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Experimental Study for Asphalt Laying Using Control of Pavement Compaction Technology on Roads

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Abstract. Hot mix asphalt (HMA) is produced and laid at high temperature and therefore it is subjected to segregation due to differential cooling, which usually occurs during asphalt material transportation and road pavement construction. If mixing temperature is inconstant the degree of compaction may vary, and this will inevitably result in poor performance of the newly laid road pavement. This study describes factors influencing the quality of asphalt pavement construction and analyses results of repair of the selected road section using the solutions of the asphalt mix compaction control technology with the aim to increase the service life of road pavement and to reduce construction costs. Data were obtained by the asphalt pavement compaction control system TOPCON C-63A built in the HAMM company rollers HD-75 and HD-120 used at the paving site, and by the TROXLER 3451 device used for the self-control density measuring tests. The data obtained enabled to determine the number of rolling passes, temperature differentials of asphalt pavement and pavement compaction.

Keywords: pavement, asphalt pavement compaction, hot mix asphalt (HMA), compaction control system.

Conference topic: Roads and railways.

Introduction

Lithuania has a long-standing tradition of producing asphalt mixes. In our country, composition of asphalt mixes, paving and maintenance technologies were being improved over the last fifty years. From the moment when the first "true" asphalt pavement was laid, the production and laying of asphalt pavement have evolved to the computerised mixing, laying and compaction equipment. Today, foreign countries use the self-control technologies of asphalt pavement compaction and asphalt mix laying operations.

Compaction of hot mix asphalt (HMA) is influenced by numerous factors, some of them are related to environmental conditions, some are determined by asphalt mix and structural composition, and some may be controlled by contractor during construction process. The most crucial factors are supposedly those influencing the HMA temperature and cooling speed. Those are production temperature, transportation time and distance, initial temperature of asphalt mix to be laid and layer thickness, temperature of the surface on which pavement is laid, ambient temperature and wind speed, compaction process (Milovanovic *et al.* 2012).

One of the most important characteristics of asphalt binders that must be addressed in test methods and specifications is that their precise properties almost always depend on their temperature (Bražiūnas *et al.* 2013). If mixing temperature is inconstant the degree of compaction may vary, and this will inevitably result in poor performance of the newly laid road pavement (Shangguan, Al-Qadi 2015; Yiqiu *et al.* 2014).

Compaction of asphalt pavements during their construction is essential to the long-term performance of the pavement. The current quality control techniques determine the quality at a limited number of points and are not indicative of the overall quality of the pavement (Beainy *et al.* 2012). Based on foreign experience, it has taken a long time to determine the cause of defects in asphalt pavements (thermal segregation) and the measures to deal with this problem. In the USA, this type of research was carried out from 1995 to 2006 (Sebesta *et al.* 2006). The increase of even 1% of air voids in asphalt pavement reduces road pavement life by 10%, and the 14 °C thermal segregation increases percentage of air voids (1–2%).

The asphalt industry is constantly attempting to reduce its emissions as concerns are growing on global warming. This is done by decreasing the mixing and compaction temperatures of asphalt mixes without affecting the properties of the mix which is possible through numerous available technologies in the industry (Kheradmand *et al.* 2014).

To ensure asphalt pavement durability the self-control compaction equipment intended for the rollers is used, which measures asphalt pavement temperature, the number of rolling passes, and records their working regime (vibrations and oscillations), compaction angle, amplitude and resonance.

The use of this equipment increases labour productivity. Integration of digital technologies into road constrution will ensure the management of quality of works and productivity. This is aimed at a more effective control of road structure in each of its life-cycles from the early stage of planning and project preparation to the transfer of a digital road project model into the 3D-based mechanisms and the use of reverse information for operational tasks.

The self-control technologies of pavement compaction and asphalt mix laying operations have been also started implemented in Lithuania to build or reconstruct roads. The study deals with how to extend the asphalt pavement service life and to reduce construction, repair and routine maintenance costs by suggesting solutions for introducing the asphalt mix compaction control.

The analysis of good practice of foreign countries in laying asphalt pavements with the use of self-control pavement laying and compaction equipment showed that in some projects it is possible to reduce construction and maintenance costs by up to 50% (Xu, Chang 2014; Milanovic *et al.* 2012).

Implementation of new technologies enables road building companies to remain competitive in the construction market where there is enormous competition, and by implementing smart technologies it is possible to speed up certain works at a construction site. Road building companies have been speedily introducing the automated control systems into their mechanisms, as there is clear evidence of their benefit in relation to the quality assurance, speed of works and saving of resources. Introduction of the automated control systems also changes planning of works. The automated control systems not only contribute to the construction of road infrastructure but also register and send real-time information about the results achieved.

Methodology of the experiment

Experimental study was carried out on the road of national significance A6 Kaunas–Zarasai–Daugavpils, from km 14.26 to km 17.46, on the right side of the road (Fig. 1). The total length of the section 3200 m. Pavement condition of the road section planned to be repaired is satisfactory, there are scattered ruts.

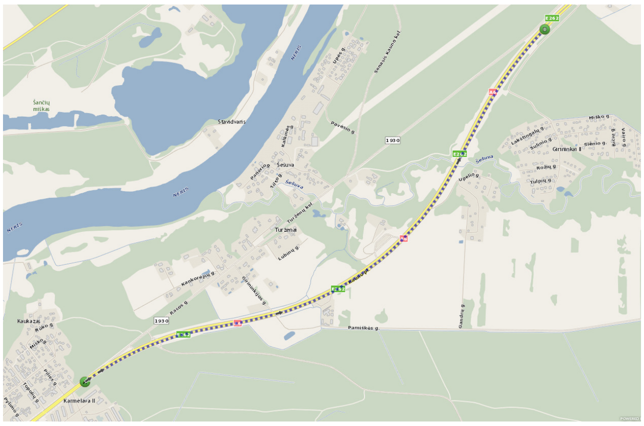

Fig. 1. The road section under investigation

During the experimental study the position and rolling location of the rollers were determined, as well as the surface temperature of asphalt concrete pavement during compaction, operating speed of the roller and compaction degree of asphalt concrete pavement.

On the right side of the road an ordinary repair of asphalt concrete pavement was carried out: filling of potholes with asphalt mix, cleaning of undelayer, laying of the base course AC 22 AS on the existing structure (4–10 cm thick) with the binder PMB 45/80-55, laying of the wearing course SMA 11 S (4 cm thick) with the binder PMB 45/80-55E. Roughness of the wearing course was increased by embedding granite chippings of fraction 2/5.

The works were carried out by the “Vögele” feeder and paver with the maximum paving width of 7.5 m. Advantages of the feeder are as follows: non-stop paving process, non-contact asphalt loading process, multifunctional use of machine, maximum manoeuvrability, up-to-date material heating system, which increases construction quality, and high level of environmental protection.

Pavement conctruction was also carried out by two “HAMM” rollers HD-75 and HD-120 equipped with the asphalt pavement compaction control system TOPCON C-63A. The system operates with the permanent GNSS stations of the Lithuanian Global Positioning System LitPOS.

The asphalt pavement compaction control system consists of the control computer, which filtrates and integrates data, displays position, the number of passes, the current number of the pass and temperature, also the temperature sensor, which measures surface temperature, and the GNSS antenna used to determine the roller’s position and rolling locations.

During construction the speed of the paver shall be stable and uniform. A type, weight and number of rollers shall be selected depending on the paver’s capacity, layer thickness, type of asphalt mix, also on weather conditions, time of the year and local conditions. When compacting stone mastic asphalt mixes the heavy static rollers shall be used and/or the appropriate vibratory dynamic rollers. In such case, vibratory compaction can be executed only under the sufficiently high mixing temperature (at least 100 °C) and only after the initial compaction by the static roller. The rollers shall be used in a way to avoid residual imprints, unevennesses or cracks (*Regulations for the Construction of Road Pavement Asphalt Layers* ĮT ASFALTAS 08, 2009).

It is aso important to properly select the number of roller passes depending on the thickness of the asphalt layer to be constructed (Table 1).

Table 1. Selection of the number of passes by vibratory roller

Thickness of asphalt layer, cm		Number of roller passes	
		7t	12t
Asphalt concrete AC	4	2–4	2–4
	6	4–6	2–4
	10	4–8	4–6
Stone mastic asphalt	4	4–6 + a pass of the static roller	4–6 + a pass of the static roller

One pass refers to one pass in forward or in reverse direction.

To ensure uniform compaction of asphalt concrete pavement the roller's operator must observe a compaction scheme and to monitor compaction results on the screen of compaction control device.

Temperature is a decisive factor influencing the stability of asphalt mix during its production, transportation, laying and compaction, also the performance of the newly laid road pavement.

Temperature of the asphalt mix shall be measured after mixing, when stored in a hopper, during transportation, paving and compaction. Paving and compaction control equipment helps to control and detect temperature differentials in asphalt mix. In this way, the thermal segregation areas will be detected.

Requirements for the transportation of asphalt mixes are related to their workability, which is highly dependent on temperature. Therefore, in the feeding, transportation, re-loading and laying stages of asphalt mix the temperature losses shall be minimized. During transportation and technological breaks the asphalt mix shall be protected against cooling-off and direct air (by using covered bodyworks, temperature-maintaining bodyworks or containers, etc.). The minimum and maximum temperature for asphalt mixes AC 22 AS and SMA 11 S is 150–180 °C. The minimum limit values are applicable for the mix unloaded at the construction site, the maximum limit values are applicable for the mix when loading it from the mixer into the storage bin. A higher production temperature may damage asphalt.

Temperature of the HMA mix is directly related to the bitumen viscosity, and thus – to the compaction properties. As the HMA mix temperature decreases, bitumen becomes more viscous, which results in a lower compaction of air voids under the same compaction effort. Thus, in order to ensure a high quality of pavement construction the asphalt pavement shall be compacted within a certain time period while the mix is still hot (Fig. 2).

The required compaction could be reached only when the HMA temperature after laying is higher than 70 °C and the temperature differential is not higher than 14 °C. Due to numerous factors, influencing the HMA temperature, it is very difficult to reach that. The laying and compaction control equipment helps to timely observe the temperature differentials.

If the mix temperature is inconstant the degree of compaction may vary, and this will inevitably result in poor performance of the newly laid road pavement.

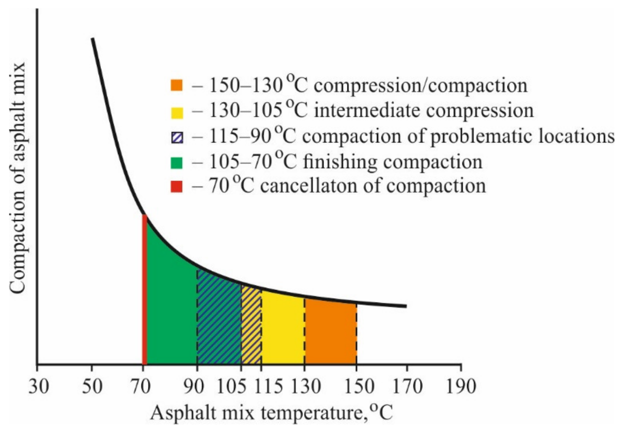

Fig. 2. Compaction of asphalt mix versus temperature

During the self-control density measuring tests the non-destructive device TROXLER 3451 was additionaly used.

Data analysis and evaluation

Data were received by the asphalt pavement compaction control system TOPCON C-63A. Analysis of the data was performed with the use of the VETA 3 software.

During data analysis the sites were detected where during compaction the number of rolling passes was different (Fig. 3). The considerably large differences were noticed at the end of the section and at the edges of pavement. After the winter, when the section under investigation was visited by the authors, the pavement defects were obvious at the joints with the old pavement. The sites of pavement defects were in full coincidence with the sites indicated by the compaction control equipment. The edges of asphalt pavement are not used by heavy traffic, thus, due to the adverse effect of climate, defects may occur after several years. During compaction the asphalt pavement temperature is also recorded by the asphalt pavement compaction control system (Fig. 4).

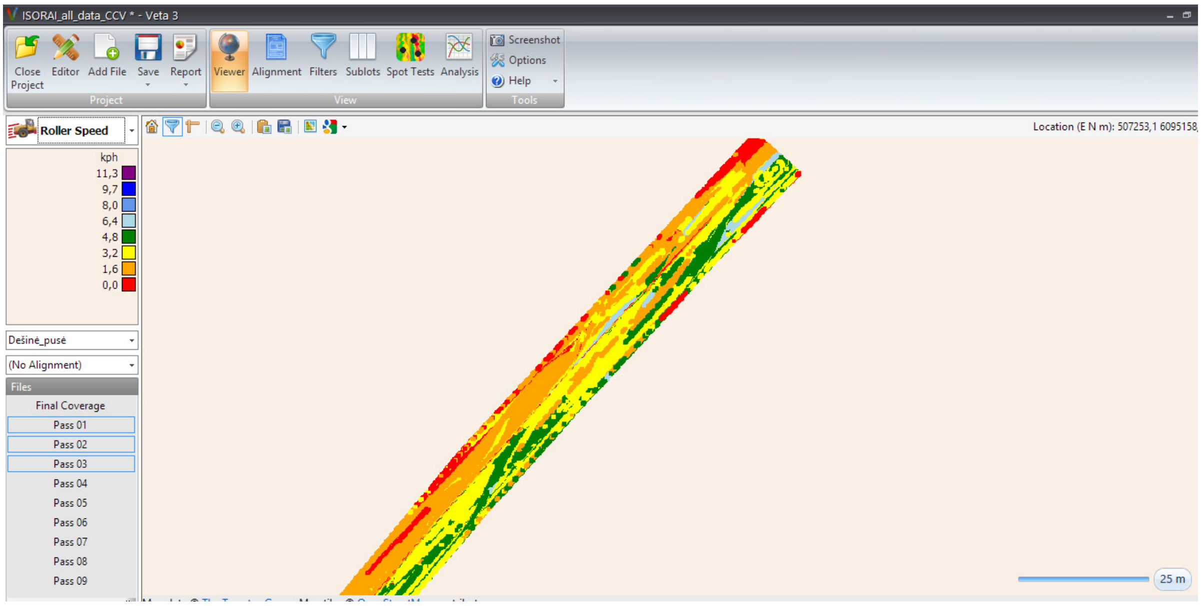

Fig. 3. Data analysis by the VETA 3 software

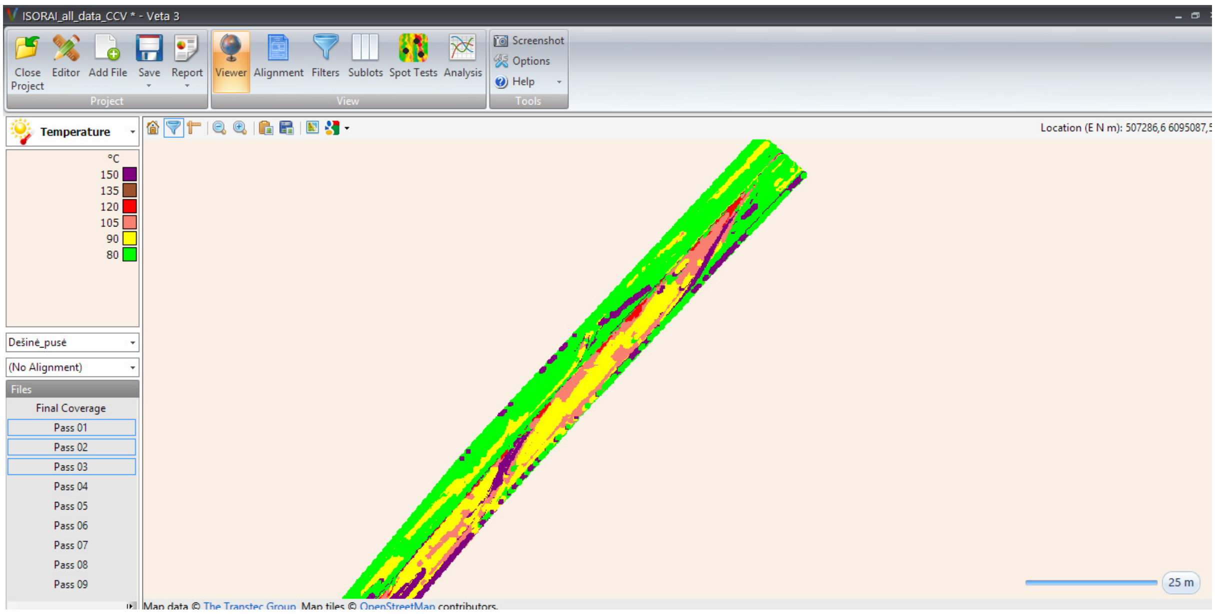

Fig. 4. Pavement temperature recorded by the asphalt pavement compaction control system

The Veta 3 software allows analysing compaction data of the entire road section or divides it into individual blocks based on the selected length. Each block can be analysed separately. The below histrogram gives data of one of blocks the length of which is 50 m. The temperature histogram (Fig. 5) shows that the compaction temperature required for the first static compression of asphalt mix was too low. Additional rolling passes were necessary (Fig. 6) to compact asphalt mix. Due to compaction of excessively cold mix and due to thermal segregation in spring the pavement defects occured.

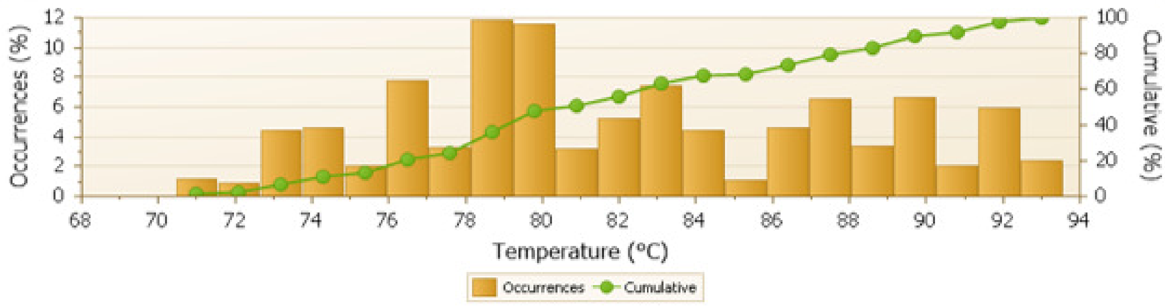

Fig. 5. Temperature of asphalt pavement

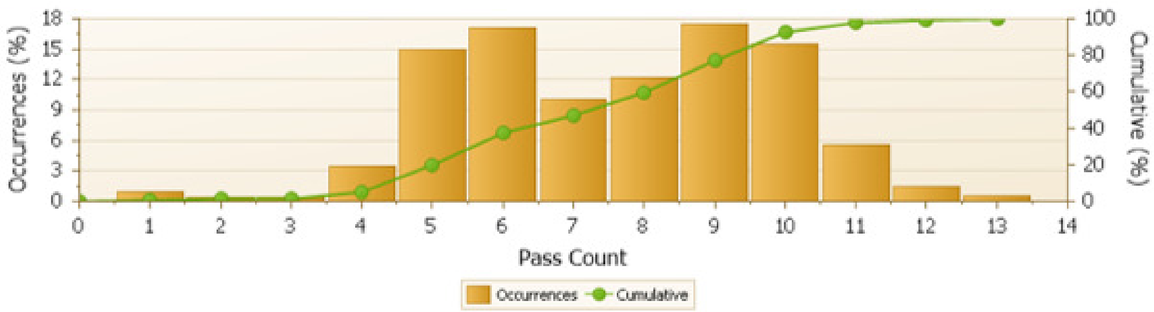

Fig. 6. Number of rolling passes

Analysis of the remaining blocks of the road section revealed that part of the data was missing and because of this the results were incorrect. The results could be influenced by the breakdown of the compaction control equipment or the use of additional rollers without the equipped compaction control facilities. Therefore, it is necessary to continuously control and ensure that the equipment is switched on and is properly working. Also, no additional rollers or compaction machines should be used without the control equipment. The roller's operator should follow indications sent by the compaction control equipment.

When measuring temperature in the process of road construction it is possible to detect areas of improper temperature and to take appropriate measures for avoiding temperature differentials. With the help of GPS all the road characteristics can be mapped and the areas of likely defects can be exactly identified.

During the self-control density measuring tests the non-destructive device TROXLER 3451 was used. The data obtained are given in Figure 7.

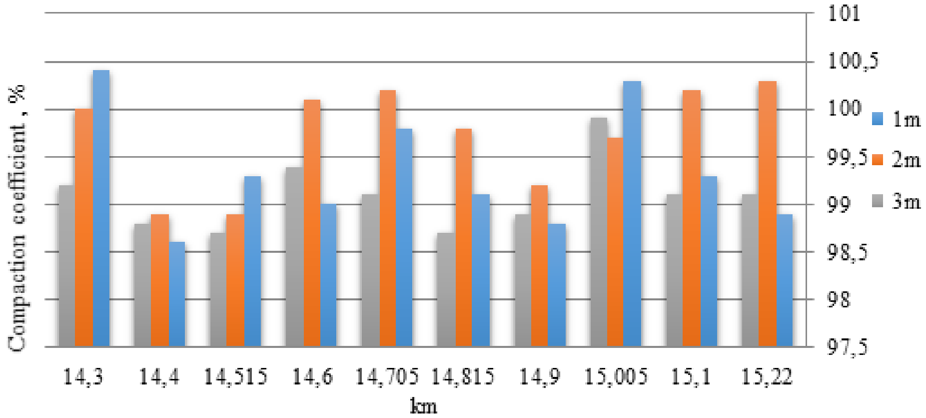

Fig. 7. Compaction coefficient for the first road lane (asphalt mix AC 22 AS)

The above diagram shows that all the measurements with the TROXLER 3451 device meet the design requirements (compaction coefficient was not lower than the projected ≥97%). The accomplished measurements, however, do not ensure compaction quality of the entire newly laid pavement since measurements were taken only in certain points without considering continuous compaction of pavement. During such self-control measurements it can happen to miss the uncompacted or recompacted places where subsequently, under high traffic loads, defects will occur.

The equipment records measurements by the GPS coordinates and saves them. Measuring data can be transfered to the VETA 3 software where they can be compared with the data of TOPCON C-63A equipment.

In all cases locations measured by TROXLER 3451 did not coincide with the locations where the compaction control equipment TOPCON C-63A indicated the possibly too low pavement compaction and areas of thermal segregation (when taking cores no check was carried out). By implementing only ordinary spot measurements of the quality of asphalt pavement the defects may be missed. Therefore, the interval between the repairs of asphalt pavement becomes shorter.

Conclusions

The main factor influencing asphalt compaction is the temperature of asphalt mix. Each step of road pavement construction (production, laying and compaction of the mix) shall be performed within the proper temperature range.

For the experimental study the "HAMM" rollers of 12t and 7t were selected equipped with the compaction control equipment TOPCON C-63A. By analysing data of roller passes, locations with the less number of passes were determined and this could influence asphalt compaction.

When analysing data of the compaction control equipment built in the rollers, the certain inaccuracies were determined in the obtained data and results. Therefore, it is necessary to continuously control and ensure that the equipment is switched on and is properly working. Also, no additional rollers or compaction machines should be used without the control equipment, and the roller's operator should follow indications displayed on the screen.

Having made the self-control density tests by the TROXLER 3451 on the selected experimental road section where the asphalt compaction control equipment was used the density of asphalt met the design density of 97%.

The automated pavement compaction process has a large perspective in road repair and building sector in future. A proper pavement compaction will help to avoid a rapid pavement distress under the effect of external environmental factors.

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