Innovative longitudinal joints between new and old Porous Asphalt

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Abstract For both lane and carriageway wide maintenance of Porous Asphalt (PA) in the Netherlands, contractors increasingly make use of so called joint protectors to prevent premature damage to longitudinal joints in the warranty period of 7 years. Mostly strips of bituminous material are placed on those joints or the joints are poured with hot bitumen and sanded, but sometimes no measures are taken. Those joint protectors can eventually go smooth and/or shiny. Rijkswaterstaat (RWS) gets relatively many complaints of especially motorcyclists, because they are more vulnerable and driving in the middle of the lane where sometimes the joint is. Claims are also made. Sometimes joint protectors are mistaken for “ghost” marking, especially during rainfall, because they are more visible than the mark. In short, RWS was not satisfied with the current joint protectors. In order to remedy this, RWS started a competition to come up with improvements. Contractors came with 11 ideas that were assessed on skid resistance, shine, traffic hindrance, environmental friendliness and costs. Five winners were selected by an independent jury. Those prize winners were able to demonstrate their idea on a PA test section on motorway A59. Cores from these test sections, drilled on the joint, were investigated in the laboratory. One year after construction the joints were visually inspected, and the skid resistance and horizontal water drainability was measured. This paper discusses the winning ideas, the construction of the test sections, the laboratory and field tests and results.

Keywords longitudinal joints, Porous Asphalt, maintenance, skid resistance.

1 Introduction

Since 1990 the policy in the Netherlands is to apply only silent pavements on motorways. In 2014 more than 90% of the motorways has a Porous Asphalt (PA) wearing course. Due to the higher traffic load, the slow lane is mostly replaced after 11 years. The average end of service life of the fast lane is 17 years. So, the most applied maintenance technique is to replace after 11 years only the slow lane PA and lay a new PA wearing course carriageway wide after 17 years. Due to the inlay after 11 years, a longitudinal joint is created between old and new PA. The purpose of joint protectors is to preserve the connection between new and old PA. Joint protectors are increasingly used by contractors in predominantly longitudinal joints to avoid premature damage during the 7 years warranty period. Damage of the joint can be caused by the fast milling speed of old PA, which can initiate micro cracks in the mortar forming bridges between the coarse aggregate. Also the bonding between hot new PA and cold old PA is not optimal. A hot to hot PA construction gives a better bonding, so this is preferred. The old PA can also be preheated with a joint heater. If a joint is widening, it is often the start of raveling and can sometimes be a slot formed in the PA.

In recent years RWS was increasingly confronted with complaints from road users about joint protectors. Joints are often poured with hot bitumen and whether or not sanded with fine mineral aggregate, bituminous strips are sometimes stuck on, there are other types of joint protectors, but sometimes also nothing is done and hot PA is directly placed to cold old PA. Many of these joint protectors become smooth or slippery over time and will shine.

There are relatively common complaints, especially from motorcyclists, about too smooth joint protectors. This is because they are more vulnerable, but there are also complaints from other road users. During rainfall they assess shiny joint protectors sometimes as ‘ghost’ markings. These 'ghost’ markings may be specifically present in curves where the joint is between marking lines and that can lead to dangerous situations. RWS has already received claims related to motorcycle accidents due to a too smooth surface of the joints. Measurements with the Skid Resistance Tester (SRT) have confirmed this. SRT-values between 28 to 32 were found, while the requirement is ≥ 45.

Because traffic safety is top priority, RWS decided to challenge the market to come up with good solutions.

1.1 Competition joint protectors

In order to improve the current protectors for longitudinal joints, RWS started a competition to challenge the contractors to come up with improvements. The main idea is to develop an innovative durable joint with good skid resistance and no

shining. The water permeability in horizontal direction should also be sufficient. The following selection criteria were applied by the jury:
1. skid resistance and no shining (weighing factor 4);
2. durability and life-time of joints (weighing factor 3);
3. minimum traffic hindrance during application (weighing factor 1);
4. environmental friendly materials and application process (weighing factor 1);
5. costs of production and application of the joints (weighing factor 1).

Fig.1 Airjetseal

Fig.2 Jointfix PB

Fig. 3 Jointfix UV

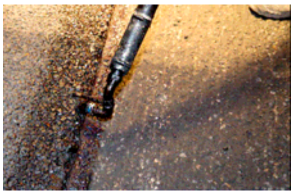

Fig. 4 Direct Vertical Seal

Fig. 5 Lassealer

Five winners got the opportunity to demonstrate their ideas on a PA test section on the motorway A59 near Waalwijk during the night from September 27 to 28, 2013. This motorway had to be maintained with an inlay in the slow lane. As shown in Table 1, in five test sections the joints between old and new PA were treated with the innovative joint protectors of the five winners. The A59 has two carriageways with 2 lanes and one emergency lane per carriageway. The slow lane was milled and a new PA mixture was laid back. The joint between old and new PA is approximately 50 mm left of the middle marking. The old PA contained crushed river gravel with a minimum PSV value of 53, the new PA contained a crushed quarry material with a minimum PSV value of 58.

Table 1 Overview of locations test sites on motorway A59 HRL1

Joint	Airjet seal	Referen-ce	Jointfix PB	Direct vertical seal	Jointfix UV	Las-sealer
Code	H	R	E1	B	E2	M
start (km)	11.23	11.21	11.18	11.16	11.14	11.12
end (km)	11.21	11.18	11.16	11.14	11.12	11.10

Due to the fast milling process on the slow lane, the mortar bridges in the old PA on the fast lane can be damaged and initial micro cracks can grow further. To heal these micro cracks, it is a standard method in the Netherlands to apply a bitumen emulsion containing a rejuvenator on 0.5 m of the adjacent old PA. In this case, only the reference test section (R) was treated with such a product. In this project Modimuls TT was used. Also to avoid premature damage in the old PA, on Dutch motorways it is forbidden to drive with rollers on the old PA.

2 Research plan

Field cores of diameter of 150 mm were drilled out of the test sections in such a way that the joint between new and old PA is in the middle of the core.
In table 2 an overview is given of the whole test program. More background information about the lab tests can be found in (Houben 2014) and more background information about the field tests carried out one year after construction can be found in (Buurman 2014).

Table 2 Overview of tests

Test	Reasons
CT	Internal structure of the joints
Direct Tension Test (DTT)	Bonding strength at low temperature
Permeability test (lab)	Water permeability of the joints (lab)
Rotating Surface Abrasion Test (RSAT)	Raveling resistance of the joints
Skid Resistance Test (SRT)	SRT before and after RSAT
Permeability test (field)	Water permeability 1 year after construction
SRT	In situ SRT 1 year after construction
Visual inspections	Performance of the joints after 1 year

2.1 Siemens CT scanner

The internal structure of the joint system is assessed using the Siemens medical CT scanner (on 150 mm core). Dependent on the grey scale of different compositions (stone, mortar+clogging, air voids) due to density difference, different compositions can be distinguished with a resolution of 0.3 mm. The distribution of the compositions can be obtained each 1 mm over the horizontal and vertical direction of the specimen. The internal joint system can also be visualized.

2.2 Permeability tests

Permeability tests were carried out on specimens taken from the test section directly after application and in situ after one year.

2.2.1 Permeability tests on laboratory specimens

In order to measure the bonding strength of the system a beam specimen was produced through the 150 mm samples with length*height*width of 90*45*60 mm^3. There is a slope of the interface between the old and new PA. A permeability test was applied to the samples. The surrounding of the specimens was sealed and a modified Becker test was designed as shown in Figure 6. The sample is placed under the Becker test allowing water passing through from old PA (top) to new PA (bottom), simulating the water flow from the fast lane to the slow lane. 500 ml of water was applied from the top of the specimen. The time for the water draining to the bottom of the specimen was recorded.

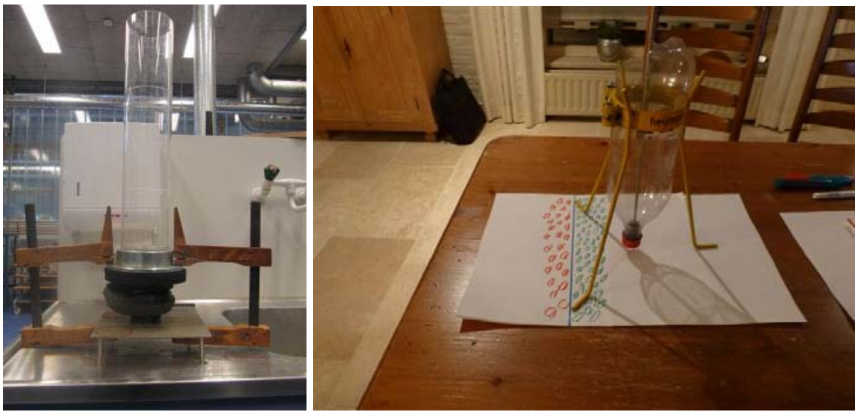

Fig. 6 Illustration of permeability lab test (left) and Breda Bottle Test (right), green is old PA, red is new PA

2.2.2 In situ permeability test for joints

A 1.5 liter PET bottle is mounted upside in a frame. The bottleneck can be closed and opened by moving a rubber ball with a steel rod. The bottleneck is placed 20 mm above the old PA and 100 mm from the joint (see figure 6). During the test 1 liter water flows over the old PA to the new PA due to the slope of 2%. If there is no barricade of the joint, the water spot at the location of the joints is small. If there is a barricade due to the joints, the water spot is wider. So the width of the water spot measured in cm is the result of the Breda Bottle test.

2.3 Direct tension test

As shown in Figure 7, the rectangular samples were tested in the temperature controlled UTM to measure the failure strength at low temperature (-5°C) which is most critical with respect to widening of the joints. Three LVDTs were used to control the displacement speed. The global force-displacement curve was recorded.

Fig. 7 Illustration of the direct tension test

The direct tensile tests are carried out with a low speed of 0.012 µm/s to simulate the displacements in the PA in the field when it is cooling down in winter.

2.4 Raveling resistance

In order to investigate the surface performance of the joints, RSAT tests were performed 3 to 4 months after application of the innovative joints. Prior to the RSAT tests the cores were stored at a temperature of 5°C.
As shown in Figure 8, in a RSAT test an octagonal plate of 500 mm in diameter is charged by a wheel with a solid rubber tire. Three cores with a diameter of 150 mm from the road surface are glued in a plate. The wheel is vertically loaded with a contact pressure of 0.6 MPa and tilted (33.7°) with the direction of back and forth movement to introduce horizontal forces on the surface. The entire surface of the test plate is substantially uniformly loaded by rotating the test plate during the test (496 circles per hour). During the 24 hours test at a temperature of 20°C, the loss of material from the surface is collected continuously with a vacuum cleaner. The loss of stones with a grain diameter of more than 2 mm is reported as raveling damage.

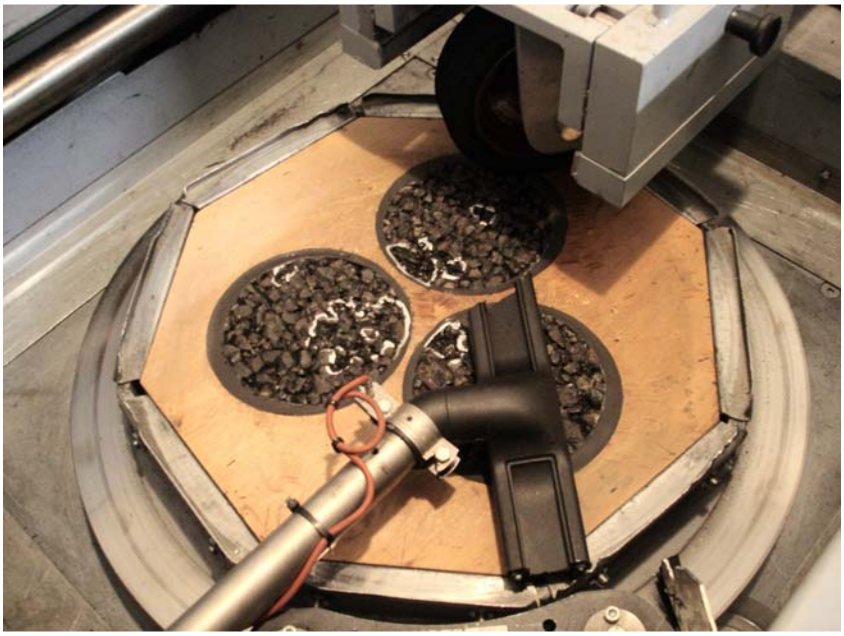

Figure 8 Illustration of RSAT

The intention was to perform a skid resistance test before and after the RSAT test, to evaluate the skid resistance of the joints before and after the accelerated loading. However, after the RSAT test the surface of all the RSAT specimens was seriously damaged, thus the skid resistance test could not be performed.

2.5 Skid resistance

The skid resistance of the joint samples taken just after construction and in situ after 1 year were measured with SRT. The requirement for joints is ≥ 45.

3 Results

3.1 CT scans

Figure 9 shows an example of a CT scan of a joint specimen. From the CT scanning, the old PA (left part of the scan) and the new PA (right part of the scan) can clearly be differentiated due to the different density of the stones. It can also be observed that the old PA has a low air voids content due to severe clogging. And the new PA has a high air voids content. As far as the interface between the new PA and the old PA is concerned, a clear interface is observed, and sometimes with slightly higher air voids content. Figure 10 also shows that beneath the new PA about 10 mm old PA is still there, so not the whole old PA layer was milled. Probably the layer was thicker than the expected 50 mm.

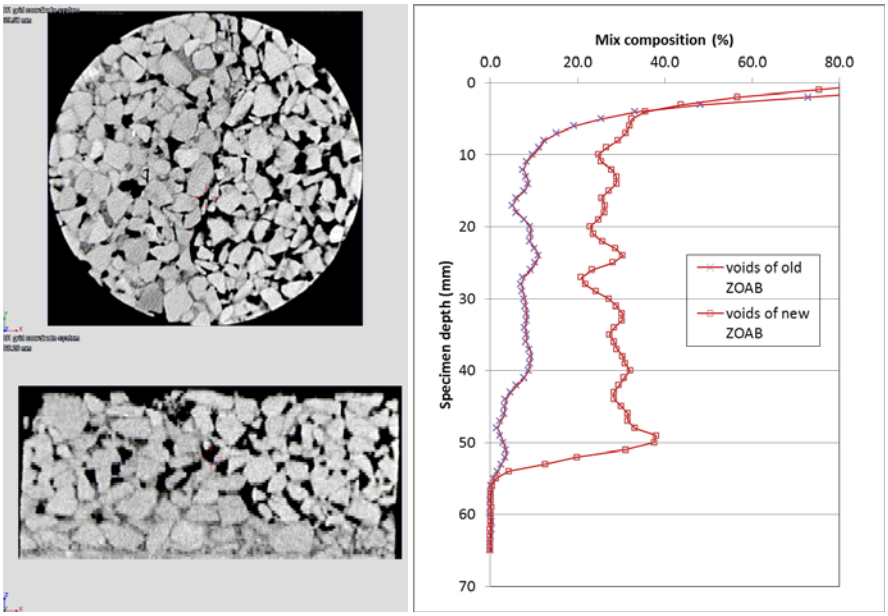

Fig. 9 Example of CT scan. Right graph: distribution of air voids in new PA and old PA

3.2 Permeability tests

3.2.1 Permeability tests on laboratory samples

In figure 10 the results of the laboratory tests are presented. It can be seen that there is a huge variation in draining time between the various solutions, i.e. in the permeability in horizontal direction across the joint. It should be realized that this laboratory permeability test is different from the standard Becker test, prescribed by RWS (Morgan 2008) in which for new PA draining times up to 25 seconds are measured.

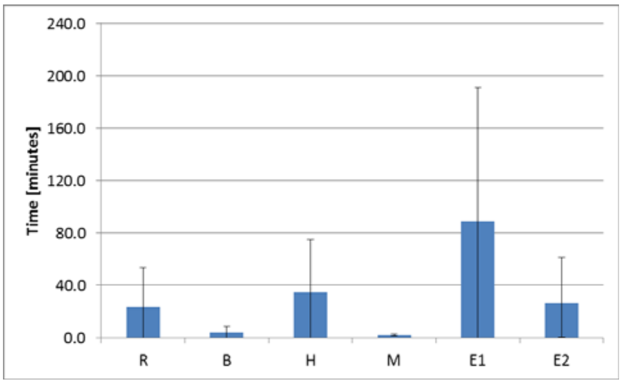

Fig. 10 Laboratory permeability tests of beam samples

3.2.2. Permeability field tests

In table 3 the results of the in situ permeability measurements, one year after construction, are presented. Besides the test sites (3 measurements per test site), also the fast lane (FL), slow lane (SL) and the Emergency lane (EL) were measured (2 measurements per test site).

Table 3 Results of in situ permeable measurements with Breda Bottle test; the numbers represent the width (mm) of the water spot at the joint (see 2.2.2)

	R	B	H	M	E1	E2	FL	SL	EL
average	823	680	910	577	850	640	903	335	730
SD	116	78	270	31	70	61	301	49	14

Table 3 learns that the reference joint as well as all the innovative joints exhibit a smaller width of the water spot. i.e. a better permeability, than the fast lane. This means that none of the joints between the fast lane and the slow lane forms an obstacle for the water flow. It should be remarked that the permeability of the joints between the slow lane and the emergency lane was not measured. It further should be realized that in the fast lane as well as in the emergency lane old PA is present, while new PA with a much higher permeability is present in the slow lane. It is striking that the results from the laboratory permeability tests (Fig. 11) and the results from the field permeability tests after 1 year (Table 3) show the same trend.

3.3 Results of direct tensile tests

In table 4 the results are given of the DTT. The following was measured or calculated: maximum strength, displacement at maximum load, initial stiffness and energy till maximum load.

DTT results indicate an improvement of the displacement at break for H, E1 and E2 joint protectors. B and M show less displacement at break. A lower strength of B is also observed. Failure of the specimens always occurred at the joints and not in the old or new PA, with the exception of the B joint protector.

Table 4 Results of dry DTT

	R	B	H	M	E1	E2
Strength (MPa)	0.93	0.39	0.81	0.81	0.86	0.87
Displacement (mm)	0.025	0.018	0.028	0.018	0.037	0.035
Initial stiffness (kN/mm)	126	71.6	94.4	128.8	29.7	24.4
Energy (J)	0.020	0.005	0.016	0.011	0.022	0.022

3.4 Results of RSAT tests

In table 5 the results of the RSAT tests are given. Most of the stone loss was coming from the old PA. The E1 and E2 solutions exhibit a much higher resistance against raveling than the reference solution and the other 3 solutions, where it should be noted that the testing of the reference and B solutions had to be stopped after 17 and 18 hours, respectively, because of excessive stone loss.

Table 5 Results of RSAT

	R	B	H	M	E1	E2
Duration of the test (h)	17	18	24	24	24	24
Stone loss (g)	61.7	83.3	45.7	95.8	17.0	21.4
Stone loss (g/h)	3.6	4.6	1.9	4.0	0.7	0.9

3.5 Skid resistance

In table 6 the results are given of the SRT measurements on drilled cores taken just after construction and in situ measurements one year after construction.

Table 6 SRT results after construction and 1 year after construction

	R	B	H	M	E1	E2
SRT joint after construction	61	69	67	53	52	80
SRT joint 1 year after construction	-	51	53	45	52	48
Old PA	48	44	44	45	50	46
New PA	61	60	60	65	59	64

One should realize that the SRT measurements were done 1 year after construction and at that time the applied joint solutions as well as the mortar of the new PA were worn off from the pavement surface. So, actually the SRT measurements were done on the coarse aggregates of the PA. The old PA had an age of more than 10 years and contains crushed river gravel with a required PSV-value of ≥ 53. The new PA contains quarry aggregate with a PSV-value ≥ 58. Basically the skid resistance at the joint is equal to the skid resistance of the surrounding PA and not influenced anymore by the joint protector.

3.6 Visual inspections

One year after construction no damage was observed of the joints. All material on the surface of the joints was weared off by traffic loading, so the surface looked like normal PA, and was not shiny. The adjacent old PA of all the joint had some light raveling caused by the poor quality of this old PA.

4. Conclusions and recommendations

The five innovative joint protectors are a good alternative for the current used joint protectors: the skid resistance after construction and one year after construction is sufficient, also the permeability and bonding between old and new PA is sufficient.

Based on the experimental results, the following can be concluded:

- Innovative joint protectors can be visualized using CT scan technique;
- The permeability tests show a huge variation of the results due to clogging of the old PA. After construction the B and M joint protectors indicate better permeability than the other ones. One year after construction joint protector H performs worse in comparison with the other joint protectors. The performance of joint protectors B and M is still good, but also the performance of E1 and E2 is good;
- DTT tests indicate an improvement of the displacement at break for H, E1 and E2 joint protectors. B and M show less displacement at break. A lower strength of B is also observed. Failure of the specimens always occurred at the joints and not in the old or new PA, with the exception of the B joint protector;
- RSAT tests show a large amount of stone loss for all joint structures tested. When comparing the different joint protectors, B and M are comparable with the reference. And H, E1 and E2 show less stone loss. For these 3 innovative joints the relative low stone loss goes together with relative good mechanical performance;
- After construction SRT tests show a higher skid resistance of the B, H and E2 joint protectors when compared with the reference. Lower skid resistance values are observed for M and E1;
- The five innovative joint protector did not barricade the water flow between the old PA of the fast lane and the new PA of the slow lane;
- The Breda Bottle test is a good test to get an impression of the horizontal water flow through the longitudinal joint;
- Visual inspections one year after construction show that all joint protectors still are in good condition and meet the requirements for skid resistance;
- It is recommended to follow the performance of these innovative joints in time by measurements and visual inspections, in such a way that the findings of this laboratory and in situ research can be correlated.

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