Investigation of the granule loss of poroelastic road surfaces using the Aachener-Ravelling-Tester (ARTe)

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ABSTRACT

This research concentrates mainly on the reduction of tyre/road noise by means of noise-reducing road surfaces. In addition to the known approach to noise reduction through porous asphalt, so-called poroelastic road surfaces (PERS) have been developed in recent years. What can be seen as problematic however is the resistance of PERS to shear load. Particularly in turn-off areas and bends and through sudden starting and sharp braking processes strong shear forces occur which result in granule breakout on the road surface. In the scope of this paper 20 variants of PERS were designed and subjected to a polishing shear load with the Aachener-Ravelling-Tester (ARTe). The result showed that binder content and rate of compaction are crucial for the resistance of PERS pavement to shear load and granule loss.

1. INTRODUCTION

In addition to the approach to the reduction of road traffic noise through porous asphalt, so-called poroelastic road surfaces have been developed in recent years. These are characterised by pronounced elasticity combined with extreme porosity (void content up to 40 Vol.-%), which leads to both a decrease in the road surface noise and also in particular to a reduction of tyre/road noise [1-3]. Poroelastic road surfaces consist of rubber granules which are gained from old tyres and supplemented by sand, rocks or other friction-increasing additives (Fig. 1). Polyurethane is normally used as a binder. In initial tests in Japan and Sweden a noise-reducing effect of these road surfaces of up to 10-12 dB(A) could be proved [1-5] (Fig. 2).

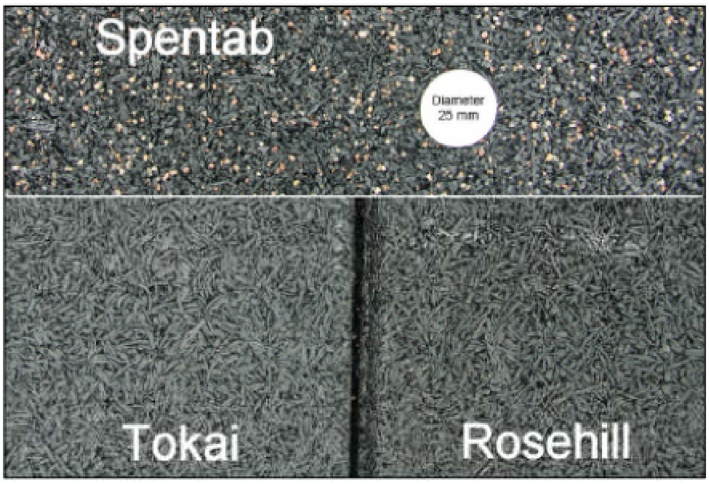

Figure 1 - The surfaces of the three tested PERS materials [1-2]

Figure 2 - PERS pavement [1-2]

However the single-granule structure based on an open-pored asphalt road surface does not yield enough granule-to-granule contact surfaces, resulting in considerable problems with regard to the resistance to any shear load which occurs and thus to increased granule breakout in areas of sharp bends or where braking and accelerating processes are carried out. So on the basis of findings found in the literature, this investigation focuses in particular on the aspects of the problem of poroelastic road surfaces with regard to granule breakout in turn-off areas and bends, and an attempt at optimisation is undertaken.

2. INVESTIGATION METHOD

The concept of the poroelastic road surfaces observed in these tests is oriented towards the results of investigations in Sweden, Norway, Japan and the Netherlands. With a desired void content of 26 vol.-% 20 variants were designed which differ with regard to the:

- proportion of rubber granules G
    - coarse rubber granules G_c (granule size: 3.1 - 6.0 mm; 80 - 90 M.-%),
    - fine rubber granules G_f (granule size: 0.2 - 0.8 mm; 5 - 8 M.-%)
- proportion of quartz sand Q (granule size: 0-2 mm; 2 - 15 M.-%)
- binder content B (Polyurethane; 10 - 15 M.-%)
- rate of compaction k (ca. 85 - 100 %)

The strategy of this research is illustrated as in Fig. 3.

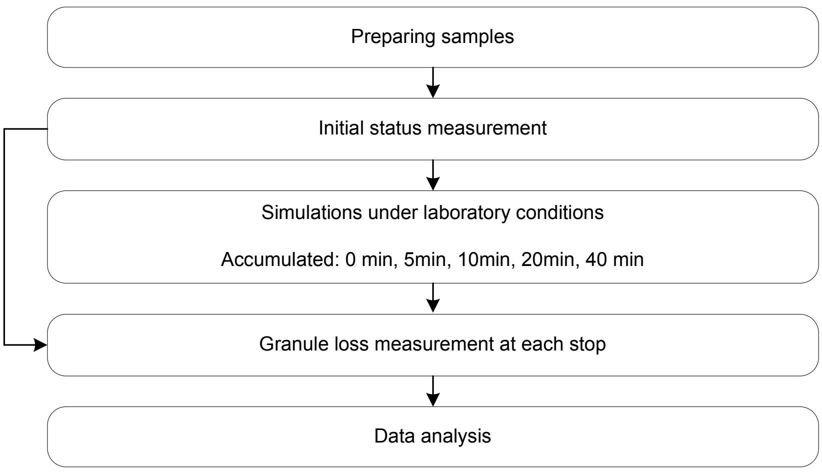

Figure 3 - Methodology of evaluation on the aggregates

Test plates measuring 260 x 320 x 40 mm were used as samples (Fig. 4). The poroelastic road surface was applied with a thickness of 16 mm to a concrete foundation plate with a thickness of 24 mm and compressed by rolling processes [3].

Figure 4 - Manufacture of the test items

The wear and tear simulations of the road surface in turn-off areas and bends were carried out in the laboratory using the Aachener-Ravelling-Tester "ARTe" (Fig. 5). This process is based on two rotating car tyres ("Continental Vanco 165/75 R14 C") above an oscillating slide with integrated sample plates, whereby a "real life" transfer of the rolling and slippage conditions of a tyre on the sample road surface is achieved. Through a variation of tyre-load and tyre-pressure the contact areas and the penetration depth of the polishing process can be vary (adjustment of the polishing intensity). Standard measurement conditions correspond to a tyre pressure of 2.0 bar and a tyre-load of 100 kg per tyre (~ 1000 N). During the test two tires mounted on an axis rotate around a vertical axis, while the slide on which the test plates are mounted moves to and fro translationally on a horizontal plane below the tyres. The horizontally operating slide has a timing frequency of 9 translation movements per minute. The tyres turn around their own axis at 41 revolutions per minute. The Aachener-Ravelling-Tester exerts a uniform polishing load on the whole surface. A total of four load stages was planned, which were defined based on the polishing stages according to the friction coefficient tester Wehner/Schulze (PWS) (s. Table 1) [6].

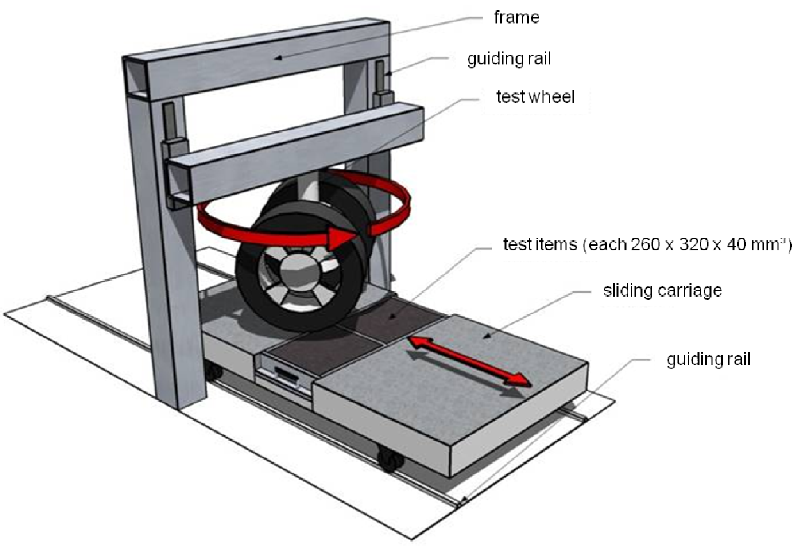

Figure 5 - The Aachener-Ravelling-Tester

Table 1 - Definition of the polishing stages

Polish step	Accumulated polishing rotations in the PWS [-]	Polish duration in the ARTe [min]
0	0	0
1	1.500	5
2	3.000	10
3	6.000	20
4	12.000	40

In order to evaluate the granule loss it was recorded Δh in [cm] after each load stage:

$$\Delta h = h_0 \cdot (1 - \frac{M_t}{M_0}) \qquad \text{Formula 1}$$

with:

- h_0: Initial height [cm], = 1.6 cm
- M_0: Initial weight of the test plate [g]
- M_t: Weight of the test plate after a polish duration of t minutes [g]
- t: polish duration [min]

3. RESULTS AND EVALUATION OF THE INVESTIGATION

3.1 Influencing factors on granule loss

A typical development of granule loss depending on the duration of polishing is illustrated in Fig. 6. Two variants are represented with a rate of compaction of 94 % and binder contents of 10 M.-% and 15 M.-%. The mass proportions of the rubber granules and the quartz sand remain constant. A degressive increase in granule loss becomes evident in the graph. The variant with the greater binder content of 15 M.-% shows less granule loss in comparison to the variant with a binder content of 10 M.-% after a total load duration of 40 minutes. To sum up, it becomes clear from the test results that granule loss tends to decrease with increasing binder content (s. Fig. 6).

In addition to the influence of the binder content which was identified, a strong influence on granule loss is attributed to the rate of compaction k of the samples. In Fig. 7 the granule loss in relation to the rate of compaction is exemplified. The binder content and mass proportions of the rubber granules and of the quartz sand are constant. The chart clearly illustrates that with a higher rate of compaction less granule loss can be expected with a constant mix composition. The plausibility of the results is given through the order of the four variants illustrated, as in general with a higher the rate of compaction a higher level of stability can be expected.

From the analysis of granule loss depending on the proportion of coarse and fine rubber granules and the quartz sand proportion it becomes evident that these factors do not have a conclusive influence on granule loss. In Fig. 8 the relevant granule loss is outlined for two different rates of compaction with a constant binder content. It becomes evident from the charts that the development and the sequence of both curves do not indicate a clear connection.

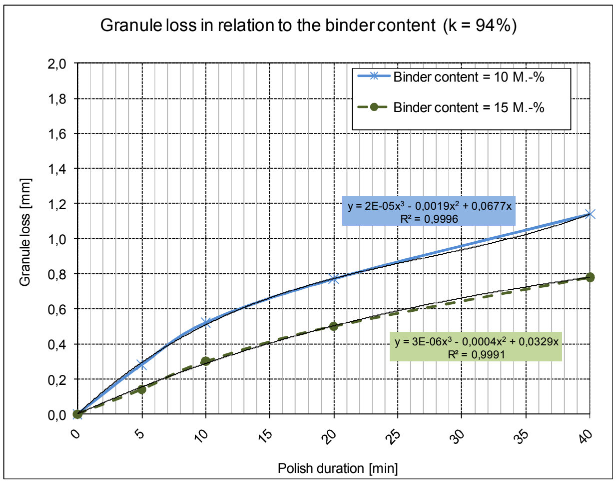

Figure 6 - Granule loss in relation to the binder content (k=94 %)

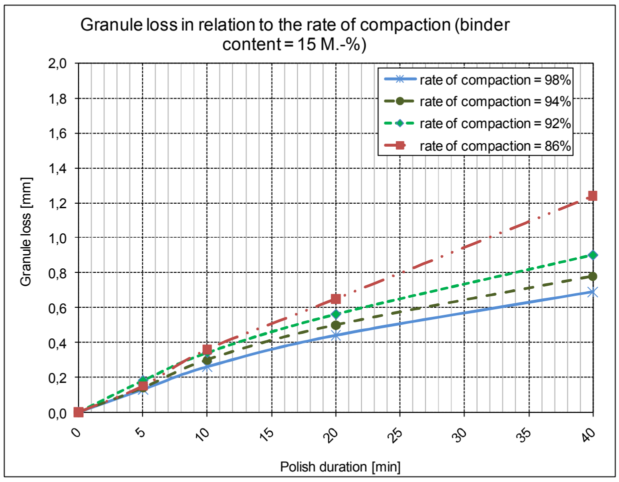

Figure 7 - Granule loss in relation to the rate of compaction (B=15 M.-%)

Accordingly no significant correlation of the factors influencing granule loss can be determined. However a lower rate of compaction k seems to negatively influence the variant with a quartz sand proportion of 15 M.-% of the aggregate mix to a greater extent than the variant with a quartz sand proportion of 2 M.-% of the aggregate mix:

- proportion quartz sand Q = 15 M.-%: + 0.7 cm
- proportion quartz sand Q = 2 M.-%: + 0.4 cm

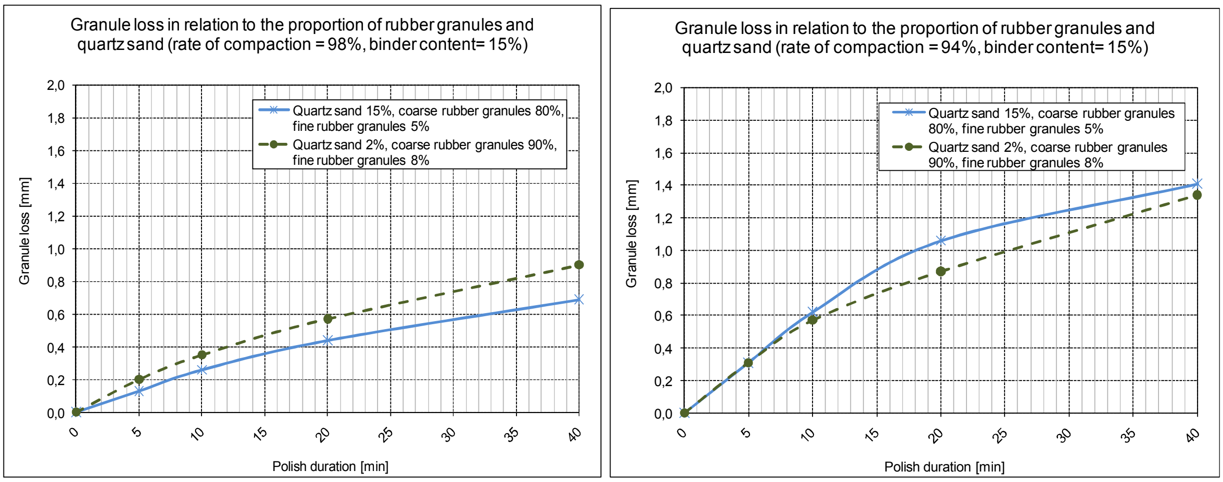

Figure 8 - Granule loss in relation to the proportion of coarse and fine rubber granules and the quartz sand proportion

It is thus essential to ensure a high rate of compaction in the case of a high quartz sand proportion in order to prevent the strong increase in granule loss which was determined at lower rates of compaction. In view of the above-mentioned results, the multiple linear regression analysis only takes into account the influencing factors polishing duration t, rate of compaction k and binder content B. Other factors such as the quartz sand proportion and proportion of rubber granules are not significant and can thus be excluded from the regression analysis. As a result of the regression analysis the following regression function could be derived with which the degressive increases in granular breakouts in Fig. 6 can however only be inadequately indicated.

$$\Delta h = 2.250 + 0.25 \cdot t - 0.15 \cdot k - 0.54 \cdot B \qquad (R^2 = 0{,}872) \qquad \text{Formula 2}$$

The derived regression coefficients of the regression function can be considered as statistically significant on the existing data base (80 = 20 variants x 4 load stages). The results make it evident that granule breakouts increase steadily with increasing load duration and can be reduced through an increasing rate of compaction and binder content. Furthermore the binder content has the greatest influence on granule loss. So considering the low granule density of rubber granulate a higher binder content is recommended. The influence of the rubber granules (coarse and fine) and of the quartz sand could not be proved contrary to the findings in the literature [1-4].

3.2 Factors influencing skid resistance

Furthermore the influencing factors of poroelastic road surfaces on skid resistance were examined. Due to the concept of poroelastic road surfaces and the strongly pronounced initial granule loss on the surface which was established, the evaluation of skid resistance was only carried for load stage 0, i.e. in the no-load condition. An evaluation of skid resistance with the SRT surface friction tester for the load stages 1 to 4 proved to be of no use, so that in the investigations presented here statements can only be made concerning the initial skid resistance of the poroelastic road surfaces $\mu_{SRT,0}$. In this regard it can be observed that the poroelastic road surfaces examined in this case proved to have sufficient initial skid resistance of over 52 SRT units and outflow times <1 second.

During the multiple linear regression analysis the influencing factors binder content B, quartz sand proportion Q and total proportion of the rubber granules G (G_c + G_f) are taken into account. As the two factors quartz sand proportion and total proportion of the rubber granules are directly dependent on each other, these influences are not considered separately. The following regression function could be derived as a result of the regression analysis.

$\mu_{SRT,0} = 78.961 - 0.233 \cdot B - 0.248 \cdot G$ with G=100-Q (R^2 = 0,972) Formula 3

The derived regression coefficients of the regression function can be considered as statistically significant based on the existing data base. Accordingly it is evident that a high binder content and a high proportion of rubber granules can be rated negatively in terms of skid resistance. In contrast a high quartz sand proportion can be rated positively, i.e. the SRT value increases with increasing quartz sand proportion.

4. CONCLUSION

On the basis of the results of these investigations the following conclusions can be drawn with regard to resistance to granule breakout and with regard to initial skid resistance:

- With increasing load the granule breakouts increase degressively.
- The binder content B has the greatest influence on granule loss. Thus considering the low granule density a higher binder content is to be recommended.
- With increasing compaction k the granule breakouts decrease.
- Contrary to the findings in the literature, no influence of the rubber granules G and the quartz sand Q on granule breakout could be proved.
- With increasing binder content B or a reduced proportion of rubber granules G the initial skid resistance decreases, while with increasing quartz sand proportion Q the SRT value increases.

On the basis of these correlations it is recommendable to use a binder content of at least 15 M.-% with regard to the bituminous mix and a quartz sand proportion of a least 15 M.-% with regard to the aggregate mix in order to guarantee sufficient resistance to granule loss in turn-off areas and bends and sufficient initial skid resistance. At the same time achieving a rate of compaction of > 98% is recommended to ensure sufficient durability of the road surface.

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