MONITORING MOVEMENT

S T HERATH

1.0 Movement can be defined as change of position over a period of time. To determine position one has to resort to Survey Techniques. The Techniques, adopted will depend on the accuracy required. Movement studies are required in a wide variety of fields, such as:

(a) Industry for essembling machinery; ship building, Aircraft manufactures.

(b) Measuring Terrain movement: Landslides, Subsidence, Earthquakes.

(c) Deformation measurements on structures: Concrete and Earth Dams, Bridges.

The accuracy requirements for each of these are different. For industrial purposes, movements to within fractions of millimeters have to be determined. For deformation studies, of Dams accuracy around ± 3mm is generally required. For monitoring Terrain movements lesser accuracies may be acceptable.

This paper is confined to monitoring movement of Hill slopes. Here too the following different Techniques can be adopted with varying degrees of accuracy.

(a) Geodetic Techniques
(b) Terrestrial Photogrammetric Techniques

2.0 GEODETIC TECHNIQUES

An actual task carried out by Mr S D F C Nanayakkara, Surveyor General and myself at Kotmale will be described.

The Left Bank slope of Kotmale Oya close to the Dam was found to be unstable by the Geologists. The task assigned to us was to determine any movement on this hill slope.

It was not possible for us to monitor every inch of the hill slope. Hence with the assistance of the Geologist on the site critical areas of the hill slope were marked with small yellow crosses and numbered. There were altogether 90 such crosses. These had now to be observed from a stable area. Again with the help of the Geologist.

Six (6) sites were selected on the right bank for the construction of control stations. However in order to get a reasonable triangulation Figure a Temporary point No. 1 was selected on the unstable Left bank(vide Fig. 1).

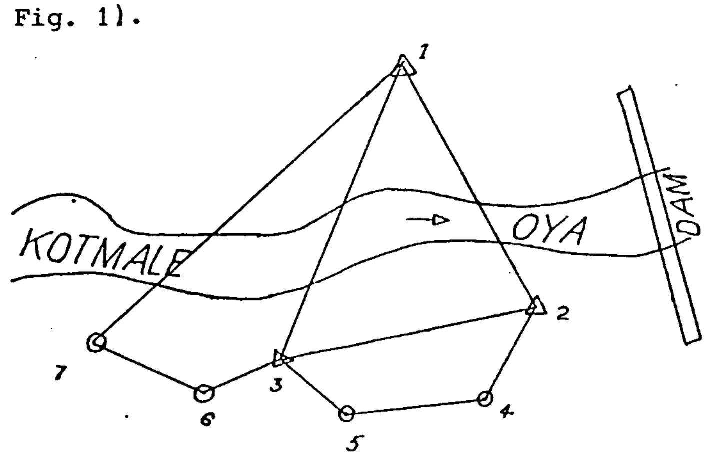

FIG. 1

This point was only used for the initial triangulation and thereafter discarded. Concrete blocks were buried at these sites and a centre mark established.

2.1 OBSERVATION PROCEDURE

The instruments used were the Precision Wild T 3 Theodolite and the Wild DI-3S EDM Equipment.

The angles of the triangle Pt 1, Pt 2, Pt 3 were first observed. At each station four rounds of angles were observed using both Face Left & Face Right. Vertical Angles too were recorded. So in all there were 16 pointings to each station. The distance Pt 2, Pt 3 was also observed. Two Traverses (Fig I) were also run connecting Pts 4, 5 and 6 and 7.

The triangulation and the traverses were adjusted and completed and coordinates (X, Y, Z) of Pts 1 to 7 were established. The coordinates were with reference to the National Grid.

2.2 MONITORING

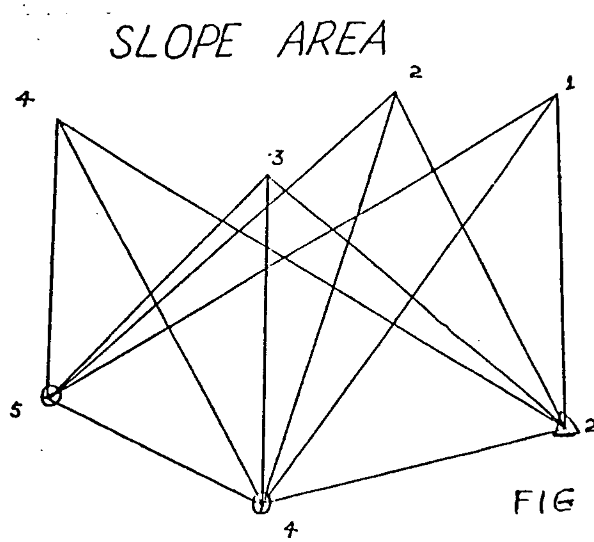

FIG 2

The control stations (2) to (7) on the Right Bank were occupied in turn and all the target points on the L B Slope were observed. The instrument used was the Wild T 3 precision Theodolite. Two rounds of angles were observed on both Face Left & Face Right. Both horizontal and vertical angles were observed. Specially designed forms were used for recording the field data.

2.3 COMPUTATIONS

The Computer used was the Survey Department ICL 2903 Main Frame Computer. The raw field data was fed into the Computer. Specially written software was used to check the field data for errors and inconsistencies. Averages were then extracted for both Horizontal and Vertical angles and stores in a direct access file on Discs.

It will be seen that each target had been observed from more than two control stations. So these redundant observations were used to do a least squares adjustment and obtain the best possible values for[2] the coordinates (X, Y, Z) for the target points. These coordinates for each target point along with the date of monitoring were stored on a direct access file on the computer.

A few months later another monitoring survey was done. Again the Raw field data was fed to the computer, the adjusted coordinate values for each target point obtained and stored in the direct access file along with date of monitoring. The arrangement of the file is shown in Fig 3.

Point No. 1	Date of Monitoring	X	Y	Z	Date of Monitoring	X	Y	Z

IRG	Point No. 1	Date of Monitoring	X	Y	Z	Date of Monitoring	X	Y	Z

IRG	Point No. 1	Date of Monitoring	X	Y	Z	Date of Monitoring	X	Y	Z

FIG 3

There will be a separate long record for each target point, where coordinates from any subsequent monitoring can be stored. The next task for the Computer is to compare the X Y Z coordinates of each point from the current monitoring with the corresponding values from any previous monitoring and obtain the differences. The difference will give the movement. These were tabulated in a computer print out.

It should be noted that once the raw data from the field has been entered and accepted by the computer the rest of the process is fully automatic and the final print out is produced showing movements if any.

The field observations for each monitoring took 3 to 4 days.

The data entry and the computations took less than ½ a day.

SOURCES OF ERROR

The main sources of errors are:

(a) Errors due to Centering
(b) Errors due to Refraction

(a) Errors due to Centering

For normal monitoring work where high precision is not required the Theodolite is mounted on a tripod. As mentioned earlier the control station is a concrete block with a centre mark punched on it. The block is just below the surface of the ground. The Theodolite on the tripod has to be centered over this mark generally with the help of a Plumb Line. It is difficult to get exact centering and errors in the order of 5 mm are possible. At the computation stage this error is transferred to the target as a movement.

For precise work forced centering devices are used. Hence the control station is a monument about 1.3 meters high. A steel socket is buried at its centre - vide Fig 5. To the base of the Theodolite a special ball device is attached. This ball just fits into the socket.

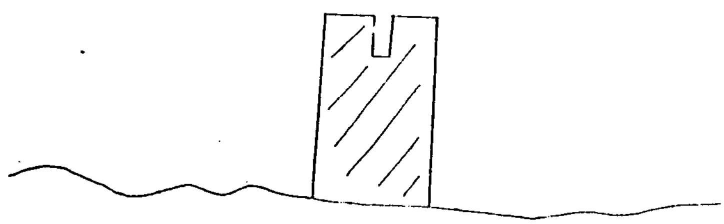

FIG 5

So everytime the Theodolite is fitted on to the socket it will always be in the same identical position. The centering error is almost zero.

(b) Refraction Errors

During daytime the ground get heated up. Hence the layers of the atmosphere closer to the ground is at higher temperatures than those above. In other words, there is a temperature gradation. Hence the reflected sublight reaching the Theodolite from the target is not straight. So although the actual target is at A the position as seen by the Theodolite is at A1. It appears elevated - vide Fig 6.

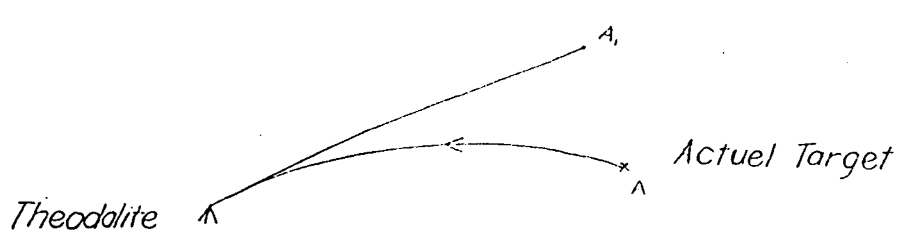

FIG 6

This error cannot be eleminated, but can be minimised by having shorter sights and applying corrections.

3.0 USE OF TERRESTRIAL PHOTOGRAMMETRY

The instrument required for this is a calibrated terrestrial camera. That is we should know the focal length and the position of the pinciple point in relation to the fiducial marks and the photoplane. (internal orientation of the camera). The camera used by us was the Wild P31 Terrestrial Camera belonging to the Cultural Triangle Project. It has a focal length of 100 mm and a format size of 4 in. by in.

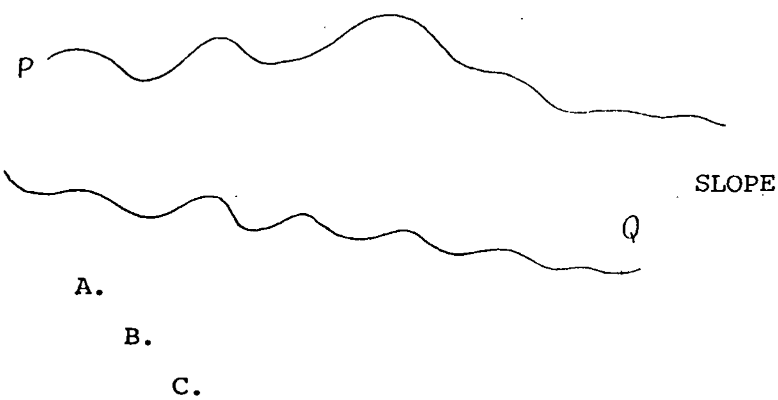

FIG 7

PQ is the slope to be studied A, B, C, D, etc. are camera stations. The selection of these stations has to be done carefully. The following points are of importance.

(i) The distance between sequential stations is the photo base (b). Suppose the average distance to the slope is D

$$\text{Then } \frac{D}{10} < b < \frac{D}{5}$$

(ii) These stations should be more or less be at the same level.

(iii) These stations should preferably be at a slightly higher level than the slope in order to obtain an orthogonal projection of the slope to be measured.

The positions and heights of these camera stations should then be determined accurately.

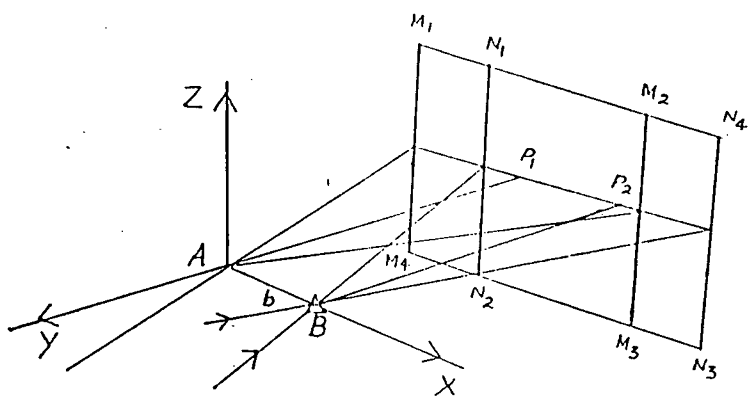

FIG 8

A and B are 2 camera stations. M_1, M_2, M_3, M_4 is the negative plan obtained from station A and N_1, N_2, N_3 N_4 is the negative plan obtained from station B and P_1 is the principal point for A and P_2 is the principal point for B. The base 'b' is selected so that there is a COMMON overlap. In this case the overlap is N_1, M_2, M_3, N_4. It is not essential to have the camera axis AP_1 and BP_2 parallel. The tilt of the camera axiscan be set to the optimum value (vide point (iii) above).

These two photographs (positive) can then be mounted on a precision universal tereo plotter (WILD A 10 or A7).

The following procedure has to be gone through

(i) Inner orientation

(ii) Relative orientation

At this stage we should be able to see a 3-dimensional model of the slope. But the terrain will not be at any particular scale nor will it be at the correct orientation in relation to the ground. To overcome this problem we require 4 points on the common overlap area whose coordinates on the ground are known. There are the so-called Ground Control Points. The model can then be scaled and levelled using these points. This is referred to as absolute orientation.

At this stage two methods are possible based on the system of coordinates shown in Fig 8.

(i) Plot the projection of the slope on the X-Z plane. The variation in the Y direction will be plotted as contours.

(ii) Locate all identifiable points on the model and determine their (X, Y, Z) coordinates. This can be transformed to the ground coordinate system.

After a lapse of time the same area can be rephotograpted from stations A and B. The procedure described earlier can be followed and we will end up with either a map with contours or a new set of coordinates for the same points as in (ii) above. A comparison of the 2 sets of maps or the 2 sets of coordinates will show any movement. This technique is not meant to show very small displacements, but provides the advantage of a map showing the pattern, and area and extent of movement.

For this technique the actual phtography took less than a day. But 3 to 4 days were required to plot the result on a map using a Wild precision photogrammetric plotter.

CONCLUSIONS

It was seen that the Geodetic Technique is accurate and is able to detect small movements. With the use of a reasonable size computer and special softwork it is possible to give the result without delay.

The photography too could be done along with the Geodetic Monitoring Survey. But it is necessary to plot from the photographs only if the Geodetic Monitoring Survey shows movement.