

AGATA CZARNIGOWSKA\*, ZBIGNIEW TOKARSKI\*\*

## ASPHALT-AGGREGATE MIX HANDLING PROCESS OF POROUS PAVEMENT REHABILITATION PROJECT

---

### ANALIZA PROCESU DOSTAW MIESZANKI MINERALNO- -ASFALTOWEJ PRZY REKONSTRUKCJI NAWIERZCHNI Z ASFALTU POROWATEGO

#### Abstract

The paper presents a case study of an innovative method of porous pavement rehabilitation works. The innovation consists in applying an additional piece of plant to collect the supplied asphalt-aggregate mix and feed it pavers. Observations and measurements of construction process output collected during an A73 highway rehabilitation project in the Netherlands can be used for creation of asphalt-aggregate mix supply models and comparing efficiency of using certain plant sets.

*Keywords: pavement rehabilitation, porous asphalt, highway, process innovation*

#### Streszczenie

Artykuł prezentuje zastosowanie innowacyjnej metody organizacji robót przy wymianie warstwy ścieralnej nawierzchni autostrady z asfaltu porowatego. Innowacyjność rozwiązania polega na zastosowaniu dodatkowych podajników mieszanki mineralno-asfaltowej. Przedstawiono wyniki obserwacji i pomiarów dokonanych w czasie robót na autostradzie A73 w Holandii. Wyniki pomiarów mogą posłużyć do budowy modelu dostaw mieszanki i porównań efektywności stosowania różnych zestawów maszyn.

*Słowa kluczowe: rehabilitacja nawierzchni, asfalt porowaty, autostrada, innowacja procesowa*

---

\* Ph.D. Eng. Agata Czarnigowska, The Faculty of Civil Engineering and Architecture, Lublin University of Technology.

\*\* Ph.D. Eng. Zbigniew Tokarski, Faculty of Civil and Environmental Engineering and Architecture, University of Technology and Life Sciences in Bydgoszcz.

## 1. Introduction

The European road transport infrastructure is currently in the state of rapid development (as in Poland and other “new” EU members) or rehabilitation and reconstruction. Polish highways are predominantly constructed using well established methods and materials. The works are conducted by means of traditional methods with typical plant sets of trucks and pavers, and traditional approach to work organization and logistics. However, new materials are being developed and more economical structures are being tested. Soon there will be a need for designing efficient construction processes (and selecting plant sets) related with application of these new materials. Observing the Polish highway construction sites one may have an impression that while the pavers are usually modern and cutting-edge technology, the means of transport tend to be time-worn and thus more prone to failure. This however changes as contractors replace their fleets in answer to recent high demand for their services. Modern plant is but a part of a project success. This was demonstrated by some spectacular failures in terms of project management, knowledge, and experience.

Polish highways are quite new, but massive rehabilitation works will have to be conducted sooner or later, and to assure their smooth execution, work planning should be based on real-life data. These may be gathered by observing works conducted in other countries. The Netherlands are one of the Europe’s leaders in all aspects of road infrastructure planning, construction and maintenance innovation [2, 6]. The Netherlands’ subsoil conditions are particularly unfavorable, and the lack of natural aggregates implies that construction material reclamation stays the focus of each project [13]. This is one of the “natural” causes of searching for new efficient materials and techniques. Moreover, the Dutch highways are already “mature” structures, and their wearing courses reach now the end of service and need to be replaced. Thus, the rehabilitation projects (using modern materials and plant) are run on a large scale. The experience of Dutch contractors, and their willingness to share it [14], was the basis of this paper.

## 2. Sustainable development in road construction

A road’s lifecycle comprises four basic phases: programming and design, construction, operation and maintenance, and decommissioning. A project’s objective function is, naturally, case-specific. Traditionally, it is minimizing construction time span (so reducing construction-related inconvenience to the public and improving the picture of public sector efficiency – important for political reasons), minimizing cost (so lowest bid procurement), and maximizing durability of the delivered infrastructure (so preference for proven, usually raw material-intensive solutions); whereas the product stays fit for purpose. Nevertheless, there are other objectives whose growing importance is reflected in the development in EU policies [9]. These are minimizing impact on the broadly understood environment, improving user safety, and reducing life cycle costs. These aims cannot be reached without careful planning in the initial stages of project preparation [6]. The need to turn to the sustainable development works its way to Polish road infrastructure. Utilization of reclaimed material and waste is being investigated into and more and more often reaches prototype stage [12], and public clients invest in research and development projects. One of the main aims is

to provide the society with low-energy-consuming, pollutant emission-free, safe, durable and affordable pavements. It becomes important that they could be obtainable with less non-renewable resources. Thus, living conditions and resource-use meets current needs without undermining the sustainability of natural systems and the environment, so that future generations may also have their needs met – which is the underlying idea of sustainable development [4].

### 3. Porous asphalt

Porous asphalt is one of the relatively recent and promising inventions in the field of pavement materials. According to PN-EN 13108-7 standard [11], it is defined as a mineral-asphalt mixture designed in a way that provides large content of interconnected voids that allow for air and water flow through the material. To improve mechanical properties of the material, small quantities of organic or inorganic fibers can be added to the mix. The porous asphalt's origins are in nineteen-seventies in the USA. As the tests on trial sections were promising, the technology has spread throughout most European countries and Japan [10]. Porous asphalt seems to answer the requirements for a perfect wearing course – with a high content of coarse-grain fraction the structure does not deform under traffic loads, and the surface is rough, which improves safety. Due to rainwater being quickly removed from the surface, there is no aquaplaning, and glare in the nighttime is reduced. Also the traffic noise-reduction qualities cause growing interest in this type of wearing courses (e.g. [1, 5, 16]. Figure 1 compares the sound absorption properties of porous pavements of varying void content, illustrating to what extent the mix design can affect noise properties.

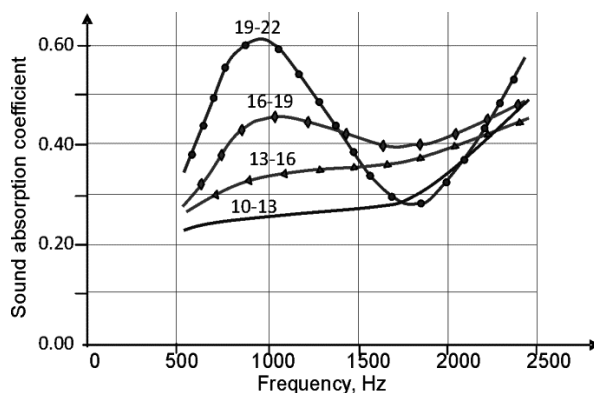


Fig. 1. Efficiency of sound absorption vs. sound frequency according to void contents in porous asphalt pavements. Based on [16]

The material cannot be designed without careful consideration of local conditions, so there is no possibility of a direct country-to-country transfer of experiences [8]. The Polish research community interest in this technology dates to early nineteen-nineties and is growing – in terms of material science [12] and construction methods [15]). There exist related standards

[11] and recommendations [17], but practical applications are still limited to trial sections [7]. It is to be expected that a material with a large content of open pores is potentially more vulnerable to environmental and traffic loads, and its service life can be shorter than that of traditional materials. The condition of the wearing course of porous asphalt deteriorates over time, so the noise absorption and other advantages of the material may be lost. The long-term impact of high and low temperatures, clogging with dust and traffic-related abrasion on the properties of porous asphalt structure are being vigorously investigated all over the world (e.g. [1, 3, 5]) to verify the rather optimistic observations of its long service life. The reasonable service life of a wearing course is understood as the period of service life with the qualities of the surface staying on the declared level. Draining properties of porous asphalt are measured by coefficients of horizontal and vertical permeability ( $K_h, K_v$ ) and are defined by requirements towards voids content ( $V_{min}$  and  $V_{max}$ ) related with aggregate gradation. Water sensitivity is related with the category of indirect tensile stress ratio (ITSR). To determine the condition of the wearing course one measures particle loss (PL). As the wearing course loses its properties, it needs to be replaced.

#### 4. Case study: Rehabilitation of A73 highway section in the Netherlands

##### 4.1. Project background

The surface of A73 highway section being the object of the analysis was completed in 1997, and by 2013 it was subject only to routine and preventive maintenance, with local repairs of the wearing course. The structural design (Fig. 2) was based on Dutch standards on semi-rigid and rigid pavements. The road section is shown in Fig. 3.

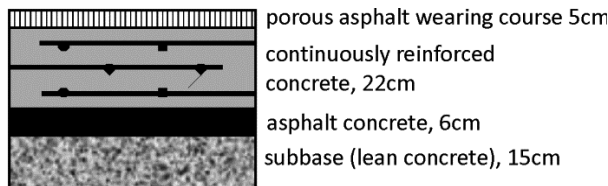


Fig. 2. Structure of the A73 highway pavement

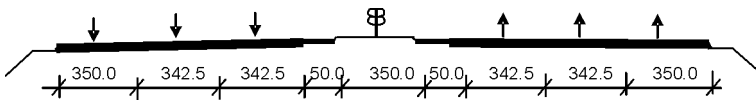


Fig. 3. Cross-section of the A73 highway

The continuously reinforced concrete layer of the A73 lanes was constructed in 1993-1997. The longitudinal joints were executed as the concrete was placed and floated. Fig. 4a and Fig. 4b present the type of machinery used in this process: a portable concrete batching plant MOB 60 and concrete paver CAT SF350.

The original porous asphalt overlay was placed in a traditional way, by means of a machine set composed of one/three pavers served by trucks. Fig. 5 presents the works.

In September 2013, the wearing course had to be replaced in the A73 section between the towns of Venray and Venlo (Fig. 6). The traffic was completely closed in one carriageway of the whole section. However, the time window allowed for the works was between Friday, 8:00 p.m. and Monday, 6:00 a.m. (on weekends the traffic is considerably lower as no freight vehicles are allowed to travel; and car detours are easier to plan). Therefore, one of the objectives was to complete the works as soon as possible. To speed up the works, an innovative method was used: the pavers were equipped with additional feeders with receiving hoppers able to hold 10 Mg of the mix. The feeders were intended to make mix unloading easier and to protect the workflow from disruption caused by material delivery delays. This way, the pavement quality standards are easier to be met, and the environment is less affected by the construction-related emissions. Fig. 7 presents the machine set used on site.

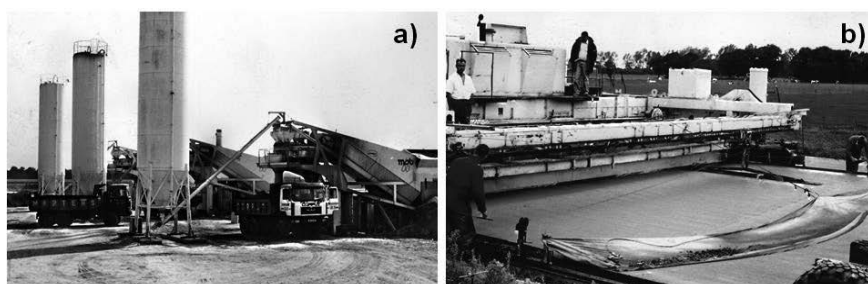


Fig. 4. Construction of concrete layer (1997): a) concrete batching plant, b) placing concrete (source: Z. Tokarski)

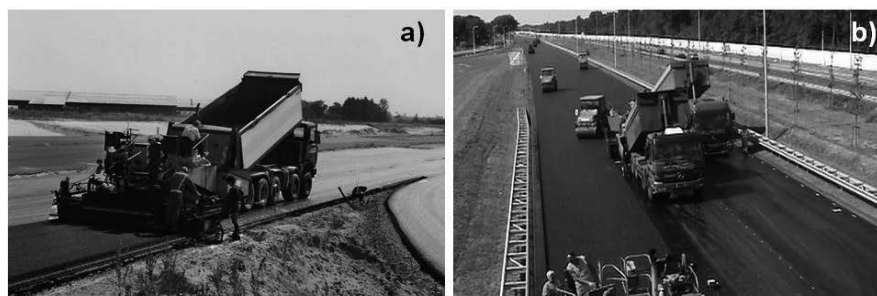


Fig. 5. Placing the original porous asphalt course (1997): a) one paver, b) three paver set (source: Z. Tokarski)

#### 4.2. Rehabilitation works and on-site observations

The rehabilitation works in 2013 were planned with the assumption of continuity of works – and continuity of supplying the site with the mix. Therefore, the plant sets had to

be selected with the utmost care. Actual quantity of material delivered by the trucks was determined at the asphalt batching plant on the basis of the plant's scales readings. The results (selected), together with average values and sample standard deviations are presented in Table 1, according to the type of truck. The analysed works were supplied by means of 4-, 5- and 6-axle dump trucks. Trucks of the same axle number were equipped with the same capacity of the box. Actual unloading rates of the trucks supplying the MT-3000-2 Vögele mix feeders are presented in Table 2 (selected measurements).

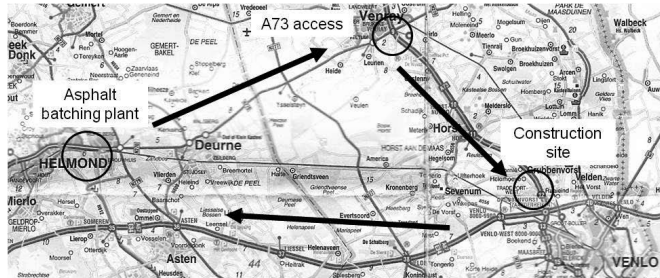


Fig. 6. Location of the works (2013)



Fig. 7. Resurfacing: machine set of paver, feeder and truck at work (2013) (source: Z. Tokarski)

Table 1

**Quantity of asphalt mix loaded on consecutive trucks of each size**

No.	Mix quantity on truck, kg		
	6-axial	5-axial	4-axial
1.	32700	28380	25680
2.	33260	29880	25280
3.	33680	28340	25460
4.	32180	29120	25240
5.	33020	30080	25660
6.	33720	29680	22040
...	...	...	...
Average	32638	29341	24198
Std. dev. (sample)	1458	692	1776

**Truck unloading rates**

No.	Arrival	Departure	Axle number	Truck ID	Mix quantity, Mg	Unloading rate, Mg/min
1.	11:59:00	12:03:35	5	BL-RJ-84	28.320	6.179
2.	12:13:50	12:18:26	5	BX-RR-66	29.120	6.330
3.	12:44:20	12:48:40	5	BV-HB-54	30.060	6.937
4.	12:50:30	12:54:12	6	BL-ZX-41	29.940	8.092
5.	13:09:43	13:13:15	6	BS-NF-85	31.560	8.932
6.	13:13:46	13:17:45	5	BS-XZ-20	30.160	7.571
7.	13:23:00	13:27:00	5	BR-SZ-39	29.880	7.470

Measurements taken on site by courtesy of the contractor allowed the authors to assess the actual average capacities of the plant and their distribution parameters, so to collect input for constructing models of construction processes planned in the future. The data were collected with the aim of comparing them with measurements taken during other projects with different work organization and different plant. Having recorded e.g. the unloading time, one can calculate the rate of feeding the mix from the feeder to the paver or assess the scale of advantage on using feeders. There are a relationship between the quantity of transported mix, unloading time and feeder output. 6-axle trucks are naturally most productive, but due to their size their maneuvering time is longer, and so is their work cycle – only on-site measurements allow the planners to assess consequences of selecting trucks of certain sizes. The measurements in the asphalt batching plant provide data for estimating material flow to the construction site even if truck sizes are various, and arrivals sequence is random. The truck-by-truck measurements help determine distribution parameters of time and output of particular operations, and frequencies and scale of disturbances. With such input, models of construction processes can be more accurate, which is important in planning projects with extremely short time spans and usually high contract penalties.

## 5. Conclusions and further research

The conclusions from the observation of the works and on-site measurement is that one of the key success factor of high-speed repaving works is controlling the supplies. Discontinuity of supplies causes work stoppage, and this affects quality of the product. The decision variables (such as truck capacities and number, mix placing methods) and independent variables are numerous and subject to uncertainty. On-site measurements provide input for planning future works. They are the basis for decision on selecting most suitable plant sets to reduce idle time at reasonable work stoppage risk: in the presented project, the contractor decided to use additional feeders, not necessary from the point of the effect of the works, and related with additional cost – to assure that the pavers receive the mix continuously, and to speed up truck unloading process. Future work is aimed as using the data for constructing queuing models and simulation models considering the progress of the works and changing distance between the batching plant and the construction site.

## References

- [1] Beckenbauer T., Weissenberger W., Kuehne R., Attenberger, A., *Langezeiterfahrungen mit Zweischichtigem Offenporigem Asphalt in Inneroertlicher Situation*, Larmbekämpfung, 3 (6), 2008, 252-260.
- [2] Caeterling J.S. et.al., *Technology development projects in road infrastructure: The relevance of government championing behaviour*, Technovation, 31/2012, 270-283.
- [3] Huuman M., Mo L., Woldekidan M.F., *Porous asphalt raveling in cold weather conditions*, International Journal of Pavement Research and Technology, 3/2010, 110-118.
- [4] Kapliński O. (red). *Metody i modele badań w inżynierii przedsięwzięć budowlanych*, PAN, Warszawa 2007.
- [5] Kowalski K.J., Król J., Radziszewski P., Otkalło K., *Projektowanie i badania mieszanek mineralno-asfaltowych o strukturze otwartej*. Drogownictwo, 5/2013, 156-158.
- [6] Lenferink S, Tillma T., *The potential of a life-cycle approach for improving road infrastructure planning in the Netherlands*, Bijdrage aan het Colloquium Vervoersplanologisch Speurwerk, Santpoort, 20–21 November 2008.
- [7] Otkalło K., Kowalski K.J., Piłat J., *Wykonanie odcinka prototypowego projektu CiDRO*, Drogownictwo, 6/2013, 174-176.
- [8] Ostrowski P., Boratyński J., Gorol J., *Znaczenie rozpoznania warunków klimatycznych w projektowaniu mieszanek mineralno-asfaltowych*, Drogownictwo, 4/2013, 99-104.
- [9] Pacheco Torgal F., *Eco-efficient construction and building materials research under the EU Framework Programme Horizon 2020*, Construction and Building Materials 51, 151-162
- [10] Piłat J., Radziszewski P., *Nawierzchnie asfaltowe*, WKiL, Warszawa 2007.
- [11] PN-EN 13108-7:2008 Mieszanki mineralno-asfaltowe. Wymagania. Cz.7: Asfalt porowaty.
- [12] Radziszewski P., Piłat J., Kowalski K., Pomorski J., *Kierunki rozwoju technologii nawierzchni drogowych w Polsce w aspekcie zrównoważonego rozwoju*, [In:] *Organizacja przedsięwzięć budownictwa drogowego*, Tokarski Z. (red), Uniwersytet Technologiczno-Przyrodniczy, Bydgoszcz 2013, 51-64.
- [13] Tokarski Z., *Recykling w budownictwie drogowym*, Radar, Bydgoszcz-Toruń 2005.
- [14] Tokarski Z., Sobotka A., *Wymiana doświadczeń ważnym czynnikiem stosowania innowacji procesowych i produktowych w budownictwie drogowym*, [In:] *Organizacja przedsięwzięć budownictwa drogowego*, Tokarski Z. (red), Uniwersytet Technologiczno-Przyrodniczy, Bydgoszcz 2013, 11-36.
- [15] Tokarski Z., Sobotka A., Czarnigowska A. *Scheduling material transportation for highway repaving project*. Procedia Social and Behavioral Sciences 48/2012, 847-856.
- [16] Woźniak M., Dąbrowski W., Olszacki J., *Bezpieczniej i ciszej dzięki nawierzchniom porowatym. Część 2: Hałas komunikacji drogowej – problem XXI wieku*, Magazyn Autostrady 5/2007, 108-109.
- [17] WT-2: 2010. *Nawierzchnie asfaltowe na drogach krajowych. Mieszanki mineralno-asfaltowe. Wymagania techniczne*, Zał. nr 2 do Zarz. nr 102 GDDKiA z 19.11.2010.