Observation of Deformation for Soil Foundation Using Photogrammetry

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1 Introduction

Generally, it is not so easy to measure the overall model deformation for soil foundation in bearing capacity test due to the model is usually bounded by container. Digital photogrammetry has provided a powerful solution for the deformation observation. Most of researchers tend to embed the targets into the soil or print grids on the surface of model as measured points. But they are not so effective for measuring the overall deformation due to the limited point's number and the influence of embedded targets is more or less unavoidable for the soil behavior. In this paper, a newly-developed photogrammetry and image analysis method [1], without resource to any targets, is used to study the deformation for soil foundation and the results have been obtained successfully.

2 Materials and methods

(1) Materials

The sand foundation model was made of Toyoumura sand, which average water content is less than 0.1%, specific density is 1.61gf/cm^3, and average relative density is about 87%. The size of soil model is 400 × 300 × 200 mm, and the model was prepared by pullviation method in the air from the height of 1m.

(2) Apparatus and photogrammetry

The test was operated on newly-constructed centrifuge system in Tokushima University. The effective radius, maximum acceleration and capacity are 1.55m, 200g and 40tg respectively. The experiment setup is shown in Fig.1. The footing was made of aluminum block with a width (B) of 30mm. Four control standard points for image calibration or coordinate transformation during image analysis were pasted on the transparent glass plate. A digital camera with resolution of 5.24 million pixels was installed in the front of observed surface of soil model, and pictures were taken at every footing displacement (S) of 0.5mm. Right image in Fig.1 is a picture of soil model taken when S=4mm with scale of 0.17mm/pixel.

(3) Deformation analysis method

A powerful technique based on image correlation matching method has been developed successfully for measuring the deformation of physical soil model. More detailed information about this method is available in the reference [1]. Using this technique, the maximum standard deviation by validation test within the range of 10mm translation can be up to 0.19 pixels.

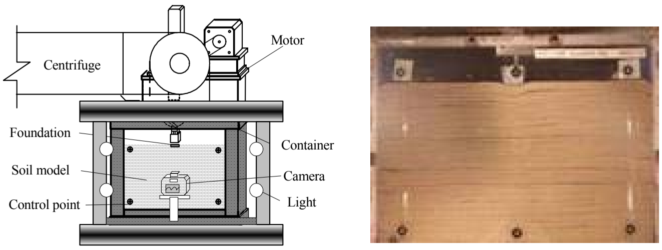

Fig.1 Test apparatus and an analyzed test photo

3 Test results

(1) Relation between load and displacement

The relation between normalized load pressure and relative footing displacement is shown in Fig.2. One of noticeable characters is that the load pressure increase gradually before peak value and decrease like staircase in the post-peak, on the other words, the deformation in centrifuge test is characteristic of remarkable progressive failure.

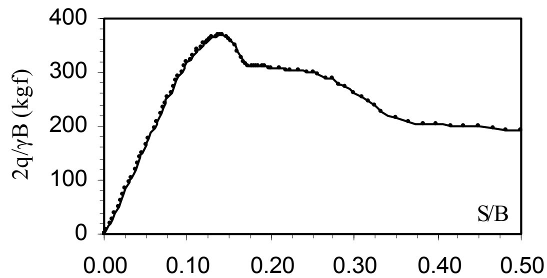

Fig.2 Curve of normalized pressure against relative disp.

(2) Displacements distribution

The displacement vectors of model is shown in Fig.3 at peak value point (S=4.2mm). The ability of digital photogrammetry may be seen intuitively from this result.

Key words: Image analysis, displacement measurement, bearing capacity, centrifuge test
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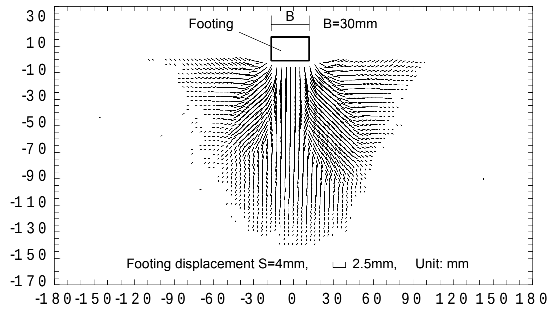
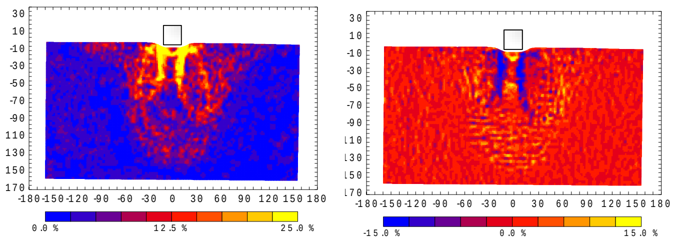


Fig.3 Displacement vectors on sand model

(3) Strains distribution

Distributions of maximum shear strain (Fig.4-a) and volumetric strain (Fig.4-b) of soil model at peak are shown in Fig.4. The punching shear band is clearly captured by the photogrammetry method. The soil dialtancy behavior of expansion in shear band and compression out of shear band is also observed (Fig.4-b). In fact, the shear band occurred before the peak point and then developed gradually until S=10mm, when the full slip surface was formed completely.



(a) Maximum shear strain (b) Volumetric strain

Fig.4 Fields of maximum shear strain and volumetric strain

(4) Slip surface

Figure 5 is a sketch of slip surface (including punching shear zone and radial shear zones) and deformation outline from image analysis results. From this figure, it can be said that the shape of deformation area is something like an inverted cap. The depth and width of deformation area are about 5 and 11 times of footing width. The angle α between slip and model upper surface is about 27º.

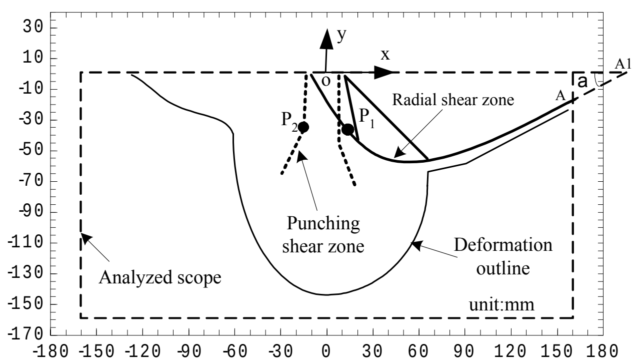


Fig.5 Deformation area and slip surface in sand model

(5) Quantitative analysis for progressive failure

The progressive failure can be seen from the quantitative analysis. Figure 6 and figure 7 represent the curves of footing displacements against the maximum shear strains and volumetric strains. The two points' coordinates are P_1 (11,-32) and P_2 (-16,-32) respectively on the soil model with the origin of the center of footing bottom (Fig.5). The magnitudes of shear strain and volumetric strain for P_1 in radial shear zone are 16% and 10.3% at peak while for P_2 in punching shear zone are 25.5% and 18.6%, respectively. So before the peak, the deformation is relatively concentrate in the potential punching zone, and in post peak, the shear strains increase remarkable for the radial shear zone while remain almost constant for the punching shear zone. In addition, the negative value of volume strain also shows the expansion in shear failure area or shear band.

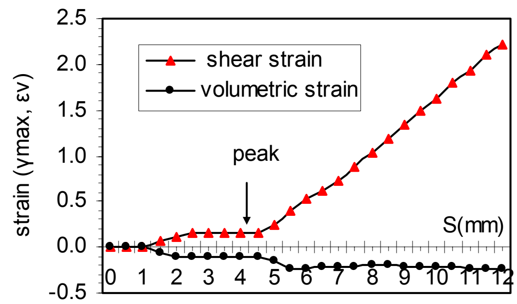


Fig.6 Curve of strain against footing displacements for P_1

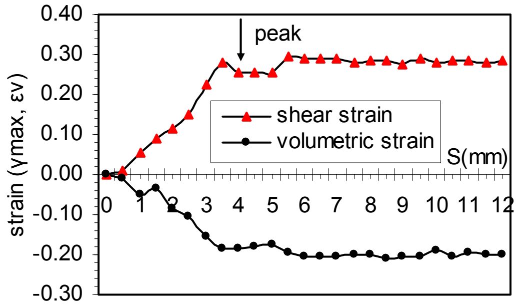


Fig.7 Curve of strain against footing displacements for P_2

4 Conclusions

The follow conclusions can be drawn from this study: (1) Digital photogrametry is a powerful tool for the observation of deformation of soil model. The progressive failure, slip surface and deformation outline in soil foundation test are obtained successfully using this technique. (2) Digital photogrametry also gives us a practical and simple solution for quantitative analysis of the local deformation of soil model. (3) It is worth to improve the accuracy of the deformation measurement technique based on image analysis further in the later.

Reference

1. Katsutoshi UENO, LI Yuanhai, Sreng Sokkheang et al. Application of Cross-Correlation Method with Sub-pixel Accuracy in Two Dimensional Model Tests. Proceedings of JSEM 2002 Annual Conference on Experimental Mechanics, Aug., 5-6, 2002, Wakayama University.