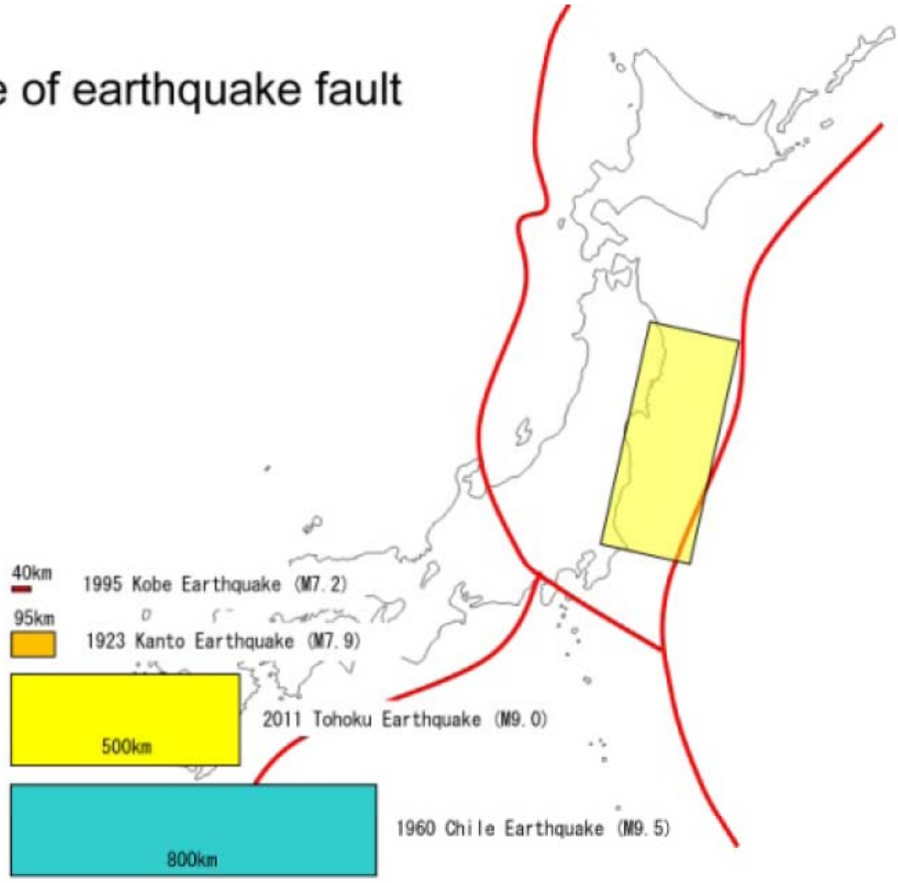
LESSONS OF RECENT GIGANTIC EARTHQUAKE DISASTERS IN JAPAN

Taiki SAITO

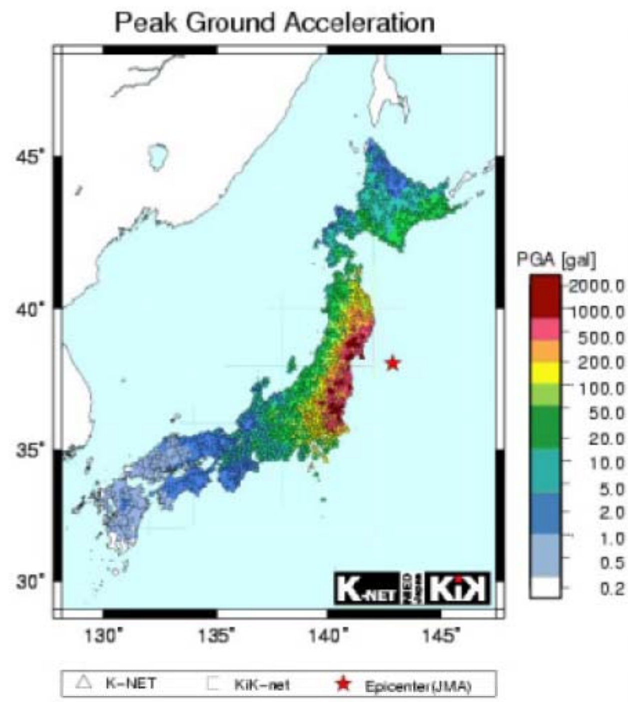
Chief Research Engineer,
International Institute of Seismology and Earthquake Engineering (IISEE),
Building Research Institute (BRI)

	1923 Great Kanto Earthquake	1995 Great Hanshin Awaji Earthquake	2011 Great East Japan Earthquake
	Kanto Earthquake	Kobe Earthquake	Tohoku Earthquake
Date	1923.09.01	1995.01.17	2011.3.11
Time	11:58	05:46	14:46
Magnitude	7.9	7.2	9.0
Death & missing	Around 105,000	6,434	19,312 as of Dec.2011
Main cause of death	Fire 85%	Build. Collapse 75% Fire 12%	Tsunami 92%

Size of earthquake fault



Intensity of Tohoku Earthquake

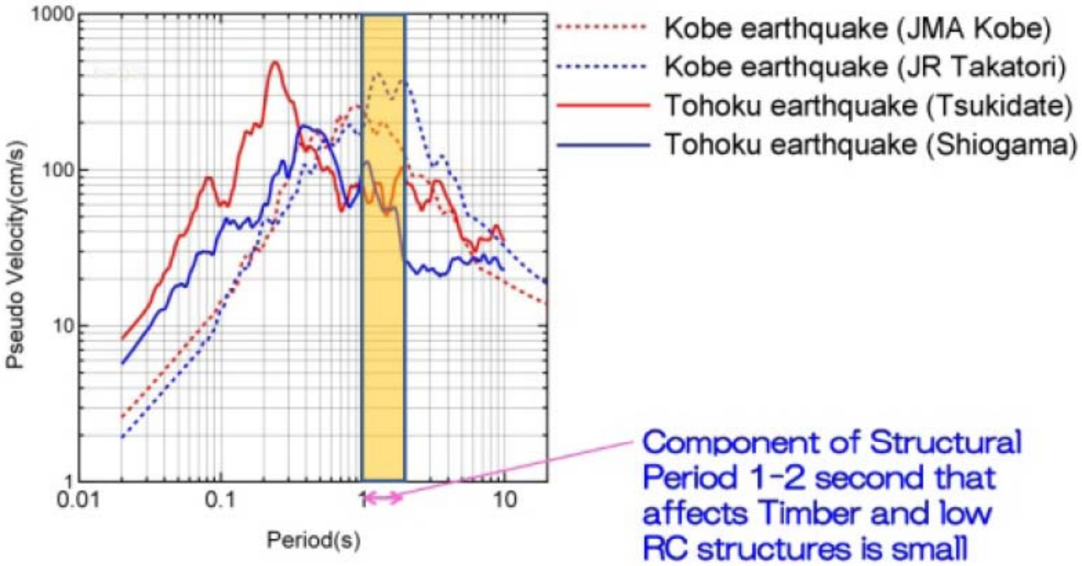


2011/03/11−14:46 38.103N 142.860E 24km M9.0

No	Name of station	The maximum acceleration
1	K-NET筑馆(MYG004)	2933gal
2	K-NET盐灶(MYG012)	2019gal
3	K-NET日立(IBR003)	1845gal
4	K-NET仙台(MYG013)	1808gal
5	K-NET鉾田(IBR013)	1762gal
6	K-NET今市(TCG009)	1444gal
7	K-NET白河(FKS016)	1425gal
8	KiK-net西乡(FKSH10)	1335gal
9	K-NET大宫(IBR004)	1312gal
10	KiK-net芳贺(TCGH16)	1305gal

(data from National Research Institute for Earth Science and Disaster Prevention)

Comparison between TOHOKU and KOBE Earthquakes

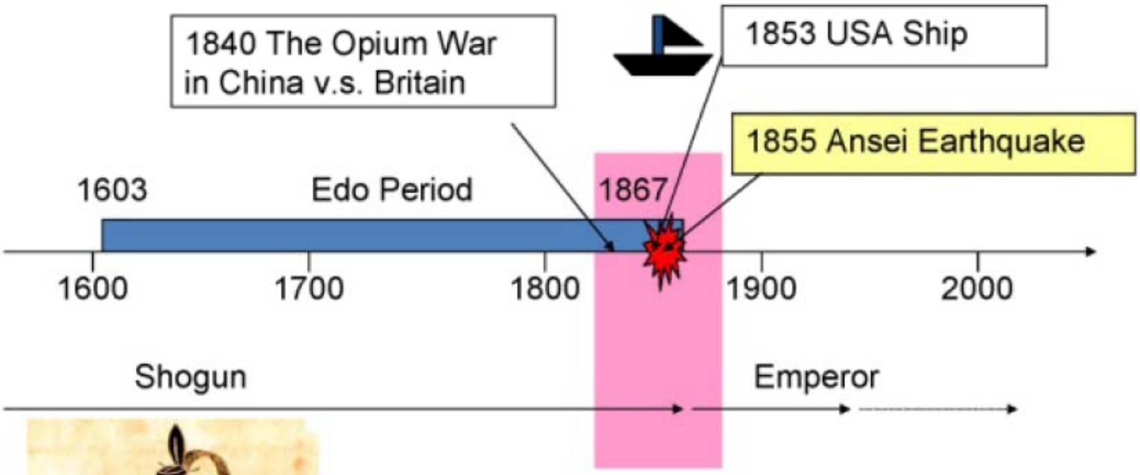


- Component of Short period is dominated at around the epicentre
- Component of the period of 1-2 second that affects structure is small.

(slide from ATC-JSCA meeting)

1923 Great Kanto Earthquake (Kanto Earthquake)

Transition to western culture



Tokugawa Family

Traditional wooden house

Western style brick house

Government recommended buildings made of brick.

Ginza Brick Street (1873)

Asakusa Brick Tower (1890)

1891 Nobi Earthquake (M8.0)
1923 Great Kanto Earthquake(M7.9)
1924 The first seismic code

Brick → Reinforced Concrete

Ginza Brick Street (1873)

Asakusa Brick Tower (1890)

Lessons from 1923 Kanto Earthquake

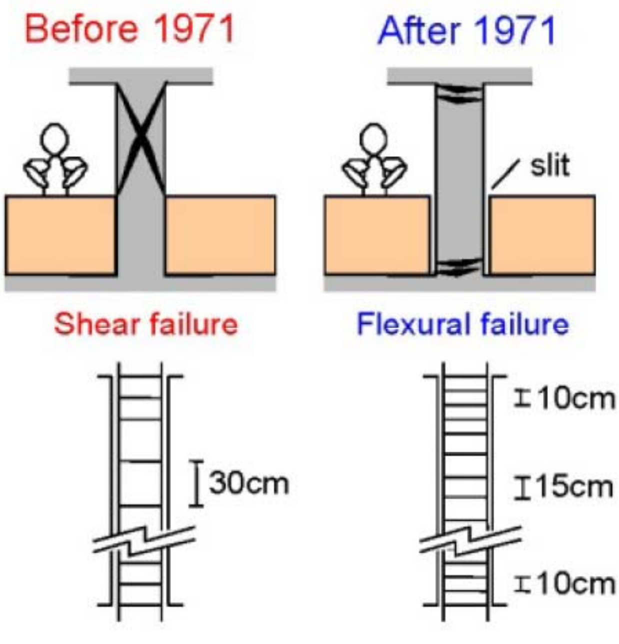
- Brick building was introduced as the symbol of western culture and fire resistance structure.
- No scientific study about seismic resistance.
- It was a trigger
  - to develop the first seismic design code in the world,
  - to give up brick structure and shift to RC structure,
  - to develop original structure (SRC, RC shear wall)

Quick and brave decision.

1995 Great Hanshin-Awaji Earthquake (Kobe Earthquake)

1968 Tokachi-oki Earthquake

1971 Revision of AIJ Standards for RC



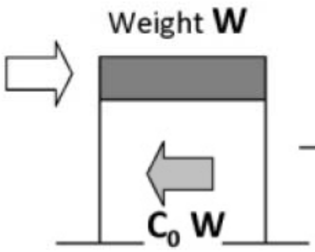
1978 Miyagiken-oki Earthquake

1981 Revision of Building Standard Law

Two stage design procedures

Seismic force

$F = C_0 W$



Shear resistance

$C_0 = 0.2$ moderate earthquake

1st Level — Elastic analysis

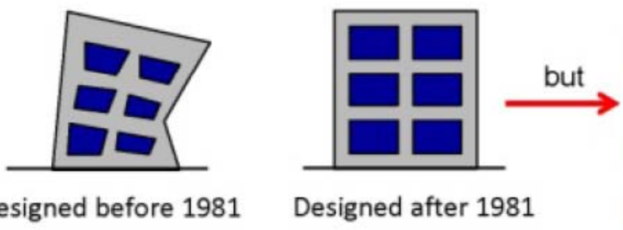
Building must be elastic based on allowable stress design.

$C_0 = 1.0$ strong earthquake

2nd Level — Limit state analysis

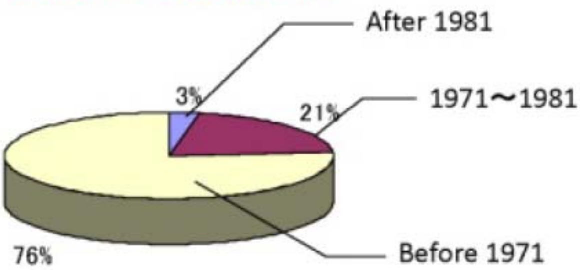
Building capacity must be checked to prevent collapse.

1995 Great Hanshin-Awaji Earthquake



Collapse of buildings designed after 1981

Collapse of buildings



1995 Law on the promotion of the earthquake resistance of building

Lessons from 1995 Kobe Earthquake

- Seismic design code was revised every time after severe earthquake damage of buildings.
- The biggest revision was made in 1981 introducing the regulation to check the seismic capacity of a building.
- The building designed after 1981 survived well at the 1995 Kobe earthquake.
- It was a trigger to promote seismic retrofit of existing buildings designed before 1981.

2011 Great East Japan Earthquake (Tohoku Earthquake)

Introduction

Casualties

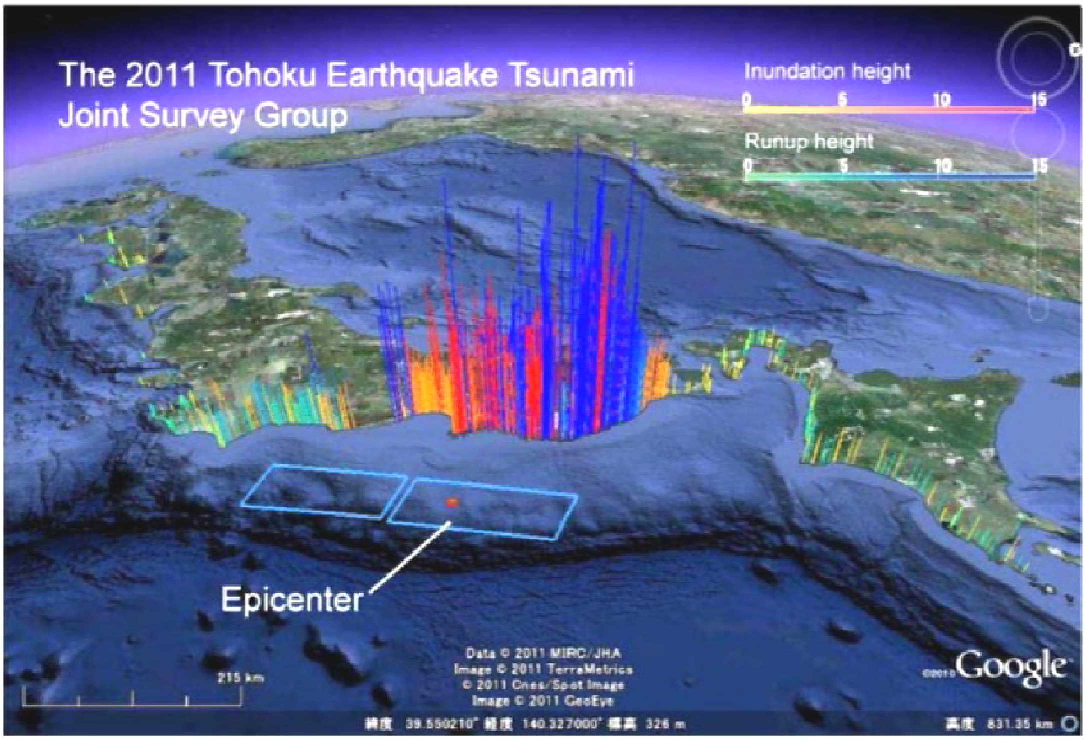
Deaths	**15,843**
Missing	**3,469**
Injured	**5,890**

Damage to buildings

Total collapse	**126,315**
Partial collapse	**227,339**

More than 92% of casualty was caused by Tsunami induced by the earthquake.
The earthquake shaking was also strong in wide area of Japan; however, the damage of buildings due to shaking was limited.

Source: National Police Agency, as of 22 December 2011

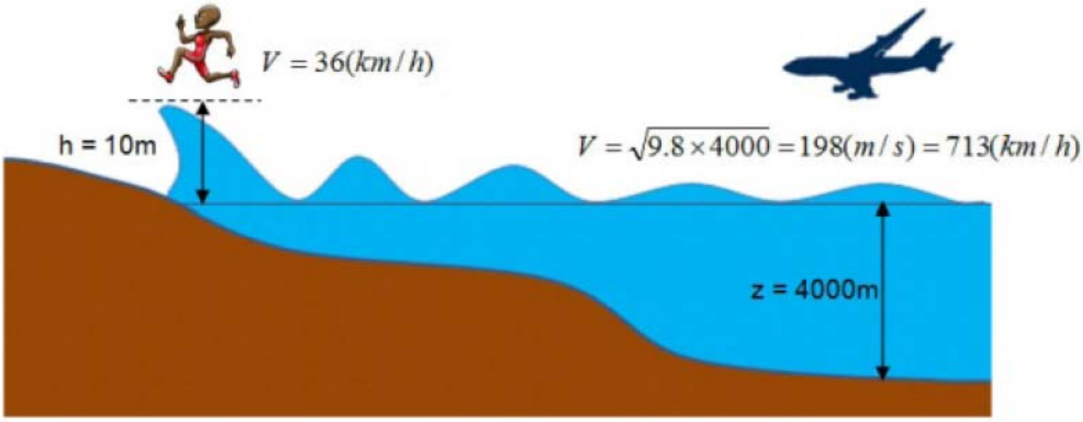


By JSCE Coastal Engineering Committee

Tsunami Speed

$$V(m/s) = \sqrt{g(m/s^2) \times (z(m) + h(m))}$$

Where g : gravity acceleration(=9.8 m/s²), z : depth of water, h: tsunami height



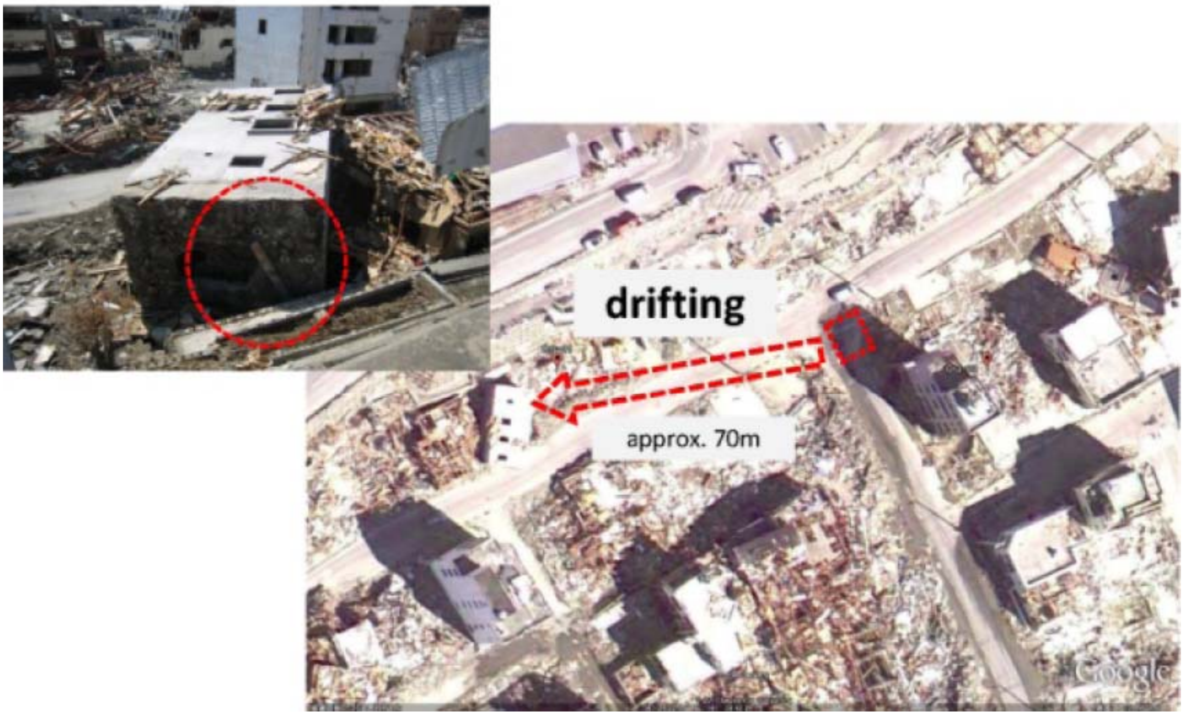
Typical damage state – RC structure (1)

turnover of an entire building

Typical damage state – RC structure (2)

21

- turnover and drift of an entire building



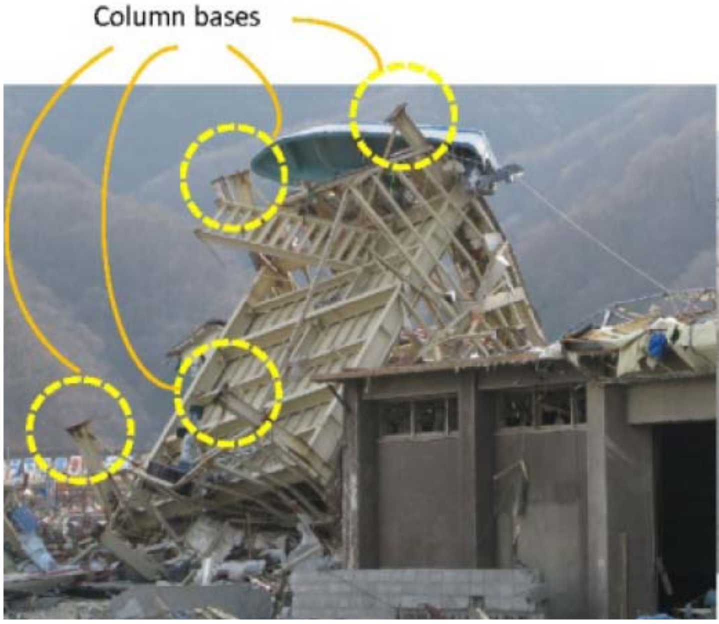
Typical damage state – RC structure (3)

22

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

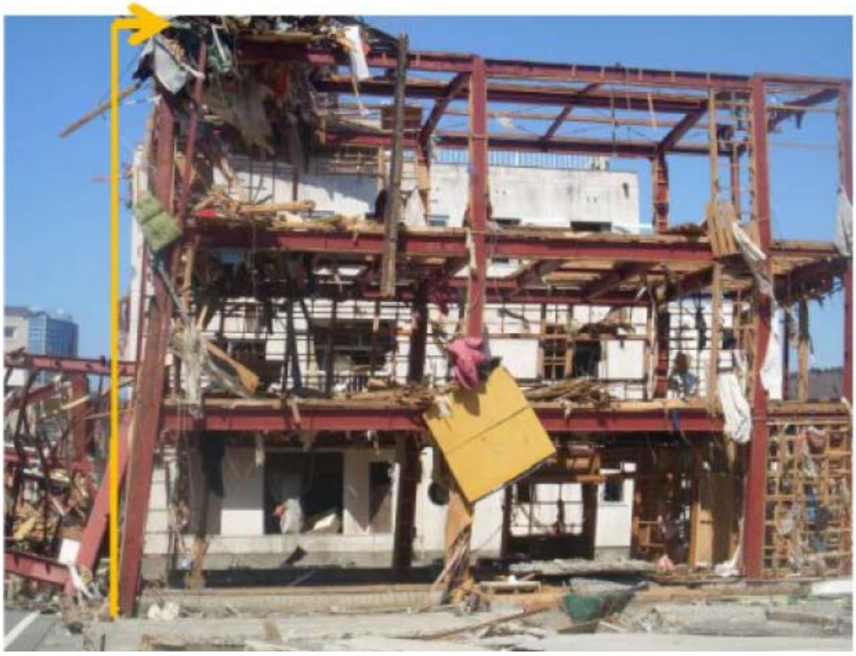


Typical damage state – Steel structure (2)

- 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.

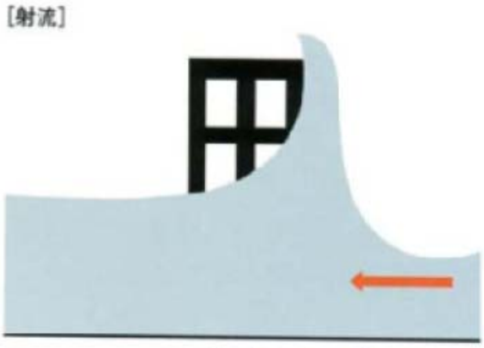
Typical damage state – Timber structure (2)

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.

Normal flow

$v<\sqrt{gD}$ Smooth Tsunami

Flush flow



$v>\sqrt{gD}$ Atrocious Tsunami

V; flow speed
g; gravity acceleration
D; water depth

Water depth is shallow and flow speed is very high. When it attacks the building, it goes jumping up.

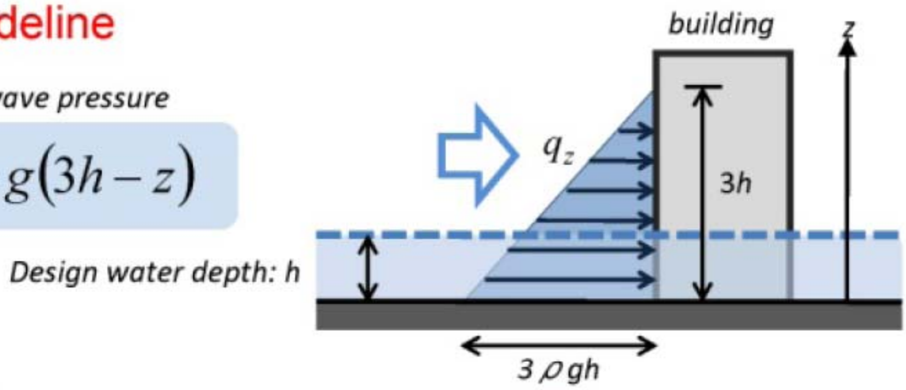
Nikkei Construction, Outline of Infrastructure Damages, Nikken BP, 2011

Guideline on the structural design of buildings for vertical evacuation from tsunami

2005 guideline

Design wave pressure

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



2011 guideline

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

$\alpha \rho gh$ (α =1.5 – 3.0)

Lessons from 2011 Tohoku Earthquake

- There is a need to consider tsunami force in building design in a tsunami hazard area.
- Building damage due to earthquake shaking was limited to old buildings designed before 1981.
- However, the following problems emerged;
  - Extensive liquefaction occurred,
  - Nonstructural damage such as fall of ceiling panels caused human loss and regulation must be reviewed.
  - Highrise building sufferred large & long time shaking.

Conclusion

- Tsunami has attacked Tohoku regions repeatedly. However, people forgot such lessons and started living again in dangerous areas near the ocean.
- The return period of the gigantic earthquake is too large for human to keep awareness of disaster prevention.
- Therefore, it is important to change regulations or make the new ones reflecting the lessons as soon as possible. Also, sharing such experience with other countries is very important.

Japanese people are deeply grateful of the strong support and encouragement which people in other countries have given us through this difficult time.

Thank you very much for your kind attention.