DURABLE PAVEMENTS WITH COMPACTASPHALT

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ABSTRACT

Building pavements with compactasphalt is not a new subject but it gets increasingly meaningful as it has shown noteworthy performance and became a standard technique in Germany. With compactasphalt wearing course and binder course are laid hot-on-hot in tandem and compacted together. The higher thermal capacity enables the thickness of wearing course to be reduced by concurrently increasing binder course thickness and to achieve higher compaction. Those are the crucial points which lead to better performance.

Better performance of compactasphalt, especially its high resistance to deformation such as rutting, compared to conventionally built asphalt pavements were shown in praxis already within several reports, long-term consideration, and laboratory-studies. This and the existing experience were the basis for its admission to standard.

Recently, it was theoretically shown that in compactasphalt-pavements rutting occurs to a lesser extent. The designed model, which is based on the risk analysis method and also allows detailed analysis, showed conclusive results. For example 4 mm mean rut depth is forecast within the considered compactasphalt-section after about 13 years of utilization. Whereas, on conventionally built section with comparable traffic and environmental loads this mean rut depth will occur within approximately 8 years.

Beyond resistance to deformation, compactasphalt exhibit the advantages of less ageing by less void, economical use of natural resource by reduced wearing course thickness, and relatively safe application in adverse weather conditions by high thermal capacity.

The paper comments technique and possibilities to build durable pavements by compactasphalt, and the designed model to forecast pavement-performance.

Keywords: compactasphalt, durability, design of pavement, modeling, rutting, pavers, compaction, permanent deformation

1 INTRODUCTION

Studies ([1], [2], [3]) have shown that a thinner wearing course accompanied by a thicker binder course is preferable as the durability and resistance to deformation respectively increase. But usually, the thickness of a wearing course counts about 4 cm, which corresponds to the well-known rule of thumb saying the compacted course should be about 3 to 3.5 times as thick as the maximum grain size (whereupon in new German guidelines [4] this value is reduced to 2.5 nowadays). This rule bases on the one hand on the mechanical processes that happens while compacting, and thus it is to avoid any further crushing of the aggregates at that time. On the other hand, the thickness is due to the heat capacity of the asphalt that is required for a sufficient duration to compact and hence the possibility to achieve the required compaction. Generally, experiences as well as several studies have shown that the durability of asphalt courses (for example measured by the resistance to rutting or to any other deformation) rises by increasing rate of compaction. Admittedly, this is primary valid for wearing course made of stone mastic asphalt and the binder course; asphalt concrete shows worse resistance to deformation if the rate of compaction exceeds 100 % ([4], [6]).

For the compactasphalt technique these limitations can be neglected because the asphalt of the lower course possesses enough heat to avoid the asphalt of the upper course from (too) fast cooling. And as the lower course is still soft and malleable when compacting, the aggregates may be shifted against each other in the boundary zone. In consequence it is also possible to reduce the thickness of the wearing course by corresponding increase of the thickness of the binder course (to preserve load capacity). Another advantage of this construction technique to be mentioned is the better bond between courses; by compacting the two malleable courses at once the bond arises from both adherence of the asphalt's bitumen and a deep interlocking of the course's aggregates. Thus, by developing compactasphalt-pavements it was expected to enhance pavement performance because of its higher compaction, the changing of course structure, and better bonding (attend with a better conduction of strengths). Beyond, construction duration of the pavement decreases because of contemporaneous paving of two courses, an application of a tack coat on the binder is no longer required, and top-quality natural resources that are required and used for the wearing course are economized. Another advantage that rises from the heat capacity again poses the applicability of the technique at low temperatures. ([1], [7], [9])

The technique of compactasphalt was initially developed by the German construction company Hermann Kirchner and Professor Richter, professor at the University of Applied Science in Erfurt then. Since the first applications on a trial basis in 1995 to 1997 ([7], [9], [10]), a long process of development, enhancement, observation and testing was undergone with the following considerable milestones:

1997	first two official test sections built with compactasphalt on different motorways
1999	first test section built with the so-called compactasphalt-paver that is manufactured by the machine manufacturer Dynapac
2001	release of the first guideline to build compactasphalt-pavements [11]
2007	admission of the compactasphalt technique as a standard technique [4]
2011	release of the second edition of the guideline to build compactasphalt-pavements [12]

2 PROPERTIES OF AND REQUIREMENTS ON COMPACTASPHALT

In ZTV Asphalt-StB 07 [4] a "compactasphalt-pavement" is defined as an asphalt pavement, where the wearing course, which is made of roller-compacted asphalt, and the binder course are built by paving them directly one after another hot-on-hot. The compaction of both courses is executed afterwards with rollers all at once.

According to this definition two possibilities exist to build compactasphalt-pavements: For one thing by using a so-called compactasphalt-paver and for another thing by using two pavers or the so-called inline-paver. The major difference between these two possibilities reside in the usage of the lower course; while the lower course is not used to pave the upper course if done with compactasphalt-paver, the lower course has to be used by the second paver to build the upper course if fielding two pavers or the so-called inline-paver.

The compactasphalt-paver possesses two screeds and two repositories, respectively one for the asphalt of the (lower) binder course and one for the asphalt of the (upper) wearing course, see Figure 1. While paving, asphalt is filled into the repositories for the wearing course and binder course with a feeder that moves forth and back respectively; thus, feeding has to be done carefully to not mix up the asphalt for the wearing course and the asphalt for the binder course.

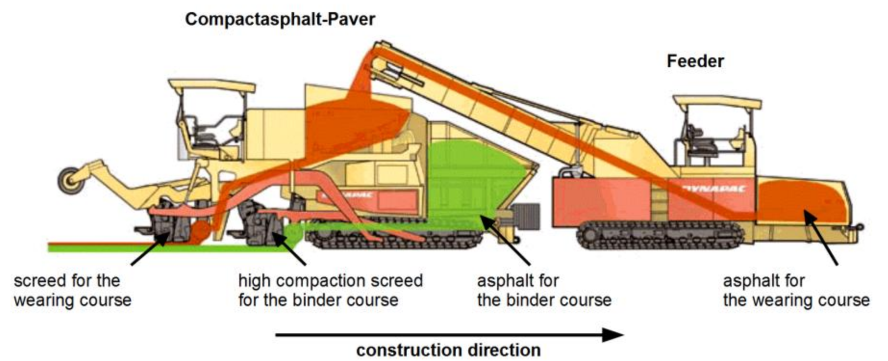

Figure 1 : Scheme of Compactasphalt-Paver [13]

The inline-paver consists of two somewhat modified pavers. Thereby the lower course has to be pre-compacted enough by a high compaction screed so that the second paver that uses the lower course to lay the upper course does not leave remarkable tracks of the chassis on the surface of the lower course. Here, too, a feeder is used to carry the asphalt into the particular proper repositories.

Laying the courses “hot-on-warm” is a third possibility mentioned in the guideline ([11], [12]) to build compactasphalt-pavements. Here, two paving trains (that consist of both paver and rollers) are used and the lower course is built and completely compacted by rollers before laying the upper course. The difference towards conventionally built pavements lies in the prompt construction why the lower course still possesses heat; the heat has to be not less than 80 °C. But as this technique shows up some weak points, especially its full compliance with all the typical properties of compactasphalt-pavements and necessity of extensive logistic planning, it is not broadly used; only 5 out of 59 compactasphalt-pavements were built with this technique in Germany in the years 1995 to 2005 [14].

In the guidelines and standard ([4], [12]) that are valid in Germany nowadays various requirements and recommendations, which base on experience as well as research and which enable both the contracting entity and the contractor to achieve the expected compactasphalt-pavement performance. Some important aspects are presented in the following.

Typically, the thickness of the wearing course of a compactasphalt-pavement is reduced to 2.0 cm to 2.5 cm; conversely, the thickness of the binder course is accordingly raised. Thus, the binder course thickness comes to 10 cm at motorways at the most; but in detail it depends of the construction class of the road. The paving width is bounded in principal by the paving width of the pavers, but may be extended by usage of staggered moving pavers to build the compactasphalt-pavement in strips hot-to-hot. However, because of the huge mass of asphalt needed then, it may be necessary to mix asphalt in different mixing plants at the same time. If so, variation of certain asphalt parameters between the asphalt from different mixing plants is limited (for example differences between the respective bitumen contents, gradations, densities of the aggregate mixture and void contents of Marshall-sample). This is to ensure almost identical asphalt and to achieve good quality. Otherwise, the compactasphalt-pavement can be paved in strips hot-to-cold as well. In either case the joints of the strips have to be executed in a good and workmanlike manner [12].

The rate of compaction of both wearing course and binder course is required not to be less than 99 % [12]. In order to compensate the higher rate of compaction and to achieve an adequate void content in the course anyhow, the asphalt mix design has to be slightly adapted: The void content acquired at Marshall-samples on initial type testing should be oriented to the upper boundary.

Compactasphalt can be paved as long as the temperature is not less than 0 °C and the substrate is not all wet, snowy or icy[4]; this is due to the heat capacity again. But for that same reason it is recommended to let time of 36 hours in minimum lapse away after laying the compactasphalt-pavement and before using the new pavement [4], to provide sufficient cooling and thus to avoid any deformation or exaggerated initial post-compaction.

Maintenance and recycling of compactasphalt-pavements does not differ from any other asphalt pavement.

3 EXPERIENCE WITH COMPACTASPHALT

3.1 Performance of compactasphalt-pavements

Several studies and reports (for example [3], [14], [15], [16], [17], [18], [19]) exist which consider the performance of compactasphalt-pavements in Germany in the long term. All of them prove the good performance that is even better than expected sometimes. But not only in Germany also in foreign countries compactasphalt-pavements have been built, to date in the Netherlands, Hungary, Poland, Russia, and China among others.

During an 11-years period starting with the first test section in 1995 and ending at the end of the year 2005, altogether 59 compactasphalt-pavements were built in Germany on motorways, highways, and rural roads. In the process the application of two pavers, which reflect the beginning of the compactasphalt technique, decreases by increasing application of the compactasphalt-paver since availability. [14] Afterwards and based on the development of modified pavers started in 2006, the number of compactasphalt-pavements built with two pavers increased sharply [20].

The specifications and requirements given by the standards and guidelines were accomplished, the better by using compactasphalt-paver as well as by increasing experience: The target thickness of the courses was in average put properly in practice, where the wearing course tended to be slightly thicker than preset and the binder course slightly thinner. The variation of the thickness of the wearing course was reduced by the application of compactasphalt-paver. The thickness of the binder course deviates relatively less. The rate of compaction met the requirements most often as well and without any dependency on the technique. Associated with the high rate of compaction, some sections showed a very small void content. It counts less than 3 V.-% three times in the binder course and two times in the wearing course; moreover 17 out of 56 sections feature a void content in the wearing course between 3 V.-% and less than 4 V.-%. Here, a linkage to the construction technique can be recognized; paving with the compactasphalt-paver facilitates a lower void content in both binder course and wearing course. ([14], [15])

A relatively small void content is theoretically said to be unfavourable as the aggregate skeleton and thus the bearing capacity of the pavement may be negatively affected. But even here, a compactasphalt-pavement on a motorway showed good performance already since its construction in 1998, despite an ascending gradient that is up to 6.6 %, continual solar radiation, and commonly occurring congestion. In 2008 the average daily traffic of this 4.1 km long section has attained barely 34,000 motor vehicles per day, of that 21.7 % heavy vehicle traffic. The years ago these values changed in parts, but were overall about the size of it. The section was paved in December at temperatures between -1 °C and 5 °C by using compactasphalt-paver for the first time. Originally, it was provided to build wearing course with mastic asphalt. But due to two reasons the contracting entity decided to apply the at that time new technique: First, paving mastic asphalt was not feasible because of the weather conditions. Secondly, it was basically declared intention to complete the construction before onset of winter in order to shorten inconvenient traffic routing through the construction site as far as possible. The rate of compaction in the binder course came to 102.1 % to 107.0 %, and in the wearing course from 99.2 % to 101.5 % after completion. Accordingly, the void content was relatively small in the binder course and amounted to 0.4 V.-% to 4.8 V.-%, in the wearing course it was about 3.0 V.-% to 6.6 V.-%.

Investigations ([16], [17]) conducted in 2004 and 2010, meaning after 6 and 11 years of usage respectively proved the noteworthy performance. In the process, the condition of the surface of the whole section was survey and the transverse profile was measured at four different stations. In 2004, no cracks, no patches, no fretting or any other surface losses were found; the rut depth was determined between 1 mm and 2.5 mm without any fictional water depth in the rut. In 2010 the ruts could not be detected anymore at all those stations. But as far as relatable, no enlargement of the rut depth occurred except for one transverse profile where the rut depth of the right rut increased to 6.8 mm (the left rut counts 0 mm). Though the transverse profile changed remarkable in the meantime, it is not generally owed to the compactasphalt-pavement as subsidence in the sides of the lane had happened. That the deformation does not result from deformation in the pavement was examined by taking and testing five cores at a transverse profile. By contrast, in the subsequent section with a wearing course made of mastic asphalt of the same age a rut depth up to 15.5 mm was measured, the fictional water depth in the rut is 2 mm.

In most of the cases the compactasphalt-pavement consists of wearing course made of stone mastic asphalt and any binder course [14]. But basically it is also possible to pave a wearing course made of asphalt concrete or that the lower course is a base course; these designs were executed only a very few times. However, the compactasphalt technique was also adapted to double layer porous asphalt in the Netherlands as well as on some construction sites in Germany more frequently ([20], [23], [24], [25]).

3.2 Forecasting of rutting

Recently, durability of asphalt pavements was estimated within a study ([26], presented in the following), where durability was considered as a result of the quality of materials used and production basically, but diversified by applied traffic load and environmental effects during utilization phase. In terms of serviceable life durability was defined as the duration from production of asphalt pavement until such time as it or a particular course does not meet the standard of normal use anymore. Normal use of a wearing course can be described by surface characteristics that are detected in Germany in the context of condition survey. Thus the end of serviceable life corresponds to such time as the considered or relevant characteristic exceeds specific threshold values.

In the process, rutting as one of the different surface characteristics was exemplary considered and its development was forecasted as well as compared for two sections, the one section was a compactasphalt-pavement paved with compactasphalt-paver and the other section was conventionally built. Therefore, the different processes and their interaction in the context of the production of asphalt pavement and the thereby predetermined change of the surface characteristics during use as rutting were analysed and graphed systematically in several part models (from production of asphalt mixture to the end of serviceable life of surface course). These part models consist of input parameters, which are transformed to output parameters by intermediate steps that include status and activity. They are interconnected as the output parameters of any part model are input parameters of a following part model. Such a theoretical model is shown for the development of rutting in Figure 2.

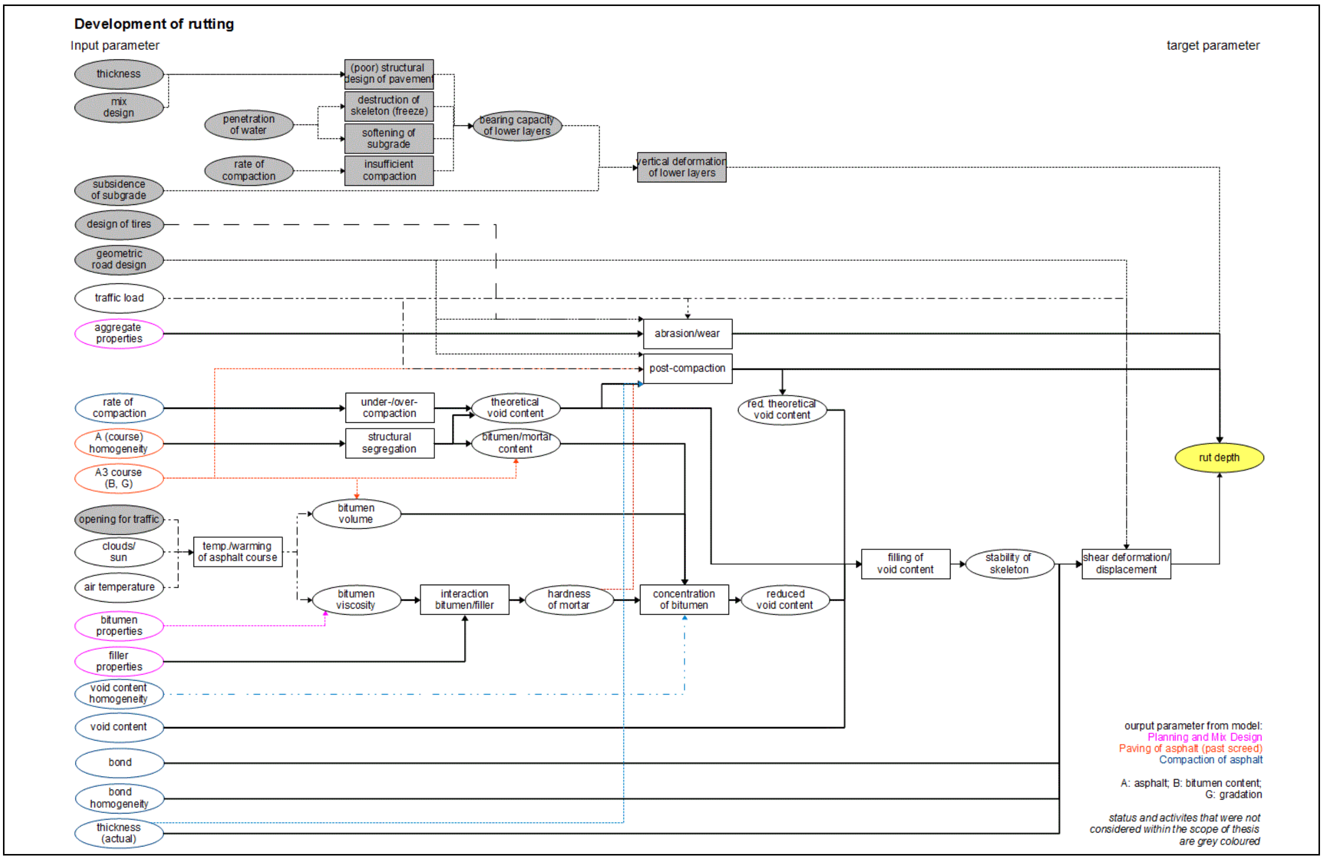

Figure 2 : Theoretical model of development of rutting [26]

With appliance of the method of risk analysis and particularly the "Darmstädter Risk Analysis Tool" (DRAT, [27]) in mind the theoretical part model "development of rutting" was converted into a quantitative model. So, the statuses and activities are defined and formulated mathematically in the quantitative model, where the general functions and factors based mainly upon correlations. Specific input parameters of the sections derive predominantly from measured data in the framework of control inspection.

Comparability of the sections is given; the two sections were finalised in mid-2004, the respective pavement was paved across the whole width and both base course and subgrade of the two sections are alike. Beyond, the average daily traffic on these sections during utilization phase is level and as the two sections lie nearby, the environmental effects are supposed to be similar. What makes the difference is the varied course structure of both binder course and wearing course: The compactasphalt-pavement consists of 2 cm wearing course made of stone mastic asphalt (with 8 mm maximum grain size and polymer modified bitumen PmB 45 A) and 10 cm binder course made of asphalt concrete (with 22 mm maximum grain size and polymer modified bitumen PmB 45 A). The conventionally built pavement is composed of 4 cm wearing course made of stone mastic asphalt (with 11 mm maximum grain size and polymer modified bitumen PmB 45 A) and 8 cm binder course made of asphalt concrete (again with 22 mm maximum grain size and polymer modified bitumen PmB 45 A).

Ensuing and as seen in Figure 2, rut depth of the two sections with significantly different course structure was calculated by summing up the deformations owing to post-compaction as well as to shear deformation of both wearing course and binder course, plus the abrasion of the wearing course.

The rut depth that was measured on the sections within condition survey in 2009 (about five years after construction) was used for comparison with the rut depth being calculated with the quantitative model. Furthermore, the measured rut depth served as target and thus, to adjust the model, what was done exemplarily.

By forecasting the development of rut depth over a 20 year period of use, the progression of rutting in time is conclusive for both sections. The forecasted development of rut depth is presented in Figure 3 for the section with compactasphalt-pavement and in Figure 4 for the section with conventionally built pavement.

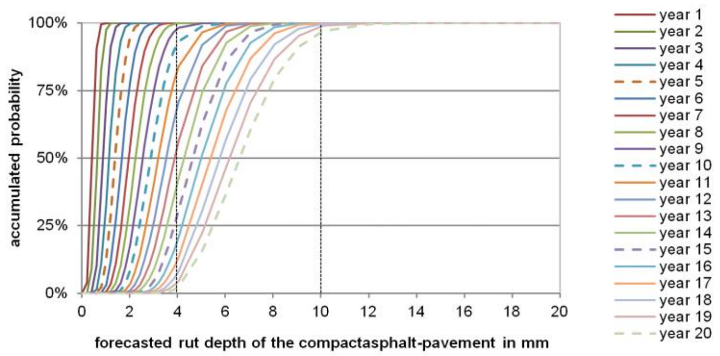

Figure 3 : Forecast of the development of rut depth over a 20 year period of use of the compactasphalt-pavement [26]

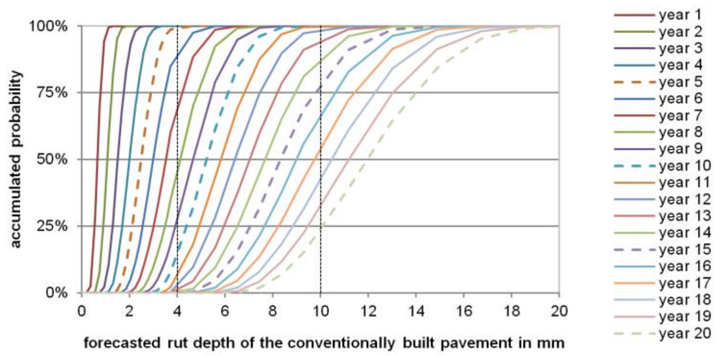

Figure 4 : Forecast of the development of rut depth over a 20 year period of use of the conventionally built pavement [26]

Defining the end of serviceable life as the average rut depth that equates to warn level (10 mm) within condition survey in Germany, and which requires careful consideration about possible maintenance work, for the conventionally built section one can expect a serviceable life of 17 to 18 years. These values correspond to literature saying that stone mastic asphalt (when conventionally built) possesses serviceable life of at least 15 years and on average 20 years. As expected the serviceable life of the section with compactasphalt-pavement is longer: After a 20 year period of use the 10 mm rut depth is estimated for only 2 % of the whole section or in other words with a probability of 2 %. Although it cannot be assessed whether the extension of serviceable life is appropriate, as there is to less data base for compactasphalt-pavement due to its limited application, comparisons with other compactasphalt-pavement sections at earlier times suggest, that the model fit to practice also for compactasphalt-pavement.

4 CONCLUSIONS

Basically, the system of compactasphalt-pavement was created in order to build pavements that sustain higher traffic volume. But through its principle additional benefits result as consequence at once:

- Due to the thinner wearing course top-quality and thus costly natural resources are economized; by reducing the thickness of the wearing course from usually 4 cm to now 2 cm, only half of that material is needed. The thickness of the lower course has to be appropriately increased, but here the requirements are lower and more material is suitable for use. Whether this connotes a price advantage depends of the local selling conditions.
- If paving both wearing course and binder course directly one after another hot-on-hot and compacting these all at once, it is almost impossible not to achieve a good bond between the two courses.
- As experiences as well as research have shown, the durability of compactasphalt-pavement is extended because of better resistance to deformation, less ageing, and good bond between wearing course and binder course.

Besides, experience has shown that once one know how to control compactasphalt-paver (or modified pavers), compactasphalt-pavements becomes reliable and safe to build. They are insensitive to deviations and small mistakes as the good performance of compactasphalt-pavements is affected adversely very seldom to the present.

In summary it can be said, therefore, that both material and financial resources are sustainably applied when building compactasphalt-pavements.

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