



**CETRA** 2018

5<sup>th</sup> International Conference on Road and Rail Infrastructure  
17–19 May 2018, Zadar, Croatia

## Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR



**FEHRL**

Organizer  
University of Zagreb  
Faculty of Civil Engineering  
Department of Transportation



**CETRA**<sup>2018</sup>

**5<sup>th</sup> International Conference on Road and Rail Infrastructure**

17–19 May 2018, Zadar, Croatia

TITLE

Road and Rail Infrastructure V, Proceedings of the Conference CETRA 2018

EDITED BY

Stjepan Lakušić

ISSN

1848-9850

ISBN

978-953-8168-25-3

DOI

10.5592/CO/CETRA.2018

PUBLISHED BY

Department of Transportation

Faculty of Civil Engineering

University of Zagreb

Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE

minimum d.o.o.

Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY

“Tiskara Zelina”, May 2018

COPIES

500

Zagreb, May 2018.

Although all care was taken to ensure the integrity and quality of the publication and the information herein, no responsibility is assumed by the publisher, the editor and authors for any damages to property or persons as a result of operation or use of this publication or use the information's, instructions or ideas contained in the material herein.

The papers published in the Proceedings express the opinion of the authors, who also are responsible for their content. Reproduction or transmission of full papers is allowed only with written permission of the Publisher. Short parts may be reproduced only with proper quotation of the source.

Proceedings of the  
5<sup>th</sup> International Conference on Road and Rail Infrastructures – CETRA 2018  
17–19 May 2018, Zadar, Croatia

# Road and Rail Infrastructure V

**EDITOR**

Stjepan Lakušić  
Department of Transportation  
Faculty of Civil Engineering  
University of Zagreb  
Zagreb, Croatia

## ORGANISATION

### CHAIRMEN

Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering  
Prof. emer. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering

### ORGANIZING COMMITTEE

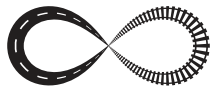
Prof. Stjepan Lakušić  
Prof. emer. Željko Korlaet  
Prof. Vesna Dragčević  
Prof. Tatjana Rukavina  
Assist. Prof. Ivica Stančerić  
Assist. Prof. Maja Ahac  
Assist. Prof. Saša Ahac  
Assist. Prof. Ivo Haladin  
Assist. Prof. Josipa Domitrović  
Tamara Džambas  
Viktorija Grgić  
Šime Bezina  
Katarina Vranešić  
Željko Stepan

Prof. Rudolf Eger  
Prof. Kenneth Gavin  
Prof. Janusz Madejski  
Prof. Nencho Nenov  
Prof. Andrei Petriaev  
Prof. Otto Plašek  
Assist. Prof. Andreas Schoebel  
Prof. Adam Szeląg  
Brendan Halleman

### INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Stjepan Lakušić, University of Zagreb, president  
Borna Abramović, University of Zagreb  
Maja Ahac, University of Zagreb  
Saša Ahac, University of Zagreb  
Darko Babić, University of Zagreb  
Danijela Barić, University of Zagreb  
Davor Brčić, University of Zagreb  
Domagoj Damjanović, University of Zagreb  
Sanja Dimter, J. J. Strossmayer University of Osijek  
Aleksandra Deluka Tibljaš, University of Rijeka  
Josipa Domitrović, University of Zagreb  
Vesna Dragčević, University of Zagreb  
Rudolf Eger, RheinMain Univ. of App. Sciences, Wiesbaden  
Adelino Ferreira, University of Coimbra  
Makoto Fujii, Kanazawa University  
Laszlo Gaspar, Széchenyi István University in Győr  
Kenneth Gavin, Delft University of Technology  
Nenad Gucunski, Rutgers University  
Ivo Haladin, University of Zagreb  
Staša Jovanović, University of Novi Sad  
Lajos Kisgyörgy, Budapest Univ. of Tech. and Economics

Anastasia Konon, St. Petersburg State Transport Univ.  
Željko Korlaet, University of Zagreb  
Meho Saša Kovačević, University of Zagreb  
Zoran Krakutovski, Ss. Cyril and Methodius Univ. in Skopje  
Dirk Lauwers, Ghent University  
Janusz Madejski, Silesian University of Technology  
Goran Mladenović, University of Belgrade  
Tomislav Josip Mlinarić, University of Zagreb  
Nencho Nenov, University of Transport in Sofia  
Mladen Nikšić, University of Zagreb  
Andrei Petriaev, St. Petersburg State Transport University  
Otto Plašek, Brno University of Technology  
Mauricio Pradena, University of Concepcion  
Carmen Racanel, Tech. Univ. of Civil Eng. Bucharest  
Tatjana Rukavina, University of Zagreb  
Andreas Schoebel, Vienna University of Technology  
Ivica Stančerić, University of Zagreb  
Adam Szeląg, Warsaw University of Technology  
Marjan Tušar, National Institute of Chemistry, Ljubljana  
Audrius Vaitkus, Vilnius Gediminas Technical University  
Andrei Zaitsev, Russian University of transport, Moscow



## HOT ASPHALT MIXTURE CONTAINING WASTE PRODUCTS

Roxana Ungureanu<sup>1</sup>, Carmen Răcănel<sup>2</sup>, Georgeta Grîsîc<sup>1</sup>

<sup>1</sup> Centre for Road Technical Studies and Informatics, Bucharest, Romania

<sup>2</sup> Technical University of Civil Engineering Bucharest, Romania

### Abstract

The use of waste materials to obtain new products with significant potential to replace conventional materials in road construction has two big advantages: protecting the environment and conserving natural resources. Blast furnace slag is the most important by-product of the steel industry, through the available quantity, through existing and potential reuse fields. Also, over time researchers demonstrated that asphalt mixtures prepared with polymer modified bitumen make their performance improved and increase the lifetime of the road. A considerable source of polymer for the modification of road bitumen are the used tires and by recycling them, it is obtained the crumb rubber. The main purpose of this study is to evaluate the behaviour of two asphalt mixture recipes: one for binder course (AC22.4) and one for base course (AC25) with blast furnace slag and crumb rubber in different percentages. The laboratory tests were performed according European norms, in the Roads Laboratory of Centre for Road Technical Studies and Informatics. For the sample preparation, the crumb rubber was added directly in the bitumen (wet procedure) and natural aggregates were successfully replaced by blast furnace slag. In this paper, results and analyses from laboratory tests are presented, by comparing the initial recipes, without waste materials, with the ecological recipes.

*Keywords: asphalt mixture, blast furnace slag, crumb rubber*

### 1 Introduction

The priority trend of road builders and road managers is to produce road pavement with improved performance regarding aging and fatigue resistance, better behavior both in summer and winter, as well as increased values for dynamic properties. In this regard, there is a permanent concern to find new materials and technologies for the preparation of asphalt mixtures, which give the layers the desired properties.

The current trend in the world is the development of road structures from composite asphalt mixtures where, in addition to classical materials, fillers or reinforcing materials are generally added in the form of powders, granules, fibers. These new materials can be of the most diverse classes of chemical compounds, inorganic (glass, asbestos, ceramics) and organic (natural and / or synthetic polymers).

The notion of “green composite asphalt” is a new concept, emerging from the need to produce sustainable and durable road pavement, but also the need to use the industry's waste, which “suffocates” and pollutes the environment more and more aggressively.

Blast furnace slag is the most important by-product of the steel industry, through the available quantity, through existing and potential reuse fields. Iron blast furnace slag results from the fusion of fluxing stone with coke ash and the siliceous and aluminous residues remaining after the reduction and separation of iron from the ore. The blast furnace operation is a continuous process with the carefully controlled raw materials being fed in (burden) and the uniform products, molten iron and liquid slag, being drawn off at regular intervals. Selective

cooling of the liquid slag results in four distinct types of blast furnace slag: (1) air-cooled (solidification under ambient conditions), which finds extensive use in conventional aggregate applications; (2) expanded or foamed (solidified with controlled quantities of water, sometimes with air or steam), which is mainly used as a lightweight aggregate; (3) granulated (solidified by quick water-quenching to vitrified (glassy state), which is mainly used in blended cement manufacture; and (4) pelletized (solidified by water and air-quenching in conjunction with a spinning drum), which is used both as a lightweight aggregate and in blended cement manufacture. Air cooled blast furnace slag is used as aggregate in granular base, hot mix asphalt and portland cement concrete, [1, 2].

The first experiences in the application of slag as an aggregate in asphalt mixtures date from 1969, when a trial road section was built in Toronto, on which steel slag was utilized as an aggregate in base courses and road asphalt surfaces. The studied asphalt mixtures have demonstrated very good properties in terms of bearing capacity, resistance to external impacts, and durability, [3].

Crumb rubber is a material obtained from grinding used tyres. Due to the high content of thermoplastic polymer, it can be used in road construction for the preparation of asphalt mixtures with modified bitumen that have improved characteristics in terms of traffic behavior, fatigue strength and permanent deformations. In addition, technologies that manage to use non-degradable waste in the manufacturing process, turning them into a useful product, align with the current trend for greening and environmental protection, [4].

Lundy et al. presented three case studies using crumb rubber with both the wet process and dry process at Mt. St. Helens Project, Oregon Dot and Portland Oregon. The results showed that even after a decade of service crumb rubber products have excellent resistance to thermal cracking. Although, asphalt-rubber mixtures can be built successfully, quality control ought to be maintained for good performance. Rubber Pavement Association found that using tyre rubber in open-graded mixture binder could decrease tyre noise by approximately 50 %. Also, in spray applications, rubber particles of multiple sizes had better sound absorption. The benefits of using crumb rubber modified bitumen are lower susceptibility to varying temperature on a daily basis, more resistance to deformation at higher pavement temperature, proved age resistance properties, higher fatigue life for mixes, and better adhesion between aggregate and binder. Ever since then, the use of crumb rubber has gained interest in pavement modification as it is evident that crumb tyre rubber can improve the bitumen performance properties [5].

Studies [6] shows how asphalt mixes with polymer modified bitumen and those with granular furnace slag would be the most environmentally damaging.

Other research conducted by the authors [7-9] leads to the main conclusion that partial or total substitution of calcareous aggregates significantly affects physical and mechanical characteristics of the asphalt mix. Better results were obtained by replace one limestone fraction 16/31.5 with slag and by replace 50 % limestone with 50 % slag for each aggregate fraction. Also, adding polymer and crumb rubber in asphalt mixture leads to an improvement of bitumen characteristics.

## 2 Objective

The main purpose of this study is to evaluate the behaviour of two asphalt mixture recipes (AC22.4 notted by "A" and AC25 notted by "X") for binder course and for base course with blast furnace slag and crumb rubber in different percentages.

The laboratory tests were performed according European norms, in the Roads Laboratory of Centre for Road Technical Studies and Informatics.

### 3 Used materials and asphalt mixture recipe

The materials used to prepare the asphalt mixtures recipes for this study are presented in table 1. The grading curve for asphalt mixture meets the European norm requirements and the Romanian standard requirements, too. Starting from the initial recipes (A and X), without any recyclable wastes, natural aggregates were partially replaced with blast furnace slag, than crumb rubber was added directly in the bitumen using wet procedure, in two different percentages: 0.8 % and 0.5 % (table 2 and table 3).

**Table 1** The used materials in asphalt mix recipe

AC22.5	AC25
Aggregate crushed rock from Niculitel Quarry	Aggregate crushed rock from Soimos Quarry
Blast furnace slag from Arcelor Mittal Galati	
Limestone filler from Holcim	
Bitumen OMV 50/70	Bitumen ORLEN 50/70 + 0.5 % ADETEN 03-800 additive

**Table 2** Recipes for binder course

Asphalt mixture	Recipe	Content of waste products
AC 22.4	A	- (the control asphalt mixture)
	B	21 % slag by mix (total replacement of fraction 4-8)
	B1	21 % slag by mix (total replacement of fraction 4-8) + 0.8 % crumb rubber
	B2	21 % slag by mix (total replacement of fraction 4-8) + 0.5 % crumb rubber
	C	43 % slag by mix (total replacement of fraction 4-8 and 8-16)
	C1	43 % slag by mix (total replacement of fraction 4-8 and 8-16) + 0.8 % crumb rubber
	C2	43 % slag by mix (total replacement of fraction 4-8 and 8-16) + 0.5 % crumb rubber

**Table 3** Recipes for base course

Asphalt mixture	Recipe	Content of waste products
AC 25	X	- (the control asphalt mixture)
	Y	18 % slag by mix (total replacement of fraction 4-8)
	Y1	18 % slag by mix (total replacement of fraction 4-8) + 0.8 % crumb rubber
	Y2	18 % slag by mix (total replacement of fraction 4-8) + 0.5 % crumb rubber
	Z	32 % slag by mix (total replacement of fraction 4-8 and 8-16)
	Z1	32 % slag by mix (total replacement of fraction 4-8 and 8-16) + 0.8 % crumb rubber
	Z2	32 % slag by mix (total replacement of fraction 4-8 and 8-16) + 0.5 % crumb rubber

### 4 Experimental study and results

In order to determine the influence of waste materials on asphalt mixture behaviour, in the Roads Laboratory of CESTRIN were performed the following tests:

- Bulk density according to EN 12697-6;
- Marshall test on cylindrical specimens, according to EN 12697-34, at 60°C test temperature;
- Air void content, according to EN 12697-8;
- Stiffness test, according to EN 12697-26 Annex C, at 20°C test temperature;
- Water sensitivity according to EN 12697-12 and EN 1697-23.

The results regarding the performance of asphalt mixtures containing waste products are presented as graphs in Figure 1 – Bulk density, Figure 2 – Marshall Stability, Figure 3 – Air void content, Figure 4 – Stiffness and Figure 5 – Water sensitivity ITSR.

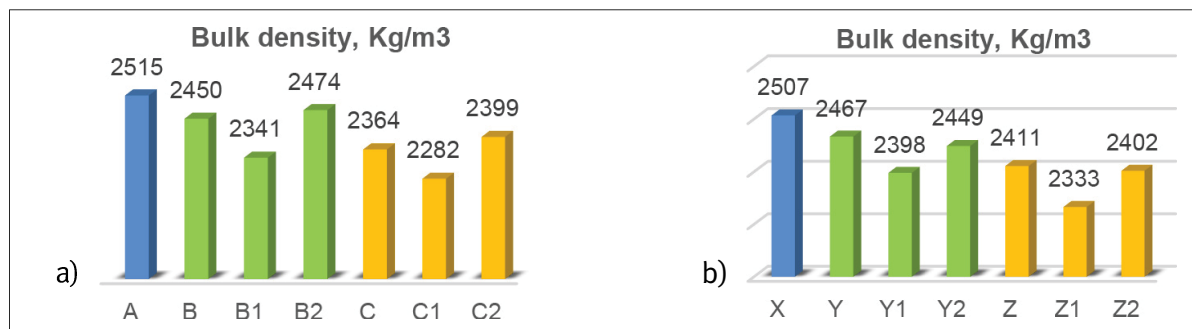


Figure 1 Bulk density: a) for binder course; b) for base course

Figure 1 shows that bulk density for the control recipes is lower than those obtained for mixture with blast furnace slag and crumb rubber. Also, the value of bulk density of mixtures containing 0.5 % crumb rubber is higher than bulk density for asphalt mixture with a higher percentage of crumb rubber (0.8 %).

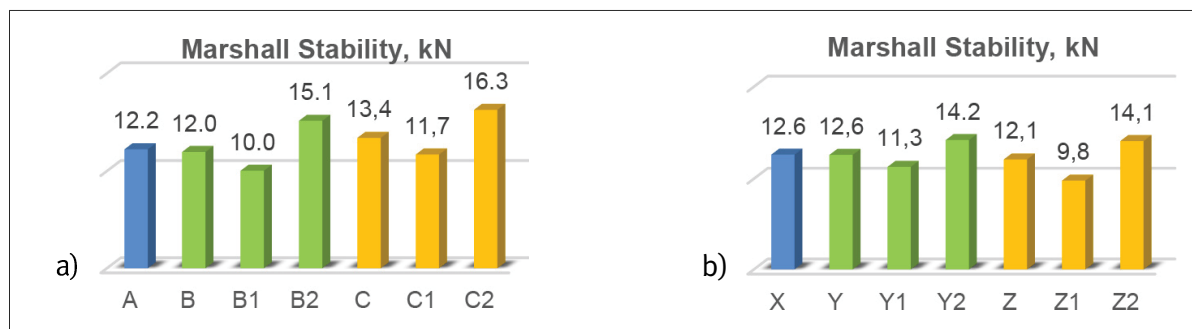


Figure 2 Marshall Stability: a) for binder course; b) for base course

It appears from Figure 2 that generally, Marshall Stability has close values for the initial recipes and the asphalt mixtures containing blast furnace slag. The crumb rubber seems to have an important role for the Marshall test. The values obtained for the Marshall Stability of recipes with 0.8 % content of crumb rubber are lower than the control recipes, and for 0.5 % crumb rubber, Marshall Stability increased.

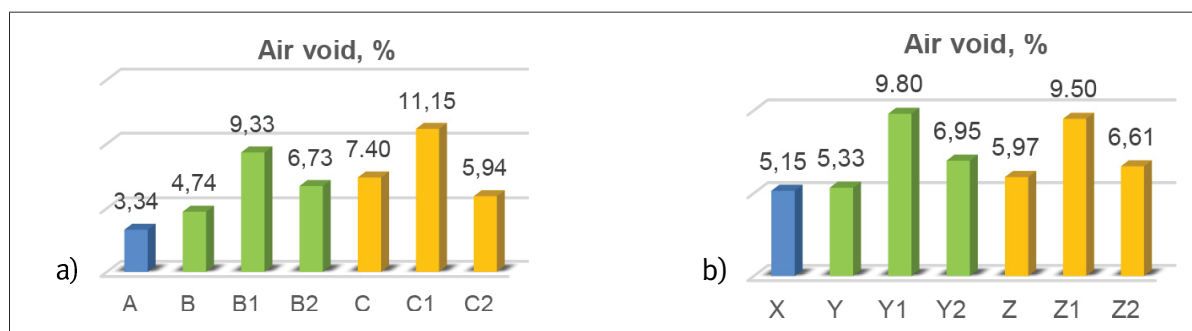


Figure 3 Air void content: a) for binder course; b) for base course

Air void for asphalt mixtures with slag is higher than air void for asphalt mixture with natural aggregate. Also, the use of crumb rubber influences the air void content. For the binder course, values obtained for mixture containing 0.8 % crumb rubber are higher than the control



recipe by approximately 180 %-230 %. The same trend can be observed for the base course, where the air void is higher by approximately 85 %-90 %.

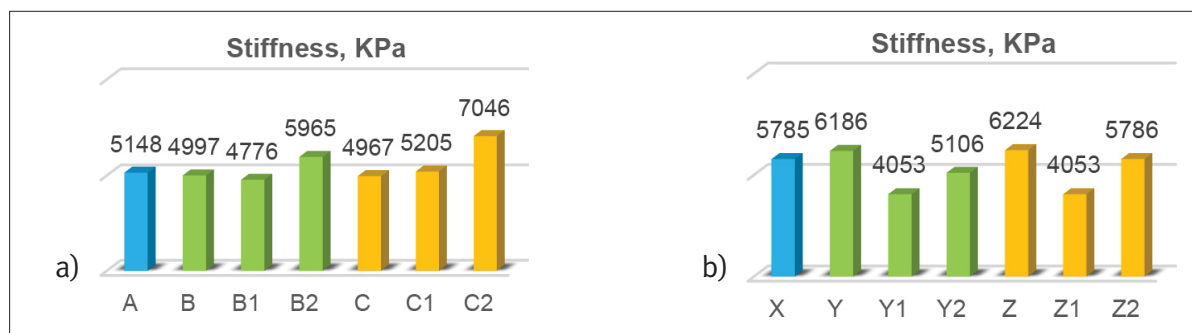


Figure 4 Stiffness: a) for binder course; b) for base course

As shown in Figure 4, the value of stiffness modulus for AC 22.4 without waste products is close to those obtained for mixture with blast furnace slag and crumb rubber (0.8 %), and higher values are obtained when recipes have a lower content of crumb rubber (0.5 %). For AC 25, stiffness modulus for asphalt mixture with blast furnace slag is higher than stiffness modulus for asphalt mixture with natural aggregate by approximately 7 %. By adding crumb rubber, stiffness modulus decreases between 12 %-30 %.

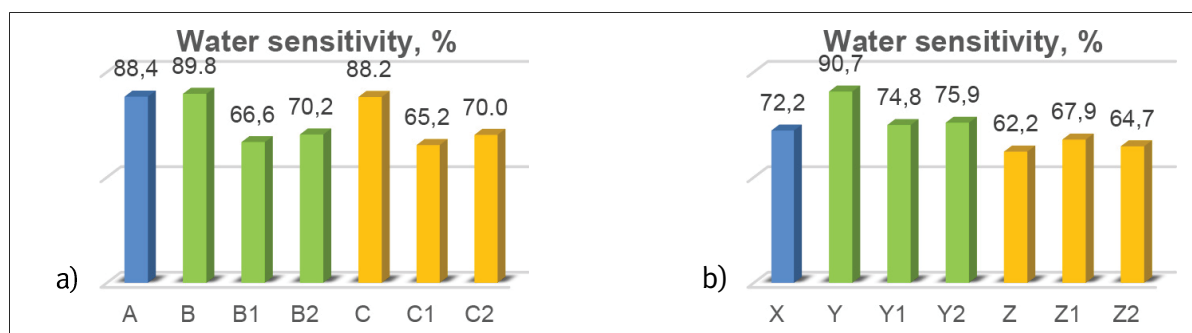


Figure 5 Water sensitivity: a) for binder course; b) for base course

According to national norm, water sensitivity for binder course and for base course should be min. 80 %. Figure 5 a) shows that the original mixture (A) and the recipes with blast furnace slag meet this condition. Water sensitivity decreases between 20 %-26 % when crumb rubber is added. In case of the recipes studied for the base course, utilization of waste products improves water sensitivity value only for the recipes with fraction 4-8 replaced with blast furnace slag. When we replace fraction 4-8 and fraction 8-16, water sensitivity is lower than the control recipe (X). Generally, when only blast furnace slag was added in the mixture, water sensitivity is increasing. This behavior may be due to the chemical composition of the blast furnace slag which has latent hydraulic properties, hardens in the presence of water and improves its mechanical properties.

## 5 Conclusions

Today, a serious problem that leads to environment pollution is the abundance and increase of waste materials. For the research study presented in this paper, there are two asphalt mixtures with natural aggregates as reference mixtures, one for binder course, and one for base course. For the other recipes presented during the study, conventional aggregates were replaced by blast furnace slag. Also, crumb rubber was added in the bitumen.

Laboratory tests performed leads to the conclusion that mixture has comparative results with the control recipes, excepting the values for water sensitivity. When 0.5 % crumb rubber is added in the mixture, better values for Marshall Stability and stiffness modulus are obtained. Utilising blast furnace slag and crumb rubber is not only beneficial in terms of cost reduction but also has less ecological impact in keeping the environment clean and to achieve better balance of natural resources.

Further will be necessary in order to study in laboratory the fatigue and permanent deformation behaviour of asphalt mixture with blast furnace slag and crumb rubber.

## Acknowledgments

The authors would like to thank UEFISCDI, Education and Research Ministry from Romania for contract no. PCCA 101/2013, PN II Program for the support of this work. Thanks are also expressed to the company Arcelor Mittal for providing the blast furnace slag.

## References

- [1] Blast furnace Slag (National slag association), <http://www.nationalslag.org/blast-furnace-slag>
- [2] Emery, J.: Steel slag utilization in asphalt mixes, [http://www.nationalslag.org/sites/nationalslag/files/documents/nsa\\_186-1\\_steel\\_slag\\_utilization\\_in\\_asphalt\\_mixes.pdf](http://www.nationalslag.org/sites/nationalslag/files/documents/nsa_186-1_steel_slag_utilization_in_asphalt_mixes.pdf)
- [3] Ovidijus, Š.: The Influence of Crumb Rubber on Modified Bitumen Properties, “Environmental Engineering” 10<sup>th</sup> International Conference, Vilnius Gediminas Technical University, Lithuania, 27–28 April 2017, DOI: <https://doi.org/10.3846/enviro.2017.147>
- [4] Barišić, I.: Possibilities of application of slag in road construction, Technical gazette, 17(4), December 2010, pp. 523-528
- [5] Nuha, S. M.: A Review on Using Crumb Rubber in Reinforcement of Asphalt Pavement, The Scientific World Journal, 2014, doi: 10.1155/2014/214612
- [6] Popescu, D., Burlacu, A.: “Ecological solutions applied on hot mix asphalt”, ROMANIAN JOURNAL OF TRANSPORT INFRASTRUCTURE, Vol.4, July 2016, No.1, ISSN 2286-2218, ISSN-L 2286-2218
- [7] Racanel, C., Burlacu, A.: Ecological asphalt mixtures with blast furnace slag, 16th Geo Conference – “International Multidisciplinary Scientific Geo Conference SGEM Albena, Bulgaria, 30 june – 6 july 2016 ISBN 978-619-7105-64-3, ISSN 1314-2704, DOI: 10.5593/sgem2016B42, pp.33-40.
- [8] Racanel, C., Burlacu, A.: Using crumb rubber in warm asphalt concrete, 15th Geo Conference – “International Multidisciplinary Scientific Geo Conference SGEM Albena, Bulgaria, 18 – 24 june 2015 (factor impact 3) ISBN 978-619-7105-38-4, ISSN 1314-2704, DOI: 10.5593/sgem2015B41, pp. 795-802.
- [9] Cătălina Lixandru, C., Dicu, M., Racanel, C., Burlacu, A.: “Ecological solutions applied on hot mix asphalt”, ROMANIAN JOURNAL OF TRANSPORT INFRASTRUCTURE, Vol.4, July 2015, No.1, ISSN 2286-2218, ISSN-L 2286-2218