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# Design and methods of Geoinformatics analyses of Engineering structure according to loading.

R. Ehigiator – Irughe[1*], M. O. Ehigiator[2]

[1] Siberian State Geodesy Academy, Department of Engineering Geodesy and GeoInformation Systems, Novosibirsk, Russia.

[2] Faculty of Basic Science, Department of Physics and Energy, Benson- Idahosa University, Benin City, Nigeria.

* E-mail of corresponding author: raphehigiator@yahoo.com

**Abstract**

A tropical Engineering Structure that is subjected to loading and offloading is above surface vertical circular tanks. Cylindrical storage Tanks are commonly used in oil and gas industries for storing crude oil, petroleum products, etc. and for storing water in public water distribution systems. Such tanks require periodic surveys to monitor long-term movements and settlements of the foundation or short-term deflection, deformation of the structures and early warning. One of the most effective geometric parameters of circular vertical tanks is determining it's out of roundness, distortion and the deformation as a result of age. To ensure the security of civil engineering structures, it is necessary to carry out periodic monitoring of the structures. The deformation monitoring scheme consist of measurements made to the monitored tank from several monitoring stations (occupied stations), which were established around the tanks. This paper attempts to evaluate the monitoring-performance of a reflectorless total station according to loading. For this purpose, the defining parameters of a plane are determined through a least squares estimation, by using 3-Dimensional coordinates derives by the application of the intersection technique.

**Keywords:** Monitoring, deformation, diameter, oil volume, intersection, accuracy, oil tanks.

## 1.0 Introduction

Technical structures are subject to natural causes and to human interaction that may lead to collapse or structural failure. On the latter occasion the development of an appropriate methodology for the distant structure monitoring is crucial for safety reasons. In order for such occasions to be confronted, engineers are appropriately equipped with instruments capable to cope with the special conditions arising. More specifically, the use of laser technology in surveying instruments' industry led to the development of reflectorless total stations. The instrument category does not require the use of special targets.

Hence, the need for distant monitoring in hazardous or not accessible environments is fulfilled. The problem arising is how accurately engineers can define the position of points or the mathematical equation of a specific surface. Hence, what needs to be certified is whether these instruments meet the high accuracy requirements arising on deformation monitoring occasions, not only examining deformation on the spot but also through changes of the surface equation parameters.

It is necessary to model the structure of oil storage tank by using well-chosen discrete monitoring points located on the surface of the structure at different levels which, when situated correctly, accurately depict the characteristics of the structure.

Any movements of the monitoring point locations (and thus deformations of the structure) can be detected by maintaining the same point locations over time and by performing measurements to them at specified time intervals. This enables direct point displacement comparisons to be made. A common approach for this method is to place physical targets on each chosen discrete point to which measurements can be made. However, there are certain situations in which monitoring the deformations of a large structure using direct displacement measurements of targeted points is uneconomical, unsafe, inefficient, or simply impossible. The reasons for this limitation vary, but it may be as simple as placement of permanent target prisms on the structure is too difficult or costly.

To obtain the correct object point displacements (and thus its deformation), the stability of the reference stations and control points must be ensured. The main conclusion from the many papers written on this topic states that every measurement made to a monitored object must be connected to stable control points. This is accomplished by creating a reference network of control points surrounding a particular structure.

## 2.0 Methodology

To develop a reliable and cost effective monitoring system of any of the storage oil tanks, deformation monitoring scheme consisted of measurements made to the tanks from several monitoring stations (occupied stations), which are chosen in the area around the tank, that are referred to several reference control points. The geodetic instruments are setup at these monitoring stations (occupied stations) and observations carried out to determine the coordinates of monitoring points on the tank surface.

The circular cross section of the oil storage tank is divided into several monitoring points distributed to cover the perimeter of this cross section. These monitoring points are situated at equal distances on the outer surface of the tank. The (stud) points are fixed, with each stud carrying an identification number and made permanent throughout the life of the tank. The purpose is to maintain the same monitoring point during each epoch of observation.

To determine the coordinates of occupied stations around the monitored oil storage tank, traverse network was run from the control points around the vicinity of the tank to connect the bench marks used for the monitoring.

Three control points (BM8A, BM8B and BM8C) with known coordinates were fixed around the tank. Eight occupied stations (PEG1, PEG2, …, PEG10) were established. To determine the coordinates of the eight occupied stations, a closed loop traverse was designed around tank № 8.

In this closed traverse there are 9 measured angles and 9 side lengths. The observed angles and sides of the traverse loop together with computed accuracy using Calson2011 software are presented in table 1.

## 3.0 Computation and adjustment of observations

By using least square theory, method of condition equation the traverse loop traverse was adjusted as follows:

The number of total observations (n) = 10 angles + 10 distances

Total number of observation = 20.

The number of conditions (r) = 3 and these include:

1. Angular misclosure condition:

$$\Delta_1 = (\Sigma \text{ interior angle of loop traverse}) - (n_{angles} - 2)(180^{o}) \quad (1)$$

2. Sum of the departures is equal to zero:

$$\Delta_2 = \sum_{i=1}^{n} D_i * Sin\,\theta_i \quad (2)$$

Where $D_i$ – the length of traverse side, $\theta_i$ – bearing of traverse side

3. Sum of the latitude is equal to zero:

$$\Delta_3 = \sum_{i=1}^{n} D_i * \cos\theta_i \quad (3)$$

Hence, the number of necessary observations:

$$n_o = n - r = 17 \quad (4)$$

The first step in solving traverse using conditional least square is finding the adjusted values of observations (9 interior angles and 9 lengths) and its accuracy. Secondly, from these values and accuracies, the adjusted coordinates of the traverse stations (eight occupied points) and its accuracy can be determined depending on the geometry of the traverse figure. All of these steps were carried out using Carlson2011 program. The adjusted coordinates of the traverse stations are presented in table 1.

Table 1 – Least – square solution of Tank 8 observations

```
Starting Point 2: E 324951.639 N 148189.825 Z 0.000
BackSight Point 1: E 325174.013 N 148157.213 Z 0.000


Solution Converged in 3 Iterations
Reference Standard Deviation: 0.945
Chi-Square statistic: 1.786, Range for 95%: 0.103 to 5.990
Adjustment Passes Chi-Square test at 95% confidence level

Max adjustment: 0.086

Starting Point 2: E 324951.639 N 148189.825 Z 0.000
Backsight Point 1: E 325174.013 N 148157.213 Z 0.000
```

| Point No. Description | Horizontal Angle | Zenith Angle | Slope Dist | Inst HT | Rod HT | Easting | Northing | Elev |
|---|---|---|---|---|---|---|---|---|
| 3 PEG1 | AR268.3821 | 90.0000 | 65.965 | 0.000 | 0.000 | 324959.658 | 148255.301 | -0.000 |
| 4 PEG2 | AR196.4045 | 90.0000 | 36.401 | 0.000 | 0.000 | 324974.267 | 148288.642 | -0.000 |
| 5 PEG3 | AR220.2414 | 90.0000 | 58.132 | 0.000 | 0.000 | 325026.545 | 148314.066 | -0.000 |
| 6 PEG4 | AR231.3409 | 90.0000 | 58.503 | 0.000 | 0.000 | 325079.290 | 148288.755 | -0.000 |
| 7 PEG5 | AR210.5047 | 90.0000 | 64.962 | 0.000 | 0.000 | 325115.162 | 148234.597 | -0.000 |
| 8 PEG6 | AR244.0412 | 90.0000 | 70.804 | 0.000 | 0.000 | 325079.172 | 148173.622 | -0.000 |
| 9 PEG7 | AR248.3311 | 90.0000 | 75.560 | 0.000 | 0.000 | 325004.564 | 148185.577 | -0.000 |
| 10 BM-8B | AR175.3331 | 90.0000 | 53.089 | 0.000 | 0.000 | 324951.650 | 148189.893 | -0.000 |
| 11 BM-8A | AR3.4153 | 90.0000 | 224.752 | 0.000 | 0.000 | 325174.013 | 148157.213 | -0.000 |

### 3.1 Determination of accuracy standard

Traversing and level network were computed and subjected to a rigorous least square adjustment. The linear, angular and level accuracy standards are presented below.

Table 2: Linear and Angular Accuracy

| Class Description | Allowable linear misclosure $\frac{\sqrt{\Delta x^2 + \Delta y^2}}{\sum L}$ | No of stations (n) | Total dist.(m) | $\Delta x$ | $\Delta y$ | Obtained linear misclosure $\frac{\sqrt{\Delta x^2 + \Delta y^2}}{\sum L}$ | Allowable angular misclosure 10” $\sqrt{n}$ | Obtained angular misclosure 10” $\sqrt{n}$ | Remark |
|---|---|---|---|---|---|---|---|---|---|
| Main Control Traverse | 1:30,000 | 14 | 3338.743 | 0.019 | 0.037 | 1:81,361 | 37.417” | 23” | ok |
| Main Control Traverse | 1:30,000 | 6 | 1153.413 | -0.011 | -0.008 | 1:83,265 | 24.495” | 18” | ok |
| Main Control Traverse | 1:30,000 | 9 | 1230.909 | 0.010 | -0.007 | 1:99,004 | 30” | 1” | ok |
| Main Control Traverse | 1:30,000 | 9 | 820.199 | 0.023 | 0.002 | 1:35,089 | 30” | 9” | ok |
| Minor control Traverse | 1:15,000 | 6 | 637.993 | 0.008 | 0.028 | 1:22,143 | 24.495” | 19” | ok |
| Main Control Traverse | 1:30,000 | 16 | 2434.439 | -0.030 | 0.033 | 54,586 | 40” | 14” | ok |
| Minor control Traverse | 1:15,000 | 5 | 290.099 | 0.002 | -0.014 | 1:20,513 | 22.361” | 16” | ok |

### 3.2 Subsidence measurement

Precise leveling method is commonly used to determine the elevation of monitoring points on the oil tank surface from other known control points - Bench Marks (B.M) – around the tanks. It is important to conduct an In-Situ check with Precise leveling instrument to establish the integrity of the Bench mark whose elevation has been determine previously or during control extension

Leveling from the control points to the monitoring points (studs) were carried out in the mornings and evening hours of the day. This is to allow for the elimination of midday heat effects of the sun which is likely to cause uneven expansion of the tanks. Using the established geodetic control points, repeated levels and other measurements were carried out in several cycles at different times for the tanks.

The level and accuracy and least squares solution is presented below:

Table 3: Level Accuracy

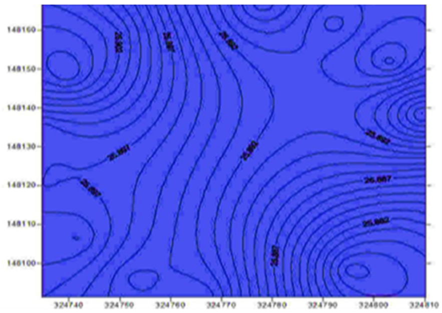
| Loop | No of stations | Distance (km) | Obtained Misclosure | Determination of class $3mm\sqrt{km}$ | Class | Remark |
|---|---|---|---|---|---|---|
| 1 | 18 | 0.596 | -0.00075 | 0.002 | 1 | ok |
| 2 | 18 | 0.798 | 0.00249 | 0.003 | 1 | ok |
| 3 | 17 | 0.540 | -0.00012 | 0.002 | 1 | ok |
| 4 | 17 | 0.540 | -0.00086 | 0.002 | 1 | ok |
| 5 | 19 | 0.540 | -0.00023 | 0.002 | 1 | ok |
| 6 | 17 | 0.614 | 0.00003 | 0.002 | 1 | ok |
| 7 | 17 | 0.629 | -0.00065 | 0.002 | 1 | ok |

LEAST SQUARES VERTICAL ADJUSTMENT REPORT

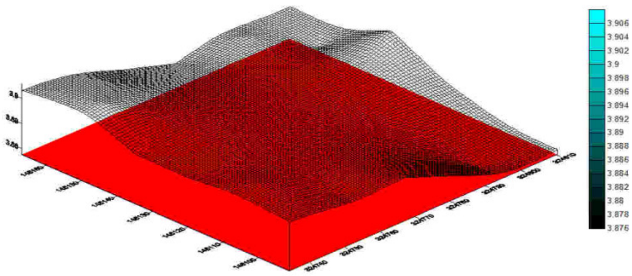
adjusted Level Report

| Pt. Num. | BS | HI | FS | adjusted El. | Desc. |
|---|---|---|---|---|---|
| BM-9A | 1.307 | 4.231 | | 2.924 | |
| STUD9 | 0.421 | 4.316 | 0.336 | 3.895 | |
| STUD8 | 0.341 | 4.228 | 0.429 | 3.887 | |
| STUD7 | 0.454 | 4.283 | 0.399 | 3.829 | |
| STUD6 | 0.370 | 4.203 | 0.450 | 3.833 | |
| STUD5 | 0.422 | 4.262 | 0.363 | 3.840 | |
| STUD4 | 0.119 | 3.970 | 0.411 | 3.851 | |
| STUD3 | 0.247 | 4.087 | 0.130 | 3.840 | |
| STUD2 | 0.147 | 3.992 | 0.242 | 3.845 | |
| STUD1 | 0.265 | 4.105 | 0.152 | 3.840 | |
| STUD16 | 0.123 | 3.970 | 0.258 | 3.847 | |
| STUD15 | 0.474 | 4.329 | 0.115 | 3.855 | |
| STUD14 | 0.439 | 4.298 | 0.470 | 3.859 | |
| STUD13 | 0.383 | 4.234 | 0.447 | 3.851 | |
| STUD12 | 0.293 | 4.134 | 0.393 | 3.841 | |
| STUD11 | 0.360 | 4.213 | 0.281 | 3.853 | |
| STUD10 | 0.322 | 4.220 | 0.315 | 3.898 | |

We present a 3D view of the contour, bottom and top of the Tank Elevation.



Bottom of the tank Contour



3D View of the Tank Bottom

### 3.3 Mathematical model of Tank volume and distortion.

From coordinates of several points (more than three points) on the circumference of circular section, the radius of the tank r and coordinates of center ($X_C$, $Y_C$) can be determined using least square method as follows:

For any monitoring point on circular section of tank surface ($X_i$, $Y_i$) must fulfils the equation of circle:

$$(\hat{x}_i - \hat{x}_c)^2 + (\hat{y}_i - \hat{y}_c)^2 - \hat{r}^2 = 0 \qquad \text{i= 1, 2, 3, …, n} \tag{5}$$

Where: $X_C$, $Y_C$ – the coordinates of center of circular section, r – the corrected value of radius.

The general form of least square as following:

$$\underset{(n,u)}{A} \cdot \underset{(u,1)}{X} + \underset{(n,m)}{B} \cdot \underset{(m,1)}{V} + \underset{(n,1)}{L} = \underset{(n,1)}{0} \tag{6}$$

Where:

n – The number of equations (in this case equals the number of monitoring points because each equation has one monitoring point);

u – The number of unknowns (in this case equals 3; radius r and coordinates of center $X_C$, $Y_C$);

m – The number of observations (in this case m = 2 n; because each point has two coordinates X, Y).

By applying least square theory, approximates values of unknowns (radius $r^0$ and coordinates of center $X^0$, $Y^0$) must be assumed or calculated. To achieve this goal, the coordinates of center can be approximated by the arithmetic mean of coordinates as follows:

$$X_C^0 = \frac{\sum_{i=1}^{n} X_i}{n}, \qquad Y_C^0 = \frac{\sum_{i=1}^{n} Y_i}{n}. \tag{7}$$

Approximate value of radius $r^0$ can be obtained from tank manual or by using three points on the perimeter of tank to estimate it.

The matrices can be formed by the following methods:

$$\underset{(n,3)}{A} = \begin{bmatrix} \frac{\partial f_1}{\partial X_C} & \frac{\partial f_1}{\partial Y_C} & \frac{\partial f_1}{\partial r} \\ \frac{\partial f_2}{\partial X_C} & \frac{\partial f_2}{\partial Y_C} & \frac{\partial f_2}{\partial r} \\ \dots & & \\ \frac{\partial f_n}{\partial X_C} & \frac{\partial f_n}{\partial Y_C} & \frac{\partial f_n}{\partial r} \end{bmatrix} = \begin{bmatrix} -2(X_1 - X_C^0) & -2(Y_1 - Y_C^0) & -2r \\ -2(X_2 - X_C^0) & -2(Y_2 - Y_C^0) & -2r \\ \dots & & \\ -2(X_n - X_C^0) & -2(Y_n - Y_C^0) & -2r \end{bmatrix} \tag{8a}$$

$$\underset{(n,1)}{L} = \begin{bmatrix} (X_1 - X_C^0)^2 + (Y_1 - Y_C^0)^2 - (r^0)^2 \\ (X_1 - X_C^0)^2 + (Y_1 - Y_C^0)^2 - (r^0)^2 \\ \dots \\ \dots. \\ (X_1 - X_C^0)^2 + (Y_1 - Y_C^0)^2 - (r^0)^2 \end{bmatrix} \tag{8b}$$

$$\underset{(n,m)}{B} = \begin{bmatrix} \frac{\partial f_1}{\partial X_1} & \frac{\partial f_1}{\partial Y_1} & 0 & 0 & 0 & 0 & \dots.. \\ 0 & 0 & \frac{\partial f_2}{\partial X_2} & \frac{\partial f_2}{\partial Y_2} & 0 & 0 & \dots.. \\ \dots. & & & & & & \\ \dots.. & & & & & & \\ \dots... & & & & & & \\ 0 & 0 & 0 & 0 & \dots.... & \frac{\partial f_n}{\partial X_n} & \frac{\partial f_n}{\partial Y_n} \end{bmatrix} \tag{8c}$$

In this model the weight matrix W will have the dimension (m, m) or in other words has dimensions (2n, 2n) and has the form:

$$\underset{(m,m)}{W} = \begin{bmatrix} \frac{1_1}{(\partial X_1)^2} & 0 & 0 & 0 & 0 & 0 & \ldots \\ 0 & \frac{1}{(\partial Y_1)^2} & 0 & 0 & \ldots & & \\ \ldots & & & & & & \\ \ldots & & & & & & \\ \ldots & & & & & & \\ 0 & 0 & 0 & 0 & \ldots & 0 & \frac{1}{(\partial Y_n)^2} \end{bmatrix} \tag{9}$$

The Oil volume in $m^3$ is give as:

$$V = \pi r^2 H \tag{10}$$

where $V$ is the Oil volume, $r$ is the derived radius, $H$ is Oil level

Then, a of least squares solution is performed to find the corrected values of radius, coordinates of center, their accuracies and the distortion of the tank shell

## 4.0 Results and discussions

By using the presented technique of calculating radius and coordinates of circular section center, the values of radii and coordinates of center point and distortions of Tank 8 at Forcados Terminal were determined at three oil levels from three epochs of observations using MATLAB program. The results are presented in tables 4 and 5 below.

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Tables 4 – determination of radius of tanks and coordinates of their center

| First cycle of observations<br>mid oil level (10m)<br>15.02.2003 | | | Second cycle of observations<br>mid oil level (10m)<br>24.08.2004 | | | Third cycle of observations<br>mid oil level (10m)<br>7.10.2008 | |
|---|---|---|---|---|---|---|---|
| r, m | 38.213 | Radius | r, m | 38.197 | Radius | r, m | 38.200 |
| $\sigma_r$, mm | 4.0 | | $\sigma_r$, mm | 3.1 | | $\sigma_r$, mm | 2.7 |
| X, m | 324772.436 | Coordinates of center | X, m | 324772.439 | Coordinates of center | X, m | 324772.524 |
| $\sigma_X$, mm | 5.4 | | $\sigma_X$, mm | 4.2 | | $\sigma_X$, mm | 3.6 |
| Y, m | 148129.011 | | Y, m | 148129.007 | | Y, m | 148128.998 |
| $\sigma_Y$, mm | 5.7 | | $\sigma_Y$, mm | 4.5 | | $\sigma_Y$, mm | 3.9 |
| Diameter | 76.426m | | | 76.394m | | | 76.400m |
| Actual Volume | $45874.584m^3$<br>396745.8bbl | | | $45836.176m^3$<br>396413.7bbl | | | $45843.377m^3$<br>396476.0bbl |
| Nominal Volume | $45603.673m^3$<br>394402.9bbl | | | $45603.673m^3$<br>394402.9bbl | | | $45603.673m^3$<br>394402.9bbl |

| First cycle of observations<br>full oil level (19m)<br>15.02.2003 | | | Second cycle of observations<br>full oil level (19m)<br>24.08.2004 | | | Third cycle of observations<br>full oil level (19m)<br>7.10.2008 | |
|---|---|---|---|---|---|---|---|
| r, m | 38.220 | Radius | r, m | 38.230 | Radius | r, m | 38.234 |
| $\sigma_r$, mm | 3.3 | | $\sigma_r$, mm | 3.7 | | $\sigma_r$, mm | 2.2 |
| X, m | 324772.436 | Coordinates of center | X, m | 324772.434 | Coordinates of center | X, m | 324772.5208 |
| $\sigma_X$, mm | 4.4 | | $\sigma_X$, mm | 4.9 | | $\sigma_X$, mm | 3.0 |
| Y, m | 148129.013 | | Y, m | 148129.018 | | Y, m | 148128.999 |
| $\sigma_Y$, mm | 4.4 | | $\sigma_Y$, mm | 5.2 | | $\sigma_Y$, mm | 3.2 |
| Diameter | 76.44m | | | 76.460m | | | 76.468m |
| Actual Volume | $87193.646m^3$<br>754093.4bbl | | | $87239.279m^3$<br>754488bbl | | | $87257.536m^3$<br>754645.9bbl |
| Nominal Volume | $86646.979m^3$<br>749365.5bbl | | | $86646.979m^3$<br>749365.5bbl | | | $86646.979m^3$<br>749365.5bbl |

Table 5 - Tank 8 Distortions

| STUDS | 2003Low mm | 2003Mid mm | 2003Full mm | 2004Low mm | 2004Mid mm | 2004Full mm | 2008Low mm | 2008Mid mm | 2008Full mm |
|---|---|---|---|---|---|---|---|---|---|
| STUD1 | -87.492 | -56.672 | -23.244 | 438.05 | -13.067 | 458.06 | -57.933 | -25.136 | 9.6489 |
| STUD9 | -118.96 | -81.888 | -55.86 | -4.9426 | -43.617 | -4.1533 | -49.708 | -24.706 | 6.9 |
| STUD16 | -74.91 | -54.681 | -13.414 | -12.1 | -10.352 | 14.263 | -91.859 | -9.7979 | 28.24 |
| STUD8 | -102.91 | -74.732 | -39.184 | -6.7749 | -33.592 | -8.3302 | -80.34 | -45.213 | 0.8752 |
| STUD2 | -81.624 | -47.132 | -31.219 | 18.099 | 13.479 | 47.923 | -59.957 | -30.896 | 3.1295 |
| STUD10 | -119.93 | -101.71 | -82.46 | -31.868 | -66.918 | -27.153 | -47.711 | -21.012 | 16.677 |
| STUD4 | -80.7 | -27.692 | 7.9384 | -15.906 | -17.04 | 15.722 | -71.06 | -46.995 | -2.153 |
| STUD12 | -167.47 | -126 | -79.96 | -64.336 | -108.38 | -69.696 | -67.424 | -38.07 | -2.1742 |
| STUD3 | -65.995 | 5.4712 | 24.493 | 23.594 | 12.181 | 49.431 | -78.773 | -46.509 | -14.287 |
| STUD11 | -98.772 | -108.43 | -57.164 | -32.082 | -58.302 | -21.456 | -26.554 | -1.742 | 33.226 |
| STUD5 | -65.727 | -15.258 | -0.6684 | -35.492 | -52.224 | -22.073 | -57.058 | -33.602 | 7.2398 |
| STUD13 | -114.73 | -91.798 | -68.178 | 60.313 | 26.714 | 52.766 | -59.831 | -41.05 | -6.615 |
| STUD7 | -21.403 | 0.60187 | 28.374 | 74.753 | 30.868 | 75.713 | -10.013 | 8.9676 | 58.307 |
| STUD15 | -93.652 | -63.679 | -37.232 | -8.4607 | 23.627 | 46.115 | -45.482 | -24.654 | 21.3 |
| STUD6 | -41.42 | 0.39721 | 20.854 | 4.2939 | 9.8724 | 55.221 | -45.5 | -11.735 | 36.221 |
| STUD14 | -70.983 | -51.525 | -24.8 | 65.465 | 54.179 | 80.974 | -29.982 | -10.558 | 38.071 |

The tables above are the results of the diameter of the tank and it accuracy, coordinates of the centre, and the actual volume of oil in the tank at different oil level and at three epochs of observations.

When the oil volume was at10m for the three epochs, the following was deduced. In 2003, diameter was 76.426m, excess oil volume was 2342.9bbl, and distortion was maximum at stud11 with value of 108.43mm and minimum at stud6 with a value of 0.40mm. In 2004, diameter was 76.44m and excess oil volume was found to be 2010.8bbl, distortion was maximum at stud12 with value of 108.38mm and minimum at stud6 with a value of 9.87mm. In 2008, the tank diameter was found to be 76.40m while the crude oil excess was found to be 2073bbl; distortion was maximum at stud4 with value of 46.99mm and minimum at stud11 with a value of 1.74mm

Again, the oil volume was increased from 10m to 19m for the three epochs, the following was also deduced. In 2003, diameter was 76.44m, excess oil volume was 4727.9bbl, and distortion was maximum at stud10 with value of 82.46mm and minimum at stud5 with a value of 0.67mm. In 2004, diameter was 76.46m and excess oil volume was found to be 5122.5bbl, distortion was maximum at stud1 with value of 458.06mm and minimum at stud9 with a value of 4.15mm In 2008, the tank diameter was found to be 76.468m while the crude oil excess was found to be 5280.4bbl, distortion was maximum at stud16 with value of 28.24mm and minimum at stud8 with a value of 0.88mm

The diameter was computed from the radius and compared with the nominal diameter at 19m oil level. For 2003 epoch, there is an expansion of 0.24m, in 2004 the expansion was found to be 0.26m and for 2008 the expansion was found to be 0.268m. From the above result, i.e. the determined diameter, actual oil volume and coordinates of center of tank no. 9, it can be seen that there are a clear difference in these values between each epoch of observations and the nominal volume and diameter. This we mean that there has been deformation in the wall of the tank since after their construction.

## CONCLUSION

Monitoring of tanks and tank walls help in identifying and quantifying deteriorations which may lead to tank failure and early warning. The history of tank disaster throughout the world reveals that problems often arise undetected due to inaccurate evaluation of the tank defects.

For an effective tank monitoring programme, the equipment used for the monitoring must be precise and of the highest quality. The monitoring personnel must be experienced in not only data capture but also the analysis of the acquired data. The period of observation should be yearly and consistent throughout the life of the tank

Further studies should be carried out on the tank to ascertain the character of the tank over the years. The use of the mathematical model and associated designed MATLAB program to determine the radius and coordinates of center of circular oil tanks from geodetic data especially during the process of monitoring the structural deformation was found to be very correct and economical. The period of observation should be every year and consistent throughout the life of the tank. The results obtained in this study may however be acceptable to the structural Engineer depending on the tank specifications and its properties at the design stage.

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