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DETERMINING TEMPERATURES IN CONCRETE MASONRY OF DAMS UNDER CONSTRUCTION, ALLOWING FOR HEAT CONDUCTIVITY AND THE THERMAL STATE OF THE FOUNDATION

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This report presents mathematical methods for determining temperatures in concrete masonry of dams under construction. These methods take into consideration both heat conductivity and the thermal state of the foundation.

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DETERMINING TEMPERATURES IN CONCRETE MASONRY OF DAMS UNDER CONSTRUCTION, ALLOWING FOR HEAT CONDUCTIVITY AND THE THERMAL STATE OF THE FOUNDATION

GIDROTEKHNICHESKOYE STROITEL'STVO in Russian No 9, 1966 pp 15-20

[Article by G.I. Chilingarishvili, candidate of technical sciences]

[Text] The problem of the temperature conditions of blocks of dams under construction, being concreted consecutively, allowing for the effect of the foundation, causes considerable mathematical difficulties. Several solutions are known for this problem, obtained due to simplifying assumptions made. In the work by R. Glover [1], a solution is given to the one-dimensional problem, using the analytic method for blocks of equal height h, placed one after the other at regular intervals, τ_0, on the assumption of the equality of the thermophysical characteristics of the concrete and the rock of the foundation and the assumption of other simplifications. The heat release function is taken in the form of the formula

$$\theta(\tau) = \theta_0(1 - c^{-m\tau}). \qquad (1)$$

where θ_0 and m are the invariable numbers for the given concrete.

R. Carlson [2] solved this problem with the same prerequisites by the method of nets according to a four-point implicit system, which necessitates the joint solution of a large number of equations in finite differences. The work by I. Babushka and L. Meyzdik [3] gives the results of solving a two-dimensional problem, obtained by the method of nets. The same method was used for the one-dimensional problem in the work by V.M. Shteynberg, I. Ye. Prokopovich and I.V. Gol'dfarb [4], for a more general case, when the thermophysical characteristics of the concrete and the foundation rock are not identical. This problem is most widely studied in the recently published works of Sh. N. Plyat and L.B. Saposhnikov [5, 6]. The use of a digital electronic computer made it possible for the authors to examine the problem with more general prerequisites. Specifically, they used the finite differences solution of one-dimensional and plane problems with various thermophysical characteristics of the concrete and the foundation and the relationship of the heat release not only to the time, but also to the temperature.

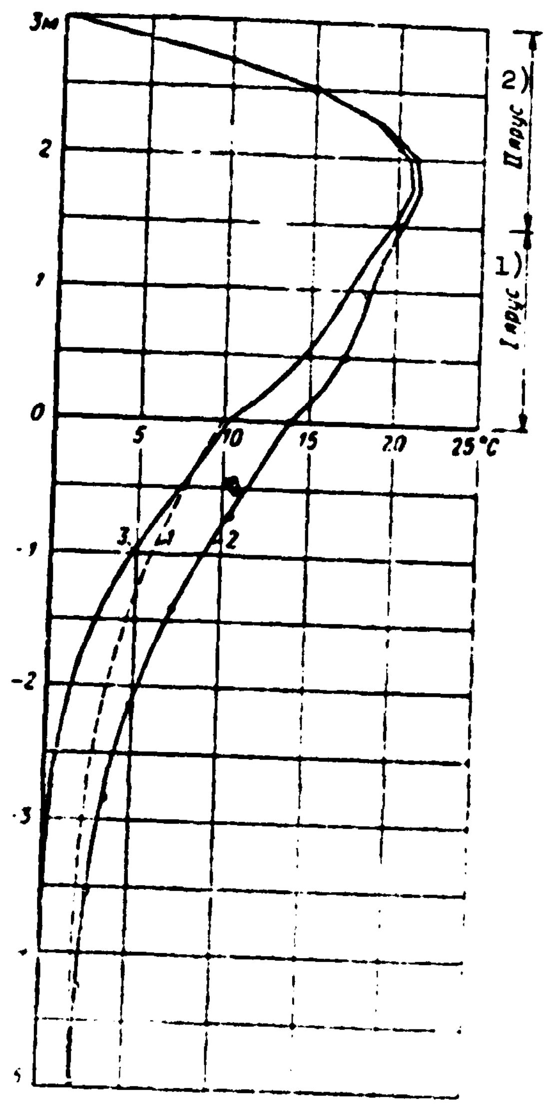

Figure 1. Graphs of Temperature Distribution in the Blocks and Foundation Depending on the Initial Heat Conditions of the Foundation

1--initial heating of the foundation; 2--72 hours after placing the block of the second tier (144 hours from the moment when the first block was placed) 3--same with no initial heating of the foundation.

Key:

1. 1st tier
2. 2d tier

In all the above-mentioned solutions, obtained by the method of nets, equations in finite differences with normal precision were used. Achieving the assigned precision with practical calculations often requires a substantial refining of the net. Practical considerations often require its considerable enlargement, and therefore a reduction in the degree of error of the method of nets becomes quite important. This can be efficiently achieved by using equations in finite differences with increased accuracy. This method was used in the work by the author [7] to solve the unidimensional problem of the heating of blocks placed consecutively outside the rock area. Presented below is a solution to this problem, taking into consideration the effect of the foundation with different thermophysical characteristics of the concrete and the foundation. In order to reduce the calculations, we shall restrict outselves to a discussion of the case in which the heat release is an arbitrary function of time $\theta(\tau)$, but does not depend on the temperature. We shall also assume that the blocks have an identical height, h, and time of curing τ_0. We will begin the accounting of the time τ at the beginning, from the moment of pouring each new tier of the block, and the upper face of this tier we will take as the beginning of the x axis with its direction downward along the vertical.

The thermal process, with a source of heat available, is described, as we know, by a nonhomogeneous differential equation. To bring it to a homogeneous one, we introduce for the blocks the transformed equation function, $t'_m(\chi, \tau)$, related to the unknown temperature function by the relationship

$$t_m(x, \tau) = t'_m(x, \tau) + \vartheta_\eta(\tau), \qquad (2)$$

where m is the number of the tier of the block, η is the number of the time interval τ_0 from the moment of pouring the given block.

Obviously, we have the following equality:

$$\vartheta_\eta(\tau) = \theta[(\eta - 1)\tau_0 + \tau] - \theta[(\eta - 1)\tau_0]. \qquad (3)$$

We will designate by λ and k the coefficients respectively of the heat and temperature conductivity of the concrete; λ_0 and k_0 the same coefficients of the rock of the foundation. Let the initial distributions of the temperatures be given: in the blocks --$t_H^{m}(\chi)$, in the foundation--$t_H^{(0)}(\chi)$ and the temperature of the upper face of the blocks $t_n^{(m)}(\tau)$. Then the problem for the transformed temperature function of the block of the 1st tier $t'_1(\chi, \tau)$ and the unknown temperature function of the foundation $t_0(\chi, \tau)$ may be mathematically represented in the following form:

$$\frac{\partial t'_1(x, \tau)}{\partial \tau} = k \frac{\partial^2 t'_1(x, \tau)}{\partial x^2}, \qquad (4)$$

$$< [illegible] 0 < \tau < \tau_0;$$

$$\frac{\partial t_0(x, \tau)}{\partial \tau} = k_0 \frac{\partial^2 t_0(x, \tau)}{\partial x^2}, \qquad (5)$$

$$x > h,\ 0 < \tau < \tau_0,$$

$$t'_1(x, 0) = t_{\text{н}}^{(1)}(x); \quad (6)$$

$$t_0(x, 0) = t_{\text{н}}^{(0)}(x); \quad (7)$$

$$t'_1(0, \tau) = t_{\text{п}}^{(1)}(\tau) - \theta_1(\tau); \quad (8)$$

$$t'_1(h, \tau) = \theta_1(\tau) = t_0(h, \tau); \quad (9)$$

$$\lambda \frac{\partial t'_1(h, \tau)}{\partial x} = \lambda_0 \frac{\partial t_0(h, \tau)}{\partial x}. \quad (10)$$

In the designation of the transformed temperature function t'_m, with the transition to relationships in finite differences, for convenience of recording, we omit the upper index and carry the lower index up, placing it in brackets. When using the four-point explicit net scheme, the equation in finite differences for the block of the m-tier may be represented in the form of the equality

$$t_{i,j}^{(m)} = \sigma t_{i-1,\, j-1}^{(m)} + (1 - 2\sigma)\, t_{i,\, j-1}^{(m)} + \sigma\, t_{i+1,\, j-1}^{(m)}, \quad (11)$$

where the first lower index with t indicates the number of the pitch along the x axis, and the second--the number of the pitch along the τ axis.

$$\sigma = \frac{k\Delta\tau}{(\Delta x)^2}, \quad (12)$$

$$\Delta x = \frac{h}{n} \quad (n - \text{целое}); \quad (13)$$

and at the same time the period of time τ_0 should be a multiple of the pitch $\Delta\tau$:

$$\Delta\tau = \frac{\tau_0}{\nu} \quad (\nu - \text{целое}). \quad (14)$$

Assuming $\sigma = 1/6$, from formula (11) we obtain the equation in finite differences of increased precision:

$$t_{i,\, j}^{(m)} = \frac{1}{6}\left(t_{i-1,\, j-1}^{(m)} + 4t_{i,\, j-1}^{(m)} + t_{i+1,\, j-1}^{(m)}\right); \quad (15$$

in this case, from formula (12) we have:

$$\Delta x = \sqrt{6k\Delta\tau}. \quad (16)$$

Retaining the equation (15) for the foundation (with the substitution of the index m for 0) and the value of the pitch in time $\Delta\tau$, the pitch along the χ axis is determined by the following formula:

$$\Delta x_0 = \sqrt{6k_0\Delta\tau} = \sqrt{\frac{k_0}{k}}\, \Delta x. \quad (17)$$

We record the conditions (6)-(8) in the finite differences in the following form:

$$t^{(1)}_{i,0} = t^{(1)}_{H,i}; \quad (18)$$

$$t^{(0)}_{i,0} = t^{(0)}_{H,i}; \quad (19)$$

$$t^{(1)}_{i,j} = t^{(1)}_{H} - \theta_{1,j}. \quad (20)$$

With respect to the conditions at the border of the two media (9) and (10), of them, (9) may be used directly. With respect to condition (10), we note the following: with the transition to the equations in finite differences, the even curve of temperature distribution is replaced by a broken one, with the salient points at the nodes of the net, reflecting the changes in the heat flow with certain jumps; condition (10) expresses the equality of the heat flows entering and leaving in the contact node, which is valid when $\Delta\chi \to 0$, but cannot be assumed with calculations for finite differences.

An analysis shows that the values of the temperatures at the contact of the block and the foundation should be expressed by the formulas:

$$t^{(1)}_{n,j} = \frac{t^{(1)}_{n-1,j-1} + 2t_{n,j-1} + \beta(2t^{0}_{n,j-1} + t^{0}_{n+1,j-1})}{3(1+\beta)} + \frac{1}{1+\beta}\theta_{1,j}; \quad (21)$$

$$t^{(1)}_{\tau,j} = t^{(0)}_{n,j} - \theta_{1,j}; \quad (22)$$

$$\beta = \frac{\lambda_0}{\lambda}\sqrt{\frac{k}{k_0}} = \sqrt{\frac{\lambda_0 C_0 \gamma_0}{\lambda C \gamma}}, \quad (23)$$

where C and γ is the coefficient of heat capacity and the volume weight for the concrete;

C_0 and γ_0 are the same values for the rock of the foundation.

It is easy to see that formula (22) represents the condition (9), recorded in finite differences, and formula (21) in the particular case when $\theta = 0$ and $\beta = 1$ are turned into a formula of the type (15).

From the moment when the block of the second tier is poured, the transformed temperature functions for the blocks will be connected with the unknown functions in accordance with relationship (2) by the formulas

$$t_2(x,\tau) = t'_2(x,\tau) + \theta_1(\tau); \quad (24)$$

$$t_1(x,\tau) = t'_1(x,\tau) + \theta_2(\tau). \quad (25)$$

The transformed temperatures at the contact between the blocks in the finite differences are expressed by the following formulas:

$$t^{(2)}_{n,j} = \frac{t^{(2)}_{n-1,j-1} + 2t^{(2)}_{n,j-1} + 2t^{(1)}_{n,j-1} + t^{(1)}_{n+1,j-1}}{6} - \frac{\theta_{1,j} - \theta_{2,j}}{2}; \qquad (26)$$

$$t^{(1)}_{n,j} = \frac{t^{(2)}_{n-1,j-1} + 2t^{(2)}_{n,j-1} + 2t^{(1)}_{n,j-1} + t^{(1)}_{n+1,j-1}}{6} + \frac{\theta_{1,j} - \theta_{2,j}}{2}. \qquad (27)$$

Formula (15) is used for the inner points of the blocks, and for the contact between the block of the first tier and the foundation, formulas (21) and (22) are retained, with the index n replaced by the index 2n.

Sample calculation. A block 1.5 m high with a uniform initial temperature t^{1}_{H} = 10°C is placed ont he foundation, the surface of which is heated to 20°C, and the temperature at the depth dies down to 12°C in accordance with the given law $t^{(0)}_{H}(x)$. The block is cured for the time, τ_0=72 hrs at a constant temperature for its upper surface, equal to $t^{(0)}_{H}$=10°C. The coefficients are assigned: k=0.0035 m^2/hr, k_0=2k, λ_0=2λ and the function of the adiabatic heating of the concrete according to the formula

$$\Theta(\tau) = \Theta_0 e^{-a\tau^{-\delta}}, \qquad (28)$$

where Θ_0=48.56°C, α=2.293, δ=0.313.

From formula (23) we find β=1.4142. We assume for the concrete block Δx=0.5 m and from formula (12) when $\sigma = \frac{1}{6}$, we find:

$$\Delta\tau = \frac{0{,}5^2}{6\cdot 0{,}0035} \approx 12 \text{ hr}$$

for the foundation from formula (17) we obtain Δx_0=0.7071 m.

The sequence of the calculation for the 1st and 2d tiers of blocks is shown in Table 1. For convenience of calculation, a conditional temperature scale is adopted with zero at the level of the initial temperature of the block, equal in our example to 10°C. First the column j=0 is filled in: for the points of the block of the 1st tier, in accordance with condition (18), zero is recorded (according to the conditional scale), and for the points of the foundation the initial temperatures are recorded, calculated from the given function t^{0}_{H} (x). On line 1 (i=0), according to formula (20), the values of the function $\Theta_1(\tau)$ are recorded, with the reciprocal sign, preliminarily calculated in a separate table for each pitch of Δτ. Then the columns are filled in successively from top to bottom: for the intermediate points (i=1, 2, 4, 5, 6, ...)--from formula (15), and for the contact points (i=3)--from formulas (21) and (22). After the filling in of the column for all the pitches i, the values of A and B of this column are calculated. These values are used to calculate the temperatures at the contact point of the next column. As the result of all these calculations, for the points of the foundation, we obtain the unknown temperatures, and for the points of the block--the values of the transformed temperature function t'_1. The transition to the unknown temperatures for the points of the block is made in the next column of Table 1, according to the formula (2) for τ_0=72 hours. Then the temperature is calculated in the concrete masonry and the foundation after the block of the 2d tier is placed, on the conditions $t_H^{(2)}=t^{(2)}=0$ (according to the conditional scale). Line 16 (i-0) and column j=0 for the block of the 2d tier is filled in just as for the block of the 1st tier, as the result of the identity of the initial and limit conditions for both blocks. For the points of the block of the 2d tier and the foundation in the column j=0 (lines 25-28 and 31-39) the initial temperatures for the points of the block of the 1st tier and the foundation are transferred, respectively, from the column of the latter and j=6. Lines 20-22 and 24 are also filled in preliminarily.

Entered as the latter in the column j=0 are the values A", A' and B', which are calculated from the formulas indicated respectively in lines 23, 29 and 30. The next columns of Table 1 are filled in consecutively from top to bottom, by calculating the temperatures in the intermediate points of the blocks and the foundation from formula (15) and at the contact points--from the formulas given in lines 19, 25, 28 and 31. In the last column the transition is filled in to the unknown temperatures in the blocks of both tiers with the aid of formulas (24) and (25) for the last time interval (j=6). This transition is not required for the points of the foundation, since for them the values of the unknown temperatures are obtained directly.

Figure 1 shows the distribution curves of the temperatures in the two tiers of blocks and in the foundation at the end of the period of curing the block of the 2d tier with τ_0=72 hours with the pitches of the net $\Delta\chi$=0.25 m and $\Delta\tau$=3 hours. Marked by circles are the results for curve 2 with the enlargement of the intervals of the net to $\Delta\chi$=0.5 and $\Delta\tau$=12 hours (according to the data from the last column).

The curves in Figure 2 show the temperature distribution in the same blocks with various thermophysical characteristics of the concrete and the rock of the foundation. The calculations for these graphs were made from the same net with pitches Δx=0.25 m and $\Delta\tau$=3 hours. Plotted with the same pitches of the net in Figure 3 were the temperature districution curves in the area near the rock of a concrete block 6 m high, constructed with blocks 1, 1.5, 2 and 3 m high. These curves express the temperature distribution at the end of the curing of the blocks of the last tier.

From the results of the calculations made, "envelope" curves may be plotted, for each variant, of the greatest temperatures attained at each pitch for this period of existence of the block. The ordinates of these "envelopes" for the areas of a block 1 m high, adjacent to the foundation, for the period studied by us (288 hours) are shown in Table 2.

Table 1

№ п/п	Высота точки от поверхности основания, м	i	j	0	1	2	3	4	5	6	$t_i = t_{i,j} + \theta_i$, $j = 6$
			$j\Delta\tau$, ч	0	12	24	36	48	60	72	
			Определение температур в блоке 1-го яруса и в основании								
1	1,50	0	$t_0^{(1)} = -\theta_0$	0	−16,94	−20,80	−23,00	−24,54	−25,69	−26,62	0
2	1,00	1	$t_1^{(1)}$	0	0	−2,82	−5,48	−7,85	−9,96	−11,84	14,78
3	0,50	2	$t_2^{(1)}$	0	0	−0,77	−2,19	−3,84	−5,53	−7,17	19,45
4	0,00	3	$t_{3,j}^{(1)} = t_{3,j}^{(0)} - \theta_{1,j}$	0	−4,63	−7,25	−8,79	−9,96	−10,92	−11,81	14,81
5			$A = \frac{1}{3}(t_2^{(1)} + 2t_3^{(1)})$	0	−3,09	−5,09	−6,59	−7,91	−9,12	—	
6			$B = \frac{\beta}{3}(2t_3^{(0)} + t_4^{(0)})$	12,77	15,00	16,40	17,28	17,88	18,25	—	
7	0,00	3	$t_{3,j}^{(0)} = \frac{(A+B)_{j-1} + \theta_{1,j}}{1+\beta}$	10,00	12,31	13,55	14,21	14,59	14,77	14,81	
8	−0,71	4	$t_4^{(0)}$	7,08	7,20	7,68	8,23	8,74	9,18	9,54	
9	−1,41	5	$t_5^{(0)}$	4,85	4,98	5,10	5,28	5,51	5,77	6,03	
10	−2,12	6	$t_6^{(0)}$	3,38	3,49	3,60	3,70	3,81	3,94	4,08	
11	−2,83	7	$t_7^{(0)}$	2,58	2,65	2,72	2,79	2,86	2,94	3,02	
12	−3,54	8	$t_8^{(0)}$	2,20	2,24	2,28	2,32	2,36	2,40	2,45	
13	−4,24	9	$t_9^{(0)}$	2,06	2,07	2,09	2,11	2,13	2,15	2,18	
14	−4,95	10	$t_{10}^{(0)}$	2,00	2,01	2,02	2,03	2,04	2,05	2,06	
15	−5,66	11	$t_{11}^{(0)}$	2,00	2,00	2,00	2,00	2,00	2,01	2,02	

Table 1 (Continued)

(4) Определение температур в двух ярусах блоков и в основании

[illegible]	[illegible]	$t_0^{(-)} - \theta_1$	0	−16,94	−20,80	−23,00	[illegible]	[illegible]	[illegible]	0
[illegible]	[illegible]	$t_1^{(-)}$	0	0	−2,82	−5,50	−7,85	−9,87	−11,61	15,01
[illegible]	[illegible]	$t_2^{(2)}$	0	0	−0,94	−2,08	−3,28	−4,49	5,66	[illegible]
[illegible]	[illegible]	$t_{3,j}^{(2)} = $ [illegible]	0	−5,63	−5,88	−5,88	−5,96	6,15	−6,46	[illegible]
		$(\nu+j)\Delta\tau$	72	84	96	108	1?0	132	144	
		$\theta_{\nu+j}$	26,62	27,?	28,0?	28,59	29,0?	29,53	29,92	
		θ_*	0	0,76	1,41	1,97	2,47	2,9?	3,39	
[illegible]	[illegible]	[illegible] $(t_2^{(\cdot)} + 2t^{(\cdot)} + 2t^{(1)} + t_4^{(\cdot)})$	2,46	[illegible]	4,?4	[illegible]	5,24	[illegible]	[illegible]	$t_c - t_1 + \theta_*$
		[illegible]	∞	[illegible]	[illegible]	10,?	11,01	11,?9	11,6?	[illegible]
		[illegible]	0	1?	[illegible]	17,16	16,12	16,63	[illegible]	[illegible]
	[illegible]	$t^{(1)}$	14,78	[illegible]	[illegible]	[illegible]	13,32	14,?4	[illegible]	[illegible]
		[illegible]	15,45	17,6?	[illegible]	13,41	11,?	11,14	[illegible]	17,?
	[illegible]	[illegible]	11,81	[illegible]	11,1?	12,3?	11,7?	11,?	[illegible]	[illegible]
		[illegible]	16,?6	1?	11,7	[illegible]	1?	1?		
		[illegible]	18,45	18,?	18,?	18	18,?	[illegible]		

Table 1 (continued)

(1)	(2)	i	j	0	1	2	3	4	5	6	[illegible]
			$j\Delta\tau$, h	0	12	24	36	48	60	72	
31	0,00	6	$t_{6j}^{(0)} = \frac{(A'+B')_{j-1}+\theta_{6,j}}{1+\beta}$	14,81	14,74	14,59	14,39	14,20	14,04	13,91	
32	−0,71	7	$t_7^{(0)}$	9,54	9,83	10,06	10,23	10,35	10,43	10,49	
33	−1,41	8	$t_8^{(0)}$	6,03	6,29	6,54	6,77	6,98	7,16	7,32	
34	−2,12	9	$t_9^{(0)}$	4,08	4,23	4,38	4,54	4,70	4,86	5,01	
35	−2,83	10	$t_{10}^{(0)}$	3,02	3,10	3,19	3,28	3,38	3,48	3,58	
36	−3,54	11	$t_{11}^{(0)}$	2,45	2,50	2,55	2,60	2,66	2,72	2,78	
37	−4,24	12	$t_{12}^{(0)}$	2,18	2,20	2,23	2,26	2,29	2,32	2,36	
38	−4,95	13	$t_{13}^{(0)}$	2,06	2,07	2,08	2,10	2,12	2,14	2,16	
39	−5,66	14	$t_{14}^{(0)}$	2,02	2,02	2,02	2,03	2,04	2,05	2,06	
40	−6,36	15	$t_{15}^{(0)}$	2,00	2,00	2,00	2,00	2,00	2,01	2,02	

Key:
1. Nos in order
2. Height of the point from the surface of the foundation, in m
3. Determination of the temperatures in the block of the 1st tier and in the foundation
4. Determination of the temperatures in two tiers of blocks and in the foundation

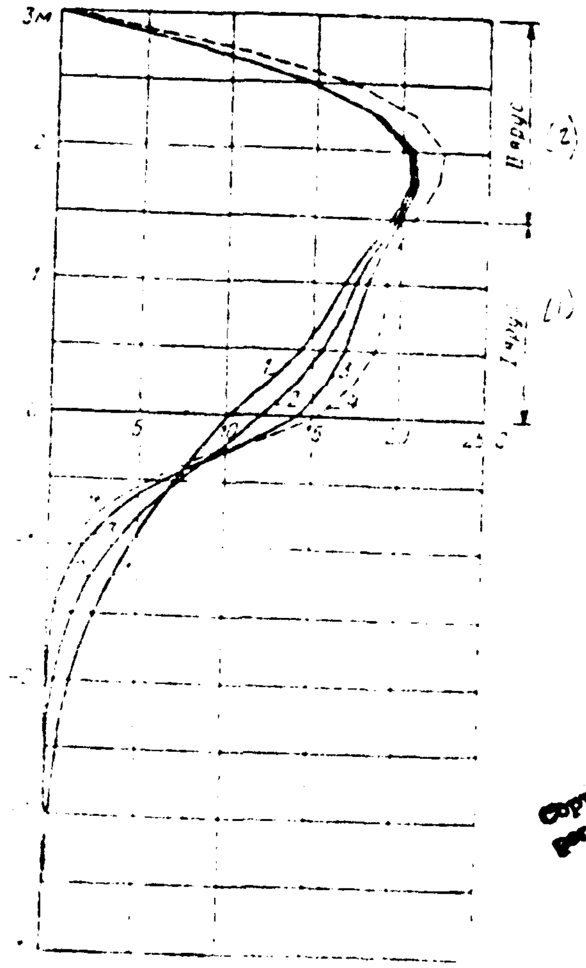

Figure 2. Graphs of Temperature Distribution Depending on the Thermo-Physical Characteristics of the Concrete and the Foundation

For values k=0.0035 m^2/hr; 1--when β=1.4142; 2--when β=1; 3--when β=0.7071; 4--for k=0.0026 m^2/hr and β=0.7071

The accuracy of the calculations made and the choice of the optimal pitches of the net are of practical interest. The evaluation of the accuracy of the results according to Runge's principle [8, 9], obtained for the above graphs with the pitches of the net $\Delta\chi$=0.25 m and $\Delta\tau$= 3 hours shows that the degree of error everywhere remains less than 0.1°C, i.e., has the order of a round-off error, usually assumed with thermal calculations for structures. Therefore, the results with these pitches of the net can practically be regarded as fully precise. When the pitches of the net are enlarged to $\Delta\chi$=0.5 m and $\Delta\tau$=12 hours, the greatest deviation of the result for the curves given in

Figure 1 is 0.2°C (at the contact between the blocks), and the average deviation remains less than 0.1°C. Here the number of nodes of the net resulting from its enlargement is reduced eight times and the amount of computation work decreases accordingly.

Table 2

... точки от ...ания, м	Наибольшие достигнутые ... при бетонировании блоками вы...			
	[illegible] м	[illegible] м	2,[illegible] м	[illegible]
[illegible]	11,5	12,7	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	16,8	[illegible]	[illegible]	[illegible]
[illegible]	18,1	[illegible]	[illegible]	[illegible]

Key:
1. Height of point from the foundation, in m
2. Highest temperatures attained (°C) in concreting with blocks of a height of

In practice it is often sufficient to make the temperature calculations of the concrete blocks with an accuracy up to 0.5-1°C. With the suggested method this accuracy may be ensured even with a more substantial enlargement of the net up to $\Delta\chi$=1 m and $\Delta\tau$=48 hours.

We note, however, that to avoid greater errors, should not be accepted over 1/3 the height of the block in the initial period of heating the masonry. In Figure 3 the nodal temperatures for the fourth variant of constructing the block (two tiers of blocks each 3 m high), obtained with a calculation with pitches $\Delta\chi$=1 m and $\Delta\tau$=48 hours, are marked by circles. The intermediate points between them every 0.25 m, connected by a dotted line, are obtained by interpolation at intermediate intervals of by Bessel's formula, which is most convenient for the existing inflections of the curves, and in the uppermost interval--by Newton's formula: it is impossible to use Bessel's formula here. For both formulas we were limited to differences of the second order. It can be seen from Figure 3 that the precise curve 4, in practical calculations may be completely replaced by a dotted one, and its construction by the above combined method takes only a few hours of work by one calculator. With this substantial reduction in the computation work, there is no longer any need to connect them with the use of a digital electronic computer. The greatest deviation of the dotted curve from the precise one here is less than 0.6°C (at a height of 5 m from the foundation of the block), and the average deviation is less than 0.1°C. To achieve the same order of precision on the basis of equations in finite differences of normal precision would require that pitches be taken at least no larger than $\Delta\chi$=0.25 m, and $\Delta\tau$=9 hours and the number of nodes of the net would increase over 20 times.

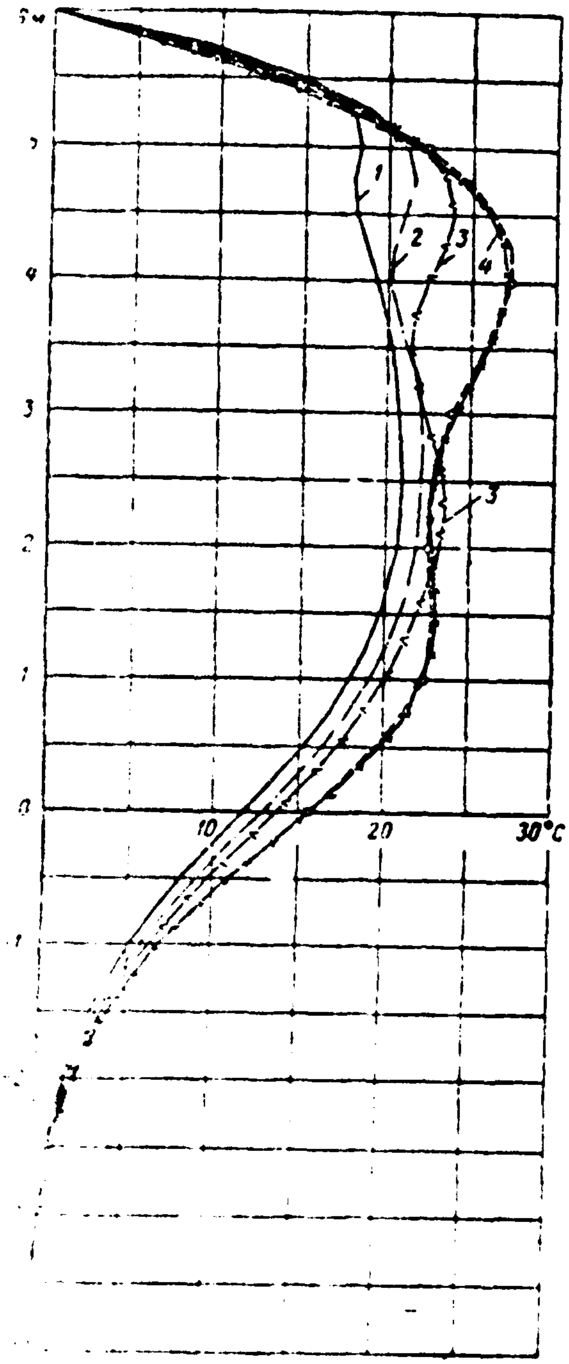

Figure 3. Graphs of Temperature Distribution in Concrete Block 6 m High 12 Days After the Beginning of the Concreting, Depending on the Height of the Blocks h With an Identical Rate of Building the Structure Δh=0.5 m per Day
For values k=k =0.0035 m^2/hr and β=1; 1--h=1 m; 2--h=1.5 m; 3--h=2 m; 4--h=3 m

The facts presented above indicate the effectiveness of the method suggested for determining the temperatures in dams under construction.

BIBLIOGRAPHY

1. R. Glover, "Calculation of Temperature Distribution in a Succession of [illegible] Due to Release of Chemical Heat," JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, Vol 9, No 2, 1937.

2. R. Garison, and A. Simple. "Method for the Computation of Temperatures in Concrete Structures," JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, Vol 9, No 2, 1937.

3. I. Babushka, and L. Meyzlik. "Calculation and Measurement of Temperature Stresses in Gravity Dams," "Report No 59 at the 4th International Congress on Large Dams," New York, 1958.

4. V.M. Shteynberg; I.Ye. Prokopovich; and I.V. Gol'farb, "Practical Method of Studying the Temperature Field in the Embankment of Monolithic Concrete Hydraulic Engineering Structures," "Sbornik trudov Odesskogo gidrotekhnicheskogo instituta" [Collection of Works of the Odessa Hydraulic Engineering Institute], No 5, Odesskoye Obl. Izdatel'stvo, 1953.