PROGRAMMING OF GEODETIC OBSERVATIONS FOR SEDIMENTS OF ENGINEERING STRUCTURES

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Abstract

Terrestrial geodetic techniques observe the Earth surface and its changes, sea level, gravity field and the height by sensors on or near to the Earth surface. Such terrestrial techniques are: Tide Gauge measurements to measure sea surface heights at the coast. Absolute and relative gravity measurements on ground. The article analyzes the issues of programming methods for geodetic observations of precipitation and horizontal displacements of engineering structures, which, despite the noted features, are used in the study and forecasting of the state of structures during their operation. In the article questions of methods of programming of geodetic observations of precipitation and horizontal displacements of engineering structures are analyzed, which, despite the noted features, find application in studying and forecasting the state of structures in the process of their operation.

Key words: *precipitation observations, engineering structures, construction forecasting, programming, geodetic observations.*

Introduction. In scientific papers published in geodetic and specialized literature, the cyclic nature of field observations of deformations of engineering structures by geodetic methods is shown, it is based on the use of one of the following quantities: settlement, settlement velocity, accuracy of settlement measurements, time interval, time characteristic of a random function, and h.d. Such approaches to solving the issue under consideration testify to the ambiguity of calculations and timing, and, consequently, the cost of funds for the production of geodetic observations, the establishment of a suitable type of function that describes the process of settlement of the body of various engineering structures.

This can be easily verified by analyzing the cases described above to justify the cyclical nature of geodetic observations of the settlements of engineering structures. If, in this case, we are guided by the magnitude of the draft, then it is different at different points of the same total structure, the final value is indefinite and the time to reach it is known.

The production of geodetic observations at regular intervals is provided for effectively only in the initial years of operation of an engineering structure, because. during this period, its deformation changes significantly over characteristic time intervals, when it is usually required to trace its evolution in detail, since this requirement, as a rule, puts forward observation with a fairly short time interval in the initial years of operation of engineering structures. In subsequent years of operation, for characteristic times quantities characterizing the deformation structures change little, detailed representation of their course is not required[1, p.18], [6, p.27]. Therefore, in practice research deformations facilities geodetic Observations are made at long time intervals . meeting the requirements for accuracy.

Usage at establishing cyclicity of precipitation velocity observations, flowing different for individual points of the same building, which is function of two indefinite quantities precipitation at the beginning and end of the time interval is also controversial. Consequently, the accuracy of geodetic observations should stay for the whole period exploitation structures, regardless of intensity precipitation and its magnitude can be judged about changing the degree of deformation construction and if it is commensurate with accuracy, then make an assumption about possible stabilization of the structure and make a decision to terminate observations.

Calculation of the periodicity and date of production of geodetic observations according to the methods, described above is associated with the uncertainty quantity and production time geodetic measurements for each of the marks, installed on the same structure. At the same time, the implementation of geodetic observations at a given time through equal time intervals is also not justified, tk. in the first years of operation of the foundation of the vast majority of engineering structures are more susceptible to deformation, than in subsequent years. It is easy to verify this by comparing the sediment increments calculated by formula (1), where the sediment rate decreases exponentially, therefore, in order to measure equal sediment values, the time interval between subsequent observations can be increased.

The solution of these issues is of great practical importance, because. from his result depends establishing the processes taking place in time, specification of types and parameters calculation formulas used for predicting values characterizing deformations and their comparison with theoretical ones; usage results similar working conditions of other engineering structures, correct organization operational measures planning forces and means to perform geodetic works, prevention of emergencies and early warning capability accidents.

And finally, consideration of the draft of each points of an engineering structure as an implementation tea function too not deprived pedostatov, tk. timing characteristics this feature is not available in most cases. stationary - mean variance precipitation changes over time especially when this is concerns engineering structures having different heights according to the studied alignments, for example, along the crest of dams reservoirs.

Materials and methods

This is indicative of the diversity methods geodetic programming observations by precipitation and horizontal displacements of engineering structures, which, despite the noted features, they find application in the study and forecasting the state of structures during their operation. In addition to these surveys In this paper, an attempt is made to justify the possibility of reducing the number and the best organizations at given quantity geodetic observations due to the optimal choice of interpolation nodes researched functions rainfall next calculation formula [1, p.19], [5, p.32].

$$S_{t_i} = S_k(1 - e^{-\alpha t_i}) \quad (1)$$

For this, let us first turn to Fig. 1, where a schematically smooth curve shows the theoretical function of the settlement of an engineering structure, described by expression (1) and possible cases of its approximation by piecewise linear functions $S_n(t)$, provided that geodetic observations are carried out: a - at regular intervals, i.e. .

$$\Delta t_{i+1,i} = t_{i+1} - t \rightarrow const$$

b - through equal increments of sediment, i.e. when $\Delta S_{t_{i+1,i}} = S_{t_i} \rightarrow const;$

$S_n(t)$ uniformly approaches the function (1), i.e. when

$$\Delta S_{t_{i+\frac{1}{2}}} = \frac{S_{t_{i+1}} - S_{t_i}}{2} - S_{t_{i+\frac{1}{2}}} \rightarrow const(2)$$

Getting the largest deviation values $S_{t_{i+\frac{1}{2}}}$ approximable piecewise linear functions $S_n(t)$ on the approximate S_t , in different areas gives rise to suppose that they are the two extremes with the planning of the timing of the production of geodetic observations for a given number of them. The subtopic in such a case arises the task of organizing geodetic observations that provide best approximation of functions $S_n(t)$ to S_t the obtained results will make it possible to objectively evaluate the deformation process, taking into account its speed, the time interval between observations, and the number of observations that can serve one of the optimality criteria for research by geodetic method deformations engineering structures, provides minimum costs with the necessary accuracy, obtaining a dynamic picture deformations of structures , o definitions the necessary composition and volume of observations.

In the problem under consideration, the settling curve described by expression (1), is approximated by a piecewise linear function (Fig. 1) , which results in a set of segments of linear functions, the broken link of which is constructed in accordance with the expression

$$S_{t_{n+1}} = S_t + S_{t_n^1}(t_{i+1} - t_i) \qquad (3)$$

As in all interpolation problems, we First of all, we are interested in the accuracy of the formula, which can be increased by eliminating requirements for equality of interpolation nodes.

When choosing the optimality criterion function approximations $S_n(t)$ functions S_t we can proceed from the condition that on a discrete set of segments [ab] maximum deviation $\Delta \max = \max[S_{t_i} - S_n(t)]^2 \Delta_t$ standard deviations at a given number of nodes n

$$\Delta_{k^2} = \frac{1}{b-a} \sum [S_{t_i} - S_n(t_t)]^2 \Delta_{t_i} \qquad (4)$$

were maximum.

Criterion (4) also gives the best approximation in the case of using the approximating polynomial fixed degree, t.s. polynomial of uniform approximation. In that case the process of settlement of an engineering structure is described by a polynomial of the n th degree:

$$S_n = a_0 + a_1 t + a_2 t^2 + \ldots + a_n t^n \qquad (5)$$

here t - observation time or cycle number, if measurements are carried out at regular intervals: $a_0, a_1, a_2, \ldots, a_n$ equation coefficients. Calculating the values of the coefficients a_t, the polynomial, $S_n$further uniform approximation to the function $8_{r<}$ is very time consuming.

Criterion (3) and (4) have the property additivity, those. is composed of elementary values of the same criterion obtained at individual points.

The task formulated above is discrete optimal control problem consisting in the choice of such nodes interpolation providing $t_{i_1}$the best approximate piecewise linear function $S_n(t)$ to the approximate S_{i_1}[2, c.17].

Therefore, it lends itself only to numerical methods of solution, requiring the calculation of the increment of settlement, $\Delta S_{tj}$for various Δt_{tj}. Equations of type (3) obtained for such values are called functional. The composition of such equations includes the same function for different values of the arguments, and therefore their solution requires the use of the dynamic programming method developed by R. Bellman [2, p.25].

The essence of this method is based on the following use of the following principle of optimality: if a certain sequence of solutions is optimal, then separate subsequent solutions within it are optimal with respect to the previous solution.

Optimality criterion (4) for our example can be represented as follows:

$$[\Delta^2] = \sum_{i=0}^{n} \left(\frac{S_{t_i} + S_{t_{i+1}}}{2} - S_{t_{i+\frac{1}{2}}}\right)^2 \rightarrow \min \qquad (6)$$

To achieve this goal, we expand the terms on the right side of expression (6) to the form

$$\Delta = \frac{S_{t_0} + S_{t_i}}{2} - S_{t_{i+\frac{1}{2}}} = \frac{S_t t_i + S t_2}{2} - St_{i+\frac{1}{2}} = \ldots \frac{St_i + St_{i+1}}{2} - St_{i+\frac{1}{2}} \qquad (7)$$

Replacing the value of the function S_{t_i}(1) with the values of its corresponding arguments after converting the resulting one, we have:

$$-e^{-at_i} + 2e^{-at_{i+\frac{1}{2}}} - e^{-at_{i+1}} - \frac{2\Delta}{S_k} = 0$$

t . to .

$$t_{i+\frac{1}{2}} = t_i + \Delta t_{i+\frac{1}{2}} \quad , \quad t_{i+1} = t_i + 2\Delta$$

t o

$$e^{-at_i} - 2e^{-a(t_i + \Delta t_{i+\frac{1}{2}})} - \frac{2\Delta}{S_k} = 0$$

where

$$e^{-at_i}\left(e^{-2a\Delta t_{i+\frac{1}{2}}} - 2^{-a\Delta t_{i+\frac{1}{2}}} + 1\right) - \frac{2\Delta}{S_k} = 0(8)$$

Such an equation can be formed from any component of expression (6), since the date of the initial observation $t_i$is assigned or calculated by the recursive formula (4), when calculating its first multiplier, it is a certain number given or calculated from the results of previous observations. Therefore, dividing all components of the expression (8) , we obtain a quadratic equation of the following form

$$e^{-2a\Delta t_{i+\frac{1}{2}}} - 2e^{-2a\Delta t_{i+\frac{1}{2}}} + \frac{2e^{-at_i}}{S_k} = 0 \qquad \text{(nine)}$$

The solution of this equation with respect $e^{-\Delta t_{i+\frac{1}{2}}}$to using a negative root, which gives a value less than one, allows you to consistently find $\Delta e_{i+\frac{1}{2}}$, by the recursive formula

$$\Delta t_{i+\frac{1}{2}} = \ln\left(1 - \sqrt{\frac{2\Delta e^{-at_i}}{S_k}}\right)/a \qquad (10)$$

and predict the timing of the next i +1 cycles of observations using the formula

$$t_{i+1} + t_i + 2\Delta t_{i+\frac{1}{2}} \qquad (11)$$

Thus, formulas (10), (11) with known valuest_i , a , S_k, determined based on the results of the first three cycles of observations according to the methodology, make it possible to calculate the acceptable timing for the implementation of subsequent cycles of observations, which allows you to optimally organize the timing of each cycle of geodetic observations with a given number and accuracy [4, c.31].

Table 1

Δ=5mm	T_I	1.0	2.3	3.4	6.1	9.7	20.2	
	St_I	114	208	282	336	370	385	
Δ=3mm	T_I	0.8	1.7	2.8	4.1	5.8	8.2	12.1
	St_I	90	168	235	288	331	361	379
Δ=1mm	T_I	0.4	0.9	1.4	2.0	2.6	3.4	4.2
	St_I	53	1.3	148	190	228	261	290
	T_I	5.1	6.2	7.5	9.3	11.8	16.3	
	St_I	316	338	355	369	378	38	

To illustrate the possibility of practical implementation of the above methodology in a specific case, we use a semi-empirical formula that describes the process of sedimentation of the crest of the dam of the Kattasai reservoir, which has the form

$$S_t = 385,1(1 - e^{-0,338t}) \qquad (12)$$

Discussion

The data of this table indicate that when approximating the studied exponential function of the dam settlement S_t(1) by a set of segments of the piecewise linear function S_t(t) (where n - number of observations) with a maximum deviation of D = 5 mm, it is sufficient to carry out 6 cycles of geodetic observations at times close to those given in the first row of the table with expanding (12) time intervals and obtain the sediment values approximately given in the second row, and at A = 3 mm, it is required to increase the number of cycles of geodetic observations to 14.

The considered example shows that with a given number of observations and with known values of $S_k$and, *and* obtained by a theoretical calculation or according to the results of three cycles of observations described in, it becomes possible to organize the timing of the production of subsequent cycles of geodetic observations so that the settlement function is best approximated by a set of piecewise linear or other functions that reliably describe the process of settlement of an engineering structure [4, p.42].

Conclusion

The implementation of the developed methodology for the rational organization of geodetic observations can be carried out according to the following technological sequence.

1. According to the results of the first three cycles of geodetic observations or theoretically

the parameters $S_k$and are determined, *and* the functions of the settlement.

2. According to the obtained formula, the period of possible stabilization of the settlement of the structure is predicted, upon reaching which it is supposed to stop geodetic observations.

3. The required accuracy and the total number of observations are assigned, and the dates of production of each cycle of geodetic observations are calculated using formulas (10), (11).

4. After the implementation of each cycle of observations, the values of the parameters of the semi-empirical formula (1) are specified and the period for the production of subsequent cycles of observations is calculated.

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