Chapter 11

Damage to Transportation Facilities

The damage of transportation facilities were mainly associated with roadways and bridges along the west coast between Banda Aceh and Meulaboh cities in Aceh province. The significant damage including washout of bridge superstructures and soil structures were caused by the tsunami waves. Some damage to bridge bearings caused by earthquake ground motion was also observed. In the following, the damages to the transportation facilities in cities of Banda Aceh and Lho'nga, and along the route between cities of Banda Ache and Meulaboh are briefly summarized.

11.1 Damage to Bridges and Roadways

11.1.1 City of Banda Aceh

The city of Banda Ache is located at the north of the Sumatra Island. There are about 20 bridges in the affected area by the tsunami at Banda Aceh. The height of the tsunami in the seaside area was estimated to be about 5-10m. Out of 20 bridges in the affected area, the superstructures of 3 bridges were completely washed out and fallen down, and 7 bridges were remarkably affected by the effect of the tsunami.

Photos 11.1 and 11.2 show one of the significantly damaged bridges. The simply-supported pre-stressed concrete girder bridge with a span of about 20m was washed out by the tsunami. The girder was just set on the top of abutments and there seemed to be no shear connection at the bearing supports. The tsunami height was just as the same height as the ceiling level of the 1st story of the houses. A temporary bridge was built soon after the earthquake to assure the traffic. At the time of investigation (about two month after the

Photo 11.1 Repair of Washed-out Girder Bridge

Photo 11.2 Collapse of Water Pipes

the earthquake), the washed-out girder was reused and already placed on its original location as the permanent repair.

Photos 11.3 and 11.4 show another bridge where the superstructures were completely washed out. It was reported that the bridge had a relatively shallow superstructure made of wooden materials. Substructures were made of masonry materials connected with concrete.

Photo 11.3 Complete Washout of Bridge (being reported as wooden bridge)

Photo 11.4 Masonry Substructure and Washout Effect of Surrounding Soils

The complete washout of superstructures was observed at one more bridge although its picture is not shown in this report. It was made of a pre-stressed concrete girder and had a shallow deck with 1 lane. The substructures to support girder laterally was failed by the lateral force effect of the tsunami and the girders were washed out as a result.

Photos 11.5 to 11.8 show the typical damage to a bridge in which the significant lateral displacement was developed by the effect of Tsunami. The superstructure of the bridge was 3 span simply-supported reinforced concrete girder bridge and was supported by the wall type reinforced concrete piers. The rubber sheet type bearings were used and there was no shear key to connect between girder and substructures. The decks were moved about 50cm laterally and the rotation occurred at the decks since the decks were wedged geometrically between the both abutments. The handrails were partly but heavily damaged and it was estimated that the handrails were broken by the effect of the impact of boats or driftage. The washout effect at the backfill soils of abutments was also found.

Photos 11.9 and 11.10 show another bridge where the significant displacement was observed. The bridge is a simply-supported reinforced concrete girder with a span of about 20m. The deck was moved in the transverse direction about 1m due to the tsunami effect. The girder was supported by the rubber sheet type bearing and there was no shear connection between girder and substructures.

Photo 11.5 Damaged Bridge

Photo 11.6 Washout Effect of Backfill Soils

Photo 11.7 Lateral Displacement of Deck

Photo 11.8 Rubber Sheet Type Bearing and Lateral Displacement at Bearing

Photo 11.9 Lateral Displacement of Deck

Photo 11.10 Displacement at Bearing

Although several bridges were significantly damaged caused by the tsunami effect, there are several bridges without any significant damage even though they seemed to be strongly affected by the tsunami. Photos 11.11 and 11.12 show a bridge without any significant

damage by the tsunami. The height of the tsunami was estimated to be about several meters over the bridge deck level. Heavy damages to houses were found around the bridge. The bridge was a long bridge with a 10 span simply-supported concrete girder bridge which was supported by circular reinforced concrete columns. The rubber bearings were used and the concrete block shear keys were provided. Although the attached facilities beside the girders were heavily failed, the main body of the bridge was not damaged. Slight damage to the shear keys such as cracking was observed. Although the detailed investigations such as the tsunami height are necessary, it was estimated from the bridge behavior that the shear keys seemed to work well to resist against the lateral force imposed by the tsunami.

Photo 11.11 Undamaged Bridge by Tsunami

Photo 11.12 Concrete Block Shear Keys

Photos 11.13 and 11.14 show another bridge to show the slight damage to shear keys. The bridge was a 3 span simply-supported concrete girder bridge and supported by the rubber bearing and concrete block shear keys. The bridge was not affected by the tsunami. The shear keys were slightly damaged including the concrete cracking. The damage was considered to be caused by the strong ground motions.

Photo 11.13 Bridge affected by Shaking

Photo 11.14 Slight Damage to Shear Keys

As will be discussed later, many truss bridges with relatively longer spans were washed out along the west coast route from Banda Aceh to Meulaboh. Although The detailed investigation could not be made for all of the collapsed bridges, some collapsed bridges did not have the connection and shear keys between decks and substructures. Photo 11.15 and 11.16 show the behavior of the truss bridge with stiff connections between deck and substructures. Since the bridge is located at the east of Banda Aceh, the Tsunami height might not be so significant. But the Tsunami height was clearly exceeded over the upper member level of the truss. There was no damage at the bridge. It seems that the stiff connections between deck and substructures can be one reason for “no damage”.

Photo 11.15 Steel Truss Bridge without Damage

Photo 11.16 Steel Bearing Supports

Photo 11.17 and 11.18 show the damage to soil embankment structures. Complete washout of river dikes and damage to pavement on the river dikes was found. Since the height of the tsunami was estimated to be widely over the height of the river dikes, the washout effect of soils were observed at several sections.

Photo 11.17 Washout of River Dike

Photo 11.18 Washout of Pavement and Soils

11.1.2 City of Lho'nga

The city of Lho'nga is located at the west of Banda Aceh along the west coast. The area was significantly affected by the Tsunami and the Tsunami run-up height is estimated to be over 30m at maximum. Photos 11.19 to 11.21 show the complete washout of a 2-span steel truss bridge, which was supported by the wall type reinforced concrete columns. The decks were supported by the bearings and bolts were used to connect deck and substructures. There was no shear connection between deck and substructures except the bolts. Since the truss girders were washed out to the upstream side and the bolts connecting deck and substructure were bended toward the upstream side, it is estimated that the decks were washed out by the tsunami waves in the direction of upstream side. This route is an important route to connect Banda Aceh with the Meulaboh in south, the temporary bridges were built for emergency measures. It should be noted here that it is estimated the truss type bridge is employed for a relatively longer span bridge in the area.

Photo 11.19 Washing out of Steel Truss

Photo 11.20 Temporary Bridge

Photo 11.21 Bearing Support and Bolt to connecting Deck and Substructures

Photo 11.22 and 11.23 show the behavior of the reinforced concrete box culvert bridge. The bridge is located in the cement factory, which was significantly damaged by the tsunami. Some damage was found at the sidewall but there was almost no damage on the main body of the bridge.

Photo 11.22 Concrete Box Culvert Bridge

Photo 11.23 Concrete Box Culvert Bridge

11.1.3 Route from Banda Aceh to Meulaboh

The city of Meulaboh is located at about 250km south from the city of Banda Aceh. There is a seaside route which is only roadway to access many towns and villages along the seaside between two cities. The tsunami was significantly affected the route. According to the data investigated by the Katahira & Engineers International, total section of 56.6km of roads was impassable and 126.7km was seriously damaged. Also, there are 186 bridges along the roads and 81 bridges were washed out or heavily damaged. Although the JSCE team could not investigate all bridges through the land survey, the investigation from the helicopter was made.

Photos 11.24 to 11.28 show the washout of the bridges in the route. All photos shown here were taken by UN on the behalf of Aceh Provincial Government. There are several steel truss bridges and the deck was completely washed out toward the upstream side. Since the most piers and abutments remained at the original location, it is estimated that the superstructures were washed out by the tsunami. Although detailed investigations are needed, it is estimated that the stiff connection or shear key enough to withstand the washout force was not provided at the bearings in view of the bridge designs in Banda Aceh.

Photo 11.24 Washout of Truss Bridge (1)
(courtesy of Aceh Provincial Government)

Photo 11.25 Washout of Truss Bridge (2)
(courtesy of Aceh Provincial Government)

Photo 11.26 Washout of Truss Bridge (3)
(courtesy of Aceh Provincial Government)

Photo 11.27 Washout of Truss Bridge (4)
(courtesy of Aceh Provincial Government)

Figure 11.28 Washout of Truss Bridge (5) (courtesy of Aceh Provincial Government)

Photos 11.29 to 11.33 show the washout of the roadways, which were completely eroded by the tsunami effect. The land itself was also estimated to have sunk one half to one meter in elevation along the coast but the erosion of the coastline was much more significant.

Photo 11.29 Washout of Bridge and Soil (courtesy of Aceh Provincial Government)

Photo 11.30 Erosion of Road and Coastline (courtesy of Aceh Provincial Government)

Photo 11.29 Erosion of Road and Coastline (courtesy of Aceh Provincial Government)

Photo 11.30 Erosion of Road and Coastline (courtesy of Aceh Provincial Government)

Photo 11.31 Erosion of Road and Coastline (courtesy of Aceh Provincial Government)

11.1.4 Summary of Damage to Bridges and Roads

Detailed investigations and careful reviews of the damage are still needed. Nevertheless, the following findings were so far obtained on the bases of the above investigations.

1) Tsunami Effect: Since Tsunami is basically fast, strong and thick water flow with driftage, lateral water pressure, floating effect and washout effect are the primary mechanical effects.
2) Concrete Bridges: If a bridge had a concrete deck with appropriate shear keys at bearing supports, the bridge did not have a significant displacement or was not washed out during Tsunami effect. If there was no shear key, there were some bridges in which the deck was completely washed out or significantly displaced in the transverse direction.
3) Steel Bridges: The detailed investigation for all of the collapsed steel truss bridges could not be made. The washed-out truss bridge located in Lho'nga did not have any shear keys. On the other hand, one truss bridge with stiff bearings at the east of Banda Aceh did not suffer any damage. Therefore, it is estimated that the shear keys work well against the lateral tsunami force. For a steel bridge, which is relatively lighter, the effects of weight and thrust of driftage should be considered for the design of truss bridges. The floating effect can be also controlled by the uplift stopper which connects between superstructures and substructures at bearings.
4) Foundations: It was found that some of the substructures as well as superstructures were completely either washed out or missing. It is also important to protect the substructures against the washout. Wall-type piers, which are usually used in this area, seemed to be survived well, and the foot protection work at foundation section is effective if the surrounding material is prone to wash out.
5) Abutment Backfill Soils: Several damaged abutments with the backfill soils washed out were observed. To fill the soils as a temporary measure to assure the traffic is relatively easy. But if such damage should be prevented for higher abutments in long term, more substantial repair works are necessary after the earthquake and the bank protection measures for abutments are effective.
6) Soil Structures: If the roads are constructed on the stiff ground (possibly, cutting ground, stiff clay layer/rock and so on), the roads seemed to be survived. On the other hand, the roads are on the soft or sandy soils (possibly, soil embankment with soft materials which is easy to be washed away), the roads seemed to be completely washed out. Such sandy soils sections are generally located closed to the seaside, or the current or past river areas. Also, the erosion effect is so significant.
7) Ship Effect: As observed during the investigation, the driftage of large ships seemed to influence the damage significantly. But to directly consider the effect of the impact of ships on structural design is not generally reasonable. Ship control measures during tsunami should be devised.

11.2 Damage to Airports

The only airport in the affected region by the earthquake is the Iskandar Muda Airport to which commercial flights are in operation. This airport was not damaged either by ground shaking or by tsunami waves as shown in Photo 11.32. At the Meulaboh Airport, the dislodgement at the airstrip was developed as shown in Photo 11.33 and the section of 1,100m within 1,300m was used for the flight.

Photo 11.32 No Damage to Iskandar Muda Airport

Photo 11.33 Damage of Airstrip at Meulaboh Airport

Photo 11.34 Damage of Airstrip (courtesy of Dr. Osumi)

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