Building Deformation Monitoring

By

Zaim Aiman Bin Che Rosli

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Engineering (Hons)

(Civil Engineering)

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CERTIFICATE OF APPROVAL

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Approved by,

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(AP. Dr. Abdul Nasir Bin Matori)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(ZAIM AIMAN BIN CHE ROSLI)

ABSTRACT

This paper is focusing on determining the capability of reflector-less total station in monitoring building's deformation as well as to check the deformation of Universiti Teknologi Petronas (UTP) Academic Complex canopy system. Monitoring building deformation is an essential practice in order to determine whether the structure is within a safe behavior or not. There are numerous methods to be used such as the application of close-range photogrammetric, application of fiber optics, application of LiDAR technologies as well as geotechnical method (inclinometer, accelerometer, and tiltmeter). However, there are certain limitation and constrain faced by the mentioned methods in order to perform deformation monitoring at the building edges and critical area. Therefore, this project is to check the capabilities of reflector-less total station (RTS) in monitoring deformation of structure as well as the accuracies of the data obtained by performing a field data measurement. Topcon GPT 7501 series is used in this field data measurement for monitoring the deformation of canopy system situated in front of building 13 and building 14, UTP academic complex with 4 observation points. The spatial data coordinate obtained in the first reading will be used as a base data for subtracting with the following continuous reading performed. Total displacement recorded based on field data measurement shows the maximum movement is 1.61 mm towards the structural beam on column 3 and 4 in front of building 14, Universiti Teknologi Petronas. Even though the result of monitoring displacement up to millimeter movement has been achieved, the result is insignificant as the movement recorded is not within the boundary of the capability reflector-less total station as the accuracy of the instrument is ±5 mm in its non-prism mode. Therefore the displacement or movement does not occur as after subtraction being done, the movement is below ±5 mm accuracy of the equipment. However, based on the field data measurement conducted, the overall objective of this project has been achieved for checking the capability of reflector-less total station in monitoring deformation.

ACKNOWLEDGMENT

In the name of ALLAH S.W.T, the most merciful and compassionate, praise to ALLAH, he is the almighty, eternal blessing and peace upon the Glory of the Universe, our beloved Prophet Muhammad (S.A.W), and his family and companions.

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This special thanks and appreciation are also dedicated to all my colleagues who are directly or indirectly contributed towards the success of this project. With the full cooperation from various people above, the author has successfully achieved the objective of this project.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Monitoring structure deformation can be classified into two major categories which are geodetic and geotechnical survey. As technology has been improving day by day, the usage of terrestrial survey in monitoring building deformation has been questioned due to the accuracy and precision yielded by this equipment.

The usage of Fiber Optics sensors and Global Positioning System (GPS) has been selected by most of the surveyor companies for monitoring structural's deformation as compared to the usage of total station. This is due to the reason of using total station needs at least two persons in carrying out the monitoring purposes as well as it requires complex procedure to be done in order to obtained the desired result.

As recent years, the manufacturer of total station companies such as Leica, Topcon, Nikon, etc. have been able to come out with new solution and improves their design towards this equipment. In making task easier most of the manufacturer has now introduced a reflector-less total station (RTS). This equipment provides a function of recording data that does not require the usage of prism to capture and reflect the laser emits by the total station in its reflector-less mode.

Reflector-less total station can be used to carry out any deformation monitoring on complex and mega structure such as bridges, tunnel, and inaccessible section of man-made structure to check the deformation or the deflection rate.

1.2 Problem Statement

When it comes towards monitoring structure deformation, the application of geotechnical as well as geodetic method can be fully utilized in order to get the desired results. Geotechnical method is a study based on the soil or ground parameters for checking the rate of settlement or movement. Not to be denied that this method also is not solely based on the study of soil itself as there are other method falls under this category such as crack gauge measurement, accelerometer and so on.

For every method available, certainly there are advantages as well disadvantages towards the usage of it. In example, accelerometer can be very useful in detecting deformation or deflection of a structure. But, due to certain factors such as surrounding environment as well as height factor, this accelerometer has become a major constraint as it requires to be put on the structure to be monitored.

For crack gauge method, the constraint of using this method is that, there is no crack formation occurs at the desired structure from naked eyes to be monitored for initial assumption. As the structure to be monitored is made from steel structure as well as height factor, the selection of this method is in a difficult manner. And for this reason, this method is not being considered for this project.

In Malaysia, the usage of Global Positioning System (GPS) has been one of the most favorable tools when it comes towards monitoring building deformation. Due to its application in detecting movement of the building without the usage of many labors has made this equipment as number one application tool by the surveying company in carrying their duties.

But there are certain limitations towards the application of GPS in capturing or monitoring building deformation. In order to monitor the deformation of roofing system, this device need to be placed at the target area and leave for a certain amount of period before the device can yield desired data.

Therefore a solution to encounter this problem is by using reflector-less total station in monitoring the deformation of structure. By selecting this method and equipment, the height factor will not be a problem anymore since this equipment can be operated to certain angle in monitoring the target area. Besides, inaccessible and critical area for monitoring purposes such as edges of the building, tower and roofing system can be performed in any condition for getting data needed.

1.3 Objective of Project

The objective of this project is to monitor the deformation or deflection behavior of canopy system in UTP by using reflector-less total station (Topcon GPT 7501 series). Main objectives of the project are as follow:

i. To investigate the capability of Topcon GPT 7501 in monitoring deformation at critical and inaccessible area.
ii. To monitor the deformation of UTP canopy system.

1.4 Scope of Study

Scope of study for this project involved a field data measurement as a case study at one of the targeted structure at Academic Complex in Universiti Teknologi Petronas (UTP). Target structure of the case study will be the canopy system used for the academic complex.

This structure has been chosen since the roofing system for UTP is unique enough where it is based on the usage of round pillars and tension cable to sustain the roof from collapsed. A certain tolerance for deformation or sway has been specified by the designer of civil consultant in-charged for the roof to be safe subjected to external load.

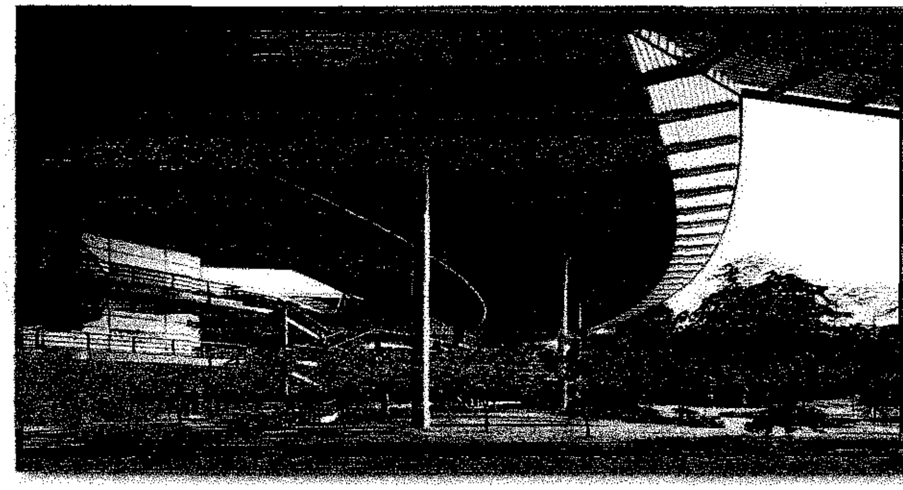

Figure 1: UTP's academic complex for roofing (canopy) system to be monitored by using Topcon GPT 7501 series

The study will be in 4 stages, where the first stage is aimed to study more on the equipment to be used in carrying out the project as well as software needed in determining the data for deformation. The second stage is to test the equipment whether it is in its best condition to be used as well as calibration of the equipment for better accuracy.

Third stage is conducting field data measurement which is for this case study, the roofing structure at third level of building 14, Civil Engineering Department in 9 continuous days. Last Stage is to check and generate data recorded from the reflector-less total station to access if there is any deformation or deflection on the structure and specified the deformation rate.

1.4.1 Relevancy of Project

As variety methods available to perform deformation monitoring, reflector-less total station has been chosen due to certain advantages compared to other techniques. Besides, it is quite relevant nowadays since this project will help solving monitoring high rise building where the application of other specified method is not feasible enough when a safety factor had to be counted as such dealing with height factors and location of structure to be monitored.

As for the usage of GPS equipment, it needs to be put at the exact target point for the deformation or deflection behavior to be monitored and if one is to climb up towards 5 storey height, that personal is prone to injuries or even death if safety precaution is not being taken seriously.

Another constraint faced by other method such as Photogrammetric is due to the cost consideration or budget needed as it uses a photograph taken with special cameras mounted in fixed wing aircraft or helicopters. This photogrammetric method will be useful for hazardous situation such as earthquake and volcanic activity monitoring. In this case, new budget need to be allocated for purchasing this equipment as this equipment is not available by the civil engineering department.

Even though using a reflector-less total station in monitoring building deformation do have a certain disadvantages when comparing with other available method, the usage of total station is still being selected due to the cost and time constraint in determining the desired outcome.

1.4.2 Feasibility of Project

The project will commence by collecting materials needed such as books, journals, engineering manual for carrying out deformation monitoring and technical papers. All available method that is relevant towards this project is being taken into consideration and selection is based on the reliability as well as time constraint in getting accurate result. Research has been performed from time to time as part of getting a better understanding on this issue due to the advantages of each described as well as the disadvantages that come along with it in monitoring building deformation.

This project will then focus on field data measurement by using the selected device and analysis will be done on the deformation or deflection of building based on data yielded. This project also will be completed in a period of eight months. All equipments needed to perform this project are available in the Civil Engineering Laboratory as well as the software involved. With all the resources provided, this project can be considered as a feasible project within the time frame given.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Literature Review

Measuring technique for building or structure deformation monitoring can be categorized into two groups traditionally which are geodetic survey as well as geotechnical survey (USACE, 2002). (Wan Aziz et al, 2001) is very definite: "the selection of most appropriate technique or combination of techniques for any particular application will depend upon cost, the accuracy required, and the scale of the survey involved" (p.2).

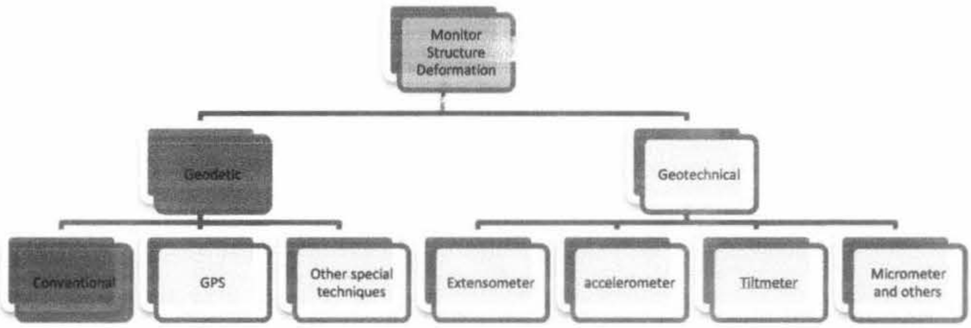

Figure 2: Method available to monitor deformation of structure

2.1.1 Geodetic Survey

Geodetic survey comprise of an observation through a network of point interconnected by bearing and distance measurement which are sufficient for the statistical evaluation of quality and detection of errors for the study to be conducted (USACE, 2002). For geodetic survey, it can be carried out either by using a conventional method (terrestrial survey), Global Positioning System (GPS), Photogrammetric, Remote Sensing (application of LiDAR) and other new technique or method in the market which is the application of fiber optics sensor in measuring deformation or deflection of structure.

2.1.1.1 SOFO System

Application of fiber optics sensor or most knowingly as SOFO (Structural Monitoring by using Optical Fibers) system has been increasingly become popular for structural monitoring. This method involve the usage of optical fiber to be installed at the desired place for checking deformation or deflection of building in maintaining historical structures. The measurement system was made on low-coherence interferometry of the fiber optics.

For every deformation structure that will occur and thus resulting in a change between the lengths of two fibers installed. The reason for the implementation is due to the advantages of this method which is easy to handle, dielectric, immune to Electromagnetic disturbance such as thunderstorm and also able to accommodate deformation up to a few percents (Daniele Inaudi et al, 2001).

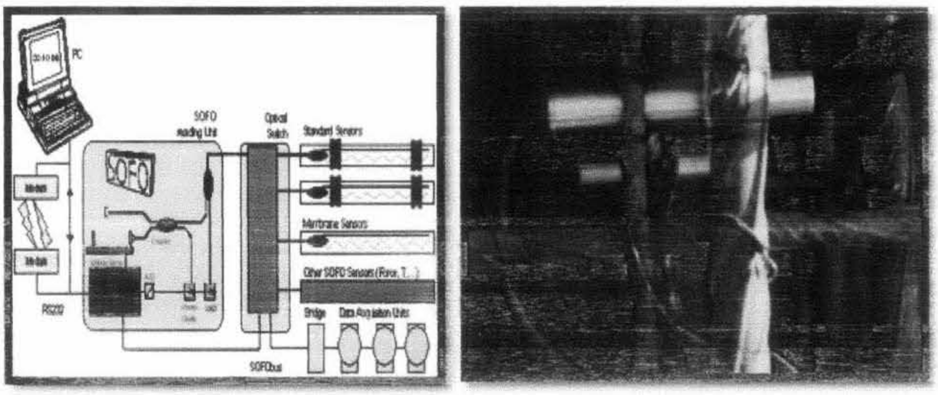

Figure 3: SOFO System schematic diagram and how it is installed at the structure to be monitored

This method has been applied successfully in most mega structure as for example tunnel, bridges, nuclear reaction plant, piles, anchors as well as harbor structures. But due to the required amount of fiber optics to be used is up to certain numbers, the cost of using this equipment will not be the choice of selection as this method need a constant periodic monitoring (Daniele Inaudi et al, 2001).

2.1.1.2 Photogrammetric Method

Another possible method to be implemented is the usage of photogrammetric technique in monitoring deformation or deflection of the desired structure. Photogrammetric method is a measurement where 3 dimensional (3D) coordinates or displacements of an object can be obtained by using 2 dimensional images taken from different locations and orientation (Muammer Ozbek et al, 2010).

The application of photogrammetric measurement are currently in used and proven to give very accurate measurement for a wide variety of discipline. Main advantage this method is that it can be used to capture or monitor static or dynamics deformation measurements. Besides, model analysis and system identification as well as 3-D shape determination can be determined from the photo obtained.

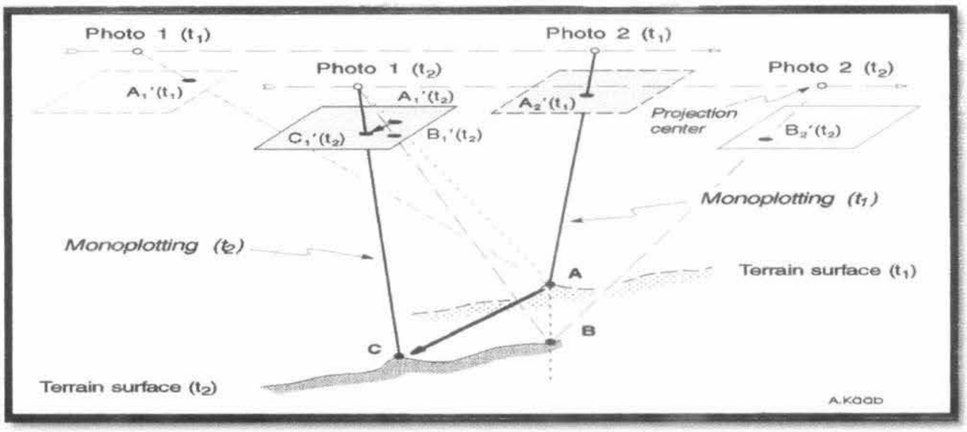

Figure 4: Photogrammetric measurement for deformation monitoring based on movement recorded

As having advantages, this method also has some restriction upon it which the size of the object to be tracked is usually restricted due to the problems such as insufficient illumination, difficulties in calibration and low resolution (megapixel) of camera used (Muammer Ozbek et al, 2010).

2.1.1.3 Global Positioning System

Global Positioning System (GPS) is a satellite positioning system which based on the use of satellite retrieved information. The main goal of the usage of this method is to provide worldwide, all weather, continuous radio navigation support to users to determine position, velocity and time throughout the world.

This method consists of three segment which are the space, control and user segment. Under the segment of space, the application of Global Positioning System can provide an absolute and relative geodetic point positioning for deformation monitoring purposes. It also had an enormous success for determining seismic movement, very slow displacement and deformation of some major engineering structures such as bridge and dams (A.Nickitopoulou et. Al, 2006; Behr et al,1998).

This system works by sending a signal from the navigation satellite in the outer space towards the receiver. Once the signal has been received by satellite, it will reflect another signal that contains the spatial data on the location towards the transmitter. The coordinate obtained will be in term of Northing (N), Easting (E) and Zenith (Z) location of the specific place where the transmitter is being put.

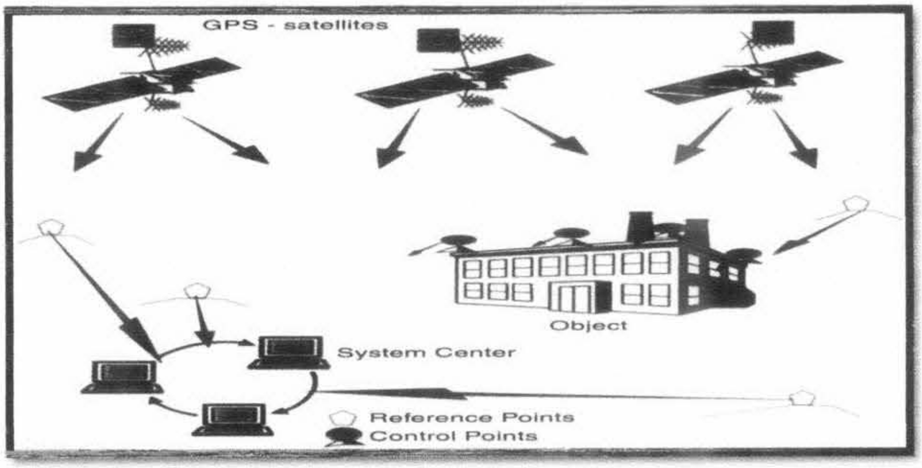

Figure 5: Global Positioning System works by transmitting signal from navigation satellite towards receiver

Global Positioning System (GPS) on its own has two major limitations that make it unsuitable to be used for deformation monitoring. First is that the signals are received from the satellite, may subjected to multipath issue. Second limitation is the current precision levels of GPS are limited to ± 1cm horizontally and ± 2cm vertically (H.S Park and H.M. Lee, 2007; Breuer et al., 2007).

2.1.2 Geotechnical Survey

As for Geotechnical survey, it involves the usage of tilt meters, accelerometers, micrometers and other various available options. As for this method have mainly been used for relative deformation measurement within deformable object and its surrounding. But due to technical progress in recent years, the difference of using geodetic survey as well geotechnical survey and the application between these two methods are becoming not as obvious when comparing to twenty years ago (USACE, 2002).

For geotechnical methods such as tilt meter, accelerometer, extensometer as well as micrometer available, these methods involve further research on the field study towards the soil or ground movement as well as direct measurement towards the cracking that happened towards the building or structures. Accelerometer traditionally used for measuring dynamic parameters of structure.

The basic problem of using this method is that it has a certain limitation which for the measurement or displacement. This method derive displacement by serious errors ("drift") induced by double numerical integration while non-geodetic sensor can only measure relative displacements or deformation and not the displacement of the structure relative to a fix reference frame which independence of the structure itself (Fanis Moschas, Stathis Stiros, 2010; Yang J. et al, 2008)

2.1.3 Selected Method

As there are plenty of available method describe above can be used in monitoring deformation or deflection of building structure, as for conducting this project, it has been narrowed down to a geodetic survey. The method that will be focused more is on terrestrial survey method as due to the availability of this equipment by the civil engineering faculty.

2.1.3.1 Conventional Terrestrial Survey

This project is more on towards investigating the capability of electronic distance measurement (EDM) in monitoring building deformation. Terrestrial survey method such as precision triangulation of traversing and geodetic leveling has been establish in the society since 1940's for monitoring big structures whether it is during construction or after the completion of it such as bridges, dams, tunnels, high and low-rise building, etc. (Casaca and Henriques, 2002).

With the technological progress in the last few years, the differences between using GPS system as well as conventional method technique seems negligible compared to twenty years ago (Mat Rahim Ibrahim et al, 2010; USACE,2002). GPS and conventional terrestrial are the two most preferred techniques to be used especially when it comes to deformation monitoring under geodetic method. Selection for the monitoring techniques depends heavily on the type, magnitude and the rate on deformation of the building.

Therefore the proposed measuring schemes need to be based on the best possible combination of all available measuring instrumentation. As for this purpose of project, high accuracy and precision of data need to be obtained in order to check deformation of building structure. Furthermore, in order to choose the best selection in carrying out the project, many factors need to be taken into consideration for example the limitation of each methods that is available as well as advantages each method has over one another.

In order to achieve accurate and high precision of data to monitor deformation of building, the millimeter (mm) to sub-millimeter accuracies is required rather than centimeters (cm) (Gethin ROBERTS et al, 2007). It is a big challenge to obtain accuracies and precision in millimeter level when quantifying deformation of an object between different epochs for any experiment to be conducted (Roderik Lindenbergh et al, 2009).

2.1.3.2 Reflector-less Total Station (RTS)

More recent active methods, including reflector-less total station and laser scanning system have become viable options for the capture of structural measurement in term of deformation (mills et al, 2004). The use of laser technology in surveying instrument's industry has led to the development of reflector-less total station (RTS).

Reflector-less total station operates by sending out an infrared laser beam to its target that has been appointed by the help of pointing laser application in three different functions according to the manufacturer's specification. The laser transmitted will hit the target surface area and reflected back to the instrument. The value for the horizontal distance and angle of reflection or spatial co-ordinate in term of northing, easting and zenith then will be computed.

The application of reflector-less total station (RTS) has been previously tested on the suitability and credibility of this equipment in performing the monitoring deformation of big and complex structure internationally. Among the paper that is discussing the credibility of this equipment can be found in the 11^{th} FIG symposium on deformation measurement in Greece 2003 (D. Stathsas et al, 2003) on the topic of "New Monitoring Techniques on the determination of structure deformation".

The advantages and disadvantages for the usage of reflector-less total station had been discussed widely by researches over the last few years. Reflector-less total station (RTS) can be used for monitoring the deformation or deflection of any structure required without having to use reflector as required when using conventional total station.

Besides, another advantages of this equipment is that it make task easier when the work requires observation of point situated at inaccessible place by using conventional total station such as critical edge of bridges, high tower, roofing system and reservoir. A highly critical area can be defined as a place where it is hard enough to be accessed due to the location, height and environment factor involved (D. Stathas et al, 2003).

As for the disadvantages of this equipment, it could not be free from having source of error when obtaining the data required. Calibration of the equipment is the only way to reduce the possibility of having error that can cause inaccuracies in determining the desired data. Most of the manufacturer company has specified that there are three errors that could occurs when using the reflector-less mode which are zero error, cyclic error and Scale error (Nurrohmat Widjajanti et al, 2008; Western Australian Land Information Authority).

Besides, reflector-less total station's performance is influenced by color, shape and surface of the measured object. As zero error, different target material in term of color needs to be considerate as this material reflection may cause variations in the error and lead to inaccurate data measurement. For various target material, tile surface can caused high value of zero error which 8.7 millimeter, followed by black with 8.4 millimeter, concrete surface color with 7.1 and white with 6.4 millimeter. The lowest value of error caught is by using the reflectivity of prism with 2.9 millimeter (Nurrohmat Widjajanta et al, 2008).

Thus due to the advantages and disadvantages as have been claimed by researches such as the reflector-less mode for capturing or performing deformation monitoring is not capable of measuring key features of buildings such as edges and corners for curve (Bai Chengjun, et al, 2009), this project is aimed to perform a field study in order to check the capability of the total station by monitoring the deformation rate of the UTP Academic complex roofing (canopy) .

A fix steel base tripod need to be used for this project in order to ensure the accuracy of obtaining deformation rate is achieved in the end of field measurement. If the measurement is being carried out by using normal tripod, it will interrupt the accuracy of data obtaining due to other factors such as the screw that is locking the tripod at the desired point as well as changes of height. When the height for the setting up of reflector-less total station is being changes, it will eventually give a huge difference in term of deformation rate recorded if reference point is not being used.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

The procedure identification flow is shown in Figure 6.

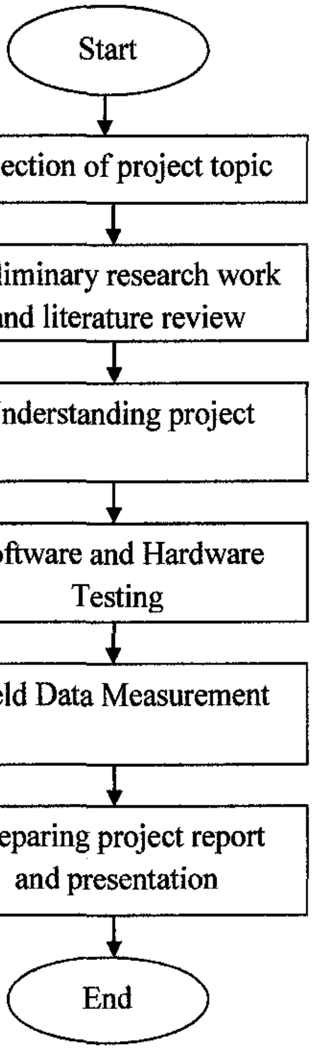

Figure 6: Procedure Identification Flow of the Project

At the beginning of semester, titles for the Final Year Project had to be chosen or proposed. After the project title was chosen or approved, preliminary research work and literature review will be carried out based on the project title. The next task takes place is to understand more regarding the project and learn from the literature reviews and researches.

After understanding about the significance of project, case study has been on-going by using actual software and hardware application needed. Next step is simulating the data obtained through-out the case study that is being implemented for the project. The last step involved is preparing project report, technical paper and presentation.

Testing and getting familiar with the system of the equipment to be used needs to be done in the first stage as such operating the equipment, study the manual of the equipment, test performance of equipment, as well as calibration to minimize possible error from occurring.

3.2 Tools and Equipments Required

In order to perform the case study, the equipment and software required can be referred at table 1 below.

Table 1: Required Hardware and Software for the project to be performed

Hardware	Software
Topcon GPT 7501	Microsoft Excel
Steel Base Tripod	
Measuring Tape	

3.3 Process Flow

Overall methodology involve for this case study can be divided into four main stages. The stages are as follow:

i. Setting up and Testing of equipment
ii. Calibration of Equipment
iii. Field Data Measurement
iv. Analysis data yielded to detect the deformation behavior

3.3.1 Setting Up & Testing of Equipment

The equipment to be used has been identified from laboratory technician which is TOPCON GPT 7501 series. This equipment will be tested and used to carry out the case study since this reflector-less total station (RTS) is new and has not been test on its performance and capabilities.

Before case study to be carried out, familiarization with the potential and capabilities of the equipment is the main priority. This is to check and understand how the equipment operates by studying the manual that came with this equipment.

After the instrument has been familiarized, the observation location or control point for the field data measurement has been selected. The accessibility of control point must be ensured as compare to other possible location for the measurement to be performed especially on non-working days to avoid delay in getting data.

Next, the distance for selected observation point need to be choose carefully as in the reflector-less mode, the maximum distance it can handle is 250 meters. And due to this, the observation point selected must not be far away from the reflector-less total station in order to ensure the accuracy and validity of the data acquired.

3.3.2 Calibration of Equipment

Calibrating the equipment is highly needed even if the manufacturer has calibrated it before handing to the end user. Calibration of equipment will be required to determine the precision as well as accuracy of the reflector-less total station (RTS) to be used (Nurrohmat Widjajanti, et al, 2008).

The calibration of equipment as for the time being can be performed by comparing one known distance by manual check and the displayed distance from reflector-less total station. A known distance of 5.74 meter with accuracy up to two decimal places that has been calculated manually will be made as a comparison with the data obtained by using Topcon GPT 7501 series. The illustration for calibration of equipment can be seen below in the figure 7.

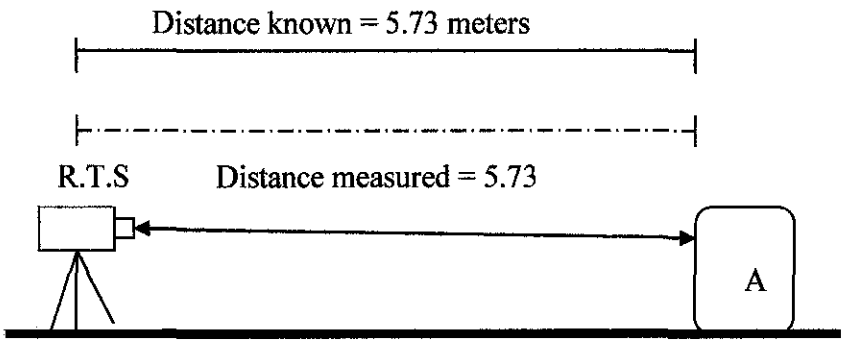

Figure 7: Calibration procedure for reflector-less total station

3.3.3 Field Data Measurement

As for field data measurement, the place to conduct this experiment need to be determined carefully to avoid any possible error that can lead to inaccurate result. Besides, the surface material of the observation point should be carefully selected and it has been set that the canopy used for this case study is the canopy system along Building 13 and Building 14 of Civil Engineering Department, University Teknologi Petronas (UTP).

The basic concept in monitoring movement of canopy system can be viewed in figure 8. The system can be divided into three stages for obtaining the spatial coordinates of each point to be monitored.

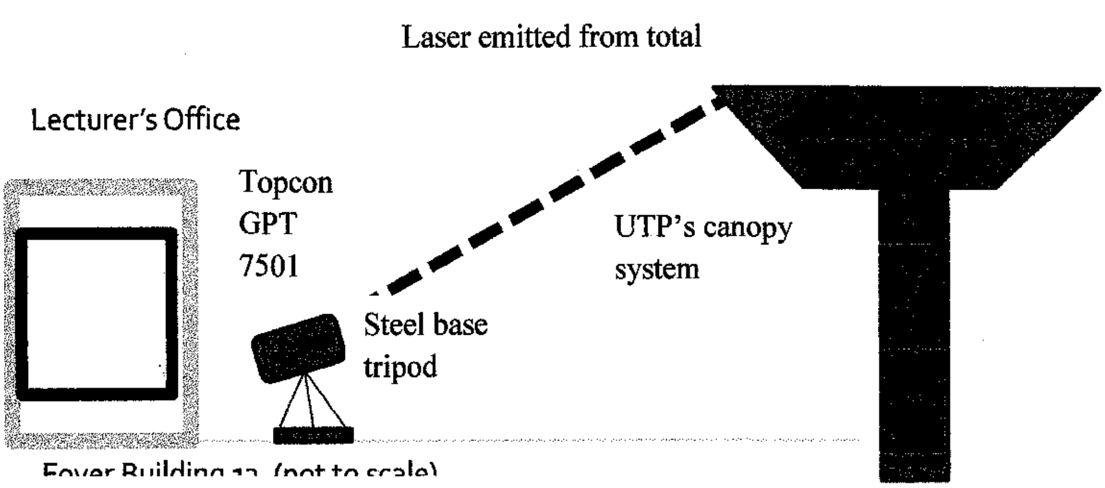

Figure 8: Basic Concept for case study to be performed

There are two methods for reflector-less total station (RTS) works in observing deformation or deflection of desired structure. The two most discussed methods generally can be classified into Phase shift method and Time of flight (Pulse Laser) method.

3.3.3.1 Phase Shift Method

This method works by modulating a measuring signal onto a continuous carrier wave signal. Electronic Distant measurement will eventually transmit a coaxial intensity modulated optical measuring beam that is scattered by a surface on which the beam is directed. The phase difference between the transmitted light and the reflected received light will be detected and it represents the distance between monitored points in horizontal direction.

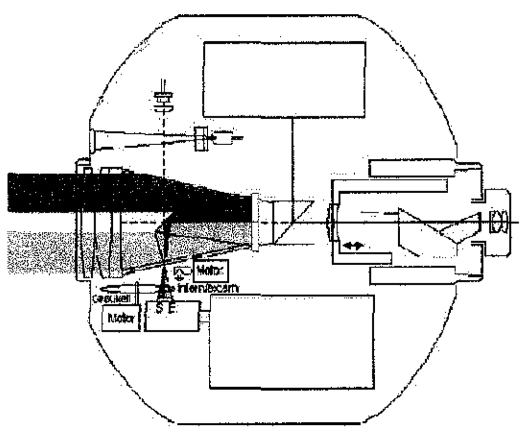

Figure 9: Principle behind phase shift method

The instrument measures a constant phase offset despite inevitable variations in the emitted and received signal. Initially a cycle ambiguity prevents the total distance from being estimated directly, this is resolve using multiple measurement modulation wavelengths which provides a unique integer number of cycles. Once the integer number is achieved, the distance to the target can be very accurately determined. Phase shift technology has the ability to resolve a distance to a remote object to a range of up to 240m with an accuracy of ± (3ppm+2ppm) (Hougland R, 2005).

3.3.3.2 Time of Flight (Pulse Laser)

Time of flight is a method that measures the time information to calculate the range measurement by generating many short infrared or light pulses between the equipment's emitter towards the desired point. The infrared or light pulses transmitted to the target structure through telescope inside the instrument as seen in the figure 10.

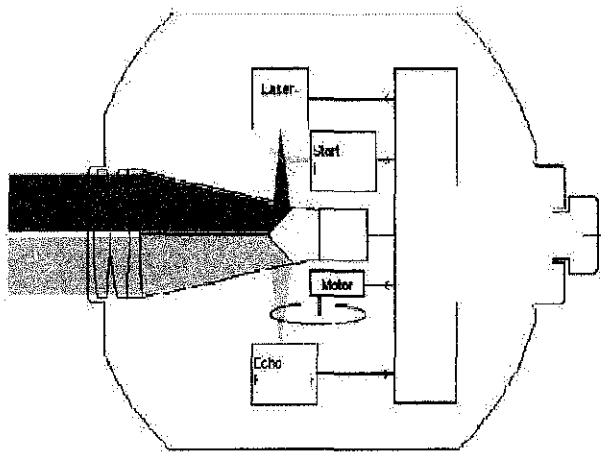

Figure 10: Principle behind Time of Flight (TOF) method

Time of flight method typically produces the longest range while meeting the highest standards for eye safety. It is because the intervals between the laser pulses prevent the accumulation of energy, typically 20000 pulsed laser measurements are taken every seconds.

3.3.3.3 Case Study for Deformation Monitoring.

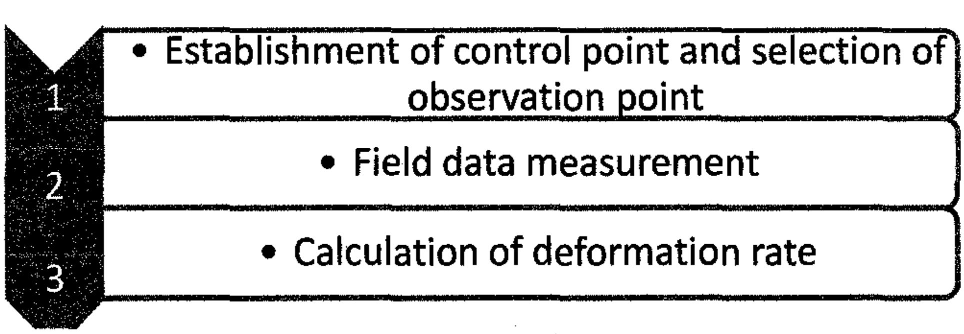

Figure 11: Process Flow on deformation monitoring

1. Establishment of control point and selection of observation point.

As for the establishment of control point, location on the building 14 has been chosen due to its accessibility during weekdays as well as weekend for the monitoring job to be performed. And since this location has given the advantages towards the author for easy access on performing field data measurement, it has been chosen as the place for setting up control station.

Another reason for the selection of this place is because this location gives whole view of the target structure to be monitored without having the obstacle or obstruction. And since the capability of total station in reflector-less mode only able to operate within a maximum distance of 250 meter, this is another reason why this location has been chosen by the author.

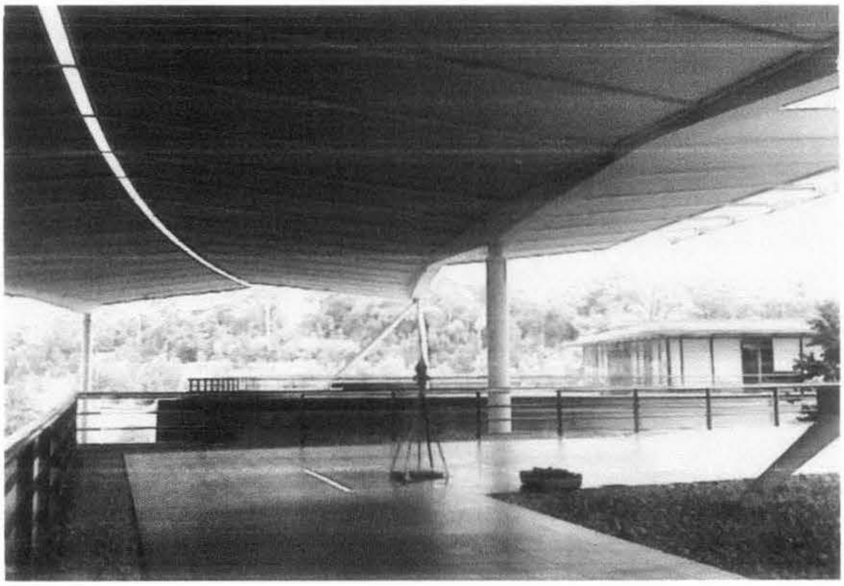

Figure 12: Foyer of building 14, location of control station

After control station has been selected, setting up parameter surrounding the control station is needed to ensure the instrument is not being touched by any people towards the fixed steel base moving from its original position. Therefore in order to do so, the author has put a marking tape and marked the area as a restricted area from any other personnel to enter the area besides the author.

This is the best way in author's mind to avoid interference from external factor such as movement from its original position. This is due to procedure needed to be done if the author chooses to seal the area by having to acquire permission from department as well as university's authority that will definitely consumes more time than needed.

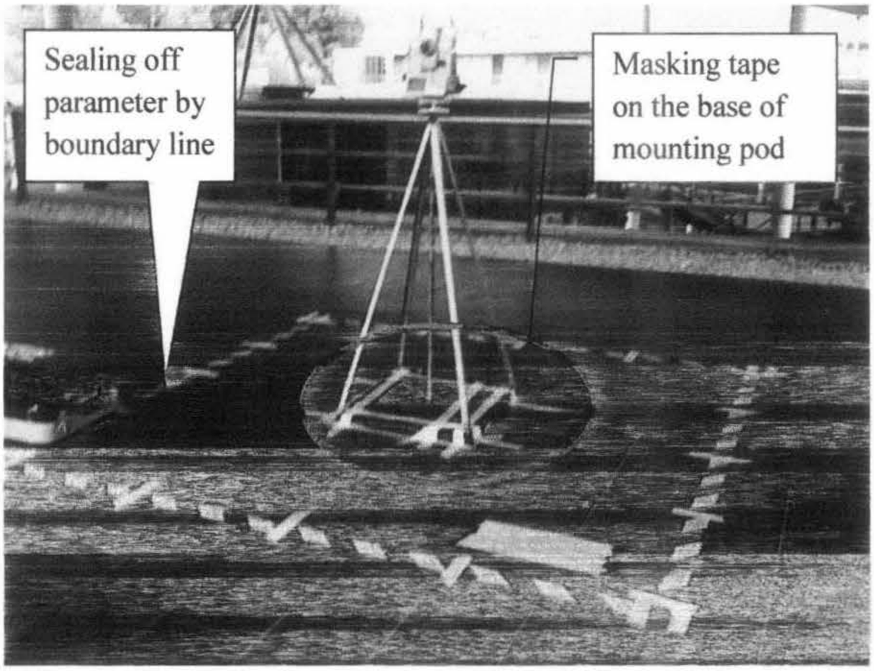

Figure 13: Boundary line for restricted area to avoid possible error due to external forces

The base of fix steel tripod also needs to be kept fixed at all the time towards the ground. This is to ensure there is no slight movement from occurring as such as tilting at the tripod due to wind, vibration from the floor area that might cause error to the reading.

The reason according to figure 13 for putting masking tape on the base of mounting pod is due to deformation of mounting pod as it has not been kept properly and exposed to weather condition. The first idea initially was to put a concrete nail at all edges of mounting pod. But again, the procedure for doing so may be consuming more time as to request for approval from university's authority.

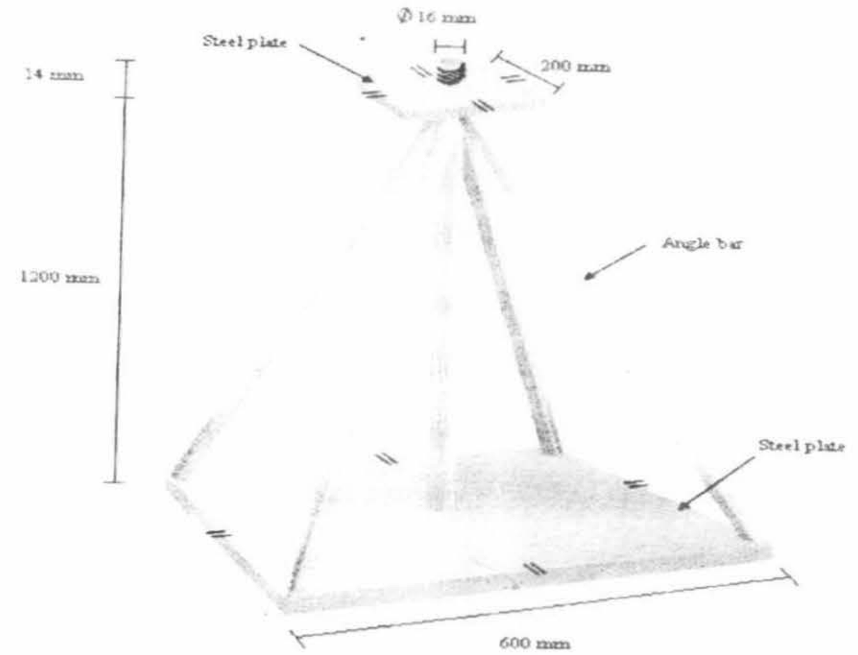

Figure 14: Reflector-less total station mounting pod's dimension

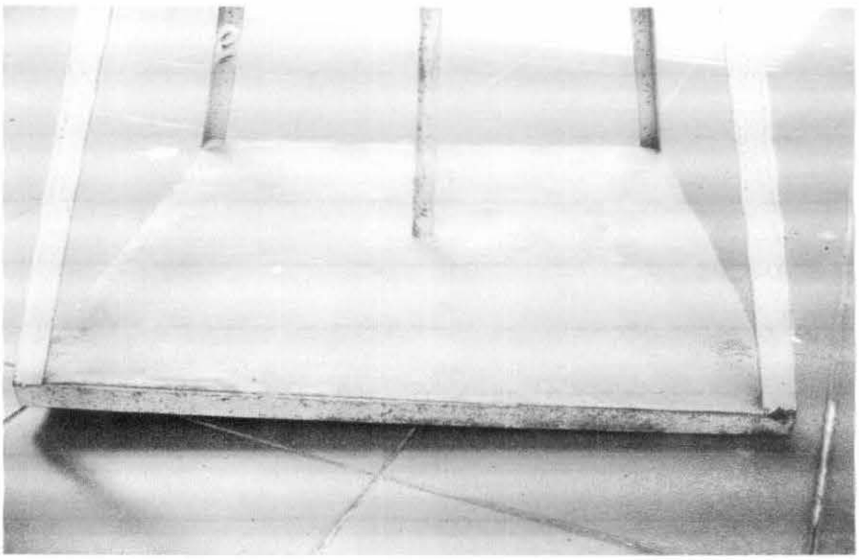

Figure 15: Initial base of mounting pod that has been undergone deformation

As shown in the figure 15, the base of the fix steel mounting pod had undergone deformation and can be tilt easily. Modification has been done towards this tool by adding a series of steel plates at the mounting pod's base in order to make it stable and rigid when it is placed on the ground.

By having modification being performed at the mounting pod, the height now has been increased from initial height mentioned in figure 14. The new height measured from ground to the marking line of reflector-less total station now is 1.500 meter.

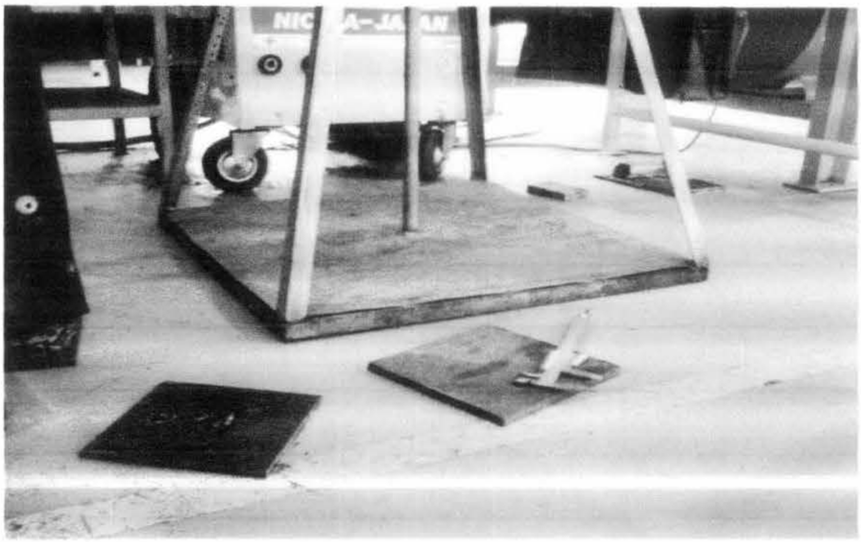

Figure 16: Modification performed at the base of mounting pod

Figure 17: Steel Plate welded at the base of the mounting pod

Reference point also is needed to be established when performing this field data measurement. It is used as a reference to determine the true height of the reflector-less total station from the ground level to reduce the possibilities of error from occurring due to centralizing bull's eye level by using Knuckle screw every time reflector-less total station is attached at the mounting pod.

Figure 18: Reference point used for the field data measurement

2. Field Data Measurement

For the field data measurement, the observation point to be picked must be selected according to the capabilities of reflector-less total station in its reflector-less mode. The maximum capability or distance can be measured by this equipment is maximum 250 meter from the control station. Therefore based on this fact, the author has chosen observation points that are based on author's mind suit the capability of this equipment in giving its best performance and thus reducing possible interference of error towards data obtained.

The author has selected 4 points on the structural beam that is supported by the columns of the canopy system in front of building 14. For selection of observation points, the author has made the secondary steel beam on the canopy system to act as primary mark and drag down until the very edge of the beam itself to be monitored.

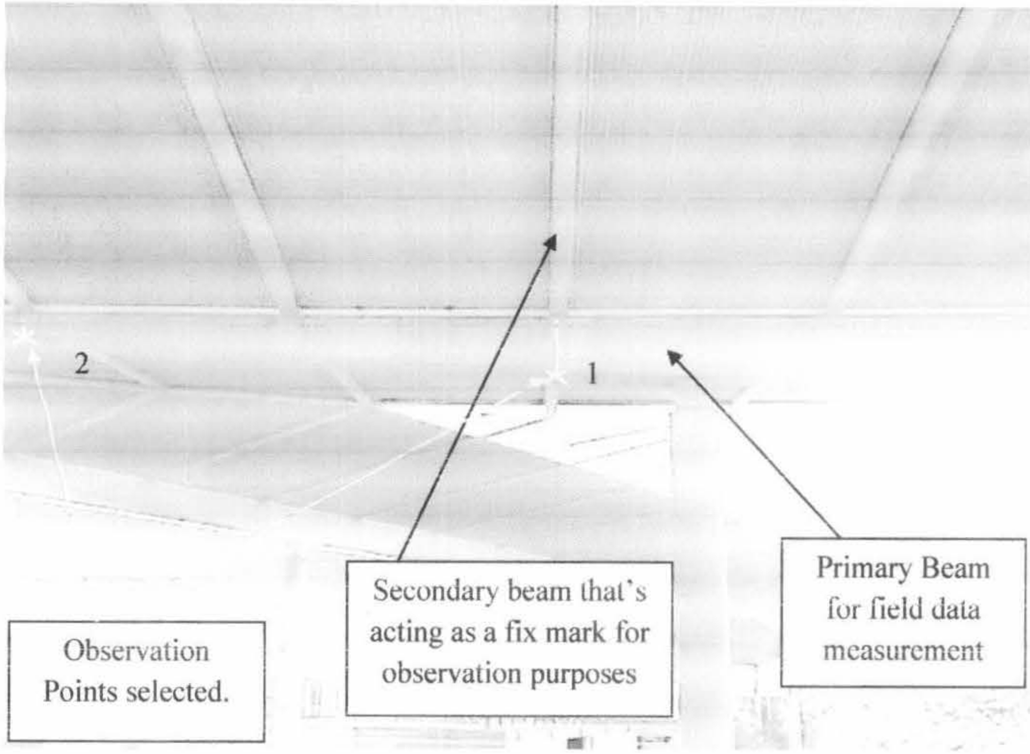

Figure 19: 2 Observation Points at structural beam canopy system on column 3.

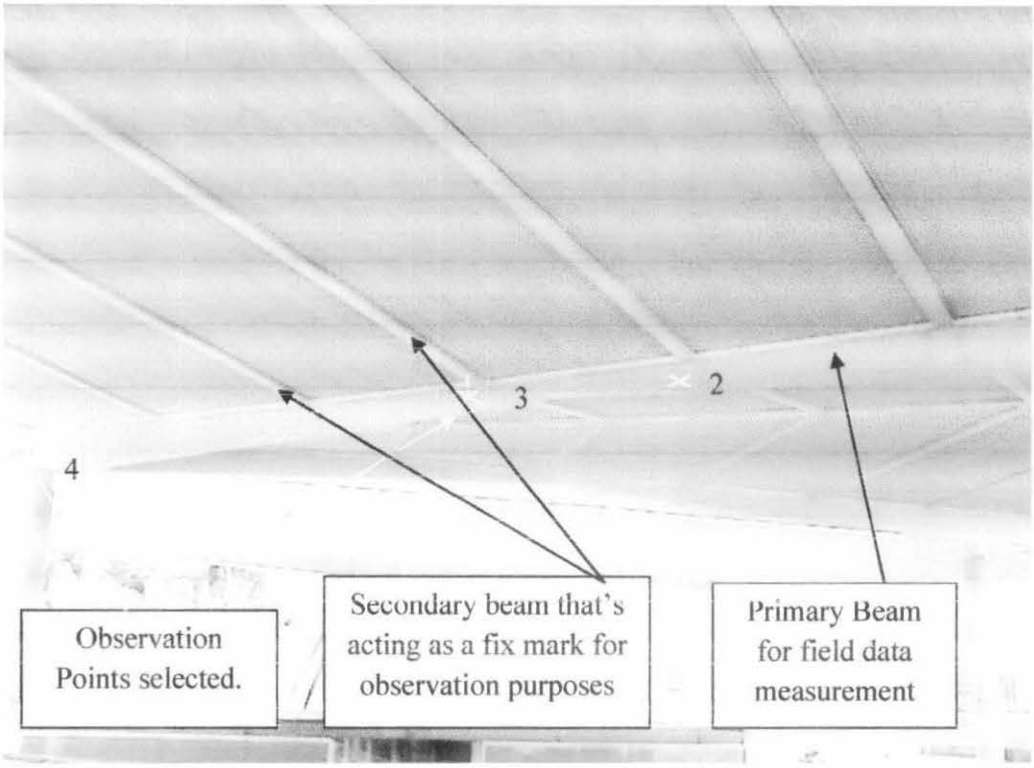

Figure 20: 2 Observation Points at structural beam canopy system on column 4

After the selection of the observation points have been made, setting up reflector-less total station which is TOPCON GPT 7501 series on the mounting pod is performed. The setting up of reflector-less total station can be referred in appendix C in the appendix section for further detail procedure in term of leveling by using Knockout screw as well as centering the bull's eye level.

Data obtained in the end of measurement will then be tabulated in table form by using Microsoft excel software. This is easier to be done as compared to other software that is available in the market. By using Microsoft excel, the validity of the data obtained can be further tested by using statistical analysis that is available within the software itself. An example of the table that will be used for data computation can be seen in table 2.

<u>Structural Beam Canopy System column 1</u>

Table 2: Table for data computation recorded by Topcon GPT 7501

Points	Control Station	Northing (Y)	Easting (X)	Zenith (Z)	ΔX Planes	ΔY Planes	ΔZ Planes	Total Displacement
1	1							
2	1							
3	1							
4	1							

<u>3. Calculation of the displacement and total displacement.</u>

As for time 1, laser will be transmitted from the Topcon GPT 7501 series towards the edge of the roofing system. And as soon as the laser transmitted reached the surface material, it will be reflected back towards the total station and give result in term of $northing_1$ (y_1-axis), $easting_1$ (x_1-axis) and $zenith_1$ (z_1-axis) coordinates.

For time 2, laser will be transmitted again from the reflector-less total station (RTS) towards the same point location as the first reading obtained. The process remains the same but this time, the spatial coordinates obtained will become the second reading which is $northing_2$ (y_2-axis), $easting_2$ (x_2-axis) and $zenith_2$ (z_2-axis).

$$Displacement = (X_2, Y_2, Z_2) - (X_1, Y_1, Z_1)$$

X_2,Y_2,Z_2 = Northing, Easting, Zenith data for 2nd monitoring

X_1,Y_1,Z_1 = Northing, Easting, Zenith data for 1st monitoring.

Thus, the second spatial coordinate will minus the first spatial coordinate obtained in order to determine the displacement of structure. And as the monitoring is being performed, the different will be recorded and tabulated into a table system as similar in table 2.

Then after having two different spatial coordinate in term of northing (y axis), easting (x axis) and zenith (z axis), total displacement is obtained by using next equation as follow.

$$\textit{Total Displacement}, \text{ d} = \text{Square root} (\Delta x^2 + \Delta y^2 + \Delta z^2)$$

Once the table has been completed, all the spatial coordinates recorded by reflector-less total station (RTS) will be collected manually by the author. Then this data will be graphed to show the total displacement having by the structure.

3.4 Gantt Chart for the field data measurement

The workflow of the field data measurement has been planned in the early phase of the commencement final year project 2. The timeline for the gantt chart can be seen in appendix section E for both final year project 1 and final year project 2.

3.5 Milestone for the field data measurement

The milestone that has been discussed with the assist of supervisor can be seen in the attachment at appendix section. The process workflow can be found in appendix F of this report.

CHAPTER 4
RESULT AND ANALYSIS

4.1 Calibration of Equipment

Calibration of the reflector-less total station has been done in a control environment at the laboratory of civil engineering department. The calibration process involves a known distance that has been measured by using measuring tape (5.73 meter) to be compared with the distance given by data recorded from reflector-less total station.

The reason for calibration not to be done outside of control environment is to avoid the possibilities of error from happening towards the measurement being performed. In this case Topcon GPT 7501 series is used along with single prism in performing calibration process. Result obtained by the reflector-less total station has given a result of 5.7476 meter. Based on the data recorded by reflector-less total station, differences is only by 1.76 centimeter or equal to 17.6 millimeter with the known distance by using measuring tape.

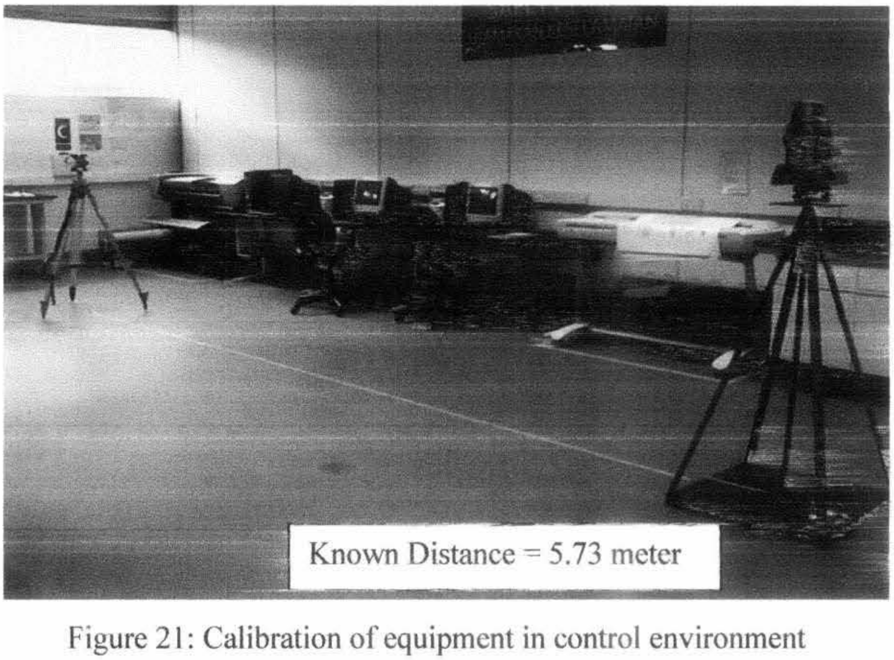

Figure 21: Calibration of equipment in control environment

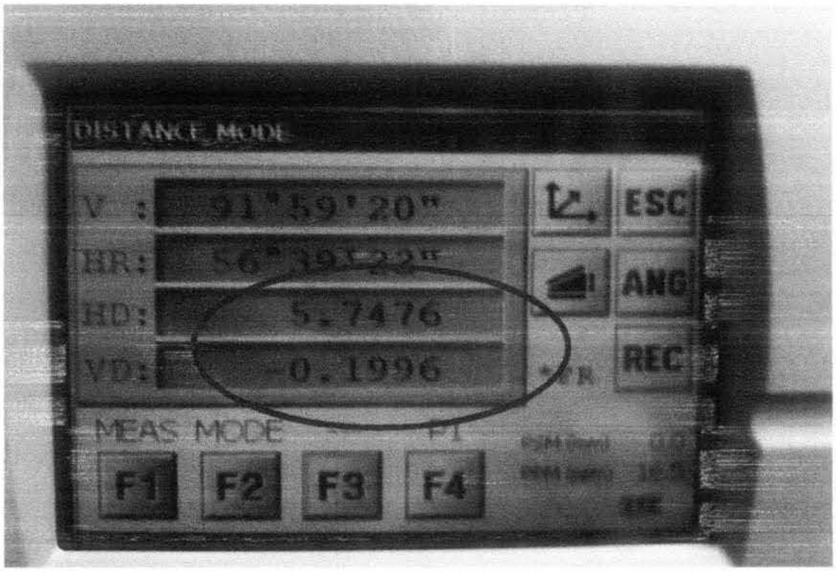

Figure 22: Confirmation distance from reflector-less total station

4.2 Field Data Measurement

As for the field data measurement, it has been successfully recorded for the structural beam canopy system in front building 14 of Universiti Teknologi Petronas (UTP) for the 5 readings. The structural beam canopy system as shown in figure 19 to figure 20 had been observed by using Topcon GPT 7501 series in its non-prism mode.

As according to the manufacturer's claim, the accuracy of reflector-less total station is ±5 millimeter. When the subtraction of data is done, the accuracy of the equipment will be 10 millimeter or 1 centimeter. The explanation of this accuracy can be seen below:

1) 1^{st} data obtained, = 1048.3596 E, 1051.4490 N, 107.3666 Z
2) 2^{nd} data obtained, = 1048.8460 E, 1051.6562 N, 107.3662 Z
3) Deformation rate, = 0.4864 E, 0.2072 N, 0.0004 Z
4) Total displacement, = 0.5287 m ± 10 mm
= 52.9 cm ± 1 cm.

Based from the explanation shown, the displacement of the structure under displacement can either be 53.9 centimeter or 51.9 centimeter displacement occurred. During the field data measurement, 2 observation points on column 3 and 2 observation points on column 4 has been selected. The movement occurred in term of all axes has been calculated by using the equation mentioned in chapter 3.

4.2.1 Structural beam canopy system

For field data measurement recorded, the data obtained for the spatial coordinate shows an insignificant movement towards all axes in term of millimeter movement. Table 3 below shows the computation of displacement recorded by Topcon GPT 7501 series in 4 time series. The movement recorded by reflector-less total station is in meter unit and had been converted into millimeter for making clear observation towards detail movement that happened at the structure.

Table 3: Field data measurement recorded at all the observation points

Points	Deformation Rate time series 1 (mm)			Deformation Rate time series 2 (mm)		
	ΔY	ΔX	ΔZ	ΔY	ΔX	ΔZ
1	0	10	1.8	4.4	2.4	1
2	-0.4	-1.4	-1.6	0.8	0	-0.4
3	0	0.4	-0.8	0	0.2	-0.6
4	-1.2	1.6	0.6	-0.8	1.6	0
Points	Deformation Rate time series 3 (mm)			Deformation Rate time series 4 (mm)		
	ΔY	ΔX	ΔZ	ΔY	ΔX	ΔZ
1	4.6	3.2	1	3.2	7.4	2
2	0	-0.2	-1	0.4	-0.6	-1.2
3	0.4	2.8	-0.4	-0.8	1	-2
4	0	3.2	-0.2	-0.8	3.2	0

The movement recorded in meter unit will show the actual movement that has been recorded towards the observation points. Therefore, conversion from meter unit to millimeter is essential in order to observe the small movement undergone by the structure for indicating the external factors such as due to weather factor as well as wind factor.

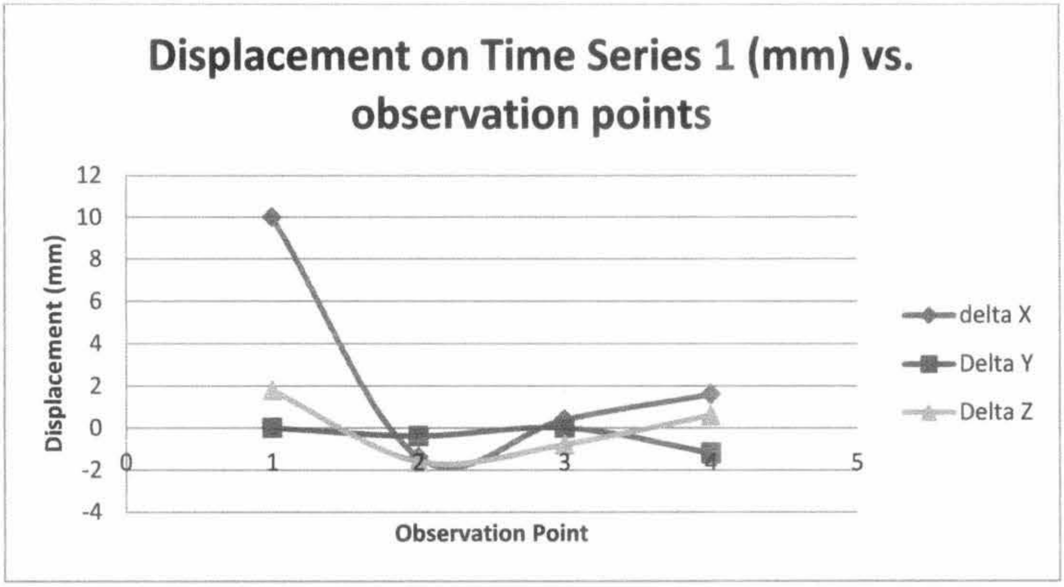

Figure 23: Displacement (mm) for Time series 1 at all observation points

Figure 23 above shows the displacement in term of millimeter for time series 1 where the initial base value recorded has been subtracted with the second data field measurement being performed.

For displacement in X-axis, the first data reading has recorded 10 millimeter movement at observation point 1 and the lowest value is 0.4 millimeter at point observation 3. While for Y axis, the movement recorded for time series 1 based on the graph shown above is having 0 millimeter movement at observation point 1 and decreasing value with 0.4 movements.

The maximum displacement recorded is at the observation point 4 with 1.2 millimeter movement but it occurs in the opposite plane direction as the value obtained is a negative value. For the observation point 3, the displacement recorded is 0 millimeter. As for the Z-axis, the initial base value recorded due to it has undergone an uplift situation towards the canopy system up to 1.8 millimeter at observation point 1 and the value obtained for observation point 2 shows the movement has been encounter in opposite direction with 1.6 millimeter. As for observation point 3, the movement is 0.8 millimeter in different direction and it is being encountered by the movement obtained at the observation point 4 with 0.6 millimeter.

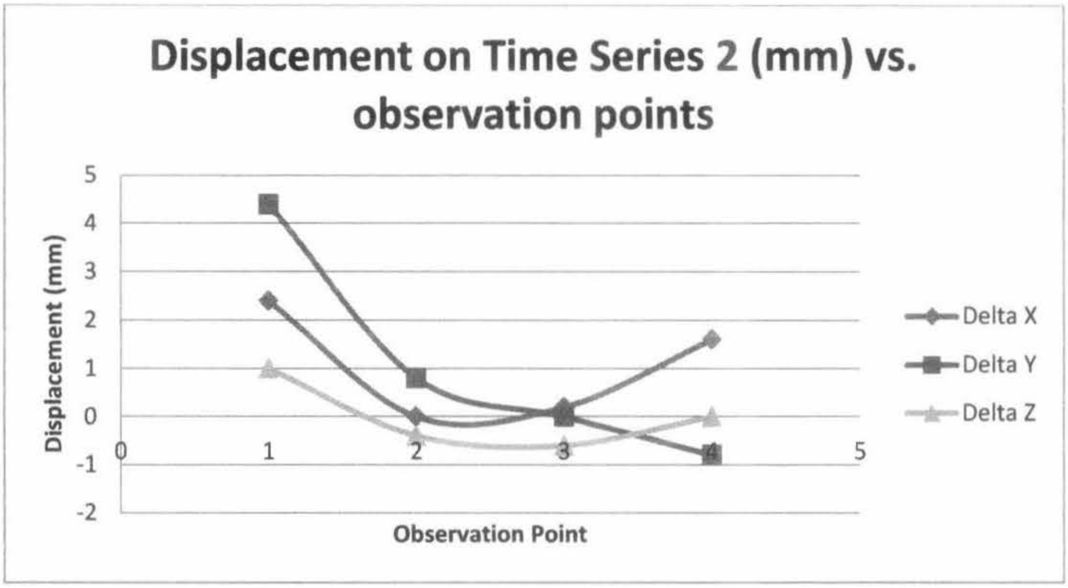

Figure 24: Displacement (mm) for Time series 2 at all observation points

From figure 24, the graph shows the displacement recorded at the observation points for time series 2. The displacement in X-axis now has been reduced to 2.4 millimeter compare to the previous movement recorded at observation point 1 for time series 1 with 10 millimeter movement. On the observation point 2, there is no displacement occurred in X-axis that has been recorded while for observation point 4, the displacement is 1.6 millimeter.

For Y-axis, the displacement having by the observation point 1 is 4.4 millimeter and shows the maximum displacement as compare to others observation points in the same plane. The displacement at observation point 2 is 0.8 millimeter and being balanced by the movement at observation point 4 with the same movement which is 0.8 millimeter as well but is acting in opposite direction. While for observation point 3, there is no movement has been recorded. The cause of this major movement at the observation point 1 can be said due to wind load acting on the structure by swaying it in Y-axis.

As for Z-axis or zenith axis, the movement recorded by the Topcon GPT 7501 series shown the displacement having by observation point 1 is 1 millimeter. But the movement occurred at the observation point 1 is being balanced by the movement at observation point 2 and 3 with the value of 0.4 millimeter and 0.6 millimeter both in different direction. As for observation point 4, there is no movement has been recorded in this time series.

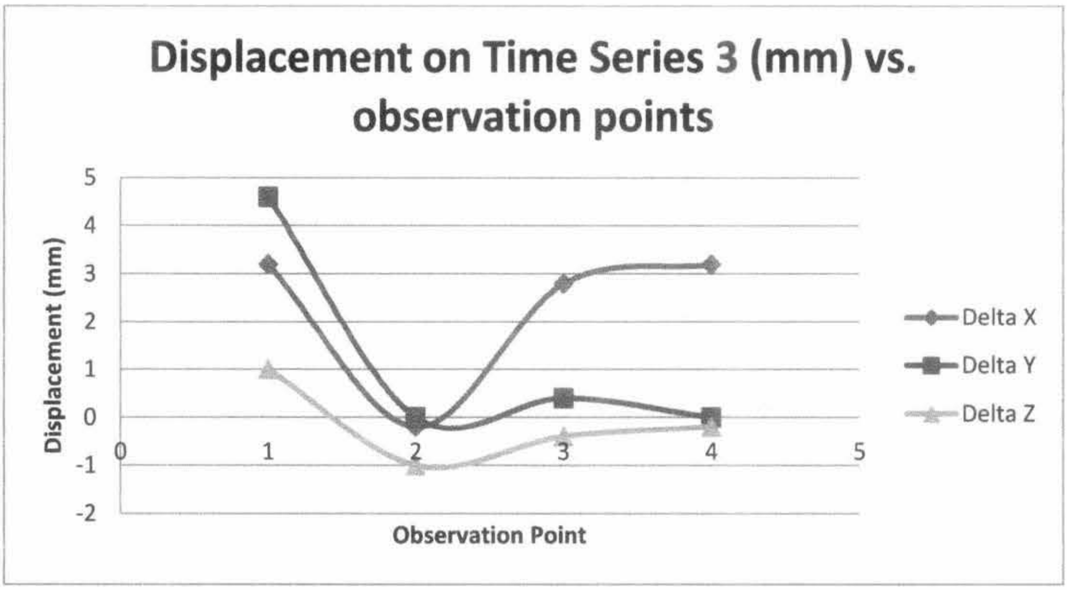

Figure 25: Displacement (mm) for Time series 3 at all observation points

As for figure 25, the displacement calculated for time series 3 shows a major movement has been recorded especially at observation point 1. In both X and Y axes, the observation points are having a high movement with 3.2 millimeter and 4.6 millimeter. At the observation point 2, the movement for X axis is 0.2 millimeter and point 3 is 2.8 millimeter. As for observation point 4, the movement recorded is 3.2 millimeter same as the movement having by the observation point 1.

At both observation point 2 and 4, there are no movement has been recorded. While for observation point 3, the displacement recorded is 0.4 millimeter. While for Z axis, still at observation point 1, the movement is 1 millimeter but it has been encountered by the movement from observation point 2 with the same value but acted in the opposite direction of plane. As for observation point 3 and 4, the movements recorded are 0.4 millimeter and 0.2 millimeter in opposite direction of the Z-axis.

The reason for major movement occurred in all three axes at observation point 1 in this time series can be assumed that it has been caused by wind loading imposed on the structure and thus causes the movement recorded. Besides, the field data measurement has an error occurred such as the bull's eye level is not in center position after wind hitting on the Topcon GPT 7501 series.

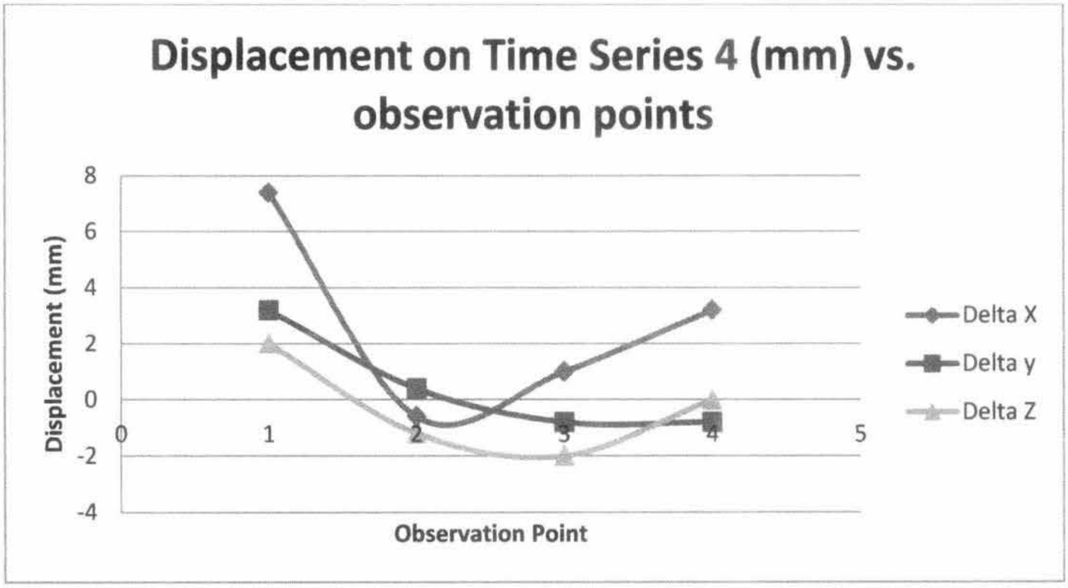

Figure 26: Displacement (mm) for time series 4 at all observation points

Figure 26 above shows the displacement having by the canopy system for time series 4. The graph computed shows that the movement in X axis is having the highest movement with 7.4 millimeter at observation point 1. While for observation point 2, the movement is 0.6 millimeter in opposite direction and for observation point 3 is 1 millimeter. While for observation point 4, the displacement recorded is 3.2 millimeter.

As for Y axis, the displacement from the graph shown is still having the highest displacement at observation point 1 with 3.2 millimeter movement. At observation point 2, the displacement recorded is 0.4 millimeter while for observation point 3 and 4 both shows the displacement is 0.8 millimeter in the opposite direction. While for Z-axis, the displacement recorded at observation point 1 again still is the highest value with 2 millimeter. But the displacement having by observation point 1 is being encountered by displacement at observation point 3 with

2 millimeter in the opposite plane direction. As for observation point 4, there is no movement has been recorded.

Table 4: Total Displacement (cm) for all observation points calculated.

Points	Total Displacement 1 (cm)	Total Displacement 2 (cm)	Total Displacement 3 (cm)	Total Displacement 4 (cm)
1	1.0161	0.5111	0.5692	0.8307
2	0.2163	0.0894	0.1020	0.1400
3	0.0894	0.0632	0.2857	0.2375
4	0.2088	0.1789	0.3206	0.3298

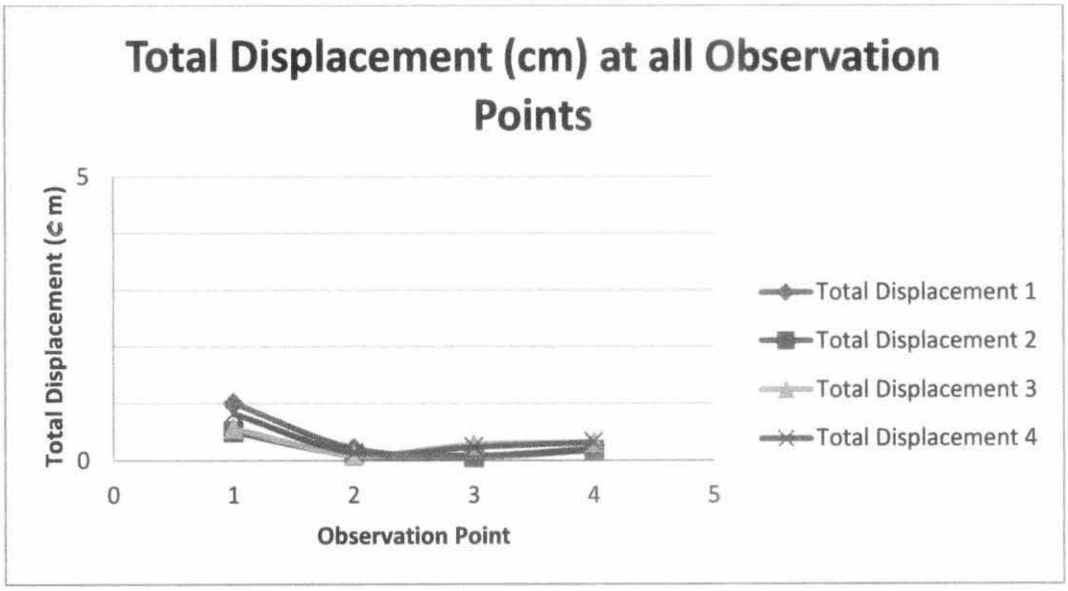

Figure 27: Total Displacement at all observation points

Table 4 and figure 27 above shows the total displacement undergone at all the observation points for the whole section in the field data measurement. Based on this calculated value, the average in these 4 calculated total displacement has been averaged to obtain the mean average value for the actual displacement having by the structure. The total displacement recorded in the graph of figure 27 shows the movement is in the same pattern for the whole observation points where the movement recorded is having a maximum displacement at observation point 1. As for observation point 2,3, and 4, the displacement having by these three points are in the same value that is almost equal to 0 centimeter.

As the specification mentioned that the actual accuracy in non-prism mode is ±5 millimeter and based on the explanation under section 4.2, the movement is less than 1 centimeter. Therefore, there is no displacement having by all of the observation points as the result is insignificant since the value calculated above in table 4 except for point 1 in total displacement 1, is less than the accuracy value of ±10 millimeter. For total displacement 1, the movement occurred after subtraction being done is 1.61 millimeter.

4.3 Statistical Analysis

Based on the data obtained from the field data measurement, validation on the accuracies on the movement by reflector-less total station still need to be performed. In order to check the data obtained, there are few possible methods that can be implemented in order to validate the result obtained. The methods are regression analysis, chi-square test, ANOVA or analysis of variance test as well as student t-test analysis.

There are various methods available to be used in order to perform statistical analysis towards the obtained data. As for this field data measurement's validation, three statistical analysis methods has been found that can be used. One is ANOVA or analysis of variance, student t-test analysis and regression analysis. And these methods can use Microsoft excel software to make an assessment towards data computation [26].

Analysis of variance or ANOVA test will calculate the probability of the observed point or greater differences among it. This field data measurement is involving various data being recorded, therefore both of this test are seems applicable to be implemented.

As for time being, the author still need to learn more on this topic as the author still has not familiarized with the methods. The knowledge gain is still not adequate for the author to make necessary steps in order to validate the data obtained. This statistical analysis can be further research on it in the higher level of studies for example, focusing on this subject as to validate the result for post-graduate studies.

As to overcome this problem, the author has chosen another method to validate the data obtained from field data measurement by calculating the mean average value of the data as well as standard deviation. From the Standard Deviation calculated towards the total displacement having by the structure can be used in determining on which displacement is within one standard deviation of the mean.

Table 5: Mean average value and Standard Deviation of the total displacement

Points	Total Displacement		Mean Average	Standard Deviation
	Time series	(cm)		
1	1	1.0161	0.7318	0.2351
	2	0.5111		
	3	0.5692		
	4	0.8307		
2	1	0.2163	0.1369	0.0571
	2	0.0894		
	3	0.1020		
	4	0.1400		
3	1	0.0894	0.1690	0.1093
	2	0.0632		
	3	0.2857		
	4	0.2375		
4	1	0.2088	0.2595	0.0769
	2	0.1789		
	3	0.3206		
	4	0.3298		

Table 5 shows, the summary of standard deviation and mean average value for the total displacement in 4 time series at all observation points. Standard deviation of the total displacement by point 1 in time series 1 to 4 is 0.2351 centimeter with mean average value of 0.7318 centimeter. While for point 2, the standard deviation calculated is 0.0571 centimeter with mean average value of 0.1369 centimeter for time series 1 until time series 4.

As for observation point 3, the mean average towards all 4 displacement calculated is 0.1690 centimeter and the standard deviation of the data collected is 0.1903 centimeter. While for the last observation points, the mean average value calculated is 0.2595 centimeter and the standard deviation is 0.0769 centimeter.

4.4 Possible interference of errors

4.4.1 Source of Errors

This result obtained has source of error that may occur due to human error as well as instrument error. The eye movement of the author may have selected different point rather than the fixed point that has been recorded. Besides, the base for supporting the reflector-less total station on top of it should be rigid and should not have any movement as with a slight movement occurs.

If the base is not rigid, it would cause error towards reading as the bubble mark in the reflector-less total station mode is highly sensitive. Even with the occurrence of wind nearby the reflector-less total station, it caused the electronic bubble meter not in center position and causing some error towards the reading.

Another potential error that may occurred in the field data measurement is the instrument error that can be from internal factor as well as external factor. As for the error that is coming from reflector-less total station, there are 3 kind of error that has been identified which are zero error, scale error as well as reflective error (Bambang Kun Cahyono, Abdul Nasir Matori, 2008).

Another error that may have occurred during the field data measurement being carried out is due to the surface material reflection. Each material has its own reflectivity for the laser beam emitted from total station. Prism has given the lowest value in term of zero error with 2.9 millimeter and the highest zero error is given by tile target with 8.7 millimeter (Nurrohmat Widjajanta et al, 2007).

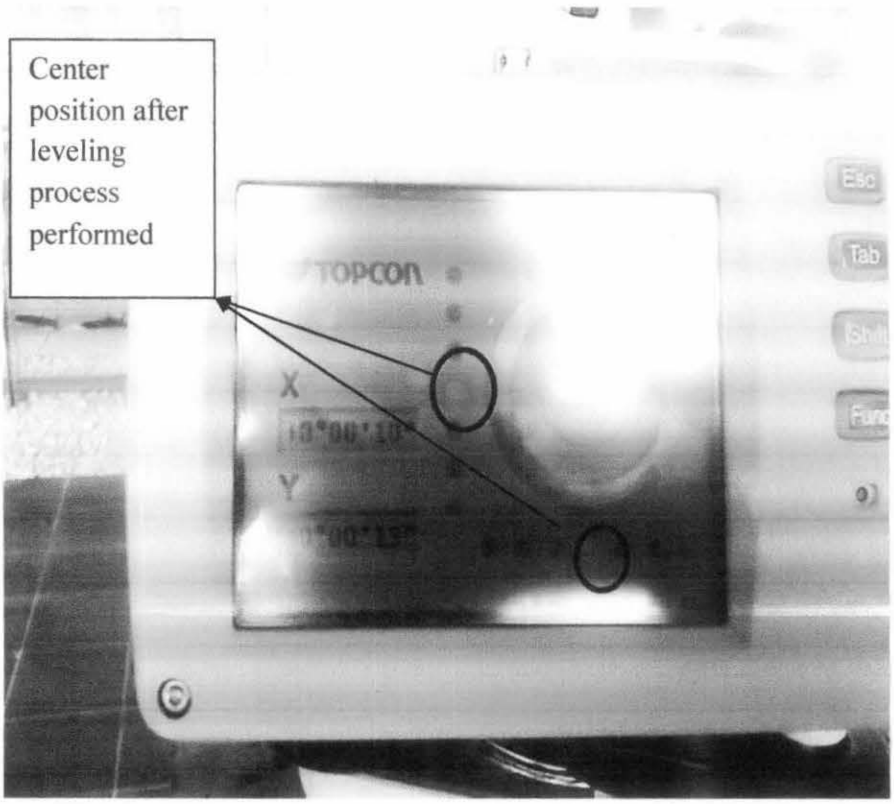

Figure 28: Center of Electronic Circle Level after being level using knockout screw at the equipment

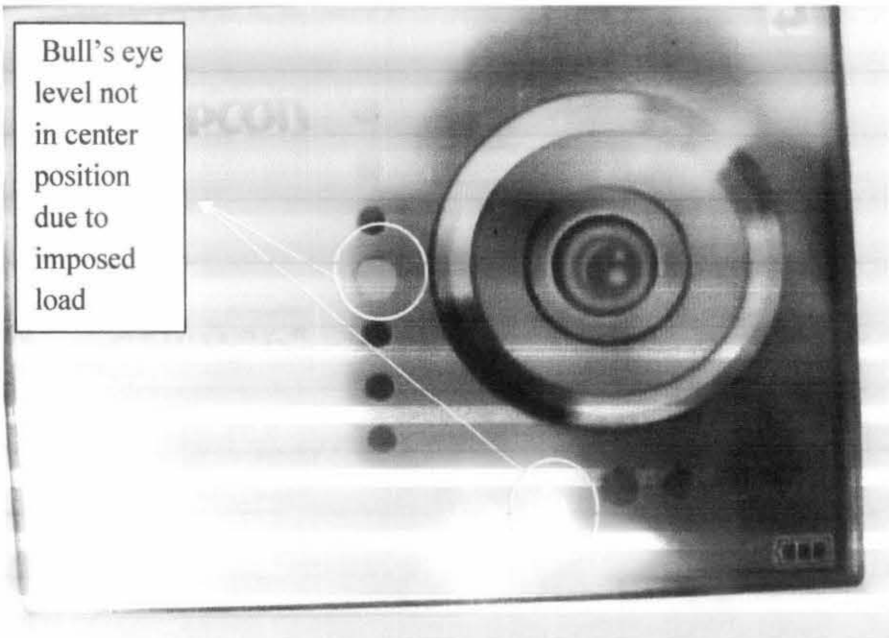

Figure 29: Interruption on the Electronic Circle Level due to Wind acting on the equipment

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Based on field data measurement that has been performed, reflector-less total station has been concluded as not been able to monitor deformation of canopy system. The movement recorded by Topcon GPT 7501 series for this field data measurement shows the displacement having from all the time series towards one another is below the accuracy as specified by the reflector-less total station in its non-prism mode. The movement of the canopy system is supposed not to be permanent and in the end, it will eventually go back to its original position.

As the result and finding found from the field data measurement that shows the displacement having by reflector-less total station is insignificant, this project is successful because the overall objective of this project has been achieved. The objective on testing the capability of reflector-less total station in monitoring deformation of structure has been achieved by the result obtained from field measurement that has been conducted.

5.2 Future work

As for this project, there are definitely more room for future work to be executed. As mentioned in the section 4.2.2, statistical analysis should be further investigated in order to verify the validity of data obtained. Even though calibration result shown that the distance known and calculated by using reflector-less total station is having 0.01 mm differences, statistical analysis still need to be performed and investigated by applying ANOVA test, Student t-test or regression analysis towards the gathered data.

This statistical analysis however needs further and deeper knowledge in order to reach desired outcome. As for future recommendation in the post-graduate studies, this matter can investigated in detail manner.

Another possible continuation from this project also is the checking on the errors that has occurred during the field data measurement being taken. For reflector-less total station, there are to be known three kinds of error that might occur within the instrument itself. As has been specified in the section 4.3.1, Interference of Error, every surface material has its own reflectivity factor according to the color.

Different color will give a different material reflection and based on journal produced in internet, the lowest reading recorded is obtained by the usage of prism compare to other color surface that is acting as a reflector. This error can be further investigated for future work to find the connection of surface color reflectivity with accuracy of data for the post-graduate level by using reflector-less total station.

The project can also be done by using both geotechnical method as well as geodetic method in the same time. The result obtained by using both method then can be compared in order to check and verify either the displacement having by the structure is valid or not. The application of fiber optic sensor (SOFO) system as well as Photogrammetric Method can be utilized fully with the application of Reflector-less Total Station in monitoring the deformation of the canopy system in future work.

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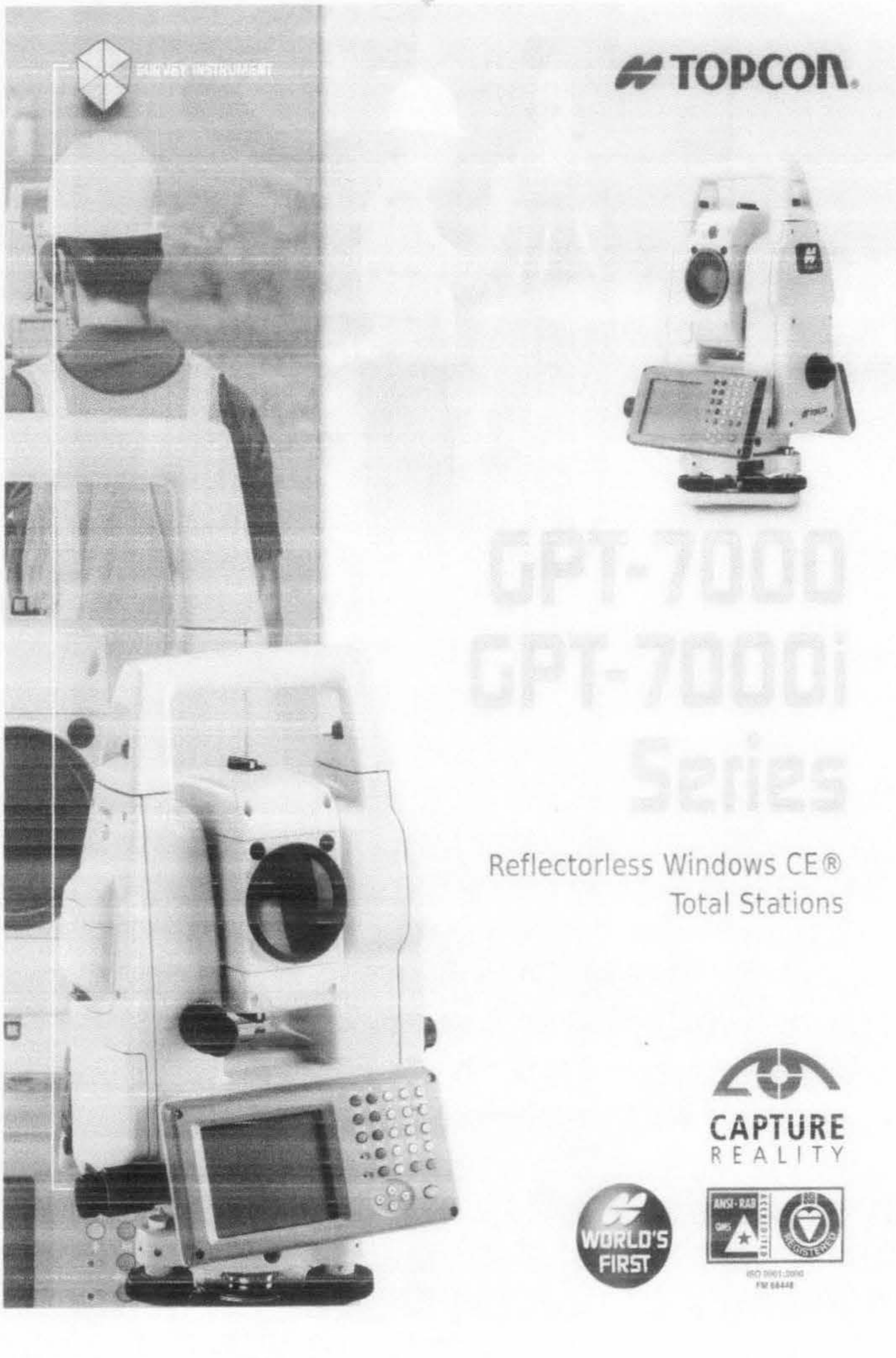
APPENDICES

Appendix A

Topcon GPT 7501 series specification



III


Finally, an on-board solution that makes hands free surveying a reality, with advanced reflectorless capability that outperforms all other instruments in its class! The GPT-7000 series, only from Topcon!
TOPCON
New technology dual optical reflectorless capability
Long range reflectorless operation out to over 820'
Super bright, color, Windows® CE touch screen operation
GUI (Graphical User Interface) boosts your productivity
Built-in CCD Camera with Wide and Finder view (GPT-7000i Series)
Field images recorded with field coordinates data (GPT-7000i Series)
Complete with TopSURV™ on-board data collection software
The GPT-7000 series gives you up to 250m reflectorless range, the longest in its class! Measure up to 3000m with a prism. The unique dual optical EDM design takes pulse laser reflectorless measurement to a higher level. Even at long distances, it maintains focused beam accuracy and allows you to measure only the target you select.
IMAGING TOTAL STATIONS
Capturing the Reality with Revolutionary Technology!
Topcon revolutionizes surveying with another World's First Technology. The GPT-7000i features a built-in digital camera for capturing job site images. The GPT-7000i provides you the best performance and most efficient surveying with precise long range EDM, TFT colour graphic display, and the latest Windows® CE technology, and the addition of image information.
CAPTURE REALITY
At Topcon efficiency and productivity are our priority. By adopting the latest Windows® CE technology, Topcon brings the advantages of the GUI (Graphical User Interface) to a Total Station. The large 3.5" TFT color LCD display is large and bright enough for you to view all your data at a glance. In bright sunlight, it adjusts automatically so you can see the display clearly. And the added advantage of a touch screen increases the convenience and ease of use of the GPT-7000 series. Whether you are an experienced user or just a beginner, the GPT-7000 will allow you to get up and running in no time.
GTS-720 Series
FC-100
GTS-820 Series
GPT-3000W Series

Specifications

Measurement Range

Prism Mode	
1 prism	3,000m (9,900 ft) *
* Condition 1: Sight haze with visibility about 20Km (12.5miles) moderate sunlight with light heat shimmer	
Non-Prism Mode	1.5 - 250m (5 - 820 ft)

Accuracy

Prism Mode	
To 25m	±(3mm+2ppmxD*)m.s.e.
25m or more	±(2mm+2ppmxD*)m.s.e
Non-Prism (1.5m or more)	±5mm

Least Count in Measurement

S. Fine Measurement Mode	0.2mm(0.001 ft)
Fine Measurement Mode	1mm(0.005 ft)
Coarse Measurement Mode	1mm(0.005 ft)
Tracking Measurement Mode	10mm(0.02 ft)

Measuring Time

S. Fine Measurement Mode	0.2mm: Approx. 3.0 sec.(Initial 4.0 sec.)
Fine Measurement Mode	1mm: Approx. 1.2 sec.(Initial 3.0 sec.)
Coarse Measurement Mode	1mm: Approx. 0.5 sec.(Initial 2.5 sec.)
Tracking Measurement Mode	10mm: Approx. 0.3 sec.(Initial 2.5 sec.)

Angle Measurement

Method	Absolute Reading			
Minimum Reading	0.5"/1" (0.1/0.5mgon)	1"/5" (0.2/1mgon)	1"/5" (0.2/1mgon)	1"/5" (0.2/1mgon)
Accuracy	1" (0.3mgon)	2" (0.6mgon)	3" (1.0mgon)	5" (1.5mgon)

Tilt Correction

Type	Dual axis
Method	Liquid type
Compensating Range	±4'
Correction Unit	1"(0.1mgon)

Computer Unit

OS	Microsoft® Windows® CE.NET 4.2
Processor	Intel XPA255 400MHz
Memory	
RAM	128MB (SDRAM)
ROM	2MB (FlashROM) + 256MB (Flash Memory) (A portion is used for pre-installed programs and data management functions)
Display Unit	320 x 240 (QVGA) dots Graphic LCD TFT color display with back lights and touch panel function 2 Sides / 1 Side
Card System	CompactFlash™ Card (Type I/II)

Interface

Serial I/F Port	RS-232C (6 pin)
	USB (Type Mini-B) for ActiveSync®

Level Sensitivity

Circular Level	10'/2mm
Plate Level	30"/2mm

Optical Plummet

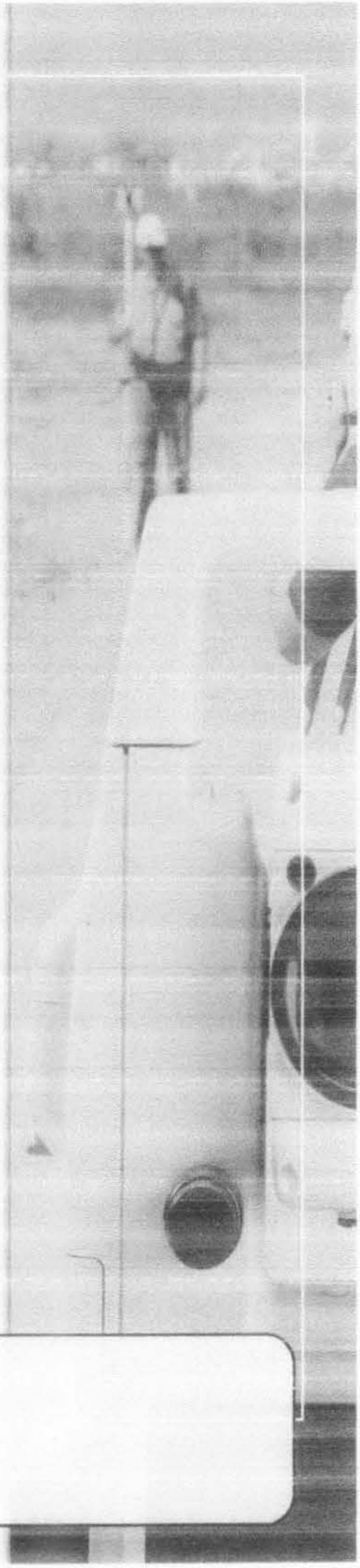
Magnification	3x
Focusing Range	0.5m to infinity
Image	Erect

Durability

Water and Dust	IP54 (Based on the standard IEC60529)
Ambient Temperature	-20°C to +50°C (-4°F to +122°F)

Laser Class

Class 1 (for distance measurement)
Class 2 (Laser Pointer On)

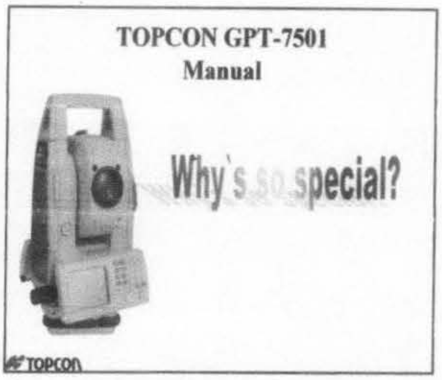


TOPCON
7400 National Dr.
Livermore, CA 94551
Phone: (925) 245-8300

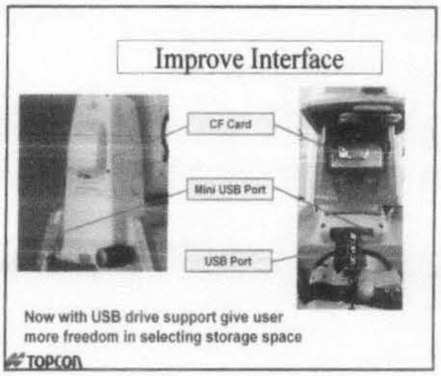
Specifications subject to change without notice

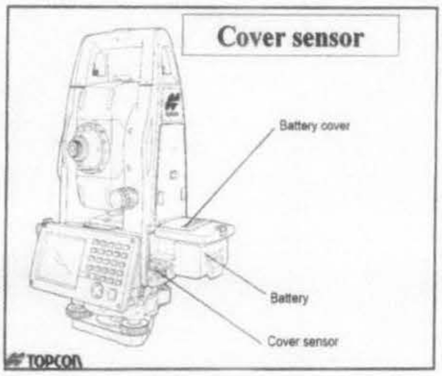
P/N: 7010-0705 Rev. A Printed in U.S.A. 11/04

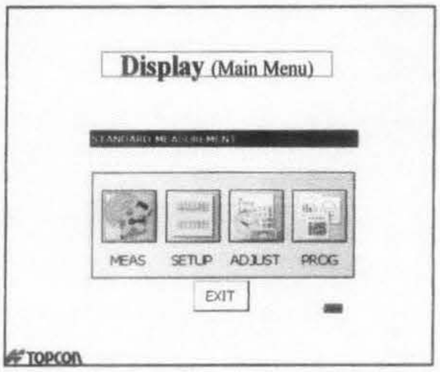
Your local TOPCON dealer is:

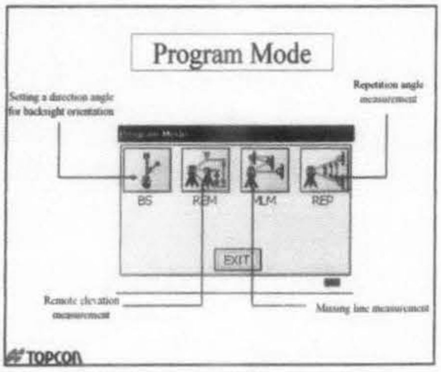

TOPCON GPT-7501
Manual
Why's so special?
TOPCON


Easy Keyboard
GPT-7500 Series
GTS-750 Series
Bigger and brighter Keyboard
TOPCON


Improve Interface
CF Card
Mini USB Port
USB Port
Now with USB drive support give user more freedom in selecting storage space
TOPCON

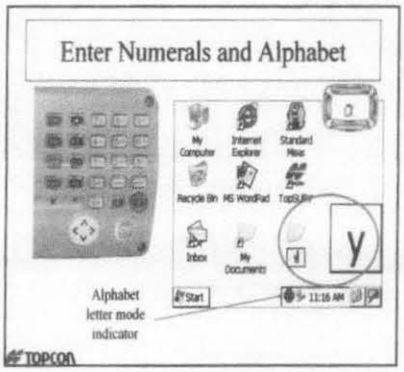

Cover sensor
Battery cover
Battery
Cover sensor
TOPCON

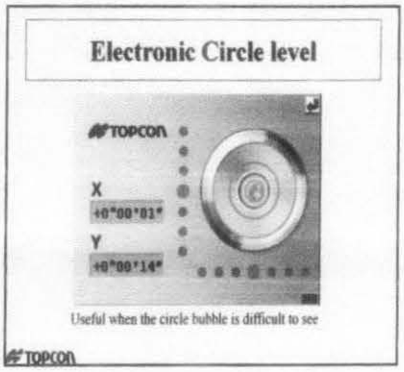

Display (Main Menu)
STANDARD MEASUREMENT
MEAS
SETUP
ADJUST
PROG
EXIT
TOPCON

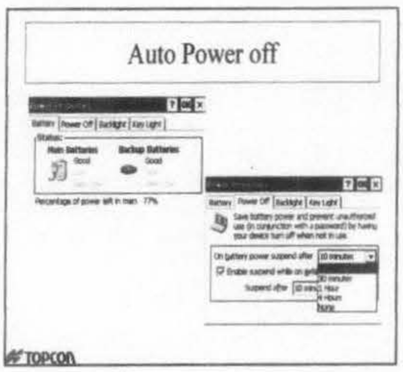

Program Mode
Setting a direction angle for backsight orientation
Repetition angle measurement
Program Mode
BS
REM
MLM
REP
EXIT
Remote elevation measurement
Missing line measurement
TOPCON

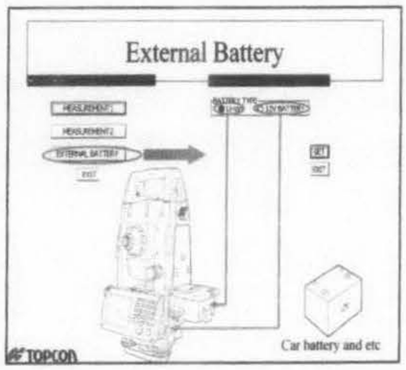

Touch Panel & Operation Panel Keys
F1 F2 F3 F4
Stylus pen
TOPCON


Virtual keyboard
Input Panel
TOPCON

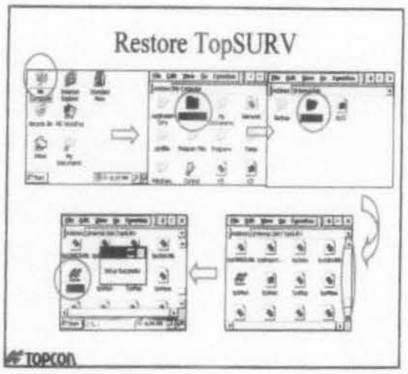

Enter Numerals and Alphabet
My Computer
Internet Explorer
Standard Meas
Recycle Bin
MS WordPad
Inbox
My Documents
Start
Alphabet letter mode indicator
TOPCON

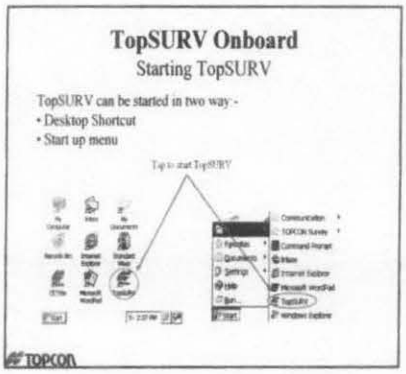

Electronic Circle level
TOPCON
X
+0°00'01"
Y
+0°00'14"
Useful when the circle bubble is difficult to see
TOPCON

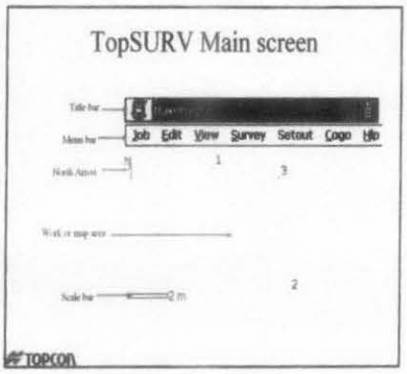

Auto Power off
TOPCON

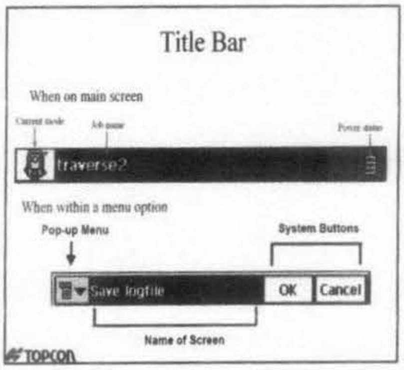

External Battery
Car battery and etc
TOPCON

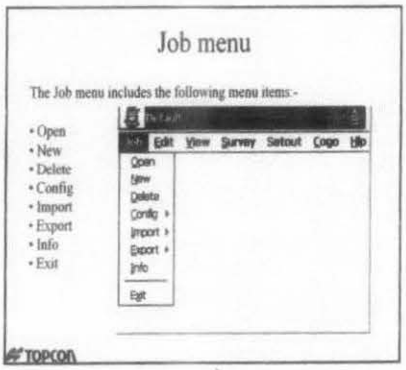

Installing TopSURV
TopSURV OnBoard
Get the Cab file from TSA workshop via email
Copy it into the CF card or USB thumb drive
Copying files...
Cancel
TOPCON


Restore TopSURV
TOPCON


TopSURV Onboard
Starting TopSURV
TopSURV can be started in two way:-
• Desktop Shortcut
• Start up menu
Tap to start TopSURV
TOPCON


TopSURV Main screen
Title bar
Menu bar
Job Edit View Survey Setout Cogo Hlp
North Arrow
1
3
Work or map area
2
Scale bar
TOPCON

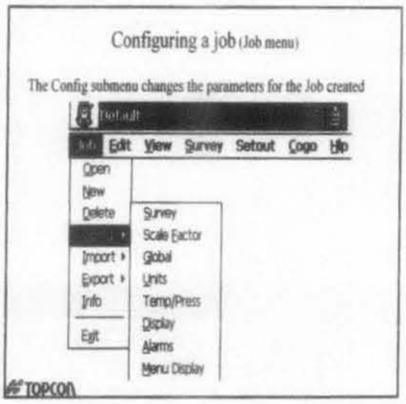

Title Bar
When on main screen
Current mode
Job name
Power status
traverse2
When within a menu option
Pop-up Menu
System Buttons
Save logfile
OK
Cancel
Name of Screen
TOPCON


Job menu
The Job menu includes the following menu items:-
• Open
• New
• Delete
• Config
• Import
• Export
• Info
• Exit
Job Edit View Survey Setout Cogo Hlp
Open
New
Delete
Config
Import
Export
Info
Exit
TOPCON

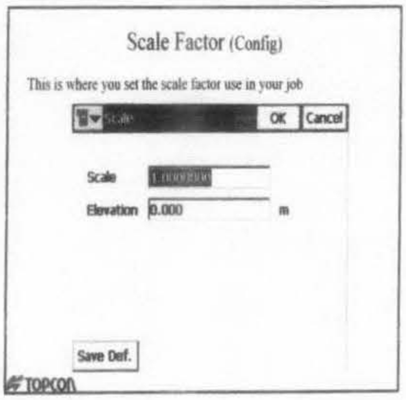

Open (Job menu)
Open job is use to select an open job
Cancel
Current Job:--traverse2
Job List
training
Default
Created:
07/16/2005
14:18
Modified:
07/16/2005
15:14
\Internal Disk\TopSURV\Jobs
Browse
Open
TOPCON

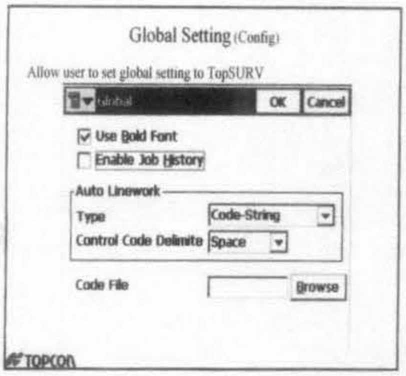

New job (Job menu)
The New Job screen starts the new job creation process all your need to do is just key in the name of the job and etc.
Cancel
Name
training
Created By
teacher
Comments
for testing only
Current Date
5/16/2007 15:38 PM
Create
TOPCON

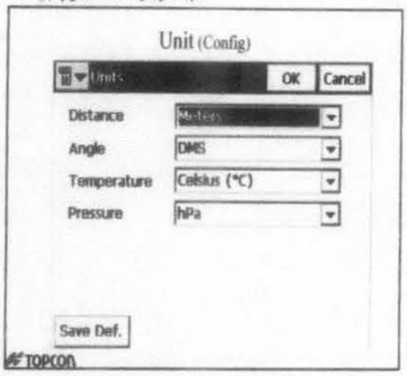

Delete job (Job Menu)
The delete job screen deletes jobs. Once deleted from the job list, the file containing the job chosen is deleted from Total Station
Close
Current Job: test
Job List
traverse2
traverse
Default
Created:
07/14/2005
16:45
Modified:
07/26/2005
18:09
Browse
Delete
Note : Current open job can not be delete
TOPCON

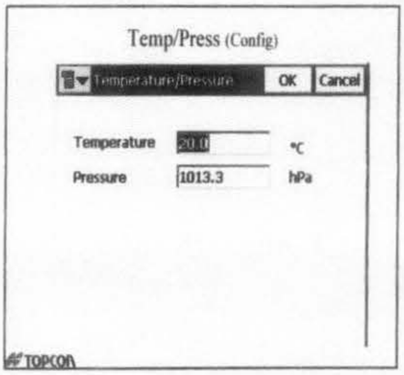

Configuring a job (Job menu)
The Config submenu changes the parameters for the Job created
Default
Job
Edit
View
Survey
Setout
Cogo
Hlp
Open
New
Delete
Import
Export
Info
Exit
Survey
Scale Factor
Global
Units
Temp/Press
Display
Alarms
Menu Display
TOPCON

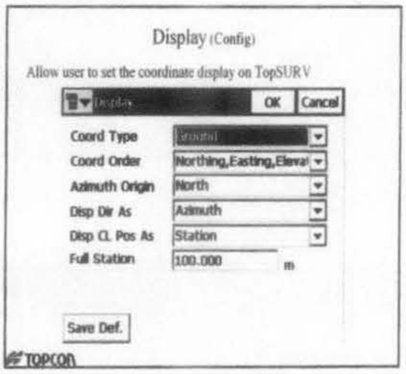

Survey (Config)
The survey is where you set surveying parameter use in your job
TOPCON

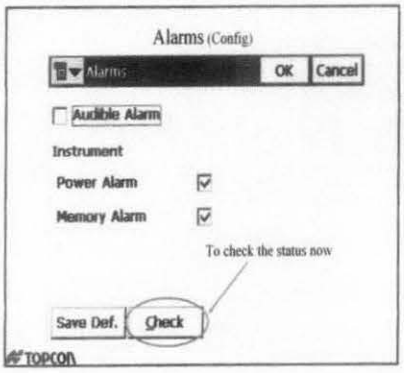

Scale Factor (Config)
This is where you set the scale factor use in your job
Scale
OK
Cancel
Scale
Elevation
0.000
m
Save Def.
TOPCON

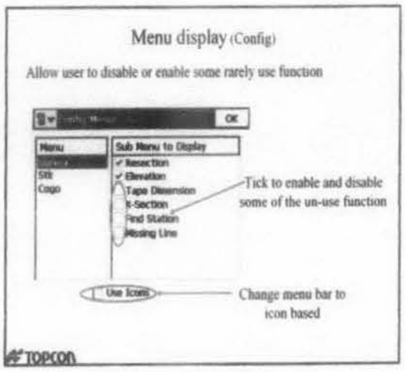

Global Setting (Config)
Allow user to set global setting to TopSURV
Global
OK
Cancel
Use Bold Font
Enable Job History
Auto Linework
Type
Code-String
Control Code Delimite
Space
Code File
Browse
TOPCON


Unit (Config)
Units
OK
Cancel
Distance
Meters
Angle
DMS
Temperature
Celsius (°C)
Pressure
hPa
Save Def.
TOPCON


Temp/Press (Config)
Temperature/Pressure
OK
Cancel
Temperature
20.0
°C
Pressure
1013.3
hPa
TOPCON


Display (Config)
Allow user to set the coordinate display on TopSURV
Display
OK
Cancel
Coord Type
Ground
Coord Order
Northing,Easting,Eleva
Azimuth Origin
North
Disp Dir As
Azimuth
Disp CL Pos As
Station
Full Station
100.000
m
Save Def.
TOPCON


Alarms (Config)
Alarms
OK
Cancel
Audible Alarm
Instrument
Power Alarm
Memory Alarm
To check the status now
Save Def.
Check
TOPCON


Menu display (Config)
Allow user to disable or enable some rarely use function
Tick to enable and disable some of the un-use function
Use Icons
Change menu bar to icon based
TOPCON

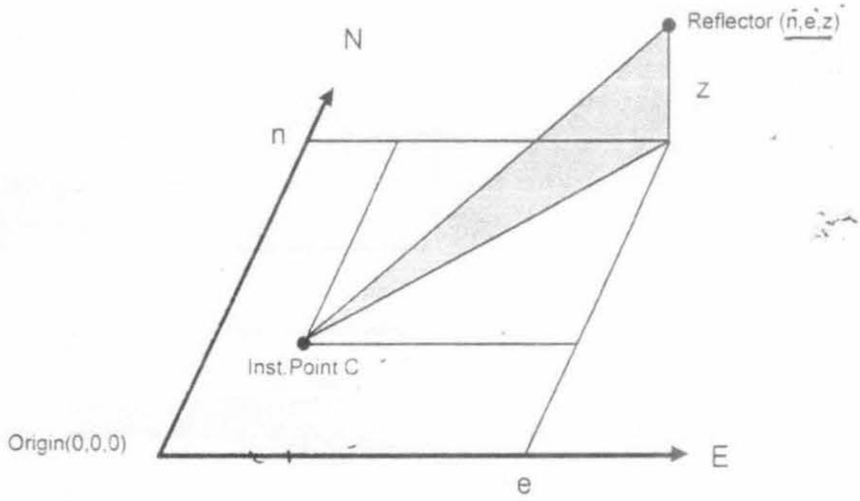
5

Appendix B

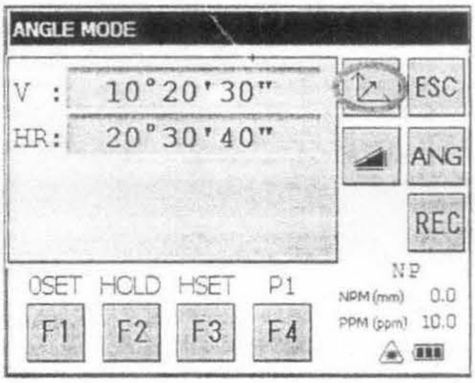
Procedure and Steps involved for obtaining Spatial Coordinate in Reflector-less Mode using TOPCON GPT 7501 Series.

3.3.1 Setting Coordinate Values of Occupied Point

Set the coordinates of instrument (occupied point) according to coordinate origin, and the instrument automatically converts and displays the unknown point (reflector point) coordinates following the origin.

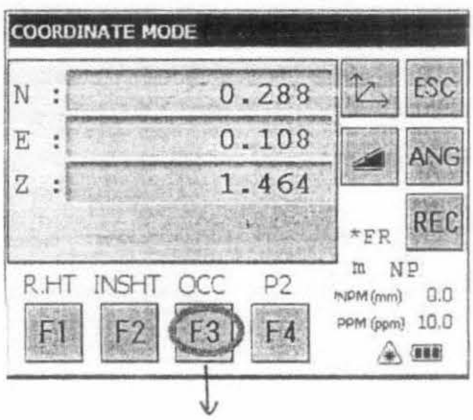


Confirm the angle measurement mode.

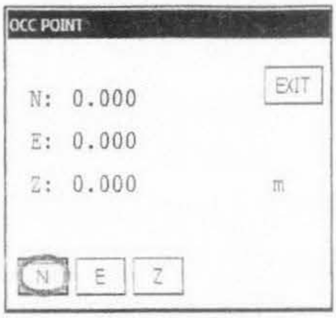


1 Press the [ ] key.

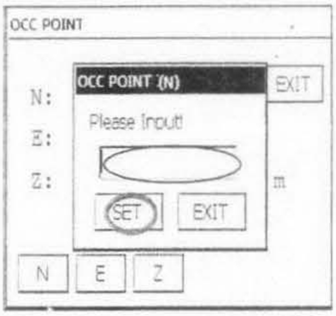
2 Press the [F4] key.



3 Press the [F3] key.
The previous data will be shown.



4 Press the [N] key.



5 Input the N coord.
6 Press the [SET] key.*1)

7 Press the [E] key.
8 Input the E coord.
9 Press the [SET] key.*1)

10 Press the [Z] key.
11 Input the Z coord.
12 Press the [SET] key.*1)
13 Press the [EXIT] key.

The display returns to coordinate measurement mode.

*1)To return to the previous mode, press the [EXIT] key.

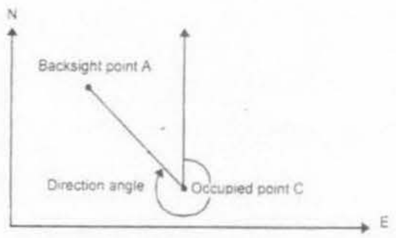
Setting Up Back sight reference Point for Field Data Measurement

4.1 Setting a Direction Angle for Backsight Orientation(BS)

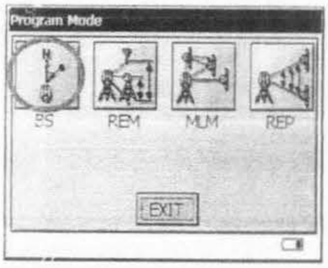
(Entering the instrument and backsight coordinate values)

This program uses the input coordinate values of the occupied point, (instrument), and backsight point to calculate the backsight orientation direction angle.

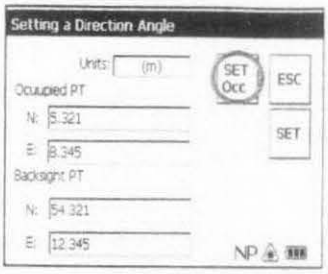
The occupied and backsight coordinate input display appears.
After the coordinate values are entered for both points, the instrument calculates the backsight direction angle for orientation.
Also the occupied coordinate values are stored in memory. The program does not store the backsight coordinate values in memory.



Example: Occupied point C : N coordinate 5.321m, E coordinate 8.345m
Backsight point A : N coordinate 54.321m, E coordinate 12.345m



1 Press the [BS] icon.



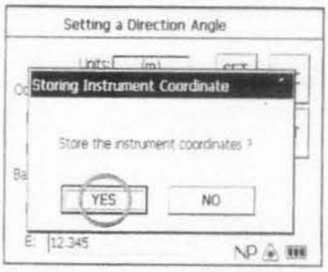
2 Input N and E coordinate of occupied point C.

Example : N coordinate: 5.321m
E coordinate: 8.345m

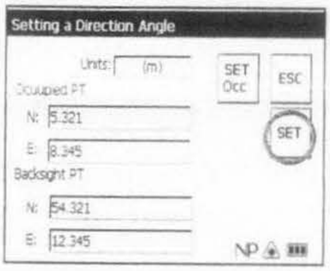
3 Input N and E coordinate of backsight point A.

Example : N coordinate: 54.321m
E coordinate: 12.345m

4 To memorize the occupied point, press the [SET OCC] key.

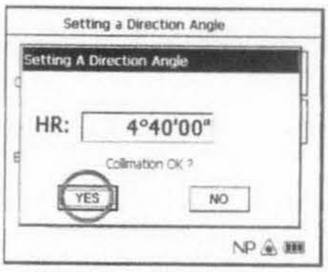


5 Press the [YES] key.



6 Press the [SET] key.

7 Collimate the backsight.



8 Press the [YES] key.

The display returns to Program mode menu.

Appendix C

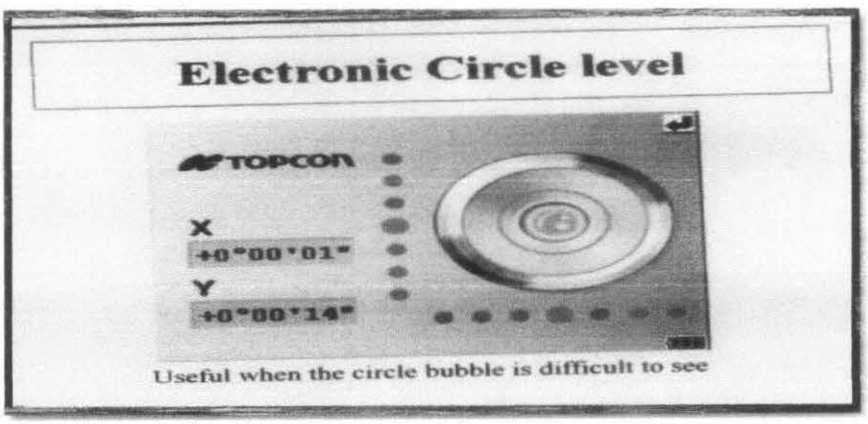
Setting up Reflector-less Total Station (Topcon GPT 7501 Series)

Leveling the Instrument

1. Reflector-less total station is placed on the mounting pod at the fix steel base tripod.

2. Bull's eyes level needs to be centered by using three knuckle screws for better adjustment. After centering bull's eye level, the user need to center line level by first using two knuckles screws concurrently. Then the reflector-less total station needs to be turned 90 degrees, and the third knuckles screw need to be used to center the line level.

Leveling Topcon GPT 7051 Series



Electronic Circle Level of Topcon GPT 7051 Series

Appendix D

Gantt Chart for Final Year Project 1

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Research on the topic : Building Deformation Monitoring														
2	Consultation with the supervisor														
3	Research journal/thesis related to case study														
4	Understanding mechanism involve in advance non prism total station														
5	Extended Proposal Report														
6	Submission Extended Proposal Report														
7	Preparation for Viva presentation														
8	Viva Presentation/ Defending Proposal														
9	Survey potential area for case study to be performed														
10	Familiarizing with equipment														
11	Field Data Measurement														
12	Start performing case study														
13	Submit Draft Report														
14	Submit Interim Report														

Suggested Milestone

Process

Gantt Chart for Final Year Project 2

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Field Data Measurement														
2	Consultation with the supervisor														
3	Research journal/thesis related to case study														
4	Understanding mechanism involve in reflector-less total station														
5	Progress Report														
6	Submission Progress Report														
7	Continue with Field Data measurement														
10	Poster Presentation for Engineering Design Exhibition														
11	Viva Presentation														
12	Draft Final Report														
13	Technical Report Submission														
14	Submit Final Report														

Suggested Milestone

Process

Appendix E

Milestone for Final Year Project 1

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of projects topic														
2	Research on the topic : Building Deformation Monitoring														
3	consultation with the supervisor														
4	Research for journal or thesis on the respective topic														
5	writing summary for the journal/thesis														
6	Extended Proposal Report														
7	Submission Extended Proposal Report														
8	Preparation for Viva presentation														
9	Viva Presentation/ Defending Proposal														
10	Project works continue														
11	Sumbit Draft Report														
12	Submit Interim Report														

Milestone for Project Flow of Final Year 1

Suggested Milestone

Process

Milestone for Final Year Project 2

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Field Data Measurement	■	■	■	■	■	■	■	■	■	■	■			
2	consultation with the supervisor								■	■	■	■	■	■	■
3	Research for journal or thesis on the respective topic	■	■	■	■	■	■	■	■	■	■	■	■	■	
4	Progress Report							●							
5	Submission Progress Report								●						
6	Poster (EDX) Presentation											●			
7	Submit Draft Report												●		
8	Submit Final Report													●	
9	Viva Presentation														●
10	Submit Dissertation														●

Milestone for Project Flow of Final Year 2

● Suggested Milestone

■ Process

Appendix F

Field Data Measurement Spatial Coordinates

1. Spatial Coordinates measure on column 3
2. Spatial Coordinates measure on column 4

1. Spatial Data Coordinates on column 3

Building Deformation Monitoring
Field Data Measurement
Building 14

Date: 23.08.2011

Time: 8.00 am (time 1)

Points	Northing (y)	Easting (X)	Zenith (Z)
1	995.5666	977.5944	106.5412
2	990.2264	984.6236	107.0088

Deformation Rate time series 1 (t2 -t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	0	10	1.8
2	-0.4	-1.4	-1.6

Time: 10.00 am (time 2)

Points	Northing (Y)	Easting (X)	Zenith (Z)
1	995.5666	977.6044	106.543
2	990.226	984.6222	107.0072

Deformation Rate time series 2 (t3-t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	4.4	2.4	1
2	0.8	0	-0.4

Time: 12.00 pm (time 3)

Points	Northing (Y)	Easting (X)	Zenith (Z)
1	995.571	977.5968	106.5422
2	990.2272	984.6236	107.0084

Deformation Rate time series 3 (t4-t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	4.6	3.2	1
2	0	-0.2	-1

Time: 2.00 pm (time 4)

Points	Northing (Y)	Zenith (Z)	Zenith (Z)
1	995.5712	977.5976	106.5422
2	990.2264	984.6234	107.0078

Deformation Rate time series 4 (t5-t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	3.2	7.4	2
2	0.4	-0.6	-1.2

Time: 4.00 pm (time 5)

Points	Northing (Y)	Easting (X)	Zenith (Z)
1	995.5698	977.6018	106.5432
2	990.2268	984.623	107.0076

Total Displacement (cm)

Point	Displacement 1	Displacement 2	Displacement 3	Displacement 4
1	1.0161	0.5111	0.5692	0.8307
2	0.2163	0.0894	0.1020	0.1400

Mean Average Value (cm)

Points	Average Displacement
1	0.7318
2	0.1369

Points	Average Displacement
1	0.169
2	0.2595

2. Spatial Coordinates on column 4

Building Deformation Monitoring
Field Data Measurement
Building 14

Date: 23.08.2011

Time: 8.00 am (time 1)

Points	Northing (y)	Easting (X)	Zenith (Z)
1	987.664	988.2192	107.1008
2	980.4636	999.2856	106.4574

Deformation Rate time series 1 (t2 -t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	0	0.4	-0.8
2	-1.2	1.6	0.6

Time: 10.00 am (time 2)

Points	Northing (Y)	Easting (X)	Zenith (Z)
1	987.664	988.2196	107.1
2	980.4624	999.2872	106.458

Deformation Rate time series 2 (t3-t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	0	0.2	-0.6
2	-0.8	1.6	0

Time: 12.00 pm (time 3)

Points	Northing (Y)	Easting (X)	Zenith (Z)
1	987.664	988.2194	107.1002
2	980.4628	999.2872	106.4574

Deformation Rate time series 3 (t4-t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	0.4	2.8	-0.4
2	0	3.2	-0.2

Time: 2.00 pm (time 4)

Points	Northing (Y)	Zenith (Z)	Zenith (Z)
1	987.6644	988.222	107.1004
2	980.4636	999.2888	106.4572

Deformation Rate time series 4 (t5-t1) (mm)

Points	Delta Y	Delta X	Delta Z
1	-0.8	1	-2
2	-0.8	3.2	0

Time: 4.00 pm (time 5)

Points	Northing (Y)	Easting (X)	Zenith (Z)
1	987.6632	988.2202	107.0988
2	980.4628	999.2888	106.4574

Total Displacement (cm)

Point	Displacement 1	Displacement 2	Displacement 3	Displacement 4
1	0.0894	0.0632	0.2857	0.2375
2	0.2088	0.1789	0.3206	0.3298

Mean Average Displacement (cm)

Points	Mean displacement
1	0.1690
2	0.2595