Asphalt production, paving and compaction techniques

Evaluation of innovative automated systems for monitoring asphalt pavement surface conditions in England. Part 2: Automated quality monitoring systems.

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Abstract

England's road construction sector is facing another leap in technology, particularly associated with pavement assessment and compliance testing. Traditional site testing and data recording involve manual handling, files of paperwork and long-chained approval systems, which can lead to health and safety risk, low productivity and ultimately loss in profit. On the contrary, digitization has been a new norm in industries such as manufacture, finance and commerce, where leaner technologies are frequently emerging and adopted. In response to the new norm, the road construction industry has started adopting the latest advancements in construction and assessment technology. In the last 5 years, the UK industry has started trialling and implementing digitalisation and BIM (Building (Better) Information Management), aiming to improve productivity levels, quality and safety of the industry and to minimise impact on the environment. This paper presents findings from recent collaborative research commissioned by Highways England, Mineral Products Association, and Eurobitume UK carried out by AECOM on automated construction systems incorporating paver recording, intelligent compaction and temperature sensing systems, in addition to surface regularity and texture in Part 1. The submission will provide an overview on opportunities and challenges, as well as lessons learnt from selected local and national road construction schemes in England. Although still in the early stages, the concept of integrating automated construction data into cloud-based asset management tools will be explored. It will also discuss the potential benefits associated with smart automation, predictive intelligent, real-time data exchange and 4D executions.

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1. INTRODUCTION

1.1. Background

The construction industry tends to be conservative when dealing with changes and challenges against innovations and new technology. However, England's road construction sector is gearing up to consider new technologies, particularly associated with pavement assessment and compliance testing. Traditional site testing and data recording involve manual handling, files of paperwork and long-chained approval systems, which can lead to health and safety risk, low productivity and ultimately loss in profit. On the contrary, digitalisation has been a new norm in industries such as manufacture, finance and commerce, where leaner technologies are frequently emerging and adopted. In response to the new norm, the road construction industry has started adopting the latest advancements in construction and assessment technology. In the last 5 years, the UK industry has started trialling and implementing digitalisation and BIM (Building (Better) Information Management), aiming to improve productivity levels, quality and safety of the industry and to minimise impact on the environment.

1.2. Scope

This paper presents findings from a recent collaborative research project commissioned by Highways England, Mineral Products Association and Eurobitume UK, and undertaken by AECOM on automated construction systems. The aim of the project was to explore the possibility of incorporating recent technological advancements and automation in quality monitoring equipment and technologies, as an alternative to the conventional testing and monitoring of asphalt pavements. A driver for this review is that the conventional methods inherently carry safety risks for site technicians who undertake the works. The use of automated technologies currently available to the construction industry could remove and/or mitigate the exposure of site technicians.

The automated assessment of surface regularity and texture is excluded from this paper and has been presented separately [1]. This paper presents the findings on automated construction systems incorporating paver recording, intelligent compaction and temperature sensing systems. This paper provides an overview on opportunities and challenges, as well as lessons learnt from selected local and national road construction schemes in England. Although still in the early stages, the concept of integrating automated construction data into cloud-based asset management tools will be explored. It will also discuss the potential benefits associated with smart automation, predictive intelligent, real-time data exchange and 4D executions.

Three suites of technologies were considered, namely the automated APEX, PAVE-IR and Roller systems. These technologies provide continuous streams of large datasets automatically captured during the construction [2]. To assess the APEX paving record system, Roller (intelligent compaction) system and the PAVE-IR system, the information from 14 projects were reviewed as part of the study, including a mixture of local roads and strategic road network in England, as summarised in Table 1. The following sections give a brief introduction of each system and a couple of examples of the applications.

Table 1 Automated System Datasets Reviewed in the Study [3]

Sites	Paver Laying Record	Roller System	Pave-IR Scanner
M4 Junction 4	✓	✓	✓
A269 Ninfield Road	✓	✓	
A46 Hobby Horse to Widmerpool	✓		
A134 Thetford	✓	✓	
A143 Harleston	✓	✓	
A1066 Garboldisham	✓	✓	
Town Street, Upwell	✓	✓	
London Road, Thetford	✓	✓	
B1146 Quebec Road	✓	✓	
Mill Lane, Repps Road and High Road Marham	✓	✓	
Little Plumbstead, Belt Road	✓	✓	
London Road, Wymondham	✓	✓	
A76 Templetone Roundabout to Little Heath	✓	✓	

2. AUTOMATED QUALITY MONITORING SYSTEMS

2.1. Automated Laying Records

Traditional laying records is highly dependent on manual data input, which is associated with low cost efficiency and inevitably human errors. To overcome these short comings, the APEX system facilitated by use of vehicle tracking technology can automatically collect, analyse and upload data. Individual lorry locations can be tracked from weighbridge to and from the construction sites. Vehicle data and weighbridge load can be automatically uploaded through the suppliers' terminals. Figure 1 shows a screenshot of the tablet version of the APEX interface. In this example, three lorries with a load of 1 tonne each left the weighbridge at 14:26 and were in transit to the construction site. The real-time locations are shown in the map, based on which the site manager would be able to monitor the upcoming loads remotely and more efficiently.

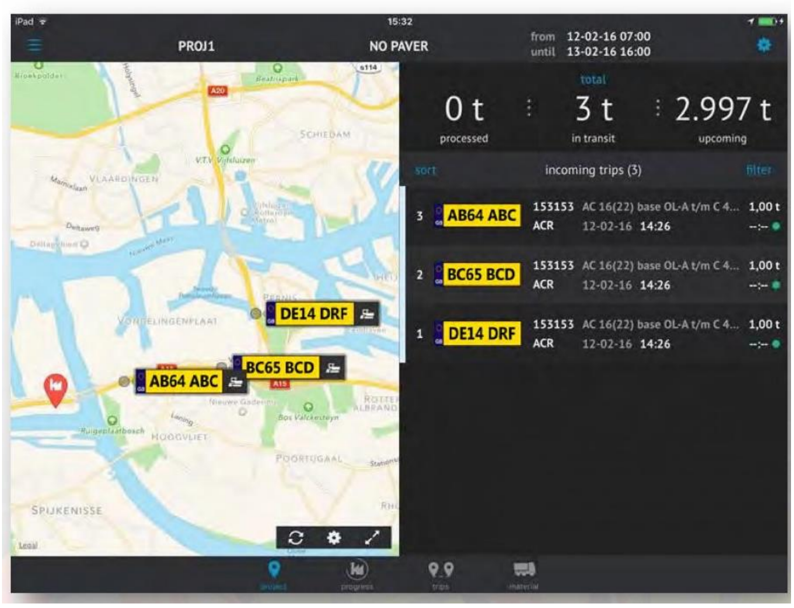

Figure 1 Screenshot of the Interface [4]

The APEX system can provide laying records in '.csv' format including paver registration, material, tonnage, load time and time at paver, GPS coordinates, material temperatures, rain/humidity, air temperatures and wind speeds. Plotting the pavers on a map using the GPS locations, it provides an intuitive map for every load of material at its destination road sections, as shown in Figure 2. The temperatures, delivery time and weather conditions can be graphically represented, as shown in Figure 3.

These types of systems provide a full record of the materials from dispatch to unload and the paving conditions. They can be used to highlight any delay in the delivery and provide real-time locations, loads and weather conditions to assist onsite planning. Overall, they optimise the efficiency of paving process.

Figure 2 Example Load Location Map

Figure 3 Example Graphs

2.2. PAVE-IR Scanner System

Temperature monitoring is essential in asphalt pavement construction because of the influence that temperatures (material, ground and air) have on the end product. This includes compaction and ride quality of the asphalt pavement.

The operation of dipping a temperature probe in the material is slow and inherently carries safety risks for operators when they work alongside construction traffic and also potentially in proximity to live traffic (depending on site specific traffic management).

Contact-free automatic tools have been developed and adopted for real-time screening, to improve construction quality and efficiency. The infrared wave detection tools provide instant temperature measurements based on material heat radiation without the need to be in contact with the material. Considering the differences in the technologies, the surface temperatures measured by infrared are likely to differ from the under-surface temperature measured by probes. Therefore, these are only indicators of the temperature and require calibration to a reference method.

The PAVE-IR scanner system consists of a set of three infrared temperature sensors including two at auger and one at hopper, a GPS locator and a weather station for wind speed, ambient temperature, air pressure and humidity and an on-board display. The data is automatically uploaded to a central server.

Report output comprises the thermal profile (Figure 4), temperature plot and paver stops graph (Figure 5) and the weather conditions. In the thermal profile, the black colour indicates a cold temperature, which could be existing pavement. The mean temperature from the three sensors is used to determine the material delivery temperature.

The temperature patterns help to identify cold spots and, therefore, have potential to be used to inform operational decisions on a) locations that need urgent compaction; b) need for cutting joint; and c) provision of feedback for continuous improvement.

It provides a continuous indicator of progress relative to temperature, such as paver stops. Combined with other information, such as the waiting time from APEX, the roller temperatures from roller systems and weather conditions, it helps to demonstrate if, where and why the cold spots have led to unfavourable outcomes, and hence, enables the operators to take positive actions to avoid cold spots and/or to mitigate the negative impact. Although the current thermal cameras on the market can provide the temperature profiles on the asphalt mat, the PAVE-IR scanner system offers the advantages of profiling the entire pavement width, collecting, displaying, saving, uploading and analysing temperature readings while in operation and providing continuous thermal profiles with integrated GPS locations and environmental conditions. Essentially, the main advantage is being an integrated system. Meanwhile, the temperatures by remote methods are only indicators of the rolling temperatures and should not be used as a compliance measure.

This information can be used in identifying cold mat areas for subsequent core density testing which would complement the current QA/QC procedure.

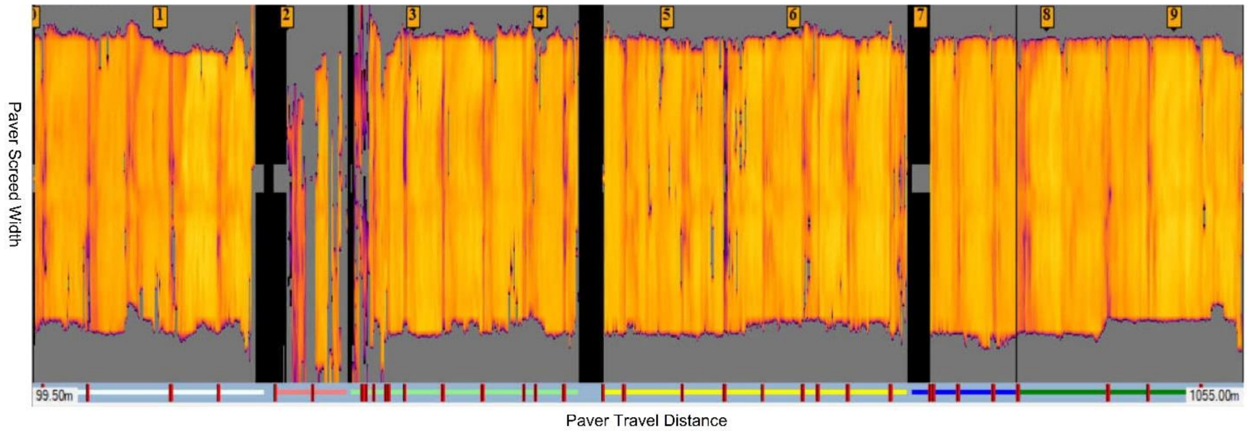

Figure 4 Thermal Profile

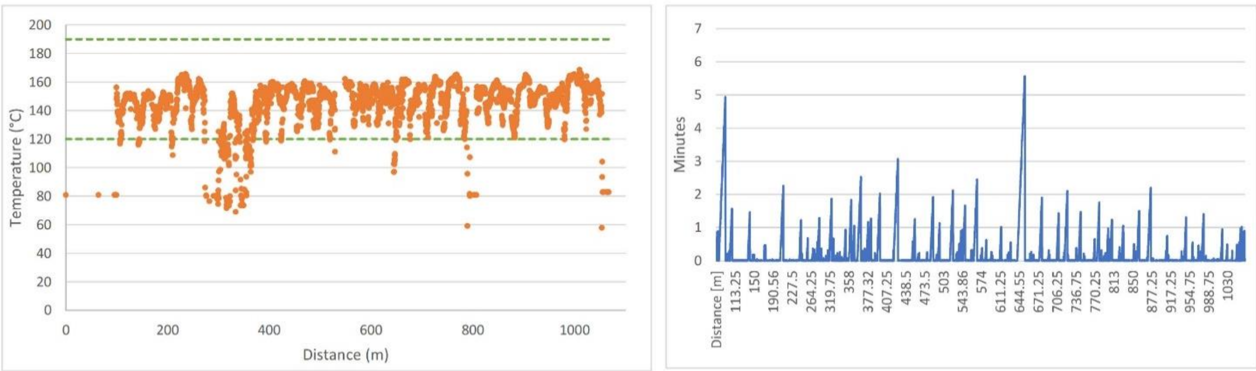

Figure 5 Temperature Plot and Paver Stops

2.3. Roller System (Intelligent Compaction System)

Originally developed in 1980s for soil and sub-base and then adapted for asphalt pavement in 1990s, the concept of Intelligent Compaction (IC) was to use rollers that can modify the compactive effort to produce asphalt pavements with the desired stiffness [6]. In theory the stiffness could be correlated to the in-situ density, providing a real-time tool for assessing compliance requirements [6]. However, the uptake of IC for real-time density measurement has been limited due to it being relatively unproven for asphalt [7]. This is because measured stiffness can be affected by temperatures, loading rates, material thickness and the stiffness of the underlying layers. Hence, any change in the measured stiffness may or may not be caused by the variation in the material density [8].

The correlation between stiffness (or similar parameters measured by IC systems) and density is still being investigated [6], however, these methods gained favour especially in the US under the regulation by AASHTO [9]. A recent investigation on suitability of IC methods for asphalt pavement QC and QA concluded that IC can improve both the compaction coverage and the compaction for quality control applications. However, no solid evidence is available to support the possibility of substituting core density values with IC for compliance [10].

Equipment developed and used worldwide typically includes a compaction measurement value, GPS-based documentation, on-board color-coded display, surface temperature measurement and automatic feedback system [6]. This enables the roller operator to track the roller passes and make adjustment to the compaction patterns [7].

The system reviewed as part of this study incorporates a GPS sensor, an infrared temperature sensor and an on-board display for roller passes and temperatures. The digital information can be automatically uploaded to a central server for real-time monitoring and for potential incorporation into the asset management systems at a later stage. The roller static passes and the maximum rolling temperature, as shown in Figure 6 and Figure 7, were extracted from an example final compaction report. The real time data collection might have been stored in the central server, although it was not presented in the report, which may highlight the cold areas in every roller passes.

This was used as a quality control measure by the Contractor on a Local Authority scheme. The asphalt surfacing requires a minimum rolling temperature of 80°C. A section of cool material, dictated by the blue and green colours, was identified by the maximum rolling temperature plot in Figure 8. Assessment of the site records confirmed the material was delayed on site and a follow-up site inspection was undertaken. The roller system contributed in the identification of non-compliances so that the defect could be proactively monitored.

In the London Road, Thetford scheme, fatty material was identified during rolling and subsequently removed. The roller system was used retrospectively to help understanding the causes and preventing it from happening again. The roller passes and temperatures from the roller system and the automated laying record proved to be helpful in the investigation.

In the A76 Templeton roundabout to Little Heath scheme, the results from the Pavement Density Measurement (PDM) testing were entered into the system and plotted on a plan to look at the corresponding temperatures and roller passes and therefore to identify causes for non-compliance results. The information was used retrospectively to help improve work quality onsite.

The above examples suggest the system helped with quality control, contributed to the risk mitigation in the lessons learnt and enabled the responsible party to take a proactive approach towards any residual risks.

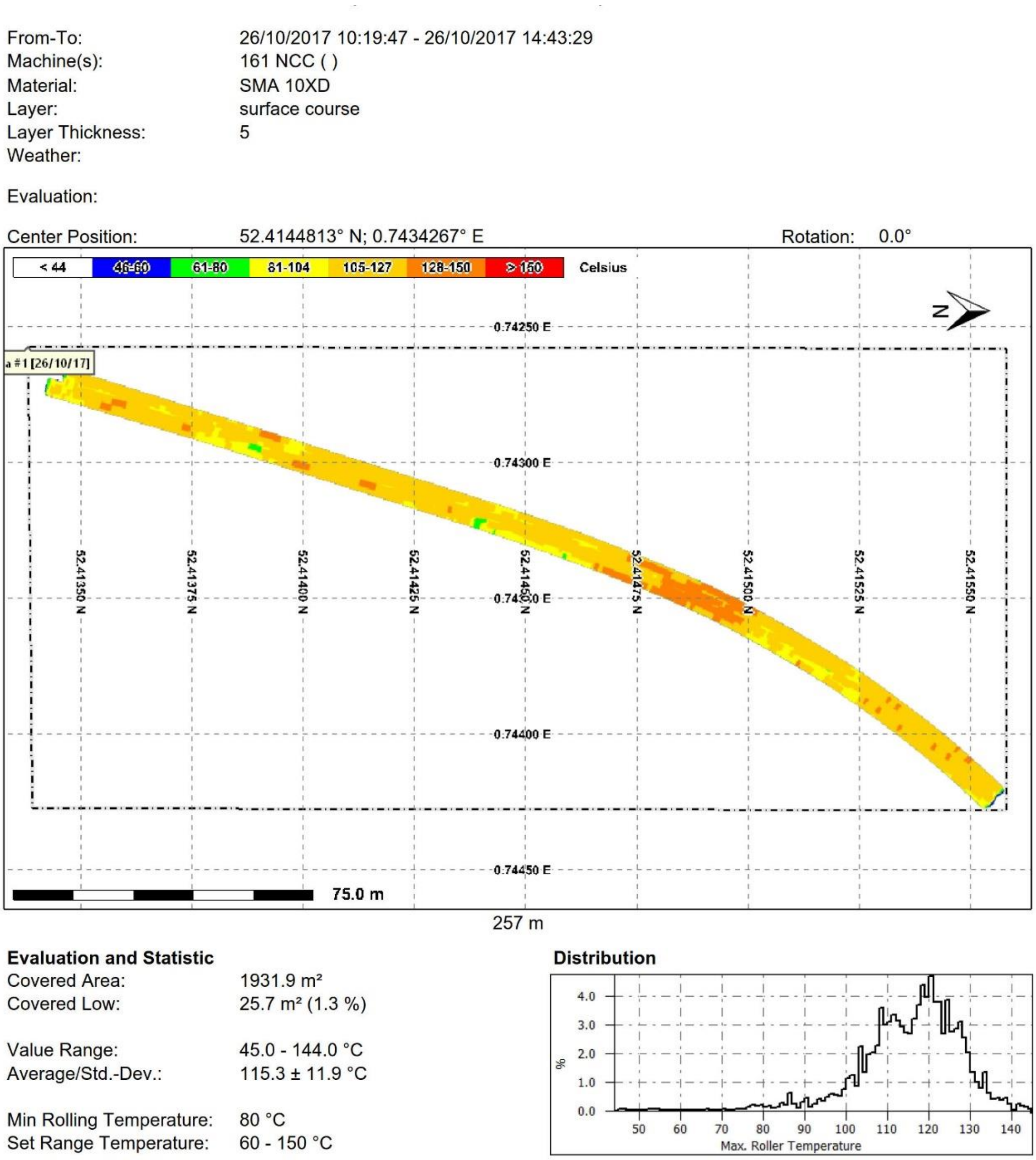

Figure 6 Maximum Roller Temperature Plot

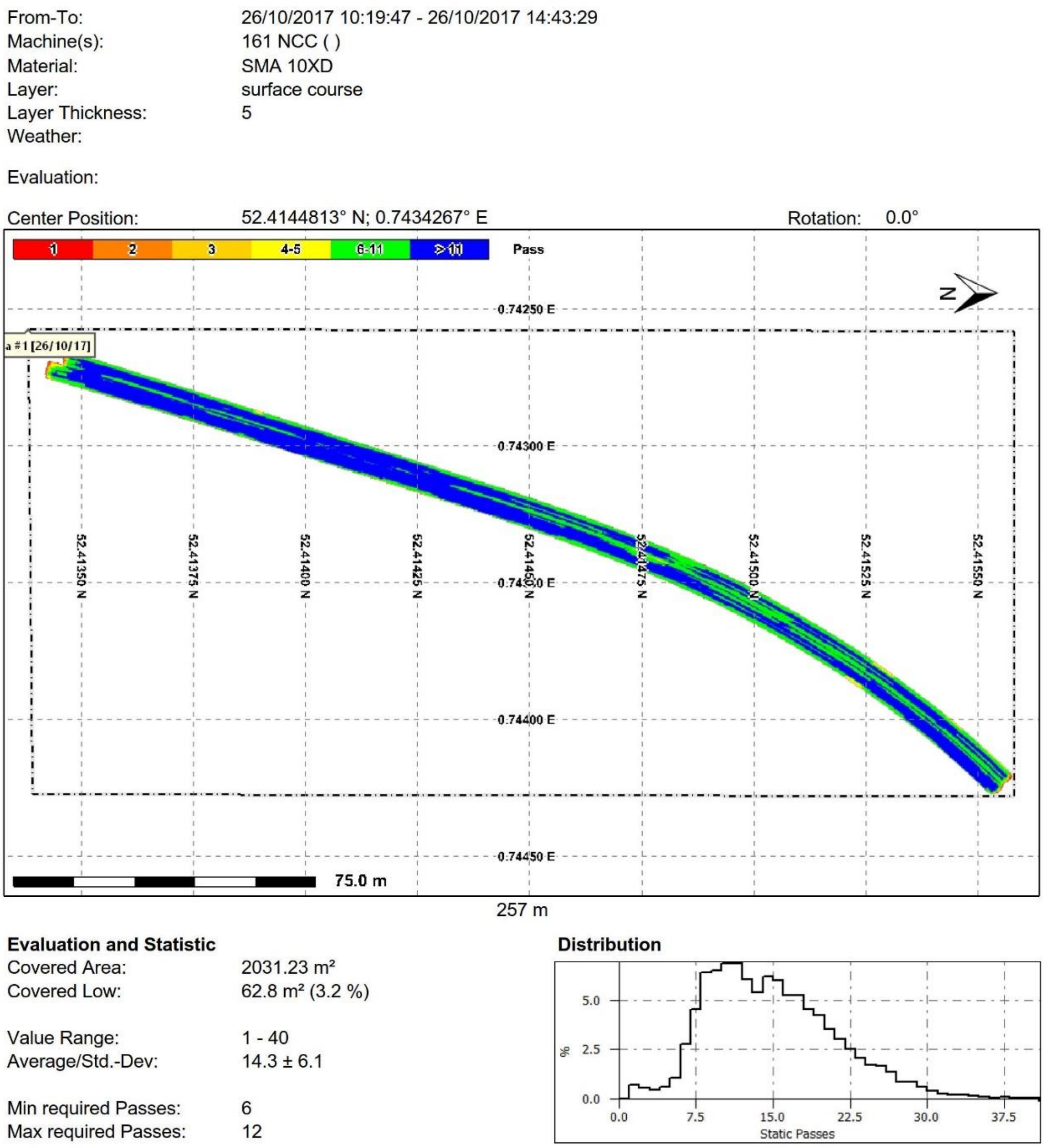

Figure 7 Roller Static Passes Plot

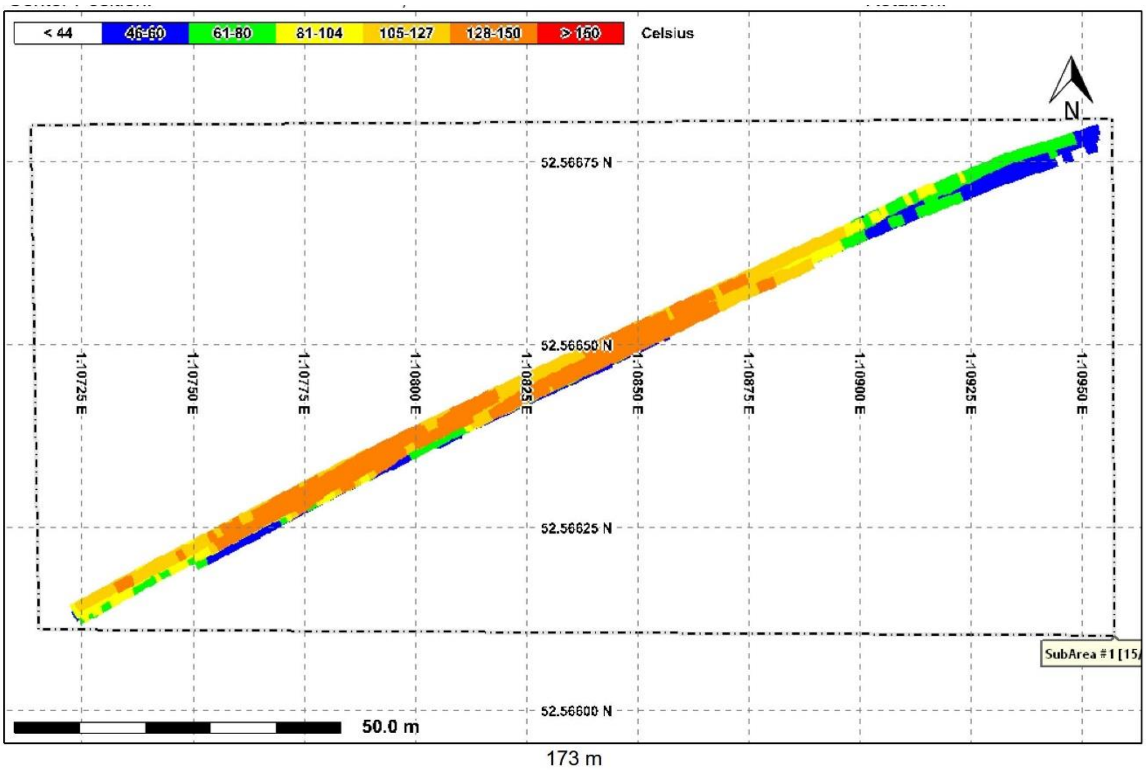

Figure 8 Cool Material highlighted in the Temperature Plot

2.4. Asset Management System (data collection at construction stage)

These automated systems can be used as quality control measures during pavement construction. Subject to further study on the correlations with the existing performance criteria, they may present themselves as quality assurance tools for compliance. Moreover, they could benefit the asset management with automated data collection, recording and uploading. The automated data collection provides highly accurate and comprehensive data with minimal post-processing. On the contrary, manual data collection would require considerably more time and cost in walking / windshield surveys, manual recording, back-tracking the construction information and manual inputting onto the asset management platform. Plus, the manual data collection bears a greater chance for human errors.

The automated datasets, such as roller passes, can be integrated with an established asset management interface. As shown in Figure 9, the colour-coded roller passes in dots are overlaid on an intuitive road map from a typical asset management interface [5]. The study is at an early stage. To materialise an integrated asset management system with the automated construction data, it is essential to understand two questions as follows:

- To what level of detail would it be practical and beneficial for asset management, considering the large datasets?
- How to manage and make most of the datasets?

These are areas for further consideration.

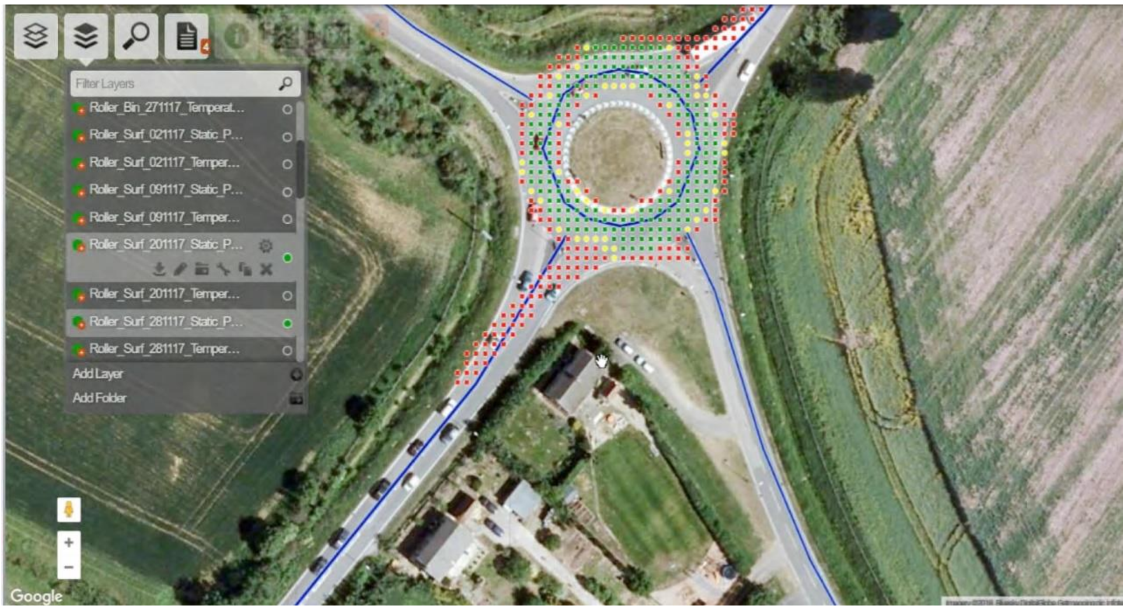

Figure 9 Roller Passes Displayed using the Asset Management Interface [3]

3. CONCLUSIONS

The study provides an overview on the benefits, challenges and lessons learnt from experimenting automated construction systems on selected local and national road construction schemes in England. Due to the limited datasets and experience with the automated systems, further work is required to develop the technologies and materialise the integration of these new technologies into the industry. The table below summarizes the advantages and disadvantages of individual system.

Table 2 Summary of Individual Systems

Systems	Automated Laying Records	Roller System	Pave-IR Scanner
Advantages	- Auto data collection from weighbridge to and from site - Real-time remote monitoring - Optimise the efficiency of paving process	- Intuitive GPS-based colour-coded mapping of temperature and roller passes - Comprehensive datasets for quality control	- Efficient and safe comparing to a temperature probe - Comprehensive datasets
Disadvantages	- More benefits for large scale of works	- No established correlation with density and air voids - Not ready for QA purpose.	- Only measure surface temperature - Not for compliance checking - Require calibration to a reference method

The automated systems provide continuous large datasets from the automated data recording during construction, which is likely to be more efficient and accurate than manual recording. The real-time monitoring can provide access to the information for suppliers, laying teams and project managers, which could help to inform operational decisions. The comprehensive information can also assist in procedures managing quality. However, this is dependent on how the datasets are used.

Meanwhile, these systems do not currently collect certain asset data, such as cover locations and utilities. This is considered of more importance on local roads than strategic networks. Considering the nature and scale of the works, the systems are considered more suitable and beneficial for large scale works, but less so for local repairs, such as trench repairs and pothole reinstatements. The correlation between the compaction passes and the current performance criteria, such as density and air voids, is dependent on more variables. The temperatures by remote methods are only indicators of the rolling temperatures and still requires calibration with a referencing temperature probe. The automated systems use GPS coordinates whilst most traditional tests/records tend to use local chainages and OS grid references. Since the automated systems will not replace the traditional methods completely in the short term, cross-referenced locations would help in the data interpretation and correlation. Training is required to analyse and assess the output information. Considering the amount of data produced, a protocol for standardised data exchange would be useful to keep data manageable and consistent between projects.

Above all, the automated systems enhance data recording and management, can help to inform operational decisions and assist with investigations and prevention. They may be considered suitable as quality control measures to support existing performance tests. However, they have limited application unless reliable correlation with performance parameter can be identified. Overall, the automated systems are not considered technology ready for compliance purposes.

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