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Poor Water Pressure Rises during Earthquakes

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Poor Water Pressure Rises during Earthquakes

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SYNOPSIS A set of piezometers were embedded in sand deposits on a reclaimed island in Tokyo Bay and a seismograph was placed on the ground surface nearby in order to monitor insitu pore water pressures simultaneously with the horizontal accelerations during earthquakes. During the September 25, 1980 earthquake, the instruments registered increases of pore water pressures corresponding to 19 % and 16 % of the effective confining pressure at depths of 6.0 m and 14.0 m, respectively. At the same time, a maximum horizontal acceleration of 95 gal was registered at the ground surface.

TEST PROGRAM AND RESULTS

As a test site for in-situ measurements of pore water pressures and accelerations during earthquakes, Owi Island No.1 located on the west side of Tokyo Bay, as shown in Fig.1, was selected. This island was reclaimed from 1961 to 1969 with soils dredged from the nearby seabed to open the navigation route. The depth of the seabed before filling was approximately 10 m. Soils with different grain size were transported in slurry through pipes and discharged in the area being filled.

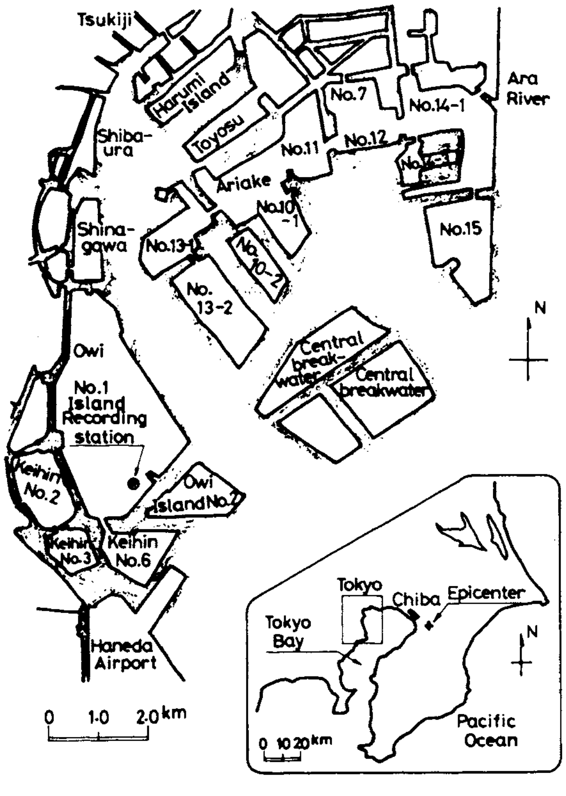

Fig.1 Location of the recording station

Two set of peizometers were embedded at two depths, 6 m and 14 m, in the ground, as shown in Fig.2. A two-component seismograph was installed on the ground surface to measure the horizontal acceleration. The positions of the installed seismograph and embedded piezometers are shown in Fig.2.

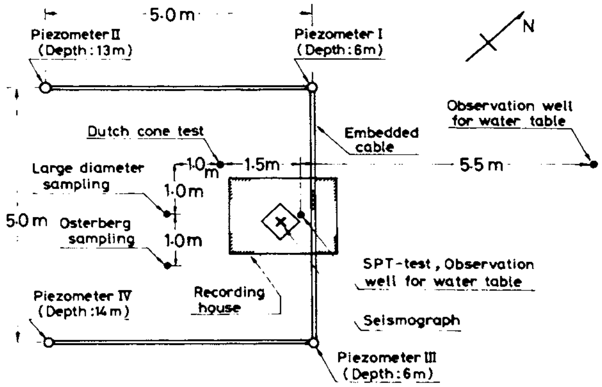

Fig.2 Layout of positions of instruments and in-situ sampling and sounding tests

The soil conditions at the test site were investigated by the standard penetration test, Dutch cone test and also by a series of laboratory tests on undisturbed soil specimens obtained by the large diameter sampler and Osterberg sampler. The positions in plane where the sounding and sampling were performed are shown in Fig.2. The soil profile at this site established as a result of the standard penetration test, is demonstrated in Fig.3. When the piezometers and the seismograph were installed at the test site in 1977, undisturbed soil samples were procured from the five depths shown in Fig.3. The locations of the samplings in plane view are indicated in Fig.2. Undisturbed samples were obtained by means of the large diameter sampler. Small specimens obtained from the large diameter samples were subjected to cyclic triaxial tests to determine the cyclic strength of the soil. An earthquake with a magnitude of 6.1 shook the are of Tokyo Bay at 2:54 a.m. on September 25, 1980. The earthquake, named Mid-Chiba earghquake, had a focal depth of about 20 km, and its epicenter was located about 15 km due south of the city of Chiba, as indicated on the map of Fig.1.

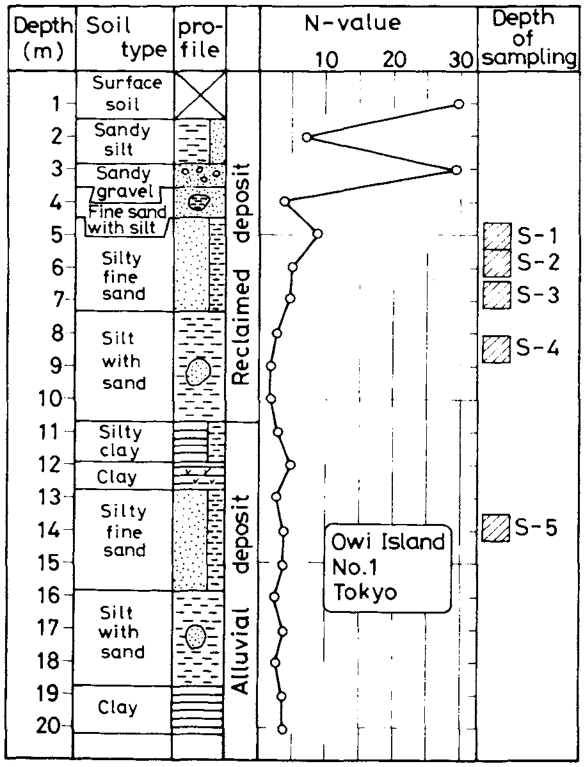

Fig.3 Soil profile at the test site

The intensity in the area surrounding the Tokyo Bay near the epicenter was V in terms of the Japanese Meteorological Agency scale. This area has been seismically quiet during the last 50 years. Therefore, this was the biggest earthquake that had ever shaken this area since 1929. The seismograph and piezometers installed on Owi Island No.1 was successfully triggered by this earthquake and recorded motions and pore water pressures. Recorded accelerations in two horizontal directions are shown in Fig.4(a) and 4(b) for a time duration of 40 seconds. Recorded time change of pore water pressures are also shown in Fig.4(c) and 4(d). It can be seen that the pore water pressures at the two depths of monitoring began to increase almost simultaneously with the occurrence of the peak accelerations. After the passage of the highest-intensity shaking, the pore water pressures began to decrease with a faster rate within 3 seconds immediately following the peak accelerations and with a much slower rate thereafter. It may be seen in the figure that the pore water pressure at the depth of 6.0 m dissipated by about 75 % within 20 seconds, whereas only one-half the pore water pressure in the deposit at depth 14.0 m dissipated within that time period. This difference in the rate of pore water pressure dissipation can be explained by the fact that the silty sand at the depth of 14.0 m was less permeable as it contained 27 % fines as compared to 12 % fines present in the sand deposit at the depth of 6.0 m. At 5:04 a.m. of the same day (September 25, 1980), a small aftershock shook the test area. The set of instruments was again triggered, but no pore water pressure increase was recorded as a result of this small earthquake. However, it is of interest to note that the initial positions of the two pore water pressure traces of this aftershock were completely back to the positions of the pore water pressure traces at the beginning of the main shock, as illustrated in Fig.4(c) and 4(d). Therefore, it can be concluded that during the two-hour period between the two earthquakes, the pore water pressures generated by the main shock had completely dissipated. For detailed studies, a trajectory in plane view of the two components of accelerations is depicted on the diagram in Fig.5 with the time inscribed as a parameter. Values of the pore water pressures as they varied with changes in acceleration are also indicated in Fig.5. It may be seen that the pore pressure at depth 6.0 m ceased to increase when the acceleration trajectory moved around clockwise about 180° to the point A in Fig.5, whereas the pore pressure at depth 14.0 m continued to increase until the trajectory come back round one cycle to the point B in Fig.5. Thus it may be mentioned that the increase in pore water pressure took place virtually in the course of one cycle excursion of the peak acceleration. Since the shear stress changes in the horizontal plane near the surface are considered proportional in magnitude to and in phase with the changes in the horizontal acceleration on the ground surface, the above observation suggests that the pore water pressure buildup during the earthquake was essentially caused by the one-cycle application of the shear stress involving the peak, and the shear stress after the peak had exerted no influence on the pore water pressure buildup.

REFERENCE

ISHIHARA, K. "In-situ Pore Water Pressures Measured during an Earthquake", Submitted to Soils and Foundations.

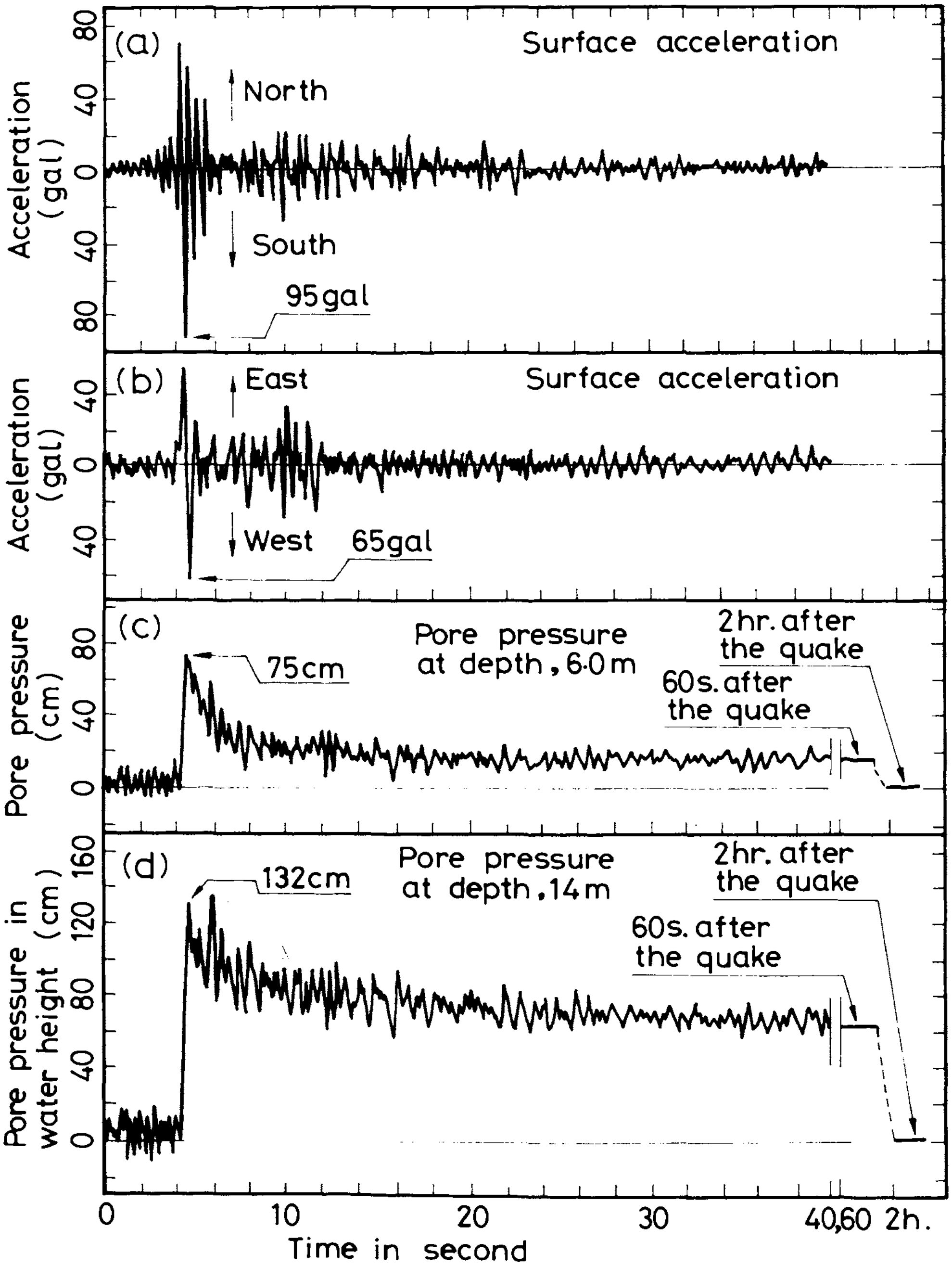

Fig.4 Surface accelerations and pore water pressures recorded during the Sept.25, 1980

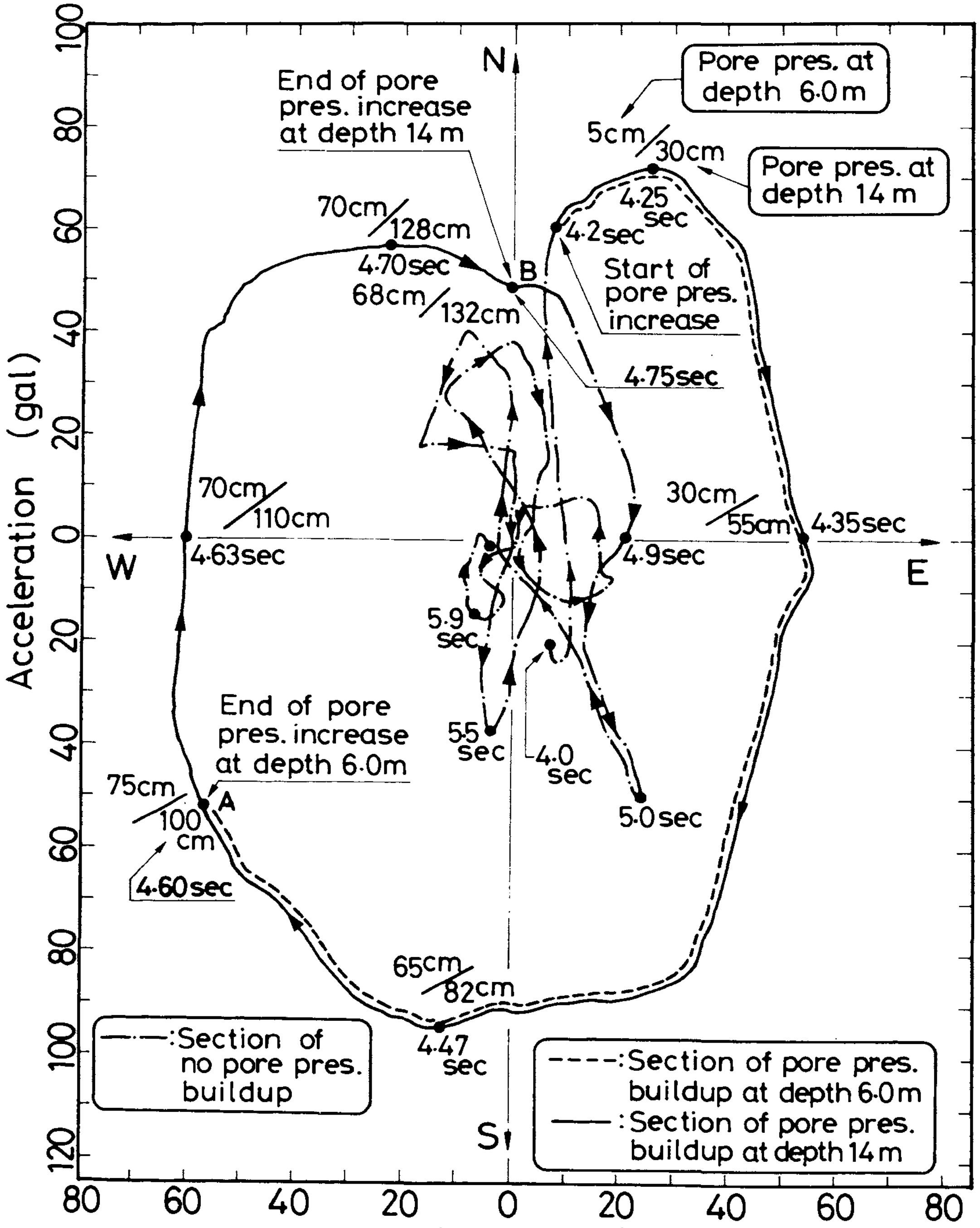

Fig.5 Trajectory of the recorded accelerations in plane view