APPLICATION FEA FOR CALCULATION OF LOADING ON AN ISOLATED STRUCTURE FROM AN ICE COVER AT INCREASE OF TEMPERATURE OF ICE

Ivchenko, A.B. and Vasiliev, S.P.[1]

ABSTRACT

The calculation scheme and, accordingly, calculation dependences for a case of interaction of an isolated structure and ice cover which is locate between this structure and a coast is improved.

The case is considered, when the ice cover is between an extended coast and isolated structure. On the other hand structure of an ice cover is not present, that results in temperature displacement free, not contacting with a structure edge of ice. The extent of an ice cover in a direction to perpendicular effort is not limited. The structure impedes with temperature expansion not only opposite of a strip of an ice cover, but also sites, next to it. The scheme of interaction is given in a fig. 1. It is obvious, that loading on such structure will be much greater, than on a coastal structure. The mechanical pro-

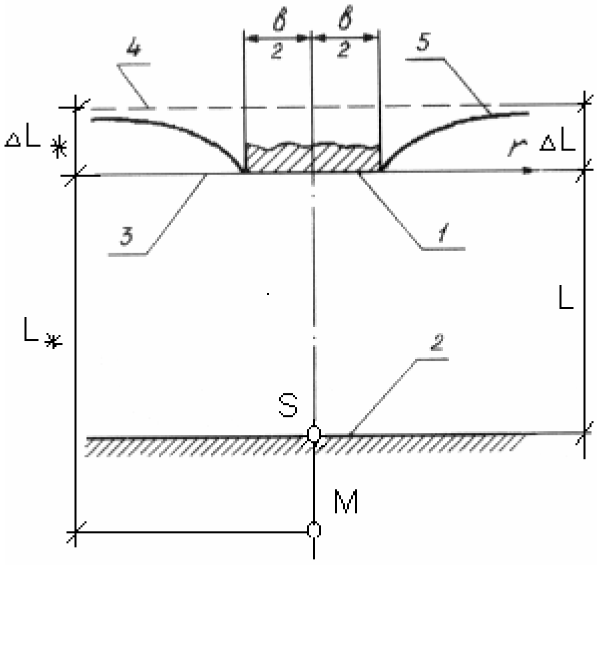

Fig 1.

1- structure; 2- bank - a line actually attachment of an ice cover; 3- initial location of an ice edge; 4- possible location of an ice edge after the temperature rise when structure is absent 5- ice edge after temperature rise; M - point of equivalent fastening of a plate; S - point fastening of a plate in the assumption is earlier received

[1] State Siberian University of Transport, Novosibirsk, Russia

perties of polycrystalline ice are described by the rheological model of an elastic-viscous body [1]. The ice cover is considered as a plate from a modeling material.

The solution for definition of loading on an isolated structure in the assumption is earlier received, that the ice cover is fixed in one point of a coastal line (point S in fig. 1) [3]. Such fastening insufficiently strictly corresponds to real conditions, as all other points of a line of contact have an opportunity to be displaced. Actually attachment of an ice cover is carried out on a line (2 in fig. 1). The specification of the accepted before calculation scheme is necessary.

Between a separate structure and point of fastening of a plate, in case of increase of temperature there is a line of zero exists on an axis y (is below shown, that it proves to be true also by results of numerical experiment). The valid line of zero displacement can be replaced by a straight line. We accept that this straight line coincides with a coastal line and on it the plate (line 2 in fig. 1) is fixed. Then a point M in fig. 1 - point of equivalent fastening of a plate. The deflections of edge of a plate at fastening on a line under a stamp and in an equivalent point are identical. Distance from a stamp up to a point of equivalent fastening L_* will be determined from a condition of equality of effort of interaction at that and other way of fastening of a plate.

Deflection in any point of edge elastic of a plate of unity thickness fixed in a point (fig. 1) on J.H. Michell [4]

$$y = \frac{2}{\pi E} \int_{r_1}^{r_1+b} q(r) \ln \frac{L_*}{r} dr - \frac{1+\nu}{\pi E} \int_{r_1}^{r_1+b} q(r) dr \ , \qquad (1)$$

where E – module of elasticity; b – extent of the loaded site; y and r – coordinate axes; $q(r)$ – law of distribution of loading; L_* – distance from a structure up to a point of equivalent fastening; ν – factor of elastic cross deformation.

Distribution of loading on contact of a plate and rigid stamp shall accept, as well as in [3], on M. Sadowsky [4] as:

$$q(r) = \frac{q_o b}{\pi \sqrt{\left(\frac{b}{2}\right)^2 - r^2}} \ , \qquad (2)$$

where q_0 – average on a line of contact the continuous load. We substitute dependence (2) in (1). We pass to a dimensionless coordinate axis. Then, and, having changed borders of integration, we shall receive a deflection under the centre of a stamp:

$$\Delta L_* = \frac{4bq_0}{\pi^2 E} \int_0^1 \left(1-\zeta^2\right)^{-0,5} \ln \frac{2L_*}{b\zeta} d\zeta - \frac{2(1+\nu)bq_0}{\pi^2 E} \int_0^1 \left(1-\zeta^2\right)^{-0,5} d\zeta \ . \qquad (3)$$

Relative distance from a structure up to a coastal line – $m_b = \frac{L}{b}$, and up to a point of equivalent fastening $- m_{b*} = \frac{L_*}{b}$.

After integration we receive the formula for a deflection under a stamp

$$\Delta L_* = \frac{bq_0}{\pi E}\left[2\ln\left(4c_0 m_b\right) - 1 - \nu\right], \tag{4}$$

where $c_0 = \dfrac{L_*}{L}$ – relative distance up to a point of equivalent fastening. The numerical value should be determined.

For the ice cover surrounded with a rigid closed contour, complete absolute temperature deformation of any horizontal layer as the function of time is equal

$$\Delta L_i(t) = \frac{\left[1 - \nu_{di}(t)\right]c_0 L}{E_{di}(t)dh} q_i(t), \tag{5}$$

where $\nu_{di}(t)$ – factor of full cross deformation for a considered layer, $q_i(t)$ – linear continuous load from a layer limited in the plan to a rigid contour, $E_{di}(t)$ – apparent module of elasticity or module of deformation, dh – thickness of a layer.

Loading, as the function of time, is determined by the published methods [1, 2]. We replace in (4) the module of elasticity variable in time with the module of deformation. We take into account, that for an elementary layer $q_0 = q_{oi}(t)$; $\nu = \nu_{di}(t)$; $\Delta L = \Delta L_i(t)$. Received from (4) size of a deflection of a layer "i", we equate to the appropriate size from dependence (5). The continuous load from of a layer "i" on a separate structure

$$q_{oi}(t) = \frac{\pi c_0 m_b \left[1 - \nu_{di}(t)\right]}{2\ln(4c_0 m_b) - 1 - \nu_{di}(t)} q_i(t). \tag{6}$$

We summarize on thickness of an ice cover of loading from layers determined in (6). We believe factor of full cross deformation by size practically constant. Average on a line of contact variable in time loading on a separate structure

$$q_o(t) = \frac{\pi c_0 m_b (1 - \nu_d)}{2\ln(4c_0 m_b) - 1 - \nu_d} q(t), \tag{7}$$

where ν_d – average value of complete cross deformation; q (t) – loading from all thickness of an ice cover at the same change of temperature and rigid closed contour, as function of time (the methods of its definition is published [1, 2]).

Dependence (7) is possible to present as:

$$q_o(t) = K_o q(t), \tag{8}$$

where

$$K_o = \frac{\pi c_0 m_b (1 - \nu_d)}{2\ln(4c_0 m_b) - 1 - \nu_d}. \tag{9}$$

According to (8) relative loadings

$$K_0 = \frac{q_0(t)}{q(t)}. \tag{10}$$

From dependences (8) and (9) follows, that change of temperature in a more thickly ice cover, mechanical properties and the physical characteristics of ice are taken into account at definition $q(t)$.

From (9) follows, that the influence of mechanical properties and physical characteristics on K_0 is limited to factor ν_d, which is accepted constant. Then relative loading, on dependence (9), depends only on a ratio of the geometrical sizes. Then at calculation till (10) relative loadings K_0, the replacement of a plate from visco-elastic of a material by a plate from an elastic material with factor of complete cross deformation as at ice in conditions of a considered problem is possible. In this case loadings $q_o(t)$ and q (t) are determine as for an elastic plate and do not depend on time and the numerical experiment can be carried out on a plate from an elastic material.

By a method of finite elements is considered plane stress a condition of a plate of unity thickness from an elastic material. Proceeding from conditions of symmetry, half of plate (ice cover) is considered, the least size of a plate in a cross direction is established, the character of fastening of sides of a plate is determined.

As a result of account the line of zero displacement for a case of fastening of a plate in one point (fig. 2) is received. As is told above, we replace such line of a straight line and are considered as a line of an attachment of an ice cover to a coast.

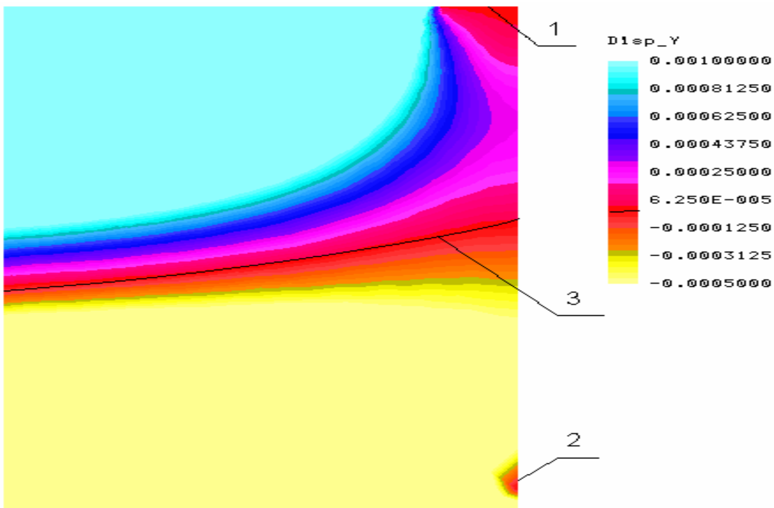

Fig 2.
1 – structure; 2 – point of equivalent fastening of a plate; 3 – line of displacement equal zero

At a real attachment of an ice cover to a coast (on a line) purpose of account was the definition of relative loading K_0, and relative distance c_0. The values of loadings $q_0(t)$ and $q(t)$ at change of temperature are determined by a method of finite elements for a plate from an elastic material with factor d, as at ice. In a fig. 3 is shown edge of an ice cover about a support after increase of temperature and diagram of stress on contact of a support and ice cover in one of calculation. The significance $q_0(t)$ is determined for different L, b and m. Relative loading K_0, at various value m_b, is determined by (10) at experimental significance of loadings $q_0(t)$ and $q(t)$. It is established, that K_0 depends from m_b and does not depend on absolute value L and b. Experimental dependence $K_0 = f(m_b)$ - line 1 in fig. 4.

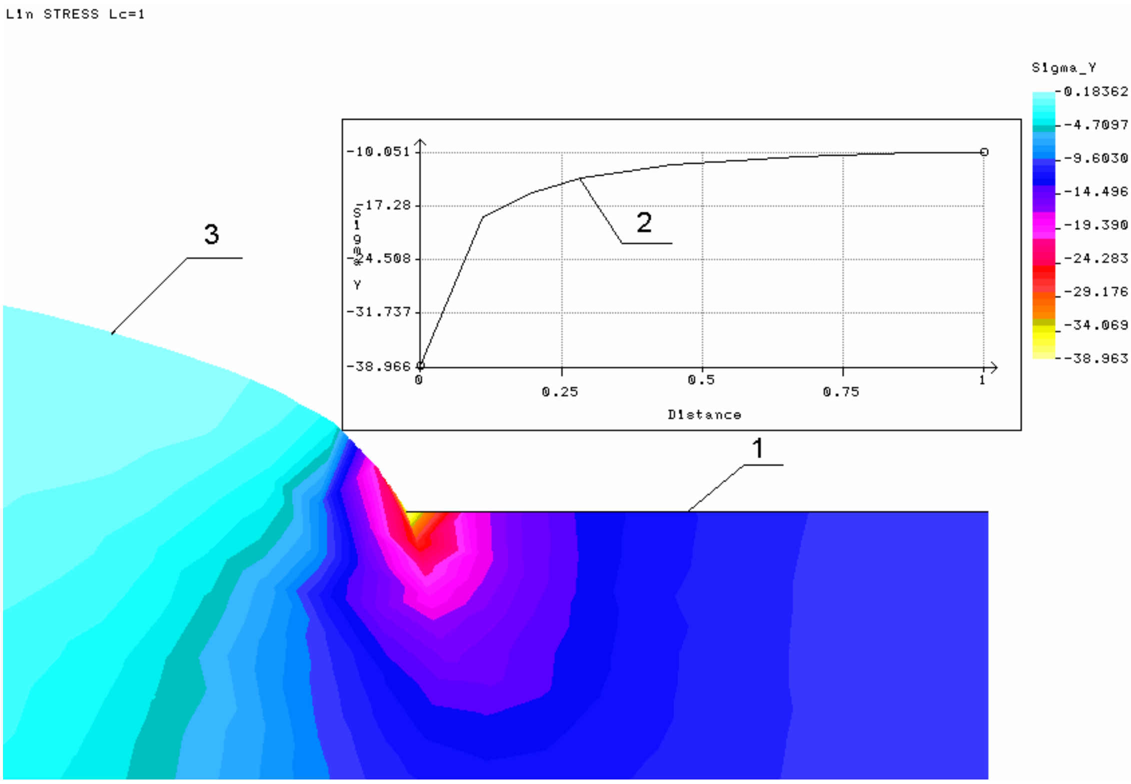

Fig 3.
1 – foot of die; 2 – diagram of stress in on foot of die; 3 – free ice edge after temperature rise (increase 100)

Comparison of calculation dependence (9) with the experimental data (the diagram 1 in fig. 2) has shown, that it is really possible to consider factor c_0 as value practically constant and equal 1.63 ($m_b \geq 2.5$). The calculation dependence received on (9) at c_0 =1.63 (curves 2 in fig. 2), well coincides with the experimental data (curve 1 in fig. 4). Recommended above experimental dependences is possible to use at $m_b \geq 2.5$.

At definition of calculation loading on a separate structure on dependence it is possible to count up (8) relative loading K_0, on (9) or to receive under the diagram 1 of fig. 2.

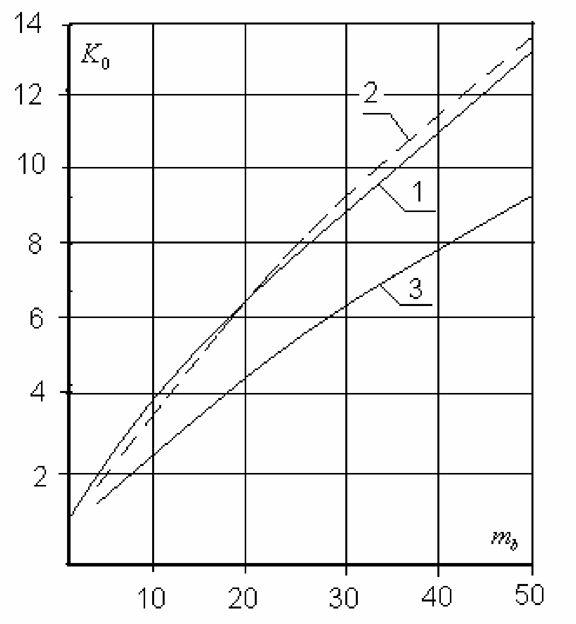

Fig. 4. Dependence $K_0 = f(m_b)$:

1 – experimental curve, when the plate is fixed on line; 2 – calculation curve, when the plate is fixed in point M; 3 – calculation curve, when the plate is fixed in point S

Calculation dependence $K_0 = f(m_b)$ at the former calculation scheme [3], when the plate is fixed only in one point on a coastal line (point S in fig. 1), is submitted by a line 3 in fig. 4. The given research has allowed essentially making more precise calculation` definition of loading on a separate structure.

It is known, that the mechanical properties of fresh-water and sea ice coincide, but the physical characteristics differ essentially. For example, factor of temperature expansion of sea ice strongly depends on temperature and other factors. The considered settlement technique can be distributed to a case of interaction of a separate structure with a sea ice cover at the known characteristics last.

REFERENCES

1. Ivchenko A.B. Rheological Model of Polycrystalline Ice. *Proceedings of the 10th International Symposium on Ice* 1. Espoo (Finland), (1990) 230-237.

2. Ivchenko A.B. Investigation of Stress of Ice Cover under Changes of Temperature. *Proceedings of the 10th International Symposium on Ice* 3. Espoo (Finland), (1990), pp. 149-157.

3. Ivchenko A.B. Ice forces on isolated structures under temperature changes. *Proceedings of the 14th International Symposium on Ice* 2. Potsdam, New York, USA (1998), pp. 907-909.

4. Michell J.H. The inversion of plane stress. *Proceedings of the London Mathematical Soc.* 34. London, (1902), pp. 134-142.

5. Sadowsky M. Zweidimensionale Probleme der Elastizitatstheorie. *Zeitschrift fur angewandte Mathematik und Mechanik.* Bd.8, H. 2-S. (1928), pp. 107-121.