Maintenance and Rehabilitation

# The benefits of spray applied asphalt surface preservation system on the strategic network

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## Abstract

The use of spray applied Asphalt Preservation systems is known to have a fast application process, mostly applied at night to increase productivity, reduce traffic congestion and to keep within time restricted road closures. These innovative preventative maintenance systems have been applied to motorway networks and airfield runways alike for many years now, and some networks have had additional re-applications to preserve their asphalt infrastructure as they whole life cost benefits. Developments within the UK and European roads industry for a number of years, asphalt preservatives, both seal and protect the asphalt surface course in its current condition (at the point of application). Developments in the specification guidance has exhibited greater adoption within the strategic network in line with many large DBFO operators continue to make financial savings by utilizing preservation within their asset management plans. The paper further looks into this innovative maintenance system, which forms part of the asset management strategy. Road authorities have engaged with pavement teams in order to clarify the different systems on the market and to give further guidance on the use of preservations systems on the Strategic Road Network (SRN). Reference sites have been installed on the network which are being monitored, include onsite inspections, rheological data gathering, deterioration curves of the existing asphalt and best practice for when preservation systems need to be applied and predictions of life extension these systems would bring. Together with data reviews with a view to developing a full specification in due course. Along with other data, these sites will deliver important information with regard to performance over time of a surface preservation system under challenging conditions throughout its service life, with the intention of extending the life of the road with minimum interventions.

This paper was first published in 2020 in version 1.0 of the proceedings of the 7th E&E Congress. This second edition (version 1.1.) of the proceedings is published in June 2021. The content of this paper has not changed, but the author(s) may have provided additional information in the form of an annex.

## INTRODUCTION

Bitumen is one of the constituents of asphalt and is an organic substance which is slowly oxidised when in contact with atmospheric oxygen, UV light and water. This ageing causes rheological and mechanical changes to the asphalt material.

Ageing of bitumen is the conversion of the lighter elements/aromatic oils within the bitumen such as maltenes into asphaltenes. Loss of volatiles is a contributing factor to ageing of the bitumen, the degree to which this occurs is dependent on the temperature and conditions of exposure.

The imbalance of key molecules causes the bitumen to age and subsequently become brittle and less flexible within the asphalt, which can adversely influence the service life and durability of an asphalt pavement.

Over the life of an asphalt surface course, the aggregate / bitumen bond is weakened due to effects of oxidisation (exposure to air, UV and water) caused by weathering and UV degradation. As the binder ages, fine micro cracks appear in the binder film that allow more of the oxidising agents into the pavement surface and the loss of the cohesion can lead to raveling and the formation of potholes.

Asphalt Penetrative Preservative treatments have been used for many years to prevent the pavement deterioration due to ageing, loss of surface aggregates, cracking and pothole formation. They work by providing a seal on the surface of the asphalt pavement that prevents the ingress of water and reduces the rate of oxidation of the bitumen. Some products provide an increased surface toughness that is resistant to raveling and helps retain surface aggregate. Asphalt Penetrative Preservation keeps the pavement surface in the condition it is in at the time of application for longer. They protect the pavement and slow down the deterioration process. The use of Asphalt Penetrative Preservatives has the potential to extend the serviceable life of the pavement (Widyatmoko et al, 2012).

This solution is best utilised as a preventative maintenance measure in asset management. By preserving the asphalt surface course in its current condition and making it last longer, you can reduce reactive maintenance. Extending the service life will also reduce the number of resurfacing interventions over the life of the pavement. When this is adopted successfully it becomes a sustainable maintenance technique as it puts less demand on natural mineral resources, minimises congestion through reduced maintenance and interventions and provides monetary savings over the life-cycle of the project. When compared to conventional resurfacing, preservation can provide a 94% saving in $CO_2$ emissions.

Preservation is a fast application process and is usually applied by an integrated spray tanker that applies the preservative and a very fine grit simultaneously to ensure grip levels meet the requirements of the works specification. Depending on road space and with tanker re-fills, it is possible to treat areas from 12,000m$^2$ up to 60,000m$^2$ in a single shift. The application can take place at night for ease of access and requires minimal plant and personnel. This process minimises the disruption to road users. Therefore, causing less congestion and generally cures within 1 - 4 hours.

To improve the performance life of the asphalt it is recommended that the surface course is treated with asphalt preservation about 2 years before major patching / intervention is required. Network managers generally know how long they get from their asphalt materials and a preventative maintenance approach can be easily planned. Treating a road in a good (green) condition will keep it in that condition for much longer. Repeated applications at 5 yearly intervals have doubled the life of some asphalt surface courses (Ref. M40, A50 and Aberconway Road).

Asphalt surfaces considered to be approaching ‘end of life’ can also be treated, but the life extension may be shorter. Many airfields have been treated in this way, where the airport manager wants to hold the surface together for 3 – 5 years to delay the full rehabilitation.

This paper evaluates some of the factors which effect the deterioration of a pavement and how the benefits of Asphalt Penetrative Preservation can help extend the operational life of the pavement making it an innovative and cost-effective option in road asset management. This paper focuses on using test reports from sites, laboratory studies and client testimonials of successful and repeated use.

## ASPHALT PENETRATIVE PRESERVATION PERFORMANCE TESTING

Asphalt preservation application will have the following key benefits:

1. Improves the waterproofing properties of the surfacing; As you spray on the top of the surfacing to which it penetrates, it is likely to close some of the surface's inter-connecting voids, reducing the overall exposure to UV and air, and minimising water ingress.
2. The treated surface becomes more resistant to stone loss due to the hard grade nature of the preservative used.
3. Seals in essential oils and resins. Thus, slowing down the rate of oxidation of the binder.
4. Application of asphalt preservation can extend the operational life of the asphalt pavement.

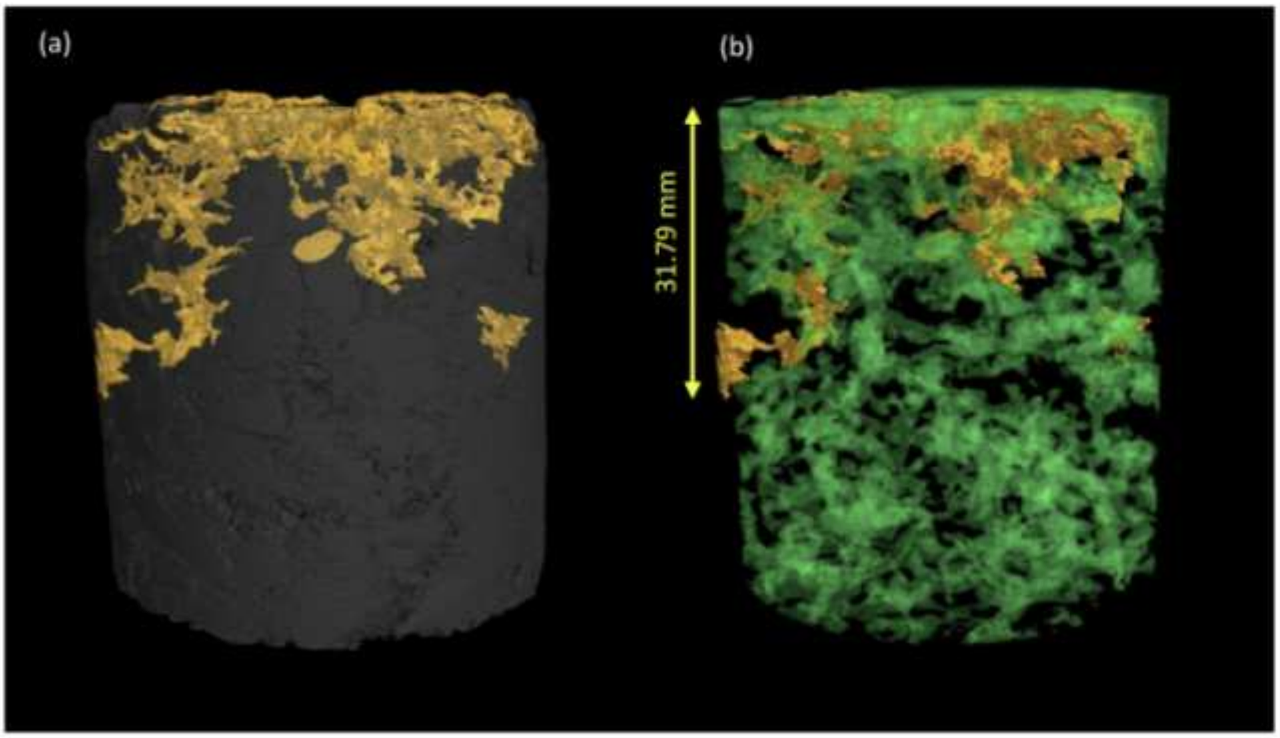
Data from sites around UK and Europe was used.

**X-Ray CT Scan**

Penetrative asphalt preservatives have been shown to seal the surface of the asphalt and penetrate into the asphalt via any interconnecting voids. The treatment locks into the binder and forms a protective seal against the ageing effects of weathering and oxidation.

A specialized UK University carried out an X-Ray CT scan on a sample of 10mm Stone Mastic Asphalt (SMA) Surface course with circa 7% in-situ air voids. The asphalt sample was a 50mm diameter core and 50mm in depth. It was scanned before and after the application of the penetrative asphalt preservative on the top surface of the core. All scans were conducted under identical image conditions. The distance the preservative treatment had penetrated through the porous network of the core was 31.79mm. In the 3D visualisation of treatment distribution (Figure 1a&b) some regions of disconnection can be seen. This shows that although SMA is designed to be non-porous, there is a degree of inter-connecting voids.

**Figure 1 shows the depth of treatment penetration into the asphalt**




Inter-connecting voids that penetrate 50% into the depth of an asphalt surface course allowing water to get in could lead to durability issues. The post application scan was taken 45 minutes after the preservative was applied, simulating what happens during initial application. The preservative locks into the binder film and flows through the negative texture and through any voids or micro cracks within the material.

## Improving Waterproofing of the Surface

The bitumen is the waterproofing component of asphalt. With ageing and oxidation, the properties of the bitumen are damaged. Micro cracks form within aged bitumen and between the bitumen/aggregate interface increases with the ageing of asphalt material by letting water in, and water ingress accelerates the deterioration of an asphalt pavement by weakening the aggregate-bitumen bond.

Treatment with an asphalt preservation system both seals the asphalt surface and minimises the ingress of water into the existing pavement and penetrates into the existing surface course reducing the quantity of voids at the surface and improving the resistance to water into the pavement which would typically occur without such a treatment.

It is reasonable to conclude that a reduction in water permeability is a result of reduced porosity in the surfacing. A reduction in porosity would indicate a positive impact on the level of photo-oxidation and weathering which occurs on preservative treated asphalt and thus providing a resistance to further evaporation of light oils/resins.

Examples of work carried out illustrating improvements in water permeability are discussed below;

### M4, Junction 10 (Bracknell) and Junction 11 (Reading Central), UK

A preservation product was applied in July 2014 to a SMA proprietary thin surface course system that was installed in December 2012. The installation is located on Lane 1 of the westbound carriageway of the M4 between Junction 10 (Bracknell) and Junction 11 (Reading Central).

Testing was carried out in accordance with DD229:1996. Measurements were performed at two locations within the treated section and two within the non-treated (control) section. The asphalt surface course is a SMA, and although not considered to be a permeable/porous surfacing under the requirements of the test specification, it is a suitable measure due to the mixtures network of interconnected voids and the micro cracks found in older asphalt surfaces. The tests on the non-treated (control) section took more than three minutes on average, while those on the treated sections were stopped after 10 minutes as no notable leakage was evident.

**Table 1 – 2018 Testing**

| Test Location | Mean Outflow Time (s) | Relative Hydraulic Conductivity |
|---|---|---|
| Average Control | 214.8 | $4.75 \times 10^{-3}$ |
| Average Treated | >600 | $1.77 \times 10^{-3}$ |

### M40, Junctions 1 – 14, UK

The M40 is one of the busiest motorways in the UK with some sections carrying in excess of 15,000 commercial vehicles per lane per day. It is a 123km section of 6 lane carriageways, managed under a 30-year DBFO contract. The UK Highways have been using asphalt preservation since 2008 (following a 5-year assessment trial, commencing in 2003) and by 2019 had treated nearly 5,000,000m$^2$. They are now on their 3$^{rd}$ application.

Testing was carried out in accordance with DD229:1996 on the surface course of initial trial sections. The results are given in Table 2, showing outflow time for the SMA section that was originally installed in 2002.

A reduction in the hydraulic conductivity with the increase in the number of treatments was particularly observed for the SMA.

For the SMA, the first application increased the average outflow time by a factor of 1.6. The second application had more significant effect on the average outflow time, i.e. increased by a factor of 6.6 from the first application. Increased outflow time can indicate lower permeability.

**Table 2 – Results of Permeability**

| Material/Trial Section/Location | Outflow Time (s) | Hydraulic Conductivity (m/s) |
|---|---|---|
| SMA Untreated (Control) | 98 | $1.02 \times 10^{-2}$ |
| SMA Treated Once 2005 | 164 | $6.11 \times 10^{-3}$ |

| | | |
|---|---|---|
| SMA Treated Twice 2005 & 2010 | 1092 | $9.20 \times 10^{-4}$ |

**A1(M) Junction 2 and 1, UK**

An asphalt preservative was applied in 2011 to a SMA which had been installed in 2009. Traffic levels recorded on this section are in excess of 5000 cv/lane/day (reference www.dft.gov.uk). Testing was carried out in May 2017 by TRL UK, 6 years post application. Table 3 shows hydraulic conductivity testing done in accordance with DD 229:1996 between treated and control sections. As stated earlier, SMA materials are not considered to be a permeable/porous surfacing under the requirements of the test specification, but the treated sections presented significantly reduced permeability results.

**Table 3 – Hydraulic Conductivity, A1(M)**

| Test Location | Average Outflow Time (s) | Relative Hydraulic Conductivity |
|---|---|---|
| Control area | 211.3 | $9.61 \times 10^{-3}$ |
| Treated section | 749.4 | $1.73 \times 10^{-3}$ |

**Improving Aggregate Retention**

Penetrative preservation products fortify the asphalt matrix at the surfacing where it arrests aggregate loss. The preservative penetrates the surfacing through the inter-connecting voids, where the rheological modified grade bituminous blended base bonds with the existing asphalt/bitumen mortar resulting in the reinforcement of the existing asphalt surfacing in terms of cohesion and adhesive strength.

**A96, Germany**

Overlays of porous asphalt were installed on the BAB A96, Munich—Nuremberg motorway, Germany in 2004. Due to signs of wear, isolated cracks and loss of chippings it led the client to consider preventative maintenance techniques. Asphalt preservation was chosen to prevent further aggregate loss whilst maintaining the existing acoustic quality of the road.

Previous experiences by the client had shown that overlays of porous asphalt will usually become damaged during the cold seasons. Freeze-thaw cycles coupled with heavy traffic aided the deterioration of a pavement. The situation led to the observation that the overlay of porous asphalt applied as protection against winter conditions should be preserved with minimal spraying as a preventative measure, to prevent loss of aggregate and maintain the existing evident good construction and acoustic quality at least until restructuring starts in a few years.

The porous asphalt surface courses on the Munich carriageways of the A96 motorway between AS Windach and AS Greifenberg were treated with asphalt preservation in 2013 to protect against further ageing and aggregate loss. The acoustic effect remained largely the same. The site was monitored, and cores were obtained for laboratory assessment in 2013 and 2016.

To simulate freeze-thaw cycles, the Dr-ing Gauer Institute Laboratory, Germany, adopted a procedure used for concrete testing. The surface of the test cores were first saturated in 3% Sodium Chloride solution to a depth of 2cm, and then, while partially immersed, frozen and thawed again in rapid succession. A total of 56 freeze-thaw cycles were performed.

To determine the effectiveness of the preservative under a mechanical load, a test method now published in PR CEN/TS 12697-50:2016, named The Darmstadt scuffing device (DSD) developed by *Universität Darmstadt*, Germany was used. This test imposes horizontal thrust forces on the surfacing of the sample, in alternating directions, to test the adhesive strength of the aggregate or asphalt.

**Table 4 – Aggregate Loss through Abrasion Test results A96, Germany**

| | | Before Preservation | After Preservation | |
|---|---|---|---|---|
| | | 2013 | 2013 | 2016 |
| Core Location | | Abrasion (g) | Abrasion (g) | Abrasion (g) |
| DIR Munich | Wheel track | 163 | 15 | 99 |
| | Oil track | 111 | 20 | 110 |
| DIR Lindau | Wheel track | 128 | 75 | 89 |

| | | | | |
|---|---|---|---|---|
| | Oil track | 174 | 89 | 141 |
| **Mean Values** | | **144** | **50** | **110** |

The cores from the untreated area before preservation showed abrasion in the range of 111-174 grams. The mean value is 144 grams. After preservation, only significantly fewer aggregate grains could be removed from the surface in the surface wear testing machine. The abrasion quantities here are between 15 and 89 grams with an average value of 50 grams. The results of the test clearly showed that the preserved core top layers had a significantly higher aggregate retention capacity than the untreated cores.

In 2016 it was noted that the treated road surfaces on the A96 have not changed significantly since preservation in 2013. The traffic as well as three winter periods with frost and de-icing salt exposure were tolerated without further damage to the surface of the porous asphalt surface course.

**Foreign Object Debris (FOD)**

Alderney Airport in the Channel Islands has an asphalt runway approximately 18 – 20 years old and heavily oxidised. Some large areas had been resurfaced over the last few years. Routine FOD sweeps of the runway, taxiway and apron were collecting up to 50kg each run, with a noticeable increase during the winter months.

The client was looking at a detailed solution for redeveloping the airport. Treatment with an asphalt preservative would provide a major improvement in the surface quality of Alderney Airport's runway, aprons and taxiway for aircraft. Thereby, extending the operational life of the runway.

All of the works took place at night after the airport closed and this has enabled the airport to maintain services during the day. The runway surfaces were grip-tested each day to ensure continued safe operations and the results showed no significant change in friction levels compared to results taken before the work commenced.

The airport runway, taxiway and apron were all treated with asphalt preservative in September 2018, Table 5 shows the results of the annual FOD collections up to June 2019.

**Table 5 – Annual FOD Collections**

| Year | FOD Mass (kg) |
|---|---|
| 2013 | 2105 |
| 2014 | 2197 |
| 2015 | 3155 |
| 2016 | 4342 |
| 2017 | 3227 |
| 2018 | 3014 |
| 2019* | 177 |

* Up to, and including June 2019

In 2018, the average monthly FOD mass collected was 321kg before treatment. Following treatment in September 2018, the FOD mass has now reduced to a monthly average of just 34kg.

The results in reduction of FOD Mass are evident from continued monitoring and maintenance of the runway, taxiway and apron surfaces. To date we have seen a near 90% reduction in material being shed from the surface and this is a very visible measure of the effectiveness of the product.

**Rheological Data**

An application of the Asphalt Penetrative Preservation will protect the surface course binder against the effects of oxidation. It is sealing the surface of the asphalt, preserving the condition of the bitumen, which would be expected to directly extend the life of the pavement, and slow down the rate of oxidation.

It is considered that once installed, a 40/60 (50) Pen bitumen will drop to around the 30 – 37 Pen range due to the immediate hardening effect of the high temperature required in the asphalt mixing process. Further oxidation will see this value reduce over time. When applying asphalt preservation to a relatively fresh surface course it is possible to measure the rate of oxidation over a period of time by comparing the bitumen properties with an untreated control section.

**M4, Junction 10 (Bracknell) and Junction 11 (Reading Central), UK**

Asphalt Penetrative Preservation was applied in July 2014 to an SMA surface course, 18 months after installation that took place in December 2012. Cores were extracted in April 2018, nearly 4 years post application.

Dynamic Shear Rheometer (DSR), penetration (EN 1426) and rheological ageing testing were carried out on bitumen samples recovered from cores extracted on the M4 and compared to a typical 40/60 Pen grade bitumen.

**Table 6 – Rheological Data, M4**

| | **Penetration (dmm)** | **Softening Point °C** | **G*/Sin(d) x10-5** | **Initial** | **Post RTFOT** | **Post Pav** |
|---|---|---|---|---|---|---|
| Average M4 Control | 23 | 60.3 | 10.0 | | | |
| Average M4 Treated | 36 | 57.3 | 5.2 | | | |
| PG 40/60 Pen | | | | 51 | 37 | 22 |
| G*/Sin(d) 40/60 Pen | | | | 3.52 | 5.92 | 19.61 |

Looking at the binder penetration data, the untreated asphalt has aged hardened to 23 Pen, which is typical for a 5 - 6 years old thin layer SMA. The treated asphalt is exhibiting a binder penetration value similar to a relatively freshly laid 40/60 Pen asphalt material. The rate of oxidation has been slowed down to show that the treated asphalt is also nearly 6 years old but has the binder properties of a freshly laid asphalt.

G*/Sin(d) can be indicative of aged binder when comparing paving grade bitumen results. Reviewing the results, the penetration of the binder of the treated section is decreasing more slowly over time than that of the binder recovered from the non-treated section. The differences in softening point are less marked, however they are also suggestive that the softening point of the binder in the treated section is lower than that in the non-treated section.

The results illustrate that an increasing G*/Sin(d) figure shows aged binder. The results from binders analysed from the M4 support the need for preservation, G*/Sin(d) figure from treated binder is almost half the figure from the control binder. Whilst the dataset is small, the findings do suggest that preservation slows down the rate of oxidation.

**Aberconway Road, London, UK**

Aberconway Road was surfaced with a 14mm SMA in 2001; 18 months later in 2002 a large section of the site received an application of preservation treatment. In 2009 part of the treated section received a further application of Asphalt Penetrative Preservation. This site encompassed a control, a treated once and a treated twice sections to demonstrate the performance of the preservative over the life of an asphalt surface course using a repeat second application.

Recovered binder properties are used as an indicator of bitumen hardening through in-service ageing. Recovered penetration values from the untreated control section of cores extracted in 2009 had a figure of 18 Pen, and the carriageway was deemed to be performing satisfactorily. At the time of testing, this result was typical of a 7 - 8 years old 40/60 Pen binder.

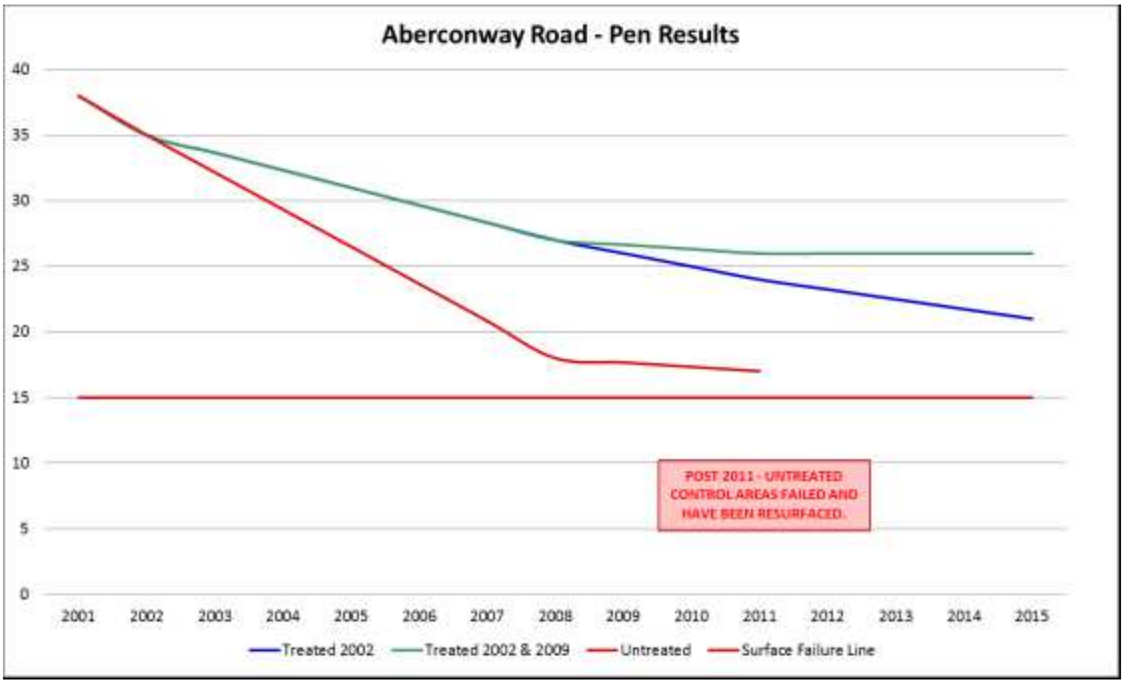
Recovered penetration values from the treated once section extracted in 2009 had a figure of 27 Pen. This material was not showing the signs of deterioration that were expected for a 7 - 8 years old material. The result was much higher than the untreated control section, demonstrating that the binder is retaining its flexibility.

Experience in the UK shows that negative textured materials such as SMA oxidise down to a penetration of below 15 Pen over approximately 10 years. Once the binder falls below 15 Pen the embrittlement is such that it can no longer flex and hold the matrix together. Most of original untreated control section on this site was replaced in 2011.

Comparing the chart lines with the untreated section that shows the natural deterioration, in 2015 the treated once section was showing similar results to a 6 years old asphalt surface course, and the treated twice section the same as a 4 years old asphalt surface course after 14 years' service life.

The client normally expects SMA material to last for 7 – 8 years before reactive maintenance, and in 2019 the treated sections of asphalt are still performing some 17 years after the asphalt preservation treatment was applied. The treated twice section is looking much better than the treated once section and the results of the recovered binder testing are showing that the ageing has almost flat-lined.

**Figure 2 – Aberconway Road, UK Penetration Test Results**




**Asset Management – Client Testimonials**

Interviews have been undertaken with many highway network and airport managers regarding the use and benefits of Asphalt Penetrative Preservation, who after many years of repeated use have adopted it as part of their preventative maintenance schedule.

**M40 Motorway, UK**

"UK Highways is satisfied that the Asphalt Penetrative Preservation system has delivered on its performance claims for significantly reduced maintenance and repair costs and has delivered improved network availability and resilience. As a result, we anticipate substantial lifecycle cost savings over the course of the remaining period of our concession, which runs to 2026." [John Gardner, General Manager, M40, June 2019]

**A50 Dual Carriageway, UK**

"Connect has used an Asphalt Penetrative Preservation system on its road concessions since 2008 and found it to be a cost-effective method of extending the life of its bituminous surfacing materials. During this period Connect have experienced a 65% improvement on interventions on treated versus untreated areas. Because of this Connect expects to continue to utilise surface preservatives where appropriate for the remainder of its concession's lifespans." [Dave Groves, Regional Operations Manager, Connect Roads, A50, June 2019].

"The original material, SMA was installed in 1998 and first treated with an Asphalt Penetrative Preservation system in 2009 after 11 years of service. At this time, the surface would have been considered as reaching the end of its normal life expectancy. In 2013 circa 2000 $m^2$ of the 6300 $m^2$ required patching but two thirds (circa 4300 m2) of the treated area was still considered serviceable and were retreated with Rhinophalt®. These remaining areas were reviewed and retreated in 2018 as they were still considered serviceable 9 years after their first treatment and 20 years after installation." [Matthew Nance Operations Manager, A50, June 2019].

**Alderney Airport, UK**

"This project will result in a major improvement in the surface quality of Alderney Airport's runways, aprons, and taxiway for aircraft and it represents a significant investment in the island's transport infrastructure. The results in reduction of

FOD Mass are evident from our continued monitoring and maintenance of the runway, taxiway and apron surfaces. To date we have seen a near 90% reduction in material being shed from the surface and this is a very visible measure of the effectiveness of the product." [Colin Le Ray, General Manager, Alderney Airport, June 2019]

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