Mansoura Engineering Journal, (MEJ), Vol. 32, No. 4, December 2007. C. 12

Developing the Procedures of No Contact Geodetic Measurements for High Building's Facades with Complicated Separate Elements

تطوير الرصد الجيوديسي دون لمس لواجهات المنشآت العالية، التي تحتوي علي عناصر منفصلة معقدة

BY

Zaki Mohamed Zeidan El-Sheikha

Associate professor, public works department, faculty of engineering

El-Mansoura university, Egypt.

الملخص العربي

تم في هذا البحث التوصل لحل رياضي للتوقيع المساحي لمكان ومركبات والمراقبة العملية لإنشاء واجهات المنشآت . هذا الحل مناسب للعناصر المنفصلة ذات الأشكال الهندسية المعقدة في الواجهات.
كذلك تم تطوير خطوات ونتائج الأرصاد والحلول الرياضية للحل المقترح ,حيث يتم استخدام طرق التقاطع العكسي لحساب إحداثيات النقط الأرضية ونقط التقاطع الأمامي للنقط على واجهة المنشآت.
كذلك تم معالجة هذه الأرصاد. بواسطة الإحداثيات التي تم الحصول عليها ومعالجتها , تم التوصل لحركة عناصر الوجهة في الاتجاهات الثلاثة.
هذه الطريقة مناسبة وملائمة لتوقيع واجهات المنشآت ذات الارتفاعات العالية.

Keywords:

facades, geodetic, shift, matrix of rotation, processing the results.

Abstract

In this paper was developed a methodology and executive surveys of the position, component and operational monitoring of façade constructions.

This methodology is available for separately façade elements with different and complicated geometric shapes.

Procedures and interpretation of the results of measurements with the appropriate theoretical substantiation of the proposed solutions are developed in this thesis, resection method used for determining the coordinates in the most probable plan and intersection method used for the coordinates of the separate element points.

The results of the geodetic measurements were processed. The coordinates of the separate elements of the façade were calculate the position and the deviation of the most probable plane of real facade.

This methodology is very suitable for setting the facades of the high-rise building.

Accepted December 11, 2007

Introduction

In the last decade in the domestic town building vigorously is developed the industry of facade constructions, called to regulate questions of standardization production, operation and safety. As any of the components of building, facade needs the operational monitoring (executive surveys) of its position. In the same time facade possesses a number of the signs, which substantially release it in a number of components, which compose building. First of all, facade, regarding, is the element of the surface mounting. Second distinctive property this, as a rule, large planar sizes of separate elements, which reach 6m along horizontal and 4m on the heights. The properties of facade to be the external construction of building and to have significant sizes in two measurements are the main characteristics, which define the need for the definition of the position of each element of facade both with the installation, and with the executive surveys.

If with the installation of each facade element geodetic work on its installation is carried out, as a rule, from within building and by predominantly contact method, then with executive survey appears the need of applying the no contact methods. Especially this relates to the high-rise buildings by the height of more than 100m. It is completely obvious that the no contact methods of executive survey require the application of the most contemporary high-precision means of measurements. Furthermore, is necessary the development of procedure and interpretation of the results of measurements with the appropriate theoretical substantiation of the proposed solutions. In the present on the basis of the executed developments all aspects of the procedure of no contact geodetic measurements for high building's facades with separate elements are presented to work [4].

Determination of the form of the attached facade's elements of the buildings

As the basic coordinate system let us accept the most utilized Cartesian coordinate system: X, Y, H. With the calculation of position and parameters of the most probable plane it will necessary produce transformation of coordinates, which are produced with the use of a matrix of rotation with the orthogonal conversion [1,2,3]:

$$\begin{pmatrix} X' \\ Y' \\ H' \end{pmatrix} = \begin{pmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{pmatrix} \begin{pmatrix} X \\ Y \\ H \end{pmatrix} + \begin{pmatrix} \delta X \\ \delta Y \\ \delta H \end{pmatrix} \qquad (1)$$

Where:

X, Y, H - Coordinates of the observed objects in the reference system of coordinates;

X′, Y′, H′ - Coordinates of the same objects in the system of coordinates of the most probable plane;

$\delta X, \delta Y, \delta H$ - Shift of the origin of the coordinates of the most probable plane relative to the reference system of the coordinates;

$$A = \begin{pmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{pmatrix}$$ matrix of rotation.

The matrix of rotation is obtained via the sequential turn of the coordinate axes to the angle of rotations $\alpha, \omega\, and\, \gamma$:

$$A = A_\alpha A_\omega A_\gamma, \quad (2)$$

Where:

$$A_\alpha = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{pmatrix}; \quad (3)$$

$$A_\omega = \begin{pmatrix} \cos\omega & 0 & -\sin\omega \\ 0 & 1 & 0 \\ \sin\omega & 0 & \cos\omega \end{pmatrix}; \quad (4)$$

$$A_\gamma = \begin{pmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{pmatrix}. \quad (5)$$

As a result the multiplication of matrices we will obtain the following values of matrix elements A:

$$\left.\begin{aligned} a_1 &= \cos\omega\cos\gamma \\ a_2 &= \cos\omega\sin\gamma \\ a_3 &= -\sin\omega \end{aligned}\right\}; \quad (6)$$

$$\left.\begin{aligned} b_1 &= \sin\alpha\sin\omega\cos\gamma - \cos\alpha\sin\gamma \\ b_2 &= \sin\alpha\sin\omega\sin\gamma + \cos\alpha\cos\gamma \\ b_3 &= \sin\alpha\cos\omega \end{aligned}\right\}; \quad (7)$$

$$\left.\begin{aligned} c_1 &= \cos\alpha\sin\omega\cos\gamma + \sin\alpha\sin\gamma \\ c_2 &= \cos\alpha\sin\omega\sin\gamma - \sin\alpha\cos\gamma \\ c_3 &= \cos\alpha\cos\omega \end{aligned}\right\}. \quad (8)$$

When observation of the building it is conducted in the united coordinate system, it is necessary around the building to create the field control (fig. 1,2) in the local coordinate system.

Axis H is parallel to plumb line, axes X and Y are directed approximately in parallel to the major axes of building perpendicular to axis H (in the horizontal plane).

With the calculation of the coordinates of the points of field control, for example, to point 1, we attach any value of coordinates, and the arbitrary value of grid azimuth is given to lines 1-2. In this coordinate system the coordinates and the heights of the points of field control are determined.

The creation of field controls around the observed building by the method of polygon measurement, is not only possible method. It is in certain cases expedient to use intersection and resection methods [2] (resection method used for determining the coordinates in the most probable plan and intersection method used for the coordinates of the separate element points) .

Processing the results of the geodetic measurements

As a result the field observations of the attached ventilation facades is obtained the collection of coordinates X_i, Y_i, H_i, according to which it is necessary to calculate the position of the most probable plane [2] and the deviation of real facade from the most probable plane. By most probable plane we will understand such plane, which satisfies the condition:

$$F_i = \sum_{i=1}^{n} X_i'^2 \rightarrow \min. \qquad (9)$$

For guaranteeing the monotony of calculation formulas let us accept for the rule:

- the origin of the coordinate system, which determines the most probable plane, to have near the left angle of the facade being investigated;
- the inclination of axis H' determines the inclination of the facade of building relative to the plumb line (axis H);
- axis X' is directed outside from the wall of building;
- axis Y' is directed in parallel to the major axis of the wall of building.

In this case the angle of turn around (axis Y') ω determines the inclination of the most probable plane relative to plumb line, angle γ determines the turn of the most probable plane (axis Y') relative to the reference system of coordinates, angle and determines the inclination of Y' axis relatively horizontal plane.

In connection with the fact that the coordinates of the observed points are obtained in the reference system of coordinates (system of coordinates of field control), it is necessary to accomplish a transfer of the coordinate system so that the position of new axis H' relative to the reference system of coordinates would determine the inclination of the observed wall (ω angle of the turn of axis Y'), and angles α and γ also in reflected the angular displacement of the major axes of building relative to the reference system of coordinates. With this selection of the coordinate systems the inclination of the wall of building and is low value, but the angle of the turn of the major axis of building γ can reach the significant magnitudes. Consequently, for bringing the matrix of rotation (2) to the linear form it is necessary to find the approximate values of the angle of turn around the axis H'-γ. In accordance with formulas (1) - (8) transformation of coordinates we will produce according to the formulas:

$$\left.\begin{aligned} X_i' = {} & X_i \cos\omega\cos\gamma + Y_i \cos\omega\sin\gamma - \\ & - H_i \sin\omega + \delta X; \end{aligned}\right\} \qquad (10)$$

$$\left.\begin{aligned} Y_i' = {} & X_i(\sin\alpha\sin\omega\cos\gamma - \cos\alpha\sin\gamma) + \\ & + Y_i(\sin\alpha\sin\omega\sin\gamma + \cos\alpha\cos\gamma) + \\ & + H_i \sin\alpha\cos\omega + \delta Y; \end{aligned}\right\} \qquad (11)$$

$$\left.\begin{aligned} H_i' &= X_i(\cos\alpha\sin\omega\cos\gamma+\sin\alpha\sin\gamma)+\\ &+Y_i(\cos\alpha\sin\omega\sin\gamma-\sin\alpha\cos\gamma)+\\ &+H_i\cos\alpha\cos\omega+\delta H. \end{aligned}\right\}\quad(12)$$

The angle of the turn of the system of coordinates of the most probable plane relative to the axis X' is small and does not influence the fundamental characteristics of the most probable plane. In connection with this it is expedient not to calculate this value, counting α = 0, therefore, formulas (10) - (12) let us represent in the form:

$$\left.\begin{aligned} X_i' &= X_i\cos\omega\cos\gamma+\\ &+Y_i\cos\omega\sin\gamma-\\ &-H_i\sin\omega+\delta X; \end{aligned}\right\}\quad(13)$$

$$\left.\begin{aligned} Y_i' &= -X_i\sin\gamma+Y_i\cos\gamma+\\ &+\delta Y; \end{aligned}\right\}\quad(14)$$

$$\left.\begin{aligned} H_i' &= X_i\sin\omega\cos\gamma+\\ &+Y_i\sin\omega\sin\gamma+\\ &+H_i\cos\omega+\delta H. \end{aligned}\right\}\quad(15)$$

In connection with the fact that equations (13) - (15) are nonlinear relative to the angles of the turn of the coordinate axes, the approximate value of the angle of turn γ let us calculate in two stages. In the first approximation, taking into account that the angle of the slope of the most probable plane is small, let us accept ω = 0, and equation (13) let us write down in the form:

$$\left.\begin{aligned} X_i' &= X_i\cos\gamma+Y_i\sin\gamma+\\ &+\delta X. \end{aligned}\right\}\quad(16)$$

Let us designate,

$$\cos\gamma = C_\gamma;$$

$$\sin\gamma = S_\gamma.$$

and equation (16) let us represent as:

$$\left.\begin{aligned} X_i' &= X_iC_\gamma+Y_iS_\gamma+\\ &+\delta X. \end{aligned}\right\}\quad(17)$$

The calculation of the most probable plane let us produce with the observance of condition (9):

$$F=\sum_{i=1}^{n}\left(X_iC_\gamma+Y_iS_\gamma+\delta x\right)^2\rightarrow\min.\quad(18)$$

Condition (18) will be observed with:

$$\left.\begin{aligned} \frac{\partial F}{\partial C_\gamma}&=0;\\ \frac{\partial F}{\partial S_\gamma}&=0;\\ \frac{\partial F}{\partial \delta X}&=0. \end{aligned}\right\}\quad(19)$$

Or:

$$\left.\begin{aligned} &C_\gamma\sum_{i=1}^{n}X_i^2+S_\gamma\sum_{i=1}^{n}X_iY_i+\delta X\sum_{i=1}^{n}X_i=0\\ &C_\gamma\sum_{i=1}^{n}X_iY_i+S_\gamma\sum_{i=1}^{n}Y_i^2+\delta X\sum_{i=1}^{n}Y_i=0\\ &C_\gamma\sum_{i=1}^{n}X_i+S_\gamma\sum_{i=1}^{n}Y_i+n\delta X=0 \end{aligned}\right\}\quad(20)$$

Solving the system of linear equations (20), let us calculate C_γ, S_γ *and* δX. From where we will obtain the approximate values of angles γ:

$$\gamma_1 = \cos^{-1} C_\gamma;$$
$$\gamma_2 = \sin^{-1} S_\gamma.$$

As the final value let us take the average value of the angle of the turn $\tilde{\gamma}$:

$$\tilde{\gamma} = \frac{\gamma_1 + \gamma_2}{2}. \qquad (21)$$

The precise value of angle γ is equal to:

$$\gamma = \tilde{\gamma} + \delta\gamma. \qquad (22)$$

Equation (13) let us write down in the form taking into account (22):

$$\left.\begin{aligned} X_i' &= X_i \cos\omega \cos(\tilde{\gamma} + \delta\gamma) + \\ &+ Y_i \cos\omega \sin(\tilde{\gamma} + \delta\gamma) - \\ &- H_i \sin\omega + \delta X. \end{aligned}\right\} \qquad (23)$$

Let us expand trigonometric functions in the Taylor series, being limited to the first-order terms of the smallness:

$$\left.\begin{aligned} X_i' &= (-X_i \sin\tilde{\gamma} + Y_i \cos\tilde{\gamma})\frac{\delta\gamma}{\rho} - \\ &- H_i \frac{\omega}{\rho} + \delta X + X_i \cos\tilde{\gamma} + \\ &+ Y_i \sin\tilde{\gamma}. \end{aligned}\right\} \qquad (24)$$

It is final the value of angles ω, $\delta\gamma'$ and displacement δX let us calculate from the objective function (9), after accepting the designations:

$$Z_i = -X_i \sin\tilde{\gamma} + Y_i \cos\tilde{\gamma};$$
$$l_i = X_i \cos\tilde{\gamma} + Y_i \sin\tilde{\gamma}.$$

Consequently,

$$F_1 = \sum_{i=1}^{n}\left(\frac{Z_i}{\rho}\delta\gamma - H_i\frac{\omega}{\rho} + \delta X + l_i\right) \to \min;$$

and:

$$\left.\begin{aligned} \frac{\partial F_1}{\partial \delta\gamma} &= \frac{\delta\gamma}{\rho}\sum_{i=1}^{n} Z_i^2 - \frac{\omega}{\rho}\sum_{i=1}^{n} H_i Z_i + \\ &+ \delta X \sum_{i=1}^{n} Z_i + \sum_{i=1}^{n} Z_i l_i = 0 \\ \frac{\partial F_1}{\partial \delta\omega} &= -\frac{\delta\gamma}{\rho}\sum_{i=1}^{n} Z_i H_i + \frac{\omega}{\rho}\sum_{i=1}^{n} H_i^2 + \\ &+ \delta X \sum_{i=1}^{n} H_i + \sum_{i=1}^{n} H_i l_i = 0 \\ \frac{\partial F_1}{\partial \delta X} &= \frac{\delta\gamma}{\rho}\sum_{i=1}^{n} Z_i - \frac{\omega}{\rho}\sum_{i=1}^{n} H_i + \\ &+ n\delta X + \sum_{i=1}^{n} l_i = 0 \end{aligned}\right\} \qquad (25)$$

The final value of angle γ let us calculate according to formula (22), and then the values of abscissas X ' according to the formula (13). The calculated values of the abscissas X' characterize the deviation of the real position of the attached facade's elements from the most probable plane. Analogously they observe and all facades of building are processed. The obtained parameters of the most probable plane of all facades of buildings make it possible to compose idea about the real form of entire construction as a whole.

Conclusions

1-The domestic town building vigorously is developed the industry of facade constructions, called to regulate questions of standardization production, operation and safety.

2- The installation of each facade element geodetic work on its installation is carried out, as a rule, from within building and by predominantly contact method, then with executive survey appears the need of applying the no contact methods.

3- It is completely obvious that the no contact methods of executive survey require the application of the most contemporary high-precision means of measurements.

4- All aspects of the procedure of no contact geodetic measurements for high building's facades with separate elements are presented to work.

5- The obtained parameters of the most probable plane of all facades of buildings make it possible to compose idea about the real form of entire construction as a whole.

References

[1] Bronshtein I.N., Semendiev K.A1998., "Reference book on mathematics" Naoka. Physics-Mathlit, M.,1998.

[2] Klushin E B., Kiselev M.I., Mikhelef D.SH.2006, Feldman V.D., "Engineering geodesy." Akadimkniga, 6-th tom M.,2006.

[3] Leovitch B.A., Kroglov V.M, .Matveev C.I,2006,"The geo-information theory of transport". Veheteram,Moscow,2006.

[4] Nazarov I. A.2006, "Study of influence on the accuracy of measurement by the nonreflective electronic tacheometer of the angle of incidence of laser beam and reflecting surface properties". Spornik Trodov MGSU, M. 2006.

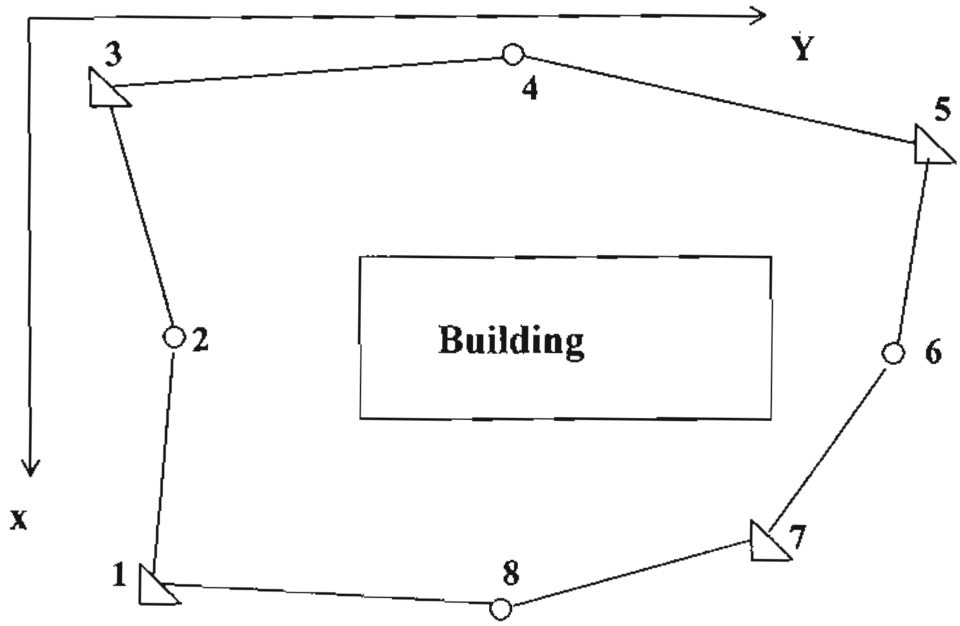

Fig.1 Plan of the field control

1,3,5,7 - Connecting points

2,4,6,8 - Points for the survey of building by the polar method

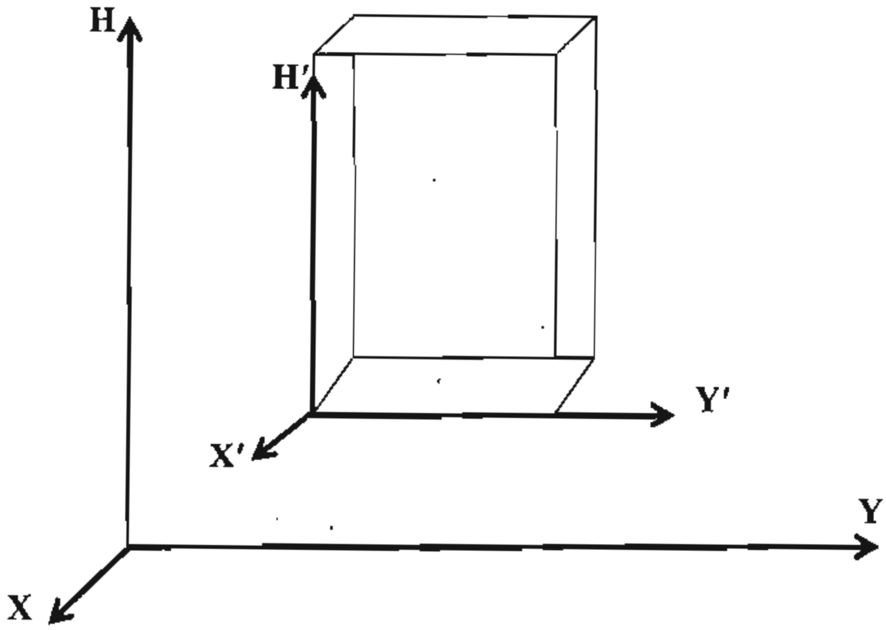

Fig.2 Side view