NEW TECHNOLOGIES IN THE PAVING PROCESS NEED TO BE BASED ON "COMMON PRACTICE" AND OPERATORS' HEURISTICS

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Abstract: This paper describes an initiative that aims to integrate process modeling with the tacit knowledge of site personnel in order to accelerate professionalism and widen the application of technology in the asphalt paving process. A preparatory study was conducted to gain insight into operational strategies from operators' perspectives. Interviews and observations confirmed that operational choices in the asphalt paving process depend heavily on craftsmanship, and that the work methods and equipment are mainly selected based on tradition and custom. Furthermore the operators were reluctant to use new (available) technologies. Since improving the paving process requires integrating new technologies with the learning of new work methods. For that task the paper proposes an action research strategy.

INTRODUCTION

Over the last three years, since the parliamentary enquiry into the construction sector, the business environment within the road construction sector has changed dramatically in the Netherlands. According to (Dorée, 2004) the collusion structure that regulated competition has fallen apart. Public clients have introduced new contracting schemes containing incentives for better quality of work (Sijpersma & Buur, 2005). These new types of contracts, tougher competition, doubled guarantee periods, risk transfer, and the urge to make a distinction in the market, spur the companies to advance in product and process improvement. These changes have significantly altered the playing field for competition.

More quality and endurance risks are transferred to the contractors. They therefore seek better control over the paving process. Improved control is the key to reduce the risks of failure of the paving during the guarantee period. To be able to improve process control, the relevant operational parameters need to be known and the relationships between these parameters and the end results need to be thoroughly understood. Surprisingly such efforts to systematically map and analyze the process of asphalt paving are few. A scan of literature showed a field of asphalt research which is well developed. It indicates that the majority of the research deal with the characteristics of asphalt from the perspective of construction material. Papers on the asphalt paving process from production-operation-management perspective were only a fraction of the total of papers published on asphalt. It seems the process-perspective on asphalt pavement is hardly developed systematically.

METHODOLOGY

This work forms part of an overall project focusing on the improvement of the Hot Mix Asphalt paving process aiming at improved quality and consistent reduction of quality variability. A preparatory study was conducted to gain insight into operational strategies in the asphalt paving process from operator perspectives. The purpose of conducting interviews with specialists conducting paving tasks is three-fold. Firstly, to validate those factors influencing the asphalt paving process found in an earlier literature review. Secondly, to validate anecdotal evidence suggest that the work was largely based on tradition and custom and lastly, to gain deeper insight into the manner in which the paver, screed and roller operators undertake their tasks (in conjunction). Using an exploratory approach through observation and structured one-on-one on-site interviews with twenty-eight operators, this study explored the operational experiences of those closest to the asphalt paving process.

PAVING OPERATIONS - THEORY AND PRACTICE

The text below expresses a more general view on the processes achieved by paver, screed and roller operators. The table inserts show a few selected points emphasized by the operators.

Paver Operators: The paver is the prime mover which receives material from a truck, stores it on board and has a conveying system that takes the material from the hopper to the rear of the machine and dumps it on the paved surface (NCAT, 1991). The paver is comprised of two basic machines: the tractor unit and the screed unit, each with its own operator. Paving operations consists out of transforming the bulk asphalt mixture, transported to a position just in front of the screed, into a smoothly finished layer of the right dimensions viz. thickness, width, profile and evenness (Asphalt-Institute, 1989). According to the institute responsible for operator training in The Netherlands, the paver operator regulates the speed, position and course of the machine and takes care of the supply of the mix from of the hopper to the screed (SBW, 2004). The operators confirmed that these indeed are their main tasks. The paver operators stated that in doing so they paid particular attention to the supply of asphalt to the road site. They considered the "quantity of asphalt in the hopper" and the "quantity of asphalt in front of the screed" critical to delivering a good product. The supply of asphalt was considered to be the main factor for controlling the speed of the paver. In addition, they also consider overall safety around the paver as an important responsibility.

Paving machine operator (7 interviewees)	
feels specific responsibility for …	• Supply mixture to screed • Speed of paving
pays specific attention to …	• Amount of mixture in hopper • Position of asphalt paver
finds these tasks difficult to perform …	• Estimating amount of mixture that is needed for a specific road • Paving curves, intersections etc.

Screed Operators: The most critical feature of the paver is the self-leveling screed unit which determines the profile of the material being placed (NCAT, 1991). The screed weight plus the vibrating energy it imparts raises materials density until a slightly compacted state. A number of forces are acting on the screed as it moves during the paving process. The interviews confirmed that screed operators spent most of their time working on keeping the screed in a "state of equilibrium". The operators consider their most important tasks to be those related to regulating the layer thickness, the width and the profile of the road. Also, they consider the working relationship with paver operators to be the most important since their work was largely influenced by the quantity of asphalt in front of the screed and the speed of the paver. The paver speed and the type of asphalt mix were important factors to be considered in setting the height of the screed which influenced the desired layer thickness. Both paver and screed operators indicated that this “state of equilibrium” was affected in difficult areas e.g. ramps, roundabouts, curves, water inlets and intersections. They also stressed that they found it difficult to work in areas where the tolerances were small. A minority of the screed operators stressed that they are able to influence uniform delivery by changes to the screeds' temperature. If they do so, these changes are made purely based on "gut feeling".

Roller Operators: Whilst the paver and screed operator’s working relationship focuses on the speed of the paver, width being paved and the work method employed, the discussions between screed and roller operators appear to be focused, quite correctly, on changes in layer thickness of the asphalt mat. This is because the thicker the mat the longer it retains the heat and the longer the time during which compaction can be achieved (Asphalt-Institute, 1989). Interestingly, the speed of the paver was not considered to be an important point of discussion between screed and roller operators. This raises the issue of whether the screed operators were aware of the effect of temperature differentials if the paver was too far away from the roller operator’s working zone. The influence of temperature differentials on hot mix asphalt paving has been studied extensively (Stroup-Gardiner *et al.*, 2002; Timm *et al.*, 2001).

One of the major practical problems roller operators deal with is that whilst they are responsible for the final compaction level of the asphalt mat, they are not able to measure that degree of compaction during the compaction process itself. When final rolling has stopped the target density should ideally have been achieved since it would be difficult to achieve further compaction when the asphalt mat cools down . However, most roller operators interviewed indicated that they were not informed of the final density of the completed layer despite its importance. This is a significant shortcoming in terms of quality, shows an absence of “closing the feedback loop”(Montgomery, 2005) and negatively affects any learning that could occur. Also, roller patterns directly influence compaction (Leech & Powell, 1974). A concern is that most operators did not keep track of the number of passes completed during rolling. They also appear to base key operational decisions on what they “feel” and “see” since they do not know what the temperatures and the material characteristics are during the process of compaction. This makes working at night problematic. Roller operators indicated that they specifically looked for the occurrence of “cracking” and “shoving” and the rapid cooling of the asphalt during the compaction process. Of the operators that had temperature measurement tools at their disposal, a minority confirmed to use these. They apparently understand that a change in layer thickness directly affects the cooling rate of the asphalt mat. However, in practice the roller operators are mostly not informed about the discontinuities as a result of adjustments made by the paver and screed operators – such as paver speed and screed vibration.

The Roller operator (14 interviewees)	
feels specific responsibility for……	• Final compaction level of the layer • Final evenness of the newly laid layer
pays specific attention to …	• The behavior of the asphalt mixture during compaction (“cracking” and “shoving”). • Cooling of the material under compaction. • Effect of weather conditions on cooling of asphalt.
finds these tasks difficult to perform …	• Working in Urban areas. Projects with curves, intersections, roundabouts, etc.

Craftsmanship and Common Practice: The interviews conducted with operators confirmed anecdotal evidence which suggested that work in the asphalt paving process depends heavily on craftsmanship, that work is being carried out without measuring the key process parameters and that the work methods and equipment are selected based on tradition and custom. There is also evidence that no direct feedback is given to operators. Machine settings are done mainly on the basis of “feeling and experience”. Compactor operators visually note the behavior of the mix to determine if the desired density has been achieved. Although the interviewees all refer to common and proven practice in machine setting, the actual settings and operational strategies varied widely from team to team. So, there is not really one common practice, but a wide array of “common practices” which probably leads to extensive variability in the final product. Asphalt paving in many ways still is a process driven by craftsmanship, heavily dependent on tradition, and on operators' experience, gut feeling and tacit knowledge.

NEW TECHNOLOGIES FOR PROCESS CONTROL - A CAUSALITY DILEMMA

Our interviews indicated that operators are not comfortable with new technologies. Over the last decennia several technologies were developed to improve process information and process control. New features and functionalities were added to the equipment. However, most operators acknowledged that they hardly made use of the available technology. They just don't know how or why to use the new "gadgets".

Global Positioning Systems (GPS) have been extensively used to monitor asphalt paving and compaction operations (Bouvet *et al.*, 2001; Krishnamurthy *et al.*, 1999; Oloufa, 2002; Peyret *et al.*, 2000). However, although some of these experiments were developed into industrial applications, it appears that few have been accepted widely by industry and are frequently used on the construction sites. The data provided by GPS systems does not help the operators because they do not know that these data might be relevant for their operational choices and work methods. The adoption of technology process may also be hindered by skepticism and reluctance of the operators - who feel that their workmanship is being devalued or that management could use the technology to track their movements and possibly use it punitively. Also several authors also argue that the construction industry typically lags behind other industries in adopting technology (Bowden *et al.*, 2006; Halpin & Kueckmann, 2002). For evaluating the adoption of technology one could use the innovation adoption factors as given by Rogers (2003). When the data produced by the GPS systems do not match with the operators' operational reasoning, at least three of the Rogers' five attributes will not be full filled – and adoption will be problematic. Tailoring the GPS solutions to overcome this mismatch is difficult because the operational reasoning of the operators is tacit and implicit.

Factors for likelihood innovation adoption
(Rogers 2003)

- relative advantage
- compatibly
- complexity
- trialability
- observability

New Research Approach: So, developing better operational strategies requires adoption of new technologies, but new technologies are not adopted due to insufficient understanding of current operational strategies (the common practice). This resembles a chicken or egg problem, a causality dilemma. Against that background the research project will follow an action research strategy alternating steps of technology introduction and mapping of operational strategies based on the approach of (Chisholm & Elden, 1993). Through monitoring of the learning processes of the operators, and evaluating the operational choices with them, the tacit knowledge of the "common practice" will become explicit. As such this provides the opening for further development of process understanding, tools and operational strategies. The key issue here is that the operators need to be involved in, and take responsibility for the process. They are in fact largely responsible for the success of the process. Unraveling of their tacit knowledge opens up new opportunities for process control and technology development, and the new technology will assist in further unraveling of the operational strategies (and so on).

CONCLUSIONS

New public procurement spurs the Dutch asphalt paving contractors towards quality improvement and process control. As a consequence contractors experiment with new technologies in the paving process, but the operators are reluctant to use the new technologies. Research shows that the operational decisions are primarily based on common practice, tacit knowledge and personal judgment. Operators know the relevance of key parameters as temperature, layer thickness, density and roller passes, but hardly keeps track of the values. Adoption of the new technologies that provide such values is hampered because of a mismatch with the work method and operational heuristics of the operators. Technology can provide vital assistance to the operators, but to be successful the development must coincide with thorough exploration and explication of the tacit knowledge and operational heuristics of the operators. This two-track approach makes the operators part of the technology development, and may overcome the current stalemate in professionalizing the asphalt paving process. It is good for the industry that road building companies and equipment manufacturers invest in improving quality and process control. However, they should be aware of the manner and speed in which they develop and introduce new technologies for the paving process, and invest at least as much into transforming the "common practice" of the operators towards more evidence based operational strategies.

As authors we acknowledge the results of interviews can be perceived as predictable and well known in the construction realm. So why bother asking the crew members? Well, it seems that this "common" anecdotal knowledge prevents crew members from sharing their experiences explicitly with their colleagues. When crew members assume that all relevant issues are known, then they will feel little urge to share and challenge the common practice. Such "all is known" assumptions hinder process improvement and adoption of new technologies. In our research project we introduce new technologies to challenge the common practice views and to promote sharing of knowledge and experiences that would otherwise stay tacit and individual. Sharing the experiences and views will open up new opportunities for process improvement and better understood operational strategies.

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