Influence of mineral aggregate on asphalt pavement surface properties

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Abstract. The road surface roughness is one of the factors influencing road safety. Therefore, the choice of materials and mixtures for the wearing course of pavement is important. The paper presents the results of research on the influence of the composition of asphalt mixtures on the surface parameters of PTV and MTD, which were analyzed according to the type of mixture, type of aggregate, and maximum aggregate size on laboratory-produced samples and samples with bitumen stripped surfaces. The skid resistance of SMA 11 and AC 16 mixtures were higher (PTV value 64.2 and 66.2) compared to AC11 and AC8 mixtures (PTV value 56.8 and 58.6) with all tested aggregates. After bitumen stripping from the surface, the PTV values of mixtures increased and the influence of the aggregate type and texture became more significant. To achieve better skid resistance properties, it is suitable to use coarse aggregate from andesite or granodiorite rocks (PTV value 67.0 or 65.8). Of the tested aggregates, limestone had the worst results (PTV value 63.3). Above all the portion of coarse aggregates, size distribution, and shape characteristics as shape index, angularity, determine the macrotexture of the surface.

1. Introduction
The extent to which a road can ensure functional requirements (safe pavement serviceability and pavement efficiency) depends on many factors, in particular its design and construction, environmental conditions, but also the amount and type of traffic load that uses the road [1, 2]. When assessing the quality of the road surface, the most important is the safety of road traffic, which is determined by the surface roughness by the macrotexture and microtexture of the surface. Insufficient road surface roughness can lead to skidding of the vehicle wheels as a common cause of an accident [3]. Many detailed analyses of accident sections performed on the territory of the Slovak Republic show that the reduction of roughness on a wet surface has a share of 25 % in a traffic accident.

Friction between the pavement and the wheel is influenced by a wide range of factors such as tyre parameters (pressure, tread pattern and depth), vehicle parameters (type, weight, speed, braking system), environmental characteristics (temperature, season, presence of water, surface contamination), the road horizontal and longitudinal alignment, and last but not least the surface texture and frictional characteristics (type and parameters of the mixture in the wearing course). The texture of the pavement surface, the type and parameters of the tyre, the presence of water on the road, and the speed of the vehicle have a major influence on the friction between the wheel and the pavement.

The aggregate size distribution and the void in the mineral aggregate in the wearing course of the pavement form the macrotexture of the surface. The high portion of bitumen binder and fine aggregate in asphalt mixture does not form the necessary surface texture. The critical values of air void content are about 2% and about 90% of the void filled with bitumen binder. Aggregates form the supporting
skeleton of each building mixture. The maximum size and the particle size distribution of aggregate in the mixture are decisive for the macrotexture of the surface. The rock type of aggregate forms the microtexture of the pavement surface and the ability to maintain an aggregate surface texture during the effects of climatic conditions and traffic load. Therefore, the aim of the paper is determination the influence of the type of aggregate with the different minerals and different surface texture on the surface parameters of the asphalt mixture and the maximum aggregate size in the mixture and the type of mixture on the surface texture parameters.

2. Research methodology
The study of the influence of different mineral aggregate on asphalt surface properties conducted in laboratory-produced asphalt mixtures used in practice in the Slovak Republic. The asphalt concrete AC and stone mix asphalt SMA mixtures with maximum aggregate size 8 mm, 11 mm, and 16 mm were used. Figure 1 shows the particle size distribution of the aggregate mixture of tested asphalt mixtures AC 8, AC 11, AC 16, and SMA 11. Each mixture was produced with coarse and fine aggregates, limestone filler, and paving grade bitumen 50/70. The composition of asphalt mixtures, mass by weight in percentage, see in table 2. The used coarse aggregate, made from rocks from three different sources in terms of mineralogical composition content, were andesite (A), limestone (V), and granodiorite (G) rocks. The main physical characteristics of aggregate rock are in table 1. It was assumed that these aggregates would differ in micro and macro surface texture. The limestone fine aggregate used in all mixtures was the same. The mixtures SMA 11 additionally contained 0.3 % of natural cellulose fibers additive Viatop.

Table 1. Physical characteristics of aggregate rock [4].

| Property                  | Aggregate          |
|---------------------------|--------------------|
|                           | Andesite | Limestone | Granodiorite |
| Density (kg.m⁻³)          | 2 701     | 2 715     | 2 666        |
| Particle bulk density (kg.m⁻³) | 2 565     | 2 703.9   | 2 665        |
| Porosity (%)              | 5.04      | 0.39      | 0.17         |
| Water absorption (%)      | 0.94      | 0.11      | 0.22         |

Figure 1. The particle size distribution of asphalt mixtures.
Asphalt mixtures have been designed in accordance with the requirements of European standards EN 13108-1 and EN 13108-5 and to meet the requirements specified in the national regulation KLAZ [7] (grading, bitumen content, air voids content, water sensitivity, resistance to permanent deformation). The decisive factor of the design was the grading of the aggregate mixture. The aim was to design the individual mixtures with different aggregate rocks that differed from each other as little as possible (figure 1). The proposed mixtures were produced in the laboratory of authors.

| Mixture | Type of coarse aggregate | Content in a mixture (%) | Bitumen |
|---------|--------------------------|--------------------------|---------|
|         | Filler 0/2 (mm) 2/4 (mm) 4/8 (mm) 8/11 (mm) 8/16 (mm) 50/70 |
| AC8     | Andesite 1.9 35.9 26.4 30.2 - - 5.6 |
|         | Limestone 1.9 35.9 24.5 32.1 - - 5.6 |
|         | Granodiorite 1.9 35.9 25.5 31.1 - - 5.6 |
| AC11    | Andesite 4.7 22.7 24.6 23.7 18.9 - 5.4 |
|         | Limestone 4.7 21.8 23.6 21.8 22.7 - 5.4 |
|         | Granodiorite 4.7 22.7 23.7 19.9 23.6 - 5.4 |
| SMA11   | Andesite 5.6 22.7 7.3 31.8 26.2 - 6.4 |
|         | Limestone 5.6 21.3 7.7 28.1 30.9 - 6.4 |
|         | Granodiorite 5.6 21.5 7.5 26.2 32.8 - 6.4 |
| AC16    | Andesite 3.8 20.8 18.0 17.1 - 35.0 5.3 |
|         | Limestone 3.8 20.8 18.0 14.2 - 37.9 5.3 |
|         | Granodiorite 3.8 20.8 18.0 15.2 14.2 22.7 5.3 |

The tests of asphalt texture parameters were performed on a specimen prepared by roller compactor with dimensions 300×400×40 mm. The measurements of skid resistance of a surface (PTV value) using the pendulum (according to EN 13036-4) and the measurements of texture depth (MTD value) using a volumetric patch technique (according to EN 13036-1) were used to determine asphalt surface texture. The pendulum test measures the skid resistance of a small area of 0.01 m². The representative value of the surface was determined as a mean of four individual PTV measurements (four determinations and areas on the surface) separately for the dry surface and wet surface. The outlier values of determination were not included in the result.

In practice, after the construction of the asphalt pavement surface, vehicle moving and climatic effects remove the bitumen film from the aggregate surface. Then the vehicle tire is in contact with the aggregate surface texture. After initial texture measurements, the bitumen film was removed from aggregate on the sample surface using a solvent. The determination of PTV values of all surfaces was performed under the same conditions.

3. Test results and discussion

The results of the PTV parameter (figure 2, left) showed differences between the single mixtures as well as between the coarse aggregate rocks. In terms of the type of mixture and the maximum aggregate size in the mixture, the highest values were obtained on the surfaces of mixtures of type SMA11 and AC16, the lowest values on the mixture AC11, which were comparable with the values of the mixture AC8.

It was assumed that mixtures with a larger contact area (AC8 and AC11) would have higher result values. However, it showed that the PTV value is influenced not only by the size of the contact area but also by the inter distribution of aggregate particles and the shape of particles, there may be a predominant “hysteresis” component. The pendulum impacts on larger protrusions on a surface (larger aggregate particle) when catching and braking than on samples with smaller aggregate particle size.
Figure 2. Results of skid resistance of asphalt mixture surfaces (samples after production – left, samples after removing the asphalt film from the aggregate surface – right).

Figure 3. Skid resistance values PTV of different types of asphalt mixtures (samples after production – left, samples after removing the asphalt film from the aggregate surface – right).

Figure 4. Skid resistance values PTV according to the type of rock of coarse aggregate (samples after production – left, samples after removing the asphalt film from the aggregate surface – right).
After removing the bitumen from the aggregate surface (figure 2, right), the PTV values of the AC8 and AC11 mixtures increased, the differences between the single types of mixtures increased partially (PTV in the range of 61.5 to 68.7), but the influence of the aggregate type became more significant. For all mixtures, it can be seen that in terms of skid resistance of the surface, the highest values were on the mixture with andesite aggregate and the lowest with limestone rock aggregate.

If we compare the mixtures with each other, regardless of the type of aggregate used (figure 3), the skid resistance of the dry surface of asphalt mixtures is equal (PTV in the range of 86.8 to 90.9). On a wet surface, the values are significantly lower. Mixtures SMA11 and AC16 had a higher skid resistance, which could be due to the good macrotexture of these compounds, which ensures good drainage of water from the surface and close contact of the tire on the surface. By removing the bitumen from the aggregate surface and the appearance of the aggregate texture, the differences between the mixtures were reduced, the skid resistance of wet surfaces increased, dry surfaces decreased.

From the results of the skid resistance of surfaces with stripped aggregate particles on the mixture surface (figure 4), we can see the positive effect of aggregate micro and macro texture that depends on aggregate rock. However, to determine the extent to which the aggregate texture affects the skid resistance of the surface, it is necessary to perform further measurements with several types of the aggregate of the same and different rock type and determine the texture parameters of the aggregate surface, e.g. scanning methods, scanner with high resolution 2.49 \( \mu \)m to determine the surface amplitude characteristics [10].

![Figure 5](image.png)

**Figure 5.** Average values of skid resistance PTV according to the type of aggregate rock (wet surface – left, dry surface – right).

Figure 5 shows the summary results of the tested surfaces from the coarse aggregate rock point of view. Small differences in average values can be observed on the coated samples. On dry surfaces of all mixtures, sufficient skid resistance (high PTV values) is ensured. The type of rock affects the skid resistance of the wet surface and contributes to road safety. The average PTV values according to the aggregate type clearly showed a positive increase, especially in the case of aggregates from andesite and granodiorite rocks, as well as limestone after bitumen stripping. The skid resistance of surface with andesite aggregate was PTV 67.0 and with the limestone aggregate 63.3 at an average of all tested mixtures.

The Mean Texture Depth using a volumetric patch technique is one of the methods that express a macro texture of surfaces. The measurements showed differences in the types of mixture and maximum aggregate size in the mixture (figure 6). It was confirmed that above all the portion of coarse aggregates, their size distribution, and shape characteristics as shape index, angularity, which also affect the air void content of the mixture, determine the macrotexture of the surface.
Finally, the macrotexture parameter was compared with the PTV values of the coated samples and stripping samples see figure 7. The correlation dependence of the parameters was higher on coated samples on which the bitumen film suppressed the aggregate microtexture. Skid resistance is mainly affected by the macrotexture.

![Figure 6: Average macrotexture depth of asphalt mixture surfaces.](image)

![Figure 7: Comparison of MTD and PTV parameters.](image)

4. Conclusions

The paper aimed to determine the effect of the mixture composition on the texture of the asphalt surface by expressing the roughness parameters PTV and MTD, which were analyzed according to the type of mixture, type of aggregate, and maximum aggregate size in the mixture.

The results obtained from the research showed that the coated samples, where the microtexture is absent, show that skid resistance depends on the macrotexture to some extent. The increasing values of macrotexture, the increase in the coefficient of friction. PTV values of stripping samples increased as expected, which is due to the effect of the aggregate microtexture, which affects friction. The effect of macrotexture has been eliminated to a minimum, the low values of the coefficients of determination as evidence, which may be due to the microtexture detection. This confirms the assumption that microtexture has a greater effect on the standardised value of skid resistance than macrotexture. In the case of dry conditions, the PTV values of stripping samples decreased compared to coated samples, which have higher adhesion forces, which are greatest on dry and smooth surfaces according to theory.

In terms of the type of aggregate rock, the skid resistance of asphalt mixture with coarse andesite aggregate was the highest, then granodiorite aggregate and the lowest value of PTV was on the surface with a mixture with limestone rock aggregate. To determine the extent to which the aggregate type affects the skid resistance of the surface, it is necessary to perform further measurements with several types of aggregate of the same rock and determine the texture parameters of the aggregate surface, e.g. scanning methods.

These measurements showed the results and dependencies on the produced and compacted mixtures. However, it is important the asphalt mixtures, used in road pavement, maintain these properties over the service life.

Acknowledgments

The paper is a result of the research supported by the research project VEGA 1/0537/17 „The influence of pavement surface morphology on pavement serviceability and emissions production“.
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