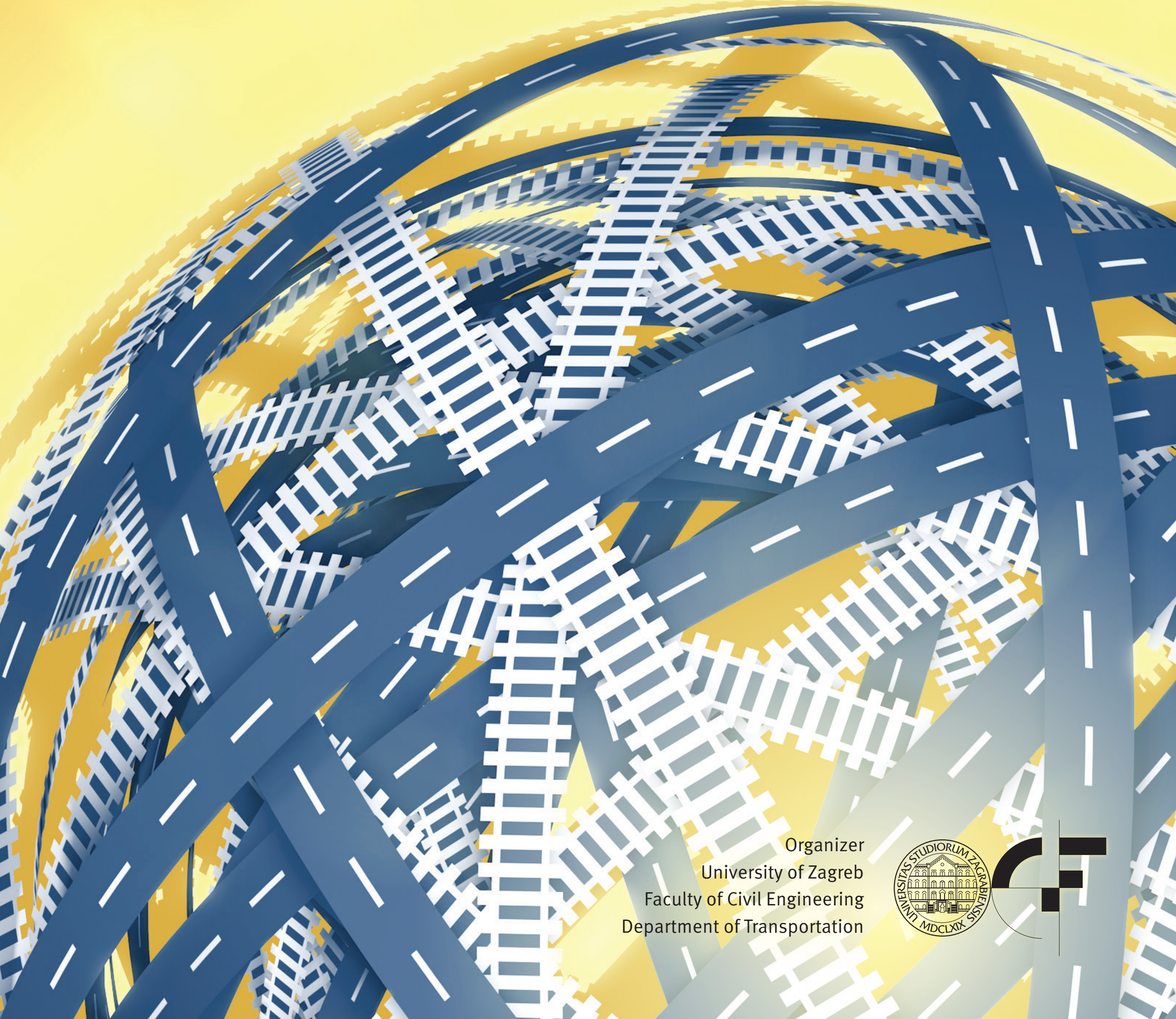
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA^{2016}
4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

TITLE
Road and Rail Infrastructure IV, Proceedings of the Conference CETRA 2016

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

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 2016

COPIES
400

Zagreb, May 2016.

Proceedings of the
4th International Conference on Road and Rail Infrastructures – CETRA 2016
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

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. Saša Ahac

Assist. Prof. Maja Ahac
Ivo Haladin, PhD
Josipa Domitrović, PhD
Tamara Džambas
Viktorija Grgić
Šime Bezina

All members of CETRA 2016 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Davor Brčić, University of Zagreb
Dražen Cvitanić, University of Split
Sanja Dimter, Josip Juraj Strossmayer University of Osijek
Aleksandra Deluka Tibljaš, University of Rijeka
Vesna Dragčević, University of Zagreb
Rudolf Eger, RheinMain University
Makoto Fujiu, Kanazawa University
Laszlo Gaspar, Institute for Transport Sciences (KTI)
Kenneth Gavin, University College Dublin
Nenad Gucunski, Rutgers University
Libor Izvolt, University of Zilina
Lajos Kisgyörgy, Budapest University of Technology and Economics
Stasa Jovanovic, University of Novi Sad
Željko Korlaet, University of Zagreb
Meho Saša Kovačević, University of Zagreb
Zoran Krakutovski, Ss. Cyril and Methodius University in Skopje
Stjepan Lakušić, University of Zagreb
Dirk Lauwers, Ghent University
Dragana Macura, University of Belgrade
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
Dunja Perić, Kansas State University
Otto Plašek, Brno University of Technology
Carmen Racanel, Technological University of Civil Engineering Bucharest
Tatjana Rukavina, University of Zagreb
Andreas Schoebel, Vienna University of Technology
Adam Szeląg, Warsaw University of Technology
Francesca La Torre, University of Florence
Audrius Vaitkus, Vilnius Gediminas Technical University

CETRA2016 23–25 May 2016, Šibenik, Croatia
4th International Conference on Road and Rail Infrastructure

POROSITY EFFECT ON PHYSICAL AND MECHANICAL PROPERTIES OF PERVIOUS CONCRETE PAVEMENT

Miloš Šešlija, Vlastimir Radonjanin, Nebojša Radović, Đorđe Lađinović
Faculty of Technical Sciences, University of Novi Sad, Serbia

Abstract

The paper presents the results of previous researches of different mixtures of pervious concrete pavements in the world, as well as the advantages and disadvantages of the structural formation on the mechanical properties of porous concrete. The porosity of pervious concrete ranges from 15% to 35%. The most important properties of pervious concrete pavement were analyzed: compressive strength, flexural strength, splitting tensile strength, frost resistance and abrasion resistance. Different types of aggregates (natural, recycled), different fractions and granulometric composition of aggregates, different amounts of fine aggregate, different types and amounts of additives in pervious concrete and various water-cement ratio, were used in the analyzed studies. According to obtained results, the relationship between the most important properties of pervious concrete and its porosity was established. It was concluded that increasing of the porosity directly affects to decreasing of the concrete compressive strength and frost resistance, while abrasion resistance is increasing.

Keywords: pervious concrete, porosity, physical and mechanical properties

1 Introduction

The pervious concrete pavement is a special form of concrete pavement, which is mostly used in the United States, a little less in Europe, while in Serbia there are still no application and research of this type of concrete. It is the concrete which has a distinct porosity and therefore leaks water, reduces noise, reduces the need for building of system for water drainage from the roadway, facilitates water purification, etc. With the aspects of preserving the natural environment the pervious concrete is quite beneficial compared to other types of road surfaces. The first application of the pervious concrete occurs in 1852 for the building of two houses in the UK, this concrete is composed of coarse gravel and cement [1, 2]. Then appears in the construction of houses in Scotland 1874-5 and the other buildings till the period of 1890 [3]. In the Netherlands, after World War I, it was first used and made of crushed brick as aggregate with the addition of cement [4]. The pervious concrete is a mixture of cement, water and one fraction aggregates which does not contain the fine particles of aggregates. Contains a large amount of voids, which leads to a reduction of strength and weight [5, 6]. Pervious concrete has different names in English, for example no-fines concrete, pervious concrete, porous concrete and zero-fines concrete. These are the names can be found in worldwide literature and indicate already mentioned concrete [7]. The void content ranges from 15-35%, if its preparation is done in America, or 15-25% of void content if the pervious concrete is made in Europe [8]. The recommended aggregate sizes for this concrete are taken in a range of 9.5 to 19.5 mm, therefore completely omits small aggregate or added in the lower percentage. Due to such structure, the pervious concrete made with no additives has a relatively low compressive strength from 2.8 MPa do 28 MPa. In order to avoid the filling of pores with cement

paste, its amount is regulated by a lower water-cement factor, which is usually in the range from 0.26 to 0.50 [9].
The paper presents the different composition of the mixtures, the results of previous researches in the world, the advantages and disadvantages of the structural formation on the physica and mechanical properties of porous concrete.

2 Review of the mix composition and properties of pervious concrete

Analyzed articles in this area of the production and use of pervious concrete and related laboratory tests differ in the composition of the mixture and laboratory tests were carried out according to the research objectives of individual works. Detailed analysis of published papers dealing with this topic, showed the possibility of using pervious concrete for the construction of the parking areas and pavement on low traficked streets, the bicycle and pedestrian paths, tennis courts and the floors in greenhouses and breeding animal farms. Since the aggregate takes between 70-80% of the total concrete amount, aggregate strength greatly affects on the final strength of the concrete. Type of aggregate, aggregate fraction, as well as additives and its quantity are shown in Table 1, with indicated authors that have carried out studies of the pervious concrete.

Table 1 Composition mixture of pervious concrete

Ref.	Aggregation	Aggregate fraction [mm]	The chemical and /or mineral admixtures	Water-cement ratio
[10]	Granite	4.75-9.5	Silica fume, superplasticizer, fly ash, polymer	0.28-0.34
[11]	Limestone	4.75-12.5	Retarders, admixtures	0.29
	Sand	0-4		
[12]	Gravel	3-5; 5-10; 10-20, 15-30	Silica fume, superplasticizer, fly ash, polymer	0.20-0.35
	Sand	0-2.5		
[13]	Gravel	2.36-4.75, 4.75-9.5, 9.5-12.5	Synthetic rubber products, silica fume, air entraining admixtures, superplasticizer	0.22-0.27
	Limestone	4.75-9.5		
	Lightweight Aggregates	2.36-4.75, 4.75-9.5		
	Sand	0-1		
[14]	Gravel	1.18-9.5	Latex rubber, fibre, superplasticizer, air entraining admixtures, retarders	0.26-0.36
	Limestone	1.18-9.5, 2.36-9.5		
[15]	Gravel	10-12.5		0.27
	Recycled rubber products	0-1, 1-4, 4-8		
[16]	Gravel	10-12.5		0.27
	Recycled rubber products	0-1, 1-4, 4-8		

2.1 Compressive strength of pervious concrete

Based on all inspected papers [10-15] it can be noticed that compressive strength at 28 days ranges from 6.54 MPa to 61.2 MPa. Displayed compressive strength values are given based on different aggregation type, aggregate fraction, chemical/mineral admixtures and water-cement ratio (Table 1). It must be underlined that compressive strength of pervious concrete mainly depends on ratio between coarse aggregate and fine aggregate and water-cement ratio. Using coarse aggregate with fine aggregate, along with solid compacting, adequate water-cement ratio and admixtures, it can be accomplished significantly larger compressive strength values [10, 12] in comparison with expected values from papers. In the Figure 1 is summary of results from some of the considered papers and the dependence between compressive strength and void content of 28 day old concrete has been given. It is noticeable that there is a large dispersion of results and that is not possible to determine compressive strength as a function of void content. With decrease in void content there is increase in dispersion of results (so as vice versa).

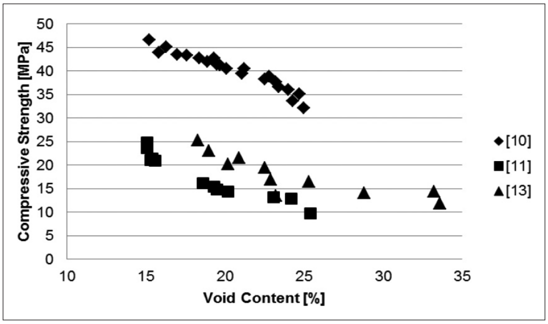


Figure 1 Plot of compressive strength as a function of void content

2.2 Flexural strength

The sharp shape and rough surface of crushed aggregate are favorable for an aggregate-cement paste bond, which affect the increase in flexural strength. Tested 28-day old samples have flexural strength in values between 0.4 – 8.5 MPa [10, 12, 16]. It has been used various aggregate fractions and admixtures for the preparation of mixtures, in a variety of test conditions (Table 1). With an increase in amount of rubber material [16] there is a decrease in value of flexural strength, and with an optimal amount of fine aggregate (sand) [12] there is significant increase in flexural strength. In considered papers it can be seen that the increasing of porosity decreases the flexural strength (and vice versa).

2.3 Splitting tensile strength

This type of test procedure has appeared much later than traditional tests for bending and nowadays is regarded as quite reliable measure for determining tensile strength of concrete. According to the papers [11, 13, 14], splitting tensile strength at 28 days ranges from 1 MPa to 4 MPa. The characteristic values are taken for the different aggregate fractions, with or without air entraining admixtures, and with or without recycled aggregate.

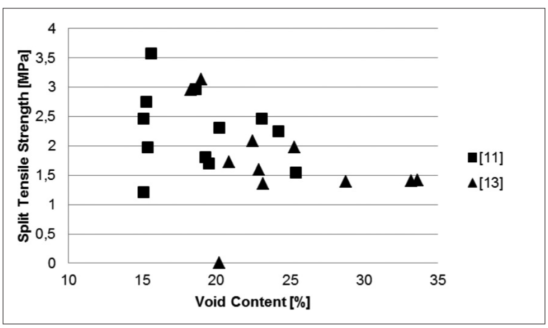


Figure 2 Plot of splitting tensile strength as a function of void content

Figure 2 shows the dependence of splitting tensile strength on the amount of pores for 28-day old samples. Considering all obtained results it can be seen that there is a large dispersion of the results for the same splitting tensile strength and porosity, so that it cannot be determined a particular correlation between previously mentioned parameters. It is impossible because of the participation of various types of aggregates, chemical and/or mineral admixtures, as well as various types of binders.

2.4 Abrasion resistance

Abrasion, as a way of mechanical process of wearing concrete away, is very important in assessing durability of concrete. This phenomenon usually appears in high-traffic areas, sidewalks and parking lots. Concrete is more resistant to abrasion with larger compressive strength, which means that it should be used crushed stone aggregate with less participation of fine aggregates, high-early strength cement and lower water-cement ratio. Therefore, superplasticizers and plasticizers are used to reduce the required amount of water, since in any case should not be allowed to come to the separation of the cement paste to the surface. Abrasion resistance has been analysed in papers [11] and [16], but the different aggregate types, fractions and number of cycles have been used. Figure 3 presents summarized results from the analyzed papers and shows the loss of weight as a percentage. Usage of reduced amounts of fine aggregate and adding admixtures [11] results with a smaller weight loss in comparison to samples which have a certain amount of fine aggregate fraction. Nevertheless, using recycled rubber [16] instead of natural aggregates also reduces the mass loss of samples.

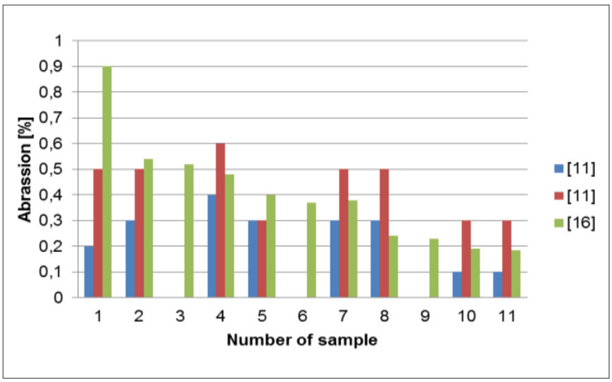


Figure 3 Abrasion test

2.5 Frost resistance

The main reasons for concrete destruction on lower temperatures are internal stresses that occur during freezing water in the pores of concrete. Volume of liquid water at room temperature will increase in volume by 9% after freezing, which generates internal stresses. However, in order to prevent the destruction of concrete, it is necessary to use sufficiently low water-cement ratio as well as various admixtures, especially air entraining admixtures. According to paper [11, 13, 14, 16] frost resistance is tested with about 300 freeze-thaw cycles. Figure 4 presents a plot of number of cycles as a function of mass loss. It is shown that frost resistance can be improved by using sand, recycled rubber as well as air entraining admixtures so that the number of freeze-thaw cycles can reach up to 300. According to mentioned Studies, the best frost-resistant mixtures consist of natural aggregates along with certain amount of sand and chemical admixtures (Table 1).

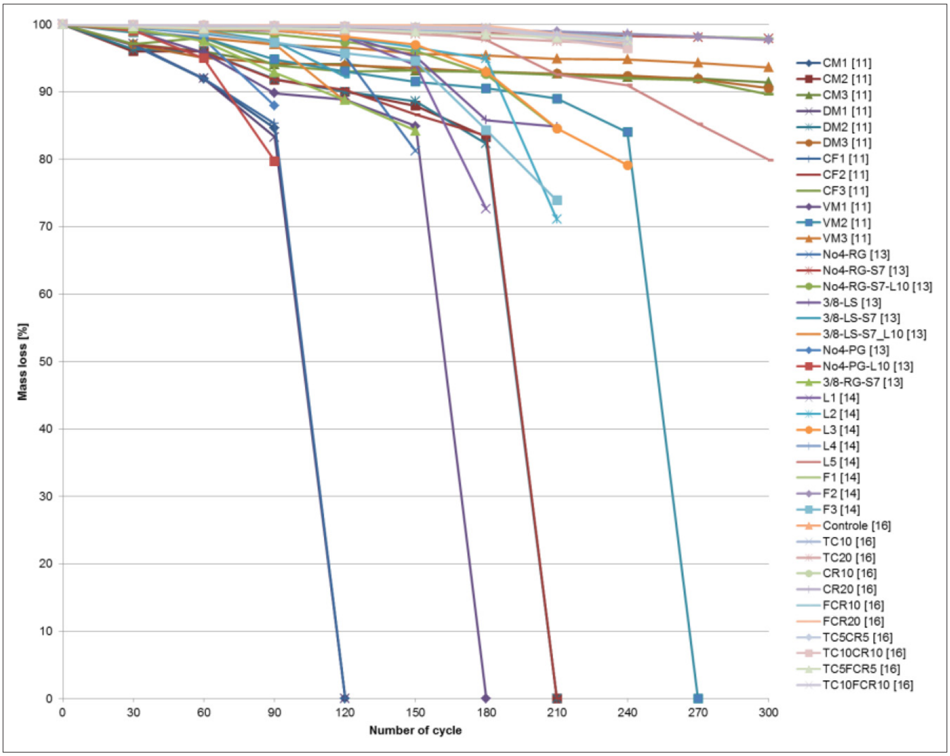


Figure 4 Frost resistance of pervious concrete at 28 days

2.6 Porosity

Pore size is one of the main factors which impacts on pervious concretes' properties. It is recommended large pore volume because they can prevent themselves from clogging [17]. Pore size increases with larger participation of coarse aggregate in coparison to fine aggregate. This is explained by the fact that between the large grains remain empty spaces [18]. Namely, porosity has an effect on flexural strength, compressive strength, splitting tensile strength and frost resistance. It has been shown that at a lower porosity, regardless of the type of aggregate that was used, compressive strength is higher. In case of using recycled aggregation there is about 60% lower compressive strength in comparison to mixtures with natural aggregation (with the same level of porosity). Type of aggregate (natural or recycled) has an effect on coefficient of permeability and porosity for pervious concrete mixtures.

3 Conclusions

The analyzed results can be summarized as follows:
- with the same level of porosity there have been different values of flexural strength, compressive strength and splitting tensile strength due to different water-cement ratio. With an increase in porosity there is a decrease in strength of pervious concrete.
- with larger participation of fine aggregate and higher water-cement ratio, the frost resistance is higher but the abrasion resistance is lower.
- porosity of pervious concrete is strongly affected by the type and fraction of aggregation, with taking into account that the minimal porosity for pervious concrete is 15%.

Properties of pervious concrete are strongly affected by the porosity along with type of aggregate, participation of fine aggregates, shape of aggregate grains, type of used admixtures, water-cement ratio etc. All the mentioned factors are in certain correlation and they need to be chosen in such a way that the higher values of flexural strength, compressive strength, splitting tensile strength, abrasion and frost resistance are achieved. If is used with improved properties, pervious concrete can be used in heavy traffic load as well.

4 References

[1] Ghafoori, N., Dutta, S.: "Laboratory Investigation of Compacted No-Fines Concrete for Paving Materials", Journal of Materials in Civil Engineering, 7 (1995) 3., pp. 183-191.

[2] Patil, V.R., Gupta, A.K., Desai, D.B.: "Use of Pervious Concrete in Construction of Pavement for Improving their Performance", Journal of Mechanical and Civil Engineering (2010), pp. 54-56.

[3] Urquhart, D.: "Historic Concrete in Scotland Part 1: History and Development", Historic Scotland, Edinburgh, March, 2013.

[4] Moss, J.K.: "No-fines building gives energy-conserving homes, a system that saves both energy and cement", International Construction Sutton, Surrey, England, 1979.

[5] Šešlija, M., Radović, N., Trivunić, M., Bibić, D., Peško, I.: "Analysis of pervious concrete pavement", International Conference on Contemporary Achievements in Civil Engineering 2015, Faculty of Civil Engineering Subotica, Subotica, Serbia, pp. 429-434, 2015

[6] Šešlija, M., Radonjanin, V., Milović, T., Šupić, S., Vukoslavčević, S.: "Application of pervious concrete in road engineering", 16th International Conference on Macedonian Association of Strxuctarl Engineers, Struga, Ohrid Lake, Macedonia, pp. XX-XX, 2015.

[7] Harber, P.J.: "Applicability of No-Fines Concrete as a Road Pavement", Bachelor of Engineering (Civil), Univeristy of Southern Queensland, Australia, 2005.

[8] Kevern, J.T.: "Advancements in pervious concrete technology", Iowa State University, United States, 2008.

[9] Mrakovčić, S., Čeh, N., Jugovac, V.: "Effect of aggregate grading on pervious concrete properties", GRAĐEVINAR 66 (2014) 2, pp. 107-113, doi: 10.14256/JCE.977.2013

[10] Chen, Y., Wang, K., Wang, X., Zhou, W.: Strength, fracture and fatigue of pervious concrete, Construction and Building Materials 42 (2013), pp. 97-104.

[11] Amde, A.M., Rogge, S.: Development of High Quality Pervious Concrete Specifications for Maryland Conditions, Department of Civil and Environmental Engineering, University of Maryland, College Park, February 2013.

[12] Yang, J., Jiang, G.: Experimental study on properties of pervious concrete pavement materials, Cement and Concrete Research 33 (2003), pp. 381-386.

[13] Schaefer, V.R., Wang, K., Suleiman, M.T., Kevern, J.T.: Mix Design Development for Pervious Concrete In Cold Weather Climates, Center for Transportation Research and Education, Iowa State University, Ames, February 2006.

[14] Shu, X., Huang, B., Wu, H., Dong, Q., Burdette, E.G.: Performance comparison of laboratory and field produced pervious concrete mixtures, Construction and Building Materials 25 (2011), pp. 3187-3192.

[15] Gesoglu, M., Guneysis, E., Khoshnaw, G., Ipek, S.: Investigating properties of pervious concretes containing waste tire rubbers, Construction and Building Materials 63 (2014), pp. 206-213.

[16] Gesoglu, M., Guneysis, E., Khoshnaw, G., Ipek, S.: Abrasion and freezing-thawing resistance of pervious concretes containing waste rubbers, Construction and Building Materials 73 (2014), pp. 19-24.

[17] Blažok, D.: Propusni beton za kolnike, Tehnički glasnik (2010) 4, pp. 15-18.

[18] Stojanović, M., Šešlija, M., Malešev, M., Radonjanin, V.: Svojstva propusnog betona i mogućnost njihove primene u savremenoj putogradnji, Prvi srpski kongres o putevima, Beograd, pp. 829-838, 2014.