Study of Lateral Flow due to Different Duration of Liquefaction

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1. - Introduction

Liquefaction of saturated sand layers during earthquake disasters has often been a destructive factor to civil engineering, structures and people. Sudden severe settlement, tilting, floating, slope failure, sand fountains or the combination of these kinds have occurred during earthquakes. The phenomenon of liquefaction and the lateral flow of the ground were some of the reasons for such damages. Now, in real sites, there are silt or clay layers within the saturated sand and these layers may have weak parts caused by the non-uniformity of the membrane. The purpose of this study is focused on the behavior of a sandy ground, which includes a thin impermeable layer within, tested by two sets of vibration and provoking liquefaction, lateral flow and re-liquefaction.

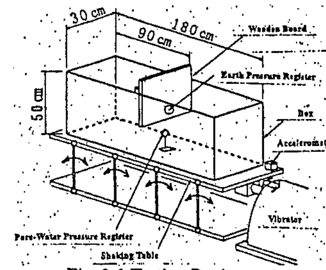

Fig. 2-1 Testing Device

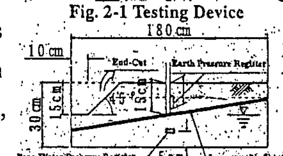

Fig. 2-2 Model and End-Cut

2. - Experimental Technique

Device and Materials

The testing device, as shown in fig.2-1, consists on an acrylic rectangular box. At the center of the box, there was set a pore-water pressure register, 25cm deep from the surface of the ground. Similarly, a lateral earth pressure register was fixed on a wooden board at a profundity of 13cm, just above the impermeable sheet, facing the longitudinal direction of the model. The sand is from the Agano River, with maximum particle size of 2mm. It was used a vinyl sheet as the impermeable layer.

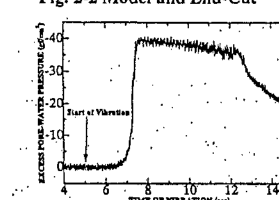

Fig 3-1 Pore-Water Pressure (a)

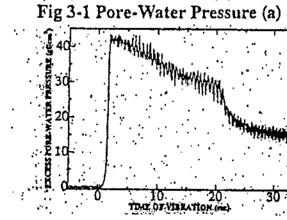

Fig. 3-2 Pore-Water Pressure (b)

Experimental Method

(1) Filling of the box: the filling of sand was proceeded by the method of submersed precipitation. First the lower layer, then the impermeable sheet and finally the upper layer. The water level was lowered to 15cm from the bottom of the box and rested for 24h. **(2)** End-cut: There was made a cut to the upper sand layer at one end of the longitudinal direction of the box (fig.2-2). **(3)** Induced Excitement: acceleration of 300gal, frequency of 6Hz.

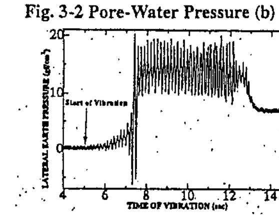

Fig. 3-3 Lateral Earth Pressure (a)

Types of Tests

(1) Properties of the sand: There was a variation on the sand used as upper layer. One set of tests consists of an upper wet sand layer, which will be called **(a),** of 15cm and the other of a dry sand layer **(b)** of 10cm. **(2)** Time of first vibration: The first vibration was a variation. One of 8sec and the other of 2sec. **(3)** Second vibration: In every test, there was induced a second vibration of 20sec to the ground.

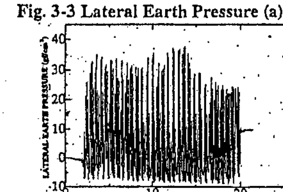

Fig. 3-4 Lateral Earth Pressure (b)

[Keywords] Liquefaction Re-Liquefaction Lateral Flow Vibration Time Lateral Earth Pressure

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3. – Results of the Experiment

Mechanism of lateral flow varying the physical conditions of the upper layer (first vibration)

The characteristics of the ground along the first vibration can be separated in 4 phases. **1st** No liquefaction in both conditions **(a) (b)**. **2nd** Excess pore-water pressure rises to 39gf/cm^2 for **(a)** (fig.3-1) and to 42gf/cm^2 for **(b)** (fig.3-2), reaching the static condition of the effective stress. The lower layer suffers liquefaction and this is proved as follows:

for **(a)**: $\Delta u=\sigma_0'=\gamma_t\times(h-h_{sat})+(\gamma_{sat}-\gamma_w)\times h_{sat}=$ 38.9gf/cm^2;

for **(b)**: $\Delta u=\sigma_0'=\gamma_d\times(h-h_t)+\gamma_t\times(h_t-h_{sat})+(\gamma_{sat}-\gamma_w)\times h_{sat}=42.2$gf/cm^2.

Δu: excess pore-water pressure (gf/cm^2)

γ_d, γ_t, γ_{sat}, γ_w: unit weight of dry sand, wet, saturated sand and water

h, h_t, h_{sat}: distance from pore-water register to the surface, boundary plane of wet layer and water level (cm)

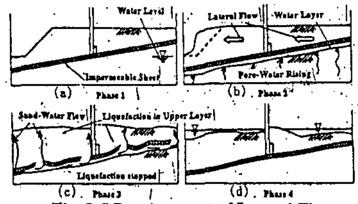

Fig. 3-5 Development of Lateral Flow

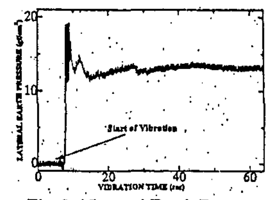

Fig. 3-6 Lateral Earth Pressure

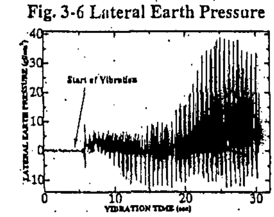

Fig. 3-7 Reliquefaction

In this moment, a thin water layer is situated just below the impermeable sheet (fig.3-5) and the upper layer starts its lateral displacement as a solid mass, rising the lateral earth pressure. **3rd** The sand water flow is produced through the edges of the vinyl sheet. For **(a)**, this sand-water flow saturates the upper layer and liquefaction is produced, changing its condition of solid to a liquid-like material. It continues its lateral flow and the maximum lateral earth pressure is reached slowly (fig.3-3). For **(b)**, the upper layer does not change its solid condition and continues its lateral displacement producing the maximum lateral earth pressure (fig.3-4). **4th** The vibration is stopped.

Mechanism of lateral flow after first vibration stops

The fig.3-6 shows the values of lateral earth pressure of a test with vibration time of 2sec. The value rises suddenly to 15gf/cm^2 and decreases after the vibration is stopped. But even after, there still is a variation of this value during approximately 40sec due to lateral displacement of the upper layer.

Mechanism of soil re-liquefaction

The mechanism of the soil reliquefaction can be divided in 4 phases along time. **1st** The second vibration starts and the pore-water pressure suddenly reaches its maximum value around 20 gf/cm^2, generating a shearing stress cut off along the water layer located just blow the vinyl sheet, producing lateral displacement of the upper layer as a solid mass. The lateral earth pressure rises suddenly (fig.3-7). **2nd** Liquefaction is produced at the upper layer and its solid-like condition changes gradually to a liquid-like. The lateral earth pressure remains constant due to the re-arrangement of the sand particles. **3rd** The lateral earth pressure reaches its maximum value around 14gf/cm^2 due to the lateral flow of the upper layer. **4th** After vibration, reliquefaction stops as well as the lateral displacement of the upper payer.

3. – Conclusions

① The condition of solid-like and liquid-like material of the upper layer is reflected on the speed of reaching the maximum lateral earth pressure, so to say the lateral displacement of the ground.

② The water layer located just below the impermeable sheet produces the continuance of the phenomenon of lateral displacement even after the vibration is stopped.

③ Soil re-liquefaction occurs when the first liquefaction is not completely accomplished.

[References]

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