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COOLING MODE RESEARCH FOR ITEMS MADE OF VIBROEXTRUDED CONCRETE

The analysis of features of the tense state of hardening under pressure concrete is conducted in the process of cooling taking into account the arising up here gradients of temperature and to pressure, and also through the difference of properties of deformations of component components, the most complete are generalized equalizations of criteria of intensity of decline of temperatures and pressure at cooling of wares from of vibration and pressing concrete.

Keywords: *vibration and pressing concrete, tense the state, gradient of temperature, equalization of intensity of decline of temperatures*

Intensification of production, ensuring high turnover of press molds during the manufacturing of items from vibrocompressed concrete is possible in case of ensuring the minimum duration of heat processing cycle which includes the periods of heating and cooling. The items from vibrocompressed concrete usually harden in air fight forms, partially or totally eliminating evaporation of moisture from the surface and allows for slower cooling of concrete.

Let's consider the peculiarities of temperature field distribution, pressure and specific humidity on the cut of the plate from vibrocompressed concrete (VCC) during the one sided and double sided cooling. The state, characterized by the temperature Δt, humidity ΔU and pressure ΔP will be demonstrated for the unlimited plate in the middle of the cooling period τ_{III}. Distributing of the temperature fields, humidity and pressure which cause the corresponding streams of liquid phase in concrete q_{mt},, q_{mu}, q_{mp}, which make the mass of internal moisture move to the surface of the item (fig.1).

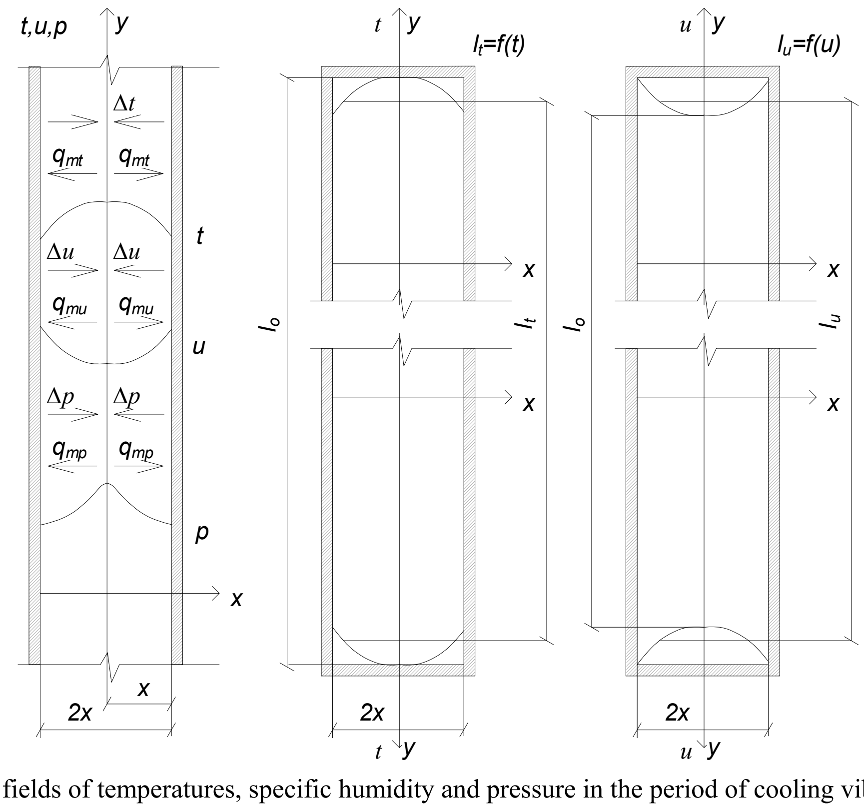

Fig.1 Chart of the fields of temperatures, specific humidity and pressure in the period of cooling vibration extruded concrete.

As the temperature of the press mold and concrete decreases, the plate tends to shorten on the surface by the value l_{tq}, and simultaneously, influenced by q_{mt}, stipulated for by the temperature gradient, the humidity of the surface layer increases, which causes the increase of linear sizes of the plate by the valueless. The resulting deformation of plate can be expressed as $l_{об}= l_{tq}- l_{uq.}$ The surface layers of concrete of the item undergo the maximum tension from the temperature drop Δt and humidity ΔU, as well as drop of pressure, the influence of which increases, together with the increase of cooling speed. The temperature deformations of the mold metal considerably exceed the deformations of the concrete, as the cooling of items is much slower then that of the riggings. Temperature drop between the hot concrete and the press mold, which cools very quickly, can reach 45...55°C (fig.2).

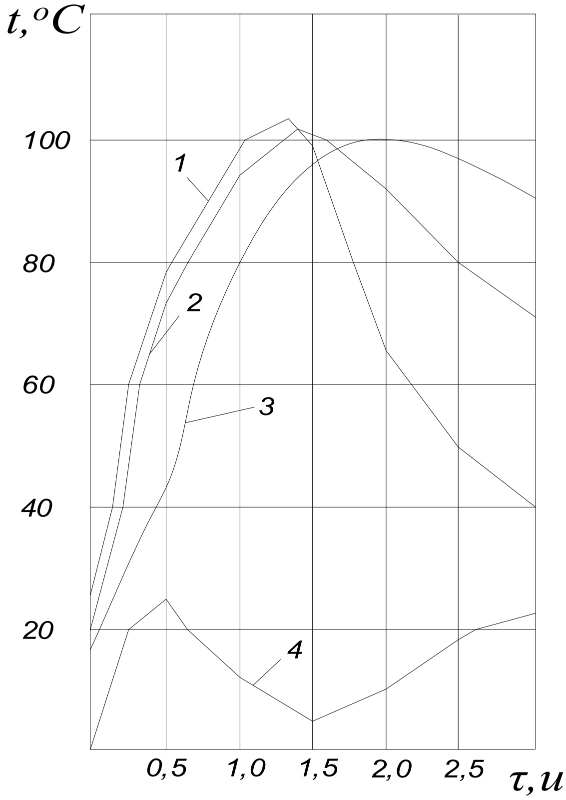

Fig. 2 Distributing of temperatures in the period of cooling of reinforced concrete vibration extruded pipe after two sided heat processing in metallic hubcaps.
1, 2, 3 is a temperature of external form, concrete in protective and under to the armature layers of good accordingly, 4 – temperature of internal form.

This causes the tangent fusions in the place of contact of concrete and metal, which compresses the item in the process of cooling. If the form has at least one plate not tightly connected with concrete, then from its side the stretching tension can appear in the result of plate bending from the influence of tangent tension from the hard form (fig.3).

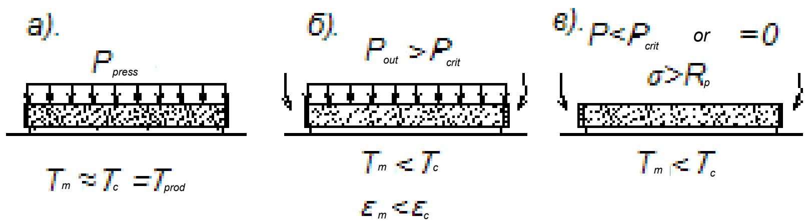

Fig. 3 Diagrams of interaction of item from vibrocompressed concrete with the mold
a – in the period of the isothermal warming up; b – cooling under pressure; c – the same with absence of external influencing.

Let us consider the influence of succession of pressure release on the tensioned state of the flat plate. Let's assume that at the beginning of cooling process the pressure of movement will decrease up to the atmospheric one within the short time interval (0,10...0,15 Hrs.). If causes the strengthening efforts in the upper arrear, and if their values exceed the boundary allowed breaking tensions *Rp*, the micro cracks will appear on the surface of the concrete plate.

In the case of cooling under the conditions of preserving the overall pressing, the absolute value of which is sufficient for creation of counter force, necessary to compensate for influence of bending forces, the crack formation will be absent. Critical pressure value of thermal loading P_{pres}^{crit} is the function of temperature drop Δt, height of item h, concrete strengthening as for deformation *Rp*, thermal physical peculiarities of the concrete and the mold, as well as its construction:

$$P_{pres}^{crit} = \int (\Delta t_{f.c.}, R_p^c, h, \alpha_f, \alpha_c ...).$$

On the other side, in the process of concrete cooling heated under the pressure up to the temperature over 100°C, the sharp pressure decrease causes the phenomenon of „boiling” of the unbound liquids in the result of its overheating, which, as is known, favors the creation of the directed porosity and worsening of concrete structure. The condition, under which the overheating of the liquid phase is impossible, that is, the „boiling”, is excluded, can be presented in the kind of:

$$\bar{t}_c^{\,i} \le 100\sqrt[4]{P_{pres}^t} - \Delta t_{st}; \quad (1)$$

$$P_{pres}^t \le \left(\frac{\bar{t}_c^{\,i}}{100} \right) + \Delta P_{st} \quad (2)$$

where P_{pres}^t - external pressure on the concrete surface during its cooling at any time, $\times 10^{-1}$ of MPa; $\bar{t}_c^{\,i}$ - average temperature of concrete on the item cut, °C; Δt_{st} - safe temperature decrease below the points of satiation, caused by temperature drops in the item; ΔP_{sp} - increase of pressure over the satiation pressure caused by the non equal pressure and temperature distribution.

The values Δt_{st} and ΔP_{st} account for gradients of temperature and pressure on the cut and serve as the additional factor which excludes the possible local steam formation in the item points with maximum temperature. The necessary value of additional pressure, when the temperature gradient on the cut does not exceed 10°C, depending on the maximum temperature of the concrete heating (from 100 up to 200°C) change within 0,04...0,428 MPa (tabl.1).

As is commonly asserted, there is the internal field of tension in the concrete, caused by compression, heterogeneity of moisture, temperature and pressure [1]. Following the data of the meters, placed in the concrete after hardening, there had been fixed the compressed tensions of the value 2,0...3,0 MPa within three days under normal conditions. During the hardening of the concrete in the process of thermal processing in the environment with 100% moisture, there hadn't been determined the availability of the compressive tension on the filler-meter [2]. In the compressed concretes, which harden under the pressure, there should be the compressed filler of tension theoretical value of which reaches 3,0...4,0 MPa (depending on the filler kind, its deformation peculiarities and pressure of movement) [3].

However, the results of experimental researches, did not confirm the existence of the latest neither during the shrinkage, nor during the influence of external pressing pressure with the value of 2,0 MPa and more after hardening within 18...21 days [4]. As is stated in [4], this phenomenon can be explained by the contraction of the cement stone during its hardening, which removes the external pressure on the filler up to the end of the process of concrete structure formation.

Table 1

Dependence of the movement pressure value on average concrete temperature and temperature drop in the item

Average temperature of concrete T_c,°C	100	110	120	130	140	150	160	170	180	190	200
Necessary size of pressure $P_{pres}\times10^{-1}$ MPa	1,42	2,02	2,78	3,77	5,00	6,48	8,3	10,46	13,02	16,03	19,83
Pressure of saturated steam $P_s\times10^{-1}$ MPa	1,01	1,43	1,98	2,70	3,61	4,76	6,18	7,92	10,03	12,55	15,55
Value of additional pressure fused by drop of temperature $(T_c - T)$=10°C	0,41	0,55	0,80	1,07	1,39	1,72	2,12	2,54	3,00	3,48	4,28

Let's now consider the physical phenomena, appearing during the cooling of an item from the vibropressed concrete. The decrease of movement pressure by value ΔP for times Δt causes the decrease of steam density, which, in turn, is accompanied by appearance of the additional volume of situated steam, $\Delta G=\Pi_{fr}\partial_1''/\text{-}\partial_\tau$. If causes the excessive pressures in the concrete layer pores equaling $\partial P\Delta x/\partial x$, which will toy to tear this plate layer of the surface, which will result in appearance of stretching tensions from the side of the free surface. To determine the value of the efforts caused by excessive pressure, the dependence is recommended to be used [2]:

$$d\tau_p = \frac{\overline{\Pi}_{fr}\, dP\Delta x}{100dx}, \tag{3}$$

where $\overline{\Pi}_{fr}$ - is a volume of free pores in a concrete; Δx - is a thickness of layer of plate under consideration; $\frac{dP}{dx}$ - is a gradient of pressure on the thickness of plate.

The allowed drop of pressure on the plate cut can be determined under the condition when the value of the internal tensions on any cutting place will be lower than the strength limit of current on stretching $R_p^{(x)}$:

$$\Delta P_{ac} = \frac{100R_p^{(x)}K_{ac}^{-1}}{\Pi_{fr}}. \tag{4}$$

If to substitute the values of all variables in the expression (4), the value of allowed pressure drops, caused by the influence of additional steam formation for vibrocompressed concrete with the strength against pressure (after thermal processing) 20,0...40,0 MPa, will make up 1,02...2,0 MPa.

As is known, there appear the substantial temperature drops on the cut in the process of cooling the concrete items. The allowed value of tensions in the concrete, caused temperatures gradient can be determined following the analytical dependence:

$$\sigma_{x(t)} = \frac{\alpha(\bar{t} - t_{(x,\tau)})\overline{E}}{1-\mu} \le R_p^{(x)}K_з^{-1}, \tag{5}$$

where α - is a factor of temperature expansion of concrete; $\bar{t}$ - is a average temperature of concrete on a cut; $t_{(x,\tau)}$ - is a temperature in a layer in the moment of time of τ; $\overline{E}$ - is a average value of the module of deformation for cut; μ - is a factor of Puassona of concrete; K_3 - is a factor of supply.

Inserting the initial data for a vibrohydrocompressed concrete allows to determine the value of the allowed temperature drop of the cut of the item:

$$\Delta t_{max} = \bar{t} - t_{(x,\tau)} = \frac{R_p(1-\mu)}{E\alpha} = \frac{1,5\cdot10^{-4}(1-0,2)}{1\cdot10^{-2}} \approx 12^o C, \tag{6}$$

where R_p/E relation accepted as equal to the maximum tensility of vibrohydrocompressed concrete, which is within 1,5•10^{-4}; μ – value of the factor of Puasson is set within 0,2.

Proceeding from such condition allows to calculate the allowed pressure drop on the item cut, which in this case will not exceed 0,5•10^{-1} MPa. And the temperature drop on the cut causes the tension on the plate surface, and pressure drop – in the perpendicular plane on the item thickness.

Tensions in VCC stipulated for by the gradient of humidity, on the item cut may be determined by the formula:

$$\sigma_{x(u)} = \varepsilon_{x(u)} E = \frac{\beta_y (U_x - \overline{U})}{1-\mu} E \le R_p^{(x)} K_з^{-1}, \tag{7}$$

where β_y - is a factor of linear pressing of concrete which equals approximately β_y=3•10^{-1} $\frac{mm/mm}{g/g}$; $U_x, \overline{U}$ - is the concrete humidity in the layer x and average on a cut.

The possible drop of specific humidity on a cut must not exceed value ΔU_{max}:

$$\Delta U_{max} = \frac{(1-\mu)R_p^{(x)}}{E\beta_y} = \frac{1{,}5\cdot 10^{-4}(1-0{,}2)}{3\cdot 10^{-2}} = 0{,}4\cdot 10^{-2}\ \frac{g/g}{mm/mm}. \tag{8}$$

The analysis of the peculiarities of the tensioned state of the concrete, which hardens under pressure during cooling, considering the appeared temperature gradients, content of humidity and pressure, as well as the difference in deformative peculiarities of the components, allowed to get the most generalized criteria equations of intensivity of decrease in temperatures and pressures during the cooling of items from vibrocompressed concrete:

$$R_p^{(x)} \ge K_з \left\{ \frac{П_{fr}}{100} \Delta P_{(x,\Delta)} + \frac{E}{1-\mu}\left[\alpha(\bar{t} - t_{(x,\tau)} + \beta_y (U_x - \overline{U})\ \right] + \sigma_p^{pac} - \right\}, \tag{9}$$

$$t_c^{max} \le 100\sqrt[4]{P_{max}^{t}} - \Delta t_з^{t_{max}}. \tag{10}$$

Thus, solving the optimization fasts for the cooling mode of vibrocompressed concrete according to equations (9), (10) requires to consider the condition, that the total sum of internal own tensions in any cut of the item on drop of pressure, temperature, humidity and decrease of pressure during pressing-out, multiplied by the supply factor, should not exceed the drop of limit of concrete strength on stretching, and maximum temperature lower than the temperature of satiating, which answers the final pressure of pressing out and decreased by the value of temperature drop on the item cut.

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