INDONESIA-JAPAN JOINT SEMINAR
ON MAPPING-OUT STRATEGIES
FOR BETTER SEISMIC DISASTER MITIGATION

February 2007

Japan Society of Civil Engineers

Architectural Institute of Japan

Engineers Without Borders,Japan

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ITINERARY

Date	Itinerary	Stay
2/09	1) Leave for Indonesia (Group A) *JL725: Departure from Narita at 11:20 / Arrival at Jakarta at 17:20*	Jakarta
2/10	1) Leave for Banda Aceh *GA180: Departure from Jakarta at 06:00 / Arrival at Banda Aceh at 09:45* 2) Survey ・Road (Banda Ache – Lamno) ・House	Banda Aceh
2/11	1) Survey 2) ･Banda Aceh 3) Leave for Jakarta *GA189 Departure from Banda Aceh at 12:20 / Arrival at Jakarta at 16:10*	Jakarta
	1) Leave for Indonesia (Group B) *JL725: Departure from Narita at 11:20 / Arrival at Jakarta at 17:20*	
2/12	1) Internal meeting 2) Workshop 3) ･14:00-18:45 ･Meeting room of a Public Works 4) Courtesy Call ･Djoko Kirmanto [Minister for Public Works]	Jakarta
2/13	1) Seminar ･09:30-15:45 ･Auditorium of a Public Works 2) Courtesy Call ･JICA Indonesia office ･Embassy of Japan 3) Return to Japan *JL726: Departure from Jakarta at 22:10 / Arrival at Narita at 07:20(+1)*	Over night flight
2/14	1) Arrived at Natrita 2) Break up	

Group A : Prof. K. Konagai, Mr S. Sato and Mr T. Ikeda

Group B : Prof. M. Teshigawara, Prof. Y. Nakano and Dr. S. Miwa

INDONESIA-JAPAN JOINT SEMINAR ON MAPPING-OUT STRATEGIES FOR BETTER SEISMIC DISASTER MITIGATION

JAKARTA – INDONESIA, MONDAY, 12 FEBRUARY, 2007
MEETING ROOM, BALITBANG PU - JL. PATTIMURA 20, KEBAYORAN BARU, JAKARTA SELATAN

Objective : To facilitate discussion on mapping out strategies for better seismic disaster mitigation.

Output : Notion of the establishment of Indonesian Disaster Mitigation Association.

Schedule :

14:00 – 14:30 Opening remarks by
- Dr. Basuki Hadimuljono, Director General of Agency for R&D, Ministry of Public Works;
- Prof. Kazuo KONAGAI, The University of Tokyo, Japan

14: 30 – 16:30 Discussion on :
- Soil Investigation;
- Seismic Inspection and Retrofit of Buildings;
- Low Cost and High Seismic Performance House;
- Data Achieved of Damage caused by Massive Earthquakes;
- Agenda of Future Cooperation

16:30 – 17:30 Summary of the Workshop by Prof. Kazuo KONAGAI

17:30 – 17:45 Closing Remarks by Dr. Basuki Hadimuljono

Attendance:

Indonesian Experts

Ministry of Public Works
- Dr. Basuki Hadimuljono, *Balitbang PU*
- Agus Widjanarko, *Cipta Karya PU*
- Adi Sarwoko, *Expert Staf to the Minister*
- Supardi*, Balitbang PU*
- Anthonius Budiono, *Cipta Karya PU*
- Nana Terangna Ginting, *RCHS*
- Researchers from RCHS
- Researchers from RCWR
- Researchers from RCRB

Coordinator Ministry of People Welfare Affairs
- Budianto, *Deputy Ass.*

Bakornas Penanggulangan Bencana
- Sugeng Triutomo, *Deputy*

Professional Association
- Dr. Hermanto Dardak, *PII*
- Prof. Dr. Wiratman, *PII*
- Tulus Sukaryanto, *PII*
- Bachtiar Sirajuddin, *PII*
- Samuel Sibarani, *PII*
- Kayan Sutisna, *PII*

University
- Dr. Krisna Pribadi, *ITB*
- *Dr. Wayan Senggara, ITB*

Private Sector
- Dr. Joshie Halim, *Consultant*

Japanese Experts

University
- Prof. Kazuo KONAGAI, *The Univ. of Tokyo*
- Prof. Hirokazu IEMURA, *Kyoto University*
- Prof. Masaomi TESHIGAWARA, *Nagoya Univ.*
- Prof. Yoshiaki NAKANO, *The Univ. of Tokyo*
- Takaaki IKEDA, *The Univ. of Tokyo*

Private Sector
- Dr. Shigeru MIWA, *Tobishima Corporation*

Professional Association
- Shinichiro SATO, *Engineers without Borders*
- Tomoji SUZUKI, *JSCE*

Observer(s)
- JICA expert(s)

INDONESIA-JAPAN JOINT SEMINAR EARTHQUAKE NATURAL DISASTER MITIGATION MAPPING OUT STRATEGIES FOR BETTER SEISMIC DISASTER MITIGATION

Jakarta – Indonesia, on Tuesday, 13 February, 2007

TENTATIVE SCHEDULE

Time	Program	Speaker / Moderator	Remarks
08.30 – 09.30	Registration		
09.30 – 10.00	Opening Ceremony - Report by Organizing Committee - Address by JSCE - Address by PII - Opening Remarks	 Nana Terangna Ginting Prof. Kazuo KONAGAI Dr. Hermanto Dardak Dr. Basuki Hadimuljono Director General, Agency for R&D, Ministry of Public Works	 Venue: Sapta Taruna Room
10.00 – 10.30	Coffee Break		
10.30 – 12.00	Keynote Speechs - Activity of Tsunami memorial pole project - Seismic Diagnosis and Seismic Capacity Index Seismic Inspection and Retrofit of Buildings - Building Law and Code with regard to Earthquake Resistant - Discussion	 -Prof. Hirokazu IEMURA -Prof. Yoshiaki NAKANO -Anthonius Budiono	 Moderator: Samuel Sibarani
12.00 – 13.00	Lunch		
13.00 – 14.00	Panel Discussion Geotechnical Session - Soil Investigation - Characteristics of Earthquake Geo-technical Engineering	 Dr. Shigeru MIWA and Prof. Kazuo KONAGAI Prof. Paulus Rahardjo	 Moderator Wayan Senggara
14.00 – 15.00	Building and Housing Session - Low Cost and High Seismic Performance House - Building and Housing Safety Design - Discussion	 Prof. Masaomi TESHIGAWARA Prof. Dr. Wiratman	Moderator: Prof. Yoshiaki NAKANO
15.00 – 15.30	- Summary of the Seminar - Closing Remarks	Nana Terangna Ginting Dr. A. Hermanto Dardak	

Keynote Speech

Earthquake and Tsunami survey, experiments, and memorial poles

Hirokazu IEMURA and Mulyo Harris Pradono

Seismic evaluation and rehabilitation of vulnerable RC buildings, -Experiences and lessons in Japan

Yoshiaki NAKANO and Masaomi TESHIGAWARA

Panel Discussion

Support Activities for the recover and reconstruction by transferring the technique on geotechnical investigation in NIAS Island damaged by the M8.7 Off-Shore Sumatra Earthquake, March 28, 2005

Shigeru MIWA, Ömer AYDAN, Hiroyuki KODAMA, Junji KIYONO,
Ichiro ENDO, Tomoji SUZUKI and Masanori HAMADA

Damage and design on non-engineered buildings

Masaomi TESHIGAWARA and Yoshiaki NAKANO

Data archives for rational rehabilitation of areas affected by massive earthquakes, -Experiences and lessons in Japan

Kazuo KONAGAI

EARTHQUAKE AND TSUNAMI SURVEY, EXPERIMENTS, AND MEMORIAL POLES

Hirokazu IEMURA[1] and Mulyo Harris Pradono[2]

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Key Words: seismic and tsunami questionnaires, tsunami damages, tsunami experiments, and the pole project

INTRODUCTION

The fourth largest earthquake in the world since 1900 has happened on December 26, 2004, at 00:58:53 UTC (or 07:58:53 local time), off the west coast of Northern Sumatra, Indonesia. The magnitude was 9.0, the focal depth was 30 km, and the epicenter is 255 km from Banda Aceh, the nearest provincial capital in Sumatra (National Earthquake Information Center, 2005). The earthquake itself caused some damages and casualties in Banda Aceh and Meulaboh. The subsequent tsunami killed more than 125,468 people, and left 94,550 people missing in Northern Sumatra region. In total, at least 283,100 people were killed by the earthquake and subsequent tsunami in 10 countries in South Asia and East Africa. The tsunami caused more casualties than any other in recorded history.

Lessons from this huge disaster shall be learnt by locals and people all around the world. A Japanese group of researchers led by the first author departed to Banda Aceh and surrounding areas in attempt to study the lessons by the huge earthquake and tsunami.

SEISMIC AND TSUNAMI QUESTIONNAIRES

Questionnaires have been distributed to the people affected by the earthquake and tsunami. The purpose of the questionnaires was to collect information of what happened and what were expected by the affected people to be safe against future earthquake and tsunami.

The seismic intensity was calculated based on questionnaires conducted in Banda Aceh. Professor Ota's method (Ota, et al., 1979) is used to calculate the local intensity. There are 35 questions such as: Feel the quake? Where? Duration? Could you move? Structures were damaged? Hanging stuff swinging? Unstable stuff falling? Heavy stuff moving? and other 27 questions. The results show the seismic intensity in Banda Aceh is around 5+ in Japan Meteorological Agency scale (Figure 1).

The other questionnaires are related to the tsunami. One question is about the tsunami height predicted by the witnesses. The tsunami height in Figure 2 shows that the tsunami water mainly came two or three times to the affected areas. The highest height mainly happened at the second or third wave.

Intensity 5+～6−

A	5.49 (5+)
B	5.35 (5+)
C	5.61 (6−)
D	5.41 (5+)
E	5.43 (5+)
F	5.63 (6−)
G	5.47 (5+)
H	5.44 (5+)
(Inside the city)	5.50 (5+)
I	5.43 (5+)
J	5.19 (5+)
K	6.14 (6+)
L	5.66 (6−)

USGS MMI: IX（or 6）

Figure 1. Seismic Intensity in Banda Aceh based on Questionnaires

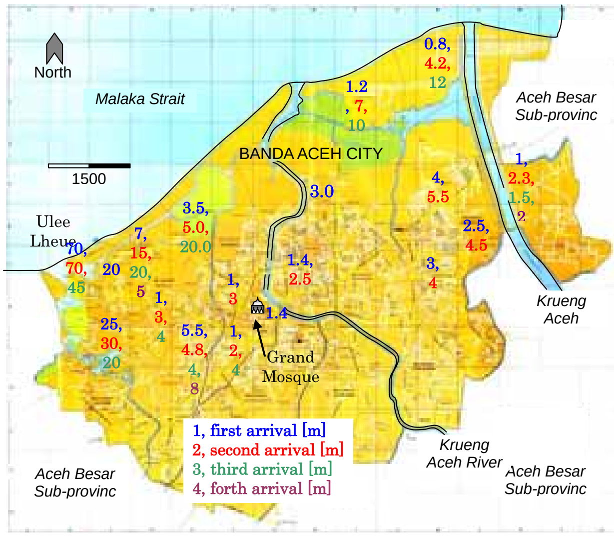

Figure 2. Heights and Sequence of Tsunami Water in Banda Aceh

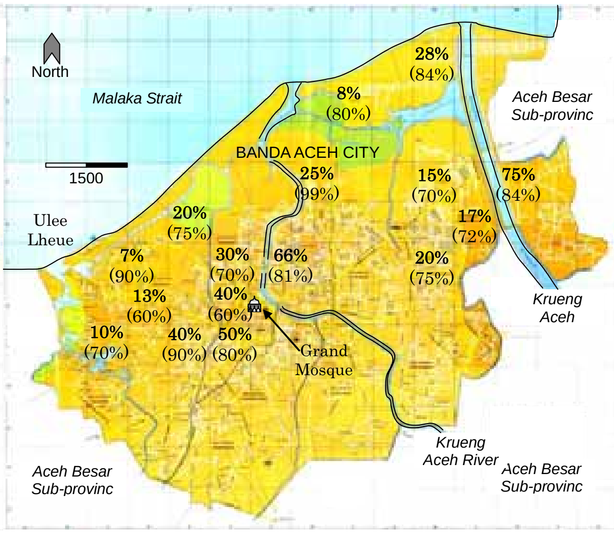

Figure 3. Percentage of Survivors in Banda Aceh

Figure 3 shows percentage of survivors (and expected survivors if they immediately run away just after the big earthquake) according to respondents. One important result is that even if people had started running away just after the big earthquake, the percentage of expected survivors would have been less than 100% (Figure 3, numbers in parenthesis). The practical implication is that education, socialization (software) and escape structures, warning system, wave resisting structures (hardware) are among important factors for people to be safer against future earthquake and tsunami attacks.

STRUCTURAL DAMAGES BY EARTHQUAKE

The earthquake caused significant damages to structures, especially multi-story structures (structures with relatively long natural period). Examples are shown in Figure 4. Five-story Balai Gading Hall was significantly damaged, although nearby one-story wooden house was intact. Five-story Kuala Tripa Hotel was pancaking at the first story. Governor-office Annex which was under construction went down with soft-story mechanism of failure (see Figure 4).

(a) Balai Gading Hall

(b) Kuala Tripa Hotel

(c) Governor Office Annex

Figure 4. Structural Damages caused by Earthquake

STRUCTURAL DAMAGES BY TSUNAMI

Basically, structures damaged by subsequent tsunamis are much severe than those by earthquake. Some examples are shown in Figure 5. Conveyor belts transporting cement material from plant to sea shore were washed away (Figure 5a), 600-ton generator ship was drawn 3 kilometers inland (Figure 5b), girders were ripped off from piers (Figure 5c), liquid tank was flown hundred meters away (Figure 5d), damages were more severe near the sea shore (Figure 5e), and a survived two-story house near the sea shore (Figure 5f).

(a) Cement Factory

(b) Generator Ship

(c) Washed Away Girders

d) Washed Away Tank

(e) Aerial View at Ulee-Lheue

(f) House near Sea-shore

Figure 5. Structural Damages caused by Tsunami

DETAILED DAMAGES OF BRIDGES BY TSUNAMI

Some of the bridges surveyed were shown in Figure 6. The figure shows satellite photo after the disaster (DLR, 2005) at Meuraxa Ward (North-Western part of Banda Aceh city) where the tsunami water was coming from the North-West direction.

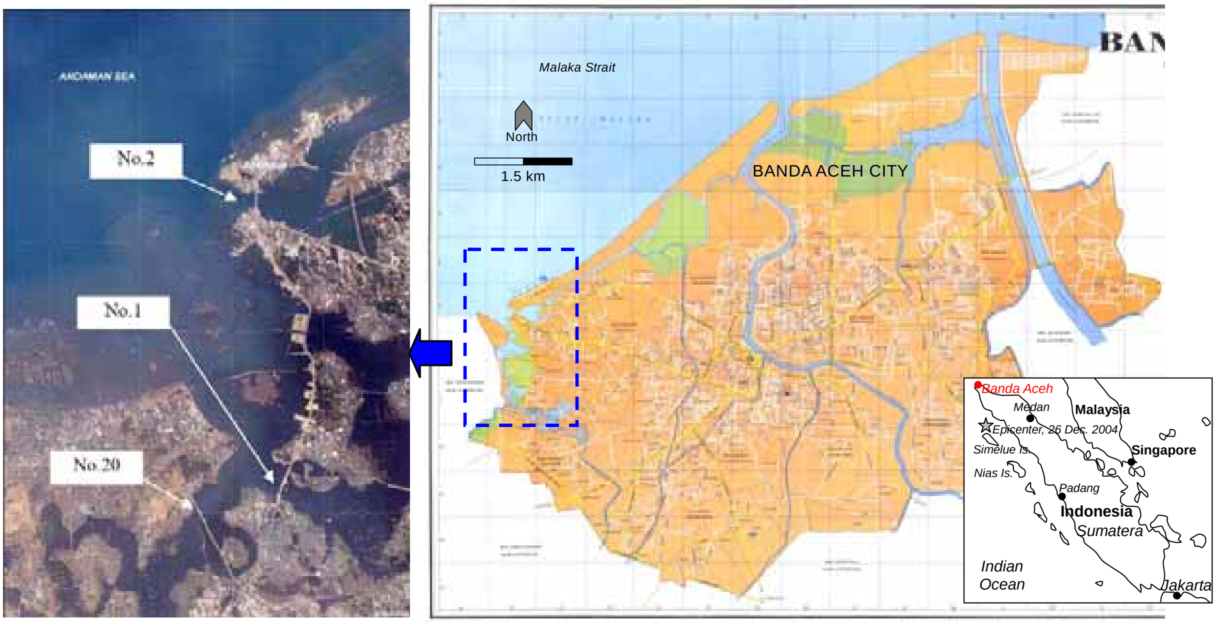

Figure 6. Location of the Surveyed Bridges in Banda Aceh

The condition of Bridge No.2, Ulee Lheue Bridge, is shown in Figure 6. It is a three-span bridge supported by two abutments and two piers. One span consists of a deck supported by five prestressed-concrete girders. From the plan view (Figure 6a), it is clear that the bridge decks were displaced in the direction of the tsunami water flow. The bridge is still functioning although some damages were clearly spotted. The bridge is located very close to the coast. The tsunami height in Ulee Lheue coast is estimated as 12 meter (Matsutomi, et al., 2006). Therefore, the bridge and its surroundings should have undergone severe hydrodynamic force by the tsunami.

Bridge No.1, Asoe Nanggroe, also underwent similar damage mechanism (Figure 8). The deck movements were not uniform and prevented from being washed away. The minimum water velocity capable of displacing the decks of this bridge is calculated as 18.89 km per hour. Since the decks moved non-uniformly in the lateral direction, they were locked to each other and prevented from being washed away. This non-uniformity can be seen from the gap between the two decks.

Bridge No. 20, Peukan Bada, a one-span bridge, also underwent similar mechanism (not shown in the figure). The minimum water velocity is calculated as 14.7 km per hour. It is smaller than the previous ones since the deck is lighter.

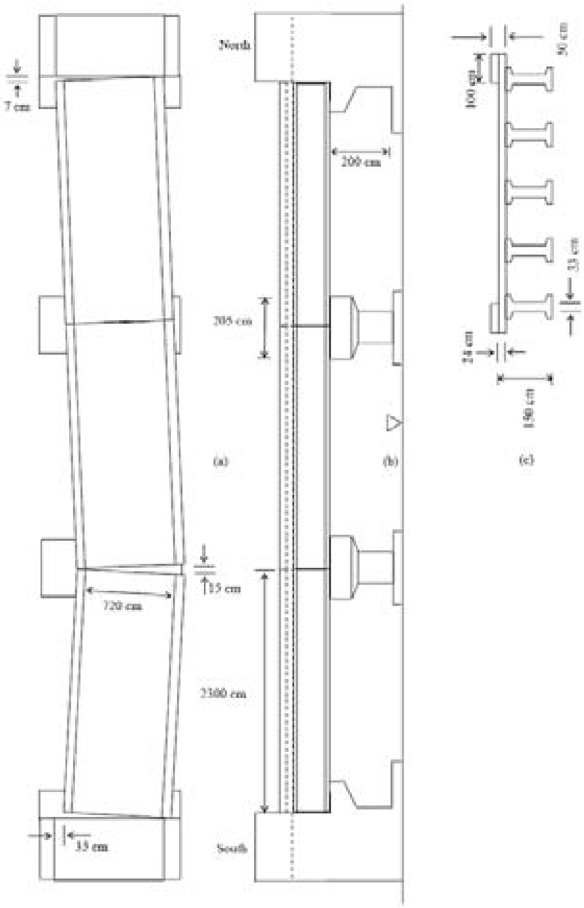

Figure 6. Displacement and Dimension of Ulee Lheue Bridge after 2004 Tsunami

Figure 7. Asoe Nanggroe Bridge after the 2004 Tsunami

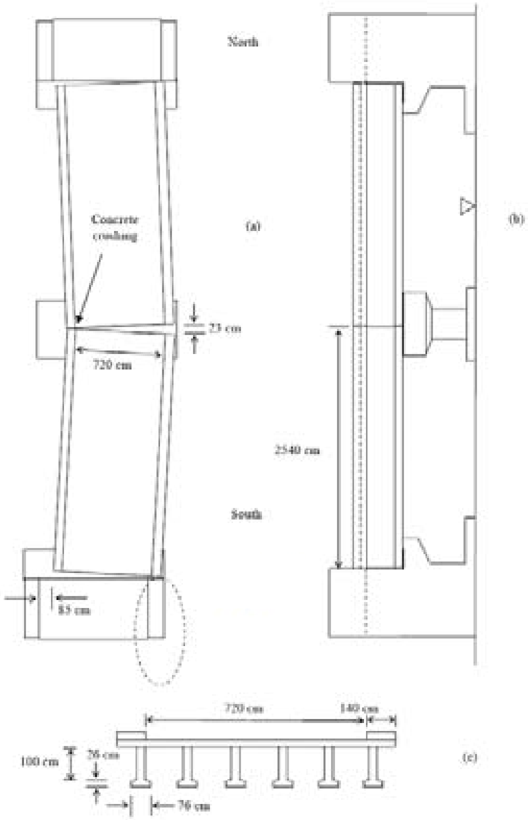

Figure 8. Displacement and Dimension of Asoe Nanggroe Bridge after 2004 Tsunami

EXPERIMENTAL TESTS ON TSUNAMI FORCES

Experimental tests were carried out to measure the hydrodynamic force on bridge models, which is a function of the bridge shape, water depth, water velocity, and floating debris. Factors responsible for resisting and reducing the hydrodynamic forces for design purposes are also studied.

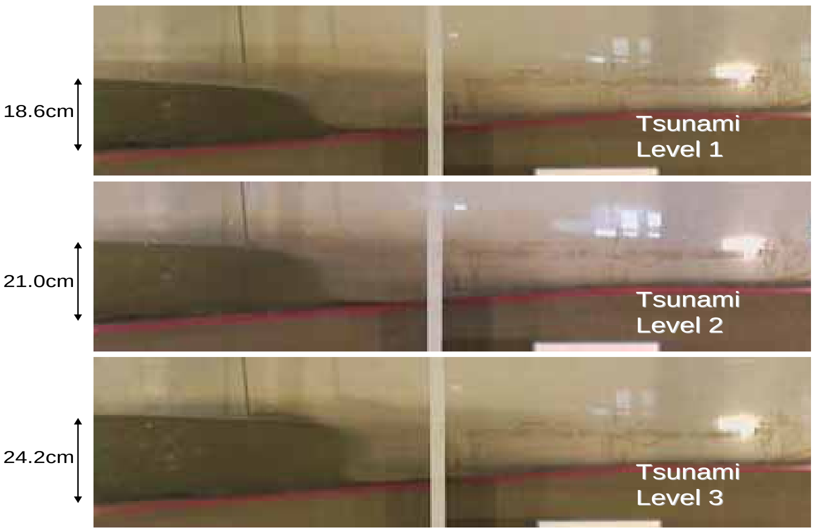

Figure 9. Tsunami Levels for the Experiments

Cases Studied (with 3 different tsunami heights (Figure 9)):

- Ulee Lheue Bridge in Banda Aceh, Indonesia, is modelled (1:77 Scale) and the model is attached on Force Measuring Table; This is called Normal Case.

- Ulee Lheue Bridge Model (1:77 Scale) is attached on Force Measuring Table; Two girders are removed to represent a three-girder bridge; This is called 3Girders Case.
- Ulee Lheue Bridge Model (1:77 Scale) is attached on Force Measuring Table; Debris Model is put in front of the bridge model; This is called Debris Case.

From Figure 11, the results show a correlation between the tsunami water velocity and the force on the bridge. Figure 4a shows the force vs velocity on the 5 girder bridge model which represents the Ulee Lheue Bridge. The force becomes larger when the amount of girder is less (Figure 11b, for a 3-girder bridge model). The force is also larger when debris model is included in the experiments (Figure 11c). Figure 11d shows the correlation between debris force and velocity. The effect of adding a breakwater in front of the bridge in order to reduce the tsunami force and velocity to the bridge are also studied. The results show that a breakwater height of about less than half of the tsunami runup height (tall breakwater) is not effective in reducing tsunami force and velocity.

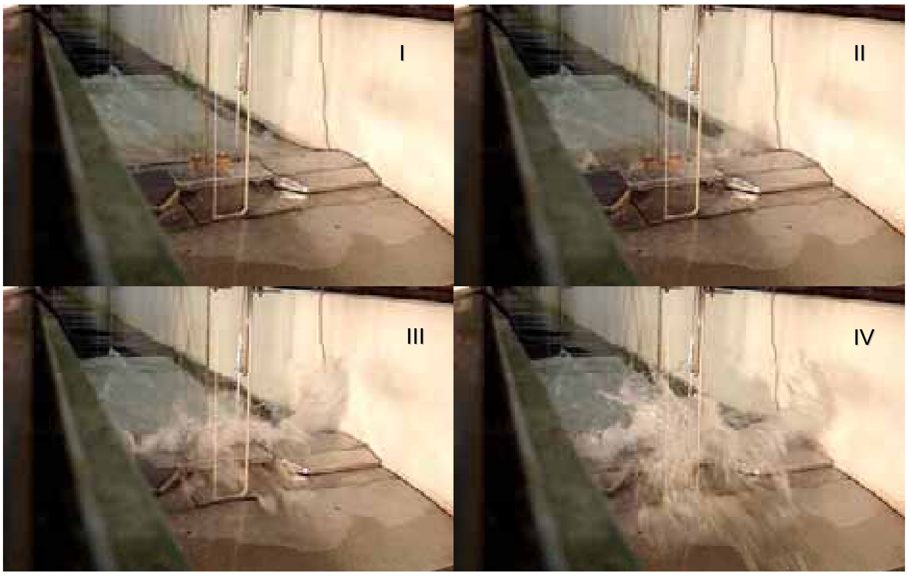

Figure 10. A Bridge Model under Sequence of Tsunami Runup Model

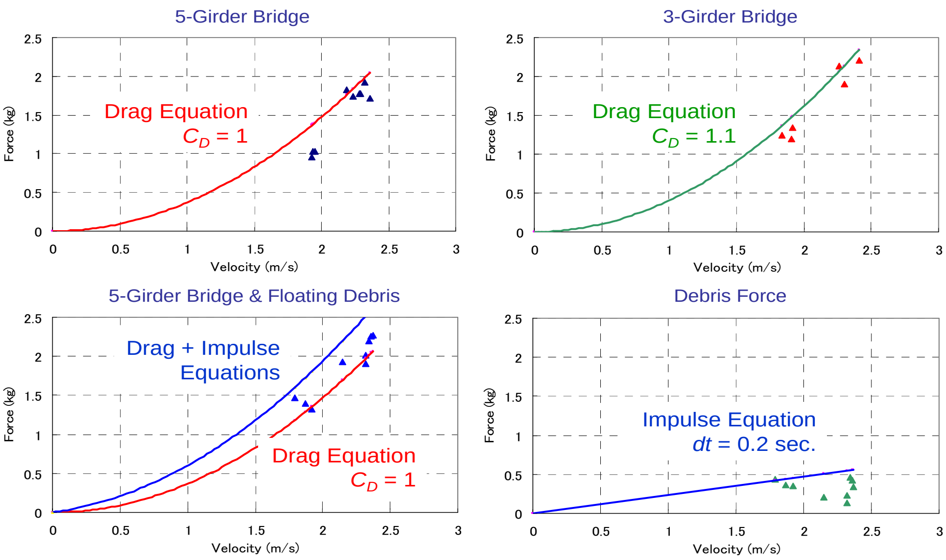

Figure 11. Correlation between Velocity and Force to the Bridge Model (a) five-girder bridge, (b) three-girder bridge, (c) five-girder bridge with floating debris, and (d) debris force

TSUNAMI HEIGHT MEMORIAL POLES

Eighty five Tsunami Height Memorial Poles are now being under construction in Banda Aceh and surrounding areas with the help of Japanese people. The objectives of the poles are:

- encourage people to be prepared for the next one,
- keep the memory of tsunami attack,
- educate next generation the important lessons from the tsunami,
- mourn the passed away people and to restore and reconstruct Banda Aceh from the disaster,
- keep accurate data of tsunami-height for future planning,
- be escaping sign with the tsunami-height,
- encourage local people to live with hope and ease under tsunami risk, and be a symbol of Banda Aceh as the tsunami-attacked city.

Figure 12. Site Visit to a Tsunami Pole near a Mosque

Figure 13. A Tsunami Pole at a School

Figure 14. Tsunami Pole Locations in Banda Aceh

Figure 15. Message Written on a Pole

The height of the pole is the height of tsunami runup in the area. At the middle, information on height, direction, name of location, and distance from shore is written. Also written are memory, advice, pray, organizer, and sponsor.

Locations of the poles are selected for the people to easily see the sign on the pole and to run to the evacuation sites during a future tsunami attack. The project is sponsored by Japanese people through Embassy of Japan in the Republic of Indonesia under a project named “The Project for Supporting Education of Tsunami Disaster Prevention in Nanggroe Aceh Darussalam”. The project was started on December 25, 2005.

(a) Explaining the Importance of Poles to Locals
(b) A Pole at an Elementary School
(c) A High Pole near the Coast

Figure 16. Some of the Tsunami Height Memorial Poles

SUMMARY

The important lessons from the disaster should be passed to the next generations. People should be encouraged to be prepared for the next disaster by education. Accurate data of past disaster should be kept for future planning. Local people should be encouraged to live with hope and ease under the risk of natural disaster.

ACKNOWLEDGMENT

Professor Tomotsuka Takayama’s assistance in realizing the tsunami experimental tests is gratefully acknowledged. The research on tsunami force was funded by the Japan Society for the Promotion of Science. The authors would like to express their gratitude to the institution and people who are generously supporting the survey, experiments, and the projects mentioned in this paper.

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SEISMIC EVALUATION AND REHABILITATION OF VULNERABLE RC BUILDINGS - EXPERIENCES AND LESSONS IN JAPAN -

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Key Words: seismic evaluation, seismic rehabilitation, RC buildings

INTRODUCTION

Japan is located in an earthquake-prone region and has experienced numbers of damaging earthquakes. During the last several decades, various efforts have been made on the development of seismic design methodologies, evaluation of existing buildings, upgrading vulnerable buildings. In this paper, background experiences on damaging earthquakes, current efforts and countermeasures are briefly overviewed focusing on RC buildings in Japan, and key issues on seismic evaluation and related technical aspects which may help future development of seismic upgrading of buildings in Indonesia are discussed.

BRIEF HISTORY OF DAMAGING EARTHQUAKES AND SEISMIC EVALUATION IN JAPAN

Since 1920's, a large number of RC buildings have been designed and constructed in Japan according to the seismic code (see Table 1). Damage to buildings due to past earthquakes such as 1968 Tokachi-oki earthquake or 1978 Miyagiken-oki earthquake, however, revealed that some of the existing RC buildings may not have sufficient seismic capacity and may sustain serious damage due to severe earthquakes. The most important lessons learned from the observed damage was that the ultimate lateral resistance of existing building might be different even if they had been designed according to the same seismic code, i.e., some buildings may have lateral resistance significantly exceeding code-specified strength while others may have insufficient resistance and ductility against strong shakings. It was, therefore, an upsurge among earthquake engineers to develop the technique to find out and rehabilitate vulnerable buildings to mitigate damage against future earthquakes.

After the 1968 Tokachi-oki earthquake, comprehensive research projects to revise the seismic code and to develop the new seismic design methodology actively started. At the same time, various techniques to estimate seismic capacity of existing RC buildings have been proposed. In 1977, the

Table 1 Damage statistics due to past earthquakes in Japan

	Damaging earthquakes and related issues	Magnitude	Fatalities	Damaged buildings	
				Heavy	Moderate
1891	Nobi	8.4	7273	142177	-
1923	Kwanto	7.9	99331	128266	126233
1924	***Urban Building Law (applied to buildings in urban cities)***				
1944	Tohnankai	8.0	998	26130	46950
1946	Nankai	8.1	1330	11591	23487
1948	Fukui	7.3	3895	35420	11449
1950	***Building Standard Law (applied to buildings throughout the country)***				
1964	Niigata	7.7	26	2134	6293
1968	Tokachi-oki	7.9	50	928	4969
1971	***Revision of Seismic Code***				
1977	***Seismic Evaluation Standard and Rehabilitation Guidelines (RC)***				
1978	Miyagiken-oki	7.4	28	1383	6190
1981	***Revision of Seismic Code***				
1990	***Revision of Standard and Guidelines (RC)***				
1995	Hyogoken-Nambu (Kobe)	7.3	6432	105000	144000
	Law to promote Seismic Evaluations and Rehabilitations				
2001	***Revision of Standard and Guidelines (RC)***				
2004	Niigata-ken-chuetsu	6.8	65	3175	13792

unified standard and guidelines for seismic evaluation and rehabilitation of existing RC buildings (JBDPA a, b) were developed by the special committee at the Japan Building Disaster Prevention Association under the sponsorship of the Ministry of Construction, Japanese Government, and have been applied to existing buildings. Their applications had been, however, localized in Tokyo Metropolitan Area including Chiba and Kanagawa prefectures, or in Shizuoka prefecture where a large-scale earthquake named “Hypothetical Tokai Earthquake” is predicted to occur in the near future from the seismological point of view.

The 1995 Hyogoken-nambu (Kobe) earthquake caused devastating damage to urban centers and triggered a new direction in seismic evaluation and rehabilitation of existing vulnerable buildings in Japan. Fig. 1 shows the damage statistics of RC school buildings due to the Kobe earthquake (Nakano 2004, after AIJ 1997). In the last 4 decades, the Japanese seismic design code was revised in 1971 and 1981 (see Table 1). As can be found in the figure, the damage rate is highly dependent on the code generation, and those designed in accordance with the pre-1981 code had more serious damage. The widespread damage to older buildings designed to meet the code criteria of the time of their construction revealed the urgency of implementing rehabilitation of seismically vulnerable buildings.

Since the catastrophic event of Kobe earthquake, various integrated efforts have been directed by the Japanese Government and engineering professionals toward upgrading seismic performance of vulnerable buildings and implementing learned and re-learned lessons for earthquake loss mitigation. Several new laws such as *Special Measures Law on Earthquake Disaster Prevention* and *Law to Promote Seismic Rehabilitation* promulgated soon after the event have undoubtedly served as fundamentals for nationwide programs for seismic rehabilitation of vulnerable buildings. It should be noted, however, that it was almost 20 years since the Seismic Evaluation Standard was first developed in 1977.

BASIC CONCEPT OF SEISMIC EVALUATION IN JAPAN

Basic Concept of Evaluation

Since the first development of the Standard and the Guidelines in 1977, they have been revised twice in 1990 and in 2001 but the basic concept to evaluate seismic capacities of buildings has been unchanged. In the Standard, the seismic capacity of a structure is expressed by the *Is*-index at each story level and each direction, defined primarily in the following function form.

$$Is = f\,(C, F, S_D, T) \qquad (1)$$

where, *Is*-index is seismic capacity index; C- and *F*-index are lateral resistance index and ductility index, respectively; S_D- and *T*-index are modification factors to allow for the negative effects on seismic capacity due to the structural irregularity and deterioration after construction, respectively. Detailed descriptions on the seismic evaluation procedure can be found in Appendix in this paper.

As is well accepted in the earthquake engineering field, the ductility and strength is essential factors to design a structure. This is all the same in evaluating the seismic capacity of existing buildings and even in analysis. As summarized in Table 2, the difference among them is "what is given ?" and "what will be obtained ?".

This Standard has been widely applied to the existing building in Japan, especially after the nationwide projects on seismic evaluation and rehabilitation started following the 1995 Kobe earthquake. Fig. 2 shows the histogram of *Is*-index of existing RC buildings in Japan, where more than 1,600 buildings are evaluated. This graph provides valuable information about seismic capacity

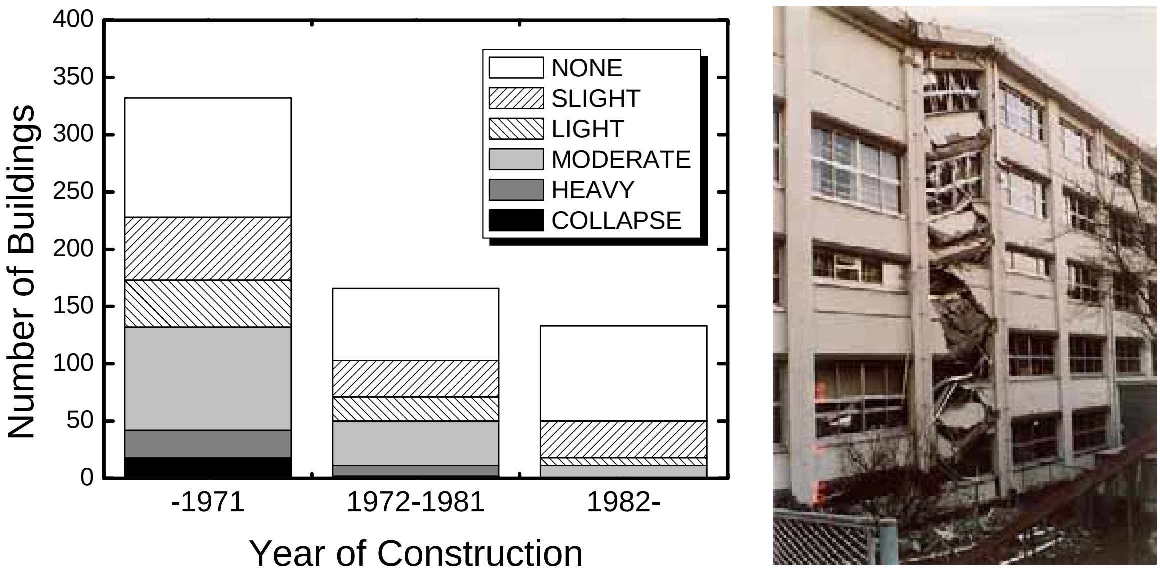


Fig. 1 Damage statistics of RC schools after 1995 Kobe earthquake (Nakano 2004, after AIJ 1997)

Table 2 Relationship of analysis, design and evaluation

	response analysis	seismic design	seismic evaluation
earthquake motion (Max acceleration)	given	given	to be obtained
resistance (yield strength)	given	to be obtained	given
displacement (ductility)	to be obtained	given	given

of RC buildings before damaging earthquake and further serves as the fundamental data for damage estimation to future earthquakes, criteria setting to identify candidate buildings to be seismically rehabilitated, investigations of rehabilitation effects on damage mitigation (Okada and Nakano 1988).

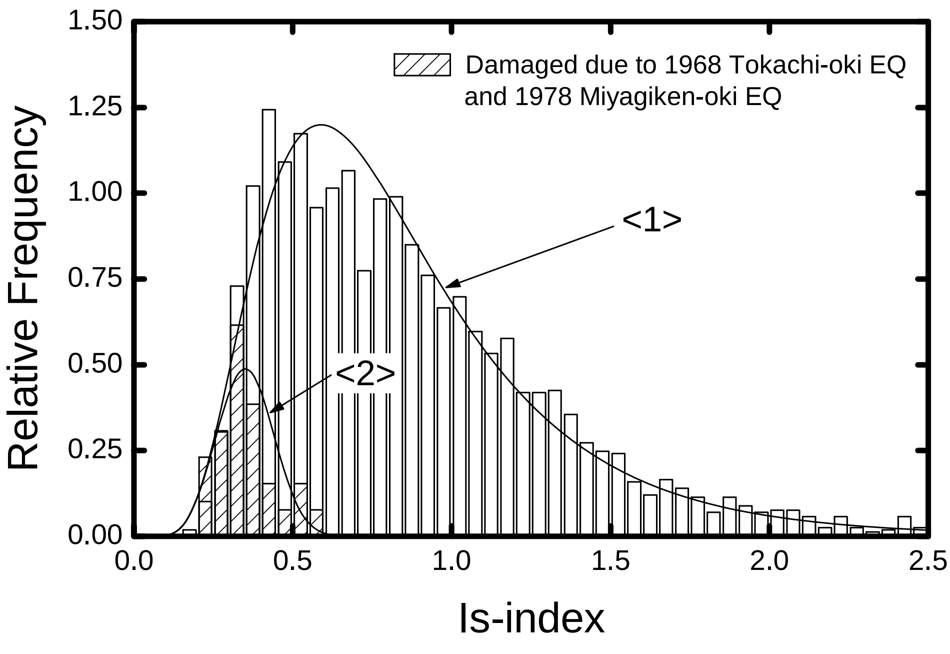
Criteria to Identify Safe Buildings

To evaluate the structural safety against future earthquakes, it is also essential to determine the required seismic capacity, i.e., criteria to identify buildings for seismic rehabilitation. In the Guidelines (JBDPA b), a building with *Is*-index larger than the required seismic capacity index, *Iso*, as shown in Eq. (2) is judged "safe."

$$Is \geq Iso \qquad (2)$$
$$Iso = Es \text{ x } Z \text{ x } G \text{ x } U$$

In Eq. (2), *Es*-index is a basic seismic capacity required for the building concerned. *Z*-, *G*-, and *U*-index are factors to allow for the seismicity, ground condition, and importance of the building, respectively.

One possible way to determine the required seismic capacity is to compare the capacity between damaged and survived buildings in the past earthquakes. The hatched area in Fig. 2 shows the histogram of *Is*-Indices for moderately or severely damaged buildings due to 1968 Tokachi-oki earthquake or 1978 Miyagiken-oki earthquake. As can be found in the figure, no major damage was found in buildings with *Is*-index higher than 0.6 during these two earthquakes. Similar investigations were also made after the 1995 Kobe earthquake, and the basic required capacity index 0.6 is considered appropriate for the criteria to identify candidates for seismic rehabilitation.



NOTE: The histogram in white represents the distribution of *Is*-index of more than 1,600 RC buildings in Shizuoka prefecture before damaging earthquakes. The distribution can be approximated with a log-normal function shown with the curve <1>. The hatched area indicates damaged buildings due to two major earthquakes. As can be found in the figure, no major damage was found in buildings with *Is*-index higher than 0.6 during these two earthquakes. The curve <2> in the figure is obtained from a probabilistic study to numerically estimate the damage distribution.

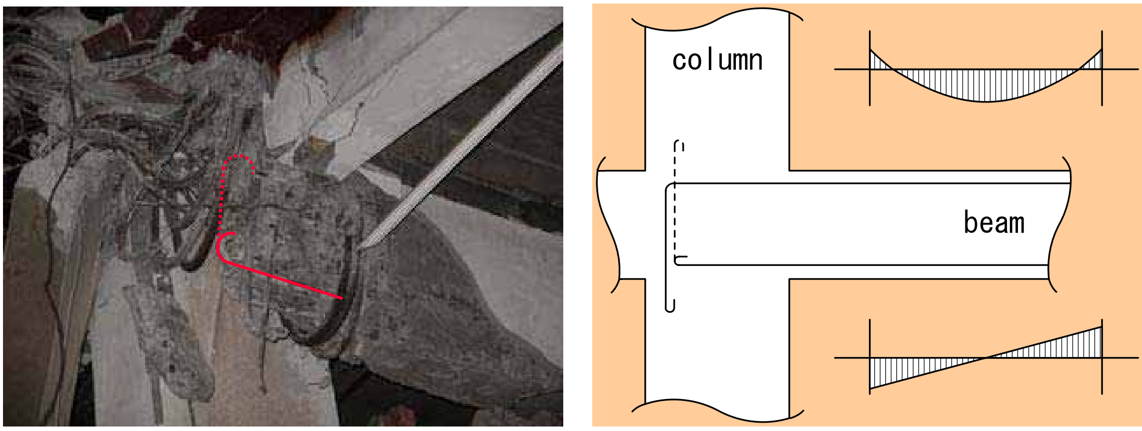
Fig. 2 Distribution of *Is*-index in Japan (Okada and Nakano 1988)

ESSENTIALS FOR SEISMIC EVALUATIONS

Weak Link Governing Structural Performance

Strength and ductility of structural members are the most essential factors for seismic evaluation of structures. Their flexural and shear strengths are usually of great significance in evaluating seismic capacity of RC buildings when either flexural or shear strength of members governs the structural behavior. This is especially so when the joints between members such as beam-column joints are rigidly connected, and damage is expected to occur primarily along structural members. It should be noted, however, that premature failure due to pull-out failure of beam rebars at beam-column joints and/or beam-column failures are often found after 2006 Central Java earthquake as well as other damaging earthquakes as shown in Photos 1 and 2. This damage is attributed to the improper design detailing of reinforcement placed in members, causing strength and ductility lower than potential member performance.

To properly estimate the structural performance and the seismic capacity of buildings in Indonesia, pull-out failures of rebars and beam-column joint failures as well as typical shear (and also flexural) failure in columns and walls should be taken into account in evaluating member strength and



Note: Some beam bottom reinforcing bars were improperly detailed and pulled out of the beam-column joints. They had 180-degree hooks in the ends but were straightly terminated in the joints without bent anchorage into the joint core concrete. Rigid beam-column joints properly confined with lateral reinforcement and beam reinforcement bent into the joint core to develop its full anchorage are most essential for RC structures to perform successfully during earthquakes.

Photo 1 Pull-out failure of beam rebars at joint during 2006 Central Java Earthquake

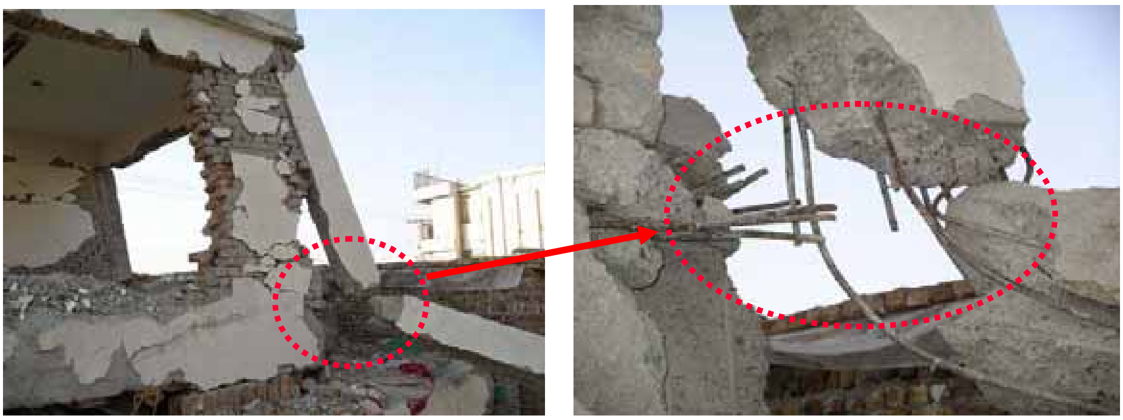


Photo 2 Collapsed 3 story building due to beam-column joint failure during 2005 Pakistan Earthquake

estimating the failure pattern of an entire structure. To identify the weak link is also of great importance to properly determine strategies (i.e., where and how to strengthen) for seismic rehabilitation of vulnerable buildings.

Highly sophisticated computer programs may not help much understand structural responses and predict failure sequences during strong shakings unless expected failure modes are properly considered in computations.

Contribution of Nonstructural Elements to Structural Performance

Nonstructural elements placed in RC frames, which are most typically masonry walls, are often neglected in the structural design. Past damaging earthquake, however, often revealed that they significantly affected structural responses due to column shortening, stiffer frames causing unexpected soft story in the adjacent story above and/or below, etc. as shown in Photos 3 and 4. Although the conservative strength may be obtained through neglecting effects of nonstructural elements, they may give adverse effects on structural performance and eventually cause brittle failures.

To evaluate the seismic capacity, effects of nonstructural elements on structural behavior should be properly taken into account.

1992 Erzincan EQ (Turkey) 2004 Chuetsu EQ (Japan) 1999 Chi-Chi EQ (Taiwan)

Photo 3 Contribution of nonstructural elements to column shortening and damage

Photo 4 Contribution of nonstructural elements to soft first story (1992 Erzincan EQ)

Appropriate Structural Modeling

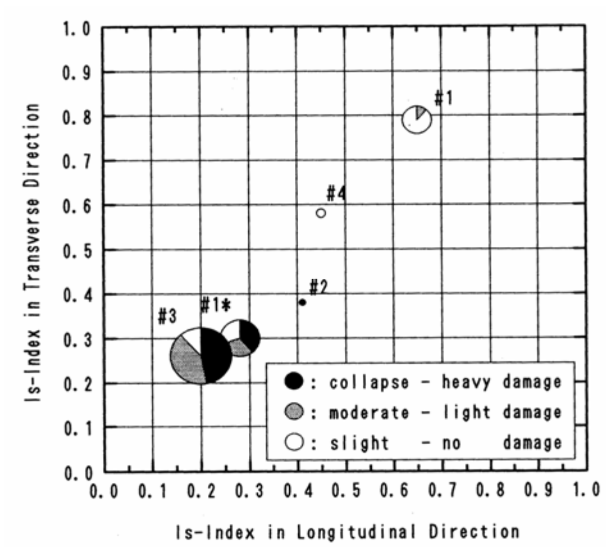
Existing structures are mathematically modeled in computing their responses. The results are therefore definitely dependent on the appropriateness of structural modeling. When the mathematical model describing a structure concerned does not represent the *real* structure, the calculated results would not be reliable enough to predict their behavior. The structural modeling for computation, therefore, would be a key factor to obtain right answers. This is exactly so even when a sophisticated computer programs are used to estimate the seismic behaviors of buildings.

Existing buildings are not often well balanced from the structural design point of view, and this may cause difficulties in their mathematical modeling to obtain right answers. The importance of rational structural modeling rather than high level computer codes (e.g., 3D or FEM etc.) should be highly focused and recognized by engineers for successful seismic evaluations.

Data Collection for Criteria Setting

The criteria to identify safe buildings, or the required capacity against future earthquakes expected at the site, should be determined through comparison between evaluation results and observed damage as well as numerical simulation results. As described earlier, the required capacity in Japan is made through intense studies on the relationship between *Is*-index and observed evidence in the past damaging earthquakes, together with statistical/probabilistic studies and nonlinear response analyses.

The Japanese Standard also has been applied to buildings outside Japan such as Mexico (after 1985 Mexico EQ), Turkey (after 1992 Erzincan EQ and 1999 Kocaeli EQ), Taiwan (after 1999 Chi-Chi EQ), Pakistan (after 2005 Kashmir EQ), etc. to investigate their seismic capacities and to identify major reasons of damage (Okada et al. 1988, Nakano and Kato 1994). Fig. 3 shows an application example after 1992 Erzincan earthquake in eastern Turkey. In this study, the correlation of seismic performance and *Is*-index of 5 standard structural designs (types #1, #1*, #2, #3, and #4) is investigated. In the affected area, approximately 100 buildings were designed and constructed according to either design type #1, #1*, or #3. The size of each circle in the figure corresponds to the number of buildings constructed according to an identical standard design type and the shaded portion shows the ratio of 3 structural damage categories shown in the legend. As can be found in the figure, the damage ratio increases according to decrease in *Is*-index, and the index can be a good estimator to identify vulnerable buildings in the affected area in Turkey.



General view of type #1 and #1* buildings in the affected area

Fig. 3 Application example of Japanese Seismic Evaluation Standard after 1992 Erzincan Earthquake in Turkey (Nakano and Kato 1994)

Statistical investigations utilizing seismic capacities of both damaged and survived buildings, as described above, are effective to find rational criteria. Note that the data on buildings that survived an event or those that have not yet experienced damaging earthquakes should also be collected since they are valuable for criteria setting through comparison with those on damaged buildings.

Review of Evaluation Results

To predict seismic performance that is most likely to be achieved under strong ground shaking is the first priority for seismic evaluations. This would lead the building to successful rehabilitation if it needs redesign for upgrading seismic performance. To this end, a review committee consisting of professionals on building engineering such as university professors, practitioners, building officials etc. is generally set up in each local district in Japan. In the committee, structural modeling, calculations results, and rehabilitation proposals are reviewed from the effectiveness and economical engineering practice point of view based on sound engineering and scientific principles and knowledge.

This system helps engineers find rational solutions for seismic evaluation and rehabilitation of buildings in Japan.

Education Programs of Engineers

The main objective of seismic evaluation is to properly estimate structural behaviors. It should be, however, noted that the seismic evaluation as well as redesign for rehabilitation is often more difficult than designing new constructions. Proper estimations can be made through knowledge and experiences on structural mechanics and dynamics, structural design and practice, and lessons learned from earthquake damage. Transfer of engineering knowledge and experiences from well-experienced professionals is of great importance for continued activities to evaluate seismic capacity of existing buildings and to upgrade seismic performance of vulnerable buildings since a safer city can bot be built in a day.

CONCLUSIONS

Seismic evaluations are undoubtedly most important for a better understanding of seismic capacities of existing buildings and predicting their responses. Rational strategies to upgrade seismically vulnerable building can be identified only with right estimations of structural performances. The estimated results should be, of course, consistent with the weak link and the consequent failure mechanism observed in the past damaging earthquakes. For this purpose, the development of evaluation procedure that can describe primary behaviors governing the responses of entire structure is most essential.

Criteria setting to identify safe buildings is another task when a seismic evaluation is made on a building. This can be achieved through a combination of comparison between evaluation results and observed damage, numerical simulations, and earthquake hazard.

To complete a system for seismic evaluation is a hard task which may need persistent and patient efforts, but it can not be achieved without rational observation of evidence. The authors do hope that engineers in Indonesia could develop and implement seismic evaluation procedure through sharing information and knowledge obtained from earthquake damage in both countries.

APPENDIX: BASIC CONCEPT OF JAPANESE STANDARD FOR SEISMIC EVALUATION OF EXISTING RC BUILDINGS

The Standard for Seismic Evaluation (JBDPA 1990a, 2001a), designed primarily for pre-damaged existing RC buildings in Japan, defines the following structural seismic capacity index *Is* at each story level in each principal direction of a building.

$$Is = Eo \times S_D \times T \tag{A-1}$$

where, *Eo* : basic structural seismic capacity index, calculated by the product of Strength Index (*C*), Ductility Index (*F*), and Story Index (ϕ) at each story and each direction when a story or a building reaches the ultimate limit state due to lateral force ($Eo = \phi \times C \times F$)

C : index of story lateral strength expressed in terms of story shear coefficient

F : index of story ductility, calculated from the ultimate deformation capacity normalized by the story drift of 1/250 when a typical-sized column is assumed to fail in shear. *F* is dependent on the failure mode of a structural member and its sectional properties such as bar arrangement, member's geometric size etc. *F* is assumed to be in the range of 1.0 to 3.2 for ductile columns, 1.0 to 1.27 for brittle columns, and 0.8 for extremely brittle short columns; 1.0 to 2.0 for ductile walls and 1.0 for brittle walls.

ϕ : index of story shear distribution during earthquake, estimated by the inverse of design story shear coefficient distribution normalized by the base shear coefficient. $\phi = (n+1)/(n+i)$ is basically employed for the *i*-th story of an *n* story building

S_D : reduction factor to modify *Eo* index due to stiffness discontinuity along stories, eccentric distribution of stiffness in plan, irregularity and/or complexity of structural configuration, basically ranging from 0.4 to 1.0

T : reduction factor to allow for time-dependent deterioration grade, ranging from 0.5 to 1.0

A required seismic capacity index *Iso*, which is compared with *Is*-index to identify structural safety against an earthquake, is defined as follows.

$$Iso = Es \times Z \times G \times U \tag{A-2}$$

where, *Es* : basic structural seismic capacity index required for the building concerned. Considering past structural damage due to severe earthquakes in Japan, the standard value of *Es* is set 0.6.

Z : factor allowing for the seismicity

G : factor allowing for the soil condition

U : usage factor or importance factor of a building

Typical *Iso* index is 0.6 considering *Es* = 0.6 and other factors of 1.0. It should be noted that $C_T \times S_D$ defined in Eq. (A-3) is required to equal or exceed $0.3\ Z \times G \times U$ in the Standard to avoid fatal damage and/or unfavorable residual deformation due to a large response of structures during major earthquakes.

$$C_T \times S_D = \phi \times C \times S_D \tag{A-3}$$

Seismic rehabilitation of existing buildings is basically carried out in the following procedure.

(1) Seismic evaluation of the structure concerned (*Is* and $C_T \times S_D$)

(2) Determination of required seismic capacity (*Iso*)

(3) Comparison of *Is* with *Iso* and of $C_T \times S_D$ with $0.3\ Z \times G \times U$

* If $Is < Iso$ or $C_T \times S_D < 0.3\ Z \times G \times U$ and therefore rehabilitation is required, the following actions (4) through (6) are needed.

(4) Selection of rehabilitation scheme(s)
(5) Design of connection details
(6) Reevaluation of the rehabilitated building to ensure the capacity of redesigned building equals or exceeds the required criteria

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(Submitted: February 5, 2007)

SUPPORT ACTIVITIES FOR THE RECOVERY AND RECONSTRUCTION BY TRANSFERING THE TECHNIQUE ON GEOTECHNICAL INVESTIGATION IN NIAS ISLAND DAMAGED BY THE M8.7 OFF-SHORE SUMATRA EARTHQUAKE, MARCH 28, 2005

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Key Words: Reconstruction, Geotechnical Investigation, Swedish weight Sounding, Strong Motion, Liquefaction, Lateral Flow,

INTRODUCTION

The Sumatra Earthquake of December 26, 2004 caused the most disastrous tsunami in Indian Ocean and great disaster to the countries around the Indian Ocean, especially in Indonesia. Three months after the earthquake, another large earthquake with a magnitude 8.7 occurred on March 28, 2005 nearby Nias Island at the west coast area of Sumatra 500km away from the epicenter of the 2004 earthquake. Severe damage was caused by strong ground motion especially in Nias Island. For these disasters, Japanese organizations in cooperation with some Indonesian organizations conducted support activities for the recovery and reconstruction of the affected areas. These included making recommendations and giving instructions for geotechnical investigations and the practical utilization of its results for temporary repair and rehabilitation of infrastructures and buildings (e.g. Support Team of JSCE, 2005; Miwa et al., 2006a). Also educational activities on disaster prevention (e.g. Hamada et al., 2005a; Tsukazawa et al., 2005; Kitajima et al., 2006) as well as the reconnaissance surveys of earthquake affected areas. In this article, the support activities for recovery and reconstruction on transferring a geotechnical investigation and example of its result conducted by JSCE team (e.g. Aydan et al. 2005; Miwa et al. 2006a, Miwa et al. 2006b, Miwa et al. 2007).

SUPPORT ACTIVITIES FOR RECOVERY AND RECONSTRUCTION

Background of activities

After the Sumatra Earthquake of December 26, 2004, which caused the most disastrous tsunami in Indian ocean and severe disaster to the countries around the Indian Ocean, especially in Indonesia, Japan Society of Civil Engineers (JSCE) had dispatched a reconnaissance team to Banda Ache for the investigation of the damage to Infrastructures such as road, bridges, port facilities, riverbanks and lifeline systems in February, 2005 (Goto et al., 2005). Also, JSCE dispatched an expert team for disaster prevention education to assist the educational activities for young people on tsunami and earthquake disaster in cooperation with the government agencies of the concerned countries. In order to continue and enlarge such an activity, students of Waseda and Kyoto University have conducted disaster prevention education several times at damaged and liable to damage areas in Indonesia, in 2005 and 2006.

On the other hand, temporary repairs and rehabilitation of infrastructures, like roads, bridges and so on are of the most urgent subjects in Nias Island since many structures were damaged by strong ground motion during the large earthquake that occurred on March 28, 2005. By the request of government and legislature of province, JSCE dispatched the expert team to support the repair works and rehabilitation of public facilities in April 2005. The team visited Nias Island to investigate the damage of the infrastructure, and make recommendations for temporary repair and rehabilitation to concerned government agencies such as the Nias public work office and the government of the province of North Sumatra.

For example, the contents of the recommendations are as follows. As for the bridges, temporary supporting methods were introduced for the emergency stage. The existing truss decks of bridges can be used with some replacement of damaged parts for economical reconstruction during the reconstruction stage, but almost all bridges should be re-constructed because foundation structures were heavily damaged due to ground failure such as lateral movement or liquefaction. Pile design should be re-considered and their length should be sufficiently long to have required end bearing. The foundation pile should be designed to resist to the lateral flow force of liquefied ground. As for the foundation of buildings, box-like (mat, raft) foundations should be used in liquefiable areas in case piles could not be used. As for the structural design of foundation structures and for urban rehabilitation planning, ground investigations should be done to have fundamental data on ground characteristics.

Transferring the technique on geotechnical investigations

Although nine months elapsed from the earthquake at the end of 2005, the infrastructures and buildings in Nias Island had still no prospect of being re-constructed. In order to initiate recovery and reconstruction work in the region, the soil exploration data such as boring data is essential. However, available data is scarce and not sufficient for recovery and reconstruction works at the present time. Also, government of the province of North Sumatra requested for continuation of support. Therefore, experts and engineers were dispatched again by JSCE to Nias Island and the expertise advises and technical supports for recovery and re-construction were provided as the joint activity with the Institution of Engineers, Indonesia (Persatuan Insinyur Indonesia: PII) in January 2006.

In this project, transferring the technique on geotechnical investigations was one of the major purposes. Swedish Weight Sounding Test as an practical ground surveying methods was introduced to local engineers for the prediction methods of ground liquefaction and their applications to the recovery and reconstruction of the damaged areas. JSCE donated one Swedish cone penetration device to the Public works office of Nias Island Local Government upon the training of engineers. Also, JSCE donated the second device with an additional pull out device to Road and Bridge Office, North Sumatra Province October 2006. Activities of the support team were as follows; 1) Training on ground survey methods with Swedish Weight Sounding Test, 2) Training on the assessment methods of ground liquefaction and counter-measures against ground liquefaction based on the data obtained from the ground surveys, 3) Training for applications of the obtained soil data to actual recovery and reconstruction projects.

Swedish weight sounding tests were conducted by engineers in Indonesia under the instruction of engineers from Japan at two locations in Gunung Sitoli and at one location at Idano Gawo bridge in Nias Island, not only for obtaining the geotechnical information but also for training the local engineers at the technique on geotechnical investigations. Also, short courses for engineers in Nias Island and North Sumatra province were held on the utilization of the data obtained from the ground survey for the bearing capacity, the liquefaction assessment and so on. Meetings with the government of Nias prefecture, Agency of Recovery for Banda Aceh and Nias, North Sumatra road and bridge office were held about the activities at that time and in the next period of time. Figure 1 shows a photo of training of Swedish Weight Sounding Test. Training was continued until night. Figure 2 shows the photo of the short course in Nias Island and the meeting with the Governor of North Sumatra Province.

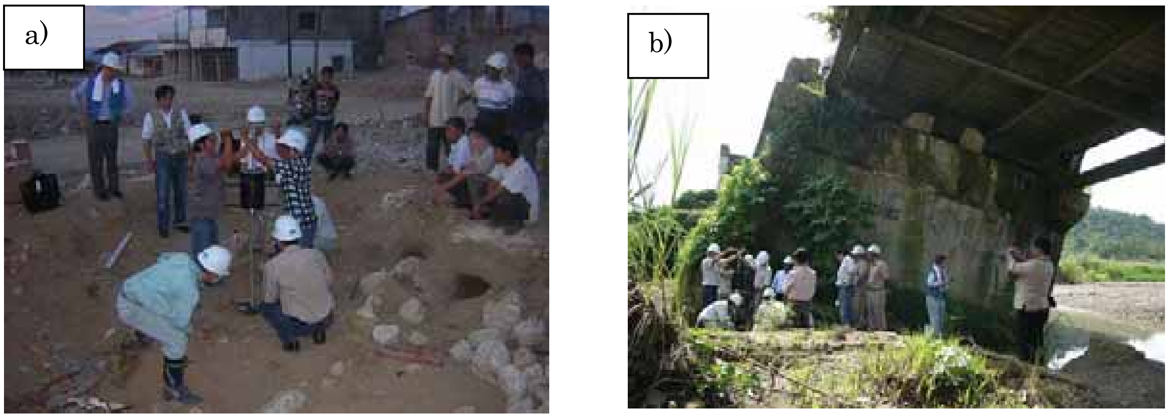

Figure 1. Training on Swedish Weight Sounding Test at (a) Gunung Sitoli b) Idano Gawo Br.)

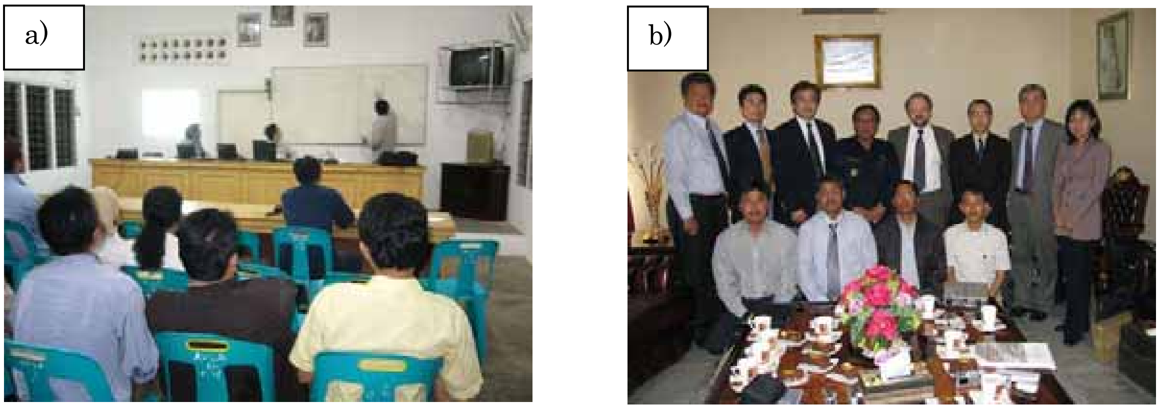

Figure 2. a) Short course in Nias Island, b) Meeting of the Government of North Sumatra Province

Issues for the future

In the future, the direct contribution of civil engineers to the society will be one of the most important issues. The activity at this time, which is an example of the direct contribution to the society, made a positive influence in training of engineers on geotechnical investigation and the planning of recovery and reconstruction projects to be carried out in Nias Island and other disaster-affected regions. However, the geotechnical investigations of ground are still lacking in Nias Island and it would be desirable to carry out both such technical support activities and investigations by local engineers in Nias Island. Continuation of the technical support and dissemination of transferred techniques, which have been done so far, are necessary for firm establishment of the technique for the reconstruction and future earthquake disaster prevention activities in Sumatra island, and implement those activities to the practical use. In order to continue the support activities for recovery and reconstruction of affected region or country, raising funds and recruiting talented people are necessary. Therefore, it is important to establish collaborative relationships among the societies of engineers, universities, government, local governments, citizens, citizens' group and private enterprises in Japan. NPO is thought to be most suitable and make such activities easier as compared with existing organizations. Therefore, NPO “Engineers without Borders, Japan” has been established for such a purpose (Hamada, 2005b).

As for the actual activity in the country suffered by disaster, it is important to make collaborative relationships with the society of engineers, universities, local governments and private enterprises in the countries affected by the disaster. At present time, a member of PII and some members of soil investigation companies and construction companies participated in our activity and took part of the work like translation the English materials to Indonesian, explanation in Indonesian language to the local engineers, logistics and so on. As for transferring the technique for soil investigation, in order to be used continuously in the region, machines should be simple and the prototype of a machine should be donated so that the required quantity of machines can be manufactured in the region.

Continuous training is necessary for the soil investigation method to be taken root in this region. Moreover, West Sumatra Province requested us to carry out the technical support and training local engineers for geotechnical investigations for earthquake disaster prevention. Therefore, JSCE decided to dispatch a third Team consisting of experts and engineers to Nias Island for providing the expertise advises and technical supports for recovery and re-construction again, and also to Medan and Padang for providing the expertise advises and technical supports for earthquake disaster mitigation between February 17 and February 25, 2007, next week. The roles of The JSCE Team are as follows;

1) Continuation of the technical support and dissemination activity of transferred techniques, which have been applied so far, for the reconstruction and future earthquake disaster mitigation activities in Sumatra island.

a) Transferring the techniques on geotechnical investigations

・Training on ground survey methods with Swedish Weight Sounding Test.

・Training on the assessment methods of ground liquefaction and counter-measures against ground liquefaction based on the data obtained from the ground surveys.

・Training for applications of the obtained soil data to actual recovery and reconstruction projects.

b) Assistance for preparing a hazard map, restoration plan of lifeline systems, urban planning, etc.

SWEDISH WEIGHT SOUNDING TEST

Swedish Weight Sounging Test is one of the sounding test used for measuring the static penetration resistance of soft ground in 10m. SPT-N Value, Bearing capacity, unconfined compressive strength can be obtained from the result of the test by using the relationship of the result of the test and strengh, bearing capacity of the soil. İt is useful for obtaining the basic characteristics of soil at the damaged area for reconstruction. Figure 3 shows the flowchart of Swedish Weight Sounding Test. Figure 4 shows the equipment of the Swedish Weight Sounding Test. Figure 5 depicts the relationship between N-value and Wsw, Nsw, which are the results obtained from the test. Once SPT-N value is obtained, liquefaction assesment can be conducted, that is very useful for reconstruction at the liquefieable area.

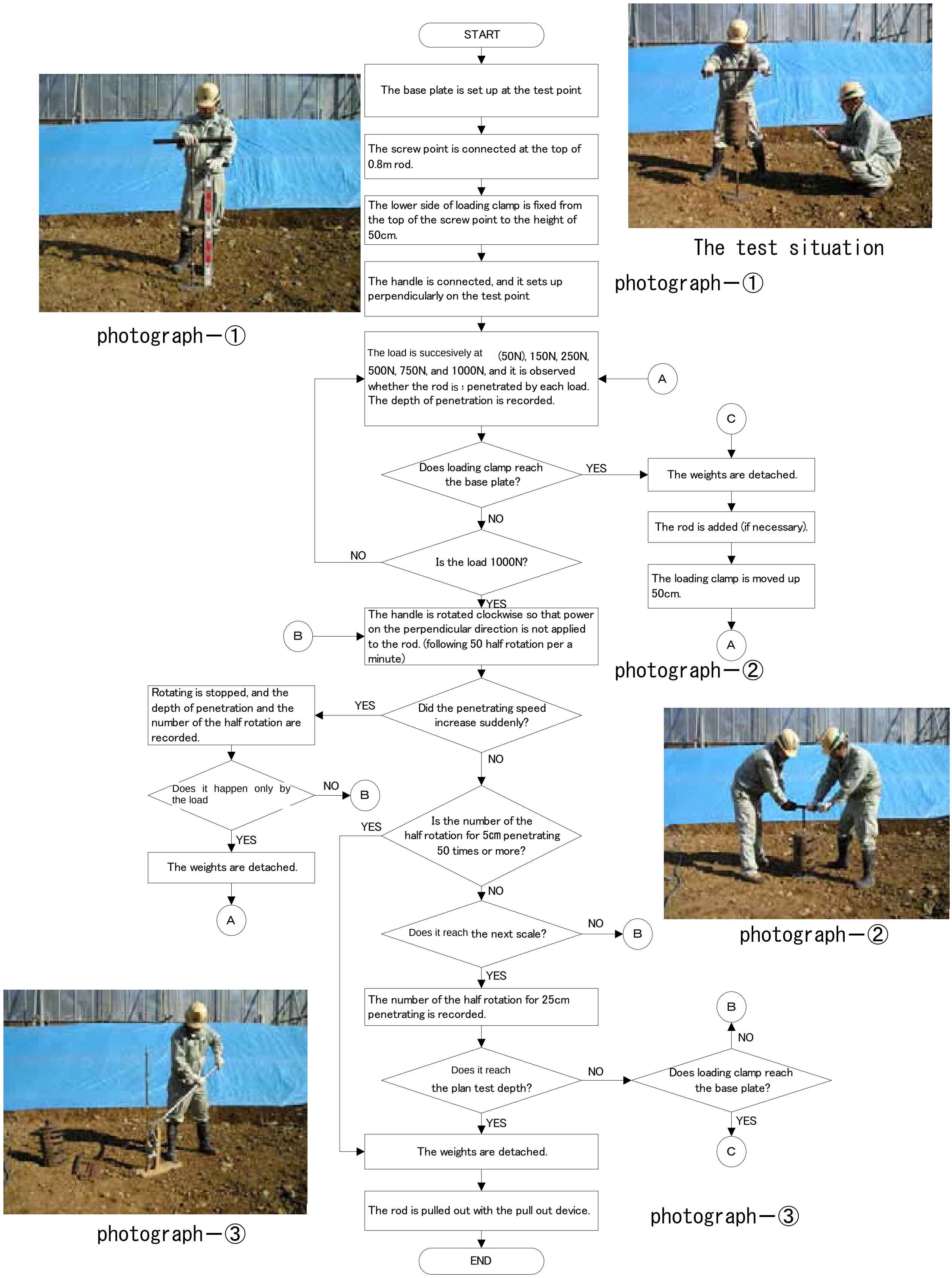

Figure 3. Flowchart fo the Swedish Weight Sounding Test

Figure 4. Equipment of the Swedish Weight Sounding Test

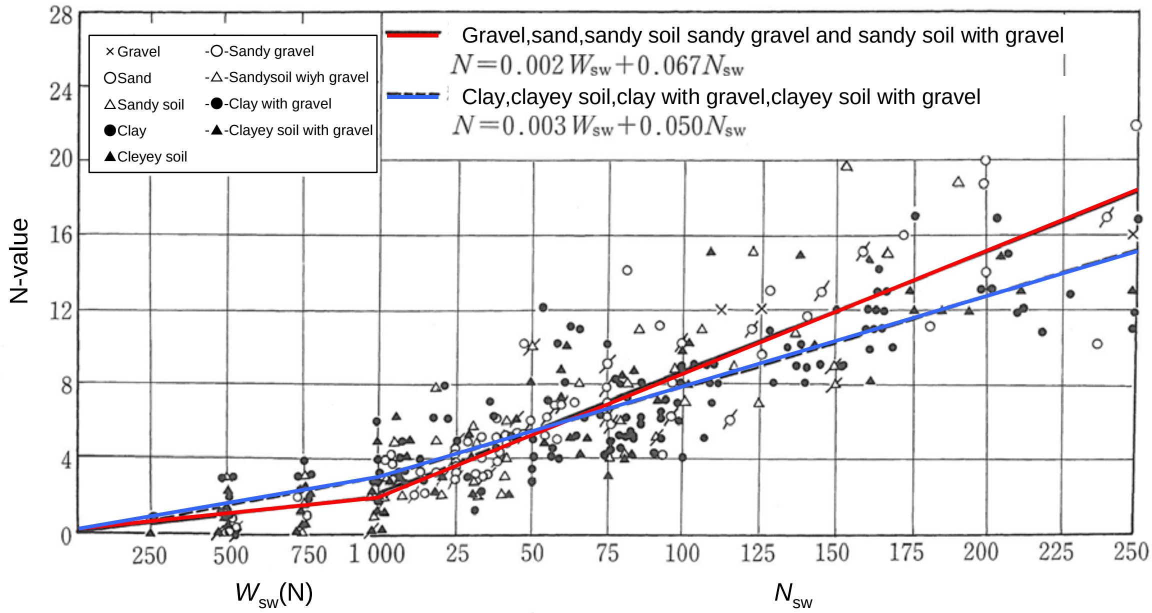

Figure 5. Relationship between N-value and Wsw, Nsw, (JGS, 2004)

APPLICATION OF GEOTECHNICAL INVESTIGATION FOR LIQUEFIED AREA

As expected from the magnitude of this earthquake, the liquefaction of sandy ground is very likely. The sandy ground is observed along seashore and riverbanks in Nias Island. Permanent ground movements such as settlement and lateral spreading, and associated structural damage due to liquefaction were widely observed in various locations along the coastal area and reclaimed ground. The lateral spreading of ground nearby bridge abutments were almost entirely associated with liquefaction of sandy soil layer. The damage induced in Gunung Sitoli due to ground liquefaction is widespread along the coastal area, reclaimed ground and riverbanks. All the possible forms of ground movements and the effects of ground liquefaction were observed such as sand boils, lateral ground movements and settlement. As a result, many buildings in such areas were heavily damaged with partial settlement, inclination and uplift of ground floor. The buildings without raft foundations and continuous tie-beams could not resist to ground failures due to liquefaction unless they are built on piles extending into the non-liquefiable layer. Figure 7 shows the damages of buildings due to liquefaction. In Figure 8 grain size distribution curves for soil samples in Gunung Sitoli can be seen. It can be seen that these soils have almost the same grain size and they are very liquefiable. Swedish weight sounding tests were conducted at 2 points in Gunung Sitoli. Soil profile, converted SPT N-value from Swedish weight sounding test and Liquefaction Potential based on the result of geotechnical investigation are shown in Figure 9.

Figure 6. Effect of liquefaction and lateral spreading on RC building and truss bridge

Method of liquefaction assessment is according to the Recommendation for Design of Building Foundations, Architectural Institute of Japan (Architectural Institute of Japan, 2001). In this study, maximum acceleration of strong ground motion is taken as 350cm/s^2 for ultimate limit, which is as large as observed in liquefied area during the Hyogoken-Nambu earthquake. There is a 3m thick loose sandy layer at the subsurface of reclaimed ground (see the case of shop house in Figure 8), which is inferred to be easily liquefiable from the result of Swedish weight sounding. As mentioned above, many buildings in such areas were heavily damaged with partial settlement, inclination and uplift of ground floor. As a result, almost all buildings were demolished. At the site of Governor's house, there exists a sandy layer, but having relatively large N-value and partially liquefiable during strong ground motion obtained from the assessment based on the test result. The elevation of the site is slightly higher than that of the reclaimed area and only small damages such as cracking in floor concrete were observed after the earthquake.

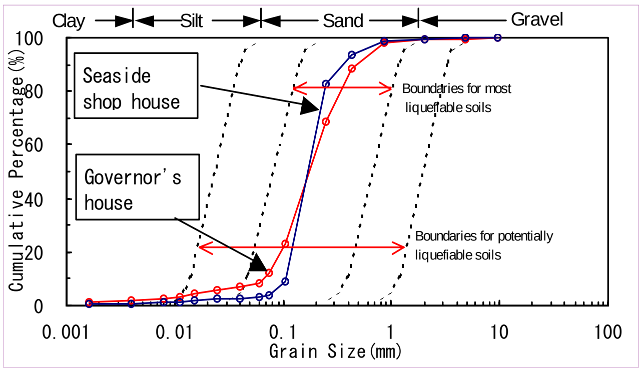

Figure 7. Grain size distribution curves for soils at 2 sites in Gunung Sitoli

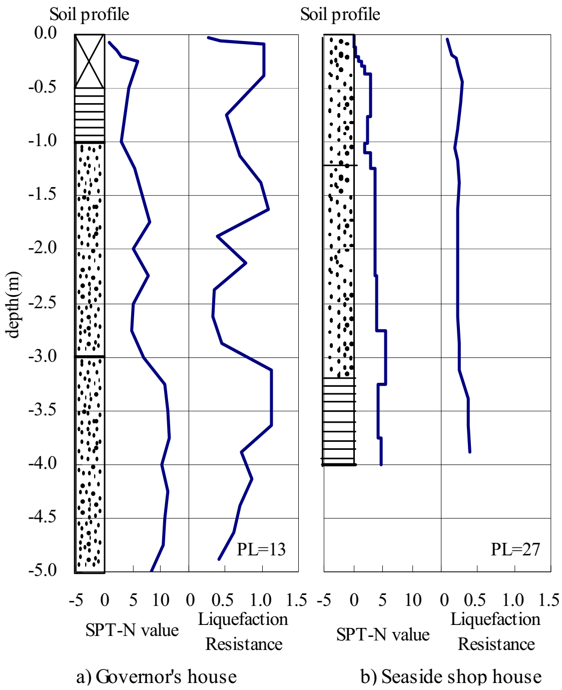

Figure 8. Soil profile, Converted SPT N-value from Swedish weight sounding test and liquefaction resistance at 2 sites in Gunung Sitoli

The results obtained from geotechnical investigation are in accordance with the observed damages caused by the earthquake. However, the geotechnical investigations of ground are scarce in Nias Island and it would be desirable to carry out such investigations in areas particularly affected by ground liquefaction in relation to recovery and reconstruction of Nias Island.

CONCLUSIONS

The conclusions obtained from the investigations and support activities in Nias Island following the March 28, 2005 earthquake are summarized as follows:

1) A very large earthquake with a magnitude of 8.7 occurred nearby Nias Island of Indonesia on March 28, 2005. Strong ground motions induced large number of casualties and damaged infrastructures such as roads and bridges, and buildings.

2) The team of experts was dispatched and made recommendations for temporary repair and rehabilitation of infrastructures and buildings. Because available soil investigation data is scarce and not sufficient at the present time, the Swedish Weight Sounding Test as a practical ground surveying method was introduced to local engineers for the prediction methods of ground liquefaction and their applications to the recovery and reconstruction of the damaged areas.

3) Support activities for recovery and reconstruction as well as disaster prevention education or technical support to the area suffered by natural disaster should be conducted and continued as the direct contribution of the society of civil engineers. In order to continue the support activities for recovery and reconstruction, the building of good collaborative relationships between the government, local governments, societies of engineers and NPO both in Japan and the country affected by the disaster are necessary.

ACKNOWLEDGEMENTS

The activities described in this paper are mainly the activities of the Support Team of the Japan Society of Civil Engineers (JSCE) for the Restoration and Rehabilitation of Infrastructures and Buildings and the Joint Team of JSCE and Institution of Engineers, Indonesia (PII) for Instruction for Geotechnical Investigation and the Practical Utilization of its Results for Recovery and Reconstruction of Nias Island. The Infrastructure Development Institute – Japan, supports a Part of this activity. The contribution and the support for this work are highly appreciated. The authors would also like to thank all members of many organizations in Indonesia and Japan for the cooperation and support to prepare the material, to conduct investigation, to hold meetings, to provide training courses in Nias Island, Medan and Jakarta. We are also very thankful to local people for their cooperation, although they suffered most from the earthquake consequences. Finally, we are honored and proud to be the first team of Engineers Without Borders, Japan to disaster area.

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APPENDIX 1:

JSCE (Japan Society of Civil Engineers)
- NPO: EWB (Engineers Without Borders, Japan)
Joint TEAM
FOR
INSTRUCTIONS FOR GEOTECHNICAL INVESTIGATION AND THE PRACTICAL UTILIZATION OF ITS RESULTS FOR RECOVERY AND RECONSTRUCTION OF NIAS ISLAND AND FOR DISASTER PREVENTION OF NORTH SUMATRA AND WEST SUMATRA PROVINCE

Feb. 17 -25, 2007

Japan Society of Civil Engineers
Engineers Without Borders, Japan

1. PURPOSE OF DISPATCHING THE JSCE TEAM

A great earthquake with a magnitude of 8.5 hit North Sumatra, Nias Island on March 28, 2005. The earthquake caused extensive damage to mainly bridges, port facilities, houses and other buildings. Temporary repairs and Rehabilitation of infrastructures, load, bridges and so on is on of the most urgent subjects in Indonesia. By the request of a state legislature, JSCE dispatched the expert team to support the repair works and rehabilitation of public facilities in April 2005. The team visited Nias Island to investigate the damage to the infrastructure, and to make recommendations for temporary repair and rehabilitation to concerned government agency.

Especially, in Gunung Sitoli, the capital of Nias Island, its infrastructure including lifeline systems, which was seriously destroyed due to liquefaction of the ground, had no prospect of being re-constructed after many months elapsed from the earthquake. In order to initiate recovery and reconstruction work in the region, the soil exploration data such as boring data is essential. However, available data is scarce and not sufficient for recovery and reconstruction works at the present time. Therefore, Japan Society of Civil Engineers dispatched experts and engineers to Nias Island again and provided the expertise advises and technical supports for recovery and re-construction with the close cooperation of the Institution of Engineers, Indonesia (Persatuan Insinyur Indonesia: PII). In this project, Swedish Weight Sounding Test as a practical ground surveying methods was introduced to local engineers for the prediction methods of ground liquefaction and their applications to the recovery

and reconstruction of the damaged areas.
Continuous training is necessary for the soil investigation method to be established in this region. Moreover, West Sumatra Province requested us to carry out the technical support and training local engineers for geotechnical investigations for earthquake disaster prevention. Therefore JSCE decided to dispatch the third Team of experts and engineers to Nias Island for providing the expertise advises and technical support for recovery and re-construction again, and also to Medan and Padang for providing the expertise advises and technical supports for earthquake disaster mitigation.

2. Roles of JSCE Team

The roles of The JSCE Team are as follows;
1) Continuation of the technical support and dissemination activity of transferred techniques, which have been done so far, for the reconstruction and future earthquake disaster mitigation activities in Sumatra island, and to implement those activities into the practical use.
a) Transferring the techniques on geotechnical investigations
・Training on ground survey methods with Swedish Weight Sounding Test
・Training on the assessment methods of ground liquefaction and counter-measures against ground liquefaction based on the data obtained from the ground surveys
・Training for applications of the obtained soil data to actual recovery and reconstruction projects
b) Assistance for preparing a hazard map, restoration plan of lifeline systems, urban planning, etc.

3.List of Dispatched members

No.
1 Dr. Junji KIYONO, Associate Professor, Kyoto University, Kyoto, Japan
2 Dr. Ömer AYDAN, Professor, Tokai University, Shizuoka, Japan
3 Dr. Shigeru MIWA, Director, Research Institute of Technology, Tobishima Corporation, Chiba, Japan
4 Mr. Ichiro ENDO, Expert Engineer, Taisei Kiso Sekkei Co., Ltd. Tokyo, Japan
5 Mr. SUZUKI Tomoji International Branch, Tobishima Corporation, Jakarta, Indonesia,

4.List of supporting member at Tokyo

No.
1 Dr. Masanori HAMADA, Professor , Waseda University, Tokyo, Japan

5. Itinerary: February 17-25, 2007

Date	Itinerary	Stay
Feb.17(Sat.)	1) Leave for Indonesia JL 725: Departure from Narita at 11:20/ Arrival at Jakarta at 17:20 2) 19:40 – 21:50: JAKARTA – MEDAN (GA 196) 3) Internal Meeting	Medan Polonia
18(Sun.)	1) 9:00-15:00 Field Investigation in Medan with North Sumatra Road & Bridge office 2) 16:00 Internal Meeting 3) 17:00 - Preparation for the activity	Medan Polonia
19 (Mon.)	1) 08:30 - 10:00: Meeting with Head of North Sumatra Road & Bridge Office 2) 10:30 - 12:00: Courtesy call to Governor of North Sumatra 3) 13:00 - 16:00: Training for engineers on Ground Survey Method in Medan 4) 16:30 - 18:30: Lecture class for engineers in North Sumatra Province in Medan	Medan Polonia
20 (Tue.)	1) 07:30 - 08:40: MEDAN - NIAS (MZ 5424) 2) 10:00 - 12:00: Meeting with Regency Head, Meeting with Regency Head, Head of Regional Development Planning Board, Head of BRR of Nias Regency etc. 3) 13:00 - 17:00: Training for engineers on Ground Survey Method in Gunung Sitoli city 4) 18:00 - 20:00: Lecture class for engineers in Nias Island at Public Works Auditorium, Nias Regency	Nias Gunung Sitoli Mega Beach
21 (Wed.)	1) 09:00 - 12:00: Training for engineers on Ground Survey Method in Gunung Sitoli city 2) 13:00 - 14:00: Meeting with Regency Head 3) 15:25 - 16:35: NIAS - MEDAN (MZ 5427) 4) 17:30: Meeting with Deputy Head of Road & Bridges Office, North Sumatra Province 5) 19:30 Meeting with Japan Consulate General	Medan Polonia
22 (Thu.)	1) 07:00 - 08:00: MEDAN – PADANG (RI 089) 2) 09:00 - 10:30: Meeting with West Sumatra Head of Road & Bridge Office 3) 10:30 - 12:00: Courtesy call to Governor of West Sumatra 4) 13:00 - 16:00: Training for engineers in West Sumatra Province on Ground Survey Method in Padang 5) 16:30 - 18:30: Lecture class for engineers in West Sumatra Province	Padang Bumi Minang
23 (Fri.)	1) 09:00 - 12:00: Training for engineers in West Sumatra Province on Ground Survey Method in Padang 2) 13:00 - 15:00: Lecture class for engineers in West Sumatra Province 3) 15:00 - 16:00: Meeting with West Sumatra Head of Road & Bridge Office 4) 20:05 - 21:45: PADANG – JAKARTA (GA165)	Jakarta Nikko
24 (Sat.)	1) 09:00 Meeting with PII 2) 11:00 Meeting with JICA, JICS, JBIC (if possible) 3) 15:00 Reports preparation 4) 22:10 - 07:25 JAKARTA – NARITA(JL726)	
25 (Sun.)	1) 07:25 Arrival at Narita	

APPENDIX 2:
DAMAGE OF NIAS ISLAND DURING 2005 OFFSHORE SUMATRA EARTHQUAKE

THE CHARACTERISTICS OF THE EARTHQUAKE AND OUTLINE OF THE RECONNAISANCE

Table 1 gives the main characteristics of the earthquake inferred by USGS (USGS, 2005) and Harvard University (Harvard Univ., 2005). USGS estimated that magnitude (Mw) was 8.7 and hypocenter was just beneath Banyak Islands to the north of Nias Island. The hypocenter estimated by Harvard was further south and nearby Nias Island. Rupture and slip characteristics estimated by Yagi (Yagi, 2005) and Yamanaka (Yamanaka, 2005) are given in Table 2. Figure 1 shows the rupture area estimated by Yagi (Yagi, 2005). The length and width of rupture area were inferred to be about 470km and about 100km, respectively and slip was about 10m. The earthquake is a low-angle reverse fault type mega earthquake in inter-plate subduction zones. Severe damage occurred in Nias Island because of the high energy release just beneath the island.

Table 1. Main characteristics of Earthquake

Institute	Mw	Latitude (N)	Longitude (E)	Depth (km)
USGS	8.7	2.076°	97.013°	30.0
Harvard	8.6	1.64°	96.98°	24.9

Table 2. Rupture and Slip Characteristics of the earthquake fault

	Yagi (2005)	Yamanaka (2005)
Strike, Dip, rake	(329,14,115)	(320,12,104)
Moment Tensor Scale	1.6×10^{22} Nm	1.3×10^{22} Nm
Rupture Duration Time	150s	120s
Depth	28 km	27 km
Rupture Area	about 150×470 km	about 120×250 km
Slip	about 10 m	about 12 m

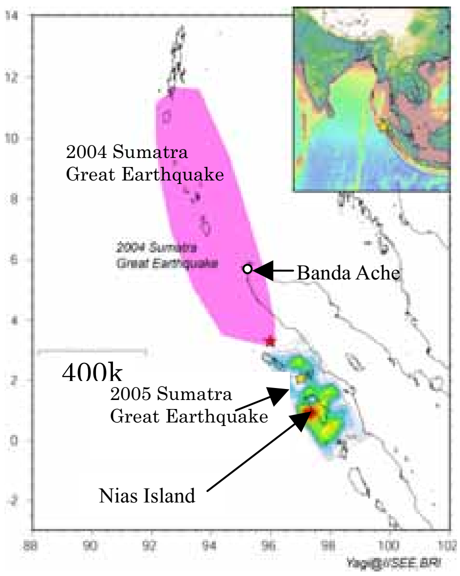

Figure 1: Epicenter and ruptured zone (revised by Yagi (2005))

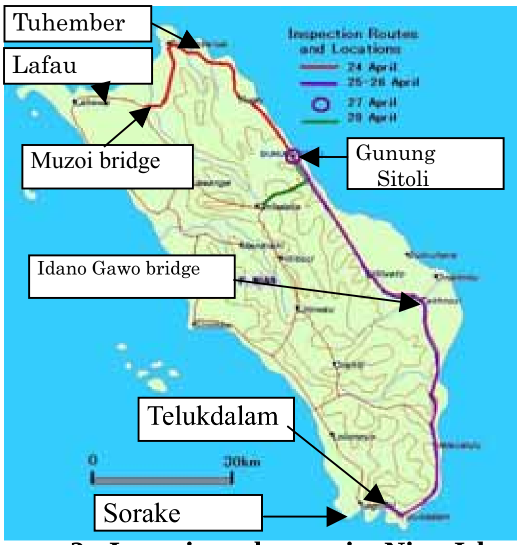

Figure 2: Investigated area in Nias Island and locations of damaged structures and area

Nias Island is about 150km long from north to south and about 50km wide from east to west, with a total population of 700,000. The economical centers are Gunung Sitoli in the north and Telukdalam in the south with concentrated population and buildings. The exact number of casualties and injured people is not well-known. They change depending upon the sources. According to information of the

United Nations (UN OCHA, 2005), the number of lethal casualties is more than 850, and injured people is more than 6000. Anyhow, the town of Gunung Sitoli on Nias Island is severly hit by this earthquake. The casulaties and injuries were mainly caused by the collapse of RC buildings and brick and wooden houses. Site investigations were carried out four times, twice in April, 2005 with support activities of providing expertise knowledge and recommendations, once in January, 2006 with support activity for training of local engineers for geotechnical investigations and once in February, 2006. Figure 2 shows the inspection routes. The investigations were mainly conducted in eastern area, because of inaccessible road conditions in western area at the time of the investigations. Typical damaged structures and major cities and towns are also shown in the figure.

STRUCTURAL DAMAGE

Damage to Bridges

The roads connecting Lahewa in the northern part of island to Gunung Sitoli, Gunung Sitoli to Telukdalam in the southern part along eastern coast, and Gunung Sitoli to Telukdalam through the center of island are main roads. Bridges in Nias Island may be broadly classified as Truss bridges, RC bridges, RC Box Culvert bridges, Wooden paved steel framed bridges, and Wooden bridges. Long span bridges are either truss bridges or RC bridges with or without box culverts. Truss bridges were especially used for long span bridges along main roads. The list of bridges and dominant forms of their damage are listed in Table 3 and locations of these bridges are shown in Figure 3.

The heavily damaged non-accessible large bridges within the surveyed area are Lafau bridge and Muzoi bridge in the northern coast between Gunung Sitoli and Lahewa route and Idano Gawo bridge between Gunung Sitoli and Telukdalam nearby Tetehosi at the eastern coast. These bridges mainly consist of truss super-structures with RC foundation piers or RC box culverts. The piers of Lafau bridge and Muzoi bridge were tilted and settled due to the reduced bearing capacity and lateral spreading problems associated with liquefaction of ground. The approach embankment road was settled and laterally moved towards the river due to liquefaction. Figures 4 and 5 show the damage of these bridges respectively. A part of about 50 m to 70 m length of the approach embankment at both the sides of Muzoi bridge is settled by 4.5m at maximum and laterally moved towards the river, which can be clearly inferred from the tilted electric poles next to the bridge while the lateral movement of the ground was more than 4m on both sides. The piers were founded on piles. However, the piles were fractured at the top with exposure of the reinforcement and were not functional. The engineers of Department of Public Works pointed out that piers have piles reaching rock formation. It seems that the piles were designed against vertical loads and horizontal loads were not considered.

Figure 6 shows the damage of Idano Gawo bridge. The second pier of Idano Gawo bridge was tilted and slid towards the upstream side of the river and the box-culvert next to this pier was also tilted and slid together with the pier. The upper deck of the truss section of the bridge is horizontally shifted by about 1.3m. The river flow is directed towards the pier and box-culvert. It seems that the toe erosion of the pier and box culvert, bearing capacity of foundation and large horizontal shaking may be the major causes of the damage to Idano Gawo bridge.

The lateral spreading of liquefied ground damaged RC bridges and Truss bridge in Gunung Sitoli town. The bridge foundations have some piles and some of these piles were broken at the top. The approach embankments of bridges are generally damaged and settled due to lateral spreading of ground and failure of wing-embankment walls. The settlements were generally greater than 30cm in many locations.

Many truss bridges along Gunung-Sitoli and Telukdalam route and along Gunung-Sitoli and Lahewa route were damaged by permanent movement of abutments as a result of lateral spreading of liquefied ground. The ground consists of mudstone-like layer, sand layer and clayey-silty soil and top organic soil from bottom to top. Sandy layer is generally found at the water level of river and it is expected to be fully saturated. During earthquake shaking, it seems that this sandy layer was liquefied and caused the lateral spreading of the ground.

Table 3. List of bridges and its damages

Point No.	Subject	remarks
	East and North Coast Road of NIAS (Gunung Sitoli- Lahewa)	
1	RC 1Span (L=20m)	Crack at the approach embankment
2	RC bridge	Crack and settlement of the approach embankment
3	(I-type steel beam girder+ wooden floor)L=15m	Crack and settlement of the approach embankment
4	RC bridge L=8m	Crack and settlement of the approach embankment (1.2m)
5	(I-type steel beam girder+ wooden floor)L=21m	Crack and settlement of the approach embankment
6	RC bridge L=14m	Crack (W=5-30cm) and settlement of the approach embankment, crack and movement of the retaining wall, lateral displacement of ground
7	(I-type steel beam girder+ wooden floor)	Crack and failure of the approach embankment
8	(I-type steel beam girder+ wooden floor)L=15m	No damage
9	Damage of the road	crack of the road, collapse of the house by slope failure
10	Truss Bridge L=40m	Crack and settlement of the approach embankment, sand boil at the village near the bridge
11	Damage of the road	crack, slope failure
12	(I-type steel beam girder+ wooden floor)L=7.5m	No damage
13	(I-type steel beam girder+ wooden floor)L=11m	Severe Crack and settlement(1.2m) of the approach embankment
14	(I-type steel beam girder+ wooden floor)L=7m	Severe Crack and settlement of the approach embankment
15	Damage of the road	crack, liquefaction, tsunami
16	Damage of the road	crack, liquefaction, tsunami
17	(I-type steel beam girder+ wooden floor)L=19m	Crack and settlement of the approach embankment, difference in level (80cm), hardly to pass
18	Damage of the road	Crack, difference in level (50-100cm), hardly to pass
19	Sawo bridge: Truss 1Span 50m	Severe Liquefaction, Lateral Flow, Large amount of sand boil, Crack and settlement of the approach embankment, abutment of the left bank moved 30cm to the river
20	Muzoi Bridge RC 2span(10m each) +Truss 1span (51m)	Severe Liquefaction, Lateral Flow, settlement of the approach embankment (3-4.5m at the right, 0.2-1.5m at the left bank), movement of the abutment and the pier (400cm) to the river, piles were broken at the piletop, Truss moved, Impassable after the earthquake
21	Lafau bridge Truss 1span 55m	Severe Liquefaction, Lateral Flow, settlement of the approach embankment, movement of the abutment and the pier to the river, piles were broken at the piletop, Truss was dropped from the abutment at the right bank, Impassable after the earthquake
22	Lahewa port	a wharf collapsed and settled due to the separation from the piles.
	East and South Coast Road of NIAS (Gunung Sitoli- Telukdaram)	
101	Idano Goho bridge RC bridge 3 Span L=47m, Truss bridge 1Span	Lateral Flow, settlement of the approach embankment, movement of the abutment to the river, piles were broken at the piletop,
102	RC bridge 1 Span L=25m	Crack and settlement of the approach embankment, lateral flow
103	RC bridge 1 Span L=26m	Crack and settlement of the approach embankment
104	slope failure	Rock fall of porous limestone.
105	Truss bridge 1 Span L=60m	Settlement of the left approach embankment (50cm), abutment moved to the river, lateral flow
106	(I-type steel beam girder+ wooden floor)L=8m	Crack at the bank
107	(I-type steel beam girder+ wooden floor)L=8m	No damage
108	RC 3box culvert bridge L=15m	Small crack at the approach embankment, Good performance
109	RC bridge 1span L=36m	Crack and settlement of the approach embankment, Fall down of the abutment, piles were broken at the pile top.
110	Idano Sebua bridge RC bridge 3 Span L=50m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
111	RC ridge 2Span L=34m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
112	Truss bridge 1Span L=62m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
113	Idano Gawo bridge Truss bridge 2 Span L=80m, with Box Culvert bridge 28m on both side	Tilting of box culvert and pier at right side, Impassable after the earthquake
114	Truss bridge 1 Span L=30m	Crack and settlement (1.2m) of the right approach embankment, Fall down of the abutment, lateral flow, Truss moved
115	Idano Mizawo bridge Truss bridge 1 Span L=45m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow, Truss moved
116	Idano Mola Bridge Truss bridge 2 Span L=60m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow, Truss moved
117	Truss bridge 1 Span L=55m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow, Truss moved (85cm)
118	RC bridge 1 Span L=25m	almost no damage
119	RC bridge 2 Span L=35m	almost no damage
120	RC bridge 1 Span L=25m	No damage
121	Susuwa Bridge Truss bridge 1 Span L=65m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
122	RC bridge 1 Span L=10m	No damage
123	Truss bridge 1 Span L=54m	Truss moved
124	Truss bridge 3 Span L=90m	No damage
125	Truss bridge 1 Span L=30m	No damage
127	slope failure	Rock fall of porous limestone.
[illegible]	slope failure	Rock fall of porous limestone.
128	Bailey bridge +wooden floor L=60m	almost no damage, Small crack at the approach embankment
129	Failure of the retaining wall at the seaside	Failure of the stone masonry retaining wall at the seaside
130	Telukdaram port	a part of wharf sank into the sea and some pile heads were fractured by collision of wharf segment.
131	Traditional wooden house	Good performance
132	Sorake beach	Tsunami
	West Coast Road of NIAS (Gunung Sitoli- Terukdaram)	
201	Idano Tanosaruru bridge Bailey bridge 30.5m	twisted and deformed, Crack and settlement of the approach embankment
202	Idano Oyo bridge (I-type steel beam girder+Bailey bridge+wooden floor) 55m	pier is tilted, settlement of the approach embankment
203	Idan Siwarawa bridge (Bailey bridge+wooden floor) 30.5m	collapse of abutment
204	Idano O'ou bridge (Bailey bridge+wooden floor) 185m	Bailey bridge is deformed

The lateral spreading of ground was particularly amplified on the convex side of the riverbank as the ground can freely move towards the river. These movements caused high lateral forces on the abutments, which caused the sliding and tilting of piers or fractured the piles of the abutments of truss bridges. Similar situations are also observed on RC bridges. The approach embankments of bridges are generally damaged and settled due to lateral spreading of ground and failure of wing-embankmentwalls. The settlements were generally greater than 30cm in many locations. The backfill materials of approach embankments consist of gravelly soil and it is expected that the potential of settlement or liquefaction is low. The bearing supports of many bridges do not have shear-keys or stoppers against both horizontal and vertical movements. The truss section shifted horizontally towards the upstream side or downstream side at some bridges.

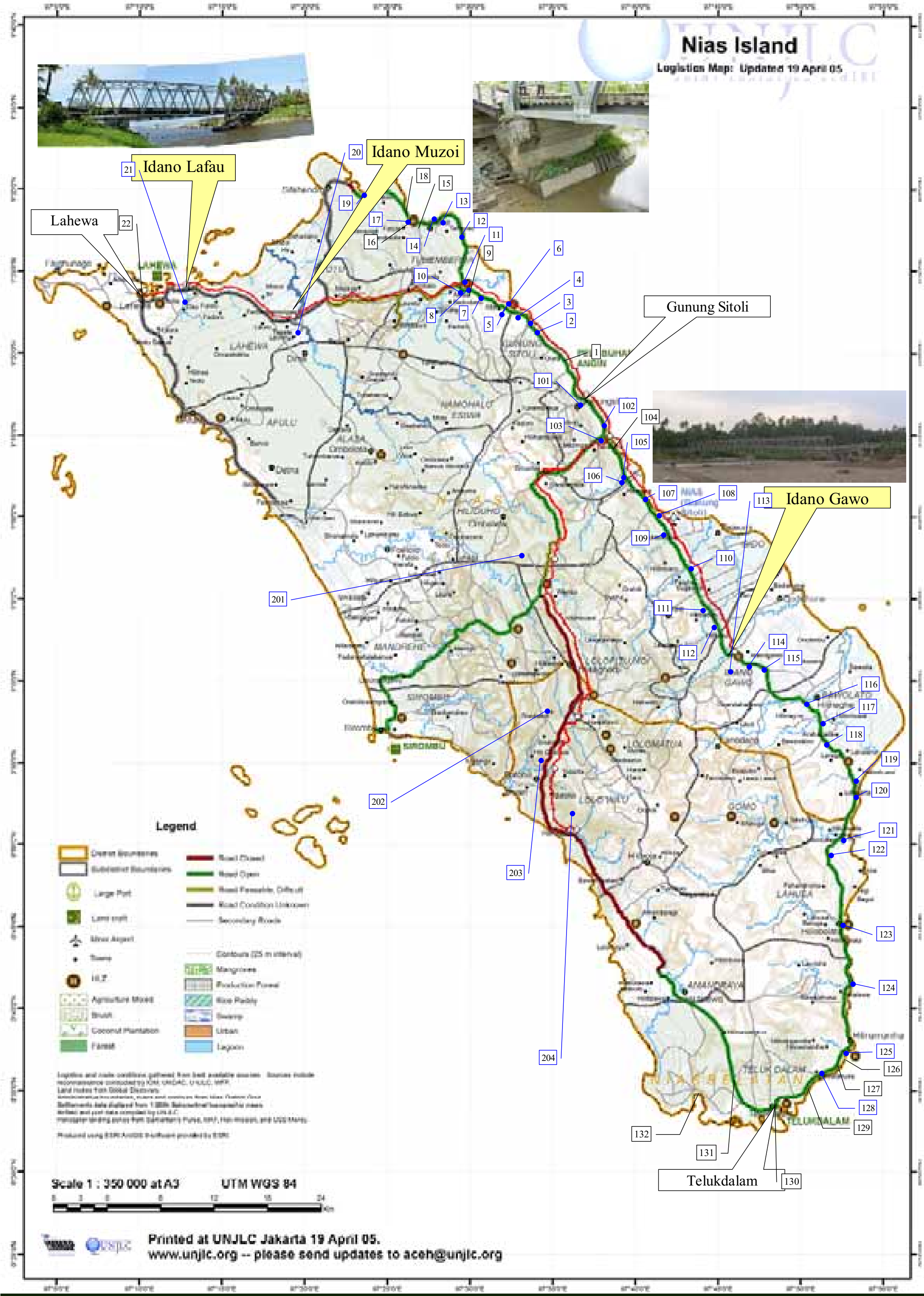

Figure 3. Investigated bridges and major cites and towns

The damaged bridges generally need to be re-constructed and It should be moved next to existing piers where geotechnical investigation of ground and its characteristics are necessary. The present truss decks can be used in the new-constructions with some replacement of damaged elements and bolts and bearings together with appropriate stopper against horizontal and vertical relative movements.

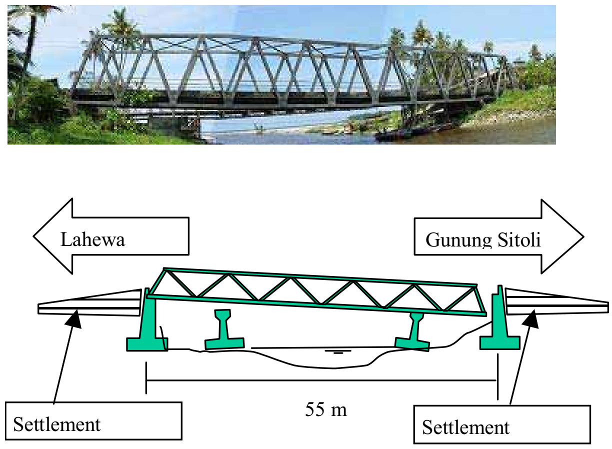

Figure 4. Damage of Lafau Bridge

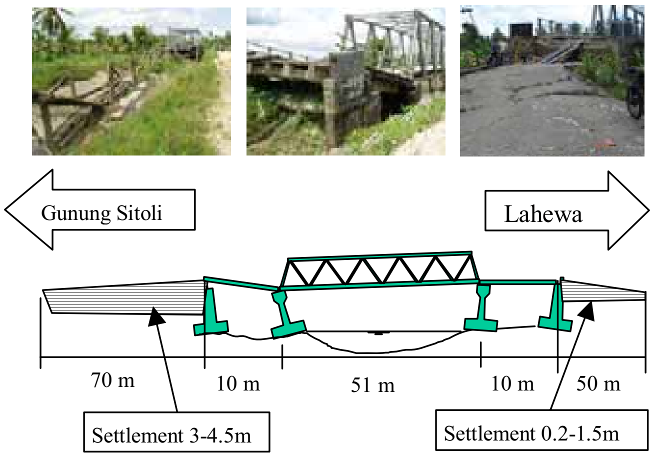

Figure 5: Damage of Muzoi Bridge

Figure 6. Damage of Idano Gawo Bridge

Damage to Roadways and Slope Failure

Roadways were damaged at many locations of the Nias island due to embankment failure, landslides, lateral spreading, of liquefaction. Many cracks and settlements more than 1m were observed.

Roadways were generally narrow (less than 5m) and the asphalt surfacing of roadways was generally in poor condition having many potholes. Many rockfalls were observed particularly along the roadways passing through porous coral limestone. These rockfalls directly hit the roadways and obstructed roadways just after the earthquake in some locations. There were many slope failures along the road in mountainous areas between Gunung Sitoli and the west coast in the center of Nias island, where slopes consisted of weathered rock resulting in closed roads.

Damage to Port Facilities

There was some damage to port structures in Nias island due to ground shaking. In Telukdalam new port in southern part of Nias island, a part of wharf sank into the sea and some pile heads were fractured by collision of wharf segments. The lateral spreading caused the fracturing and settlement of piles. The wharf of old Gunung Sitoli port located in the liquefied area, where many buildings were heavily damaged by settlement and tilting, was damaged by the lateral spreading of liquefied ground. As a result, the pile heads fractured and settled . Furthermore, there was a relative movement of 15cm between the segments of the wharf.

CONCLUSIONS

The conclusions obtained from the investigations and support activities in Nias Island following the March 28, 2005 earthquake are summarized as follows:

1) A very large earthquake with a magnitude of 8.7 occurred nearby Nias Island of Indonesia on March 28, 2005. Strong ground motions induced heaviy casualties and damaged infrastructures such as roads and bridges, and buildings.

2) Many bridges were damaged by strong ground motion and permanent movement of abutments as a result of lateral spreading of liquefied ground. The heavily damaged non-accessible large bridges within the surveyed area are Lafau bridge, Muzoi bridge and Idano Gawo bridge, which mainly consisted of truss superstructure and RC abutments and piers.

3) The earthquake induced widespread liquefaction and lateral spreading. These phenomena were the primary cause of heavy damage to bridges and buildings in Nias Island. Damage of ground such as settlement, lateral spreading and associated structural damage due to liquefaction were widely observed in various locations along the coastal area and reclaimed ground.

4) The reclaimed area in the coastal region of Gunung Sitoli was strongly affected by the earthquake, while settlement and lateral spreading of ground occurred. As a result, many buildings in such an area were heavily damaged with partial settlement, inclination and uplift of ground floor. The buildings without raft foundations and continuous tie-beams could not resist to ground failures due to liquefaction unless they are built on piles extending into the non-liquefiable layer. Swedish weight sounding tests were conducted at 2 locations in Gunung Sitoli. The results obtained from geotechnical investigation are in accordance with the observed damages caused by the earthquake.

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DAMAGE AND DESIGN ON NON-ENGINEERED BUILDINGS

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Key Words: Masonry, Un-reinforced, Low Cost, Non-Engineered, Seismic Design

INTRODUCTION

A strong earthquake occurred in mid Java Island, Indonesia, May 27, 2006. Much number of houses collapsed, toll of lives were over 5,700, and more than 37,000 casualties were reported.
Bantul prefecture in Yogyakarta province suffered much damage, toll of lives were more than 4,100, and more than 120,000 houses collapsed.
According to the investigation by United Nations as of November 20, only 30,000 houses are reconstructed among 250,000 damage houses.
Houses are the base of life and activity of local communities. But support from government for reconstruction of individual houses is very difficult. Heavy earthquake damage means collapses not only building but also the basis of individual life and communities.
This paper focused on the damage and main reasons of damage of non-engineered buildings, such as houses school which structure is un-reinforced masonry. And several actions on reconstruct for house, schools are introduced.

DAMAGE OF HOUSES AND SCHOOL (NON-ENGINEERED STRUCTURES) [1)]

Tempel Elementary School (SD Tempel at Bambanglipuro, Kecamatan Baglipuro / URM / 1F)

No lintel beams were found and the roof truss was directly placed on un-reinforced masonry (URM) walls. Major damage was found in URM walls and the timber roof truss, and some ceiling boards fell down in the classrooms.

Photo 1 SD Tempel at Bambanglipuro, Kecamatan Baglipuro

Houses in Imogiri

Houses in Imogiri were extensively devastated. They were URM structures with timber truss system and roofing tiles on it. URM walls were typically 20 to 25cm thick with 2 or 1.5 brick units, having a geometry size of 26cm x 12cm x 6cm. Since demolitions to reconstruct damaged houses had started in some damaged houses, it was not easy to identify which debris were due to shaking and which were not. Those with RC frames to confine URM walls often survived the shaking although they had some damage.

Photo 2 Devastated URM house Photo3 Survived house with URM and RC frame

Parangtritis 2nd Elementary School (SD2 Parangtritis at Parangtritis, Kecamantan Kretek / URM+RC column / 1F)

Each class had 2 bays in the longitudinal direction. Each bay was 3.5m long and the column size in the middle was 175mm thick and 350 mm wide. The eaves were supported by Γ-shaped RC columns with cantilever beam. No major damage was found in the structure. Note that less damage was found in the coastal area around Parangtritis (to Opak River) than inland areas.

Photo 4 SD2 Parangtritis

School at Trimulyo (SLB-PGRI Trimulyo, Kecamatan Jetis / URM(+RC column?) / 1F)

Each class had 2 bays in the longitudinal direction. Each bay was 3.5m long. Columns had flexural cracks at both ends. The presence of reinforcing bars was not confirmed at the site since the building had minor cracks and rebars were not exposed.

Photo 5 SLB-PGRI Trimulyo

Kembangsongo 2nd Elementary School (SD 2 at Kembangsongo / URM+RC column / 1F)

The school was located just north of the school at Trimulyo. The eaves were supported by Γ-shaped RC columns with cantilever beam, which was similar to SD2 Parangtritis. The exterior URM wall was damaged and repaired, but no other major structural damage was found in the structure.

Photo 6 SD 2 at Kembangsongo

Traditional houses in Gantiwarno Sub-Regency (Kecamatan Gantiwarno)

Traditional stone masonry houses in Gantiwarno Sub-Regency had some damage in masonry walls. They had some RC beams on the wall but no RC columns were provided in the house. Although they were heavy, the stone masonry walls were thick and long enough to resist and survive the shaking. Another traditional house older than the stone masonry construction had minor damage since they had light bamboo-net walls. The bamboo-net house investigated by the reconnaissance team was older than 70 years.

Photo 7 Stone masonry house

Photo 8 Bamboo-net wall house

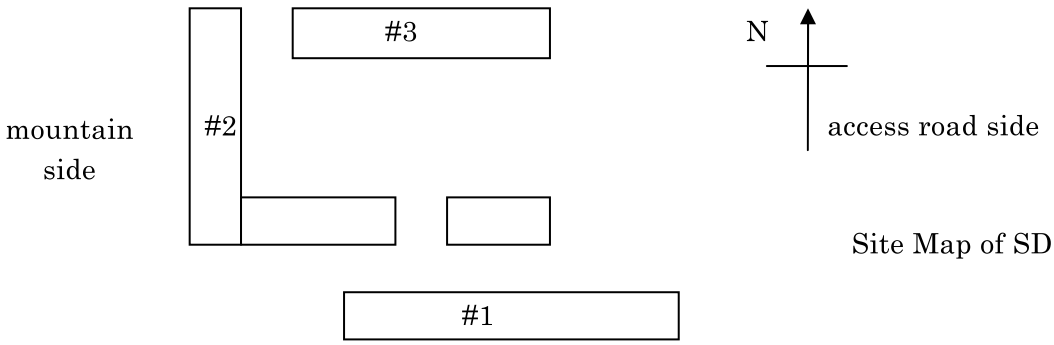
Sawit Elementary School (SD Sawit at Gantiwarno, Kecamatan Gantiwarno / URM / 1F)

The school building most probably had RC columns only at the 4 exterior corners but no columns in the middle of the structure. Each class had 2 bays and each bay was 3.5m long. Extensive damage was found in 20cm URM walls and the roof system.

Photo 9 SD Sawit at Gantiwarno

Katekan Elementary School (SD Katekan at Katekan, Kecamatan Gantiwarno / URM & URM+RC column / 1F)

The school had 3 buildings, one of them (building #2) were stone masonry structure constructed in the 1970s while the other two buildings (#1 and #3) were URM structure with RC columns. Each classroom of the building #1 had 3 bays, each of which was 3m long. Damage to the roof system and ceiling boards was found in buildings #1 and #3 while cracks in URM stone walls were found in building #2.



Site Map of SD Katekan

Building #1：URM with RC columns

South side of building #1

Building #1

Building #1：RC column and beam

Building #2: Stone masonry structure

Damage to corner wall

Photo 10 Katekan Elementary School

Pesu Elementary School (SD Pesu at Pesu, Kecamatan Wedi / URM+RC column / 1F)

The school had two buildings, one was seriously damaged in the roof system and the other survived the shaking. Columns having the 150mm x 150mm section with 4-ϕ13 rebars and ϕ6 hoops were provided between classrooms. A mid-span wall was 150mm thick and 500mm wide. The roof was supported by the timber truss fastened to RC columns above.

Photo 11 SD Pesu

MAIN STRUCTURAL REASONS OF THE DAMAGE

Damage to URM walls

Devastating damage was found in URM houses in Bantul Regency, Yogyakarta City, and Klaten Regency, killing residents due to heavy debris of brick walls. URM houses with RC beams and columns confining URM walls, however, had relatively less damage, even when they had some damage. Providing RC frames to confine masonry walls is strongly recommended to reduce structural damage to URM houses.

Educational programs would provide opportunities to train practitioners and to disseminate the important role of confining frames.

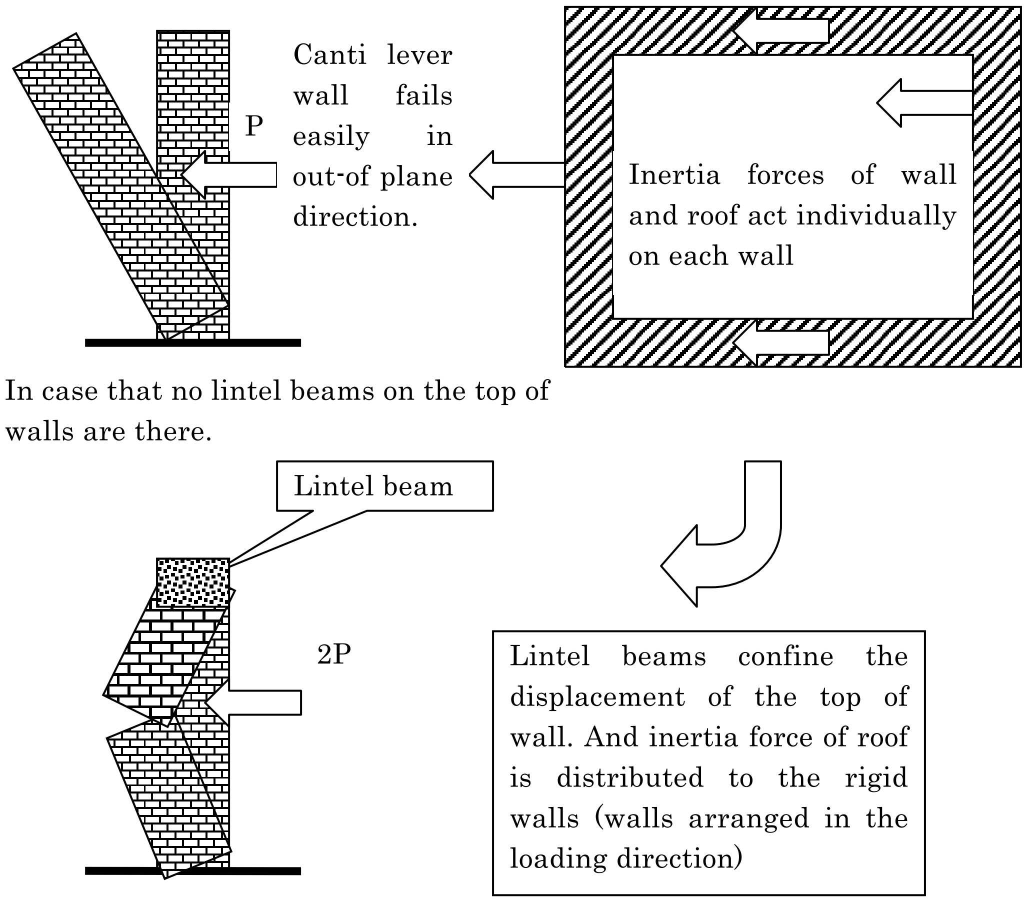


Fig. 1 Roll of Lintel beam in URM

Damage to Roof system

Even when a building had minor structural damage, some schools had significant damage to their roof system. Since the earthquake occurred early in the morning, the loss of human lives was minimized. Falling debris such as bricks, ceiling boards, roofing tiles etc. are significantly life-threatening especially to school children. The structure underneath the roof should be rigid and strong enough to properly support the roof system. As pointed out above, providing RC frames is strongly recommended to provide sufficient in-plane and out-of-plane stiffness and strength of buildings.

AIJ Standard for Structural Design of Unreinforced Masonry Structures (1989 Edition)[2)]

Architectural Institute of Japan provides the structural design standard for un-reinforced masonry structures. The standard specifies following items.

Article 1. Scope

Article 2. Classification of masonry structures

Table 1. Classification of masonry

Classification of masonry structures	Kinds of masonry	Compressive strength of masonry unit per gross cross-sectional area * (kg/cm²)
Class 1	Stone, concrete block	not less than 60
Class 2	Stone, clay brick, solid concrete block	not less than 100

* The compressive strength of concrete blocks at the age of four weeks

Article 3. Maximum height of masonry structures

Table 2. Height of structures

Class of masonry structures	Thickness of wall	Height of structure (m)
Class 1	When Article 5 is applied	6
	Increased 20% or more as much as above case	9
Class 2	When Article 5 is applied	9

[Remark] The height of parapet shall not exceed 1.2 m, and may not be taken into account for the height of structures. Parapets shall not be made of masonry.

Article 4. Arrangement and length of walls

Table 3. Divided floor area

Class of masonry structures	Divided floor area (m²)
Class 1	40
Class 2	60 (40 m² in case of a building without reinforced concrete roof slabs)

The horizontal length of each wall shall not exceed 10 m.

Article 5. Thickness of walls

Table 4. Thickness of wall

Number of stories \ Length of wall	5 m or less	More than 5 m and 10 m or less
One	20 cm	30 cm
Two or three	30 cm	40 cm

Article 6. Openings of walls

Article 7. Reinforcement for upper part of openings

Article 8. Grooves of walls

Article 9. Walls in timber or steel frames

Article 10. Floors and roofs

In the structures with more than one story, roof slabs and floor slabs shall be constructed with reinforced concrete or rigid precast RC.

Article 11. Collar beams

11.1. Reinforced concrete collar beams shall be provided effectively and continuously along the top of each wall, expect for the case when reinforced concrete roof slabs are provided for one-story buildings.

11.2. Depth of collar beams shall not be less than 1.5 times as much as the thickness of the walls, nor less than 30 cm. In addition, collar beams shall have adequate strength to resist vertical and horizontal loads.

11.3. Width of collar beams shall not be less than the thickness of adjacent walls, and longitudinal double reinforcement shall be provided.

11.4. When Collar beams are not placed monolithically with the reinforced concrete or precast concrete roof slabs, effective width of the collar beams shall not be less than 1/20 of the distance between center lines of the adjacent parallel walls. In addition, structural safety against lateral load shall be taken into consideration. When collar beams have L- or T-shape cross-sections as shown in Figure 1, width of the flange whose thickness is equal to or more than 12 cm can be taken as effective width (see to Figure 2).

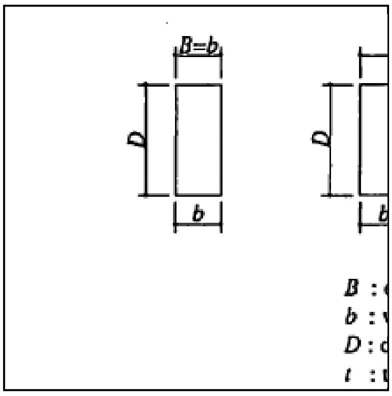


Fig.2 Effective width of collar beams

11.5. Concentrated load transferred from spandrels walls or roof system shall be supported by collar beams. When a large concentrated load is applied to the part where no collar beams is provided, a steel or reinforced concrete member shall be provided under the application point of the concentrated load so as to distribute the concentrated load safely to the wall below.

11.6. Masonry wall shall not be constructed for gables and other parts located above the uppermost collar beams or roof floor slabs. When reinforced concrete collar beams are provided on the top of the said masonry parts, construction shall be permitted.

Article 12. Structural details of footings

12.1. Along the bottom of each wall in lowermost story, reinforced concrete footing beams or foundation tie beams shall be provided continuously to support the walls safely and to connect the walls to each other. In case of one-story building and firm soil condition, unreinforced concrete construction may be permitted only for footings and footing beams.

12.2. Width of footing beams or tie beams shall not be less than the thickness of the adjacent walls.

12.3. Depth of footing beams or tie beams shall not be less than 1/12 of the height of eaves nor less than 60 cm (45 cm for one-story buildings). Longitudinal reinforcement shall be provided at the top and bottom of these beams.

TRIAL FOR STRENGTHENING AND REHABILITATION OF HOUSES IN INDONESIA

Seismic technology transferring

"Japan transfers his seismic technologies to the carpenters in Indonesia" was reported in Mainichi Shimbun dated on 31. Aug., 2006[3)].
This report introduces the activity of Japanese engineer performing the trial of teaching seismic structure technology for local carpenters.
Indonesian Islam University Earthquake Engineering Center in Yogyakarta instructs the seismic structure technology to the local carpenters who carry the work to reconstruct damaged houses, under the cooperation with JICA.
In this institute, demonstrations of the effectiveness of RC frame confining the brick wall are conducted.

Prof. Sarwidi of Indonesian Islam University insisted on the effect of the confinement by RC frame, and demonstrate this effect by the scaled model on the shaking table, and make the poster to prevalent this technology.

Through transferring the seismic structure technology to local carpenters by cooperation with local researchers, a real big effect is expected.

Photo12 Demonstration of the different failure mode between brick wall house confined by RC frame(left) and usual unconfined brick wall house(right) on the shaking table at Indonesian Islam University

Photo13 Desirable foundation for a house

Photo15 Details of RC frame

Photo14 Poster insisting the importance of confining wall by RC frame

RISHA at the Research Center for Human Settlements (RCHS), BANDUNG

“RISHA”, an abbreviation of instant healthy modest house, is a method developed at RCHS for constructing cost-efficient prefabricated houses, in which precasted reinforced concrete beams are assembled together with bolts and thin steel plates. A cross-section of RISHA beam consists of a thin web and a lib. The beam can be made in situ. A house with 36 ㎡ wide costs about 33 million RP, namely 900,000 RP per square meters. In Banda Aceh, Sumatra, about 7000 RISHA houses have been constructed for tsunami survivors, each $48m^2$ wide, costing 60 million RP. A school with 3 class rooms (6*6 m^2 for each) was also built there at the cost of 800 million RP. RCHS provides a two-days training for RISHA construction to any person on demand.

The questions in RISHA system are followings:
1. Controlling length may be difficult when the RISHA members are assembled together as a pile foundation,
2. RISHA elements are fastened together with bolts. Too tight fastening would cause either cracking or crumbling concrete elements. Too lose fastening would cause serious deformations of assembled structures.
3. Bolts will gather rust.

(a) Two-story RISHA model house: Each structural member is 1.5 m long.

(b) Beam connection; Beams are fastened together with thin tie plates and bolts.

(c) RISHA members can be used as a foundation.

(d) A column is fastened upright with bolts at its bottom end to the foundation.

Photo16 RIHSA model houses at the Research Center for Human Settlements (RCHS), BANDUNG

Rehabilitations in the aftermath of the May 27, 2006, Mid-Java Earthquake

(1) Schools in Bantul/Imogiri areas

Though reconstruction of schools seems to be hardly speeded up with limited amount of budget, those under reconstruction are generally in a good state of repair. Damaged bricks are all being replaced with either new or intact ones, and they are being confined with RC frames. Roofing systems are much stiffer than those before the earthquake. The following pairs of photos below compare the same schools at different times (June 12, 2006 and Sept 16, 2006, respectively).

(2) Dwellings

Devastation is seen yet as it was immediately after the earthquake. Holes in many masonry walls punched out in the earthquake were temporally patched up with bamboo-woven panels. Even thatched houses covered up with bamboo-woven panels were seen here and there. Though only a small number of houses are being repaired, they are generally in a good state of repair. Damaged bricks are all being replaced with either new or intact ones, and they are being confined with RC frames. Roofs with traditional joguro-structure are much stiffer than those before the earthquake. Asahi Shinbun morning editions dated on 12 December, 2006 reported "Reconstruct a house with dignity"[4)].

A reconstructed house in which height of a brick bearing wall is equal to or less than 1m, the wall is plywood, and materials of column is Lasi costs about 10,000,000 rupiah (130,000 yen). As for the floor area, the house is much wider than a general temporary house (6*6 meters), and has a traditional high roof style. All households at in Gibian area of Chanden village in Bantul prefecture, finish reconstructing 65 houses by collaboration in the whole village until October. Mr. Eco. Puraot, Director of architecture Dept. in Duta Wachana Christian Univ. design this type of house.

Mr. Murai, civic center for an overseas disaster support (Kobe, CODE) finished 25 houses in WijoKlaten village, in the end of November, and completed to hand them over.

2006.06.12 original. SD2 Parangtritis

2006.09.16 Repairing. Top ends of walls are connected with RC beams

2006.09.16 SD2 Parangtritis Under repair

2006.09.16 SD2 Parangtritis Under repair

2006.06.12 SLB-PGRI TRIMULYO

2006.09.16

2006.06.12 cracks are found in the middle column

2006.09.16 Repaired, but method is unknown

2006.06.12

2006.09.16 New school on the left is under construction. The school on the right shows its original structure, No repair work has done yet.

A China organization funds the reconstruction of this school.

Roofing framework and beams along the top ends of walls are seen.

Photo17.Reconstruction of school

Shop house? At the corner of cross section of Bantul to Imogiri. RC frame confines brick wall.

Connection beam is observed

House at Parangtritis Beach. RC frame is observed.

Reinforcement.

Bamboo house at Bantul

Bamboo products are sold along the road in Bantul.

Photo18.Reconstruction of house

Photo 19 Reconstructed houses. Habitants built houses by themselves[4)]

CONCLUSIONS

Support of JICA[5)] is applied to reconstruction of public accommodation such as a school, a public health center. Reconstructing and repairing of a school are also promoted by Chinese or Islam communities. These are pushed forward by a local effort (mutual aid). However there are traditional mutual aid in Indonesian, reconstruction of the house that is a base of life are not progressed. The same as the reconstruction of a personal house in Hanshin / Awaji great earthquake disaster in Japan, the difficulty of public support to personal property can understand, but reconstruction of a house is an important because reconstruction of a house activates a damaged area.

Therefore it is thought to be very effective that the rebuilding of the safe house utilizing local materials and training the local carpenter to get the seismic technology.

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ACKNOWLEDGMENT

Authors would like to sincerely express thanks for each organization and member which had helped this investigation.

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(Submitted: February 5, 2007)

DATA ARCHIVES FOR RATIONAL REHABILITATION OF AREAS AFFECTED BY MASSIVE EARTHQUAKES - EXPERIENCES AND LESSONS IN JAPAN -

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Key Words: Data archives, rehabilitation, geotechnical issues

INTRODUCTION: SIMILARITY BETWEEN INDONESIA AND JAPAN

Indonesian people suffered massive natural disasters in rapid succession. At 7:58 in the morning local time on December 26, 2004, a massive undersea earthquake occurred with its epicenter off the west coast of Sumatra Indonesia, causing a series of devastating tsunamis that spread throughout the Indian Ocean, The most reliable estimates have put the world wide number of persons lost at 229,866, including 186,983 dead and 42,833 missing.

A moderate-sized magnitude earthquake occurred in mid Java Island, Indonesia, at 5:53 local time, May 27, 2006. Though its moment magnitude of 6.3 (United States Geological Survey (USGS) and Earthquake Research Institute (ERI), University of Tokyo) calculated for this earthquake was not surprisingly large compared to major earthquakes that have occurred before in this country, Bantul-Yogyakarta area, with Mt. Merapi, spewing hot ash immediately north behind, was seriously ravaged. At least 6,200 people were reportedly killed, more than 30,000 injured. The earthquake was followed by an undersea earthquake again, which took place off the southern coast of Java island on July 17, 2006. The shake felt on the Java Island was not intense enough to cause any immediate casualties, but tsunami smashed into a 180 km stretch of Java's coast line about one hour, killing at least 550 people and leaving at least 229 missing. Though tsunami bulletins were issued and transferred to Indonesia by both the Pacific Tsunami Warning Center, Hawaii (PTWC) and the Japan Meteorological Agency (JMA) twenty minutes before the first tsunami attack, they were not publicized immediately.

Japan is about 4500 km away from Java, Indonesia. But Japanese people cannot view the above-mentioned earthquakes as something that cannot happen in Japan. At 6:37 local time in the morning on June 15, 1891, a massive undersea earthquake happened. The magnitude estimated for the quake was extremely large reaching 8.5 on Richter scale, but shakes felt along the eastern coast of Sanriku did not seem to be large enough to scare people, and probably was at most 2 to 3 on JMA Intensity scale (Usami, 1990). The shake was much smaller than that happened in 1889, two years before this event; the 1889 earthquake caused a little tsunami at Miyako and Ofunato. Therefore people never came across ideas that they would get killer tsunamis, and total 26,000 were killed in the tsunami that smashed eastern coast of Sanriku about 30 minutes after the quake and surged mountain sides up to 20 to 30 m above the sea level. Another big tsunami caused by a magnitude 8.1 earthquake (2:30 AM) struck the same area in 1933, 44 years after the 1889 Sanriku earthquake. This time, the shake was really intense enough to wake up people. But people believed in a superstition that they would not get any tsunami attacks in a sunny day in winter. They fell asleep, and about 26,000 people were killed in the tsunami flush.

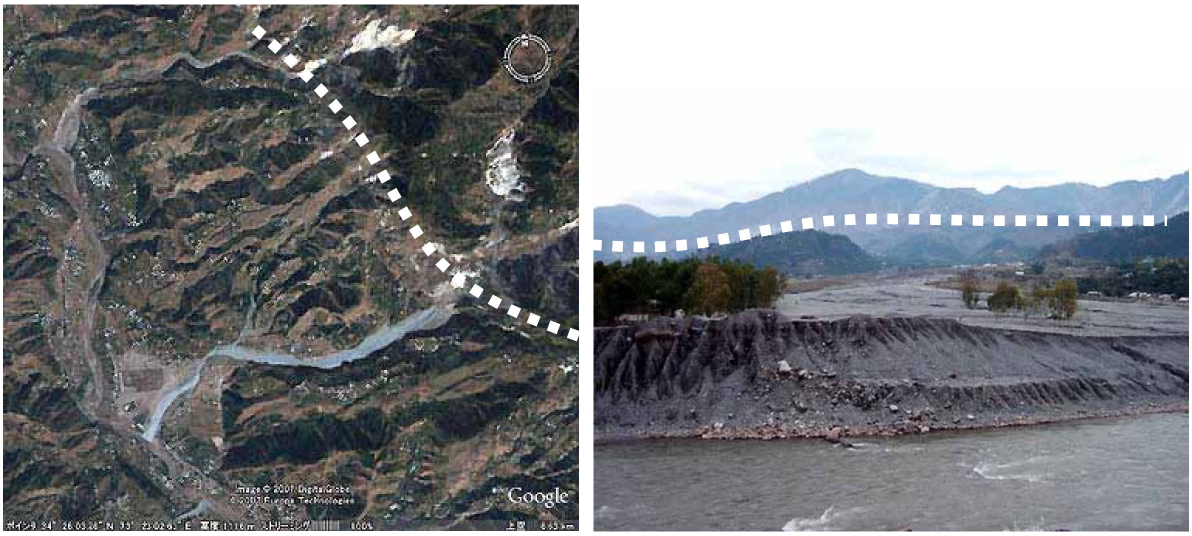
The abovementioned episodes symbolize that it is often difficult for people to have a right understanding of scientific features of disasters, and lessons are hardly transmitted over generations. Therefore it is very important to archive data in a systematic and scientific manner. Deaths and those missing in earthquakes that happened in Japan in the past century make up 165,000, and among them 143,000, namely 90% of casualties, are only from the Kanto Earthquake of 1923. A massive earthquake is an extremely rare event, but once it does happen, its impact on society can be this large beyond the capacity of government. One good thing among many bad things in the Kanto earthquake was that Japan got enormous supports from all over the world. Many voluntary contributions came from the United States including total 525 million US dollars in cash. These donations were mostly for quick rehabilitations to be sure, but some of them were used for documenting and compiling the tragic experiences in scientific manner. The General Assembly of the League of Nations agreed on a resolution that 36 nations and organizations would donate to the Library of the Tokyo Imperial University. The Earthquake Research Institute of this university was founded two years after the Kanto earthquake.

An earthquake research and information center can be an important facility for people to be prepared for massive earthquakes. But the center will not necessarily be in a massive concrete building with lots of facilities. Research facilities are important items to be sure, but the first priority must be put on the idea that all data and lessons obtained at the cost of many lives are to be opened and transferred for interdisciplinary discussions and for rational rehabilitations.

EXAMPLES OF SCIENTIFIC DATA ARCHIVES IN JAPAN

Long-lasting Issues after Massive Earthquakes

Rehabilitation issues often attract less attention than those in the immediate aftermaths of earthquakes, and have never given to prominent coverage by news media. However, both, the 1999 ChiChi earthquake, Taiwan, and the 2005 Kashmir earthquake, Pakistan, formed a great number of debris sources along their activated faults. Heavy rains in the monsoon of 2006 that followed the Kashmir earthquake of 2005, Pakistan, were responsible for raising river beds. At Ghari Habibullah village, 4 to 5 kilo meters west of the northern segment of the Muzaffarabad fault, about 4 to 6 meters thick debris sediment was formed at the exit of a canyon onto a flat plain along Kunhar river (Fig. 1). The ChiChi earthquake was followed by a number of typhoons in rapid succession. They included Toraji and Nari in 2001, Mindulle and Aere in 2004. About 3.9 typhoons on the average over the past ten years (1996-2005) have hit Taiwan, causing three-fold increased risk of debris flows. In these typhoons, increases of river bed elevations of about 4 to 8 meters have been reported (W.F. Lee, 2007). All these cases show that a massive earthquake can trigger a long-lasting change of landforms. Steady and continuous efforts for rehabilitation will certainly lead to developing nation-wide capacity for coping with disasters, and for better rehabilitation tactics, monitoring changes of landforms will be a key to this success. Some attempts going on in Japan are given below.



(a) Sattelite imagery (Google earth) (b) Debris deposit

Fig. 1 Debris deposit from activated fault in Kashmir (Ghari Habibullah village): White broken lines show the activated fault in the Oct. 8, 2005, Kashmir Earthquake, Pakistan.

Fig. 2. Derailed train of Shinkan-sen in the Oct. 23, 2004, Chuetsu Earthquake.

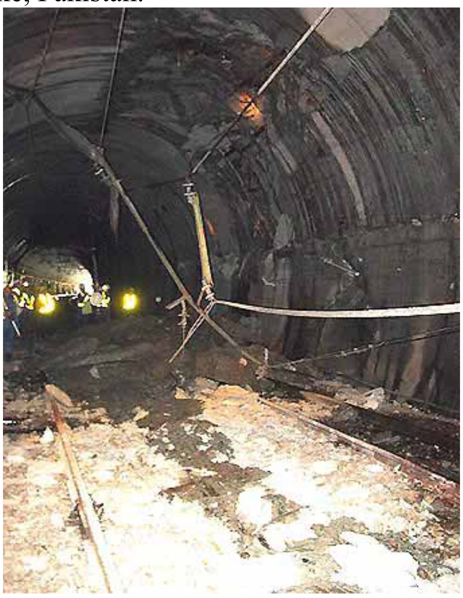


Fig. 3. Wanazu tunnel of JR Joetsu line

Data Archives of Damage caused by Earthquakes in Active-folding Zones

Background

In active folding zones weakened soft rocks can be easily and quickly eroded; the erosion can cause steady changes in surface configurations. An intense earthquake of magnitude 6.8 jolted Mid Niigata Prefecture, central Japan at 17:56 JST on October 23, 2004. The hypocenter of the main shock was located at 37.3 N; 138.8E with depth of 13 km. The maximum intensity of 6+ on the 7-grade Japanese intensity scale was reached.

The earthquake was followed by a series of strong aftershocks in rapid succession. The area suffered four seismic events of magnitude 6 or greater within 38 minutes after the main shock. The focal mechanisms of those major earthquakes are the reverse fault type with the compression axis oriented

NW/SE, which is consistent to the historical solutions of major earthquakes in this area. Aftershocks are distributed along the northeast and southwest direction with a length of about 30km. The maximum acceleration of 1500 cm/s^2 was recorded at Ojiya station, the nearest K-NET site to the hypo-center. This acceleration was much greater than that recorded during the 1995 Kobe earthquake.

The earthquake suspended the function of major trunk railways, the Kanetsu and Hokuriku highways, and national routes along Uono and Shinano rivers, both major rivers form meanders through hills characterized by the geological fold. A Joetsu-Shinkansen high-speed train derailed while in service for the first time since the Shinkansen railway network opened and started expanding nationwide (Fig. 2). Uonuma tunnel of the Joetsu-Shinkansen and Wanazu tunnel of JR Joetsu line (Fig. 3) suffered serious damage probably because the surrounding soil compressed the tunnel along its axis.

An abundant number of landslides in the Higashiyama mountain area forced the local authorities to suspend the operation of totally 233 segments of several prefectural routes and the national route No. 249. As a result, a total number of 61 village areas were completely isolated. The number of blocked road segments increased even more after the intense aftershocks that include the one happened at 10:40am, Oct. 27, in which the maximum intensity of 6-weak on JMA scale was recorded. For fear of additional aftershocks and heavy rains, which are often an early sign of snow season there, the restoration of the damaged segments as well as further analysis for better measures for the upcoming snow-melting season, became a very difficult task.

This earthquake is not an unheard-of event. Reading old literatures extensively, we come across some photographs, lithographs and/or illustrations showing similar geotechnical hazards. They include the Zenkoji earthquake of 1847 and Akita-Senboku earthquake of 1914, both jolted active folding zones, which are mostly found several-tens-kilometer inland along the northwestern coast of the Honshu with much higher mountain ridges rising further inland. It is remarkable that a landslide mass movement triggered in the 1847 Zenkoji earthquake had been moving slowly but steadily for longer than 100 years, occasionally showing a dramatic large movement of about 100 m/year. Massive earthquakes can leave a noticeable amount of unstable soils/debris, which can be sources for long lasting soil mass movements.

Gradually changing landforms

In active folding zones weakened soft rocks can be easily and quickly eroded; the erosion can cause steady changes in surface configurations (Fig. 4). Monitoring this change as well as discussing how the ground has been displaced in the massive earthquake will provide a good and essential perspective for rehabilitating affected areas in a rational manner. SAR (Synthetic Aperture Radar) would be one of the most advanced technology allowing precise elevation changes to be obtained. However, thick vegetation and thousands of landslides have made fringe patterns too much complicated for extracting pure elevation changes. In this project, digital elevation models (DEM, hereafter) have been and being obtained at different times.

(a) Dec. 17, 2004 (b) June 29, 2005

Fig. 4. Example of slow but steady change of landform (Dainichi-yama, Niigata, Japan)

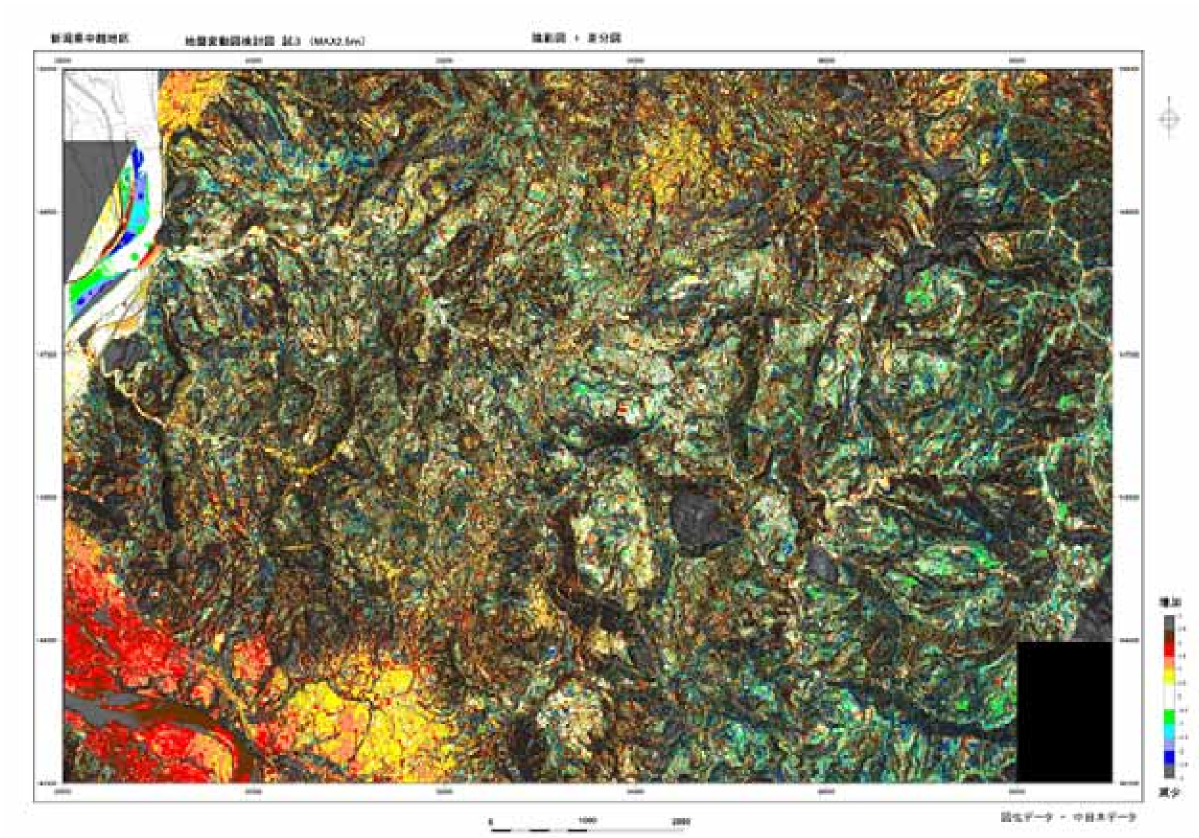
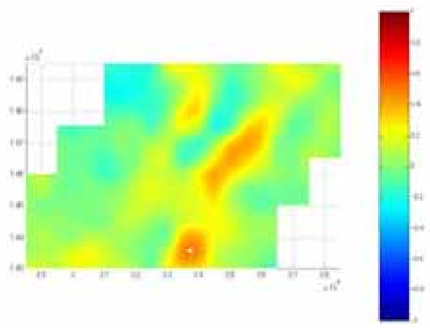
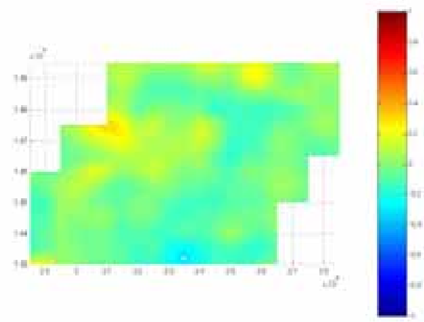
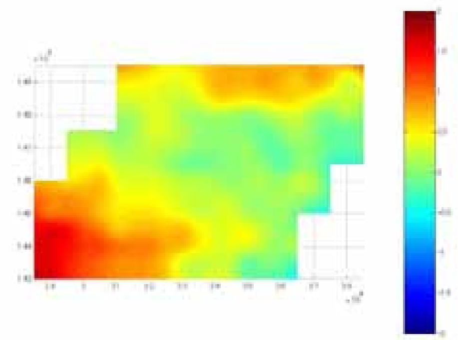


Fig. 5. Elevation changes between two digital elevation models at two different times, Oct. 24, 2004 and 1975-1976, respectively. Warm colors (yellow, red etc.) show increase in elevation while cool colors (green, blue etc.) indicate decrease in elevation. See legend.







Upper left: East-west components
Upper right: North-south components
Lower left: Up-down components

Fig. 6 Three components of ground displacement. Differences between two times, Oct. 24, 2004 and 1975-1976, respectively. Landslides are all excluded. (MEX Project: Earthquake Damage in Active-Folding Areas, Figures prepared by Tomohiro Fujita, 2007)

Fig. 5 shows elevation changes for 11 * 7 km^2 area of Higashi-yama mountains affected by the earthquake. Numerous amounts of dots with their elevations displayed with different colors are all arranged in 2m by 2m square. The result shows the elevation changes in Eularian coordinates, namely, changes observed from points fixed in space. Therefore they are not identical to displacements of soil particles (Lagrangian particles). Moreover, the elevation data from 1970's are from aerial photographs, while the data for the post earthquake landforms are obtained through laser-profiling from aircrafts. In each method, careful data conditionings were made to minimize systematic errors. The Lagrangian particle motions were obtained first and then the elevation changes were compared at several points of triangulations to verify the obtained result (See Fig. 6).

Fig. 6 shows that the middle reaches of the Shinano river, where it is joined by Uono river, has been pushed up by about 1 to 1.5 m (see lower left of the figure). It is noted that Uonuma bridge and Uonuma tunnel of Joetsu-Shinkansen crossing this zone were damaged in the earthquake.

Project of disclosing digital-formatted borehole data

Though some soil databases are available in different countries, they were mostly developed for mining industries. For disaster prevention, Taiwan became a pioneer for developing and disclosing soil data after the ChiChi earthquake of 1999. In Japan, Ministry of Land, Infrastructure and Transport (MLIT) is starting a project for disclosing digital-formatted borehole data. An advisory committee (Chairman; Kazuo KONAGAI, IIS, University of Tokyo) has been organized for this objective.

There are two major data sources that can be a platform for the system. They include:

(1) TRABIS (Technical Report and Boring Information System)

The original system dates back in late 1980's. It became in 1986 a must for all trustees of Ministry of Public Works projects to deliver borehole data written on prescribed sheets. The data delivered were then digitized and kept at MPW computer center. The system was largely updated in 1994 in such a way that all trustees deliver their data on floppy disks following the prescribed format. The most updated format is available on web. So far about 100,000 boreholes have been gathered.

(2) In 1984, Port and Harbor Research Institute of the Ministry of Transport started to collect borehole data for providing important pieces of information for constructing ports and harbors. Microsoft Access has been the platform for this database. Total 28,300 boreholes are now available on the database.

IDEAS FOR POSSIBLE DATABASE IN INDONESIA

Making up geotechnical data archives will be a draft proposal that we can use as a basis for working into a final and feasible plan. It is desirable that the database can be used for solving the following problems in Indonesia:

(1) Long-lasting issues: With a number of active volcanoes, a huge amount of volcanic products (pumice, loam) cover wide areas of Indonesia. It is seemingly often that gritty **sandy loam of volcanic products** is used as fill materials. These soils often have inclusion of porous fragments of pumice. When they are dry, they loose cohesion. But when moist, they are plastic, and retain water easily. When porous wet pumice fragments are crushed, pore water pressure increases causing the entire soil to fluidize. (see **APPENDIX I**)

(2) **Tsunami deposits**: Tsunami not only erodes coastal areas but also leave deposit of soils and other matters on the inundated areas. The ground can be littered with trashes that were swept inland, sediment deposits, bricks, and other debris. For rehabilitating these inundated areas, shallow soil profiles and their natures are also to be studied (see **APPENDIX II**).

For realizing geotechnical data archives taking hints from the MLIT plan, one should recognize that few boreholes are found in rural areas, while they are densely available in urban areas. Therefore, soil soundings would complement what borehole data do not provide.

(3) Transferring practical use of **Sweden Cone-penetrometer** for detecting shallow soil profile:
Since shallow soils including those mentioned above have been greatly responsible for serious destructions in earthquakes, practical methods for quick sounding are to be transferred. JSCE taskforce has been involved in this technology transfer. The obtained soil profiles will be certainly important not only for rehabilitating areas affected by massive earthquakes but also for mapping out tactics for future disaster mitigation.

APPENDIX I

A bridge of Mataram canal, supplying drinking water and irrigating 19,000 ha of land extending the lower basin of Progo and Opak river, was damaged in the May 27, 2006, Mid-Java Earthquake, as shown in Fig. A1. The sandy soil mass of the right embankment behind the masonry abutment of about 10m high slid down towards the river. The scar was formed 26 m west behind the abutment immediately beneath a construction joint of the open channel, suggesting that water might have been seeping through the joint into the embankment soil. It is seemingly often that gritty sandy loam of volcanic products (tephra*) is used as fill materials. These soils often have inclusion of porous fragments of pumice. When they are dry, they loose cohesion. But when moist, they are plastic, and retain water easily. When porous wet pumice fragments are crushed, porewater pressure increases causing the entire soil to fluidize. But they yet can drain well where the surface configuration allows. Fill materials with the features mentioned above, requires appropriate drainage works.

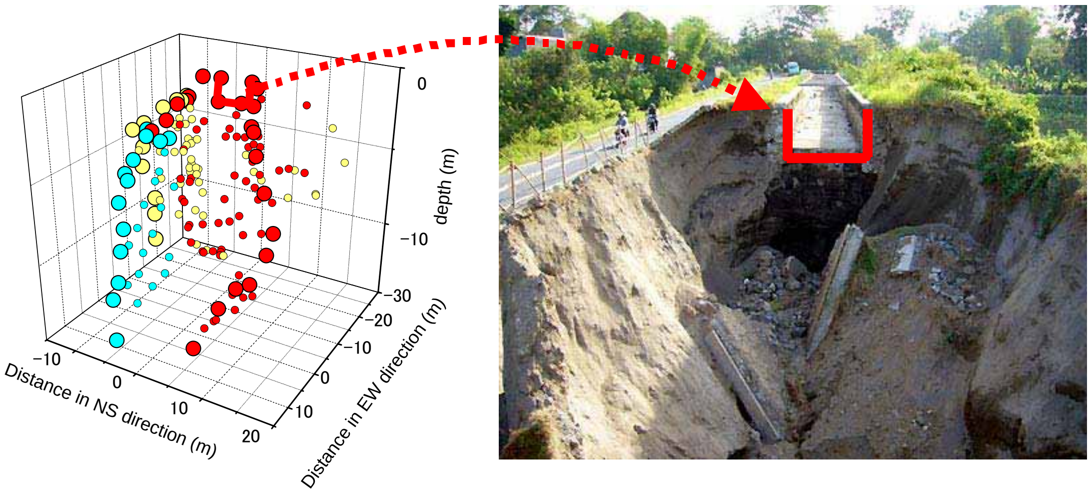


Fig. A1 Damaged embankment leading to Mataram canal bridge: The cave of the embankment was laser-scanned for its 3D image. Total soil volume about 2,000 m^3 has gone. Scar did appear immediately beneath the construction joint.

* Tephra is air-fall material produced by a volcanic eruption regardless of composition or fragment size.

APPENDIX II

Tsunami deposit can often be used to extend the record of tsunamis farther into the past. But deposits features may have to be studied from civil-engineering aspects as well for better rehabilitation of the inundated areas. Thickness of tsunami sediment differs from point to point reflecting how the tsunami flowed over the area (See Fig. A2).

Fig. A2. These photos put side by side can be perceived as a single image in terms of depth, and Iruma town is found spreading over a 7-8m thick tsunami sediment, the sediment was formed in the Ansei earthquake.

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