

## LABORATORY STUDIES ON THE PRODUCTION OF ASPHALT MIXTURE BAD 22,4 WITH PET (PLASTIC BOTTLE FIBERS)

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### *Abstract*

Plastic is a versatile and cheap material, but extremely durable and nearly impossible to decompose in nature. Plastic waste is not only a visual pollution issue but also a global health problem, as microplastics enter the food chain, affecting both marine life and humans. Moreover, the mass production of plastic is closely linked to greenhouse gas emissions and the depletion of natural resources. Pollution caused by PET (polyethylene terephthalate) is one of the most severe forms of environmental pollution due to excessive use and inadequate recycling of these materials. PETs are mainly used in the form of containers (bottles), and because of their durability and slow degradation in nature, these objects become a major source of pollution, affecting both terrestrial and aquatic ecosystems.

Thus, the present article discusses the recycling and use of PET in the form of fibers for reinforcing asphalt pavements, similar to cement concrete applications. These fibers were added as a percentage of the optimal binder content, and Marshall specimens were fabricated to determine apparent density, water absorption, Marshall stability and flow. The results obtained are favorable.

**Keywords:** pollution, PET, recycling, laboratory studies, roads

## **1. INTRODUCTION**

The issue of plastic waste has become a major global concern in recent decades, with a significant impact on the environment, ecosystems, and human health. Plastic, a versatile and cheap material used in an immense variety of products, has proven to be extremely durable but also nearly impossible to break down in nature. The introduction of plastic addressed many immediate needs of human society, and over time it has contributed to the formation of a culture in which the idea of removing it from the market becomes increasingly difficult to envision.[1] Every year, approximately 350 million metric tons of plastic waste are generated worldwide. Most of this plastic waste is either incinerated or sent to landfills, ultimately leading to the pollution of our air, land, and oceans. [2]. Furthermore, the massive production of plastic is closely linked to greenhouse gas emissions and the depletion of natural resources.

Among the most discussed and dangerous types of plastic waste are PET bottles (polyethylene terephthalate), which are commonly used in the manufacture of beverage bottles and other packaging. PET is a lightweight, durable, and recyclable plastic, but unfortunately, it is one of the most common causes of plastic pollution. Although recyclable, the recycling rate of PET bottles is still insufficient, and the majority of them end up being discarded irresponsibly, contributing to environmental pollution. This problem of PET accumulation raises critical questions about the efficiency of existing recycling systems and the ways in which we can reduce our dependence on plastic packaging in a sustainable manner. To contribute to CO<sub>2</sub> reduction, it is essential to shift away from the current practice of preferentially using virgin PET and promote the production of recycled PET. [3] Therefore, it is crucial to develop sustainable, efficient, cost-effective, and environmentally friendly methods for recycling waste PET plastics and converting them into high-value-added products.[4]

Plastic waste recycling is an essential process for reducing pollution and conserving natural resources. Plastic is a synthetic material, and recycling it involves processing used plastic materials, transforming them into new products, thus reducing the need to produce new plastic. There are several types of plastic that can be recycled, but the process is not always efficient due to contamination, the diversity of plastic materials, and the costs associated with recycling.

An emerging field for the use of plastic waste is asphalt mixtures. The technique of incorporating other materials into bitumen or asphalt mixtures is not a recent one. The first experimental projects in Europe using asphalt modified with virgin polymers took place around 1930, and the first asphalt-modified road was constructed in 1970.[5] In recent decades, research and innovations have

demonstrated that recyclable plastic can be integrated into the asphalt used for road construction. This not only helps reduce the amount of plastic that ends up in landfills or the environment but also improves the durability of roads. Mixing plastic waste into asphalt can contribute to increased wear resistance, reduced cracking, and better road performance under extreme temperature conditions. Additionally, this technology reduces the amount of bitumen required in asphalt production, another ecological advantage.

## **2. MATERIALS AND METHODS**

In this chapter, laboratory results are presented, specifically the physical-mechanical characteristics of asphalt mixtures made with PET. To assess the mechanical performance of asphalt mixtures, cylinder specimens (100.6 mm in diameter and 63.5 mm in height) were compacted with 50 blows of compaction energy per side using a Marshall Compactor, while the slabs were prepared using a wheel-roller machine. The dimensions of the slab specimens were 300 mm in length, 300 mm in width, and 50 mm in thickness.[6] Polyethylene terephthalate fibers are used in asphalt mixtures for reinforcement purposes, with the percentage determined based on the establishment of the optimal binder dosage. The percentage of fibers is 2%, 4%, 6%, 8%, and 10% of the optimal binder content. We encounter two types of processes for inserting PET fibers into asphalt mixtures: wet and dry. These techniques are commonly used, providing flexibility based on the melting points of the plastics used.[7]

### **2.1. Preparatory Operations.**

#### **2.1.1. Bringing the materials needed for the preparation of asphalt mixtures:**

-Filler – Hoghiz, Braşov County, Bitumen – Almatar, Buzău County, Natural Sand – Tupilaţi, Neamţ County, Crushed stone – Suseni, Harghita County according figure 1.



**Figure 1.** Crushed stone – Suseni, Harghita County

### 2.2.2. Drying the aggregates



**Figure 2.** Drying the aggregates

In the second stage (figure 2), the aggregates were dried in the laboratory.

In order to determine the physical and mechanical characteristics of the asphalt mixtures, two asphalt recipes were prepared, namely BAD 22,4 – control specimens and BAD 22,4 – specimens made with PET fibers. In order to create these asphalt mixture recipes, the following aggregate grades were required: crushed stone 16 - 22,4 mm, crushed stone 8 - 16 mm, crushed stone 4 - 8 mm, crushed sand 0 - 4 mm, natural sand 0-4 mm and filler. In Table 1, the results are presented.

**Table 1.** The passage through the set of sieves of the aggregates used

<b>Crushed Sand 0-4 mm</b>						
<b>D, mm</b>	<b>Retained</b>			<b>Retained Σ g</b>	<b>Retained %</b>	<b>Passed %</b>
	<b>I</b>	<b>II</b>	<b>III</b>			
8	-	-	-	-	-	100
4	15,4	11,9	8,1	35,4	2,36	97,64
2	185,4	219,4	169,9	574,7	38,31	59,33
0,125	239,9	221,8	257,7	719,4	47,96	11,37
0,063	25,1	23,00	30,8	78,9	5,26	6,11
<0.063	32,3   34,2	22,3   23,9	31,9   33,5	91,6	6,11	-
Total	500,00	500,00	500,00	1500,00	100,00	-
<b>Crushed stone 4 - 8 mm</b>						
<b>D, mm</b>	<b>Retained</b>			<b>Retained Σ g</b>	<b>Retained %</b>	<b>Passed %</b>
	<b>I</b>	<b>II</b>	<b>III</b>			
16	-	-	-	-	-	100
11,2	-	4,0	-	4,0	0,133	99,87
8	134,3	123,2	134,9	392,4	13,08	86,79
4	849,2	858,2	854,2	2561,6	85,38	1,40
<4	15,6   16,5	13,7   14,6	10,2   11,0	42,10	1,40	-
Total	1000,00	1000,00	1000,10	3000,10	100,00	-
<b>Crushed stone 8 - 16 mm</b>						
<b>D, mm</b>	<b>Retained</b>			<b>Retained Σ g</b>	<b>Retained %</b>	<b>Passed %</b>
	<b>I</b>	<b>II</b>	<b>III</b>			
22,4	-	-	-	-	-	100
16	19,8	17,6	23,5	60,9	1,015	98,99
11,2	496,6	617,0	743,1	1856,7	30,938	68,05
8	1319,7	1247,4	1134,3	3,701,4	61,67	6,37
<8	161,5   164,6	115,8   118,2	97,8   99,5	382,3	6,37	-
Total	2000,7	2000,2	2000,4	6001,30	100,00	-
<b>Crushed stone 16 - 22,4 mm</b>						
<b>D, mm</b>	<b>Retained</b>			<b>Retained Σ g</b>	<b>Retained %</b>	<b>Passed %</b>
	<b>I</b>	<b>II</b>	<b>III</b>			
31,5	-	-	-	-	-	100
22,4	423,9	343,5	272,2	1039,6	6,930	93,07
16	3409,5	3614,4	3580,8	10604,7	70,694	22,38
11,2	1150,7	1021,4	1129,2	3301,3	22,007	0,37
<11,2	15,6   17,7	18,8   20,6	14,7   17,0	55,3	0,37	-
Total	5001,8	4999,9	4999,2	15000,9	100,00	-
<b>Natural Sand 0 - 4 mm</b>						
<b>D, mm</b>	<b>Retained</b>			<b>Retained Σ g</b>	<b>Retained %</b>	<b>Passed %</b>
	<b>I</b>	<b>II</b>	<b>III</b>			
11,2	-	-	-	-	-	100
8	0,9	-	-	0,9	0,06	99,94
4	6,5	7,1	10,8	24,4	1,627	98,31

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Laboratory studies on the production of asphalt mixture BAD 22.4 with pet fibers

2	66,5	64,7	81,5	212,7	14,18	84,13			
0,125	381,1	384,1	371,0	1136,2	75,747	8,39			
0,063	31,9	30,1	24,8	86,8	5,786	2,60			
<0.063	13,1	11,9	13,4	14,0	10,8	11,9	39,0	2,60	-
Total	500,00	500,00	500,00	1500,00	100,00	-			
Filler									
D, mm	Retained			Retained Σ g	Retained %	Passed %			
	I	II	III						
2	-	-	-	-	-	100,00			
0,125	12,9	9,7	16,13	38,73	12,91	87,09			
0,063	11,8	13,5	10,73	36,03	12,01	75,08			
<0.063	73,5	75,30	76,10	76,80	71,82	73,14	225,24	75,08	-
Total	100,00	100,00	100,00	300,00	100,00	-			

According to the AND 605/2016 standard, the limits of aggregate and filler percentages from the total quantity of aggregates, as well as the gradation range of the aggregate mix for each type of asphalt mixture, are specified in Table 2,3.

**Table 2.** The limits of the percentages of fillers and natural aggregates

Natural aggregates – fractions from the total mixture	Wear layer			Bonding layer	Base layer	
	BA8 BAPC8	BA11.2 BAPC11.2	BA16 BAPC16	BAD22.4 BADPC22.4 BADPS22.4	AB22.4 ABPC22.4	AB31.5 ABPC31.5 ABPS31.5
Filler and sand fractions < 0.125 mm, %	9.0... 18.0	8.0... 16.0	8.0... 15.0	5.0... 10.0	3.0... 8.0	3.0... 12.0
Filler and fraction (0.125-4 mm), %	The difference until 100					
Natural aggregates > 4 mm, %	22.0... 44.0	34.0... 48.0	36.0... 61.0	55.0... 72.0	57.0... 73.0	40.0... 63.0

**Table 3.** The granulometric area of bituminous concretes and bituminous coating

The mesh size of the sieve conforming to SR EN 933-2, [mm]	BA 8 BAPC 16	BA 11,2 BAPC 12	BA 16 BAPC 16	BAD 22,4 BAPC22,4 BAP 22,4	AB 22,4 ABP 22,4	AB 31,5 ABPC31,5 ABP 31,5
45	-	-	-			100
31,5	-	-	-	100	100	90...100
22,4	-	-	100	90...100	90...100	82...94
16	-	100	90...100	73.....90	70.....86	72.....88
11,2	100	90.....100	-	-	-	-
8	90...100	75.....85	61...82	42...61	38.....58	54...74
4	56.....78	52.....66	39.....84	28...45	27...43	37.....60
2	38.....55	35...50	27.....48	20...35	19...34	22.....47
0,125	9.....18	8...16	8.....15	5...10	3...8	3.....12
0,063	7.....11	5...10	7.....11	3.....7	2...5	2.....7

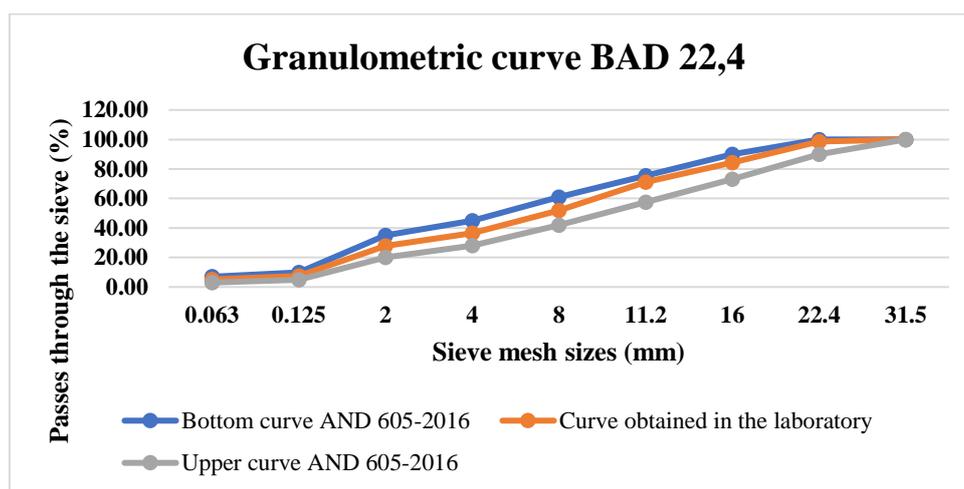
Thus, taking into account the granularity of each aggregate, resulting from the laboratory sieving, the following percentages of aggregates were established for the realization of asphalt recipes, according to the table 4 and figure 3,4:

**Table 4.** Aggregate dosages for asphalt mixture - BAD 22,4

Aggrega-tes	%	0,063	0,125	2	4	8	11,2	16	22,4
Filler	5	3,73	4,31	5,00	5,00	5,00	5,00	5,00	5,00
Natural sand 0-4 mm	16	0,42	1,34	13,47	15,74	16,00	16,00	16,00	16,00
Crushed sand 0-4 mm	16	0,98	1,82	9,49	15,62	16,00	16,00	16,00	16,00
Crushed stone 4-8 mm	15	-	-	-	0,21	13,02	14,98	15,00	15,00
Crushed stone 8-16 mm	28	-	-	-	-	1,78	19,05	27,72	28,00
Crushed stone 16-22,4 mm	20	-	-	-	-	-	0,07	4,48	18,61
<b>Average curve BAD22,4 AND 605- 2016</b>	100	<b>3... 7</b>	<b>5... 10</b>	<b>20... 35</b>	<b>28... 45</b>	<b>42... 61</b>	<b>.....</b>	<b>73..... 90</b>	<b>90... 100</b>
<b>Average curve laboratory</b>	100	<b>5,13</b>	<b>7,49</b>	<b>27,96</b>	<b>36,57</b>	<b>51,80</b>	<b>71,10</b>	<b>84,20</b>	<b>98,61</b>



**Figure 3.** Sieving and determination of the gradation of natural aggregates



**Figure 4.** Granulometric curve BAD 22,4

In table 5, the dosage of the asphalt mixture recipe, prepared in the Laboratory of Roads of the Faculty of Civil Engineering and Installations Iași, is presented.

**Table 5.** Percentage values for preparing asphalt mixture recipes

Aggregate / Recipe	BAD 22,4
Filler (%)	5,00
Natural Sand 0-4 mm (%)	16,00
Crushed sand 0 - 4 mm (%)	16,00
Crushed stone 4 - 8 mm (%)	15,00
Crushed stone 8 - 16 mm (%)	28,00
Crushed stone 16 - 22,4 mm (%)	20,00

## 2.2. Determination of bitumen characteristics

The following presents the results for bitumen obtained in the laboratory. These results refer to: penetration at 25°C, softening point (figure 5), and penetration index according to table 6.

**Table 6.** Bitumen characteristics

Characteristics of D50/70 Bitumen	Values obtained in the laboratory:	SR EN 12591-2009 (STAS 754-99)
Penetration at +25°C, 1/10 mm	67	50...70
Softening point (I.B.), °C	51,9	46...54
Penetration Index I.P.	-0,012	-1,5...+0,7



**Figure 5.** Determination of the softening point in the laboratory

Similar to the process of adding PET fibers to asphalt mixtures, an experiment was carried out with the modification of bitumens with coffee grounds waste (SCG) by replacing them with coffee grounds powder and ash in percentages of 0,1,3,5 and 8%. Incorporating SCG powder up to -12 °C and SCG ash up to -6 °C enhanced the resistance to low temperatures. While both SCG powder and ash showed strong performance across high, moderate, and low temperatures, SCG powder performed better in colder regions, while SCG ash was more effective in temperate and tropical climates. [8]

### 2.3. Determination of bitumen dosages and preparation of Marshall specimens

The optimal bitumen dosage for the asphalt mixture recipe was determined through laboratory tests, taking into account the recommendations of AND 605-2016, as presented in the table 7.

**Table 7.** Minimum binder content

Layer type	Asphalt mixture (type)	Binder content in the mixture (minimum) %
Binder	BAD 22,4 BADPC 22,4 BADPS 22,4	4,20

To determine the optimal binder dosage, Marshall specimens were prepared, including control specimens and specimens with PET fibers, using different bitumen dosages. For the SMA (Stone Mastic Asphalt) mixture, bitumen with a penetration grade of 80/100 was used in different percentages, ranging from 5% to 7% of the weight of the aggregates. Different amounts of PET were used, from 0% to 1% by weight of the aggregates. Marshall stability and Marshall flow showed optimal values for 5.88% bitumen and 0.18% PET. [9]

The following characteristics were determined:

- Determination of the asphalt mixture density;
- Determination of water absorption;
- Determination of Marshall stability

#### 2.3.1. Determination of the asphalt mixture density

The density of the asphalt mixture was determined according to SR EN 12697-8:2019. Below are the results (figure 11 and 16). The determination involved the following steps:

- a. Keeping the specimens in a water bath at a temperature of 20°C for 60 minutes, after which they are removed and wiped with a damp cloth to remove the surface water.

b. Determining the mass of the specimen in its dry state by weighing it in air ( $m_1$ ) figure 6, and then submerging the specimen in water to determine its mass ( $m_2$ ) figure 7.

c. The apparent dry bulk density of the specimen ( $\rho_{dry}$ ) is calculated, rounded to the nearest  $1 \text{ kg/m}^3$ , as follows:

$$\rho_{dry} = \frac{m_1}{m_1 - m_2} \times \rho_w \quad (1)$$



Figure 6, 7. Determination of masses  $m_1$  (dry state) and  $m_2$  (by immersion)

### 2.3.2. Determination of water absorption;

This determination was carried out according to the AND 605-2016 standard. Water absorption represents the amount of water absorbed by the available voids on the outer surface of a specimen from an asphalt mixture when kept in water under vacuum, and is measured as a percentage of the initial mass or volume of the specimen (figure 12 and 17). Working steps:

a. The specimens are placed in the absorption equipment (vacuum chamber) figure 8,9, which is kept at a temperature of  $20 \pm 1^\circ\text{C}$ . The vessel is then sealed and activated for three hours to achieve a pressure of 15–20 mm Hg after approximately 30 minutes.



**Figure 8, 9.** Absorption equipment - Faculty of Constructions and Installations - Department of Roads

b. After three hours, the vacuum chamber is turned off, and the specimens are kept in water for an additional two hours at atmospheric pressure.

c. After the 2 hours, the specimens are removed from the water and wiped with a damp cloth. They are then weighed in air ( $m_3$ ) and in water ( $m_4$ ).

d. The initial volume ( $V$ ) and final volume ( $V_1$ ) of the specimen are calculated using the following formulas:

$$V = (m_1 - m_2) \frac{1}{\rho_w} \text{ [cm}^3\text{]} \quad (2)$$

$$V_1 = (m_3 - m_4) \frac{1}{\rho_w} \text{ [cm}^3\text{]} \quad (3)$$

e. Water absorption is calculated as follows

Water absorption can be reported either to the volume of the specimen ( $A_v$ ) or to its mass ( $A_m$ ). The formulas differ depending on whether  $V > V_1$  or  $V < V_1$ . The formulas are as follows:

e.1 When  $V > V_1$

$$A_m = \frac{m_3 - m_u}{m_u} 100 \quad (4)$$

$$A_v = \frac{(m_3 - m_u) - \rho_w}{(m_1 - m_2) - \rho_w} 100 \quad (5)$$

e.2 When  $V < V_1$

$$A_m = \frac{m_2 - m_u - [(m_2 - m_4) - (m_1 - m_2)]}{m_u} 100 \quad (6)$$

$$A_v = \frac{m_2 - m_u - [(m_2 - m_4) - (m_1 - m_2)]}{(m_1 - m_2) - \rho_w} 100 \quad (7)$$

### 2.3.3. Determination Marshall stability

This test measures the resistance of the asphalt specimen to plastic deformation when subjected to a load, providing an indication of the durability and stability of the mixture under traffic conditions, according to SR EN 12697-34:2020 (figure 10). Also, the limits are mentioned in the AND 605 standard according table 9. The results from these tests allow us to determine the optimal binder content, and subsequently, PET fibers will be added as a percentage of the bitumen dosage (figure 13, 14, 15, 18, 19, 20).

The objective of the test is to determine the breaking strength of a cylindrical specimen, with the force being applied to a generator. Working steps:

a. The unused specimens for the absorption test are placed in water at a temperature of 60°C and maintained for 30 minutes.

b. After 30 minutes, the specimen is removed from the water bath and placed in the Marshall test apparatus.

c. The test is started – the specimen is loaded at a rate of 50 mm/min. When it is observed that the test does not continue to increase, but instead starts to decrease, the test is stopped.

d. The Marshall stability represents the load, expressed in kN, that was reached when the specimen broke. The Marshall flow (creep) is the deformation reached by the vertical diameter of the specimen at the moment of rupture and is expressed in mm.



Figure 10. Determination of Marshall stability and Marshall flow

### 3. RESULTS:

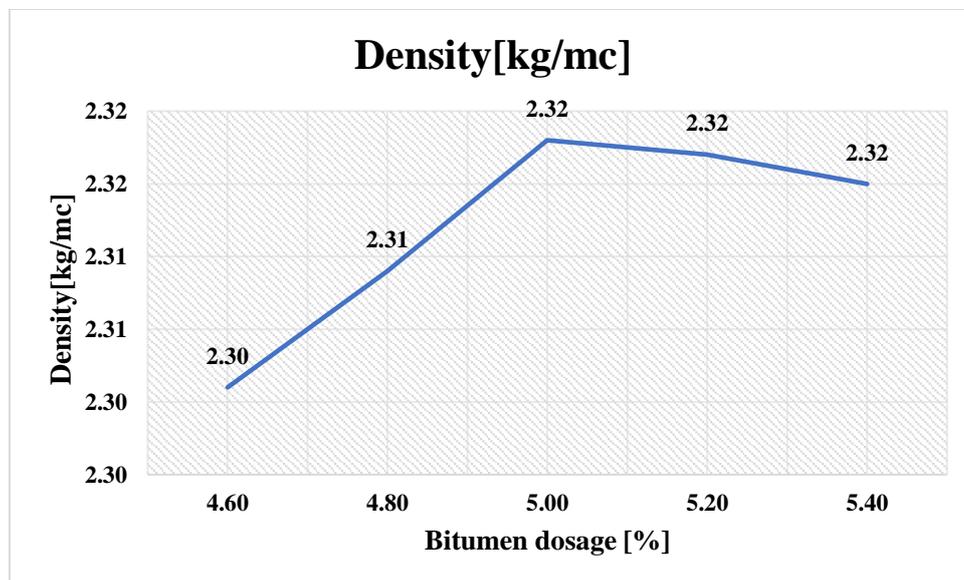
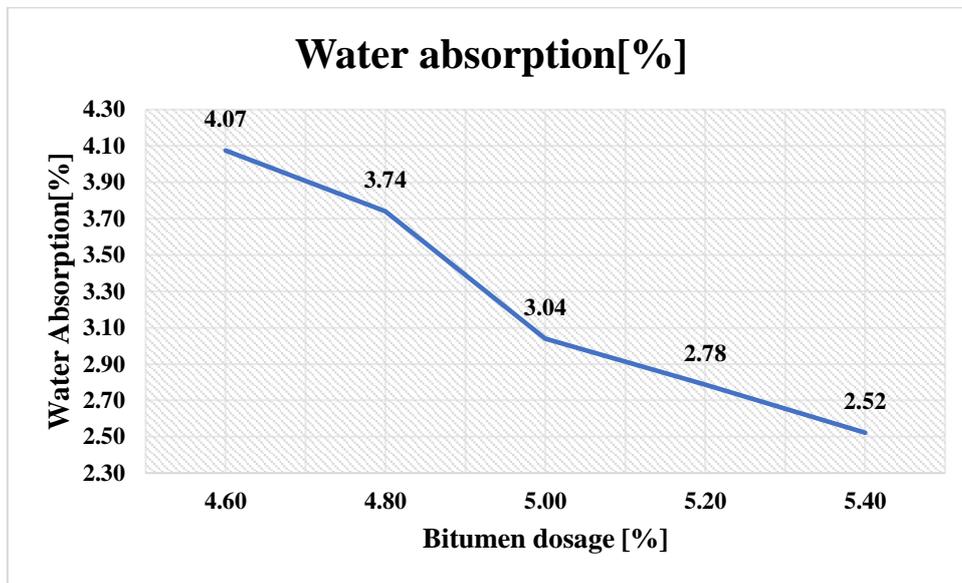
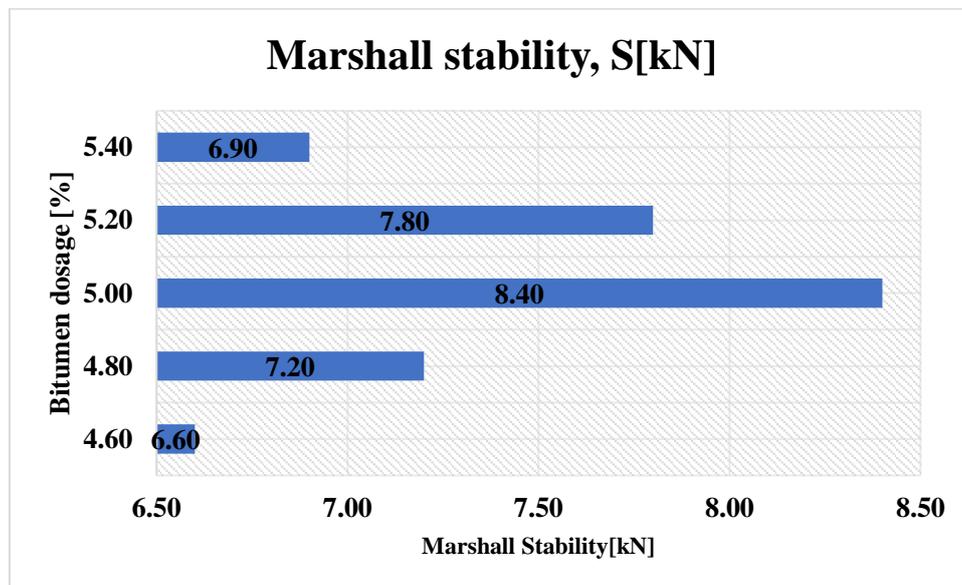


Figure 11. Density values for BAD 22,4 - control specimen



**Figure 12.** Water absorption values for BAD 22,4 - control specimen



**Figure 13.** Marshall stability values for BAD 22,4 - control specimen

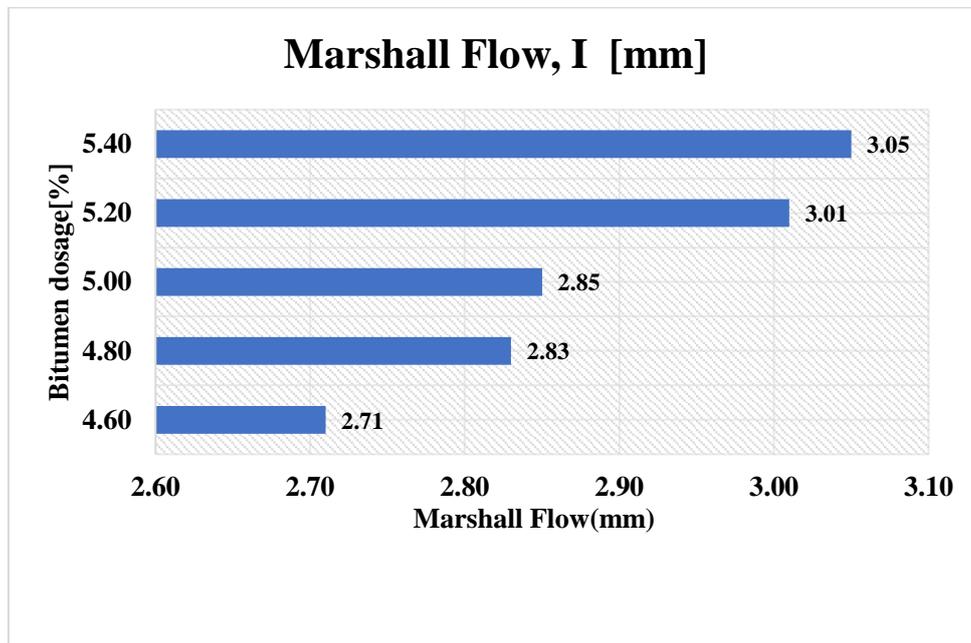


Figure 14. Marshall Flow values for BAD 22,4 - control specimen

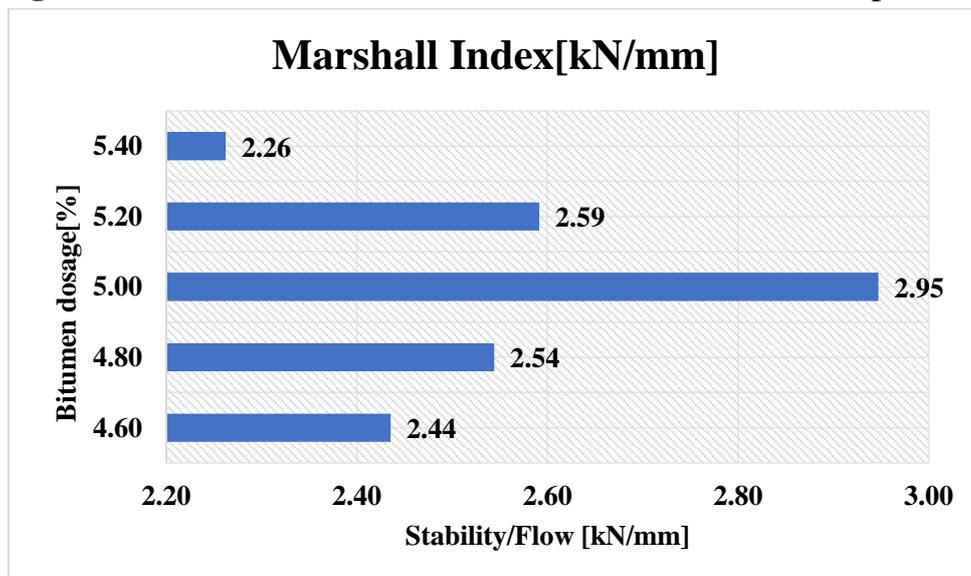


Figure 15. Marshall Index values for BAD 22,4 - control specimen

Table 8. Bitumen - optimum dosage

Mixture	Optimum dosage of bitumen, %	Minimum bitumen content in the mix, % AND 605-2016
BAD 22,4	5,00	4,20

The optimum bitumen content is 5,00% as shown in Figure 16 and table 8.

As can be observed, for a bitumen content greater than 5.00%, the stability, and the Marshall Index, decreases. Thus, for bitumen contents greater than 5.40%, it was no longer justified to produce specimens and laboratory tests. Additionally, the minimum bitumen content of 4.20% was taken into account. For this content, asphalt mix specimens of the BAD 22,4 asphalt mix type with PET fibers are made with dosages starting from 2% to 10% following the same work steps as for the asphalt mix as a control. For example, recycled plastics can replace either a percentage of aggregates or serve as a bitumen modifier. Studies in the United Kingdom on asphalt mixtures containing recycled plastics, mainly Low Density Polyethylene (LDPE), which replace about 30% of the 2.36-5 mm aggregates, show a number of advantages such as increasing Marshall's stability and increased tensile strength. [10]

The PET fibers were made with a diameter/width of max. 2 - 2.5 mm, and their length was a maximum of 400 - 500 mm (max. 200d). Thus, the resulting lengths of the PET fibers were a maximum of 500 mm. This solution was adopted similarly to special concretes [11]. The fibers have a width of about 5 mm and are added in higher quantity (1% by weight of concrete) respect to previous tests. Another series of tests has been performed on little concrete beams reinforced with long PET strips positioned similarly to reinforcement bars in concrete beams. Results show a high adherence level between PET fibers and concrete with the further aim to utilize round or flat PET bars (or networks in case of plates and slabs) in substitution of steel reinforcement with the important result to avoid corrosion problems and reduce the deterioration of concrete structures. [12] The fibers were added to the asphalt mixture along with the aggregates, without being preheated or melted. The mixture was homogeneous, and the temperature at which the aggregates were heated and mixed with the PET fibers was 200°C, below the melting point of 260°C for polyethylene terephthalate. The melting temperature of plastic is a crucial factor in asphalt modification, as it influences the correct mixing temperature to ensure effective integration with asphalt binders. [13]

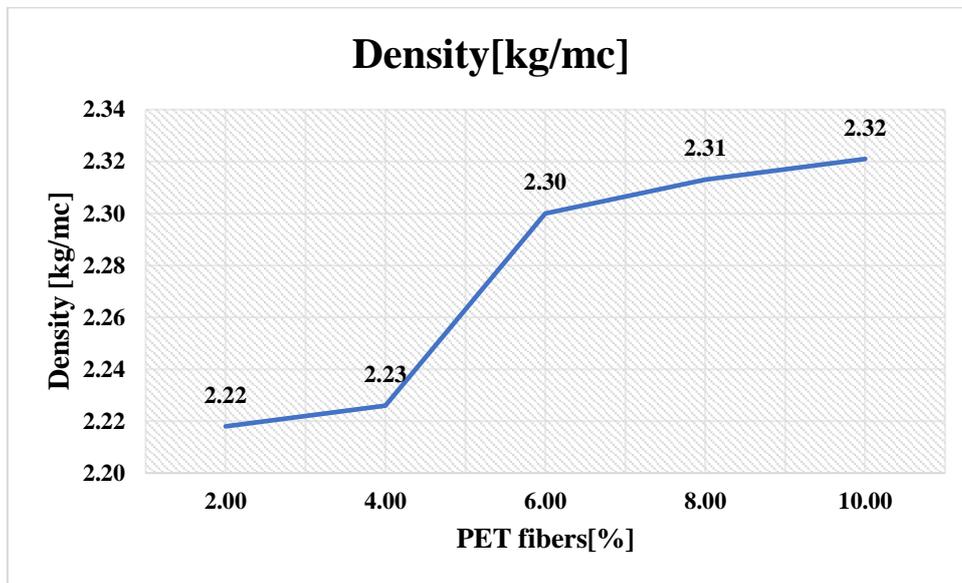


Figure 16. Density values for BAD 22,4 – specimen with PET fibres

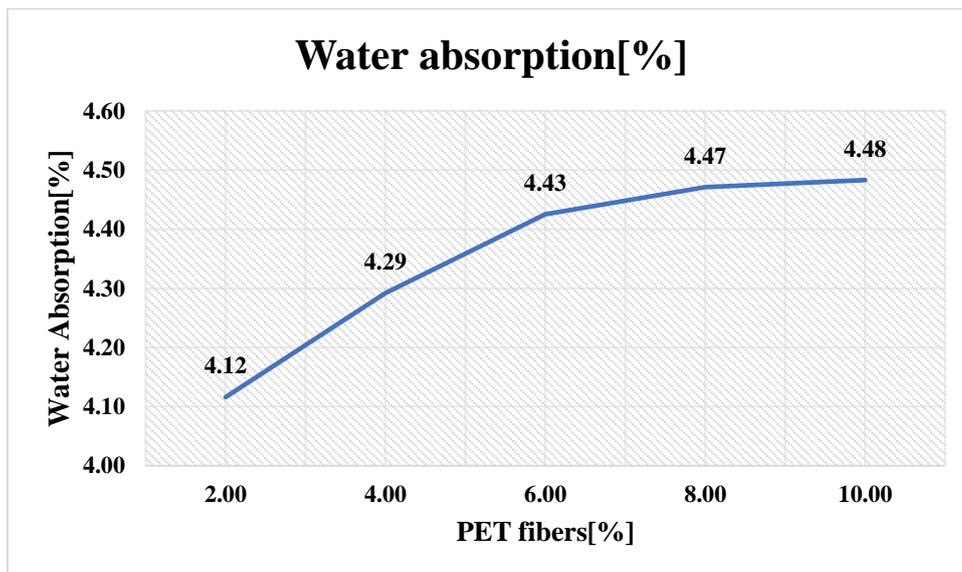


Figure 17. Water absorption values for BAD 22,4 – specimen with PET fibres

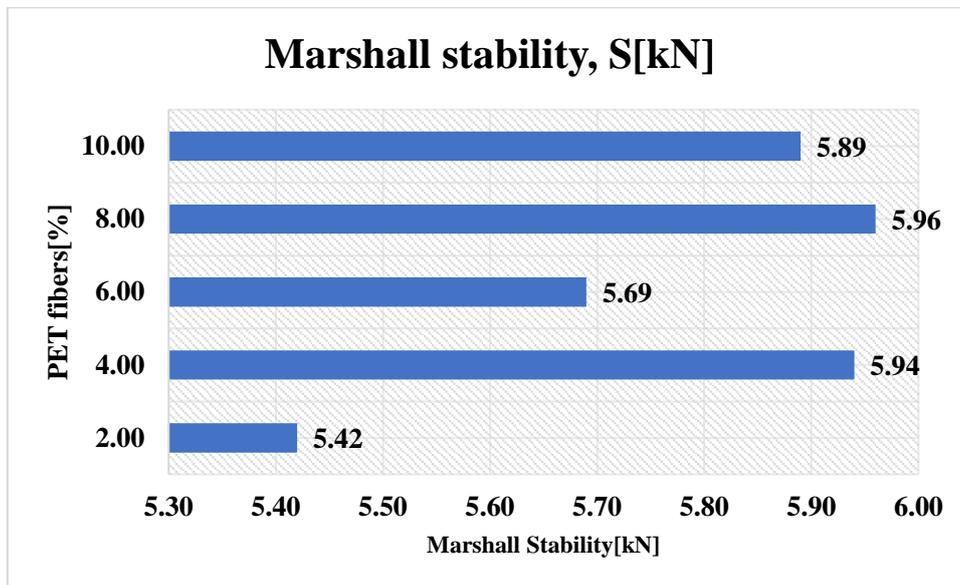


Figure 18. Marshall stability values for BAD 22,4 – specimen with PET fibres

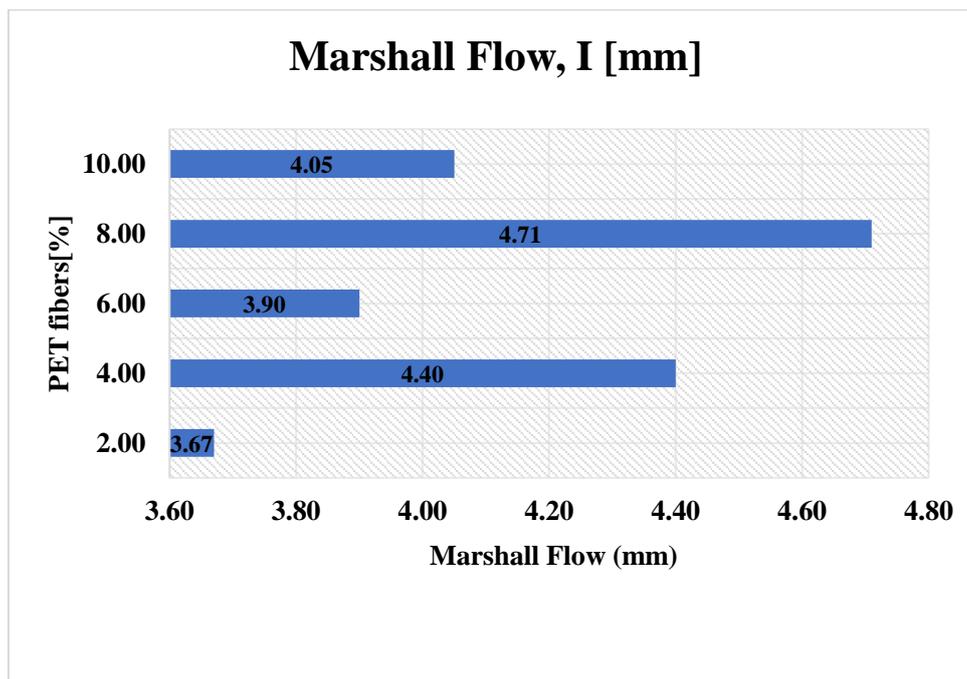
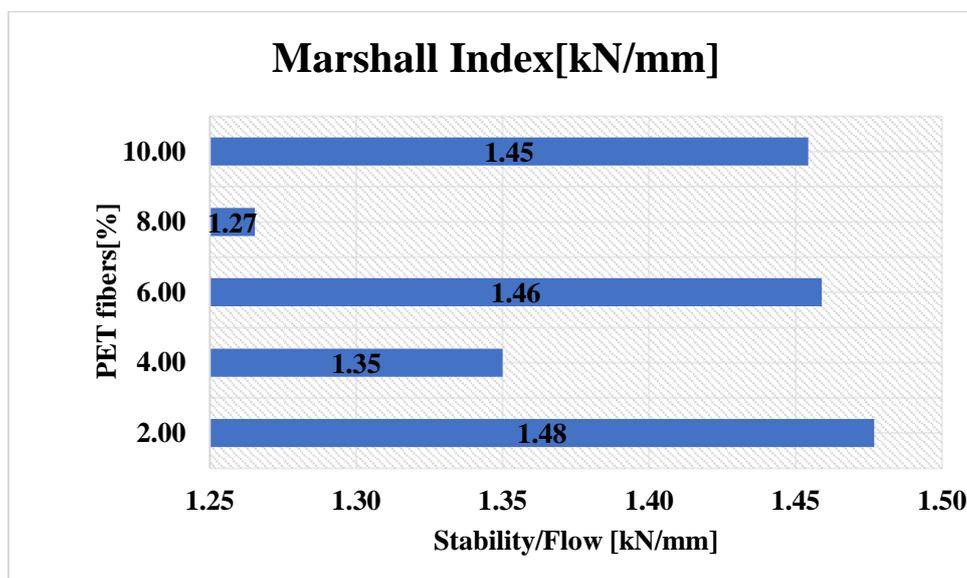


Figure 19. Marshall Flow values for BAD 22,4 – specimen with PET fibres



**Figure 20.** Marshall Index values for BAD 22,4 – specimen with PET fibres

**Table 9.** Physical and mechanical characteristics determined through testing on Marshall cylinders – according to AND 605/2016

Type of asphalt mixture	Stability at 60°C (kN)	Marshall Flow (mm)	Marshall Index (kN/mm)
Open bituminous concrete	5,0.....15	1,5....4,00	1,2

## 4. CONCLUSIONS

Below are the conclusions for this study:

- Recycling PET bottles and incorporating them into asphalt mixtures represents an innovative and sustainable solution to combat plastic pollution.

- In the laboratory were made recipes for asphalt mixture BAD 22,4 control specimens and specimens made with PET fibers with quarry aggregates brought in: Filler - Hoghiz, Brasov County, Bitumen 50/70 - Almatar, Buzău County, Natural Sand - Tupilați, Neamt County, Crushed stone - Suseni, Harghita County.

- After sieving, the granulometric curve for BAD 22.4 falls within the limits imposed by AND 605.

- The mixture BAD 22.4 designed in the road laboratory of the Faculty of Civil Engineering and Installations, Iași, are composed of: filler (5,00%), natural sand 0-4 mm(16,00%), crushed sand 0 - 4 mm (16,00%), crushed stone 4 - 8 mm (15,00%), crushed stone 8 - 16 mm (28,00%), crushed stone 16 – 22,4 mm

(20,00%). Thus, specimens were taken from the control asphalt mixture and the asphalt mixture made with PET fibers

- As a result of determination of the asphalt mixture density, of water absorption and Marshall stability the optimal bitumen percentage, for which the Marshall Index had the highest value, was 5%. Asphalt mixtures with 2%, 4%, 6%, 8%, and 10% PET fibers were prepared for this bitumen percentage.

- The optimal fiber percentage for reinforcing the asphalt mixture, which resulted in the best Marshall Flow [kN/mm] ratio, was 2.00% PET fibers. Additionally, favorable results were also obtained for other percentages of PET fibers. Due to the positive outcomes achieved so far, further static and dynamic tests will be conducted.

- For example, the stiffness and fatigue behavior of PET-modified asphalt mixtures were assessed at two test temperatures, 5°C and 20°C. Various amounts of PET (ranging from 2% to 10% by mass of bitumen) were incorporated into the asphalt mixture using a dry mixing method. The primary objective of this study was to develop models for the fatigue and resilient modulus of the examined mixtures. Laboratory results indicated that the fatigue life of the asphalt mixes is influenced by the initial strain. Additionally, the slope of the fatigue curves decreased as the temperature was reduced. [14] Adding 2.0% glass and steel fibre to the asphalt mixture results in lower fatigue life. [15]

## REFERENCES

- [1] KRANTZBERG G., JETOO S., GROVER I. V. and BABEL S., *Plastic Pollution: Nature Based Solutions and Effective Governance*, Crc Press, **2023**, 5, <https://doi.org/10.1201/9781003137740>
- [2] WERTZ L.J, BEDUE O., and PEREZ S., *Plastics in the oceans Toward Sustainable Solutions*, Crc Press, **2024**, 8, <https://doi.org/10.1201/9781003532477>
- [3] IWASAKI K., HIRABAYASHI K., YAMAGUCHI E., FUJII S., KIMURA T., YAMAMOTO M. and TANABE T., *Non-contact terahertz evaluation of the melting point for PET bottles*, *Thermochemica Acta*, **2024**, 736, <https://doi.org/10.1016/j.tca.2024.179732>
- [4] WANG .K, GUO C., LI J, WANG K., CAO X., LIANG S. and WANG J., *High value-added conversion and functional recycling of waste polyethylene terephthalate (PET) plastics: A comprehensive review*, *Journal of Environmental Chemical Engineering*, **2024**, 12, <https://doi.org/10.1016/j.jece.2024.113539>
- [5] CARDOSO J., FERREIRA A., ALEMIDA A. and SANTOS J., *Incorporation of plastic waste into road pavements: A systematic literature review on the fatigue and rutting*

- performances*, Construction and Building Materials, **2023**, 407, <https://doi.org/10.1016/j.conbuildmat.2023.133441>
- [6] RĂCĂNEL C., BURLACU A., "Environmental Protection through the Use of New Technologies for Asphalt Mixtures," International Conference on Road and Railway Infrastructure - CETRA **2014**, "Road and Railway Infrastructure III," Proceedings of the CETRA 2014 Conference, Dubrovnik, Split, April 28-30, 2014, ISSN: 1848-9842 (pp. 395-400)
- [7] USMAN U. I and KUNLIN M., *Influence of Polyethylene Terephthalate (PET) utilization on the engineering properties of asphalt mixtures: A review*, Construction and Building Materials, **2024**, 411, <https://doi.org/10.1016/j.conbuildmat.2023.134439>
- [8] MOGHADDAM M.Z., ARABANI M., "A comparative study into the effect of spent coffee powder and ash on improving mechanical properties of bitumen", Construction and Building Materials, **2024**, 449, <https://doi.org/10.1016/j.conbuildmat.2024.138319>
- [9] BAAJ T., KARIM R.M., SOLTANI M., MOGHADDAM B.T., "Optimization of asphalt for polyethylene terephthalate modified asphalt mixtures using response surface methodology", Measurement, **2015**, 74, 159-169, <https://doi.org/10.1016/j.measurement.2015.07.012>
- [10] POPESCU DIANA, BURLACU ADRIAN, "Considerations On The Benefits Of Using Recyclable Materials For Road Construction", Romanian Journal Of Transport Infrastructure, Article No. 4, pp. 43-53, Romanian Journal of Transport Infrastructure, Vol. 6, July **2017**, No. 1, ISSN 2286-2218, ISSN-L 2286-2218.
- [11] PROF.ING. C. AVRAM and PROF.ING. C. BOB, *New types of special concrete*, Editura Tehnica, **1980**, 96,97,98,99
- [12] FOTI D., "Use of recycled waste pet bottles fibres for the reinforcement of concrete", Composite Structures, **2013**, 96, 396-404, <https://doi.org/10.1016/j.compstruct.2012.09.019>
- [13] SHAH M. M., YOUSAF J., KHALID U., LI H.M, YEE J.J and NAQVI Z. A. S., *Plastic roads: asphalt mix design and performance*", Discover Applied Sciences, **2024**, 6, 195, <https://doi.org/10.1007/s42452-024-05772-x>
- [14] HAMED H., MODARRES A., "Developing laboratory fatigue and resilient modulus models for modified asphalt mixes with waste plastic bottles (PET)", Construction and Building Materials, **2014**, 68, 256-267, <https://doi.org/10.1016/j.conbuildmat.2014.06.054>
- [15] GRENFELL J., THOM N., PARRY T., MOHAMED M., "Microstructure and mechanical properties of fibre reinforced asphalt mixtures", Construction and Building Materials, **2020**, 240, <https://doi.org/10.1016/j.conbuildmat.2019.117932>