The asphalt paving process

Real-time data-processing and visualization

Supervision UT: André Dorée, Timo Hartmann, Alexandr Vasenev (a.g.doree@utwente.nl)
Language: English

The Challenge
At the outset the asphalt paving process seems to be simple. Trucks deliver hot mix asphalt from plants to the construction site. There the asphalt is loaded on asphalt pavers that evenly spread the asphalt. Finally, compactors compact the asphalt to its required density. Despite this relatively structured process our research shows that there are significant discrepancies in the final compaction grade and quality of newly asphalted road sections. It turns out that asphalt paving operations are to a certain extend knowledge intensive because of two reasons. First, compactor operators do have little explicit understanding about the temperature of the asphalt during the compaction processes. Such understanding, however, is crucial as asphalt can only be compacted in a certain temperature window. If the asphalt is too hot, the compactor will merely shove the asphalt forward. If the asphalt is too cold, little compaction can be reached. The second reason why asphalt paving operations are knowledge intensive is that asphalt compaction is team work. Seldom a road section is compacted only by one single compactor, most of the times multiple compactors are working together to reach the desired compaction grade. Again adequate information about the joint activities are not available to individual operators. Hence, it is hard to understand for the individual compactor operators which part of the road has been compacted how often. It is not surprising that roads currently are compacted highly inhomogeneous.

Our Research
To overcome this problem we developed a theoretical method to provide asphalt operators with adequate information about temperature and compaction processes that we developed to overcome the above described dilemma. In particular, we use a network of temperature sensors and GPS tracking devices to collect operational data. We then process this data to meaningful visualize the process to provide information to roller operators in real time during roller operations and in retrospect to enable organizational learning activities of asphalt paving crews. Adequate visualizations of this processed data is then provided to machine operators in real time and in retrospective feedback sessions with the goal to improve the operator’s understanding about their paving processes.

The Task
In a next phase of this research, we aim at automating the data processing steps of the method. Currently, much of the processing is done manually and, hence, processing is quite work intensive. This hinders us currently to timely provide feedback to operators. To support us in this next phase, we are looking for interested students with a background in signal processing and experience in the Matlab and JAVA programming languages. The engagement of the student can be in the form of a student assistantship or in the course of a Master or Bachelor project. If you are interested or know somebody who might be interested, please contact Prof. Andre Dorée (a.g.doree@utwente.nl) directly by mail.

More information
ASPARi is short for Asphalt Paving Research & Innovation. It is a cooperative network of organizations that work together in research projects and technology development to improve the performance of the asphalt road construction industry. The issues around more professional approaches to asphalt paving became relevant and pressing due to changes in the business environment. Therefore, the ASPARi founders a conglomerate of Dutch asphalt contractors established ASPARi to bundle the ongoing activities and to confirm the network structure. To see more about the ASPARi approach and projects: www.aspari.nl.
Study ‘The black gold’ in the laboratory
Supervision UT: André Dorée, Frank Bijleveld, Henny ter Huerne (a.g.doree@utwente.nl)
Languages: Dutch, English

Possible companies / contractors: Ooms (Scharwoude), Dura Vermeer (Eemnes), Ballast Nedam (Nieuwegein)

Problem domain and importance
The problem domain can be summarized through the following statements:

- Asphalt plays a vital role in global transportation infrastructure and drives economic growth and social well-being in developed as well as developing countries. In 2007, the estimated world production of asphalt was about 1.6 trillion metric tonnes of asphalt and Europe produces about 435 million metric tonnes per year. In Europe public investment in highway, street, and bridge construction totals about 80 billion euro per year and in the USA the public investment is around 55 billion euro per year. Also, in the USA and Europe the asphalt paving industry collectively employs about 400,000 workers.

- Traditional practice of asphalt paving companies leans heavily on the experience and craftsmanship (tacit knowledge) of the asphalt paving teams on site. This results in individual implicit learning. Therefore, it is difficult to understand the quality of operations during this asphalt paving process.

- Contractors seek for deeper insights into the relationships between the paving and compaction operations and the corresponding project conditions as well as the circumstances at the final functional and mechanical properties of the asphalt pavement. Contrary, knowledge, design rules and models, for these relationships are absent.

- Although the impact and importance of the paving and compaction process to the final quality of the asphalt pavement are recognised – in scientific community and journals – the knowledge about the effects on the quality of the pavement still is in academic infancy. So it is generally unknown how operations impact asphalt pavement quality. The major part of the literature and the research deals with the characteristics of asphalt from a material-perspective.

The challenge
The overall aim of this Msc/Bsc-research is to develop deeper insights into the relationship between operational strategies, the project conditions and circumstances, and the final quality of the asphalt layer. From these insights new paving and compaction strategies can be developed: A set of design rules and models for the paving and compaction process that better fits current policies of the asphalt paving industry (clients and contractors) towards improved and consistent asphalt pavement quality.

So, for contractors it is necessary to understand the (causal) relationships between operational strategies and the resulting quality of the asphalt pavement. An initial study (Bijleveld, 2010) about the effect of compaction at certain temperatures at the final quality of the pavement show that these relationships can be vital and also gives an impression about the research that should be done (http://essay.utwente.nl/59418/).

But still questions arise - what are for example the effects of the total number of roller passes of the quality of the pavement? The different types of rollers they use? The sequence of the roller passes and the time and temperature windows they compact in?
Research methodology and expected results

To study and evaluate the effects of these different operational strategies, it is difficult and complex to make use of real construction projects. In these projects it is really difficult to distinguish causal relationships because of the number of variables and the inflexibility to control these variables. Because of the large number of variables and the difficulty to control these in practice, the effects of different strategies on the quality of the asphalt layer will be evaluated in a laboratory setting, where variables can be controlled and certain variables can be isolated.

For the lab-experiments a Roller Sector Compaction (RSC) will be used to simulate the compaction process in the laboratory – see the compaction equipment in the figure below. Several studies showed that this rolling compactor has the potential to closely simulate field compaction. With this laboratory compaction equipment, different strategies will be simulated under varying conditions to determine the effects of different strategies and which strategies are best under which conditions.

With the results of these lab-experiments, it is possible to determine the effects of different operational compaction strategies on the quality of the asphalt layer and design an ideal compaction process to understand why one process is better than the other, and based on which variables the on-site process can be steered. The results from the lab-experiments lead to a deeper insight into the paving and compaction process, the operational behaviour and the effects on the quality of the pavement.
The asphalt paving process

From implicit individual learning to explicit organizational learning

Supervision UT: André Dorée, Frank Bijleveld (a.g.doree@utwente.nl)
Languages: Dutch, English

Possible companies: 11 contractors within the ASPARi-network (located in almost every region in the Netherlands)

Problem domain and importance

The problem domain can be summarized through the following statements:

- Asphalt plays a vital role in global transportation infrastructure and drives economic growth and social well-being in developed as well as developing countries. In 2007, the estimated world production of asphalt was about 1.6 trillion metric tonnes of asphalt and Europe produces about 435 million metric tonnes per year. In Europe public investment in highway, street, and bridge construction totals about 80 billion euro per year and in the USA the public investment is around 55 billion euro per year. Also, in the USA and Europe the asphalt paving industry collectively employs about 400,000 workers.
- Traditional practice of asphalt paving companies leans heavily on the experience and craftsmanship (tacit knowledge) of the asphalt paving teams on site. This results in individual implicit learning. Therefore, it is difficult to understand the quality of operations during this asphalt paving process.
- Contractors seek for deeper insights into the relationships between the paving and compaction operations and the corresponding project conditions as well as the circumstances at the final functional and mechanical properties of the asphalt pavement. Contrary, knowledge, design rules and models, for these relationships are absent.

The challenge

Where the quality of the product (asphalt mixture) is pretty good defined through different functional and mechanical properties of the pavement (like stiffness, resistance against fatigue, rutting, stripping, etc.), the quality of the paving process is mainly unknown, because the key characteristics of the paving process are not monitored and mapped systematically and their variability’s are mostly unknown.

Miller (2010) developed a measurement framework (see appendix 1) to make these paving processes and operational strategies explicit and to work towards continuous improvement, called Process Quality improvement (PQi). Within this framework the operational strategies are made explicit with GPS-technology, a laserlinesscanner, thermocouples, and infraredcameras to provide insights into the paving process. This data can be transferred to graphs and animations (Miller and Hartmann, 2010) and give feedback to asphalt teams. This measurement framework is shortly described in appendix 1 and in more detail in Miller (2010). Every year the contractors will monitor two projects a year, so with 11 contractors in the ASPARi-network this means 22 project per year. In this project you will help the contractors to conduct the measurements and compare the results of the different contractors. So, are the working methods of one contractor different from the other and that implications does this have for the final quality of the pavement?
Appendix 1: The ‘Process quality improvement (PQi)’ framework

A process quality improvement (PQi) framework, is developed by Miller (2010). This is a method-based approach for improving process quality by monitoring and analysing the paving process. The aim of the PQi-framework is the improvement of ‘Process Quality’ by closely monitoring HMA construction work and making operational behaviour explicit. The explicit data is made available to HMA teams so that they can reflect on their work, discuss and analyse the results and propose improvements to their work methods and operational strategies. The PQi methodology combines elements of reflection theory (De Man, 2007), elements of process improvement (Garvin 1988), quality control (Montgomery 2005) and feedback systems (Anderson et al. 1994). The typical PQi cycle shown in the figure below consists of:

- **Day 1: Preparation and definition** – check site design, undertake site calibration, record site conditions and hold a preparatory meeting with the HMA team;
- **Day 2: Data collection** – temperature profiling, monitoring all HMA machine movements, monitor weather conditions, nuclear density profiling and recording all noteworthy events;
- **Days 3 and 4: Data analysis** – analyse all data and prepare visualisations and animations;
- **Day 5 – Feedback session** – discuss all results, visualisations and animations with the HMA team, laboratory technicians and others directly involved in the project and determine improvements for next projects.

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<tr>
<th>Direct results PQi:</th>
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<tr>
<td>- A 4D animation of the entire paving process</td>
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<td>- HMA temperature and density progression</td>
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<tr>
<td>- The paver’s operational characteristics</td>
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<tr>
<td>- Compaction behaviour and number of passes</td>
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<tr>
<td>- Variability in results and working methods</td>
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<tr>
<td>- Vulnerable areas and issues</td>
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<tr>
<td>- Recommendations for process improvement</td>
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<tr>
<th>Indirect results PQi:</th>
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<tr>
<td>- A georeferenced dossier for future failure analysis</td>
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<tr>
<td>- Increased awareness of quality for asphalt team</td>
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<td>- Improved communication within and with asphalt team</td>
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<td>- More insights into the differences between HMA teams</td>
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<tr>
<td>- Identification and selection of “best practices”</td>
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<td>- Quality improvement and the limitation of risks</td>
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Miller implemented existing technologies (like GPS, laser and infrared) in this framework to show the working methods of the asphalt team and show the variability within these methods and results. An impression of technologies used in the measurement-framework is shown on the next page.
GPS rovers mounted with magnets on the top of the rollers

Linescanner 1m behind the creed of the paver constant measuring surface temperature

GPS base station & weather station

Nuclear density measurement after every roller pass

Het Cooling Curve Calibration Unit (CCCU)

Thermocouples + datalogger to measure in-asphalt temperatures

Infrared camera to measure surface temperature at a certain spot