I-B 433 A Discussion of Porous Soil-Structure Interaction in the Kobe Alluvial Fan

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Introduction

The devastating Great Hanshin Earthquake of 1995 which left more then 6,000 dead, also left many problems for civil engineering researchers. In Kobe city there are many elevated sections of expressways and railways damaged without any clear traces of settlement and lateral flow of soil. These elevated sections lie on a series of porous alluvial fans spreading out towards the Osaka bay. As a whole, soils of high ground water level surrounding the embedded foundations of those structures seems to have been noticeably stiff during the quake. Thus the porous soil-ground water-structure interaction should be appropriately taken into account.

About the Alluvial Plain in Kobe

Since the behavior of soil surrounding an embedded structure has a great effect on its dynamic response, it is important to know well the characteristics of the alluvial plain in Kobe. The Kobe alluvial plain is composed of a series of alluvial fans which were formed with the sediment brought by several old rivers. These rivers originate in the Rokko mountains where large amount of decomposed granite is easily eroded and carried down to these river mouths by flooding. As a consequence the main component of soil in the alluvial plain is sand and gravel. Fig.1 shows the soil profile of an alluvial fan in the vicinity of the Asiya river. Though there are some soft clayey deposits interspersed among the sand and gravel layers, the average value of the boring log is quite high.

Using the data recorded at the Kobe Marine Meteorological Observatory, Jan. 17, 1995, the response of this ground is calculated by inputting the acceleration time history, through a dashpot, to the stiffer diluvial soil layer (Fig.2). The dashpot represents the effect of energy dissipation by the waves going down into the infinite extent. Though the peak acceleration of 818cm/s^2 has been reached, the deformation of the alluvial layer is rather small. This is mainly due to the high stiffness of the alluvial layer.

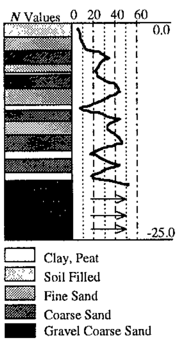

Fig.1 *Soil Profile*

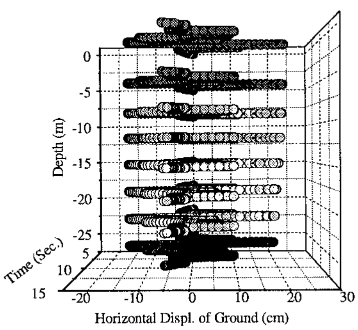

Fig.2 *The Response of the Alluvial Fan*

In order to find a clue to the actual deformation of the ground, the mention of the damage to manholes in this vicinity has been looked up in the materials provided by Kobe city. A typical manhole shaft is an upright pile of concrete rings (90cm in diameter and 60cm in height). Since these rings are pasted to each other with mortar, the lateral ground motion easily leaves its traces on their joints. Fig.3 shows the spatial distribution of damaged manhole joints. Dislocated rings are mostly found 1 to 2 m below the ground surface, and the maximum dislocation of 20cm has been reached among them. No mention of the dislocations smaller than 5cm has been made in these materials, and needless to say, the data do not provide us with any information of ground motion below the embedment depths (-7.3m) of manholes. It is, however , convinced that the surface soil has not left any residual deformation beyond this extent.

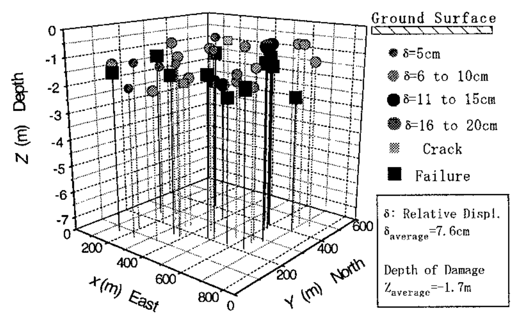

Fig.3 *Damage Statistics of the Manholes Embedded in the Alluvial Fan*

Evaluation of Porous Soil-Structure Interaction

Saturated porous soil is a material composed of solid and fluid phases, which manifests obvious deforming and diffusing characteristics under dynamic loading. For analysis of the response of porous soil-

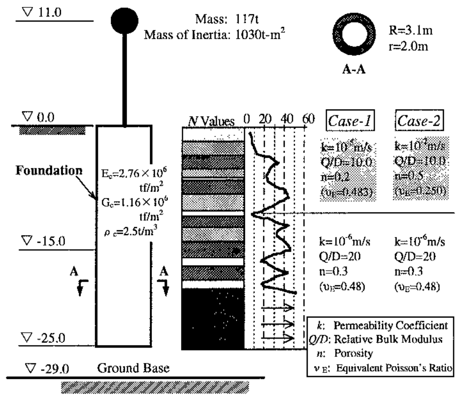

Fig.4 *The Sketch of the foundation With the Soil Profile*

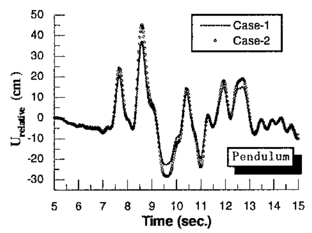

Fig.5 *Time History of the Relative Displ.*

structure systems, the porous soil surrounding the foundation is cut into uncoupled slices with semi-infinite extent. Grasping the typical patterns of wave radiation through the sliced elements, the impedance functions for various vibration modes of the embedded disk are approximated by the syntheses of springs and dashpots. The constants of these springs and dashpots are frequency-independent, and are the functions of the equivalent Poisson's ratio. Since the values of the equivalent Poisson's ratio are dependent on the properties of porous soil (*k, Q/D, n*) (Fig.4), the present models are capable of analyzing the time-domain response of porous soil-structure systems[1].

In order to discuss the effect of pore pressure generation on the response of a structure, an embedded foundation as shown in Fig.4 is taken as an example. The foundation, with an inverted pendulum on its top, is assumed to be of Timoshenko-beam-type. Two extreme cases of saturated soil profiles are given as illustrations within the possible extents of parameters for the soils shown in Fig.4. Case 1 premises the presence of an upper soil layer with comparatively impermeable property, whereas a permeable upper soil layer in case 2

By inputting the ground-displacement time histories shown in Fig.2, the response of the structure is calculated. Fig.5 shows the time history of the relative displacement of the pendulum mass to that of the base layer beneath the embedment depth (-25m). It is clear from the figure that about 30% reduction of the peak values of displacement in case 1 is due to the decrease of the permeability of the surface soil layer. This result offers an important revelation that the equivalent Poisson's ratio for a completely saturated soil is possibly much smaller than the one from the PS logging. It is not seldom that the PS logging provides the measured longitudinal wave velocity of about 1500m/s, which is equal to the velocity of the sound through water, thus yielding the Poisson's ratio of about 0.5. Hence, for a water-saturated loose sandy soil deposit with comparatively high permeability, the value of the Poisson's ratio used in calculation should be reduced following the change of the coefficient of permeability.

Conclusion

The conclusions of this study are summarized as follows:

(1) The investigation of the actual damage to manholes in the vicinity of the Ashiya river mouth provided the information of the lateral residual displacements of soil. These values are expected to be used for checking the results of nolinear response analyses of the ground.

(2) The present porous soil model is a synthesis of springs and dashpots, and thus is capable of analyzing the time-domain response of a porous soil-structure system. In the present model, the effect of pore pressure can be incorporated by introducing the equivalent Poisson's ratio as the functions of the coefficient of permeability, degree of saturation and porosity of soil.

(3) The equivalent Poisson's ratio for a completely saturated soil can be much smaller than the one obtained from the PS logging. Therefore the Poisson's ratio used in calculation should be determined, being given the permeability coefficient of soil as well.

Acknowledgment

The authors acknowledge gratefully the support from the Bureau of Sewage, Kobe city.

Reference

[1] Xiu LUO, Kazuo KONAGAI, Assadolla NOORZAD, Toyoaki Nogami: Simplified Time-Domain Expressions for Porous Soil-Structure Interaction, Proceedings of the 11th Word Conference on Earthquake Engineering (be accepted for publication)