

CETRA²⁰¹⁴

3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

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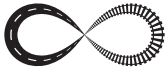
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REDUCING COST OF INFRASTRUCTURE WORKS USING NEW TECHNOLOGIES

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Abstract

In the economic and financial conditions of our time the cost of infrastructure works is often the main factor upon which decide to whether or not to make an investment in the South – Eastern Europe. Another important factor to be taken into account in the development of infrastructure investments is the environmental impact of construction. Thus, since the design phase is focused on using new technologies, performing to ensure two objectives: low cost and low environmental impact. This paper aims to draw up possibilities to reduce costs by using new technologies both to the foundation layers and layers of asphalt mixtures. The focus is on the use of new materials and technologies that have a positive environmental impact by reducing both transportation and production costs. Since the design phase, based on laboratory studies, it is proposed the use of hydraulic binders for execution of road foundation layers, the use of asphalt mixtures with high stiffness modulus and warm mix technology.

Keywords: roads infrastructure, management, optimization, road structure design, asphalt mixture stiffness, fatigue

1 Introduction

In our days it can be seen a general increase in traffic flow and higher axle loads of trucks on Romanian roads which have steadily increased the demand for stronger and more durable road pavements. The increase in traffic flow also means that traffic interruption for maintenance becomes less desirable for roads user, since almost 60% of total amount of passengers and goods use roads network. The need to increase the service life of pavement submitted to traffic of growing magnitude imposes the use of asphalt mixtures with high performance. A solution that has been adopted in the last decades is the modification of conventional bitumen through the incorporation of polymers, enhancing fatigue resistance and reducing permanent deformations. With the purpose of extending pavement life, new technologies like high modulus asphalt mixes (MAMR), called “enrobé à module élevé” (EME), developed in France, have been developed.

A relatively new processes and products in Romania use various mechanical and chemical means to reduce the shear resistance of the mix at construction temperatures while reportedly maintaining or improving pavement performance. Warm-mix technology is distinguished from other asphalt mixtures technologies by the temperature regimes at which they are produced and the strength and durability of the final product. Cold asphalt mixtures are manufactured at ambient temperatures, on the order of 20° to 50°C, while hot-mix asphalt is typically produced in the range of 150° to 180°C. Warm mixes are produced in the temperature range of 120° to 140°C. Hot-mix asphalt has higher stability and durability than cold-mix asphalt, which is why cold mix is used in the lower pavement layers of low-volume roadways. The goal with warm mix is to obtain a level of strength and durability that is equivalent to or better

than hot-mix asphalt. By conducting laboratory tests, the goal of this study is to highlight the properties of asphalt mixtures made with respect of these two technologies and to use laboratory data (as stiffness modulus) in pavement design process. When it is about to design a pavement structure, there are few important factors to care about: initial cost, rate of degradation, effects of roads work by user delay cost and accident costs, environmental costs and state agency costs by maintenance cost and traffic management costs.

2 Benefits and problems associated with new technologies

2.1 Warm mix technology benefits

Warm mix technology has great benefits regarding the environmental protection and the improvement of paving operations. These benefits are described below.

Energy savings reported on WMA trials ranged from 20 to 35 % at the plant depending on the WMA system, moisture content of the aggregate and the type/efficiency of the plant. The energy savings may be equivalent to approximately 1.5 to 2.0 liters of fuel per tone of material. Lowering the mixing and placement temperatures of bituminous mixes provides enormous gains in reduction of asphalt fumes. Visual observations of WMA during placement clearly show reduction in asphalt fumes and reports indicate reduction in the magnitude of 30 % while other more optimistic studies are indicating reductions of up to 90 % behind the paver. Warm mix asphalt technologies facilitate compaction. Certain systems have been described as “Flow Improvers” to improve “compatibility” of bituminous mixes even in adverse windy and cold weather conditions. The objective of WMA systems is to modify the temperature/viscosity relationship in a manner such that, suitable mixing and compaction viscosities are achieved at lower temperatures, while adequate viscosity is maintained at service temperatures.

Warm mix asphalt facilitates transportation. Transportation constraints/distances may consist in a problem for placement of conventional HMA mixes. In a sense, transportation time consumes some of the HMA compaction time. This may become a major constructability issue when mixing and placement temperatures are relatively close. Increasing mixing temperature to compensate for long transportation is not viable as increased mixing temperature will likely damage the binder. Warm mix asphalt provides more flexibility; it is possible to increase mixing temperature above the “WMA mixing temperature” (but below the HMA mixing temperature) with limited binder damage.

With most WMA systems the temperature of the bituminous material at the end of compaction is lower than with HMA, and also closer to service temperature. Accordingly, the usage of WMA allows quick return to traffic. For the same reasons, multiple lifts of WMA may be placed on top of one another within a short period of time. This is a net advantage whenever, deep fill of bituminous materials is required to be placed in a trench in a short period of time.

2.2 Warm mix technology possible problems

There is a general concern for WMA rutting performance that is connected with the decreased mixing temperature which may lead to incomplete drying of aggregates and insufficient coating with bitumen. Another aspect that may influence decreased resistance to permanent deformations is the decreased oxidative hardening of bitumen due to the lower production and compaction temperature. These problems might be treated with adding active adhesion agents or initially choosing harder bitumen grade [1].

Potential rutting problems require careful evaluation of asphalt in laboratory. Testing samples should be prepared carefully, because there might be a necessity for mixture aging before compaction to ensure proper correlation with actual production process. The choice of the

right compaction method might also be a problem, because some methods might not be sensitive enough to temperature changes.

Due to low mixing temperatures, moisture contained in the aggregate may not completely evaporate during mixing and the retained water in the aggregates could lead to increased susceptibility to moisture damage. Because of residual moisture left behind by the microscopic foaming process, this is even more critical for WMA technologies that involve foaming as a binder viscosity lowering action. These problems, if they occur, may be successfully treated with active adhesion agents.

WMA is reported to have better compaction potential due to decreased viscosity and less bitumen ageing in the production process. This can allow saving compaction energy and reducing the time necessary for compaction which may be especially important in low temperature paving. The reduced compaction risks, if realized, cause the cost that can far exceed additional costs for WMA production. However, if wax technologies are used, they require additional attention regarding the temperature conditions for rolling. The compaction must be finished before the wax starts to crystallize; after this temperature the wax forms lattice structure in the asphalt that may be damaged if the compaction is continued. This means that compaction window is shorter than for HMA and additional rollers may be required to reach the necessary density in the given time window [2].

2.3 High modulus asphalt mixtures technology benefits

Introduction of this concept is not new, it appears in 1980's, and, gradually, have proved to main advantages. Improvement of asphalt mixture layers performances by a stiffer behavior, a better fatigue behaviour and a higher rutting resistance combined with a better durability – moisture resistance. Its properties conduct to a use of this asphalt mixture on heavily trafficked roads, especially where traffic is slow and with heavy loads – truck routes, container terminals. It has excellent load-spreading properties due to its high elastic stiffness, which is mainly achieved by using low penetration grade binders, often polymer modified binders used. The high resistance to permanent deformation of high modulus asphalt mixtures makes it an ideal base layer for thin wearing courses in areas of high risk of rutting – combined with SMA (Stone Mastic Asphalt) as a wearing layer.

Another great advantage is from economical point of view, because this type of mixture allows thinner layers and it has a better responses to the increase of traffic loads and intensity. All these comes with savings of aggregates, maintenance and traffic interruptions.

The places where it should be used includes construction sites where a greater degree of responsibility has been passed onto the contractor, for example in the type of contract under which the contractor will design, build, finance and operate roads in return for payments related to vehicle usage.

2.4 High modulus asphalt mixtures technology problems

There are two important aspects regarding at problems raised by this technology. First, it is about the implementation of this new concept in a country with its own norms, design methods and not always comparable tests methods. Another aspect is related by the ability of local asphalt contractors to manufacture and lay the new material, including storage facilities for binder, maintenance of appropriate asphalt temperatures and appropriate compaction equipment – high modulus asphalt mixtures needs a higher compaction temperature (because of polymer modified bitumen) and heavy compactors for rolling. The main aspects that need to be considered during construction are:

- Ensuring that there is good bonding between subsequent layers (the application of a optimum tack coat is essential);

- Ensuring that the mixing temperature is between 160 and 180°C and that the compaction temperature never drops below 140°C;
- Ensuring that the support layer is sufficiently stiff so as to enable high modulus asphalt mixtures to be compacted to the required density;
- Ensuring that the average thicknesses are met, and particularly the minimum thicknesses;

3 Laboratory studies

Experimental study aimed that through laboratory results to highlight high modulus asphalt mixture performance when WMA technology is used. This study was carried out on two types of high modulus asphalt mixtures designed according to French Norms: an asphalt mixture – noted by “MAMR16 – HMA” and an asphalt mixture produced with “WARM MIX – L”, an organic additive (WMA type) – noted by “MAMR16 – WMA”. The materials (aggregates, fiber and bitumen) used to prepare the asphalt mixtures and the asphalt mixtures recipes are the following: crushed rock from Turcoaia (8/16 – 36%, 4/8 – 30%, 0/4 – 24% by mix), filler from Holcim – 10 % by mix, polymer modified bitumen OMV 25/55-65 STAR FALT – 4.12% by mix and organic additive (WARM MIX-L) – 0.5% by bitumen – used for WMA mix.

The organic additive used is a liquid additive mixed in bitumen, dissolving easy when bitumen is hot, without any special mixing equipment.

To highlight the performance of both new technologies, in Roads Laboratory of Faculty of Railways, Roads and Bridges (Technical University of Civil Engineering of Bucharest) were conducted tests for stiffness, Marshall characteristics, fatigue and permanent deformation tests. Each value is a mean value of a specified tests numbers according with european norms. In table 1 are summarized temperatures used for preparing and compacting of asphalt mixtures in laboratory. Two temperatures were used for warm mix compaction – 160°C and 145°C to highlight the influence of warm mix additive on asphalt mixture behaviour.

In figures 1 and 2, 3 are presented the results obtained for high modulus asphalt mixture using hot technology.

Table 1 Temperatures used at preparing and compacting of asphalt mixtures

Technology	Aggregates Temperature °C	Bitumen	Mixing	Compaction
“warm mix”	150	160	160 & 145	160 & 145
“hot mix”	180	175	180	175

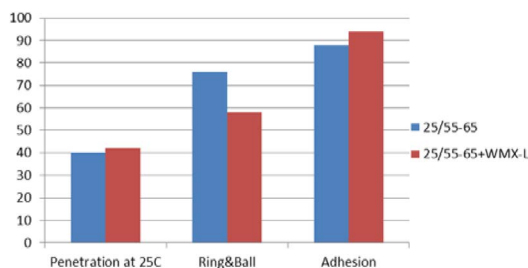


Figure 1 Changing of OMV 25/55-65 bitumen characteristics when additive is used

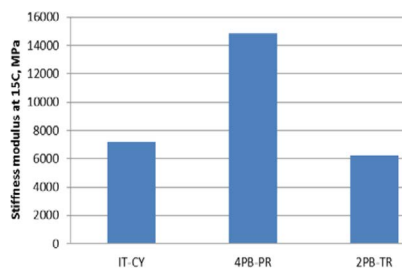


Figure 2 Asphalt mixture modulus with test type

Table 2 Physical – mechanical characteristics

Characteristic	Asphalt mixture type		
	HMA	WMA1	WMA2
	Compaction temperatures		
	175 °C	160 °C	145 °C
Density, kg/m ³	2496	2479	2465
Water sensitivity, %	63	70	78
Marshall stability (S), kN	16.80	17.22	15.42
Marshall flow (I), mm	3.87	4.9	4.82
Marshall index (S/I), kN/mm	4.34	3.51	3.20

4 Pavement design depending on asphalt mix stiffness

Starting from idea that flexible pavement design based on elastic multistrat theory it must be took on consideration the values obtained in laboratory for stiffness modulus, authors propose a road structure to do case studies, according with romanian norm for pavement design (table 3).

Table 3 Road structure proposed for calculation

Road layer	Layer thickness [cm]	Stiffness modulus [MPa]	Poisson number
Asphalt mixture in wearing course	4	E_m	0.35
Asphalt mixture in binder course	5		
Asphalt mixture in base course	6		
Foundation of crushed rock	20	500	0.27
Ballast foundation	30	260	0.27
Soil type P1		100	0.27

Using the program ALIZE5 (based on Burmister theory) it was establish stress and strain state in road structure under action of standard 115 kN axle. So, it could be determined the fatigue damage ratio based on horizontal tension strain (ϵ_r) at the bottom of asphalt layers, and vertical strain (ϵ_z) at subgrade level. For calculation it was considered a 2 m.o.s. (m.o.s. means million of standard 115 kN axle) values of traffic volume N_c for a perspective period of 15 years. First case used stiffness modulus stipulated on romanian norm for pavement design (PD 177) – $E_m = 3895$ MPa – and the second case used the stiffness modulus obtained in laboratory – $E_m = 7607$ MPa. The medium stiffness was calculated using formula:

$$E_m = [S(E_i^{1/3} \times h_i) / Sh_i]^3 \quad (1)$$

Results obtained from pavement design are presented in table 4.

Table 4 Results obtained from pavement design

Mixture stiffness	horizontal tension strain [ϵ_r]	vertical strain [ϵ_z] at subgrade level	RDO (fatigue damage ratio)	vertical admissible strain ϵ_z adm
Laboratory	117.6	237	0.72	272.84
Design norm	150.1	271.4	2.05	272.84

As it can see from Table 4, the structure with stiffness values from laboratory fulfill the requirements for specified traffic volum, whilst the structure with stiffness values from design norm fail the fatigue damage ratio criteria, which should be lower then 0,85.

Raising the value of traffic volume it can be find out that the structure with stiffness values from laboratory can acomodate a traffic value of 3.5 m.o.s., which correspond to a higher traffic class, according romanian norms. In this case, it can be taken in consideration lowering the thickness of asphalt layer, by taking out the binder course, without negative effects on bearing capacity of pavement structure.

5 Conclusions

Warm-mix asphalt presents an opportunity for the asphalt industry to improve its product performance, construction efficiency, and environmental stewardship. The challenge is to thoroughly research and implement this new technology in the least restrictive manner possible in order to encourage innovation and competition. Using this type of additive contribute to a slight increasing of penetraion at 25°C and a decreasing of ring and ball point, all these coming with a improvement of bitumen adhesion at aggregate, for a better durability.

Because of the additive which decrease bitumen viscosity, it can be seen a small decrease of Marshall stability for temperature of 145°C. For 160°C values are close to hot mix technology, which cand lead at conclusion that using this additive assure a longer time for asphalt mixture transportation and compaction.

The potential increase in pavement life from the combined technologies will result in significant reductions in emissions and energy costs, which is expected to outweigh the energy cost required to produce the desired additives and good quality aggregates.

High modulus asphalt mixture can assure – with a small extra cost, using high quality materials – an up to 35% reduction of asphalt layer thickness. Adding warm mix technology for this mixture, the economical and envinronmental savings are even bigger.

Although the laboratory results appear to indicate some small changes in the performance of the mixtures, they do not consider aging effects and the performance functions are based on conventional mixture data, and therefore need to be validated by field data before further conclusions can be drawn.

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