Survey of September 30, 2009 Sumatra Earthquake

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ABSTRACT: On September 30, 2009 at 17:16, an intense earthquake (M7.6) occurred just off the western Sumatra coast in Indonesia. The official death toll was confirmed at 739 people, with another 296 people missing and presumed dead, primarily in Padang Pariaman District. A total of 863 people were seriously injured, and 1,356 people slightly injured. Damage to houses was widespread with 121,679 houses severely damaged, 52,206 moderately damaged, and another 57,510 lightly damaged, rendering homeless an estimated 250,000 families (UN OCHA). Japan Society of Civil Engineers (JSCE), Japan Association for Earthquake Engineering (JAEE) and Engineers Without Borders-Japan organized a survey team immediately after the event. The team was dispatched to Indonesia and conducted initial damage assessment in the damaged area. This report outlines the findings obtained from a quick survey (Oct 16-18) of the damaged area.

Key Words: Sumatra Earthquake, Masonry structure, Liquefaction, Tsunami, Disaster survey

INTRODUCTION

On September 30, 2009 at 17:16, an intense earthquake (M7.6) occurred just off the western Sumatra coast in Indonesia (Location: 0.789°S, 99.961°E). The focal depth was 80 km (USGS). The epicenter was 45 kilometers from the port city of Padang, Sumatra. An after shock (M6.2) occurred 22 minutes later, followed by a third quake (M6.8), which struck 225 km southeast of Padang. This continuous shaking caused widespread destruction in the area of Padang Pariaman District. Most inhabitants in the affected areas lost their houses to collapse caused by seismic motion or landslide. The official death toll was confirmed at 739 people, with another 296 people missing and presumed dead, primarily in Padang Pariaman District. A total of 863 people were seriously injured, and 1,356 people slightly injured. Damage to houses was widespread with 121,679 houses severely damaged, 52,206 moderately damaged, and another 57,510 lightly damaged, rendering homeless an estimated 250,000 families, many too frightened to return home (UN OCHA).

Japan Society of Civil Engineers (JSCE), Japan Association for Earthquake Engineering (JAEE) and Engineers Without Borders-Japan organized a survey team (Team leader: Dr. Masanori HAMADA, professor, University of Waseda) immediately after the event. The team was dispatched to Indonesia, and conducted initial damage assessment in the damaged area.

STRUCTURES

Over 300 building were briefly observed in a survey of the Padang and Pariaman area. In **Figure 1** blue sticks mark the observed damaged buildings. Structures affected by this earthquake were primarily low-rise residential masonry, hotel buildings, government offices and industrial facilities.

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The structural type of engineered and non-engineered structures in the affected areas may be classified in three general categories: wooden structure, unreinforced masonry structure, and masonry structure with frame. Residential wooden houses with tile or corrugated steel sheet roof are constructed with a wood frame made up of columns and beams supporting wood joists. The roof is covered with clay tile or thin corrugated steel sheets. Unreinforced-mansonry structures (non-engineered concrete construction) with masonry infill are common in Indonesia. The beams and columns of these buildings are substandard, consisting of small sections lightly reinforced with plain bars. These columns suffered significant damage from the seismic forces. Mansonry structure with frame (engineered reinforced concrete construction) generally well-constructed reinforced concrete frame structures, survived the earthquake with heavy damage in Padang. Damaged masonry and wooden buildings were also observed in the mountaineous Pariaman region.

In **Figure 2**, Photos 1 and 2 show the typical damage to wooden houses and masonry houses constructed with bricks. There were many wooden houses in the damaged area. These structures performed better than brick masonry houses with or without RC slabs and/or columns; however, there were instances of total collapse due to intense ground shaking. Photo 3 shows an old one story masonry building with no reinforced concrete slabs and columns. Low-rise residential masonry buildings are generally constructed with bricks and are either one or two stories. This type of collapse was observed even in areas with high ground acceleration. Newly-constructed buildings with concrete slabs and columns, there is no doubt that when such structural elements are integrated with masonry walls they perform better and prevent the total collapse of the buildings in spite of some structural damage. Photos 4 and 5 show a government office constructed with an engineered structure. Several cases of total collapse or heavy damage were observed. Some hotel structures also totally collapsed as shown in Photos 6 and 7. Photo 7 shows damage to a hotel which was assigned as a vertical evacuation space in the case of tsunami. People could not use this building as an evacuation structure due to its collapse. This damage illustrated the problem with vertical evacuation spaces. Pancake-type collapse was observed in the buildings of China Town, as shown in Photo 8. The concrete buildings with two or more stories either collapsed or were heavily-damaged. These type of reinforced concrete structures are framed structures with integrated or non-integrated in-fill walls.

The South and West Sumatra Earthquake on September 12, 2007, killed 25 people and caused heavy damage in Benngkulu and West Sumatora Provinces along the western shore of Sumatra Island. The structural damage was similar to the damage observed from this earthquake. Earthquake damage to structures has often been connected to the local structural type, and this type of construction is typical of low-cost and affordable housing in Indonesia.

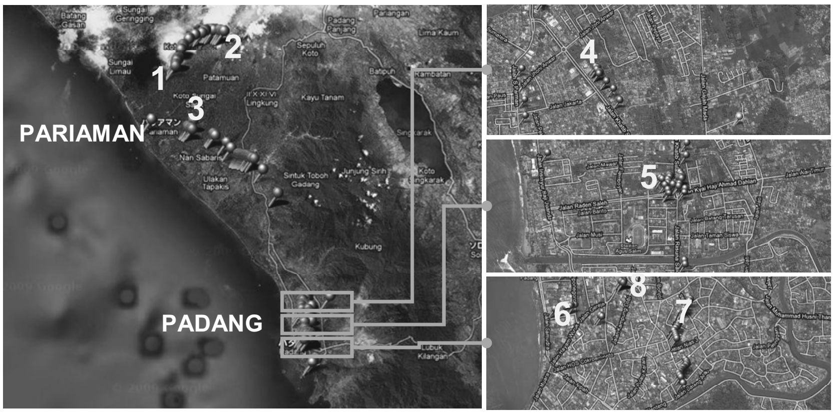

Figure 1. Damaged structures in Padang and Pariaman on Google map

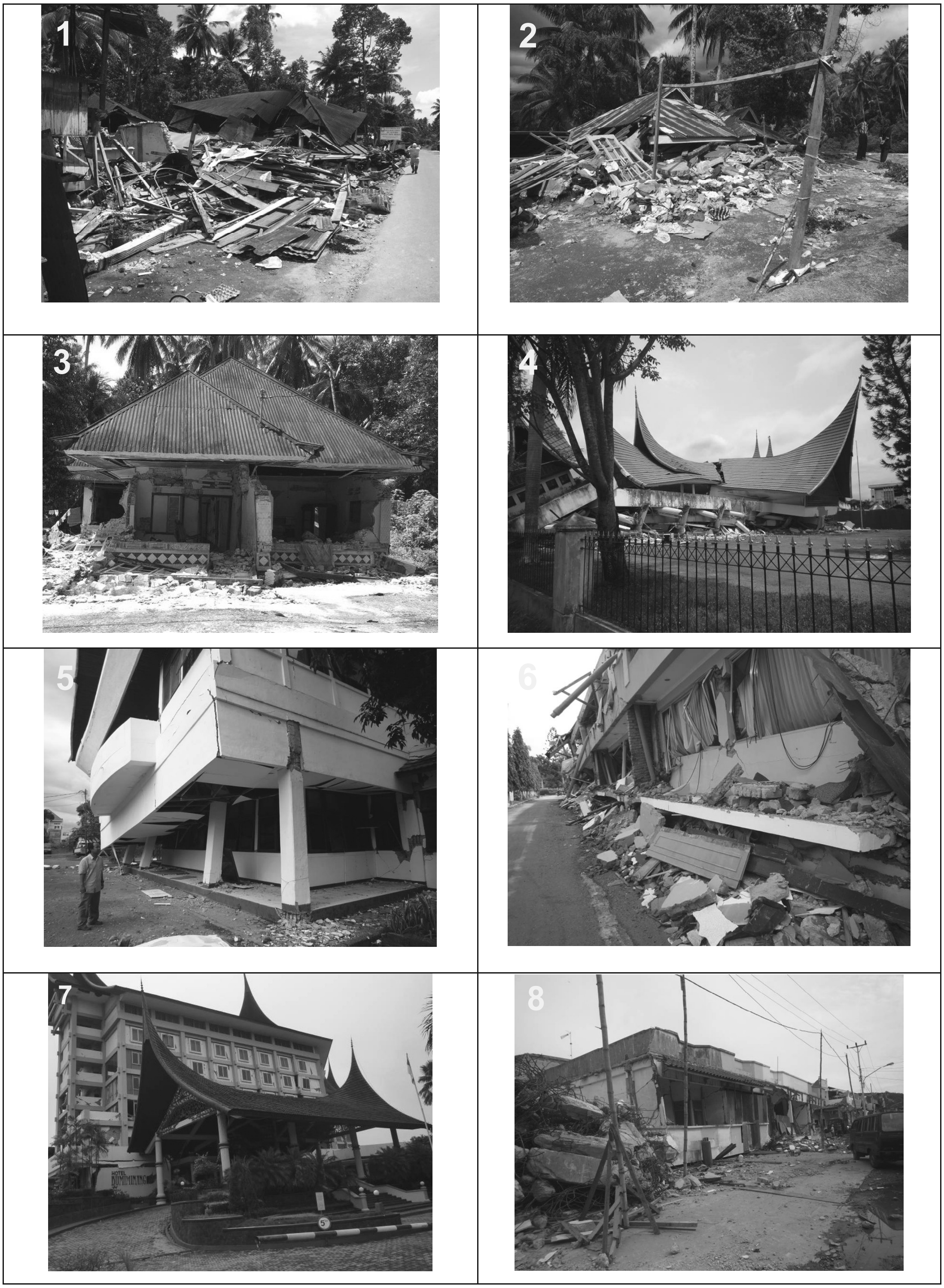

Figure 2. Photos of damaged structures in Padang

BRIDGE

An assessment of 15 bridges in Padang (14 bridges) and Pariaman (1 bridge) found no significant damage from this earthquake (**Figure 3**). The types of bridges in the epicentral area are mainly truss or simple beam bridges (**Table 1**). The earthquake shaking did not cause any visible damage to the bridge, roadways even though they were near the epicenter of the earthquake. Damage to bridges was mainly caused by the failure of approach embankments and uneven settlement of piers. However, almost all bridges were open to traffic with speed limitation.

The most heavily-damaged bridge, Sitinurbaya bridge with concrete type (No. 1), underwent settlement of around 100 centimeters in backfill soil, and lateral deformation of ground due to liquefaction at the pier was observed. However, the pier was not affected by the ground movement. Sitinurbaya bridge was constructed to withstand the seismic motion and liquefaction. Mirang bridge shown in **Figure 4** (No. 4) was constructed as a parallel concrete beam structure. Lateral movement was not observed due to the stopper at the bearing. Settlement of about 20 centimeters at abutment was also observed at Mirang bridge (**Figure 5** (a)). Lateral movement was observed, as well as the collapse of electric lamp on the beam and displacement of 2 centimeters at the bridge's rubber bearing in **Figure 5** (b). The function of road could be maintained with such light damage.

At Bungus bridge (No. 8), damage was observed with over 10 centimeters of lateral movement due to the failure of the stopper, which should reduce lateral movement.

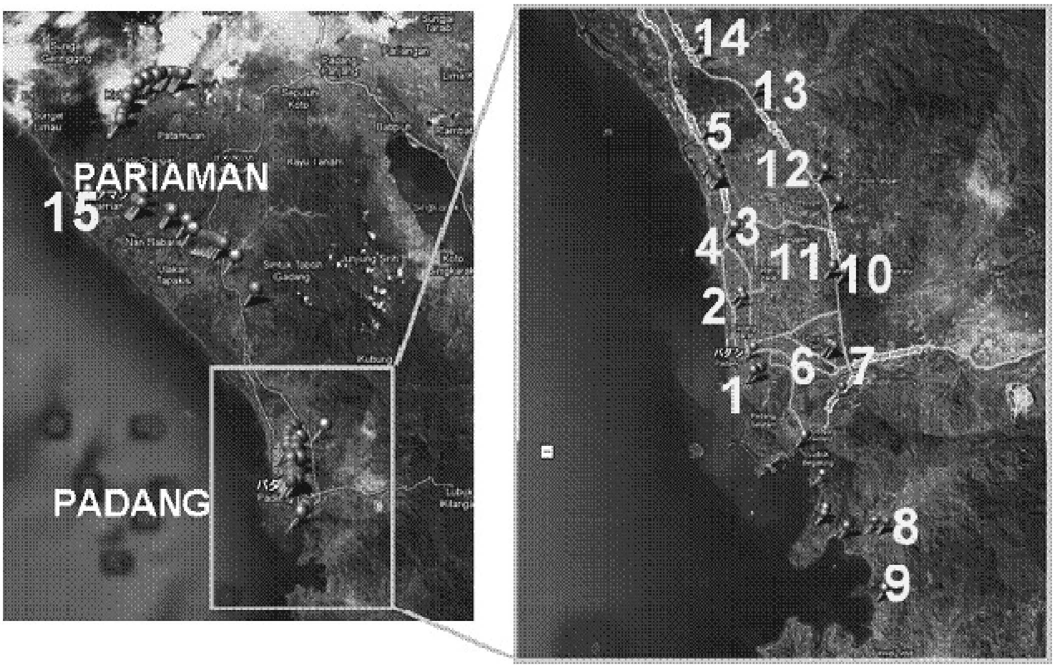

Figure 3. Surveyed bridges in Padang and Pariaman

Table 1. Surveyed bridges in Padang and Pariaman

No	name	type	damage
1	Sitinurbaya	concrete	100cm settle down
2	Purus	truss	10cm settle down
3	Mirang rail way	truss	10cm move at abutment
4	Mirang (a) (b)	concrete	(a) Lump, 2cm move (b) 20cm settle down
5	Muara Panja Linan	concrete	none
6	Lubeg 1	concrete	slightly crack
7	Lubeg 2	concrete	none
8	Bungus	truss	10cm lateral def.
9	Timbalun	truss	none
10	Kuranji	concrete	none
11	Kalawi	truss	Abutment push/ move
12	Sungai Sapih	concrete	Settle down/ 21.5cm lateral def.
13	Lubuk Minturun	concrete	15cm lateral def.
14	Kandis	concrete	Settle down back fill soil
15	Unknown	concrete	Pier crack

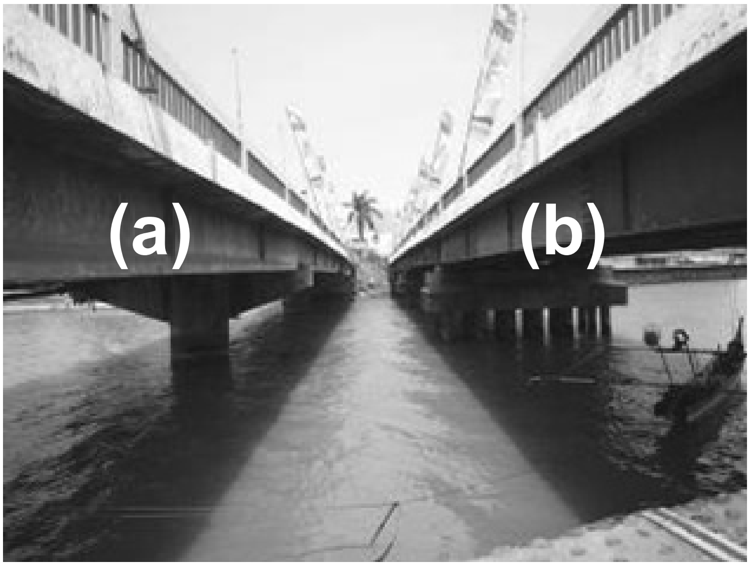

Figure 4. Mirang bridge (No. 4)

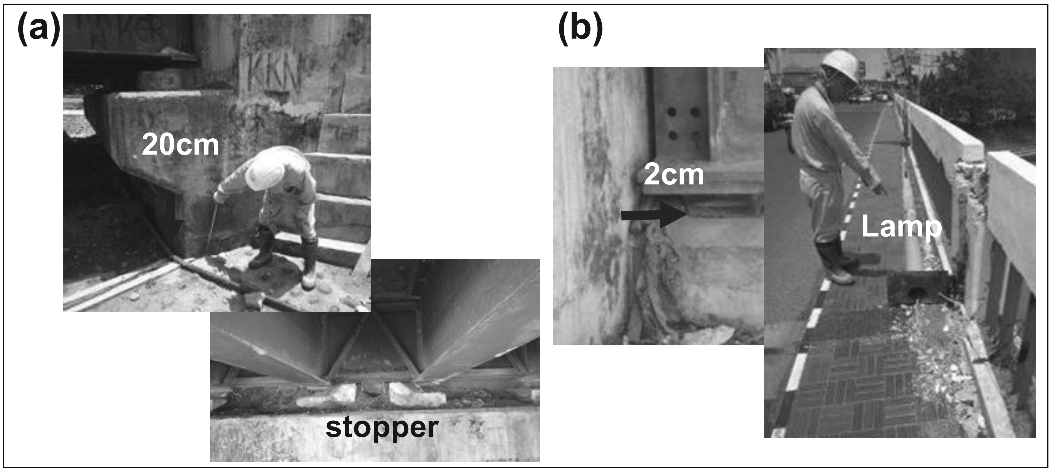

Figure 5. The damage of Mirang bridge (No. 4)

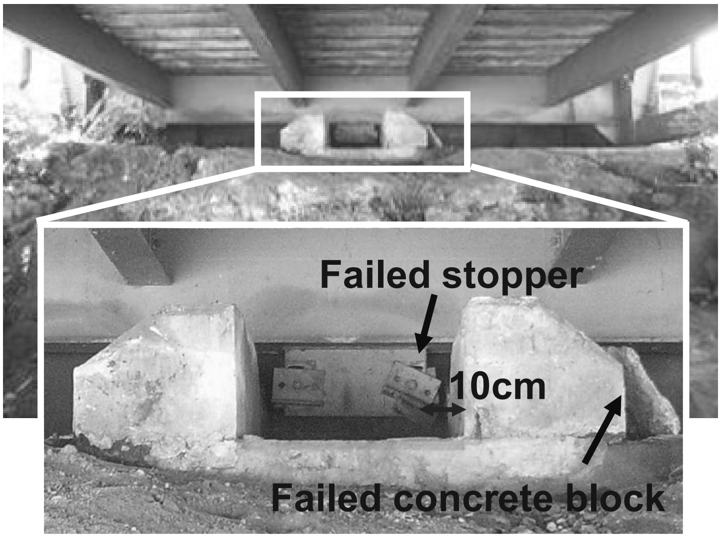

Figure 6. The damage of Bungus bridge (No. 8)

ROAD AND RAILWAYS

During the survey, roads were available to traffic in Padang. Heavy damage to roadways was observed in mountainous Pariaman area. Surface ruptures and embankment failures along the river and slope cut caused damage to roadways at several places in Padang and Pariaman. In particular, slope failures occured in places with volcanic sediments and volcanic soft rocks, such as in the mountainous Pariaman area.

Extensive slope failures were observed along the mountain roads. Some of these roadways were constructed on a thin ridge with soil surface along the river (**Figure 7**), with the failure points on the attacking side of river, where the foot of the slope had lost stability due to erosion by water flow.

Typically, the slope on the attack side may be unstable due to erosion of the foot.

Figure 8 shows a large slope failure of volcanic sediment. Since the volcanic sediment is a type of pumice soil, under water supply it can easily fail on the sliding surface of the clay layers. When the earthquake occurred, a wedding ceremony was being held on the sliding soil mass. This failure caused the deaths of 200 people attending the party. Some rock falls along the road side slope of volcanic geology at Southern Padang area were observed.

Embankment failures of roadways and rivers were also widespread in the area where the ground motions were high. The embankment failures at infilled sections of the roadways were quite severe. Since the ground was more resistant and ground shaking was mild, the translational movements did not cause the total collapse of the embankments. However, the approach embankments of bridges were severely damaged by settlement and lateral spreading of ground at their base, and access to these areas in Pariaman remains difficult.

The railway is normally used for leisure on the weekends. The railway was available on the first weekend after the earthquake. Slight failure of railway embankments was observed: however, they were completely recovered after the first leisure day (**Figure 9**).

Figure 7. Slope failure in Pariaman

Figure 8. Large Slope failure in Pariaman

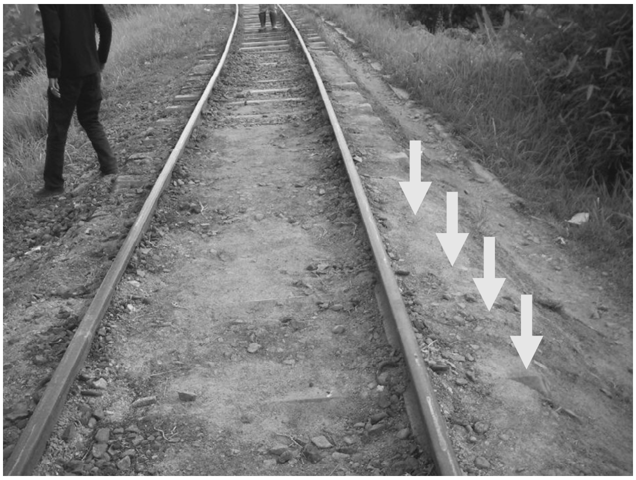

Figure 9. Embankment damage of railway

GEOTECHNICAL DAMAGE

The most remarkable geotechnical damage was caused by liquefaction and accompanying lateral movement. **Figure 10** shows the surveyed area with geotechnical damage along the sea side or the river in Padang and Pariaman.

Lateral flow and/or movement of over 10 centimeters caused damage to several houses on the affected ground at Point 1 (**Figure 11**). The liquefaction sites are located between the coastal line and a small river with ground layers of sand and a shallow ground water level in the marine deposit. Settlement of buildings and foundation damage due to liquefaction-induced ground failure and lateral spreading resulted in the collapse of masonry houses and/or severe cracking walls. The ground liquefaction caused damage due to non-uniform settlement of house foundations. Several houses needed to be supported by bar to prevent collapse due to the inclination of ground foundation (**Figure 11**). Permanent ground deformation caused extensive damage to the wide region.

Liquefaction was also observed at Points 2 and 3 along the river on the sandy ground (**Figure 12**). Sand boils was observed at Points 4 and 5. Since the ground in this region consisted of a sandy layer, liquefaction easily occurred due to intense shaking. Fortunately, no damage occurred at the sea port at Point 4.

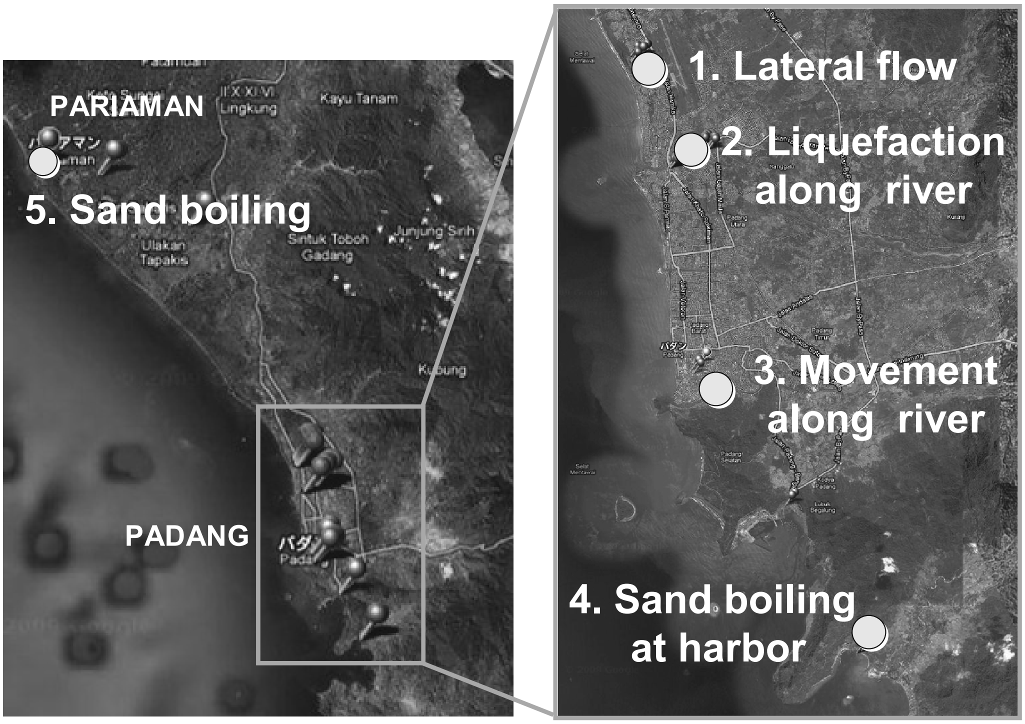

Figure 10. Geological damaged point

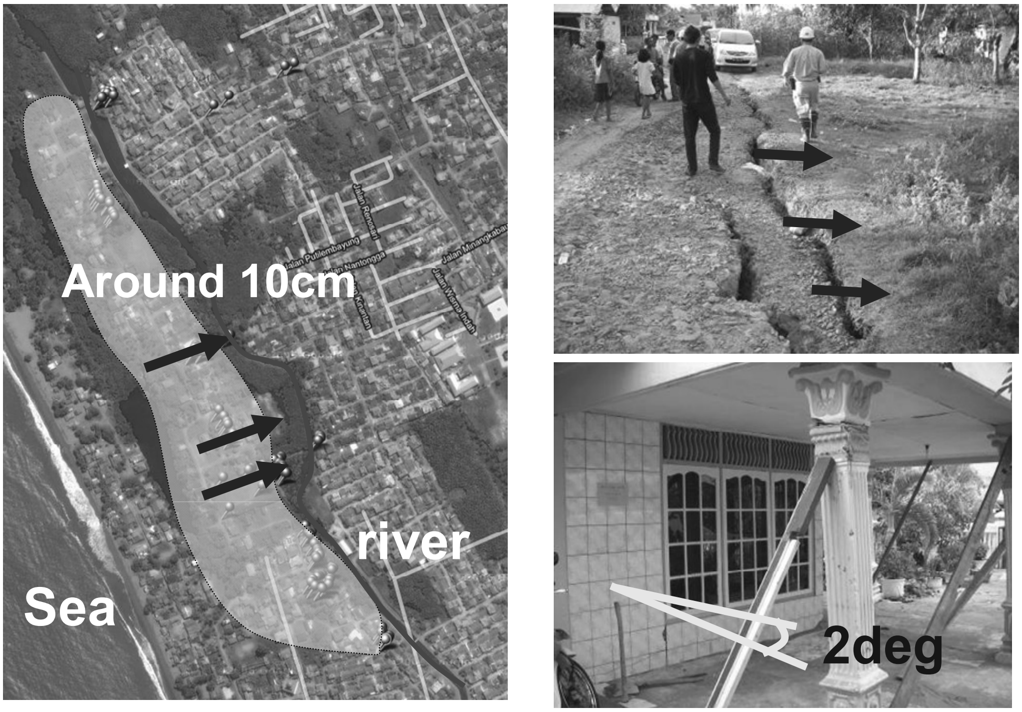

Figure 11. Lateral movement at Point 1 in Figure 10

Figure 12. Liquefaction at Point 2 in Figure 10

INDUSTRIES

Most industrial facilities are located in Southern Padang City. The earthquake did not cause any major damage to industrial facilites except some small scale damage from the inspection of some industrial plants (**Figure 13**).

Two ceramic isolators in electric power station were damaged but repaired two days later, whereas seven to ten days were needed to restore electric power in Padang city.

Two port facilities in Padang were observed. The cement plant and coal storage did not suffer from considerable damage and the economic loss due to the subsidence or lateral movement of coastal line was small. Liquefaction and slight damage at the ferry crossing were observed. No damage was found in the petroleum tank yard.

Figure 13. Industrial place and main industrial facilities

CONCLUSION

In order to prepare for the next event, the estimation and prediction of the risk associated with potential loss is necessary. Under that action, the seismically weak structures such as dwellings, public buildings and tsunami evacuation centers need to be retrofitted. Although damage due to tsunami was not observed in this earthquake, some tsunami evacuation buildings collapsed. Therefore, if tsunami damage occurred, people could not use the tsunami building for evacuation. Although the design codes for masonry and reinforced concrete were revised to include seismic design code in Indonesia, most of the houses do not comply with them. Therefore, it is important to improve the code enforcement system.

Earthquake damage to structures is often related to the local structural type, such as low-cost and affordable housing. The important things to apply such measurement are to consider the local acceptability and/or local availability in Indonesia.

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