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EXCHANGE OF HEAT IN THE PROCESS OF HMA COMPACTION

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Abstract. The temperature of asphalt mix during its laying out is not homogeneous. Apart from the aspect of the mass cooling during its transportation, the losses of heat are a result of climatic and weather conditions (the temperature and air humidity, wind, rainfall, etc.) the operation and manner of rollers compaction (their type, frequency of passes, etc.) water (technological and that contained in lower layers of the structure) and the location of the profile. Based on the rights, which govern the processes of heat exchange, one may anticipate the distribution of the temperature in a layer. This facilitates a proper planning of the process of compaction and getting required densities.

Keywords: hot mix asphalt (HMA), heat exchange, convection, radiation, conducting, compaction.

1. Introduction

Shaping the physical and strength properties of asphalt mix (AM) in the hot technology, takes place while compacting (Petkevičius *et al.* 2009). For this process to be effective, it shall take place in correct temperatures of hot mix asphalt (HMA) laying out. The scope of temperatures corresponding thereto depends upon the viscosity of the bitumen (2–20 Pa×s). The uniform viscosity of bitumen in the layer would create in this situation ideal conditions for the above-described process. Unfortunately, the hot layer in the areas of direct contact with the elements which collect the heat (edges, the lower and upper surface) gets colder much quicker, which complicates compaction and creates conditions for irregularities to occur.

The process of *in situ* (on the road) compaction has two stages. The initial compaction is ensured to the mixes by spreaders and more exactly by their spreading planks connected to a system of rams. Rams, which work in an oscillatory or vertical way with a defined amplitude and frequency (depending upon the thickness of the layers and type of AM), facilitate the flow of the material under the bottom board of the plank. The weight of the plank and the potential to have vibrating operation shall ensure getting a relevant level of compaction. Boards (tables) of spreading machines are equipped with a heating system, which allows to maintain (and even raise) the HMA temperature, in particular, in the layer close to the surface. It is this layer, which gets colder in the first sequence, in particular, at unfavourable conditions of laying out (for instance a strong wind). Thus, the system of heating improves the efficiency of table operations and surface uniformity of the mix. This also prevents the mass from gluing to the bottom surface of the table while shifting. The maintenance of the temperature of the mineral AM being laid out at a permanent level and the steady operation of the spreading machine, make it possible to get rather homogeneous (initial) compaction in the layer section.

The final mix compaction is shaped by rollers. If while operating the spreading machine, the climatic and weather conditions do not play such a significant role in shaping the mix structure, then in the further stage their importance grows (in some cases it is decisive). The specificity of the operation of rollers shall be adjusted thereto, evidently linked to their number and type and the thickness and width, as well as, the speed of the spreader's operation. The knowledge related to the impact of the individual factors on the velocity with which HMA is cooled allows defining the period of its effective compaction, which, in turn, shall help to obtain the required density of the mass and uniformity of its surface.

2. The flow of heat in the layer of HMA

Laying out asphalt mixes in the hot technology is accompanied by a process of heat exchange. In the HMA layer itself, there is a flow of an indeterminate condition. This means that the temperature in each point of the layer is different. At the same time, it changes in time, adopting lower and lower values, and finally trying to equalize it with the ambient temperature. The dynamics in the temperature changes is the result both of the heat conductivity

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of the layer itself (defined by the heat conductivity ratio λ) as well as of the ability to collect the heat by the elements, which are in the direct contact with HMA. The collection of heat may take place on the principle of conducting, radiation, and convection (this phenomena may take place separately or at the same time, for instance, radiation together with convection).

The HMA layer is understood as a system limited by two planes parallel to each other. The layer is characterised by a permanent thickness and this dimension is much lower than the two others, i. e. the width and length. The physical properties of the body (for instance density, volumetric density, heat conductivity, proper heat, the contents of void, etc.) at any point of the layer in the macroscopic understanding are permanent and homogeneous. This is a certain simplification. In the real conditions, some of the above-mentioned parameters change while being compacted, grow (volumetric density, heat conductivity) or they are reduced (the contents of free space). The adoption of final values to calculations (after the compaction of the layer) is the most disadvantageous case for the discussed issue. This means that the flow of heat in HMA is largest and with high possibilities of its collection by the environment and the speed of cooling, it aims for the max. The issue of the heat flow in the layer may be also referred to the case of finished dimensions (the width and length) but isolated lateral surfaces. This has is that the heat exchange in both cases takes place practically through horizontal surfaces.

The phenomenon of heat conducting in the indeterminate condition is also described by Fourier's differential Eq (1):

$$\frac{\partial Y}{\partial \tau} = \frac{\lambda}{c \times \rho_p} \frac{\partial^2 Y}{\partial x^2}, \tag{1}$$

where $Y = \dfrac{T - T_{oś}}{T_p - T_{oś}}$, T – temperature in the layer at τ moment and at x distance from the plane, lying in the layer axis, K; T_p – initial temperature of the layer in time $\tau = 0$, K; $T_{oś}$ – temperature of the medium where the body is, K; τ – time from the beginning of the process of heat exchange, s; λ – ratio of heat conducting of HMA layer, W/(m×K); c – asphalt specific heat, J/(kg×K); ρ_p – volumetric density of layer HMA, kg/m^3; x – distance of the considered point in the plane, lying in the axis of the layer, m.

The classical method for the solution of the Eq (1) is the method of variables separation, consisting in looking for the solution in the form of product of two functions: the time and space. Finally, for the condition of the layer cooling (with the defined border line conditions) the Eq (2) is obtained (Hobler 1984; Wiśniewski 1988), which allows to define the temperature at any place based on a number of similarity of Biot (*Bi*) and Fourier (*Fo*). *Fo* number defines the indeterminate character of the process of heat flow, and *Bi* is a characteristic nondimensional parameter, characterising the relation between the conducting resistance in the layer and the resistance of heat penetration to (or from) the environment.

$$T_{(x)} = T_{oś} + \left[\left(\sum_{n=1}^{n=\infty} e^{-\delta_n^2 Fo} \frac{2 \sin\delta_n}{\delta_n + \sin\delta_n \cos\delta_n} \cos\delta_n \frac{x}{s_m} \right) \times (T_p - T_{oś}) \right], \tag{2}$$

$$Fo = \frac{\lambda \times \tau}{\rho_p \times c \times s_m^2}, \tag{3}$$

$$Bi = \frac{\alpha \times s_m}{\lambda}, \tag{4}$$

where T, T_p, $T_{oś}$, λ, τ, ρ_p, c, x – as above; δ_n – values of the points of the intersection of functions $y_1 = ctg\delta$ and $y_2 = \dfrac{\delta}{Bi}$; α – ratio of heat penetration to the environment, W/(m^2×K); s_m – distance perpendicular to the surface of the body from the plane lying in the body's axis, m.

The series described in the Eq (2) quickly converges so that to obtain a sufficiently precise result four first words are sufficient.

The manners of quantitative description of the phenomenon of heat exchange, which accompanies laying out HMA into the pavement, which have appeared up to now in the literature (Chadbourn *et al.* 1996; Timm *et al.* 2001) have been based on a simplified model. It was the result of an assumption that the value of thermal conductivity coefficient of a given body $\lambda = \infty$ (or is very high), which leads to omitting temperature differences in the material itself and means that the temperature at the board at any place of the section is the same. For such assumptions, the average board temperature, depending upon the time and climatic and weather conditions may be determined from the Eq (5):

$$T = T_{oś} + e^{-BiFo}(T_p - T_{oś}). \tag{5}$$

The Eq (5) is right in case when it is possible to omit the drop of the temperature in the board itself (λ very high) and the averaged value of the temperature in the layer is sufficient. However, when λ is relatively low and it causes strong resistance of heat conductivity in the board and with the additional high collection of heat by the environment (expressed by the ratio α of heat penetration) the model discussed may give insufficient approximation.

3. Collection of heat by the environment

The heat is rendered from HMA by its surface and collected by external factors, which are in contact with it. The spread of the temperature in the layer depends upon the value of its conductivity coefficient and replacement coefficient of heat penetration to the environment and precisely the relation between them. The heat exchange between the hot layer during its compaction and the environment surrounding it takes place through conducting, convection and radiation.

The phenomenon of conduction takes place in contact with solid bodies, for instance, with the lower structure layer, elements of compacting machines, etc. It is related to the transfer of energy between the particles inside the medium or from one medium to another at their direct contact. The individual particles of the system may not show larger changes in the location (Wiśniewski 1988). The parameter which describes the ability of solid bodies to collect the heat is the replacement coefficient of heat penetration α_z (6).

$$\alpha_z = \frac{\lambda_z}{h_z}, \tag{6}$$

where λ_z – the thermal conduction coefficient of the material, W/(m×K); h_z – the thickness of the layer which collects the heat, m.

The value of the coefficient of thermal conduction is determined in defined conditions of temperature and humidity, most frequently for the dry material (Mrawira, Luca 2008; Xu, Solaimanian 2010; Wang *et al.* 2010). Each quantity of water in such material shall have an impact on the ability to collect the heat, especially because of its great specific heat, equal to 4.182 kJ/(kg×K). This factor shall be taken into account, in particular, close to unbounded layers of a large content of fine fractions (for instance, graded aggregate) or bonded with a large amount of void which in the periods after rainfall or snowfall can contain significant amounts of water. The water which surrounds individual grains of the aggregate and fills up the pores in the material causes a growth, both in the thermal conductivity and the specific heat of the layer, and by the same, it distinctly increases its capacity to collect the heat from the laid out HMA. This is particularly important for the layer close to the surface, which is in direct contact with the mix being spread out. In this area, a very negative phenomenon may occur (because of quick cooling), and namely boiling and steaming. These processes related to the heat exchange with the participation of water while laying out HMA have been described in (Mieczkowski 2006).

The heat from HMA is taken over by the liquid (the air, water) in the process of penetration (convection connected with he conduction in the thin layer close to the surface) and radiation. This has an effect of lowering the layer temperature and the speed which with this phenomenon occurs depends upon the summary value of the heat penetration coefficient, defined from the Eq (7):

$$\alpha = \alpha_w + \alpha_s + \alpha_r, \tag{7}$$

where α_w – the coefficient of heat penetration caused by forced convection, W/(m^2×K); α_s – the coefficient of heat penetration caused by free convection, W/(m^2×K); α_r – the replacement coefficient of heat penetration by radiation, W/(m^2×K).

In the process of convection, the whole layers of an agent with various temperatures which particles are in motion are subject to replacement. In the real conditions, the mixed convection takes most frequently place. This is the result of the forced convection α_w overlaying (the mass speed of the flow is defined unambiguously, for instance, the wind) and natural convection α_s (free convection), arising from the operation of the uplift pressure, which is the consequence of the difference in density caused by the difference of temperatures in various places of the liquid. In both cases, the routes of the individual particles of the liquid may position parallelly (laminar movement) or some whirls may occur (turbulent movement). The coefficients of heat penetration are defined from the Eq (8), based on the Nusselt's number Nu.

$$\alpha_{w,s} = \frac{\mathrm{Nu} \times \lambda_p}{d}, \tag{8}$$

where λ_p – the coefficient of heat conduction in the liquid, W/(m×K); d – characteristic dimension, for instance, the width of the layer, m.

The Nusselt's number depends upon the character of the liquid flow in the layer close to the wall (laminar or turbulent). The nature of the flow is defined pursuant to the nondimensional characteristic number of Reynolds (Re), Prandtl (Pr) and Grasshoff (Gr), expressed by Eqs (9)–(11) (Hobler 1984; Wiśniewski 1988):

$$\mathrm{Re} = \frac{w\,\gamma_p\,d}{\eta}, \tag{9}$$

$$\mathrm{Pr} = \frac{c_p\,\eta}{\lambda_p}, \tag{10}$$

$$\mathrm{Gr} = \frac{g\beta\,\Delta T\,d^3\,\gamma_p^2}{\eta^2}, \tag{11}$$

where w – the speed of liquid flow in undisturbed stream, m/s; γ_p – liquid viscosity, kg/m^3; η – dynamic coefficient liquid viscosity, N×s/m^2; c_p – specific heat of the liquid at the permanent pressure, J/(kg×K); g – acceleration of gravity, 9.81 m/s^2; β – coefficient of liquid volume expansion, 1/K; ΔT – difference between the HMA temperature and the temperature of the liquid, ambience (the air) $\Delta T = T_S - T_{oś}$, K.

In case of a forced convection, the movement of the liquid directly over the flat surface, takes place in laminar manner in the scope of the values of numbers Re < 8×10^4 – 5×10^5, and at the size 5×10^5–10^7 the nature of the flow is turbulent. The Nusselt's number for the horizontal surfaces is determined correspondingly from the Eqs (12) (laminar flow) and (13) (turbulent flow) (Wiśniewski 1988).

$$\mathrm{Nu} = 0.664\,\mathrm{Re}^{\frac{1}{2}}\,\mathrm{Pr}^{\frac{1}{3}}, \tag{12}$$

$$\mathrm{Nu} = 0.0366\ \mathrm{Re}^{\frac{4}{5}}\ \mathrm{Pr}^{\frac{1}{3}}. \tag{13}$$

The nature of the movement at free convection ("floating" of the heat) is determined pursuant to the critical value of the product of Gr and Pr, referred to as Reyleigh's number (Ra). At the laminar flow, the Ra value for the flat horizontal surface, shall be within the range from 10^5 to 2×10^7 and at the turbulent flow, ranging from 2×10^7 to 10^{13}. The averaged values of Nu numbers for the surface being cooled in accordance with Michiejew (Hobler 1984; Wiśniewski 1988), are calculated from Eqs (14) (laminar flow) and (15) (turbulent flow).

$$\mathrm{Nu} = 0.54\ \left(\mathrm{Gr} \times \mathrm{Pr}\right)^{\frac{1}{4}}, \tag{14}$$

$$\mathrm{Nu} = 0.14\ \left(\mathrm{Gr} \times \mathrm{Pr}\right)^{\frac{1}{3}}. \tag{15}$$

The losses of heat in consequence of radiation arise from the difference between the energy absorbed from the sun rays and that radiated from HMA (Diefenderfer *et al.* 2006; Mallick *et al.* 2009). This is described by the replacement coefficient of heat penetration by radiation (16).

$$\alpha_r = \frac{q}{\Delta T} = \frac{\varepsilon_1\ I_S - \varepsilon_1\ C_0 \left[\left(\frac{T_{mma}}{100}\right)^4 - \left(\frac{T_1}{100}\right)^4\right]}{T_{mma} - T_{pow}}, \tag{16}$$

where ε_1 – the ability of HMA to C_0 – a constant of the radiation of a perfectly black solid, $C_0 = 5.768$ W/(m^2×K^4); I_S – the density of the sunshine radiation, W/m^2; T_{mma} – the temperature of layer surface HMA, K; T_1 – the temperature of open space, $T_1 = 230$ K; T_{pow} – the temperature of the air, K.

4. Drops in the temperature of AM – the theory and laboratory tests

The heat transfer in the AM layer while compaction is accompanied by its exchange with the environment. The value of thermal collection is determined by the replacement coefficient of heat penetration α. This parameter depends upon technological factors and climatic and weather conditions. In the first one the steel (roller drums) and the water (technological to rinse the steel drums) play the decisive role. Although the impact of these factors is short-termed but, however, they have a significant influence on the distribution of temperatures, in particular, in the layer close to the surface (Jendia, Jarada 2005; Meczkowski 2006; Wise, Lorio 2004). In the other case the temperature, air pressure and humidity, wind velocity, the width of the layer being laid out and the intensity of the ray of the sun radiation shall decide upon the thermal collection. Focusing on the three basic ones; (the temperature, the wind and the width of the layer) the value of α parameter was determined, which ranges from about 10 to almost 80 W/(m^2×K) (with the wind up to 20 m/s). The exemplary chart of changes in the α coefficient was presented in Fig. 1.

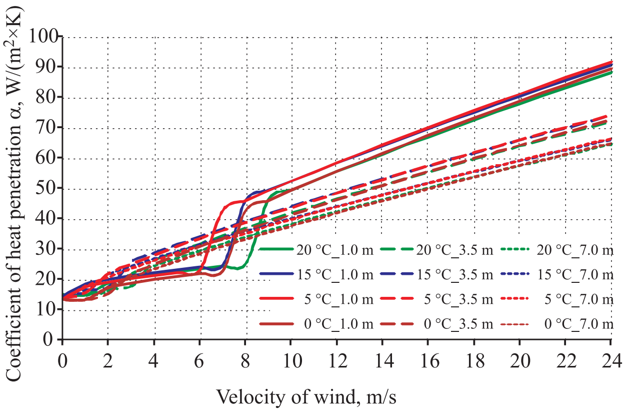

Fig. 1. The value of α coefficient of thermal penetration, depending upon the temperature of the air, the velocity of the wind and the width of the layer with the relative humidity φ = 80% and the density of the stream of sunshine radiation I_S = 205 W/m^2. Denominations: the first value – the air temperature in °C, the second value (behind the bottom line) – the width of the layer in m, for instance, 20 °C_3.5 m – the air temperature 20 °C, the width of the layer 3.5 m

It results from the calculations conducted that the largest impact on the value of the α coefficient has the wind velocity, much less the width of the layer, and the least the ambient temperature. In accordance with the Eq (2) α parameter together with the coefficient λ, of thermal conductivity, determine the drops in the temperature in the MA layer being cooled. To confirm this, a few theoretical calculations were made. Some of them were verified on the laboratory scale on samples with the dimensions of 250×250 mm and the thickness about 50 mm. The properties of one of the samples (asphalt concrete for the surface course AC 12 S 50/70) were presented in Table 1.

The research consisted in the definition of the temperature drops in MA samples heated up to 135 °C and subject to the impact of various agents, and namely:

– the air of 0 °C and wind velocity 0, 8 and 16 m/s,
– the air of 20 °C and wind velocity 0, 8 and 16 m/s.

The readings of the temperature were conducted on the surface of the samples (Fig. 2) with the use of a pyrometer, in the middle of the layer, 5 mm from the horizontal upper and lower surface of the layer, with the help of thermoelectric thermometers (fused thermocouples). To minimize the losses of heat by the side edges and lower plane, the samples were insulated by a layer of hard mineral wool (5 cm thick – side edges 10 cm thick – bottom plane) with the λ = 0.037 W/(m×K) coefficient of conductivity and a heat-proof film which fulfils the function of protection against possible humidity penetration. The manner of running the tests was discussed in details in (Mieczkowski 2006).

Table 1. Characteristics of sample AC12S 50/70 for wearing layer, designated to test changes in the temperature

No of sample	Type of MMA	*H*, mm	*B*, %	ρ_{mv}, g/cm^3	ρ_{bssd}, g/cm^3	V_m, %	*VFB*, %	λ, W/(m×K)
S1	AC12S 50/70	50.0	4.8	2.771	2.678	3.356	80.410	0.761

Denominations: *H* – height of the sample; *B* – contents of bitumen in relation to AM; ρ_{mv} – max density HMA denominated by the volume method (according to *EN 12697-5:2009 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 5: Determination of the Maximum Density*); ρ_{bssd} – volumetric density of AM sample (according to *EN 12697-6:2003 Bituminous Mixtures – Test Methods for Hot Mix Asphalt – Part 6: Determination of Bulk Density of Bituminous Specimens*); V_m – void of AM sample; *VFB* – void of the mineral mix (MM), filled in with bitumen; λ – coefficient of thermal conductivity of AM sample.

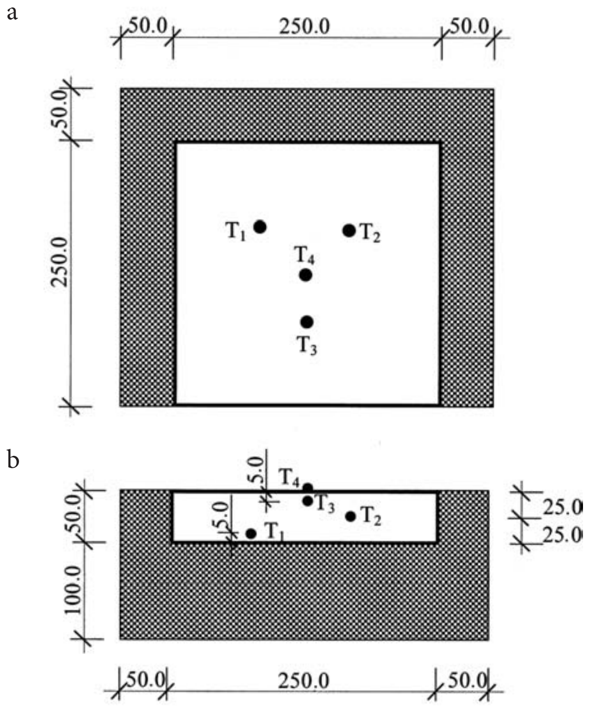

Fig. 2. The plan of thermocouples distribution to measure temperature in HMA samples being cooled: a – a view from bird's eye; b – transversal section of the sample (measures on mm)

Exemplary changes in the temperature, obtained from the theoretical calculations and measurements for S1 sample are presented in Figs 3–4. It is worth adding that with the HMA sample prepared in this way for testing, owing to the applied insulation layer, the heat is transferred in one direction. In real conditions, the thermal losses correspond to the thickness layer of 10 cm.

The laboratory tests carried out confirm the usability of the suggested theoretical model to calculate the losses of heat in the HMA layer. An analysis of the results indicates that it is not the air temperature that shall be the main decisive factor, when admitting pavement work. The velocity of the wind has a much more important impact on heat losses. Quicker cooling (with reference to the model) of the sample, practically in each of the above cases, is related to an increase in the λ thermal conductivity coefficient of the AM, and by the same, its trying to equalize the temperature quickly in the layer section. λ value grows together with the growth of the temperature (the test of the coefficient has been carried out in the board instrument in 25 °C, the heat losses were defined in the temperature over 100 °C).

5. Theoretical losses of heat in HMA layer for the assumed conditions of compaction

The exchange of heat in the process of compaction of AM is the result of its flow in the layer in an undetermined

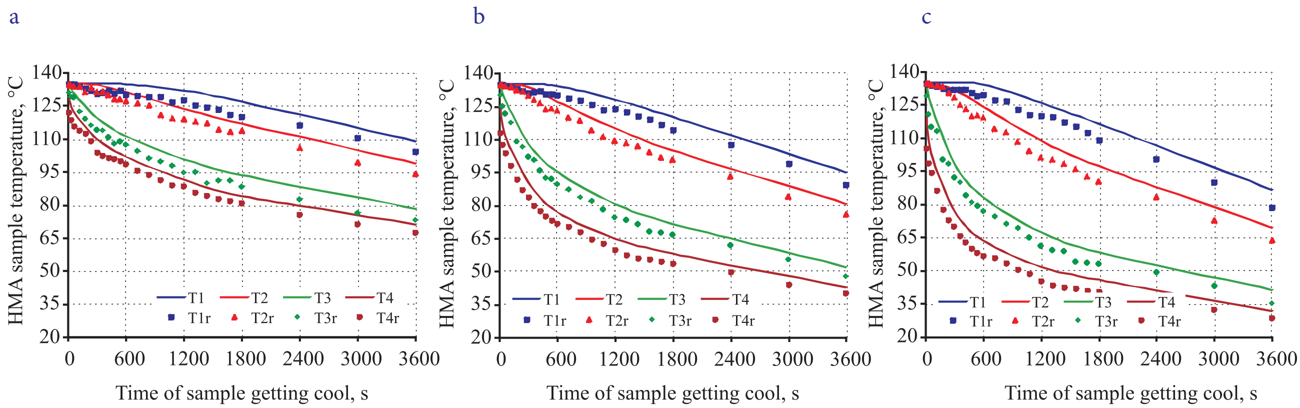

Fig. 3. The theoretical temperature, and that measured in S1 sample, 5 cm thick in the temperature of 0 °C: a – without wind; b – with wind 8 m/s; c – with wind 16 m/s; T1, T2, T3, T4 – theoretical temperature corresponding to being located in the layer in accordance to drawing 2; T1r, T2r, T3r, T4r – temperature measured in places as on drawing 2

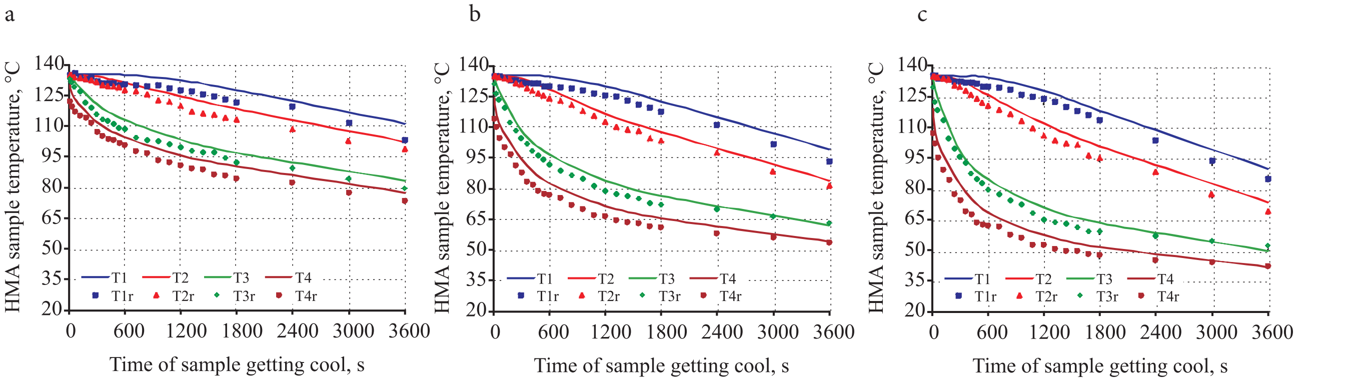

Fig. 4. The theoretical temperature and that measured in S1 sample, 5 cm thick, in temperature 20 °C. Denominations as above

manner and the collection by the external factors. In case of the bottom layer, the heat collection is relatively small and takes place practically through conduction. The asphalt or mineral mix layer with large contents of void collects the relatively small amount of heat. The situation changes where there is water in the foundation. The heat supplies change into steam which penetrating upwards cools down the laid out AM. On the upper surface of the compacted layer, besides the convection exchange (thermal exchange with the air) through radiation (energy absorbed from the sun and rendered as a result of temperature differences) or conduction (as the result of contact with roller working elements) boiling of water may be brought about (used for roller operations). In a short moment, it cools down the layer surface and in case of deep penetration inside, also its lower areas.

For the conditions close to real, calculations of heat losses in hot HMA were carried out (with a temperature of 135 °C) with the assumption of the following parameters:

- HMA layer is of 3.5 m width and 15 and 5 cm thick;
- the temperature of testing is 0 and 20 °C;
- factors which collect heat at the same time are: the air, AM layer (from the bottom of the layer), steel (from the top of the layer), water (from the top and optionally from the bottom of the layer);
- heat collection by the air and AM layer is continuous;
- the wind velocity is 0 and 8 m/s;
- heat collection by water (which does not boil) takes place in 5 s in case of interference from the top and optionally 1 s from the bottom;
- the steel contact (roller drum) with HMA takes up for 1 s, which corresponds to about 5 passes of the roller;
- the physical properties of the layer with HMA (for instance volumetric density, density, heat conductivity, specific heat, contents of free spaces, etc.) in every point in the macroscopic position are permanent and uniform. In the calculations, the impact of the compacting equipment on the heat losses of HMA was treated in a simplified way. An assumption was adopted that the impact of these factors is cumulated in the first minute (1 s – the impact of the steel drum housing which corresponds to 5 passes of the roller, 5 s – cooling down with water used to rinse the drums). In the real conditions, the operation of the rollers is carried out in a much longer time. Such treating has it that the drop of the temperature on the surface of the layer, after 1 min is so drastic because of very high coefficients of heat penetration. The results of calculations are presented in Figs 5–6.

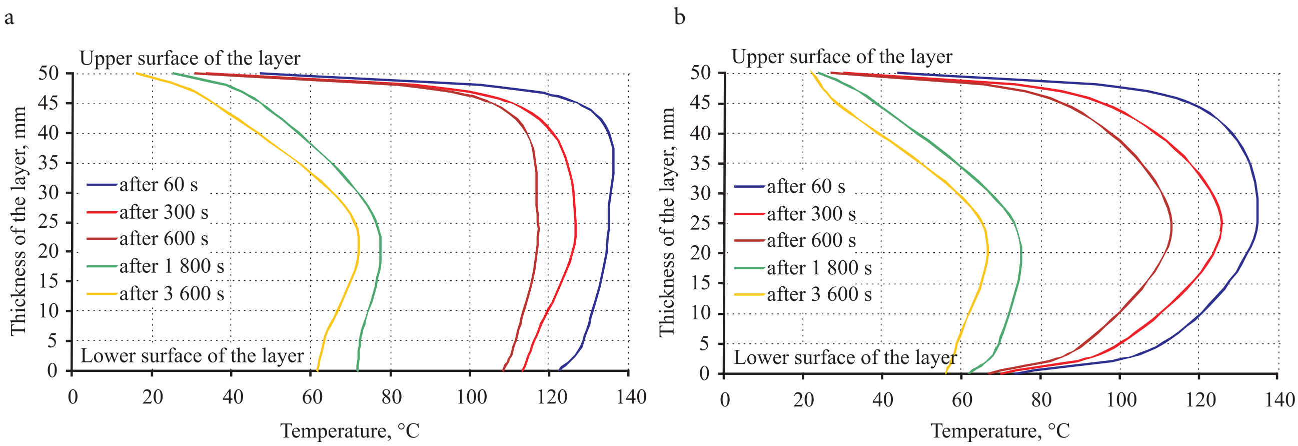

Fig. 5. Theoretical changes in the temperature in time in HMA layer 5 cm thick in the air temperature: a – 0 °C and with the wind of 0 m/s velocity (with water not staying in the foundation); b – 20 °C with the wind of 8 m/s (with water staying in the foundation)

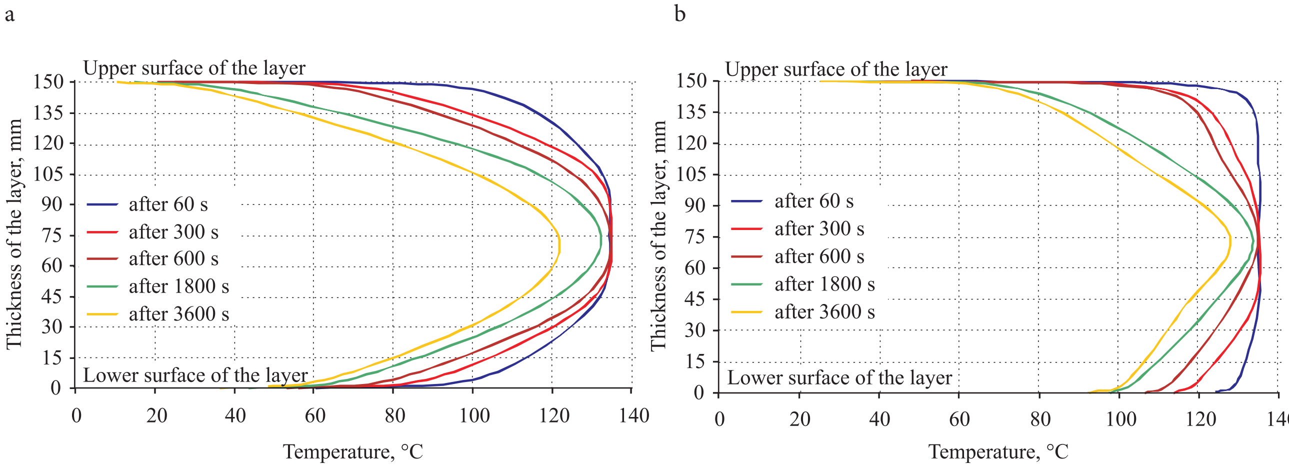

Fig. 6. Theoretical changes in the temperature in time in HMA layer 15 cm thick in the air temperature: a – 0 °C and with the wind of 8 m/s velocity (with water staying in the foundation); b – 20 °C with the wind of 0 m/s (with no water staying in the foundation)

Analyzing the above charts, we may come to the conclusion that the decisive factor for keeping up the temperature in the layer is its thickness. Even at unfavourable conditions (at 0 °C temperature, wind 8 m/s, water in the foundation and on the layer surface) the contractor has a relatively long time to compact the HMA laid out (Fig. 6a). With the application of bitumen, for instance 35/50, even after 1 hour, nearly 10 cm of cooled down layer, has a temperature over 85 °C which corresponds to a min temperature of compaction under the viscosity of bitumen (20 Pa×s).

In case of thinner layers, the drops in the temperature are decidedly larger and the additional water contained in the foundation may make it impossible to lay it out properly. That is why the quantity of water output during the operation of the roller shall be controlled as the lack of limitation may cause large losses in the heat, which practically make it impossible to conduct any further work. Even a small amount of water contained in the foundation, despite of a higher ambient temperature (20 °C), limits the period of work performance to about 8–10 min (Fig. 6a) with about 20 min in the temperature of 0 °C (Fig. 6b) when the water is not staying. Therefore, drying out of the foundation allows even in low temperatures to achieve proper compaction whereby it is necessary to control the operation of rollers which is confirmed by calculations and experimental works made in the laboratory and technical scale (in field conditions on the road).

6. Conclusions

The theoretical model presented in the paper verified by the results obtained from tests in laboratory allows to value the impact of the individual factors on the speed of HMA cooling. It is the opinion of the author that the velocity of the wind has a dramatically larger impact on the value of heat collection, than the air temperature.

In unfavourable climatic and weather conditions, the thickness of the layer compacted has a favourable impact on the efficiency of compaction.

An important problem when laying out HMA is the water staying in the foundation. When it is heated, it starts to steam and in the form of unsaturated steam it penetrates upwards the layers, cooling them down. This may have an impact on failure to compact in the layer and adhesion between the layer, reducing in this way the carrying capacity of the structure. In this context, we must distinctly claim that the sense of rinsing the foundation with bitumen emulsion directly before laying out hot AM, in particular, in thin layers, is questionable. It is, according to the author, one of more frequent contractor's errors, explained, for instance, by technological traffic.

There is a necessity to prolong the period of pavement work to late autumn, early spring, and even to winter period. It is possible in the light of tests carried out, as the most disadvantageous factor to obtain good compaction is not the air temperature (and its humidity) but the velocity of the wind. Possible disadvantage, arising from freezing of water used for compaction, may be eliminated by adding thereto a small quantity of glycol (this shall not have a disadvantageous impact on the durability of AM, as this type of substances are not dissolvers for hydro-carbon material).

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