Numerical realization of surface waves and assessing their influence on liquefaction using 2D effective stress analysis

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One of the important characteristic of surface waves is that distance attenuation is small compared with P-wave and S-wave. Therefore, it can propagate to hundreds of kilometers away from epicenter, and leads to a post-motion phenomenon of relatively large continued tremors even after the primary motion has ended. Moreover, complex interference between the surface waves and the body wave causes extensive and localized seismic damage. However, the influence of surface waves on liquefaction damage is not fully understood yet. This report tries to reproduce surface waves and assess its influence on liquefaction with the use of 2D elasto-plastic seismic response analysis considering the effect of irregularly shaped bedrock. The analysis code employed in this report was the soil-water coupled finite deformation analysis code GEOASIA[2)], which incorporates an elasto-plastic constitutive model[1)] that allows description of the behavior of soils ranging from sand through intermediate soils to clay under the same theoretical framework.
The ground model was prepared with its height 100m and width 30,000m. Bedrock was assumed to be inclined at extreme left side of the ground. Stratum organization was assumed to be Pleistocene layer in deep part, above which was a sensitive soft clayey layer, followed by a loose sandy layer with reference to Urayasu ground[3)]. The hydraulic boundary was set that the ground surface coincided with water level was set up as water pressure equal zero. The bottom face and the two lateral faces were assumed to be undrained boundaries. The seismic wave that was observed at a depth of about G.L. -36 m at Shinagawa observation point of the Tokyo Bureau of Port and Harbor (see Fig.1 (a)) was input as a 2E-wave in the horizontal direction only at the bottom face beneath the inclined bedrock area. In addition to establishing simple shear deformation boundaries at the two lateral ends of the boundaries, a viscous boundary equivalent to Vs=400 m/s was set up at the bottom face of both excitation and non-excitation area. Fig.1 (b) illustrates the velocity vector distribution 100 sec after the earthquake occurrence. Surface waves are generated at the base end section of the inclination which shows orbit in a counterclockwise direction with ongoing wave propagation to the right-hand side. Fig.1 (d) illustrates the acceleration responses at locations A, B and C. Location A sited left side of inclined bedrock shows smaller acceleration compared with location B and doesn’t generate vertical motion. On the other hand for location B, in addition to the generation of vertical motion, duration and maximum acceleration are enlarged for horizontal motion caused by the propagation of surface waves. Moreover, location C sited 20,000km away from excitation area still observed acceleration response, although the maximum amplitude is around 30gal. This seismic motion can be regarded as surface waves so that the similar acceleration response can be observed at location C’. Fourier amplitude of the surface waves is dominant at slightly long-period around 1.7 sec. Fig.1 (c) illustrates mean effective stress reduction ratio at each location. Although the reduction ratio at location A didn’t increase so much, location B gradually increases even after the primary motion and finally reaches to 95% which indicates liquefaction. Gradual increase was caused by the complex interference between the surface waves and the body wave. Moreover, location C is also gradually increased to the extent of 60% even the observed seismic motion is not so large. This result indicates that the location C has a risk of delayed-liquefaction damage with additional aftershock excitations.

1) Asaoka, A. et al. (2002): An elasto-plastic description…, S&F, 42(5), 47-57.

2) Noda, T. et al. (2008): Soil-water coupled …, S&F, 48(6), 771-790.
3) Nakai,K. et al. (2014): Liquefaction damage expansion…, JGUM, SSS23-19.

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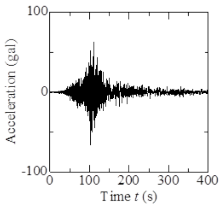
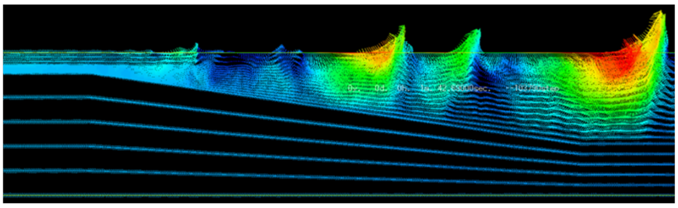
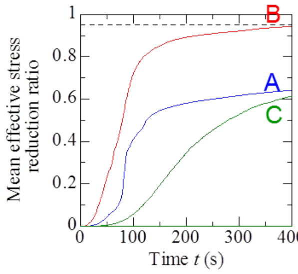


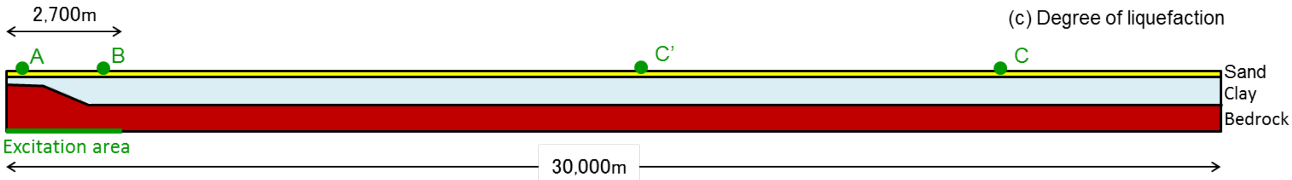
(a) Input seismic wave

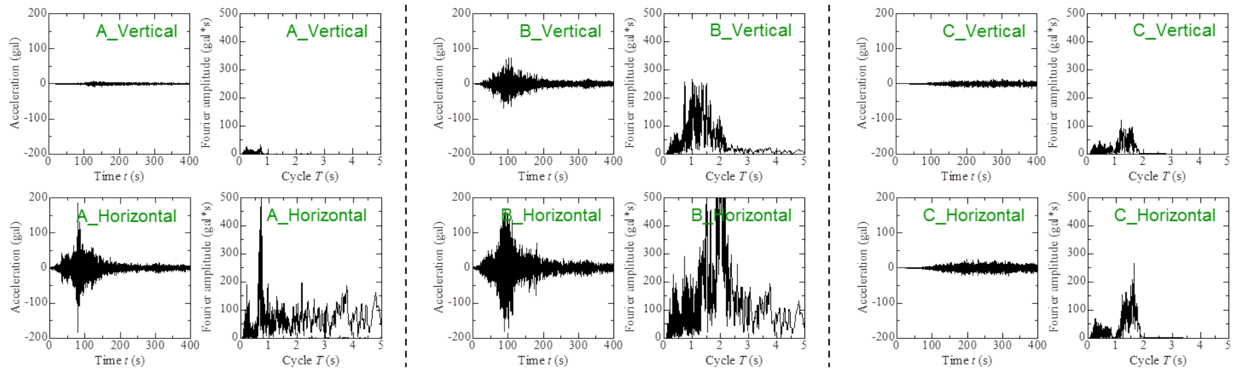


(b) Generation and propagation of surface waves from irregularly shaped bedrock (velocity vector)



(c) Degree of liquefaction





(d) Acceleration and Fourier amplitude at different subsurface place