

Issues and Lessons Learned from the Great East Japan Earthquake

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1. Overview of the Earthquake and Tsunami

Overview of the Earthquake

- The Great East Japan Earthquake occurred at 14:46 [2:46 PM] on March 11[, 2011].
- The epicenter was off the coast of the Eastern Japan in the Pacific, and the magnitude was 9.0.
- This was the fourth largest in the last 100 years after the Chile earthquake in 1960 and Sumatra in 2004.

Mechanism of Earthquake

- This earthquake is categorized as an "interplate" earthquake.
- Interplate earthquakes occur when one of colliding plates rebounds from accumulated stress.
- 4 different plates meet around Japan, causing frequent large-scale earthquakes.

Mechanism of Inter-plate Earthquake

- This figure shows the mechanism of interplate earthquakes.
- Earthquakes and tsunamis occur when accumulated stress of a plate bounces back.
- The Japanese government scientifically estimates probabilities of large-scale earthquakes in Japan. (Headquarters for Earthquake Research Promotion of the Ministry of Education, Culture, Sports, Science & Technology)
- According to the estimate, the probability of an earthquake off the coast of Miyagi-prefecture, which is one of the most affected areas of the earthquake, in 30 years was 99%.

Tsunami Generation

- On the Sanriku Coast in the Tohoku Region, the flood height from the tsunami almost reached 40 meters. [The word “Tohoku” means Northeastern in Japanese.]

Overview of Damage Human and Property Damage

- As of September 12th:
 - Over 15,000 persons died.
 - More than 4,000 are missing.
 - And, over 5,900 have been injured.
- Damages on Buildings are:
 - About 110,000 buildings were totally collapsed.
 - And over 160,000 were half collapsed.

Overview of Damage Large-scale Liquefaction

- The earthquake caused liquefaction extensively in the Tokyo Capital Area, which is far away from the epicenter.
- As far as we could confirm, the large-scale liquefaction affected at least 42km², particularly in the reclaimed lands and former river channels.

2. Damages on Roads - Lessons Learned from the Past -

- Though this earthquake caused serious damages on roads, the lessons from the past experience had been applied to prevent further devastation.

Damage on Trunk Road Network

- Right after the earthquake, 15 expressway routes and 69 sections on the national highways were closed.
- Numerous sections in the prefectural/municipal roads were closed, too.

Damage on Expressways

- On the expressways, embankments fell on the traffic lanes at 21 locations.
- However, among the 1,079 expressway bridges in the stricken areas, none of them was collapsed.

Damage on National Highways

- On the national highways, a lot of damages were observed, such as small cracks on the road surface.
- Among the 1,528 [highway] bridges, five of them were washed away by the tsunami, but none of them were collapsed by the earthquake.

Lessons Learned from the Past Earthquakes

- From the strong seismic motion of this earthquake, the peak ground accelerations of 1G (980gal) or higher were observed in various locations.
Note) The resultant peak acceleration of two horizontal components of ground motions exceeded 1G at 18 locations (Japan Society of Civil Engineers Magazine).
- Bridge collapses were prevented by having revised the standards and applied seismic reinforcements based on the lessons learned from the past earthquakes.
- In the past, the Hanshin-Awaji Earthquake in 1995 had caused significant damages, such as the expressway structure collapse. Based on this experience, seismic reinforcements of the existing bridges have been implemented as well as the seismic design standards for road bridges have been revised.
- In the Great East Japan Earthquake, the revised seismic standards functioned effectively because the impact of the medium to long-period components of the seismic motion of this quake did not exceed the assumption of seismic design standards.
- 20 of the prefectural and municipal road bridges were collapsed or closed by the severe damage because the implementations of such countermeasures had been delayed.

Damage by Tsunami

- The tsunami flooded roughly 100 km across the national highways.
- On the expressways, three interchanges and junctions were submerged.
- The tsunami brought massive debris, which covered roads, towns, and agricultural fields.
- Some local residents survived the tsunami by climbing to the expressway embankments.

Bridges Washed Away by Tsunami

- Among the nationally-administrated road bridges, five of them were washed away even though they survived the earthquake.
- In the nearby areas, the high surges from the tsunami were reported to be as high as 15 meters.

Damage on Other Transport Infrastructure

- As well as the roads, the other modes of the transport infrastructure were also significantly damaged, such as the Shinkansen [high-speed rail/bullet train], airports, and ports.
- A large tsunami struck Sendai Airport, and the runway was covered with debris and cars.
- The Tohoku Shinkansen was suspended due to the fallen catenary poles, broken wires, and damaged elevated structures.
- All fourteen ports [in the stricken areas] on the Pacific were shut down due to the tsunami damages.

3. Recovery of Roads - Emergency Recovery for Affected Area -

Steps to Recovery of Roads

- Recovery of the roads consists of the following steps:
 - First, “clearing roads” [and “temporary recovery”] to secure traffic of emergency vehicle right after the earthquake;
 - Next, “emergency recovery” to enable traffic of general vehicle;
 - “Rehabilitation” to repair the roads back to the conditions before the disaster while allowing general traffic.
- Securing the road function for emergency traffic was the top priority to enable lifesaving and rescue in the affected areas. I will focus on the recovery of the roads for emergency traffic in the next few slides.

Securing Emergency Traffic Initiated by Roads

- This figure shows the recovery of the transport infrastructure by [transport] mode.
- After the earthquake, the arterial roads (expressway and national highway) were recovered in the early stage to secure as emergency traffic networks. Therefore, the importance and needs of arterial roads were proven to be essential once more as means of providing emergency supplies to stricken areas.
- The expressways and highways were not critically damaged, which led to smooth recovery of the [transport] functions.

Securing Emergency Traffic in Entire Eastern Japan 1 Recovery Situation of Expressway

- Right after the earthquake, all expressways in eastern Japan were closed for emergency inspections.
- The day after the earthquake, almost all expressways were temporarily recovered and allowed emergency traffic.

Securing Emergency Traffic in Entire Eastern Japan 2 Emergency Recovery of Expressway Embankment

- Subsequently, the temporarily recovered sections were opened and allowed general traffic.
- The case of the Joban Expressway (Mito IC) and the recovery road work on the collapsed embankment by the earthquake.
- In this case, one day after the earthquake, the expressways were open to emergency traffic. Six days after the earthquake, the emergency recovery was completed, and the expressways were open to general traffic.
- The information of these recovery works is also presented at our Japan booth of this exhibition.

Securing Emergency Traffic in Tsunami Affected Areas 2 “Operation Comb”: Immediately after Earthquake

- Securing emergency traffic networks to the tsunami-affected areas was named as the “Operation Comb” and promptly executed by the national government.
- Because the tsunami destroyed all the 14 ports on the Pacific, the recovery of the [transport] functions started from the inland.
- The day after the earthquake, the Tohoku Expressway and National Highway [Route] 4,

which run north-south in the inland, were recovered for emergency traffic.

Securing Emergency Traffic in Tsunami Affected Areas 2
“Operation Comb”: 4 days after Earthquake

- To recover the emergency traffic networks from the inland to the Pacific Coast, 15 routes were secured to reach the coastline four days after the earthquake,
- This recovery was called the “Operation Comb” because the bird’s-eye view of the emergency traffic networks had a similar shape to a comb.

Securing Emergency Traffic in Tsunami Affected Areas 3
“Operation Comb”: 4 days after Earthquake

- The map on the right is the detail of the map on the left to emphasize the geography and elevations.
- The routes from the inland to the coast are winding because they are surrounded by the steep mountains.

Securing Emergency Traffic in Tsunami Affected Areas 3
“Operation Comb”: 4 days after Earthquake

- After securing the routes to the coast, the transportation functions were finally recovered along the Pacific Coast. About 7 days after the earthquake, the traffic for emergency vehicles was secured to enable the lifesaving activities in the affected areas.
- We recognized that proper preparation and training to secure emergency traffic networks, as done in the “Operation Comb” according to geographical conditions and road development are essential in probable areas of large-scale tsunamis.

Clearing Roads in Tsunami Stricken Area

- This picture shows clearing roads in one of the tsunami stricken areas.
- The road administrator of the national government secured traffic for emergency vehicles by clearing massive debris on the roads in cooperation with the Self Defense Forces and Police.

4. Issues in Road Infrastructure
- For the “Next” Great Earthquake -

- The Great East Japan Earthquake revealed two major issues regarding disaster recovery and the road infrastructure.

Effects and Issues of Multilayered Expressways 1 Expressway Network in Eastern Japan and Disaster Areas

- This figure shows the relationship between the expressway network in eastern Japan and the tsunami-stricken areas.
- The affected areas extend mainly along the Pacific Coast where the massive tsunami hit.
- The area circled in red is the restricted area around the Fukushima Daiichi Nuclear Power Station.

Effects and Issues of Multilayered Expressways 2 Freight Network Functioned as Alternative Route

- The freight transport routes along the Sea of Japan functioned as an alternative to the damaged coastal routes along the Pacific.
- For instance, in the routes in red, the traffic increased by 30 to 50% after the earthquake. The traffic increase proves the importance of the redundancy that the multilayered expressway networks provided.

Effects and Issues of Multilayered Expressways 3 Undamaged Sanriku Expressway

- Since the Sanriku Expressway along the Pacific coast had been designed to avoid tsunamis based on the past tsunamis, it was free of damages and served for emergency traffic from right after the disaster.
- We were reassured the importance of planning road infrastructure taking into account of tsunami risks.

Effects and Issues of Multilayered Expressways 4 Missing Links of Expressway in Stricken Areas

- However, the Sanriku Expressway had been less than 50% complete. The incompleteness left several issues as an emergency traffic network.
- For instance, it took 7 hours to drive the section between Sendai and Miyako due to detours and congestion after the earthquake. If this section of the expressway had been completed, it would have only taken 3 hours.
- The incompleteness clearly caused the congested traffic. If this expressway had been completed, we believe it could have expedited the rescue after the earthquake.

Effects and Issues of Multilayered Expressways 5 Expected Tsunami Stricken Areas and Missing Link

- In Japan, probability of other Great Earthquakes (e.g. Tokai, Tonankai, Nankai, etc.) has been pointed out.
- The areas in pink are projected flooded areas by tsunamis caused by large-scale earthquakes.
- There are missing links of expressways in these areas. We recognize that early development of thorough infrastructure in these areas is a challenge to us.

Necessary Information on Road Immediately after the Earthquake 1

- The next issue is a way to provide information right after an earthquake.
- The Great East Japan Earthquake caused road closures at various locations. After the earthquake, the national, prefectural, and municipal governments provided information separately.
- It required 12 days for the national government to consolidate such information and provide to the public.

Necessary Information on Road Immediately after the Earthquake 2

- Road users need information on “available routes” as well as “closed routes.”
- Providing useful information to road users took one month after the earthquake.
- For the future, it is necessary to provide integrated information from each road authority swiftly as well as providing information of available routes.

5. Issues and Lessons Learned from the Great East Japan Earthquake

Conclusion

- We have a number of issues and lessons learned through this East Japan Great Earthquake.
- Conclusions (major points):
 - First, by having applied the lessons of the past earthquakes (especially the Hanshin-Awaji Earthquake), such as the revised standards and associated seismic reinforcements, damages on bridges were significantly reduced.
 - Second, right after an earthquake, the top priority is to secure emergency traffic

networks. At the earthquake, we secured the road networks promptly. This case sets, good practice for the future.

- Third, we recognized the importance of multilayered expressway networks to rescue disaster areas and restoration. In Japan, the road development has been delayed in less-populated areas with low traffic volumes. We believe it is our urgent issue to promptly develop those missing links.
- Last, right after disasters, necessary information should not be provided by multiple road administrators separately to avoid confusion. Moreover, road users need information such as available road networks.