Reuse of Aspahlt as a Contribution to More Sustainability in Maintenance Management - Case Study of a Major German City

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ABSTRACT: Financial resources for road maintenance are regularly among the largest expenditure items in public budgets. For this reason, a sustainable asset management system has been set up in the Münster Department of Mobility and Civil Engineering for several years to make objective and sustainable decisions. In view of the impending climate changes and the resulting reduction in the service life of asphalt roads, the question arises as to how far today's asphalt roads will meet future requirements and how far today's assumptions for forecasts in maintenance management will hold up in the future. An important component is to increase the reuse rates in asphalt road construction beyond the current set of regulations without reducing the service life of the road. This is because the more recycled asphalt with heavily aged bitumen is used in production, the poorer the quality of the resulting bitumen contained in the asphalt mix. For this purpose - based on bitumen and asphalt tests in the laboratory - various test sections in asphalt construction with a total of 20 different asphalt mix variants in asphalt wearing courses, asphalt binder courses and asphalt base courses on service roads, residential and access roads as well as on main roads have been successfully realized. Some results of laboratory, control, and performance testing are presented here, as well as implications for maintenance management.

1 INTRODUCTION

The resource relevance of the construction industry in Germany is considerable. According to previous experience, a fundamental renewal of the municipal road is necessary approximately every 30 to 60 years, depending on the road category. Asphalt surface courses have the shortest service life of up to 20 years. However, it can be assumed that the renewal cycles and service live will become shorter in the future due to increasing stresses on the road surface (e.g. increased volume of heavy traffic, climate change) [1, 10]. Due to its thermoviscous properties, asphalt as a construction material is excellently suited for reuse or recycling. The technical regulations required for this are available in principle with corresponding limits for the addition of asphalt granulate (RAP).

However, the authors are not satisfied with these limits and therefore want to investigate, among other things, the question: How much more reuse of asphalt beyond the current German regulations is possible in practice today and in the future? Since the reuse of asphalt (granulate) has already been an integral part of the asphalt cycle for many years, it is foreseeable that rejuvenators will represent an important building block in the reuse of asphalt in the future, which will also enable the highest possible reuse rates with consistently high quality in the long term [2]. Within the scope of previous projects and contributions about rejuvenators [3, 4, 9], many positive aspects have already been identified. Further questions have subsequently arisen from the results of the projects to date and should be answered practically in several construction projects:

- Is it possible to increase the amount of RAP added without negatively affecting the quality?
- Does it generally make sense to use rejuvenators - even with low amounts of RAP?
- Can the use of rejuvenators generally improve the quality or extend the service life?

2 PREPARATION (PLANNING STEPS)

In January 2020, the idea of building test sections with an increased addition of asphalt granulate in the asphalt base course and the asphalt surface course was discussed for the first time between the construction company and the city of Münster. This will only succeed if there is close coordination between all parties involved in the project (construction company, asphalt mixing plant, test laboratory, client). In the initial meeting between the asphalt mixing plant, the testing laboratory and the client in March 2020, the project objectives and implementation were discussed and fixed. Regarding the objectives, a concept was developed to carry out comparative tests on an asphalt base course AC 22 TN and on an asphalt surface course AC 8 DN with varying proportions of asphalt granulate and in each case with and without rejuvenator (AC 8 D N with 0%, 20 % and 50 % RAP; AC 22 T N with 50 %, 60 % and 80 % RAP).

Two roads (1-Feuerstiege, 2-Hartmannsbrook) have been selected as pilot sections by the Department for Mobility and Civil Engineering of the City of Münster. The construction length in both cases is approx. 2 km. While up to 50% asphalt granulate was used in the asphalt surface course (3 cm, AC 8 DN) of the Feuerstiege with and without the addition of a rejuvenator, the proportion of asphalt granulate in the asphalt base course (6 - 8 cm, AC 22 TN) of the Hartmannsbrook was increased to up to 80% - also with and without the addition of a rejuvenator. In 2021, another road, Osthofstraße, was planned, constructed and analyzed according to the procedure described above. Due to the higher traffic load, an AC 8 D S was used as the asphalt surface course and an asphalt binder course of AC 16 B S with polymer-modified bitumen in each case. The RAP contents were 20 %, 30 % and 50 % with and without rejuvenator. The detailed results are not part of this paper.

3 TESTING METHODOLOGY AND TESTING PROGRAMME

At the beginning of April 2020, suitable asphalt granulates were available from the asphalt mixing plant in sufficient quantities for the project. Analogous to the preparation of the preliminary initial tests by the asphalt mixing plant, the base bitumen and the asphalt granules were tested in the laboratory of Eng. Company PTM Dortmund mbH [7].

Within the scope of these tests, the addition quantity of the rejuvenator was to be determined and specified by means of physical and rheological binder tests for the different variants of the asphalt wearing course AC 8 D N and the asphalt base course AC 22 T N by laboratory methods:

- Asphalt base course AC 22 T N with 50 % asphalt granulate
- Asphalt base course AC 22 T N with 80 % asphalt granulate
- Asphalt top layer AC 11 D N with 20 % asphalt granulate
- Asphalt top layer AC 11 D N with 50 % asphalt granulate.

A road bitumen 70/100 was specified as an addition binder for all variants and a road bitumen 50/70 as the target binder. VIATOP® plus RC was used as rejuvenator. For the determination of the individual binder proportions, i.e. addition binder 70/100, recovered binder from asphalt granulate and rejuvenator, reference was made to the preliminary initial tests and to the previous findings of the mode of action of the rejuvenator (Additive 2.0 from [5]).

For the project, different asphalt granulates were used for each of the two asphalt wearing courses AC 8 D N and the asphalt base course AC 22 T N. The addition of the rejuvenator was determined based on the preliminary initial tests. The addition quantity was determined classically via softening point ring and ball and rheologically via the BTSV method. Based on the bitumen analyses carried out, the addition quantities of the rejuvenator were determined for the individual asphalt mix variants and incorporated into the corresponding initial tests.

4 RESULTS

Due to the limited number of pages, only a small excerpt of the results is presented here.

4.1 *Performance Control Tests and initial interpretation of the results*

During the control tests, four asphalt cores were taken from each test area or asphalt variant and analyzed in the laboratory together with the corresponding asphalt mix sample (bucket sample).

The evaluation of the control tests of the trial patches regarding the asphalt wearing course variants shows that compaction levels of ≥ 98 % could be determined at all five test points/test patches of the asphalt wearing course. Due to the uniformly high values (between 99.6 % and 100.6 %) of the variants with asphalt granules, the sole consideration of the compaction degrees does not allow a meaningful differentiation. In contrast, variant 5 of the asphalt surface courses (without asphalt granulate), with 98.0%, shows sufficient compaction according to the regulations, but is clearly below the other variants in the overall assessment. The results for the void content of the paved layers are analogous to the compaction levels.

For the evaluation of the binder parameters softening point ring and ball, the limit values of ZTV Asphalt-StB 07/13 (recovered binder) and (informatively) the limit values according to TL Bitumen-StB 07/13 (fresh binder) were used. Based on the results, both the influence of the asphalt granulates, and the influence of the rejuvenator used can be identified. Basically, it can be stated that all variants are within the limits for a road bitumen 50/70 as defined in ZTV Asphalt-StB 07/13. A more differentiated analysis of the results shows that the variants with 0 % asphalt granulate, with 20% asphalt granulate and Rejuvenator and the variant with 50% and Rejuvenator all lie within the grade range of a fresh road bitumen 50/70. The tested equi-stiffness temperatures T further support this fact. The phase angle δ is also positively influenced by the Rejuvenator used in the direct comparison of the variants.

If the results of the asphalt base course are considered, a very high level of compaction of greater than 100% is shown overall across all six test patches. A direct influence by the Rejuvenator could not be detected at this point, i.e. purely measured by the final compaction. The increased proportion of asphalt granules, on the other hand, leads to a slight foamed bitumen effect, which in turn has a positive effect on the compaction properties of the asphalt mixture, partly due to the higher residual moisture.

In relation to the limit values of ZTV Asphalt-StB 07/13, the softening points ring and ball are clearly exceeded in the variants with 80% and 50 % asphalt granulate (box 3.2). Especially for variant 2 (80% RAP with rejuvenator), the effect of the rejuvenator can be clearly seen by the reduction of the softening point ring and ball by 10.6°C. Based on the two variants with 50% asphalt granules and the one with 60% asphalt granules, it is also possible to recognize the sometimes very high fluctuations in the binder qualities of the asphalt granules. At this point, too, the classical binder characteristic is again confirmed by the rheological investigations (here equi-stiffness temperature T). At higher addition rates of asphalt granules, the positive influence of the rejuvenator on the phase angle is also evident. For the asphalt variants with 50% and 80% asphalt granules, the phase angle is increased on average between 1.3° and 3.3°.

4.2 *Performance-Tests*

On each variant, the test variables compliance Jnr and recovery R were determined using the MSCR test according to the AL DSR test (MSCRT). For all asphalt variants, a higher addition of asphalt granules leads to a higher percentage recovery R. This is due to the higher degree of hardening of the bitumen, as the corresponding bitumen are still primarily assigned to the visco-elastic range regarding the deformation behavior at the test temperature of 60°C. The addition of the rejuvenator results in a higher percentage recovery R for all asphalt variants. The addition of the rejuvenator reduces the proportion of recovery, so that the deformation behavior increasingly shifts into the viscous range and the proportion of yielding Jnr or plastic deformations increases. The test results therefore show an approximation of both test variables to the properties of the recovered base bitumen 50/70 (test field 5 of the test section "Feuerstiege") when using the rejuvenator. This does not show any recovery (R = 0 %), since in the test temperature range the plastic aggregate state has already been reached and a completely viscous behavior with a compliance of Jnr = 2.956 kPa-1 is present. From the test results it can be deduced that, on the one hand, a higher addition quantity of asphalt granules leads to a larger recovery R and, on the other hand, that this effect can be compensated by the addition of the rejuvenator. In this case, the recovery R decreases and the compliance Jnr increases. Thus, the expected development towards the rheological behavior of the pure reclaimed road bitumen can be deduced, which, according to the present comparative investigations, exhibits a recovery R → 0.0%. Furthermore, it can be seen from the test results that the effect of the rejuvenator and thus the associated influence on the reclaim/yield increases up to a certain point with the addition percentage of the asphalt granulate. Thus, for the AC 8 D N, a reduction in recovery R of ≈ 22% at 20% RAP and of ≈ 80% at 50% RAP was determined. The bituminous binder from the asphalt base courses shows a reduction of the deformation between approx. 80% and 90% for the variants with 50% to 80% RAP.

5 CONSEQUENCES FOR MAINTENANCE MANAGEMENT, CASE STUDY MÜNSTER

A maintenance strategy for the Münster road network has been developed from the German regulations and the experience of the Münster construction administration [6, 8]. The useful lives of asphalt pavements are shown separately by layer, and these values can be used to estimate the time periods for rehabilitation measures. In addition, considering the maintenance work listed in the regulations and taking depreciation into account from the costs of the initial or replacement investment, the price for the provision of the road is obtained as follows (cf. [8, 9]).

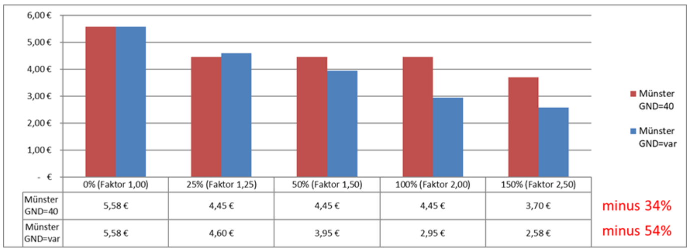

Figure 1: Price development with constant and variable total useful life

The price is very dependent on the length of the service life, so that the road authorities should be interested in using high should be interested in using high-quality and durable construction methods for the respective type of use or stress. In a comparative calculation, it is assumed that the service lives of the layers can be increased by improved material properties of the asphalt by 25%, 50%, 100%, 150%. The effect of these service life extensions is represented by the resulting price changes for the provision of the road.

Figure 1 compares the effects of a constant total useful life of 40 years on the one hand and an extension of the total useful life of up to 80 years corresponding to the extension of the useful life of the individual layers on the other. With a constant total useful life (GND), the price can be reduced by up to 34%, which results solely from the reduction in repair costs due to the elimination of repair measures due to longer useful lives of the layers. With a variable total useful life, the price can be reduced by up to 54%, which results from the reduction in repair costs and the distribution of repair costs and production costs (depreciation) over a longer total useful life. The tests on the reuse of RAP have shown that it is possible to achieve a useful life comparable to that of fresh asphalt with higher recycling rates than in the existing regulations. With further optimization of the asphalts, it can be expected that an extended service life can be achieved. Depending on the effort involved, the calculations in Figure 1 can be used to estimate whether this additional effort is worthwhile. Especially on roads with little heavy traffic, there is no reason not to use significantly more RAP and thereby reduce the costs for road maintenance. As these roads represent around 75% of the road network in the Münster example, an adjustment in maintenance management has a significant impact on future financial requirements.

The example calculation illustrates that extending the service life of individual layers or the entire road system has a significant impact on finances. In terms of finances, longer service lives can lead to reinvestments being stretched, annual road maintenance funds being reduced and balance sheet depreciation also being reduced. Positive effects from an environmental point of view are, for example, decreasing carbon dioxide emissions, less traffic disruption due to a smaller number of construction sites, and less noise emissions due to defective roads, construction work, or congestion caused by construction sites. If one adds up the above statements and draws a conclusion, one concludes that the measures and fields of action described together serve all three pillars of sustainability - ecology, economy and socio-cultural concerns. It is therefore entirely justified to speak of sustainable asset management.

6 CONCLUSION AND OUTLOOK

Based on the test sections and the corresponding laboratory tests, it could be shown that with the technical possibilities already available today, it is possible in practice to significantly increase the proportion of RAP without reducing the service life of the road. The results presented so far show very emphatically that, with the use of suitable rejuvenators, it is quite possible to reuse high quality asphalt granulate in large proportions in the asphalt mix. Based on these findings, it is also possible to make specific statements on the quality of this construction method and, based on aging and load simulations carried out, to make far-reaching forecasts on durability and sustainability. These findings have a direct influence on the maintenance cycles of a road, for example, and can in turn be used effectively for maintenance management, e.g., in estimating future financial requirements.

The exemplary calculation demonstrates that extending the useful life of individual layers or the entire road system has a significant impact on finances and the environment. Positive effects from an environmental point of view are, for example, lower carbon dioxide emissions, fewer traffic obstructions due to a reduced number of roadworks and less noise emissions due to defective roads, construction work or traffic jams caused by roadworks. If one adds up the above statements and draws a conclusion, one concludes that the measures and fields of action described together serve all three pillars of sustainability - ecology, economy and socio-cultural concerns. It is therefore justified to talk about sustainable asset management. The basic requirement for overall environmental reduction when using high rates of RAP is the use of "green" rejuvenators. In this context, only products with a low ecological footprint and basically high environmental compatibility should be used. Further investigations in the coming years will analyze and describe the development of the asphalt under traffic.

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