- знание и применение методик оценки безопасности ГТС: критерии безопасности, правила мониторинга состояния, проверка работоспособности и состояния технических средств контроля, проведение комиссионных обследований, определение значений риска аварии;

- работа с обслуживающим персоналом ГТС: учения, тренировки и теоретические занятия с работниками, оценка готовности обслуживающего персонала ГТС к предупреждению, локализации и ликвидации чрезвычайных ситуаций;

- умение осуществлять работу с населением и предприятиями, находящимися в зоне возможного затопления;

- ведение текущей и постоянной документации на ГТС в соответствии с нормативными требованиями.

Изменения в программы (программы учебных модулей) могут вноситься в зависимости от условий Договора об образовании, заключаемого с заказчиком образовательной услуги.

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UDC 641.8

METHOD OF CHARACTERISTICS ASSESSMENT OF SUPPORTIVE BEAMS OF PROTECTIVE HYDROTECHNICAL STRUCTURE

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Abstract. In the represented article we have developed the mathematical model of strength of elements of the carrying structure of supportive hydrotechnical wall. Using the mathematical model we have created the criterion of safety level assessment for protective hydrotechnical structure based on requirement of load bearing capacity preservation. On the basis of proposed mathematical model and safety criterion we have improved the method of characteristics assessment of supportive beams of protective hydrotechnical structure. It allows to calculate accurate values of the loading factors in the dynamics of the extreme situation development taking into account the complexity of the thermal and force loading regime.
Keywords: protective hydrotechnical structure, flat overlapping, supportive beam, strength

МЕТОД ОЦЕНИВАНИЯ ХАРАКТЕРИСТИК ОПОРНЫХ БАЛОК ЗАЩИТНОГО ГИДРОТЕХНИЧЕСКОГО СООРУЖЕНИЯ

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Аннотация. В представленной работе разработана математическая модель прочности элементов несущей конструкции подпорной гидротехнической стены. С использованием математической модели предложен критерий оценивания уровня безопасности для защитного гидротехнического сооружения, основанный на требовании сохранения его несущей способности. На основе предложенных математической модели и критерия безопасности усовершенствован метод оценивания характеристик опорных балок защитного гидротехнического сооружения. Он позволяет рассчитывать точные значения силовых факторов в динамике развития чрезвычайно ситуации с учетом сложности термо-силового режима нагружения.
Ключевые слова: защитное гидротехническое сооружение, плоское перекрытие, опорная балка, прочность

Introduction: To prevent extreme situationconnected with the raise of water in rivers and lakes, flooding of settlements and transport communications they use temporarily protective hydrotechnical structures. They are to block the liquid penetration from one space to another. Supportive walls stability problem resolution was represented in [1]. Methods of strength calculation for supportive walls are represented in [2-4]. However, these methods do not take into account possible deviations of the temperature in different elements of the protective hydrotecnical structure. The complex stress-strain condition arises in elements of the load-carrying structure of the wall. Its complexity is amplified with the presence of the temperature irregularities and deviations in spread of water on the surface of the plate. In the dynamics of the extreme situation development the thermal conditions may vary depending on multiple factors. Thus, application of simulation methods for evaluation of the destructive processes in the carrying structure elements is topical. The aim of simulation is to find the loading conditions that may prevent destruction of the supportive wall and provide its carrying ability as a whole.

General approach for creation of simulation models used in investigation is represented in [5]. Concerning application of the approach for specific tasks of safety provision, previously achieved are represented in [6-11]. In particular in [9-11] the problems of simulation of the complex thermal and force loading of the carrying structures are investigated.

The aim of the article is to investigate the impact of the temperature deviation on mechanical characteristics of the protective hydrotechnical structure elements. To achieve this aim we have solved the following tasks:

- the mathematical model of the strength of the elements of the carrying structure taking into account the dependence of their mechanical characteristics on temperature is built;
- criterion of safety level assessment for protective hydrotechnical structure taking into account the dependence of its elements' mechanical characteristics on their temperature is created.

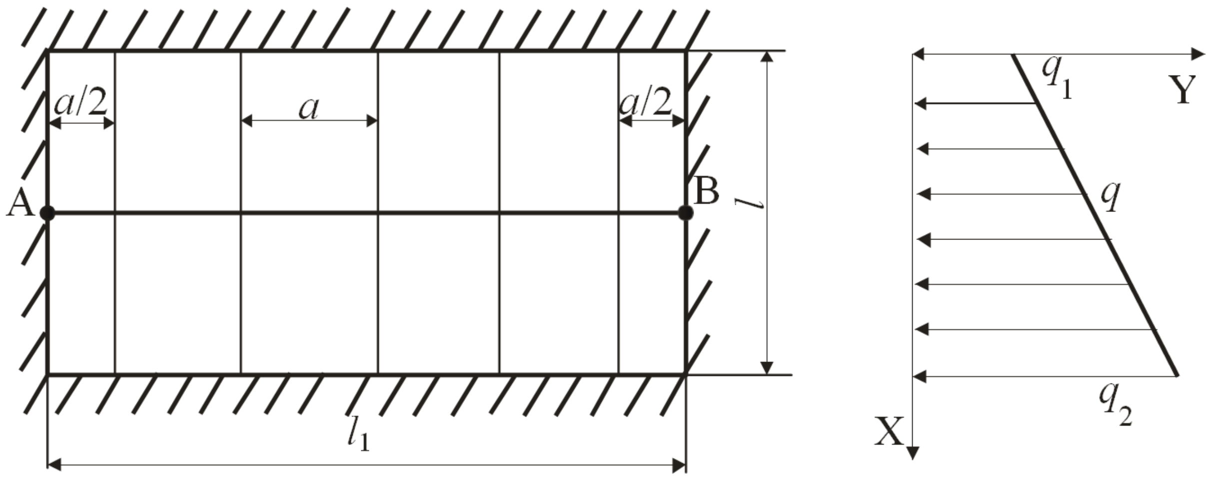
Methods of investigation: As a calculation case we have selected flat overlapping construction with the rectangular contour consisting of the plate and supportive beams. The loading carried by the plate is transferred to the system of equidistant bars called main direction beams. These beams are held by the crossbeam which is leaned on the edges as it is shown at the Figure 1, a. Let's designate the sizes of the plate in the following way: l – height of the contour, equal to main direction beam length; l_1 – width of the contour, equal to cross-beam length; a – distance between two neighboring main direction beams.

Hydrostatic pressure perceived by the plate is assumed to be evenly spread between the main direction beams. The diagram of the hydrostatic pressure for estimated case is shown at the Figure 1, b.

If we designate the depth of sinking of the top side of contour as h then the components of the hydrostatic pressure are to be calculated with the following formulas:

$$\begin{cases} q_1 = \rho g h; \\ q_2 = q_1 + \rho g l, \end{cases} \tag{1}$$

where ρ – density of the liquid; g – acceleration of gravity.



a b

Figure 1 – Flat overlapping construction with supportive beams under the impact of hydrostatic pressure

Results of investigation: Let's designate the force applied for main direction beam as q, and reaction of the cross-beam AB in the point of their contact as R_i. Then main direction beam deflection at the point of its contact with the crossbeam may be calculated with formula

$$y_i = \gamma_i \cdot q - \beta_i \cdot R_i, \quad i = 1 \ldots n, \tag{2}$$

where γ_i and β_i are coefficients, defined by the i main direction beam characteristics, q force distribution law and cross-beam location. If q force distribution law is linear (see Figure 1, b), then

$$q = \frac{q_1 + q_2}{2} \cdot a. \tag{3}$$

In general, the temperature of each beam may be different thus changing their mechanical characteristics. Let's designate the temperature of the cross-beam as T_0 and temperature of i main direction beam as T_i, $i = 1 \ldots n$.

If cross-beam is located over the mid-points of main direction beams then

$$\begin{cases} \gamma_i = \dfrac{5}{384} \cdot \dfrac{l^3}{[E(T_i) \cdot J(T_i)]}; \\ \beta_i = \dfrac{l^3}{48 \cdot [E(T_i) \cdot J(T_i)]}. \end{cases} \tag{4}$$

Here $[E(T_i) \cdot J(T_i)]$ and $[E_1(T_0) \cdot J_1(T_0)]$ – bending stiffness dependences on the temperature for main direction beams and crossbeam correspondingly.

Cross-beam is bent with the reaction forces R_i $(i = 1, \ldots, n)$, where n is a number of main direction beams. Thus, the represented calculation scheme is n times statistically indeterminate. To disclose the statistical uncertainty we use the force method with the following canonical system of equations

$$\begin{cases} (\delta_{11} + a_1)R_1 + \delta_{12}R_2 + \ldots + \delta_{1n}R_n = f; \\ \delta_{21}R_1 + (\delta_{22} + a_1)R_2 + \ldots + \delta_{2n}R_n = f; \\ \ldots \\ \delta_{n1}R_1 + \delta_{n2}R_2 + \ldots + (\delta_{nn} + a_1)R_n = f, \end{cases} \tag{5}$$

where $\delta_{ij} = \delta_{ji}$ – symmetrical coefficients of cross-beam influence, equal to its deflection at the point of its contact with j main direction beam when the unitary force is applied at the point of its contact with i main direction beam; a_1 – deflection of main direction beam in its mid-point when the unitary force is also applied in its mid-point

$$a_1 = \frac{l_1^3}{48 \cdot [E_1(T) \cdot J_1(T)]}; \tag{6}$$

f – deflection of the main direction beam in its mid-point under impact of the hydrostatical pressure

$$f = \frac{5}{384} \cdot \frac{1}{2} \cdot \frac{(q_1 + q_2)}{[E_1(T) \cdot J_1(T)]} \cdot a \cdot l^4 . \quad (7)$$

System of equations (5) defines all unknown forces $R_1(T_1), R_2(T_2), \ldots, R_n(T_n)$ determining interaction of the main direction beams with crossbeam in the points of their contact in their dependence of the temperature. Using obtained data the strength and stiffness calculation for each beam may be accomplished independently with the structural mechanics methods.

Analysis of obtained results allows creating criterion of safety level assessment for protective hydrotechnical structure based on requirement of load bearing capacity preservation in following formal representation

$$R_i \le [R_i], \quad i = 1 \ldots n, \quad (8)$$

where $[R_i]$ – maximum permissible force to be applied for the corresponding beam.

Let us notice that in the case of equalized temperature provision for the whole protective hydrotechnical structure the solution of system of equation (5) will become simpler because of the following simplification

$$T_0 = T_i, \quad i = 1 \ldots n. \quad (9)$$

The next simplification we may obtain choosing the similar main direction beams and locate them symmetrically. Then the number of unknown values is decreased:

$$\text{if } n \text{ is even then } n' = \frac{n}{2}, \quad (10)$$

$$\text{if } n \text{ is odd then } n' = \frac{(n+1)}{2}. \quad (11)$$

Such decrease provides substantial simplification of the system (5) evaluation. Further simplification we may obtain if main direction beams and crossbeams have same cross-section and are made of same material. Then their bending stiffness is also the same

$$[E(T_i) \cdot J(T_i)] = [E_1(T_0) \cdot J(T_0)], \quad i = 1 \ldots n \quad (12)$$

and may be fully excluded from all equations of system (5).

It has to be specially mentioned that if number of main-direction beams n is odd the result of evaluation of canonical system of equations (5) may include negative value of force of interaction between the central main direction beam and crossbeam. Such case shows that crossbeam of the selected design has lower bending stiffness applying additional loading to the central beam instead of strengthening. Then we have to increase bending stiffness of central main direction beam until the mentioned interaction force will reach its positive value.

Conclusions: In the represented article we have developed the mathematical model of strength of elements of the carrying structure of supportive hydrotechnical wall. The canonical system of equation for contact loading forces between main direction beams and crossbeam is built using the force method. On the basis of the obtained results we have created the criterion of safety level assessment for protective hydrotechnical structure based on requirement of load bearing capacity preservation.

On the basis of proposed mathematical model and safety criterion we have improved the method of characteristics assessment of supportive beams of protective hydrotechnical structure. The proposed improvement allows to calculate accurate values of the loading factors in the dynamics of the extreme situation development taking into account the complexity of the thermal and force loading regime.

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