



## RISK MANAGEMENT FOR THE EARTHQUAKE AND TSUNAMI OF THE HANSHIN EXPRESSWAY

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### Abstract

2011 Great East Japan Earthquake and followed tsunami desolated the coastal region of East Japan. Based on the experience of the large scale tsunami damage, road administrators in Japan are urgently preparing against tsunami impact. Hanshin expressway operates urban expressway network. Major part of the network runs through the Osaka bay area. Therefore the preparedness against tsunami inundation is one of the urgent demanded challenges in Hanshin expressway for quick recovery even in the flooded condition.

Currently, Hanshin expressway designed the countermeasures for tsunami inundation. The countermeasures consist of;

- 1) Development of disaster countermeasure office that is safe from impact of tsunami inundation,
- 2) Upgrade of maintenance and patrol base station that ensure the function in the case of tsunami inundation,
- 3) Development of self-power supply system and redundant communication line,
- 4) Development of traffic control procedures for preventing casualties caused by the tsunami inundation,
- 5) Development of the procedures for evacuation of the drivers left on the expressway viaducts.

This paper summarizes the key points of those countermeasures.

*Keywords: Tsunami, Risk management, Hanshin expressway*

### 1. Introduction

2011 Great East Japan Earthquake and followed tsunami desolated the coastal region of East Japan. Based on the experience of the large scale tsunami damage, road administrators in Japan are urgently preparing against tsunami impact. Osaka and Kobe metropolitan area is under the risk of Nankai large scale earthquake and followed tsunami. Nankai trough earthquake and followed tsunami are one of the most anticipated disasters in current Japan. Osaka and Hyogo local governments predicted that the large scale tsunami arrival and the wide inundation of Osaka bay area.

Major part of the Hanshin Expressway network runs through the Osaka bay area. The major bridge structures were already reinforced according to the lessons of 1995 Kobe earthquake; however, the preparedness against tsunami inundation is one of the urgently demanded challenges. Hanshin expressway is designated as the emergency route that ensures emergency relief and disaster restoration therefore, quick recovery is demanded even in the flooded condition.

Based on these circumstances, Hanshin Expressway has developed risk management strategy against tsunami inundation disaster.

#### 1.1 Nankai trough earthquake and followed tsunami

According to the history record, the Nankai trough earthquakes have occurred every 100-150 years. The probability of the occurrence of Nankai trough earthquake is anticipated 60-80% within 30 years. The central disaster prevention council estimated the scale of the Nankai trough earthquake and the followed tsunami in order for the master plan of the disaster prevention measures. The council defined the scale of level 1 and 2 for earthquake and tsunami according to occurrence frequency.

Level 1 is once in 100 years and the intensity of that is the maximum scale in the history. Level 2 is defined as the assumable worst-case event. This master plan of the disaster prevention measures says that the public and private enterprises should set a goal and take measures for the disaster prevention and mitigation. As for the tsunami, the master plan says that taking measures in combination hard-type with soft-type accordingly is important. In addition, the plan says saving the human lives is effective against level 2 event.



Fig. 1 – Hanshin Expressway network

Table 1 – Definition of tsunami level

Tsunami Level	Definition and countermeasure concept
Level 1	[Definition] Biggest in history (Approx. 1/100years) [Concept of countermeasure] Disaster prevention
Level 2	[Definition] Worst in scenario events (Approx. 1/1000years) [Concept of countermeasure] Disaster mitigation

## 2. Tsunami inundation area and Hanshin expressway

In the case of Osaka metropolitan area, level 2 tsunami caused by the Nankai trough earthquake should be considered. The report made by Osaka and Hyogo local government estimated the earthquake and followed tsunami hazard.

- 1) The earthquake intensity on the Osaka and Kobe metropolitan area where the Hanshin Expressway located is estimated as 6 lower.
- 2) The tsunami height of 5 meters is anticipated by the extreme earthquake, whereas the tsunami height of 3meters is estimated according to the history record of the previous tsunami. The tsunami height is assumed

from 4 to 5 meters in Osaka bay area and from 3 to 4 meters in Hyogo bay area. According to the tsunami reports, it takes from 90 to 120 minutes that tsunami reaches to Osaka Bay coast.

If level 2 tsunami has occurred, 10 viaduct routes including the routes of Osaka Bay coastal area is assumed flooded, and one tunnel route is assumed flooded and submerged. The road management facilities in the tsunami inundation area are also damaged and lost office function and telecommunications equipment.

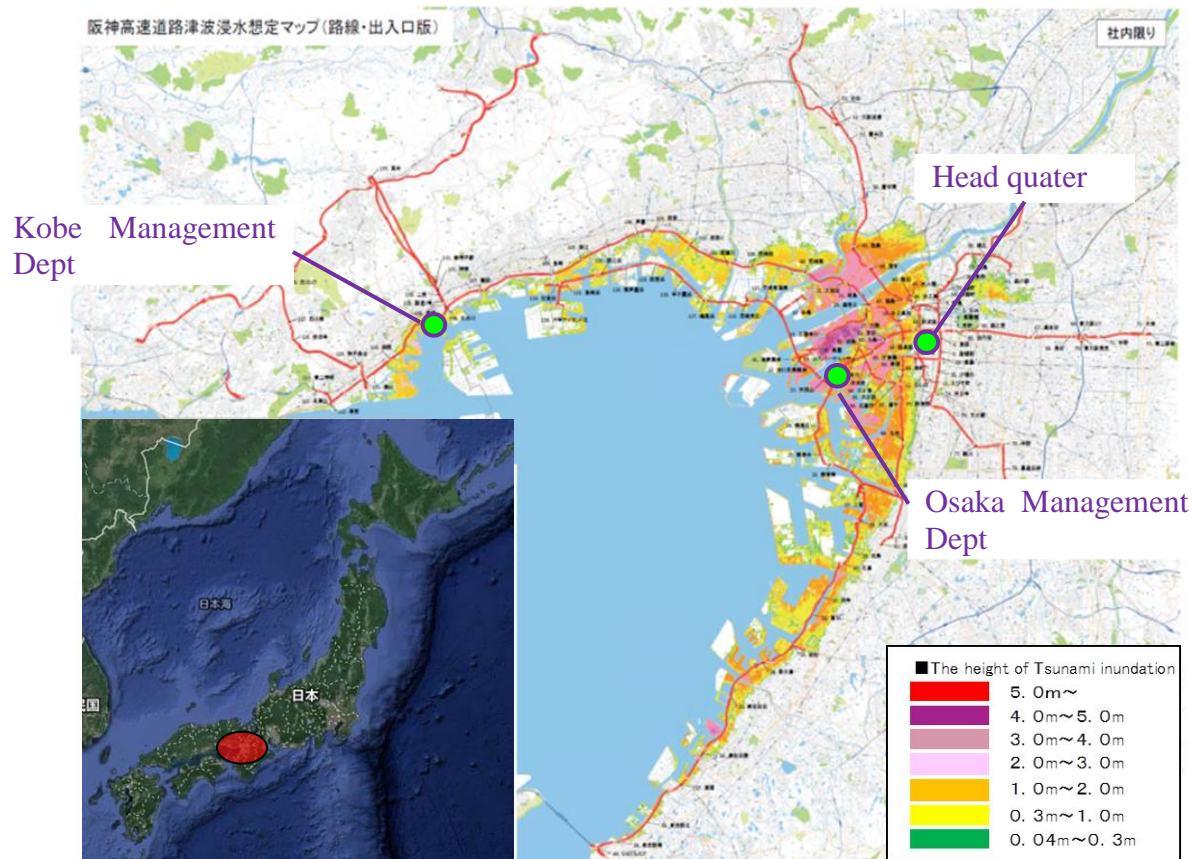


Fig. 2 –Tsunami inundation area of osaka bay area

Table 2 – Facilities in tsunami inundation area

	Facilities of Hanshin Expressway	Inundated facilities / all facilities
Important disaster prevention office	Head quarter	1/1
	Management Dept.	2/2
Disaster prevention facilities	Maintenance office	2/5
	Patrol office	4/12
Others	Power receiving facilities	4/19

### 3. Earthquake and Tsunami disaster prevention policy

The basic idea of the disaster prevention measures of the Hanshin Expressway was made based on the lessons learned from the 1995 Great Hanshin-Awaji Earthquake in order to keep "safe and secure expressway". Hanshin



expressway is also designated as one of the public road authorities required to implement disaster prevention measures by law. Therefore the Hanshin expressway set their goal and policy as follows;

1) To ensure the human safety.

Safety of customers such as drivers is the highest priority against tsunami and secondary disaster.

2) To ensure the function of the emergency road in order for contributing to disaster relief and recovery.

Clearance of obstacles on the emergency road is the second highest priority for ensuring emergency road function. Quick restoration of all expressway routes must be achieved in the case of level 1 tsunami. And quick restoration of limited expressway routes in non-tsunami affected area must be achieved in the case of level 2 tsunami.

Table 3 – Performance policy

Policy	Tsunami level 1	Tsunami level 2
The human safety	Secure with the highest priority	Secure with the highest priority
The function of the emergency road	Immediately enable to ensure emergency traffic	Immediately enable to ensure emergency traffic
	Quick restoration of all expressway routes	Quick restoration of limited expressway routes in non-tsunami affected area

#### 4. Tsunami countermeasures to ensure the human safety

##### 4.1 Provision of Tsunami information to drivers regularly

Hanshin Expressway has set up sea-level-altitude-signboards in the mouth of ramp and emergency exit as a tsunami warning sign where assumed flooded, and that count about 120.



Fig. 3 – Sea-level-altitude-signboards

##### 4.2 Evacuation guidance procedures for driver and tsunami evacuees

Hanshin Expressway has developed evacuation guidance procedures for drivers in stopping car on the expressway if the alarm of tsunami has been issued.

If the alarm of tsunami caused by the Nankai trough earthquake has been issued after the earthquake, it will take about 90 minutes to reach the tsunami to Osaka Bay coast. In the Hanshin Expressway, due to the risk of entrance and underground section of the elevated road is flooded by the tsunami, after the tsunami warning has been issued, Hanshin expressway will carry out traffic regulation until tsunami reaches.





Emergency patrol procedures and evacuation guidance procedures for tsunami evacuees are summarized as follows;

1) Traffic closure operation

Traffic closure operation for through and entrance traffic is conducted in the case that the level 5 earthquake occurs. Moreover additional exit closure is conducted in the case that tsunami warning is issued.

2) Transmission earthquake and tsunami information to the drivers

Traffic control officers will collect the information about the earthquake and tsunami. Then they will provide those information to the drivers, officers in patrol cars and the toll booth staffs.

Traffic control and road patrol officers provide the earthquake and tsunami information to the refugee customers through road side VMS, on board VMS of the patrol cars and over road side radio.

They will try to enforce the drivers to stop at the nearest road shoulders.

3) Special patrol to the underground tunnels with the risk of submerge

Special patrol team will enforce the drivers to keep out from the inundated risk tunnels by operating traffic closure gate in the through traffic and putting color cone to the tunnel mouth and the entrance and exit to the tunnel.

5) Closure of the entrance toll gate

All of the entrance toll gate will be closed as soon as after the tsunami alert is issued.

6) Ensuring the emergency traffic roads

Hanshin Expressway is designated to emergency traffic road when disaster occurs. In order to secure the traffic of Hanshin expressway as the emergency traffic road in this region, the left over vehicles will be enforced to keep out from the through traffic lanes.

If a tsunami warning has been issued, the expressway is closed for ensuring the safety of the traffic until the safety of traffic drivers is confirmed, and the drivers will be allow to stop the vehicle to the shoulder of the road, etc.

Evacuation guidance in tsunami inundation route are developed as follows,

1) Emergency activities on the expressway is active

In the case that the minor bridge damage which does not affect to the emergency activities, the left over vehicles are escorted to the exit in the no-tsunami inundation area.

2) Emergency activities on the expressway is not active

In the case that the major bridge damage, the left refugees of drivers are escorted to the parking area where the food will be provided.



Fig. 4 – Stock food supply at the parking area

## 5. Tsunami countermeasures to ensure the function of the emergency road

A huge function loss of the expressway facilities are predicted in Hanshin expressway due to the Nankai trough earthquake. In order to survive our Hanshin expressway as a very important urban transportation facility, Hanshin expressway decided to take the following countermeasures.

### 5.1 Tsunami inundation countermeasures at maintenance center

Our Hanshin Expressway has already built two important disaster prevention centers according to experience of 1995 Kobe earthquake. These prevention centers are should be earthquake resistant building. One is located in the building close to the transportation hub, and the other is in the earthquake resistant building which located in the maintenance site office close to the sea. But the both centers are located in Tsunami inundation area, therefore another new prevention center should be placed on the hill where is free from tsunami inundation. The Hanshin Expressway developed the following requirements for selecting prevention center.

- 1) The site should not be in tsunami inundation area.
- 2) The site should be large enough to emergency activities.
- 3) The site should be close to the transportation hub for the engineers to come together easily.
- 4) The site should have an earthquake resistant building.
- 5) The site should not be under the expressway viaducts.

The Hanshin expressway designs the new emergency prevention center equipped with the following management functions.

- 1) The emergency prevention center (EPC) has large command room.
- 2) The EPC is equipped with emergency power generator.
- 3) The EPC is equipped with computer servers to operate company's systems.
- 4) The EPC has accommodation rooms.
- 5) The EPC is stored emergency food and water.

The Hanshin expressway set a goal to build a new EPC within coming three years.

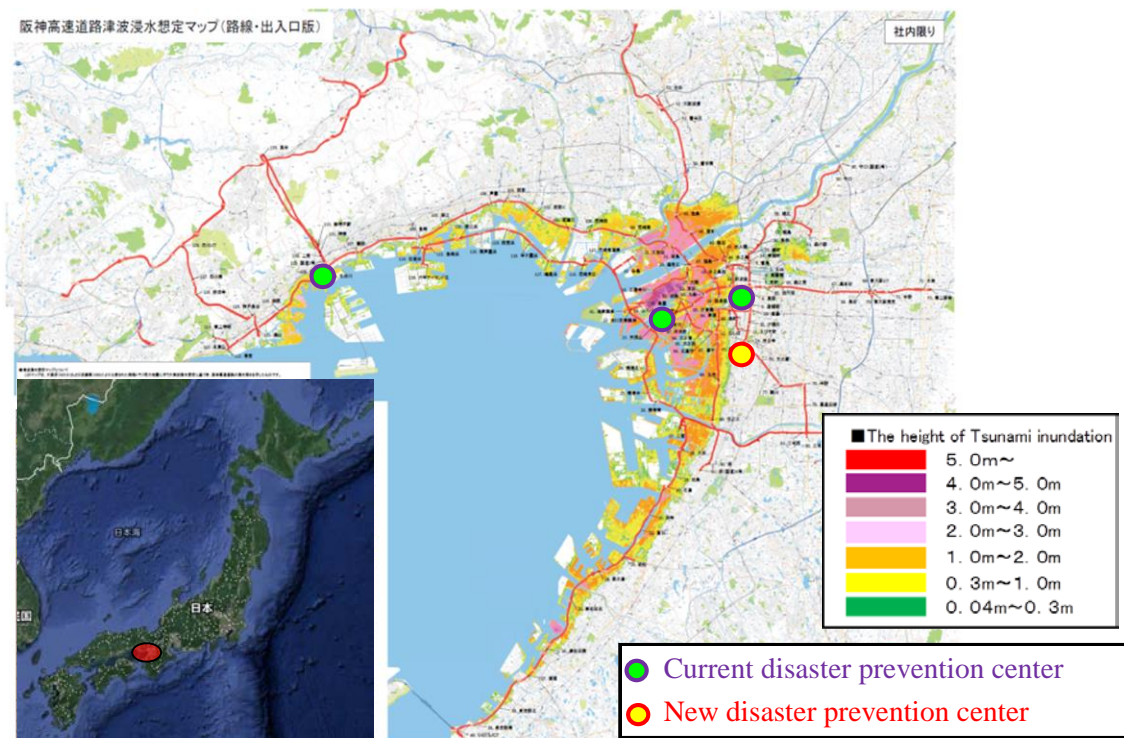


Fig. 5 – Secure the emergency prevention center

Emergency vehicles are also important for emergency activities of traffic managements and emergency restoration works. Emergency vehicles of the patrol base station are necessary to perform a traffic regulation of road closures. Emergency vehicles of maintenance base station are also very important for emergency restoration. However most of the patrol and maintenance base stations are located in the tsunami inundation area; therefore, elevated car parks will be provided to avoid emergency vehicles from tsunami damage. Tsunami inundation measures to ensure the road management functions will be completed in 2017.

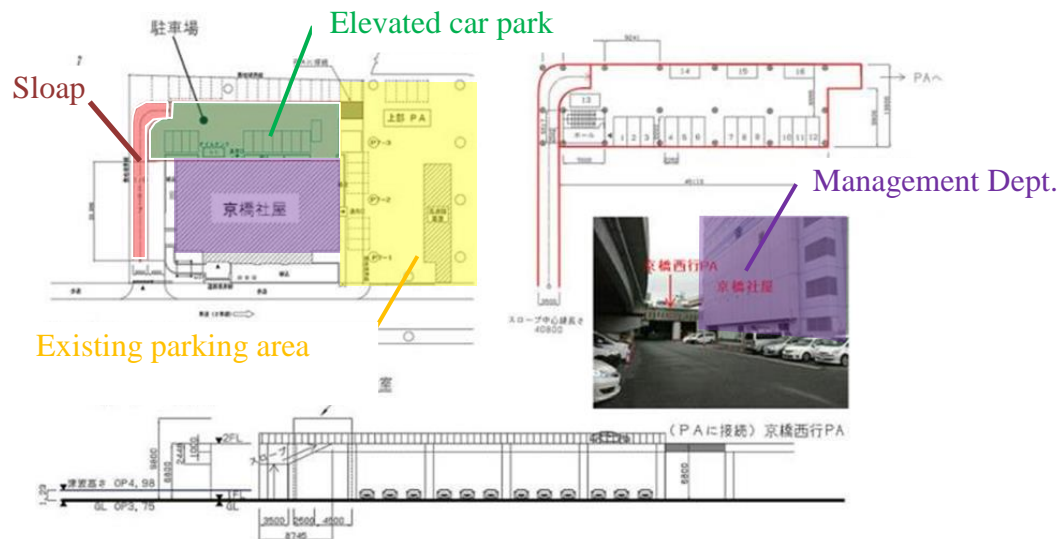


Fig. 6 –Elevated parks for emergency vehicles

## 5.2 Keep power supply function for traffic control

The Hanshin Expressway has two major maintenance department offices in Osaka and Kobe. The maintenance department office has traffic control management center that can monitor the expressway traffic and facility condition, and provide traffic information to the drivers. This traffic control center is a very important facility to provide disaster information and emergency traffic information. In order to maintain these important facilities, it is very important to keep power supply function safely. The department building is equipped with power receiving facilities and power generator in the basement. This means that the department buildings face against power loss during tsunami inundation. Therefore, the countermeasures against tsunami inundation must be provided. Two kinds of countermeasures were considered for the tsunami inundation. One is to provide water proof facilities to the disaster important buildings. The other is to relocate the power facilities from tsunami inundation area. There is no space in the urban area for relocation of the power facility buildings close to the Hanshin expressway; therefore, water proof measures were taken for the basement of the building. Three water proof goals were set as follows;

### 1) Flood prevention:

Provide water proof gate at the ground floor to prevent flooding, and provide pipe sealing to prevent water leakage.

### 2) Spread prevention:

Provide water proof doors in the basement rooms to prevent water into the power receiving and generation rooms.

### 3) Ponding prevention:

Provide pump-facility for the ponding water.

In addition, some electrical booster station and telecommunication tower in tsunami inundation area will be translated on the bridge pier until 2017.

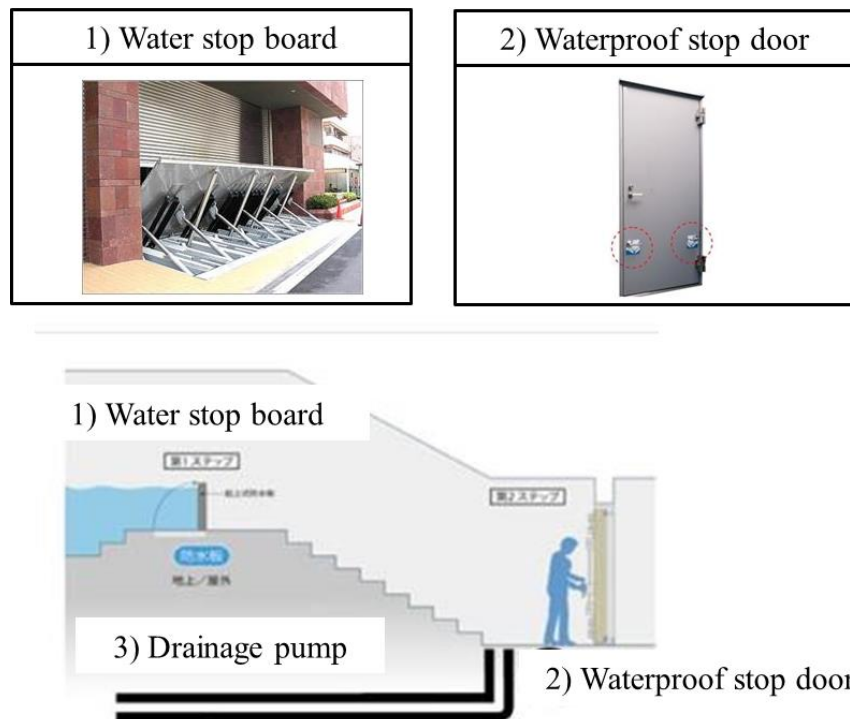


Fig. 7 – Water proof measures to keep power supply

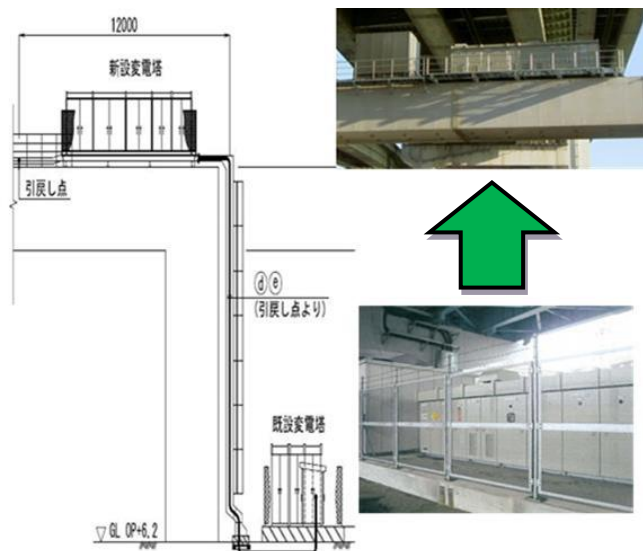


Fig. 8 – Booster station translated on non-inundation area

### 5.3 Securement of self-power supply system and redundant communication line

Black-out is the worst event to consider in the large scale disaster in terms of business continuity. In order to perform initial disaster activities as quick as possible, it is necessary to provide blackout countermeasures to maintain the business of prevention center and local maintenance offices. Self-power supply system was already equipped to major maintenance department buildings. However, the fuel was stocked for only 8-hours running before the 2011 East Japan tsunami disaster. According to the lessons of the 2011 East Japan Earthquake, 80% of the office buildings needed at least 3 days to



recover from the wide range blackout. Therefore fuel reserve is necessary for long hour running of the self-power generators. Additional fuel tank is installed for self-power generators to allow 72 hours consecutive running of self-power generators. In addition, the fuel oil for the generators will be unified to light oil in series for operational efficiency in the event of a disaster.

According to the lessons of 1995 Kobe earthquake and 2011 East Japan earthquake, all telecommunication lines were very crowded immediately after the events. Securement of telecommunication lines in the early stage of restoration phase is very important in the business continuity for the road authorities. In case of Hanshin Expressway, micro wireless communication facility has already provided for emergency communication with the national government for considering the down of the public lines. Redundancy of communication is also strengthened by the digitization and the promotion of mutual use of the communication network beyond the boundaries of the highway companies. Additionally, satellite phones will be also provided in case that the wire and wireless telecommunication lines are down. As for the improvement of the communication between management office and disaster management personnel staff, smart phone (iPhone) is provided.



Fig. 9– Satellite mobile phone

If black-out occurs at one of two traffic control centers, Hanshin Expressway can keep traffic control because of both centers has mutual backup system.

#### 5.4 Strengthening of disaster response

##### 1) Mutual cooperation agreements

Hanshin Expressway has agreement with local government, and other expressway authority for mutual cooperation. We set up periodical discussion meeting and participated in disaster prevention drill mutually. We continually establish emergency contact system beyond the boundaries of road authorities. We registered patrol cars as emergency traffic vehicle which can run under traffic regulation.

##### 2) Preparation of emergency repair

If we will find the gap on the settlement road after earthquake, we repair the gap and aim to reopen our expressway within one day. As preparation of emergency repair, we stocked materials such as sand bags around toll gates.

## 6. Conclusion



There are two challenges for countermeasure study for tsunami inundation. One is to keep road function during and after tsunami inundation. In Hanshin Expressway, major disaster prevention and operation facilities are located in tsunami inundation area. The prevention of tsunami water is recognized as the first priority measures in the tsunami preparedness. The other one is to secure the safety of the drivers and refugees. The tsunami refugees will be guided onto the expressway whereas the expressway shall be closed during the tsunami inundation. They will be guided to the service or parking area of the expressway. Hanshin Expressway has developed the manual for such rescues of the refugees. We must keep emergency traffic road by the good combination of the soft-type and hard-type countermeasures. Hanshin Expressway will conduct disaster prevention countermeasures repeatedly and continually in order to perfectly perform in the coming event.



Fig. 10– Scenery of prevention drills



Fig. 11–Emergency repair