b)The Second Stage Emergency Relief Work

The temporary closing levee was completed under the second stage emergency relief work by June 16, before the lower reaches entered the flood season. The structure was constructed of double rows of sheet steel piles driven to the elevation of the old levee. Sheet steel piles 20 meters long were used. A cross sectional view of the emergency relief work is shown in figure 4-1, and views of the restoration work are shown in photographs 4-1 and 4-2. Since it was feared that there could be unexploded bombs remaining from World War II in this area, it was necessary to perform an investigation prior to starting to drive the sheet steel piles.

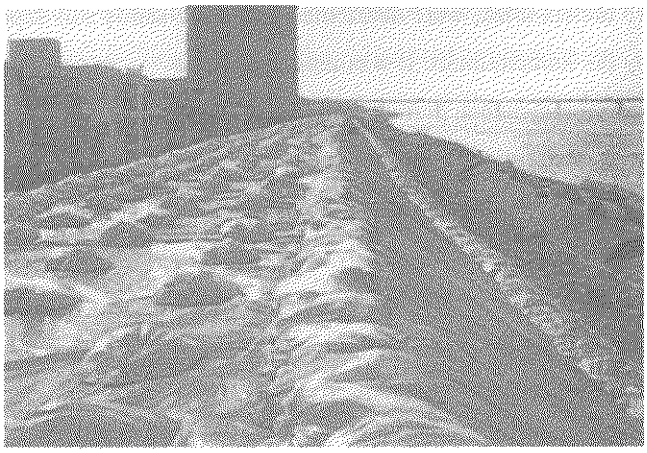

Photo 4-1 The first Emergency Relief Work

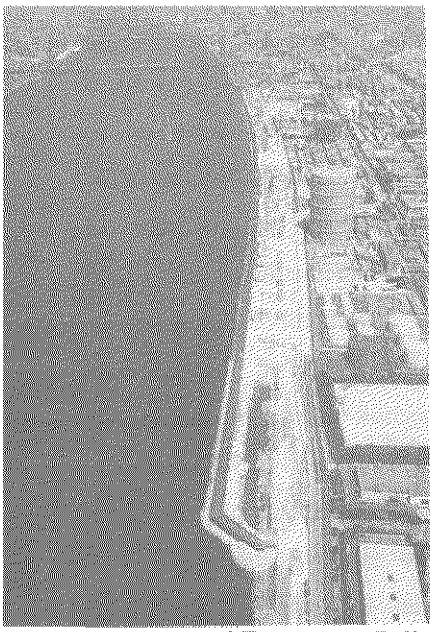

Photo 4-2 The Second Emergency Relief Work

(4)Permanent Restoration Work 3)

a)Preventing Liquefaction of the Ground

It was necessary to provide adequate measures for preventing the liquefaction of ground to prevent secondary failures prior to the restoration of the damaged levee. In order to construct the new levee within a limited time period, it was necessary to assure proper bearing strength of ground. Tests were made to determine whether or not the ground had become liquefied, and it was judged that most of the sandy alluvial deposits below groundwater table had been liquefied. For this reason, it was decided to improve all of the sandy ground. For improving the weak ground, it was necessary to select an adequate method that would not generate excessive noise and vibration, since houses, schools, and factories were densely situated adjacent to the damaged areas. Taking into consideration the limited time period for construction, the proper methods of soil improvement and performance records, a deep mixing method was employed. In locations close to housing areas in particular, a mucking type deep mixing method was employed to control lateral flow of ground under construction. Modified piles were laid out in a grid shape, a method that is highly effective and is an economical means of preventing liquefaction. The rate of improvement was set to 50%. Modified piles were designed to have an unconfined compressive strength of 5 kgf/cm2. Since dense alluvial deposits,

13 meters thick, were distributed below the sandy soil deposits, consolidation settlement could be caused by the embankment. It was assumed that a long maintenance period would be required after restoration if proper measures were not taken, so it was decided to improve the upper layer of dense sandy material to a depth of approximately 4 meters, which would limit the consolidation settlement to half.

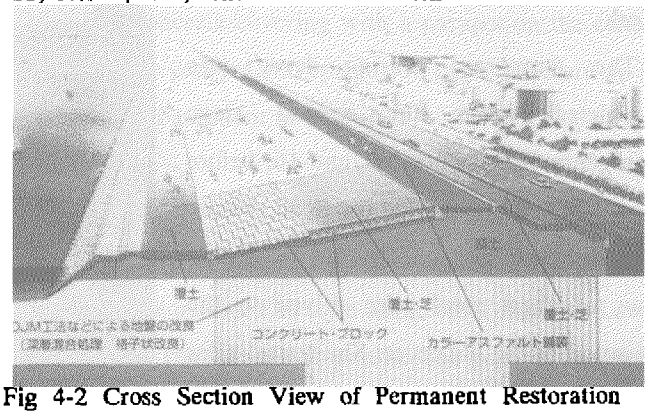

Fig 4-2 Cross Section View of Permanent Restoration Work

b)Execution of Permanent Restoration Work

For the permanent restoration project, it was decided that construction would be performed after all damaged portions of the levee were removed and soil was improved to prevent liquefaction. For soil improvement, a deep mixing method was employed. This method is classified into the dust injection mixing method (DJM method), and the slurry system mechanical mixing method (CDM method), but both methods were employed because it was estimated that a sufficient number of machines would not be available for a single method with the very limited construction schedule. The old levee had a 1.5 meter high parapet, and concrete slope protection covered the three exposed surfaces. The parapet was eliminated from the design for the new levee, and earth embankment was provided up to the top at a gentle slope of 50%. As the levee is located in areas that may be impacted by high tides, it was necessary to cover the entire surface of the levee with concrete blocks, but it was decided to provide an earth cover with sodding, taking into consideration the environment, for portions above the design high water level on the river

Photo 4-3 View of Soil Improvement Work

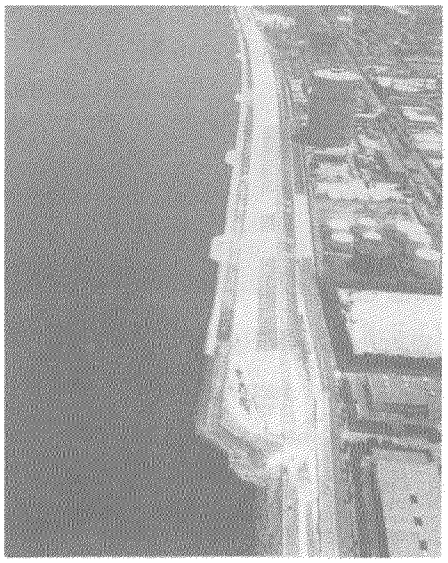

Photo 4-4 Completed view of Torishima Levee

side, and for the rear side of the levee. Lower portions of the levee facing the river was designed to form steps to provide a place of rest for the public. The cross sectional view of the permanent restoration work is shown in figure 4-2 and a view of the soil improvement work and completed view of Torishima Levee is shown in photograph 4-4.

5. Lessons Learned and Future Problems

a)Review of Disaster Prevention Plans for Modification

The Government decided, with this earthquake as a lesson, to modify the existing disaster countermeasure fundamental law and issued instructions to all related government agencies to reconsider all aspects of the existing disaster prevention master plan. The Ministry of Construction has also revised the disaster control operating plan and the Yodogawa Work Office has rechecked the disaster countermeasure operating plan accordingly. The contents of the existing disaster countermeasure operating plan was made primarily to consider how to deal with damage resulting from storms and floods, and it was not necessarily sufficient for earthquakes. Therefore, the plan has been completely reedited in to two separate parts, with Part One for storms and floods, and Part Two for earthquakes.

b)Expeditious Gathering of Information on Damage to Extended Areas

Earthquakes can damage extended areas in a moment. In order to take the necessary emergency actions immediately after an earthquake, it is necessary to gather proper information on the extent of the damage. Detailed investigations must be conducted on the ground, but investigations from the sky are effective for gathering general information on damage to extended areas immediately after an earthquake. The Ministry of Construction had only one helicopter, normally parked at the Tokyo Heliport. The Ministry purchased additional two helicopters after the earthquake. One of these helicopters was named "Kinki," and it was decided to park this helicopter at the Yao Airport. TV cameras were placed at major points on the sides of rivers, and image transfer systems for monitoring were installed in all offices to receive images of sites in an event of a disaster.

c)Improvement of Disaster Information Network

The most important information required initially after an earthquake, when considering necessary emergency response, is the seismic intensity. When seismic intensity is known, the outline of damage can be estimated to a certain level. However, the information based on data gathered from a single place for each prefecture, as experienced this time, is too rough to make a correct evaluation. After this earthquake the procedure was revised so that that seismic intensity announced by meteorological stations would be subdivided into each area. The Yodogawa Work Office has completed a network of seismometers placed along the sides of the river An optical fiber network is also being constructed so that TV camera images and seismic data can be conveyed rapidly.

d)Security of Traffic in Emergencies

Roads and railroads were interrupted by this earthquake, which resulted in heavy traffic congestion. This became a hot issue, as life saving activities and cargo transportation were obstructed. With this event as a lesson, it was decided to provide emergency river channel area roads. For the Yodogawa river, it is planned to provide 7 meter wide roads on both sides of the river within areas under the jurisdiction of Osaka Prefecture. The revival of ship transportation is also being considered as a measure for preventing disasters.

e)Security of Materials and Equipment

Required for Restoration Various materials and equipment, such as sand and soil materials, plastic sheets, sheet steel piles, and heavy equipment are required for restoration of damaged rivers. A certain amount of materials and equipment is stored for emergency repairs, but such stockpiles are not enough for a large disaster as experienced this time. Urgent help from other agencies and industries were required. For this reason, it was felt necessary that prior agreements for procurement of necessary materials and equipment should be made with related agencies and industries.

f)Setting Up Cooperation and Assistance System

The Yodogawa Work Office received personnel assistance and supplies of materials and equipment from other regional construction bureaus after this earthquake. The necessary number of personnel and the responsibility to be borne by assisting personnel could not be clearly determined in the confusion, and cooperation and assistance was not smoothly received. In this regard, it was considered necessary to set up an organization to accept personnel assistance in advance.

g)Development of Manuals for Prevention of Disasters

In order to gain the greatest efficiency from organizations and employees, it is desirable that detailed manuals on procedures for emergency action be developed. Taking this earthquake as an opportunity, the following manuals have been developed.

Manual for Initial Emergency Action after Earthquakes

Cooperation and Assistance Manual for Regional Construction Bureaus

Manuals for Effective Use of Helicopters

Public Relations Manual for Disaster Prevention

It is not necessary to say that it is important that employees be fully trained for effective use of these manuals.

h)Counterplan for Earthquake Resistance Design of Levees

After this earthquake, a Technical Committee for Earthquake Damage Prevention for River Structures (headed by Professor Kazuya Yamamura of Nihon University) was organized by the Ministry of Construction to discuss counterplans for assuring earthquake resistance design of river structures and for improvement of their design. In the paper 4) reporting the discussions made in the committee. "River embankments still maintain a portion of their functions to prevent inundation, even if they subside or are damaged by deformation, and have specific characteristics that allow them to be easily restored. For these reasons, it is more realistic that objectives be set for constructing levees that will not cause secondary disasters by inundation even when they collapse, rather than constructing rigid levees that will not collapse during earthquakes. If secondary disasters can be predicted for the levees of rivers and streams where the effects of earthquakes are not normally considered, it is necessary to provide prevention measures in advance. At this moment, countermeasures for zero-meter areas are urgently necessary." In the Yodogawa Work Office, a "Technical Committee for Earthquake Damage Prevention for Levees of the Yodogawa River" (headed by Professor Kazuya Yamamura of Nihon University) was organized with all available knowledge collected to review the earthquake resistance capacity of levees of the Yodogawa river to effectively use the review and discussions for improvement of river structures in the future.

In a portion of the damaged areas of Torishima, a super-embankment was being constructed jointly with a housing project when the earthquake occurred The super-embankment is a levee with a wide top whereby safety is assured, not only for unusual floods, but also for earthquakes. It is planned that construction of this project will be resumed. A completed view of Torishima Super-embankment is shown in figure 5-1.

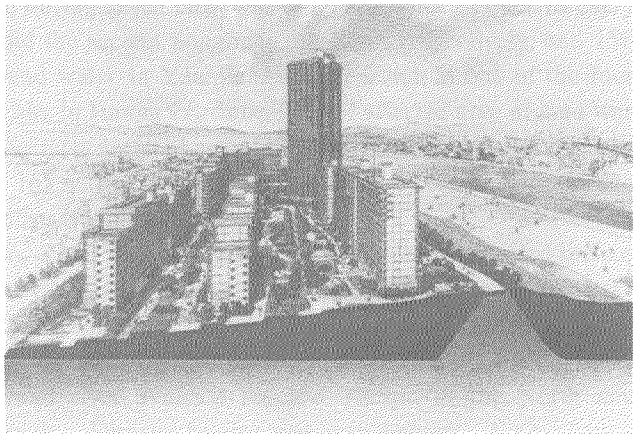

Fig 5-1 Completed View of Torishima Super-levee

6. Conclusion

The lower reaches of the Yodogawa River, which was seriously damaged by this earthquake, is a flood channel excavated in the era of the Meiji. Construction commenced in 1896, as one of the first modern flood control projects. The year 1996 is the centenary for this channel It can be fate that the Torishima Levee is being born again at the year of centenary. The new levee will assure charm and peace of mind for the public, as a fortress to properly defend the safety of the discharge basin, and will keep an eye on the vicinity as a legacy from generation to generation this record-breaking mishap With the lessons learned from this earthquake damage, we will push forward flood control projects towards the realization of safe and reliable Yodogawa river.

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4)Ministry of Construction "Report of Technical Committee for Earthquake Damage Prevention for River Structures," pp 91-92, 1996