of 40 cm from the head on the opposite side. An integrity sonic test was then carried out for six piles, which indicated that one of the seaside piles was also damaged at a depth of 7-8 meters. The location of the damage is middle part of the fill.

At point C in Figure 20, a warehouse which was supported by precast concrete piles in diameter 60 cm suffered a horizontal separation of 2.5 meters between its basement and the surrounding ground due to ground movement toward the sea. Furthermore, the ground in front of the warehouse subsided as shown in Photo 50. Exposed pile head showed that it had failed vertically as well as horizontally as shown in Photos 51 and 52. In addition, the pile heads separated from the pile caps sand were displaced due to ground movement toward the sea. The quaywalls north of the warehouse moved about 4 meters as shown in Figure 20 and the building slid by 1 meters by the movement. This implies that the primary cause of the damage was lateral ground displacement induced by liquefaction. A building at Point D in Figure 20, the distance of which from quaywall was about 100 meters also suffered damage to its foundation piles due to the ground displacements.

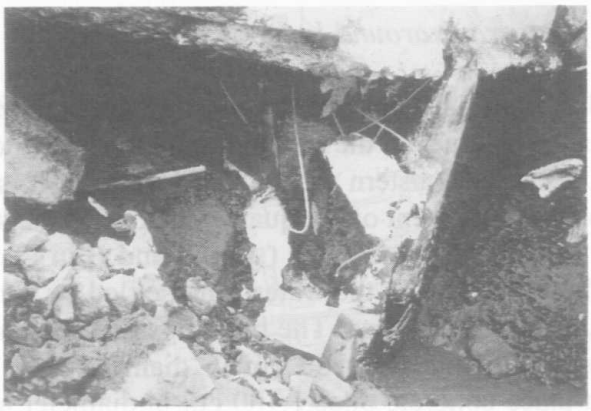

*Photo 49 Failure of pile head due to lateral ground movement*

*Photo 50 Large cracks and settlement of the ground behind quaywall due to lateral movement of the ground toward the sea (right)*

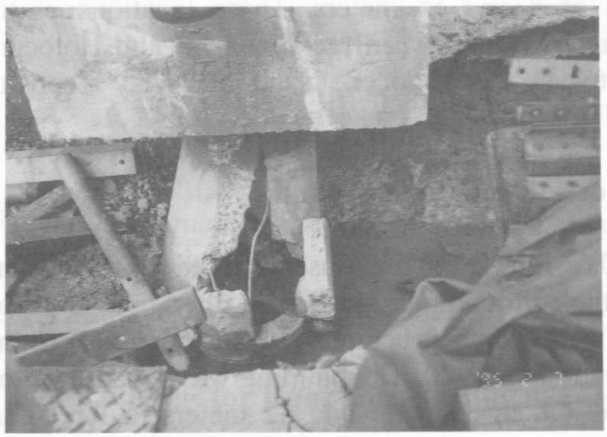

*Photo 51 Failure of pile due to ground displacement (C in Figure 20)*

*Photo 52 Separation of pile head due to ground movement (C in Figure 20)*

### (3) Buildings in Maya Wharf

At eastside of the entrance of Maya Wharf, the shoreline was largely curved due to the ground movement toward the sea, as shown in Photo 53. Figure 23 shows the ground displacement of the northern part of Maya Wharf, indicating that the quaywalls displaced eastward at a maximum about five meters. Pile heads of a 3-story building which located at Point A in the figure were exposed after the large ground settlement and found to be failed completely near the heads with slight lean toward the sea (Photo 54). Aerial survey shown in Figure 25 shows that quaywall in front of the building displaced about 3 meters toward the sea.

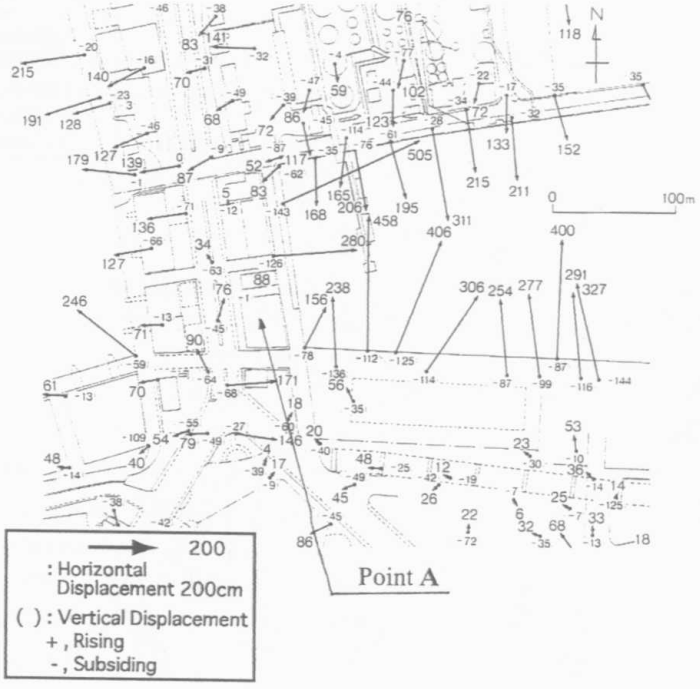


*Figure 23. Liquefaction-induced ground displacement at northern part of Maya Wharf[1)]*

*Photo 53 Curved quaywall along due to lateral ground movement toward the sea at road for Maya Wharf*

*Photo 54 Concrete pile breakage due to ground movement (A in Figure 23)*

### (4) Buildings for Kobe City facility in Fukae-hama

A Kobe city facility locates northwestern part of Fukae-hama, facing to the sea on the north and west sides. Horizontal ground displacement of 3-4 meters occurred toward the sea along the seawalls as shown in Figure 24 and Photo 55. In the site, there existed 35 buildings at the time of the earthquake, which had been gradually constructed since 1969. Fifteen were supported by point bearing steel pipe piles, one by precast concrete pile and the others by spread foundations.

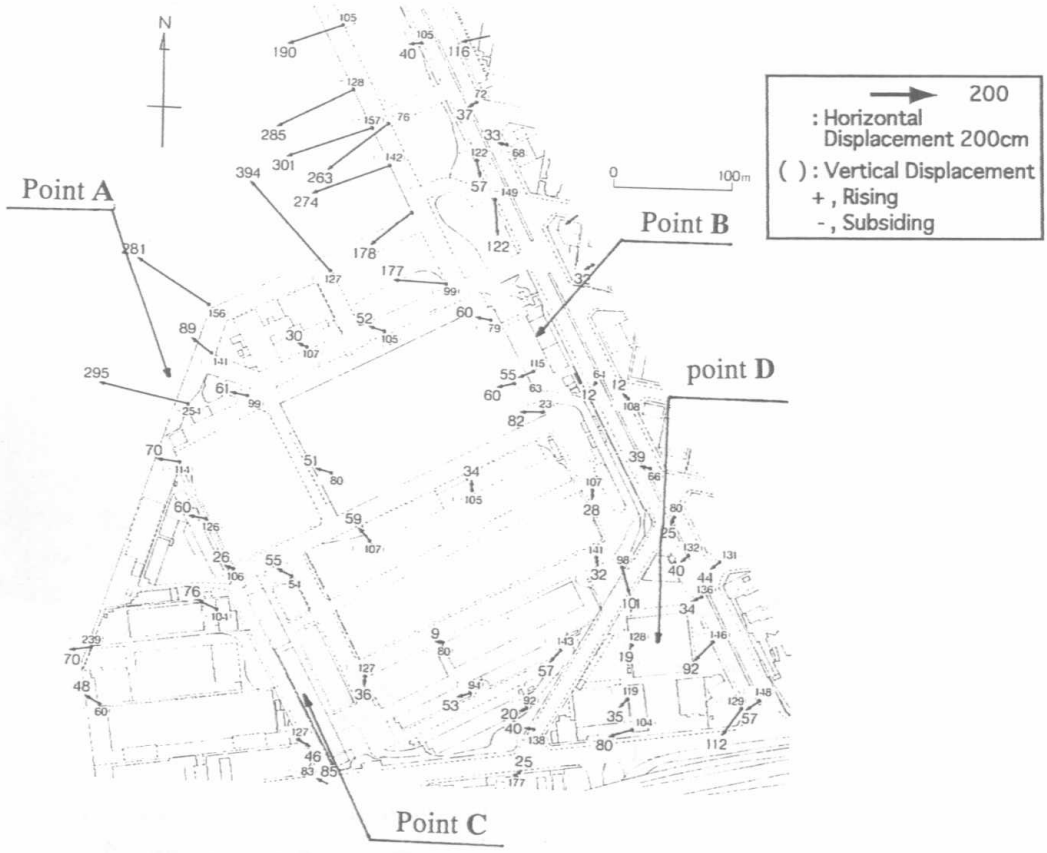


*Figure 24. Liquefaction induced ground displacement at northwestern part of Fukae-hama*[1]

*Photo 55 Large deformation of quaywall and ground behind the wall (A in Figure 24)*

Soil liquefaction induced large ground surface settlement up to 1.6 meters, exposing the heads of point bearing piles of several buildings above ground. The heads of steel Figure 24, 150 meters away from the sea wall, inclined a little. A stairway handrail of this building was deformed in response to the horizontal and vertical ground displacement as previously shown in Photo 20.

A warehouse at Point C, 150 meters away from the quaywall, settled about one meter due to ground subsidence, although it was supported on point bearing piles. Either loss of ground bearing capacity or failure of piles seems to be the cause of the settlement. A prestressed concrete pile of a 2-story market building at Point D in Figure 26, about 400 meters from the seawall cracked horizontally near its head without inclination of the superstructure. Most of the buildings with spread foundations tilted considerably with slight damage to their super-structures.

**(5) Residential buildings in Ashiya-hama**

In Ashiya-hama, several buildings facing the waterfront tilted and moved toward the sea, with considerable damage to the pile foundations as described in 4.5. At the northeast corner of Ashiya-hama, Buildings A and B in Figure 25, which are 11-story and founded on precast concrete piles 50 cm in diameter and 26 meters in length tilted by 1/58 and 1/39, respectively[24]. Damage to superstructures of three buildings appeared slight although about 50 cm wide separation occurred at the expansion joint connecting Buildings A and B. North of the buildings, numerous ground fissures occurred. According to an aerial photograph survey, the quaywall south of the buildings displaced 1 meter toward the sea. Figure 26 shows east side elevation of Building B, which suffered severest tilt and a boring log at the site

A survey by excavation of the pile heads at 4 points of two tilted buildings revealed that the pile heads on the seaside failed in shear and bending mode and the piles inclined toward the sea (Photo 56). The piles on the inland side cracked with little inclination (Photo 57). In addition, an integrity sonic test detected cracks at depths of 6 and 12 meters on the inland-side piles as well as at a depth of 6 meters on both sides of the piles[24]. The boring log shown in Figure 26 revealed that these two depths of cracks coincide with the interfaces between reclaimed fill and Holocene sand deposit, and that between the Holocene sand and clay deposits, respectively.