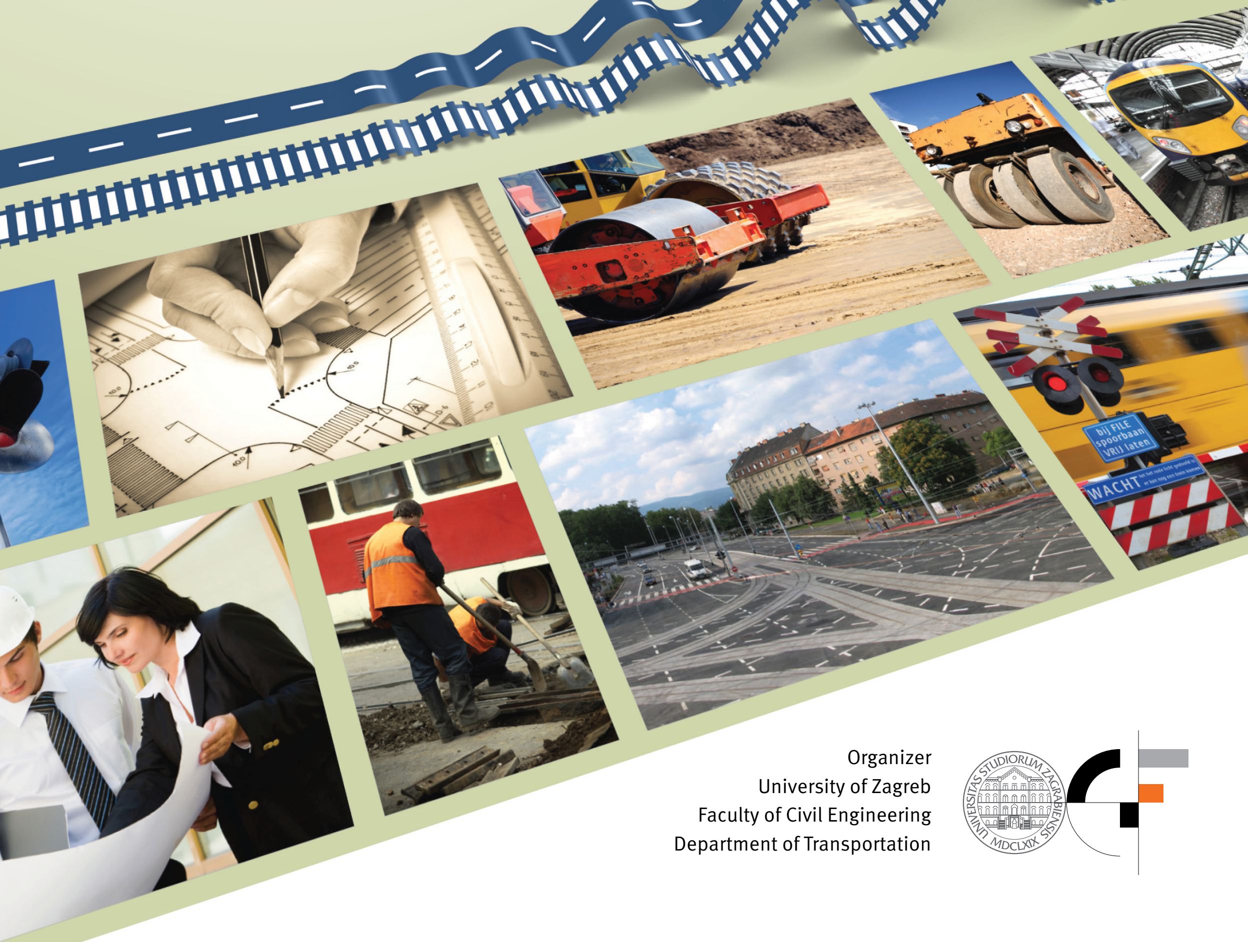
CETRA 2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure II

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RESISTANCE OF ASPHALT COURSES TO PERMANENT DEFORMATIONS IN THE FORM OF RUTS

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Abstract

The carriageway driving surface must have all the properties which guarantee safe and comfortable drive. One very significant property of the operating level of asphalt carriageways is the occurrence of permanent deformations in the form of ruts. The resistance of asphalt courses to rutting depends on several factors such as the properties of component materials of asphalt, composition of asphalt mix, properties and position of placed asphalt course in the pavement structure.
Measurements of the asphalt resistance to rutting were done using the small size Wheel Tracker measuring device, procedure B (in the air) in accordance with the standard HRN EN 12697-22. The work also included analyzing the dependence of the rut depth and the rutting speed on the composition of asphalt specimen, as well as the relative depth of rut in relation to the asphalt base in an optimal asphalt composition. The interdependence between the composition of asphalt specimen (three-component system) and composition of asphalt mix (two-component system) was also analyzed. The method of determining the resistance to rutting is described, as well as the testing requirements, testing stages and the complete procedure for determination of set parameters. The quality of asphalt mix components was previously laboratory tested, thus giving the input properties for designing the optimal asphalt composition. The confirmed optimal asphalt composition from the aspect of resistance to deformation was tested on varying thickness of courses and different combinations of asphalt courses. The influence of waterproofing and concrete carriageway slab as base on bridges was also tested for rutting. The degree of influence of bitumen as binder on the level of asphalt resistance to rutting was also tested on a series of asphalt courses, i.e. carriageway systems.
The determined dependence between parameters of asphalt courses tested by rutting and the asphalt components and asphalt mix components define the guidelines for pavement structure design. Asphalt pavement with a higher level of resistance to rutting shall fulfill the main road serviceability requirements over a longer period of exploitation.

Keywords: driving surface, ruts, asphalt mix, pavement, waterproofing

1 Introduction

Ruts are permanent deformities of asphalt pavement driving surfaces, which occur in traces of vehicles' wheels. The depressions in the form of ruts occur under traffic load, especially the canalised traffic load, on raising sections of roads and on intersections, on crossings (border crossings and toll station areas), on road sections where traffic flow is slow and on road structures. Rutting has an adverse impact to the road serviceability in terms of safety and comfort, as well as to the durability of the asphalt road structure, which is diminished due to the additional traffic-dynamic loads. Weather and exploitation conditions (high average air

temperature) cause plastic behaviour of asphalt, which may be reduced by application of an appropriate type of binder (bitumen) and of asphalt mixture whose composition shows higher resistance to permanent deformity.
Asphalt specimen is composed of stone skeleton and filler (depending on the size of particles, which can be under or over 0.09 mm in size), bitumen (absorbed, intergranulated, unboud and bound) and voids (open and closed). The basic grain size distribution of the stone skeleton of asphalt mixture remained the same, while the other two asphalt components were modified (share of filler and bitumen).
Investigation of the influence of asphalt composition to the occurrence and development of ruts in asphalt pavements served as the base for performed testing [1]. Optimised share of filler and bitumen in asphalt mixtures was determined first and than the combinations of asphalt courses and waterproofing on concrete slab were tested on resistance to rutting. Laboratory testing was carried out investigating the influence of physical-mechanical properties of asphalt specimens and share of bitumen in asphalt mix to the characteristics of ruts.

2 Interdependence of asphalt specimen composition and asphalt mix composition

The difference between asphalt specimen and asphalt mix is the content of voids in asphalt specimen; that is to say, the asphalt mix is a two-component system and asphalt specimen a three-component system. Asphalt mix is a form of asphalt specimen in which one of the components is lacking, namely the air, i.e. voids; in other words the content of voids equals zero [Figure 1].
Mathematical relations (1; 2; 3 and 4) show the relation between asphalt specimen composition and related asphalt mix composition according to [2,3]:

$$C_{B/AM} = C_{B/AU} * \frac{1}{(1 - \frac{C_{\check{S}/AU}}{100})} \tag{1}$$

$$C_{KM/AM} = C_{KM/AU} * \frac{1}{(1 - \frac{C_{\check{S}/AU}}{100})} \tag{2}$$

$$C_{P/AM} = C_{P/AU} * \frac{1}{(1 - \frac{C_{\check{S}/AU}}{100})} \tag{3}$$

$$C_{KS/AM} = C_{KS/AU} * \frac{1}{(1 - \frac{C_{\check{S}/AU}}{100})} \tag{4}$$

where:
- $C_{B/AM}$ – concentration of bitumen in asphalt mix
- $C_{B/AU}$ – concentration of bitumen in asphalt specimen
- $C_{\check{S}AU}$ – concentration of voids in asphalt specimen
- $C_{KM/AM}$ – concentration of stone material in asphalt mix
- $C_{KM/AU}$ – concentration of stone material in asphalt specimen

- $C_{P/AM}$ – concentration of filler in asphalt mix
- $C_{B/AU}$ – concentration of filler in asphalt specimen
- $C_{KS/AM}$ – concentration of stone skeleton in asphalt mix
- $C_{KS/AU}$ – concentration of stone skeleton in asphalt specimen

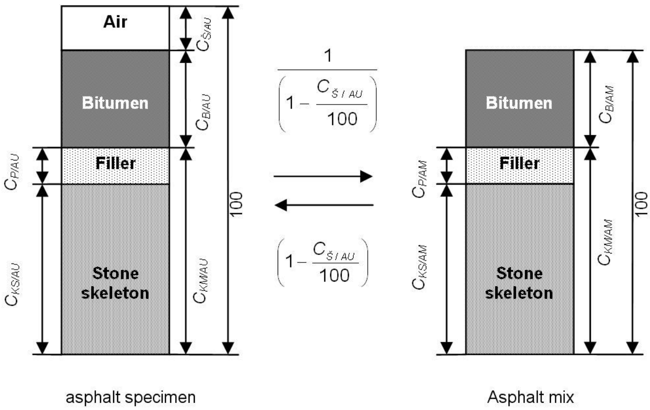

Figure 1 Relation of concentrations of asphalt specimen and asphalt mix composition elements.

Volume share of stone material $C_{KM/AU}$ in asphalt specimen presents the sum of stone skeleton share ($C_{KS/AU}$) and filler share ($C_{P/AU}$):

$$C_{KM/AU} = C_{KS/AU} + C_{P/AU} \tag{5}$$

Calculation of volume share of voids (air) $C_{Š/AU}$ in asphalt specimen according to HRN EN 12697-8 [4] requires data on spatial mass of asphalt specimen (ρ_{AU}), and density of asphalt mix (ρ_{AM}):

$$C_{\cdot\,/AU} = (1 - \frac{\rho_{AU}}{\rho_{AM}}) * 100 \tag{6}$$

Volume share of bitumen in asphalt specimen $_{CB/AU}$ is calculated as per the following relation:

$$C_{B/AU} = \frac{\%MAS_{B/AM}}{\rho_B} * \rho_{AU} \tag{7}$$

where:
- $\%mas_{B/AM}$ – mass percentage of bitumen in asphalt mix
- ρ_B – density of bitumen

3 Determination of asphalt resistance to permanent deformity

Method of determining the asphalt resistance to permanent deformity is defined in the harmonised standard HRN EN 12697-22 [5]. According to the above-mentioned standard, the small size measuring device for testing of asphalt rutting when testing procedure B (in the air) is implemented, is called Wheel Tracker (Figure 2).
The device is composed of a 47 mm wide rubber wheel of 203 cm in diameter, which applies the load of 700 N to the tested specimen. The length of wheel path is 230 mm and the testing temperature is 60 ºC; furthermore, prior to testing the specimen is tempered at the same temperature. Frequency of application of the load is 26.5 passes per minute and the total number of passes of the testing wheel amounts to 20 000 cycles, i.e. 10 000 cycles.

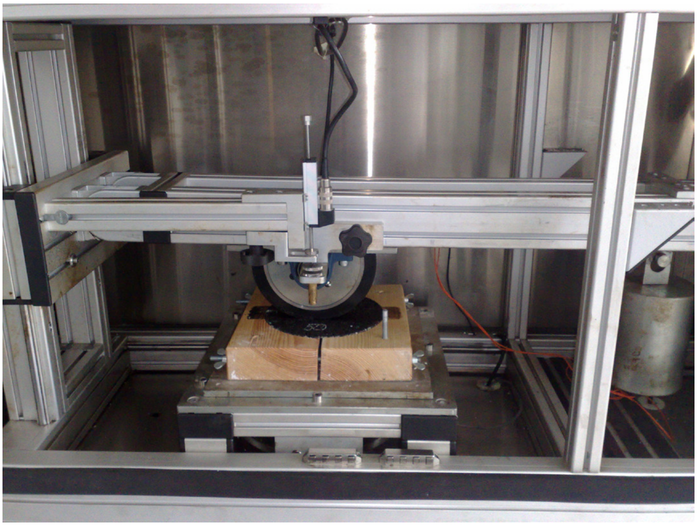

Figure 2 Wheel Tracker

3.1 Optimisation of asphalt mix composition

Asphalt-concrete AB 11 is the asphalt mix which has been used for testing of required characteristics; the mix was composed of stone material of eruptive origin, taken from Hruškovec quarry, Šumber stone dust and BIT 50/70 paving bitumen. Density of subfractions (0.09; 0.25; 071; 2; 4; 8 and 11.2 mm) was determined after sieving of stone material. Three asphalt mixes were prepared in order to select the optimal composition [Table 1]. The mixes had the same size distribution of stone skeleton, and the shares of filler in asphalt mix varied ($\%mas_{P/AM}$), as well as the share of bitumen ($\%mas_{B/AM}$). The relation (6) was used to determine the content of voids ($C_{Š/AU}$) on the prepared test Marshall specimens of different asphalt mixes. Calculation of share of voids was carried out based on previously tested density of asphalt mix (ρ_{AM}) and special mass of the resulting asphalt specimen (ρ_{AU}). In order to confirm the properties of the mix, the optimised composition of asphalt mix (AM4) was mixed with polymer-modified bitumen (PmB) and the share of voids was determined on the resulting asphalt specimen of the mix (AM5).

Table 1 Composition and properties of asphalt

Asphalt mix	$\%mas_{P/AM}$ [%(m/m)]	$\%mas_{B/AM}$ [%(m/m)]	ρ_{AM} [g/cm³]	ρ_{AU} [g/cm³]	$C_{Š/AU}$ [%(v/v]
AM1	10.7	3.6	2648	2429	8.3
AM2	9.4	7.2	2504	2455	2.0
AM3	9.0	5.1	2593	2466	5.0
AM4 -optimum	8.1	5.2	2581	2444	5.3
AM5 - PmB	8.5	5.3	2584	2468	4.5

The share of voids in asphalt specimen composed of selected stone skeleton, with share of filler ranging from 8 - 9 % and bitumen share amounting to 5.2% ±0.2%, meets requirements (according to General Technical Conditions / 2001 [6] the required range is 3.5 – 6.5 %).

Confirmation of optimised composition of asphalt mixture was obtained through testing of resistance of completed asphalt course on occurrence of permanent deformity by application of the rutting method. Asphalt mixes (AM) were prepared in laboratory mixer and asphalt courses were compacted into 305x305x50 mm large moulds, using roller compactor. Table 2 presents shares of filler, bitumen and voids in asphalt mixes with respective rutting parameters RD (total rut depth) and PRD (proportional rut depth).

Table 2 Asphalt mixes and relative rutting parameters

Asphalt mix	$\%mas_{P/AM}$ [%(m/m)]	$\%mas_{B/AM}$ [%(m/m)]	$C_{Š/AU}$ [%(v/v)]	RD [mm]	PRD [%]
AM1	10.7	3.6	8.3	2.15	4.3
AM2	9.4	7.2	2.0	8.6	17.2
AM3	9.0	5.1	5.0	2.45	4.9

Figure 3 presents increasing of rut depth expressed through tested parameters (total rut depth – RD and proportional rut depth – PRD) depending on the increase of bitumen share in asphalt mix. It was established that in case of optimal share of bitumen amounting to 5.1% (AM3), the depth of ruts meets requirements (RD=2.45 mm; PRD=4.9%), since according to the suggestions of the Technical regulation for asphalt pavement courses [7] the value of PRD should be ≤7%.

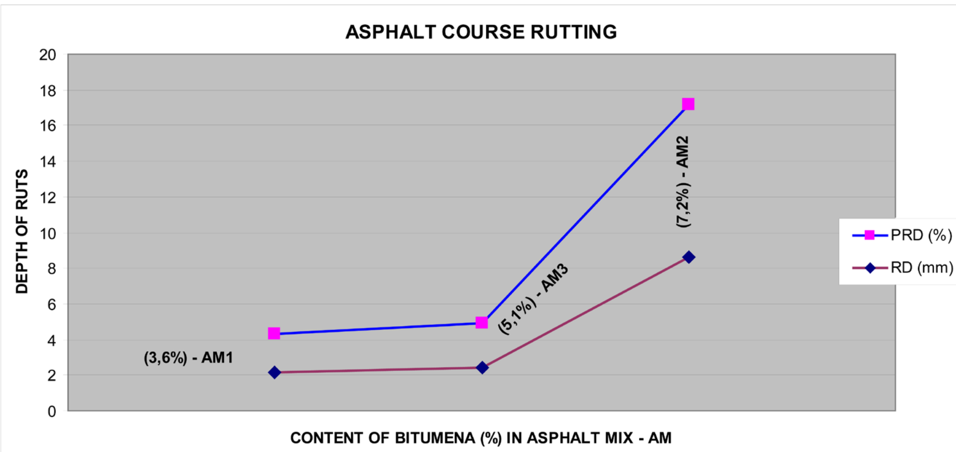

Figure 3 Dependence of the depth of ruts in asphalt course on share of bitumen

Taking into consideration the share of voids in asphalt mix specimen and determined parameters of rutting depth in tested asphalt courses, it was confirmed that the depth of ruts met requirements in case of specimens of asphalt mix which had the prescribed share of voids (AM3) (figure 4).

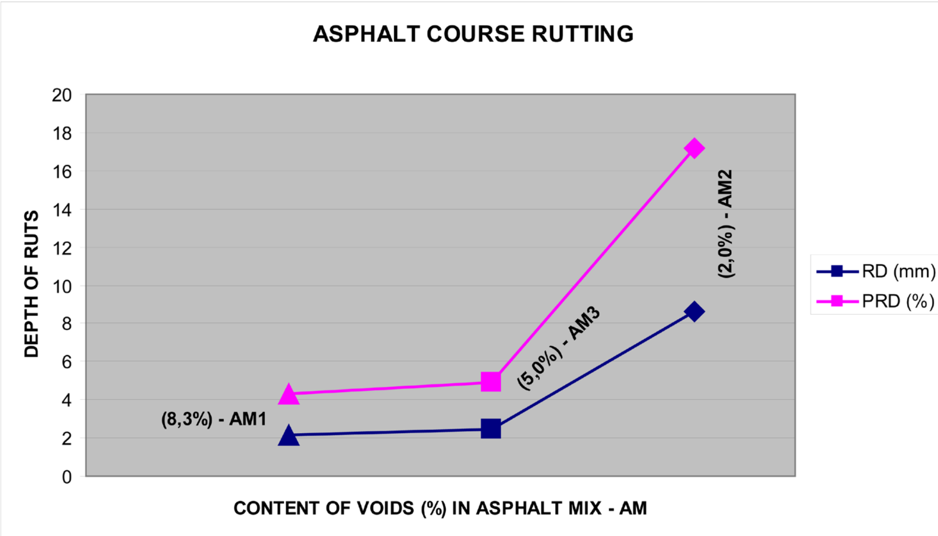

Figure 4 Dependence of the depth of ruts in asphalt course on share of voids

3.2 Resistance of asphalt courses / systems to rutting

The research was continued by testing of optimised composition of asphalt mix (AM4-optimum) to resistance to rutting in courses and asphalt-waterproofing systems of different thicknesses.

The following combinations were prepared and tested:

- Single 50 mm thick asphalt course,
- Double asphalt course of total thickness of 75 mm (40+35),
- Double asphalt course of total thickness of 100 mm (50+50),
- Single 35 mm thick asphalt course on top of a waterproofing layer (2mm) and 38 mm thick concrete slab,
- Double asphalt course of total thickness of 60 mm (30+30) on top of a waterproofing layer (2mm) and 38 mm thick concrete slab.

System specimens were prepared by execution of waterproofing layers (epoxy + polyurethane with bitumen) on top of 305×305×38 mm large concrete slabs. Asphalt courses were executed subsequently in moulds of appropriate height, using roller compactor. Steel moulds were used, of 305×305 mm large plan area and of height of 50, 75 and 100 millimetres. Figure 5 presents determined values of rutting parameters (RD and PRD) for tested thicknesses of single or double asphalt courses, executed individually or in waterproofing system on concrete slabs. The best resistance to rutting was determined in double asphalt course of total thickness of 50+50 mm, and the lowest resistance to rutting was determined in a single asphalt course of minimal technological thickness of 35 mm, executed on top of waterproofing layer* and concrete slab**. Double asphalt course of minimal technological thickness of 30+30 mm in waterproofing system shows lower resistance to rutting than a single 50 mm thick asphalt course or a double asphalt course of total thickness of 75 mm. It is obvious that waterproofing has a significant influence to the decreasing of asphalt resistance to rutting.

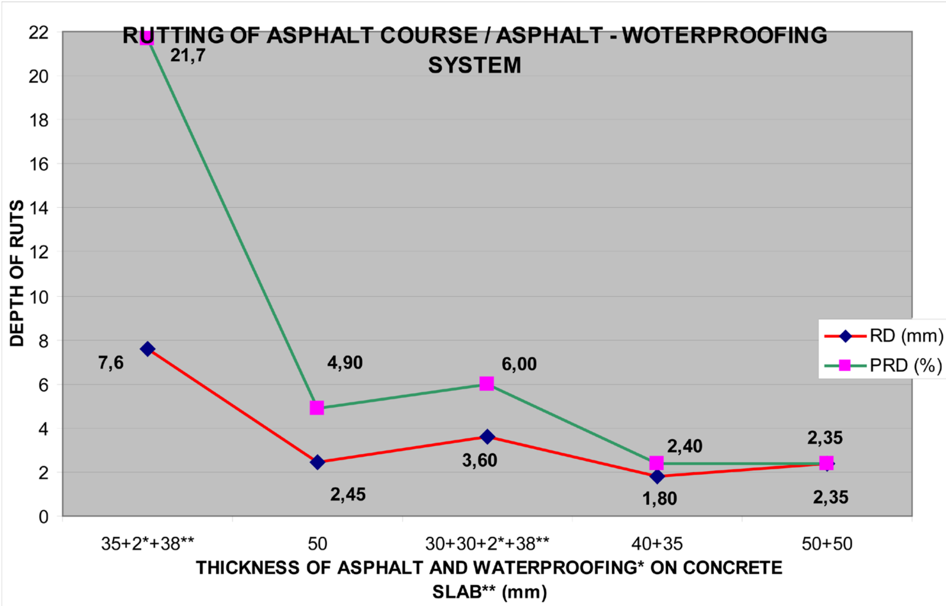

Figure 5 Dependence of depth of ruts on thickness of asphalt/waterproofing systems

4 Conclusion

The research confirmed the established experience that asphalt mix of optimum composition and prescribed physical-mechanical properties meets requirements of resistance of asphalt courses to permanent deformities in the form of rutting. Application of standardised testing method in testing of asphalt resistance to rutting serves for determination of required quality and durability of asphalt pavement. Application of this method of laboratory testing results in rationalisation, i.e. optimisation, of composition and properties of asphalt mix, taking into consideration the expected exploitation properties of pavement structure.

Influence of waterproofing in asphalt-waterproofing systems to reduction of rutting resistance urges caution in designing of pavements on bridges. The behaviour of asphalt in systems such as those executed in pavement structures of bridges, as well as the influence of waterproofing layers which are predominantly bitumen-based, have a significant influence to the exploitation level of pavement surface of a certain road.

Further research shall be directed to testing of possible improvement of asphalt-waterproofing systems' resistance to occurrence of permanent deformities through usage of polymer-modified bitumen.

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