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Highways England 2020 National Deflectograph Accreditation Trial

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Contents

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 the Highways England Strategic Road Network (SRN) and other networks. By examining and monitoring the results from the machines operating on specified test sections of the reference site, the performance of individual machines, and the performance of the whole UK fleet, are assessed.

The 2020 trial was held on the 10th and 11th March 2020. The site used was the twin horizontal straights of the Horiba-MIRA proving ground. This was the twenty-fifth year in which TRL have taken full responsibility for the planning and running of the trials. Ten machines attended the trial.

The format of the 2020 trial was broadly consistent with that of recent years, comprising two scheduled days of testing and one contingency day. 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 contingency day was not required this year.

All ten machines that participated in the 2020 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 the Highways England SRN.

With regards to the measurement of pavement temperature at depth, six of the ten machines achieved a “high” performance rating and the remaining four a “medium” performance rating.

For the 2020 trial, participants were also asked to provide air and surface temperature measurements (if they had the equipment fitted). Four machines provided air and surface temperatures. Two machines achieved a medium performance with regards to the measurement of surface temperature. The remaining two achieved a low performance. One machine achieved a high performance with regards to the measurement of air temperature and the remaining three a medium performance.

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 the Highways England 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 2020 trial was held on the 10th and 11th March 2020. 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-fifth year in which TRL have taken full responsibility for the planning and running of the trials and the eighth full trial at Horiba-MIRA. Ten machines attended the trial.

For convenience, throughout this report, the machines are referred to by their running numbers rather than by the owner. For ease of record keeping, running numbers are retained from year to year with any new machines being assigned new numbers. By agreement with Highways England, Appendix A lists the machines, owner and performance at the trial. This approach 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 constructed 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 2020 trial are discussed in Section 3 and Appendix D of this report, respectively.

2.2 Variability of nearside (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.

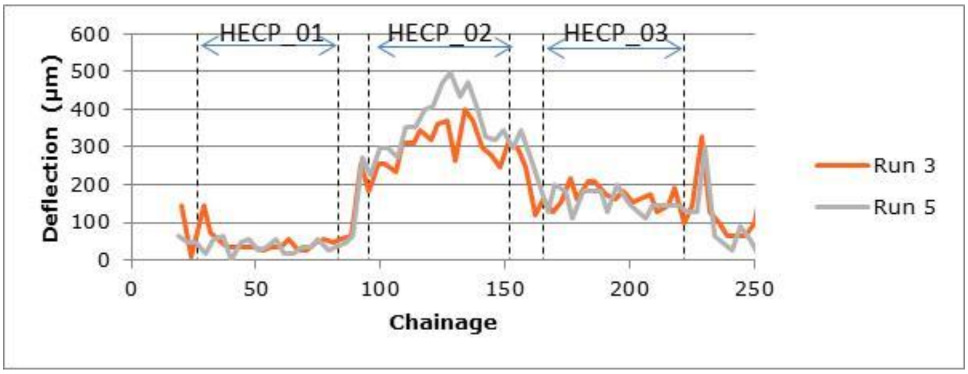

Figure 2.1: Example plot of nearside deflections for Horiba-MIRA test sections observed during the transitional trial

It was established that the high deflections occurred when the transverse location of the Deflectograph test line varied outside of the wheel path. 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 positions 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 be placed along HECP_02 for all future trials in order to reduce this variability. However, for the 2020 trial it was identified that it was too windy for the small cones to stay in place. Therefore, larger cones were positioned to achieve the same effect.

3 Trial format

The format of the 2020 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' hand-held temperature probes 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 may 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 further 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 by the survey crews using 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 distance measured to the reference measurement of the distance between the cones.

The machine running order is randomly determined before testing begins, with all machines running in convoy to cover all the sections in a single measurement run. Each machine is required to complete a warm-up lap followed by 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 test cycle with the truck wheels at a defined "beam down" point.

CS229 (DMRB CS 229, 2020) sets a maximum rate of temperature increase of 2.5˚C per hour at 40mm for deflection testing on the UK 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 pavement 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 observe the dynamic operation of each machine, including a timed section in order to verify that operating speeds are acceptable.

4 Results – Inspection day (10th March 2020)

4.1 Inspections

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

4.2 Wheel weights

The weights recorded for each machine are given in Table 4.1.

Table 4.1: Deflectograph weight distributions from 10 March 2020

Machine	Weight distribution including crew (kg)						
	Front NS	Front OS	Total Front (percentage of target)	Rear NS	Rear OS	Total rear	Total Machine
2	2355	2605	**4960***	3320	3275	6595	11555
3	2290	2430	4720	3425	3435	6860	11580
5	2300	2340	4640	3135	3280	6415	11055
8	2240	2430	4670	3125	3220	6345	11015
9	2300	2345	4645	3360	3295	6655	11300
10	2330	2380	4710	3455	3210	6665	11375
12	2200	2385	4585	3290	3235	6525	11110
14	2305	2425	**4730***	3200	3355	6555	11285
15	2370	2540	**4910***	3440	3315	6755	11665
16	2210	2320	4530	3170	3210	6380	10910

* Exceeds target limit in the accreditation and QA specification, but is within the expanded range. Further discussed below.

Machines 2, 14 and 15 exceeded the standard front axle limits given in the Accreditation and QA specification (TRL, 2020). Machines 2 and 15 have exceeded the standard 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 and re-reviewed in 2019. It was concluded that, machines falling within 15% above the target would be regarded as acceptable provided that they perform satisfactorily in the dynamic tests. A note to this effect is given in the accreditation and QA specification (TRL, 2020), which is reproduced in Appendix D. All three of these machines are within this expanded acceptability range at 110%, 105% and 109% of the target value respectively.

4.3 Beam calibration check

Prior to the familiarisation lap each crew carried out a static beam calibration check on their machine. No machines were identified to TRL as not meeting the limits specified in the accreditation and QA specification (TRL, 2020).

4.4 Familiarisation lap

Following the processing of data from the familiarisation lap it was found that the spread of machine results was within the criteria for the average of the site (but not for HECP_02 on the near side wheel path). One machine (Machine 03) was found to be more than 3 times the SD criteria away from the fleet mean on HECP_02 on the NS and between 2 and 3 times the SD criteria on HECP_03 on the NS. This information was feed back to the operators of this device and it was recommended that they investigate the device before testing on the main trial day.

4.5 Temperature probes

The operators' hand-held temperature probes were collected up and the probes allowed to stabilise to the same temperature (in a water container). Some minor issues were identified with the performance of the probes from two machines (Machines 2 and 3). This was communicated to the corresponding survey crews so that they could make corrective action before the testing on the main trial day.

5 Results – Main trial day (11th March 2020)

5.1 Beam calibration check

Prior to the main running trials each crew carried out a static beam calibration check on their machine. No machines were identified to TRL as not meeting the limits specified in the accreditation and QA specification (TRL, 2020).

5.2 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 525.117m. During the trial, the survey crews were asked to test the reference length and note down on the run log sheets the distance measured. This involves reviewing the survey file and identifying the length between the two marker points. The crews were also asked to provide these survey files.

After the trial the operator-reported lengths were compared with the lengths in the survey files and it was noted that some of the operators did not perform the calculation correctly. During normal use of the survey vehicles this calculation is not required, therefore it is not an issue for their ongoing use. For the assessment of the survey vehicles' performance, the distances recorded in the survey files were used.

The difference between the measured length from each machine and the reference length, along with the overall performance, are given in Table 5.1. The difference between the machine and the reference is highlighted in red bold text where it exceeds the threshold for the criteria as set out in Section D.1.

Table 5.1: Distance measurement results

Machine	Difference between measured length and the reference (m)						% within criteria	Performance
	1	2	3	4	5	6		
2	1.9	-0.1	0.9	-1.1	0.9	-1.1	100	Pass
3	-1.1	-1.1	-1.1	-2.1	-2.1	-3.1	100	Pass
5	-1.1	-1.1	1.9	1.9	-0.1	0.9	100	Pass
8	-2.1	-1.1	0.9	-1.1	-2.1	-2.1	100	Pass
9	-1.1	-2.1	-0.1	-0.1	-2.1	-0.1	100	Pass
10	0.9	-1.1	1.9	-1.1	-2.1	-0.1	100	Pass
12	-2.1	-1.1	-3.1	-4.1	-4.1	**-5.1**	83	Pass
14	-3.1	-3.1	-3.1	-1.1	-2.1	-1.1	100	Pass
15	-0.1	0.9	-0.1	0.9	0.9	-1.1	100	Pass
16	-2.1	-1.1	0.9	-1.1	-	-4.1	100	Pass

From Table 5.1 it can be seen that all ten machines passed the distance measurement criteria on the main trial day.

5.3 Temperatures

5.3.1 Temperatures recorded by the data loggers

Data loggers were connected to thermocouples in order to record the 40mm and 100mm depth temperatures along with the air and pavement surface temperatures. The majority of the sensors were set up on the path to the side of the test sections. However two additional sensors were set up in lane 1 measuring the 40mm and 100mm depth temperatures. The “path: 40mm” position corresponds to the location that operators were asked to take measurements with their probes. The 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 5.1 and Figure 5.2.

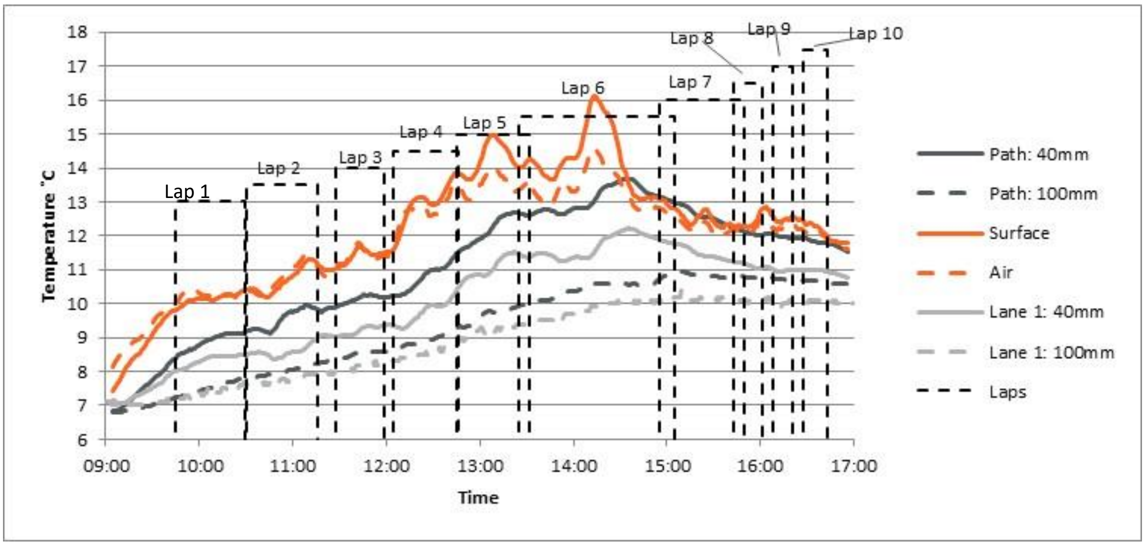

Figure 5.1: Temperature measurements from temperature station 1 (before test sections)

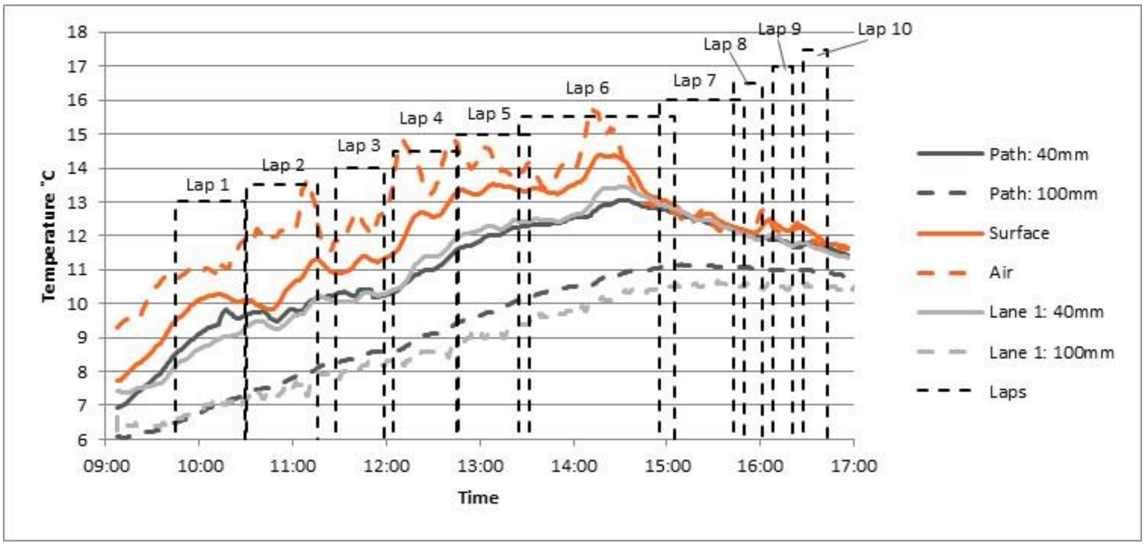

Figure 5.2: Temperature measurements from temperature station 2 (after test sections)

In general, the graphs show a general steady increase in temperatures over the course of the day up to around 14:30 where the temperatures start to decrease. The temperature measurements in the path and lane 1 were consistent in most cases with the exception of station 1 where the 40mm temperatures were approximately a degree apart throughout the day. It is possible that this may be due to differences in the amount of glycerol in these holes, issues with one of the thermocouples or differences in the temperatures of these sites. These differences will be considered in the analysis of the operators 40mm measurements.

As discussed in Section 3.2, CS 229 sets a maximum rate of temperature change of 2.5˚C per hour at 40mm for deflection testing. The temperature change per hour (calculated for each 15-minute interval) is shown in Figure 5.3.

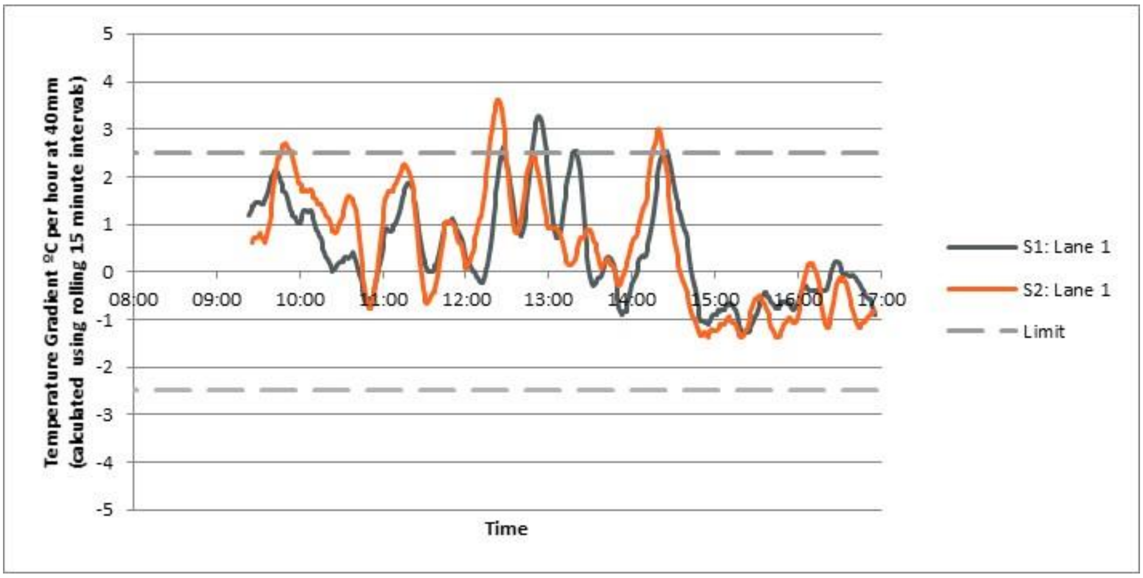

Figure 5.3: 40mm depth temperature changes (rolling 15 minute intervals), main trial day

From Figure 5.3 it can be seen that the 2.5˚C per hour criteria is exceeded at several points. Therefore, if additional variation is seen in the survey data in laps covering these periods then they may be disregarded and additional laps carried out.

5.3.2 Temperatures at depth, recorded by operators

The Deflectograph crews made measurements of temperature from the two temperature test stations at a 40mm depth (in the path). This data is shown in Figure 5.4 and Figure 5.5.

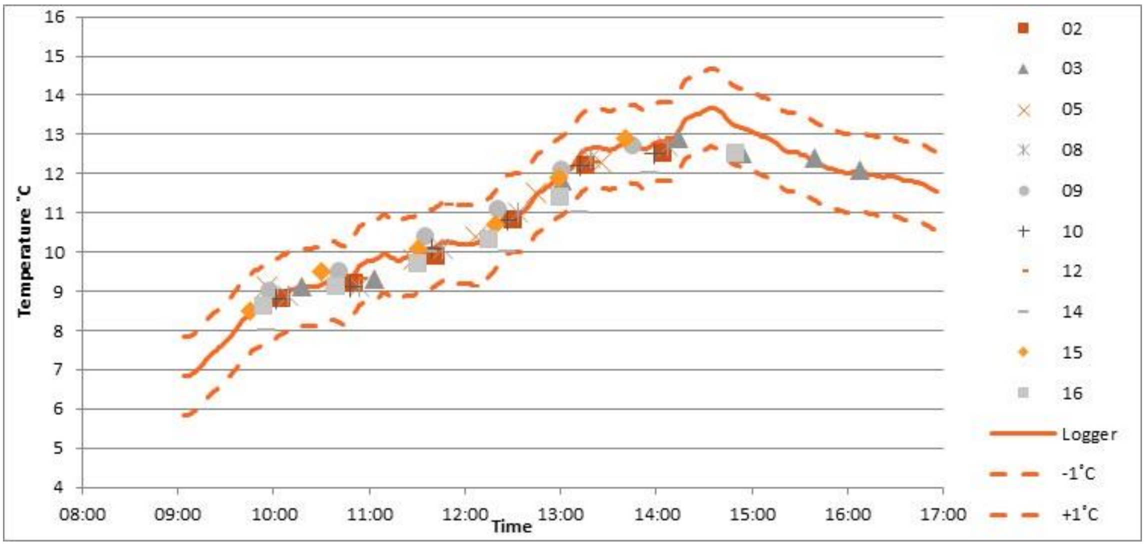

Figure 5.4: Comparison of operators' measurements against reference – Temperature test station 1, main trial day

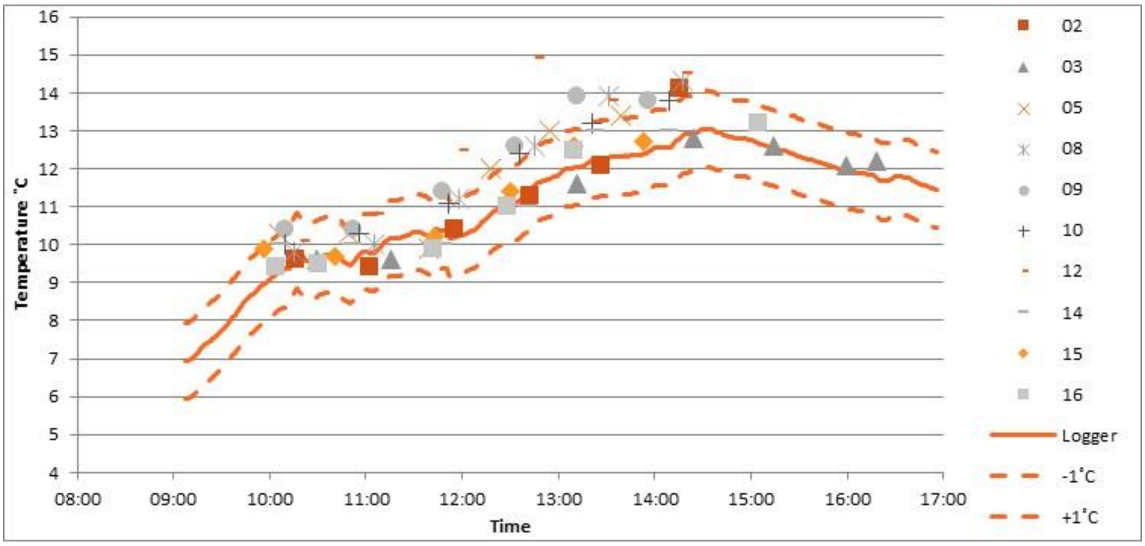

Figure 5.5: Comparison of operators' measurements against reference – Temperature test station 2, main trial day

The differences between the operators' measured values and the reference values recorded by the loggers are shown in Table 5.2. If the recorded value is more than 1˚C away from the reference then it is highlighted in bold red text. Table 5.2 also shows the performance band awarded to each operator.

Table 5.2: 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		Test 6			
	1	2	1	2	1	2	1	2	1	2	1	2		
2	-0.1	-0.2	-0.3	-0.4	-0.3	0.2	-0.2	-0.1	-0.4	-0.2	-0.3	**1.3**	91.7	High
3	0.0	0.0	-0.5	-0.6	-0.1	-0.4	0.4	-0.1	-0.7	0.1	0.1	0.1	100.0	High
5	0.4	**1.0**	0.0	0.8	-0.1	-0.3	0.2	**1.2**	0.0	**1.3**	0.5	**1.1**	66.7	Medium
8	-0.1	0.1	-0.5	0.2	-0.2	1.0	0.0	**1.0**	-0.2	**1.6**	0.1	**1.4**	75.0	Medium
9	0.3	**1.0**	0.3	0.9	0.4	**1.0**	0.4	**1.5**	0.2	**1.9**	0.2	**1.3**	58.3	Medium
10	0.0	0.6	-0.1	0.6	0.0	0.9	-0.2	**1.2**	-0.3	1.0	-0.2	**1.2**	83.3	High
12	**-8.1**	0.4	-0.3	1.0	1.0	**2.3**	**-1.1**	**3.3**	-0.4	**1.5**	0.3	**1.6**	50.0	Medium
14	-0.7	0.7	-0.2	0.5	0.0	-0.4	-1.0	-0.4	**-1.5**	0.8	-0.7	0.4	91.7	High
15	0.1	0.9	0.3	-0.1	0.1	-0.2	0.1	0.4	0.0	0.6	0.5	0.3	100.0	High
16	-0.1	0.2	-0.1	-0.2	-0.3	-0.5	-0.1	0.0	-0.5	0.5	0.1	0.5	100.0	High

Six machines achieved a high performance and four machines (Machines 5, 8, 9 and 12) achieved a medium performance.

5.3.3 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. These are included in CS 229 (DMRB CS 229, 2020) which permits Deflectograph survey contractors to use air and surface temperature measurements to estimate 40mm pavement temperatures.

At the trial, air and surface temperature data was supplied from four machines. Data was collected from the same two locations as the 40mm temperature holes (before and after the test sections on the path). The surface temperatures from the logger and the data supplied from the operators is shown in Figure 5.6 and Figure 5.7.

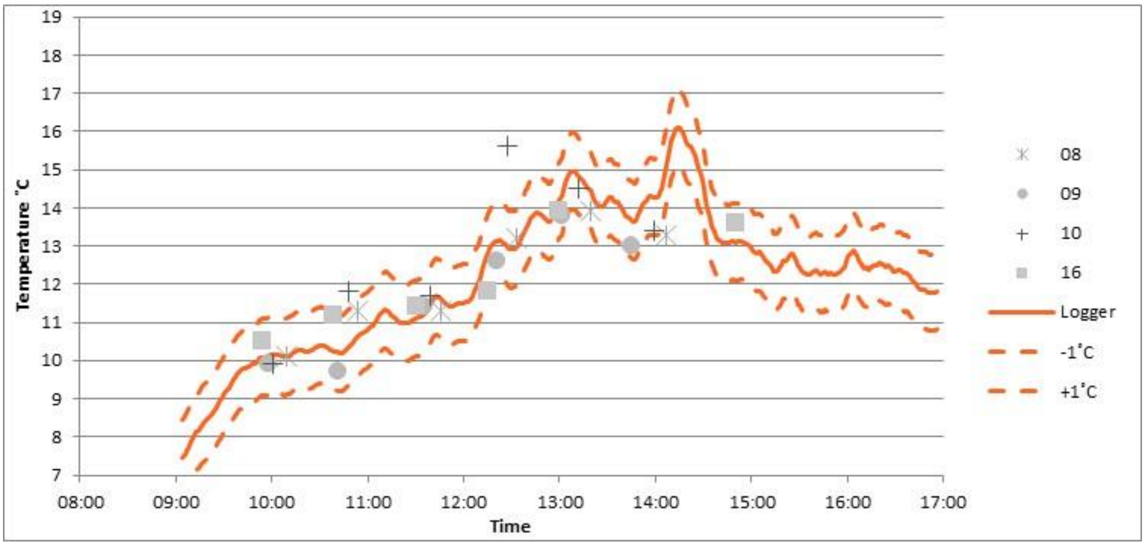

Figure 5.6: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 1, main trial day

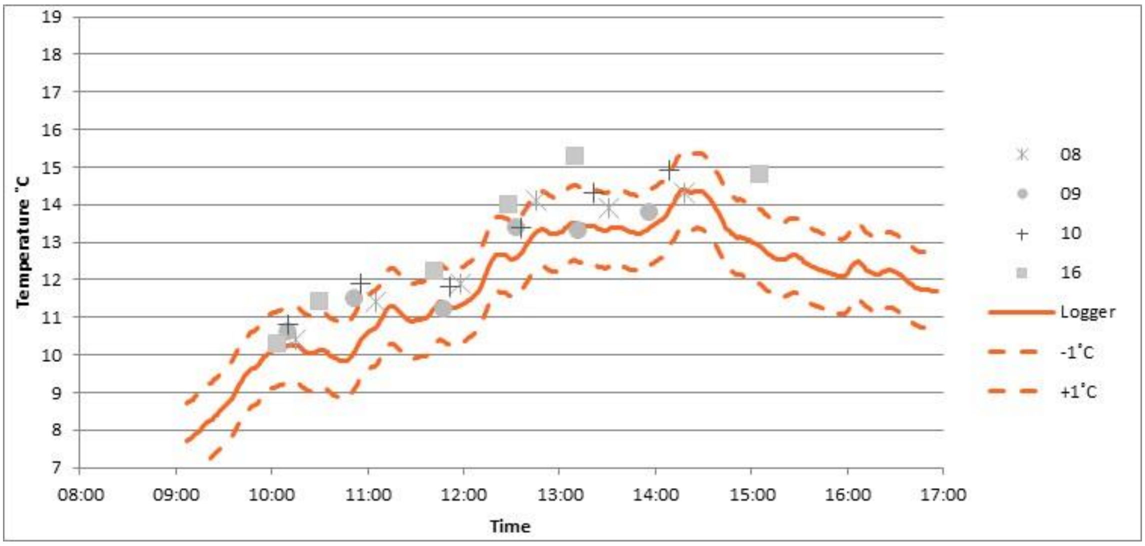

Figure 5.7: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 2, main trial day

The difference between the surface temperatures recorded by the Deflectographs and the reference are shown in Table 5.3 along with the awarded performance.

Table 5.3: 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		Test 6			
	1	2	1	2	1	2	1	2	1	2	1	2		
8	0.0	0.7	0.7	1.6	-0.3	1.7	0.2	2.5	-0.6	1.6	-1.8	1.4	50.0	Medium
9	-0.2	1.2	-0.5	2.0	0.2	0.8	-0.5	2.3	-0.5	1.3	-0.7	1.3	58.3	Medium
10	-0.2	1.4	1.4	2.2	0.2	1.6	2.6	2.2	-0.3	2.1	-0.9	2.3	33.3	Low
16	0.4	1.1	1.0	1.7	0.3	1.8	-1.0	3.0	-0.3	3.3	0.5	2.1	41.7	Low

Two machines achieved a medium performance and two machines achieved a low performance.

The air temperatures from the logger and the data supplied from the operators is shown in Figure 5.8 and Figure 5.9.

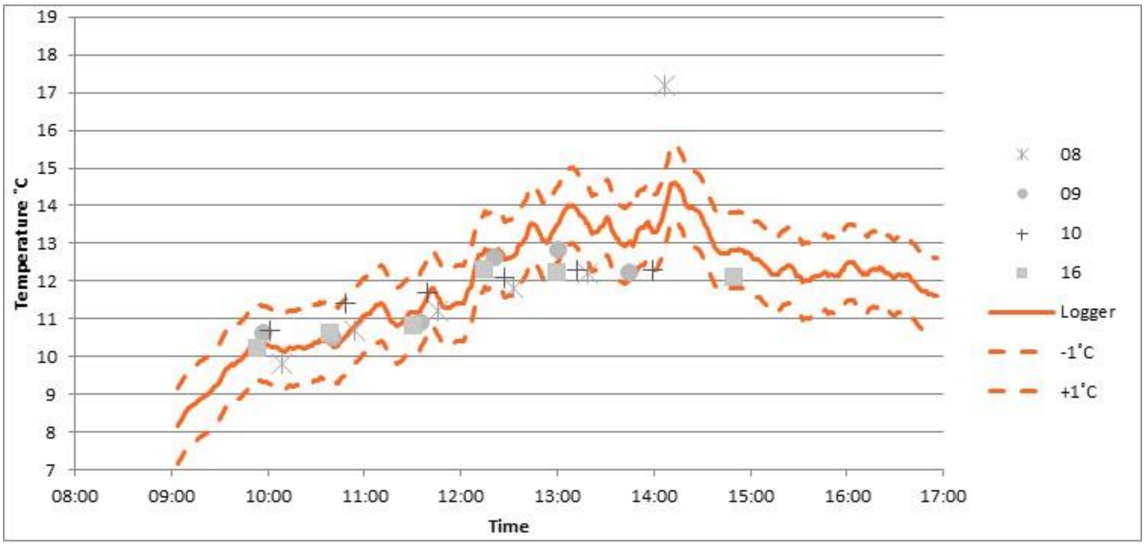

Figure 5.8: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 1, main trial day

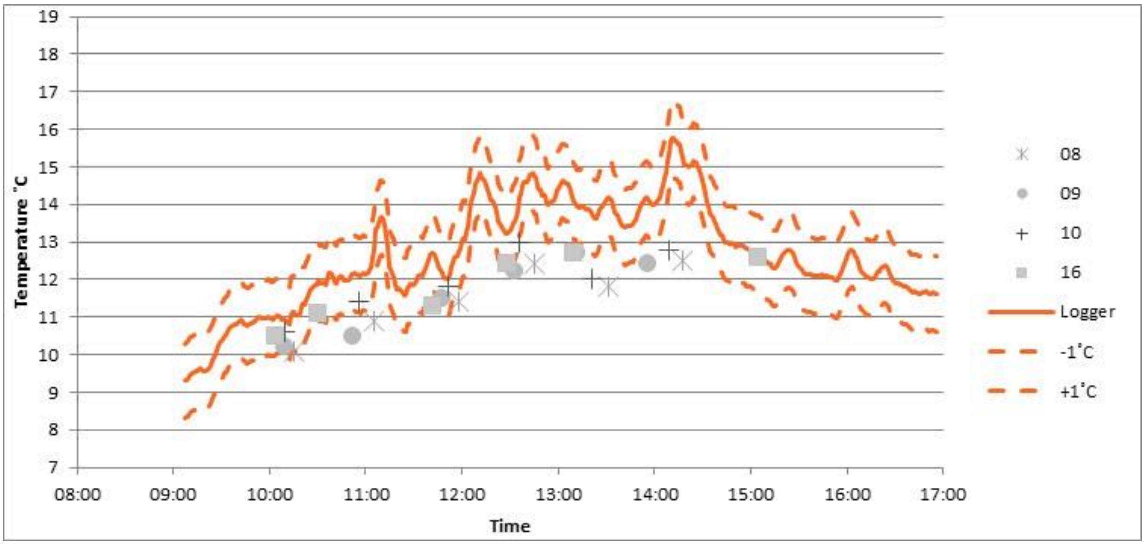

Figure 5.9: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 2, main trial day

Examination of Figure 5.8 and Figure 5.9 shows that the spread of data is reasonably consistent with a requirement to be within 1°C of the reference.

The difference between the air temperatures recorded by the Deflectographs and the reference are shown in Table 5.4 along with the performance awarded.

Table 5.4: 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		Test 6			
	1	2	1	2	1	2	1	2	1	2	1	2		
8	-0.4	0.4	-0.1	1.1	-0.4	1.2	-0.9	0.8	-1.3	-0.5	3.3	-0.4	66.7	Medium
9	0.3	0.8	0.3	1.0	-0.4	1.1	-0.2	1.1	-0.7	0.7	-0.8	-0.1	83.3	High
10	0.4	1.2	0.9	1.7	0.1	1.6	-0.5	1.8	-1.6	-0.2	-1.0	0.2	58.3	Medium
16	-0.2	1.3	0.3	1.4	-0.4	0.9	-0.5	1.4	-1.3	0.7	-0.7	-0.1	66.7	Medium

One machine achieved a high performance and three machines achieved a medium performance.

5.4 Deflection readings – Main trial day

To allow the machines to "warm up", the first lap was disregarded (after analysis). In addition due to some technical issues with some of the machines it was decided that lap 2 would also be disregarded and an additional lap (lap 7) would be undertaken. In other words, the machines would be assessed using laps 3 to 7.

During the early laps it was identified that Machine 3 was recording deflections significantly higher than the rest of the fleet on the near side wheel path. This machine was investigated and resumed testing during lap 6. After the main testing, this machine undertook three additional laps with some of the other devices in the fleet to complete its assessment. The data from this machine (Machine 3) is excluded from the tables below and the performance of this device is further discussed in Section 5.5.

5.4.1 *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 5.5.

Table 5.5: 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	4.0	6.4	19.0	13.4	7.8	11.2
5	3.1	3.3	9.6	6.1	1.6	6.7
8	0.9	2.8	21.7	17.5	15.3	8.1
9	1.9	3.4	18.2	20.9	9.7	13.0
10	4.2	4.1	18.1	11.6	7.0	7.4
12	9.8	10.2	15.9	13.5	9.1	10.4
14	1.7	4.7	11.7	12.7	11.4	7.0
15	3.3	2.0	18.5	17.6	7.7	7.4
16	5.5	2.6	14.8	14.1	4.9	7.2

It can be seen from Table 5.5 that despite some variation in the values, no machine was obviously more variable on average than the others.

5.4.2 *Mean deflection values*

Table 5.6 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 is not met are in red. Table 5.7 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).

Table 5.6: Mean deflection (µm) by section: Main running day

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	43	30	258	210	152	140	151	127
5	45	38	264	205	158	145	155	129
8	45	48	256	234	161	162	154	148
9	45	52	255	233	173	177	157	154
10	49	52	266	241	160	166	158	153
12	46	37	274	212	169	148	163	132
14	54	52	271	230	170	156	165	146
15	50	50	259	229	158	160	156	146
16	53	50	267	224	167	157	162	144
Mean	48	46	263	224	163	157	158	142
BESD	3.9	8.2	6.7	12.3	6.8	11.3	4.6	10.1
BESD criterion	11.1	11.0	16.6	15.6	14.1	13.9	13.9	13.5
CoV	8.2%	18.0%	2.5%	5.5%	4.2%	7.2%	2.9%	7.1%

Table 5.7: Deviation (µm) from overall mean deflection by section: Main running day

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	-5.1	-15.3	-5.3	-14.6	-10.8	-16.3	-7.1	-15.4
5	-2.9	-7.4	0.5	-18.7	-5.4	-11.9	-2.6	-12.7
8	-2.2	2.6	-6.8	9.6	-2.4	5.1	-3.8	5.8
9	-3.2	6.2	-8.3	8.9	9.6	20.3	-0.6	11.8
10	1.3	6.7	2.9	16.6	-3.0	9.3	0.4	10.9
12	-1.4	-8.7	10.3	-12.0	5.9	-8.8	4.9	-9.9
14	6.2	6.1	8.1	5.7	7.0	-1.1	7.1	3.6
15	2.1	4.9	-4.6	4.4	-4.7	3.5	-2.4	4.3
16	5.2	4.8	3.2	0.0	3.7	-0.1	4.0	1.6
2x BESD criterion	22.2	22.1	33.3	31.3	28.1	27.8	27.9	27.1
3x BESD criterion	33.3	33.1	49.9	46.9	42.2	41.7	41.8	40.6

From Table 5.6 it can be seen that the BESD criteria is met for the average of the site for both wheel paths, and for both wheel paths on each section. In addition from Table 5.7 it can be seen that all machines are within 2 times the BESD criterion of the fleet mean. Therefore, these nine machines are considered as meeting the trial criteria for deflection measurement.

5.5 Assessment of Machine 3

As previously mentioned, Machine 3 was identified as an outlier in the initial laps on this day. The crew for Machine 3 investigated the device and found some minor issues with the beam and cable connections which they resolved prior to taking part in laps 6 and 7 with the rest of the fleet.

To assess a device for deflection performance it is necessary to have 5 laps with a suitable reference dataset to compare against. Therefore, three additional laps (8, 9 and 10) were undertaken. Along with Machine 3, a subset of the fleet also took part in the testing to allow analysis of the data and to compare it with the rest of the fleet. A subset is used to allow the laps to be carried out over a shorter timescale so that they can be completed within the available time on the track. The machines selected for this were 8, 12, 14, 15 and 16.

The between-run standard deviation values for all these machines on these laps (i.e. laps 6 to 10) is shown in Table 5.8

Table 5.8: Between-run standard deviation for additional testing, main running day (day 2)

Machine number	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
3	3.3	4.2	7.4	5.0	2.9	10.8
8	3.5	2.8	7.3	6.1	3.7	8.2
12	4.7	5.0	5.2	5.8	8.5	7.7
14	3.6	4.7	8.1	8.5	10.5	8.8
15	4.1	2.5	9.4	1.4	10.6	6.9
16	5.9	2.6	9.6	5.4	2.1	5.5

As with the main testing, it can be seen from Table 5.8 that despite some variation in values, no machine was obviously more variable than the others.

The mean deflections recorded on each section, together with summary statistics for laps 6 to 10 for these machines are shown in Table 5.9. The deviations from the overall mean are shown in Table 5.10.

Table 5.9: Mean deflection (µm) by section: Additional testing, main running day

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
3	31	35	262	226	146	152	146	138
8	49	49	276	247	176	168	167	155
12	44	34	282	224	171	150	166	136
14	57	52	284	238	177	165	173	151
15	51	52	272	240	166	166	163	153
16	55	50	287	242	170	162	171	152
Mean	48	45	277	236	168	160	164	147
BESD	9.5	8.4	9.5	9.2	11.2	7.6	9.6	8.2
BESD criterion	11.1	11.0	17.0	16.0	14.2	14.0	14.1	13.7
CoV	20.0%	18.7%	3.4%	3.9%	6.7%	4.7%	5.8%	5.6%

Table 5.10: Deviation (µm) from overall mean deflection by section: Additional testing, main running day

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
3	-17.0	-10.7	-15.9	-10.4	-21.3	-8.4	-18.1	-9.8
18	1.3	3.7	-0.9	11.0	7.9	8.1	2.7	7.6
12	-3.8	-10.9	4.7	-12.0	3.2	-10.3	1.3	-11.1
14	9.5	6.4	7.1	1.4	9.6	4.1	8.7	4.0
15	3.0	6.4	-5.0	4.0	-2.0	5.1	-1.3	5.1
16	7.0	5.1	10.1	6.0	2.6	1.5	6.5	4.2
2x BESD criterion	22.2	22.1	34.0	31.9	28.4	28.0	28.2	27.3
3x BESD criterion	33.3	33.1	51.0	47.9	42.6	42.0	42.3	41.0

From Table 5.9 it can be seen that the BESD criterion is met for each wheel path and section combination. In addition, from Table 5.10 it can be seen that all machines are within 2 times the BESD criterion of the fleet mean. This would initially suggest that Machine 3 could be considered as meeting the trial criteria. However, this analysis is based on a subset of the fleet which means that it might not reflect the average of the whole fleet. Therefore, it is also necessary to combine this data with the main dataset from the trial before making a final decision.

In order to combine the data from the two datasets, the average deflection values for each wheel path and section for the reference machines was calculated for each dataset i.e. for laps 3 to 7 and for laps 6 to 10 . The ratio between these values was then applied to the data from Machine 3 (from laps 6 to 10) to provide an estimate of the likely deflections that this machine would have measured if it had operated in its current configuration during the main set of testing (i.e. laps 3 to 7).

The average deflections from the two datasets for the machines acting as reference and the calculated ratios are shown in Table 5.11.

Table 5.11: Reference data values and estimation ratio

	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
Average laps 3 to 7	50	47	265	226	165	156
Average for laps 6 to 10	51	47	281	238	172	162
Ratio	0.97	1.00	0.95	0.95	0.96	0.96

Table 5.12 shows the mean deflections recorded on each section for the combined dataset, 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 is not met are in red.

Table 5.13 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). In both of these tables Machine 3 is in blue italic text to highlight that it is an estimate.

Table 5.12: Mean deflection (µm) by section: Combined dataset

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	43	30	258	210	152	140	151	127
3 (estimate)	*30*	*35*	*247*	*214*	*140*	*147*	*139*	*132*
5	45	38	264	205	158	145	155	129
8	45	48	256	234	161	162	154	148
9	45	52	255	233	173	177	157	154
10	49	52	266	241	160	166	158	153
12	46	37	274	212	169	148	163	132
14	54	52	271	230	170	156	165	146
15	50	50	259	229	158	160	156	146
16	53	50	267	224	167	157	162	144
Mean	46	44	262	223	161	156	156	141
BESD	6.7	8.5	8.1	12.0	9.6	11.1	7.4	10.1
BESD criterion	11.1	11.0	16.6	15.6	14.0	13.9	13.9	13.5
CoV	14.7%	19.1%	3.1%	5.4%	6.0%	7.1%	4.7%	7.2%

Table 5.13: Deviation (µm) from overall mean deflection by section: Combined dataset

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	-3.4	-14.2	-3.7	-13.6	-8.6	-15.3	-5.2	-14.4
3 (estimate)	*-16.1*	*-9.8*	*-14.4*	*-9.2*	*-20.3*	*-9.1*	*-16.9*	*-9.4*
5	-1.1	-6.3	2.1	-17.7	-3.1	-10.9	-0.7	-11.6
8	-0.4	3.7	-5.2	10.7	-0.1	6.1	-1.9	6.8
9	-1.4	7.3	-6.7	10.0	11.9	21.3	1.3	12.9
10	3.1	7.8	4.5	17.7	-0.7	10.3	2.3	11.9
12	0.4	-7.6	11.9	-11.0	8.1	-7.8	6.8	-8.8
14	8.0	7.2	9.7	6.7	9.2	-0.1	9.0	4.6
15	3.9	6.0	-3.0	5.5	-2.4	4.5	-0.5	5.3
16	6.9	5.9	4.8	1.1	6.0	0.9	5.9	2.6
2x BESD criterion	22.1	22.0	33.2	31.2	28.0	27.8	27.8	27.0
3x BESD criterion	33.2	33.1	49.8	46.8	42.0	41.6	41.7	40.5

It can be seen from Table 5.12 that the BESD criterion is met for the average of the site and for each section in both wheel paths. It can also be seen (

Table 5.13) that all machines are within 2 time the BESD criterion of the fleet mean.

Therefore, following this additional testing all ten machines are considered as meeting the trial criteria for deflection measurement.

6 Conclusions

The 2020 National Deflectograph accreditation trials were held on the Horiba-MIRA proving grounds by TRL on behalf of Highways England on the 10th and 11th March 2020. 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

Seven machines were within the standard front axle limits defined in the Accreditation and QA specification (TRL, 2020). The remaining three were within the extended front axle limits. All ten machines were within the rear wheel weight limits.

(II) Deflection measurement

After additional testing all ten machines that participated in the 2020 trial met the criteria for deflection measurement.

(III) Distance measurement

All ten machines that participated in the 2020 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

Six of the ten operators achieved a high performance with regards to the measurement of temperature at depth. The remaining four achieved a medium performance.

(V) Temperature measurement – surface temperature

Surface temperature data from four machines was supplied at this trial. Two machines achieved a medium performance, and two achieved a low performance.

(VI) Temperature measurement – air temperature

Air temperature data from four machines was supplied at this trial. One machine achieved a high performance, and three a medium.

A summary of the machines that attended the 2020 accreditation trial and the criteria that they met/performance achieved can be found in Appendix A.

References

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DMRB CS 229. (2020). *Design Manual for Roads and Bridges CS 229 Data for Pavement assessment [online]. [Accessed 3rd April 2020]*. https://www.standardsforhighways.co.uk/dmrb/: The Stationery Office.

TRL. (2016). *Accreditation and Quality Assurance of Deflectograph Survey Devices.* http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-collection/deflectograph.cfm.

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Acknowledgements

The author wishes to thank the operators of the Deflectograph devices for their co-operation in the accreditation process in particular to the crews of the devices which supported the additional laps. The author is also grateful to David Gershkoff who provided expert technical advice on deflection measurements and to Darius Singfield, Joanna Slicner, Kevin Green, Patrick Werro and Roy Jaques for their assistance with the trial.

Appendix A Machine identification

Table A.1: Machine identification

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

Appendix B Layout of test sections at Horiba-MIRA

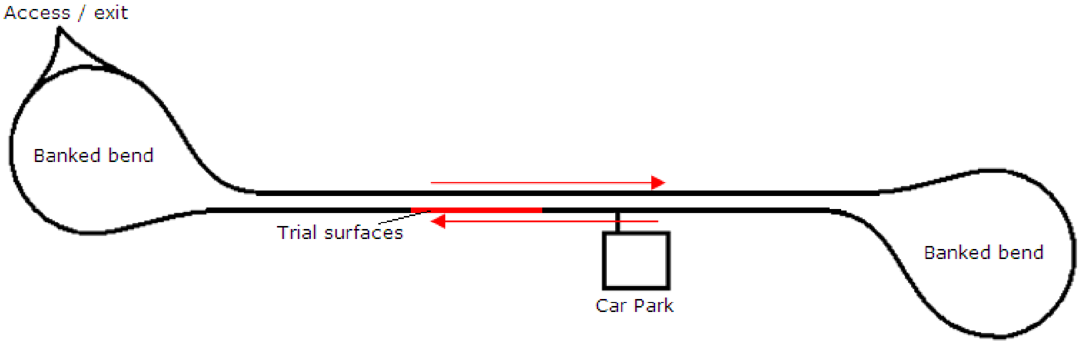

Figure B.1: Test route on the Horiba-MIRA twin straights

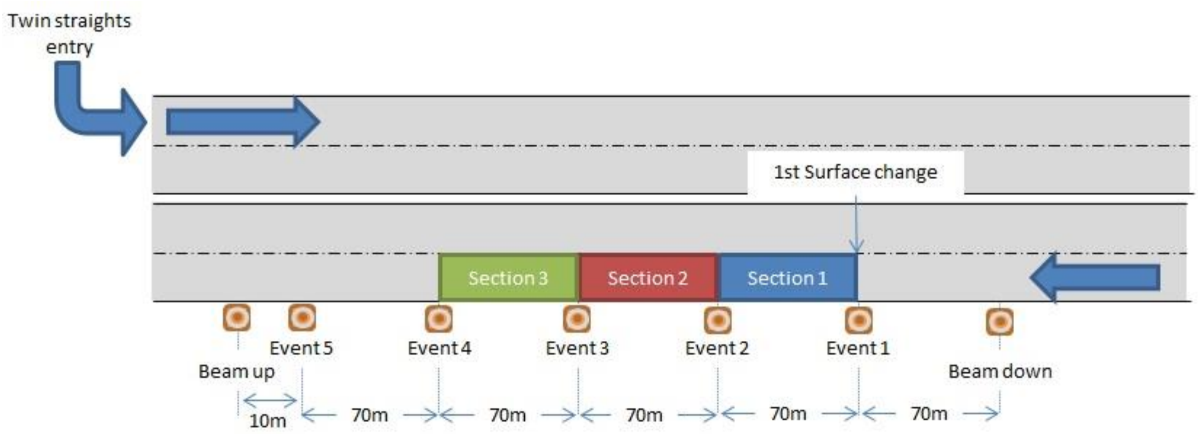

Figure B.2: Location of marker cones and test sections on Horiba-MIRA twin straights

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

Appendix D Criteria for acceptability

The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Deflectograph Survey Devices" (TRL, 2020). This document is a live document (i.e. is subject to change) and the most recent (Feb 2020) version of the document was used for the trial. The relevant section of the document is reproduced verbatim below in Section D.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 the Equipment belongs and to whom Accreditation Certificates are awarded. Note that the copied text refers to other parts of the accreditation document which are not reproduced in this report.

D.1 Trial criteria from the Accreditation and QA document

E3. Equipment inspection

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

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

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

Table 1 – Criteria for wheel weights

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

E3.4 A simple assessment of the temperature probe used for the direct measurement method 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 15% above the 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 expanded front axle range would continue to be regarded as acceptable provided that they performed satisfactorily in the dynamic tests.

E3.5 Equipment which has infra-red temperature sensors for determining surface temperature fitted should be checked to confirm that the emissivity settings have been set to the manufacturer's recommended setting for asphalt.

E.4 Running Trials

E4.1 Overview

E4.1.1 As detailed in in Appendix B, trials shall 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 shall 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 shall be collected at a test speed of 2.4±0.1 km/h. Equipment shall be checked by measuring the time taken to travel a known length. If the Equipment is found to be surveying outside the test speed range, the survey operator shall be asked to adjust their speed accordingly. Laps for Equipment where the survey speed requirements are not met shall be excluded from the assessment.
- Instances where the rate of change in temperature measured at 40mm is greater than 2.5˚C per hour measured over a period of 15 minutes shall be investigated. If the variation of deflection data is seen to be to large then the lap should be disregarded and an additional lap undertaken.

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

E4.2.4 The Auditor shall 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 shall 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 shall be used to assess the repeatability of each individual Equipment.

E4.2.5 The BRSD shall 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 shall 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 shall 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 shall be further examined to identify outlying Equipment. This shall include examining the Fleet BESD and data from individual Equipment. Outlying Equipment shall 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 shall fail Accreditation. Any Equipment that is between two and three times the BESD criterion from the Fleet mean shall 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 shall 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 shall be assessed for both wheel paths separately. To achieve Accreditation the Equipment shall meet the requirements for both the NS wheel path and the OS wheel path.

E4.2.11 In addition to the above assessments the Auditor should review the profiles of the Survey Data over the site for each Equipment and investigate any anomalies. Based on the results of the investigation the Auditor may withhold Accreditation for Equipment and/or issue an Improvement Notice as detailed in Section H.

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 – direct measurement method

E5.2.1 If undertaking this test, the Contractor should 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. These probes are required to provide results to a resolution equal to or better than 0.1˚C. Therefore if the probe does not then it shall be identified as “Not Suitable” regardless of the performance seen for the measurements (with a note identifying the reason for the performance given). The criteria for the assessment of the direct measurement method are given in Table 4.

Table 4– Criteria for direct measurement method

Performance level	Measurement of temperature
High	≥80% of the measurements are within 1.0ºC of the reference
Medium	≥50% of the measurements are within 1.0ºC of the reference
Low	≥15% of the measurements are within 1.0ºC of the reference
Not Suitable	Otherwise

E5.3 Temperature measurement –Contactless measurement

E5.3.1 If undertaking this test, the Contractor shall be required to make measurements of the air and surface temperature (at locations specified by the Auditor) so that at least eight pairs of measurements are taken during the course of the test laps. These sensors are required to provide results to a resolution equal to or better than 0.1˚C. Therefore if the sensor does not then it shall be identified as “Not Suitable” regardless of the performance seen for the measurements (with a note identifying the reason for the performance given). The criteria for the assessment of surface temperature measurement are given in Table 5 and the assessment of air temperature measurement are given in Table 6.

Table 5– Criteria for surface temperature measurement

Performance level	Measurement of temperature
High	≥80% of the measurements are within 1.0ºC of the reference
Medium	≥50% of the measurements are within 1.0ºC of the reference
Low	≥15% of the measurements are within 1.0ºC of the reference
Not Suitable	Otherwise

Table 6– Criteria for air temperature measurement

Performance level	Measurement of temperature
High	≥80% of the measurements are within 1.0ºC of the reference
Medium	≥50% of the measurements are within 1.0ºC of the reference
Low	≥15% of the measurements are within 1.0ºC of the reference
Not Suitable	Otherwise

E5.3.2 In addition to providing the air and surface temperatures the Survey Contractor shall provide the predicted temperature at 40mm depth using this data. The Auditor may allow Survey Contractors to provide these predicted temperatures after the trial to allow for processing time. The Auditor shall confirm on the Accreditation Certificate whether the calculations have been accurately calculated.

Highways England 2020 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 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 2020 accreditation trial run by TRL and held on the HORIBA-MIRA proving ground between 10th and 11th of March 2020.

Other titles from this subject area

PPR1018	Highways England 2019 National Deflectograph Accreditation Trial. S Brittain. 2022
PPR939	Highways England 2018 National Deflectograph Accreditation Trial. S Brittain. 2020
PPR941	Highways England 2017 National Deflectograph Accreditation Trial. S Brittain. 2020
PPR942	Highways Agency 2016 National Deflectograph Accreditation Trial. S Brittain. 2020

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