Question

Is it possible to survive from tsunami?
Earthquakes in the world

Tsunami generation

Source: British Geological Survey

Atwater et al., 1999
Tsunami generation

2:46 PM, 11 March 2011 (JST)
The 2011 off the Pacific Coast of Tohoku Earthquake (M9.0)

Source: JMA

Source: Headquarters of Earthquake Research Promotion
Tsunami has no borders

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Tsunami has no borders

DCRC, TOHOKU UNIV.
The 2004 Indian Ocean Tsunami Simulation

The 2011 Tohoku Tsunami
The 2011 Tohoku Tsunami

15:59:24:21

12 March 2011
Damage Summary

- Fatality
  - 15,781 people were killed, and 4,086 people are still missing (nation wide).

- Structural damage
  - Washed-away/Collapsed buildings were up to 115,151.

- Tsunami debris
  - 23 mil. ton, 80% removed.

- Economic losses
  - 16 to 25 trillion JPY, ¼ of annual budget of Japan.

Kesen-numa
Fatality : 1467
The tsunami was far more extensive than expected

Sendai
Fatality : 755

Lesson

There are two aspects of meaning in hazard maps...
Devastated coastal communities

Sendai city

Tsunami fragility curve
Lesson

Over 2 m tsunami flow depth potentially causes severe damage on houses or may devastate.

High-rise/robust reinforced concrete buildings can withstand and be used for vertical evacuation. But the regulation should be revised.

School buildings should also have similar requirement to ensure children’s safety.

Okawa elementary school

If only the school building were 3-story.

Lost 74 pupils out of 108
Onagawa, Miyagi Pref.

www.town.onagawa.miyagi.jp:
Fatality: 455. Missing: 739 (Pop.10,010). 12% of population were killed or missing.
Destroyed houses/buildings: 4432. 70% of houses in town was severely damaged.
Survivor videos
Onagawa, Miyagi Pref.
Time series of tsunami inundation interpreted from the video

Flow depth (m)

Tsunami Force = 50 tf

Return Flow velocity 7.5 m/s

Flow velocity 6.3 m/s


1st. Wave attack [15:21]

Buildings swept [15:26]

Tsunami peak [15:36]

Lesson

The sea does NOT always recede when tsunami comes.
Lesson

NEVER go to the coast to watch a tsunami.
Speed of tsunami propagation (m/s)
\[ \sqrt{gh} \]

\( g \) : Gravitational acceleration (=9.8 m/s\(^2\))
\( h \) : Water depth (m)

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Tsunami disaster countermeasures in Japan

1. Coastal protection
   Building seawalls and breakwaters to protect life and property

2. Building tsunami-resilient community
   Urban planning, land use, relocation.

3. Emergency response and preparedness
   Tsunami warning, evacuation (horizontal and vertical), public education.
Tsunami breakwater in Kamaishi
Length: 2km, Surface height above sea level: 8m, Width: 20m

Seawalls down
Lesson

Breakwaters and seawalls can NOT always protect our lives and properties.

Relocation
Kamaishi
[Iwate Pref.]

The 1933 Showa tsunami
(50 days after the event occurred)

Source: B.E.R.I
Lesson

To build tsunami-resilient communities, NEVER forget the memories of disasters and keep it around us.

JMA Tsunami warning issued based on 100,000 cases of pre-computed database of tsunami forecasting

1st warning issued based on the estimation of M7.9 within 3 minutes after the quake.

Iwate: 3m
Miyagi: 6m
Fukushima: 3m

The tsunami warning revised after the offshore tsunami observation 28 minutes after the quake.

Aomori: 3m
Iwate: 6m
Miyagi: >10m
Fukushima: 6m
Ibaraki: 4m
Chiba: 4m

Revised using offshore tsunami gauge
Lesson

Still limitations exist on reliability of science and technology used in the limited amount of time.

Tsunami warning information is to know we are in danger, but it does NOT guarantee our safety.

Do NOT wait for official information.

If you can walk or run, driving is not a good idea
Lessons

• Knowing risks
  - Very important to know risks but sometimes the nature is beyond our science and technology.
  - Remember negative aspects of hazard maps.
  - Computer simulation can NOT predict whole picture of disaster.

• Structural vulnerability
  - Breakwaters and seawalls can NOT always protect our lives.
  - Do NOT rely on coastal protection.
  - Over 2 m tsunami flow depth potentially causes destruction on houses.
  - Multi-story (high-rise) reinforced and robust concrete buildings can withstand and be used for vertical evacuation. But the regulation should be reconsidered.
  - School buildings should have the similar requirement to ensure children’s safety.

Lessons

• To survive
  - Go to higher place as soon as possible.
  - Strong ground shaking is the 1st. alert to take action.
  - NEVER go to the coast to watch a tsunami. Otherwise, you must run faster than motorcycles.
  - The sea does NOT always recede when tsunami comes.
  - Where to go? (Higher ground, Designated RC buildings for vertical evacuation)
  - Reduce difficulties of the access to shelter to reach within several minutes.
  - How to go? If you can walk or run, do not use a car.

• Tsunami warning and information
  - Increase the reliability.
  - Quick, accurate and robust disseminations system.
  - Attitude NOT to rely on official information.
Muchas Gracias!