Geotechnical damage caused by the recent gigantic earthquake in Japan

Download an article from the site of April Issue, Bulletin, ISSMGE

Ikuo Towhata
University of Tokyo

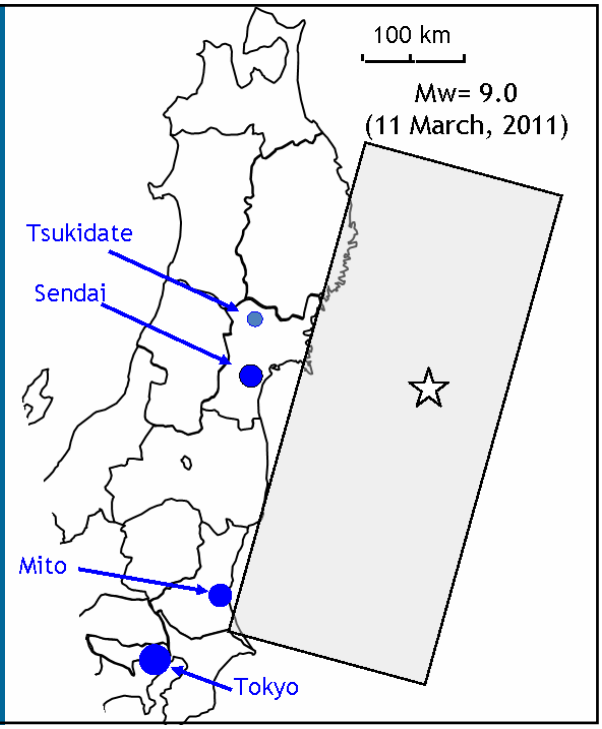
Presentation at 3rd INTERNATIONAL CONFERENCE ON GEOTECHNICAL ENGINEERING FOR DISASTER MITIGATION AND REHABILITATION (GEDMAR) in Semarang, Indonesia

Features of the earthquake

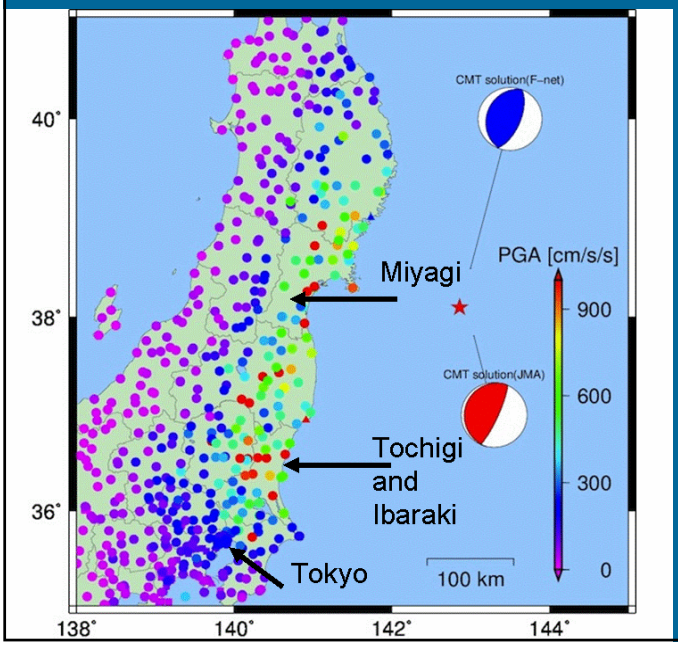
- Time of occurrence: 14:46 Local time on March 11, 2011
- Magnitude of earthquake (JMA scale) = 9.0
- Size of fault rupture : 500km * 200km
- Death toll : not finalized. Probably over 25,000

Rupture zone

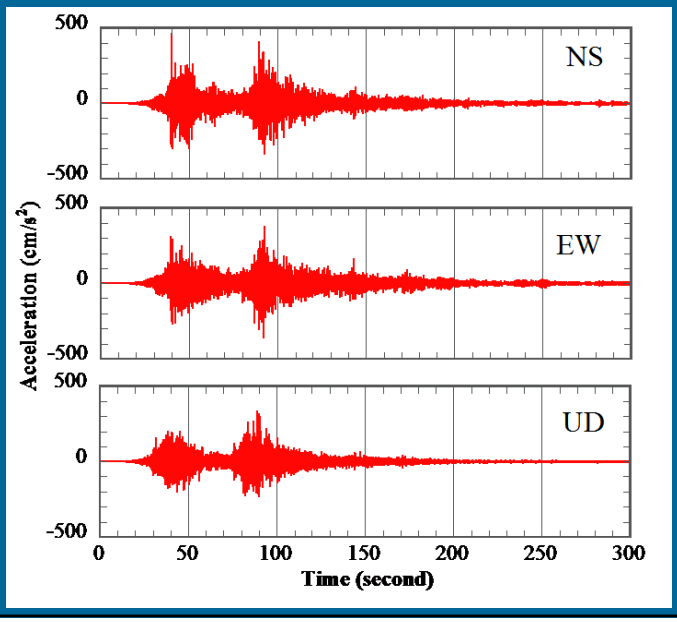
Previous earthquake of similar scale and area occurred in AD 869.



On earthquake motion



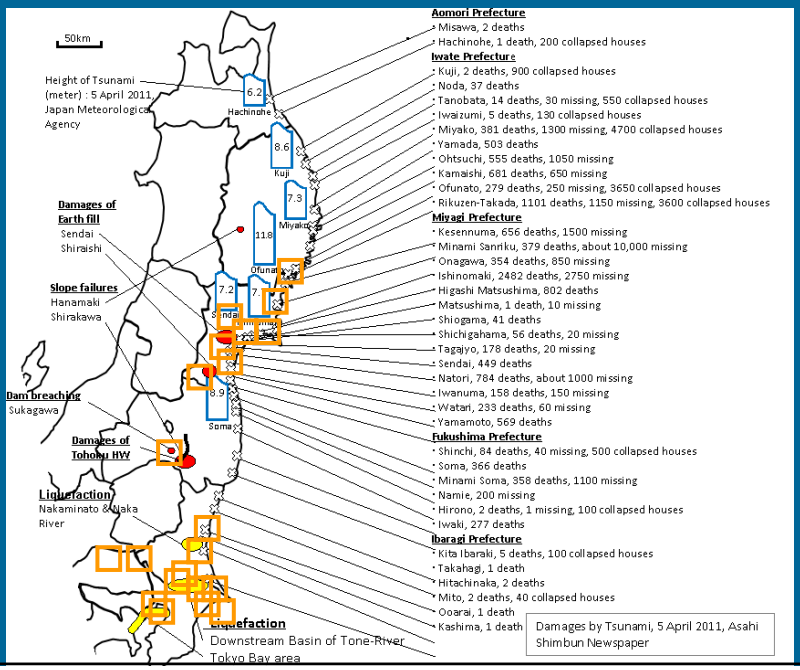
Acceleration records in Sendai City



Special feature of the damage

- The affected area was vast.
- Number of damage was huge; e.g. nearly 2000 damages in river levees
- Damages affected each other and made the entire effects more significant: delay and difficulty in emergency action and restoration.

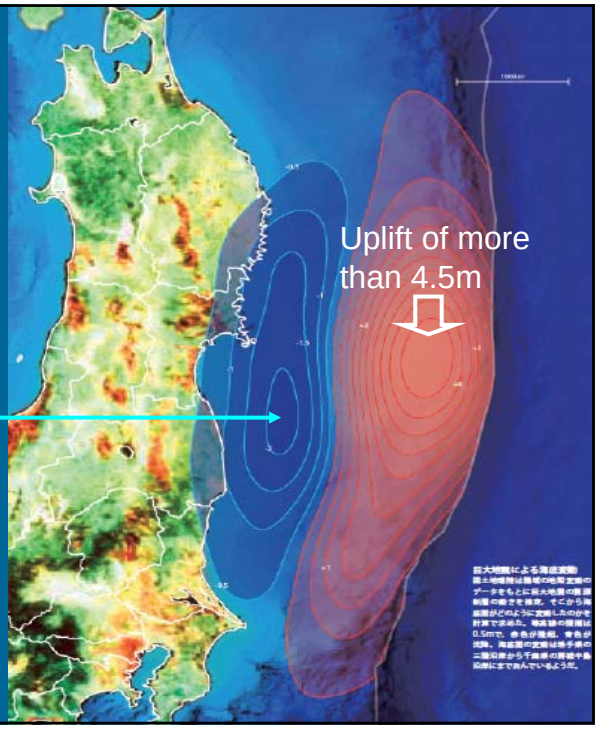
I have visited the following places: ☐



Tectonic movement

Subsidence of more than 2m in sea floor

Subsidence of coast was max. 1.2m



After Nikkei Science Magazine

Coseismic subsidence in coastal area

Photos by Mr. Daiken Suzuki, former master student, Univ. Tokyo

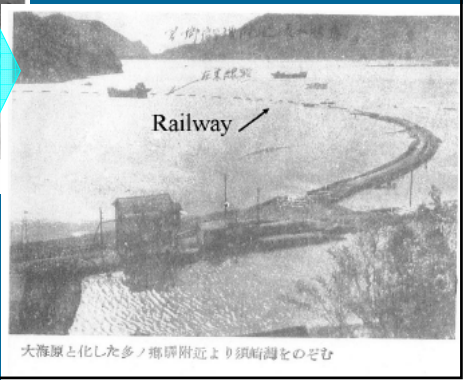
Ground level is lower than before; Difficulty in drainage Risk of flooding in typhoon season

Coseismic subsidence during past earthquakes

Valdivia 1960, Chile、Kohchi, 1946, Japan,

1999 Izmit Bay, Turkey, 1964 Alaska

Fig. 16.55 Inundation of Valdivia City (Soto Melo)

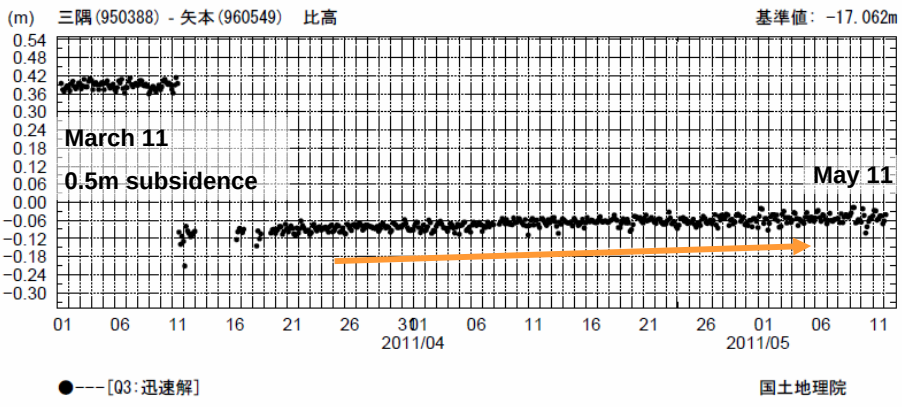


大海原と化した多ノ郷駅附近より損船潟をのぞむ

Later, ground came up.

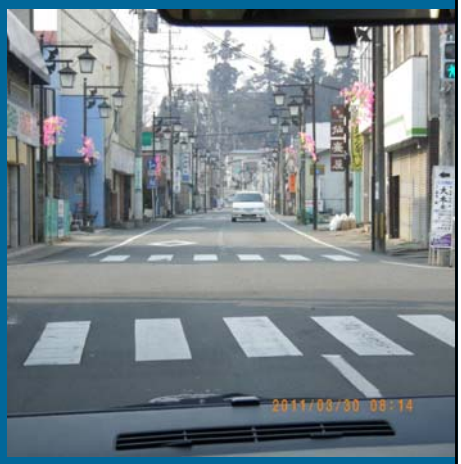
Tectonic motion of coast after March 11

Near Sendai City, ground is coming up but very slowly



Building damage was minor

Intact buildings in downtown Sendai



No damage in Tsukidate town in spite of nearly 3000 Gal and seismic intensity=7

Types of geotechnical damage

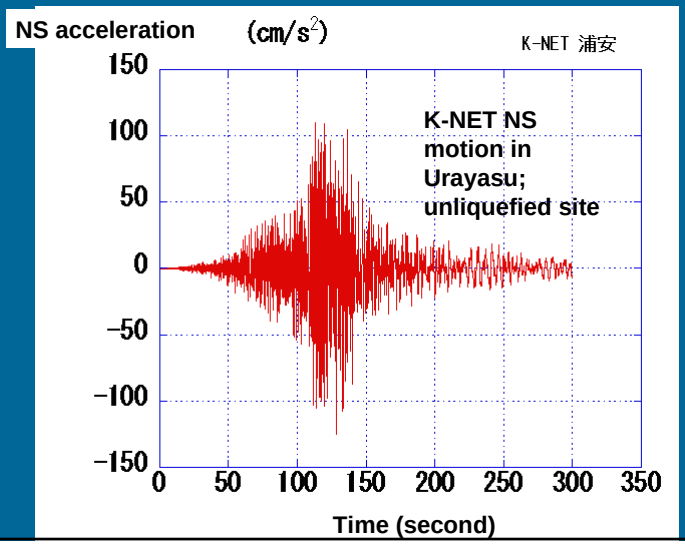
- Liquefaction in young sandy deposits
- Lifeline
- Embankment: road and levees
- Failure of residential development fills

Note: the large number of damage in each category above made restoration very difficult or still impossible.

Liquefaction in young sandy deposit (Urayasu City near Tokyo)

Feature of earthquake motion in Tokyo Bay area

Magnitude = 9.0; Long duration of shaking and many number of cyclic shear; liquefaction easy to occur.

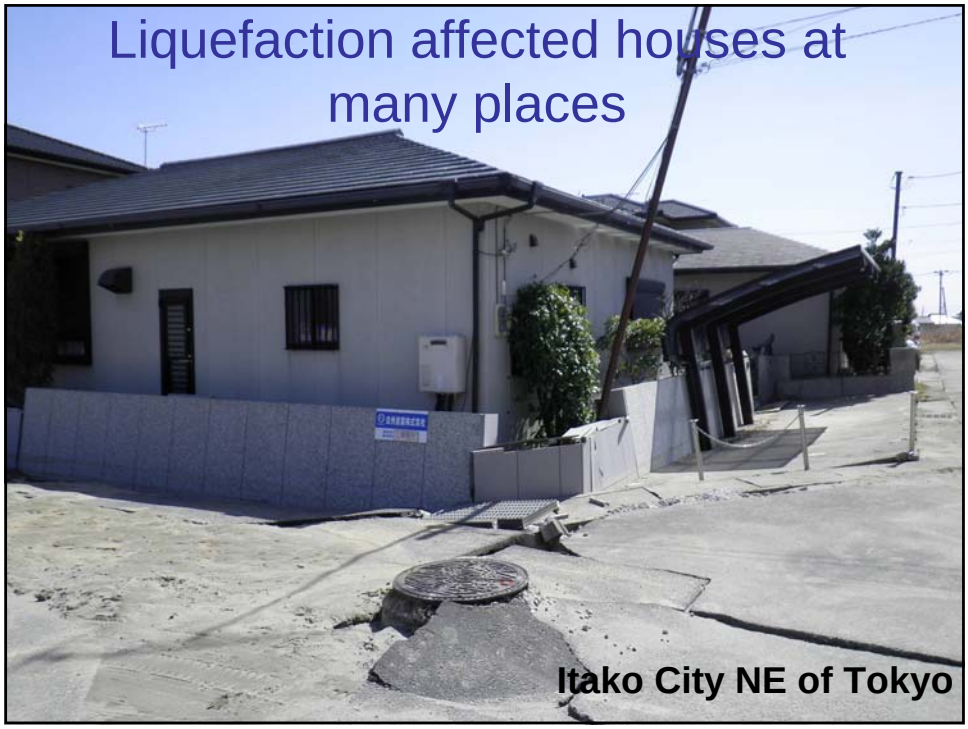


Liquefaction in residential area (Urayasu City)

Financial support is desperately needed for restoration

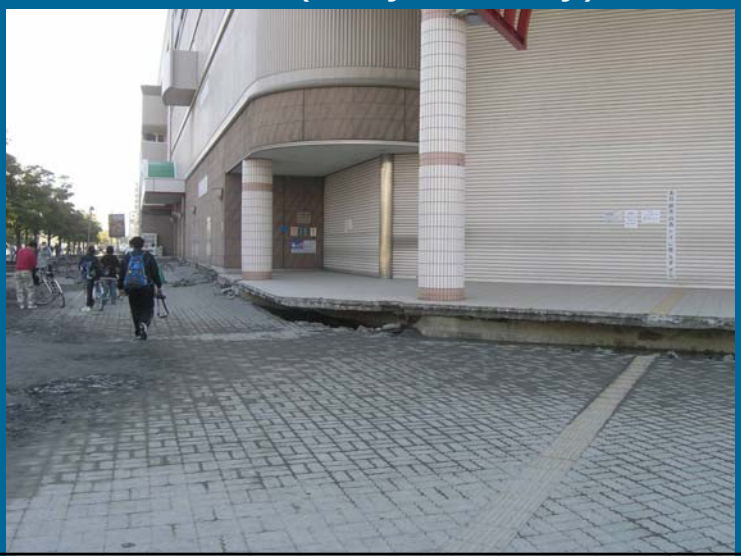
House tilting in Chiba City

Liquefaction affected houses at many places



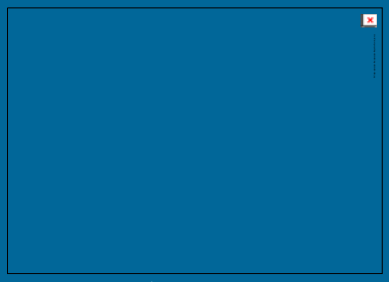
Itako City NE of Tokyo

Differential subsidence around pile-supported building and disconnection of lifeline (Urayasu City)

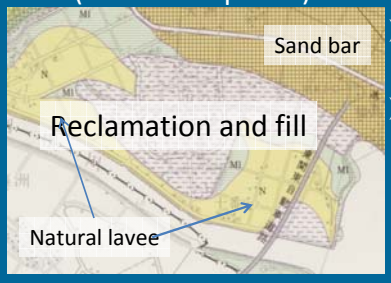


Original topography of Itako City

(Present airphoto)



(1928年の旧地形図)



Surface geology

- Used to be a small lake 100 years ago
- Reclaimed in 1977 already

Liquefaction occurred within this former lake

Successful soil improvement; Sand compaction piles and gravel drains

Lifeline damage

Floating of sewage manhole caused by liquefaction of ground and backfill

Sewage pipelines were destroyed at extremely many places

Liquefaction in former swamp; not indicated in liquefaction hazard map: public dispute

Ignorance of old topography and too much reliance on bore hole database

Problems of river levees
Nearly 2000 sites of damage

Liquefaction in foundation, subsidence, and lateral spread

Sand boiling on river side

Liquefaction in foundation

Sliding inside levee body. Foundation was intact.

Lateral spread as well, but no evidence of liquefaction

Split laterally and subsidence by 1.8m

Repeated liquefaction; 4th time

1978 main and after-shocks, 2003 and 2011

Most damages in river levees were associated with liquefaction in foundation or inside the levee.

Liquefaction is repeatable.

Tsunami effects

Heavy erosion and scouring behind sea walls → Walls were lost upon the first tsunami attacks → No more protection during the following tsunamis

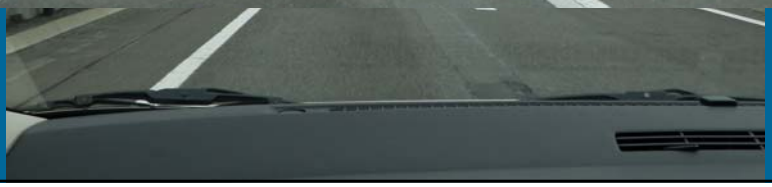
Total demolition

Tsunami debris block transportation

Situation was made worse by tectonic subsidence: insufficient levee height

Quick restoration of earth structure

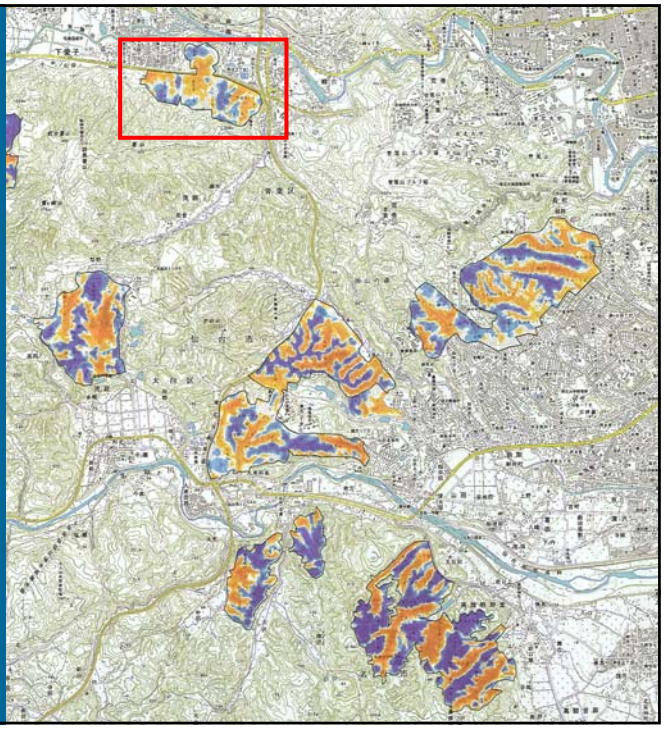
Expressway was restored quickly as well: importance of transportation route

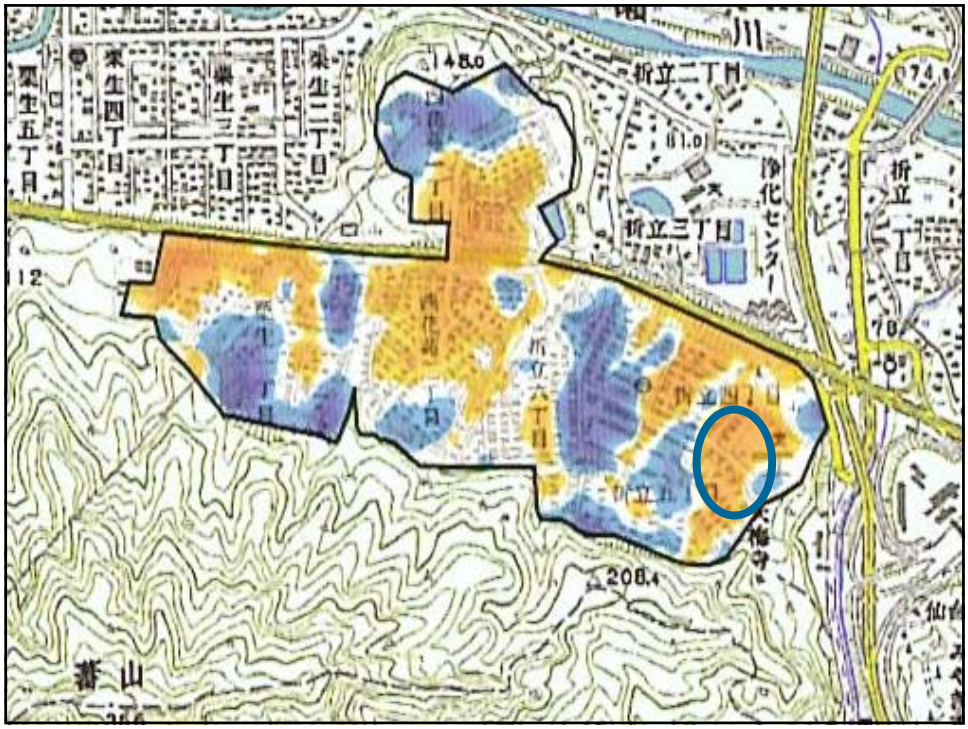


Damage in residential development in hilly area: cut and fill construction

Site of previous slope failure in 1978

In Sendai City, there are many residential developments in hill areas:



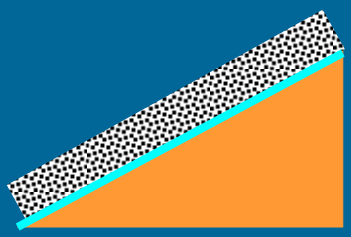


In Sendai City: On Fill,

On cut part, *in contrast, damage is much less*

Problems in residential fills

- Requirement for cutting cost
- Original surface (soft) soil remaining at the bottom
- Soil filling without removing vegetation
- Consequently, formation of soft layer between original ground and fill



Breaching of Fujinuma (irrigation) Dam

First dam was eroded and 150万m^3 of water attacked a downstream village

Distortion of second dam; quick draw-down effect? No overtopping

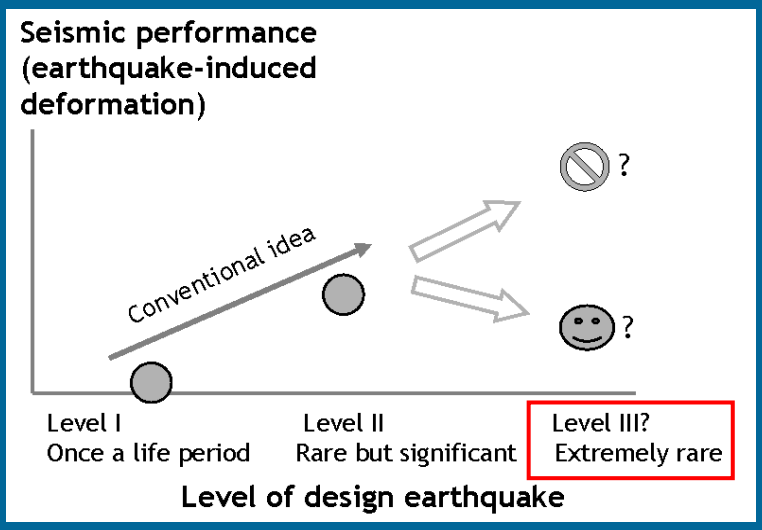
Flooded channel

8 victims in this village

Failure was rare in natural slope. Exception:

Long-distance flow

Consideration on performance-based design



Summary

- Vast area was affected and many damage occurred.
- Liquefaction affected private houses
- Residential development was damaged
- People need help from geotechnical discipline
- Individual damage is not so serious but number is significant.
- Should we revise design codes?