III－119 SIMULATION MODEL FOR WAVE-INDUCED LIQUEFACTION ON SEDIMENTARY SEABED

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1 Introduction

Many theoretical and experimental studies on wave-induced liquefaction have been carried out in the past few decades[1]. It is now well-known that this phenomenon may have caused the settlement and/or failures of some offshore structures and breakwaters.

A new approach is now proposed for simulating the consolidation and unsaturated seepage processes, based on a simplified relationship between soil particles and their voids[2),3),4)]. This approach is applicable to the wave-induced liquefaction process, which is an unsteady flow caused by excess pore water pressure through the voids. Only the concept and simulation procedure are described in this paper.

2 Mechanism of liquefaction and its simulation

Figure 1 shows the concept for wave-induced liquefaction and densification proposed by Zen and Yamazaki[1]. The fluctuation in pressure is observed at the surface of the seabed where wave frequency is relatively low and permeability coefficient is high. With the water level above the SWL(still water level), positive excess pressure in pore water is generated near the seabed and the pore water falls due to a positive hydraulic gradient into the sand layers. This process will densify the soil mass. On the other hand, when the water level falls below the SWL negative pore water pressure is generated with the pore water rising. This action is equivalent to quick sand effect, hence causing liquefaction.

It is proposed that the seabed can be divided into n layers, as shown in Fig.2(a), while the relationship between any three consecutive layers is given in Fig.2(b). In the case that the hydraulic gradient is not zero, the pore water flowing through these thin layers is assumed to follow Darcy's law, which can be expressed as

$$\triangle V_{m,f}=S\cdot k_m\cdot i_m\cdot\triangle t \qquad (1)$$

where $\triangle V_{m,f}$= volumetric change of pore water in the m-th layer during time-step $\triangle t$,
S= cross-sectional area of the soil column in Fig.2,
k_m= permeability coefficient of the m-th layer,
i_m= Hydraulic gradient across the m-th layer,
$\triangle t$= time increment.

Consequently, the volumetric change of the pore water in the m-th layer during $\triangle t$ is given by

$$(\triangle V_m)_j=(V_m)_j-(V_m)_{j-1}=(\triangle V_{m-1,f})_j-(\triangle V_{m,f})_j \qquad (2)$$

where $(\triangle V_m)_j$= volumetric change of pore water in the m-th layer during $\triangle t$,
$(V_m)_j$= volume of pore water in the m-th layer at time-step j,
$(\triangle V_{m,f})_j$= volume of pore water flowing from the m-th to the (m+1)-th layer during $\triangle t$.

Combining Eqs.(1) and (2) results in the change of pore water pressure as

$$(\triangle p_w)_j=(\triangle V_m)_j/\{(\frac{e}{1+e})\cdot S\}\cdot\gamma_w \qquad (3)$$

where $(\triangle p_w)_j$= change of pore water pressure during $\triangle t$,

e= void ratio,

γ_w= unit weight of pore water.

The distribution of pore water pressure in the soil column can be obtained from Eq.(3) for each time-step j. Liquefaction occurs in the sedimentary layers where the excess pore water pressure is larger than the effective vertical stress, hence, causing deformation to the soil column, which can be estimated quantitativelly as in the consolidation process[4].

The simulation procedure, as outlined in Fig.3, can be used to calculate the wave-induced liquefaction on a sedimentary seabed.

3 CONCLUSIONS

In this paper a basic concept and procedure are proposed for the simulation of liquefaction due to wave action. The proposed model can be extended to analyse the settlement of seabed and/or the sand drift upon considering the variation of effective stress at the particle scale, which is less difficult than the usual methods based on continuum mechanism. The validity of this approach can be established upon comparing the results of simulation with the laboratory and/or field measurement to be made in the future.

REFERENCES

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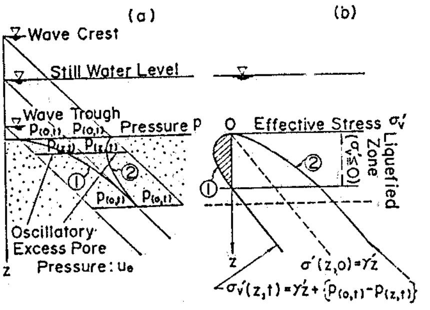

Fig.1 Concept of liquefaction[1]

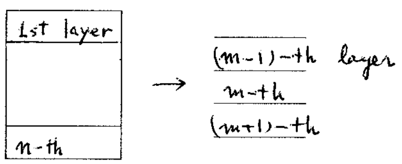

Fig.2 Soil column showing division of layers

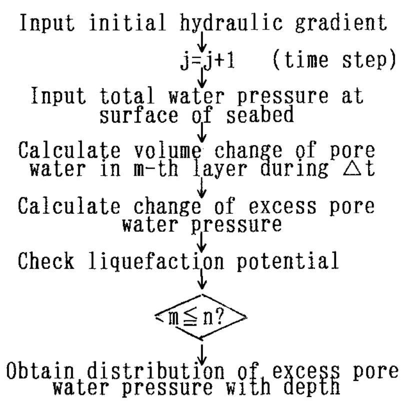

Fig.3 Simulation procedure