SLIDING SURFACE WITHIN THE INFINITE SLOPE SUBJECTED TO THE EARTHQUAKE SHAKING

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INTRODUCTION

A new approach of evaluating the infinite slope motion during an earthquake was applied to the Tottori Western Earthquake records (See reference). The theoretical approach was calibrated against field observations. The width of cracks and the calculated displacement of soil layers were almost the same. According to field observations the sliding of the soil layer occurred along the bedrock and the calculation was made with this assumption. The present work aims to prove experimentally that for the soil layer of natural slope sliding occurs along the bedrock.

THEORETICAL APPROACH

According to the conventional method for evaluating the effect of an earthquake load on the stability of slopes, the inertia force is treated as equivalent concentrated force acting at the center of gravity of the potential sliding mass.

The present inquiry into the dynamic response of the soil layer is based on the perfectly plastic, Coulomb-type model, assuming the soil layer to be homogeneous without performing any liquefaction. The motion of the soil layer of infinite slope is assumed to be similar to rigid block model susceptible to move relatively along a sliding surface. Once the relative motion starts, the sliding surface remains the same and no hardening occurs along the sliding surface.

It is postulated that the block model representing the infinite slope in Fig.1 is stable under its own weight, but it is subjected to shaking. The acceleration at which the slope becomes unstable is defined as critical, and the following analysis indicates how this critical acceleration could be defined.

From Fig.1, the following fundamental equilibrium equations could be written

$$N = \rho h\left[\left(\alpha_v^{'} + g\right)\cos\beta - \alpha_h^{'}\sin\beta\right] \quad (1)$$

$$T = \rho h\left[\left(\alpha_v^{'} + g\right)\sin\beta - \alpha_h^{'}\sin\beta\right] \quad (2)$$

$$S = N\tan\phi + c/\cos\beta \quad (3)$$

Where ρh is the mass of the block of unit width, $\alpha_v^{'}$ and $\alpha_h^{'}$ are the vertical and horizontal components of the block acceleration, β is the slope inclination angle, ϕ and c are the angle of shear resistance and the cohesion within the sliding interface.

Evidently, when the transmitted acceleration reaches a yielding value the block model would start to move relatively along a defined surface of weakness. This might occur when the tangential forces reach the shear resistance along the sliding surface ($T=S$). Then the following equation could be written

$$\alpha_h = (\alpha_v + g)\tan(\phi - \beta) + \frac{c\tan(\phi - \beta)}{\rho h\cos^2\beta(\tan\phi - \tan\beta)} \quad (4)$$

It is evident from this equation that for soil layer made of cohesive material the critical acceleration is a function of the thickness h of the soil layer. The theoretical graph in Fig.2 presents the variation of the critical acceleration α_{cr} (when α_v=0 and β=0) as a function of the thickness of the soil layer. We could then suppose that within the homogeneous soil layer, the slippage would occur along the deepest surface on the harder formation.

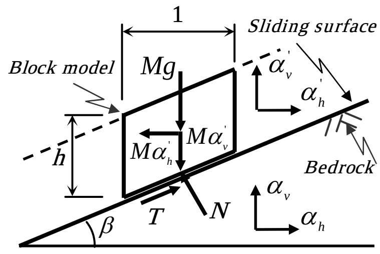

Fig.1 Infinite slope model

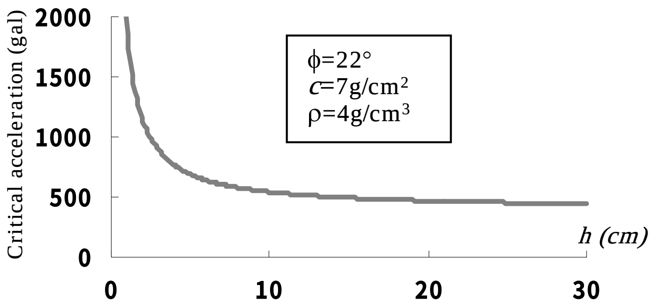

Fig.2 Relation between the thickness of soil layer and the critical acceleration

LABORATORY TESTS

1- Description of the experimental setup

The experimental model was based on the representation of the horizontal soil layer by two plates (upper and lower) susceptible to move relatively to each other and to the base plate (presenting the bedrock) tied to the shaking table. The upper and lower plates had an area of 20×30 cm^2 with overburden weights of 6.5 kgf under each plate (Fig.3).

The sliding was allowed to occur along two sliding surfaces. In both sides of every sliding surface triangular baguettes were tied to the plates and a sandy soil was inserted in between. Such design ensured the sliding occurred between the sand grains.

2- Sand type and specimen preparation

Toyoura sand having D_{60}=0.1 was used as a soil band representing the shearing surfaces. The strength parameters of this sand were defined using the shear test apparatus. In dry state, this sand was considered cohesionless and had an angle of internal friction of about 33°. When this sandy soil contained 10% of water (by weight) the cohesion was 0.51 kPa/cm² and the angle of internal friction was 32°.

3- Test procedure

The experimental tests provided dynamic responses of the plates using the shaking table facilities (with β=0). The motion of the shaking table was only unidirectional and quasi-sinusoidal.

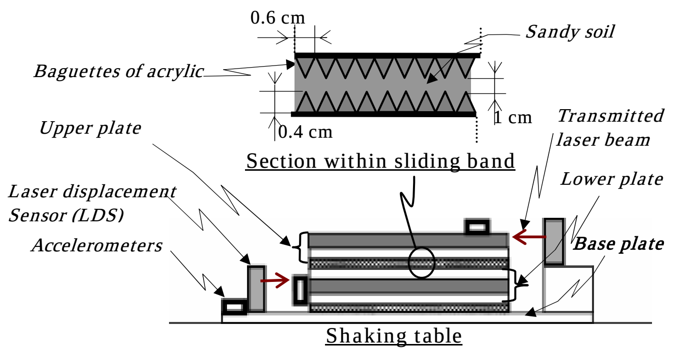

Fig. 3 Experimental setup on the shaking table

The acceleration was measured using three accelerometers fixed to the base plate, the lower plate and the upper plate. Noises associated with the acceleration records were eliminated using 60Hz low pass filter. Two laser displacement sensors were tied to the base plate to measure the displacement of the upper and lower plates relatively to the base plate. The motion displacement was calculated by double integration of the acceleration using raw acceleration records of the upper and lower plates.

EXPERIMENTAL RESULTS AND DISCUSSION

When the sliding surfaces were filled with the unsaturated sand soil (w=10%), the response of the plates to 6.5 Hz input frequency (α_{max}=846gal) is represented in Fig. 4(a). The measured and calculated displacement is represented in Fig. 4(b). Because of the noises and the double integration, the calculated displacement δ_{cal} was different than the measured displacement δ_{mes}. From the results shown in Fig.3, we could conclude that the upper and lower plates held the same motion. This means that there is no relative motion between the upper and lower plates and the sliding occurs only along the lower

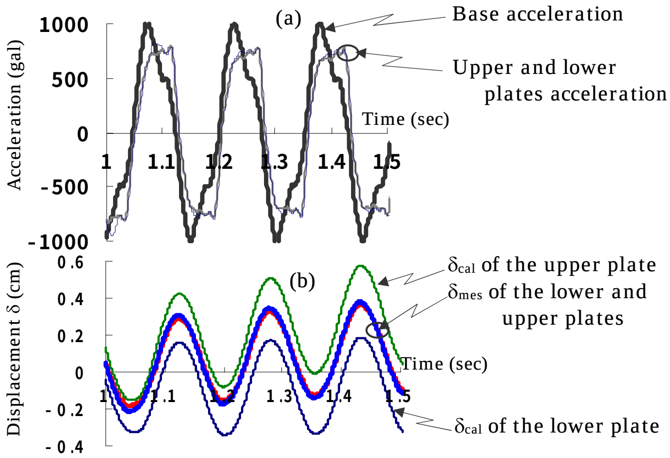

Fig.4 (a) and (b) Experimental results corresponding to cohesive sandy soil

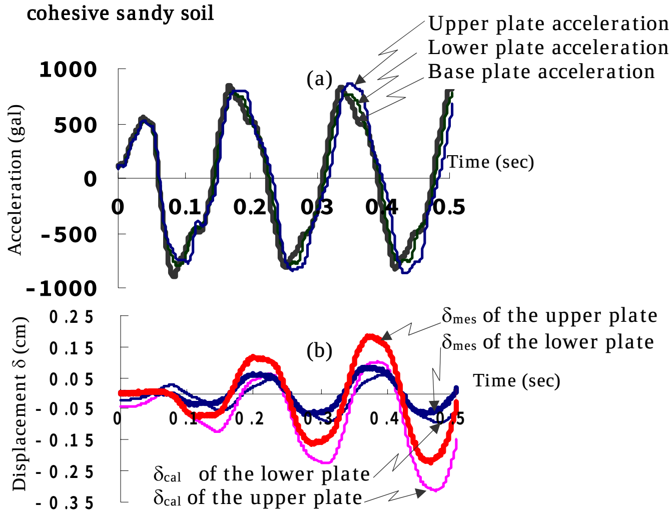

Fig.5 a) and (b) Experimental results corresponding to cohesionless sandy soil

sliding surface.

Fig. 5(a) shows the acceleration records of the plates when the sliding bands were filled with dry sand. The input frequency was 6 Hz and α_{max}=721gal .The accelerations show that the upper and lower plates held different motions. The calculated and measured displacement presented in Fig. 5(b), show clearly that the sliding occurred along both the upper and lower sliding surfaces.

CONCLUSION

We could confirm experimentally that for the infinite slope whose soil layer is made of homogeneous and cohesive material the sliding would occur along the bedrock. For cohesionless material, the sliding will occur with the same probability along any surface parallel to the bedrock. Therefore, for natural slopes, cohesion due to the capillary forces and the existence of roots acts within the soil layer. Hence, it would be more probable that the sliding occurs along the deepest surface.

REFERENCE

榎明決、平成 12 年度科学研究費補助金（特別研究促進費）研究成果報告書、　pp.　155-164、2001.