CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main focus of this study is to study the application of a reflector-less Total Station as a data acquisition tool in slope deformation monitoring. The data observation was carried out in order to determine the propagation of errors in angle and distance measurements before the final coordinates of the monitored points are calculated. The effect of errors in azimuth and distance observations will affect the computed latitude and departure, which are required for the final coordinates determination in order to see the displacement magnitude of the monitoring target points.

The calibration of the main instrument, reflector-less TS is very important in order to obtain the correction values of systematical errors. The calibration of the reflector-less TS was performed to obtain the correction value of zero-error (due to incorrect reflective signal), as well as scaling factor and constant value of the TS (both values show the accuracy of the device to get the appropriate data) for distance measurement. Since there are no permanent target points fitted on the slope area, any natural or man-made structures such as retaining concrete wall, drain, sign box, or prism pole can be the target point. Therefore, the TS instrument must be calibrated on targets of various materials and colour in order to generate the correction values for those particular items.

Based on the experimental result, the reflector-less TS can be applied to any types of material targets, but it is important to avoid outliers. This can be achieved by ensuring the cross-hair of the telescope is exactly on the centre of the target when aiming at the target. Care also need to be taken when measuring to a point where a secondary object is in the foreground or background, otherwise the reflected distance will be incorrect. Evaluation of the zero error as a systematic error is important in calibrating the TS instrument. All measurements must be corrected to achieve good result in future monitoring work.

Referring to the zero error calibration result, black material target yields the biggest value of zero error (7.054 ±0.002 millimetres) while prism target has the smallest value (0.093 ±0.001 millimetres). Other targets yield different zero error corrections which lie between these two values. Furthermore, the result of t-student statistical test also has indicated that the zero error of all targets exists significantly. Thus it can be concluded that the zero error of Total Station instrument has different values depending on either the colour or material of the targets.

Referring to the calibration result of the TS, black coloured and wood targets yield the two largest values of scaling factor: 14.987 ppm and 12.130 ppm compared to the value as mentioned in the instrument specification, 10.000 ppm; while prism target gives the smallest constant values: 1.031 for a, and 2.040 ppm for b, but its scaling factor is still larger than the specification, 2.000 ppm. Hence, the t-computed result for all targets (except for prism target) are larger than 2.145. However, the t-computed value of prism is lower than 2.145. This indicates that there are no errors in the distance measurement tool in the Total Station and its standard prism. Instead, the error exists mainly in the reflector target made of various materials and colour.

The result shows that the value of the constant and scaling corrections for the prism and the various targets is less than the values of the instrument's specification, which means the Total Station is functioning well and could be used for precise structural deformation monitoring.

After the calibrations were completed and the TS instruments have been confirmed to be in good condition, deformation monitoring works were carried out with three epoch observations within six months interval. The statistical study and reported observation result show that there have been several significant mass movements in the study area. In that period, there has been much as 9 cm in the northing, 8 cm in the easting and as much as 12 cm in the elevation in some of the points during the 18 months observation period. These showed that there were apparent movements in the study area.

Apart from that, it was found that the reflector-less TS method does not differ much with the standard prism method which was captured by the MTD survey team. From the data captured by the MTD survey team, in epoch 1 and epoch 2, target points P12 and P15 have displacement deformation as much as 0.069m in the northing, 0.005m in the easting and 0.089m in the elevation for P12 and as much as 0.063m in the northing, 0.007m in the easting and 0.076m in the elevation for P15. Whereby, compared to the reflector-less TS data at the same target points P12 gave a result of 0.065m in the northing, 0.006m in the easting and 0.088m in the elevation while the result for target points P15 were 0.065m in the northing, 0.001m in the easting and 0.084m in the elevation.

In addition for epoch 2 and epoch 3, target point P16 has displacement deformation as much as 0.065m in the northing, 0.012m in the easting and 0.086m in the elevation. Compared to the reflector-less TS data, target points P16 gave a result of 0.070m in the northing, 0.014m in the easting and 0.111m in the elevation.

And finally for epoch 1 and epoch 3, target points P12 and P16 have displacement deformation as much as 0.064m in the northing, 0.042m in the easting and 0.119m in the elevation for target point P12, while for target point P16 gave a result of 0.129m in the northing, 0.091m in the easting and 0.070m in the elevation. Compared to the reflector-less TS data, target points P12 gave a result of 0.076m in the northing, 0.027m in the easting and 0.109m in the elevation. Whereby, target point P16 gave a result of 0.019m in the northing, 0.084m in the easting and 0.068m in the elevation.

Furthermore, the results of t-student statistical test also have indicated that the difference between prism standard Total Station and reflector-less Total Station is not significant or acceptable. Its show that indeed the reflector-less Total Station distance measurement technology works well and it is accurate enough for slope deformation and for others applications. Therefore it can be concluded that reflector-less is acceptable in slope deformation monitoring.

The risk level from landslide hazards in the vicinity of Chainage 23+800m at Simpang Pulai - Loging highway is high and will increase if appropriate action is not taken. State authorities or government agency should take early precaution to reduce the likelihood of catastrophic collapse of the active landslide. New system such as real time monitoring is highly recommended for implementation in the area. Therefore the need for monitoring and maintenance are seemingly very important as a dependable warning system in the event of any significant deformation is detected. This will not only reduce the consequences of catastrophic collapse of the active landslide but also as a security measure to safeguard the users of the Simpang Pulai - Lojing highway and to minimize losses should collapse occur.

5.2 Recommendations and Future Works

There are several different methods that can be used in slope deformation monitoring and the choice depends on the desired accuracy of the measurement and the size of landslide hazards. Generally those techniques have advantages and disadvantages; in this research the main approach is to minimize the risk on the surveyors and reduce cost on installation of instrument/devices such as prism pole or GPS rovers. With this technique, the data can easily be captured even in dangerous and inaccessible area. However, there is still a venue for improvement in this method. The following are some recommendations which can be considered for future studies:

1) There is a possibility that weather conditions might influence the data measurement. Since Cameron Highland is located in the highland area, where the weather is different from the lowland, the target material condition is different than at the low land because of weather conditions. Some of the targets monitoring points were wet; therefore fields test should be carried out on wet surface targets for example on wet concrete retaining wall.

2) When measuring to targets which have various observed angle such as narrow sight angle or narrow objects such as cables and overhead wires, the beam divergence effect need to be considered. This can be done by applying the field test when measuring at the corners and vertices of the objects. This test is to ensure that when the laser beam is pointed directly at a corner, some of the measurements energy is reflected by the wall before they reach the right corner.

3) To apply a simple test that can affect the beam divergence and accuracy of the instruments by measuring to a point where the secondary object is in the foreground or the secondary object is in the background. The purpose of this test is to obtain the correct distance.