Seismic-Resistant Technology in Japan

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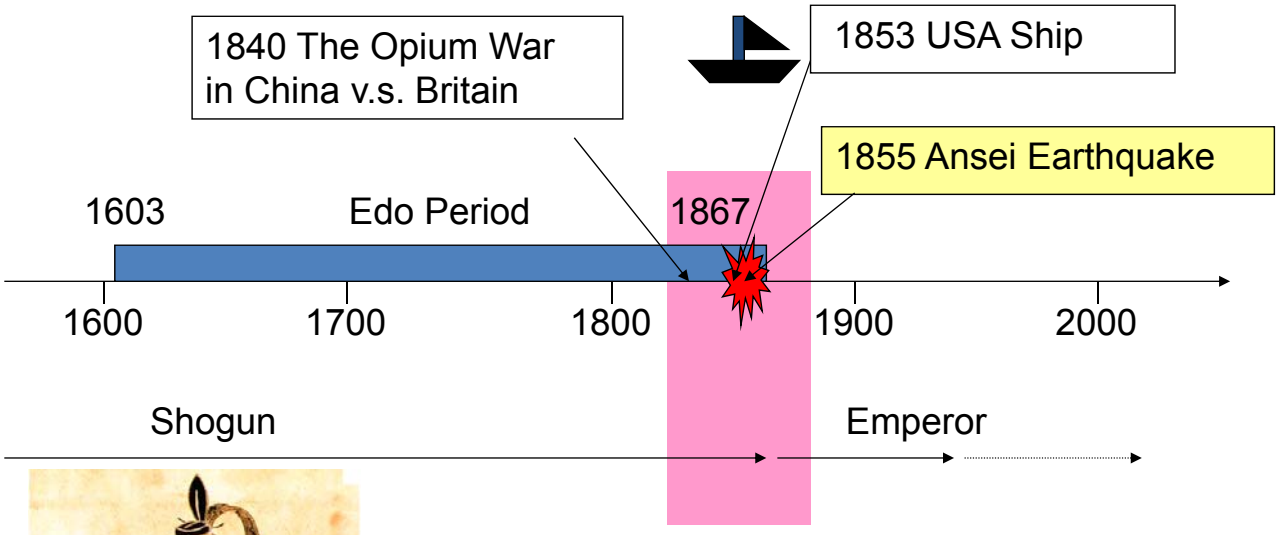
Lessons of recent gigantic earthquake disasters in Japan

	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%

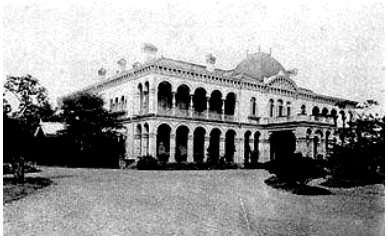
1923 Great Kanto Earthquake (Kanto Earthquake)

Transition to western culture



Tokugawa Family

Traditional wooden house



Western style brick house

Government recommended buildings made of brick.

Ginza Brick Street (1873)

http://www.sice-et.com/f/archives/2010/06/

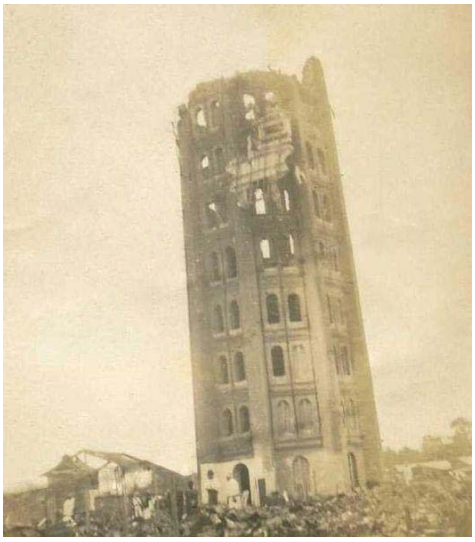
Asakusa Brick Tower (1890)

http://shigekeura.exblog.jp/15727970/

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

Brick → Reinforced Concrete

Ginza Brick Street (1873)
http://www.ginza-machidukuri.jp/column/column2-1.html



Asakusa Brick Tower (1890)
http://shigekeura.exblog.jp/15727970/

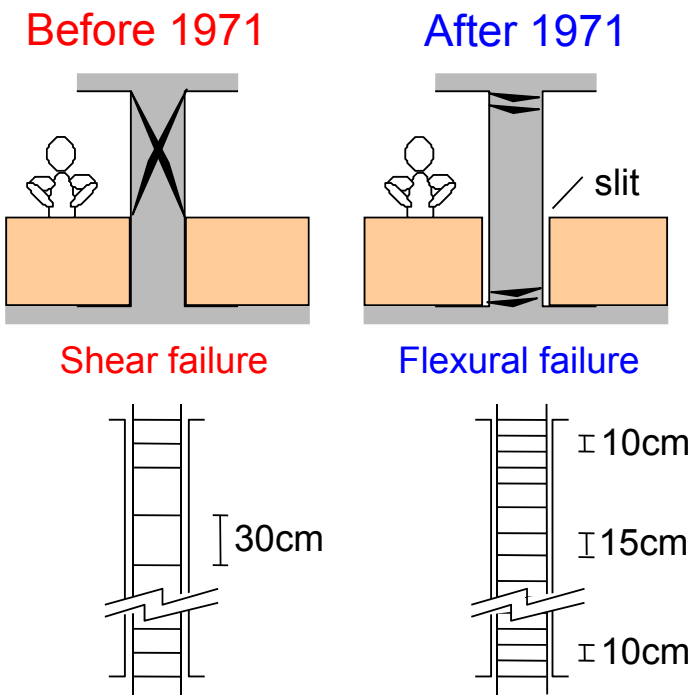
Lessons from 1923 Kanto Earthquake

- 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 seismic structure (SRC, RC shear wall)

1995 Great Hanshin-Awaji Earthquake (Kobe Earthquake)

1968 Tokachi-oki Earthquake

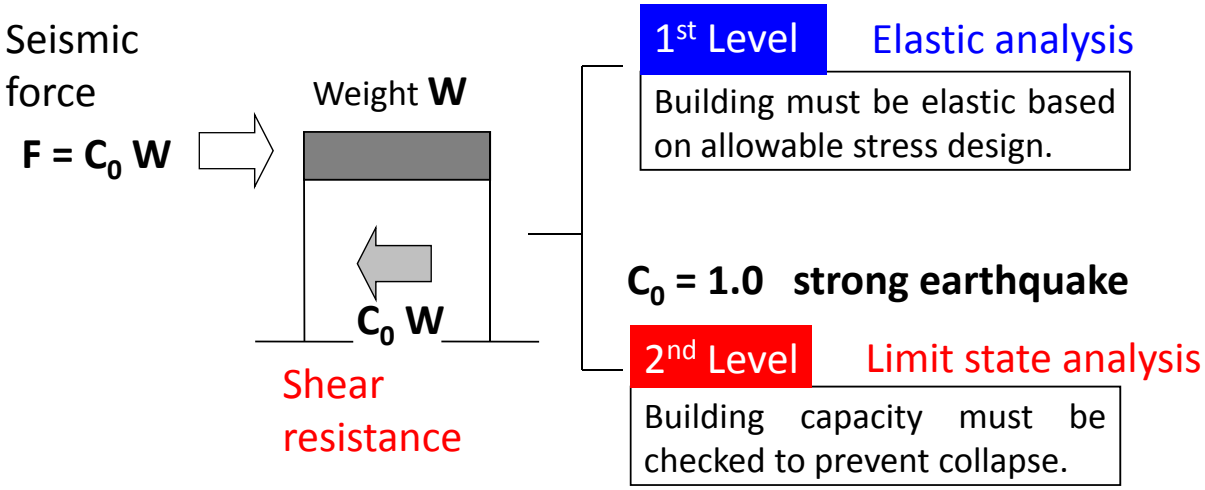
1971 Revision of AIJ Standards for RC



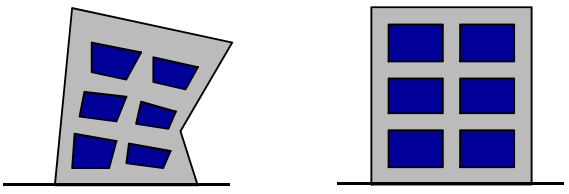
1978 Miyagiken-oki Earthquake

1981 Revision of Building Standard Law

Two stage design procedures



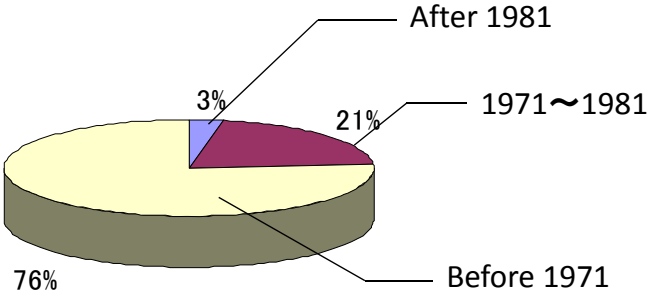
1995 Great Hanshin-Awaji Earthquake



Designed before 1981 Designed after 1981

1995 Law on the promotion of the earthquake resistance of building

Collapse of buildings



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)

Damage Statistics

Casualties

Source: National Police Agency, as of 22 December 2011

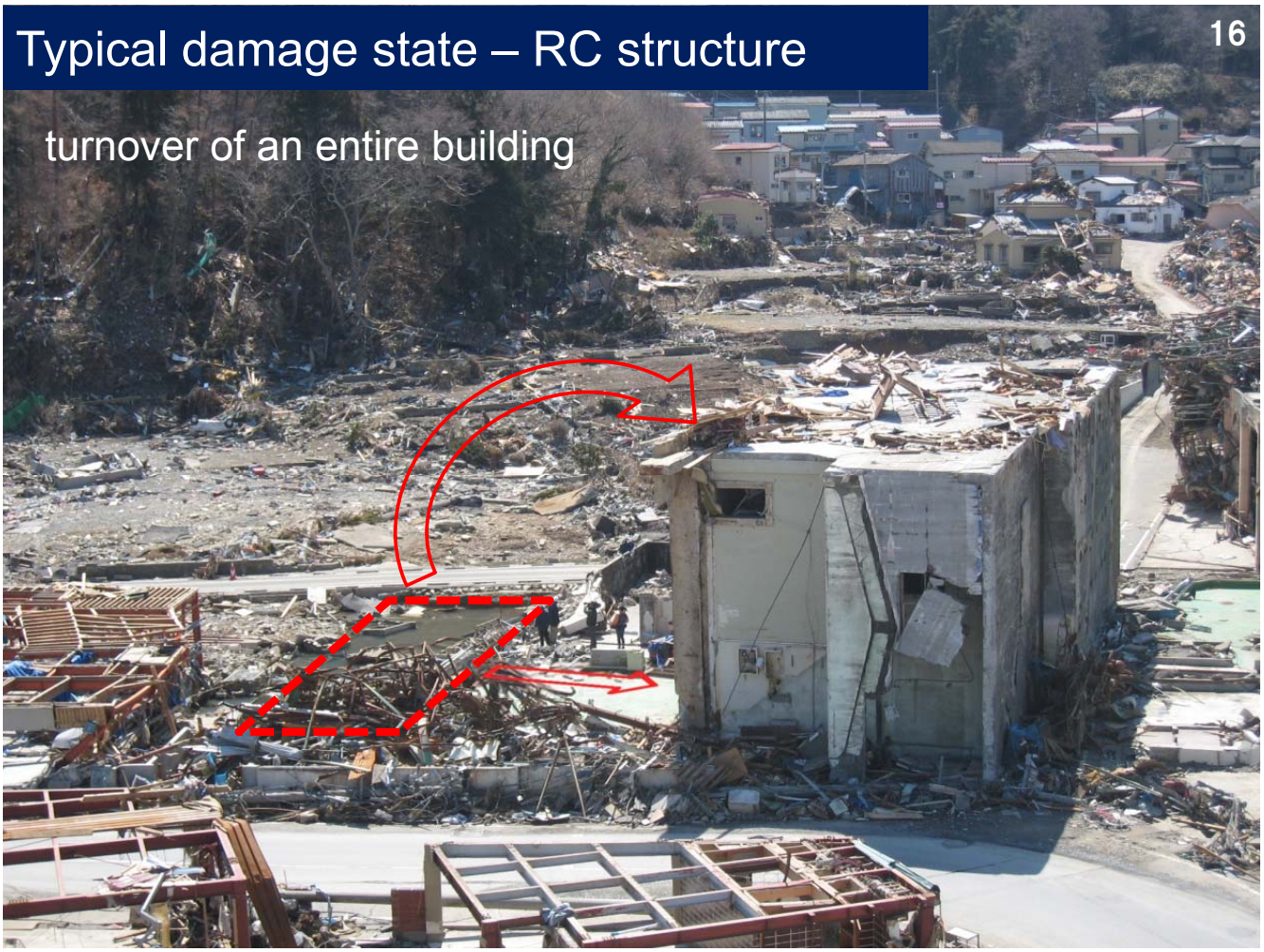
Deaths	**15,843**
Missing	**3,469**
Injured	**5,890**

More than 92% by Tsunami

Other factors (not official source)

- 0 building collapse
- 5 fall of ceiling panels
- 3 falling down of bridge
- 3 falling down of outer wall
- 25 land slide
- ....

Typical damage state – RC structure



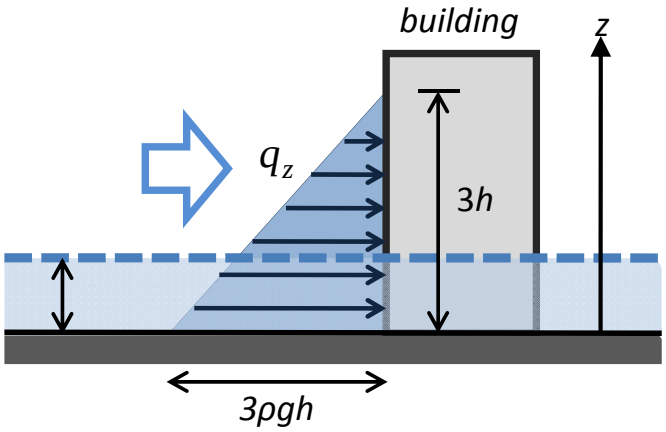
Guideline on the structural design of buildings for vertical evacuation from tsunami

2005 guideline

Design wave pressure

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

Design water depth: h



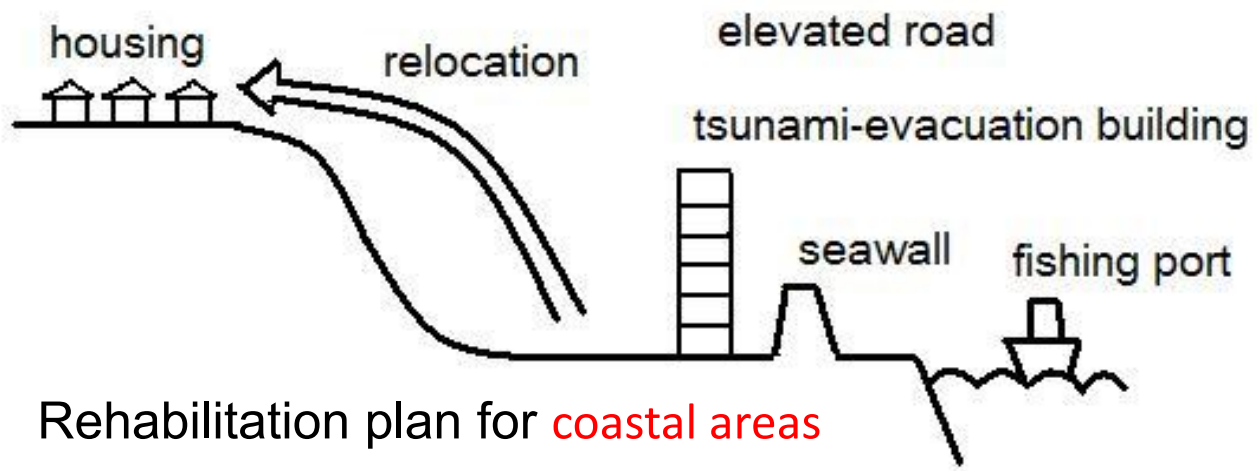
2011 guideline

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

$\alpha\ \rho gh$ (α =1.5 – 3.0)

Rehabilitation plan under discussion

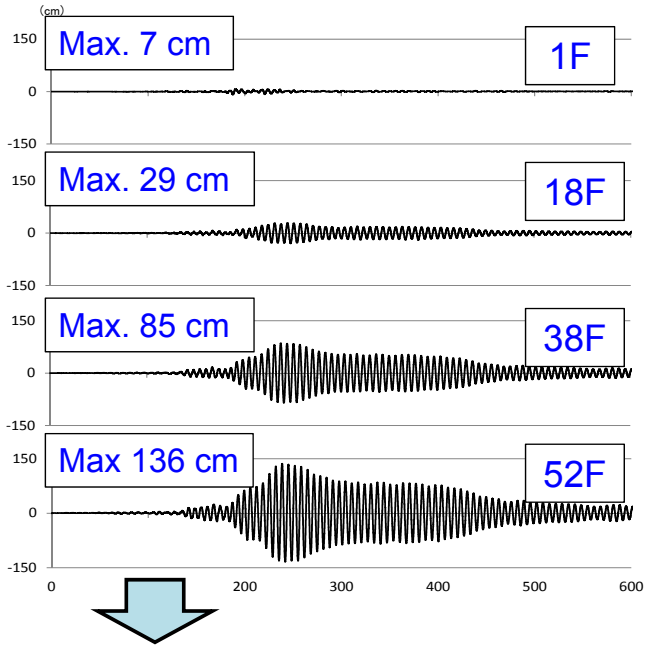
Rehabilitation plan for plain areas



Rehabilitation plan for coastal areas

Building Response by Long-period E.Q. Motions

Sakishima governmental office of Osaka



Review of the building regulations

3m movement by BRI shaking table

From NHK

Fall of Suspended Ceiling in Symphony Hall

Review of the building regulations

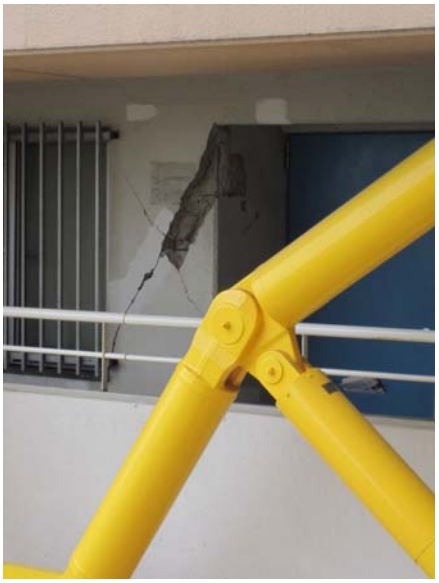
Damage of Non-Structural Element

Buildings designed according to the current seismic codes

Damage of non-structural wall

Damage of door

Damage of Retrofitted Building



Damage of non-structural walls of a building retrofitted with oil dampers

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;
  - High-rise building suffered large & long time shaking.
  - Nonstructural damage such as fall of ceiling panels, damage of non-structural walls was observed.

Conclusion

- Tsunami has attacked Tohoku regions repeatedly. However, over the years, people forget such lessons and start 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.
- Long time effort to keep memory of disaster and educate people not to loose awareness is necessary.
- Sharing such experience with other countries is also important.