PUBLISHED PROJECT REPORT PPR843

Monitoring of retextured concrete surfaces, M25 J10 to J8

Final report

P D Sanders
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Executive summary

After an extended period in service, concrete carriageways suffer from a loss of surface laitance, leading to deterioration in skid resistance and texture depth. This is a combination of factors that is associated with reductions in high speed friction and a potentially higher accident risk.

A method of rectifying these issues is through the process of re-texturing; the mechanical removal of surface material to create surface texture. Highways England are currently assessing the performance of various concrete re-texturing techniques and the work presented in this document will add to the current body of knowledge pertaining to the fine milling process.

The fine milling process is an adaptation of the cold milling process which uses a rotating profiled drum to remove surface material. The fine milling process differs from cold milling in that the drum is constructed from hundreds of point attack tools arranged in a grid pattern with spacings less than 8 mm; cold milling spacings are generally larger.

The fine milling treatment is being used on the M25 under a departure from standards granted by Highways England. As a requirement of the departure TRL was commissioned to monitor the skid resistance, friction and surface condition at two locations that were treated in March and September 2015 respectively. The monitoring was carried out as a series of five surveys undertaken between May 2014 and May 2017.

From the measurements carried out the following conclusions can be made:

- Average side-force skid resistance measurements from the most recent survey are very close to the Investigatory level for non-event dual carriageways and measurements are now below those measured before the sites were treated.
- The treatment appears to have created a marked improvement in high speed friction values, but these have reduced over the monitoring period to levels similar to those before application.
- The texture depth performance of the sites is highly variable but the bulk of the measurements were within TRACS Condition Category 2 (lower level of concern).
- Texture depth and side-force skid resistance measurements are highly variable along the length of the sites which appears to be indicative of the treatment.
1 Introduction

After an extended period in service, concrete carriageways suffer from a loss of surface laitance, leading to deterioration in skid resistance and texture depth. This is a combination of factors that is associated with reductions in high speed friction and a potentially higher accident risk (Roe, Parry, & Viner, 1998).

The fine milling process is an adaptation of the cold milling process which uses a rotating profiled drum to remove surface material. The fine milling process differs from cold milling in that the drum is constructed from hundreds of point attack tools arranged in a grid pattern with spacings less than 8 mm; cold milling spacings are generally larger. During milling, the rapidly revolving drum is forced into the pavement surface and is pulled along the road at a constant speed. The milling drum cuts a fine texture into the road surface and also removes some of its large scale undulation.

The fine milling treatment is being used on the M25 under a departure from standards granted by Highways England. A requirement of the departure is that monitoring be carried out to assess the side-force skid resistance, high speed friction and road surface condition independently of the annual assessments of side-force skid resistance and texture depth.

TRL was commissioned to monitor the skid resistance, friction and surface condition of two locations treated with the fine milling technique in March and September 2015 respectively. The monitoring was carried out as a series of five surveys undertaken in:

- May 2014
- May 2015
- October 2015
- March 2016
- May 2017

This regime of surveys was chosen in order to capture the early life and longer term performance characteristics of the treated surfaces. This report presents the results of the monitoring; discussion about the performance of the surfaces is given throughout.
2 Measurement equipment used

2.1 Skid Resistance Development Platform

The Sideway-force Coefficient Routine Investigation Machine (SCRIM) is the standard device for monitoring the side-force skid resistance condition of the UK trunk road network, and is also used by many local authorities. The Highways England Skid Resistance Development Platform (SkReDeP) incorporates SCRIM equipment and is shown in Figure 2-1. Measurements from this device provide information that can be used to compare surfacings with the requirements for skid resistance laid out in the Design Manual for Roads and Bridges (HD28/15 Skidding resistance, 2015).

![Figure 2-1 Skid resistance development platform, incorporating SCRIM](image)

SCRIM uses a smooth test tyre angled at 20 degrees to the direction of travel, mounted on an instrumented axle, to record a SCRIM Reading (SR) for every 10 m length of road. The SR is the average ratio between the measured side-force and the vertical load. SCRIM readings are speed-corrected to the standard test speed of 50 km/h and converted into SCRIM Coefficient (SC), by applying a correction factor, for reporting and comparison with the relevant standards.
2.2 Pavement Friction Tester

The Pavement Friction Tester (PFT) (Figure 2-2) is a locked-wheel friction testing device comprising a tow vehicle and trailer. The trailer holds the test wheel, which is mounted on an instrumented axle. The test wheel can be independently braked and the forces acting upon it measured to determine the friction between the test tyre and road surface. For the purposes of this study the PFT was used with a smooth ASTM test tyre (ASTM, 2008) under wet conditions at 90 km/h.

During testing, the tyre contact patch slides over the surface at the same speed as the towing vehicle (i.e. test speed is the same as slip speed). During testing, the load and drag forces on the tyre are measured every 0.01 seconds throughout the braking cycle and from this the peak\(^1\) and locked-wheel\(^2\) friction are determined.

![Pavement friction tester](image)

**Figure 2-2 Pavement friction tester**

The use of the PFT is described in ASTM standard E274/274M-11 (ASTM, 2011) which was used as reference throughout the monitoring. Measurements made with the PFT were compared with pertinent historic data.

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\(^1\) Peak friction is the maximum friction value generated as the test wheel begins to slip.

\(^2\) Locked-wheel friction is the friction value generated when the test wheel is fully locked.
2.3 Highways Agency Road Research Information System

The Highways Agency Road Research Information System (HARRIS) 2 (Figure 2-3) is used to demonstrate the application of state of the art technology for the assessment of pavement condition at traffic speed.

![Figure 2-3 HARRIS 2](image)

This vehicle is equipped with high resolution systems for the measurement of road shape and visual condition along with the additional capabilities of ground penetrating radar and road marking retro-reflectivity measurements. HARRIS 2 uses a combination of image gathering and laser displacement measurements to:

- Measure road alignment in terms of crossfall, gradient and curvature
- Measure texture at user-definable longitudinal intervals as short as 0.2 mm
- Measure transverse road profile using a single scanning laser at 1000 points across a 4 m width of traffic lane
- Measure longitudinal road profile along twenty-five measurement lines, coincident with the measuring points for transverse profile, at 50 mm longitudinal intervals
- Collect road surface images at a resolution better than 2 mm over a survey width of 3.5 m in order to detect surface defects
- Collect wide angle forward facing images using three cameras and on board real time image stitching.
3 Description of the monitoring sites

Measurements were made on two lengths of the anti-clockwise (anti-C/W) carriageway of the M25 between Junction 10 and Junction 8. The locations of the sites are described in Table 3-1 and shown on the map in Figure 3-1. Most of the surface material on both sites is concrete but some asphalt areas exist at bridge decks for instance. Side-force skid resistance and texture measurements were made on the asphalt areas but omitted from the analysis.

Table 3-1 Details of monitoring sites

<table>
<thead>
<tr>
<th>Surface</th>
<th>Date treated</th>
<th>Approximate marker post</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>Site 1</td>
<td>September 2015</td>
<td>71/5</td>
<td>64/1</td>
</tr>
<tr>
<td>Site 2</td>
<td>March 2015</td>
<td>59/0</td>
<td>52/8</td>
</tr>
</tbody>
</table>
Figure 3-1 Location of the monitoring sites (Ordnance Survey)
4 Monitoring programme

The monitoring programme consisted of a series of surveys carried out over a three year period. Table 4-1 summarises the survey dates and the nominal ages of the treatment when the surveys were carried out.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Nominal age of the treatment at date of survey</th>
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</thead>
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<tr>
<td></td>
<td>May 2014</td>
</tr>
<tr>
<td>Site 1</td>
<td>-16 months</td>
</tr>
<tr>
<td>Site 2</td>
<td>-10 months</td>
</tr>
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</table>

Side-force skid resistance measurements were made using SkReDeP on each surface at a test speed of 80 km/h, in the nearside wheel path of lane 1; these measurements were then speed corrected to represent measurements made at 50 km/h and reported as values of SC.

High speed peak and locked-wheel friction measurements were made using the PFT at a test speed of 90 km/h, in the nearside wheel path of lane 1 with a smooth test tyre and a water film thickness of 1 mm. A minimum of five determinations of peak and locked-wheel friction were made on each site but owing to the site lengths more measurements were typically made. Peak and locked-wheel friction values collected at 90 km/h are reported as measurements of P-Fn90 and L-Fn90 respectively.

HARRIS 2 was used to determine the following parameters in lane 1:

- Texture (Sensor measured texture depth (SMTD)), measured in the nearside wheel path
- Transverse road profile, reported as rutting values for both wheel paths
- Longitudinal road profile, measured in the nearside wheel path

Multiple test passes were made with SkReDeP and HARRIS 2 on each surface to ensure the validity of the results but the results from a single run are reported in the following chapter.
5 Results of the May 2017 survey

This chapter presents the results collected during the most recent survey carried out in May 2017. A full set of graphs showing results collected from previous surveys is available in the appendices and average measurements from previous surveys are used for comparison in Chapter 6, which presents trends in the data.

Side-force skid resistance results are presented with reference to the Investigatory Level (IL) for motorways, usually 0.35, described in HD28 of the Design Manual for Roads and Bridges (HD28/15 Skidding resistance, 2015). The IL is the level at or below which an investigation of the surface performance is triggered.

High speed friction results are shown with typical ranges that have been observed on concrete and Thin Surface Course Systems (TSCS). The typical ranges represent the 90th percentile range of several thousand friction tests measured on surfaces of these types. They have been included as a guide and do not imply safe, nor acceptable performance.

Road surface condition results have been compared to the categories describing road condition laid out in HD29 of the Design Manual for Roads and Bridges (HD29/08 - Data for pavement assessment, 2008) and shown in Table 5-1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Sound – no visible deterioration.</td>
</tr>
<tr>
<td>2</td>
<td>Some deterioration – lower level of concern. The deterioration is not serious and more detailed (project level) investigations are not needed unless extending over long lengths, or several parameters are at this category at isolated positions.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate deterioration – warning level of concern. The deterioration is becoming serious and needs to be investigated. Priorities for more detailed (scheme level) investigations depend on the extent and values of the condition parameters.</td>
</tr>
<tr>
<td>4</td>
<td>Severe deterioration – intervention level of concern. This condition should not occur very frequently on the motorway and all purpose trunk road network as earlier maintenance must have prevented this state from being reached. At this level of deterioration more detailed (scheme level) investigations should be carried out on the deteriorated lengths at the earliest opportunity and action taken if, and as, appropriate.</td>
</tr>
</tbody>
</table>

5.1 Side-force skid resistance

Figure 5-1 shows average SC values and the 5th and 95th percentile values (represented by the error bars) for each test section. Figure 5-1 shows that both sites are providing an average skid resistance very close to the IL. The 5th percentile of measurements for both sites is well below the IL.
Figure 5-1 Summary of side-force skid resistance measurements

Skid resistance values for each 10 m section of carriageway along the length of each site are shown in Figure 5-2; the shaded areas represent lengths of asphalt surfacings which have been excluded from the analysis. This figure shows that the skid resistance performance of both sites is highly variable, ranging between approximately 0.15 and 0.75 SC.

Figure 5-2 Side-force skid resistance measurements along the sites
5.2 High speed friction

Average Locked-wheel (L-Fn90) and Peak friction (P-Fn90) values and the 90\(^{th}\) percentile range of values (represented by the error bars) are shown in Figure 5-3 and Figure 5-4 respectively. These figures show that both sites are providing high speed friction values well within the range expected of concrete materials. The variability of peak friction measurement is much greater than that of the locked-wheel friction, but this is to be expected as the peak friction determination is made over a much shorter distance than the locked-wheel friction.

![Figure 5-3 Average locked-wheel high speed friction values, L-Fn(90)](image1)

![Figure 5-4 Average peak high speed friction values, P-Fn(90)](image2)
5.3 Surface condition

5.3.1 Texture depth

Texture depth values in all of the four TRACS condition categories were measured on both sites, but the bulk of these measurements lie within Category 2 (0.8 mm to 1.1 mm SMTD), see Figure 5-5. A large variability in texture depth values can be observed in Figure 5-6 with values ranging from around 0.25 mm to in excess of 2.00 mm SMTD. Variability in texture depth is common for concrete roads, but the levels shown in Figure 5-6 are much greater than would normally be expected.
5.3.2 Rutting

Concrete pavements are inflexible and so rutting is not expected. The majority of values are therefore within TRACS Category 1 (<6 mm) and Category 2 (6 mm to 11 mm).

![Rutting summary](image)

5.3.3 Longitudinal profile

Longitudinal profile measurements are generally within TRACS Category 1 and Category 2. Site 2 is demonstrating a greater variation in longitudinal profile than Site 1 with some values being recorded in Category 4. On both sites there is a prevalence for a greater variability in longitudinal profile at the 10 m wavelength; this has been observed on other concrete sites and could be related to the stepping between bays which are typically 5 m long.

![Longitudinal profile summary](image)
6 Historical trends

The following graphs show how the surfaces performed over the length of the monitoring period. Average side-force skid resistance, high speed friction, and texture results are compared for each visit. Average values for each measurement have been presented with reference to the nominal age of the treated surface at the time of testing.

6.1 Side-force skid resistance

The historical side-force skid resistance trend for Site 1 (Figure 6-1) shows as subtle improvement was achieved after the application of the treatment. This improvement slowly declines over the 20 month observation period to a level slightly below that observed before the treatment was applied.

The trend for Site 2 also shows a reduction in side-force skid resistance over the length of the observation period. An improvement in skid resistance, from that measured 10 months prior to treatment, was however not observed as a result of the treatment.

It is noteworthy that average levels of skid resistance before the treatment was applied, on both sites, were above the 0.35 unit investigatory level for these sites.

![Figure 6-1 Side-force skid resistance trend](image-url)
6.2 High speed friction

The historical locked-wheel and peak high speed friction trends (Figure 6-2 and Figure 6-3) show the same pattern of behaviour for both sites. Initially the friction values increase substantially after the treatment is applied, and then a progressive decline occurs leaving the most recent values similar to those recorded before treatment was applied.
6.3 Texture depth

The historical trends in texture depth data (Figure 6-4) show a marked improvement in values between the before and after treatment surveys. Interestingly there does not appear to be a reduction in values with time over the observation period. Texture depth and locked-wheel high speed friction are usually highly correlated for concrete materials but no such correlation is observed in these data.

It is noteworthy that the texture depth values in Figure 6-4 are average values from a highly variable dataset. Whilst this is a suitable metric for assessing the overall texture depth performance of the materials it may be inappropriate for assessing the correlation with high speed friction measurements made at discrete locations.
7 Conclusions

This report has detailed surveys on two sites on the M25 anti-clockwise carriageway where the concrete surfacing was reported to have undergone a fine milling retexturing treatment.

From the measurements carried out the following conclusions can be made:

- Average side-force skid resistance measurements from the most recent survey are very close to the Investigatory level for non-event dual carriageways and measurements are now below those measured before the sites were treated.
- The treatment appears to have created a marked improvement in high speed friction values, but these have reduced over the monitoring period to levels similar to those before application.
- The texture depth performance of the sites is highly variable but the bulk of the measurements were within TRACS Condition Category 2 (lower level of concern).
- Texture depth and side-force skid resistance measurements are highly variable along the length of the sites which appears to be indicative of the treatment.
References


Appendix A  Side-force skid resistance

Figure A - 1 Side-force skid resistance values May 2014

Figure A - 2 Side-force skid resistance values May 2015

Figure A - 3 Side-force skid resistance values October 2015

Figure A - 4 Side-force skid resistance values March 2016

Figure A - 5 Side-force skid resistance values May 2017

Figure A - 6 Side force skid resistance trend
Appendix B  High speed friction

B.1  Locked-wheel friction

Figure B - 1 Locked-wheel high speed friction May 2014

Figure B - 2 Locked-wheel high speed friction May 2015

Figure B - 3 Locked-wheel high speed friction October 2015

Figure B - 4 Locked-wheel high speed friction March 2016

Figure B - 5 Locked-wheel high speed friction May 2017

Figure B - 6 Locked-wheel high speed friction trend
B.2 Peak friction

Figure B - 7 Peak high speed friction May 2014

Figure B - 8 Peak high speed friction May 2015

Figure B - 9 Peak high speed friction October 2015

Figure B - 10 Peak high speed friction March 2016

Figure B - 11 Peak high speed friction May 2017

Figure B - 12 Peak high speed friction trend
Appendix C  Texture depth

Figure C - 1 Texture depth May 2014

Figure C - 2 Texture depth May 2015

Figure C - 3 Texture depth October 2015

Figure C - 4 Texture depth March 2016

Figure C - 5 Texture depth May 2017

Figure C - 6 Texture depth trend
Monitoring of retextured concrete surfaces, M25 J10 to J8

This document presents the results of an assessment of a fine milling treatment applied to the M25 under a departure from standards granted by Highways England. As a requirement of the departure TRL was commissioned to monitor the skid resistance, friction and surface condition at two locations that were treated in March and September 2015 respectively. The monitoring was carried out as a series of five surveys undertaken between May 2014 and May 2017.

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