# Application of Image Analysis in Physical Model Test

Dept. of Civil Engineering, University of Tokushima Non-member Yuanhai, Li
Member Katsutoshi Ueno,
Student member O Tetuya Sadano &
Member Akitoshi Mochizuki

## 1. Introduction

Reliable assessment of soil behavior in geotechnical physical model test requires not only accurate but also convenient measurement of deformations and strains. Normal displacement transducer can be placed at the boundary of a physical model, but if the observed surface of model is attached with something like glass such as centrifuge model or bearing capacity test on soil, it is difficult to place the transducers. A new technique based on digital image process has been developed to overcome the above-mentioned problem and more convenience can also be available.

Processing image method and ensuring the high precision are the most significant factors of the technique. It is necessary to install intrusive colored target markers in the observed soil. In order to obtain high-contrasting and less-deformed image, we should make effort to adjust the used lamp and apply CCD camera with high pixel resolution before conducting model test. In this paper, the process method will be presented emphatically, which is realized through a program called by ITAP (Image-based Target Analysis Program).

## 2. Mechanics and method of ITAP

Generally speaking, the processed images should be corrected beforehand since: 1) the camera lens may not be perpendicular to the model plane and 2) the camera will not produce a perfect perspective projection. Also, the experiment may include a window through the rays are reflected. Correcting image will eliminate these effects. To carry out camera calibration, a set of control targets which model-space coordinates are accurately known and they are also used to transform the image-space coordinates to model-space coordinates of target markers.

The color and size of a marker are two important parameters to recognize the centroid or gravity center. The color is used to make the image binary, and the size is used to detect whether a target exists in a searched rectangular scope or not. The centroid coordinates (x,y) of the scope range from ($i_1$, $j_1$) to ($i_2$, $j_2$). The coordinates (x,y) of a target can be obtained by bellow equation, where detV[i,j] is a normalized value which describes the approximate level of color of pixel in coordinates (i,j) with the actual color of target marker.

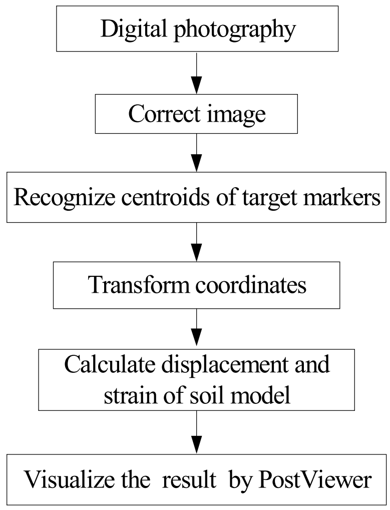


**Figure.1 Outline of ITAP**

$$X = \frac{\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} \det V[i,j] \times i}{\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} \det V[i,j]} \qquad Y = \frac{\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} \det V[i,j] \times j}{\sum_{i=i_1}^{i_2}\sum_{j=j_1}^{j_2} \det V[i,j]} \tag{1}$$

For ITAP program, in order to achieve the model-space coordinates of targets, the isoparametric transformation method widely used in FEM (as shown in Figure.2) is adopted to perform the coordinate transformation. After the coordinates of every target markers are obtained, the displacements and strains subsequently can be calculated. The final result will be presented by another self-developed program named PostView. The outline of process is shown in Figure.1. In addition, ITAP program with windows GUI provides some convenient and flexible methods to recognize the target such as in an automatic, semi-automatic and manual manner.

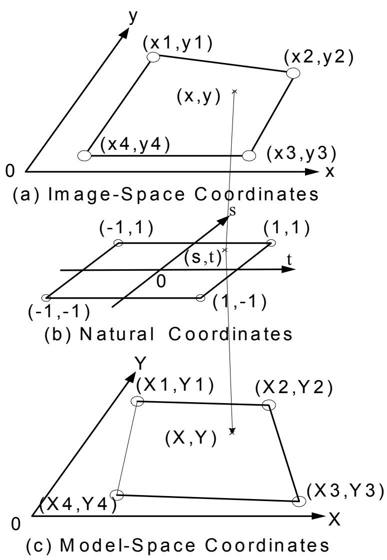


**Figure.2 Coordinate Transformation**

## 3. Precision validation

A validation experiment was conducted to assess the precision of ITAP. The main apparatus include a direct-shear box, one displacement transducer with

**Key words**: digital image process, soil, physical model test.
Zip: 770-8079 Department of Civil Engineering, University of Tokushima Tel/Fax 088-656-7342

precision of 0.002mm, a data logger, a camera of Dimage7 type of MINOLTA which CCD has a total of 5.24

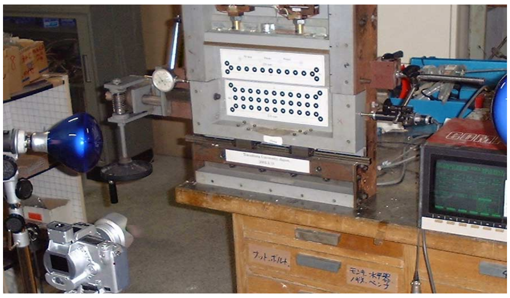

**Figure.3 Experiment apparatus for assessment of precision of ITAP**

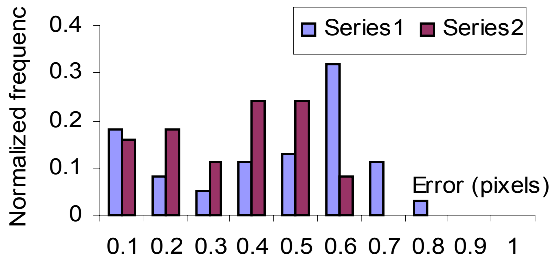


**Figure.4 Distribution of error of ITAP**

million pixels (2658×1970) and two lamps (shown in Figure.3). Two sheets with drawn targets were pasted on the fixed part and moveable part of shear box respectively. Two series test of distances of 60cm and 120cm between camera and shear box were performed. For each series, the moveable part was pushed by handle with 8 cases of displacements of 0mm, 1mm, 2mm, 3mm, 4mm, 5mm, 7mm, and 10mm, and the displacements were recorded by the data logger. Comparing the actual movement and calculated value by ITAP, the average error was presented in Table1, and the distribution of error was shown in Figure.4 The result showed that the target markers can be detected to a precision of (0.12-0.56) pixels in the case of series 2, which corresponds to (5/100000$^{th}$-2/10000$^{th}$ ) of the field view. (Here, resolution of the image is about 0.12mm/pixel).

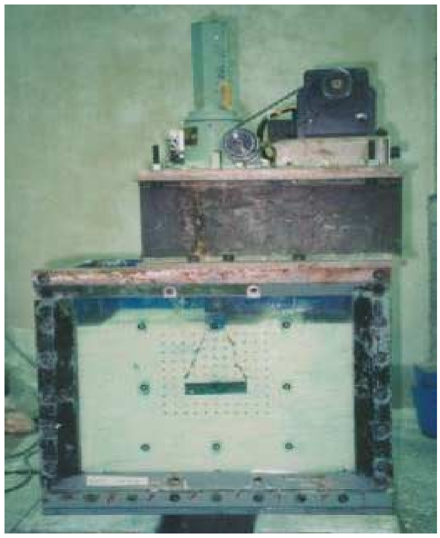

**Figure.5 Experiment model of clay test**

## 4. Application : bearing capacity test of clay foundation with a cave

Here is an example application using ITAP to have analyzed two photos from bearing capacity test of clay foundation model with a cave. Figure.5 is a photo of the physical model. 89 colored target markers were embedded in the soil around the cave in order to measure the displacements, and another 9 fixed black targets were pasted on the glass window as control points for coordinate transformation. Model size is 300 mm by 400 mm. Two images from the initial test step and the final step, which displacements of the footing are 0mm and 12mm respectively, were analyzed by ITAP. Figure.6 represents the displacement and strain distribution on the clay model surface, which are drawn by the self-developed program named by PostViewer.

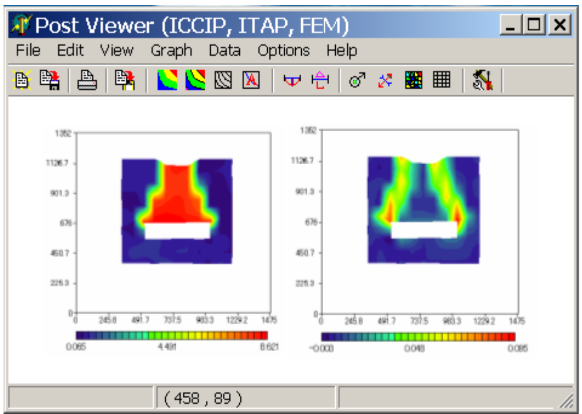


**Figure.6 Contour map of displacement and strain**

## 5. Conclusion

The digital image technique has been applied to develop a deformation measure system for physical model test. It has been demonstrated that the planar deformation can be detected to a precision of (5/100000$^{th}$-2/10000$^{th}$) of the field view. Precision for this technique will be further improved in the later research.

**References**

1.Katsutoshi Ueno, 2001, 3. Development of a displacement field measuring technique.

2.D.J. White, W.A. Take, M.D.Bolton & S.E. Munachen. (2001). A deformation measurement system for geotechnical testing based on digital imaging, closed-range photogrammetry, and PIV image analysis.15$^{th}$ International Conference on Soil and Geotechnical Engineering. Istanbul, Turkey.