THE IMPROVEMENT OF ASPHALT CONCRETE PLACEMENT BY WARM-MIX ASPHALT APPLICATION

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ABSTRACT

One of the typical problem arises during a hot asphalt mixture placement is a low compaction of it due to the rapid cooling. Traditional method of placement using the hot asphalt mixes can also cause a heavy damage of the material structure due to the substantial temperature tension because of a high temperature gradient.

An effective way of solving such kind of problem is to use Warm-Mix Asphalt (WMA), which is possible to pave and compact in lower air temperature conditions. Moreover, it has the same physical-mechanical properties as the hot-mix asphalt does.

WMA has a lot of advantages, namely: paving season extending, reduction in energy consumption during production, reduction emissions during production and paving, binder aging reduction etc. However, earlier it has not been focused much on how WMA can reduce temperature tension which appears within just paved layer because of the high temperature gradient. Therefore, this is to be distinguished as one of the advantages as well. It has been conducted some research with regard to this issue. According to the result of research, it has been found the influence of a big cooling rate of asphalt mix during its placement on level of temperature tension within asphalt layer and its influence on damage of material structure. It has been also calculated an index of material structure damaging.

To sum up, the results of research show that the using of warm-mix asphalt can cause a reduction of asphalt concrete damaging during placement and raise durability of asphalt concrete.

Keywords: Warm-Mix Asphalt, Cold Weather Paving, Temperature Tension, Structure Damage Index, Durability

INTRODUCTION

Warm mix asphalt refers to the modern eco construction technique with sustainable attitude to the environment. It is a well-known fact that the use of warm-mix asphalt (WMA) helps to solve a number of important practical problems, such as: to reduce a negative impact on environment during production and paving of asphalt mixtures, to save energy sources, to extend a paving season and to improve a pavement quality.

Improving of pavement quality, applying WMA, is mostly considered as this that increases compaction quality of asphalt mixtures. At the same time, it is known, that one of the problem face with during the hot asphalt mixture paving, is its undercompaction caused by quick cooling. Especially, it becomes urgent in a situation of a need to pave asphalt mixture in low-temperature environmental conditions, because of the necessity to finish current projects before fall-winter season comes. According to the modern practice, it is possible to extend a road construction period significantly by using WMA. The necessity to pave in low-temperature conditions causes a high speed of pavement cooling and, eventually, a risk to damage the structure of the pavement material because of the temperature tension fluctuation within it. In this case, it may cause an acceleration of formation and development of temperature cracks on an early stage of a road operation. This fact attracted researcher's attention. According to R. Duebner, for instance, the excessive cooling of asphalt mixture, before paving of it ends, may cause a number of typical defects of pavement during its operation. Especially this question is urgent for regions with sharply continental climate. It is known that temperature cracking arises as a result of cooling in conditions of environmental temperature fluctuations and is the most spread kind of asphalt pavement damages. Temperature cracks can occur 40-80% of all pavement damages and are very often one of the primary reasons of other damages. Crack arising leads to weakening of entire road pavement structure. Water could trickle down through cracks to all layers of pavement that leads to reducing of frost resistance of the pavement and to overwetting of roadbed soil. Arising of temperature cracks can cause going down of road pavement untimely.

In addition, the road cracks affect the evenness of pavement, namely worsens it. This may cause a decrease of comfort conditions of driving on a road, road safety; a growth of transport expenses, frequent road repairs with traffic jams as the results, and, as the worse outcome, an impact on the environment.

Therefore, the decrease of probability of temperature cracks creation on the asphalt concrete pavement is an urgent task of the current road construction practice with an aim to increase an asphalt concrete pavement quality. Although, today the issue of direct decrease of the risk of temperature cracks on the asphalt concrete pavement with the WMA applying is not studied enough. According to the current scientific research the temperature cracking in material occurs mainly as a result of tensile stress because of the temperature fluctuation. These tensions cause the rapture of connections and formation of macro cracks.

MAIN BODY

In this paper it is examined the problem of evaluation of warm asphalt mixtures influence on decreasing of temperature cracks formation on the phase of paving asphalt mixture in cold weather conditions. To calculate temperature tension which appears during its placement it was used the mechanism of thermo viscoelasticity. However, to calculate a structure damage index it was used the main points of the kinetic theory of strength of a solid body. This research shows an influence of big cooling rate of asphalt concrete mix during its placement on a level of temperature tension within asphalt concrete layer and its influence on a possible damage of material structure.

Such research allowed an implementation of hard wax usage and technologies of placement warm asphalt mixtures in cold weather conditions in many projects in Ukraine. Moreover, the results of such research were useful in creation of Ukrainian standard of asphalt mixture paving in cold weather conditions.

It is necessary for studying process, referred to temperature cracks creation within asphalt concrete pavement, to calculate an analytical dependence. This will be useful for the description of the regime of pavement temperature fluctuation and, in addition, for prediction of temperature tensions within asphalt concrete pavement under temperature variety conditions. Therefore, the main task of theoretical survey is considered as a determination of a dependence, which takes into account a typical temperature fluctuation, technologies of layer placement and peculiarity of road construction, termoreological characteristics of asphalt concrete.

In the research asphalt concrete was considered as a composite material with a regular structure in entire volume, and was formed of asphalt mixture with specified proportion of components. Therefore, asphalt concrete was considered as a quasihomogeneous isotropic material. Determination of thermo stressed and marginal state of pavement was conducted on a macroscopic level with using the phenomenological approach.

Using a well known in theory of thermo viscoelasticity integral dependence of Bolzman-Volter it was defined the principal dependence between longitudinal stress σ_T and deformations ε_T of pavement as viscoelastic simple thermoreological material.

$$\sigma_T(t) = \int_0^t R(\xi(t) - \xi(\tau)) d\varepsilon_T(\tau),$$

hereafter R – function of relaxation, t- moment of time, τ – moment of time before time *t*, $\xi(t)$ and $\xi(\tau)$ – modified time for moments of time t and τ, which are determined according to the principle of temperature-temporal analogy:

$$\xi(t) = \int_0^t \frac{dt}{a_T(T(t), Q)},$$

$$\xi(\tau) = \int_0^\tau \frac{d\tau}{a_T(T(\tau), Q)},$$

hereafter $a(T,Q)$ – function of temperature-temporal shift, that shows in how many times «accelerates» run of time for deformation by constant basic temperature Q in comparison with deformation by constant temperature comparing with the deformation T (if $Q>T$), t – moment of time for determining of σ або ε; τ – moment of time before t ($0 \le \tau \le t$).

Relaxation function or creep function are determined experimentally. Relaxation function is a ratio of tension $\sigma(t)$ and deformation ε_o.

$$R(t) = \sigma(t)/\varepsilon_o,$$

Relaxation function of asphalt concrete also can be expressed using the modified exponential law:

$$R(t) = H + (B - H) \times (1 + \frac{t}{r})^{-m},$$

hereafter m and r – constants, that are determined from relaxation experiment; H and B – long-term and short-term modulus of elasticity.

As it is known, viscoelastic properties of asphalt concrete are in great dependence on temperature. Therefore, relaxation function of asphalt concrete should be a function of two arguments $R(t, T)$: time t and temperature T.

During determination of temperature tensions, it was considered asphalt concrete behave as lineal thermo-rheological simple viscoelastic material.

To assess a crack resistance under different in time temperature, it is necessary to have condition, which includes time characteristic of destroying under tension and temperature, both dependent on time changes, namely, the condition of durable firmness. Based on this, it may be formulated the criteria of the condition of the durable firmness, which allows to calculate the time till destruction t_p under variable in time tension $\sigma(t)$ and variable temperature $T(t)$.

The most widespread criterion of the condition of durable firmness is the one, defined by Bailey, which refers to termoreological behavior of organic and mineral materials when they crack.

$$\int_0^{t_p} \frac{dt}{t_p^*(\sigma, T)} \le 1,$$

hereafter t_p – time till destruction(cracking) of asphalt concrete layers;
t^* – function of durability of asphalt concrete;
T – asphalt concrete temperature which changes with pace of time.

Moreover, it is reasonable for approximation of durability function to make use of more general modified relation by Bartenev in the form of exponential relation.

$$t_p^*(\sigma, T) = B_\tau(T) \times \sigma^{-b_\tau(T)},$$

hereafter $B_\tau(T)$, $b_\tau(T)$ – parameters of function of durable firmness (defined experimentally).

Therefore, it has been engineered the mechanism of assessment of index of asphalt concrete structure damage. In order to use it, it is necessary to apply the Bailey's criterion. As a result, it is possible to get the analytical dependence in order to study the index of asphalt concrete layers damage:

$$M(\sigma_T, b_\tau, B_\tau) = \int_0^t \frac{\sigma_T(t)^{b_\tau(T,t)}}{B_\tau(T,t)} dt$$

The evaluation of the warm asphalt mixtures influence on quality enhancement of asphalt concrete pavement which was built in cold weather conditions is shown in the following example. Data about cooling rates were taken from plots of MultiCOOL software. The temperatures were approximated with a help of Microsoft Excel. In the result an equation of curves of cooling rates accurate within 0,99 (figure 1) was got.

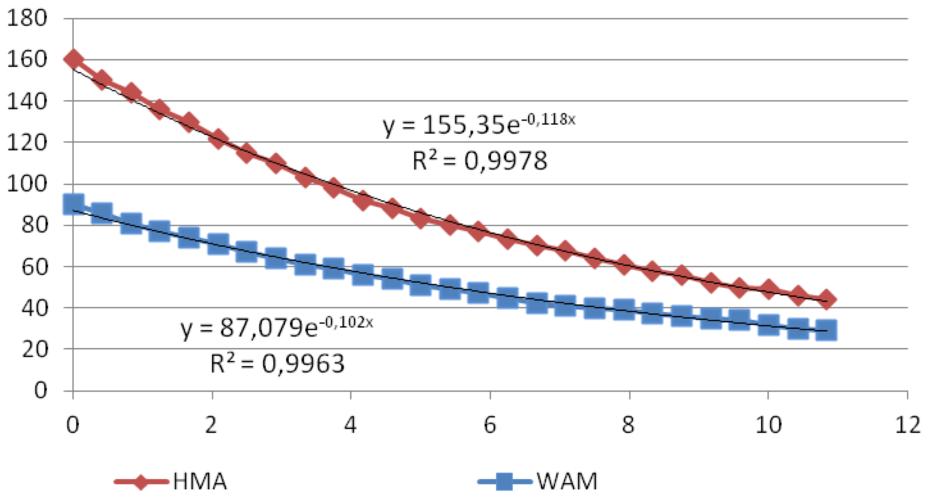

Figure 1. Cooling rates of asphalt concrete layers depending on initial temperature of cooling

Based on the above-given analytical dependences, temperature tensions, which were created within a layer of recently paved asphalt concrete under its cooling down till environmental temperature, were found. From graph it may be seen the temperature tensions which were created within an asphalt concrete layer and cooled from the start point 160°C, are bigger in 1,8 times than ones created in an asphalt concrete layer and cooled from the start point 90°C.

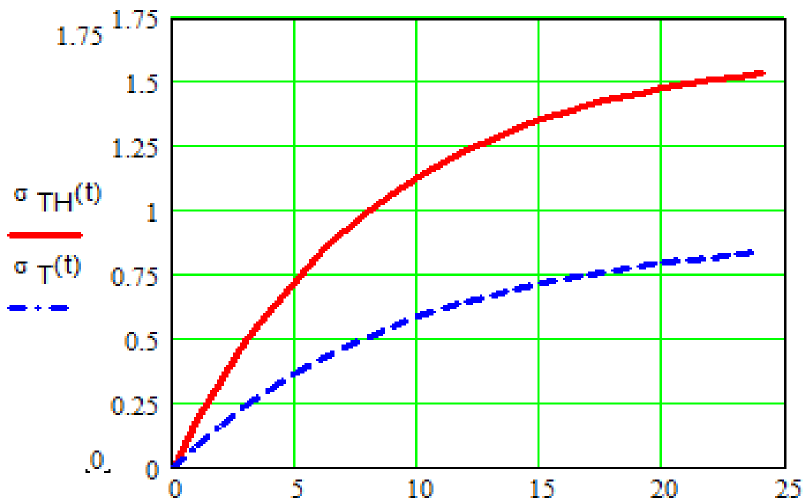

Figure 2. Temperature tensions which occur within asphalt concrete layer because of cooling after placement in cold weather conditions: ——— - temperature tensions of hot asphalt mixtures, initial

temperature 160°C($\sigma_{TH}(t)$); - temperature tensions of warm asphalt mixtures, initial temperature 90°C ($\sigma_T(t)$)

To assess the measure of the asphalt concrete damage risk caused by temperature tensions, it was defined the index of the structure damage for the hot and the warm asphalt concretes. For instance, the measure of structure damage for the warm asphalt concrete is in 2 times smaller than for the hot one. Therefore, this pattern shows the essential influence of the warm asphalt concrete applying on the increase of the quality of asphalt concrete pavement.

The results of the research were proved in the numerous projects in Ukraine. Thus, for instance, during the period 2006-2009 it was conducted the scientific project monitoring of the major repairs of the road Kyiv-Moscow on the section Kipti-Hluhiv-Bachivsk. Moreover, in some cases the distances of asphalt concrete mixture transportation were approximately 100 km. The minimum air temperature during the work performance was −3°C - − 7°C.

Figure 3. Asphalt layers paving in below 0°C conditions

Summarizing all experience of asphalt mixture paving in cold weather conditions researchers of Road building materials and chemistry Department of National Transport University (Kyiv, Ukraine) have designed the normative document GBN B.2.3-218-547:2010 'Asphalt concrete layers paving in cold weather conditions'.

This document establishes the requirements for materials, designing method of asphalt mixtures, technological sequence of operations during asphalt mixture placing, parameters of temperature range of asphalt mixture compaction, and methods of quality controlling.

CONCLUSIONS

To sum up, the warm asphalt mixes technologies provide the best alternative in modern road construction because of its cost-effectiveness, high quality of pavement, and environmentally friendly characteristics, compared with traditional materials. Application of warm asphalt mixes creates new conditions to improve the quality of road pavements and at the same time helps to reduce harmful impact on the environment. Moreover, the research states that warm asphalt mixtures application gives an opportunity to get all the above-given advantages and to decrease the measure of asphalt concrete structure damage in order to raise pavement durability. Obviously all these are fundamental steps to realize the principal of sustainability as essentially protect resources of the environment and keep them available for the future generations.

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