GEODESY

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METHODS OF INDIRECT TRANSFER OF INTERNAL GEODETIC NETWORK POINT COORDINATES OF A BUILDING TO AN ASSEMBLY HORIZON

This paper presents the analysis of the methods of indirect transfer of internal geodetic network points coordinates of buildings to an assembly horizon. Method of vertical, optical or laser projection, method of mechanical (string) line, and method of inverse linear-angular intersection which do not require zenith holes in the slabs are considered. Either fixed and portable hinged metal consoles or tables which are fixed on outer walls and floor slabs of the building are used in the methods of vertical projection. Two or three output points coordinates placed on the extensions of the principal axes of buildings are mostly transferred. To build a layout network on an assembly horizon light range finders or sighting marks are placed at the points transferred to the elevation. Ground-surveying traverse with coordinate or azimuth binding to the direction of the distance checking objects is plotted. In the absence of conditions for building vertical lines behind the buildings, methods of inverse linear-angular intersections with equipments (Total Stations) are used to determine the horizontal (or spatial) position of the internal geodetic network points on an assembly horizon on the basis of the terrestrial (transferring) points of the external geodetic network of the building site or the surrounding area. Different models of construction of the inverse linear-angular intersections are analysed depending on the conditions of observation of ground points located within the boundaries of the construction object. In order to simplify the technology of geodetic engineering for the transfer of internal geodetic network points from the source to the assembly horizon and to study the results of executive survey of bearing structures on each floor, the coordinates of the translation points should be determined in the axial coordinate system of the internal geodetic network built on the output tier. Accuracy calculations of the indicated methods show that the mean square errors of the transfer of points and the construction of the internal geodetic network at the assembly horizon do not exceed 5–9 mm, established by the State Building Standards (DBN) V.1.3.2 - 2010 for four categories of structures.

Key words: internal geodetic network, optical, laser and string vertical lines, assembly horizon, hinged console, two-coordinate table, axial ground surveying, inverse linear-angular intersection, reduction of approximate points

Introduction

For many years during the construction of high-rise buildings, the control of the position (coherence) of structures (columns, panels, elevator shaft blocks, etc.) was carried out from the points of the internal geodetic network, which is built on the slab of the initial horizon (mainly the first floor) and then sequentially transmitted to the assembly horizon by the method of vertical projection using optical and laser devices of the PZL-100 type [Levchuk et al., 1981; Viduev, 1978; Geodezja inżynieryjna, 1979, 1980; Hennecke & Werner, 1980; Schofield, 2001]. However, these works are related to the need to arrange coaxial zenith holes in the floor slabs which provide high accuracy of measurements but also make the process of the hole arrangement more complicated because of the need to coordinate the locations of the holes in the slabs with house-building factories, which often leads to errors and cutting down concrete. In addition, as the height of the structure increases, the scales of the coordinate pallets are diminished, requiring either their illumination or the use of a stepwise procedure of point coordinates transfer [Baran & Borysiuk, 2006; Baran, 2012].

It is known that internal geodetic networks are not built for the buildings which are up to 30 m high and the axles are transferred to the assembly horizon by an inclined projection method which is not suitable for high-rise construction. Therefore, it remains relevant to search for methods of increasing the efficiency of point coordinates transfer to the assembly horizon using modern methods and technical means, especially with the use of the GPS method and the methods of triangulation network construction or linear-angular intersection using equipment.

The GPS method is extremely promising but the accuracy of measurements in conditions of the saturated metal structures can be significantly reduced due to distortion of radio signals. Construction practice requires thorough theoretical and experimental studies of this method to establish the real accuracy of construction of the layout networks on the assembly horizon of high-rise buildings, without rejecting this method for long-term monitoring of structures.

Thus, the problem of modernization of linear-geodetic development using modern equipment and the technique of vertical projection of geodetic points remains relevant. It is important to point out that according to the State Building Standards [DBN V.1.3.2: 2010], the mean square errors of the transfer of internal geodetic network points coordinates or axis points to the assembly horizon should not exceed the following values 1; 2; 3; 5 mm – minimum and 2; 4; 6; 11 mm – maximum for construction sites of 1st, 2nd, 3rd, and 4th categories respectively. It is obvious that the choice of transmission methods must be based on the minimum transfer error. Figure 1 shows the distribution of these errors with the height of the buildings or the number of floors of the building which can be measured using modern electronic geodetic engineering equipment.

The analysis of tolerances (Fig. 1) indicates that for structures of the first category internal geodetic network points should be transferred to the assembly horizon by PZL type vertical projection devices or by a mechanical (string) vertical method with an error of up to 3 and 5 mm to a height of 100 and 200 m respectively. For the buildings of the 3rd and 4th categories, this error cannot exceed 5.7 and 9 mm respectively, which is achieved with the help of linear-angular construction methods using high and medium-precision equipment.

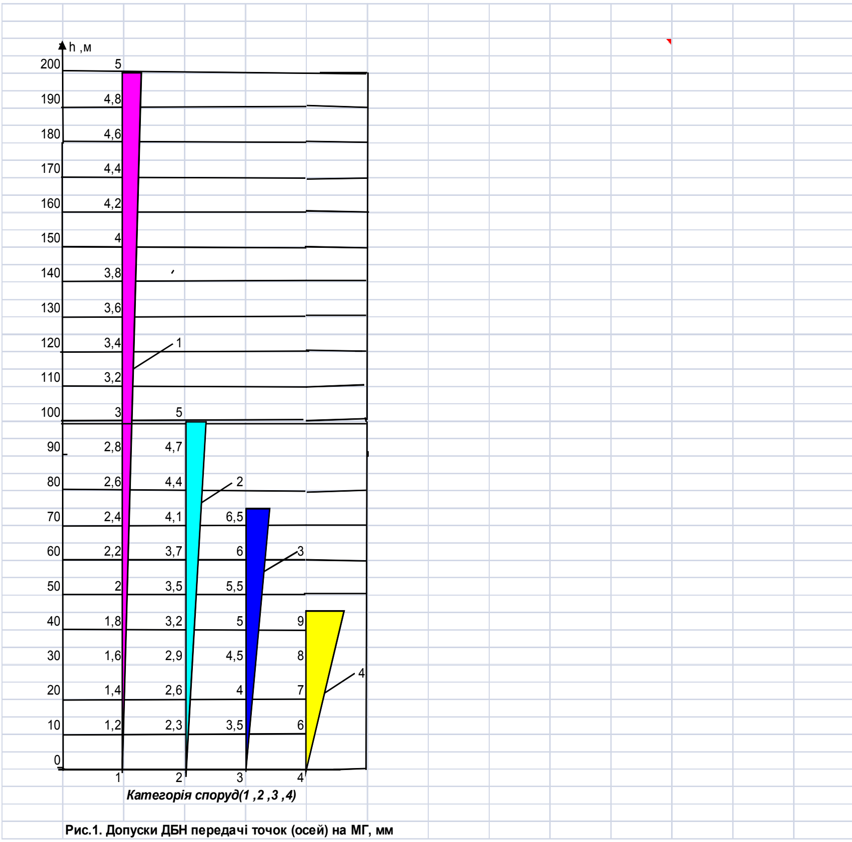

Fig. 1. Tolerances of the State Building Standards (DBN) for points (axes) transfer to the assembly horizon, mm

Aim

Given the relevance of the problem in the practice of erecting high-rise buildings, it is advisable to consider indirect methods of optical, laser and mechanical vertical lines, axial ground surveying and inverse linear-angular intersections using the external geodetic network points of the construction site (or adjacent area) to transfer the internal geodetic network points to the assembly horizons while maintaining the current axial coordinate system of the construction object.

Methodology and results

1. Method of vertical lines. To implement the given method, the ground reference points of the external geodetic network must be located near the basement of the structure or on the wall of the 1st floor with the condition of maximum margin of the vertical line (up to 0.5 m) to the walls of the building with the aim to reduce the length of the hinged console with a coordinate pallet or other receiving device. It is necessary to do so because of the need for surveyors at the assembly horizon to access them. It is obvious that these points should not be located on the south side of the building where refractive distortion of the sighting or laser vertical line due to the solar heating of the wall is possible [Baran, 2007, 2012, Levchuk et al., 1981; Hennecke & Werner, 1980]. Ground control points that are connected to the external geodetic network points of the construction site should be selected on the main axis of the structure and fixed on metal consoles secured in the holes between the basement and the wall of the building. The points are transferred to the console plate from the ground points of the main axis and fixed with a 16 mm diameter hole for installation of optical/laser plummet.

On the assembly horizon, a similar console with a hole for a coordinate pallet or a nadir optical or laser plummet is placed on a reliable supporting metal frame with a fence (Fig. 2), which is temporarily welded to the intermediate slab. The misalignment of the pallet lines with respect to the axes of the structure shall not exceed 1°, requiring the approximate positioning of the principal axis in the working area or the choice of the appropriate reference point on the extension of the principal (main) axis of the structure. Instead of a pallet, it is advisable to use a two-coordinate table [Baran & Borisyuk, 2006; Baran, 2012] with a triple prism 360°(Leica, Trimble), which is run with rudder agent command from the bottom. Here, it is better to use a nadir device, which is run by the operator with the help of the two-coordinate table vertically from the bottom point.

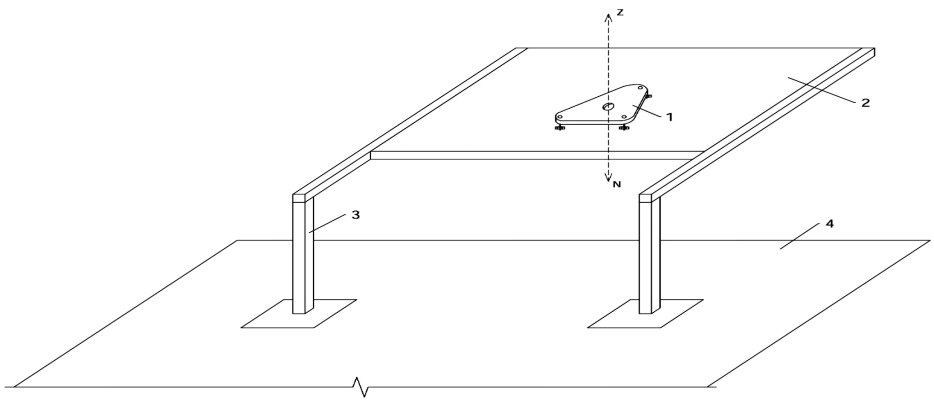

Fig. 2. The design of a metal table with cantilever plate and pedestal for optical and laser plummets: 1 – stand; 2 – table; 3 – rack; 4 – floor slab

Either direct or inverse plummet is used when applying the method of mechanical (string) vertical line. The latter is more convenient because the string is fixed at the bottom. At the same time, the tank in the form of a toroid (“non-leaching”) is fixed on the cantilever plate with a hole for the string on the assembly horizon. It is filled with antifreeze (oil) to install a float connected to the string [Baran, 2012, p. 143–145]. A triple prism for remote distance measurement is set on the axis of the float. This system is more productive because it provides automatic float installation on the vertical line and an easy way to transfer the points coordinates on the next horizon by changing the length of the string with a diameter of 1–1.5 mm at the bottom of the anchor.

2. Axial ground surveying method. This method can be used for multi-section buildings and structures in the form of elongated polygonometric stroke with azimuth and coordinate binding [Baran, 2012, p. 177]. Fig. 3 shows the construction of a pivot (axial) line with two ground points A and B securing the main or marking axis with three intermediate points C_1, C_2, C_3 on the assembly horizon respectively, separated from the end walls of the house at the distance between S_1 and S_4.

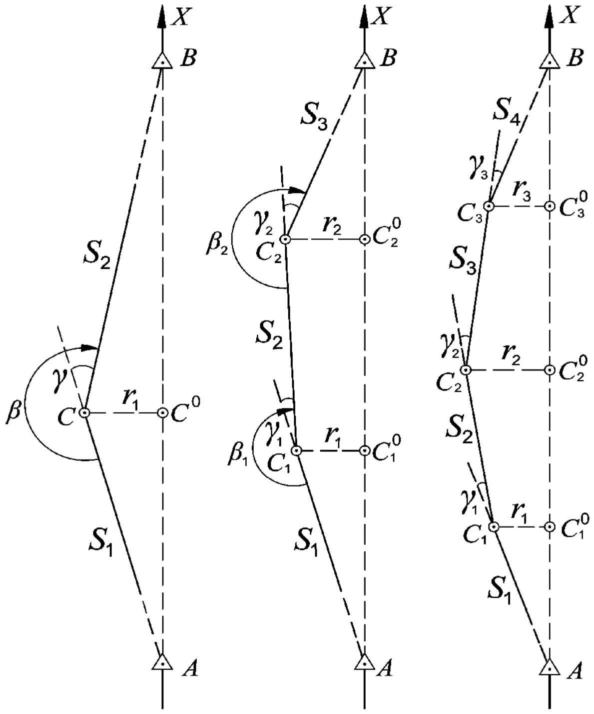

Fig. 3. Point reduction in bipolar intersection mode

After measuring the $\gamma_1, \gamma_2, \gamma_3$ angles in one, two or three points of their reduction r_i $(i = 1, 2, 3)$ per section line is calculated by the formulas [Baran, 2012]:

$$r_1 = \frac{S_1 S_2}{[S]} \sin\gamma;$$

$$r_1 = \frac{S_1(S_2 + S_3)\sin\gamma_1 + S_1 S_3 \sin\gamma_2}{[S]};$$

$$r_2 = \frac{S_3(S_1 + S_2)\sin\gamma_2 + S_1 S_3 \sin\gamma_1}{[S]}; \qquad (1)$$

$$r_2 = \frac{1}{[S]}\{(S_1 + S_2)(S_3 + S_4)\sin\gamma_2 + $$
$$+ S_1(S_3 + S_4)\sin\gamma_1 + (S_1 + S_2)S_4 \sin\gamma_3\};$$

$$r_1 = \frac{S_1}{S_1 + S_2}(r_2 + S_2 \sin\gamma_1);$$

$$r_3 = \frac{S_4}{S_3 + S_4}(r_2 + S_3 \sin\gamma_3),$$

here $[S]$ – is the length of the AB side.

The errors of determination of reductions practically depend on accuracy of measurement of angles of misalignment and are calculated by formulas for one, two and three intermediate points respectively:

$$1)\ m_r \approx 0{,}50\frac{Sm_\gamma}{\rho};$$

$$2)\ m_{r_1} = m_{r_2} \approx 0{,}58\frac{Sm_\gamma}{\rho}; \qquad (2)$$

$$3)\ m_{r_1} = m_{r_3} \approx 0{,}61\frac{Sm_\gamma}{\rho};$$

$$m_{r_2} \approx 1{,}22\frac{Sm_\gamma}{\rho},$$

here S – is the average length of the side of the section line traverse; m_γ is a measurement error of the misalignment angle.

The method of calculation of errors of more points of a section line is given in the following article [Baran, 2012, p. 450].

Using the above described method, it is possible to mark intermediate points of the main axis on the basis of the two endpoints A and B transmitted upwards by the methods of optical, laser, or mechanical vertical lines. The simplest method is to determine initially one point by the two measured lengths of sides S_1 and S_2 and the misalignment angle $\gamma = \varepsilon$ between them with the calculation of the reduction (perpendicular) r to the AB section line using the 1st dependence of the formula (1). Then, by shifting the equipment to the section line, other points of the principal axis are marked. They are then used to mark points of the parallel axes, constructing an assembly grid with parallel lines.

The ways to determine the reductions for two and three intermediate points are somewhat a little more complicated (see dependences 2 and 3). Options with the intermediate points being located at the edges of the assembly horizon and the end points A and B being ground ones and fixing the main axes of the building can be considered as the advantage of the latter two methods. Then instead of using the method of vertical lines to transfer these points, a system of three internal geodetic points can be easily built on the assembly horizon with their reductions to obtain design distances $S_2^0 = C_1^0 C_2^0$ and $(S_2^0 + S_3^0) = C_1^0 C_3^0$. The disadvantage of this method is the coordinate referencing is eliminated by using a checking point that is 2–3 km away from the object.

Hereafter an example of calculating reductions for three range points and their errors with the following input is given: S = 20 m; n = 4; $\gamma_1 = 309''$; $\gamma_2 = -165''$; $\gamma_3 = 227''$; $m_\gamma = 10''$, namely: $r_1 = 20$ mm; $r_2 = 10$ mm; $r_3 = 16$ mm; $m_{r_1} = 0.6$ mm; $m_{r_2} = 1.2$ mm; $m_{r_3} = 0.6$ mm. If the lengths of the adjacent sides to ground points reach 100 m, then the above mentioned errors remain unchanged.

3. Method of linear-angular intersection. The transmission of internal geodetic network points coordinates from the initial to the assembly horizon is carried out using this method by means of auxiliary external geodetic network translator points located on the construction site or adjacent territory, using modern equipment. In this case, the accuracy of the design position of the translator points should be twice as precise as the internal geodetic network. Reliability is guaranteed by the transmission of not less than three internal geodetic network points on the basis of which a system of location survey axes (assembly grid) is built on the assembly horizon with one line for two rows of structures (columns, panels). Due to that, there may be no need to make more than 100 zenith holes on a 34-storey building.

To illustrate the method in a simple way, a well-known Hanzen's intersection of determining two points 1, 2 of the internal geodetic network from the two translator points A and B of the external geodetic network is taken (Fig. 4). Ground points are located in safe places and fixed using either typical soil signs or better tubular signs with screws for compulsory centring. A metal fence is installed to protect from destruction.

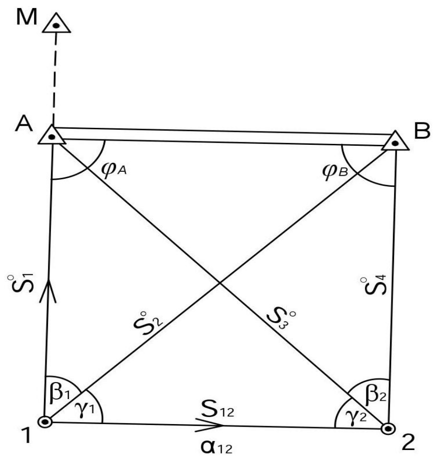

Fig. 4. Hanzen's intersection for two points

As a mere formality, the problem is considered in such a way that the internal geodetic network is already built at the initial horizon. Its two main points 1 and 2 have coordinates in the coordinate system of the building (object) and must be transferred to the assembly horizon. If the coordinates of A and B ground translator points are determined from these two points, it will be possible to determine coordinates of any points (including points 1 and 2) from the inverse linear-angular intersection. Therefore, by installing equipment on the assembly horizon in the approximate points of the indicated points, which are easily marked using linear references to the exits of the structures, it will be possible to determine the exact coordinates of the indicated points with the help of the measured horizontal distances $S_1^0, S_2^0, S_3^0, S_{12}$ and angles β1, γ1, β2, γ2 which are sufficient for high-quality point intersections, even without control measurements from the ground reference points. Then, directional angles (azimuths) $\alpha_1^0, \alpha_2^0, \alpha_{12}^0$ will be calculated as a result of the analysis of the intersection on the PC, using such LKM programs as Topograd, Inventgrad, CREDO, and others.

Bringing temporary points to the design position, which should be consistent with the position of these points at the initial horizon, is conducted using a method of reduction, which somewhat complicates the transfer process. Therefore, in order to simplify this process, it is advisable to use linear angular intersection. To do this, a sighting mark M, which is additionally equipped with a triple prism for distance control, is placed on the continuation of one of the lines of the intersection (for example, 1-A), which provides the proper conditions for the easy transfer of the points coordinates of the layout axis 1–2 on any assembly horizon. In this case, the equipment is set at the extension of the MA section line first at point T close to point 1, and then, at point 1 after the exact distance S_1^0 is defined. Having the balanced values of the azimuths subtraction $(\alpha_{12}^0 - \alpha_1^0)$ and of the distance S_{12}^0, the second point 2 is fixed, which should correspond to similar points of the initial horizon.

It should be noted that sightings from point 2 to point B may be restricted. Therefore, in order to control the marking of these points, it is necessary to measure distances S_1, S_2, S_3, S_{12} and horizontal angles $\beta_1, \gamma_1, \gamma_2$, as well as to balance the intersection with the inclusion of additional (control) values $S_2^0, \gamma_1^0, \gamma_2^0$ from the initial horizon, that is, with six measured values instead of 9 at the initial horizon.

By comparing the obtained coordinates with the coordinates of the identical initial horizon points, it is possible to estimate the transfer quality and, if necessary, with the difference of those points to reduce them to their design position. Obviously, this task can be simplified by constructing two reference section lines.

For angles φ_A і φ_B near the initial points, the following formulas can be used to control the measurement of the 4 angles in the Hanzen's intersection [Baran et al, 1986]

$$\begin{aligned}
&\frac{\varphi_A + \varphi_B}{2} = \frac{1}{2}[180^\circ - (\beta_1 + \gamma_1 + \beta_2 + \gamma_2)];\\
&\frac{\sin\beta_1 \sin(\beta_2 + \gamma_2)\sin(\beta_1 + \gamma_1 + \gamma_2)}{\sin\beta_2 \sin(\beta_1 + \gamma_1)\sin(\beta_2 + \gamma_1 + \gamma_2)} = K;\\
&M = \frac{K-1}{K+1};\\
&\frac{\varphi_A - \varphi_B}{2} = arctg[Mtg\frac{\varphi_A + \varphi_B}{2}];\\
&\varphi_A = \frac{\varphi_A + \varphi_B}{2} + \frac{\varphi_A - \varphi_B}{2};\\
&\varphi_B = \frac{\varphi_A + \varphi_B}{2} - \frac{\varphi_A - \varphi_B}{2}.
\end{aligned} \tag{3}$$

It is necessary to point out that the coefficient $K \approx 1$, $M \approx 0$ and $\varphi_A \approx \varphi_B$ in the intersection of a rectangular form.

If the length of the side 1–2 is measured, these angles are more easily determined by the formulas

$$\begin{aligned}
\sin\varphi_A &= \frac{S_{12}\sin\beta_1 \sin(\beta_2 + \gamma_2)}{b\sin(\beta_2 + \gamma_1 + \gamma_2)};\\
\sin\varphi_B &= \frac{S_{12}\sin\beta_2 \sin(\beta_1 + \gamma_1)}{b\sin(\beta_1 + \gamma_1 + \gamma_2)},
\end{aligned} \tag{4}$$

here $b-$ is the length of the initial side AB.

The quality of the work is guaranteed by transferring of at least three internal geodetic network points, which serve as the basis for marking the assembly axes of the structures or the assembly grid to the assembly horizon. The implementation of such technology in practice eliminates the process of arrangement of zenith holes in the slabs. However, it requires the observation of ground points from the highest floor of the building. This means that when the height of the structure is more than 100 m and the possible angle of view of the visual tube of the equipment equals $\nu = -45^\circ$, the horizontal distance to the reference point should also be longer than 100 m. Obviously, it is better to place the above mentioned reference points away from the end walls of the building in order to extend this distance. However, this only applies to one control point, such as A, which is located at the 1-M line at a remote local land mark (spire, antenna, cross, or sighting mark with a reflector) mounted on the wall of a reliable small building due to possible deviation of the building from the vertical line under the influence of subsidence of its foundation or lateral solar heating.

It is advisable to use the network design shown in Fig. 5 to transfer three internal geodetic network points coordinates, which is more technological under the conditions of transfer control. It is a modification of the previous linear-angular intersection, in which point 3 together with two points 1 and 2 should belong to one line. The positions of points 1, 2, and 3 at the initial horizon are determined with the help of ground points A and B by measuring 8 sides and 6 angles.

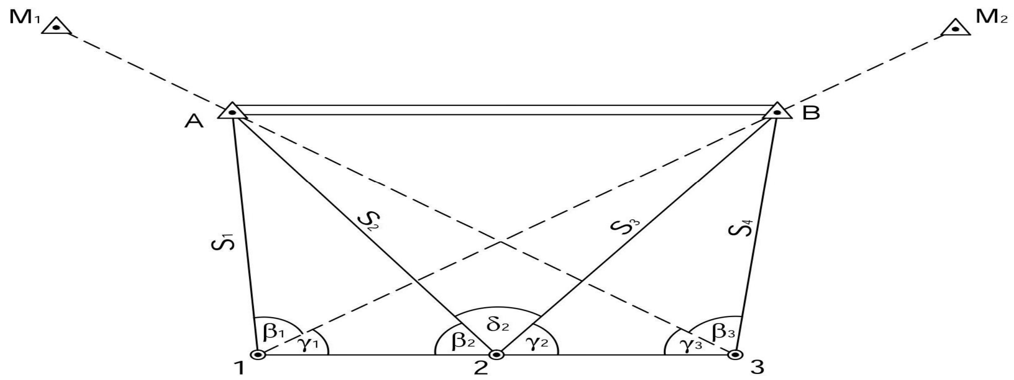

Fig. 5. Inverse linear-angular intersection of the 3 internal geodetic network points

The middle point 2 is the first to be marked at the assembly horizon with the help of the section line AM. A mark with its reflector (cataphotic film) can be placed on the wall of the building. However, if it is impossible to observe point A, then another section line can be taken as a base, for example, 1-B-M2 (both section lines are effective for controlling the marking). If the stability of points A and B can be trusted, the basic intersection can be extended to determine the position of 4 or more internal geodetic network points.

In order to improve transfer reliability, the number of ground broadcasting points can be reduced to three (Fig. 6). At the same time it is enough to measure only 7 sides and 6 angles at the assembly horizon.

It should be noted that to ensure the exact installation of the equipment on the extension of the section line *M-A*, the angle ε of misalignment (Fig. 7, *a*) can be measured at the approximate point T and its linear value a (perpendicular to side *1-A*) can be calculated by the following formula [Baran, 2012, p. 254]:

$$\varepsilon = N_M - N_A; \quad \gamma = \varepsilon + \delta; \quad a = S\sin\gamma = S \cdot S_M \sin\varepsilon / L, \tag{5}$$

here S, L, S_M are the distances measured by the equipment (the last is the one with the direction measurement $N_M = TM$).

If a has a minus sign, the perpendicular is placed to the left of the selected section line, and if it has the plus sign it is placed to the right. For a distance of S = 100 m and a small angle $\varepsilon = 6'$, the misalignment a = -174 mm, is placed in the direction of the section line. Then the time point is fixed and, having installed a equipment in it, the distance to point A is measured. After comparing it with the design distance S_2, the equipment is shifted to the design point 2.

Misalignment error

$$m_a = \frac{(L+s)m_\varepsilon}{L\rho} \approx s(1+\frac{s}{L})\frac{m_\varepsilon}{\rho} \tag{6}$$

is a transverse component of the error of the internal geodetic network point, which decreases as *L* increases. However, if the design mark M is used to control the marking of the designed distance *s*, then this distance must be reduced. Therefore, it is advisable to take *L=2s* when the expression in brackets approaches 1.5. Then with *s* = 100 m and $m_\varepsilon = 5''$ the error equals $m_a \approx 3{,}6$ mm.

As the angle of misalignment increases, the linear element of reduction increases and complicates the process of outputting the equipment, especially when the control mark M is located outside the 2-A section line (see Fig. 7, *b*). In such a case, it is necessary to measure the sides of the misalignment triangle? As well as the angle φ and to calculate the elements of reduction ω and r by the formulas:

$$\sin\delta = \frac{S}{L}\sin\varepsilon;\ \ \gamma = \varepsilon + \delta - \varphi;$$

$$a = S\sin\gamma;\ \ q = S_2 - S\cos\gamma;\ \ r = \sqrt{a^2 + q^2};$$

$$\text{If } S_2 \le S,$$

$$\text{то } \omega = \arcsin\left(\frac{S\sin\gamma}{r}\right), \tag{7}$$

$$\text{otherwise } \omega = 180^\circ - \arcsin\left(\frac{S\sin\gamma}{r}\right).$$

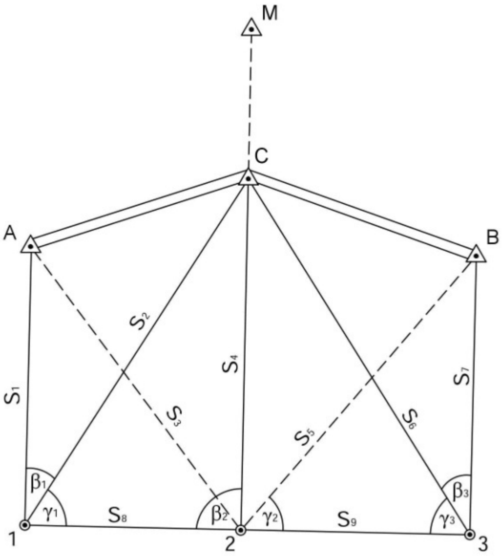

Fig. 6. Hanzen's checking point intersection for 3 points

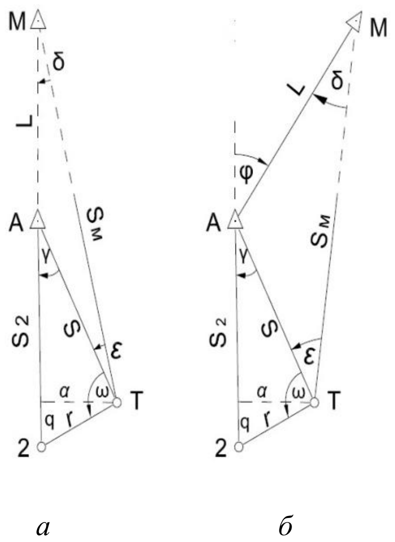

Fig. 7. Before the equipment reduction at the section line to the project point

Then, having plotted the polar angle ω and reduction r, the equipment is installed at the obtained point and, by checking the orientation of the device along the section line the distance to the reference point A or mark M is measured. Having compared it with the design one, the device is shifted to the design point 2 if necessary. Afterwards, points 1 and 3 are marked by the corresponding angles and lengths of the sides of the initial horizon. Then, the network is balanced by the control measurements of the angles and distances using the planned values of the output tier. After comparing the obtained coordinates with the planned ones, the points are reduced to in the design location and they are finally attached to the assembly horizon.

The relative error of measurement of the misalignment angle can be determined by the formula

$$m_\delta \approx \sqrt{2}\frac{m_L}{L}\rho tg\delta;$$

$$m_r \approx \frac{S_2 S\sin\gamma\, m_\delta}{r\rho}; \tag{8}$$

$$m_\omega \approx \frac{S\sin\gamma\, m_r\rho}{r^2\cos\omega},$$

here m_r/r, m_L/L are the relative errors of measuring the reduction and the distance of the reference mark from the reference point of the section line.

If the lengths of all sides of the misalignment triangle are close to 100 m, for example, 100 and 95 m, and the angles $\varepsilon = \delta = 10'$ і $\gamma = 20'$, then with $r \le 5$м and $m_r \le 1$мм both the measurement errors and the determination of the angles ε and δ cannot exceed the magnitudes $m_\varepsilon \le 4''$ and $m_\delta \le 20''$. As L increases, the measurement error of this angle should be reduced. Therefore, reference points should not be selected at great distances from the construction site.

With large angles of misalignment, for example,

$\varepsilon = \delta = \varphi = 30^\circ$; $m_\varphi = m_\varepsilon = 5''$; $m_L/L = 1:5000$; $m_\gamma = m_\delta \approx 24''$ and $r \approx 5$ m error is $m_r = (24/108000)\cdot 5000 = 1$ mm. Therefore, to improve the conditions for ensuring the accuracy of the reduction of time points to the design position, it is necessary to reduce the angles φ i γ, i.e. to approximate the reference mark to the section line and reduce the magnitude of the reduction to 5 m.

The accuracy of the inverse linear-angular intersection method of transferring points coordinates to the assembly horizon can be improved by using some angles and distances measured at the initial horizon but they should not be measured under the conditions of visibility from the assembly horizon. However, the feasibility of using them as additional control measurements can only be confirmed by practice. Network designs based on combinations of inverse linear-angular intersections with computer processing may be somewhat more complex. However, basic checking sides will be the main and effective elements of such networks.

It is advisable to use 50×50×2 mm metal (duralumin) dies, which are glued to the clean surface of the concrete with synthetic Sekunda glue or dowels, to secure the internal geodetic network points on the assembly horizon. The final position of the point on the dies is fixed by a hole 2 mm in diameter, using a mini-drill. The advantage of such marking is the ease of finding the point, the ease of centering the devices, and the high accuracy of measurements.

At the end of the analysis of the inverse linear-angular intersection method, it is worth mentioning that the external geodetic horizon points can be technologically selected after the construction of the internal geodetic network at the initial horizon, and the conditional coordinates of this network can be transmitted to ground points by the method of coordination with s, including determination of their altitude position in the system of heights of the building site. Then, it is possible to significantly simplify the technology of marking works and executive removal of structures by specifying the coordinates of internal geodetic network points and centres of structures in the conditional and unified axial coordinate system of the building. At the same time, it is necessary to transfer the elevation marks by the method of trigonometric levelling from the translator points of the external geodetic network of the construction site in the process of determining the planned position of the internal geodetic network points [Baran, 1997, 2012].

It should be noted that in both these processes it is necessary to take into account the temperature deformation of the structure caused by the change of its temperature, which can affect both the change of coordinates and altitudes of the tier points due to the deviation of the building from the vertical line and the the change of its height [Baran, et al.; 2007, Baran, 2012; Hennecke & Werner, 1980]. For long-term monitoring, it is advisable to use the three main points of the internal geodetic network by installing GPS receivers in them.

In summary, it should be pointed out that the above discussed methods of transferring points coordinates to the assembly horizon do not limit possible designs of networks both by the number of individual initial points and the designs of their axial systems (for many rows of columns, panels, or points created using elevator and ventilation shafts). Visibility of the territory from the assembly horizon makes it possible to freely choose the support and reference points of the external geodetic network of the construction site outside its boundaries.

Conclusions

1. Based on the analysis of the methods of transfer of the internal geodetic network points coordinates to the assembly horizons during the construction of high-rise buildings, it has been revealed that the vertical projection method of the points, despite its high accuracy, loses its economic and technical attractiveness due to the need to arrange zenith holes in the slabs, especially on structures up to 100 m high.

2. The technological advantages of the vertical projection method can be successfully realized in external ways of transfer of points to the assembly horizons by means of optical and laser devices or string plummets placed on both stationary and portable consoles with coordinate pallets.

3. It is advisable to transfer internal geodetic network points by the methods of inverse linear-angular intersections, which do not require zenith holes in the slabs of the building in the absence of conditions for the implementation of external vertical projection method. Technologically, these methods can be implemented in the system of coordinates of the external geodetic network of the site. However, it is easier to do that in the conditional axial system of coordinates of the

building when the coordinates of the internal geodetic network points and the centres of building structures are defined in it.

4. In the near future, a serious alternative to these methods may be the GPS method which is free from the negative impact of the metalwork of the construction object on the reception of radio signals.

REFERENCES

Baran, P. I., Mickiewicz, V. I., & Polishchuk YU. V. (1986). Application of Geodetic Intersections, Their Generalized Schemes and Methods of Machine Solution. Moscow: Nedra, 166 p.

Baran, P. I., Solovyov, F. F., & Chernokin, V. Ya. (1997). Trigonometric levelling in geodetic engineering works. Edited by prof. P. I. Baran. Kyiv: Ukrgeodezkartografiya, 130 p.

Baran, P. I., & Borisyuk, L. V. (2006). Modernization of instruments and equipment for performing geodetic works in high-rise construction. *Geodetic and Mapping Bulletin*, 1, 13–16.

Baran, P. I. (2007). Taking into account the temperature deformation in the measurement of horizontal and vertical displacements of engineering structures. *Geodetic and Mapping Bulletin*, 4, 14–20.

Baran, P. I. (2012). Engineering Geodesy: Monograph. Kyiv: PAT "VIPOL", 618 p.

DBN B.1.3-2: 2010. System for Ensuring Accuracy of Geometric Parameters in Construction. Geodetic Works in Construction. Kyiv: Ministry of Regional Building of Ukraine. 69 p.

Geodezja inżynieryjna. Vol. 1, 2. Warszawa: PPWK. 1979, T. 1, 638 p.; 1980, T. 2, 602 p.

Hennecke, F., & Werner H. (1980). Ingenieurgeodäsie. Anwendungen im Bauwesen und Anlagenbau Verlag fur Bauwesen. 534 p.

Levchuk, H. P., Novak, V. E., & Konusov, V. H. (1981). Applied Geodesy. Basic Methods and Principles of Geodetic Engineering Works. Moscow: Nedra, 438 p.

Schofield, W. (2001). *Engineering Surveying: Theory and Examination Problems for Students*. Elsevier.

Viduev, N. G. (Ed.). (1978). Handbook of Engineering Geodesy. Kyiv: Vyshcha Shkola, 376 p.

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МЕТОДИ НЕПРЯМОГО ПЕРЕДАННЯ КООРДИНАТ ПУНКТІВ ВНУТРІШНЬОЇ ГЕОДЕЗИЧНОЇ МЕРЕЖІ БУДІВЛІ НА МОНТАЖНИЙ ГОРИЗОНТ

Розглянуто методи непрямого передання координат пунктів внутрішніх геодезичних мереж (ВГМ) будинків на монтажний горизонт (МГ), зокрема вертикального оптичного або лазерного проеціювання, механічної (струнної) вертикалі та створно-обернених лінійно-кутових засічок, які не потребують влаштування зенітних отворів у плитах перекриття будинків та споруд. У методах вертикального проеціювання використовують стаціонарні й переносні навісні металеві консолі або столики, які закріплюють на зовнішніх стінах та плитах перекриття будівлі. Переважно здійснюють передання координат двох-трьох вихідних пунктів, розташованих на продовженні головних або основних осей споруди. Для побудови розмічувальної геодезичної мережі на монтажному горизонті на переданих наверх пунктах встановлюють трипельпризми або візирні марки та прокладають між ними ходи осьової полігонометрії з координатною або азимутальною прив'язками до напрямків на віддалені орієнтирні місцеві об'єкти. За відсутності умов для побудови позабудинкових вертикалей застосовують методи обернених створно-орієнтованих лінійно-кутових засічок (СОЛКЗ) із електронними тахеометрами для визначення планового (або просторового) розміщення пунктів ВГМ на МГ на основі наземних (трансляційних) пунктів зовнішньої геодезичної мережі (ЗГМ) будівельного майданчика або прилеглої до нього території. Проаналізовано різні моделі побудови СОЛКЗ залежно від умов забезпечення спостережень наземних пунктів, розташованих в зоні розміщення об'єкта будівництва. З метою спрощення технології інженерно-геодезичних робіт із передання пунктів ВГМ з вихідного на МГ та опрацювання результатів виконавчого знімання несних конструкцій на кожному поверсі координати трансляційних пунктів доцільно визначати в осьовій системі координат ВГМ, побудованій на вихідному ярусі. Розрахунки точності вказаних методів свідчать, що середні квадратичні похибки передання пунктів та побудови внутрішньої геодезичної мережі на МГ не перевищать 5–9 мм, встановлених ДБН В.1.3.2 -2010 для чотирьох категорій споруд.

Ключові слова: внутрішня геодезична мережа, оптична, лазерна і струнна вертикалі, монтажний горизонт, навісна консоль, двокоординатний столик, осьова полігонометрія, обернена створно-орієнтована лінійно-кутова засічка, редукування наближених пунктів.

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