Determination of Orthometric Height for TBM in Hydrographic Surveys Work

Mohd Zahirudin Mohammed Na'aim[1*], Che Zaidi Che Hassan[1], Stuart Otto Wilson Munan[1]
[1]Department of Civil Engineering, Politeknik Kuching Sarawak, KM 22 Jalan Matang, Petra Jaya, 93050 Kuching, Sarawak, Malaysia
*Corresponding author: mzahir@poliku.edu.my

Abstract

The temporary benchmark (TBM) is a reference value for each height. Observational data in the field always has differences and it is often with the measurement activities carried out. For example, the factor of measuring equipment, lack of skill in using measuring equipment and atmospheric effects that will cause differences to exist in the data. With the latest technology, level measurement using the Global Navigation Satellite System (GNSS) can provide high accuracy and precision. There are several TBM points in the Lundu town that have not been adjusted for a long time and it is possible that these TBM have a different height than the actual height. In this study, two techniques were carried out, GNSS levelling using RTK technique and the levelling survey technique for the purpose of establishing TBM. The results of these two techniques will be studied and discussed. The comparison of height differences between the two techniques proves that GNSS levelling produces accurate and precise results.

Keywords: - Orthometric Height, GNSS-RTK, Levelling Survey

1. Introduction

"Orthometric Height" means the height above the mean sea level (MSL) datum local or gravimetric geoid surface matched with local MSL. Mean sea level is a significant phenomenon in geodetic science and oceanography (Isiaka et al., 2023). TBM is one of the most important aspects in every hydrographic survey work. This TBM will be used as a datum or referred to before starting each Hydrographic Surveys work. A control survey should be carried out to determine the elevation based on the datum created from the observation of tides. The objective of the study is to established a TBM in Hydrographic Surveys Work at the Lundu town using GNSS-RTK techniques and levelling survey techniques.

The use of orthometric height in geodetic applications provides elevations on the physical topographic surface of the earth rather than ellipsoidal heights that are not inconformity with the physical topography (Fusami et al., 2023). Orthometric and normal heights are the two most commonly used types of heights for a practical realization of geodetic vertical controls by physically establishing levelling benchmarks (Tenzer & Nsiah Ababio, 2023). The use of GNSS to determine the orthometric height requires a geoid model which is used as a transformation linkage between ellipsoidal height and orthometric height (Sikder et al., 2020).

The optimal combination of geometric heights obtained from global positioning system GPS measurements with geoidal undulations derived from a gravimetric geoid model, in order to determine orthometric heights with respect to a vertical geodetic datum, is well suited for many practical applications (Fotopoulos et al., 2003). The advent of the Global Navigation Satellite System (GNSS) particularly the Global Positioning System (GPS) has enhanced accurate determination of points position (Raufu & Tata 2022).

Orthometric height is the generally adopted type of height worldwide and in geomatics community. Development of geoid modelling is based on geodetic, gravimetric and astrogeodetic techniques. In order to define a high precision geoid, GNSS/levelling, one of the geodetic techniques, can be employed (Albayrak et al., 2020).

Levelling survey errors can be categorized into three main types: systematic errors, random errors, and gross errors. Systematic errors are predictable and consistent inaccuracies that occur due to the equipment or environment. Instrumental errors arise from imperfections or miscalibrations in the equipment, such as improperly adjusted level bubbles or faulty leveling rods. Natural errors are caused by environmental factors like temperature variations, wind, and refraction, which can affect measurements.

Random errors are small, unavoidable inaccuracies that occur due to the limitations of human perception and the instruments used. These errors are unpredictable and vary in magnitude and direction. Although they cannot be completely eliminated, random errors can be minimized through repeated measurements and averaging the results, thus improving overall accuracy.

Gross errors, also known as blunders, are significant mistakes made by the surveyor. These can include misreading the level rod, recording incorrect values, or setting up the instrument incorrectly. Gross errors are usually the result of human error and can be significantly reduced by following proper procedures, double-checking work, and ensuring thorough training and attentiveness of the surveyors.

Mitigating these errors involves proper instrument calibration, careful observation, repeated measurements, and systematic recording of data. By addressing these different types of errors, surveyors can achieve more accurate and reliable levelling results. Global Navigation Satellite System (GNSS) is a method of positioning that gives a set of point coordinates in predefined reference coordinate system (Zrinjski et al., 2018).

Real-Time Kinematic (RTK) positioning is an advanced satellite navigation technique that enhances the precision of position data obtained from satellite-based positioning systems like GPS (Global Positioning System) and GLONASS (Global Navigation Satellite System). RTK achieves this by using the phase of the signal's carrier wave in addition to the information content of the signal and a network of fixed ground-based reference stations.

Real-Time Kinematic positioning leverages carrier wave phase measurements and real-time corrections from a single reference station or an interpolated virtual station to provide extremely precise positioning data, achieving up to centimeter-level accuracy. This high precision makes RTK invaluable across various fields that require exact positioning.

Overall GNSS levelling offers several advantages over traditional levelling methods:

1. High Accuracy: GNSS levelling provides precise vertical measurements, often achieving centimeter-level accuracy, which is essential for many engineering and construction projects.
2. Time Efficiency: GNSS surveys are typically faster than traditional levelling methods, especially over long distances. This efficiency reduces the overall time and cost of surveying projects.
3. Wide Area Coverage: GNSS can cover large areas without the need for line-of-sight between stations, making it ideal for extensive or difficult terrain where traditional methods would be impractical.
4. Flexibility: GNSS levelling can be performed in various environments and conditions, including urban, rural, and remote areas, providing versatility in application.
5. Data Integration: GNSS data can be easily integrated with other geospatial information systems (GIS) and digital elevation models (DEMs), enhancing the overall utility and application of the survey data.
6. Reduced Human Error: Automated data collection and processing in GNSS levelling minimize the potential for human errors associated with manual readings and recordings.

2. Methodology

After the research problem is understood, a literature review is done to complete the theory and principles related to the research problem. The selection of the location of the TBM has also been made after a site visit was conducted around the area of the Batang Kayan Jetty Lundu town (Fig. 1). Such as where the observed the tide level reading must experience fluctuations according to the tides of the sea, be easy to visit and have safety features from any disturbance.

To begin the hydrographic surveys work, a TBM must be built at the jetty from a known reduce level (RL) point that is a benchmark (BM), and a levelling survey technique and GNSS-RTK is used to do so. A temporary benchmark is important because it provides a stable and reliable reference point for elevation during a survey. This ensures consistency and accuracy in measurements, allowing for precise calculations and comparisons throughout the project.

The suitable location to establish a temporary benchmark should have the following characteristics:

1. Stability: The site should be on stable ground that is unlikely to shift or move, such as solid rock or well-compacted soil.
2. Protection: It should be in a location protected from potential disturbances, including construction activities, traffic, or natural elements like flooding.
3. Accessibility: The benchmark should be easily accessible for surveyors throughout the duration of the project without being obstructive or posing safety hazards.
4. Visibility: It should be clearly visible and marked so that it can be easily located and identified by all surveyors working on the project.
5. Proximity: Ideally, it should be near the area of the survey to minimize travel distance and potential errors due to long measurement lines.

In this study, we established 6 TBMs which are TBM1, TBM2, TBM3, TBM4, TBM5 and TBM6. The levelling survey starts from K0259’s benchmark (BM K0259) where it’s located on the right side of the road between Pekan Lundu and Pandan. Being directly across the street from electric pole No.107. In this study, the leveling survey includes 2 loops (1.5km). This means that the survey process is performed using a closed loop configuration. Each loop begins and ends at the same point with known elevations, allowing for the detection and correction of any measurement errors. This levelling survey takes 2 days to complete.

Fig. 1. Study area

Real Time Kinematic (RTK) GNSS observations are carried out with the Base and Rover technique where two GNSS receivers are required, one acting as a reference control point and one GNSS receiver as a Rover. The Topcon Hyper VR GNSS receiver is installed at the base station which is used as a reference and has fixed coordinates in the Borneo Rectified Skew Orthomorphic (BRSO) coordinate system and has fixed height as shown in Fig. 2. For this study, Observations are carried out for two (2) epochs and for 10 - 30 minutes for each session while the observation interval is 5 second. There are six 6 TBMs observed using GNSS-RTK technique which are TBM1, TBM2, TBM3, TBM4, TBM5 and TBM6. This GNSS-RTK observation takes a half day to complete.

Fig. 2. Base at BM K0259

GNSS-RTK observations at the rover stations as shown in Fig. 3 are carried out and set up in an unobstructed and protected area. This is because multipath error is one of the main sources of tracking error in GNSS receivers. Satellite signals are reflected, scattered and sometimes blocked by trees, roofs and walls of tall buildings, bridges, etc. This is because the GNSS-RTK Observation technique has many obstacles, and many shelters will cause the GNSS-RTK observation to be accurate at the decimeter level.

Fig. 3. Rover at TBM

3. Result and Discussion

After all the observation work in the field i.e. 6 TBMs using the GNSS Levelling and levelling survey technique is completed in the field. Next, the measurement data processing using the levelling survey was carried out manually to produce the results while for the GNSS-RTK observations where the data process was carried out by using the Magnet Field software.

Table 1 shows the orthometric height difference of the GNSS-RTK technique and the levelling survey technique for the six selected TBM. From Table 1 it was found that the TBM 1 resulted in a difference of 0.018m, the TBM 2 resulted in a difference of 0.012m, TBM3 resulted in 0.035m, TBM 4 resulted in 0.031m, while the TBM5 produces 0.024m and the TBM6 produces a difference of 0.015m

Table 1. Differences of Orthometric Height using GNSS-RTK technique and levelling survey technique.

TBM	Orthometric Height		Diff (m)
	GNSS-RTK(m)	(Levelling Survey) (m)	
TBM 1	2.437	2.455	0.018
TBM 2	3.019	3.031	0.012
TBM 3	2.72	2.755	0.035
TBM 4	2.304	2.335	0.031
TBM 5	2.036	2.06	0.024
TBM 6	2.465	2.48	0.015

From the finding above, the value difference between the GNSS levelling technique and levelling survey technique is 1cm to 4cm. Accuracy within the acceptable limit is 6 cm set by KPUP circular No. 6 2009. That shows that GNSS levelling delivers highly accurate vertical measurements, frequently reaching centimeter-level precision, which is crucial for numerous engineering and construction projects. GNSS surveys generally outpace traditional levelling methods, particularly over long distances. This increased efficiency significantly cuts down the overall time and cost of surveying projects. Automated data collection and processing in GNSS levelling reduce the human errors that can occur with manual readings and recordings.

4. Conclusion

The comparison of Orthometric height differences between the two technique proves that GNSS levelling produce accurate and precise results. Based on the discussion above, the value difference between the GNSS leveling technique and the leveling survey technique ranges from 1 cm to 4 cm. This falls within the acceptable accuracy limit of 6 cm set by KPUP Circular No. 6. 2009. This shows that the establishment of TBM using the GNSS-RTK technique very practical and produces high accuracy and precision and it can also save time and does not require a lot of manpower.

This study was conducted to established a TBM at the Lundu town using GNSS-RTK techniques and levelling survey techniques. From this study, the TBM has been produced and it will be used as a reference datum for the hydrographic surveys work for Diploma in Geomatic Students Politeknik Kuching Sarawak. It is hoped that this study will be able to benefit students to experience the real work environment and the results of this study will be used as a guide in establishing a TBM.

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