CALCULATIONS FOR THE WARMING OF HOUSE FOUNDATIONS
ĒKU PAMATU SILTINĀŠANAS APRĒĶINI

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Abstract. Heat losses of the houses built according to the standards of the former Soviet Union are larger than the heat loss of houses in the Western and Scandinavian countries. The heat loss occurs through the foundation and floor. In order to work out an economically reasonable recommendations for heat insulation of the foundation and floor, a mathematical model of thermal resistance is worked out. Thus it enables to make calculations for heat insulation parameters of the foundation and floor of buildings.
Key words: foundation, floor, heat insulation, temperature, thermal resistance, complex plane.

1. Introduction

The thermal resistance of livestock premises built in accordance with the standards of the former Soviet Union was calculated to economise building materials and outlay of production. It results in larger heat losses than the same building in the Western and Scandinavian countries. A lot of heat energy is lost through the foundation and floor particularly near the outer walls. To work out the projects for reconstruction of these buildings it is important to know the economic benefit which could be got. Besides, the floor of livestock premises has to be warm enough near the outside walls, too, in order to place animals along all of the floor. But at present there are no both a united manner for a practical calculation of thermal losses through the foundation and floor, and an economically based method for the calculation of the necessary heat insulation of the foundation and floor, in order to decrease the heat losses through them (H. Šterns, 1996; PAROC, 1997).

2. Method of calculation

In order to work out an economically based recommendation for heat insulation of buildings the temperature of which is 15° C and higer, at first it is necesessary to determine the heat loss through these conctructions. Such buildings are livestock premises, buildings for processing of food products, houses and premises for social life, etc. To work out the method of calculation let us make a mathematical model for square shape building with lengh and width of 12 m. For simulation let us use a round shape house (I. Ziemelis et al., 1997). With the floor area 144 m^2, which corresponds to a square shape building. The radiuss of the round shape house is R=6.77 m. The inside air temperature of the house let us assume 18 °C, but the outside air temperature equal to the average air temperature during the heating period at the city Dobele – minus 0.5 °C. Let us assume the house has 10 cm thick concrete floor, the coefficient of heat conductivity of which is λ=1.0 W/(m·K). In order to decrease the heat losses through the foundation of a house let us anticipate to use the heat insulation of the following kinds:

1. outside a house horizontally at the level of soil up to 3.00 m from the axes of a wall with the calculated step 0.30 m;
2. heat insulation inside a house horizontally together with heat insulation of the floor at a distance up to 3.00 m from the axes of a wall with the calculated step 0.30 m;
3. vertically along the axes of a house up to 1.50 m under the upper level of the foundation with the calculated step 0.15 m. Besides, it is possible to apply different combination of the above mentioned kinds of heat insulation.

Let us calculate thermal resistance of ground by means of the method of conformable reflection (U. Iljins, I. Ziemelis, 1997). As this method without thermal resistance gives an infinitely large heat flow it is necessary to take a definite initial resistence value, which can be calculated by a model (I. Ziemelis et al., 1997).

3. Calculation of thermal resistance

Let us imagine the foundation of a building (Fig.1a) as a cross-section in the complex plane (Fig.1b). Along lines $A_2;A_4 - A_3$ and $A_5;A_7 - A_6$ the section is made. Co-ordinates of points A_2, A_4 and accordingly A_5, A_7 are equal, but they are located in different sides of the section. Further at plane ω (Fig. 2) these sections will be "streched" – reflected in a shape of a line.

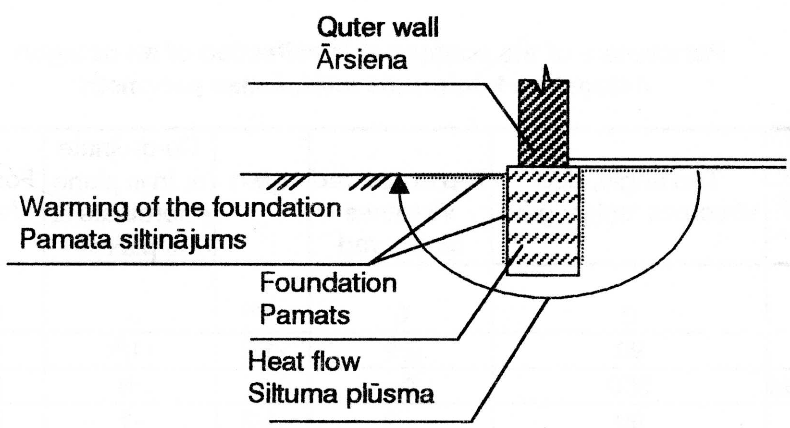

Fig. 1a. Scheme of the house foundation.
1a. att. Ēkas pamata skice.

Let us assume that thermal insulation is ideal (heat flow through it equals to zero, t.i., boundary conditions of the second kind) and the temperature on the upper layer of the ground inside a house T_1 and outside T_2 are fixed (boundary conditions of the first kind). In such case the heat flow from inside to outside by the method of conformable reflections can be calculated.

Let us have a look at a system of two symmetrical flat heat insulators placed into the infinite setting (Fig.1b), cross-section of which in the complex plane z is shown.

The upper half-plane z (shaded part) forms an octagon (tops A_1, A_2,...;A_8) parameters of which are summarized in the Table.

The octagon ($A_1 - A_8$) which is placed at the upper half-plane of the complex plane *z* by means of Shwarth-Cristophel integral, which by the formula (1) is given, let us reflect as the upper half-plane of the complex plane w (A. Свешников, 1974) (Fig. 2).

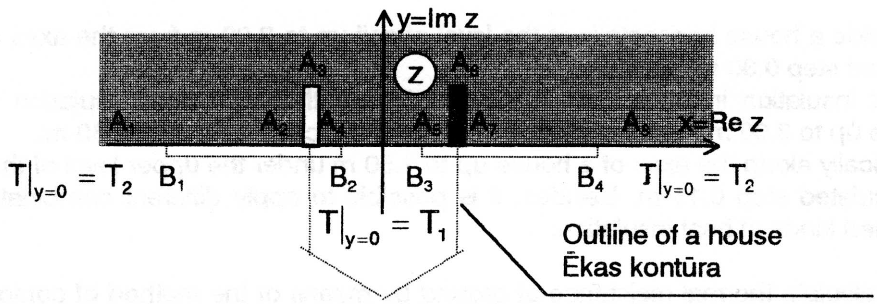

Fig. 1b. Scheme of the calculations of heat insulation of the foundation of a house:
A_1B_1 and B_4A_8 - part of the ground outside a house without heat insulation;
B_1A_2 and A_7 B_4 - heat insulation outside a house horizontally at the level of soil;
sections A_2 A_3A_4 and A_5 A_6 A_7 - vertical heat insulation of the foundation;
A_4B_2 and B_3A_5 - heat insulation inside a house horizontally at the level of soil;
B_2B_3 - part of the ground inside a house without heat insulation.
1b. att. Ēkas pamatu siltuma izolācijas aprēķina shēma:
A_1B_1 un B_4A_8 - grunts daļa ēkas ārpusē bez siltuma izolācijas; B_1A_2 un A_7B_4 - siltuma izolācija ēkas ārpusē horizontāli zemes līmenī; griezumi $A_2A_3A_4$ un $A_5A_6A_7$ - pamatu vertikālā siltumizolācija; A_4B_2 un B_3A_5 - siltuma izolācija ēkas iekšpusē horizontāli zemes līmenī; B_2B_3 - grunts daļa ēkas iekšpusē bez siltuma izolācijas.

Table/Tabula

Parameters of the conformable reflection of an octagon[1]
Astoņstūra konformās attēlošanas parametri

Tops k Virsotnes k	A_k	Top angle, deg Virsotnes leņķis, grad	Top angle, rad Virsotnes leņķis, rad	α_k/π-1	Co-ordinate a_k in ω plane Koordināte a_k ω plaknē	Form an octagon Veido astoņstūri
1	∞	0	0	$-1^{(x)}$	∞	Form/Veido
2	-α	90	π/2	-1/2	-1/k	Form/Veido
3	-α+βi	360	2π	1	-b	Form/Veido
4	-α	90	π/2	-1/2	-1	Form/Veido
5	α	90	π/2	-1/2	1	Form/Veido
6	α+βi	360	2π	1	b	Form/Veido
7	α	90	π/2	-1/2	1/k	Form/Veido
8	∞	0	0	$-1^{(x)}$	∞	Form/Veido
Tops k Virsotnes k	B_k					
1	-γ	180	π	0	$-\omega_1$	Do not form Neveido
2	-δ	180	π	0	$-\omega_2$	Do not form Neveido
3	δ	180	π	0	ω_2	Do not form Neveido
4	γ	180	π	0	ω_1	Do not form Neveido

[1]In the Table with an asterisk $^{(x)}$ are marked the tops of the octagon, which in the integral (1) would not be counted because points (A_1; A_8) are placed in the infinity;
Tabulā ar zvaigznīti $^{(x)}$ apzīmētas tās astoņstūra virsotnes, kuras integrālī (1) nav jāievieto, jo punkti (A_1; A_8) atrodas bezgalībā.

$$z=\frac{C}{k}\int_0^{\omega}\prod_{k=1}^{8}(t-a_k)^{\frac{\alpha_k}{\pi}-1}dt=\frac{C}{k}\int_0^{\omega}\frac{(t-b)(t+b)dt}{(t-1/k)^{1/2}(t-1)^{1/2}(t+1)^{1/2}(t+1/k)^{1/2}}=$$
$$=C\int_0^{\omega}\frac{(t^2-b^2)dt}{\sqrt{(1-t^2)(1-k^2t^2)}}=C\int_0^{\omega}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}-Cb^2\int_0^{\omega}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}=$$
$$=C\cdot D(\omega;k)-Cb^2\cdot F(\omega;k), \qquad (1)$$

where *C*, *b* – for the present unknown constants;
k – Legendre module of elliptic integrals, which also is indefinite;

$F(\omega;k)=\int_0^{\omega}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}$ - incomplete elliptic integral of the first kind; (2)

$D(\omega;k)=\int_0^{\omega}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}$ - supplementary defined elliptic integral. (3)

Constants C, b and Legendre module k will be determined later by means of condition that at the next reflection points A_i are described as points A'_i accordingly; after that as A''_i etc.

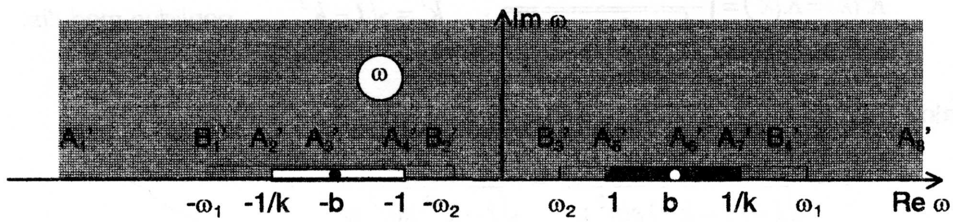

Fig. 2. Complex ω plane.
2. att. Kompleksā ω plakne.

By means of incomplete elliptic integral of the first kind (A. Свешников, 1974)

$$w=\int_0^{\omega}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}} \qquad (4)$$

it is possible to describe the upper half-plane of the complex plane ω as quadrangle in the complex plane w (Fig. 3).

Further the constantes *C*, *b* and module *k* ought to be determined. For that let us insert the top co-ordinates of the ortagon (plane z) into the integral (1). From the top A_6 ($\omega=b>1;\ z=\alpha+i\beta$)

$$\alpha+\beta i=C\int_0^{b}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}-Cb^2\int_0^{b}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}=$$
$$=C\left(\int_0^{1}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}+\int_1^{b}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}\right)-Cb^2\left(\int_0^{1}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}+\int_1^{b}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}\right)=$$
$$=C\left(\int_0^{1}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}+i\int_1^{b}\frac{t^2dt}{\sqrt{(t^2-1)(1-k^2t^2)}}\right)-Cb^2\left(\int_0^{1}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}+i\int_1^{b}\frac{dt}{\sqrt{(t^2-1)(1-k^2t^2)}}\right)=$$
$$=C\left(D(k)+iD'(b;k)\right)-C\,b^2\left(K(k)+iF'(b;k)\right). \qquad (5)$$

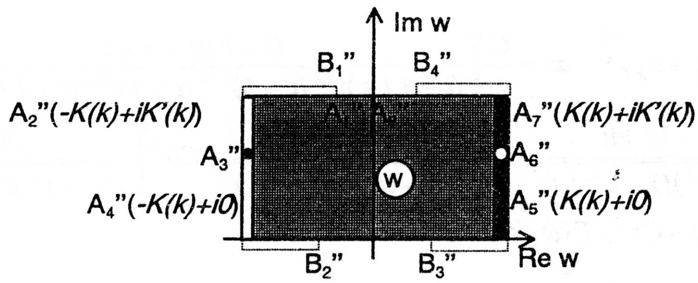

Fig. 3. Complex w plane: $K(k)=\int\limits_0^1 \frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}$ *- elliptic integral of the first kind;*

$$K'(k)=K(k')=\int\limits_0^1 \frac{dt}{\sqrt{(1-t^2)(1-k'^2t^2)}} \;;\; k'=\sqrt{1-k^2} \quad \text{- additional module .}$$

3. att. Kompleksā w plakne: $K(k)=\int\limits_0^1 \frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}$ *- 1. veida pilnais eliptiskais integrālis;*

$$K'(k)=K(k')=\int\limits_0^1 \frac{dt}{\sqrt{(1-t^2)(1-k'^2t^2)}} \;;\quad k'=\sqrt{1-k^2} \quad \text{- papildus modulis.}$$

At first let us calculate the integral *D'(b;k)*. It is possible by using a substitution

$$t=\frac{1}{\sqrt{1-(1-k^2)\sin^2\psi}}=\frac{1}{\sqrt{1-k'^2\sin^2\psi}} \quad . \tag{6}$$

Then

$$D'(b;k)=\int\limits_1^b \frac{t^2dt}{\sqrt{(t^2-1)(1-k^2t^2)}}=\frac{1}{k^2}\left(E(k')-E\left(\arcsin\sqrt{\frac{1-k^2b^2}{k'^2}};k'\right)\right), \tag{7}$$

where $E(k')=\int\limits_0^1 \sqrt{\frac{1-k'^2t^2}{1-t^2}}\,d \;=\int\limits_0^{\pi/2} \sqrt{1-k'^2\,si^2\Psi}\,d\Psi$ – complete elliptic integral of the

second kind with a module k';

$$E\left(arcs\sqrt{\frac{b^2-1}{k'^2b^2}};k'\right)=\int\limits_0^{\sqrt{\frac{b^2-1}{k'^2b^2}}} \sqrt{\frac{1-k'^2t^2}{1-t^2}}\,d\;=\int\limits_0^{arcs\sqrt{\frac{b^2-1}{k'^2b^2}}} \sqrt{1-k'^2\,si^2\Psi}\,d\Psi \;-$$

incomplete elliptic integral of the second kind with a module k' .

Using the same substitution (6) the next integral can be soved

$$F'(b;k)=F\left(\arcsin\sqrt{\frac{b^2-1}{k'^2b^2}};k'\right). \tag{8}$$

Inserting formulas (7) and (8) into the expression (5) gives

$$\alpha+\beta i=C\big(D(k)-b^2K(k)\big)+iC\big(D'(b;k)-b^2F'(b;k)\big). \tag{9}$$

In comparision the complete parts of the right and left halfs of the formula (9)

$$\alpha = C\left(D(k) - b^2 K(k)\right) \tag{10}$$

and incomplete parts

$$\beta = C\left(D'(b;k) - b^2 F'(b;k)\right). \tag{11}$$

From the top $A_7(\omega = 1/k;\ z = \alpha + i0)$ follows

$$\alpha = C\int_0^{1/k} \frac{t^2 dt}{\sqrt{(1-t^2)(1-k^2t^2)}} - Cb^2 \int_0^{1/k} \frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}} . \tag{12}$$

The further alternation is similar to formulas (5) ... (7), in which a boundary b by $1/k$ is replaced. At this boundary incomplete integrals $D'(b;k)$ and $F(b;k)$ change to complete elliptic integrals $D'(k); k'(k)$. Therefore instead of the expression (11) the following is obtained

$$0 = C\left(D'(k) - b^2 F'(k)\right). \tag{13}$$

Expressions (10), (11) and (13) make a system of three equations for the determination of values C, b^2 and k. From the coherence (13)

$$b^2 = \frac{D'(k)}{K'(k)} \tag{14}$$

And inserting it into formulas (10) and (11) gives

$$\alpha = C\left(D(k) - \frac{D'(k)}{K'(k)} K(k) \right), \tag{15}$$

$$\beta = C\left(D'(b;k) - \frac{D'(k)}{K'(k)} F'(b;k) \right). \tag{16}$$

From expressions (15) and (16) the value C can be excluded

$$\frac{\beta}{\alpha} = \frac{D'(b;k) - \dfrac{D'(k)}{K'(k)} F'(b;k)}{D(k) - \dfrac{D'(k)}{K'(k)} K(k)} . \tag{17}$$

The transcendental equation (17) gives solution for the value k. Therefore let us change it in the form, which is suitable for the work with a table of elliptic integrals (E. Янке et al., 1968). At first let us calculate $D(k)$:

$$D(k) = \int_0^1 \frac{t^2 dt}{\sqrt{(1-t^2)(1-k^2t^2)}} = -\frac{1}{k^2}\int_0^1 \frac{(1-k^2t^2-1)dt}{\sqrt{(1-t^2)(1-k^2t^2)}} =$$

$$= \frac{1}{k^2}\left(\int_0^1 \frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}} - \int_0^1 \frac{(1-k^2t^2)dt}{\sqrt{(1-t^2)(1-k^2t^2)}} \right) =$$

$$= \frac{1}{k^2}\left(\int_0^1 \frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}} - \int_0^1 \sqrt{\frac{1-k^2t^2}{1-t^2}}\,dt \right) = \frac{K(k) - E(k)}{k^2}. \tag{18}$$

The integral $D'(k)$ from the formula (7) can be determined

$$D'(k) = \int_1^{1/k} \frac{t^2 dt}{\sqrt{(t^2-1)(1-k^2t^2)}} = \frac{E(k')}{k^2} . \tag{19}$$

Inserting into the formula (17) expressions (7), (8), (18) and (19) results in

$$\frac{\beta}{\alpha}=\frac{\frac{1}{k^2}\left(E(k')-E\left(\arcsin\sqrt{\frac{1-k^2b^2}{k'^2}};k'\right)\right)-\frac{E(k')}{k^2\cdot K(k')}F\left(\arcsin\sqrt{\frac{b^2-1}{k'^2b^2}};k'\right)}{\frac{K(k)-E(k)}{k^2}-\frac{E(k')}{k^2}\cdot\frac{K(k)}{K(k')}} \qquad .(20)$$

By changing a sign, cancel on k^2 and finding a common denominator it follows

$$\frac{\beta}{\alpha}=\frac{E(k')\cdot F\left(\arcsin\sqrt{\frac{b^2-1}{k'^2b^2}};k'\right)+K(k')\cdot E\left(\arcsin\sqrt{\frac{1-k^2b^2}{k'^2}};k'\right)-E(k')\cdot K(k')}{E(k')\cdot K(k)+E(k)\cdot K(k')-K(k)\cdot K(k')} \qquad .\ (21)$$

Considering the Legendre's coherence

$$E(k')\cdot K(k)+E(k)\cdot K(k')-K(k)\cdot K(k')=\frac{\pi}{2}, \qquad (22)$$

it is possible to rewrite the formula (21) as follows

$$\frac{\pi\beta}{2\alpha}=E(k')\cdot F\left(\arcsin\sqrt{\frac{b^2-1}{k'^2b^2}};k'\right)+K(k')\cdot E\left(\arcsin\sqrt{\frac{1-k^2b^2}{k^2}};k'\right)-E(k')\cdot K(k') \qquad .(23)$$

Inserting into formula (23) the coherence (14), into which the expression (19) is inserted, the transcendental equation for the calculation of elliptic integrals is obtained

$$\frac{\pi\beta}{2\alpha}=E(k')F\left(\arcsin\sqrt{\frac{E(k')-k^2K(k')}{k'^2E(k')}};k'\right)+K(k')E\left(\arcsin\sqrt{\frac{K(k')-E(k')}{k'^2K(k')}};k'\right)-E(k')K(k') \qquad .\ (24)$$

The Legendre module k of elliptic integrals computed by the formula (24) in dependence on the value β/α in Fig. 4 is shown.

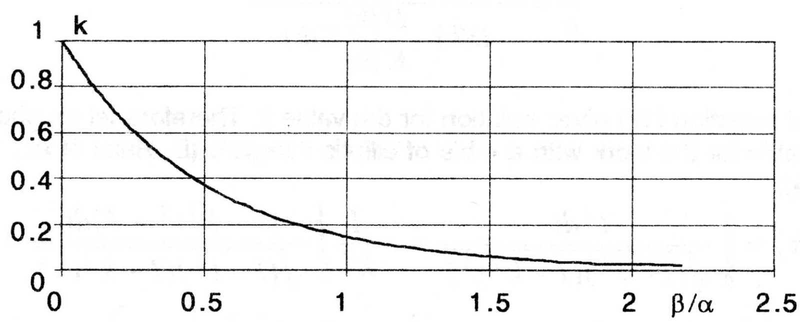

Fig. 4. Coherence k = f(β/α).
4. att. Sakarība k = f(β/α).

Further at known values b^2, which are found by the formula (14) and C, found by the formula (15), values ω_1 and ω_2 can be obtained. In order to determine $\omega_2 <= 1$ the formula (1) can be used, which in the top B_3 ($z=\delta$) gives

$$\delta=C\int_0^{\omega_2}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}}-Cb^2\int_0^{\omega_2}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}=C\cdot D(\omega_2;k)-Cb^2\cdot F(\omega_2;k). \qquad (25)$$

Equation (25) is transcendental with respect to ω_2 .The top B_4 $(z=\gamma)$ gives $(\omega_2 <= 1/k)$

$$\gamma = C\int_0^{\omega_1}\frac{t^2dt}{\sqrt{(1-t^2)(1-k^2t^2)}} - Cb^2\int_0^{\omega_1}\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}} =$$

$$= \alpha + C\int_{1/k}^{\omega_1}\frac{t^2dt}{\sqrt{(t^2-1)(k^2t^2-1)}} - Cb^2\int_{1/k}^{\omega_1}\frac{dt}{\sqrt{(t^2-1)(k^2t^2-1)}} =$$

$$= \alpha + \frac{C}{k^2}\left((1-k^2b^2)\cdot F\left(\arcsin\sqrt{\frac{k^2\omega_1^2-1}{k^2(\omega_1^2-1)}};k\right) + \omega_1\sqrt{\frac{k^2\omega_1^2-1}{k^2(\omega_1^2-1)}} - E\left(\arcsin\sqrt{\frac{k^2\omega_1^2-1}{k^2(\omega_1^2-1)}};k\right)\right), \quad (26)$$

which is transcendental eguation with respect to ω_1. Using solutions of transcendental equations (24) ... (26) it is possible to transform the complex plane ω so that in the complex plane τ the co-ordinate of a point B_3 $(\omega=\omega_2)$ is equal to one. It can be done by the function (Fig. 5).

$$\tau = \frac{\omega}{\omega_2}. \quad (27)$$

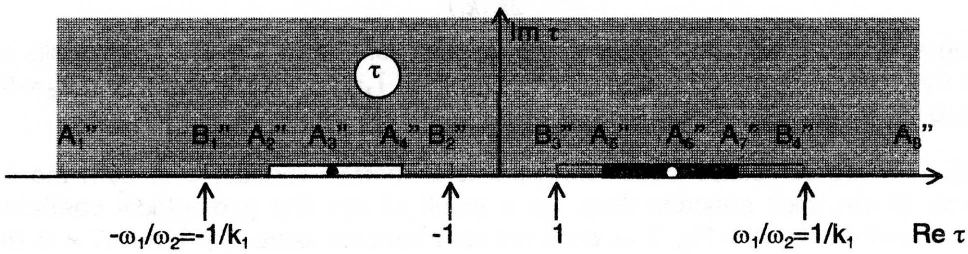

Fig. 5. Complex τ plane.
5. att. Kompleksā τ plakne.

The module k_1 of the new elliptic integrals now is given by the coherence

$$k_1 = \frac{\omega_2}{\omega_1}, \quad (28)$$

but integral

$$w = \int_0^{\tau}\frac{dt}{\sqrt{(1-t^2)(1-k_1^2t^2)}} \quad (29)$$

will describe the complex τ plane as a rectangle in the complex plane w_1 (Fig. 6).

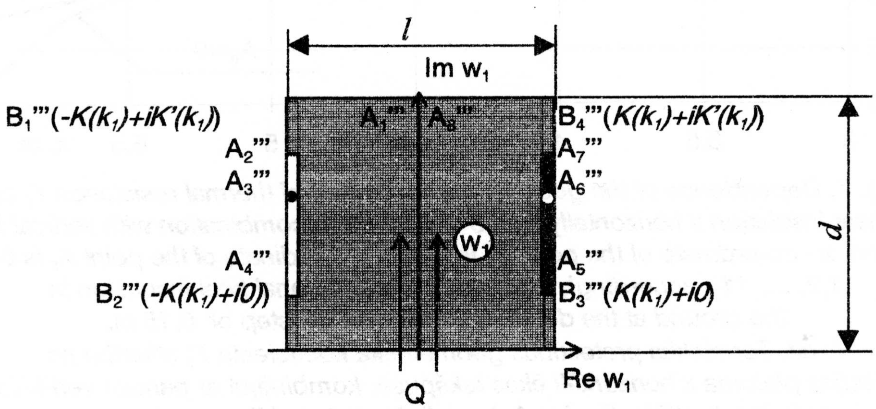

Fig. 6. Complex w_1 plane: Q - heat flow.
6. att. Kompleksā w_1 plakne: Q - siltuma plūsma.

Let us introduce the thermal resistance R_T

$$R_T = \frac{d}{\lambda \cdot S} = \frac{1}{\lambda \cdot f} \cdot \frac{d}{l} = \frac{1}{\lambda \cdot f} \cdot \frac{K'(k_1)}{2K(k_1)} = \frac{1}{\lambda \cdot f} \cdot \Gamma_T \quad (30)$$

where λ - mean value of the heat transfer coefficient of the ground, W(m .K);

d - length of the conformable refractions in plane w_1, in Fig. 6 $K'(k_1)$;

l - thickness of the conformable refractions in plane w_1, in Fig. 6 $2K(k_1)$;

f - depth perpendicular to the comlex w_1 plakne, m;

$S = f \cdot l$ - cross-section area though which the heat flow Q goes;

$$\frac{d}{l} = \frac{K'(k_1)}{2K(k_1)} .$$

The value of the coefficient Γ_T contains geometrical parameters of the task in question. Therefore heat losses Q through the foundation of a house can be found in accordance with an expression

$$Q = \frac{T_1 - T_2}{R_T} = \lambda \cdot f \cdot \frac{T_1 - T_2}{\Gamma_T} , \quad (31)$$

where

$$\Gamma_T = \frac{K'(k_1)}{2K(k_1)} . \quad (32)$$

The temperature T_1 can be determined from the solution for a round house (I. Ziemelis et al., 1997). In the definite case the temperature under the floor $T_1 = 17\ ^oC$ is chosen, and $T_2 = -0{,}5^oC$, which eguals to the average outside air temperature during the heating season.

Curves in Fig. 7.-9. are calculated considering the total thermal resistance of both the house foundation and 10 cm thick concrete floor. As a result of that the geometrical coefficient of thermal resistance of the line 1 in Fig. 7.-9. does not start from the value $\Gamma_T = 0$ but $\Gamma_T = 0.18$.

4. Results

At the definite conditions (square house with the distance between axes 12 m) the dependence on thermal resistance from different warming conditions in Fig. 7.-9. is shown.

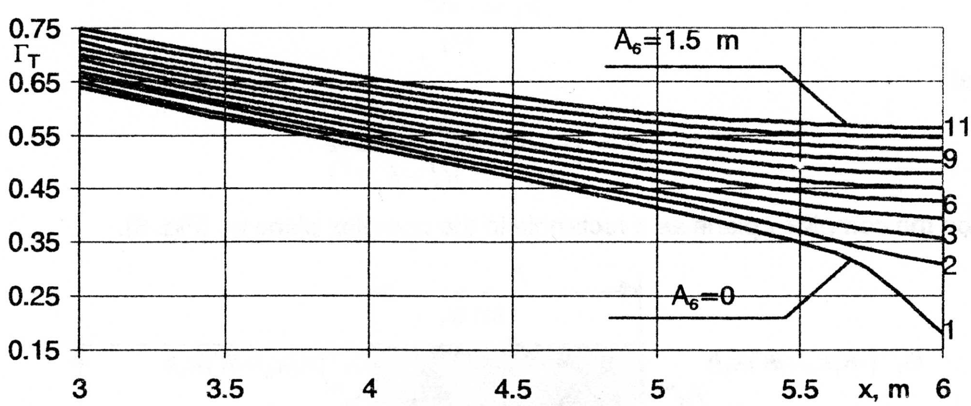

Fig. 7. Dependence of the geometrical coefficient of thermal resistance Γ_T on the width of heat insulation x horizontally inside a building in combination with vertical insulation of the foundation. x - co-ordinate of the point B_3 in Fig. 1. Co-ordinate of the point A_5 is 6 m. Curves 1,2, ..., 11 - accordingly correspond to additional heat insulation in the ground at the depth of 0-1.5 m with a step of 0.15 m.

7. att. Termiskās pretestības ģeometriskā koeficienta Γ_T atkarība no siltuma izolācijas platuma x horizontāli ēkas iekšpusē, kombinējot ar pamatu vertikālo izolāciju. x - punkta B_3 koordināte 1. attēlā. Punkta A_5 koordināte ir 6 m. Līknes 1, 2, ..., 11 - atbilst attiecīgi papildus pamatu siltuma izolācijai gruntī dziļumā no 0 līdz 1.5 m ar soli 0.15 m.

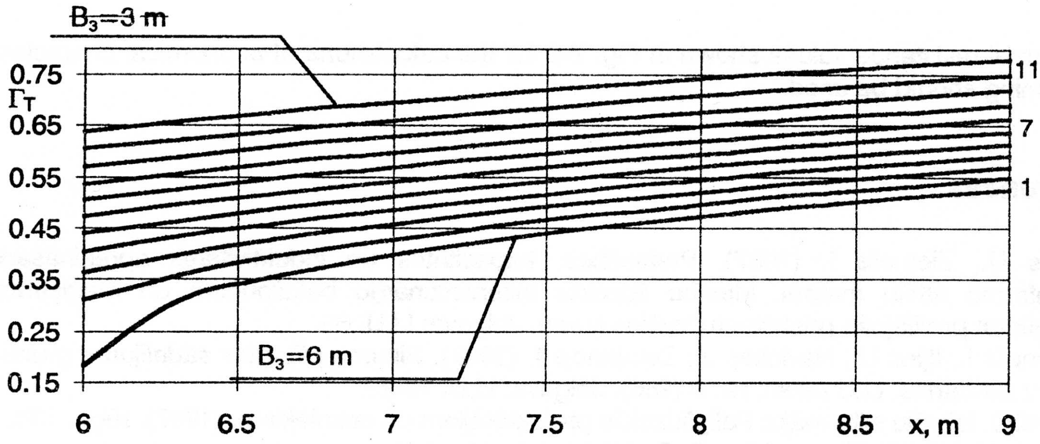

Fig. 8. Dependence of the geometrical coefficient of thermal resistance Γ_T on the width of heat insulation x horizontally outside a building in combination with heat insulation under the floor. x - co-ordinate of the point B_4 in Fig. 1. Co-ordinate of the point A_5 is 6 m. Curves 1,2, ..., 11 - accordingly correspond to additional heat insulation inside a house (alteration of the co-ordinate of the point B_3 is from 6 to 3 m with a stepof 0.30 m).

8. att. Termiskās pretestības ģeometriskā koeficienta Γ_T atkarība no siltuma izolācijas platuma x horizontāli ēkas ārpusē, kombinējot ar izolāciju zem grīdas. x - punkta B_4 koordināte 1. attēlā. Punkta A_5 koordināte ir 6 m. Līknes 1, 2, ..., 11 - atbilst attiecīgi papildus ēkas iekšējai siltināšanai (punkta B_3 koordinātes maiņa no 6 līdz 3 m ar soli 0.30 m).

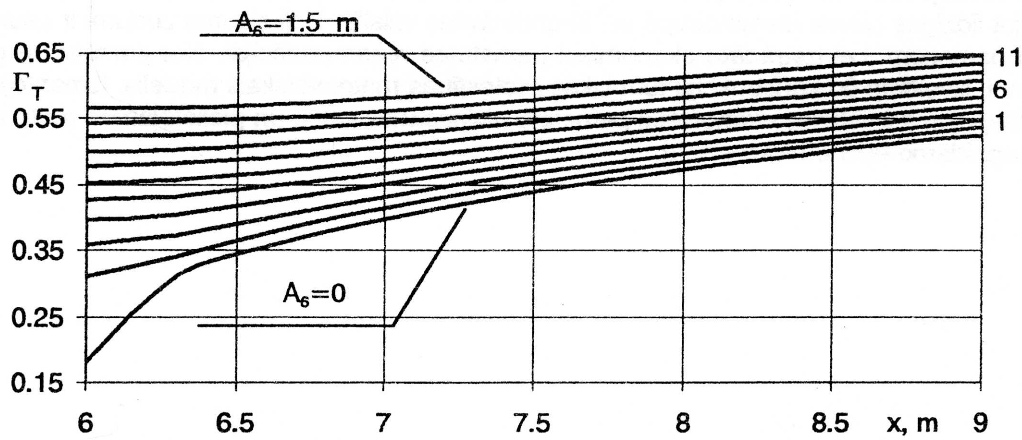

Fig. 9. Dependence of the geometrical coefficient of thermal resistance Γ_T on the width of heat insulation x horizontally outside a building in combination with vertical insulation of the foundation. x - co-ordinate of the point B_4 in Fig. 1. Co-ordinate of the point A_5 is 6 m. Curves 1,2, ..., 11 - correspond accordingly to additional heat insulation of the foundation in the ground at the depth of 0-1.5 m with a step of 0.15 m.

9. att. Termiskās pretestības ģeometriskā koeficienta Γ_T atkarība no siltuma izolācijas platuma x horizontāli ēkas ārpusē, kombinējot ar pamatu vertikālo izolāciju. x - punkta B_4 koordināte 1. attēlā. Punkta A_5 koordināte ir 6 m. Līknes 1, 2, ..., 11 - atbilst attiecīgi papildus pamatu siltuma izolācijai gruntī dziļumā no 0 līdz 1.5 m ar soli 0.15 m.

From the curves in Fig. 7.-9. by using formula (31) it is possible to compute the heat flow Q which is lost through the foundation of a house to the ground.

5. Conclusion

1. Dependence on thermal resistance of the house foundation and different warming condition parameters is obtained.

2. Thermal resistance values shown in Fig. 7-9 for the calculations of economical characteristics of warming should be used.

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ANOTĀCIJA

Pēc bijušās Padomju Savienības celtniecības normām būvētām lopu mītnēm siltuma zudumi caur ēku norobežojošām konstrukcijām ievērojami pārsniedz tos normatīvus, kādi pieļaujami projektējot līdzīgas būves Rietumeiropā un Skandināvijas valstīs. Lieli siltuma zudumi ir caur ēku grīdu un pamatiem. Lai izstrādātu ekonomiski pamatotas rekomendācijas ēku pamatu un grīdu siltināšanai, izveidots šo konstrukciju termiskās pretestības matemātiskais modelis. Izmantojot šo modeli, iespējams izvēlēties ekonomiski pamatotu siltināšanas veidu un pielietojamos materiālus, noteikt sagaidāmo ekonomisko efektu.