PROCESS SECURE AUTOMATED ROAD CONSTRUCTION

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ABSTRACT

To achieve the best possible quality in the construction process of an asphalt pavement, a large number of parameters have to be controlled and kept in their optimal range. Above all the temperature of the asphalt mixture in the process chain is a crucial factor which affects the laying and compaction. Parameters of the paver like installation speed and settings of the screed are of further importance. All parameters have a strong influence on the degree of compaction, the homogeneity and evenness of the asphalt layer. In combination with a possible segregation of the mixture during the material transfer all this can lead to a reduced service life of the asphalt pavement.

To improve and control the whole production process of a pavement, partners from industry, universities and administration initiated the research project “Process secure automated road construction”. It was started in late 2008 and is funded by the German Federal Ministry of Economics and Technology. After a detailed analysis of the weak spots was carried out, strategies for the improvement of the various processes are developed and implemented in demonstrators. The potentials of the information technology are used for process control and settings of the construction machines. Simulation models are used to tackle segregation problems and optimize material transfer. Altogether it is expected to improve the quality of the finished asphalt layer.

The results of the analysis of the weak spots were the basis for the development and production of the following demonstrators.

- Loading unit without segregation (asphalt mixing plant – dumper).
- Dumper with automated covering and thermal insulation.
- Modified auger/screw conveyor (segregation/temperature loss)
- Continuous collection and recording of relevant temperatures (paver, behind the screed, paved asphalt layer).
- Positioning system for sensors (temperature and others).

These demonstrators were tested on a construction site on a German motorway in summer of 2010. In particular the sensor technology (determination and transfer during the construction phases as well as during the life cycle) give a first step towards an “Intelligent Road”. First results were successful and promising.

1 INTRODUCTION

The mobility requirements for individual and public passenger transport and goods transport are increasing at an almost unchanged rate. This increases the risk of tailbacks and capacity bottlenecks on roads - in particular in densely populated areas. The well being and the health of people as well as the substance of the valuable infrastructure are affected. In spite of continuously improved materials, there are an increasing number of problems concerning the durability of the functional properties of road pavements. Quality-related weak points result in construction sites and unproductive waiting periods.

The elimination of quality-related weak points during the installation of asphalt pavements for traffic routes should lead to a significant improvement of the functional properties of these traffic routes, such as for traffic noise, traffic safety (skid resistance) and service life. This is to be achieved with new approaches to the automation, information and machine technology used in the installation process. This development will lead to more resource-saving and more economic construction methods, irrespective of the costs for construction materials. The variation of the installation parameters (mixture temperature, segregation and installation stops) must first be significantly reduced before the newly developed asphalt installation methods can be used on a large scale. Only then will it be possible to benefit from their improved functional qualities such as increased service life, lower noise levels and better skid resistance as well as their environmentally friendly and resource-saving construction methods.

The assumed, average lifespan of 10-15 years for the asphalt pavements and of 15-20 years for asphalt binder layers is often significantly shortened by lifespan-reducing faults. Road pavements must often be repaired or renewed after only half of their possible lifespan due to insufficient functional properties. The 15 demonstrators developed in this research project are intended to ensure that the maximum of performance is achieved by the consistent use of process secure, automated road construction.

It is furthermore essential to use existing traffic routes more efficiently with the aid of intelligent infrastructure. This requires the increased use of information and communication technologies such as the development of intelligent and multifunctional road pavements equipped with new types of sensors that inform the traffic participants about the state of the road, for example ice formation or wetness. The sensors can respond to traffic-related load and deformation/strain of the pavement layers and facilitate timely measures to create a more gentle traffic flow and to prevent structural road damage. The sensors are also able to identify vehicles that are overloaded or in questionable conditions. Multifunctional pavements that remain almost dry during rain, de-ice themselves in winter and reduce noise are currently being developed. This will create roads that respond intelligently to their environment.

2 DEVELOPMENT GOALS

The construction of demonstrators to control important material, installation and machine parameters as well as the mixture logistics and suitable machine technology for segregation-free mixture installation will contribute to the rapid implementation of the results in the form of innovative, new and extended products in the road construction sector. With the use of the developed automation, control and machine technology in construction measures and the consideration of all relevant key variables for the installation quality and performance behaviour of the road pavements the effectiveness of removing quality influencing weak spots, including the use of road rollers, shall be demonstrated. In particular, consequently the interface problem between material, application and machine technology, which is currently common in the construction industry, will be removed.

The goals of the research project – Process secure automated road construction – concern the improvement of the capacity, efficiency, safety and user-friendliness of the road traffic system and extend the life cycles of the functional properties of asphalt pavements, in particular of innovative, new pavement constructions such as compact asphalt (service life).

Figure 1 – Development goals of the joint research project – PAST

A series of investigations concerning process security in asphalt road construction has already been conducted. But in the past, the various construction and installation parameters were usually investigated in isolation. Only recent studies have worked intensively on the interaction and dependencies of the individual installation parameters. The first step is to capture and store all required installation parameters in real time, so that the installation process can be directly (automatically) adjusted. The experiences collected over time can be used for further optimisation of the individual sequences or automatic procedures. This will be required to achieve the best possible installation quality of asphalt pavements in road construction.

Once a detailed analysis of the weak spots had been carried out, strategies for the improvement of the various processes were developed and implemented in demonstrators. Information technology was used for process control and setting of the construction machines. Simulation models were used to tackle segregation problems and to optimise material transfer.

3 TESTING OF THE DEMONSTRATORS

3.1 Test track on the BAB 4 motorway in Germany

In the summer of 2010, some of the demonstrators developed were tested on a test track with a total length of 5 kilometres. A few of these demonstrators, which were tested with regard to efficiency and optimisation potential during the construction of the test track, are described below. Figure 2 shows that the test route was divided into a multitude of construction steps (colour coding) within which the demonstrators were tested.

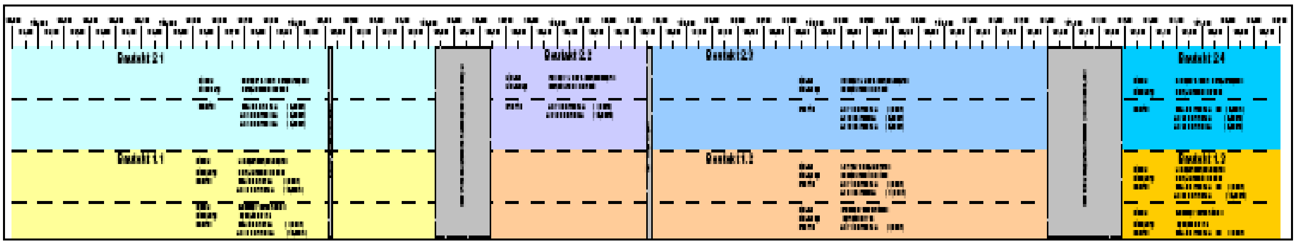

Figure 2 – Route band of the test route on the BAB 4 motorway - testing of demonstrators

3.2 Material segregation – loading and transport

Loading asphalt mixtures onto a transport vehicle and the transport drive have a significant impact on material segregation. Bulk materials that are dropped from a considerable height form material cones in which the coarse aggregates are more concentrated along the lower, outer rim. The vibration of the transport vehicle during a drive also moves the coarser aggregates towards the top of the bulk material, a phenomenon that is called the Paranus effect.

To prove the material segregation problems described, samples according to Figure 3 (with identification of the sampling points) of the asphalt mixture on a vehicle were taken after loading and then from the same places after the transport drive to the construction site. In addition, asphalt samples were taken immediately after tilting the mixture into the paver hopper and at the auger. The segregation behaviour of asphalt during the entire transport chain could thus be accurately determined. The asphalt base course material AC 32 T S was used for the tests, as it complies with the requirements of the national technical regulations.

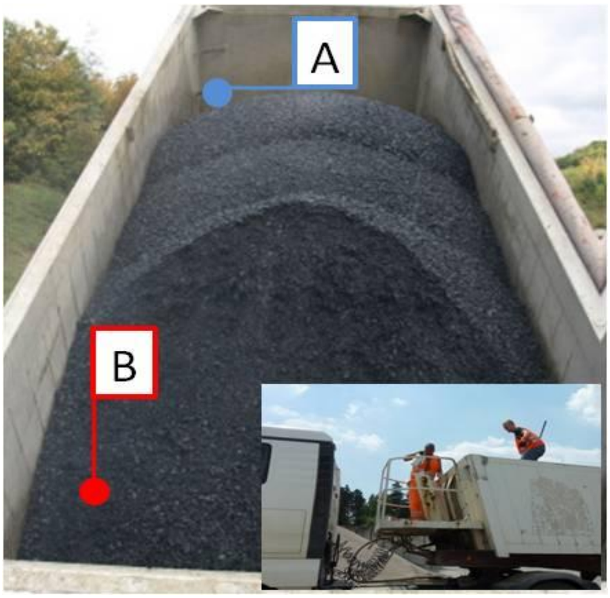

Figure 3 – Asphalt sampling on the transport vehicle

After sampling, the mixture gradation (grain size distribution) of the asphalt samples was investigated in the laboratory to determine the degree of material segregation. Figure 4 shows a graphical representation of the grain size distributions in the samples. The blue, solid line indicates the respective mixture gradation of the asphalt base course material that was taken from the areas of the transport vehicle marked in blue (Figure 3). Red marks the asphalt material taken from Position B (Figure 3).

Figure 4 shows that the grain gradation after loading the asphalt base course material onto the transport vehicle is already close to the lower tolerance limit for asphalt base course material specified in the “Technical delivery conditions for asphalt mixtures for the construction of traffic area pavements”. During the transport drive, vibration moved the larger aggregates to the top of the bulk material. The asphalt paver is therefore supplied with a considerable amount of segregated material that is inevitably also installed in segregated form.

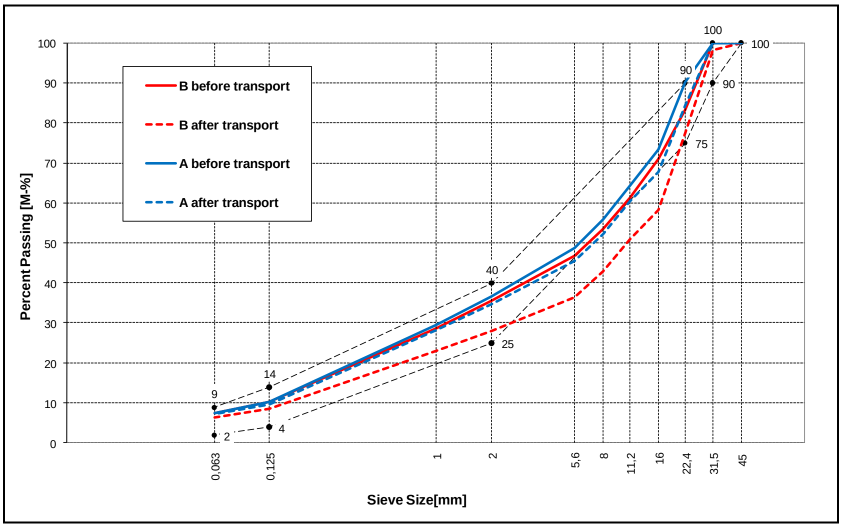

Figure 4 – Grading curves for samples taken at the transport vehicle

Vibration-dampening systems have been developed to prevent or minimise segregation of the asphalt material during the transport drive. They can be installed on the chassis of the transport vehicles. These mass-spring systems use the loading as an absorbing mass. Results are not yet available.

3.3 Material segregation – paver

A modification of the auger compartment in the asphalt paver makes a huge contribution to quality-improved asphalt installation. A material transport channel in the shape of a half-shell was installed directly below the auger to prevent segregation by the auger. It minimises the rolling and falling movements of the asphalt and the homogeneity of the mixture remains unchanged.

The lateral distribution of the mixture in the asphalt paver is achieved by the auger. It takes up the mixture at the end of the scraper conveyor and distributes it across the installation width. After lateral transport by the auger, the mixture falls to the ground and forms a trapezoidal shape. Once the coarse aggregate has left the auger, it rolls down the incline to the chain of the paver. The geometry of the mixture cone below the auger has a relatively large contact area with the ground and cooling of the mixture by the ground is enhanced.

It may be said in summary that lateral distribution by the auger leads to considerable segregation and relatively high temperature loss. Optimisation of this process phase can be achieved by guiding the mixture in a way that reduces segregation. This segregation-reducing material transport by the auger is implemented with a half-shell-shaped transport channel that is installed close to the auger Figure 5.

Figure 5 – Auger compartment of a paver, modified on one side

To allow for a direct comparison of the modified version with a conventional asphalt installation, the half-shell-shaped transport channel was only mounted on the left auger of the paver while the right auger remained unchanged. The material samples taken allow conclusions about the actual effect of the half-shell-shaped transport channel with regard to reduced segregation tendencies. Asphalt mixture samples were taken at the BAB 4 motorway test track during asphalt installation from different parts of the paver. The gradation of the samples was investigated in a laboratory. Material was sampled after the transfer of the mixture to the paver hopper (Sampling Point C), at the end of the modified auger (Sampling Point D) and at the end of the unmodified auger (Sampling Point E). The results of the sieve analysis are graphically illustrated in Figure 6. The positive influence of the modified auger gets also visible as Figure 7 demonstrates. The green line represents the symmetry axis of the auger. Material segregation can be seen on the right side of the line but not on the left side. The demonstrator can be classified as promising, as the material on the left side, which was handled in the modified auger compartment of the paver, shows no segregation (or only segregation at a far lower level).

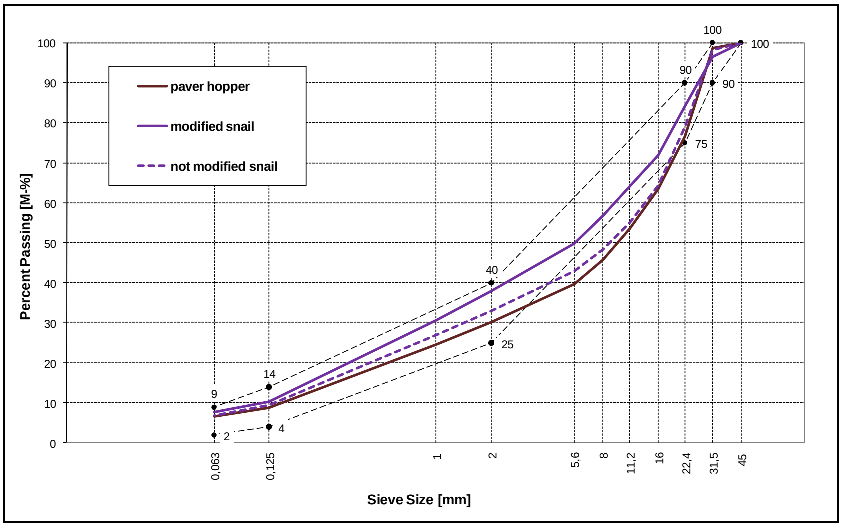

Figure 6 – Gradation curves for samples taken at the paver

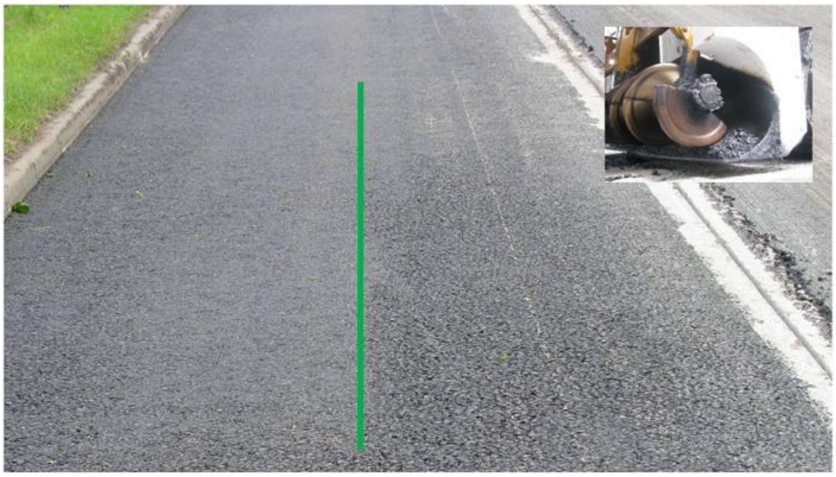

Figure 7 – Asphalt layer installed, left with modified auger compartment and right without modification of the auger compartment of the paver

3.4 Temperature monitoring (continuous)

A further important problem is temperature monitoring and the reduction of temperature losses. New, heat-insulated dumpers were investigated and new solutions were created to monitor the temperature of the asphalt mixture at short, regular intervals during the entire installation process. It was therefore possible to determine the critical periods or transfer situations during the asphalt installation process that are associated with the greatest temperature reductions. Various temperature measuring devices at the paver as well as the compaction device were installed and tested. Figure 8 shows a measuring beam that was installed at the rear of the asphalt paver and has regularly spaced temperature sensors, as well as an infrared scanner that was mounted to the roof of the asphalt paver. Later application in normal road construction operations will only use the infrared temperature scanner, as it is simpler to handle. The measuring beam used at the test track is only used for control purposes. The superposition of the two temperature graphs in Figure 8 shows that this is completely sufficient.

Figure 8 – Positioning of the temperature measurement devices on the asphalt paver (left), display unit on the asphalt paver to monitor and document asphalt mixture temperatures during installation (right)

At the same time, passive transponders to determine the prevailing temperature were buried during the installation of the asphalt. These transponders make it possible to determine the asphalt core temperature at any time. This is of particular interest for different situations/constellations. Knowledge of the actual asphalt temperature is very important for asphalt installation, in particular for compaction. The roller driver can thus be informed about the size of the time window for compaction, whether compacting can already start and whether it is no longer useful, i.e. when the asphalt material can no longer be compacted and is more likely to be fragmented. In the near future, a digital display as visible in Figure 9 will be installed on the appropriate compaction devices. But in contrast to Figure 9 it will be placed in the passenger cabin to keep the roller driver current about the asphalt temperature and other information.

Figure 9 – Installation of passive temperature sensors and reading of the current asphalt temperature in the installed layer (left) and the temperature display unit on the roller (right)

The long service life of the used passive transponders makes it possible to determine the asphalt temperatures at any time during the usage period with appropriate reading devices. These data can then be processed and forwarded. This is very important in winter for instance, as traffic participants can quickly be alerted and traffic control centres can directly influence the traffic flow. The system can also be used in the event of “prolonged heat periods” which are unfortunately happening with increasing frequency. They may lead to closure of individual lanes or whole road sections in order to increase the overall service life of the traffic structure.

3.5 Installation according to the profile

Another demonstrator is the “Big-Sonic-Ski”. It is a tool for improving the longitudinal evenness of the layer to be installed. In contrast with conventional systems, it has three ultrasound sensors that are mounted on a rail aligned at the side of the paver. The measuring results are used to calculate a mean value, which takes possible unevenness into account. This averaging procedure allows for better levelling of the support layer. The means calculations can cover a levelling range of up to 9 metres, depending on the alignment of the three sensors on the rail. Each of the three ultrasound sensors consists of five beam units that can be used to filter the measurements so that objects that protrude into the measuring area or undesirable bumps are excluded.

Before installation, evenness measurements of the support layer were performed with a planograph. Additional measurements were performed after the installation of the first and the second asphalt layer to determine changes in the longitudinal evenness of these layers and to facilitate comparisons.

Figure 10 – “Big-Sonic-Ski” mounted on the research paver, electronic display unit and automated control unit as well as planograph measurements

4 SUMMARY

It was proved that a modification of the auger compartment leads to a more homogeneous installation of asphalt mixtures that are very susceptible to segregation. It was further shown that material loading and material transport have a very significant effect on the segregation of asphalts. The newly developed demonstrators (e.g. loading device) that have not been completely tested, will therefore make an important contribution to minimising the segregation of asphalt mixtures.

The investigated/tested tools for monitoring temperatures further allow measurement and especially documentation of all mixture temperatures relevant for asphalt installation along the entire process chain. Some of these tools can also be used once the installation of the asphalt pavement has been completed. When high asphalt temperatures are detected by the sensors in the asphalt layer, individual lanes must be closed to prevent likely plastic deformation (damage). These sensors could also be used to capture or store other data (material, installation conditions, traffic load).

It can be said in summary that most of the quality-improving demonstrators developed could be successfully tested on the “BAB 4 test track”. The next step will be to establish these tools in the market. Into the future with PAST!

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