Maintenance and Rehabilitation

OPA8-Inlay as heavy maintenance measure for OPA8 Porous Asphalt.

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Abstract

The durability of Porous Asphalt is lower than conventional dense asphalt, especially in the case if noise reduction is the end of life criterion. After reaching the end of life the Porous Asphalt is replaced in full. This is not very economical with regards to raw materials and resources. As a cost-effective life-extending maintenance measure, an ultra-thin Porous Asphalt overlay system was developed in the Netherlands and approved on standard Porous Asphalt in 2003 by the Dutch road authorities (Rijkswaterstaat). With this maintenance system first a polymer modified bitumen emulsion (bond coat) is sprayed on the existing pavement and on top a thin overlay, which is placed using one single machine pass. The emulsion coats and rejuvenates the old Porous Asphalt, this without creating permeability problems (splash & spray) and ensures a good adhesion with the thin overlay resulting in a Porous Asphalt system with the same functional properties as a completely new Porous Asphalt layer. OPA8 is based on ‘derived of’ the German Porous Asphalt and has a higher noise reduction and life than the standard Dutch Porous Asphalt and was developed in 2013. In order to have an economically maintenance system a variant of the mentioned proven technique was developed. Laboratory tests were carried out and a trial section was laid in 2018. In this case 27 mm of the old OPA8 is milled off and replaced with 30 mm OPA8-Plus (improved OPA8) on top of a bond coat using one single machine pass with a so-called spray paver. The test results show that the system also can be applied with OPA8-Plus. After application the OPA8-Inlay has the same functional properties as standard OPA8. Key words: porous asphalt; ravelling; durability; polymer modified binder; noise reduction.

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1. INTRODUCTION

Porous Asphalt (PA) is the standard on the Dutch main motorways. It has many advantages compared to dense asphalt pavements such as a better visibility under rainy conditions and depending of the type of Porous Asphalt a certain noise reduction of the traffic flow. The noise reduction varies between initial 4 dB(A) for standard single layer Porous Asphalt to initial 6 dB(A) for a two-layer Porous Asphalt (2L-ZOAB). A disadvantage is however the limited service life (on average 10-11 years for standard Porous Asphalt and 8-9 years for the top-layer of 2L-ZOAB on the slow lane) compared to a standard (SMA) asphalt concrete surface (10-15 years).

For the Dutch motorway A15 near Rotterdam a new type of Porous Asphalt was introduced in 2013 based on the OPA8 in Germany [1]. This type of Porous Asphalt consists of 1 layer with a comparable noise reduction as a two-layer Porous Asphalt and has a service life of 12 years. The developed OPA8 [1] was part of a DBFM (Design, Build, Finance and Maintain) contract. This means that the contractor (A-Lanes A15) is also responsible for the maintenance (until 31 December 2035 for this project). In order to carry out the maintenance as efficiently as possible, various maintenance techniques were examined. One possibility is the OPA8 inlay based on an ultra-thin Porous Asphalt overlay system. For this is the OPA8 partially milled away and a new thin layer of OPA8 is placed (“glued”) on top.

As a cost-effective life-extending maintenance measure, an ultra-thin Porous Asphalt overlay system was developed in the Netherlands and approved on standard Porous Asphalt in 2003 by the Dutch road authorities (Rijkswaterstaat) [2]. With this maintenance system first a polymer modified bitumen emulsion (bond coat) is sprayed on the existing pavement and on top a thin overlay, which are both placed using one single machine pass. In order to have an economically maintenance system on the A15, a variant of the mentioned proven technique was developed. In this case the old OPA8 is partly milled off and replaced with a new OPA8-Plus top layer (improved OPA8).

To evaluate this so-called OPA8-Inlay system first laboratory tests were performed and in July 2018 a test trial was performed. In this paper all the aspects of the OPA8-Inlay system as a heavy maintenance measure for the OPA8 will be described.

2. OPA8 POROUS ASPHALT

The latest specification of OPA used in Germany differs from the standard Dutch Porous Asphalt; the main characteristics of OPA are summarized below [3]:

- Higher voids content 24 to 28 % compared to 20 % for standard Dutch Porous Asphalt (PA16).
- 45-50 mm thick single layer; 8 mm maximum aggregate size.
- Alternative 50-60 mm thick single layer; 11 mm maximum aggregate size.
- Application of a minimum of 6.5 m/m% (inside the mixture) polymer modified binder (PMB).
- Waterproof underlayer consisting of a SAMI (Stress Absorbing Membrane Interlayer) or mastic asphalt.
- Maximum initial noise reduction after construction 6 to 8 dB(A) compared to the Dutch reference dense surface (= 7-9 dB(A) noise reduction compared to the German reference dense surface). Decay (loss) in time 0.25 dB(A) per year [4].
- Service life of more than 10 years (on the slow lane) based on the German end of life criterion (minimal noise reduction), which is comparable to a service life of more than 12 years in the Netherlands (severe ravelling; Dutch end of life criterion Porous Asphalt) [5].

The Dutch version of OPA8 is based on (‘derived from’) the German OPA8 and was developed in 2013 for the A-lanes A15 project on the Dutch motorway A15 near Rotterdam. The overall project has resulted in an optimized supply chain for the OPA, including the selection of raw materials, the OPA production, transport, compaction protocol and quality judgement criteria, to get an economically durable Porous Asphalt with a high noise reduction. For the traffic mixture on the A15 (high volume of trucks) the optimal layer thickness was around 60 mm. In 2013, 2014, 2015 and 2016 roughly 1.2 million square meters of OPA8 was successfully applied according to this procedure [1].

For another project on the A59 near the city of Waalwijk, the OPA8 was further improved by using an improved polymer modified binder (PMB). This so-called OPA8-Plus Porous Asphalt mixture has an expected service life of at least 14 years (on the slow lane) based on advanced laboratory results [6]. In 2016 roughly 25000 square meters of OPA8-Plus was successfully applied on this project.

3. THIN ASPHALT OVERLAYS FOR POROUS ASPHALT REPAIR

Stone loss (or ravelling) is the characteristic failure mode in Porous Asphalt. This can be either due to cohesive failure (break within the mastic) and / or adhesive failure (break at the stone-mastic interface). Once the Porous Asphalt starts to degrade, moisture and frost in combination with traffic loading may lead to more severe damage, like pothole forming. To prevent potholes, an overlay with an ultra thin asphalt layer could be applied.

The criteria for such a layer are:

- Proper drainage of water should be possible.
- Adequate skid resistance.
- Good adhesion with the under layer.
- Prevention of deterioration of the existing underlying porous asphalt.

As a life-extending maintenance measure, an ultra-thin porous asphalt overlay (Microville on ZOAB) was developed and approved on Porous Asphalt in 2003 by the Dutch road authorities (Rijkswaterstaat) [2]. The Microville on ZOAB is a system where first a special polymer modified bitumen emulsion (bond coat) is sprayed (minimal 0.7 kg/m^2) and on top a thin overlay (minimal 50 kg/m^2) is placed using one single machine pass with a so-called spray paver or DSH-V paver. The emulsion coats and rejuvenates the old Porous Asphalt and ensures a good adhesion with the thin overlay resulting in a Porous Asphalt system with the same functional properties as a completely new Porous Asphalt layer. A schematic representation of the lay down is given in figure 1.

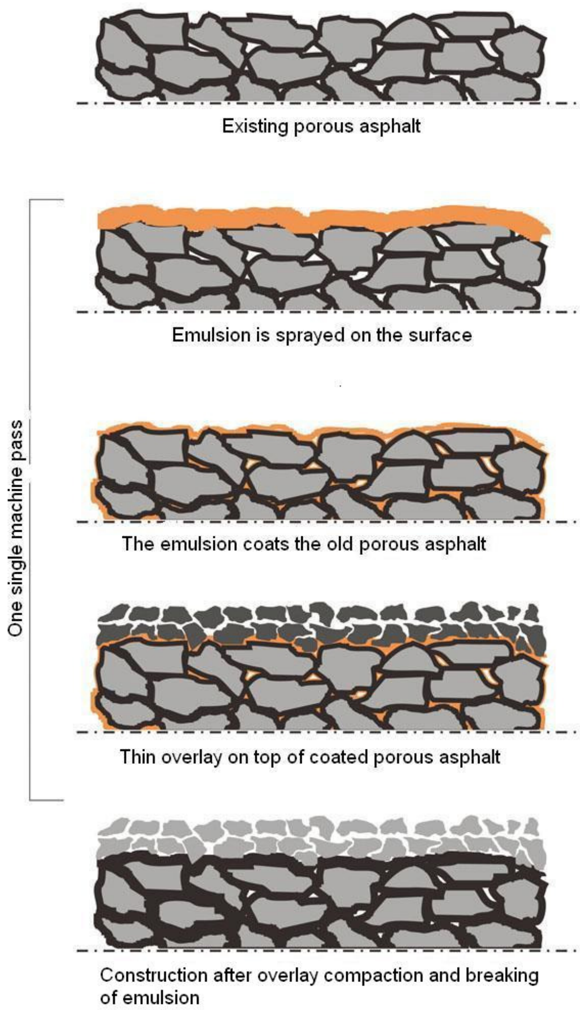

Figure 1. A schematic representation of the construction sequence

The developed system has been approved as a high-quality maintenance technique on motorways. From 2003 until today, more than 180000 m^2 porous asphalt has been rehabilitated on Dutch motorways, A6, A7, A27 and the A8. The Dutch road authorities (Rijkswaterstaat) are still enthusiastic about this method.

4. OPA8-INLAY

OPA8-Inlay is a slightly different approach than the previous mentioned proven technique on old Porous Asphalt. In this case 27 mm of the old OPA8 is milled off and replaced with 30 mm OPA8-Plus (improved OPA8 as developed for the Dutch A59 [6]) on top of a bond coat using one single machine pass. To extend the durability, an improved PMB was developed for OPA8-Plus (SFB 5-90 (PA)). In table 1 the properties of this PMB are given in combination with the basic German specifications and the PMB used in OPA8 for the Dutch A15.

Table 1: German specification polymer modified binder and selected PMBs.

Properties		German specs [7] PMB 40/100-65 A	OPA8 SFB 5-50 (PA)	OPA8-Plus SFB 5-90 (PA)
Penetration	[0.1 mm]	40-100	60-90	70-100
Softening point	[°C]	≥ 65	≥ 65	≥ 70
Fraaβ breaking point	[°C]	≤ -15	≤ -15	≤ -18
Elastic recovery 25 °C	[%]	≥ 70	≥ 85	≥ 90

Furthermore, the gradation of the new top layer is the same as the existing old OPA8 Porous Asphalt. So after application, the total OPA8 layer new and old will be the same in terms of functional properties.

To apply the system on OPA8 some laboratory preparation trials were necessary to obtain information on:
- The required amount of emulsion
- Optimal OPA8-Plus thickness
- Expected service life
- Realized noise reduction

The OPA8 inlay has to be placed with a so-called spray-jet paver or DSH-V paver (see figure 2) to be sure of proper bonding of the new top layer.

Figure 2. Example of a spray-jet paver.

An important advantage of OPA8-Inlay is the reduction of construction time for heavy maintenance. Because the OPA8-Inlay can be placed much faster. In addition, less time is required for milling (total OPA8 layer 50-60 mm vs. 27 mm) and less time is required for rolling (a thinner layer cools down quicker). Therefore, also the costs for road closures will be lower. Furthermore, less new OPA8 asphalt is needed, which reduces the CO_2-emission as well.

5. BONDING

As mentioned before, the bonding between the old OPA8 and the new OPA8-Plus is an important factor. To test the bonding first laboratory samples were prepared using the surface of a 5 year old OPA8 trial section.

5.1. Experimental

- From an old OPA8 trial section (OPA8 on top of AC16 binder course placed in 2013), asphalt specimen were retrieved (500 mm x 700 mm x 100 mm).
- After sawing, 27 mm of the OPA8 was milled off by a Wirtgen milling machine and the surface was cleaned.
- The specimens were transported to the lab and treated with different amounts of bond coat (polymer modified bitumen emulsion type C65BP2).
- In the lab the following quantities of bond coat were applied:
    - o Plate 1: 0.5 kg/m^2 Emuflex N
    - o Plate 2: 0.7 kg/m^2 Emuflex N
    - o Plate 3: 0.9 kg/m^2 Emuflex N
- The asphalt specimens were placed in a Freudl slab compactor and 30 mm OPA8-Plus was placed on top of the specimens.
- Becker's tube measurements [8] were performed to determine permeability of the new OPA8-Inlay construction.
- After 2 weeks conditioning at 15 °C, 6 cores ø150 mm were drilled out of each specimen.
- Tensile adhesion tests (TAT) prEN 12697-48 at 10 °C were carried out after 4 weeks since placing the OPA8-Inlay.

5.2 Sample preparation

In the pictures below the described steps are visually represented.

Figure 3 to 6: Sample preparation and Becker's tube measurement.

5.3. Laboratory test set-up

The tensile adhesion test (TAT) was carried out using the test set-up as described in prEN 12697-48. As preparation for this test, Ø 150 mm cores were drilled from the prepared asphalt specimens and the surface was polished. These cores were drilled in (30 mm) with a Ø 100 mm drill, through the new OPA8 layer. After this, circular metal plates were glued on the established Ø 100 mm sections in the middle. After fixation (proper hardening) of the glue, the pull-off tests were performed with the use of a servo-hydraulic actuator (100 kN MTS). A (schematic) representation of the test set-up is given in figure 7 and 8.

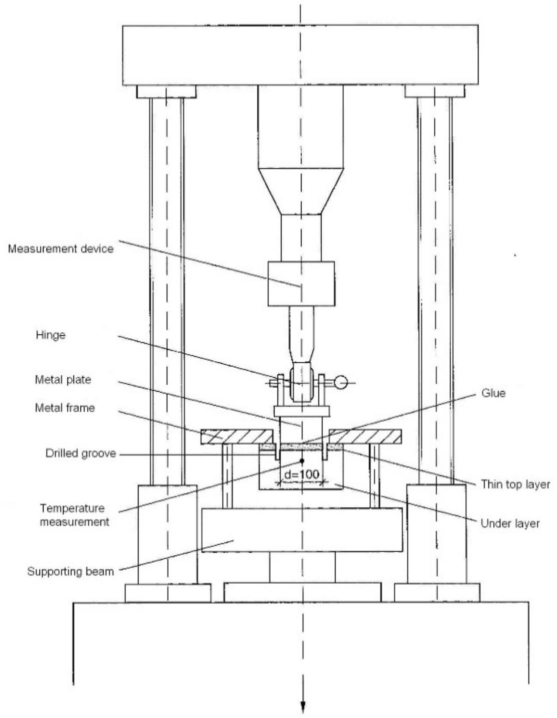

Figure 7 and 8 Schematic representation of the pull-off test set-up configuration and sample after testing

The static (monotonic) pull-off tests were carried out as described in the German specification with a constant load increase of 0,025 (N/mm^2)/s at a constant temperature of 10 °C. The maximum tension stress needed to pull-off the plate glued onto the asphalt substrate is defined as the bond strength. The fracture toughness is defined as the energy until break (separating) of the top layer.

5.4 Test results bonding

The results of the TAT test are given in table 3.

Table 3: Results of pull-off tests.

Amount of emulsion	Bond strength (n=6)		Fracture toughness (n=6)		Becker's tube outflow time	Location of failure in		
	Average [MPa]	COV [%]	Average [Nmm/mm^2]	COV [%]	[s]	T[1]	I[2]	P[3]
0.5 kg/m^2	0.51	24	0.39	34	14.0	1	99	0
0.7 kg/m^2	0.61	9	0.46	59	14.7	1	99	0
0.9 kg/m^2	0.60	10	0.43	41	20.3	1	99	0

[1] Break percentage in new OPA8 top layer; [2] Break at interface; [3] Break in old OPA8 Porous Asphalt.

From the results it can be seen that the lowest amount of emulsion gives the lowest strength, toughness and Becker's outflow. The last mentioned parameter is positive for the porosity of the Porous Asphalt and has to be below 25 seconds for good water permeability in practice. The optimum amount of emulsion looks to be 0.8 kg/m^2. More emulsion will not give a better bond strength and toughness. Furthermore, the permeability is decreasing due to filling of the air voids with emulsion.

All variants fail almost entirely at the interface between the old and new layers. The bond strength appears to be just below the expected tensile strength of OPA8-Plus itself (0.58 MPa at 15 °C; average indirect tensile test n=3 according to EN 12697-23 [9]). It is expected that this bond strength will increase over time and will become equal to the strength of the OPA8 itself.

6. TRIAL SECTION OPA8-INLAY

On 15th of June of 2018 a trial section OPA8-Inlay was placed on the ramp eastbound to the A15 (near Rhoon). The total area of the section was 2.500 m^2. For durability of the new OPA8 top layer two jet-spray pavers (Strukton and Strabag) were used to establish a hot joint between 2 lanes. Furthermore, the performed steps were basically the same as for the laboratory trial except for the sanding:

- 27 mm of the old OPA8 was milled off and the surface was cleaned.
- 30 mm new OPA8-Plus was placed using 2 simultaneously operated spray jet pavers with a minimum amount of emulsion of 0.8 kg/m^2.
- Strict protocol for use of rollers and number of roller passes to prevent overcompaction [1].
- Sanding the OPA8-Plus for optimal initial skid resistance [1]. Unfortunately, the right sanding equipment was not available (figure 11).


Figure 9 and 10: Milled off OPA8 surface and placing OPA8-Plus.


Figure 11 and 12: Rolling and sanding of OPA8-Inlay and final result.

6.1 Bond strength OPA8-Inlay trial section

Cores (Ø150mm) were drilled from the field trial section and the tensile adhesion tests were carried out using the test set-up as described previously in section 5.3. The result of the tests are given in table 4 and compared with the optimal found from the laboratory design tests.

Table 4: Results of pull-off tests trial section.

Sample	Bond strength		Fracture toughness		Becker's tube outflow time	Location of failure in		
	Average [MPa]	COV [%]	Average [Nmm/mm^2]	COV [%]	[s]	T[1]	I[2]	P[3]
1	0.60	-	0.24	-	-	1	99	0
4	0.52	-	0.16	-	-	1	99	0
8	0.63	-	0.27	-	-	1	99	0
10	0.56	-	0.32	-	-	10	90	0
14	0.55	-	0.62	-	-	10	90	0
Average	**0.57**	**8**	**0.32**	**55**	**12.1**	**95**	**5**	**0**
Lab 0.7 kg/m^2	0.61	9	0.46	59	16.7	99	1	0

[1] Break percentage in new OPA8 top layer; [2] Break at interface; [3] Break in old OPA8 Porous Asphalt.

From the results it can be seen that the average bond strength and fracture toughness in the field trial section are a little lower than found in the laboratory trial. This is caused probably by the lower temperatures during the field trial. After full curing of the bond coat the bond strength and fracture toughness will increase to the same level of the OPA8 itself.

6.2 Road surface properties OPA8-Inlay trial sections

The tire/road interaction properties (skid resistance and brake deceleration) were measured, according to the Dutch regulations [10]. Furthermore, noise reduction measurements were performed based on the CPX technique for a traffic load mixture consisting of 72% light traffic at 110 km/h and 28% traffic at 85 km/h [11]. The results are displayed in table 5.

Table 5: Tire/road interaction properties.

Properties		Measurement After 3 days	Measurement After 8 days	Measurement After 19 days	Dutch Specification [9]
Skid resistance	[-]	0.34	0.50	-	≥ 0.45
Brake deceleration	[m/s^2]	4.4	6.3	7.6	≥ 5.2
Initial noise reduction*	[dB(A)]	-	-	4.8	4.9**

*) Noise reduction compared to the Dutch reference dense surface (the noise reduction compared to the German reference dense surface is approximately 1 dB(A) higher).
**) Initial noise reduction of 2 layer Porous Asphalt.

The initial skid resistance of Porous Asphalt is always critical just after paving (the first 24 hours), because of the mastic film on top of the surface. After wearing off due to traffic, the skid resistance will increase. To improve the initial skid resistance, the Porous Asphalt was sanded with crushed aggregate size 0.5-2 mm. Due to penetrating of the bond coat through the new OPA8 the amount of sanding was not sufficient enough for a good initial skid resistance. Probably slightly more and better sanding is needed in respect to standard OPA8 Porous Asphalt. Important is also to use right equipment (see figure 12).

The Noise reduction of the OPA8-Inlay looks to be similar to the Dutch 2 layer Porous Asphalt. However the noise reduction is slightly lower than the noise reduction of a totally new OPA8 layer, which was 5.0 dB(A) for the mentioned traffic mixture [12].

7. DISCUSSION AND CONCLUSION

The test results show that the thin overlay (inlay) system could also be used as OPA8-Inlay system. This creates the possibility of cost savings for major (heavy) maintenance of an existing OPA8 layer. Instead of replacing the total OPA8 layer, it is possible to replace only the upper 27 mm of the Porous Asphalt.

The road surface properties look to be similar to the properties of a totally replaced new OPA8 top layer. Minor improvements (skid resistance and noise reduction; use of better sanding equipment and optimization of amount of bond coat) are needed to get the properties at the same level as for new OPA8.

As an environmental measure partially replacement has a major potential advantage. To rehabilitate the existing Porous Asphalt now only 50 to 60 % (depending on original thickness) of the old pavement has to be replaced. The total use of new raw materials decrease, which has a positive impact on the life cycle costs of the pavement.

The trial section was constructed in June 2018 and is still performing well after 1 winter. Longer monitoring is needed to validate the described OPA8 Inlay technique.

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Annex

ANNEX FEBRUARY 2021

The trial section was inspected again in 2020. The inspection showed that the OPA8 inlay is holding up well after 2 winters despite the slope and accelerating traffic to the main road. Unfortunately, the hard shoulder is clogged with dirt, which can cause faster deterioration of the pavement.

In the pictures below the inspection is visually represented.

Figure 1 and 2: Overview OPA8-Inlay section after 2 winters.

Figure 3: Clogged hard shoulder. Figure 4: End of trail section with on the right roller damage on the old OPA8.