Chapter 15

Summary of Findings and Proposals

We, the reconnaissance team of Japan Society of Civil Engineers (JSCE), investigated actual damage caused by the earthquake shaking as well as tsunami from March 1 to March 5 in Aceh Province of Indonesia. During our reconnaissance period, the damage to civil engineering structures and buildings caused by the main-shock and after shocks as well as those caused by the tsunami have been documented and geotechnical and structural response data were collected. We have tried to identify the causes of damage from the investigations and summarized our findings. The outcomes of these investigations are summarized and recommendations and proposals are presented in the followings

15.1 Observations and Main Findings

(1) Bridges and Roads

1) Several bridges were completely washed out by the Tsunami. Although the washed-out bridges did not have any shear keys, some bridges with shear keys, which were significantly affected by Tsunami, were not washed out and not displaced. Therefore, the appropriate shear keys and stoppers against at the bearings are one of the key design issues against the Tsunami effect. Backfill soils at abutments were washed out at several bridges.

2) When the roads were constructed on the stiff ground, the roads seemed to be survived well against Tsunami. On the other hand, the roads were on the soft or sandy soils, the roads seemed to be completely washed out by the effect of erosion. Such sandy soils sections are generally located closed to the coastline, or the current or past river areas.

(2) Port and Harbor Facilities against Tsunami

1) It was quite difficult to distinguish between damages of port/coastal area facilities caused by the earthquake motion and by the tsunami wave action. Significant damages were caused by scouring phenomenon and impact force of drifting objects during the tsunami. However, the possibility of double action effect by the earthquake motion and tsunami wave should be considered.

2) The pile-deck structures such as pile-supported wharf, pile-supported dolphin and the ferry terminal pile-deck structures (pilotis style) showed good performance during tsunami wave. A pile-deck structure with high seismic performance should be effective as a tsunami refuge structure. It must be noted that the drifting object's impact action should be considered during a tsunami.

(3) Lifeline facilities

1) Water network

- The most important issue is to attain good quality water sources.
- The quality of well water may be deteriorated due to the seepage of wastewater.
- Construction of the multipurpose dam (water reservoir, electricity generation, flood control, agricultural) should be considered rather than relying on Aceh River for water source. This would be also useful for industrial development.

2) Sewage

- It is urgently necessary to improve sewage systems to keep sanitary environment.
- It would be desirable to use separate drainage system for rainwater and wastewater. This work should start as soon as possible and the wastewater treatment plant is urgently needed.

3) Electricity

- The electricity is needed for industrial facilities as well as for the daily life of people.
- The electric capacity of the region should be increased through building multi-purpose dams.

(4) Geotechnical Damage

- Failures of river and canal banks were occurred. They were mainly due to soil liquefaction and erosion by tsunami. Liquefaction resulted in lateral spreading and settlement of the embankments. In cohesive soil, sliding took place.
- Slope failures were observed in mountainous section due to ground shaking. Failures were generally associated with the geological features of rock masses.
- Weathered loose materials on slopes at the seashores were washed away.
- Missing of the central part of small peninsula could be due to liquefaction or landslide in addition to tsunami.

(5) Damage on Buildings

Building stock in the area mainly consists of RC buildings, wooden houses and adobe houses.

1) RC buildings

- The story number of heavily damaged RC buildings generally is generally more than 3 and ground shaking mainly caused the damage.
- The RC buildings having story number less than 3 were in tsunami affected area were destructed by impact force of tsunami waves and objects dragged by tsunami.
- Some buildings survived well against the forces imposed by tsunami waves.
- Intensity of ground motion is was from 5+ to 6- on JMA scale (IIIV-IX on MKS scale).
- It seems that the ground motion has a directivity effect and many structures are either collapsed or heavily damaged in N-S direction.

2) Wooden houses

- Wooden houses were mainly damaged by the uplift force of seawater and impact force of tsunami waves and objects dragged by tsunami.

3) Adobe houses

- Adobe houses were mainly damaged by impact force of tsunami waves and objects dragged by tsunami.

(6) Education of Children for Earthquake and Tsunami Disasters

Presentations of "Evacuation from Tsunami Attack" were carried out for about hundreds students and children Sekolah Menengah Atas high school and junior high school by using a video of non-fictional story in Japan. There were many questions about the mechanism of the occurrence of the earthquakes and tsunamis and about the measures for disaster prevention. It is necessary to provide an exact information and knowledge on these topics that will result in the disaster prevention from a long-term point of view. The Japanese team will send materials such as video and books for disaster prevention to the schools in Aceh.

(7) Several of the time-shift of issues on emergency response and recovery are common with those raised by the 1995 Kobe earthquake except that it took much time to search and identify victims.

15.2 Recommendations and Proposals

(1) For the safety against tsunami

- How to escape from the tsunami disaster should be considered. Protection of tsunami is also important but it is very costly.
- A pile-deck structure with high seismic performance can be an effective tsunami refuge structure like the existing tsunami refuge terrace in Japan.
- Mosques can have a function for tsunami evacuation buildings.
- International collaboration and sharing protocol on tsunami warning must be established
- Tsunami Research Institute has to be established including tsunami simulations.
- International Symposium on the Earthquake & Tsunami Disaster should be held.
- Cooperative researches between Indonesia and Japan should be promoted.

(2) Not to forget the TSUNAMI

- The monumental exhibition hall or museum should be built.
- The stone monumental poles with the Tsunami height in the corners of streets should be erected. These monuments should keep the records of Tsunami height for a longer period of time.

(3) Education and Training

- Education and training for evacuation are urgently necessary.
- It was found that many people did not know even the word of Tsunami from hearing

surveying.

(4) Building earthquake-resistant structures

- Present RC structures should be retrofitted with the use of shear walls.
- RC structures should be built according seismic design codes.Residential houses should be built according earthquake resistant codes together with the use of low cost and effective methods.

(5)Accelerometers should be installed to measure and to have quantitative information on ground motions.

(6) New Road Construction and Rehabilitation between Banda Aceh and Meulaboh

1) Based on the fundamental policy for future city planning under the resident agreement in the area, it should be decided to reuse current route as much as possible, or to fully set-back the current route out of the Tsunami affected area (plus potential area).

2) If basically the current route is reused as much as possible, then fundamental policy can be;

- Consider the acceptable damage. Heavy damage, which is related to the loss of life or long-term repair works, is not acceptable. Without loss of life, acceptable damage to roads should be considered.
- Consider the return period of the occurrence of large earthquake (risk evaluation for next one)
- In this concept, the Tsunami warning measure is essential for the residents because the area is anticipated to suffer again in next event in future.

3) If the Tsunami effect is not acceptable completely, the cities and roads have to be totally realigned to the higher area with necessary height.

4) The bottleneck sections on roads are the following sections and conditions.

- Long bridges on wider rivers (Washout of bridges)
- Settlement at seaside (Complete erosion and missing of roads)
- Washout of soil section (Stable soil section was well-survived from the Tsunami. Soft-soil and sandy soil are generally weak.)

5) Basic Policy of Repair and Rehabilitation Work can be:

- If the reuse of current route is basically decided, the Tsunami warning measures are prerequisite to save resident lives.
- Concrete girder bridges with appropriate shear keys and wall-type columns including concrete culvert is much stable against Tsunami.
- When a steel bridge for longer span is needed, the lateral force effect and uplift force effect should be considered at the design of bearings.
- If the roads are on the soft ground condition and it can not be easily realigned, the soil improvement to strengthen against the washout effect is effective.
- If the roads are at too low level compared with the sea level, the roads should be realigned to the inland area with necessary height or make higher embankment with

stable material against washout effect.

- Some important section (sections in city area and sections which are hard to be repaired should have double routes (one be in inland area).
- In mountainous areas of the roadway, there may be landslides since rock mass is generally layered and the layers dips towards sea. Attentions should be given to the geological features for prevention of large-scale slope sliding.

15.3 Closing Remarks

Finally, we sincerely hope that the cooperation and collaboration on earthquake hazard mitigation will be strengthened between Indonesia and Japan, since two countries have shared similar experiences of huge disasters.