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# RECOVERY ALTITUDE SETTING-OUT BASE OF CONSTRUCTION OF POLOTSK HYDROELECTRIC POWER STATION

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*We consider the problem of recovery altitude setting-out base of construction and give calculations of the required accuracy location survey and describe the field and office work.*

Location survey in the course of construction has to provide setting out from points of a geodetic setting-out base with the set accuracy of axes and marks defining situation in the plan and on height of parts and structural elements of buildings according to the project documentation. As it is shown below, the accuracy of location survey in many respects is defined by the accuracy of a setting-out base. Therefore points of a geodetic setting-out base have to be in process of construction under observation for their safety and stability and to be checked instrumentally at least 2 times a year [1].

The article discusses the examination, recovery and development of the existing geodetic basis for the construction of Polotsk hydropower plant. This problem has arisen in the construction of the gantry crane. The scheme of location of points of a marking basis of rather main constructions of hydroelectric power station is provided in figigure 1.

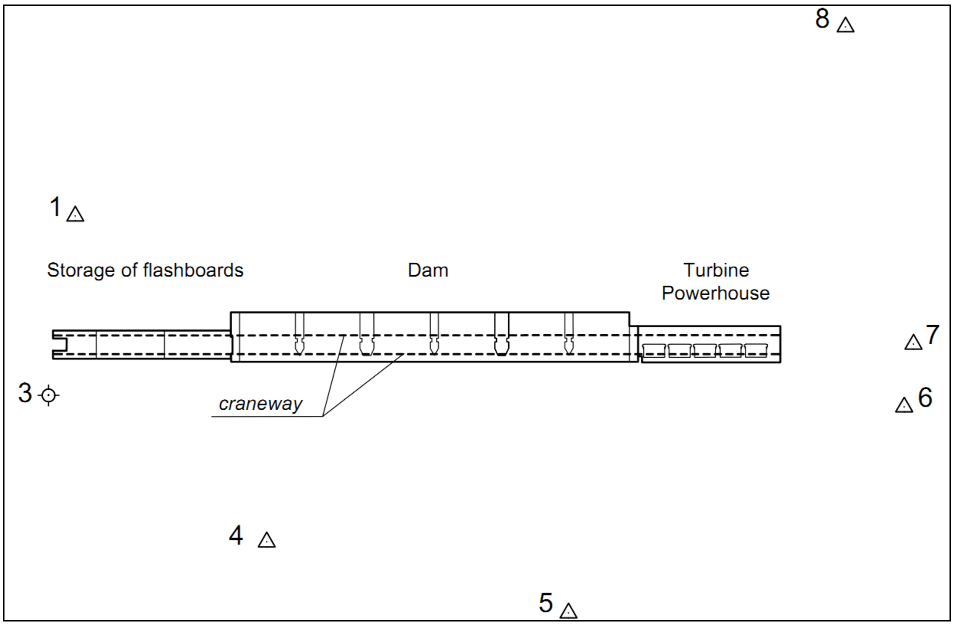


Fig. 1. The scheme of location of points of a setting-out base

Points of setting-out base fixed film reflectors which are widely used in geodesic industry. Film reflectors glued to any stable designs and coordinated from points of the terrestrial network points polar manner (at a distance of no more than 150–200 m) or direct line-angle intersection [2].

It is known that errors of carrying out of axes and marks consist of errors of location survey and mistakes in coordinates of points of a geodetic setting-out base:

$$m^2 = m_p^2 + m_u^2, \quad (1)$$

where $m$ – average square error of the position staked point; $m_p$ – average square error of the position staked point due stakeout measurements; $m_u$ – average square error of the position points geodetic setting-out base.

Efforts should be made to the error in the position of the starting points is practically no effect on the accuracy of the setting-out. In [3] it is shown that the compliance with the criterion

$$m_u \le 0{,}43m \quad (2)$$

coordinates of the source points can be considered infallible.

The project documentation for the construction of the facility is set next tolerance, referring to the position of crane runaway relative to the main and the principal axes of the object:

- a common center line, measured along the running surface, must not deviate more than 10 mm from the theoretical lines in both horizontal and vertical planes;

Then, taking $m$ = 10 mm, we obtain the $m_u$ = 4,3 mm. Thus, if the position error points of setting-out base do not exceed 4.3 mm, the location survey can be considered infallible.

**Instrumental verification of the provision of points of a setting-out base.**

For verification we compared the a priori and the actual (calculated measurement) values of the accuracy of the resection from the points setting-out base. If the actual mistakes exceed aprioristic more than for 10% [3], then on condition of high-quality measurements it is possible to speak about existence of mistakes in the provision of points of a setting-out base.

When calculating the following basic data were used:

- coordinates of starting points have an error of $m_u$ = 4,3 mm;
- coordinates of the station were modelled proceeding from possible installation sites of the tacheometer at setting-out;
- the resection was solved from three starting points, at the same time the maximum distance from the station to starting points didn't exceed 200 m, the maximum angle of inclination 20°.
- average square errors of measurement of angles – 2", distances – 3 mm;

Precalculation of accuracy of high-rise situation at a resection from three points is executed on the formulas given in [2]. We will receive the accuracy of determination of height from one point on a formula:

$$M_h^2 = (m_\alpha D \cos\alpha / \rho)^2 + m_D^2 \sin^2 \alpha, \quad (3)$$

where $m_\alpha$ – error of measurement of a vertical angle, $m_D$ – error of measurement of distance, $\alpha$ – the angle of inclination, $D$ – distance, $\rho$ = 206265".

At our basic data we will receive $M_h$ = 2,1 mm. At a resection from three points $M_h = 2{,}1/\sqrt{3} = 1{,}2 mm$. Then we will receive the maximum mistake in high-altitude position of the station:

$$m = \sqrt{m_p^2 + m_u^2} = \sqrt{1{,}2^2 + 4{,}3^2} = 4{,}5 \text{ mm.}$$

The actual errors of position of the station were calculated on measurements on starting points by means of the built-in program of the tacheometer and exceeded in certain cases 10 mm on height.

Instrumental vertification showed that it is impossible to use points 1, 5, 8 for setting-out. This fact, and also need of obtaining coordinates of point 3 served as the reasons of performance of work on restoration of a setting-out base.

**Field works on restoration of a setting-out base.**

Measurements on points of a setting-out base were performed by a polar cross-bearing the tacheometer.

Measurements were carried out from four stations. At the first and second stations the tacheometer was installed so that it was possible to measure on all points (1, 3, 4, 5, 6, 7, 8). Distances from the station to points have made from 140 to 230 meters. At the third station of measurement were carried out on points 1, 3, 4, distances to points didn't exceed 150 meters. At the fourth station – on points 5, 6, 7, 8. Distances to points didn't exceed 160 meters. The third and fourth stations got out so that to reduce distance to points, vising accuracy thereby increased, and also to provide an optimum angle of falling of a laser beam on the reflecting surface [4]. The measurements connecting stations among themselves weren't made.

In table 1 heights of points and results of measurements of heights are given in each station.

Table 1 – Input heights and results of measurements

| Num. points | | Station 1 | Station 2 | Station 3 | Station 4 |
|---|---|---|---|---|---|
| | $H^0$, m | $H^1$, m | $H^2$, m | $H^3$, m | $H^4$, m |
| ***1*** | 125,065 | 125,074 | 125,073 | 125,073 | |
| ***3*** | | 125,625 | 125,619 | 125,624 | |
| ***4*** | 118,756 | 118,752 | 118,752 | 118,753 | |
| ***5*** | 116,769 | 116,781 | 116,773 | | 116,777 |
| ***6*** | 128,300 | 128,301 | 128,299 | | 128,299 |
| ***7*** | 129,910 | 129,913 | 129,908 | | 129,909 |
| ***8*** | 123,789 | 123,802 | 123,797 | | 123,799 |

**Cameral works on restoration of a high-altitude setting base.**

The measured heights of points at each station should be considered as heights of the same points in different systems of heights. The reason of it that before measurements determination of coordinates of the station and orientation of the tacheometer it was carried out roughly owing to mistakes in coordinates of starting points. Theoretically measurements at each station can be performed without binding on starting points, i.e. in conditional system of heights. Further processing of results means transformation of heights to system of one of stations. System of the station to which we will transform, we choose proceeding from existence of the greatest number of points measured on her. These are stations 1 and 2.

So, we have heights of points in initial system of heights $H^0$ and height of the same points received from the measurements executed on four stations $H^1$, $H^2$, $H^3$, $H^4$, (Tab. 1).

Let's transform heights received at stations 2, 3, 4 in system of heights of the station 1. Transformation of coordinates comes down to parallel translation in the vertical plane of system of each station at a size $\Delta H^k$, calculated on a formula

$$\Delta H^k = \frac{1}{r}\sum_i^r H_i^1 - \frac{1}{r}\sum_i^r H_i^k \ , \tag{4}$$

where $k$ – station number (2, 3, 4), $r$ – number of the measured points at the station, $H^k$ – heights measured at the station, $H^1$ – heights measured at the station №1.

In tab. 2 the example of transformations of heights for the station 4 is given.

Table 2 – Results of transformations of heights of the station 4

| Num. points | $H^1$, м | $H^4$, м | $H^4 + \Delta H^4$, м |
|---|---|---|---|
| 5 | 116,781 | 116,777 | 116,780 |
| 6 | 128,301 | 128,299 | 128,302 |
| 7 | 129,913 | 129,909 | 129,912 |
| 8 | 123,802 | 123,799 | 123,802 |
| | | | |
| Average | 124,699 | 124,696 | 124,699 |
| $\Delta H^4$ | 0,003 | | |

The results of transformation, arithmetic-mean values of heights (Hcp), average square error of measurement of heights of $m_h$ calculated on Bessel's formula are given in tab. 3

Table 3 – Results of transformations of heights and assessment of accuracy

| Num. points | Station 1 | Station 2 | Station 3 | Station 4 | Average | ASE |
|---|---|---|---|---|---|---|
| | H, m | H, m | H, m | H, м | Hcp, м | $m_h$, м |
| **1** | 125,074 | 125,076 | 125,073 | | 125,075 | 0,002 |
| **3** | 125,625 | 125,623 | 125,625 | | 125,624 | 0,001 |
| **4** | 118,752 | 118,756 | 118,753 | | 118,754 | 0,002 |
| **5** | 116,781 | 116,776 | | 116,780 | 116,779 | 0,002 |
| **6** | 128,301 | 128,303 | | 128,302 | 128,302 | 0,001 |
| **7** | 129,913 | 129,912 | | 129,912 | 129,912 | 0,000 |
| **8** | 123,802 | 123,801 | | 123,802 | 123,801 | 0,001 |

We will transform the received average values of heights to system of heights $H^0$ lso through parallel translation in the vertical plane at a size $\Delta H$, calculated on a formula

$$\Delta H = \frac{1}{r}\sum_i^r H_i^0 - \frac{1}{r}\sum_i^r H_i^{cp} \ , \tag{5}$$

where $r$ – Number of starting points, $H^{cp}$ – Average heights, $H^0$ – Initial heights.

As a result we will receive $\Delta H$ = –0,006 nd we will calculate final values of heights $H_{ок}$ and the amendment to heights of starting points which are given in table 4.

Table 4 – Final values of heights

| Num. points | Start | Final | Corrections |
|---|---|---|---|
| | $H^0$, m | Нок, m | v, m |
| 1 | 125,065 | 125,069 | 0,004 |
| 3 | | 125,618 | |
| 4 | 118,756 | 118,748 | -0,008 |
| 5 | 116,769 | 116,773 | 0,004 |
| 6 | 128,300 | 128,296 | -0,004 |
| 7 | 129,910 | 129,906 | -0,004 |
| 8 | 123,789 | 123,795 | 0,006 |

Analyzing corrections to heights of starting points, we see, the mutual provision of the next points differs from actual on 12 mm (points 1, 4) and on 10 mm (points 7, 8). It once again confirms need of the carried-out works on restoration of high-rise network.

New heights are received with the mean square mistake which isn't exceeding 2 mm that conforms to requirements of location survey accuracy.

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