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Highways England 2018 National Deflectograph Accreditation Trial

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Executive summary

Deflectograph accreditation trials are held annually by TRL on behalf of Highways England. The objective is to monitor the performance of all Deflectographs operating on Highway's England Strategic Road Network (SRN). By examining and monitoring the results from the machines operating on specified test sections of the reference site, the performances of individual machines, and the whole UK fleet, are assessed.

The 2018 trial was held during the period 27th to 28th February 2018. The site used was the twin horizontal straights of the Horiba-MIRA proving ground. This was the twenty-third year in which TRL took full responsibility for the planning and running of the trials. Ten machines attended the trial.

The format of the 2018 trial was broadly consistent with that of recent years, comprising two scheduled days of testing and one contingency day. The 2018 trial included checks on the distance calibration first added to the 2012 trial. The first day of the trial was dedicated to static inspections and calibration checks, with the second day used for the main running trials. The reserve day was not used. The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Deflectograph survey devices" (TRL, 2016).

Nine of the ten machines that participated in the 2018 accreditation trial met the mandatory requirements of the trial (wheel weight, deflection measurement and distance measurement) and can therefore be considered for approval to survey Highways England's SRN.

Three of the ten machines achieved a high performance rating and the remaining seven a medium performance rating with regards to the measurement of pavement temperature at depth.

For the 2018 trial, participants were also asked to provide air and surface temperature measurements (if they had the equipment fitted). Five machines provided surface temperature measurements; two of these machines achieved a High performance, two a Medium and one a low. The same five machines provided air temperature measurements, however there was uncertainty on whether the reference dataset was suitable and as such no performance levels would be assigned for the air temperature measurements. It is recommended that the reference data measurement technique and the assessment criteria are reviewed and further refined in future trials.

The results from the trial are discussed in this report and are provided in the accreditation certificates issued to the trial participants. These certificates are also accessible at:

http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-collection/deflectograph/index.cfm

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1 Introduction

Deflectograph accreditation trials are held annually by TRL on behalf of Highways England. The objective is to monitor the performance of all Deflectographs operating on Highways England's strategic road network. By examining and monitoring the results from the machines operating on specified test sections, the performances of individual machines, and the whole UK fleet, are assessed.

The 2018 trial was held during the period 27th to 28th February 2018. The site used was the twin horizontal straights of the Horiba-MIRA proving ground which is further discussed in Section 2. This was the twenty-third year in which TRL took full responsibility for the planning and running of the trials and the sixth full trial at Horiba-MIRA. Ten machines attended the trial. The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Deflectograph survey devices" (TRL, 2016).

For convenience, throughout this report, the machines are referred to by their running numbers rather than by the Operator. For ease of record keeping, running numbers are retained from year to year with new machines being assigned new numbers. By agreement with Highways England, Appendix A lists the machines, operating authorities and performance at the trial. Historically, this was also agreed with the ADEPT (formerly CSS) Deflectograph Operators Group before it disbanded.

2 Test site

2.1 Details of the test site

The twin horizontal straights area of the Horiba-MIRA Proving Ground comprises two lengths of straight and essentially level track just over 1.5km long joined by banked bends at either end. During October 2010 Highways England arranged for a length of the nearside lane on one of the straights to be reconstructed, in order to produce three sections of different constructions/strength levels. These three sections were designed specifically for use in the accreditation of Deflectographs and other pavement deflection measuring devices. These sections are referred to as HECP_01, HECP_02 and HECP_03 (Highways England Calibration Pavement) during this report. The sections are each 70m in length (however the beginning and end 5m are excluded in the analysis to help avoid alignment issues, resulting in 60m sections) and the layout and test route is shown in Figure B.1 in Appendix B. Nominal construction details of the test sections can be found in Appendix C.

In order to demonstrate the suitability of the sections identified at Horiba-MIRA, a transitional trial was held on the 12th and 13th September 2011 (Brittain & Sanders, 2012). This trial compared a sub-set of the UK Deflectograph fleet, initially following the traditional approach using the historic test sections of the TRL track and then moving to follow the proposed new procedures and sections at Horiba-MIRA. The work demonstrated that the Horiba-MIRA site was suitable for the accreditation of Deflectograph machines. As well as the trial process, the accreditation criteria were reviewed following the 2011 transitional trial.

The trial process and the criteria used for the 2018 trial are discussed in Sections 3 and 4 respectively.

2.2 Variability of NS deflections on HECP_02

During the transitional trial it was found that there was a localised high deflection area in the NS wheel path of section HECP_02. This high deflection area was traversed in some but not all runs and only affected the NS wheel path of section HECP_02. This is illustrated in Figure 2.1 which is a plot of some of the data collected at the transitional trial over the three test sections.

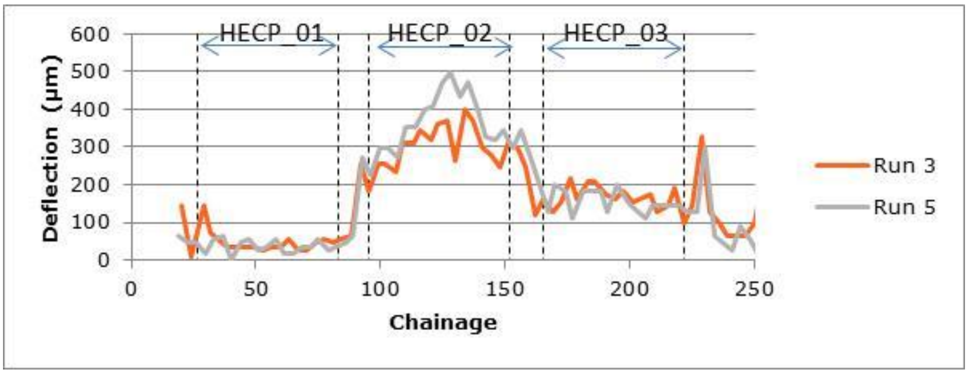

Figure 2.1 Example plot of nearside deflections for Horiba-MIRA test sections observed during the transitional trial

In order to try and reduce this effect for the 2013 trial, small cones were placed on the test track to mark the survey test line for the whole test site. These cones were placed either side of the machine's test path (as shown in Figure 2.2), so that any deviation in the test line would cause a cone to be knocked over and thereby any deviation could be recorded.

Figure 2.2 Image illustrating cone positons during testing

During the analysis of the 2013 trial it was found that this approach reduced the variability of the deflections for the NS wheel path of HECP_02. It was therefore decided that these cones will be placed along HECP_02 for future trials in order to reduce this variability.

3 Trial format

The format of the 2018 trial was kept broadly the same as that of recent years, with two scheduled days of testing and one contingency day. The review of the accreditation trial procedure following the transitional trial recommended that checks on the distance calibrations of the machines should be included. This was incorporated into the 2012 trial and has been repeated in all subsequent trials.

Each crew carried out a machine inspection in advance of the trials and a certified checklist was submitted before the machine could be included in the running trials.

3.1 Day 1

The first day is dedicated to static inspections, distance calibrations and a warm-up lap to help identify any major issues.

On arrival, each machine is weighed to determine the loads applied by each wheel to the road surface. The wheel weight values are then used in the trial software to allow corrections for rear wheel weight to be applied to the deflection data.

The operators' thermometers are collected and are compared against each other in a stabilised environment.

The machines are then taken to the test track where the survey crew perform a distance calibration followed by a single lap of the test circuit to provide some preliminary data to try and identify any machines which have any significant issues.

3.2 Day 2 and day 3

The second day is the main running trials. This includes repeat measurements of deflection, temperature and distance. If bad weather or, other unforeseen circumstances arise then the contingency day (day 3) allows for additional time to conduct these tests.

On arrival at the test track the crews are asked to perform a static calibration before undertaking laps of the test sections.

Deflection measurements are made over the three test sections, and temperature measurements are collected from two pre-drilled holes (40mm depth) located before and after the deflection test sections. The distance check involves the crews surveying a length between two cones (separated by more than 400m) and comparing the resulting data to the reference measurement of the cone separation.

The machine running order is randomly determined before testing begins, with all machines running in convoy to cover all the sections in a single circuit. Each machine is required to complete a minimum of five measurement runs. Data from the survey machines is handed in after each run and real-time data processing enables collated measurements to be available for review as the trials proceed.

In order to improve the alignment of data, at the start of each run crews are asked to stop their machines and align the deflection beam frame to the forward-most position of the cycle with the truck wheels at a defined "beam down" point.

HD29/08 (Design Manual for Roads and Bridges, 2008) sets a maximum rate of temperature increase of 2.5˚C per hour at 40mm for deflection testing on the trunk road network. This requirement is intended to ensure that temperature corrections used to adjust deflections to a standard temperature of 20˚C stay within the validity of the equations.

Although temperature corrections are not carried out in analysing data from the accreditation trial, the temperature is monitored at the same location as the operator temperature measurements (i.e. before and after the deflection test sections) at 40 and 100mm depths to inform any conclusions drawn. Automatic data-loggers are used to provide a record every minute during deflection testing.

While the machines are running, TRL staff made inspections of the dynamic operation of each machine, including a timed section to verify that operating speeds are acceptable.

4 Criteria for acceptability and the transitional trial

The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Deflectograph Survey Devices" (TRL, 2016). This document is a live document (i.e. is subject to change) and the July 2016 version of the document was used for the trial. The relevant section of the document is reproduced verbatim below in Section 4.1. Note in the text below, "Equipment" is a defined term and refers to the overall machine being assessed, incorporating the measuring systems and the survey vehicle. "System" refers to an individual measurement system installed on the Equipment e.g. the NS deflection measurement system, temperature measurement system etc. "Employer" refers to the organisation that commissions the Survey Contractor to complete a survey and will generally be the final user of the data provided. "Owner" refers to the organisation or individual to which Equipment belongs and to whom Accreditation Certificates are awarded. In addition, the copied text refers to other parts of the specification which are not reproduced in this report.

4.1 Trial criteria from the Accreditation and QA document

E.3 Equipment inspection

E3.1 Contractors will be provided with an inspection check sheet to complete and provide to the Auditor in advance of the Trial. The Contractors will also be asked to supply evidence that the required Calibrations have been performed (see section C.4).

E3.2 Equipment will also be inspected at the trial to ensure that they are in a suitable condition to conduct the tests. This will include verifying that the Equipment appears to be in good general mechanical order.

E3.3 Equipment will be weighed so that Load normalisation of the survey data can be carried out. The Equipment should be within the limits given in Table 1.

Table 1 – Criteria for wheel weights

Parameter	Acceptability Limit
Front Axle[1]	4500 kg ±5%
Twin rear wheel	3175 kg ±10%

E3.4 A simple of assessment of the temperature measurement System should be carried out to make sure that it is producing consistent results.

[1] It has been the experience in the Accreditation Trials that Equipment falling within approximately 10% of target limit for the front axle has performed acceptably with regards to deflection measurements. This matter has been investigated by TRL and Highways England. It has been concluded that, while consideration may be given to revising the specification limits at an appropriate point in the future, for the time being Equipment falling within this approximate front axle range would continue to be regarded as acceptable provided that they performed satisfactorily in the dynamic tests.

E.4 Running Trials

E4.1 Overview

E4.1.1 As detailed in in Appendix B, trials will be carried out on a test site separated into test stations, and laid out such that "laps" of the set of test sections can be undertaken by the Fleet for the purposes of repeating the measurements.

E4.2 Deflection testing – Mandatory Requirement

E4.2.1 The assessment for Deflection measurements is described below, and a worked example is provided in Appendix C

E4.2.2 The Equipment will undertake laps so that the following criteria are met:

- At least 5 laps are undertaken that comply with the requirements for Reference Data (see Appendix B, App B.3)
- Survey data will be collected at a target test speed of 2.4 km/h. Equipment will be checked by measuring the time taken to travel a known length. If the Equipment is found to be surveying more than 0.1km/h from this target, the survey operator will be asked to adjust their speed accordingly.
- The pavement temperature measured at a depth of 40mm must not change by more than ±2.5°C during the test lap.

E4.2.3 The Contractor will supply the deflection measurements for their Equipment from each test lap in the file formats specified by the Auditor.

E4.2.4 The Auditor will calculate:

- The load corrected mean for the Equipment for each wheel path and test section.
- The standard deviation of these mean values for the Fleet and for all of the Equipment at the trial, referred to as the Fleet between-Equipment standard deviation (BESD) and the Trial BESD. These values will be used to assess the consistency of the Equipment at the Trial.
- The standard deviation of the deflection values between laps for the Equipment for each wheel path and test section. This data is referred to as the between-run standard deviation (BRSD). These values will be used to assess the repeatability of each individual Equipment.

E4.2.5 The BRSD will be used in the initial assessment of each Equipment. During the Tests, the BRSD values will be affected by the variability of pavement temperatures during the course of the testing. Therefore the performance will be assessed by comparison against the performance of the other Equipment undertaking the Re-accreditation/Accreditation Tests.

E4.2.6 Where the BRSD values of the Equipment are significantly higher than the BRSD values of other individual Fleet Equipment, the data from the Equipment will undergo further investigation by the Auditor to determine if the Equipment is suitable for Accreditation.

E4.2.7 The Trial BESD is acceptable if it is below the criterion given in Table 2. If the trial BESD exceeds this criterion then the data will be further examined to identify outlying Equipment. This will include examining the Fleet BESD and data from individual Equipment. Outlying Equipment will be rejected and the data reassessed until the performance is acceptable.

E4.2.8 In addition, any Equipment that deviates by more than 3 times the BESD criterion from the Fleet Mean will fail Accreditation. Any Equipment that is between two and three times the BESD criterion from the Fleet mean will undergo further investigation by the Auditor to determine if the Equipment is suitable for Accreditation.

E4.2.9 The data from any Equipment rejected due to BRSD, BESD or otherwise identified as an outlier will not be used in the calculation of the Reference Data (App B.3.1).

Table 2 – Criterion for Deflection measurements

Parameter	Acceptability Limit
Between Equipment standard deviation (BESD)	≤0.0257 * Reference Data+9.88 (µm)

E4.2.10 The performance will be assessed for both wheel paths separately. To achieve Accreditation the Equipment must meet the requirements for both the NS wheel path and the OS wheel path.

E4.3 Location Referencing (Distance) – Mandatory Requirement

E4.3.1 Accreditation of an Equipment's ability to measure distance is carried out by comparing its measurements of a test length with the Reference Data (App B.3.2), repeated at least five times. The criteria applied to the test measurements are given in Table 3. Note: the tolerance allows for the basic method by which events are recorded in Deflectograph Survey Data.

Table 3 – Criteria for Measurement of Distance travelled

Parameter	Acceptability Limit
Distance measured	80% within 5m

E.5 Additional Tests

E5.1 Overview

E5.1.1 The criteria in this sub-section are specified as High, Medium and Low levels of performance. This reflects the lower level of maturity of this test. In future revisions to this document these may become mandatory criteria.

E5.1.2 Some Employers may require a specific level of performance in some or all of these additional tests to carry out Accredited Surveys on their Network.

E5.2 Temperature measurement – temperature sensor for measurement at depth

E5.2.1 If undertaking this test, the Contractor will be required to make measurements from holes supplied by the Auditor (40mm depth) so that at least eight measurements are taken during the course of the test laps. The criteria for the assessment of temperature measurement at depth are given in Table 4.

Table 4– Criteria for temperature measurement at depth

Performance level	Measurement of temperature
High	80% of the measurements are within 1˚C of the reference
Medium	50% of the measurements are within 1˚C of the reference
Low	15% of the measurements are within 1˚C of the reference
Not Suitable	Otherwise

E5.3 Temperature measurement – temperature sensor for surface measurement

E5.3.1 If undertaking this test, the Contractor will be required to make measurements of the surface temperature so that at least eight measurements are taken during the course of the test laps. The criteria for the assessment of surface temperature measurement are given in Table 4.

Table 5– Criteria for surface temperature measurement

Performance level	Measurement of temperature
High	80% of the measurements are within 1˚C of the reference
Medium	50% of the measurements are within 1˚C of the reference
Low	15% of the measurements are within 1˚C of the reference
Not Suitable	Otherwise

5 Results – Inspection day (27th February 2018)

5.1 Inspections

All ten machines arrived with completed inspection checklists and in good condition.

5.2 Wheel weights

The weights recorded for each machine are given in Table 5.1.

Table 5.1 Deflectograph weight distributions from 27 February 2018

Machine	Weight distribution including crew (kg)						
	Front NS	Front OS	Total Front	Rear NS	Rear OS	Total rear	Total Machine
2	2455	2635	**5090***	3140	3400	6540	11630
3	2350	2430	**4780***	3400	3355	6755	11535
5	2360	2345	4705	3320	3320	6640	11345
8	2265	2405	4670	3165	3270	6435	11105
9	2430	2375	**4805***	3180	3200	6380	11185
10	2360	2370	**4730***	3380	3290	6670	11400
12	2200	2350	4550	3430	3150	6580	11130
14	2380	2400	**4780***	3195	3450	6645	11425
15	2405	2560	**4965***	3440	3380	6820	11785
16	2205	2345	4550	3175	3255	6430	10980

* Exceeds tolerance defined in HD29 (see comment in Section 5.2)

Machines 2, 3, 9, 10 14 and 15 exceeded the published front axle limits. Machines 2 and 15 have exceeded the published limit since their introduction into the fleet. However, ever since Machine 2 (and, subsequently Machine 15) was introduced, there has been no measurable effect from the heavier front axle weight. This matter was reviewed by TRL and Highways England following the 2004 trials. It was concluded that, while consideration may be given to revising the specification limits at an appropriate point in the future, for the time being the differences will be noted but the affected machines would continue to be regarded as acceptable provided that they performed satisfactorily in the dynamic tests.

In the latest version of the accreditation and QA specification (see section 4.1) it notes that in the past devices falling within approximately 10% of the target limit for the front axle have been seen to perform acceptably with regards to deflection measurements. It is noted that two machines (Machine 2 and Machine 15) exceed the target by more than 10% (13.1% and 10.3% respectively). However, it was decided that the same approach (noting the difference and regarding them as acceptable provided that they perform satisfactorily in the dynamic tests).

5.3 Warm-up lap

Following the processing of data from the warm-up lap it was found that the spread of machine results was within the criteria for the average of the site (but not for HACP_03 on either wheel path). Therefore no machines were identified as requiring further investigation at this stage.

5.4 Temperature probes

The operators’ thermometers were collected up and the probes allowed to stabilise at the same temperature (using a bucket of water). No issues were identified from this check.

6 Results – Main trial day (28th February 2018)

6.1 Beam calibration check

Prior to the main running trials each crew carried out a static beam calibration check on their machine. Due to the low temperatures on the day it was decided that a test pass over the site would be conducted (with the beam down but not collecting the data) before carrying out the beam calibration check in order to warm-up the equipment before checking it. No machines were identified to TRL as not meeting the limits specified in HD29/08.

6.2 Distance measurement

A distance check length was set up on the track to assess the distance measurement systems on the machines. The reference length used was 529.75m. The difference between the measured length from each machine and the reference, along with the overall performance are given in Table 6.1. The differences between the machine and the reference are highlighted in red bold text if it exceeds the threshold for the criteria as given in Section 4.1.

Table 6.1 Distance measurement

Machine	Difference between measured length and the reference (m)						% within criteria	Performance
	1	2	3	4	5	6		
2	3.3	0.3	4.3	1.3	2.3	2.3	100	Pass
3	0.3	0.3	0.3	2.3	1.3	1.3	100	Pass
5	**-6.8**	-0.8	1.3	1.3	-1.8	3.3	83	Pass
8	3.3	3.3	4.3	3.3	4.3	2.3	100	Pass
9	4.3	2.3	1.3	0.3	1.3	0.3	100	Pass
10	1.3	-0.8	-0.8	1.3	1.3	3.3	100	Pass
12	-3.8	-2.8	-0.8	0.3	-1.8	0.3	100	Pass
14	**11.3**	-2.8	0.3	1.3	1.3	2.3	83	Pass
15	-1.8	-2.8	-1.8	1.3	2.3	1.3	100	Pass
16	0.3	4.3	0.3	1.3	.	1.3	100	Pass

On examination of Table 6.1 it can be seen that all ten machines passed the distance measurement criteria on the main trial day.

6.3 Temperatures

6.3.1 Temperature pattern shown by the data loggers

Data loggers were set-up along with thermocouples to record the 40mm and 100mm depths along with the air and pavement surface temperature. These loggers were set-up to record the measurements every minute. This data was then smoothed by taking a 9 point moving average (4 points before the time, the time and 4 points after). This smoothed data is shown in Figure 6.1 and Figure 6.2.

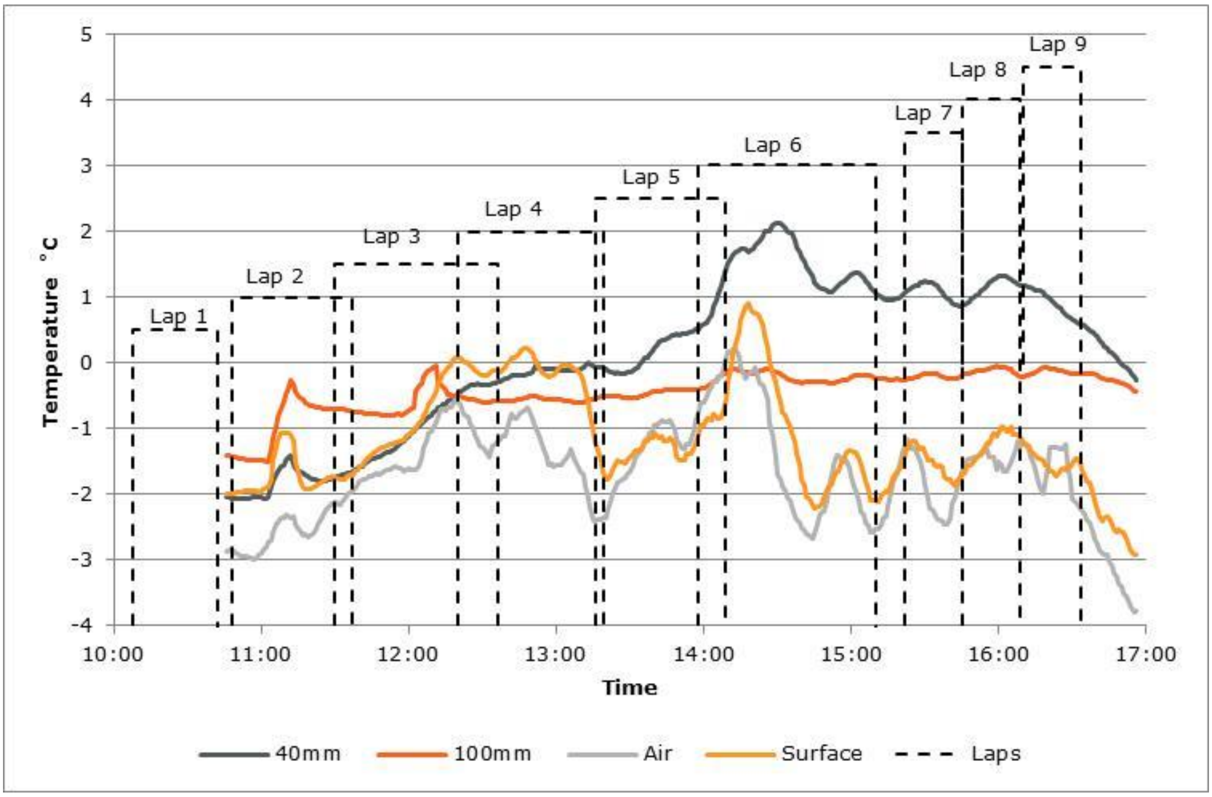

Figure 6.1 Temperature measurements from temperature station 1 (before test sections)

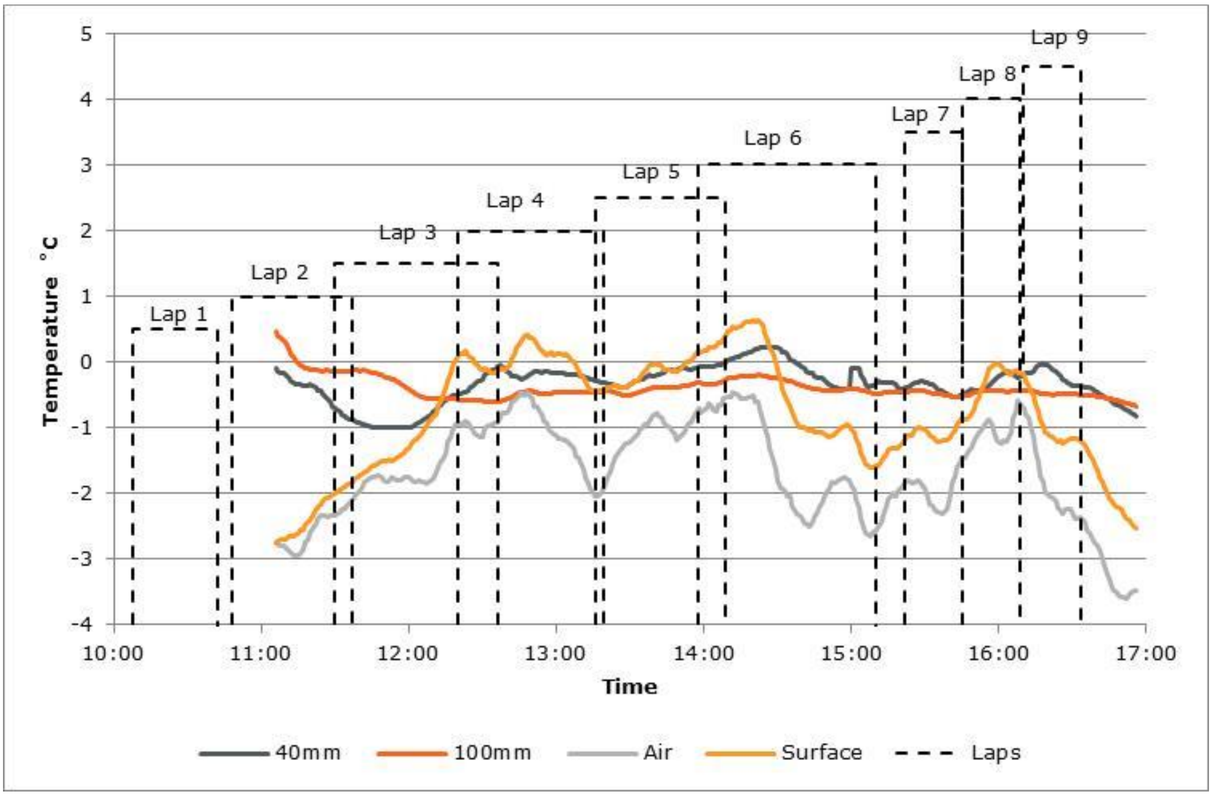

Figure 6.2 Temperature measurements from temperature station 2 (after test sections)

The graphs show the temperatures remaining relatively stable during the day. The downward slope at the start of the measurements at station 2 is due to the freshly drilled measurement holes.

As discussed in Section 3.2, HD29/08 sets a maximum rate of temperature increase of 2.5˚C per hour at 40mm for deflection testing. The temperature change per hour (calculated from 30 minute intervals) is shown in Figure 6.3.

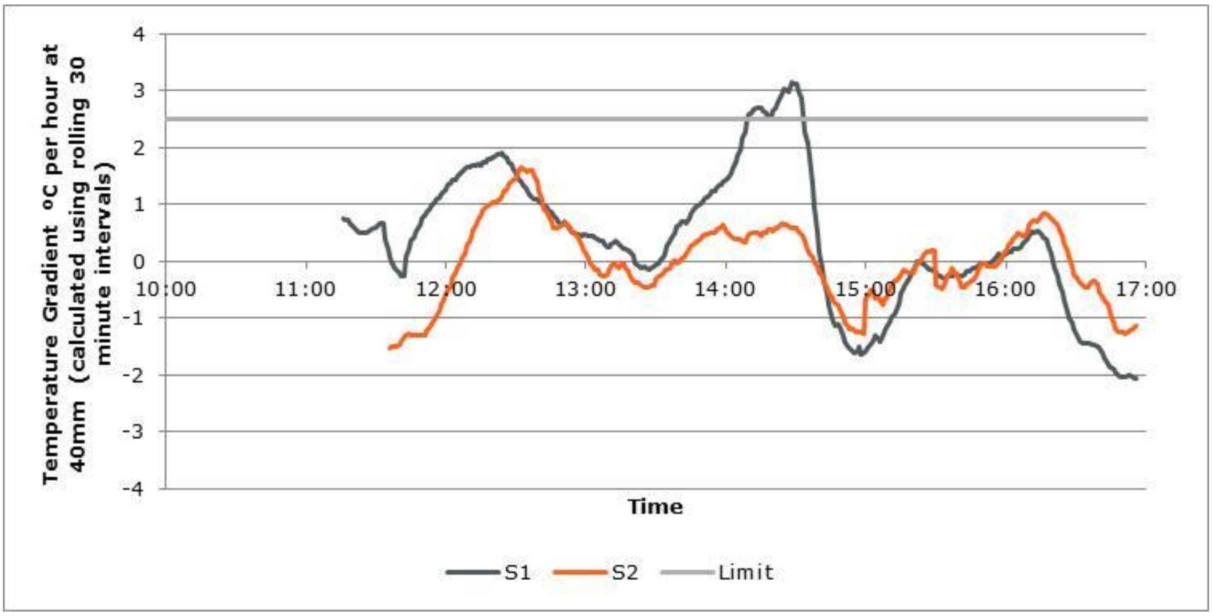

Figure 6.3 Temperature changes at 40mm depth (rolling 30 minute intervals) for the main trial day

From Figure 6.3 it can be seen that the 2.5˚C per hour criteria is exceeded between 14:00 and 14:30 at station 1. This may result in additional between machine variation during this period (lap 6) which may need to be accounted for.

6.3.2 Temperatures at depth, recorded by operators

The Deflectograph crews made measurements of temperature from the two temperature test stations at a 40mm depth. This data is shown below in Figure 6.4 and Figure 6.5.

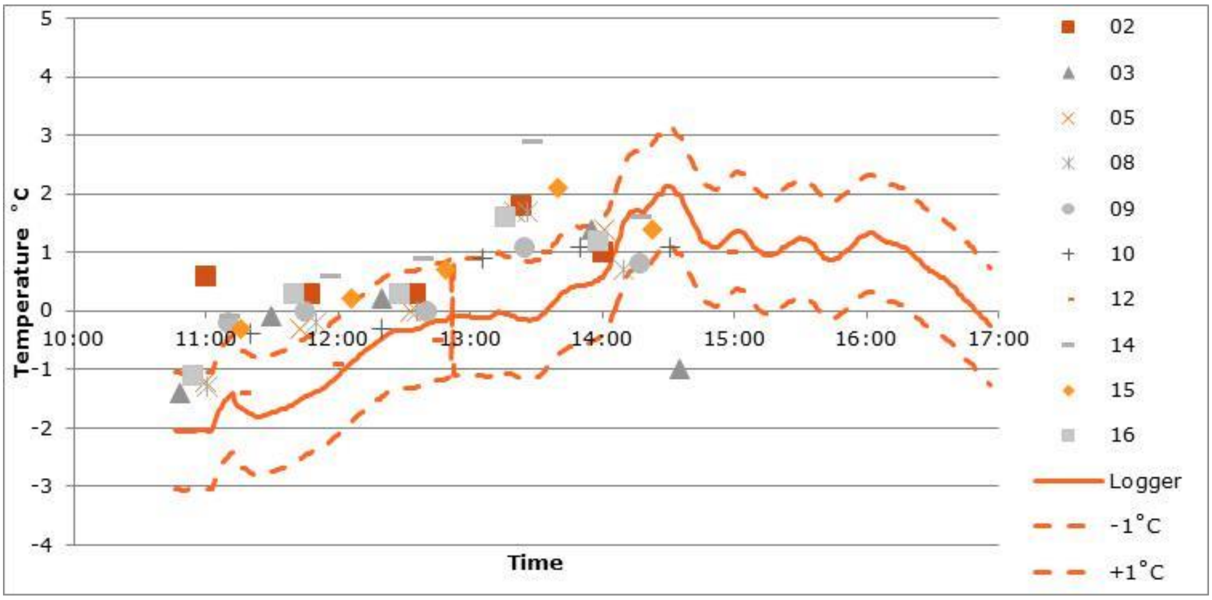

Figure 6.4 Comparison of operators' measurements against reference – Temperature test station 1, main trial day

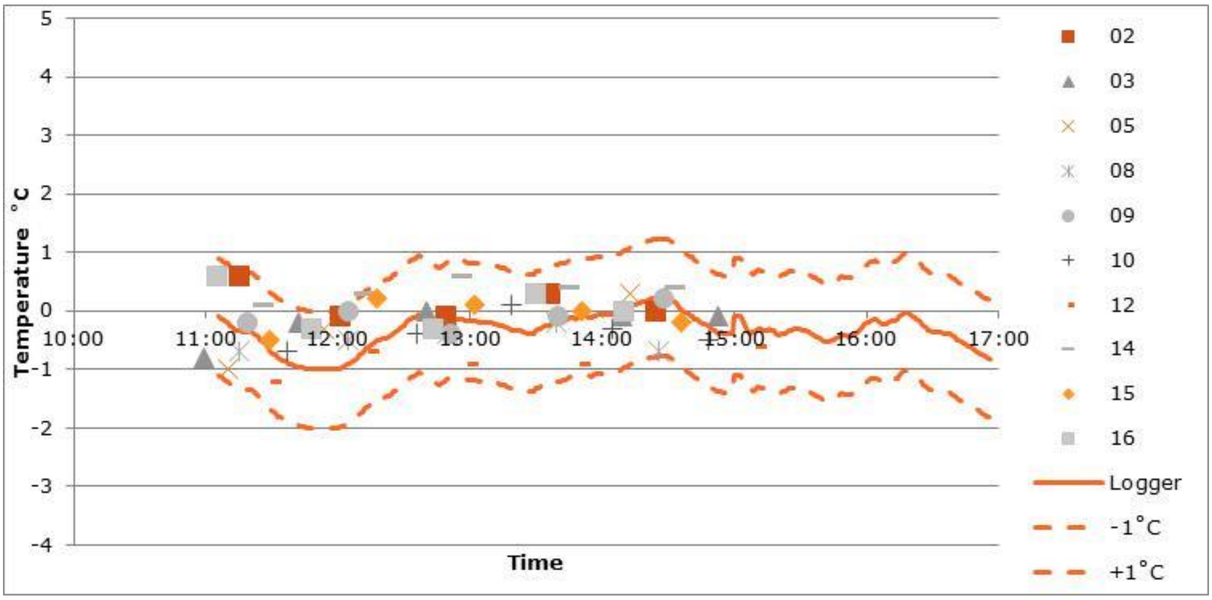

Figure 6.5 Comparison of operators' measurements against reference – Temperature test station 2, main trial day

The difference between the operators' measured values and the reference and the awarded performance are shown in Table 6.2. If the value is more than 1˚C away then it is highlighted in bold red text. For more details on this criteria see E5.2.1 in section 4.1.

Table 6.2 Difference between operators 40mm measured values and the reference

Machine	Difference between measured temperature and reference (˚C)										% within criteria	Performance band
	Test 1		Test 2		Test 3		Test 4		Test 5			
	1	2	1	2	1	2	1	2	1	2		
2	**2.6**	0.9	**1.7**	0.9	0.6	0.1	**1.9**	0.5	0.4	-0.2	70	Medium
3	0.7	.	**1.6**	0.8	0.7	0.1	0.9	-0.1	**-2.4**	0.3	78	Medium
5	0.8	-0.8	**1.2**	0.7	0.3	-0.1	**1.8**	0.6	**1.5**	0.2	70	Medium
8	0.8	-0.4	**1.2**	0.4	0.3	-0.2	**1.9**	0.0	0.5	-0.9	80	High
9	**1.3**	0.2	**1.4**	0.9	0.2	-0.3	**1.2**	0.1	0.6	0.0	78	Medium
10	**1.4**	0.2	0.2	-0.3	**1.0**	0.4	0.7	-0.2	0.2	-0.3	80	High
12	0.3	-0.5	0.3	-0.1	-0.3	-0.7	**1.1**	-0.8	0.6	-0.3	90	High
14	**1.3**	0.6	**1.8**	1.0	**1.1**	0.7	**3.1**	0.5	**1.2**	0.2	50	Medium
15	**1.4**	0.2	**1.1**	0.7	0.9	0.3	**1.9**	0.1	1.0	-0.2	70	Medium
16	1.0	.	**1.9**	0.7	0.6	-0.1	**1.7**	0.6	**1.3**	0.0	67	Medium

Three machines achieved a high performance and the remaining seven machines achieved a medium performance.

6.3.3 Air and Surface temperatures, recorded by operators

Methodologies for estimating pavement temperature from measurements of air and surface temperatures have been developed for use with deflection surveys. It is anticipated that the next version of HD29 will give survey contractors the option to supply air and surface temperatures instead of pavement temperatures along with the deflection survey data. Anticipating this change, the Accreditation and QA specification (TRL, 2016) was amended to include criteria for the assessment of pavement surface temperatures measured using an infrared temperature probe mounted on the Deflectograph. Criteria for air measurements using a thermometer device mounted on the Deflectograph will be included in a future version of the document.

To help develop the assessment method and test the criteria, survey contractors were asked to supply air and surface measurements (if they had the equipment fitted) from the test laps on the main trial day. This data would be used to provide an assessment of the surface temperature measurement accuracy and a general picture of the performance of the air temperature measurements. In both cases the data will be used to help develop the methodology for assessing the performance of the devices.

At the trial, air and surface temperature data was supplied from five machines. Data was collected from the same two locations as the 40mm temperature holes (before and after the test sections). The surface temperatures from the logger and the data supplied from the operators is shown in Figure 6.6 and Figure 6.7.

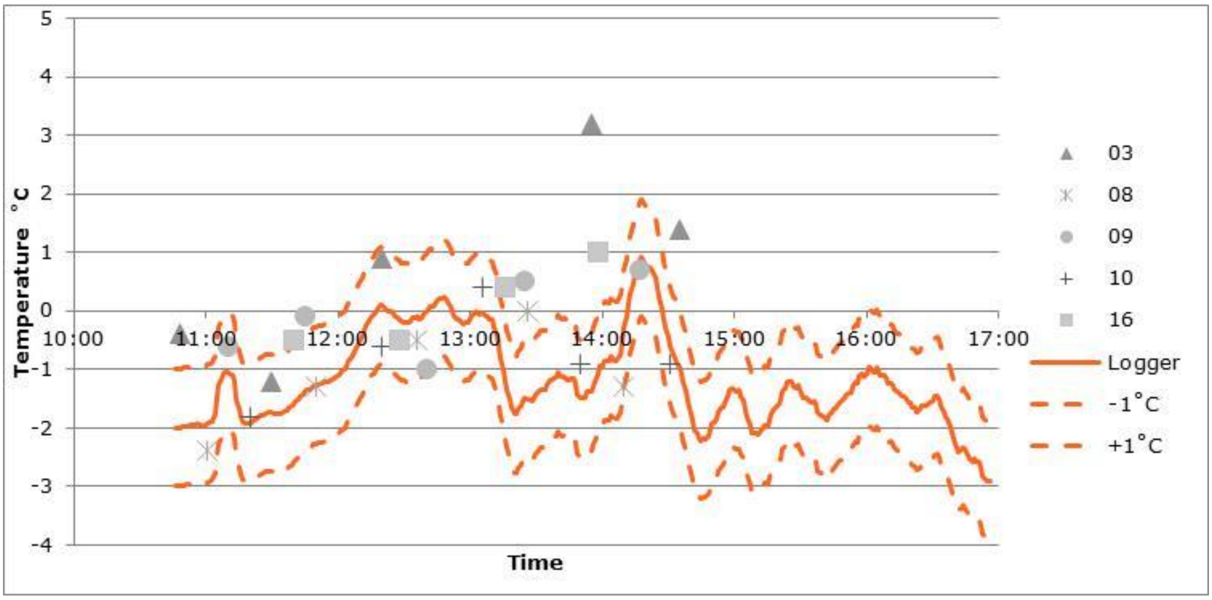

Figure 6.6 Surface temperatures – Temperature test station 1, main trial day

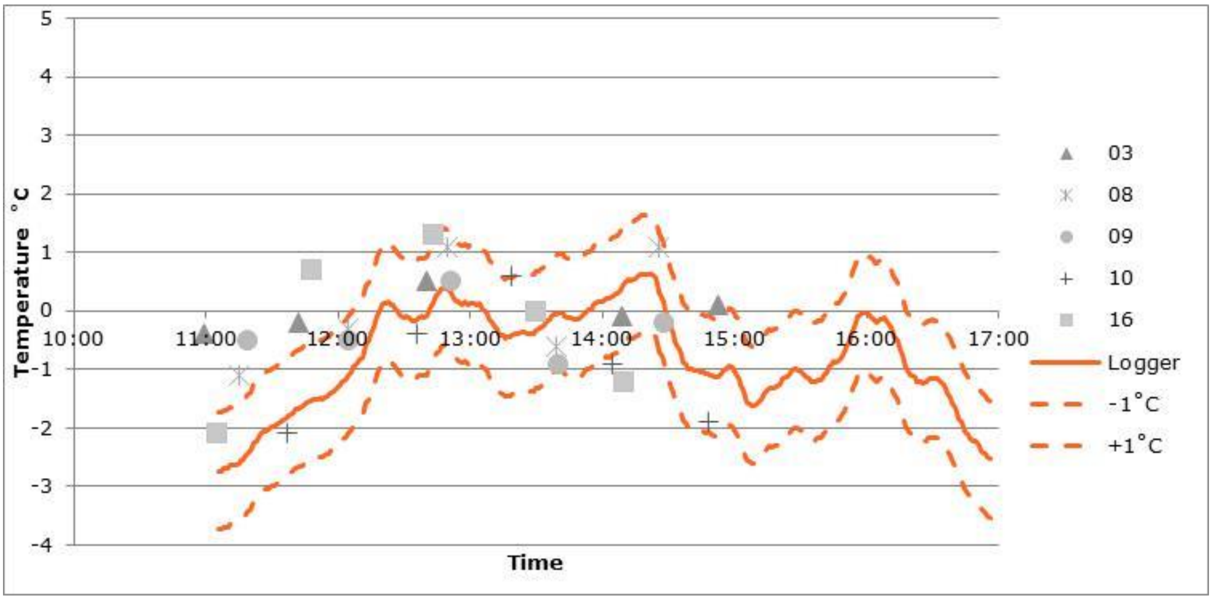

Figure 6.7 Surface temperatures – Temperature test station 2, main trial day

The difference between the surface temperatures recorded by the Deflectographs and the reference are shown in Table 6.3 along with the awarded performance. For more details on this criteria see E5.3.1 in section 4.1.

Table 6.3 Difference between operators surface temperature values and the reference

Machine	Difference between measured temperature and reference (˚C)										% within criteria	Performance band
	Test 1		Test 2		Test 3		Test 4		Test 5			
	1	2	1	2	1	2	1	2	1	2		
3	**1.6**	-	0.5	0.8	0.8	0.6	**4.6**	-0.1	**2.4**	0.5	67	Medium
8	-0.5	-0.8	0.0	0.6	-0.4	**1.3**	**1.5**	-0.4	**-1.0**	0.9	70	Medium
9	0.5	-0.1	**1.3**	0.4	-1.0	0.6	**2.0**	-0.7	-0.2	-0.4	80	High
10	0.1	**-1.2**	-0.7	-0.3	0.4	0.9	0.6	-0.8	-0.3	**-1.7**	80	High
16	-	-	**1.1**	**1.7**	-0.4	**1.5**	**1.6**	0.3	**2.1**	**-1.2**	25	Low

The air temperatures from the logger and the data supplied from the operators is shown in Figure 6.8 and Figure 6.9.

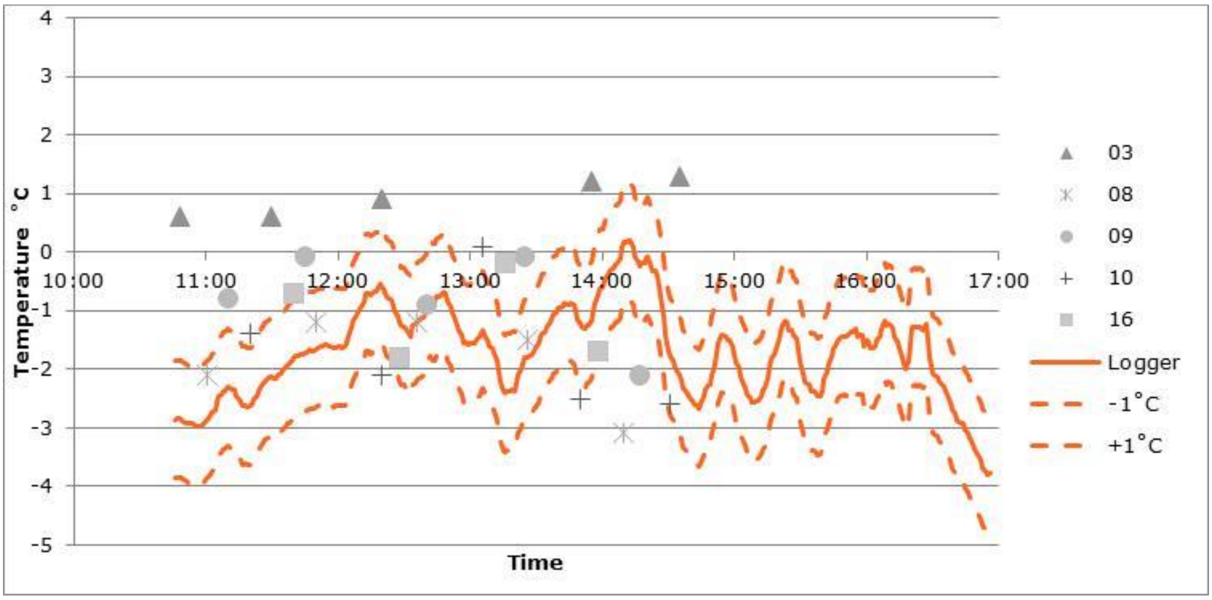

Figure 6.8 Air temperatures – Temperature test station 1, main trial day

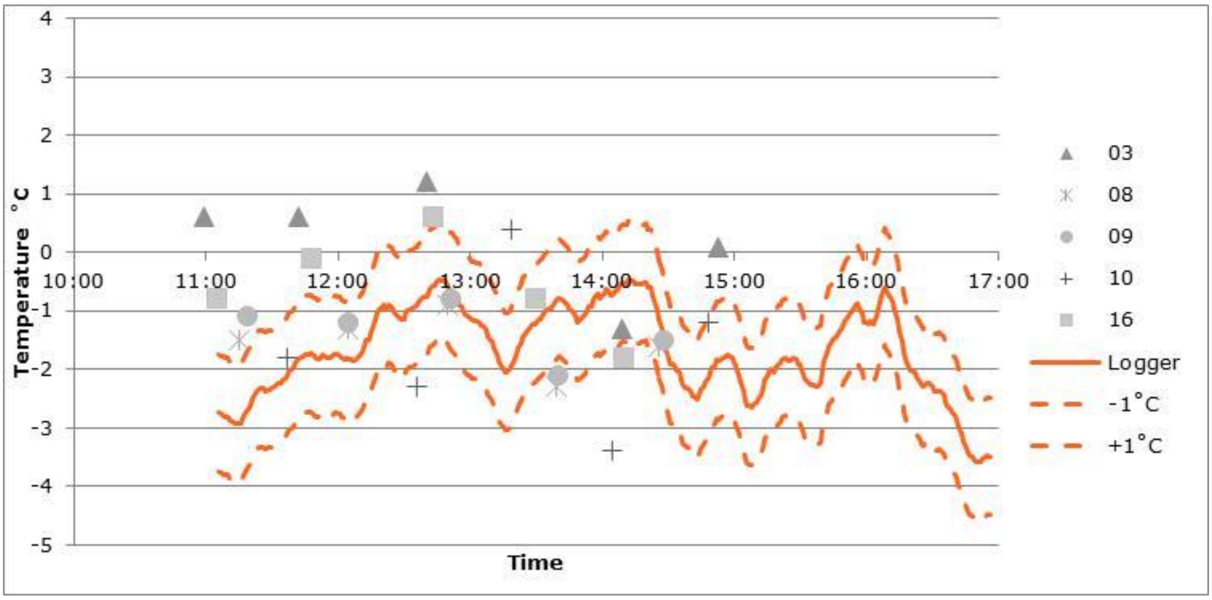

Figure 6.9 Air temperatures – Temperature test station 2, main trial day

Examination of Figure 6.8 and Figure 6.9 shows that the spread of data is reasonably consistent with a requirement to be within 1°C of the reference. However, it can be seen that a large percentage of the data is higher than the logger values. It is also noted that the temperature sensor attached to the logger was exposed to the sun and the wind and therefore the values from this device might be artificially raised or lowered (as air temperatures should be collected in the shade while still exposed to air flow but not wind). The difference between the air temperatures recorded by the Deflectographs and the reference are shown in Table 6.4 along with the performance if they are assessed against the same criteria for the surface temperatures (as no specific criteria is set in the accreditation and QA specification at this stage).

Table 6.4 Difference between operators air temperature values and the reference

Machine	Difference between measured temperature and reference (˚C)										% within criteria	Performance band
	Test 1		Test 2		Test 3		Test 4		Test 5			
	1	2	1	2	1	2	1	2	1	2		
3	**3.4**	-	**2.7**	**1.6**	**1.5**	**1.3**	**2.4**	**-1.3**	**3.4**	0.5	11	Not Suitable
8	0.8	**-1.2**	0.5	-0.4	0.0	-0.7	0.3	**-2.1**	**-3.3**	**-1.8**	60	Medium
9	**1.5**	-0.7	**1.6**	-0.3	0.1	-0.7	**1.7**	**-1.9**	**-1.9**	**-1.7**	40	Low
10	**1.2**	-0.9	**-1.5**	**-2.2**	**1.4**	0.7	**-1.3**	**-3.3**	-0.8	-1.0	40	Low
16	-	-	**1.1**	0.9	-0.6	0.8	**2.2**	-0.5	-1.0	**-1.8**	63	Medium

The results from Table 6.4 suggest that the overall performance for these devices is fairly poor. However, there is a reasonable degree of uncertainty as to whether the reference value is suitable. In addition it is possible that the very cold conditions at the trial made this test particularly difficult. The air temperature sensors are located on the Deflectographs as far away as possible from sources of heat. However, it is possible that even a small heating effect could affect the results in the very cold conditions at the trial. Due to these combined reasons, it was therefore decided that no performance levels would be assigned to these devices for this trial. It is recommended that the measurement technique and the assessment criteria are reviewed and further refined in future trials (for these devices and for the Dynamic Plate Test devices).

6.4 Deflection readings – Main trial day

As previously mentioned (see section 6.1) it was decided to carry out a pass of the test sections (with the beam down but not collecting the data) before conducting the beam calibration check. This was due to the cold conditions at the trial. To further reduce low temperature effects, it was also decided that an additional lap would be added to the main set of testing and the first lap would be disregarded. In other words, six laps would be undertaken and the machines would be assessed using laps 2-6.

During the early laps it was identified that the data from Machine 3 contained anomalous high values (or spikes) in the data. Although not strictly a criteria for the trial the presence of these spikes may be indicative of potential issues with the machine. This was communicated to the survey team for this machine. They inspected their machine and made alterations to the beam foot between laps 4 and 5. Therefore in order to obtain a full set of 5 laps for this machine (after the alteration) three additional laps were carried out after lap 6 with a reduced fleet of machines. Due to this, Machine 3 is excluded from the tables in this section. The analysis of the trial data from Machine 3 is provided in section 6.5.

6.4.1 *Between run standard deviation for deflection values*

No criteria are set relating to the between run standard deviation of each machine. It is, however, useful to consider this aspect when investigating anomalies in the behaviour of machines in case an individual machine's mean result has been unduly influenced by variations between runs, perhaps as a result of a significant variation from the expected test line. The variation between runs is indicated by the between-run standard deviation for each machine, as shown in Table 6.5.

Table 6.5 Between run standard deviation for main running day (day 2)

Machine number	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
2	11.1	5.8	32.8	29.2	24.1	12.1
5	5.3	5.5	12.3	18.3	11.2	18.6
8	7.0	12.1	24.2	23.6	16.5	21.5
9	10.4	11.2	5.6	12.4	12.3	17.1
10	15.0	4.7	26.1	8.5	23.8	12.9
12	5.9	6.3	11.6	21.9	14.4	20.5
14	8.5	8.5	24.1	21.0	13.6	10.7
15	2.4	5.5	11.3	9.4	14.3	11.7
16	10.2	6.5	15.6	10.0	17.0	11.0

It can be seen from Table 6.5 that no machine was significantly more variable than the others.

6.4.2 *Mean deflection values*

Table 6.6 shows the mean deflections recorded on each section, together with summary statistics. Instances where the between equipment standard deviation (BESD) is within the criterion are highlighted in green and instances where the criterion are not met in red. Table 6.7 shows the deviations from the overall mean and these are highlighted if they are more than 2 or 3 times the BESD criteria (orange and red respectively). For more details on this criteria see E4.2 in section 4.1.

Table 6.6 Mean deflection (µm) by section: Main running day (day 2)

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	41	53	182	144	125	114	116	104
5	53	40	173	120	127	127	118	98
8	49	49	177	141	119	119	115	109
9	35	34	156	121	97	97	96	87
10	57	50	185	153	134	134	125	132
12	44	44	172	147	119	119	112	118
14	63	57	192	153	138	138	131	127
15	48	51	162	136	117	117	109	116
16	59	53	187	151	132	132	126	123
Mean	50	48	176	141	123	114	116	101
BESD	9.1	7.2	11.9	12.7	12.4	14.0	10.6	10.9
BESD criterion	11.2	11.1	14.4	13.5	13.0	12.8	12.9	12.5
CoV	18.2%	15.1%	6.8%	9.0%	10.1%	12.3%	9.1%	10.8%

Table 6.7 Deviation (µm) from overall mean deflection by section: Main running day (day 2)

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	-8.7	5.4	5.5	3.7	2.0	0.1	-0.4	3.0
5	3.2	-8.1	-3.4	-20.5	3.7	-15.5	1.2	-14.7
8	-1.1	0.9	0.6	0.6	-4.4	-4.6	-1.6	-1.0
9	-15.3	-13.6	-20.5	-19.8	-26.5	-26.8	-20.8	-20.1
10	7.1	2.4	8.9	11.8	11.2	17.7	9.1	10.6
12	-5.6	-4.2	-4.0	6.2	-4.2	4.1	-4.6	2.0
14	13.1	8.8	15.8	12.5	15.2	13.6	14.7	11.6
15	-1.8	3.4	-14.1	-5.1	-6.0	2.5	-7.3	0.3
16	9.2	5.0	11.3	10.6	9.1	8.9	9.9	8.2
2x BESD criterion	22.3	22.2	28.8	27.0	26.1	25.6	25.7	24.9
3x BESD criterion	33.5	33.3	43.2	40.5	39.1	38.4	38.6	37.4

From Table 6.6 it can be seen that the BESD criteria is met for the average of the site, and all but one wheel path on one test section. In addition from Table 6.7 it can be seen that all machines are within 3 times the BESD criterion of the fleet mean. One machine (Machine 9) is between 2 and 3 times the BESD criterion on one of the test sections (HECP_03). This machine is only just above outside 2 times the BESD criterion on this section and therefore this machine is deemed to be suitable. Therefore these nine machines are considered as meeting the trial criteria for deflection measurement.

6.5 Deflection readings – Main trial day additional tests

As discussed in Section 6.4, Machine 3 underwent an alteration between laps 4 and 5, and was therefore required to undertake additional laps after lap 6 to get a complete set of 5 laps for the assessment. For these additional laps a sample of the fleet was also tested to provide reference data. These machines were Machines 2, 8 and 15. The data in the tables below are for these four machines for laps 5 to 9.

6.5.1 *Main trial day additional test lap results*

The results from the five assessment laps for Machine 3 and the corresponding data for the reference devices are given below.

Table 6.8 Between run standard deviation for main running day additional laps (day 2)

Machine number	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
2	5.7	3.5	5.1	6.8	6.6	7.3
3	5.0	15.1	12.3	22.0	5.8	19.1
8	2.0	3.9	13.0	7.8	2.6	3.2
15	4.4	2.4	9.6	7.8	11.7	4.8

From Table 6.8 it can be seen that the between run standard deviation is higher for machine 3 on the OS measurements in comparison to the reference devices. The results are comparable with the values seen during main testing (Table 6.5), however it is noted that the data from this machine continued to include high spikes after run 4.

Table 6.9 Mean deflection (µm) by section: Main running day additional laps (day 2)

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	54	59	211	170	150	132	138	121
3	29	36	162	154	99	113	97	101
8	57	58	203	166	133	126	131	117
15	50	55	181	148	123	123	118	109
Mean	47	52	189	160	126	124	121	112
BESD	12.8	10.9	22.3	10.2	21.1	8.2	18.3	8.7
BESD criterion	11.1	11.2	14.7	14.0	13.1	13.1	13.0	12.8
CoV	27.1%	20.8%	11.8%	6.4%	16.7%	6.6%	15.1%	7.8%

Table 6.10 Deviation (µm) from overall mean deflection by section: Main running day additional laps (day 2)

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	6.8	7.2	21.9	10.7	23.5	8.8	17.4	8.9
3	-18.7	-16.1	-27.3	-5.3	-27.0	-10.9	-24.3	-10.8
8	9.4	6.1	14.0	6.1	6.8	2.6	10.1	4.9
15	2.4	2.9	-8.6	-11.5	-3.3	-0.5	-3.1	-3.0
2x BESD criterion	22.2	22.4	29.5	28.0	26.3	26.1	26.0	25.5
3x BESD criterion	33.3	33.7	44.2	41.9	39.4	39.2	39.0	38.3

It can be seen from Table 6.9 that the BESD criteria is not met for the NS wheel path for any of the sections. This would typically mean that we would look to remove an outlier to improve the distribution of the fleet so that the criteria are met for the average of the site (and if possible each section). However, Machine 3 (the machine being assessed in this case) is within the 2x BESD criterion of the mean (see Table 6.10) in most cases and only just misses it for one wheel path on one section. In addition this is a subset of the fleet, and the nature of the criteria means that it is harder to meet it for smaller machine numbers.

Therefore it is necessary to combine this dataset with the earlier test data to fully assess this machine.

6.5.2 Combined main trial day data

In order to combine the data from the two datasets, the average deflection values for the machines that acted as the reference in the second set of tests (Machines 2, 8 and 15) was calculated for each section and wheel path for the two datasets. The ratio between the two datasets was then calculated and applied to the data from Machine 3 collected in the second dataset, to estimate the likely measurements it would have achieved if it operated in its new configuration at the start of the main trial day. The average from the two datasets for the machines acting as reference and the calculated ratio is shown in Table 6.11.

Table 6.11 Reference data values and estimation ratio

	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
Average dataset 1	46	51	173	141	120	113
Average dataset 2	53	58	199	161	135	127
Ratio	0.86	0.89	0.87	0.87	0.89	0.89

The estimated value for Machine 3 and the updated fleet statistics are shown in Table 6.12 and Table 6.13.

Table 6.12 Mean deflection (µm) by section: Estimated values for Machine 3 and resulting fleet statistics

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
3	25	32	142	134	88	100	85	89
Mean	47	46	173	140	120	112	113	100
BESD	11.7	8.4	15.6	12.2	16.1	13.9	14.1	10.9
BESD criterion	11.1	11.1	14.3	13.5	13.0	12.8	12.8	12.4
CoV	24.8%	18.3%	9.1%	8.7%	13.4%	12.4%	12.5%	11.0%

Table 6.13 Deviation (µm) from overall mean deflection by section: Estimated values for Machine 3 and resulting fleet statistics

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
3	-22.8	-14.2	-31.0	-5.8	-31.3	-12.2	-28.4	-10.7
2x BESD criterion	22.2	22.1	28.6	27.0	25.9	25.5	25.6	24.9
3x BESD criterion	33.3	33.2	43.0	40.4	38.9	38.3	38.4	37.3

It can be seen from Table 6.12 and Table 6.13 that the BESD criterion is not met for the NS deflections. In addition Machine 3 is outside of the 2x BESD criterion on all sections for the

NS wheel path. Therefore at the end of the testing on the main trial day this machine has been identified as an outlier and will require further investigation.

6.6 Decision on use of the reserve day

The original plan for the trial was to only use the reserve day where it was not possible to conduct all of the testing on the main trial day due to bad weather or other unforeseen circumstances (e.g. a “stop testing” call from track control due to an emergency). However if there is sufficient reason to believe that a machine can be investigated and fixed between the end of the main trial day and before the reserve day, then additional testing may be conducted.

In this case (due to the spikes in the data and the low values) it was identified that it would not be possible to thoroughly investigate this machine and continue testing on the reserve day. Therefore the reserve day was not utilised for this trial. The further investigation into Machine 3 is discussed in section 7.

7 Investigation into Machine 3

7.1 More detailed analysis of the trial results

As previously noted (see section 6.4) there were two effects seen with the data from Machine 03. The first was "spiky" data (primarily in the OS but occasionally in the NS) in a subset of the runs, and the second is a low average deflection value, which for the NS caused it to be identified as an outlier. An example of a "spiky" run (spikes only visible in OS for this run) can be seen in Figure 7.1 and Figure 7.2 (Machine 08 is also shown to represent the values seen by the rest of the fleet during this run).

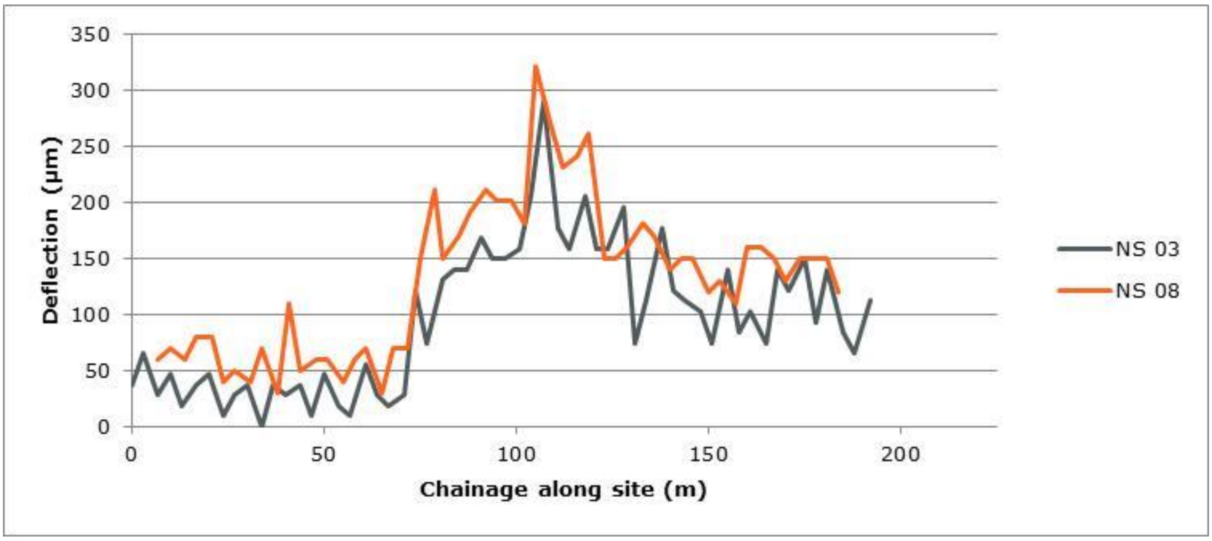

Figure 7.1 Example of spiky run for Machine 03 (run 9) - NS deflections

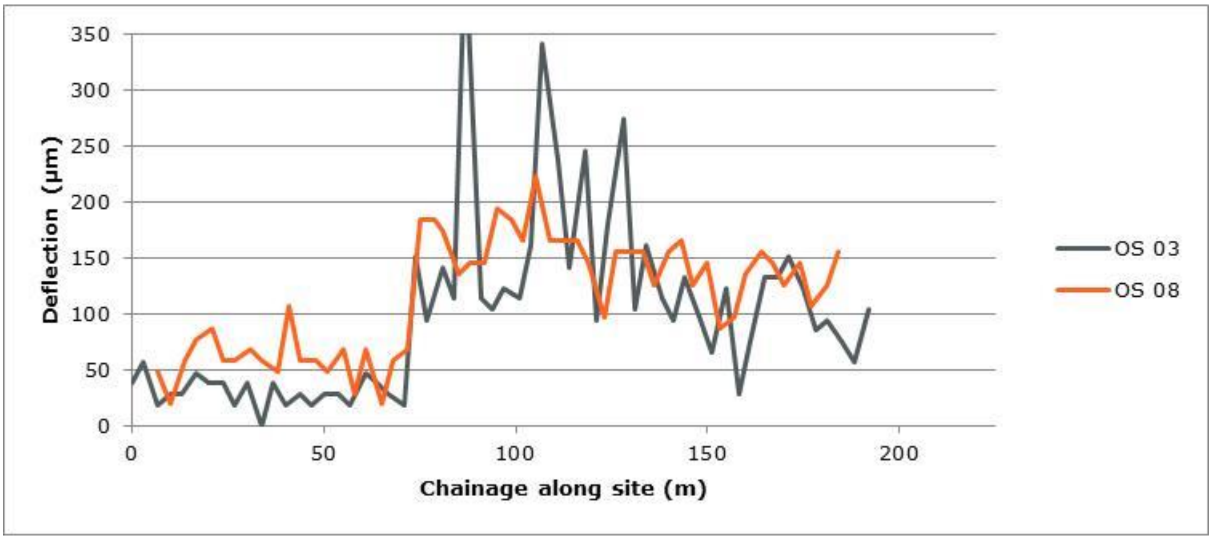

Figure 7.2 Example of spiky run for Machine 03 (run 9) - OS deflections

From Figure 7.1 and Figure 7.2 it can be seen that along with the high peaks in the OS data Machine 03 has a lower overall average in comparison to the other machine (in both wheel paths). Examination of runs where Machine 03 did not show high peaks found that overall the average was consistent with the fleet. An example of a "non-spiky" run can be seen in Figure 7.3 and Figure 7.4.

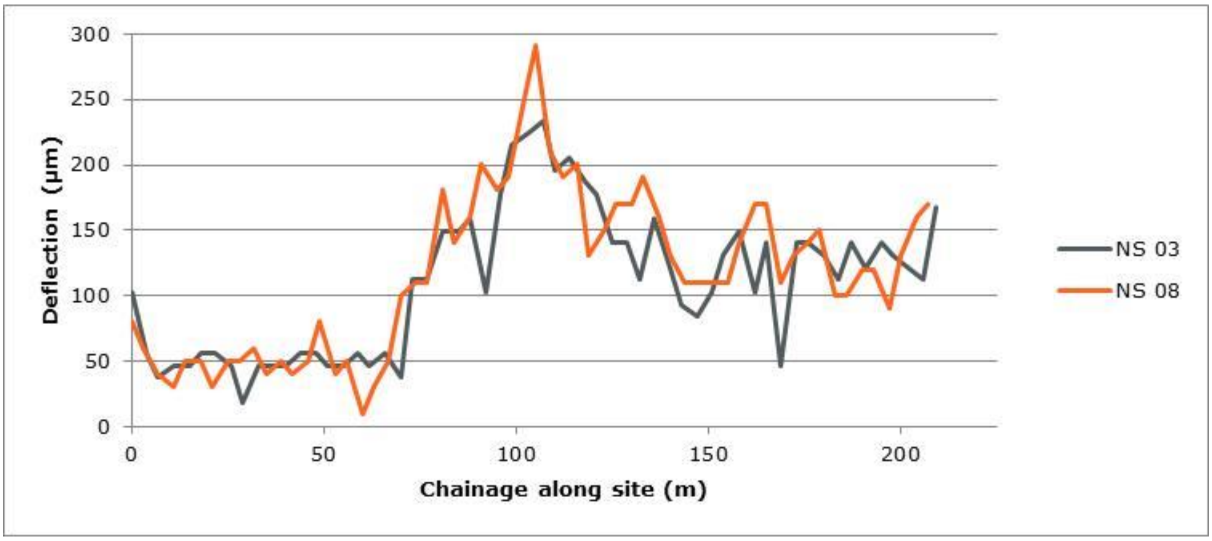

Figure 7.3 Example of non-spiky run for Machine 03 (run 4) - NS deflections

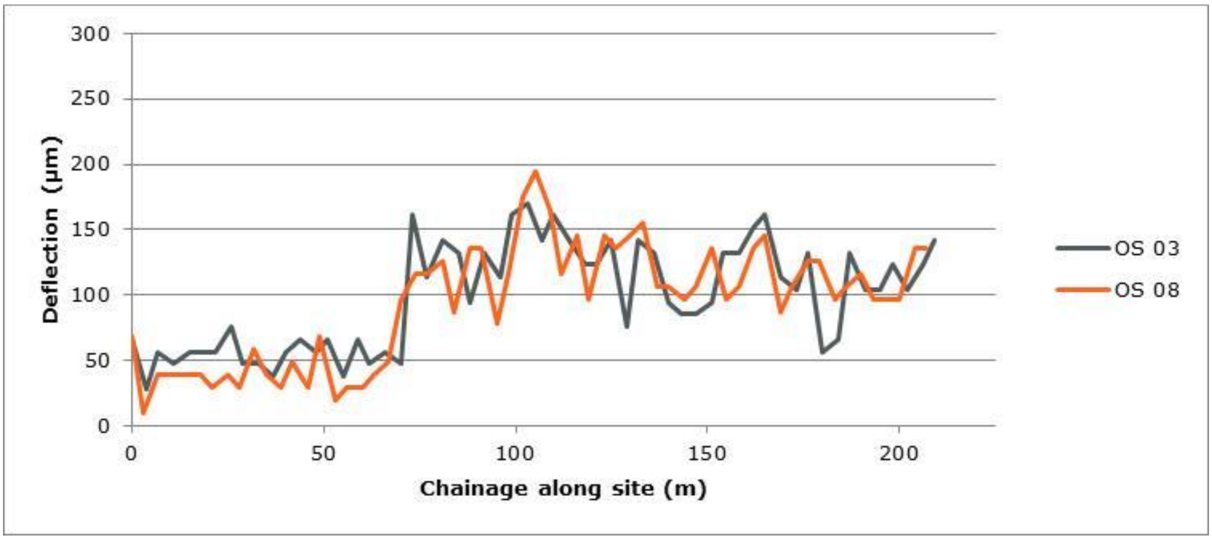

Figure 7.4 Example of non-spiky run for Machine 03 (run 4) - OS deflections

This suggests that the low average deflections and the spiky data effects could be from the same cause, and removing the cause of the spikes may also improve the average deflection values and provide data consistent with the fleet.

Further analysis of this machine and determining the suitability of the device following corrective action is outside the scope of this work and will be covered separately and paid for by the survey contractor.

8 Conclusions

The 2018 National Deflectograph accreditation trials were held on the Horiba-MIRA proving grounds by TRL on behalf of the Highways England during the period 27th to 28th February 2018. Ten of the machines in the current UK fleet attended the trial.

The following conclusions were drawn in relation to the various mandatory tests and assessments:

(I) Wheel Weights

Six of the ten machines exceeded the front axle limits defined in (Design Manual for Roads and Bridges, 2008). Following a review of this matter in 2004, machines exceeding the front axle weight limits are regarded as acceptable provided that they perform satisfactorily in the dynamic tests. All of the machines were within the rear wheel weight limits.

(II) Deflection measurement

Nine of the ten machines that participated in the 2018 trial met the criteria for deflection measurement.

(III) Distance measurement

All ten machines that participated in the 2018 trial met the criteria for distance measurement.

The following conclusions were drawn in relation to the various additional tests and assessments:

(IV) Temperature measurement – measurement at depth

At the completion of the trial, three of the ten operators achieved a high performance with regards to the measurement of temperature at depth. The remaining seven operators achieved a medium performance.

(V) Temperature measurement – surface temperature

Surface temperature data from five machines was supplied at this trial. Two machines achieved a high performance with regards to the measurement of surface temperature. Two machines a medium performance and the remaining machine achieved a low performance.

A summary of the machines that attended the 2018 accreditation trial and the criteria that they met/performance achieved can be found in Appendix A.

For the 2018 trial, participants were also asked to provide air temperature measurements (if they had the equipment fitted). There was uncertainty in the reference data collected and as such this data was not formally assessed. It is recommended that the measurement technique and the assessment criteria are reviewed and further refined in future trials (for these devices and for the Dynamic Plate Test devices).

The survey data from one machine included infrequent spikes in the data, which raised concerns on the suitability of the device. This machine then did not achieve the Deflection criteria of the trial and therefore the specification was successful in identifying an unsuitable device. However, as it stands with the Accreditation and QA specification, there would have been little scope for the auditor to withhold accredited status or require additional testing of this device if it did meet the Deflection criteria (i.e. the average values were suitable). Therefore to strengthen the Accreditation and QA specifications, they should be reviewed and additional clauses to be added to allow the Auditor to investigate, and if needed, act upon anomalies in the shape of the survey data.

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Appendix A Machine identification

Table A.1 Machine identification

ID	Operator at trial date	Registration number	Performance achieved			
			Deflection	Distance	Temperature	
					At 40mm	Surface
2	PTS Ltd	L697 BKR	Pass	Pass	Medium	Not assessed
3	TRL Ltd	B180 FBL	Fail	Pass	Medium	Medium
5	WDM Ltd	D962 JRU	Pass	Pass	Medium	Not assessed
8	WDM Ltd	BYW 80V	Pass	Pass	High	Medium
9	WDM Ltd	VGV 182X	Pass	Pass	Medium	High
10	WDM Ltd	F569 JBB	Pass	Pass	High	High
12	WDM Ltd	EOU 230W	Pass	Pass	High	Not assessed
14	Lincolnshire County Council	B195 CFW	Pass	Pass	Medium	Not assessed
15	DoE Northern Ireland	ACZ 3268	Pass	Pass	Medium	Not assessed
16	WDM Ltd	B880 XOU	Pass	Pass	Medium	Low

Appendix B Layout of test sections at Horiba-MIRA

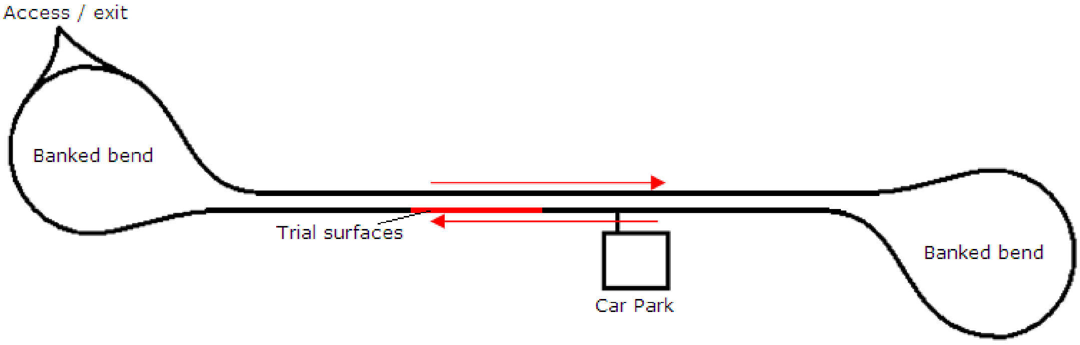

Figure B.1 Test route on the Horiba-MIRA twin straights

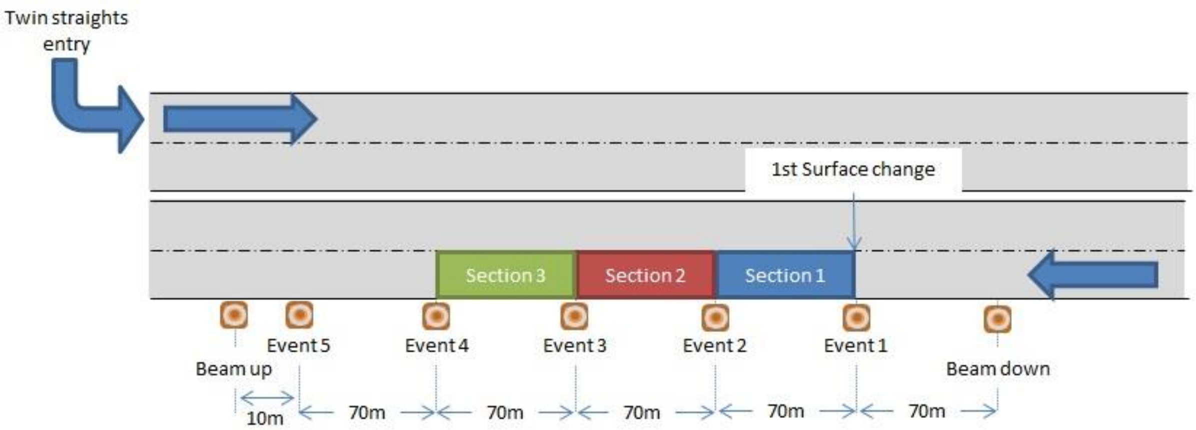

Figure B.2 Location of marker cones and test sections on Horiba-MIRA twin straights

Appendix C Construction details for Horiba-MIRA test sections

Table C.1 Design construction of Horiba-MIRA site

Section	Nominal construction details and material type (mm)			
	Surface course	Binder course	Total asphalt thickness (mm)	Sub-base
HECP_01	30 TSC	235 EME2	270	200mm C8/10 HBM
HECP_02	35 TSC	170 DBM	200	250mm 6F1 granular capping material
HECP_03	30 TSC	170 EME2	200	200 Type 1 granular material

Notes: TSC = Cl 942 Thin Surface Course EME2 = Enrobé à Module Élevé, DBM = Dense Bitumen Macadam, HBM = Hydraulically Bound Material, 6F1 = Selected granular capping.

Table C.2 Construction details for Horiba-MIRA site from cores

Section	Post Construction Results from cores (mm)			
	Surface course	Binder/ Binder+ base courses	Total asphalt thickness (mm)	Base (mm)
HECP_01	42 TSC	228	270	217 (HBM)
HECP_02	37 TSC	158	192	-
HECP_03	35 TSC	191	226	-

Notes: TSC = Cl 942 Thin Surface Course EME2 = Enrobé à Module Élevé, DBM = Dense Bitumen Macadam, HBM = Hydraulically Bound Material

Table C.3 Construction details for Horiba-MIRA site from GPR

Section	Post Construction Results from cores (mm)			
	Minimum	Average	Maximum	Material
HECP_01	192	242	272	Asphalt
	166	188	215	HBM
	388	431	468	Total bound thickness
HECP_02	167	192	240	Asphalt
HECP_03	167	199	240	Asphalt

Notes: HBM = Hydraulically Bound Material

Highways England 2018 National Deflectograph Accreditation Trial

A key element for the successful maintenance of a road network is accurate, reliable and consistent survey data. To this aim, Highways England commissions annual accreditation trials for the Deflectograph devices supported by ongoing QA for the devices. In order to undertake accredited surveys, the survey devices are required to meet the mandatory criteria of the trial.

This report covers the 2018 accreditation trial run by TRL and held on the Horiba-MIRA proving ground between 27th and 28th February 2018.

Other titles from this subject area

PPR 941	Highways England 2017 National Deflectograph Accreditation Trial. S Brittain. 2020
PPR 942	Highways England 2016 National Deflectograph Accreditation Trial. S Brittain. 2020
PPR 943	Highways England 2015 National Deflectograph Accreditation Trial. S Brittain. 2020
CPR 1845	Highways Agency 2014 National Deflectograph Accreditation Trial. S Brittain. 2014

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