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ABSTRACT

The 1999 Kocaeli Earthquake of August 17,1999 hit the western part of Turkey causing very great damages. From a result of our investigation and survey, typical geotechnical damages on this earthquake were pointed up except structural damage due to inertia force. One was a settlement and/or tilting of buildings induced by the ground deformation such as soil liquefaction or bearing failure in Adapazari City. Another was a widespread land loss in the south of coast in Izmit Bay, induced by the fault movement. In this paper we deal with the widespread land loss around Izmit Bay. The authors check into the relationship between the submerged area and the rupture of the fault, and then carried out the measurement of water depth at several cross sections of offshore in Izmit Bay. In order to clarify the aspect of loss of the coastal land, the topography of the seabed before and after the earthquake were compared. And then, some in-situ tests were conducted near the submerged area. From the result of the measurements, in-situ tests and the field survey, the causes of the loss of coastal land could be anticipated.

INTRODUCTION

The Kocaeli earthquake of August 17, 1999 brought extensive damage in the Izmit Bay area, Turkey, and its vicinity. Damage in the south of Izmit Bay was one of the most severe ones; many houses and buildings were collapsed, widespread coastal land was slipped away and submerged into the sea with the all facilities. We visited these areas as the member of second reconnaissance team from the Japanese Geotechnical Society (JGS). Also, one of the authors stayed in Turkey as a visiting technical expert from the Japan International Cooperation Agency (JICA).

The widespread loss of coastal land, which is taken effect from the fault movement and the ground condition, seems interesting from the point of view of the geotechnical engineering. We, therefore, made an investigation in this region focusing on the change of coastline and the change of water depth before and after the earthquake. After we made a survey on shore in order to pinpoint the subsided and submerged area, the water depth measurement of seabed at the several cross sections in the south of Izmit Bay. After that, Sweden sounding test and standard penetration test were conducted near the subsided area in order to clarify the ground condition and the cause of loss of land.

The general report of this investigation is already published from JGS (2000) as a part of the reconnaissance report by two reconnaissance teams from JGS, which is summarizes in this paper.he Kocaeli earthquake of August 17, 1999 brought significant damage in the Izmit Bay area, Turkey, and its vicinity. Damage in Adapazarı City was one of the most severe ones; many houses and buildings were collapsed, settled or tiled. We visited this city as the first reconnaissance team from the Japanese Geotechnical Society (JGS). The damage to buildings seems interesting from the point of view of the earthquake geotechnical engineering because two areas; area whose damage is caused by inertial force and area whose damage is caused by soil liquefaction. We, therefore, made a detailed investigation in this city especially focusing on the damage to buildings and occurrence of liquefaction. The complete report of this investigation is published from JGS (2000) as a part of the reconnaissance report by two reconnaissance teams from JGS, which is summarizes in this paper.

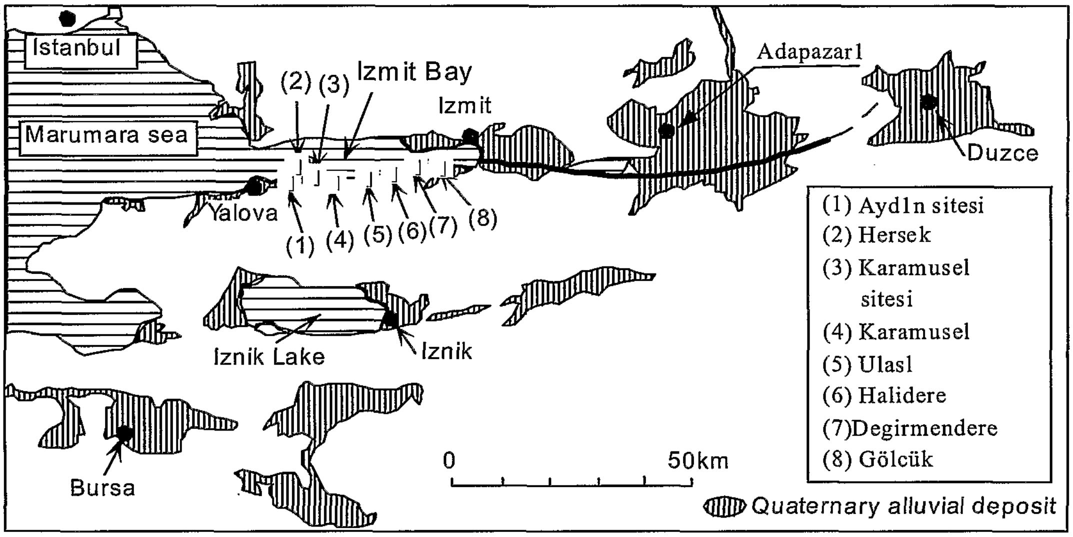

Fig. 1. Location of the sites and fault line in the severely shaken area at the time of the Kocaeli Earthquake

GENERAL DESCRIPTION OF THE DAMAGE AROUND IZMIT BAY

It is known that the rupture of the fault in the 1999 Kocaeli Earthquake was right-lateral type and ran along an east-west alignment as shown in Figure 1. It appeared on the surface about 30km west of Duzce City and disappeared into the sea in the south of Izmit City. It ran along the coastline and reached to the northward of Yalova City. On the Kocaeli Earthquake, severe geotechnical damages were frequently observed in the southern coast part of the Izmit Bay. They were ground subsidence and loss of coastal land in addition to the structural damage caused by inertia force. This section describes the typical and characteristic damages, which occurred at the cities along the southern coast of Izmit Bay during 1999 Kocaeli Earthquake, from west to east one by one.

Yalova is a middle size city that is located in the eastern side of the damaged area. Damaged to the structure was mainly caused by inertia force. East of the peninsular, Hersek district that is located north of Altinova was a lagoon that had waterlogged at high tide, but became waterlogged all the time after the earthquake. Subsidence in the widespread area indicates the possibility of occurrence of liquefaction, although we cannot definitely conclude this since clear evidence of liquefaction such as sand boils was not observed. On the other hand, significant amount of sand boil was observed in the orchard that is located west of the Hersek district, a small river flowed into Izmit Bay, and several cracks was observed parallel to the river near the river-mouth, which suggest that the ground moves towards the river. Several sand boils were also observed nearby.

The Karamusel City is the most eastern city among the areas where loss of coastal land was observed along the shoreline in the south of Izmit Bay. It seems that the main fault ran under the seabed near the coastline in the western region from Gölcük, to such cities as Degirmendere, Halidere, Ulasl and Karamusel. In these areas, aspect of damage as the coastal land, was slipped away into the sea.

On the contrary, rupture of the main- and/or sub-fault appeared on the surface in the region located in the east from Gölcük, and the vertical movement of the fault was predominated. In consequence, large-scale vertical offset was appeared and the disappearance of town due to widespread subsidence of the ground was happened. We report about the damage of ground and the change of coast line in details as follows.

COAST AREA IN THE WEST OF GOLCUK (TERTIARY DEPOSIT)

Locations of fault line and land submergence in the city of Degrimendere that is located west of Gölcük City are shown in Figure 2. The fault was observed on ground in the east of downtown Gölcük, whose traveling direction is also roughly shown in Figure 2. Two typical damages to waterfront area were observed. The stone-pilling wall was just located on and was damaged with a horizontal relative displacement in 1.5m of west-east direction and 4.3m of north-south direction. Quay wall along the coast was moved seaward, and damaged due to ground gaps by the fault.

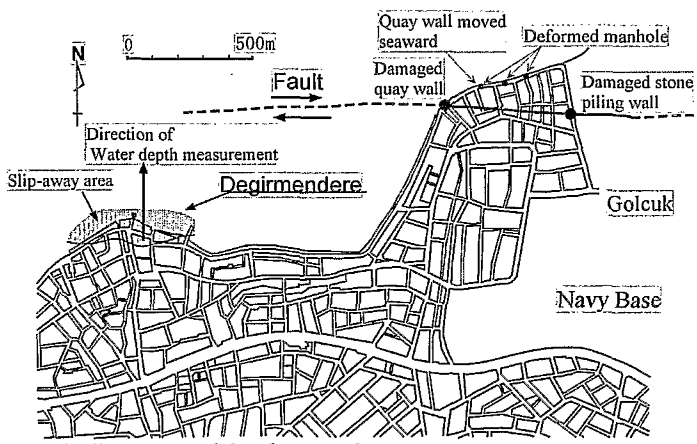

Fig. 2. Location of the damaged and slip away area in Degirmendere

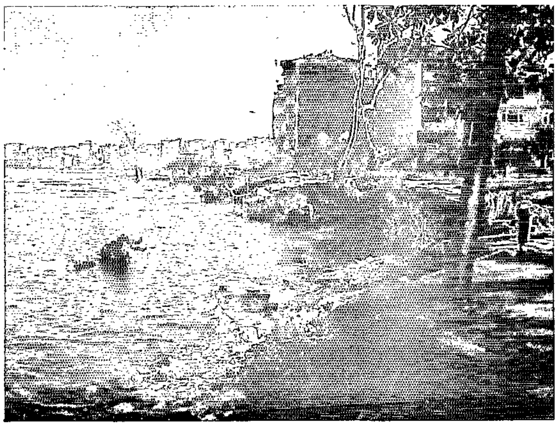

Photo 1. Slip away area in Degirmendere

In the west of the downtown, the coastal land with about 300m long and 100m wide was chopped away into the sea including all buildings on the ground just after earthquake as shown in photo 1. From the observation of outcrop and inclination of riverbed, this area was not reclaimed land but alluvial deposit, which includes many gravels with about 10mm diameter. The buildings near the boundary between flowed out areas were damaged and tilted toward the sea. The evidence of soil liquefaction could not be observed at the back ground of slipped-away area.

Following the earthquake, depth of the seabed water was measured along a cross section perpendicular to the coastline by means of an ultrasonic device illustrated in Figure 3. Location of the measurement is shown in Figure 2. Exact distance from the shore was monitored by means of Global Positioning System (GPS). The outcome of the measurement is

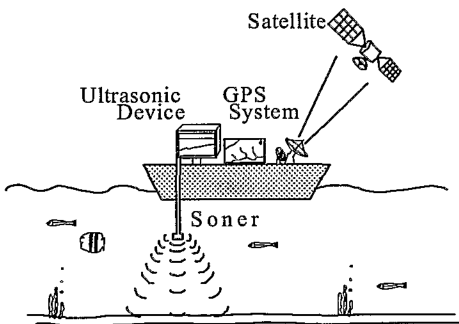

Fig. 3. Image of water depth measurement device

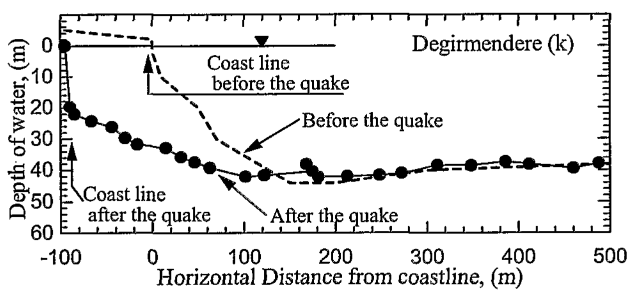

Fig. 4. Result of Measurement of water depth (Degirmendere)

demonstrated in Figure 4, together with the water depth prior to the earthquake. That was read off from the published marine chart showing contour lines of equal water depth. It can be seen that the shape of the seabed had changed drastically after the earthquake as compared to that prior to the earthquake. Amount of change of water depth reached about 20m in depth near the shore. This indicates that a landslide must have taken place under the sea. The distribution of collapse converged within 150m offshore from the coast. The fault is considered to run east to west at a location about 500m off the coast as estimated from the fault line extension in Figure 2. The obvious change of water depth can be measured at this terrain. Considering that the change of seabed in several tens meters caused by the collapse of alluvial deposit, but not the transform fault.

Figure 5 shows location of land submergence in Halidere located on west of Degirmendere City. Part of nose of alluvial cone, about 200-250m long and 20m wide, was slipped away into the sea. According as slipped away area is mainly reclaimed land and the gradient of back ground is relatively small, collapse of reclaimed land seemed to affect to natural ground. Similar measurements of water depth were carried out in two cross sections in Halidere as indicated in Figure 5. The section 1 passed through the mouth of a small river across the

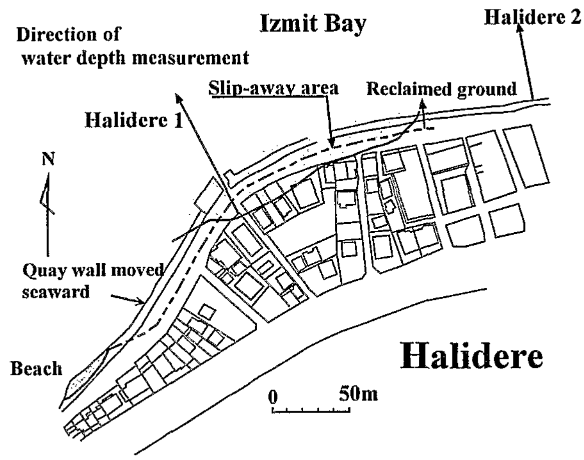

Fig. 5. Location of the damaged and slip-away area in Haliderere

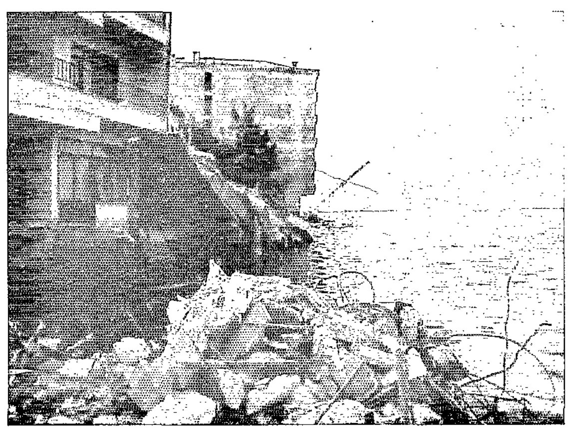

Photo 2. Slip away area in Halidere

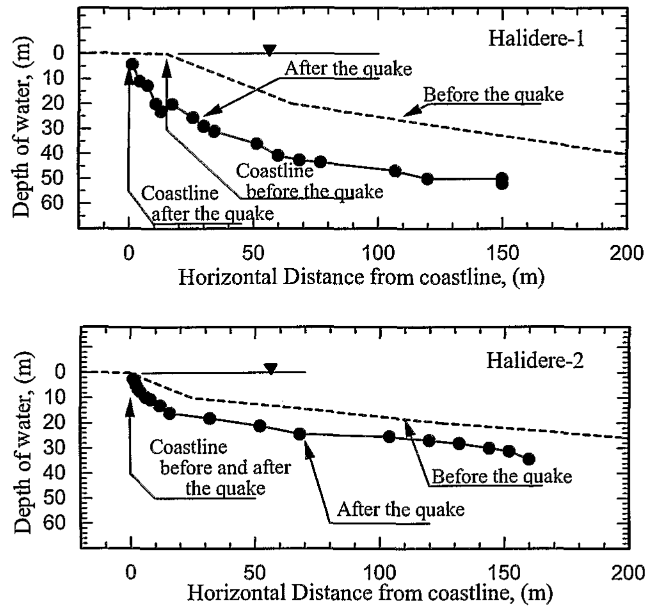

Fig. 6. Result of Measurement of water depth (Halidere)

city, and the section 2 is located east of the city where there was no loss of coastal land. Results of water depth measurement are displayed in Figures 6.

In the Halidere 2 cross section, the depth of submarine slide is inferred to be about 10m on the average, whereas the slide in Halidere 1 cross section involved the soil movement to a depth of about 20m. From these observations, it may be noted that the removal of a huge mass soils from the coastal land was caused by a large-scale submarine slide where the sliding plane was as deep as 20m beneath the original sea bottom.

COAST AREA AROUND OF GOLCUK (QUARTERNARY DEPOSIT)

Figure 7 shows a schematic map of Kavakli district in Gölcük City. Traces of the fault was observed on the ground at several sites in this district, whose direction is roughly shown in the same figure. The fault line passed through the road along the west of football stadium. The vertical offset amounted to about

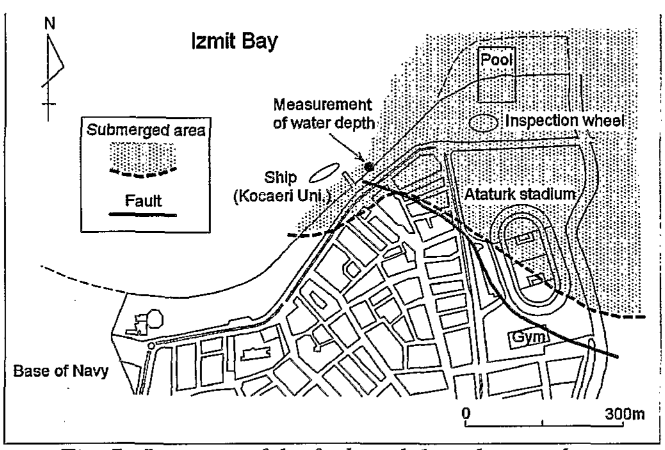

Fig. 7. Location of the fault and the submerged area

1.5-2.0m as also indicated in Figure 7. The triangular area northeast of the fault subsided with a gradual tilt toward the sea with the northern tip submerged into the sea. The submerged area is also shown in Figure 7 and Photo3. It would appear likely that the terrain about 1 km by 1 km area has moved as a whole towards the sea with lower relief. And the amusement facilities such as swimming pool and Ferris wheel in the park were submerged accompanied with the ground subsidence. Because walls, electric poles and woods in the submerged area were standing straightly after the earthquake, it would appear that the land was subsided maintaining the level of the land. Furthermore, the ground subsidence was gradually increased even after several months.

Simplified measurement of water depth was carried out at the site on Figure 7 by using plumb-bob. Figure 8 shows the schematic drawing of the change of waterfront before and after the earthquake in Gölcük. The promenade along the coast has gone under the water, and vertical displacement of the top of quay wall amounted to 2.8m. It is confirmed that the signboard of kiosk which could be seen on the water level just after the earthquake, it disappeared under the water after several months. Several cracks with sand boil could also be observed along the coast road near the submerged area. It is undeniable possibility that soil liquefaction was partly occurred and induces to the ground movement towards the sea.

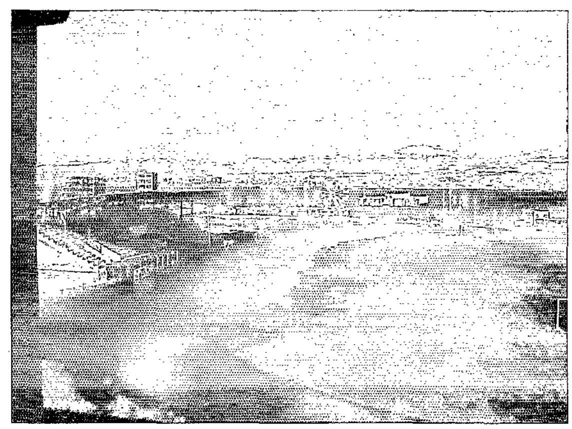

Photo 3. Submerged area in Golcuk

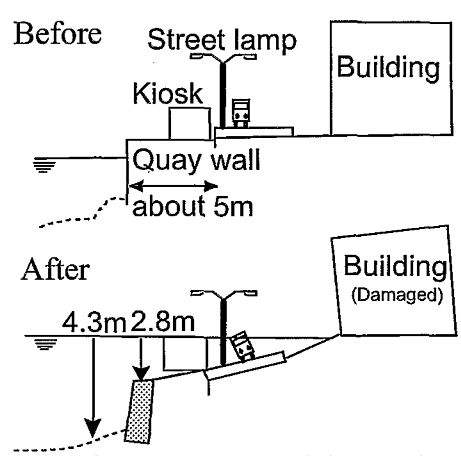

Fig. 8. Schematic Drawing of change of water depth

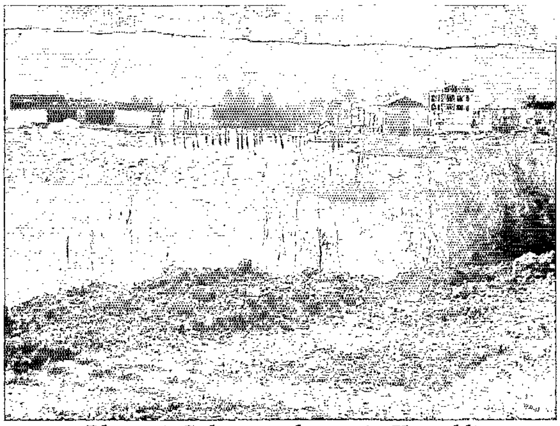

Photo 4. Submerged area in Kawakli

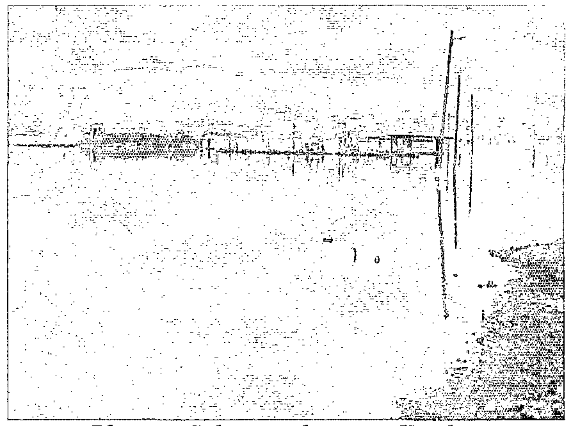

Photo 5. Submerged area in Yenikoy

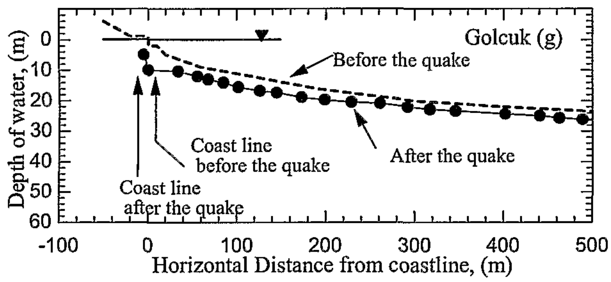

Fig. 9. Result of Measurement of water depth (Golcuk)

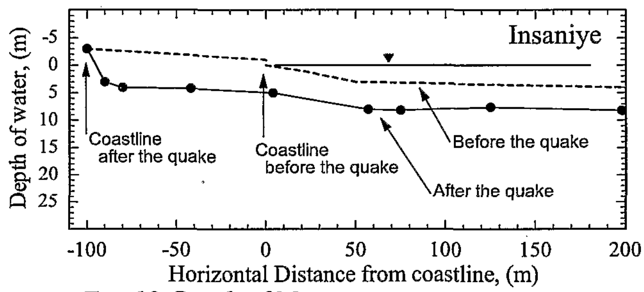

Fig. 10. Result of Measurement of water depth (Yenikoy)

There was a Ford Gölcük automotive factory south east of Kavakli district and the fault reached to at least this factory and submerged area was spread far east from here as shown in Photo 4. Several damages such as cut-off of the buried pipes under the road and heavy destruction of the mosque standing on the fault due to the ground deformation directory induced by the fault movement were found.

Measurement of water depth was carried out along the cross section toward offshore in this district. Although water depth becomes steep just in front of the shoreline, it may be seen to subside beneath except these as shown in Figure 9. Amount of the change of water depth was only 3m-4m. Shape of the seabed after the earthquake could not be seen like submarine slide, and inclination of seabed toward offshore keep tendency before the earthquake. The cause of which the coastland disappeared and the seabed settled down after the earthquake is different from the cause in another sites mentioned previously.

Furthermore, widespread land area was subsided and disappeared into the sea from the east of Gölcük City to Basiskele, head of the bay. The authors made a survey of the landform in order to define the scope of submerged land. Coastal landform was suddenly changed due to the earthquake. It could be seen that subsidence was occurred in many places on the border of main- and/or sub-fault appeared on the surface.

In Yenikoy, several colonies and grass farm at the back of colonies were sunk out of sight at the time of the earthquake, owing to the subsidence at the morass below 5m heights as shown in Photo 5. Occurrence of the landslide was not expected, because back yard of subsided area was relatively flat, and electric pole, fences and houses were subsided almost straight up to several meters. Parallel cracks toward the sea could also be observed. Water depth measurement was also carried out in Yenikoy. The result shows in Figure 10. The depth of the water after the earthquake is constant within 5m-8m in depth. Judgment from the shape of seabed, sliding does not seem to be the cause of the subsidence.

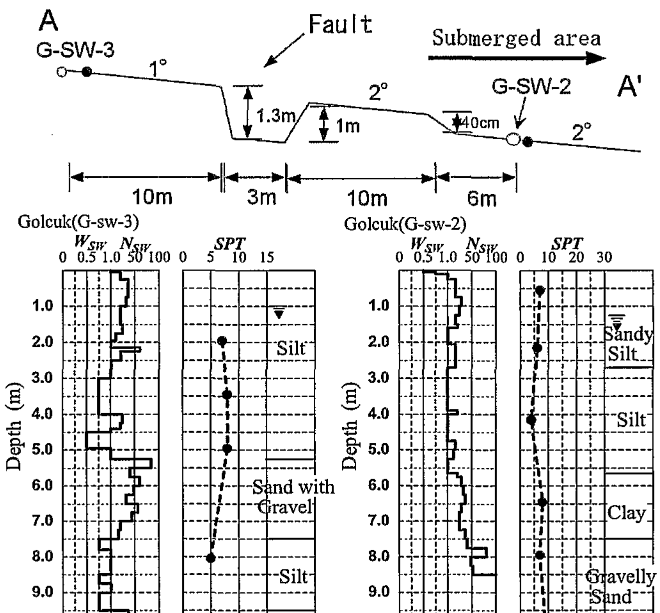

Fig.11. Result of in-situ tests and Soil Profile in Yenikoy

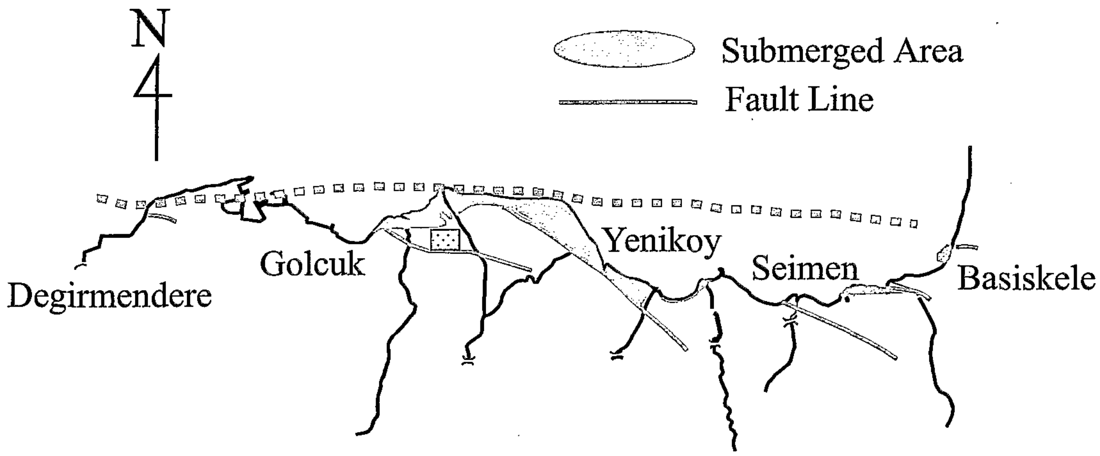

Fig.12. Location of submerged area of the south of Izmit Bay

Swedish cone penetration (Swedish Sounding) test and standard penetration test (SPT) were conducted for soil survey in order to clarify the cause of land loss along two sites stepped over the fault. The schematic drawings of the site and the sounding log from the tests are shown in Figure 11. Loose silt was deposited up to 10m in depth from the surface, and gravely sand was interstratified between silty layers. There is no significant difference soil profile between upper and lower sites. Therefore, the change of soil profile does not seem to cause to the subsidence, but fault movement caused to it directly. The existence of the soil layer indicates the possibility of the occurrence of soil liquefaction during the earthquake. It is however not sufficient to consider only volumetric change in sand layer due to soil liquefaction in order to explain the observed subsidence. Considering to the amount of subsidence from the water depth measurement, it seem to be that compressive volume change was taken place due to development of pore water pressure in silty layers during the earthquake. It is no doubt that the slip plane with soil liquefaction in interstratified sand layer, promoted the ground deformation.

The schematic drawing of the submerged area during Kocaeli Earthquake, which was inspected in this survey, is shown in Figure 12. It can be seen that large-scale submergence and subsidence were occurred in many places. From this figure, the terrain, which was surrounded between main- and sub-fault, was mainly subsided. Especially, submerged area concentrate to the coastland around river mouse and/or top of triangular of alluvial cone.

CONCLUSIVE REMARKS

As a result of careful observation of land movement and measurements of water depth near the shore, characteristic features of the ground hazards associated with fault rupture and landslide of seabed were disclosed. They are summarized as follows.

1. In the vicinity of the earthquake-generated fault line, the terrain tends to subside and move horizontally towards the area of low' relief if the land is inclined topographically.

2. If a fault line passes some distance off shore in parallel to the shore line, the ground perturbation at the fault line seems to induce submarine landslides which could propagate backwards to reach the shore and take away parches of land into the sea.

In view of the above observation, it will be necessary to perform more detailed field investigations to depths of 50 - 200m in the areas in the vicinity of the fault, and to delineate underground profiles of soil an rock deposits. This will be of help to clarify causes of the fault-induced ground damage.

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