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Evaluation of Height, Area, and Capacity of Concrete Elevated Water Reservoirs in a Tertiary Institution in Benin City, Nigeria

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ABSTRACT: The objective of this work is to determine the height, area, and capacity of two concrete elevated water reservoirs in a Tertiary Institution in Benin City, Nigeria, to serve as reference to existing controls for future monitoring exercise. The two water reservoir involved in reality are of different shapes and sizes. The elevated heights, areas, and capacities of reservoir one and two suspended above their legs are: (8.106m, 362.778m^2, 2940.680m^3, and 7.485m, 320.400m^2, 296.132m^3), respectively. The total heights of the reservoir one and two above ground level (AGL) are approximately 22m and 18m. Statistical analysis of uncertainty in height measurement showed, 0.0153 for reservoir one and 0.0412 for reservoir two. The provision of the necessary information by the REM method about the elevated water reservoirs showed its efficacy. This method is recommended for use in the measurement of inaccessible structure/feature. The type of data and information such as provided in this work are required for institutional water board documentation, water use planning, and archival purpose.

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The importance attached to an overhead freshwater storage tank cannot be overemphasised. Such structures are common place within Benin City metropolis. Water and life are two inseparable entities; the latter depends highly on the former for survival. Consequently, life depends on water, as the body fluid is composed of about 70% water on average (CosanUSA, 2018; Frank, 2020). It is therefore imperative to maintain the balance. Sufficient and sustainable water distribution depends on the quality and durability of an elevated water tank in a particular geographic location (Woldeyesus, 2016). This fact necessitated the need for preservation and effective management of existing overhead tanks to meet the basic supply of potable water for drinking, domestic, agricultural, industrial, and various other purposes. How best to manage water resources have continued to be one of the challenges facing water resource engineers, environmental scientists, hydrologists, hydrographers, and decision-makers globally (Burton, 2019; Cosgrove and Loucks, 2015). Elevated concrete water tanks find their usefulness basically in water supply and fire protection and must be studied; for any deformation using stable controls as reference points Sameh et al., 2019; Falguni and Vanza, 2012; Koramutla and Sapatla, 2019; Corum, 2017; Hart and Udeh, 2020). An elevated concrete water tank is a large water storage container constructed to hold water supply at certain height in order to provide sufficient pressure for effective water distribution within the networks system. (Gareane et, al., 2011; Koramutla and Sapatla, 2019). According to Koramutla and Sapatla (2019), the basic classifications of elevated water tanks are into three categories viz: those storage water tanks constructed to rest on the ground, those situated under the ground, and the elevated ones, suspended at some altitude (height) above the ground level. Classification can also be on the constructed tank shape such as (circular, rectangular, cylindrical, pyramidal, triangular, etc.) which are the most common. Elevated water storage tanks (reservoirs) structures are supported on staging consisting of

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masonry walls, reinforced cement concrete **(**RCC) tower, or reinforced cement concrete **(**RCC) columns braced together (Koramutla and Sapatla, 2019). Woldeyesus (2016); presented the following reasons for carrying out study about overhead storage water tanks: 1) water tanks are visually simple but structurally difficult to maintain 2) it is difficult to take the load cases and load combinations, 3) consideration for distribution of stress in the structure, 4) consideration for distribution of mass, 5) Hydro-dynamic effects, 6) very critical problem is the slab and beam joints, 7) displacement in horizontal and verticality, 8) measurement of subsidence and deformation activities after construction. Determination of the height and monitoring of completed structure of this type rarely attracts attention, in Nigeria for different reasons such as political; faulty policies and decisions; lack of and outright negligence of post-construction routine survey check recommendations; shallow knowledge; lack of maintenance culture; lack of financial budget vote for monitoring, and corruption in the system, etc. Determination of the height, shape, size, area, and volume is the beginning of information gathering for the provision of input data for the computation of the displacement in (X, Y, Z) coordinates geared toward adequate and effective subsidence and deformation monitoring of the overhead storage water reservoir(s). Monitoring involves determining the horizontal coordinate shift and the vertical coordinate displacement to discover any noticeable deformation and subsidence presence.

MATERIALS AND METHODS

Study Area: The study area is the University of Benin, Ugbowo Campus. Located almost at the boundary between Egor LGA and Ovia North-East LGA of Edo State. It is one of the premier universities founded in 1970 and took off as a full-fledged Institution by the approval of the National Universities Commission (NUC) on 1st July 1971. The geographic location can be defined as: (789069.92 mE; 708145.84 mN; 789400.47 mE, 708520.18 mN, Zone 31; UTM)

Principle of Measurement with Remote Elevation Method (REM): Remote Elevation Method (REM) principle of Measurement uses reflectorless mode to bisect a target of interest. This principle was adopted in this study since the height of the two tanks are inaccessible. Equations 1, 2, and 3 can be apply for this purpose (Xu et al., 2020; Zhuo, 2012). Figure 1 showed the diagram of the process to be undertaken while adopting the technique.

$$H_t = h_1 + h_2 \qquad 1$$

$$h_2 = S\,(sin\vartheta Z_1)\,(cot\vartheta Z_2 - S(cos\vartheta Z_1) \qquad 2$$

Therefore, the height (H_t) above ground of the inaccessible point whose position is required (that is, top of the tank in this case) is given by equation 3 (Trimble M3 DR user guide, 2010):

$$H_t = S\,(sin\vartheta Z_1)\,(cot\vartheta Z_2 - S(cos\vartheta Z_1) + h_1 \qquad 3$$

Where: H_t, is the height of object above the ground; h_1, is the height of the reflector set vertically before the object whose height above the ground is required; h_2, is the vertical height from reflector prism center to the top of the tank; *S*, is the slope distance; ϑZ_1 and ϑZ_2 are the zenith angles of the object and the prism respectively.

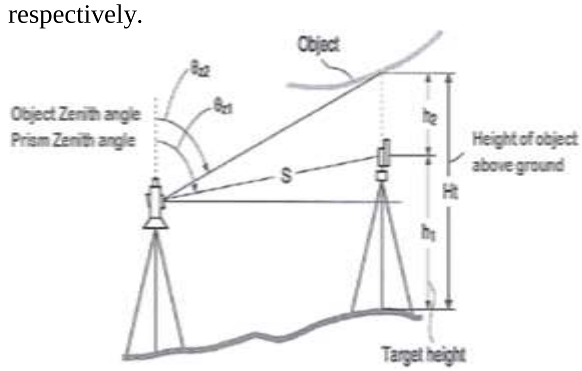

Fig 1: Method of height determination of elevated object. (Source: Trimble M3 DR user guide, 2010)

Consider Figure 1, after powering up the instrument and necessary adjustment already performed. On the TS instrument select "MENU" > "MEAS"> "REM" > to begin, the calculation of height, sight the telescope to the base point of the target object and press [MEAS] follow by pressing [REM]. Direct the telescope vertically and take a sight the to the target top point while the telescope is consciously locked. Press stop to terminate the measurement process. These steps will enable the measured slope distance, elevation, vertical angle, horizontal angle, or coordinates data to be displayed as needed. Press [ESC] to finish and return to [MEA] mode screen again. The TS instrument determines the height (Ht) above the ground using equations in 1, 2, and 3, (Zhang and Wang, 2007; Xu et al., 2020).

Accuracy of REM Method: For the preliminary estimation of the accuracy of linear measurements, we applied equation 4 which was adopted also in the works of (Reda and Bedada, 2012; Jezko 2014, Barković et al., 2016; Kukhtar et al., 2018).

$$m_s = a + b \times 10^{-6} \qquad 4$$

Where: m_s is the survey measurement; ***a*** represents the additive element and, ***b*** refers to the scale element. Note that the value of ***b*** varies and depends on the measured length of the line of interest.

According to (Kukhtar et al., 2018; Mazalová et al. 2009; Zámeþníková et al., 2014; Lambrou and Pantazis 2010; Fawzy 2015; Jezko, 2014; Kukhtar, Sami, et al., 2016), the error in distance measurement usually correlates with the magnitude of the incidence angle inclined to the surface. For this reason, Kukhtar et al. (2018) suggested further improvement on equation 4 in order to create room for additional factors in considering the incidence angle when adopting the reflectorless mode of operation. Thus, the accuracy of the distance measurement is a function of the distance ***S*** and the beam's incidence angle ***β*** (Zámeþníková, 2014).

The Description of the Overhead Water Reservoir One: The first reservoir has its location within the University of Benin Water Board (UBWB) vicinity. The coordinates of the tank location are: (788727.66mE, 708897.22mN and 788674.85mE, 708908.54mN, Zone 31; UTM). This tank can best be described as cylindrical in shape. From the principle of mensuration of plane figures/shapes in mathematics, if the radius and the height of a cylindrical part of the tank are known, then its area and capacity can be computed. The photograph of the tank taken on-site during fieldwork is as shown in Figure 2.

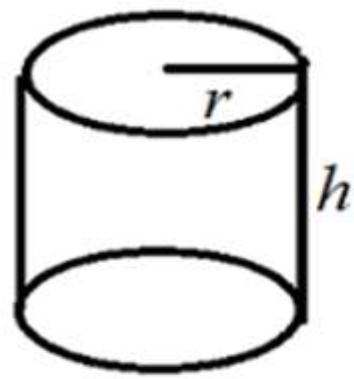

Fig 2: Overhead tank located at Uniben water board office Ugbowo

Determination of Height of Water Reservoir One: The determination of height was accomplished by the application of REM method and is in two phases. The first phase is the determination of the elevated above ground level (AGL) while the second phase has to do with the determination of the height and radius of the cylindrical part of the tank. The values obtained for the zenith angle of the prism (reflector) (Z_1) and that of the elevated object (Z_2) and the difference in height of tank one at six line of sights to the top and bottom AGL was approximately 22m. Again, the height of the cylindrical part and the radius are approximately 8m and 7m respectively. The data for height AGL is shown in Tables 1.

Table 1: Height AGL obtained for tank one

Tank One Data					
Leg	Z_1 (° ' ")	Z_2 (° ' ")	Top H. (m)	Bottom H. (m)	Diff. (m)
1	71 40 53	57 11 08	151.166	128.706	22.460
2	73 27 13	58 27 38	151.158	128.716	22.442
3	65 48 15	48 28 02	151.162	128.714	22.448
4	67 37 28	49 53 19	151.166	128.723	22.443
5	71 40 53	57 11 08	151.163	128.727	22.436
6	71 45 53	57 11 08	151.162	128.748	22.414

Determination of Area of Water Reservoir One: The determination of area of water reservoir one was accomplished using equation 5.

$$A = 2\pi rh + 2\pi r^2 \qquad 5$$

Determination of Volume of Water Reservoir One: Volume determination was accomplished with the aid of equation 6.

$$V = A * h \qquad 6$$

Description of the Overhead Water Reservoir Two: The second overhead water reservoir location is located at the Faculty of Engineering, University of Benin, Ugbowo Campus. The coordinates of its location are: (789388.45mE 708465.48mN; and 789392.32mE, 708479.75mN Zone 31; UTM). This elevated tank can best be described as a regular pyramid (polygon) type. Because of this fact, its faces are of equally sized triangles. By determining the height, width, and length, it was possible to determine its area and capacity subsequently. Figure 3 is the Google Earth street view of the second tank.

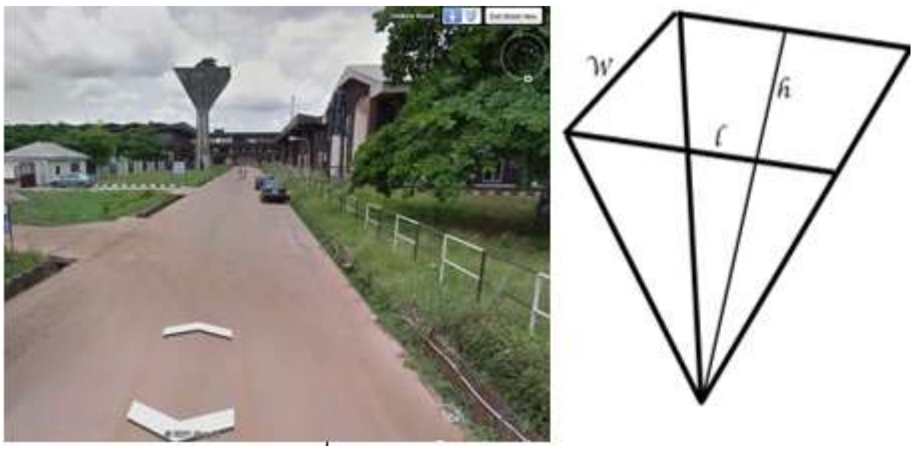

Fig 3: Tank two located at Faculty of Engineering Uniben

Determination of Height of Water Reservoir Two: With the REM, determination of height was done in two phases. Phase one was the determination of the total height of reservoir above the ground level, which is the difference in top and bottom values. This was discovered to be approximately 18m on the average as shown in the last column of Table 2.

Table 2: Tank two height determination

Tank Two Data					
Prism	Z_1 (° ' ")	Z_2 (° ' ")	Top H. (m)	Bottom H. (m)	Diff. (m)
1	89 48 33	73 02 17	146.307	128.141	18.166
2	89 41 56	72 28 39	146.329	128.260	18.069
3	89 31 01	75 05 34	146.710	128.755	18.127
4	89 32 03	80 35 55	146.340	128.240	18.100

Determination of Area of Water Reservoir Two: The area of tank two was calculated according to equation 7.

$$A = lw + l\sqrt{\left(\frac{w}{2}\right)^2 + h^2} + w\sqrt{\left(\frac{l}{2}\right)^2 + h^2} \qquad 7$$

The parameters required to achieve this was first determined from field work.

Determination of Capacity of Water Reservoir Two:

$$V = \frac{lwh}{3} \qquad 8$$

For the determination of capacity of reservoir two, only the measurement of the regular pyramid part of the tank was considered and equation 8 was used for this purpose.

Determination of Uncertainty in Total Height Measurement: The statistical method provided by Joint Committee for Guides in Metrology (JCGM 100, 2008) as presented in equations 9 and 10 was used to find the standard uncertainty in the final heights data obtained for the two overhead storage water tanks.

$$u(x) = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \qquad 9$$

Where: x_i, refers to the individual measured value and $\bar{x}$, denotes the mean which is calculated as

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad 10$$

The computed precision in measurement of final heights of tank one and tank two are 0.01528 and 0.04117 respectively.

RESULTS AND DISCUSSIONS

The results obtained from the determination of tank one properties showed that it has a height of approximately 22m above the ground level. It has a height and a radius of approximately 8m and 7m respectively for the cylindrical part. These parameters (height and radius) was incorporated into equation 5 to determine the area of tank one as: 362.778m^2.

Table 3: Determined reservoir properties

Tank_ID	Length (m)	Width (m)	Height (m)	Height AGL (m)	Radius (m)	Area (m^2)	Volume (m^3)
Tank one	N/A	N/A	8.106	22.443	7.120	362.778	2940.680

The area obtained in equation 5 was further used in equation 6 to determine the volume as: and 2940.680m^3. Table 3 showed the summary of the results. Similarly, the height of the tank two above ground level was determined to be approximately 18m. The fundamental properties of the tank like length, width, height was determined and approximated as: 10m 10m, and 7m respectively. The area and volume of the regular pyramid part of the elevated tank was determined using equations 7 and 8 as: 320.400m^2 and 296.132m^3 respectively. The summary of the determined properties of tank two are contained in table 4.

Table 4: Determined properties of tank two

Tank_ID	Length (m)	Width (m)	Height (m)	Radius (m)	Height AGL (m^2)	Area (m)	Volume (m^3)
Tank two	10.901	10.888	7.485	N/A	18.223	320.400	296.132

The computed precision in measurement of final heights of tank one and tank two are 0.01528 and 0.04117 respectively which are appropriate for a ±(3 +2ppm x D)mm in precise reflectorless measurement as recommended by the Trimble, (2010) user guide provided by the manufacturer of the Total station equipment used in data collection.

Conclusion: This work has been carried out to determine the physical properties of two tanks having different shapes and sizes using the remote elevation method incorporated in Trimble Total Station equipment. This method is good and most appropriate to perform measurement when the object of concern is inaccessible or if station occupation poses a greater risk to life. Because we are able to determine the height and radius of tank one, it was possible to determine its area and volume. For tank two, since it was possible also to determine the length, width, and height, the area and volume was equally computed.

REFERENCES

Corum, L (2017). Storage Tank Maintenance. Retrieved 28th May, 2021 from https://www.waterworld.com/drinking-water/article/14070344/.

CosanUSA, (2018). Water Composition of the Human Body. Retrieved May 5th, 2021 from https://cosanusa.net/water-composition-of-the-human-body/

Cosgrove, WJ; Loucks, DP (2015). Water management: Current and future challenges and research directions, *Water Resour. Res*; 51; 4823–4839.

Falguni, A.; Vanza, MG (2012). "Structural Control System for Elevated Water Tank", *Int J. of Adv Engr Res and Stud*.

Fawzy, H.E., (2015) Evaluate the accuracy of reflector-less total station, *Int J. of Civil Engr and Tech*. 6(3); 23-30

Frank, A (2020). Water Does a Body Good! Retrieved June 20, 2021 from https://strivemedtech.com/

Gareane, AIA; Osman, SA; Karim, OA; Kasa, A (2011). Behavior of Elevated Concrete Water Tank Subjected to Artificial Ground Motion. *Elect J. of Geotech Engr* (16): 309-406

Hart, L; Udeh, K (2020). An appraisal of high definition survey approaches in subsidence monitoring of crude oil storage tanks. *Afr. J. Environ. Sci. Tech.*, 14(9): 250-259.

Joint Committee for Guides in Metrology (JCGM 100, 2008). Evaluation of measurement data. Guide to the expression of uncertainty in measurement. (JCGM/WG 1).

Jezko, J (2014). Calibration of surveying instruments and tools - means to the quality increase of deformation measurements. *J. of Sust Min*, 13(4): 17-22.

Koramutla, T; Sapatla, A (2019). Design of Elevated Level Storage Reservoir. *Int J. of Engr Res and Tech.*

Kukhtar, D; Romaniuk, V; Savchyn, I (2018). Modelling the Accuracy Equation of Sokkia 530RK Reflectorless Total Station due to Incident Angle on the Above-Ground Pipeline's Surface. *Geodetski list, 72 (95)* (3), 197-216.

Lambrou, E; Pantazis, G (2010). Evaluation of the Credibility of Reflectorless Distance Measurement. *J. of Surv Engr*, 136: 165-171.

Reda, A; Bedada B (2012). Accuracy analysis and Calibration of Total Station based on the Reflectorless Distance Measurement, School of Architecture and the Built Environment Royal Institute of Technology (KTH) Stockholm, Sweden

Sameh, S; Zeidan, Z; Beshr, AA (2019). Study the Deformation of Elevated Water Storage Tank. 4th *Joint Int. Symp on Defor Monitor*, 15-17 May 2019, Athens, Greece.

Sami, H; Ali1, SH; Omar, N Q; Abujayyab, SK M (2016). Investigation of the Accuracy of Surveying and Buildings with the Pulse (Non Prism) Total Station. *Inter J. of Adv Res.* 4(3): 1518-1528

Trimble M3 DR user guide, (2010). Retrieved October 20, 2021 from http://geomaticsjc .lboro.ac.uk/Trimble/ TrimbleM3DR_UG_1B.pdf

Woldeyesus, M (2016). Thesis on analysis and design of overhead tank from wind load in partial fulfillment of the requirements for the degree of Master of Science (M.Sc.) in structural engineering. Addis Ababa Science and Technology University.

Xu, Y; Zhao, X; Liu, H; Xu, F; Wang, X (2020). The Improvement and application of elevation measurement method with total station. E3S *Web of Conf.* 165: 03018.

Xu, Y; Chen, Y; Guan, X; et al., (2020). Approach to Minimizing the Influence of Changeable Observational Environment on Long-Distance Sea-Crossing Trigonometric Leveling. *J. of Surv Engr*, 146(4): 04020018.

Zámeþníková, M; Neuner, H; Pegritz, S (2014). Influence of the Incidence Angle on the Reflectorless Distance Measurement in Close Range INGEO 2014. 6th *Int. Conf on Engr Surv.* Prague, Czech Republic, April 3-4, 2014

Zhuo, Y (2012). Measuring Inaccessible Points in Land Surveying and Analysis of their Uncertainty. Degree Project for a Bachelor of Science/Technology in Geomatics. Retrieved 30th, May 2021 from http://www.divaportal.org/smash/get/diva2:548707,