MAIN CHARACTERISTICS DETERMINATION OF OBSERVATION METHOD FOR MARINE HYDROTECHNICAL STRUCTURES DEFORMATION

I. Trevoho

Lviv Polytechnic National University

M. Zvyagina

State Enterprise “ChornomorNDIproekt”

Key words: deformations, deposition, insolubility, nohomogeneous measurements, basic tolerances.

Introduction.

The observations of constantly operating oil-mill deformations, which is located in port N on an outlet to the open sea from the deep bay, has functions of a wave-defending and berthing facility. The building length is 680 m, a width is 8 m, from building head opposite bank 6 km. Mole has two deep water berths on side of bay and on the sea side. The structure is nonmetal, but has a large number of metal building elements and pipelines, as on the surface of tiers placed on the vertical wall, so in the rubble in mole body.

At berths at the same time, 4 vessels with an unladen height of at least 15 m above the berth level can be loaded. Because of these and other obstacles using of GNSS-technologies is impossible.

It is necessary to provide in this article the continuation of a single numbering of formulas, tables and figures of the previous article [1].

Problem formulation.

There are still no scientifically substantiated instructions or practical guidance materials for performing precise and high precise engineering-geodetic measurements during deformation observations on marine hydraulic engineering objects. Therefore, the observation of deformations in this area is carried out according to methods, theoretical and technical level of which is based on instructions on the leveling of I - IV classes in different years of publication [2], while it is called a certain class, but taking into account the specific conditions of measurements on the object are passed requirements, which characterize this class. This means that the requirement for given accuracy of deformations detection is not used as a source for justification of required measurement methodology.

Problem statement.

It is necessary to develop a method of observation, the theoretical and technical levels of which for selected class, taking into account the specific conditions of measurements at the object, will provide the requirements that characterize this class. Then the requirement for the given accuracy of deformations determination will be used as the source for the justification of the required measurement methodology.

According to project materials, draw up schema of structure, show on sections of mole where is places of fixing observation marks, to measure the depositions and horizontal displacements, to draw up the scheme of transfer of heights from base points to observation marks and fixing the sections for measuring nonconformities. The numbering of marks should be the only one for determining planned and high-altitude displacements in the observations after the introduction of the mol into operation. From points established on land of reference network, tie the working rappers and rails of temporary water-level post and begin observation of fixed levels in system of a single zero of the seafront, which mark in the BS77 to accept the same mark as the single zero of waterpost, which operates in port N, at a distance of 5 km.

Aim.

The supporting construction network will provide study of natural conditions and conducting all types of engineering surveys in area of mol placement, and after completion of construction, planned high-altitude observation of building elements stability in accordance with the developed Technical Tasks and Observation Program, as well as periodic engineering and hydrological surveys in the water area.

Presenting main material.

Scheme of observing placement of high-altitude marks, created points and slit-shaped plates.

In the initial period of deformations observation, 29 marks were assigned, of which 12 were included in the created observation. Soon, during the exploitation of the mole, there were very large deformations, which led to a decision to increase the stability of sections of the moth. At the same time, it was decided to increase the number of observational marks by fixing so-called slit-shaped metal plates and additional stamped stamps. If the stamps were lost during operations, they were laying new ones in their place. Shortly after the commissioning of facility in sections of the mole laid 87 marks, of which 59 - observing sedimentary, 14 built-in and 14 compatible plan-high-rise. Also it fixed 25 pairs of slit-shaped plates. All observation marks and plates are shown in the diagram (Fig. 5).

Schemes of measurements

Construction of reference plan-high-altitude network is carried out in accordance with the requirements of normative documents [2, 5, 6] and latest technologies [7, 8, 9].

A. Scheme of leveling net

Fig. 6 shows scheme of leveling moves, laid through some brands of moles, which are included in closed polygons. Way No. 2 is laid between the Rp1 and Rp2 rails through observation marks 201, 203, 207, 215, 216. Way No. 1 also relies on Rp1 and Rp2 rails, but is laid in forward and reverse directions through observation marks 101b, 107b, 115, 119a and through two connecting permanently fixed points X1 and X-1-A. Way No. 3, which creates a closed field, is based on one Rp2 ramp, includes

sedimentary marks 506, 12a, 12, 6, 3a, 504 and permanently fixed points "Tum" and "Les", which allow leveling through a solid wall with counterports with the requirement of passage of the sight beam not less than 0,5 m above the underlying surface [2]

In fig. 6 is shown in course of between pairs of adjacent sediment marks of length D in meters between tool and rail at stations.

Characteristics of ways are summarized in Table. 3.

Table 3

Determination of π equal excesses in level net

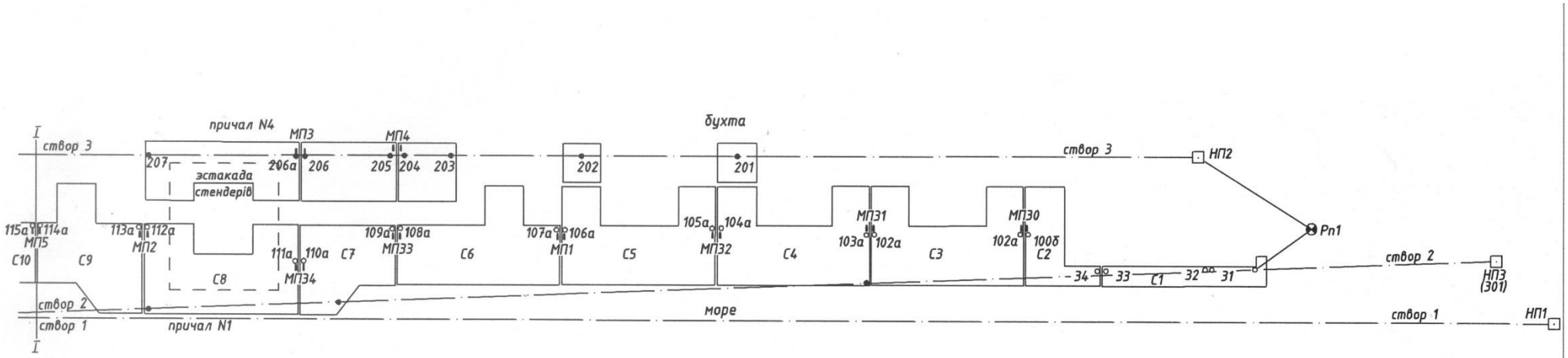
No. of ways	Actual number of measured excesses / Number of π equilibrium excesses, obtained at distances D, m															Number of π equilibrium excesses	
	25	30	40	45	55	60	70	75	85	90	110	120	135	165	195	In the ways of one direction	In ways, direct and reverse
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1/0,32	1/0,34	-	-	-	-	-	-	1 - 1,00	1 - 1,08	-	2 - 3,27	1 - 1,95	-	-	7,96	3,98
2	-	-	-	-	-	1/0,65	1/0,78	1/0,85	-	-	-	-	-	1/2,68	1/3,55	8,51	-
3	2/0,63	1	1/0,38	1/0,43	1/0,59	-	-	-	-	1/1,08	1/1,44	1/1,64	-	-	-	6,66	-

Graphs 2-16 of Table 3 show the actual numbers n of uneven excesses obtained at stations with different distances ($D_z = D_p$). According to the data of graph 5 of table 2 [1], numbers of π_{hi} of equilibrium excesses in steps 1, 2, 3 were first calculated for one direction, and then for the ways laid in the forward and reverse directions.

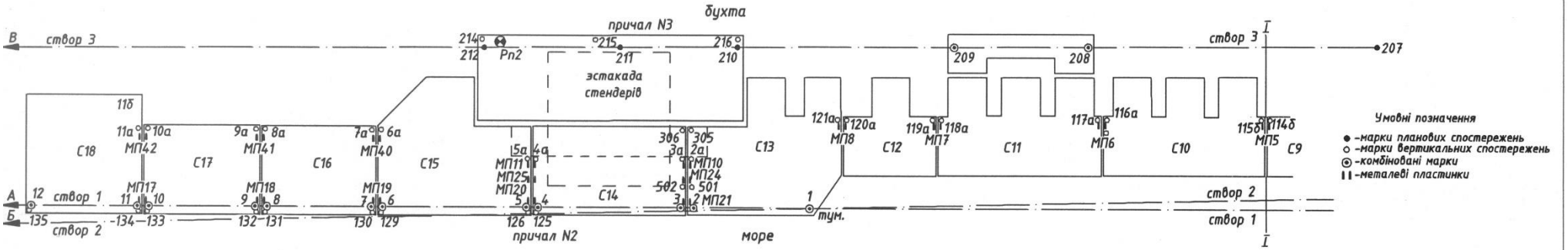
In order to level the outboard, a rocker rapper Pn1 (Fig. 6) was installed, located 50 m from the root of the oil-mill in the sloping stratum of marl rocks. From rapper Pn1 height is transmitted by double stroke through stamps, which are located on the sections of the mol 1 - 13, and the single pass - through the stamps on the piles and berthing platforms, on the Pn2 ramp mounted on deep pile of mooring pole. Thus, the marker of rapper Pn2 is obtained from three ways, and at time of each observation cycle, the output is for the standard marks on sections of the mola No. 13 - 18, both from side of sea and from side of bay.

B. Scheme of established measurements

In fig. 7 is a diagram of the created measurements, which consists of two intersecting layers laid out from sea side and third, laid out from side of coil of independent section shown in Fig. 5. Stem 1: NP1-A and stem 2: NPZ-B, Stem 3: NP2-V.



а



б

Fig. 5. Scheme of observation marks placement and plates on sections of the mole

а) –root part of the mole

б) – main part of the mole

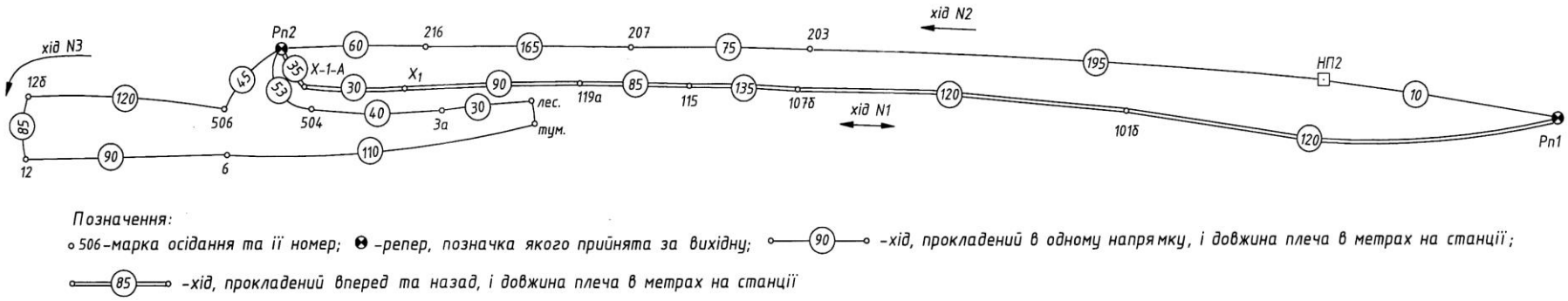


Fig. 6. Scheme of leveling ways

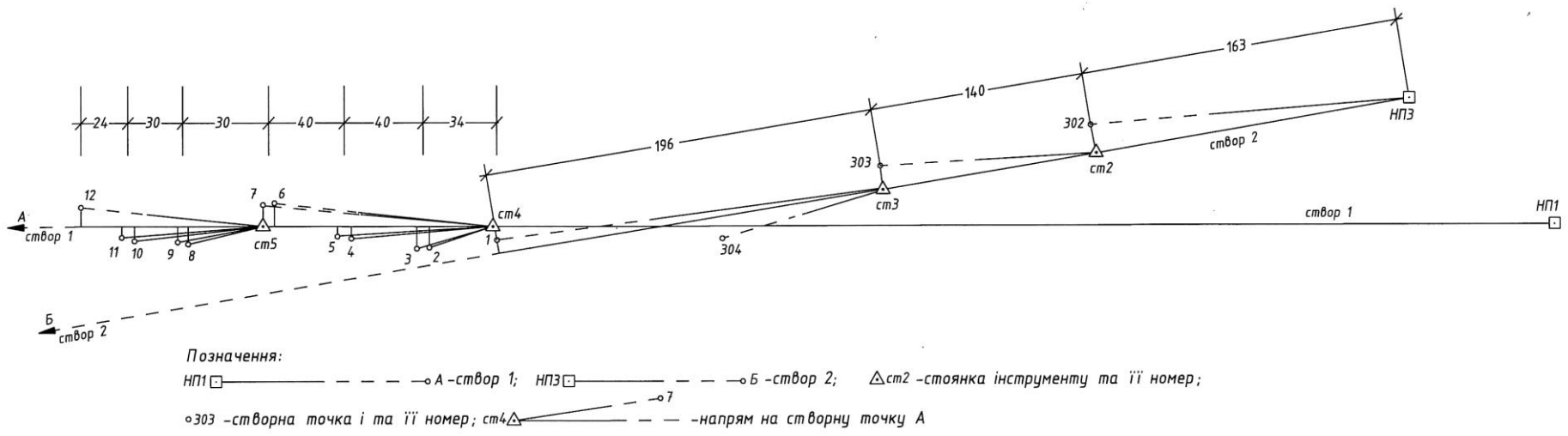


Fig. 7. Scheme of established measurements

In observations on the stem 1, points 1, 2, 3 ... 12 were included as observing points, and at observations on 2-stem, points 302, 303, 304 and 1. As a result, a point 1 appeared simultaneously near two spaces. It is arranged in such a way that the distance from point 1 to the stem 1 is equal to *q*, and to stem 2 is equal to *Δ*, so the relation between *Δ* and *q* is expressed by the formula

$$\Delta = 372 \text{ mm} - q, \tag{38}$$

where 372 mm – the distance between the stem perpendicular, lowered from point 1 to the stem 1, is taken as a constant.

Observations on stems 1 and 2 are executed from five instrument settings shown in Fig. 7. The order of observation is as follows:

1. The instrument is installed at NPZ point and, causing the axis of theodolite rotation to be in a tight position, direct the pipe at KL to the second support point B of stem 2.

2. At the observation point 304 set a moving mark.

3. Afterwards, the observer's team moves the visor target of the moving mark in a direction perpendicular to the cord, until image of stroke is not placed into bisector of the net. Entering image of visual stroke into the bisector is executed twice.

4. After removing the moving mark from the point 302, we bring the KP back to the second reference point B of stem 2.

5. After that, perform the actions mentioned in pp. 2 and 3. Listed in paragraphs 1 to 5 of action constitute one appointment. Such techniques are performed at one station not less than 8.

6. A_i counters taken from the moving mark, calculate the average count

$$\grave{A}_{ñð} = \frac{1}{8}\sum \grave{A}_s, \tag{39}$$

and, knowing a mark zero place, calculate the insolubility q_{302}, for example, points 302 from stem 2 by the formula

$$q_{302} = MO - (A_{av})_{302} \tag{40}$$

After placing gotten value q_{302} from mark 302 in the direction of the stem 2, we find the location of st. 2 in stem 2.

Above a point 2 (Fig. 7) it is centered theodolite and, after the axis of its rotation is in a steep position, perform measurements as listed in paragraphs 1 to 5 for the NPZ station. The results of measurements are calculated initially (A_{av}) and then q_i, which are deposited in direction to stem and find location of station *i*.

By analogous measurements performed at station 3, first calculate q_1, and then, using formula (38), find Δ. If you set aside the value of Δ from point 1 perpendicular to stem 1, then the end of segment Δ will fall into stem 1 and thereby determine the location of station 4 (fig. 7).

Measurement of non-constituents q_2, q_3, ..., q_7 relative to stem 1 is performed from the same station 4, performing the actions indicated in points 1 to 5 for each of the observed marks 1 to 7. For the found q_7, the location of station 5 is determined by delaying the value of $q7$ of point 7 in direction of perpendicular to the stem 1.

The theodolite is installed at the last station 5 and the insolubility q_8, q_9, ..., q_{12} measured relative to stem 1, just as it was done at station 4. This completes observation in the forward direction.

By [3] weight $P_{[q_i]_i}$ of insolubility q_i of point i, measured by one admission, is determined by the formula:

$$P_{[q_i]_i} = \frac{\ddot{A}_1^2}{\ddot{A}_{(q_i)i}^2} \tag{41}$$

where D_1 - distance from station to observation point, the weight of which is insolubility is taken as a unit; $\ddot{A}_{(q_i)i}$ – the same to a point *i*.

The value, reversed by weight, is expressed by the formula:

$$\pi_{(q_i)i} = \frac{1}{P_{(q_i)i}} = \frac{\ddot{A}_{(q_i)i}^2}{\ddot{A}_1^2} \tag{42}$$

The results of calculations performed by formula (42) are given in column 3 (Table 4) for the corresponding $\ddot{A}_{q_i}$.

Table 4

Determination of mean square error non-constituents with one and eight techniques

No.	Distance D, m between the observation marks	$\pi_q = \frac{\ddot{A}_{qi}^2}{\ddot{A}_{q(\ddot{A}=105)}^2}$	$\pi_q^1 = \frac{\pi_q}{8}$ (for 8 direct techniques)
1	2	3	4
1	163	2,4	0,30
2	140	1,8	0,23
3	196	3,5	0,44
4	114	1,1	0,14
5	84	0,6	0,08
	$\sum[\pi_q]$ straight stem	9,4	1,17
	$\sum[\pi_q]$ reverse stem		2,26

For the weight unit, an insolubility q_i was adopted, which was measured at distance of $D_1 = 105$ m. Therefore, at the object, for error in the weight unit, the mean square error $m_q = m_{(D=105)}$ of insolubility determination, measured at one station with one complete reception at D = 105 m. As insolubility for all brands, shown in Fig. 7, are determined from eight complete techniques, then in the graph 4 of tables 4 values of inverse weight of non-constituents determined from 8 methods are given.

C. Scheme of slit-dimensional measurements

On both sides, seams are fixed in a concrete on a single metal plate (Fig. 8), on both ends of which are stamped on one slit-shaped insert M_1 і M_2 (чи M'_1 та M'_2). The distances between these points are known and are intended for all observation cycles to be permanent.

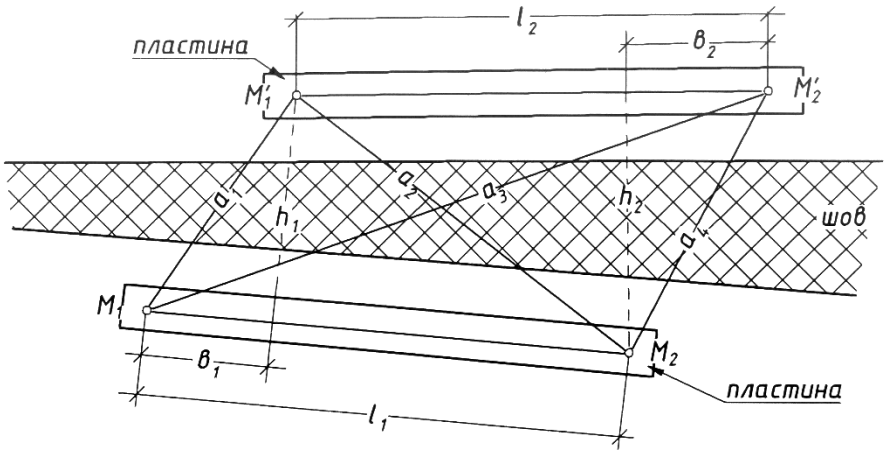


Fig. 8. Scheme of slit-shaped metal plates placement

Measure distances a_1, a_2, a_3, a_4 and after their reduction to plane (if necessary) are substituted in the formula [3]:

$$b_1 = \frac{l_1}{2} + \frac{a_1^2 - a_2^2}{l_1}, \tag{43}$$

$$b_2 = -\frac{l_1}{2} - \frac{a_4^2 - a_3^2}{l_2}, \tag{44}$$

$$b_T = \frac{1}{2}(b_1 - b_2), \tag{45}$$

$$h_1 = \sqrt{a_1^2 - b_1^2}, \tag{46}$$

$$h_2 = \sqrt{a_4^2 - b_2^2}, \tag{47}$$

$$h_T = \frac{1}{2}(h_1 + h_2). \tag{48}$$

As a control of the correctness of calculations, use the formula:

$$l_2 = \sqrt{(h_1 - h_2)^2 + [l_1 + (b_2 - b_1)]^2}, \tag{49}$$

The mutual placement of plates on both sides of seam may be such that formula (49) takes the form:

$$l_1 = \sqrt{(h_1 - h_2)^2 + [l_2 + (b_2 - b_1)]^2}$$

The gotten values (43) - (48) are used to calculate section displacement. The longitudinal movement of the S_T section relative to it in direction of longitudinal axis of the mole is calculated by the formula

$$S_{T_i} = (h_{T_2} - h_{T_1})_i, \quad (50)$$

where T_1 i T_2 – the moments (dates) of observations in the previous and subsequent cycles.

By the displacements found (50), calculate the absolute (total) displacement $\sum_{i=1}^{i=n} S_{T_i}$ sections with a number and relative to first section of the mole.

Transverse shift S_u one section relative to another adjacent to it in the direction of the perpendicular to the longitudinal axis of the mole is calculated by the formula

$$S_u = (b_{T_2} - b_{T_1})_i + \delta_{i-1}, \quad (51)$$

where δ_{i-1} – moving plates through turning sections for a period $T_2 - T_1$. Then the absolute displacement is calculated $\sum_{i=1}^{i=n} S_{u_i}$ of section *i* in the direction perpendicular to the axis of the mole and in relation to its root portion.

The possibility of determining the angle of rotation of section due to the change in width of seam based on measurements in the vapor plates is explained by the following (Fig. 9).

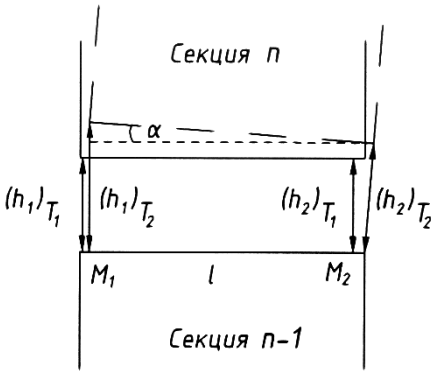


Fig. 9. Determination of change in width of seam between sections and section n rotation angle

$$tg\alpha = \frac{(h_1 - h_2)_{\grave{O}_2} - (h_1 - h_2)_{\grave{O}_1}}{l}, \quad (52)$$

where $(h_1)_{\grave{O}_1}$ – width of seam near the mark 1 at the moment T_1;

$(h_2)_{\grave{O}_1}$ – width of seam near the mark 2 1 at the moment T_1;

$(h_1)_{\grave{O}_2}$ – width of seam near the mark 1 1 at the moment T_2;

$(h_2)_{\grave{O}_2}$ – width of seam near the mark 2 1 at the moment T_2;

$l = \frac{1}{2}(\lambda_1 + \lambda_2)$ - distance betweene pairs of brands;

α - angle of the section *n* relative to the section *n-1* for a period of time T_2 - T_1 between datas T of observation.

Assessment of measurement scheme size and quality

A. Observation of precipitation

The values obtained in Figures 17 and 18 (Table 3) [π_{h_j}] are rewritten to measurement scheme shown in Fig. 10.

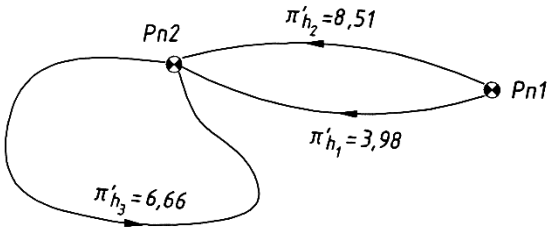


Fig. 10. Determination of inverse weight of weakly defined points

The evaluation of measurement scheme will be done by the equivalent replacement method.

According to [4]

$$\pi'_{h(p_1-p_2)}=\frac{\pi_{h1}\cdot\pi_{h2}}{\pi_{h1}+\pi_{h2}}, \quad (53),$$

and substituting the values we get $\pi_{h(p_1-p_2)}=\frac{3,98\cdot 8,51}{3,98+8,51}=2,73.$

We define the "distance" from the rapper 1 to the weakly determined point E in section 15. To do this, we first determine the number $\pi_{h_{2-E}}$ during 2-E way from rapper 2 to extreme point E.

Визначимо «відстань» від репера 1 до слабовизначуваної точки Е в секції 15. Для цього визначимо спочатку число $\pi_{h_{2-E}}$ в ході 2-Е від репера 2 до екстремальної точки Е.

$$\pi'_{h_{p2-E}}=\frac{1}{2}[\pi_{hi}] \quad (54)$$

$$\pi'_{h_{p2-E}}=\frac{6,66}{2}=3,33$$

Point E coincides with the mark of sedentary 6. From rapper Pn1 to this mark will be "distance" $\pi'_{h_{P1-E}}=\pi'_{h_{p1-p2}}+\pi'_{h_{P2-E}}=2,73+3,33=6,06$ equal excesses.

B. Observation of horizontal displacements

The values [π] of inverse weight for weakest defined points in forward and reverse sections are given in Table 4 (two lower lines). For these points the direct line with respect to refinery point will be the mark I2 (fig. 11) from π_{q12}= 1.17, and for the reverse - mark 2 (fig. 12) from π_q = 2,26.

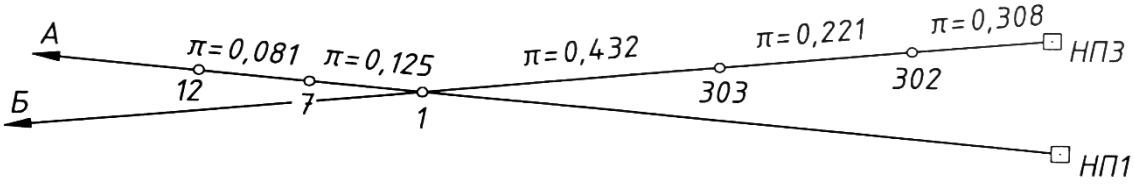


Fig. 11. Determination of inverse weight of non-constituents for a straight line

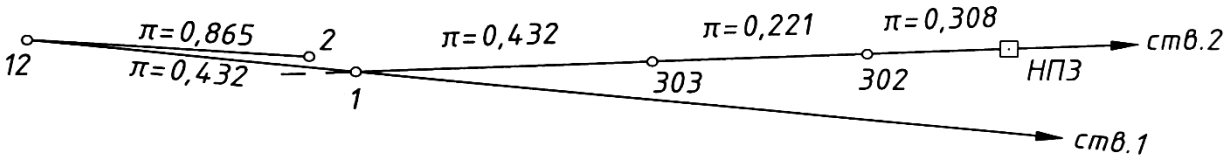


Fig.12. Determination of inverse weight of non-constituents for a reverse section

From comparison of obtained results, we see that the scheme of measurements by method of reverse compartments is qualitatively lower than the scheme of measurements by method of straight lines.

The main characteristics of measurement method

A. Measurement of sedimentation

Substituting the largest value found $\pi_{q_{P1-6}}$ into the calculation formula (37) from [1] and taking into account the given value $m_{S_{h_E}} = 3$ mm, we will get

$$\overline{\mu}_h^{4)} = \pm\frac{3}{\sqrt{2 \cdot 6{,}06}} = \pm 0{,}9 \text{ mm}, \tag{55}$$

or in tolerances of accuracy:

$$\overline{\nabla}_h = \pm\frac{9}{\sqrt{2 \cdot 6{,}06}} = \pm 2{,}6 \text{ mm} \tag{56}$$

Establish the requirements and tolerances, observance of which during observation of settlements or displacements at the object of research will confidently ensure the given accuracy.

Evaluating the accuracy of measurements results, usually neglected with very slight errors in the influence on error of weight unit. To do this, we will put a condition that failure to take into account one or several meager errors does not distort the pre-calculated error of weight unit by more than 3%. In this case, according to [3], the magnitude of error, which may not be taken into account, will be in K = 4 times less than value of mean square error μ_h of weight unit.

Then errors that come to separate sources of errors

$$(\overline{m}_1)_h \le \frac{\overline{\mu}_h}{k} \quad \text{or} \quad (\overline{\nabla}_1)_h \le \frac{\overline{\nabla}_h}{k} \tag{57}$$

For our object, that is, taking into account (55) and (56), we obtain

$$(\overline{m}_1)_h \le \frac{0{,}9}{4} = \pm 0{,}2 \text{ìì} \tag{58}$$

---

[4] $\overline{\nabla}$ i $\overline{m}$ - *horizontal risk over tolerance* ∇ *or error* m *means that the numerical values of these values are given or pre-calculated, based on the given. It is also taken into account that gross measurement errors are detected and eliminated in a timely manner.*

$$(\overline{\nabla}_1)_h \le \frac{2{,}6}{4} = \pm 0{,}6 \text{ìì} \tag{59}$$

The found values are accepted [3] to be called the basic admission.

B. Measurement of horizontal displacements

Determine the main characteristics and methods of measurements for observations on plan offsets.

For a preliminary calculation of mean square error $\overline{\mu}_q$ of weight units we use the formula (5) from [1] and we will substitute it for it $\overline{m}_{S_q} = \pm 5$ mm and calculate value $\pi_q = 1{,}17$. As a result we will receive

$$\overline{\mu}_q = \frac{m_q}{\sqrt{2 \cdot \pi}} = \frac{5}{\sqrt{2 \cdot 1{,}17}} = \pm 3{,}2 \text{ mm} \tag{60}$$

or in tolerances

$$\overline{\nabla}_q = \frac{15}{\sqrt{2x1{,}17}} = \pm\, 9{,}8 \text{ mm} \tag{61}$$

Use the formula to calculate the basic tolerances (57)

$$(\overline{m}_1)_q \le \frac{\overline{\mu}_q}{k} \quad \text{or} \quad (\overline{\nabla})_q = \frac{(\overline{\nabla})_q}{k} \tag{62}$$

Taking $k=4$ and given (60) i (61), we will get

$$\overline{m}_1 = \frac{3{,}3}{4} = \pm 0{,}8 \text{ìì} \tag{63}$$

$$\overline{\nabla} = \frac{9{,}8}{4} = \pm 2{,}5 \text{ìì} \tag{64}$$

The values found are the main admission for calculation of individual sources of errors influence on the error of weight unit.

The value of the pre-calculated mean square error $\overline{\mu}_{q_E} = 3{,}2$ mm the unit of weight in the angular degree is

$$\overline{m}''_{1\beta_i} = \frac{(\overline{\mu}_{qE})\text{ìì}}{D_1} \cdot \rho'' = \frac{3{,}2}{105} \times 2 \times 10^5 = \pm 6{,}6'' \tag{65}$$

The value of the mean square error $(\overline{m}_1)_{\beta_1}$, which comes in separate sources of error

$$(\overline{m}_1)''_{\beta_i} = \frac{\overline{\mu}_{qE}}{k} = \frac{6{,}6}{4} = \pm 1{,}6'' \quad (66)$$

$$(\overline{\nabla}_1)''_{\beta_1} = \frac{\overline{\nabla}_1}{k} = \frac{19{,}8}{4} = \pm 5'' \quad (67)$$

Prospect of further research.

It is necessary to write out methodology of geodetic measurements at object, taking into account adherence to requirements of basic tolerances, to present results of measurements on which initial data are calculated for estimation of measured values difference, the non-connection, and so on.

Conduct an analysis of measurement results (using the method of mathematical statistics) and perform an estimation of accuracy.

Conclusions.

The type of buildings with very limited conditions for choosing methods for conducting geodetic works [1] is considered. The only way to determine the heights - geometric leveling is also complicated when choosing stations. To ensure the equality of distances $D_z = D_p$ from tool to marks, the length of shoulder is increased approximately 1,5 times the distance between the marks.

When measuring insolubility by method of the cavities there is no access to the end point of cavity, in our case it is 5 km of water and 1 km of dry land.

1. The method of homogeneous measurements of excesses and non-constructions, which provides the requirements of normative documents to results of measurements, is developed.

2. The methodology provides:

a) when measuring sediment, an accuracy assessment is performed at four polygons in measurement scheme for greater reliability of results not because of number of polygons, but through the number of cycles;

b) for the measurement of non-constituents, the accuracy of estimation due to impossibility of controlling the complete set is due to an increase in the number of receptions in measurement cycles.

The estimation of size and quality of measurement scheme is carried out, the main tolerances and errors are deduced from individual sources of errors.

References.

1. Trevoho I. Osnovni teoretychni peredumovy sposterezhen za deformatsiyamy morskykh hidrotekhnichnykh sporud heodezychnymy metodamy./ I. Trevoho, Ya. Kostetska, M. Zvyagina// Suchasni dosyahnennya heodezychnoyi nauky ta vyrobnytstva. – Lviv. -2017. – Vyp. II. - ?????S….???

2. Instruktsiya po nivelirovaniyu I, II, III, IV klassov. –M.: Nedra, 1990. -175 s.

3. Piskunov M.Ye. Nablyudeniya za osadkami i gorizontal'nymi smeshcheniyami sooruzheniy geodezicheskimi metodami. MIIGAiK. Uchebnoye posobiye [tekst]. – M. 1973. -77 s.

4. Piskunov M.Ye. Metodika geodezicheskikh nablyudeniy za deformatsiyami sooruzheniy. – Moskva: Nedra, 1980. – S.21.

5. Instruktsiya z topohrafichnoho znimannya u masshtabakh 1:5000, 1:2000, 1:500 (HKNTA – 2.04-02-98).

6. DBN V.1.3-2:2010, Kyiv. Heodezychni roboty. Ministerstvo rehionalnoho rozvytku ta budivnytstva Ukrayiny. 2010.

7. Periy S.S. Vykorystannya dvostoronnoho tryhonometrychnoho nivelyuvannya u svitloviddalomirniy polihonometriyi/ S.S.Periy // Heodeziya, kartohrafiya i aerofotoznimannya. -2001. -№ 61. –S.112 – 117.

8. Periy S.S. Aprobatsiya zastosuvannya neodnochasnoho dvostoronn′oho tryhonometrychnoho nivelyuvannya z urakhuvannyam vertykal′noyi refraktsiyi/S. Periy// Heodeziya, kartohrafiya i aerofotoznimannya. -2015. -№ 82. –S.19 – 28.

9. Horb A. Analyz y problemy tochnosty GPS-yzmerenyy v setyakh opornykh stantsyy/A. Horb, A. Prokopov, H. Sydorenko, Y. Trevoho// Suchasni dosyahnennya heodezychnoyi nauky ta vyrobnytstva. – Lviv. -2005. –Vyp. II. S26 - 33.

Main characteristics determination of observation method for marine hydrotechnical structures deformation

I. Trevoho, M. Zvyagina

In the part of the study presented here, the main characteristics of the method for observing deformations of marine hydrotechnical structures (geometric leveling, measurement of incontinence and crevice works)

The values of the reciprocal weight of the equal excesses in the leveling moves and the non-fissures, measured by one full reception and eight methods, are obtained.

The values of the longitudinal and transverse shifts of the sections relative to the previous ones and the total longitudinal displacement of the entire structure from the measured data are calculated.