ASPHALT QUALITY PARAMETERS TRACABILITY USING ELECTRONIC TAGS AND GPS

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ABSTRACT: This paper begins by introducing the developmental work carried out within the scope of the OSYRIS project, in the aim of proposing a new IT infrastructure for road-building sites and by drawing attention to the need for an electronic connection between paving operations and the asphalt mixing plant. The set of system specifications required to satisfy this connection is then given, along with a state-of-the-art survey. The central section of the paper presents the proposed solution, which is based on both electronic tagging of the trucks hauling asphalt and a GPS positioning of the asphalt pavers. The first experiment conducted in 2001 is also described and the paper closes with concluding observations and an outlook.

KEYWORDS: information and communication technologies, asphalt fabrication and laying, tracability, electronic tagging, GPS, quality control.

1 INTRODUCTION

Recent research initiatives, such as the European project OSYRIS, have been proposing new IT infrastructure in support of asphalt laying and compacting operations. OSYRIS focuses on the laying and compacting tasks but does not directly address the asphalt fabrication operation, which proves to be of greatest importance since this operation serves to set the quality of the asphalt material that will constitute the pavement.

Some quality assurance procedures have already been introduced to monitor and assess material quality at the plant, yet no direct connection between fabrication and paving operations has been established, hence no direct use can be made of quality assessment at the plant during paving and compaction processes. The aim of the present research is to create an electronic link in order to fill a major void in the sequence of electronic monitoring procedures for road asphalt sites.

2 THE OSYRIS PROJECT

2.1 Key Issues And Philosophy

OSYRIS ("Open System for Road Information Support") is a European Union-funded project devoted to developing information infrastructure for road construction and maintenance processes [1].
It is intended to enable both contractors and road owners to generate their own knowledge bases and quality assurance systems, which are now expected of them given that access to critical information in real time is one of the key challenges facing the new century.

The OSYRIS philosophy lies in building openness and modularity into a system through use of compliant components. OSYRIS data storage and management is based on a product model of the road specially designed to be: compatible with the latest road management databases, object-oriented, and located within a 3D geographical reference.

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The OSYRIS project was launched in February 2000 and will last until the beginning of 2003. The Consortium partners consist of: the University of Karlsruhe (IMB) - Germany; LCPC - France; Moba - Germany; Tekla Corp. - Finland; and Skanska - Sweden. The project is funded under the European Union Program “Growth” (Contract No.: G1RD-CT1999-00080).

2.2 Expected outputs

Four following commercial OSYRIS products have been foreseen:

- *OSYRIS Standards*: a set of several pre-standards describing the format and contents of information exchanges taking place between OSYRIS components,
- *OSYRIS Machine*: a set of on-machine components developed to fulfil a contractor's basic needs in supporting paving and asphalt compaction work, for a typical asphalt-laying set-up of 1 paver and 2 rollers,
- *OSYRIS Machine Extensions*: a set of options to extend the basic *OSYRIS Machine* configuration,
- *OSYRIS Design and Documentation*: consists of a line of software for the planning, analysis, documentation and long-term storage of roadwork parameters. These products are intended primarily for consultants and road owners.

3 SPECIFICATIONS OF THE MATERIAL TRACABILITY SYSTEM

3.1 The Quality Control Chain

Generally speaking, material tracability is to be performed through eight main phases, as follows:

1. Supply of components (aggregates, binders, etc.) to the asphalt plant
2. Storage of components in piles or tanks
3. Transfer of components from storage devices to the mixing equipment
4. Fabrication, consisting of component grading and mixing, and constitution of material batches
5. Output of material batches from the plant
6. Reception of batches at the asphalt-laying site
7. Laying of the material
8. Compaction of the material.

This quality control chain contains a major natural discontinuity: the transport and delivery of materials from the plant to the construction site, between phases 5 and 6. This discontinuity often accounts for lost quantitative and qualitative information and, in some instances, delivery location errors occur. Consequently, it was decided that he system should be capable of:

- automatically collecting the most relevant fabrication-related information from the plant's existing monitoring and quality control systems for each batch of material;
- automatically downloading this information into a tag mounted on the truck headed for the paving site, along with the batch of material;
- automatically transferring this information once on site to the paver information system for use with respect to execution and documentation purposes;
- automatically locating and dating the information along the road at the particular place where the corresponding material has been laid.

4 DESCRIPTION OF THE PROTOTYPE SOLUTION

4.1 The Concept

The solution we have chosen is based on the two following technologies:

- "Radio Frequency Information Data" (RFID), for storing the data into electronic tags; and
- "Global Positioning System" (GPS), for positioning the material parameters with respect to the road-building project.

The data related to a batch of material are extracted and transferred to the tag from both the quality-monitoring computer (responsible for recording the quality parameters from the plant's main control computer) and the weighing table computer that measures the load of each truck as it leaves the plant. The transfer is performed through an interfacing box (called "i-box") connected to an antenna.

Data are conveyed to the site by the tag; while the truck is loading asphalt into the paver hopper, the data are downloaded into the OSYRIS paver's computer by a similar transmission chain working in the opposite direction.

Figure 1 shows the physical structure and data flow of the system.

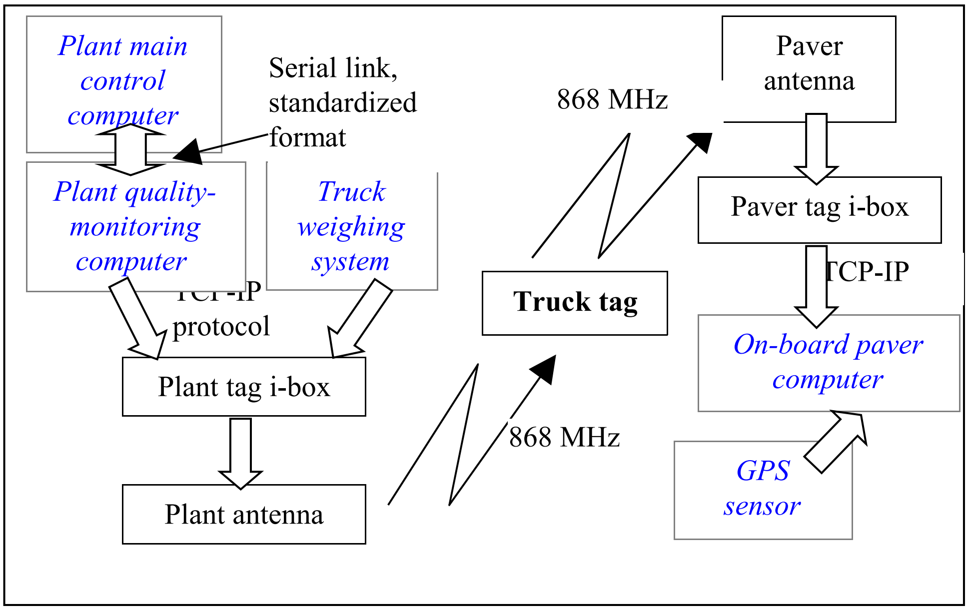

Figure 1: General structure and data flows of the system

For purposes of the feasibility experiment and due to the unavailability of the OSYRIS on-board computer and GPS receiver, SEMR and LCPC used a dedicated computer along with a GPS specific sensor. A customized software program has also been written for this demonstration.

4.2 Electronic Tagging System

The device chosen was "Flex ID", marketed by the German company DEISTER [2]. The main features of this system are as follows:

- transmission frequency: 868 MHz,
- tag dimensions: 15 cm x 3 cm x 2 cm,
- maximum number of antennae per i-box: 4,
- storage capacity of tags: 8 to 32 Kbytes,
- maximum read/write distance: nominal: 30 m; effective: 15 m,
- possible links between i-box and tag: TCP/IP, RS232 or RS485.

Figure 2 shows the tags and the antenna.

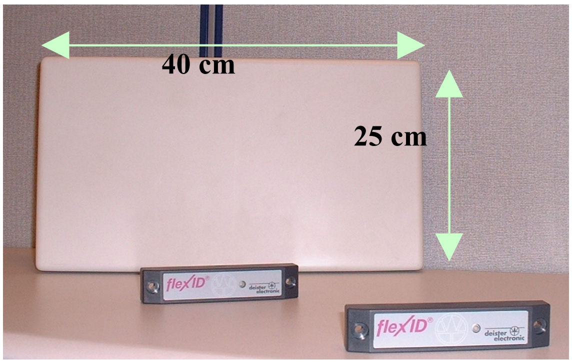

Figure 2: The Flex ID antenna and two of the tags

4.3 GPS Positioning

A stand-alone GPS is capable of providing 2D accuracy of approximately 3 to 5 meters since the Selective Availability (SA) feature was switched off by the USA in May 2000. This accuracy is not good enough for our needs, as we require being able to distinguish between the various lanes of a road.

For this reason, the GPS sensor we selected is an integrated DGPS sensor manufactured by the OMNISTAR Company; it is composed of an 8-channel Trimble receiver, a GPS antenna and a communications satellite antenna, to receive the differential GPS corrections, all embedded into the same housing.

4.4 On-board computer and software

For the feasibility study, a software program was developed to manage and display data collected from the paver's on-board tag as well as to perform a number of intermediate computations.

Although this software has been run during the evaluation experiment described below, it is not yet refined to a point of being proposed as an industrial product. In the near future, the functions proposed by this software will also be partially provided by the OSYRIS on-board computer. Nonetheless, a dedicated system focusing on the tracability between plant and paving site has also been foreseen as a separate development.

5 INITIAL EXPERIMENT

5.1 Description

In November 2001, in cooperation with the DDE 77[1] offices, an initial experimental site was set up in order to demonstrate and validate this concept. For the experiment, we designed and built a prototype system around two distinct goals: quality documentation and operator assistance. This paper will focus primarily on operator assistance aspects, which may prove more illustrative and offer the advantage of introducing the system from a more attractive perspective for contractors.

The site consisted of a thin asphalt wearing course for a new road, located in the town of Bray-sur-Seine some 60 km southeast of Paris. A two-lane course of approximately 600 m x 6.2 m was built during the first day, and a traffic circle plus the adjoining access roads were built during the second day.

At the plant, due to the absence of a standard plug for connecting a quality-monitoring computer, we had to manually enter the data read on the plant control dashboard into a laptop computer and then transfer them into the electronic tag through the i-box.

All of the trucks involved in the experiment, five the first day and five the second, were equipped with an electronic tag screwed onto the right side panel, as seen in Figure 3.

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[1] *DDE 77 stands for "Direction Départementale de l'Equipement" (Regional Bureau of the Ministry of Construction and Public Works) for French Department No. 77 and is in charge of building and maintaining the department's public roads.*

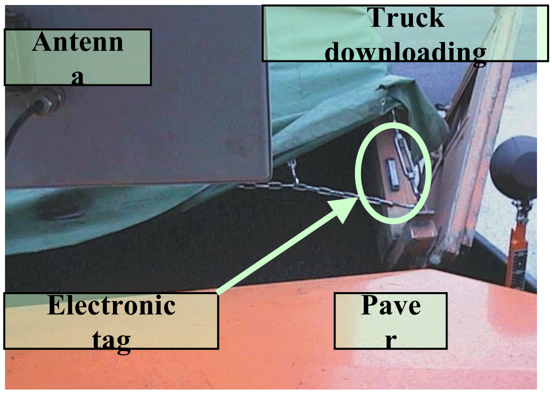

Figure 3: The tag screwed onto the truck side panel

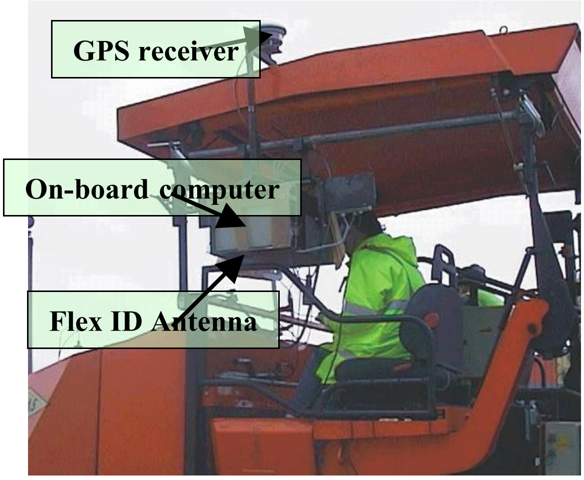

Figure 4: The paver on-board computer and GPS antenna

An i-box and antenna, placed in a suitable location for reading tags while the truck was downloading its material, were installed on the paver, as shown in Figure 4. In addition, an ultrasonic sensor was used both to detect the amount of material in the paver hopper and to validate completion of the downloading step. Figure 4 shows the on-board computer mounted on the side of the paver along with the OMNISTAR GPS receiver used.

5.2 Data recorded and displayed

The following data were selected to be recorded.

<u>Quality parameters, from the plant computers:</u>
- theoretical proportion of each component (in percent), - theoretical asphalt fabrication rate of the plant (in tons/hour), - bitumen temperature, upon introduction into the mixing tube (in °C), - asphalt temperature, when loaded into the trucks (in °C) (1), - precise bitumen weight for each batch (in kg).

<u>Quantity parameters, from the weighing station:</u>
- weight of the material batch for each truck (in tons) (2),(weight of the empty truck (in tons).

<u>Miscellaneous identification parameters:</u>
- identification of the work site, - identification of the type of mix design, - batch number, - identification number of the tag or truck (3), - starting and ending times of batch fabrication, - truck weighing time (4), - plane coordinates (using the national "Lambert" reference projection system) of the starting and ending points of the surface area covered by the batch, together with the application time, both provided by the GPS receiver.

In addition to parameters quoted (1) to (4), were displayed the following parameters, after computation by the on-board software:
- actual mass production rate of asphalt, using batch weight and fabrication time (5), - actual bitumen mass proportion for the material batch, using batch weight and bitumen weight (6), - average mass paving rate of the asphalt, computed from the batch weight and batch downloading time provided by the GPS receiver (7), - paving process output: ratio of paving rate to production rate (8), - exact average speed of the paver, thanks to GPS timing (9), - suggested correct speed of the paver, in order to increase output as much as possible (10), - average asphalt weight per unit area, using (9) and (10) and a theoretical width (11), - total cumulative asphalt weight (12), - total cumulative corresponding paving length (13), - estimated post-compaction thickness (14), using (13) and the theoretical specific mass of the compacted material (15).
Numbers 1-6 are related to fabrication, and 7-15 to the asphalt-laying operation.

5.3 Sample system output for tracability purposes

Figures 5 and 6 show examples of simple graphical outputs that may be of direct interest to the project manager or architect/engineer for checking the quality of the work.

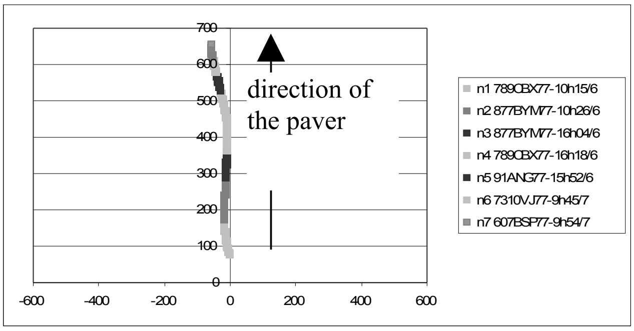

Figure 5: Location of the various batches along the road (straight line)

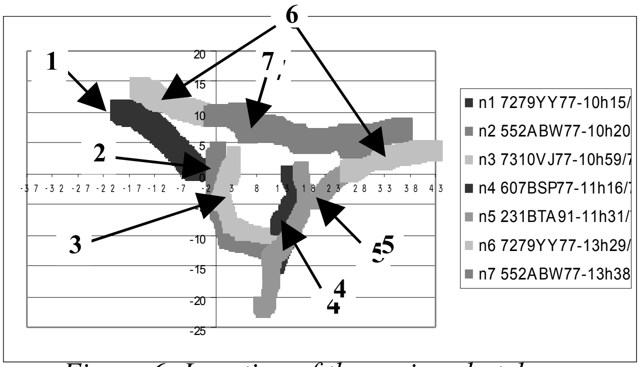

Figure 6: Location of the various batches along the road (roundabout)

Trucks are numbered in the chronological order. The scales used for both the *x*- and *y*-axes are in meters. This graphical display clearly provides valuable information on the way in which the site has been executed. For instance, it can be observed on Figure 5 that batch no. 5 was laid after batch no. 4, even though it had been loaded first at the plant. Given the availability of such output, we are convinced of site managers' and supervisors' ability to check very rapidly that site operations are running smoothly since any disturbance (e.g. abnormal delays between batches) can be detected quite easily. Figure 6 clearly illustrates the positioning accuracy obtained by GPS from traces recorded in the traffic circle, whose radius was about 10 m.

6 CONCLUSION AND OUTLOOK

This first site validated the satisfactory behavior of information transmission by means of RFID tags, which represented a novel technology for us, in contrast with the rather well-known GPS technology.

Despite the quality of results, this experiment was carried out in a semi-automatic mode and this created some problems at the site level by virtue of interfering with the execution and disturbing the process it is supposed to trace. It seems obvious that total process automation is necessary in order to attain the high level of reliability expected of the system.

In 2002, prototype improvements are foreseen to conduct further experimentation, in the aim of introducing a completely automatic mode of operations. These improvements will mainly concern software aspects. The new experimental site is scheduled to be operational by the end of the year: it will be a highway site, where we intend to trace all of the successive pavement layers.

7 REFERENCES

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