INFLUENȚA CARACTERISTICILOR MATERIALELOR RUTIERE ASUPRA SIGURANȚEI CIRCULAȚIEI
THE INFLUENCE OF ROAD MATERIALS CHARACTERISTICS ON ROAD SAFETY

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Road safety has an increasing importance, especially after UN proclaiming 2011-2020 the Decade of Action for Road Safety. As many factors contribute to producing traffic accidents, infrastructure has its own part in this. Studies related to road surface are very important, especially due to the fact that the quality of the tyre-road surface contact could influence the occurrence of road accidents. Aspects like skid-resistance, permeability, and evenness are the main properties that should be taken into consideration for a road surface. The present research paper has the aim to correlate the characteristics of materials used in the wearing layer with the risk of producing road accidents, by calculating the braking distance, as a sub-component of stopping sight distance. The results of the laboratory tests undertaken on aggregates will show that only by varying the source of materials, stopping sight distance can differ with up to 20 meters.

Siguranța rutieră are o importanță crescută, mai ales după ce ONU a proclamat perioada 2011-2020 Deceniul unei Acțiuni în Siguranța Circulației. Așa cum mulți factori contribuie la producerea accidentelor din trafic, infrastructura are propriul aport. Studiile referitoare la suprafața de rulare sunt foarte importante, în special datorită faptului că producerea accidentelor rutiere poate fi influențată de calitatea contactului pneu-carosabil. Aspecte precum rugozitate, permeabilitate și uniformitate sunt principalele proprietăți de care ar trebui să se țină cont pentru o suprafață de rulare. Lucrarea de cercetare prezentă are scopul de a corela caracteristicile materialelor folosite în stratul de uzură cu riscul de producere a accidentelor din trafic, prin calculul distanței de frânare, o subcomponentă a distanței de oprire. Rezultatele încercărilor de laborator realizate pe agregate vor arăta că varierea sursei materialelor, distanța de oprire poate să difere cu până la 20 de metri.

Keywords: *road materials, road safety, laboratory tests, roughness, polishing, stopping sight distance*

1. Introduction

Although road accidents imply many factors, in-depth studies on this issue highlighted a strong relationship between these unfortunate traffic events and the characteristics and conditions of road surface, thus the quality of tyre-road pavement contact [1-10]. Due to the fact that until now no scientific relation linking the cause of road accidents and road surface was determined, the need of more research in this direction is needed.

Taking as a lead point the most common causes of road crashes involving the quality of road surface, such as incapacity to stop in time due to the smooth surface, losing control of the wheel due to the bad quality of road surface or due to aquaplaning [11], the first step of this research was to review the international literature regarding the way the quality of the tyre-road surface contact could influence the occurrence of road accidents.

There are a series of factors related to road surface texture, factors which can have impact also on the safety of road users. The difference between these factors is due to the scale of the texture, such as [12]:

- Micro texture - Describes the roughness of the aggregate's surface, which is associated with the crystalline structure of the coarse aggregate and the sand particles in the surface laitance of a brushed concrete surface. The fine scale micro texture of the aggregate's surface is the main contributor to skidding resistance and also the dominant factor in determining skidding resistance at lower speeds.
- Macro texture - Represents the height above a road surface of the aggregate chipping, or the depth of texture below the road surface. It provides rapid drainage routes between the tyre and the road surface, contributes to the wet skidding resistance at higher speeds, and it also allows air trapped beneath the tyre to escape.

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• Mega texture - Represents the degree of surface smoothness. At a scale comparable with the tyre contact patch, it is mainly associated with tyre noise.

• Unevenness - Describes the amplitudes of longer wavelengths, which affect vehicle suspensions. In the longer ranges it causes large tyre and suspension movements that affect the handling of vehicles.

The laboratory research carried out in the present experimental program is regarding the road surface texture, more specific its micro-texture (Figure 1).

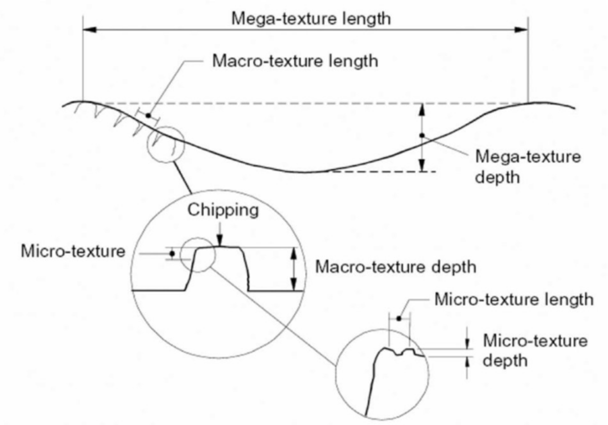


Fig.1 - Details of texture length and depths/ *Detalii ale lungimii și adâncimii texturii* [12].

Most of the materials have at first a good micro-texture, but those which maintain in time their texture or have the capacity to regenerate it, are more preferable. These aggregates are called “resistant to polishing” and their micro texture does not depend only on the nature of the material, but also depends on the environment they are used in – type of traffic, climatic conditions. All these characteristics of the surroundings give the polishing level of an aggregate and also the behaviour of its micro texture. The response of the aggregates to these environmental conditions is determined by characteristics like mineralogy, the dimension and distribution of particles, porosity and the pore dimension for each particle [13].

A good friction coefficient between the wearing course of the road surface and the tyre is one of the key elements related to the safety of a road. As it was already proved empirically, road crashes are strongly related to this friction coefficient, as presented in Figure 2.

Surface friction refers to the force developed at the tyre pavement interface to resist sliding when braking forces are applied [14]. It is particularly important in wet weather conditions because water on the pavement acts as a lubricant to reduce the direct contact between the tyre and the pavement surface. Surface friction of the concrete pavement is largely influenced by the overall texture of the pavement that is controlled by the surface finish and

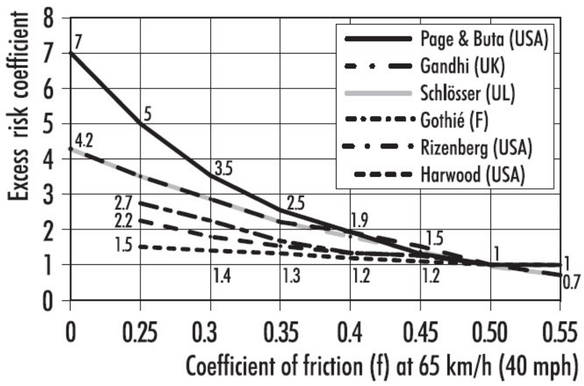


Fig.2 - Excess risk coefficient / *Coeficientul de risc excesiv* [11].

to a lesser extent by the texture of the aggregate particles, especially the fine aggregates.

The effect of aggregate polishing caused by traffic is most frequent in complicated road sections like curves, roundabouts with small radius, sections where the vehicles accelerate or decelerate and in areas close to crossings. Concurrently there is a need of a high friction level at that type of road sections to avoid accidents.

The polishing of aggregates strongly depends on the amount of traffic and the type of tyres. Heavy traffic is considered to be influencing the polishing more than small vehicles, and also the presence of dust and moisture is considered to have an impact on the polishing level.

Previous studies [15,16] highlight the fact that polishing action of traffic is an important parameter of an asphalt mixture pavement during its service life. Aggregates characteristics, specifically shape and resistance to wear are considered by many researchers very important to maintain a rough asphalt surface, and poliedric shape, hard aggregates are suitable to be used in asphalt mixture composition. Fine parts of asphalt mixture skeleton has a considerable influence only when it is in a bigger percent and for wearing courses it is recommended the use of crushed stone sand [17].

Studies [18] show that polishing behaviour of aggregates is influenced also by their mineralogy composition. A petrography examination is a valuable tool for understanding the behaviour of aggregates at polishing and their use in asphalt mixture. Rocks containing metamorphic parts are less susceptible to wearing than sedimentary materials with better frictional properties of pavement surface [19].

2. Materials and experimental procedures

Aggregates can come from either natural or manufactured sources. Natural aggregates come from rock, of which there are three broad geological classifications: igneous rock (are primarily crystalline and are formed by the cooling of molten

Table 1

Aggregates selected for the experimental program / *Agregatele selectate pentru programul experimental*

No.	Aggregate source	Region	Rock type
1.	Turcoaia	Tulcea	Rhyolite
2.	Cerna	Tulcea	Rhyolite
3.	Chileni	Harghita	Andesite
4.	Tăul Roșu	Maramures	Andesite
5.	Revărsarea	Tulcea	Diabase
6.	Hoghiz	Brasov	Limestone

rock material beneath the earth's crust), sedimentary rocks (are formed from deposited insoluble material, transformed to rock by heat and pressure) and metamorphic rock (igneous or sedimentary rocks that have been subjected to heat and/or pressure great enough to change their mineral structure so as to be different from the original rock).

Aggregates are produced in a quarry or mine, whose basic function is to convert in situ rock into aggregate with specified characteristics. Usually the rock is blasted or dug from the quarry walls then reduced in size using a series of screens and crushers.

Fortunately, Romania is one of the countries with many deposits of aggregates for construction. To highlight the importance of aggregate quality from wearing course, there were chosen six sources of aggregates from Romania, which provided the raw material necessary to perform the laboratory tests in the Road Laboratory from Technical University of Civil Engineering Bucharest, Faculty of Railways, Roads and Bridges.

Starting with 2004, the range of tests carried out on aggregates has been harmonized throughout the European Union, like Polished Stone Value (PSV), Aggregate Abrasion Value (AAV) and Magnesium Sulphate Soundness (MSS), which have been retained virtually intact. Aggregate strength is now assessed using the Los Angeles test, which has replaced the Ten Percent Fines Value. Other European tests, such as Methylene Blue, Shape Index, Impact Value (not former BS test, but based on a DIN method), Micro Deval, Freeze Thaw, Resistance to Thermal Shock, and "Sonnenbrand" of basalt, are also used in testing aggregates.

2.1. Polished Stone Value Test

The first testing method proposed for the evaluation of the micro-texture quality is the determination of the Polished Stone Value. This method was developed in Great Britain in 1950 and then it was taken over and used also in United States, New Zeeland and Australia.

The present test on aggregates has been conducted according to the European Standard EN 1097- 8:2009 [20]. This European Standard specifies the method for determining the polished stone value (PSV) of a coarse aggregate used in road surfacing. PSV is a measure of the resistance of coarse aggregate to the polishing action of vehicle tyres simulating the conditions occurring on the surface of a road. The test was carried out on aggregates passing a 10 mm sieve and retained on a 7,2 mm grid sieve and consists in two parts:

a) test specimens are subjected to a polishing action in an accelerated polishing machine (Figure 3).

Fig. 3 – Aggregate samples fixed on the wheel of PSV machine / *Probe de aggregate fixate pe roata aparatului de PSV.*

b) the state of polish reached by each specimen is measured by means of a friction test, with the Skid Resistance Tester - SRT (Figure 4).

Fig. 4 – Second stage of PSV test - Skid-Resistance measurement / *A doua etapă a încercării PSV – măsurarea rugozității*

The Polished Stone Value is calculated depending on the skid resistance test results on each sample of the aggregate, but also on the reference stone, according to the relation below:

$$PSV = S + (52.5) - C \qquad (1)$$

where: S is the medium value measured with SRT on the three aggregate samples, C is the medium value measured with SRT on the two reference stone samples.

This is the most important test that an aggregate can undergo if it is to be used in a road surface course. If an aggregate polishes too much under the polishing effect of vehicle tyres, the road surface becomes very slippery, especially when wet, and the number of skidding accidents can increase. [21]

The same types of aggregates are used to make asphalt mixtures, which are later verified with the SRT to determine the friction coefficient (μ). The classical Coulomb friction model was defined at the contact surface and the input friction coefficient was determined from the principle of conservation of energy, where the energy lost by the pendulum (Figure 5) during the swing is equal to the work done in overcoming the friction between the slider and the surface [22]:

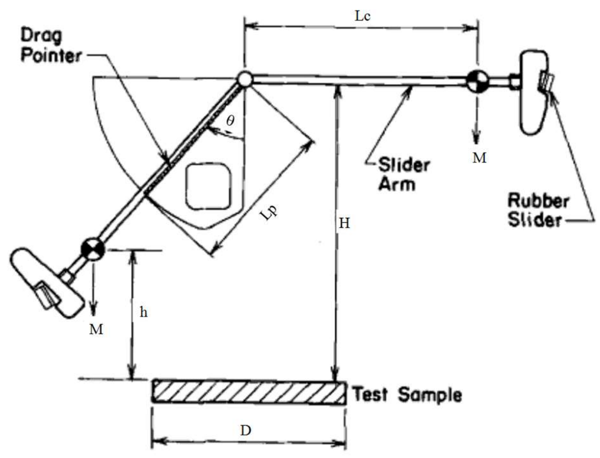


Fig. 5 - Skid Resistance Tester model / *Model pentru aparatul SRT [22].*

$$\mu = \frac{M(H-h)}{PL} \qquad (2)$$

where: M is the effective weight of the swinging arm (1.486 kg), H is the initial height of the centre of gravity in the release position, h is the height of the centre of gravity at the highest point of the swing after the slider has passed over the test surface (as indicated by the pointer), μ is the effective coefficient of friction between slider and surface, P is the average normal load between slider and surface (22 N), and L is the sliding distance (127 mm).

Since it was very important to know the initial qualities of the materials, the friction coefficient was calculated on the initials samples, before polishing, as μ_0, and afterwards, as μ_f. Also, μ was calculated on asphalt mixture, using relation (2), for each type of aggregate.

2.2. Micro Deval Test

The Micro-Deval test had its inception in France during the 1960s. Its predecessor, the Deval test, was developed in the early 1900s to evaluate the quality of railroad ballast materials. The Micro-Deval test is a modified version of the original Deval test. During its early days of development, the French sought a procedure that would apply frictional wear and degradation, without fragmentation of the aggregate. They found that the degradation was more pronounced in the presence of water than when dry. The degree to which this varies is dependent on the amount of softer minerals present, such as clays, micas, calcite and dolomite. [23]

According to SR EN 1097-1/2011 [24], the test determines the micro-Deval coefficient, which is the percentage of the original sample reduced to a size smaller than 1.6 mm during rolling. It consists of measuring the wear produced by friction between the aggregates and an abrasive charge in a rotating drum, under defined conditions. When rolling is complete, the percentage retained on a 1.6 mm sieve is used to calculate the micro-Deval coefficient. The test method described in this European Standard and used for the present experimental program is the reference method and is carried out with dry aggregate with the addition of water to give a value to a the micro-Deval coefficient.

Research studies [25] found that Micro-Deval apparatus is the only commonly used test that has adequate predictive abilities concerning toughness and abrasion resistance. The Micro-Deval also uses a rotating drum with steel spheres, but the drum is much smaller as are the spheres. The result is that the Micro-Deval test tends to smoothen aggregate particles, while the Los Angeles abrasion test tends to break them.

For each test specimen the Micro-Deval coefficient (M_{DE}) is calculated, to the nearest 0.1 g, following the equation below:

$$M_{DE} = \frac{500 - m}{5} \qquad (3)$$

where M_{DE} is the micro-Deval coefficient (in wet conditions), m is the mass of the oversize fraction retained on a 1.6 mm sieve, in grams.

2.3. Stopping sight distance

The most important aspect related to the tyre-road surface contact is the braking distance, which refers to the distance a vehicle travels from the point when its brakes are fully applied to when it comes to a complete stop. It is primarily affected by the original speed of the vehicle and the friction coefficient between the tyres and the road surface. Along with the reaction distance, which is the product of the speed and the perception-reaction time of the driver, it forms stopping sight distance.

For this particular study, it was taken into consideration both reaction time and braking time, and then calculated the stopping sight distance (SSD) with the relation below (4)

$$SSD = \frac{V_i \times t}{3,6} + \frac{V_i^2 - V_f^2}{254(\mu_l \pm i)} \qquad (4)$$

where: V_i is the initial speed [km/h], V_f is the final speed [km/h], t is the reaction time (s), μ_l is the coefficient of longitudinal friction, i is the grade [%/100].

The stopping sight distance is calculated for each friction coefficient, depending on the source quarry of aggregates and considering the same final speed (=0), but changing the initial speed (driving speed), the grade and the reaction time of the driver, each at a time. Obviously, when the reaction time of the driver is constant, we can talk about different aspects of braking distance, which solely depends on technical characteristic of the road and driver's speed.

3. Results and discussions

The results obtained after two Polished Stone Value tests in the Roads laboratory from Railways, Roads and Bridges Faculty, Technical University of Civil Engineering Bucharest, on 6 types of aggregates are presented in the table below, where the initial friction coefficient (μ_0) – before the test, and the final friction coefficient (μ_f) – after the test, are presented along with the PSV coefficient.

The aggregates which had the best results in the Polished Stone Value test are the aggregates from Tăul Roșu, with a very good initial friction and a good final result. According to this test, this is the most resistant to polishing aggregate from our experimental program.

Good results were also obtained on Revărsarea and Chileni aggregates, and mediocre results on Cerna and Turcoaia aggregates. Very bad results were obtained on Hoghiz aggregates, which although had a very good initial friction coefficient, they didn't tend to maintain it – they had a very bad behaviour concerning the resistance to polishing during traffic and their use in the upper layers is not recommended due to road safety reasons.

For the second test, using the values obtained for the two specimens, the mean value of the micro-Deval coefficient is calculated for each source of aggregate. The results obtained from the Micro Deval test on the six types of aggregates are presented in Table 3.

The results from the micro-Deval test point out that the aggregate with the best behaviour at abrasion are the aggregates from Turcoaia and Cerna quarry. The aggregates from Revărsarea have a mediocre behaviour and those from Chileni, Tăul Roșu and Hoghiz resulted in a bad behaviour towards abrasion.

The quality differences between these six aggregates used in upper road layers is very consistent if we take into consideration the two laboratory tests. The aggregates with good results at polishing turned out to be unfit from the point of view of abrasion (Tăul Roșu and Revărsarea), and the aggregates with good results at abrasion turned out to be mediocre from the point of view of polishing.

The certain result from these laboratory tests is concerning the aggregates from Hoghiz, which had very poor results in abrasion and in polishing as well, and are definitely not recommended to be used in asphalt mixtures for the wearing course.

In the graphic below (Figure 6) it can be noticed the different behaviour of the aggregates during the two different laboratory tests.

In order to find an explanation for the different results from our experimental program, the petrographic nature of the aggregates was analyzed, no matter the source of the aggregates, as highlighted in Table 2 and Table 3.

Table 2

Polished Stone Values for aggregates from the experimental program /
Rezultatele PSV pentru agregatele din programul experimental

No.	Aggregate source	Initial friction coefficient, μ_0	Final friction coefficient, μ_f	Polished Stone Value, PSV	Rock type
1.	Turcoaia	0.55	0.49	47.5	Rhyolite
2.	Cerna	0.52	0.49	49	Rhyolite
3.	Chileni	0.61	0.55	56.5	Andesite
4.	Tăul Roșu	0.67	0.56	58.22	Andesite
5.	Revărsarea	0.60	0.50	51.8	Diabase
6.	Hoghiz	0.63	0.39	41.17	Limestone

Table 3

Micro Deval values for aggregates from the experimental program
Valori ale rezistenței la uzură Micro Deval pentru agregatele din programul experimental

No.	Aggregate source	Micro-Deval coefficient, M_{DE}	Micro-Deval coefficient category, M_{DE}	Rock type
1.	Turcoaia	6.12	M_{DE} 10	Rhyolite
2.	Cerna	7.47	M_{DE} 10	Rhyolite
3.	Chileni	18.67	M_{DE} 20	Andesite
4.	Tăul Roșu	17.36	M_{DE} 20	Andesite
5.	Revărsarea	10.15	M_{DE} 15	Diabase
6.	Hoghiz	18.63	M_{DE} 20	Limestone

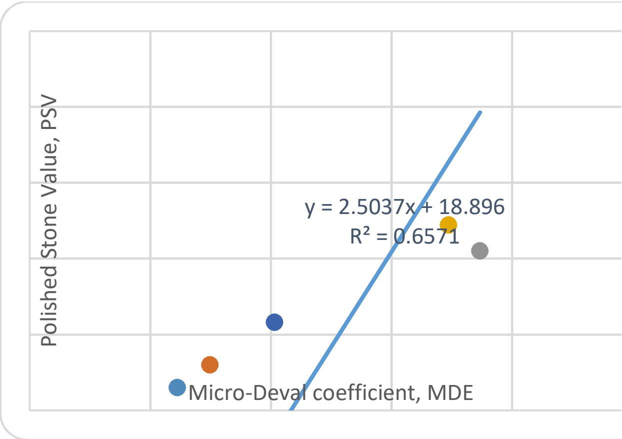


Fig. 6 – Correlation between the behaviour of aggregates during Polished Stone Value Test and Micro-Deval Test / *Corelație între comportarea agregatelor în timpul încercărilor la polisaj și Micro-Deval*

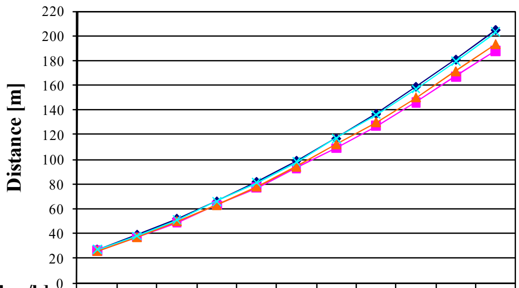
As it can be noticed, andesite aggregates have the best behaviour concerning the resistance to polishing but the worse results at abrasion, unlike rhyolite aggregates which have an opposite behaviour – they tend to act well at abrasion, but with bad results as polishing. The diabase aggregate was the one with good results at both tests, acting very good at polishing and good at abrasion, opposed to the limestone aggregates, which had the worse results for both tests.

To go to the next step and calculate the stopping sight distance, the friction coefficient of a road surface is still needed. The best and worst performing sources of aggregates were eliminated, which are Tăul Roșu and Hoghiz, and for the other four remaining, asphalt mixtures were made in the laboratory, and using the SRT, the friction coefficient was calculated empirically with relation (2), with the obtained values presented in Table 4.

After obtaining the results from all the laboratory tests, it was proceeded for the empirical calculus of stopping sight distance (SSD). The SSD was calculated by varying the speed, the grade and the reaction time of the driver, using relation (4).

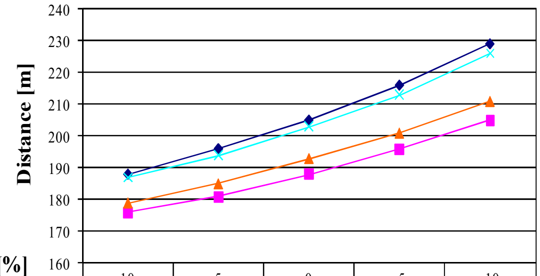
For low driving speed, the difference between stopping sight distances in the same conditions is almost absent. But, by raising the speed, the differences appear depending on the quarry source of the aggregates used in the asphalt mixtures. So, the higher the friction coefficient is, the smaller the stopping sight distances are.

It can be noticed only from the variations of the grade in the calculus of braking distance, that the values from the mixtures realized with aggregates from the quarries Revărsarea (μ = 0.68) and Chileni (μ = 0.65) are smaller than the values from the mixtures realized with aggregates from the quarries Turcoaia (μ = 0.58) and Cerna (μ = 0.59), and they are directly proportional to the driving speed, as shown in Figure 7.



Speed [km/h]	30	40	50	60	70	80	90	100	110	120	130
Turcoaia	27	39	52	66	82	99	117	137	159	181	205
Revarsarea	26	37	49	63	77	93	109	127	146	167	188
Chileni	26	37	50	63	78	94	112	130	150	171	193
Cerna	27	38	51	66	81	98	117	136	157	179	203

Fig.7 – Stopping sight distance values for 0.00% slope and 2,5 seconds reaction time, depending on the friction coefficient/ *Valori ale distanței de oprire pentru o declivitate de 0,00% și un timp de reacție de 2,5 secunde, în funcție de coeficientul de frecare*



Slope [%]	10	5	0	-5	-10
Turcoaia	188	196	205	216	229
Revarsarea	176	181	188	196	205
Chileni	179	185	193	201	211
Cerna	187	194	203	213	226

Fig.8 - Stopping sight distance values for driving speed of 130km/h and 2.5 seconds reaction time, depending on the friction coefficient and grade/ *Valori ale distanței de frânare pentru o viteză de circulație de 130km/h și un timp de reacție de 2,5 secunde, în funcție de coeficientul de frecare și declivitate*

The difference between stopping sight distance at the same design speed increases with the decrease of slopes. This way, at a driving speed of 130km/h, for a grade i =-10.00% (downhill), we have a difference of 24 meters between the maximum (Revărsarea quarry) and the minimum (Turcoaia quarry), comparing to a difference of 17 meters for a slope i=0.00% and a difference of 12 meters for a slope i=+10.00% (ramp), as can be noticed in Figure 8.

Table 4

Friction coefficient of asphalt mixtures/ *Coeficienți de frecare ai mixturilor asfaltice*

No.	**Aggregate source**	**Asphalt mixture type**	**SRT value**	**H-h (mm)**	**Friction coefficient, μ**
1	Turcoaia	MASF 16	69.8	109.7	0.58
2	Revărsarea	MASF 16	83.0	128.5	0.68
3	Chileni	MASF 16	79.9	124.1	0.65
4	Cerna	MASF 16	71.5	112.1	0.59

4. Conclusions

Although it is well known that there are many factors which interfere with the good behaviour of an asphalt mixture in service, factors such as traffic conditions, type of mixture and weather conditions, it is imperious to ensure good quality materials and adequate to serve their purpose.

As can be seen in the tests conducted in the Roads laboratory from Railways, Roads and Bridges Faculty, Technical University of Civil Engineering Bucharest, the six types of road aggregates have different behaviours concerning the relationship given by the tyre-road surface contact.

Although at the beginning of the experimental program the main purpose was to observe the behaviour of aggregates from each quarry and try to make a classification, the results of the test conducted to the fact that the resistance to abrasion and to polishing are very tight to the petrographic nature of the aggregates. So even if aggregates come from different parts of the country, they tend to have the same behaviour at different laboratory test.

From this point of view, it needs to be highlighted the fact that andesite aggregates are the ones with the best behaviour at polishing, rhyolite aggregates with the best behaviour at abrasion, diabase aggregates tend to act well in both circumstances, unlike limestone aggregates which have very bad behaviour in both polishing and abrasion and are not recommended to be used in the wearing course.

Thus, the properties of mineral aggregates used in the bituminous mix have significant influence on the performance of the pavement, with a great effect on road safety: for example on a road sector with a low friction coefficient, it is recommended to use aggregates with a high Polished Stone Value (preferable andesite) and for a road sector with heavy traffic, it is recommended to use aggregates with a good abrasion resistance and durability (preferable rhyolite). Therefore, in the production of bituminous mixes, it is important to carefully control the quality of aggregates used. Generally, this is accomplished by testing candidate aggregate materials in the laboratory and screening out those aggregates that fail to meet certain laboratory test criteria.

To obtain more consistent results in terms of quality aggregates from wearing course and the way they are influencing the tyre-road surface contact, as a future research direction it is the tendency to increase the number of quarries participating in the experimental program.

As a final conclusion, it can be said that skid resistance is an important parameter of the road surface which measures the contribution of surface to the friction force between tyre and the road. Using good quality aggregates, it will help maintain a proper roughness of pavement surface as a result of interaction between microstructure, pavement texture and tyre characteristics. Also, just by choosing the right type of aggregates for a road pavement, the stopping sight distance can be reduced by more than 20 metres.

REFERENCES

1. P. Cairney, and P. Bennett, ARRB Group, Relationship Between Road Surface Characteristic and Crashes on Victorian Rural Roads, in the 23rd ARRB Conference – Research Partnering with Practitioners, Adelaide Australia, 2008.
2. A. I. Al-Mansour, Effects of Pavement Skid Resistance on Traffic Accidents, The Journal of Engineering Research 2006, **3**(1), 75.
3. K. L. Smith, R. Larson, Engineering Safer Road Surfaces to Help Achieve U.S. Highway Safety Goal, Submitted to the 3rd International Conference on Road Safety and Simulation September 14-16, 2011, Indianapolis, IN, USA.
4. C.G. Wallman, H. Åström, Friction measurement methods and the correlation between road friction and traffic safety, A literature review, VTI meddelande 911A, 2001.
5. S. Othman, R. Thomson, Influence of Road Characteristics on Traffic Safety, Sweden, Paper Number 07- 0064.
6. D. A. Noyce, H. U. Bahia, J. Yambo, J. Chapman, A. Bill, University of Wisconsin-Madison Traffic Operations and Safety Laboratory, Incorporating Road Safety into Pavement Management: Maximizing Surface Friction for Road Safety Improvements, Project 04 – 04, June 2007.
7. J. S. Kuttesch, Quantifying the Relationship between Skid Resistance and Wet Weather Accidents for Virginia Data, September 13, 2004, Blacksburg, Virginia.
8. R. Karlsson, U. Hammarström, H. Sörensen, O. Eriksson, Road surface influence on rolling resistance, Coastdown measurements for a car and an HGV, VTI notat 24A-2011
9. W. Zhang, J. Yang, L. Cong, The Effect of Asphalt Pavement Texture on Braking Distance, Submitted to the 3rd international conference on road safety and simulation, September 14-16, 2011, Indianapolis, USA.
10. G. P. Ong, T. F. Fwa, Mechanistic Interpretation of Braking Distance Specifications and Pavement Friction Requirements, Transportation Research Record: Journal of the Transportation Research Board, No. 2155, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 145–157.
11. PIARC Technical Committee on Road Safety: Road Safety Manual, 2003.
12. HD36/06, Surfacing materials for new and maintenance construction, Standard from Design Manual for Roads and Bridges, 2006.
13. F.A. Burlacu, PhD thesis, The influence of road characteristics on road safety, Technical University of Civil Engineering Bucharest, Romania, 2014.
14. J.J. Henry, Evaluation of Pavement Friction Characteristics, NCHRP Synthesis 291, TRB, National Research Council, Washington, D.C, 2000.
15. Austroads Technical Report. A new reference aggregate for PAFV Testing. AP-T211-12, 2012.
16. Austroads Technical Report. Establishing a reference aggregate for aggregate polishing tests. AP-T212-12, 2012.
17. D.L. Bloem, Skid-Resistance: The Role of Aggregates and Other Factors. National Sand and Gravel Association Circular 109, Silver Spring, MD, 1971.
18. M.T. Do, H. Zahouani, and R. Vargiolu, Angular Parameter for Characterizing Road Surface Microtexture. Transportation Research Record 1723, Transportation Research Board, TRB, National Research Council, Washington, D.C., 2000.

19. T.R. West, J.C. Choi, D.W. Bruner, H.J. Park, and K.H. Cho, Evaluation of Dolomite and Related Aggregates Used in Bituminous Overlays for Indiana Pavements. Transportation Research Record 1757, Transportation Research Board, TRB, National Research Council, Washington, D.C, 2001.
20. SR EN 1097-8/2003, Tests for mechanical and physical properties of aggregates-Part 8: Determination of the polished stone value.
21. M. Dicu, C. Răcănel, A. Burlacu, in Proceedings of the XIII-th National Roads and Bridges Congress in Romania, Laboratory evaluation with Polished Stone Value Equipment of wearing performances for asphalt mixtures, Poiana Braşov, September 2010, ISSN 1583-820X, pg.420-426, vol.I).
22. T.B. Kulakowski, J.J.Henry, L. Chunming, A closed-loop calibration procedure for a British Pendulum Test, Surface Characteristics of roadway: international research and technologies Conference publication, 1990
23. P.W. Jayawickrama, S. Hossain, and A.R. Hoare, Long-Term Research On Bituminous Coarse Aggregate: Use Of Micro-Deval Test For Project Level Aggregate Quality Control, Texas Transportation Institute, Report No. FHWA/TX-06/0-1707-9, 2007.
24. SR EN 1097-1/2011, Tests for mechanical and physical properties of aggregates-Part 1: Determination of the resistance to wear (micro-Deval).
25. Y. Wu, F. Parker, and K. Kandhal, Aggregate Toughness/Abrasion Resistance and Durability/Soundness Tests Related to Asphalt Concrete Performance in Pavements. NCAT Report 98-4. National Center for Asphalt Technology. Auburn, AL., 1998;

MANIFESTĂRI ȘTIINȚIFICE / SCIENTIFIC EVENTS

7th International EATA Conference

Since the inaugural meeting of EATA (European Asphalt Technology Association) in Nottingham Royal Moat House Hotel on July 6th – July 7th, 2004 took place, EATA conferences were held every two years, except on 2013, in different places like Meriden (UK), Lyon (F), Parma (I), Braunschweig (D) and Stockholm (S).

In 2017 the EATA conference will make a stop-over at Empa in Dübendorf, Switzerland.

Conference Topics

- Durability and aging of binders and asphalt mixtures
- New mixtures and mixture components
- Modelling and testing
- Asphalt mixture design, modelling and testing
- Environmental aspects
- Asphalt recycling
- Advances in construction and asphalt production technologies
- Structural design
- Innovative asphalt pavements
- Damage, aging and performance of pavements
- Pavement rehabilitation

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