Computation of Deformation in Networks Geodetic by Least Squares Method and Ellipse of Errors

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Abstract

The modern analysis techniques for monitoring the deformation concrete structures network geodetic Mosul dam depends on assumption by least squares and ellipse of errors, then to carry out the adjustment for the networks. Due to the importance of the first order geodetic networks which is used in large scopes, it is used to design the other types of geodetic networks as the second and third order geodetic networks and it is used to monitoring spatially in the large structures. In this paper the geodetic network of Mosul dam has been adopted to evaluate the displacement and the direction of motion for the geodetic network points, 21 points have been used to evaluate the value of displacement in these points and study it effect into monitoring for Mosul dam. The accuracy acquaintance in geodetic networks is very important therefor this paper is aimed to compute the accuracy of geodetic network points by using a matlab program prepared to compute the ellipse of error for all points in geodetic network the resulted deformations magnitude for the (21) monitoring network pillars of Mosul Dam at two consecutive epochs (2005 and 2011) with respect to the zero epoch. The analysis shows a real displacement for dam pillars P62, P63, and P64 between the years 1989-2005 and 2011.

It is noticed from the matlab program that the adopted base line in mosul dam geodetic network is not the optimal base line because its points have an actual deformation while there is other points which have minimal ellipse of error according results, these points can be used to formation the base line for the geodetic network.

Keywords: Least Squares theory, ellipse of error, Blunder Detection Method, Global Congruency Test, Matlab.

Introduction:-

The deformation monitor usually accomplished by geodetic techniques through the use of reference ground points besides many distributed accurately over the structure body. The monitoring usually made by successive epochs. Many dam structures available in Iraq, because of the existence of two major rivers, lakes and many other water bodies. It was decided to take Mosul dam as a case study in this paper because it is considered the most important dam in Iraq. The adjustment was implemented for the monitoring network, and the adjusted coordinates of (21) pillars, standard deviations, ellipse of error were all computed after removing all the blundered observations by the standardized residual procedure. The activity of deformation or displacement monitoring is absolutely, the most importance activity because of its direct connection to the human life. Therefore many researchers efforts are directed to make science and technical development serve this domain by improving accuracy of monitoring and supplying information's as quickly as possible for safety of heavy structure [1].

Monitoring operation is strongly based on:

- Geodetic network and its efficiency in the design.
- The technology used in both field work and computation should match the accuracy of the design.
- The observation plan must be based on geometrical principles that should also match the accuracy required.

The monitoring usually made by successive observational epochs. In each epoch a least square adjustment for the geodetic network gives the most probable value of the network points coordinates. The displacement vector (d) will be computed for each point and statistically analyzed to decide if there are any actual displacements exists.[2] .The deformation monitoring usually accomplished by geodetic techniques through the use of reference ground points besides many pillars distributed accurately over the structure body.

Adjustment Computations by Least Squares

The development of the theory of least squares adjustment are based on the variance law for independent observations. The mathematical concept of weights is presented as a function of the variances (squares of standard deviations), While the use of weights, in conjunction with the variance law, leads to the idea of the variance factor. The square root of the variance factor is usually referred to as the standard deviation of an observation having unit weight.[3] The adjustment of independent observations which have equal variance least squares adjustments can be divided in to three categories:

- The observation equation.
- The condition equation.
- General or combined method.[4]

The adjustment of geodetic networks still one of the most important problems in surveying for many applications such as the networks designed for dams monitoring. With the advance development of computers, the method of adjusting the geodetic networks by “variation of coordinates” technique become the most preferred one. [5] The aim of most field survey measurements, regardless of whether they are part of a simple traverse or an over determined network, is the computation of coordinates. The technique of variation of coordinates by least squares method has received widespread recognition as the most accepted computational method. The acceptance of this technique is based primarily on the way with which true values of the coordinates and minimum measurement residuals from a consideration of the statistical behavior of the observations. [6]

Ellipse of Error

The variance or standard deviation are measures of precision for the one – dimensional case like an angle or a distance, but in the case of two dimensional problems, such as the horizontal position of a point, error ellipse may be established around the point to designate precision regions for a certain probability. The orientation of the ellipse relative to the E, N axes system (Fig.1) depends on the correlation between x and y. If they are uncorrelated, the ellipse axes will be parallel to E and N. If the two coordinates and of equal precision, or $\sigma_E = \sigma_N$, the ellipse becomes a circle. Considering the general case where the covariance matrix for the position of point p is given as

$$\sum = \begin{bmatrix} \sigma_E^2 & \sigma_{EN} \\ \sigma_{EN} & \sigma_N^2 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

The semi major and semi minor axes of the corresponding ellipse are computed in the following manner. (Raymond E. others 1981).From the elements of the variance – covariance matrix, the value of (θ) which orients the ellipse to provide the maximum and minimum semi – axes, and the numerical values for those semi – axes can be calculated as follows:

$$\tan 2\theta = \frac{2\sigma_{En}}{\sigma_E^2 - \sigma_N^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Where:

(θ) is laid off counter clock wise form the positive E axis.

$$\sigma^2_{\max} = \frac{1}{2}\left(\sigma_N^2 + \sigma_E^2 + \sqrt{\left(\sigma_N^2 - \sigma_E^2\right)^2 + 4\sigma_{NE}^2}\right) \ldots\ldots\ (3)$$

$$\sigma^2_{\min} = \frac{1}{2}\left(\sigma_N^2 + \sigma_E^2 - \sqrt{\left(\sigma_N^2 - \sigma_E^2\right)^2 + 4\sigma_{NE}^2}\right) \ldots\ldots\ldots (4)$$

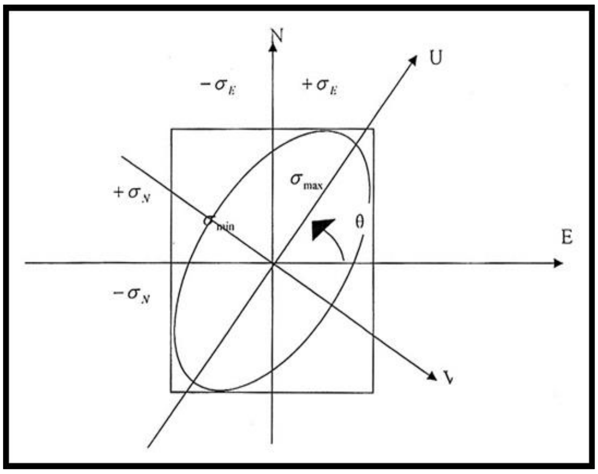


Fig. 1. Ellipse of error.

The following sections will introduce the mathematical procedure for developing the observation equations necessary in adjusting the horizontal geodetic networks by least square.[7]

Blunder Detection Method

Data sets have always been used that were assumed to be free of blunders. However, when adjusting real measurements, the data sets are often contain blunders. Not all blunders are large, but no matter their size, it is desirable to remove them from the date sets. Measurements should conform to the theory of normal distribution, which means that occasion large random errors will occur .However, according to the theory, this should seldom happen, and thus many large errors in data sets are actually blunders, when blunders are presented in a data set, a least square adjustment may not be possible or will at minimum produce poor or invalid results. To be safe, the results of an adjustment should never be accepted without an analysis of the post adjustment statistics. [2]

Deformation Survey Techniques

The general procedures to monitor the deformation of a structure and its foundation involve measuring the spatial displacement of selected object points (i. e., target points) from external control points that are fixed in position. Either terrestrial or satellite positioning methods are used to measure these geospatial displacements (Δx, Δy, Δz). The reference points are located in the structure only relative deformation is determined-e.g., micrometer joint measurements are relative observations. Absolute deformation displacement is possible if the control points are located outside the actual structure, in the foundation or surrounding terrain and beyond the area that may be affected by the dam or reservoir. Subsequent periodic observations are then made relative to these absolute control points.[8] Assessment of permeant deformations requires absolute data.[9]

Statistical Methods for the Detection of Deformations (Global Congruency Test)

The global congruency test is the most commonly method adopted for the detection of general deformations in a given area i.e. an overall change in shape.

For two epochs adjustment *(i,j)* it is possible to calculate the displacement vector d and its associated weight matrix W_{dd} from error propagation as

$$\left.\begin{aligned} d &= \hat{x}_i - \hat{x}_j \\ W_{dd} &= (Q + Q_j)^{-1} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where

d: displacement vector

$\hat{x}_i, \hat{x}_j$: Adjusted coordinates in epochs i and j respectively

Q_i, Q_j: cofactor matrices for epochs i and j respectively. [10]

The null hypothesis of the global congruency test can be stated as follows:

$$\sigma_{ij}^2 = \frac{v_i^t p_i v_i + v_j^t p_j v_j}{r_i + r_j} \quad (6)$$

$$\Omega^2 = \frac{d^{-1} W_{dd} d}{h} \quad (7)$$

Mosul Dam Monitoring Network

At late eighties of last century, the General Directorate for Survey (GDS) of the ministry of water resources Authority organized a periodic survey observation of Mosul Dam Project according to a methodology that aims to observe the horizontal network constructed by the Swiss Consultants during the construction of the dam.

Mosul Dam is located at about 50km North West of Mosul City at Ninawa Governorate on Tigris River .It takes three years to construct the dam between 1982 and 1985. The dam height is 49m and a length of 2.5km with a width of 8m at elevation of 336 M.S.L. Its width increases with depth at a rate of 2m for each 2.5m. The average dam height over the ground level is 49m. The two sides of the dam and the spillway side are covered with a rugged amour with an inclination of about 45°.[1] . The geodetic horizontal network of Mosul dam consists of many observation pillars, six of them (P61, P62, P63, P64, P65, and P66), are mounted on the upper crest of the dam structure while the other are ground control points. The observation pillars are a concrete cylinder with a diameter of 60cm and a height of 130cm above the ground level as shown in **Fig (2,c).**

The observations are carried each six month according to a procedure adopted by the Swiss Consultants using hybrid network (observed distance and angels) with double observations **Fig.** (2,b). In addition to two periodic observations, the first is carried out each two and a half years and the second is carried out each five years. [11]

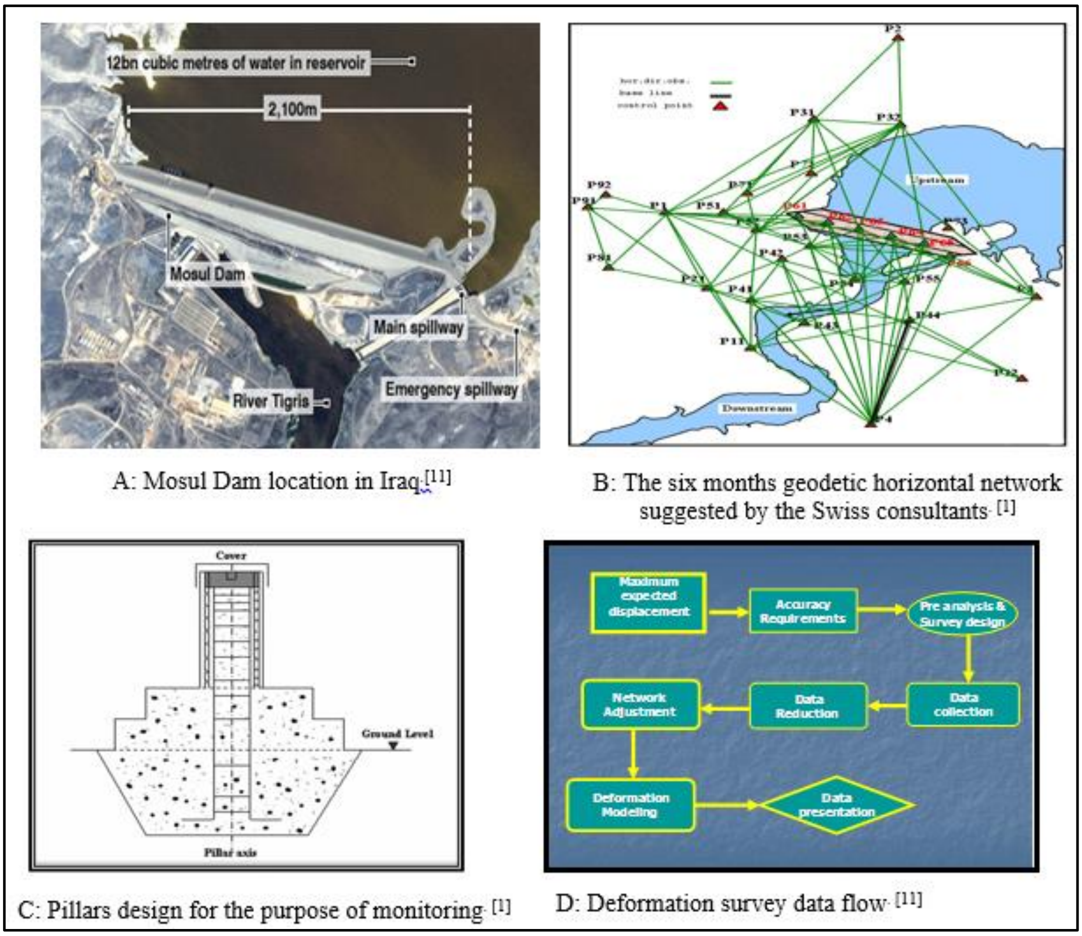
Statistical Computations and Analysis

For the purpose of studying the displacement of Mosul Dam structure, three epochs were considered, the zero epoch (1989), and two consecutive epochs 2005 and 2011. The reason for selecting these epochs was to evaluate the dam structure behavior for long and short time periods (16 years and 22 years respectively).The monitoring network was adjusted by the adjustment technique for the three mentioned epochs. The analysis was divided into two phases, the first one was the comparison between the zero and 2005 epochs. The second phase was the comparison between the successive epochs 2005 and

2011 observed year. Figure (3, a,b) .The maximum displacement was at P63 as shown in figure (3,c,d). These computed displacements were verified statistically by the Global Congruent Test and Simple Deformation Test respectively. The Global test shows that there was a horizontal displacement existed between the two epochs. **Table (1)** illustrates the magnitude of computed displacements, expected 95% probable errors, and the localization test values. **Table (1)** shows an actual displacement for the pillars P62 , P63 and P64 in the middle of the dam structure .The null hypothesis Ho was rejected for those pillars in both statistical tests while the Pillars P66,P65 and P61 was found not shifted in the Global Test. The second phase of displacement monitoring was to investigate if there is any suspected movement through the period from 2005 and 2011. These computed displacements were verified statistically by the Global Congruent Test and Simple Deformation Test respectively.**Table (2)** shows an actual displacement for the pillars P62,P63 and P64 in the middle of the dam structure .

Table. 1 Comparison between the Two Statistical Techniques for Epochs 2005 and Zero epoch

H_0 (null hypothesis)		Localization Test		95% probable error	Horizontal Displacement (meter)	Pillar No.
Simple deformation test	Global Congruency test	F Computed	$F_{95\%}$ Tabular			
Accepted	Accepted	0.014	4.756	0.011	0.027	P61
Rejected	Rejected	4.990	4.566	0.014	0.083	P62
Rejected	Rejected	127.770	4.750	0.008	0.270	P63
Rejected	Rejected	35.344	4.750	0.014	0.192	P64
Rejected	Accepted	1.576	4.751	0.008	0.065	P65
Rejected	Accepted	0.655	4.751	0.007	0.033	P66



A: Mosul Dam location in Iraq [11]

B: The six months geodetic horizontal network suggested by the Swiss consultants [1]

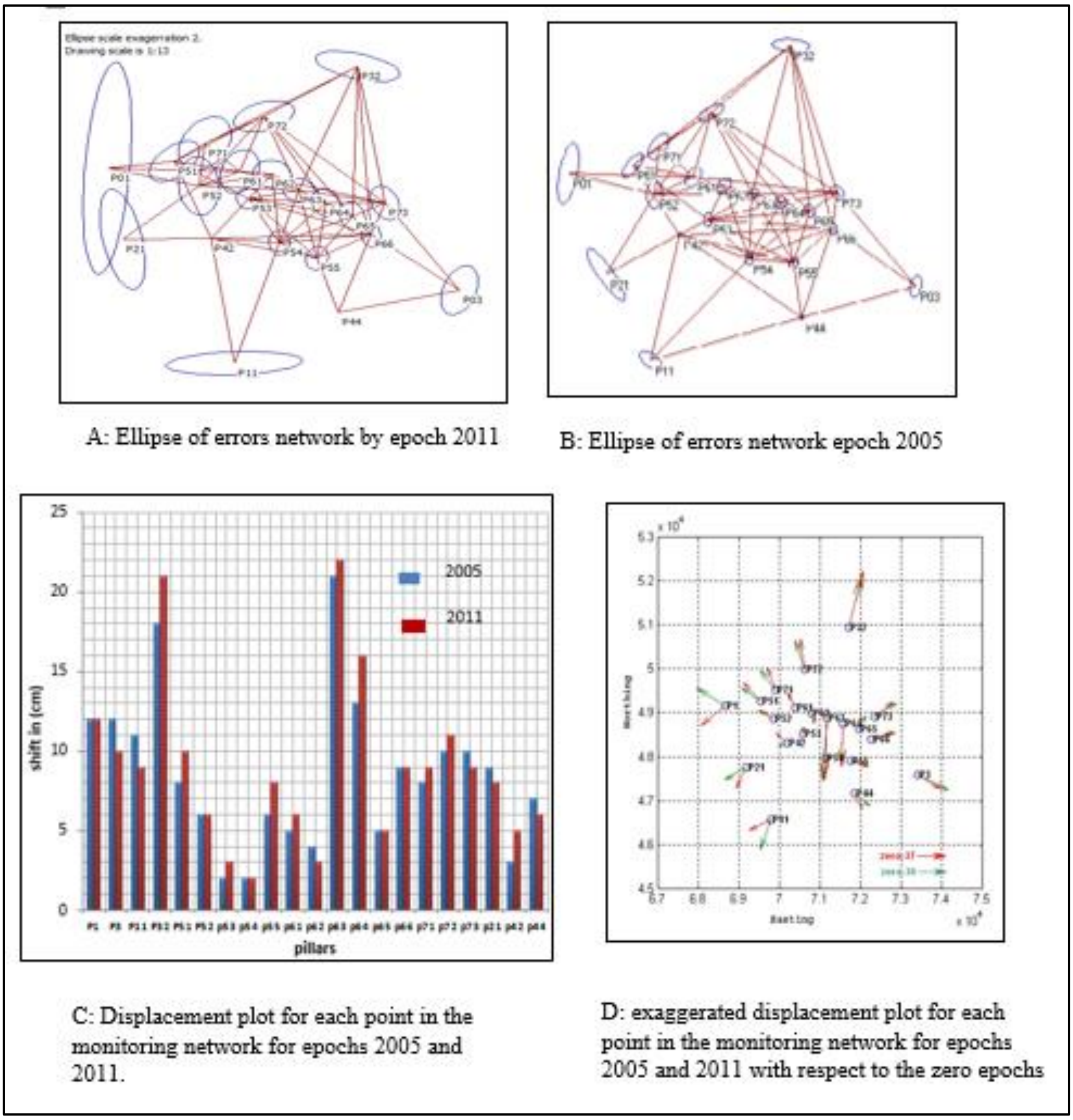
C: Pillars design for the purpose of monitoring [1]

D: Deformation survey data flow [11]

Fig. 2 monitoring Mosul Dam.

Table. 2 Comparison between the Two Statistical Techniques for Epochs 2011 and Zero epoch

H_o (null hypothesis)		Localization Test		95% probable error	Horizontal Displacement (meter)	Pillar No.
Simple deformation test	Global Congruency test	F Computed	$F_{95\%}$ Tabular			
Accepted	Accepted	0.010	4.751	0.012	0.080	P61
Rejected	Rejected	4.980	4.762	0.018	0.130	P62
Rejected	Rejected	127.760	4.752	0.015	0.341	P63
Rejected	Rejected	35.343	4.750	0.011	0.220	P64
Rejected	Accepted	1.577	4.751	0.008	0.111	P65
Rejected	Accepted	0.675	4.751	0.008	0.091	P66



A: Ellipse of errors network by epoch 2011

B: Ellipse of errors network epoch 2005

C: Displacement plot for each point in the monitoring network for epochs 2005 and 2011.

D: exaggerated displacement plot for each point in the monitoring network for epochs 2005 and 2011 with respect to the zero epochs

Fig.3 pillar in the monitoring comparison of horizontal shift between the zero epoch and epochs 2005 and 2011

Conclusions

The paper concentrates on evaluation the deformation of Mosul Dam is considered the most strategic dam in Iraq therefor this paper concentrates on evaluating the displacement in dam structure. It is found from the statistical analysis of the computed displacement, that for the long time period of 16 and 22 years between (1989 - 2005) and (1989 -2011), an actual deformations for the pillars on the dam body shows that the pillars (p63, p62, and p66) having a real shift, throw the analysis explained it is concluded that pillars p $_{63}$` having maximum deformation equal to (21 cm) from zero epoch in 1989 to 2005 and in the years from1989 and 2011 p63 having maximum deformation which is (34 cm). From the ellipse of error networks adjustment of Mosul dam it was found that pillars (p54, p55 and p71) having the minimum error ellipses, It is concluded that these pillars could be a better choice for control point instead of pillars (p42 and p44) which adopted by the General Directorate for Survey. This problem is well known as (zero order design).

References

[1] Addulamy, S. L., (2003), "Full Geodetic Treatment For Monitoring Of Heavy Structures" M.Sc. thesis, college of Engineering, University of Baghdad, Department of Surveying Engineering. A translation to Arabic

[2] Mikhail, E. M., Bethel, J. S, Glone, J. C., and Wiley, J., 2000, "Introduction to Modern Photogrammetry" 6th edition, Donnelly publisher, New York.

[3] Gabriel W., Janka S., and others, (2001), "Adjustment of the observations in a Free Geodetic Networks"**,** Acta Montanistica Slovaca, Slovakia.

[4] AL-Hussaini, H. A.,(1998), "Full Automation of Data Collection and Processing of Horizontal Control for Dam Deformation Surveying" M.Sc. thesis, college of Engineering, University of Baghdad, Department of Surveying Engineering.

[5] Bjerhamer, A.,(1973), "Theory of Errors and Generalized Matrix Inverses" Elsevier Scientific publishing company Amsterdam-London New York.

[6] Moffitt, F. H. and Bourchard, H., "Surveying", 7th edition, Harper and row, publisher, New York,

[7] Mikhail, E. M. ,(1976), "Observations and Least Squares", 1st edition, Donnelly publisher, New York.

[8] Wolf, P. R.,(1980), "Adjustment Computation", Second Edition, P.B.L. Publishing Co., Monona, Wisconsin.

[9] Vladimir, S., and Miloš, J.,2004, " Deformation Measurement on Bulk Dam of Water Work in East Slovakia", Volume L, N0.2, p.1-10, 155N 0474-8476

[10] **Acar, M., ozlu¨demir, Akyilmaz, O.¸ elik, R. N. C, and Ayan, T.,(2006),** "Deformation Analysis with Total Least Square, Istanbul Technical University", Division of Geodesy, Turkey.

[11] AL-kanani Y. H.,(2009), " Displacement computation of mousel dam by using free geodetic network adjustment", M.Sc. thesis, college of Engineering, University of Baghdad, Department of Surveying Engineering.

حساب التشوه للشبكات الجيوديسية بطريقة المربعات الصغرى ومنحني القطع الناقص للخطأ

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الخلاصة

تقنيات التحليل الحديثة لمراقبة الزحف والتشوهات للشبكات الجيودسية والمنشات الخرسانة تعتمد على طريقة المربعات الصغرى ومنحني القطع الناقص للخطأ. ونظرا لأهمية الشبكات الجيوديسية من الدرجة الأولى التي تستخدم في نطاق كبير، فانها تستخدم للرصد الدقيق في الهياكل الكبيرة و تستخدم لتصميم الأنواع الأخرى من الشبكات الجيوديسية من الدرجة الثانية والثالثة. في هذا البحث تم استخدام الشبكة الجيوديسية لسد الموصل لتقييم نقاط الضبط الارضي من خلال حساب الزحف واتجاه الحركة لكل نقطة من نقاط الشبكة الجيوديسية، وتم استخدام 21 نقطة ضبط ارضي للمراقبة وتقييم التشوه في جسم السد. وباستخدام برنامج ماتلاب المعد لحساب الانحراف والقطع الناقص للخطأ لجميع نقاط شبكة سد الموصل في رصدتيين عام2005 وعام 2011. ولقد وجد من خلال طريقة المربعات الصغرى و منحني القطع الناقص للخطاء وجود تشوهات وزحف حقيقي وملموس خلال هذه الفترة الزمنية لنقاط الشبكة الجيودسية. ولقد تم الاستنتاج أن خط الأساس المعتمد في الشبكة الجيوديسية لسد الموصل ليس خط القاعدة الأمثل لأن نقاطه لها تشوهات وزحف فعلي في حين أن هناك نقاط أخرى لها الحد الأدنى من منحني القطع الناقص للخطأ وفقا للنتائج، يمكن استخدامها في تشكيل خط الأساس للشبكة الجيوديسية.