sciendo

DOI: 10.2478/rjti-2022-0004

ROMANIAN JOURNAL
OF TRANSPORT INFRASTRUCTURE

ASPECTS CONCERNING THE PHYSICAL-MECHANICAL CHARACTERISTICS OF LOW-NOISE ASPHALT MIXTURE

Adelin Stirb, Phd. Student, University Politehnica Timisoara, adelin.stirb@upt.ro
Paul Marc, Lecturer., PhD, University Politehnica Timisoara, paul.marc@upt.ro
Andrei Forton, Asist., PhD., University Politehnica Timisoara, andrei.forton@upt.ro

Abstract

As the traffic increases in urban areas, the noise generated by the vehicles has become a major concern during the last decade and many countries have been looking for solutions to reduce the level of disturbance. The lowering of the noise level by choosing the correct type of asphalt mixture may be considered as an alternative to sound-absorbing walls.

The use of these low-noise asphalt mixtures requires a previous verification of the technical conditions and the performance levels they need to meet.

The paper presents the research and laboratory tests aimed at comparing the physical-mechanical characteristics of a maximum 16mm grain size bituminous concrete (BA16) with a low-noise bituminous concrete used in the wearing course of bituminous pavements.

This research started from the fact that the Romanian design standard for asphalt mixtures does not stipulate the physical-mechanical characteristics required by a low-noise asphalt mixture. Thus, in order to clarify this matter, the physical-mechanical characteristics of a 16mm grain size laboratory-made bituminous concrete (BA16) were compared to the characteristics of a low-noise asphalt mixture presented by the specialized literature.

The results obtained following laboratory testing of the asphalt concrete and the research of the specialized literature concerning low-noise asphalt mixtures confirm the differences as far as their physical-mechanical characteristics are concerned (voids, bulk density, dry density, Marshall stability and flow and stiffness modulus).

Keywords: low-noise asphalt concrete, voids, stiffness modulus, bulk density.

1. INTRODUCTION

Transport policy seeks to change the correlation between increased road traffic and health risks, and an integrated approach is needed to reduce the negative effects of both emissions and noise.

Regarding noise pollution, Romania has aligned itself with the European directives for noise assessment and management through a series of legislative measures. Along with the elaboration of strategic noise maps for the large urban

agglomerations in the country, action plans were formulated with the aim of reducing noise pollution and establishing the optimal ways to protect the population and the environment.

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 should provide a basis for the development and completion of existing Community measures on noise from main sources, in particular road and rail vehicles and their infrastructure, as well as additional measures in the short, medium, and long term. The aim of this Directive is to establish a common approach to avoid preventing or reducing, as a matter of priority, the harmful effects, including discomfort, caused by ambient noise.

The main sources of noise in the urban environment include roads, railways, airports and activities in industrial areas inside the agglomerations (Figure 1). Road traffic is one of the most important sources of noise and vibration in populated centers [1].

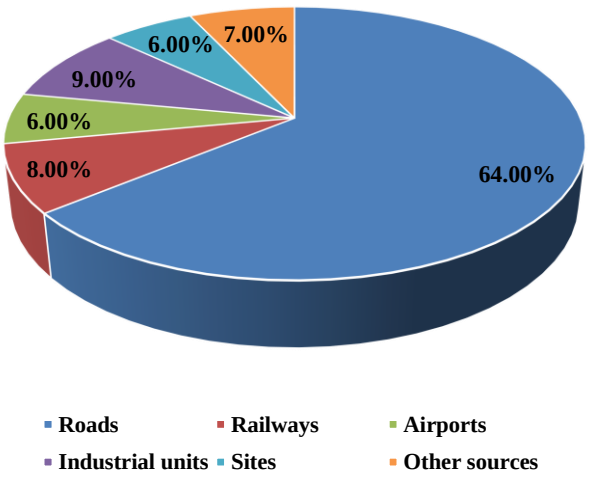


Figure 1. The rate share of noise sources in the urban environment [1].

Road traffic noise has become a major problem in society over the years. The World Health Organization has classified traffic noise (including road, rail and air traffic) as the second most important cause of illness in Western Europe [2,3].

Prolonged exposure to environmental noise leads to negative cardiovascular and metabolic effects, reduced cognitive performance in children and severe annoyance and sleep disturbance [4]. Noise level increases due to a constant growth of traffic and urbanization phenomena. The recent tendency of urbanization requires transport infrastructure to be reshaped in a way that could

provide the best mobility conditions for people and goods as well as create a good living environment [5].

The financing from the road sector is not sufficient to maintain roads at the highest level while simultaneously ensuring the lowest environmental impacts [6]. Considering such challenges, new solutions that focus on cost-efficient reduction in traffic noise must be developed and applied.

According to the air void content and efficiency in reducing tire/pavement noise, asphalt mixtures are grouped into dense (air void content is 4–9%), semi-dense (air void content is 10–14%), semi-porous (air void content is 15–19%) and porous (air void content is > 19%) asphalt [6]. Porous asphalt (PA) mixtures have been used to reduce tire/pavement noise in many countries for the past few decades [7–11]. Due to the high air void content, PA mixtures can reduce tire/pavement noise by 2–6 dB more than typical dense graded asphalt mixtures [12–15]. They also reduce the hydroplaning phenomenon, water splashing and the effect of spraying, which leads to improved visibility and driving safety [16,17]. However, some authors indicate that a large amount of voids results in higher susceptibility to moisture erosion and frost heaving [18].

Moreover, PA mixtures are not recommended for use in cold regions since winter maintenance, which leads to clogging of the pores, is applied and studied tires are used, which speeds up the ravelling process. The ravelling process of PA mixtures is also accelerated by their susceptibility to freezing and thawing cycles, which results in the loss of bonding between aggregates and binder after repeated traffic abrasions [19]. In general, ravelling reduces road performance and leads to a need to perform maintenance earlier than expected. Conducted studies show that due to ravelling, the service life of PA pavement is much shorter (10–12 years) than that of dense graded asphalt roads (15–18 years) [17,20,21].

2. EXPERIMENTAL RESEARCH

2.1. Materials for the 16 mm grain size laboratory – made BA 16

The components for the asphalt mixture design were selected according to previously conducted research [22,23].

The crushed aggregates used in this study come from a diorite quarry (3.00 g/cm3 bulk density, minimum 98% level of compaction and 0.22% water absorption). Diorite is an intrusive igneous rock composed principally of the silicate minerals plagioclase feldspar (typically andesine), biotite, hornblende, and/or pyroxene. Diorite is usually grey to dark grey in colour, but it can also be black or bluish-grey, and frequently has a greenish cast. Diorites have the qualities

needed to be used as natural stone for roads, railways and constructions. A 0-16 mm aggregate skeleton was used for the study [22].

The binder used in the present study was 50/70 asphalt binder. 50/70 asphalt binder is the most common type of binder used in the road industry in Romania. On the same type of binder used in this study a series of detailed, rheological investigations were carried out, the results being presented in the following works [24,25,26].

The properties of the selected aggregates and binder are shown in Table 1 and Table 2.

Table 1. Aggregates properties

Properties	**Unit**	**Tested value**
Resistance to wear Micro-Deval	Mde	19
Bulk density	g/cm^3	3.00
Water absorption	%	0.22
Adhesiveness	%	86.21
Affinity	%	89.84

Table 2. Binder properties

Characteristic	**Unit**	**Tested value**
Penetration at 25°C	0.1 mm	54
Softening point	°C	48.6
Ductility	cm	>150
Mass variation	%	0.04
Increase of softening point after RTFOT	°C	6.78
Residual penetration	%	5.5
Ductility after RTFOT	cm	>150

2.1.1. Asphalt mixture

Thus, in order to compare the physical-mechanical characteristics of the BA 16 mixture with a low-noise asphalt mixture used in the wearing course of bituminous pavements, one asphalt concrete BA 16 dosage has been designed (maximum aggregate size of 22.4 mm and nominal maximum aggregate size of 16 mm) with binder content 4.7%.

The research of the specialized literature concerning low-noise asphalt mixtures showed that the BBTM 8 mixture (fr. beton bitumineux très mince) is the most rational solution for low noise pavement. BBTM is an intermediate option between conventional and porous asphalt (PA) mixtures and is classified as a semi-dense asphalt mixture. It has good physical and mechanical properties as well as a good reduction in noise and hydroplaning phenomena [11].

The composition of the BA 16 mixture and the BBTM 8 are presented in Table 3 and Table 4 [27].

Table 3. BA 16 composition

Component	Asphalt mixture BA 16
Chippings 8-16, %	31.0
Chippings 4-8, %	15.0
Crushed sand 0-4, %	46.0
Sand 0-4, %	2.0
Filler, %	6.0
Bitumen 50/70, %	4.7

Table 4. BBTM 8 composition

Component	Asphalt mixture BBTM 8
Granite fr. 5-8, %	82.68
Granite powder 0-2, %	8.46
Filler, %	2.44
Cellulose %	0.40
Adhesive additive, %	0.018
Bitumen PMB 45/80-65, %	5.6

The particle size distribution of the BA 16 mixture and the BBTM 8 are presented in Figure 2.

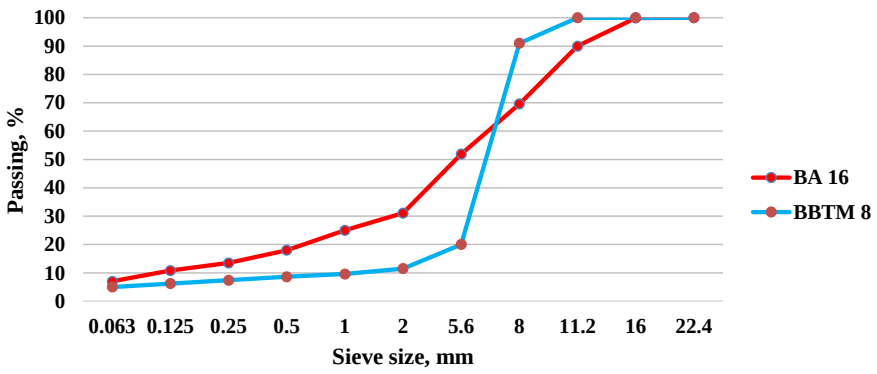


Figure 2. Particle size distribution of BA 16 and BBTM 8

2.2. Methods for BA 16 mixture

The physical - mechanical characteristics that are given below were determined in the Road Laboratory – Civil Engineering Research Infrastructures from Politehnica University Timisoara, Department of Overland Communication Ways, Foundations and Cadastral Survey, by testing 3 specimens for each asphalt mixture and for each test condition (for example, 3 specimens were tested for stiffness modulus, or 3 specimens were tested for Marshall stability and flow index).

2.2.1. Air void content

The air voids content was determined by standard SR EN 12697-8 [28]. The air voids of the asphalt specimen are calculated using the maximum density (standard SR EN 12697-5 [29], Procedure B) of the mixture and the bulk density of the specimen (standard EN 12697-6 [30], Procedure B: Bulk density – Saturated surface dry (SSD))). The specimens for determining the bulk density were prepared by a Marshall compactor according to standard SR EN 12697-30 [31] (2 x 50 blows).

2.2.2. Stiffness modulus

The stiffness of the asphalt specimens was determined by standard SR EN 12697-26 [32] Annex C: Test applying indirect tension to cylindrical specimens (IT-CY). Cylindrical specimens (approx. 65 mm height and 100 mm diameter), prepared according to SR EN 12697-31 [33] (Gyratory compactor) at 20° C reference temperature, were used in the test.

2.2.3. Marshall stability and flow index

The Marshall stability and the flow index of the asphalt specimens was determined by standard SR EN 12697-34 [34]. The specimens for determining the Marshall stability and the flow index were prepared by a Marshall compactor according to standard SR EN 12697-30 (2 x 50 blows).

2.3. Methods for BBTM 8 mixture

The physical - mechanical characteristics that are given below were taken from specialized articles [24].

3. RESULTS ANALYSIS AND INTERPRETATION

3.1. Density and air voids content

The BA 16 mixture had the lowest air void content (4.64%), while BBTM 8 had the highest air void content (12.24%). It was noticed that an increase in nominal aggregate size led to a decrease in air void content for the BA 16 mixture.

Table 5 present the density of both asphalt mixtures. A closer inspection of the graph showed that both the bulk density and nominal density for each type of asphalt mixture are related to the nominal aggregate size: the higher the nominal aggregate size is, the higher the density. BA 16 mixture had the highest values for the bulk density and maximum density compared to BBTM 8.

Table 5. Results for density of the air voids content

Asphalt mixture	Maximum density, kg/m^3	Bulk density, kg/m^3	Air voids, %
BA 16	2 609	2 488	4.64
BBTM 8	2 581	2 265	12.24

3.2. Stiffness modulus

As shown in Figure 3, the BA 16 mixture is stiffer than BBTM 8 mixture. The reason for this could be the lower air void content for BA 16 mixture, which leads to a denser asphalt mixture structure and more contact points to sustain the load. The results were reported to the minimum value specified by AND 605 [35] for an asphalt concrete used in the wearing course, technical class III-IV.

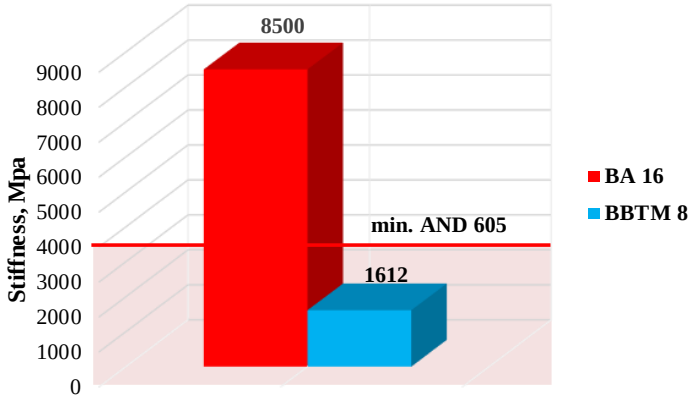


Figure 3. Stiffness modulus

The adjusted stiffnes modulus values at 20° C obtained for the BA 16 mixture fits in the imposed values by AND 605, while those of BBTM 8, not.

3.3. Marshall stability and flow index

The results presented in Figure 4 and Figure 5, show that BBTM 8 has good values regarding Marshall stability and flow index. The Marshall stability value for BA 16 is 31% higher than BBTM 8 Marshall stability value. The flow index value for BBTM 8 is 18% higher than BA 16 flow index value. The results were reported to the minimum and maximum value specified by AND 605 for an asphalt concrete used in the wearing layer. The results were reported to the minimum and maximum value specified by AND 605 for an asphalt concrete specimens prepared by a Marshall compactor.

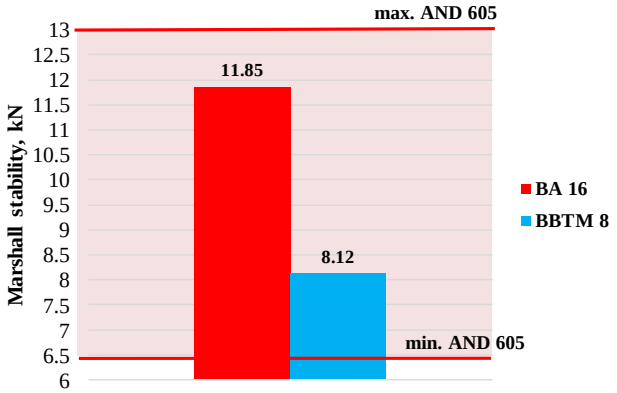


Figure 4. Marshall stability

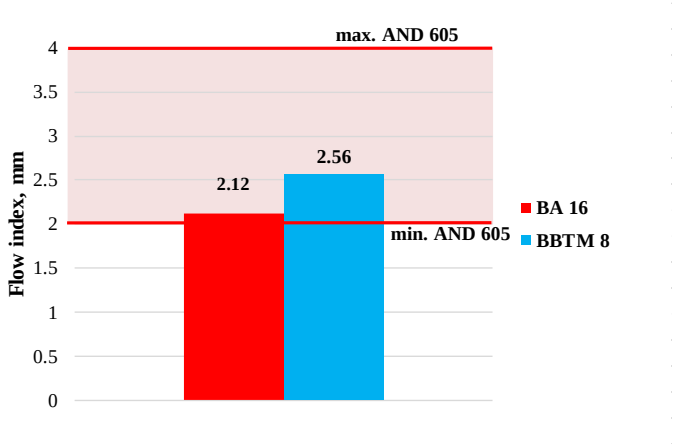


Figure 5. Flow index values

The values obtained for the BA 16 mixture and BBTM 8 mixture fits in the imposed values by AND 605 for Marshall stability and flow index.

4. CONCLUSIONS

The objective of this study was to compare the physical-mechanical characteristics of a BA 16 asphalt mixture with a low-noise asphalt mixture used in the wearing course of bituminous pavements.

The analysis of the test results (obtained in laboratory for the BA 16 mixture and those provided by the specialized articles for the BBTM 8 mixture) showed that BBTM 8 mixture has a substantially lower stiffness, bulk density, maximum density, and Marshall stability. BA 16 mixture is stiffer than BBTM 8 mixture. The reason for this could be the lower air void content for BA 16 mixture, which leads to a denser asphalt mixture structure and more contact points to sustain the load. The air voids value for BBTM 8 is much higher than the BA 16 air voids value, high air void content being efficiency in reducing tire/pavement noise.

In order to obtain a better comparison of the physical-mechanical characteristics between a classic asphalt mixture and a low-noise asphalt mixture, it is necessary to prepare both asphalt mixture in a laboratory, using the same aggregates size and repartition and the same bitumen dosage. That is why it is intended to continue the research in this field in order to establish a dosage of asphalt classic mixture and o dosage of low-noise asphalt mixture with same proportions of materials (aggregate and bitumen) in order to properly evaluatethe physical-mechanical characteristics.

After performing the laboratory validation tests on such type of asphalt mixtures, it is very important to continue the research by investigating an in-situ

characteristic performances in order to have a final product with good performances.

REFERENCES

[1] BECA I.M, PhD Thesis: "*Contribuții privind implementarea unor sisteme complexe de monitorizare a poluării fonice în contextual dezvoltării traficului urban*" (*Contributions regarding the implementation of complex noise pollution monitoring systems in the context of urban traffic development*), Cluj – Napoca, **2014**.

[2] WORLD HEALTH ORGANIZATION, *Burden of disease from environmental noise*: *Quantification of healthy life years lost in Europe*, **2011**.

[3] O. HÄNNINEN, A.B. KNOL, M. JANTUNEN, T.-A. LIM, A. CONRAD, M. RAPPOLDER, P.CARRER, A.-FANETTI, R. KIM, J. BUEKERS, R. TORFS, I. IAVARONE, T. CLASSEN, C. HORNBERG, O.C.L. MEKEL: „*Environmental burden of disease in europe: assessing nine risk factors in six countries*" Environ. Health Perspect. 122 439–446, https://doi.org/10.1289/ehp.1206154.

[4] WORLD HEALTH ORGANIZATION, *Environmental noise guidelines for the European region*, **2018**.

[5] A. VAITKUS, D. C˘ YGAS, V. VOROBJOVAS, T. ANDRIEJAUSKAS: "*Traffic/road noise mitigation under modified asphalt pavements",* Transp. Res. Proc. 14 (**2016**) 2698–2703, https://doi.org/10.1016/j.trpro.2016.05.446.

[6] RIEKSTINS, A. HARITONOVS, V, ABOLINS, V., STRAUPE, V., TIHONOVS, J. "*Life cycle cost analysis of BBTM and traditional asphalt concretes in Latvia Engineering for Rural Development*", Volume 18, **2019**, Pages 1065-1072. DOI: 10.22616/ERDev2019.18.N400.

[7] K. GLAESER: "*Road surface characteristics and type road noise"*, **2007**.

[8] U. SANDBERG, E. JERZY: "*Tyre/road noise*", Reference book (**2002**).

[9] U. SANDBERG, J. KRAGH, L. GOUBERT, H. BENDTSEN, A. BERGIERS, K.P. BILIGIRI, R. KARLSSON, E. NIELSEN, E. OLESEN, S. VANSTEENKISTE: "*Optimization of thin asphalt layers – state-of-the-art review"*, Era-Net Road 1 (**2011**) http://www.divaportal.org/smash/get/diva2:674027/FULLTEXT02.pdf.

[10] J. CESBRON, F. ANFOSSO-LÉDÉE, H.P. YIN, D. DUHAMEL, D. LE HOUÉDEC: "*Influence of road texture on tyre/road contact in static conditions*", Road Mater. Pavement Des. 9 (**2008**) 689–710, https://doi.org/10.1080/14680629.2008.9690145.

[11] H. BENDTSEN, DRI-DWW: "*Thin layer project-Final report*", DRI-DWW THIN LAYER PROJECH-FINAL REPORT 159, **2007**.

[12] J.H. SWART: "*Experiences with porous asphalt in the Netherlands*". Ministry of Transportation, Public Work. Water Manag. Proc. Eur. Conf. Porous Asph., **1997**.

[13] R.S. MCDANIEL, W. THORNTON: "*Field evaluation of a porous friction course for noise control*", Annu. Meet. Transp. Res. Board., **2005**.

[14] G. HUBER: "*Performance survey on open-graded friction course mixes"*, Transp.Res. Board. 284 (**2000**).

[15] Q. LIU, Á. GARCÍA, E. SCHLANGEN, M. VAN DE VEN: "**Induction healing of asphalt mastic and porous asphalt concrete**", Constr. Build. Mater. 25 (**2011**) 3746–3752, https://doi.org/10.1016/j.conbuildmat.2011.04.016

[16] H. KIM, K. SOKOLOV, L.D. POULIKAKOS, M.N. PARTL: "*Fatigue evaluation of porous asphalt composites with carbon fiber reinforcement polymer grids"*, Transp. Res. Rec. J. Transp. Res. Board. 2116 (**2009**) 108–117, https://doi.org/10.3141/2116-14.

[17] A. DE BONDT, K. PLUG, J. VAN DE WATER, P. THE, J. VOSKULIEN: "*Development of a durable third generation Porous Asphalt with a high noise"*, Proc. E&E Congr. (**2016**).

[18] M. HU, L. LI, F. PENG: "*Laboratory investigation of OGFC-5 porous asphalt ultrathin wearing course"*, Constr. Build. Mater. 219 (**2019**) 101–110, https://doi.org/10.1016/j.conbuildmat.2019.04.205.

[19] N. GIBSON, M. MARASTEANU, R. VELÁSQUEZ, T. CLYNE, M. TUROS: "*Investigation of low temperature cracking in asphalt mixtures using TSRST"*, in: Pavement Crack, CRC Press, **2008**, https://doi.org/10.1201/9780203882191.ch40.

[20] J.L.M. VOSKUILEN, P.N.W. VERHOEF: "*Causes of premature ravelling failure in porous asphalt"*, Perform. Test. Eval. Bitum. Mater. PTEBM'03. Proc. 6TH Int. RILEM Symp. HELD ZURICH, **2003**.

[21] L.T. MO: "*Damage development in the adhesive zone and mortar of porous asphalt concrete"*, **2010**.

[22] STIRB, A., MARC, P., BELC, A., BELC, F., BUZURIU, A: "*Research concerning the impact of geometrical characteristics of natural quarry aggregates used in the composition of asphalt concrete"* (**2020**) IOP Conference Series: Materials Science and Engineering, 960 (3), art. no. 032046.

[23] A. STIRB, P. MARC, A.L. BELC, F. BELC AND G. LUCACI: ”*Influence of natural aggregates` mineralogical composition on the adhesiveness and affinity of bitumen”*, ISBM Lyon 2020: International Symposium on Bituminous Materials, **2020**.

[24] FORTON, A., MANGIAFICO, S., SAUZÉAT, C., DI BENEDETTO, H., MARC, P: ”*Properties of blends of fresh and RAP binders with rejuvenator: Experimental and estimated results”* (**2020**) Construction and Building Materials, 236, DOI: 10.1016/j.conbuildmat.2019.117555.

[25] FORTON, A., MANGIAFICO, S., SAUZÉAT, C., DI BENEDETTO, H., MARC, P: ”*Steady shear viscosity of blends of fresh and RAP binders with rejuvenator: Experimental and estimated results”* (**2021**) Construction and Building Materials, 269, DOI: 10.1016/j.conbuildmat.2020.121236.

[26] FORTON, A., MANGIAFICO, S., SAUZÉAT, C., BENEDETTO, H.D., MARC, P: ”*Critical temperatures blending chart for binder blends produced with rap binder and rejuvenator”* (**2022**) Journal of Testing and Evaluation, 50 (1), pp. 1-20. DOI: 10.1520/JTE20200710.

[27] OVIDIJUS ŠERNAS, AUDRIUS VAITKUS, JUDITA GRAZˇULYTE, DOVYDAS SKRODENIS, MARTA WASILEWSKA, PAWEL GIERASIMIUK: ”*Development of low noise and durable semi-dense asphalt mixtures”*, Construction and Building Materials, 2021, https://doi.org/10.1016/j.conbuildmat.2021.123413.

[28] SR EN 12697-8 - *Mixturi asfaltice. Metode de încercare. Partea 8: Determinarea caracteristicilor volumetrice ale epruvetelor bituminoase (Bituminous mixtures. Test methods. Determination of void characteristics of bituminous specimens*), p. 10, **2019**.

[29] SR EN 12697-5 - *Mixturi asfaltice. Metode de încercare. Partea 5: Determinarea densității maxime (Bituminous mixtures. Test methods. Determination of the maximum density*), p. 22, **2019**.

[30] SR EN 12697-6 - *Mixturi asfaltice. Metode de încercare. Partea 6: Determinarea densității aparente a epruvetelor bituminoase (Bituminous mixtures. Test methods. Determination of bulk density of bituminous specimens*), p. 17, **2012**.

[31] SR EN 12697-30 - *Mixturi asfaltice. Metode de încercare. Partea 30: Confecționarea epruvetelor cu compactorul cu impact (Bituminous mixtures. Test methods. Specimen preparation by impact compactor*), p. 23, **2019**.

[32] SR EN 12697-26 - *Mixturi asfaltice. Metode de încercare. Partea 26: Rigiditate (Bituminous mixtures. Test methods. Stiffness*), p. 49, **2018**.

[33] SR EN 12697-31 - *Mixturi asfaltice. Metode de încercare. Partea 31: Confecționarea epruvetelor cu presa cu compactare giratorie (Bituminous mixtures. Test methods. Specimen preparation by gyratory compactor*), p. 24, **2019**.

[34] SR EN 12697-34 - *Mixturi asfaltice. Metode de încercare. Partea 34: Încercare Marshall (Bituminous mixtures. Test methods. Marshall test*), p. 12, **2012**.

[35] AND 605-2016, *Normativ privind mixturile asfaltice executate la cald. Conditii tehnice de proiectare, preparare si punere in opera a mixturilor asfaltice (Standard concerning hot mix asphalts. Technical conditions for designing, preparing and laying asphalt mixtures*), Romania, **2016**.