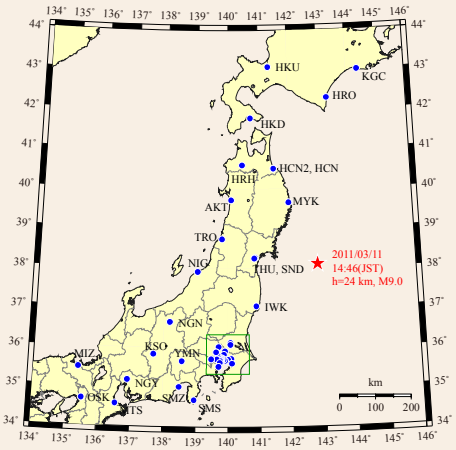
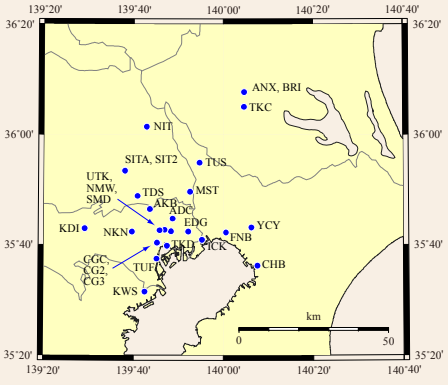
1. Strong motion observations for building structures

54 among 74 sites observed the mainshock





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

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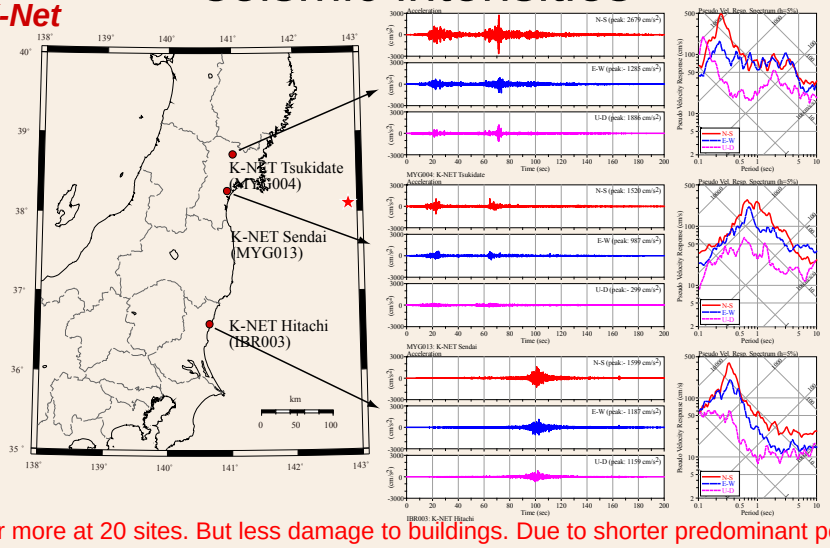
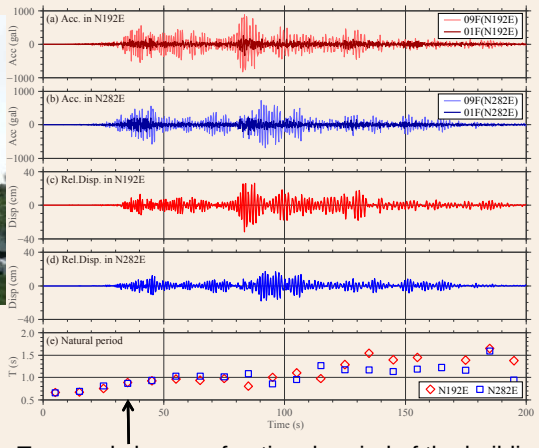
Strong ground motions with large seismic intensities

K-Net



1 G or more at 20 sites. But less damage to buildings. Due to shorter predominant periods

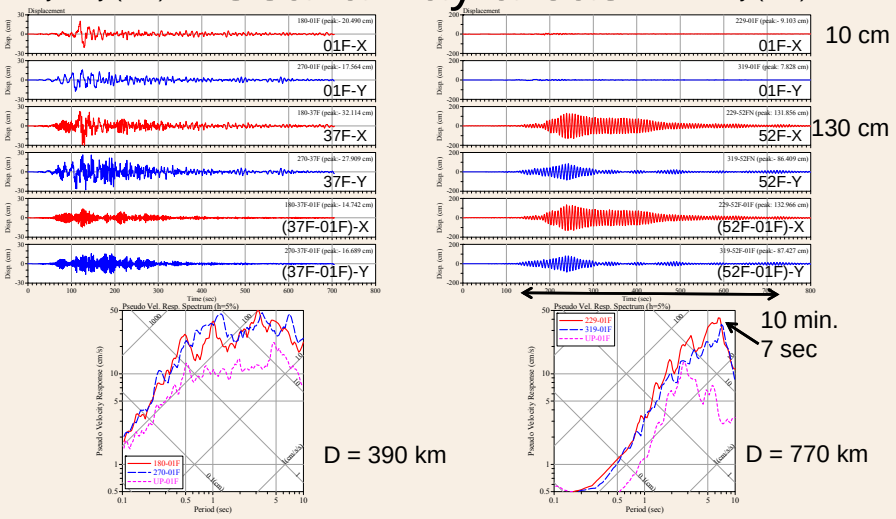
Nine-story school building of Tohoku Univ., Sendai



Lessons:
We could observe a damage process of the building. It leads to
1) Application to health monitoring.
2) Testing of non-linear response analysis method.

Temporal change of national period of the building.

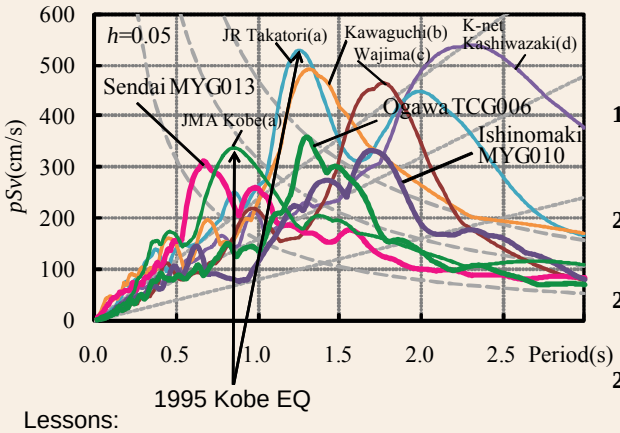
Long-period motions in Tokyo and Osaka Bay areas



Lessons: Resonance, Damping, Health Monitoring → To be retrofitted

Analysis of Seismic Response Properties

(Comparison with the past records using Pseudo-velocity response spectrum)



2011 the Great East Japan Earthquake
Sendai MYG013,
Ogawa TCG006,
Ishinomaki MYG010

1995 Kobe Earthquake
JMA Kobe (a),
JR Takatori (a)

2004 Niigata Chuetsu Earthquake
Kawaguchi (b)

2007 Noto Hanto Earthquake
Wajima (c)

2007 Niigata Chuetsu-oki Earthquake
K-net Kashiwazaki (d)

Lessons:
Building damage was caused by strong 1.0 – 1.5 s seismic waves mainly.
The Kobe EQ caused much severe damage than the Tohoku EQ.

2. Field Surveys of damage to buildings

1) Outline

2) Damage to buildings caused by Seismic motion
- Timber Structure
- Reinforced Concrete Structure
- Steel Structure, Non-Structural Elements
- Housing-Site Ground, Foundations

3) Damage to buildings caused by Tsunami

4) Damage to buildings caused by Fire

1) Outline

- Organizing field survey teams to learn lessons from structural damage state, BRI and NILIM are dispatching more than140 experts to the survey areas since March 12.

2) Damage to buildings caused by seismic motion

- Damage to Timber Structure

- Damage to RC Structure

• Cracks in columns and exterior walls

• Shear failure of non-structural wall next to entrance

- Damage to RC Structure

• 1st story of 3 storied RC building was collapsed. Front side is frame structure and back side is frame with wall structure.

• Shear failure in columns on 1st story of 4 storied RC building which shows 180 degree hooks of main bars.

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- Damage to Steel Structure and Non-Structural Elements

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- Damage to Housing-Site Ground and Foundations

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Damage to buildings caused by seismic motion

<Summary>

- Damage to buildings is not so severe whereas the seismic intensities were high and the disaster areas were extended to extremely large.
- *Timber Structure*：Typical seismic damage was observed.
- *RC Structure*：Significant difference appears between before and after the new seismic design code (1981). Typical seismic damage was observed.
- *Steel Structure*：Damage to vertical / horizontal braces and joints was observed.
- *Non-structural Elements*：The fall of exterior walls, suspended ceilings in large-scale spaces, and interior materials were observed.
- Damage occurred in some grounds of developed residential areas and sloping areas.
- The severe liquefaction damage occurred in very wide areas.

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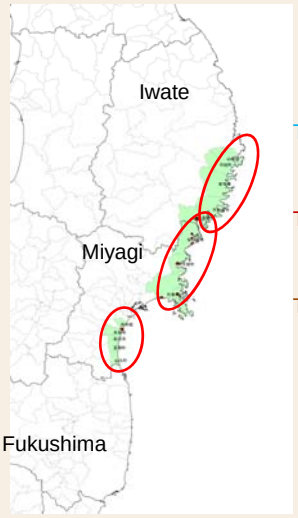
3) Damage to buildings caused by Tsunami



Survey areas

- BRI and NILIM have jointly carried out damage surveys three times since March 11th to understand the general status of damage to buildings.

Team #1 30 March – 2 April

Rikuzentakata (IWATE) , Kesennuma, Minami-sanriku, Onagawa, Ishinomaki, Natori (MIYAGI)

Team #2 6 -9 April

Yamada, Ohtsuchi, Kamaishi, Ohfunato, Rikuzentakata (IWATE), Onagawa (MIYAGII) etc.

Team #3 6 – 8 April

Sendai, Natori, Watari, Yamamoto (MIYAGI) etc.

- 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 guidelines.

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- **Damage to RC Structure**

• Collapse of 1st story of 2 storied RC frame building with concrete brick wall. The 2nd story was supported by 4 RC columns.

• Falling over of 4 storied RC frame building with shear wall. This building was flowed 70 meters.
•Photo shows the undersurface and a façade.

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・Damage to RC Structure
Buildings swept-away and fallen-over

4-story frame with shear wall structure
Pile foundation (pulled-out, ruptured)
Few Openings
Swept-away (70 m, no traces of dragged)
Fallen-over

Distance from the coast：~200 m
Depth of inundation：~15 m

・Damage to RC Structure
Buildings swept-away and fallen-over

2-story frame structure
(refrigerators)
Few openings
Swept-away and fallen-over

Distance from the coast：~200 m
Depth of inundation：Over 6.5 m

- **Damage to RC Structure**

4 storied RC frame building

- Soil flowed away by tsunami.
- Photo shows the footing basement under columns.

3 storied RC factory building

- Out of plane collapse of exterior wall with frame and without inside floor.
- The right side of photo shows no collapse of wall with floor.

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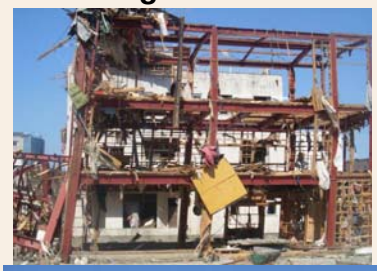
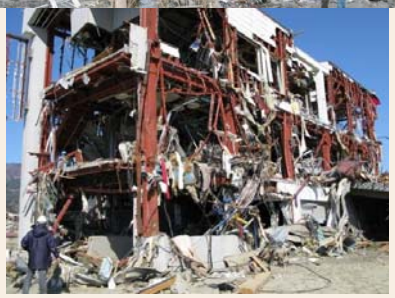
- **Damage to Steel Structure**





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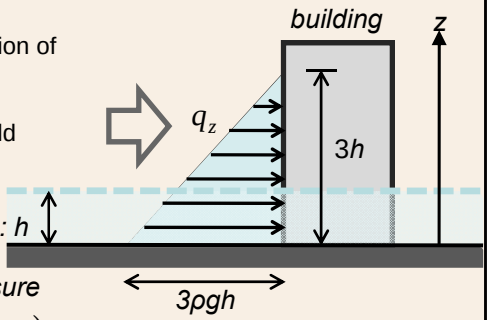
- **Damage to Timber Structure**




Review for Tsunami Evacuation Building

- Evaluation Method of Tsunami Evacuation Building

  The Cabinet Office : Proposal equation of 'Guideline for tsunami evacuation buildings' to which the hydrostatic pressure is applied using the threefold depth of design wave depth.



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

- Based on the surveyed results, the validity of the above-mentioned Tsunami Load (Tsunami Wave Pressure) is under reviewing.

4) Damage to buildings caused by fire

- Grasping the damage state of large-scale fire and fire in buildings caused by the earthquake and the following tsunami in cooperation with other institutes and universities


2011 Miyako, Iwate (IISEE/BRI)


Break water in Miyako
May 14, 2010
April 2011
2011 Miyako, Iwate (IISEE/BRI)
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World largest break water in Kamaishi Port

1,660 m long & 63 m height

1/3 collapsed, but
Tsunami height was reduced 40 %.
Arrival time delayed 6 min.
(Kamaishi Port Office)

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2011 Miyako, Iwate (IISEE/BRI)


2011 Miyako, Iwate (IISEE/BRI)

2011 Miyako, Iwate (IISEE/BRI)

2011 Ootsuchi, Iwate (IISEE/BRI)

2011 Onagawa, Miyagi (IISEE/BRI)

2011 Onagawa, Miyagi (IISEE/BRI)

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2011 Onagawa, Miyagi (IISEE/BRI)


2011 Sendai, Miyagi (IISEE/BRI)


2011 Sendai, Miyagi (IISEE/BRI)


2011 Sendai, Miyagi (IISEE/BRI)


2011 Sendai, Miyagi (IISEE/BRI)

2011 Sendai, Miyagi (IISEE/BRI)

2011 Iwaki, Fukushima (IISEE/BRI)


2011 Iwaki, Fukushima (IISEE/BRI)


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2011 Iwaki, Fukushima (IISEE/BRI)


2011 Iwaki, Fukushima (IISEE/BRI)

3. Technical support to the Ministry of Land, Infrastructure, Transport and Tourism (MILIT)

- Collaborative Research with private companies in the development and promotion project of building standards.
  1: Consideration of contributing to the development of building standards in tsunami hazard areas
  2: Consideration of contributing to the development of non-structural elements standard based on earthquake damage
  3: Consideration of the effect of long-period seismic motion on super high-rise buildings
- Building Structural Standard Committee (NILIM)
  Cooperate in research surveys and investigations of this committee appointed to consider the draft of building structural standard
- Committee of Technical Countermeasure against Liquefaction (MILIT)
  Participate as a member in this committee appointed to consider technical issues common in each infrastructure

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4. Information uploads

- Established the special website to provide official information

http://www.kenken.go.jp/japanese/contents/topics/20110311

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

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・Produced “Quick Report of the Field Survey and Research on The 2011 Off the Pacific coast of Tohoku Earthquake” jointly with NILIM and announced on the special web site on May 13, 2011.

* English version will be released on the end of August.

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建築研究資料
Building Research Data
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平成 23 年（2011 年）東北地方太平洋沖地震調査研究（速報）
（東日本大震災）
Quick Report of the Field Survey and Research on
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(the Great East Japan Earthquake)

平成 23 年 5 月

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National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure, Transport and Tourism, Japan

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Building Research Institute
Incorporated Administrative Agency, Japan

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5. Activities on going

- Continuation and expansion of the field survey and research works, and quick release and dissemination of their results.
- Active participation and technical support to activities by the national government.
- Close cooperation with concerned organizations such as Architectural Institute of Japan (AIJ).

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