

meters. Photo 37 shows the damage to abutment of Miyagawa Bridge at Point B in Figure 18, and Photo 38 shows that a steel girder overlying the road on the river bank at Point B. These suggest that the riverbank moved towards the water. Photo 39 shows the riverbank after the earthquake, and it should be noted that the line of the riverbank was maintained mostly straight and did not collapse even after the large movement of about 2. It can be assumed therefore that the riverbank and non-liquefied ground moved towards the river on the underlying liquefied soil which flowed toward the river.

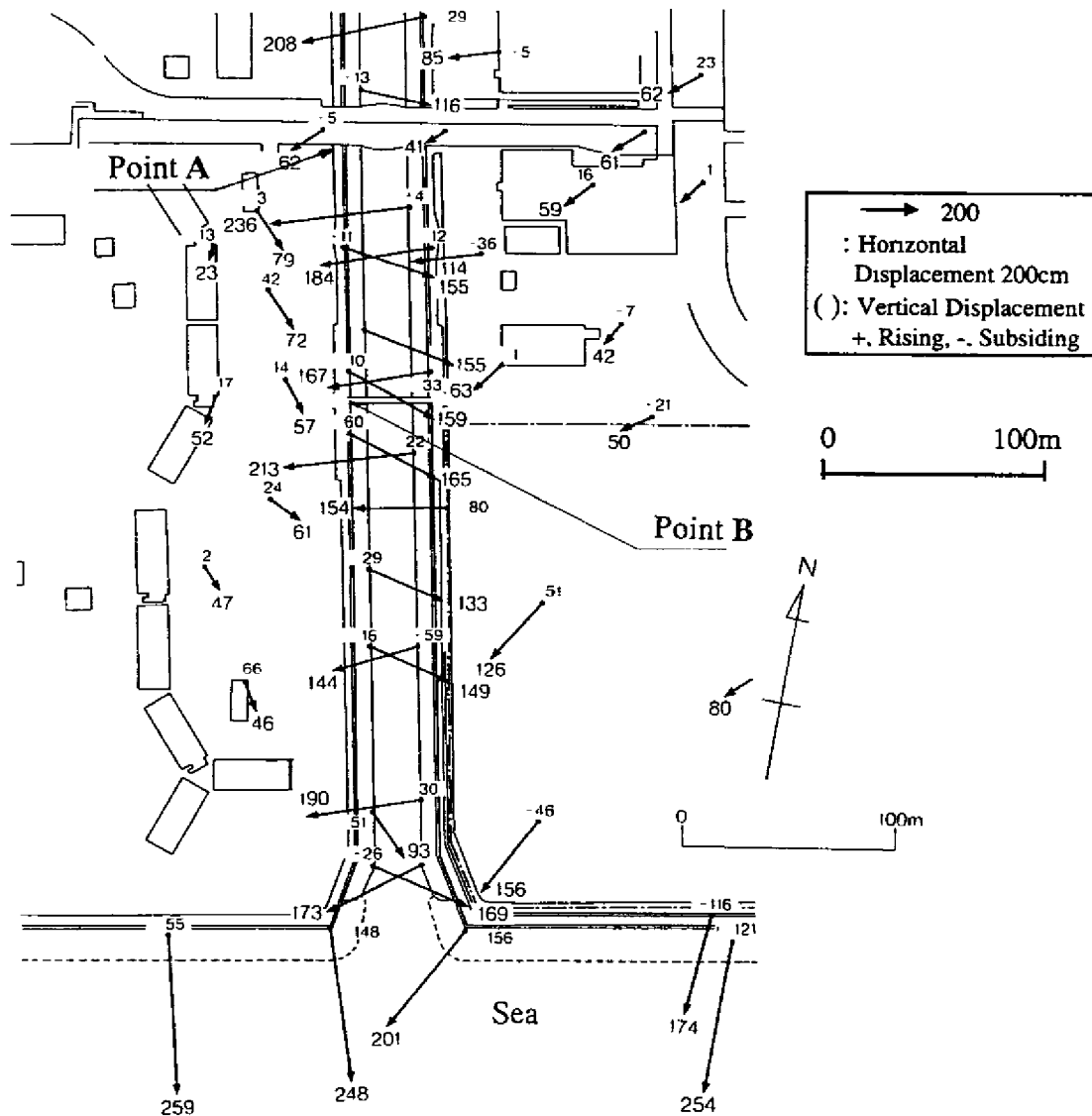


Figure 18. Liquefaction-induced ground displacement at southern end of Ashiya-hama¹⁾

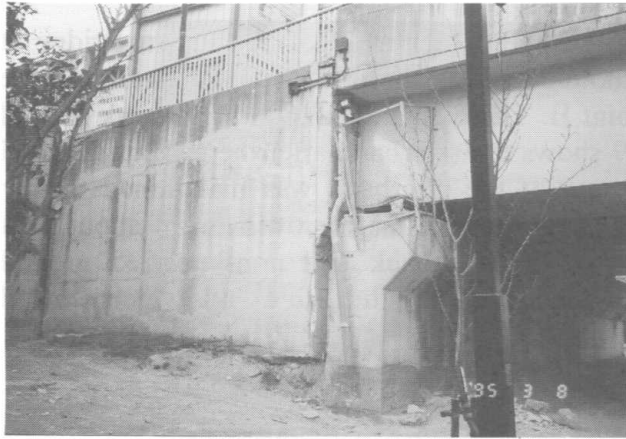


Photo 37 Abutment of Miyagawa Bridge moved and inclined due to ground movement toward the river (left) (A in Figure 18)



Photo 38 Movement of river bank at Ashiyahama (B in Figure 18)

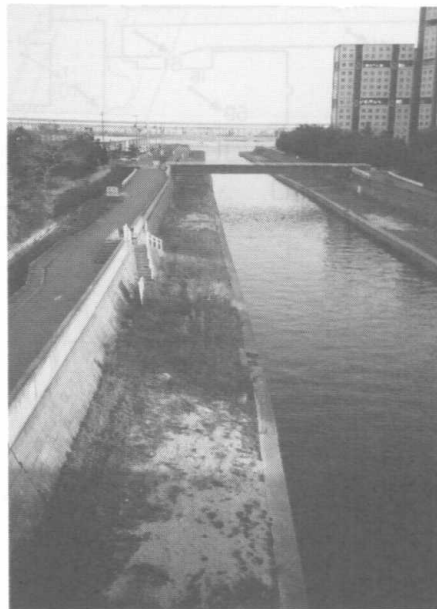


Photo 39 River bank after movement of ground at Ashiyahama

6.2 Lifeline Facilities

(1) Higashi-nada Sewage Treatment Plant

The Higashi-nada Sewage Treatment Plant locates in Uozaki-hama which was reclaimed from the sea, and suffered a severe liquefaction. Figure 19 shows the plan of the plant and distribution of ground displacements measured by aerial survey. The ground along a canal moved towards the water at a maximum about 3 meters. Photo 40 shows a concrete pier of a bridge crossing the canal inclined due to displacement of its foundation, where the top of the pier was restrained to move because of the rigidity of the bridge girder. Photo 41 also shows a similar example of evidences of the ground movement toward the canal. A concrete foundation of stairs up to a bridge crossing the canal was separated from the stairs due to ground displacement toward the canal.

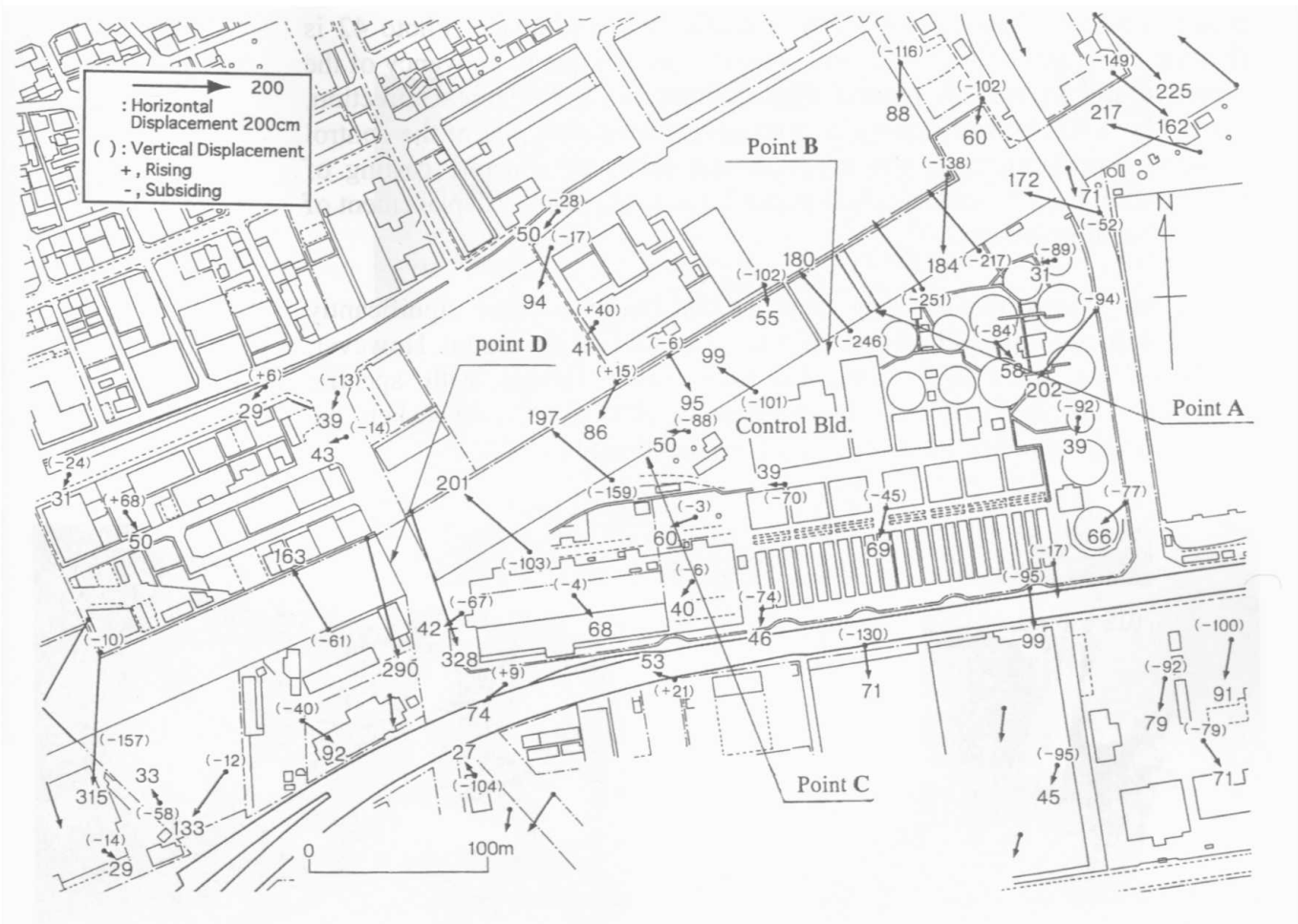


Figure 19. Plan of Higashinada Sewage Treatment Plant and ground displacements¹⁾



Photo 40 Inclined concrete pier due to ground displacement (A in Figure 19)



Photo 41 Separation between stairs of over-canal bridge and its concrete foundation due ground displacement toward the canal (left) (B in Figure 19)

The sewage facilities in the plant suffered severe damage and the function of the plant was perfectly lost after the earthquake. Photo 42 is floating and separation of inground concrete conduit due to buoyancy of the liquefied soil as well as ground displacement in the horizontal direction, while Photo 43 shows breakage of a concrete foundation pile of the control building. Furthermore, it was reported that joints of concrete casting of precipitation basins were largely separated due to horizontal displacement of the surrounding ground.

As mentioned above, many facilities and buildings were significantly damaged due to liquefaction and its related ground displacement. However, it should be noted that some facilities and buildings with specific foundations hardly suffered any damage in this plant, even when the surrounding ground moved significantly, as mentioned in 7.2.



Photo 42 Floating and separation of concrete conduit due to ground displacement (Courtesy of Mr. K. Takenaka, C in Figure 19)

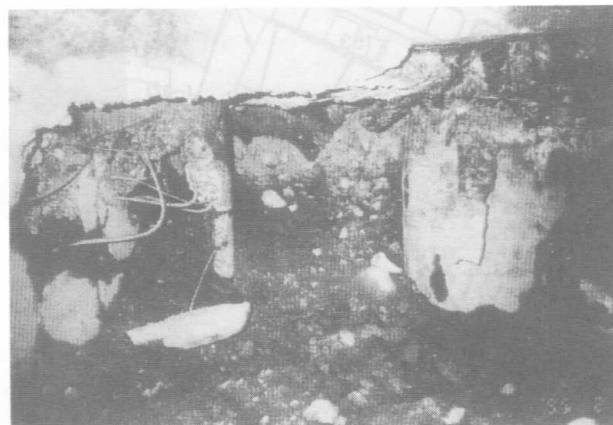


Photo 43 Breakage of foundation pile of the control building (Courtesy of Mr. K. Takenaka)

(2) Rupture of welded steel pipe for water trunk line

A welded steel pipe 60 centimeter in diameter for water trunk line in Port Island was ruptured by liquefaction-induced ground displacement. As shown in Photo 44, the pipe was horizontally separated and sheared. This rupture was caused at Point A in Figure 20. The pipe of the water trunk line was suspended in the Kobe Bridge, and was buried again in the ground in the neighborhood of Point A. Figure 20 shows that the ground of the North Park (Kita Koen) moved towards the sea over 4 meters, and a large tensile strain of the ground was caused. As shown in Figure 20 the ground strain around the rupture point of the water pipe, which was estimated from the measured ground strain is 2.5 % in tensile. This large ground strain can be considered as a direct cause of the rupture of the pipe.



Photo 44 Rupture of welded steel water pipe (A in Figure 20)

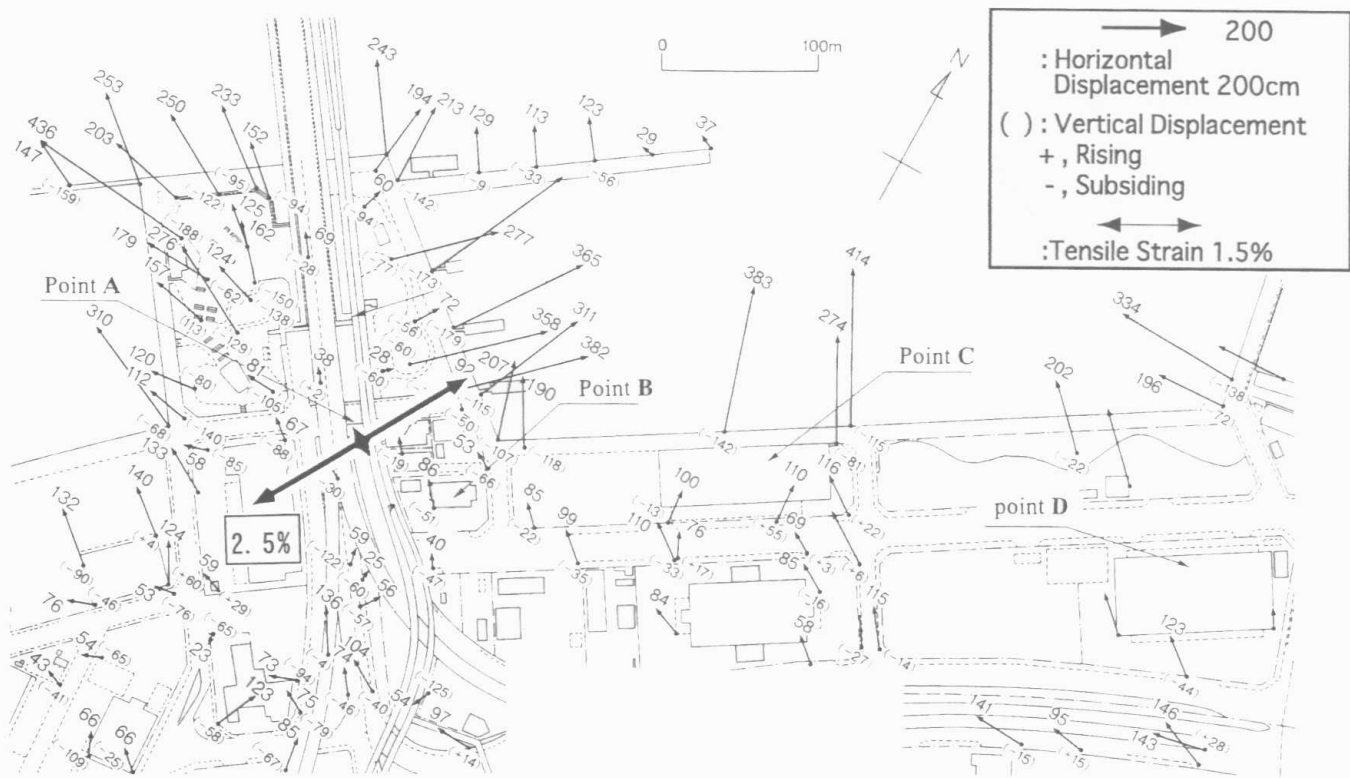


Figure 20. Liquefaction-induced ground displacement at North Park of Port Island¹⁾