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SSS37-06 Room:303 Time:May 21 10:15-10:30

Non-uniformity of Surface Layer Liquefaction Damage Caused by Layered System Organization and Dip of Deeper Layer

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During the Tohoku Region Pacific Coast Earthquake, extensive liquefaction damages were occurred in Urayasu and over a wide range of reclaimed coastal land. The characteristics of this liquefaction include the following. (1) It occurred approximately 450 km away from the epicenter, although K-net and other ground level observations recorded intensities of up to approximately 100-200 gal, but there was continuous relatively long-period ground motion. (2) Liquefaction occurred over a wide range of soils that also included intermediate soils with large fine fraction content. The latter is frequently ascribed to the long duration of the seismic motion. Previously, the authors focused on the stratum organization, with a thin layer of soft alluvial clay located directly under the alluvial sand on the inland side, where liquefaction damage was small, and this clay layer increasing in thickness as you approach to the coast, where liquefaction damage was severe. Based on the results of 1D elasto-plastic seismic response analysis, the authors indicated that in addition to the long duration of the seismic motion, the presence of a soft clay layer below the liquefied layer can amplify seismic waves over a range of longer periods, and the resulting large plastic strain may cause large damage even in clayey sand that normally resists liquefaction. Here, the authors newly focused on the dip of the boundary between the clay layer and the diluvial layer located below it and conducted 2D analysis. The analysis, performed using the ***GEOASIA*** soil-water coupled finite deformation analysis code incorporating an elasto-plastic constitutive model (SYS Cam-clay model) that contains sand, intermediate soil and clay within the same theoretical framework, showed that the presence of this inclined boundary produces non-uniform liquefaction even when liquefaction does not occur in 1D analysis.

Fig. 1 presents the analysis results from a 1D soil model showing layered system organization of soils in the analysis and the change of the excess pore water pressure ratio at the top part of the reclaimed layer with time using the same input seismic motion as Asaoka et al. (2011), except that the model uses a sequence of layers that more closely matches the actual conditions. As a result, the excess pore water pressure ratio of the reclamation layer was only approx. 0.8 at most, and liquefaction did not occur. Fig. 2 shows the results from 2D analysis. It shows the shear strain distribution 150 sec after the start of the earthquake and the change of the excess pore water pressure ratio of the reclamation layer at point A with time. The figure demonstrates that particularly large shear strain appeared near point A. The excess pore water pressure ratio exceeded 0.95, and liquefaction occurred. This was due to amplification of the input seismic waves by the alluvial clay layer and the boundary between the alluvial clay layer and diluvial layer being inclined. The calculations show generation of an SV component of seismic motion and also multidimensional propagation of seismic waves due to reflection by the inclined diluvial layer. It is also stated that large localized plastic shear deformation of the surface layer appeared at various other points in addition to point A (Fig.2).

This recent earthquake was characterized by spatial non-uniformity of liquefaction damage and the large variation therein. Although the heterogeneity of geomaterials is frequently pointed out as a possible cause, the results of this analysis showed that there was large variation in soil deformation caused by an inclined/heterogeneous layered system even with homogenous geomaterials. This is a matter that cannot be considered with 1D analysis and underscores the need for multidimensional analysis.

Asaoka, A. et al. (2011): The effect of stratum organization on the occurrence of liquefaction in silty sand, the Seismological Society of Japan 2011, fall meeting, p.56.

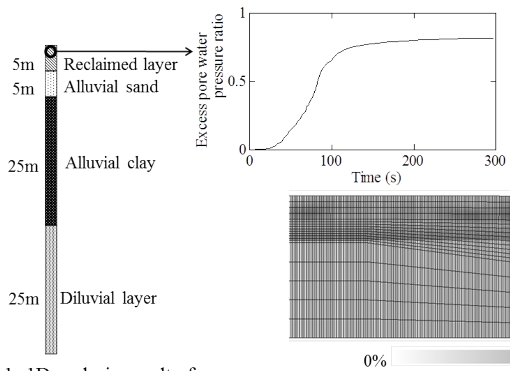

Fig.1: 1D analysis result of excess pore water pressure ratio at the center of the reclamation layer

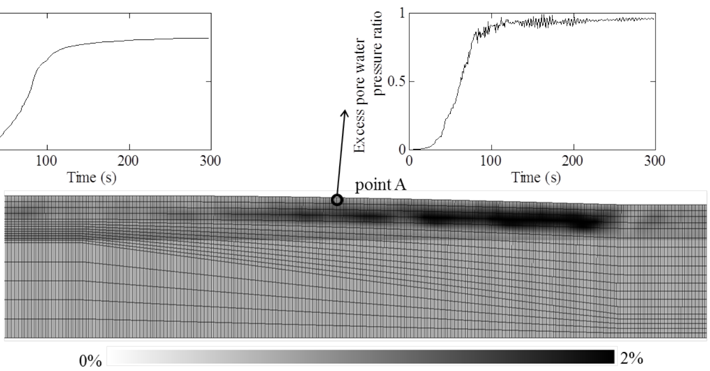

Fig.2: 2D analysis result of shear strain distribution at 150s after earthquake and excess pore water pressure ratio at the center of the reclamation layer at point A