# Deliverable D2 *Review* of post-tsunami field surveys (run up, flow depth, flow velocities, fluxes), damages, and fatalities of the 2011 Tohoku tsunami

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# Summary of revisions based on several comments raised at PARI meeting in Nov.14, 2014

1. Title of D2: Former title “Database on post tsunami field surveys” did not match in the content of the text. So, we would like to changed the title as “Literature review of..” or just “Review of ..”

2. Figures and Tables

- Fig. 2.2: Figure captions were revised to explain meaning of color gradation.
- Fig. 2.4: “mean *low* velocity” was replaced with “mean *flow* velocity”.
- Figs. 2.6 &2.7: Japanese words in the figure were replaced with English explanation. Direction of seaward has been added in Fig. 2.7.
- Table 2.1: Former number of Table (Table 1) was corrected.

3. Information on flow velocities available for other areas.

- We listed up references available for other areas in the text.

4. Information on damage of coastal dike

- We have added information of the field survey results on damages of coastal dike in section 3.2.3. Also, title of 3.2.3 has been changed from “Seawall” to “*Seawall and coastal dike*”.

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- Answer: We mean larger in terms of height. We have revised this sentence as “The higher the tsunami on coast is, the higher the casualty rate is.”
- (2) GKa32: See my previous comment above. In section 2.2.5. Is there more detailed literature/studies available on the circumstances why and where people died/or survived?
- Answer: We have added literatures discussing /analyzing on the circumstances in more detail.
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# Introduction

- The main purpose of the EU CONCERT-Japan RAPSODI (the consortium of **R**isk **A**ssessment and design of **P**revention **S**tructures f**O**r enhancement tsunami **DI**saster resilience) project is to develop a tsunami risk analysis model, based on the data from the 2011 Tohoku Tsunami. This will include derivation of empirical relations between damage/fatalities and tsunami flow depth, current velocities, fluxes, and the impact of debris. PARI, as the Japanese project leader, has a responsibility to provide data and knowledge on tsunami damage and fatalities for joint development of tsunami vulnerability models and prevention structures.
- Therefore, this report, *Deliverable 2 – Review of* post-tsunami field surveys (run-up, flow depth, flow velocities, fluxes), damages, and fatalities of the 2011 Tohoku tsunami, summarizes results of field surveys conducted after the 2011 Tohoku tsunami and provides related literature review on the database for further development of numerical models by co-researchers of this project.

# Contents

# Post-tsunami field surveys

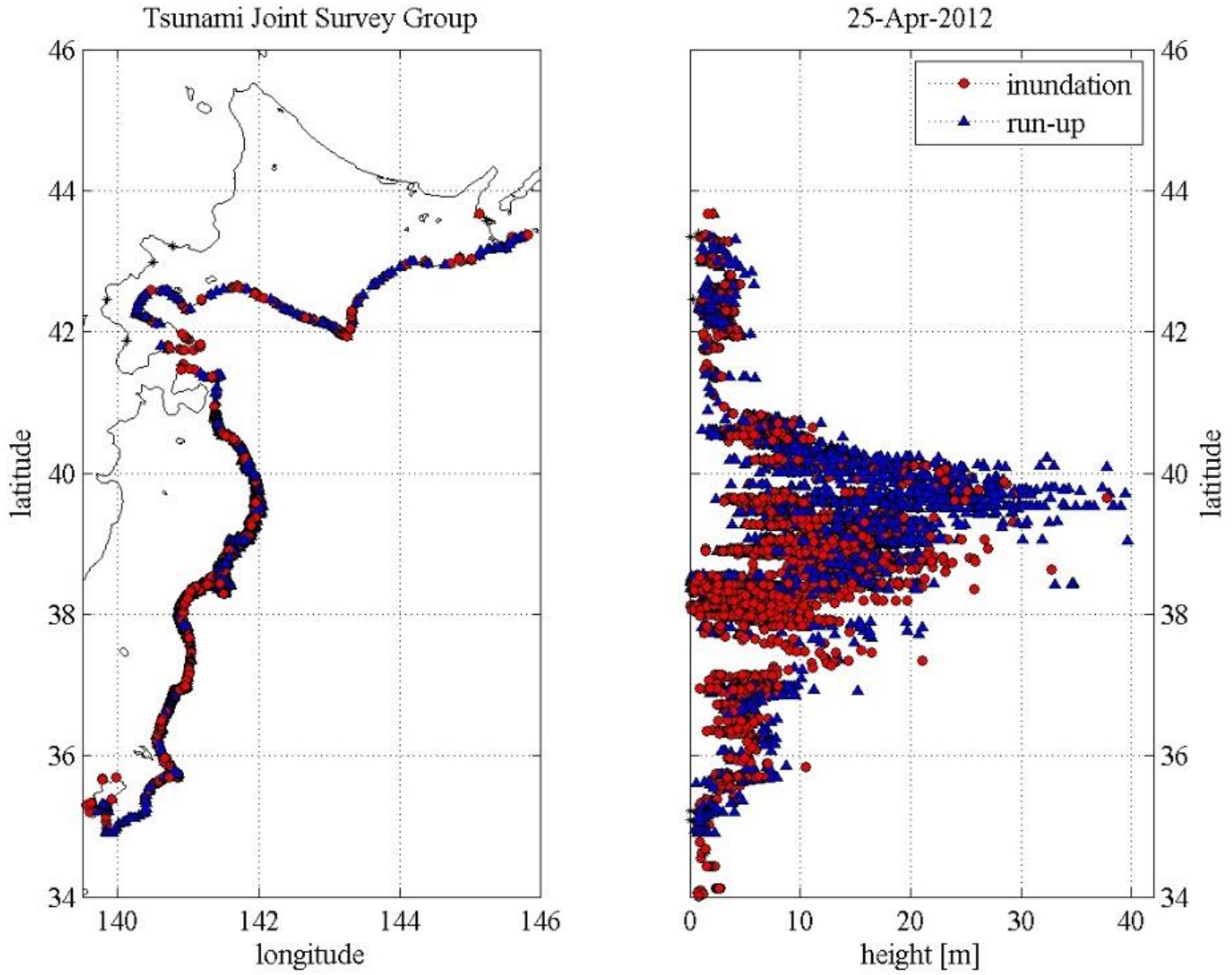



*Fig.* 2.1 Disturibution of trace of tsunami height by the 2011 Tohoku earthquake tsunami joint survey group (2012). (Only high-confidence data is included.)

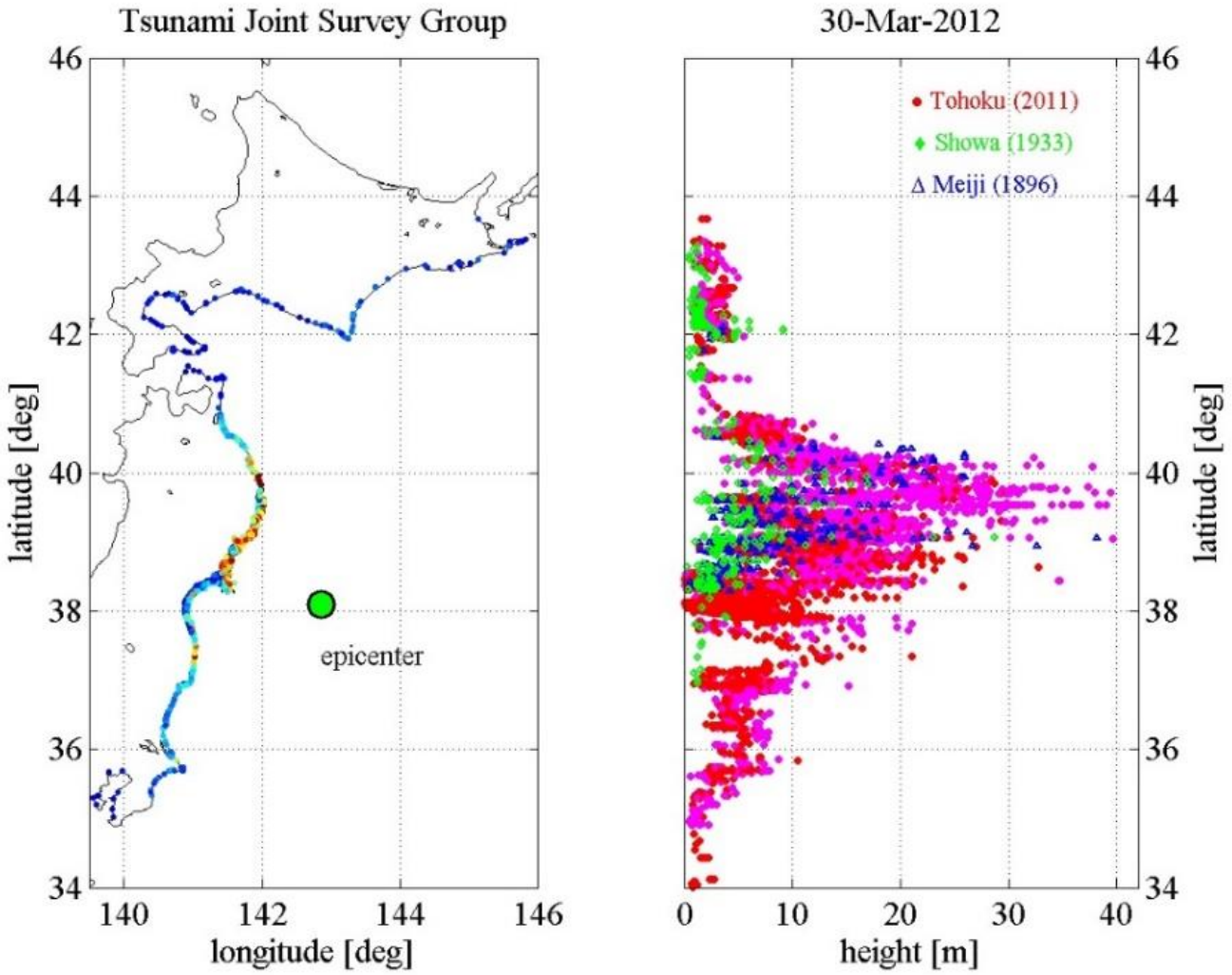



*Fig.* 2.2 Comparison of tsunami height between the 2011 event and past events (Right: purple color denotes run-up height and red inundation height). Left figure shows distribution of tsunami height at 2011 event (color denotes different level of tsunami height) (The 2011 Tohoku Earthquake Tsunami Joint Survey (TTJS) Group, 2012)

# Flow velocities

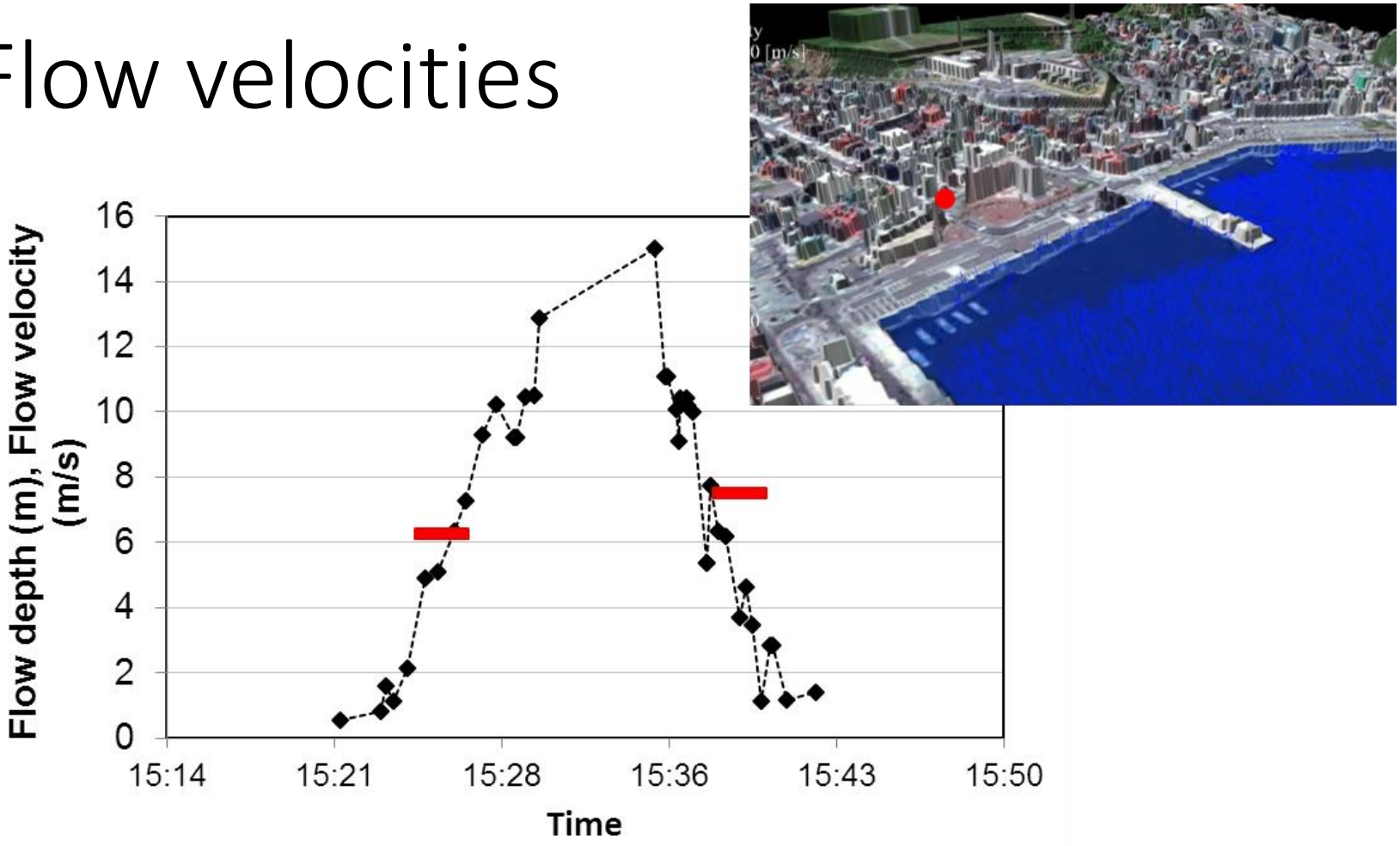
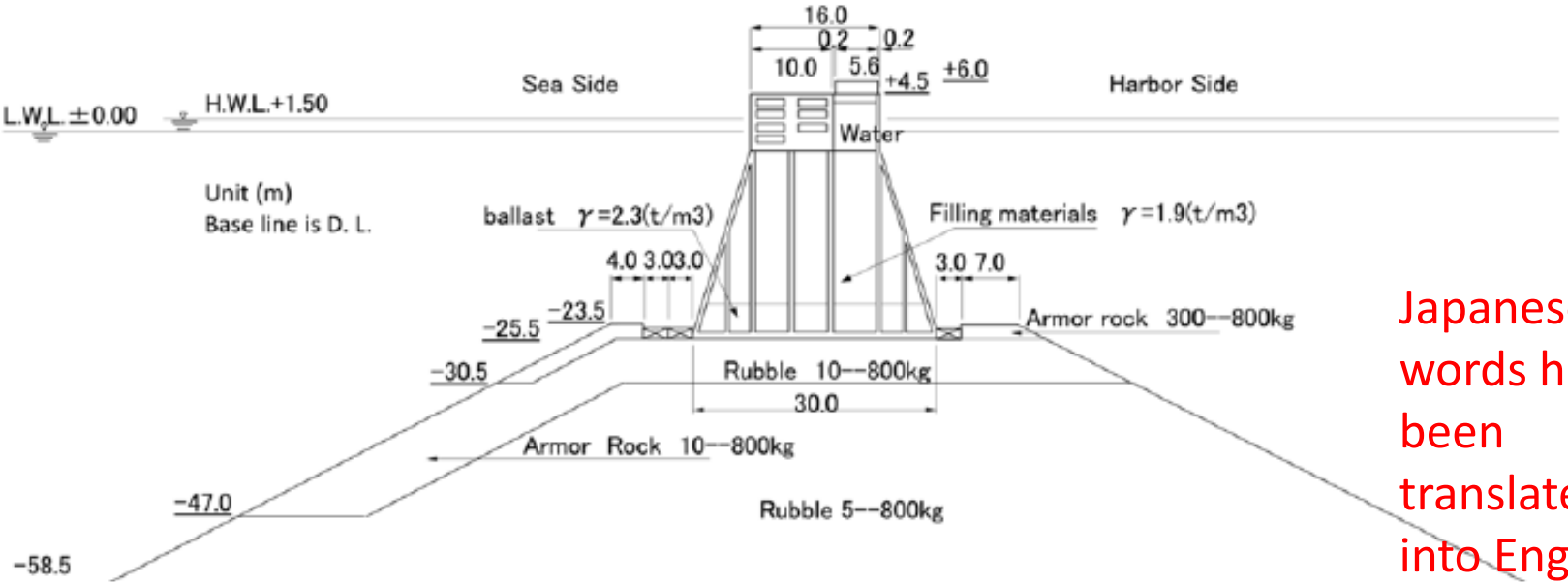



*Fig.* 2.4 Video analysis of flow depth and velocity near the coast line at Onagawa, Dots are flow depth while red lines denote mean flow velocities (Koshimura et. al. 2011)

Comments: Information on flow velocities available for other areas?
We listed up references available for other areas in the text (Sendai plain area).

# Damage


*Fig.* 2.5 The Kamaishi Bay mouth breakwaters (courtesy by Tohoku Regional Bureau)




Japanese words has been translated into English.

*Fig.* 2.6 Standard Cross section at the deep portion of the North Breakwater

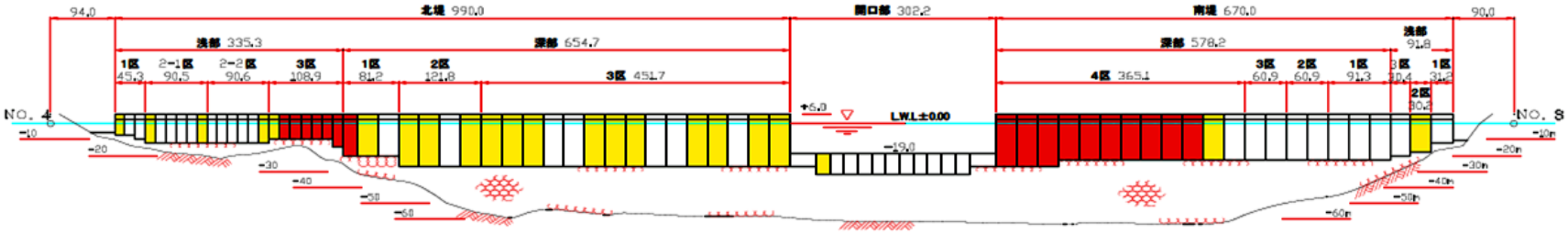



*Fig.* 2.8 State of damage of Breakwater (Red : No damage, Yellow : Tilted, White : Sliding down) (Takahashi et al., 2011)

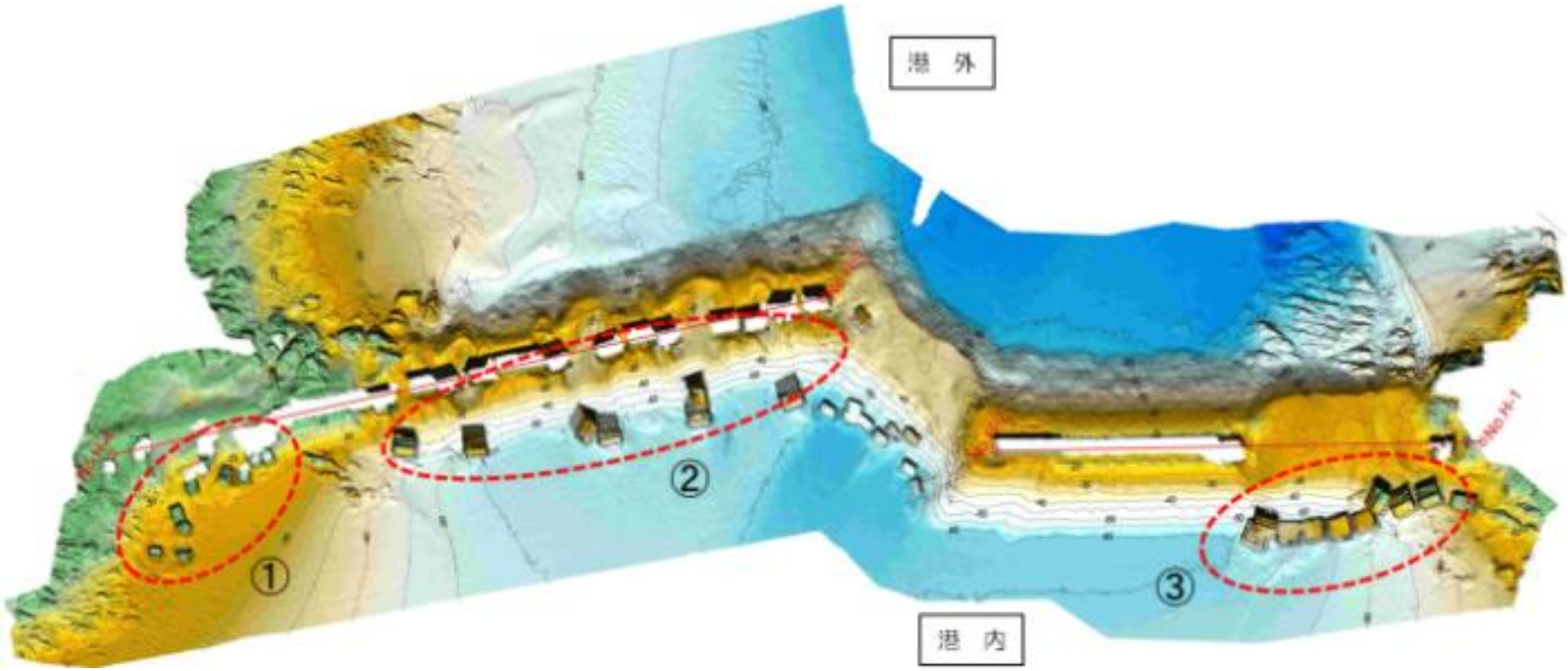



*Fig.* 2.9 State of damage of breakwater (Takahashi et al., 2011)

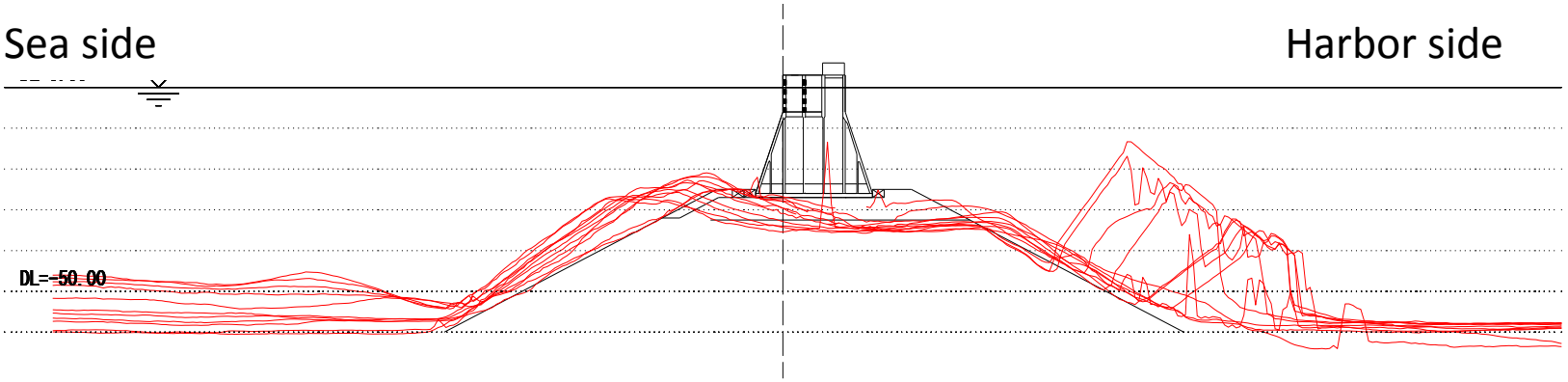



*Fig.* 2.12 Cross section of damage of North Breakwater (Arikawa et al., 2012)

| Port | Area | State of major damage | *HT*(m) | Damage Type |
|---|---|---|---|---|
| Hachinnohe | Hachitaro | Settlement of dissipating blocks | 6.2 | Scour by OF |
| | Hachitaro | Scouring of Mound in Harbor Side | 6.2 | Scour by OF |
| | Hachitaro | Sliding of Caisson | 6.2 | T. F. |
| | Sotominato | Scouring and Falling of temporary H.B. | 6.2 | Scour of H.B. |
| | Sotominato | Scouring and Falling of temporary H.B. | 6.2 | Scour of H.B. |
| | Sotominat | Scattering of amour blocks and rubble | 6.2 | Scour by OF |
| Kuji | Hanzaki | Sliding and overturning of Caisson | 8.5 | T. F. |
| | Mouth | Scour | ― | Scour of H.B. |
| Miyako | Desaki | Sliding and overturning of Caisson | 8.5 | T. F. |
| | Ryujinzaki | Scouring and Falling of temporary H.B. | 7.5 | Scour of H.B. |
| | Fujiwara | Scouring and Falling of temporary H.B. | 8.5 | Scour of H.B. |
| | Fujiwara | Scouring and Falling of temporary H.B. | 8.5 | Scour of H.B. |
| | Fujiwara | Sliding and Falling of Caisson and etc. | 8.5 | T. F. |
| | Fujiwara | Settlement by seismic motion | ― | ― |
| | Kanbayashi | Sliding and Falling of Caisson and etc. | 8.5 | T. F. |
| | Fujiwara | Sliding and Falling of Caisson and etc. | 8.5 | T. F. |
| | Fujiwara | Settlement by seismic motion | ― | ― |
| | Fujiwara | Sliding and Falling of Caisson and etc. | 8.5 | T. F. |
| Soma | Honkou | Sliding and Falling of Caisson and etc. | 14.38 | T. F. |

* *HT* means Tsunami Height. , OF means overflow, T.F. means Tsunami Force, H.B. means Head of Breakwater

*Table* 2.2 State and type of damage of breakwaters (courtesy by Tohoku Regional Bureau)

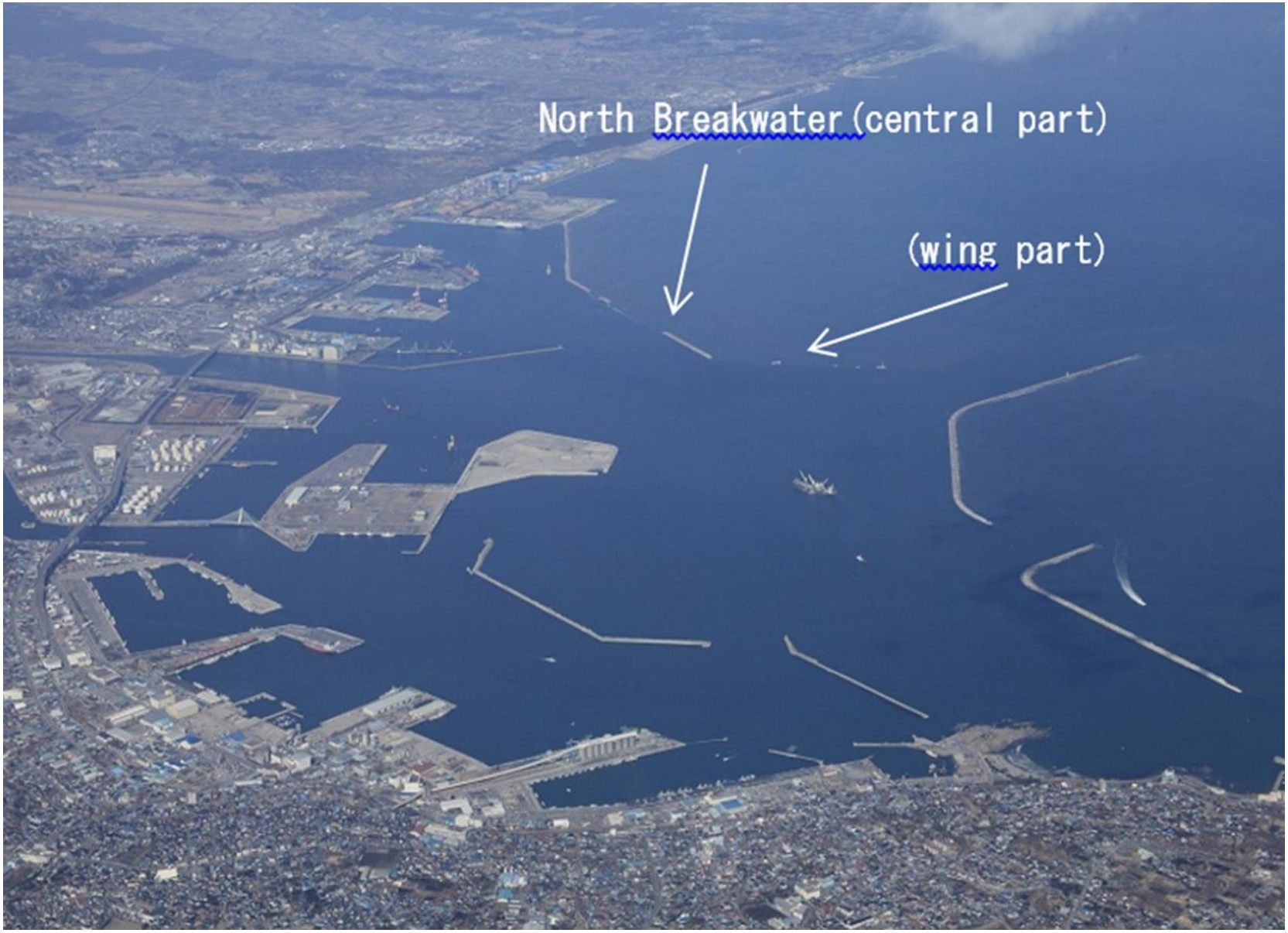



*Fig.* 2.13 State of damage at Hachinohe Port
(courtesy by Tohoku Regional Bureau)

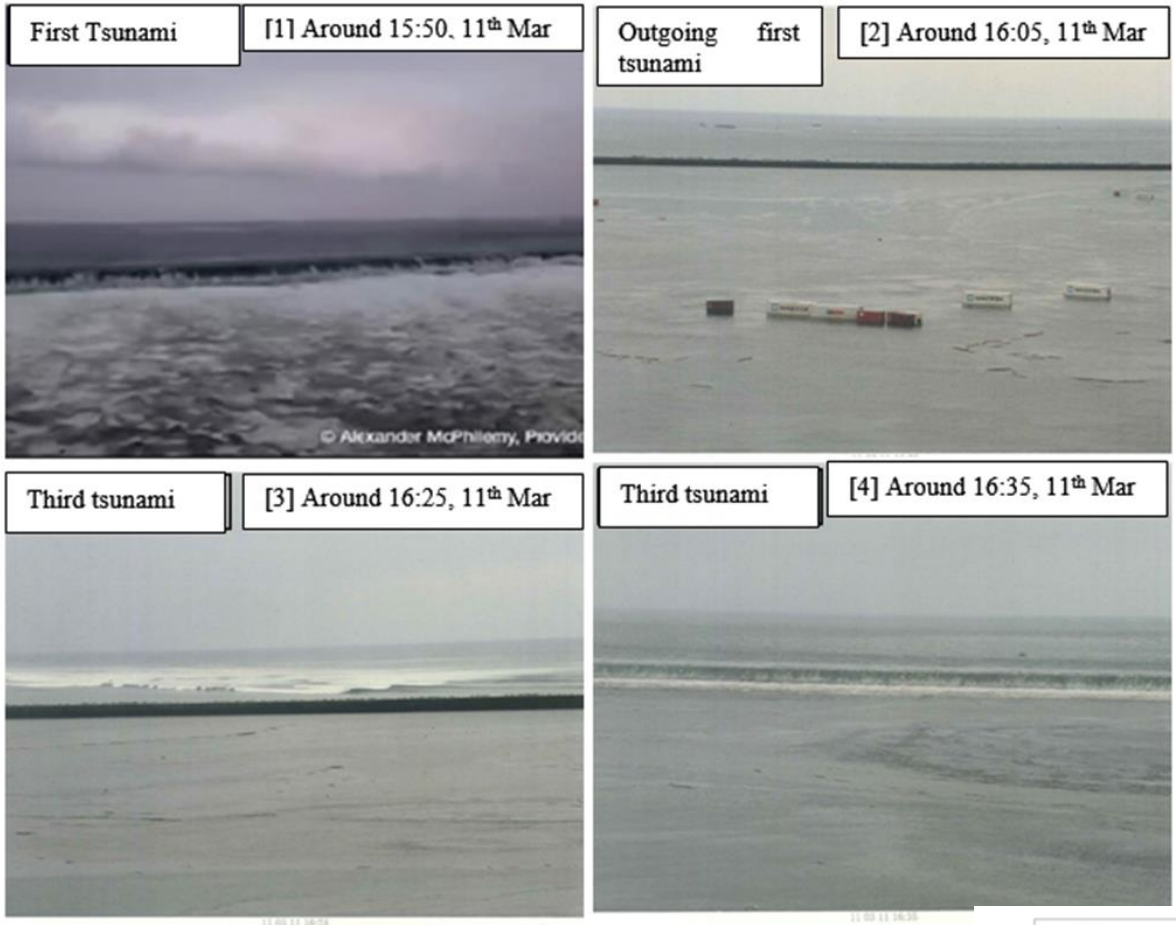
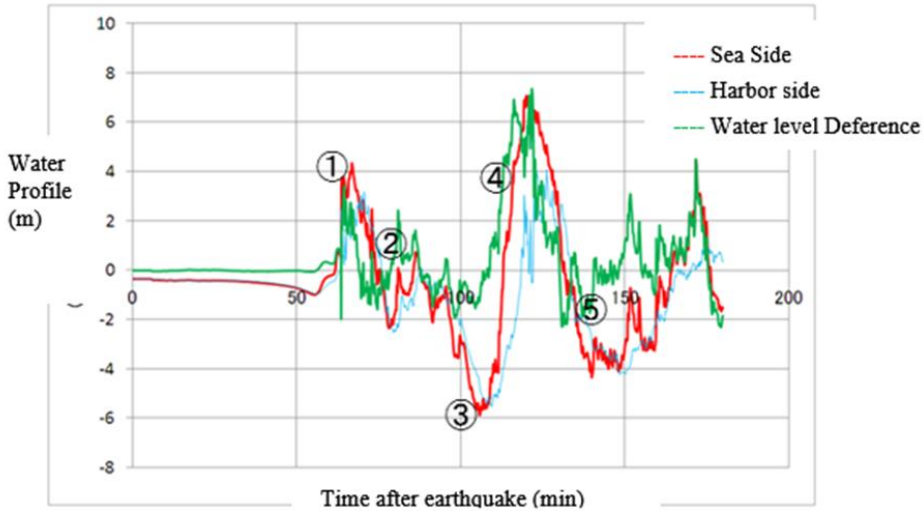



*Fig*. 2.15 Photos of the central portion of the harbor at different time intervals



(a) Seawalls collapsed towards land
(Chayamae district, coastal protection area in Ofunato port)(Crest height of walls: TP +3.40m, Observed tsunami height: TP +8.07m)

(b) Seawalls collapsed towards the sea
(Nagahama district, coastal protection area of Ofunato port)(Crown height of wall: TP +3.00m, Observed tsunami height: TP +10.02m)

(c) Severe scouring was observed on the seaside (Suga district, coastal protection area of Kamaishi port)(Crown height of wall: TP +4.00m crown high parapet, Observed tsunami height: TP +8.64m)

*Fig*. 2.16 Damage of Seawalls

| Tsunami Height (m) 1 | 2 | 4 | 8 | 16 | 32 |
|---|---|---|---|---|---|
| Wave Profile mild slope | rise in shallow | Like wall in offshore, 2nd wave breaking | Almost same profile as 2m, Possibility of breaking is increasing at toe of tsunami | Plunging breaker | |
| steep slope | like tide with fast speed | like tide with fast speed | | | |
| Wooden Houses | Partially Destruction | Destruction（2m～） | | | |
| Stone Houses | Safe | | | Destruction（7m～） | |
| Steel, Concrete Buildings | Safe（～5m） | | | | Destruction |
| Community near shore | | Partially | Damage ratio 50% | Damage ratio 100% | |

*Table* 2.3 The relationship between tsunami height and damage (Shuto, 1992)

*Fig.* 2.17 Damaged property around Natori City

*Fig.* 2.19 Three-story steel frame building in the Rikuzentakada City, Iwate Prefecture

*Fig.* 2.22 A three store apartment building that has been washed away (Takahashi et al., 2011)

129,914 houses were reported as completely destroyed, and 258,591 houses were partially destroyed.

| Pref. | Casualties | | Buildings Damage | |
|---|---|---|---|---|
| | Fatalities | Missing | Completely | Partially |
| Hokkaido | 1 | 0 | 0 | 4 |
| Aomori | 3 | 1 | 306 | 701 |
| Iwate | 4,671 | 1,222 | 20,189 | 4,688 |
| Miyagi | 9,517 | 1,581 | 84,940 | 147,613 |
| Yamagata | 2 | 0 | 37 | 80 |
| Fukushima | 1,605 | 214 | 20,607 | 68,473 |
| Tokyo | 7 | 0 | 15 | 198 |
| Ibaraki | 24 | 1 | 2,738 | 24,506 |
| Tochigi | 4 | 0 | 260 | 2,103 |
| Gunma | 1 | 0 | 0 | 7 |
| Chiba | 20 | 2 | 798 | 9,985 |
| Kanagawa | 4 | 0 | 0 | 39 |
| Total | 15,859 | 3,021 | 129,914 | 258,591 |

*Table* 2.4 Human Losses and Building Damage in Different Prefectures

The National Police Agency of Japan reported on 30 May

# Fragility curve

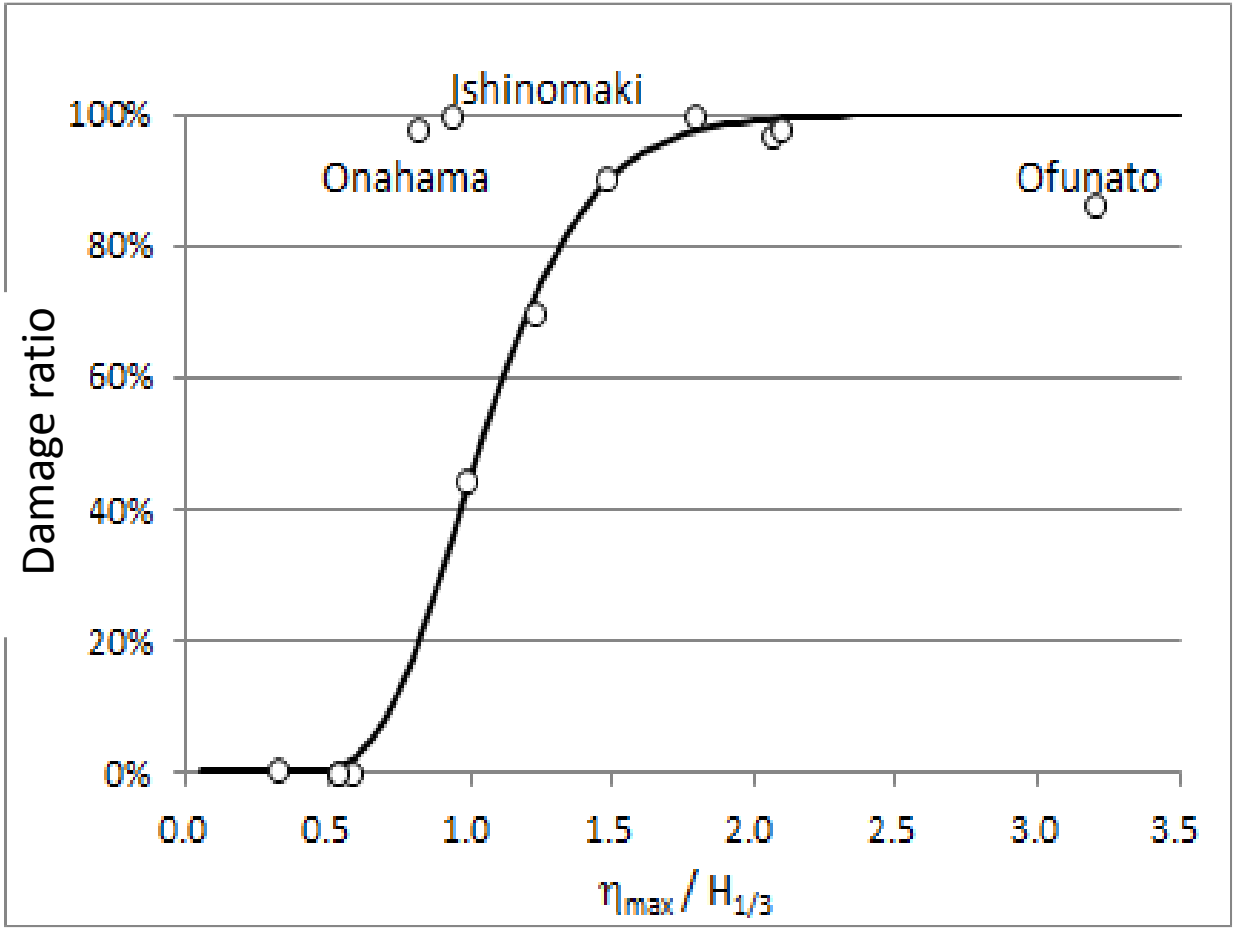



*Fig.* 2.24 Damage ratio of front-line breakwater and tsunami height of different port (PIANC, 2013)

$$F\left(\eta, H_{1/3}\right) = \Phi\left[\frac{\ln\left(\eta/H_{1/3}\right) - \mu}{\sigma}\right] \quad (\mu = 0.0386,\ \sigma = 0.279)$$

the cumulative distribution function

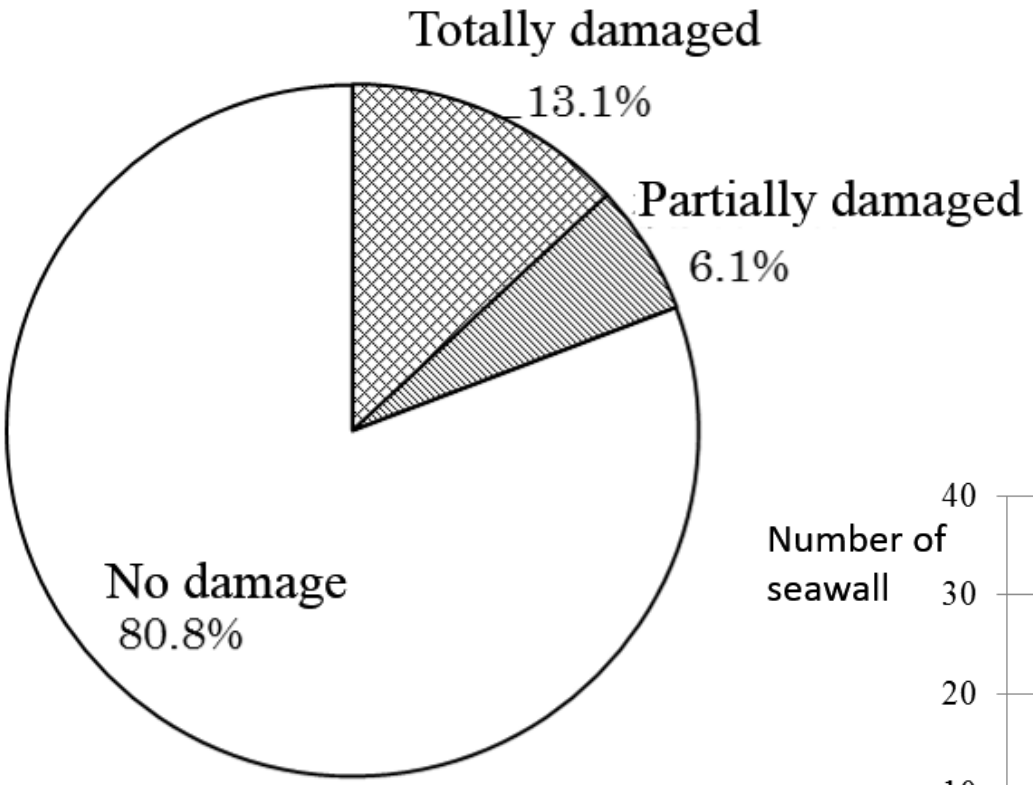



*Fig.* 2.26 Damage ratios of facilities evaluated

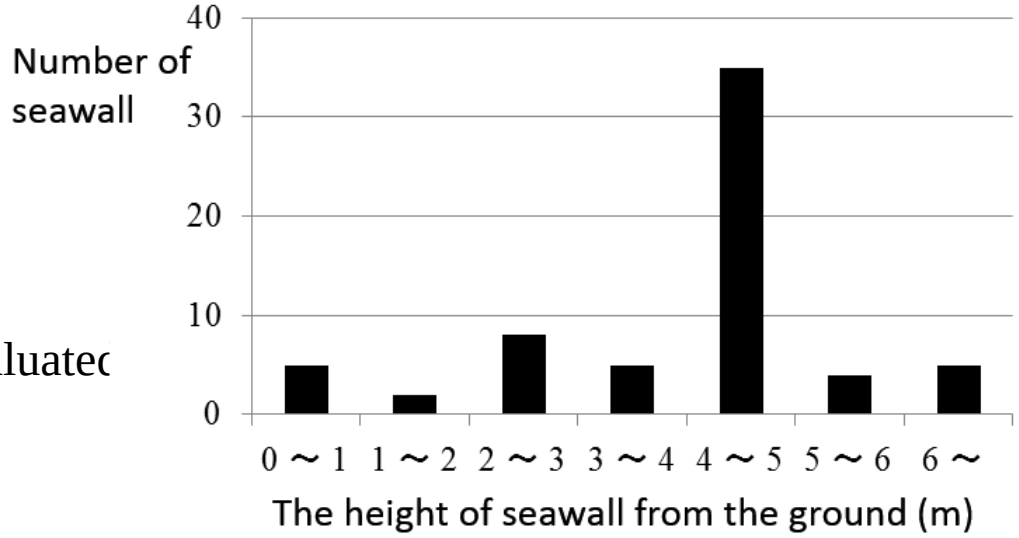



*Fig.* 2.25 Heights of seawall structures evaluated

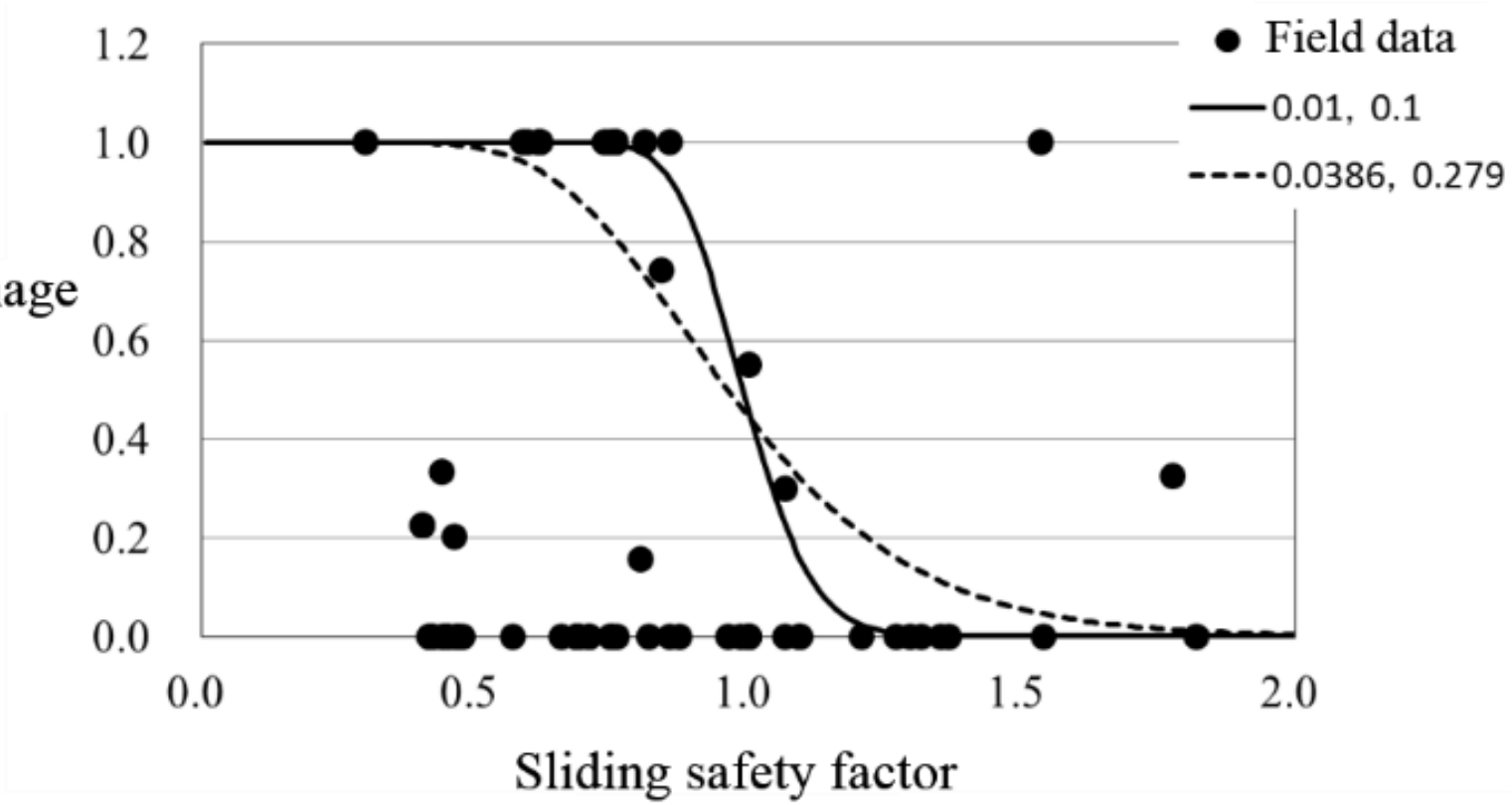



*Fig*. 2.28 Relations of safety factor for sliding to damage ratio

| Category | Total Loss (Washed Away) | Total Loss | Total Loss (Flooding Above First-floor Roof) |
|---|---|---|---|
| Main building conditions | Only foundation has remained. Building has fully washed away. | Main structure has destroyed and it is difficult to reuse in the earlier way even after repair | Inundated beyond 1st floor ceiling. Reuse possible after large-scale repair, etc. |
| Sample photographs |  |  |  |
| Number of buildings* | Approx. 94,000 | Approx. 35,000 | Approx. 9,000 |

| Category | Large-Scale Partial Loss | Partial Loss (Above-floor Flooding) |
|---|---|---|
| Main building conditions | Inundated about 1 m above floor (below ceiling) | Above floor inundation less than 1 m from floor (can be reused with partial repair) |
| Sample photographs |  |  |
| Number of buildings* | Approx. 40,000 | Approx. 45,000 |

| Category | Some Damage (Below-floor Flooding) | Total number of buildings | |
|---|---|---|---|
| Main building conditions | Can be reused if mud from underfloor is removed | | |
| Sample photographs |  | Total number of damaged buildings | Including Total Loss buildings |
| Number of buildings* | Approx. 26,000 | Approx. 249,000 | Approx. 138,000 |

Building damage conditions (image)

*Fig*. 2.29 Categories used to classify disaster condition of buildings (City Bureau, MLIT, 2012)

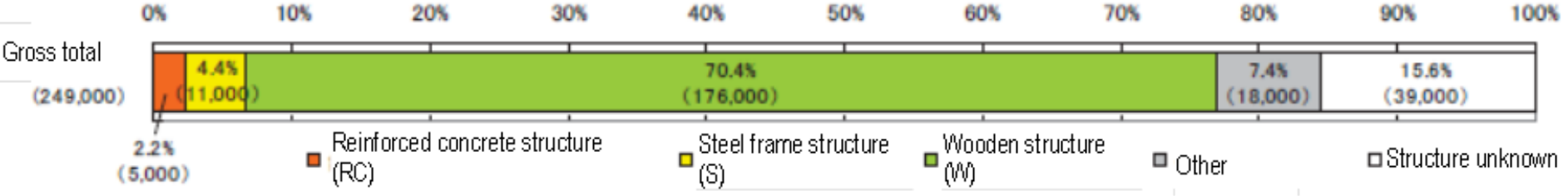



*Fig*. 2.30 Proportion of disaster condition of buildings by structure (City Bureau, MLIT, 2012)

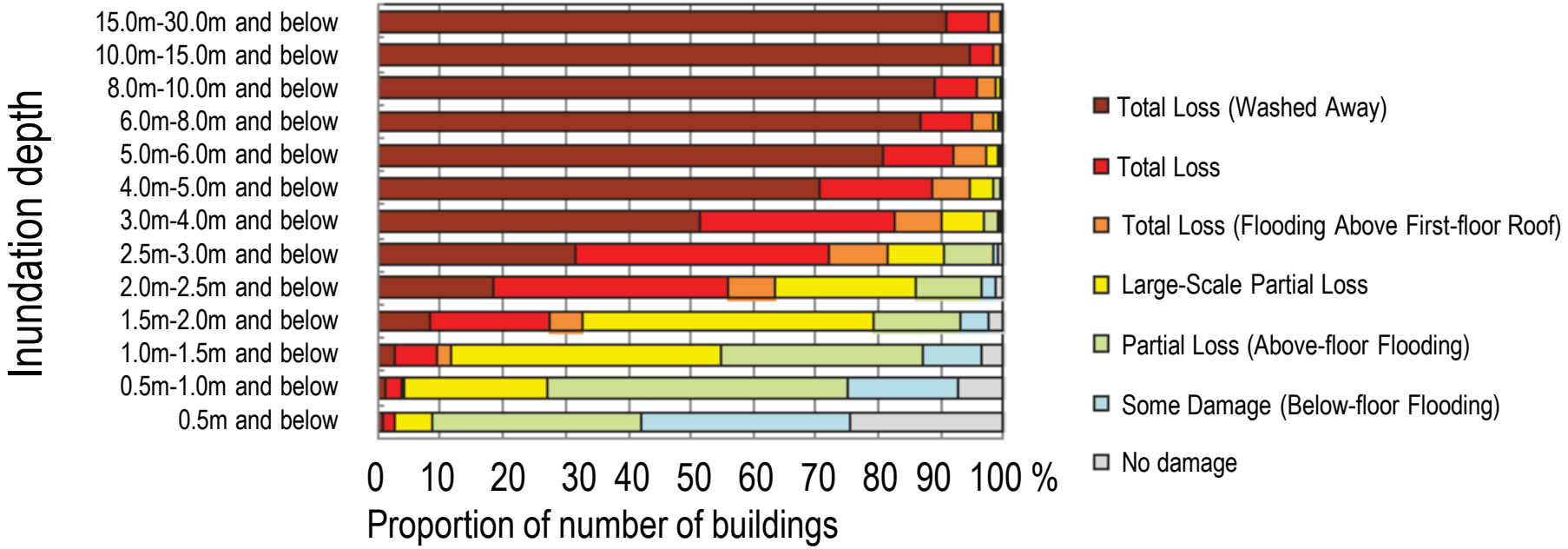



*Fig*. 2.31 Proportion of affected buildings with respect to inundation depth (City Bureau, MLIT, 2012)

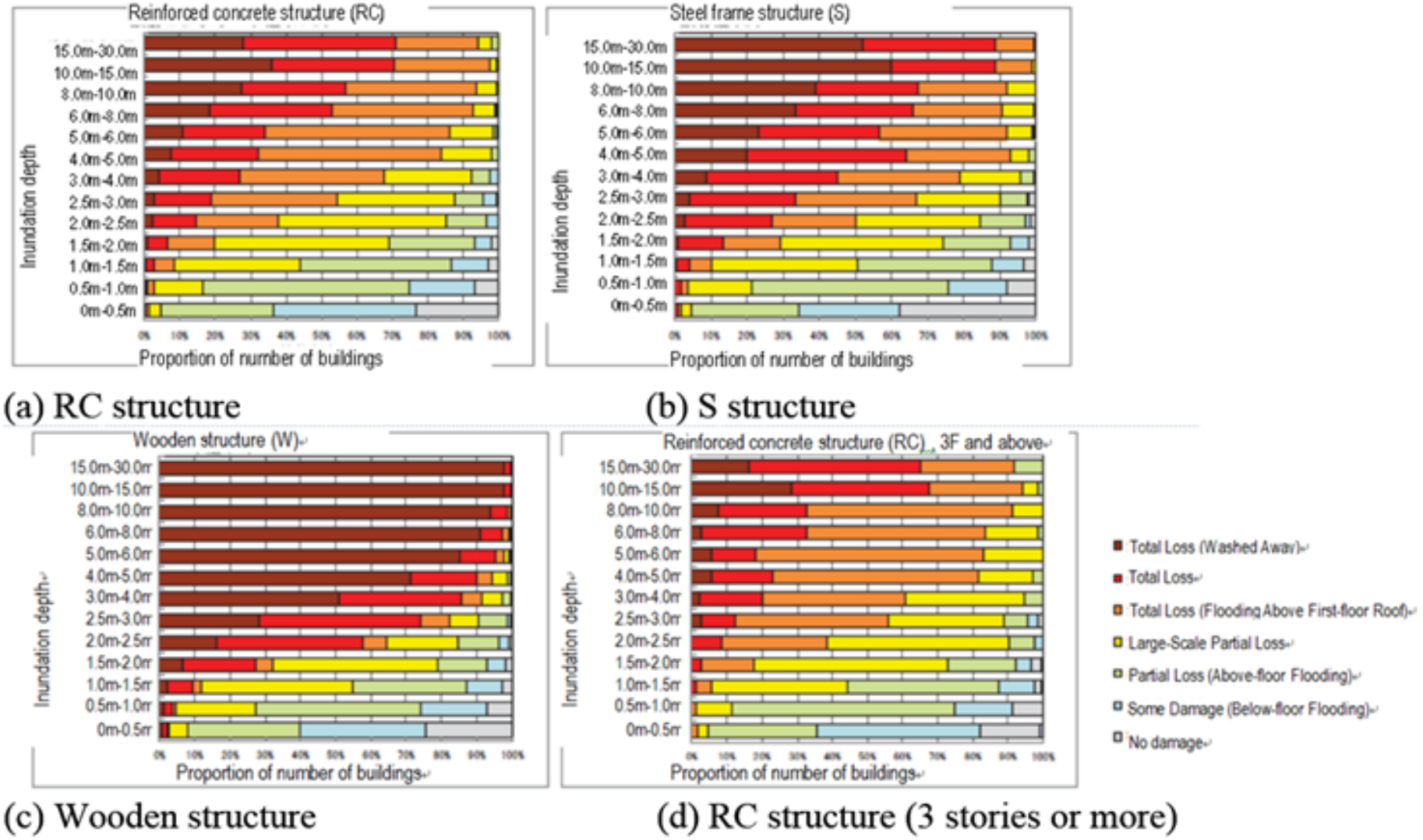



*Fig*. 2.32 Proportion of affected buildings by inundation depth, sorted by building type (City Bureau, MLIT, 2012)

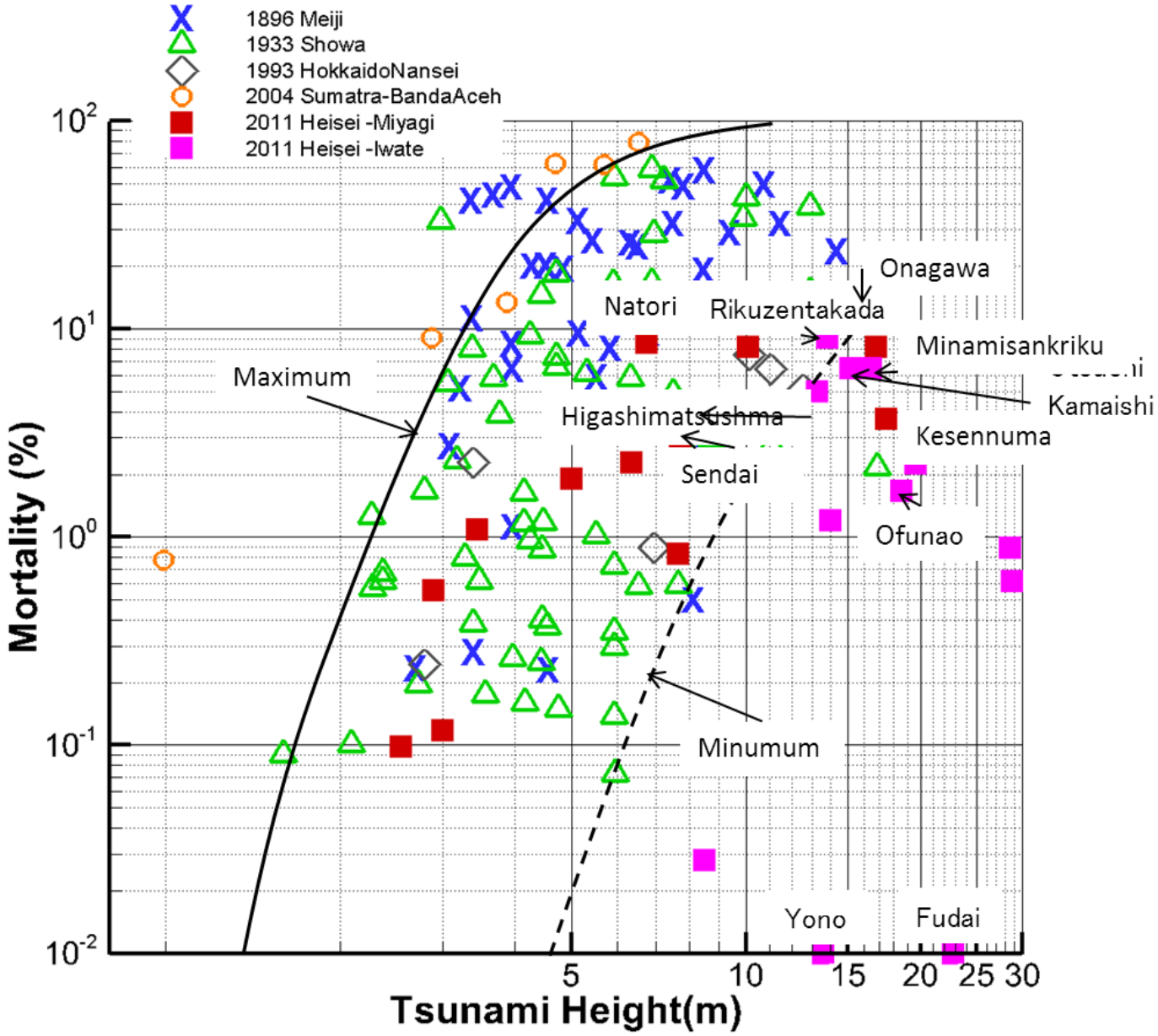



*Fig*. 2.33 Relationship between tsunami height and casualty rate

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