Quick report of the JSCE/AIJ/EWBJ Joint Survey for the Indonesia Bengkulu Earthquake of September 12, 2007 (Ver. 1.1, Feb. 1, 2008)

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1. Introduction

Indonesian people have been suffering from massive earthquakes in a rapid succession. They include a massive undersea earthquake, which occurred at 7:58 local time on December 26, 2004 west coast of Sumatra, Indonesia. The most reliable estimates have put the worldwide number of persons lost at 229,866, including 186,983 dead and 42,833 missing. When the sources of these recent massive earthquakes are plot on a map, one can find that most of them are lined up along the plate boundary, where the Indian Sea plate subducts beneath the Sumatra Island, highlighting the presence of some seismic gaps. One of the largest gaps is immediately west of Padang, and posing threat to people living in West Sumatra Province.

An inter-plate earthquake of moment magnitude 8.4 shook south and west Sumatra provinces on September 12, 2007. The earthquake was immediately followed by two large events with moment magnitudes of 7.9 and 6.8. Luckily their sources were far away from some populated areas along the western Sumatra coast, and the number of casualties reached in these events was 50. In terms of the number of deaths, this earthquake was not surprisingly large as contrasted with the others that took place in this country. However with the menace of this seismic gap, any lessons are to be learned from earthquakes that have affected areas in the vicinity of this seismic gap.

The Japan Society of Civil Engineers (JSCE) and Japan Association of Earthquake Engineering (AIJJ) jointly dispatched a first advanced body for this purpose collaborating with Indonesian counterparts including Andalas University at Padang and a tsunami-alert community NPO (KOGAMI). The preliminary strategy of the JSCE/EWBJ advance team was to make a first reconnaissance laying stress on the damage to dwellings, civil infrastructures caused by both strong ground motions and tsunami surges, and then to discuss with experts from Indonesian organizations about tactics for better rehabilitation.

The second JSCE team was dispatched on January 28, 2008 asking both Architectural Institute of Japan (AIJ) and the Engineers without Borders, Japan, (EWBJ) to collaborate, and made a quick two-days survey along the west coast of Sumatra. One of the missions of the second team was to assess rehabilitation process and some long-lasting problems. 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, earthquakes can cause landforms to change slowly and steadily, yielding some difficulties in rehabilitating affected areas. Four months time interval between the two surveys may highlight some issues to discuss for better and rational rehabilitations.

This report outlines the findings obtained through the survey and recommendations. Some descriptions in this report are not fully evidenced yet, and therefore, some comments are not yet the conclusions reached after thorough studies. However, providing both Japan and Indonesian experts and persons in charge with a quick-and-ready overview will be important for taking measures for better rehabilitations and preparedness.

It is our sincere wish that JSCE, AIJ and the abovementioned organizations, will be in tight collaborations beneficial for both Indonesian and Japanese sides.

2. Findings and recommendations

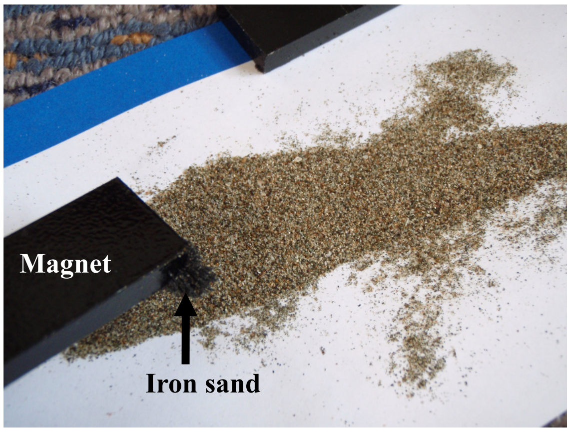
2.1 Geotechnical aspects

Geological and geomorphologic features

Coastal region is very low to poor topographic relief with low-risen terraces having about the same elevations. These terraces are often abundant in either laterite or loamy soils. Nearly all kinds of rocks can be deeply decomposed by the action of high rainfall and high temperatures. Percolating rain water causes dissolution of primary rock minerals and decrease of easily soluble elements. As the consequence remaining substances such as iron oxides goethite and hematite cause the red-brown color of these soils. When soaked up with water, laterites can be very soft allowing their cohesive slopes to slide over deep-sheeted circular slip surfaces. When dried, they are friable. With these features they are sometimes cut into blocks and used as brick-stones for house-building.

Along some shorelines, greater parts of their uplands have been gone due to the wave action of the sea. Wet and swampy areas behind these terraces are normally rich in vegetation, and eventually covered thick with peaty soils. Winds may be neither steady nor strong enough for sand dunes to be developed thick along coast lines, and yet winds and Long-shore currents often shift river mouths in the directions of gradual evolution of beaches. However, at some locations such as the Padang coast, the amount of sand washed away from the coastline may be larger than that deposited, causing the coast line eroded towards inland gradually (See Fig. 1).

(a) Dike along the coast of Padang



(b) Iron sand (see black arrow) included in a spoon-full sand

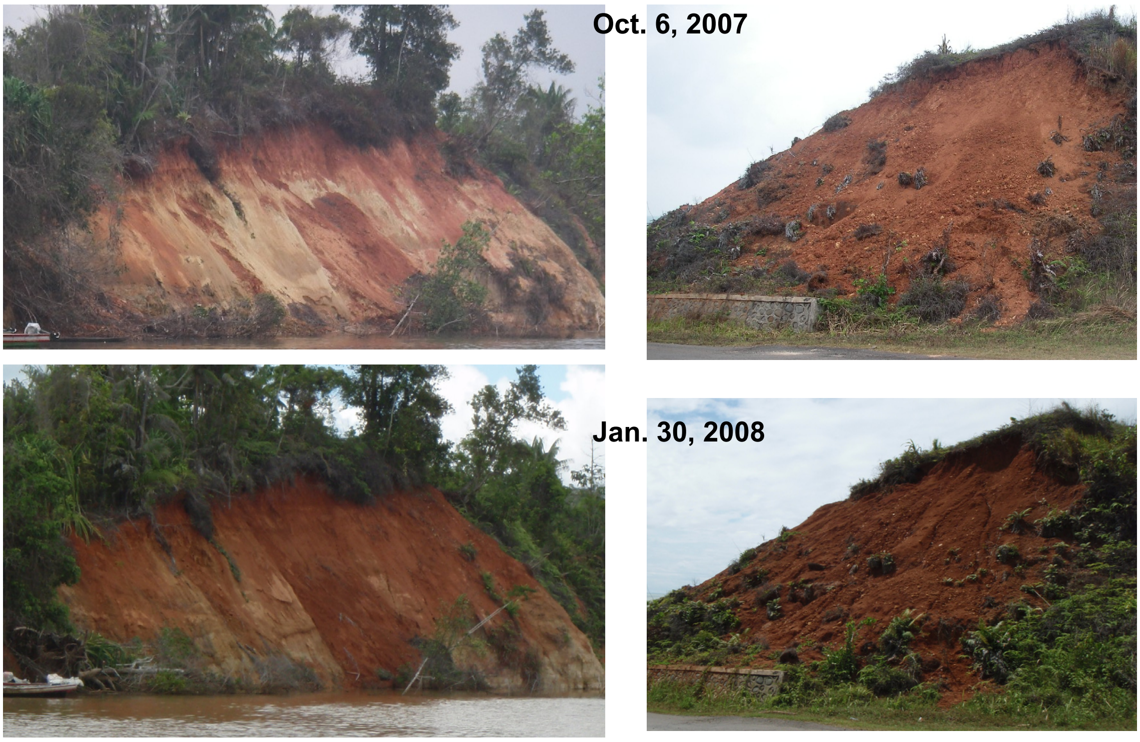
Fig. 1. Coast of Padang (Location: 00°56'48.7"S, 100°21'6.3"E): A masonry dike system (tsunami wall) of about 3m high has been constructed along the coast of Padang. Some toe stones are being embedded in the sand. A spoonful of sand ($D_{50} \cong 0.15$ mm) from the shore included some iron sand (placer sand) as shown in the photo (b). This may suggest that the shore line is being eroded inland with heavier substances remaining there. The December 26, 2004 Tsunami have strip sand off shorelines elsewhere, and the great erosion/sediment-reworking potential may be a cause of this erosion. Long term monitoring of the shoreline change is recommended.

Fig. 2. Exposed slip surface of laterite (Location 3°25'38.5"S, 101°53'51.4"E): The photo above was taken on Oct. 6, 2007 by O. Aydan, while the photo below shows the same surface four months later (photo by K. Konagai). With it toe being washed by sea waves, the slope has been eroded slightly inland. See some trees on slopes have disappeared.

Earthquake-induced landform changes and recommendations

(1) Slopes of laterites will deform slowly:

Fig. 2 and 3 compare same laterite slopes at different times. With the feature of laterite described above, their deformations will be slow. If their toe parts are being eroded steadily, sudden movements of landslide masses may occur.



(a) River-attacked laterite slope at
3°25’35.2”S, 101°53’50.4”E

(b) Cut laterite slope at
3°25’0.5”S, 101°52’30.7”E

Fig. 3. Exposed slip surfaces of laterite: The photos above were taken on Oct. 6, 2007 by O. Aydan, while the photos below show the same surfaces half year later (photo by T. Kiyota). Excluding some minor scratches, no clear change was observed.

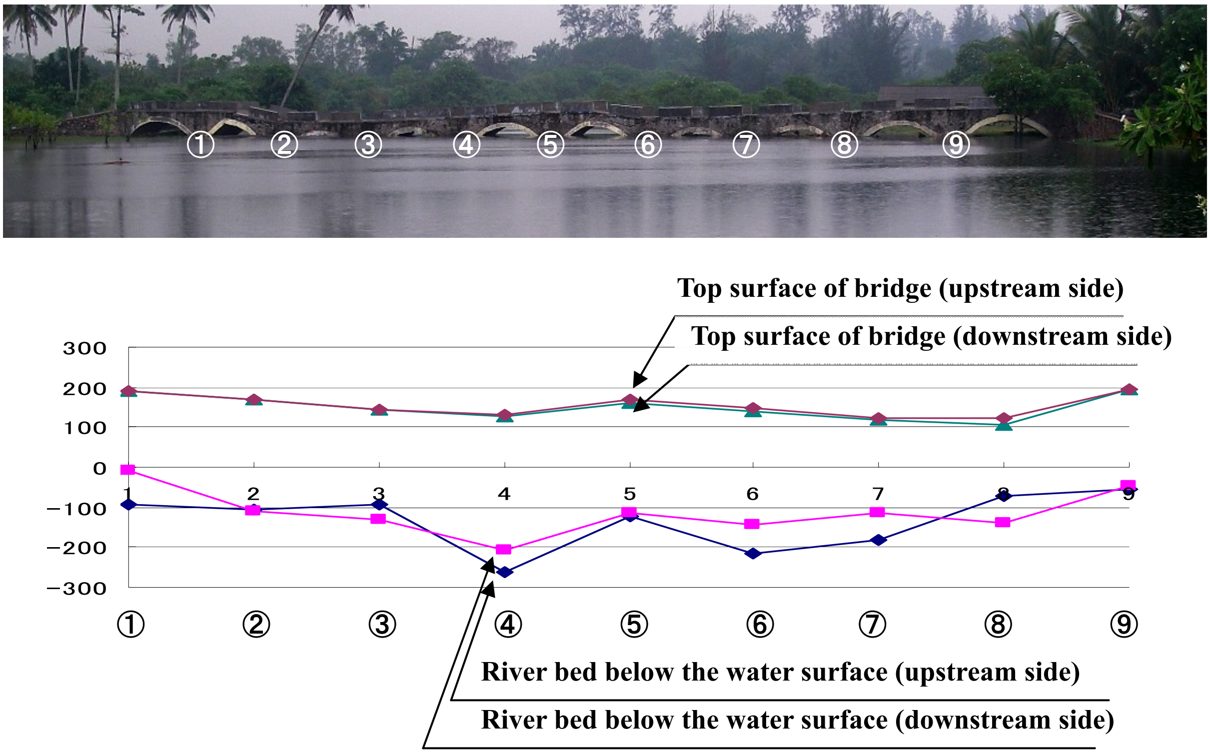


Fig. 4. Masonry arch bridge (Location 2°1'20.5"S, 100°52'42.5"E): Some foundations of this masonry arch bridge have sunken into the riverbed of fine sand. Elevations of the road surface above the water level were measured immediately above the nine piers. Though riverbed depths differ between upstream and downstream sides, cross-sections of the bridge did not show any clear sign of inclination. Riverbed erosion around piers may have happened when tsunami surged up and down the area.

(2) Liquefactions
Deposits of sand, which may have taken long time to accumulate, cover the very flat sub-soils (maybe a flat laterite layer). As far as we have surveyed, earthquake-induced lateral soil flows were seldom and insignificant. A masonry bridge in Fig. 4, however, shows that heavy structures can sink straight into sand deposits. This uneven settlement of the bridge may have caused by either sand liquefaction or tsunami surge, which might have eroded the bottoms of piers (See river bed depths in Fig. 4).

(3) Beach evolution and coastal erosion (Fig. 1)
Along gradually thinning sandy shorelines, masonry sea dikes and/or tsunami walls can sink into the sands. Some walls may not be high enough to stop tsunami waves and water may be stopped inland. The stopped water can flow back into the ocean through where the walls have been subsided seriously. At these points the flows will be fast enough for these points to be eroded further deep. Long-lasting erosion and accretion process of sand is to be monitored for laying out important facilities such as tsunami walls.

(4) Gathering and compiling geotechnical data
To cope with preparedness issues for the areas with menace of possible massive earthquakes, data of subsoil conditions are to be gathered and compiled in a systematic way. 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.

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.
[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.

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.
(1) Transferring practical use of soil-sounding devices such as Sweden Cone-penetrometer:
Since shallow soils are often responsible for serious destructions in earthquakes, practical methods for quick soil-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.

2.2 Architectural aspects

(1) Confinement of URM walls

Devastating damage was found in URM buildings but those with RC beams and columns confining URM walls (confined masonry buildings) were relatively less damaged, even when they were not intact. Providing RC frames to confine masonry walls, therefore, is strongly recommended to reduce structural damage to URM buildings.

Integrity of beams provided at the top of URM walls (lintel beams and collar beams) are most essential to effectively confine those walls, and reinforcing bars at beam-beam and beam-column joints should be carefully detailed so that they are not easily separated into members at their joints due to pull-out failure (see Figs. 5 and 6). Strengthening of the weak joints above wall is of highest priority for existing confined masonry buildings.

Fig. 5. Damage to URM wall due to pull-out failure at collar beam joint.

Fig. 6. Out-of-plane failure of URM wall due to pull-out failure at beam-column joint.

(2) Integrity of foundation system

Foundations should be properly designed and constructed for successful performance dusting strong shakings. Foundation beams in the affected areas were often found unreinforced and structurally independent of neighboring columns. Furthermore, they were often provided mainly in one direction and were not provided in the transverse direction (see Fig. 7).

Anchorage of column reinforcement to foundation underneath is another key issue to ensure successful behavior of a building system. Poor reinforcement detailing would result in deformation larger than and in lateral resistance smaller than that expected if columns are assumed in the structural design to have a fixed end at their bottom.

To form a rigid foundation system, reinforcing bars should be properly provided in foundation beams, footing slabs and columns above, and they should be properly embedded and anchored into the connection to avoid joint failure, which may lead to catastrophic damage to a superstructure.

Fig. 7. Unreinforced foundation beams are provided only in the longitudinal direction (left). Column reinforcement needs to be properly embedded into footing slab to form a rigid foundation system (right).

(3) Comparison of seismic capacity of buildings and their observed damage

Comparison of seismic capacity of both damaged and survived buildings can provide valuable information to set a criterion to identify safe buildings, i.e., a required capacity to survive the shaking that buildings in the affected area experienced during the earthquake. Furthermore, the obtained results would be of great help to discuss the required capacity of buildings against future earthquakes.

The contribution of URM walls that is usually neglected in the structural design stage may have great effects on the building's behavior such as column shortening and lateral resistance (see Fig. 8). In evaluating capacities of buildings, it is therefore essential to consider their contribution to structural performance to properly estimate their seismic capacities, although they may be deemed "nonstructural members" during structural design.

Fig. 8. URM walls are contributing to column shortening and lateral force resisting mechanism.

(4) Tsunami shelters

Tsunami attack is a life-threatening event along the coastal areas. Tsunami dikes should be provided especially where essential facilities are centered. Constructing tsunami shelters would be another possible solution to provide safe facilities to residents in the tsunami-prone areas. Multistory school buildings that are redesigned and retrofitted against both earthquake and tsunami loads expected at the site can be primary candidates for the shelters (see Fig. 9). Providing a stairway directly accessible from ground level to upper stories would be a practical solution to utilize them as emergency shelters.

Fig. 9. Multistory school buildings with balcony directly accessible from the ground level can be primary candidates for practical tsunami shelters.

(5) Falling hazard

Damage to nonstructural elements is found in some commercial buildings, and they are often left damaged long after an earthquake causing hazard likely to fall down (see Fig. 10). They would cause secondary damage due to aftershocks, heavy rainfall, strong wind etc., and removal of falling hazard is strongly recommended immediately after damage.

Fig. 10. Ceiling boards are still left damaged 4 months after the last event.