Comparison of slope failure trend just before failure in the field using newly developed tilt-sensor

Japan National Institute of Occupations Safety and Health Regular member O Tamrakar S. B.
Japan National Institute of Occupations Safety and Health Regular member Toyosawa Y. and Itoh K.
Akebono Brake Industry Co. Ltd. Non-member Kunimi T., Nishijyo A. and Okubo T.

1. Introduction

Tamrakar et al. (2006) have developed a new type of tilt-sensor which could be used to measure the movement of the slope just before the failure in terms of tilting angle. They had tested its application in the field with Narita sand embankment model using Small Size Compact (SSC) and large size Stand Alone (SA) type tilt-sensors. In this report, comparison of tilt angle measured from SSC and SA type Tilt-sensors for two different types of soil embankments (Narita sand and Kanto loam) are made and their failure pattern are discussed.

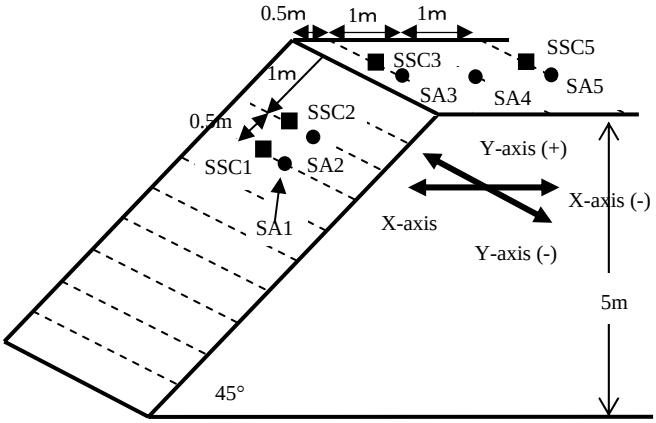

Fig. 1 Layout of tilt-sensors set up

2. Tilt- sensor and Field Test

Directions of movement of tilt-sensor (Tamrakar et. al, 2006) are shown in Fig. 1 and Photo 1. Four SSC (SSC1, SSC2, SSC3 and SSC5) and five SA (SA1, SA2, SA3 SA4 and SA5) tilt-sensors were set up on the slope surface and slope top (Fig. 1). Water content and wet density of Narita sand slope model and Kanto loam slope model obtained from sand replacement technique in the field were 1.74g/cm^3 and 29.3% and 1.18g/cm^3 and w=111.3%, respectively. Each model slope is of 5m height, 3.5 width and 45 degree slope angle. Slope surface was divided into 10 equal widths, each with 0.5 m. Excavation is started from the toe of the slope, vertically downward using a backhoe. Five minutes interval was allowed after each cut to see the failure trend. Cutting of slope was continued until the slope failure occurred. In case of Narita sand total of 6 cuts were made. Some partial failure within the slope was observed after the 5th cut. But the final large failure was occurred after 6th cut (around 51 min. elapsed time) which reached up to the slope crest. For Kanto loam, altogether 9 cuts were made. First partial failure was occurred after 8 cut (78 min. elapse time) at the right side of the slope (right wall). Large change in tilt angle could during this partial failure was stopped around 88 min. Further excavation on the left side of the slope was made so that final failure was occurred which reached up to the SA3 (SSC3) position on the slope crest.

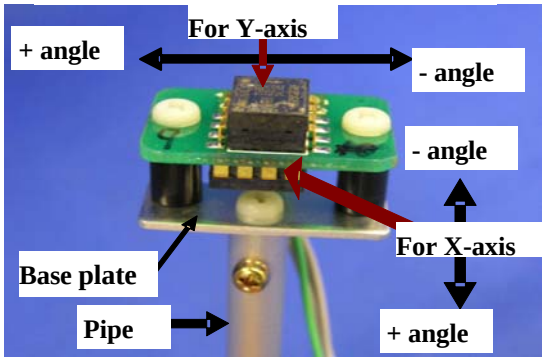

Photo 1 SSC-tilt-sensor

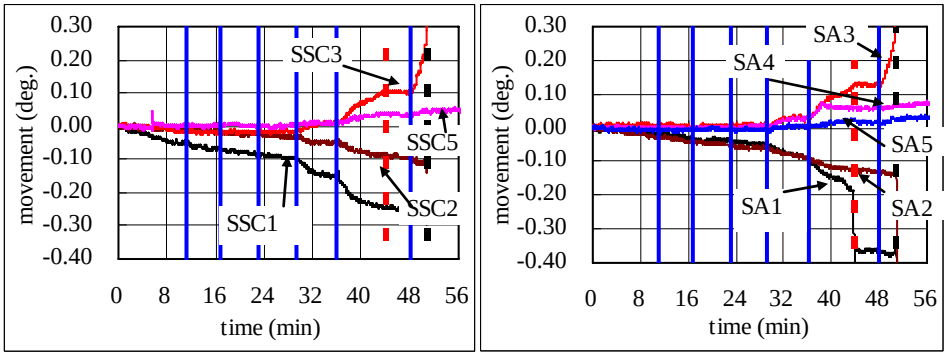

Fig. 2 Movements measured from SSC and SA Tilt-sensors (X-axis) for Narita sand

Keywords: **Monitoring on site/measurement, Slope, Excavation**
National Institute of Industrial Safety, JNIOSH, Construction Safety Division,
1-4-6 Umezono, Kiyose-Shi, Tokyo-204-0024. Tel: 042-491-4512, Fax: 042-494-6214, Email:tamrakar@s.jniosh.go.jp

3. Test Results

Movement of slope with SSC and SA tilt-sensors along X-direction for Narita sand and Kanto loam are shown in Figs. 2 and 3 (only X-direction is shown). Solid thick vertical lines in the graph show the end of excavation steps. Dotted lines in between these lines show the occurrence of partial failure where as the last thick dotted line shows occurrence of final failure. Sudden change in the tilt angles was seen just before the partial and final failures in both types of tilt–sensors. Kanto loam showed larger movement and took longer time to fail than that by Narita sand despite of wet density of Narita sand being higher than that of Kanto loam. Comparing the movements of SSC and SA for each soil, similar pattern of failure movement could be seen. In case Narita sand, SSC1, SSC2, SA1 and SA2 showed negative values while SSC3, SSC5, SA3, SA4 and SA5 showed positive value. Negative values shows the backward and downward movement of slope while the upper tilt sensors placed on the slope top showed the forward and downward movement of slope (Fig. 4(a). This shows the movement of slope during partial and final failure in different directions. In case of Kanto loam also similar movements of SSA and SC tilt-sensors were seen. Here, all the sensors moved forward and downward, showing partial and final movement taking in the same direction (Fig. 4(b)). Change in the tilt angle for each tilt-sensor along X-direction at particular elapsed time for each soil type is shown in Table 1. Comparing the amount of change in the tilt angle, it was seen that both types of tilt-sensors show almost same values except SSC2, SA2, SSC5 and SA5. This shows the application of both types of tilt-sensors with equal efficiency in the field.

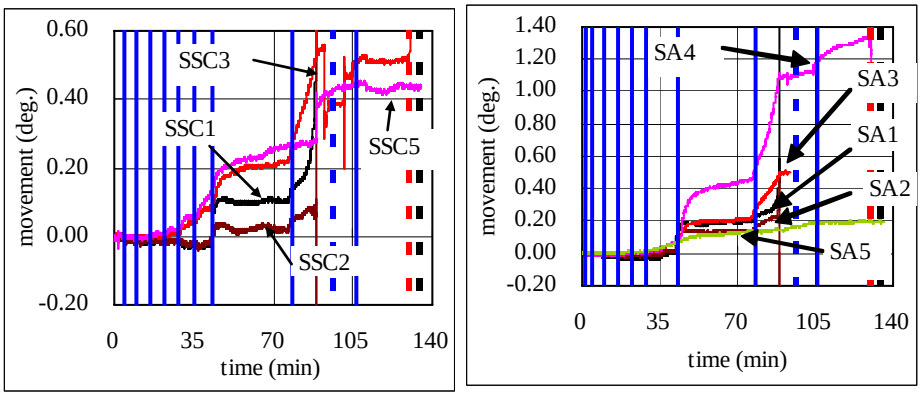

Fig. 3 Movements measured from SSC and SA Tilt-sensor (X-axis) for Kanto loam

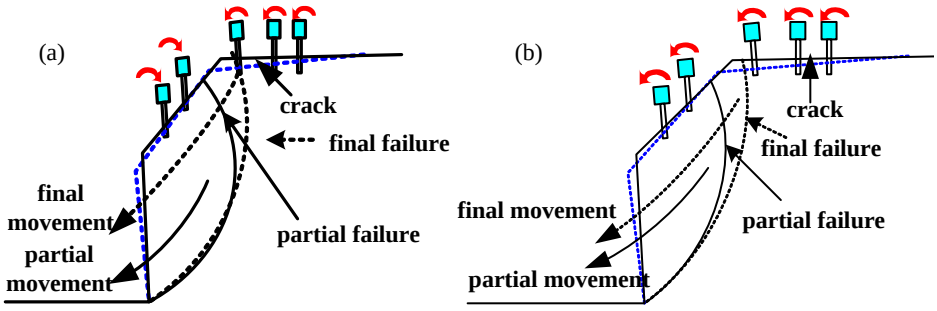

Fig. 4 Failure pattern in two types of soil models (a) Narita sand and (b) Kanto loam

Table 1 Comparison of tilt-angles measured

Narita sand (around 51 min. elapsed time)					
tilt-angle (X-axis)	1	2	3	4	5
SSC	-0.275	-0.11	0.25	-	0.025
SA	-0.300	-0.15	0.25	0.06	0.025
Kanto loam (around 88 min. elapsed time)					
tilt-angle (X-axis)	1	2	3	4	5
SSC	0.50	0.08	0.54	-	0.400
SA	0.50	0.30	0.50	1.08	0.150

4. Conclusions

1). Sudden movement just before failure could be seen in both types of tilt-sensors. Both SSC and SA tilt-sensors show almost same pattern and same amount of movement for particular soil model. This shows the application of both types of tilt-sensors in the field with equal efficiency. 2). Failure pattern of different soil could be measured with this new type of tilt-sensor. In case of Narita sand, partial and final failure directions are different whereas for Kanto loam, they are same.

Acknowledgement

This work is partially carried out under the Health and Labor Sciences Research Grants of Ministry of Health, Labor and Welfare.

References

Tamrakar, S.B., Toyosawa, Y., Itho, K., Kunimi T., Nishijo A. and Okubo S., 2006, “Development of Tilt-sensor and possibility of measurement of failure trend just before the failure”, 41th Annual meeting of Japanese Geotechnical Society (under print)