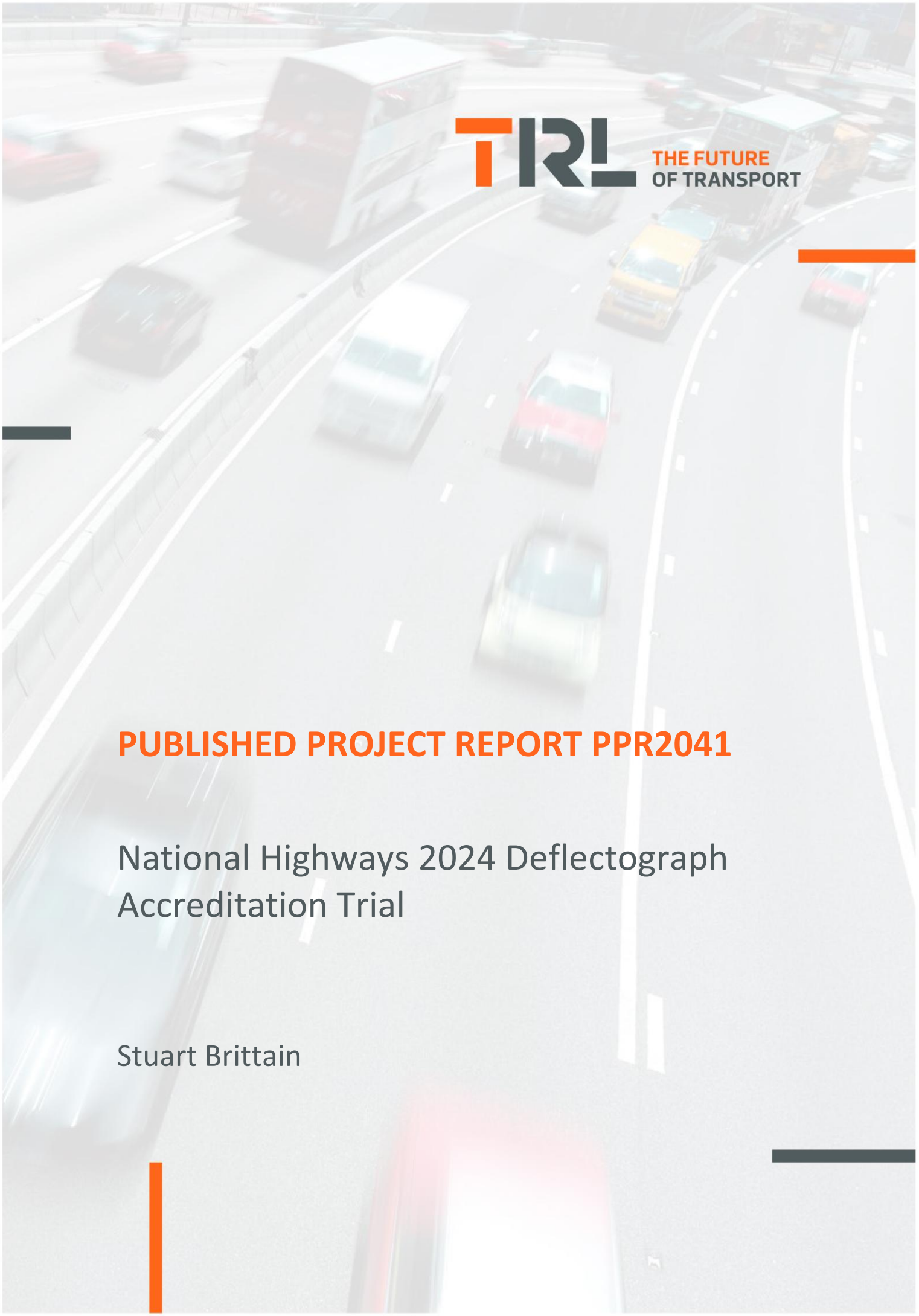

THE FUTURE OF TRANSPORT

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National Highways 2024 Deflectograph Accreditation Trial

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Executive summary

Deflectograph accreditation trials are held annually by TRL on behalf of National Highways. The objective is to monitor the performance of all Deflectographs operating on the UK road network and to ensure they are all measuring within the specified fleet tolerances. 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 2024 trial was held from the 5th to the 7th March 2024. The site used was the twin horizontal straights of the Horiba-MIRA proving ground. This was the twenty-ninth year in which TRL has taken full responsibility for the planning and running of the trials. Ten machines attended the trial which represents the entirety of the known UK fleet.

The beginning of the first day of the trial was used to weigh some of the Deflectographs and undertake distance calibrations. On the second half of the first day, the machines tested the deflection site. The second day was used to repeat the deflection assessment and to obtain distance and temperature assessments. The third day was used for repeat testing following alterations to one of the devices.

All ten machines met the mandatory requirements of the trial (i.e. weight, deflection measurement and distance measurement) and can therefore be considered for approval to survey the National Highways SRN.

With regards to the measurement of pavement temperature at depth, eight of the ten machines achieved a high performance rating, and two machines achieved a medium performance rating.

Participants were also asked to provide surface and air temperature measurements (if they had the equipment fitted) and five machines provided these measurements. With regards to the measurement of surface temperature, four machines achieved a high performance and one a medium. With regards to measurement of air temperature, all five machines achieved a high performance.

1 Introduction

Deflectograph accreditation trials are held annually by TRL on behalf of National Highways. The objective is to monitor the performance of all Deflectographs operating on the National Highways 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 can be assessed.

The 2024 trial was held from 5th to the 7th March 2024. 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-ninth year in which TRL has taken full responsibility for the planning and running of the trials and the twelfth full trial at Horiba-MIRA. Ten machines attended the trial. The trial process and the criteria used for the 2024 trial are discussed in Section 3 and Appendix D of this report, respectively. The results from the trial are discussed in Sections 4 to 6.

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 National Highways, Appendix A lists the machines, owner and performance at the trial.

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. They are joined by banked bends at either end. During October 2010, National Highways 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 NHCP_01, NHCP_02 and NHCP_03 (National Highways Calibration Pavement) in 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 effectively 60m sections) and the layout and test route are shown in Appendix B. Nominal construction details of the test sections can be found in Appendix C.

2.2 Suitability of site and management of site-dependent between run variability

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. Following the 2011 transitional trial, the trial process and the accreditation criteria were reviewed.

During the transitional trial it was found that there was a localised high deflection area on the site. This caused an increase in the between run variability in the data due to small changes in driving line. This was further investigated at the 2013 trial, and it was found that this variability could be removed by placing small cones on the test track to mark the survey test line for the whole test site. These cones were placed either side of the machines' test path (as shown in Figure 2.1), so that any deviation in the test line would cause a cone to be knocked over which could be recorded. During some stages of the 2024 trial, it was too windy to apply this approach, the wind moving or knocking-over the cones, therefore lines were sprayed onto the surface marking the test line.



Figure 2.1: Image illustrating cone positions during testing

3 Trial format

In preparation for the 2021 trial, changes were made to the test programme to mitigate the risks from COVID-19. The changes made were also found to be beneficial for the efficiency of the trial. Therefore, a variation of this approach has been used in subsequent trials. The format applied to the 2024 trial is described in this section.

Each crew is required to carry out a machine inspection in advance of the trials and a certified checklist is submitted before the machine is allowed to take part in the running trials. In addition, all crews are asked to weigh their Deflectograph (with crew in position) before the trial and provide this data.

3.1 Day 1 – Re-weighing, distance calibration and test laps

On arrival, all personnel signed in at the Horiba-MIRA Gatehouse. They then reported to the TRL reception staff. When all participants had arrived, a briefing was given by TRL to ensure that everyone involved was aware of the programme and what was required of them to ensure that the testing was completed safely and correctly.

Examination of the provided pre-trial weight data identified that two machines appeared to be over the specified weight limits. These machines were machine 2 and 14 and were subsequently re-weighed at the trial. This is further discussed in Section 4.2. During this period, the machines also undertook a distance calibration on the test track.

After completion of the re-weighing and distance calibrations, each machine undertook a static calibration followed by 8 test laps covering the three test sections. The machine running order was randomised and all machines completed the testing in convoy (with suitable gaps left between them) to cover all the sections in a single measurement run.

To improve the alignment of the measurements, crews were asked to stop their machines at the start of each run, 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.

CS 229 (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 before and after the deflection test sections (the same locations the operators measure during the main testing) at 40 and 100mm depths, to inform any conclusions drawn. Air and pavement surface temperature measurements are also collected at these locations. Automatic data-loggers are used to provide a reading every minute during deflection testing.

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

Survey data, collected via USB memory sticks, was processed during the day at track side by TRL to allow interpretation of the performance to be carried out.

The initial conclusions of the testing on this day were provided to participants before clearing the site for the day.

3.2 Day 2 – Main testing

On arrival, all personnel signed in at the Horiba-MIRA Gatehouse and then a morning briefing was held.

Crews undertook a static calibration of their machines and then proceeded to undertake the main testing. This involved undertaking deflection test laps as on day 1. In addition, during this testing, operators were asked to measure the length of a marked-out section and to record temperature measurements. The temperature measurements were taken in two pre-drilled holes (40mm depth, the same ones used for the thermocouple loggers) and also in a water bucket (set up after the marked-out length). Crews were also asked to provide air and surface temperatures for the three measurement stations if their Deflectograph has these temperature sensors fitted.

Six laps were undertaken on this day with deflection data collected on each lap and distance and temperature measurements collected by operators on the first five laps. As with day 1, data was collected and processed trackside by TRL so that updates on performance could be provided.

3.3 Day 3 – Machine alterations and Repeat testing

On arrival, all personnel signed in at the Horiba-MIRA Gatehouse and then a morning briefing was held.

Following the testing on Day 2, it was identified that one machine (Machine 3) appeared to be an outlier for deflection measurements. This machine underwent alterations on the morning of day 3.

All crews undertook a static calibration of their machines and then proceeded to undertake repeat testing. This involved undertaking deflection test laps as on day 1.

Six laps were undertaken on this day with deflection data collected on each lap (no operator distance and temperature measurements). As with days 1 and 2, data was collected and processed trackside so that updates on performance could be provided.

4 Inspections and wheel weights

4.1 Inspections

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

4.2 Wheel weights

Prior to the 2020 trial, Deflectographs had been weighed in the maintenance building on the HORIBA-MIRA proving ground. During the 2020 trial a member of staff slipped over during this process (on the smooth floor); this, coupled with the fact that the use of this facility required a number of vehicle reversing operations all within a tight space, meant that this site was deemed unsuitable on safety grounds.

Therefore, for the 2021 trial, the weight measurements were undertaken (successfully) on the twin straights (in the open air). During the 2022 trial it was identified that it was too windy to obtain accurate measurements on the twin straights. Fortunately, it was possible to undertake measurements in a workshop on site (a different location from the maintenance building used in previous years). However, the availability of this workshop could not be guaranteed for future trials as it can only be booked a week in advance. Therefore, to mitigate this risk operators are asked to make weight measurements of their devices and provide this information before the trial. If they did not have access to suitable, calibrated weigh pads they were asked to take their Deflectograph to TRL prior to the trial so that they could be weighed.

The weighing before the trial identified that machines 2 and 14 were outside of the weight limits for rear OS and rear NS, respectively (although for Machine 14 the measurements were done by a third party and there was some uncertainty as to which data was NS and which was OS).

Therefore, these two machines were re-weighed on day 1 of the trial. Unfortunately, the workshop which was used for the weighing during the 2022 and 2023 trials was not available. However, the wind speed was low enough to make measurements on a sheltered part of the test track. This re-weighing identified that Machine 2 was within weight limits. However, Machine 14 exceeded the limit on the rear OS wheel. It was decided that Machine 14 would be tested in this configuration on day 1 of the trial (extending the load correction process for the measured weight) and the weight distribution reinvestigated before the testing on day 2.

Prior to the testing on day 2, tools and spares were removed from Machine 14 and it was reweighed. This appeared to show the machine still exceeding the weight limits for the rear OS wheel. However, this weighing was undertaken on the manoeuvres area (the operator requested that the weight measurement be undertaken at a different location from day 1 to eliminate the location as the cause). The Manoeuvres area is a cracked pavement and as such the device was weighed by driving on the weigh pads in one direction and then the reverse direction (and the average taken) to attempt to eliminate any potential effects from this factor.

After the trial, the operator of this machine hired in some weigh pads and reweighed their device in the same configuration as day 2 (and day 3). This found that the machine was within the weight limits. These weight values (collected on a flat surface in a more controlled environment) were therefore used to reprocess the data collected on days 2 and 3 of the trial.

Although this configuration of Machine 14 (with the tools and spares removed) was within the load criteria, the operator of this machine identified that this was not a suitable configuration for undertaking surveys during the survey season. Therefore, they re-weighed the device in a new configuration (tools and spares included but spare wheel removed instead). The new configuration was within the load criteria. The operator undertook surveys of their dynamic calibration site in the two different configurations (and applied the corresponding load corrections). This data was provided to TRL so that we could confirm that resulting performance was consistent between the two configurations. It was found suitable and as such the weight of the configuration that the operator is planning to undertake surveys in is reported on the trial certificate for this device.

The weight values applicable to the 2024 trial are given in Table 4.1. For Machine 14, this includes the two weight values for the trial (one for day 1 and one for days 2 and 3). In addition, the weight values for the configuration for 2024 surveys for this machine is also shown. To aid comparison against the criteria, the percentage of the target weight (100% corresponds to matching the target) are shown in brackets beneath the Total front, Rear NS and Rear OS values. Any values outside of the criteria are highlighted in bold red text.

Table 4.1: Deflectograph weight distribution including crew (kg)

Machine	Front NS	Front OS	Total Front	Rear NS	Rear OS	Total rear	Total Machine
2	2572	2590	5161 (114.7%)	3173 (99.9%)	3323 (104.7%)	6496	11657
3	2365	2429	4794 (106.5%)	3404 (107.2%)	3376 (106.3%)	6780	11574
5	2326	2306	4632 (102.9%)	3166 (99.7%)	3268 (102.9%)	6434	11066
8	2270	2398	4668 (103.7%)	3186 (100.3%)	3136 (98.8%)	6322	10990
9	2362	2286	4648 (103.3%)	3196 (100.7%)	3438 (108.3%)	6634	11282
10	2386	2360	4746 (105.5%)	3472 (109.4%)	3118 (98.2%)	6590	11336
12	2246	2280	4526 (100.6%)	3164 (99.7%)	3338 (105.1%)	6502	11028
14 (day 1)	2405	2424	4829 (107.3%)	3260 (102.7%)	**3507** **(110.5%)**	6767	11595
14 (day 2 & 3)	2380	2417	4797 (106.6%)	3252 (102.4%)	3442 (108.4%)	6693	11490
14 (2024 surveys)	2392	2423	4815 (107%)	3243 (102.2%)	3423 (107.8%)	6667	11482
15	2418	2458	4876 (108.4%)	3402 (107.1%)	3368 (106.1%)	6770	11646
16	2266	2316	4582 (101.8%)	3272 (103.1%)	3114 (98.1%)	6386	10968

The final configurations for all machines are within the front axle and rear wheel limits given in the Accreditation and QA specification (TRL, 2020).

4.3 Beam calibration check

Prior to each set of testing, 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 Day 1 (5th March 2024) – Initial laps

On this day, each machine undertook seven test laps (some machines also undertook an eighth lap but this lap was stopped before completion due to track availability). However, the first lap was disregarded (after analysis) to take account of the fact that the machines were likely to be warming-up.

5.1 Machine alterations

During the first few laps on this day it was identified that Machine 12 was producing very low, anomalous results. In addition, Machine 3 was identified as a potential outlier (relative to the fleet excluding Machine 12) producing slightly low results. This information was provided to the operators of these devices so that they could investigate.

The operators of Machine 12 identified that it appeared to have a loose connection and also that the frame pull was “juddery”. They therefore replaced the data connection cable, and the winch on the device.

The operators of Machine 3 identified that there might be an issue with the latest calibration carried out and reverted to the previous (but still recent) calibration.

The changes for these two machines were completed before undertaking lap 5, therefore the deflection results shown in this section are for laps 5 to 7 (as not all machines undertook lap 8). However, it should be noted that during the trial all data was examined to ensure that no other information would need to be reported to operators of the devices.

5.2 Temperatures recorded by the data loggers

Data loggers connected to thermocouples recorded the 40mm and 100mm depth temperatures along with the air and pavement surface temperatures. The loggers were set to record the measurements once every minute. In addition to the thermocouples, on day 1, a set of platinum temperature probes was also set up near station 1 which recorded data every second. During testing it was identified that there were significant issues with the data obtained from the thermocouples and as such this data has been disregarded.

The data from the platinum temperature probes has been 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.

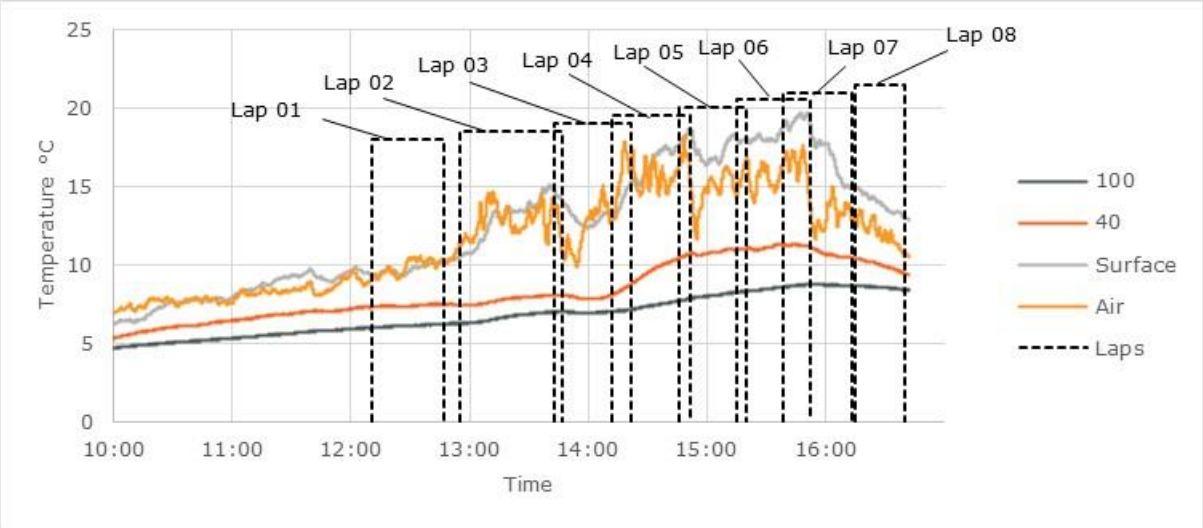

Figure 5.1: Temperature measurements from station 1 (before test sections) on day 1

The 40mm temperatures recorded at the test track were fairly stable with generally a slow upward trend during the course of the day. The exception to this is an increase in the upward trend between 14:12 and 14:52 and a slow downward trend after 15:45.

5.3 Between-run standard deviation for deflection values

No criteria are set relating to the between-run standard deviation (BRSD) of each machine. This is due in part to the BRSD being affected by both the machine performance and also due to temperature changes over the testing period. It is, however, useful to consider this parameter 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 BRSD for each machine, is shown in Table 5.1. Values (where present) which are more than two times the fleet average for the section and wheel path are highlighted in bold red text.

Table 5.1: Between-run standard deviation for day 1 (laps 5-7)

Machine Number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
2	6.2	3.8	10.4	6.7	10.3	8.1
3	6.0	**10.2**	9.0	2.5	3.3	8.3
5	3.7	4.3	3.8	5.8	3.6	6.7
8	1.4	1.5	3.2	0.9	10.3	4.5
9	3.4	4.6	17.6	10.1	4.1	6.8
10	1.8	1.8	2.8	4.2	1.6	0.9
12	3.4	5.3	14.5	**23.5**	3.1	4.8
14	7.2	6.5	20.4	5.7	8.6	6.2
15	1.8	1.7	8.3	2.1	5.0	2.9
16	2.8	3.1	8.9	6.1	5.6	6.1

It can be seen from Table 5.1 that although there is a reasonably large spread of BRSD values, only two values (Machine 3 for the NS measurement on NHCP_01 and Machine 12 for the OS measurement on NHCP_02) were noticeably higher than the rest of the fleet for the section and wheel path combination. These machines were not noticeably higher for the

other sections and wheel path combinations, therefore, this analysis did not identify any particular concerns.

5.4 Mean deflection values

Table 5.2 shows the mean deflections recorded on each section, together with summary statistics. Instances where the between-equipment standard deviation (BESD) meets the criterion are highlighted in green and instances where the criterion is not met are shown in red. This table is used to identify if the overall fleet distribution meets the BESD criterion.

Table 5.2: Mean deflection (µm) by section: day 1 (laps 5-7)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	52	45	280	239	138	135	157	139
3	31	35	236	215	103	114	123	121
5	50	44	279	221	150	143	160	136
8	43	44	285	243	140	136	156	141
9	42	49	267	224	132	134	147	135
10	58	52	291	245	159	155	169	151
12	42	35	286	223	132	121	154	126
14	62	54	283	235	147	152	164	147
15	48	50	286	245	139	137	158	144
16	47	44	274	237	138	138	153	140
Mean	47	45	277	233	138	137	154	138
BESD	8.7	6.4	15.9	10.9	14.6	12.4	12.3	8.9
BESD criterion	11.1	11.0	17.0	15.9	13.4	13.4	13.8	13.4
CoV	18.4%	14.2%	5.8%	4.7%	10.6%	9.1%	8.0%	6.5%

Table 5.3 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). This table helps to identify if any machines are significant outliers and provides further information on the distribution of the fleet.

Table 5.3: Deviation (µm) from overall mean deflection by section: day 1 (laps 5-7)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	4.6	-0.6	2.9	6.1	0.4	-1.3	2.6	1.4
3	-16.7	-9.9	-41.0	-17.3	-34.4	-22.6	-30.7	-16.6
5	2.6	-1.0	2.1	-12.0	12.0	6.2	5.6	-2.3
8	-4.5	-0.7	8.2	10.0	1.9	-0.4	1.8	3.0
9	-5.2	3.4	-9.3	-8.6	-5.6	-2.7	-6.7	-2.6
10	10.1	6.7	14.2	12.7	21.0	18.7	15.1	12.7
12	-5.3	-10.7	9.6	-9.4	-5.5	-15.8	-0.4	-12.0
14	14.1	8.6	6.2	2.3	9.1	15.1	9.8	8.7
15	0.3	5.0	9.6	12.1	0.7	1.0	3.5	6.0
16	0.0	-0.8	-2.5	4.1	0.5	1.9	-0.7	1.7
2x BESD criterion	22.2	22.1	34.0	31.7	26.8	26.8	27.7	26.9
3x BESD criterion	33.3	33.1	51.0	47.6	40.3	40.2	41.5	40.3

From Table 5.2 it can be seen that the BESD criterion is met for the average of the site for both wheel paths. On examination of Table 5.3, it can be seen that there are two instances (machine, section and wheel path) where the “more than 2 times the BESD” criterion from the fleet mean was observed. This occurred for Machine 3 on sections NHCP_02 and NHCP_03 for the NS measurements. It can also be seen that there were no instances which were more than 3 times the BESD criterion away from the fleet mean.

After completion of the day 1 testing, no outliers were identified in the final set of laps on this day. Therefore, no machines were identified as requiring alterations with regards to the deflection measurements. However, as noted section 4.2, Machine 14 required alterations to bring the load distribution within the set criteria.

6 Day 2 (6th March) – Main test Laps

To differentiate from the testing on day 1, the laps on day 2 were prefixed with a 1 so the first lap on day 2 was labelled as lap 11. Six laps were undertaken on this day. The first lap (after analysis) is disregarded to take account of the fact that the machines were likely to be warming-up.

6.1 Machine alterations

Other than changes to the load on Machine 14 (discussed in section 4.2) no machine alterations were undertaken on day 2.

6.2 Temperatures

6.2.1 Temperatures recorded by the data loggers

The issues present with the thermocouple data loggers persisted on day 2. Therefore, the data from the thermocouples has been disregarded. The platinum probes were set up at both station 1 and station 2 and were set to record data every second.

The data from the platinum temperature probes has been 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.

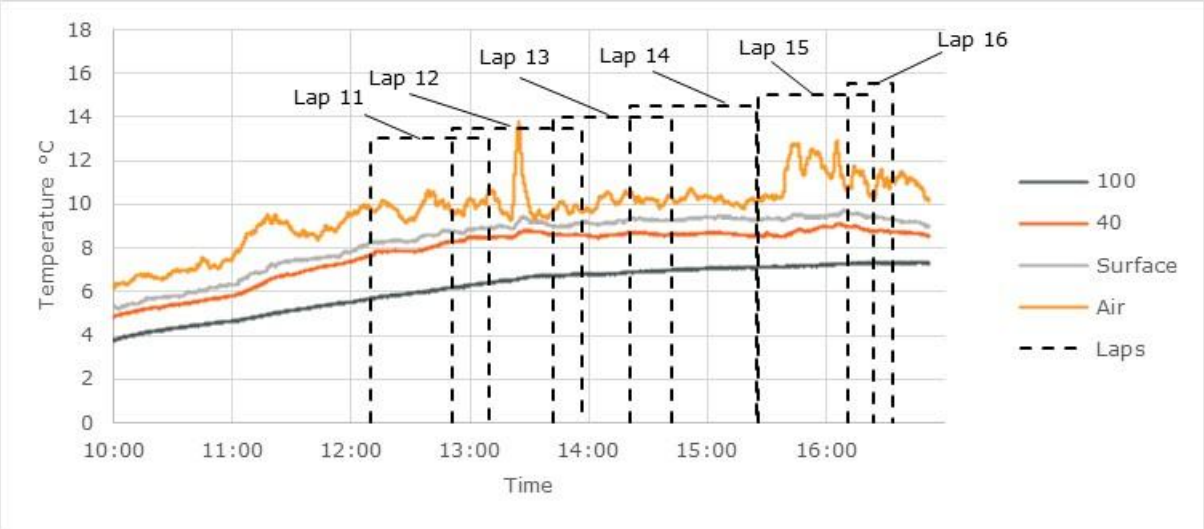

Figure 6.1: Temperature measurements from station 1 (before test sections) on day 2

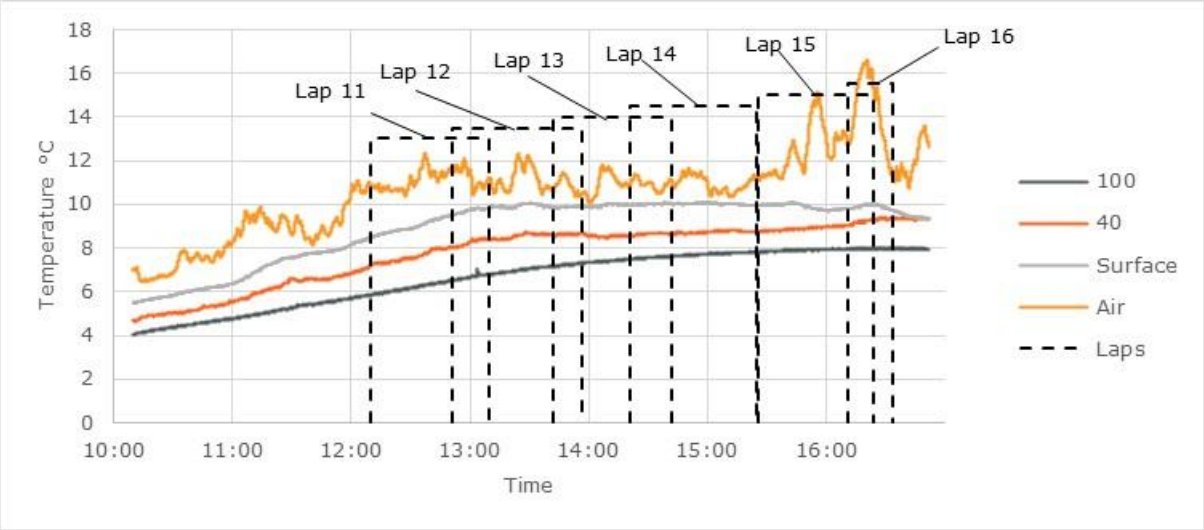

Figure 6.2: Temperature measurements from station 2 (after test sections) on day 2

The temperatures on the morning of day 2 followed a gentle upward trend. This continued for the first lap of the day (lap 11). After this point the temperatures were relatively stable with an average temperature at 40mm around 8°C.

As discussed in Section 3.1, 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 at 40mm (calculated for each 15-minute interval) for stations 1 and 2 (either side of the deflection sections) is shown in Figure 6.3.

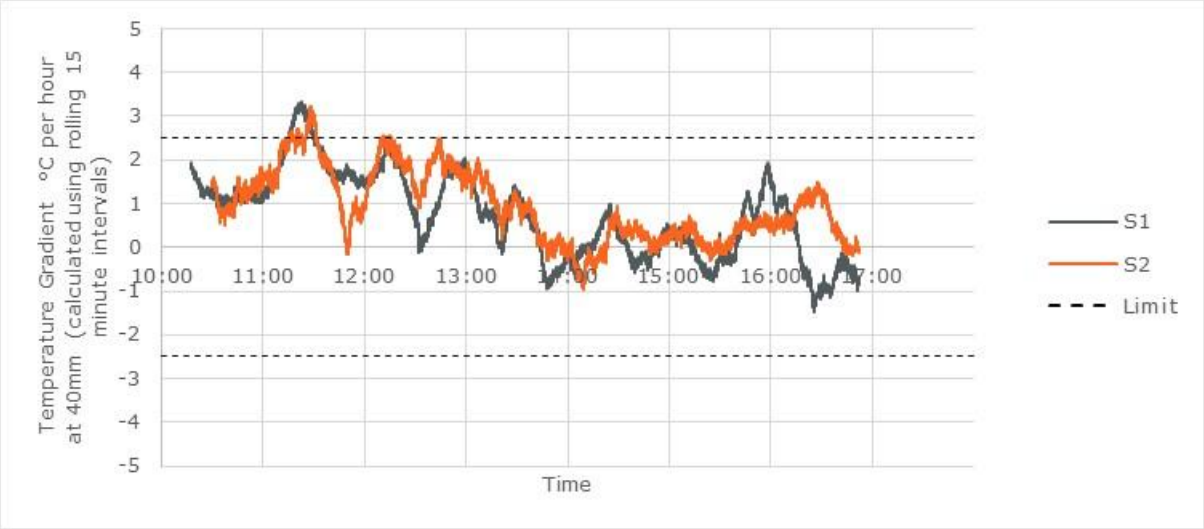

Figure 6.3: 40mm depth temperature changes day 2 (stations 1 and 2)

It can be seen from Figure 6.3 that the rate of change in temperature exceeds the limit for both stations around 11:30. However, this is before the first lap on day 2 (which started at 12:10). It can also be seen that the rate of change is close to the limit around 12:10 and 12:45. These two points both occur before the start of the second lap on this day (lap 12).

6.2.2 *Temperatures at depth and water bucket, recorded by operators*

The Deflectograph crews made measurements of temperature from the two temperature test stations at 40mm depth and, in addition, they measured the temperature of a water bucket at the third temperature measurement station. As previously mentioned, the data loggers connected to the thermocouples placed at these locations suffered issues during the trial and so the data has been disregarded. Due to the size of the platinum probes (discussed in section 6.2.1) they were located in different holes in the road than the operators probes were measuring (and none were placed in the water bucket). The measured temperatures were different between the two sets of holes. It was therefore decided that the operators would be assessed against the fleet average. The results for the three stations are shown in Figure 6.4, Figure 6.5 and Figure 6.6.

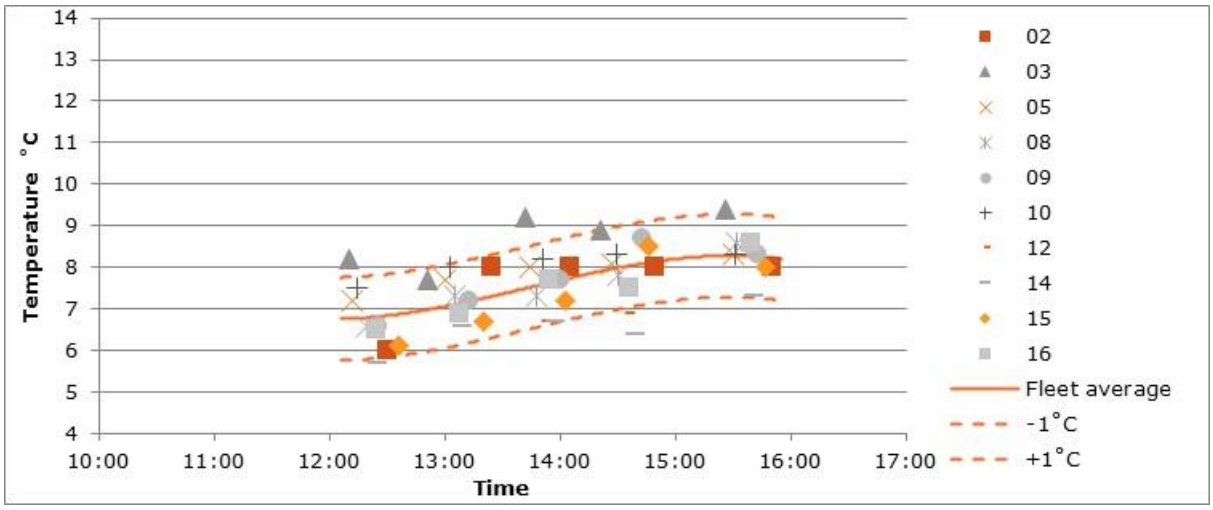

Figure 6.4: Comparison of operators' measurements against reference – Temperature test station 1, day 2

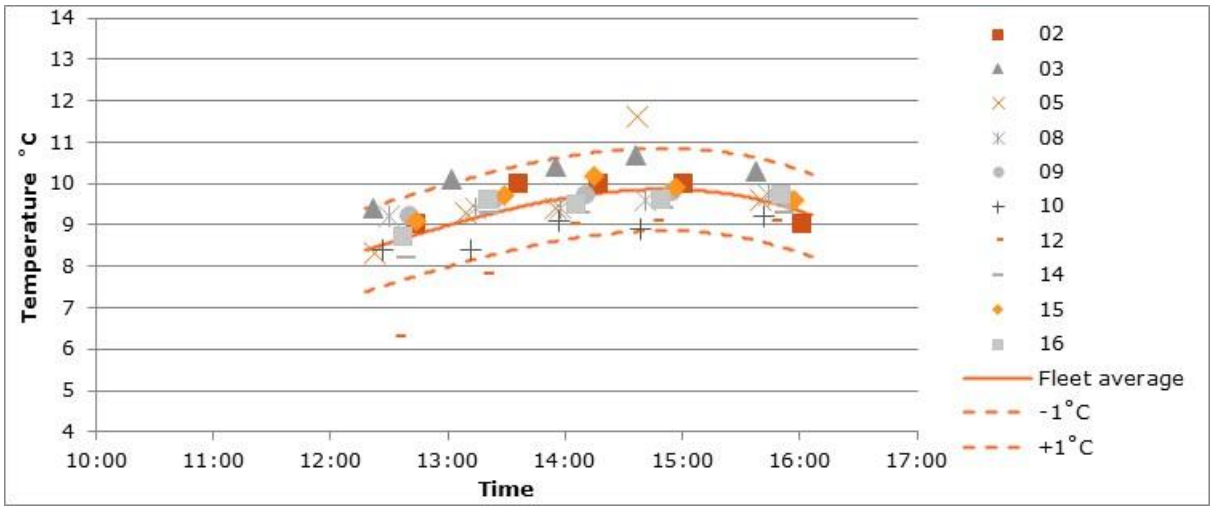

Figure 6.5: Comparison of operators' measurements against reference – Temperature test station 2, day 2

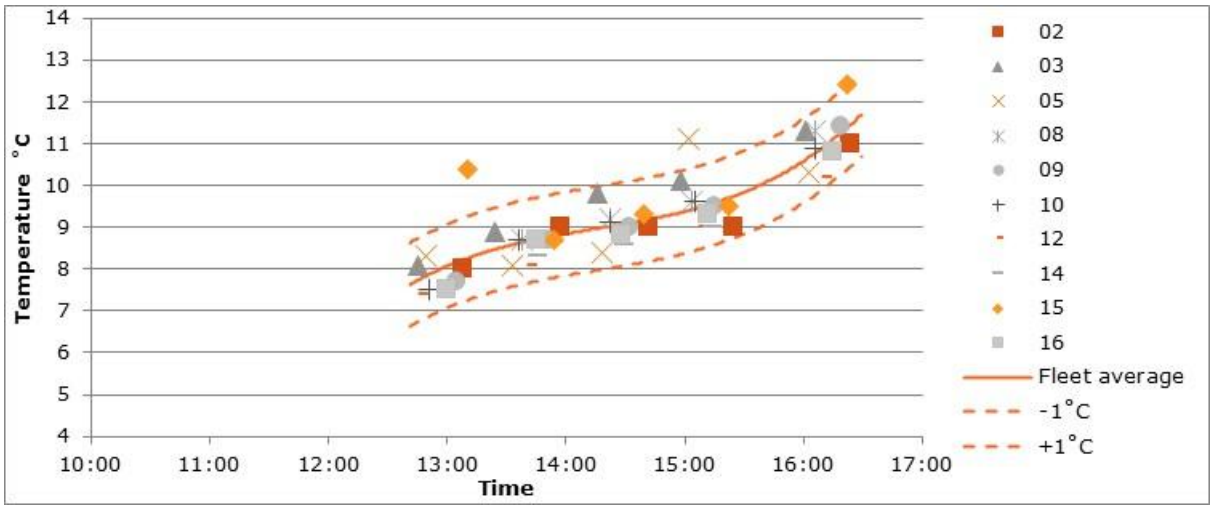

Figure 6.6: Comparison of operators' measurements against reference – Temperature test station 3 (water bucket), day 2

The differences between the operators' measured values and the fleet average are shown in Table 6.1 for station 1 , Table 6.2 for station 2 and Table 6.3 for the water bucket. Any measurements outside of the criterion are highlighted in red bold text. The overall summary performance for these measurements and performance band awarded to the operator is presented in Table 6.4.

Table 6.1: Difference between operators' 40mm measured values and the reference: station 1

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
2	-0.8	0.7	0.3	-0.1	-0.2	100%
3	**1.4**	0.7	**1.7**	1.0	**1.1**	40%
5	0.4	0.6	0.5	0.1	0.0	100%
8	-0.2	0.2	-0.3	-0.2	0.3	100%
9	-0.2	0.0	0.0	0.6	0.0	100%
10	0.7	0.9	0.6	0.3	0.0	100%
12	**-1.1**	0.0	-0.9	**-1.1**	0.4	60%
14	**-1.1**	-0.5	-1.0	**-1.7**	-1.0	60%
15	-0.8	-0.6	-0.5	0.4	-0.2	100%
16	-0.3	-0.2	0.1	-0.5	0.3	100%

Table 6.2: Difference between operators' 40mm measured values and the reference: station 2

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
2	0.2	0.6	0.2	0.2	-0.3	100%
3	1.0	**1.1**	0.8	0.9	0.7	80%
5	-0.2	0.2	-0.2	**1.8**	0.0	80%
8	0.6	0.2	-0.2	-0.3	0.1	100%
9	0.5	0.3	0.0	-0.1	0.2	100%
10	-0.1	-0.7	-0.5	-0.9	-0.4	100%
12	**-2.3**	**-1.4**	-0.7	-0.8	-0.4	60%
14	-0.5	0.0	-0.4	-0.5	-0.2	100%
15	0.3	0.4	0.4	0.0	0.2	100%
16	0.0	0.3	-0.2	-0.3	0.2	100%

Table 6.3: Difference between operators' measured values of water bucket and the reference

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
2	-0.2	0.2	-0.2	-0.7	-0.5	100%
3	0.4	0.4	0.8	0.7	0.7	100%
5	0.5	-0.5	-0.6	**1.7**	-0.4	80%
8	.	0.1	0.2	0.2	0.5	100%
9	-0.5	-0.1	-0.1	-0.1	0.1	100%
10	-0.4	0.1	0.1	0.2	0.1	100%
12	-0.4	-0.6	.	-0.5	-0.7	100%
14	-0.5	-0.4	-0.5	-0.6	-0.4	100%
15	**2.1**	-0.1	0.1	-0.2	**1.0**	60%
16	-0.6	0.0	-0.3	-0.2	-0.3	100%

Table 6.4: Summary of operators' at depth/water bucket performance

ID	% within criteria: Station 1	% within criteria: Station 2	% within criteria: Water bucket	Overall % within criteria	Performance band
2	100%	100%	100%	100%	High
3	40%	80%	100%	73%	Medium
5	100%	80%	80%	87%	High
8	100%	100%	100%	100%	High
9	100%	100%	100%	100%	High
10	100%	100%	100%	100%	High
12	60%	60%	100%	71%	Medium
14	60%	100%	100%	87%	High
15	100%	100%	60%	87%	High
16	100%	100%	100%	100%	High

Therefore, for the direct measurement of pavement temperature, eight machines achieved a high performance and two a medium.

6.2.3 Surface and Air temperatures, recorded by operators

Methodologies for estimating pavement temperature from measurements of surface and air 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 surface and air temperature measurements to estimate 40mm pavement temperatures.

At the trial, surface and air 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) and next to the water bucket (after the distance measurement lengths). The results for these three stations are shown in Figure 6.7, Figure 6.8 and Figure 6.9, respectively.

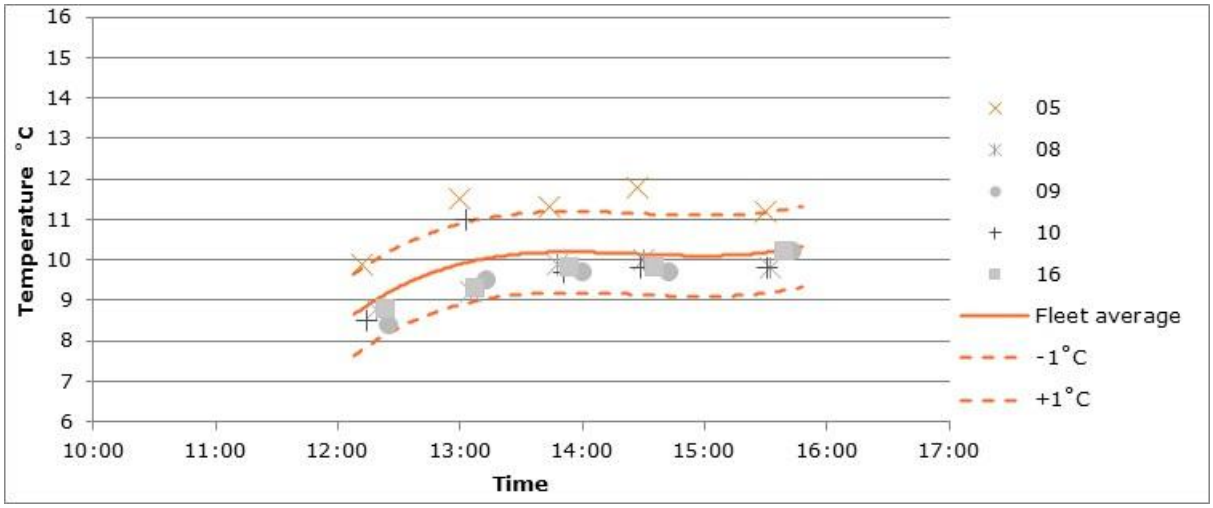

Figure 6.7: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 1, day 2

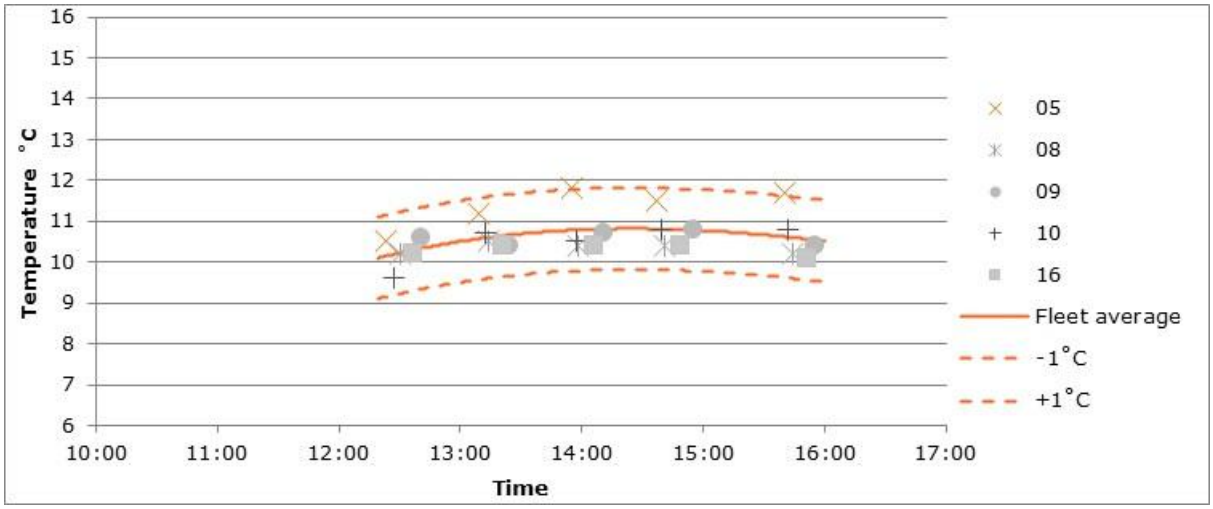

Figure 6.8: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 2, day 2

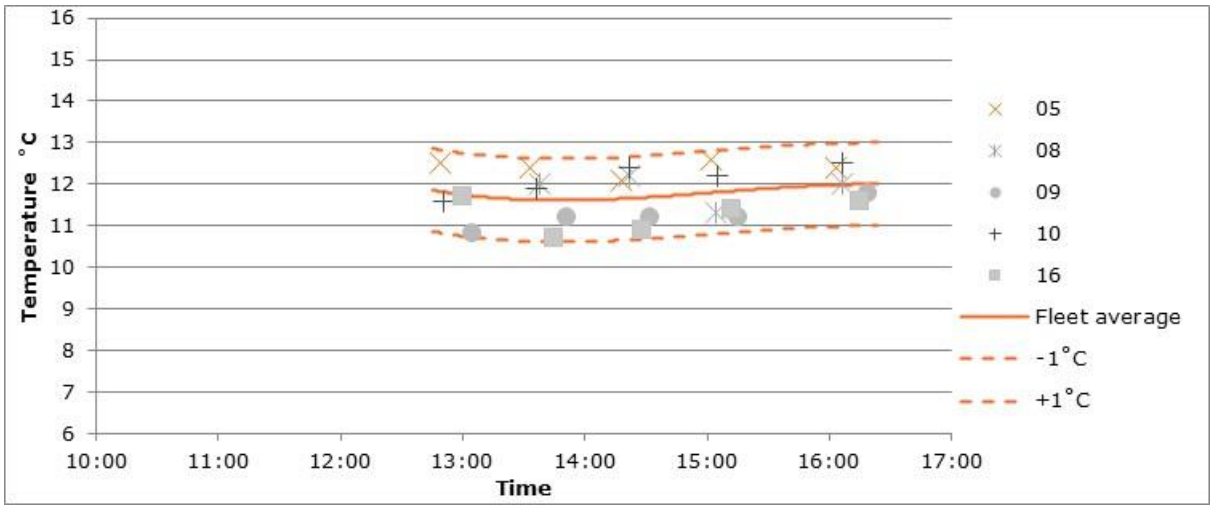

Figure 6.9: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 3, day 2

The differences between the operators' measured surface temperatures and the reference values (the fleet mean) are shown in Table 6.5, Table 6.6 and Table 6.7 for station 1, 2 and 3 respectively. Any measurements outside of the criterion are highlighted in red bold text. The overall summary performance for these measurements and performance band awarded to the operator is presented in Table 6.8.

Table 6.5: Difference between operators' surface temperature values and the reference: station 1

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
5	**1.1**	**1.6**	**1.1**	**1.7**	**1.0**	0
8	-0.2	-0.8	-0.3	-0.1	-0.4	100
9	-0.8	-0.5	-0.5	-0.4	-0.1	100
10	-0.4	**1.1**	-0.5	-0.3	-0.4	80
16	-0.4	-0.7	-0.4	-0.3	0.0	100

Table 6.6: Difference between operators' surface temperature values and the reference: station 2

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
5	0.4	0.6	**1.0**	0.7	**1.1**	60
8	0.0	-0.1	-0.4	-0.4	-0.4	100
9	0.3	-0.3	-0.1	0.0	-0.1	100
10	-0.6	0.1	-0.3	0.0	0.2	100
16	-0.1	-0.2	-0.4	-0.4	-0.5	100

Table 6.7: Difference between operators' surface temperature values and the reference: station 3

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
5	0.7	0.8	0.4	0.8	0.4	100
8	.	0.4	0.5	-0.5	0.0	100
9	-0.9	-0.4	-0.5	-0.6	-0.2	100
10	-0.2	0.3	0.7	0.4	0.5	100
16	-0.1	-0.9	-0.8	-0.4	-0.4	100

Table 6.8: Summary of operators' surface temperature performance

ID	% within criteria: Station 1	% within criteria: Station 2	% within criteria: Station 3	Overall % within criteria	Performance band
5	0	60	100	53	Medium
8	100	100	100	100	High
9	100	100	100	100	High
10	80	100	100	93	High
16	100	100	100	100	High

For surface temperature measurements, four machines achieved a high performance, and one a medium.

The air temperature data supplied from the operators are shown in Figure 6.10, Figure 6.11 and Figure 6.12.

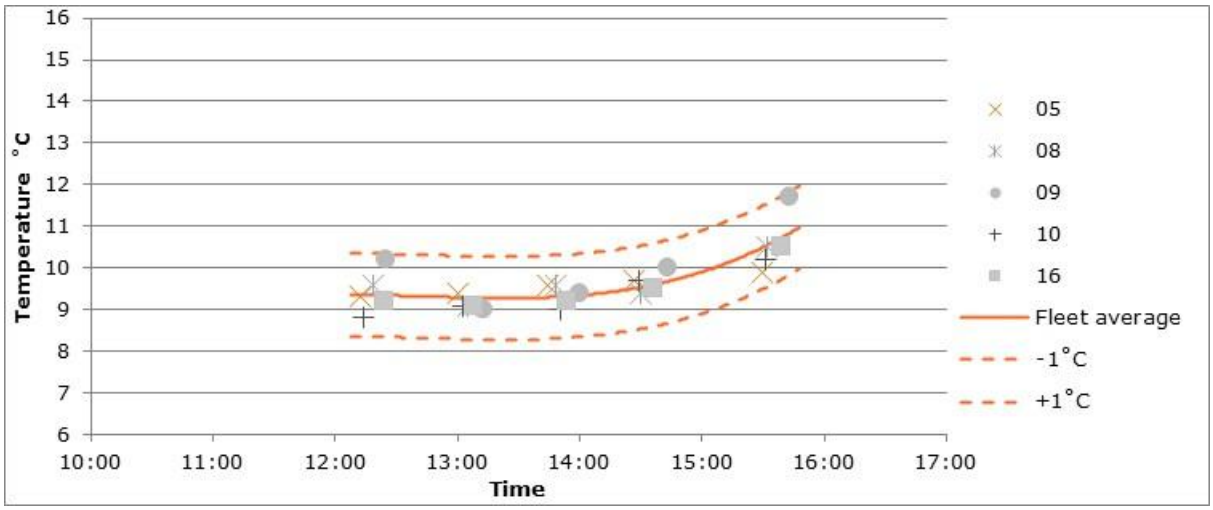

Figure 6.10: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 1, day 2

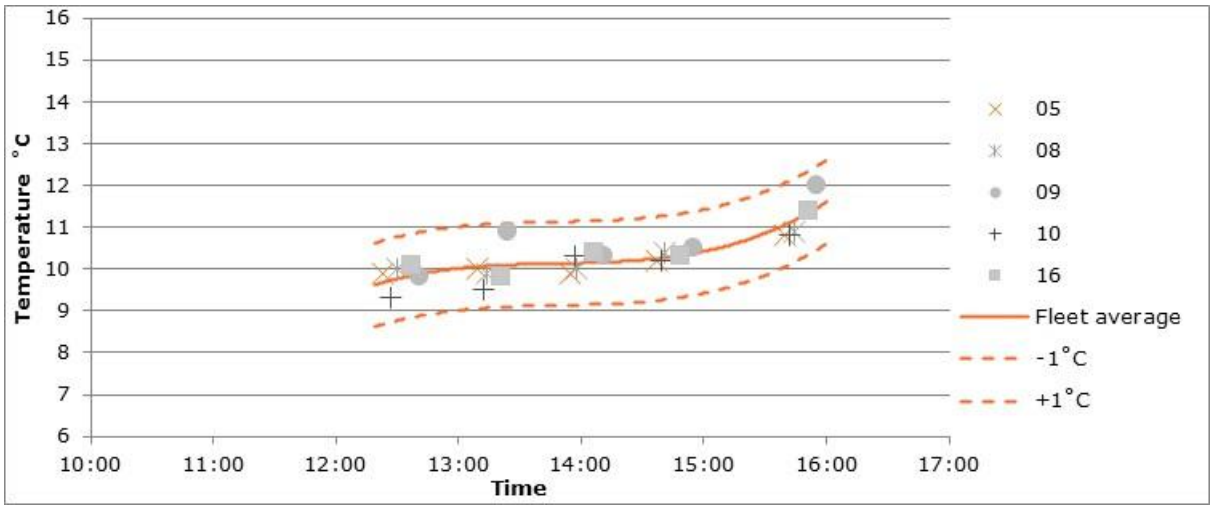

Figure 6.11: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 2, day 2

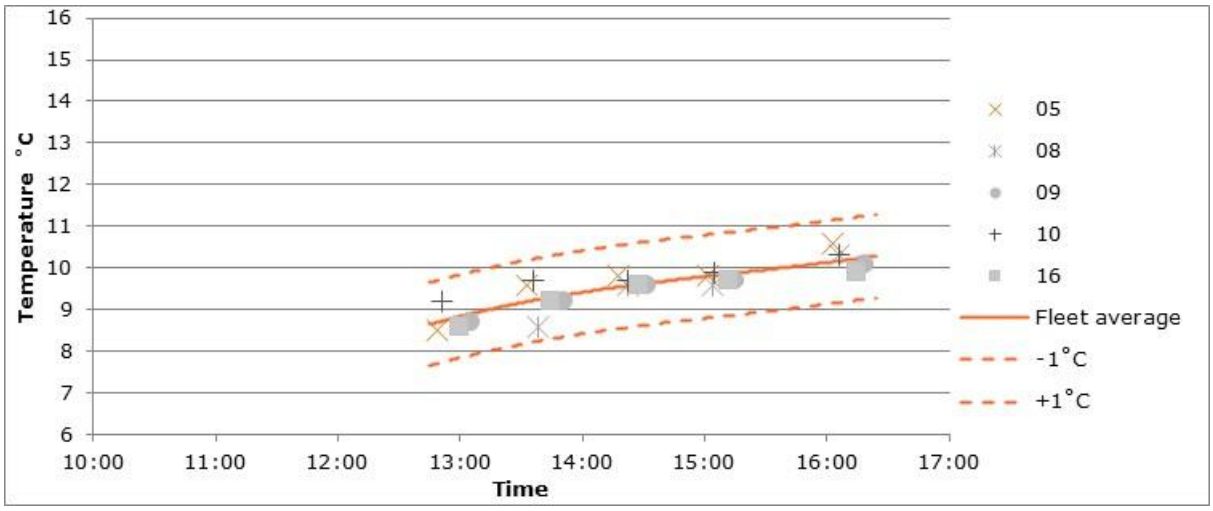

Figure 6.12: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 3, day 2

The differences between the operators' measured air temperatures and the reference values (the fleet mean) are shown in Table 6.9 for station 1, Table 6.10 for station 2 and Table 6.11 for station 3. Any measurements outside of the criterion are highlighted in red bold text. The overall summary performance for these measurements and performance band awarded to the operator is presented in Table 6.12.

Table 6.9: Difference between operators' air temperature values and the reference: station 1

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
5	-0.1	0.1	0.3	0.2	-0.6	100
8	0.2	-0.2	0.3	-0.1	0.0	100
9	0.9	-0.3	0.1	0.3	0.9	100
10	-0.6	-0.2	-0.3	0.2	-0.3	100
16	-0.1	-0.2	-0.1	-0.1	-0.2	100

Table 6.10: Difference between operators' air temperature values and the reference: station 2

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
5	0.2	-0.1	-0.2	0.0	-0.3	100
8	0.2	-0.2	-0.1	0.1	-0.3	100
9	-0.1	0.8	0.1	0.1	0.5	100
10	-0.4	-0.6	0.2	-0.1	-0.3	100
16	0.3	-0.3	0.2	0.0	0.1	100

Table 6.11: Difference between operators' air temperature values and the reference: station 3

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria
5	-0.2	0.4	0.3	0.0	0.5	100
8	.	-0.6	0.0	-0.2	0.1	100
9	-0.2	-0.1	0.0	-0.2	-0.2	100
10	0.5	0.5	0.1	0.1	0.1	100
16	-0.2	-0.1	0.0	-0.2	-0.3	100

Table 6.12: Summary of operators' air temperature performance

ID	% within criteria: Station 1	% within criteria: Station 2	% within criteria: Station 3	Overall % within criteria	Performance band
5	100	100	100	100	High
8	100	100	100	100	High
9	100	100	100	100	High
10	100	100	100	100	High
16	100	100	100	100	High

All five machines that provided air temperatures achieved a high performance.

6.3 Deflection readings

Six laps were undertaken on day 2. To allow the machines to "warm up", the first lap on this day (lap 11) was disregarded (after initial analysis to identify any early issues). Therefore, the tables and analysis below include the data from laps 12 to 16.

6.3.1 Between-run standard deviation for deflection values

The between-run standard deviation (BRSD) for each machine, are shown in Table 6.13. Values (where present) which are more than two times the fleet average for the section and wheel path are highlighted in bold red text.

Table 6.13: Between-run standard deviation for day 2 (laps 12 to 16)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
2	3.0	3.8	4.9	8.7	5.2	13.5
3	5.2	6.6	8.6	5.5	4.5	4.5
5	4.3	2.7	7.4	9.9	7.5	9.1
8	1.3	1.4	3.8	5.9	7.1	8.0
9	4.0	6.6	9.1	12.0	6.0	11.9
10	2.4	4.7	7.2	8.6	6.5	8.4
12	2.9	3.2	**19.3**	14.2	8.3	7.2
14	5.0	3.9	9.6	7.1	9.1	9.7
15	5.1	5.1	5.5	4.5	3.3	3.9
16	3.5	3.3	5.1	9.4	5.7	8.8

It can be seen from Table 6.13 that there was increased variability in Machine 12 on NHCP_02, however this variability was not seen on the other sections. Other than this observation, and despite some variation in the values, no machine was obviously more variable on average than the others.

6.3.2 Mean deflection values

The mean deflections recorded on each section, together with the summary statistics for the testing on day 2 (laps 12-16) can be seen in Table 6.14. As with the analysis for the data on day 1, 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 6.15 shows the deviations from the overall mean and these are highlighted if they are more than 2 or 3 times the BESD criteria (in orange and red, respectively).

Table 6.14: Mean deflection (µm) by section: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	54	50	276	234	152	150	161	145
3	27	35	222	194	109	112	119	114
5	51	44	267	216	158	138	159	133
8	49	50	277	235	152	152	159	146
9	46	54	275	238	149	156	157	150
10	57	52	278	237	154	150	163	147
12	52	47	289	233	160	150	167	143
14	64	55	279	233	167	156	170	148
15	53	54	271	234	151	149	159	145
16	50	49	262	228	146	144	153	140
Mean	50	49	270	228	150	146	157	141
BESD	9.4	6.1	18.2	13.5	15.7	12.9	14.0	10.7
BESD criterion	11.2	11.1	16.8	15.7	13.7	13.6	13.9	13.5
CoV	18.7%	12.4%	6.8%	5.9%	10.5%	8.9%	8.9%	7.6%

Table 6.15: Deviation (µm) from overall mean deflection by section: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	3.8	1.3	6.3	5.3	2.2	4.7	4.1	3.8
3	-22.9	-14.3	-47.5	-33.8	-41.2	-33.5	-37.2	-27.2
5	0.4	-5.0	-3.0	-12.6	8.5	-7.3	1.9	-8.3
8	-1.4	1.1	7.8	7.0	2.3	6.2	2.9	4.7
9	-4.0	5.0	5.5	10.2	-1.1	10.5	0.1	8.6
10	6.3	3.4	8.4	9.0	3.8	4.6	6.2	5.7
12	1.4	-2.3	19.7	4.8	10.3	3.9	10.5	2.1
14	13.6	6.1	9.0	4.2	17.5	10.2	13.4	6.8
15	3.2	4.5	1.4	6.1	1.4	2.9	2.0	4.5
16	-0.4	0.1	-7.6	-0.2	-3.8	-2.1	-3.9	-0.7
2x BESD criterion	22.3	22.3	33.6	31.5	27.5	27.2	27.8	27.0
3x BESD criterion	33.5	33.4	50.4	47.2	41.2	40.9	41.7	40.5

From Table 6.14, it can be seen that the BESD criteria is met for the average of the site in the OS wheel path but not the NS wheel path. On examination of Table 6.15, it can be seen that no machine is more than 3 times the BESD criterion away from the fleet mean, however one machine (Machine 03) was consistently more than 2 times the BESD criterion away from the fleet mean. Removal of this machine from the analysis causes a large reduction in the BESD as shown in Table 6.16

Table 6.16: Fleet statistics by section after excluding Machine 03: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
Mean	53	51	275	232	155	149	161	144
BESD	5.1	3.6	7.8	6.8	6.5	5.6	5.3	5.0
BESD criterion	11.2	11.2	16.9	15.8	13.9	13.7	14.0	13.6
CoV	9.7%	7.1%	2.8%	2.9%	4.2%	3.8%	3.3%	3.5%

Based on this data, Machine 03 was identified as an outlier and this information was communicated to the operator of this device. Further testing, following inspection of the device by the operator, was carried out on day 3 to identify if this could be resolved. The results of this testing are discussed in section 7.

6.4 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 544m. During the trial, the survey crews were asked to test the reference length and to 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.

The difference between the measured length from each machine and the reference length, along with the overall performance, are given in Table 6.17. Where the difference between the machine and the reference exceeds the threshold for the criteria as set out in Section D.1, it is highlighted in red.

Table 6.17: Difference between operator's distance measurements and the reference

ID	Test 1	Test 2	Test 3	Test 4	Test 5	% within criteria	Performance
2	1.0	1.0	-1.0	0.0	0.0	100	Pass
3	-3.0	-3.0	-5.0	-1.0	-1.0	100	Pass
5	0.0	-1.0	2.0	1.0	0.0	100	Pass
8	-1.0	-1.0	-3.0	-3.0	-2.0	100	Pass
9	2.0	-1.0	-4.0	-4.0	-4.0	100	Pass
10	2.0	3.0	3.0	2.0	3.0	100	Pass
12	-4.0	-2.0	-3.0	-3.0	-3.0	100	Pass
14	-2.0	-3.0	0.0	1.0	-2.0	100	Pass
15	-3.0	-3.0	-2.0	-3.0	-4.0	100	Pass
16	-2.0	-4.0	-4.0	-2.0	-4.0	100	Pass

From Table 6.17 it can be seen that all ten machines met the distance measurement requirement.

7 Day 3 (7th March) – Additional testing

To differentiate from the testing on the previous days, the laps on this day were prefixed with a 2 so the first lap on day 3 was labelled as lap 21. Six laps were undertaken on this day. The first lap (after analysis) was disregarded to take account of the fact that the machines were likely to be warming-up.

Lap 21 was carried out with all 10 machines that attended the trial. To allow them time to catch their ferry home, Machine 15 (for which the defection data was deemed suitable) was excluded from the remaining testing. Laps 22 and 23 were carried out with the remaining nine machines. This data appeared to indicate that Machine 03 was now closer to the measurements from the rest of the fleet. To ensure that a full dataset (5 laps) could be obtained for Machine 03 in a timely manner, the remaining three laps were undertaken with a subset of the fleet. This subset was machines 02, 05, 09 and 16. This data was combined with the data collected on day 2 to allow an assessment of Machine 03 and is further discussed in section 7.3.

No operator measurements of temperature or distance were undertaken on this day as all required data for this assessment was obtained on day 2.

7.1 Machine alterations

Prior to testing on this day, Machine 03 undertook a recalibration and had its winch replaced.

7.2 Temperatures recorded by the data loggers

The platinum probes were set up at both station 1 and 2 and the smoothed data is shown in Figure 7.1 and Figure 7.2. The temperature change per hour at 40mm (calculated for each 15-minute interval) for stations 1 and 2 (either side of the deflection sections) is shown in Figure 7.3.

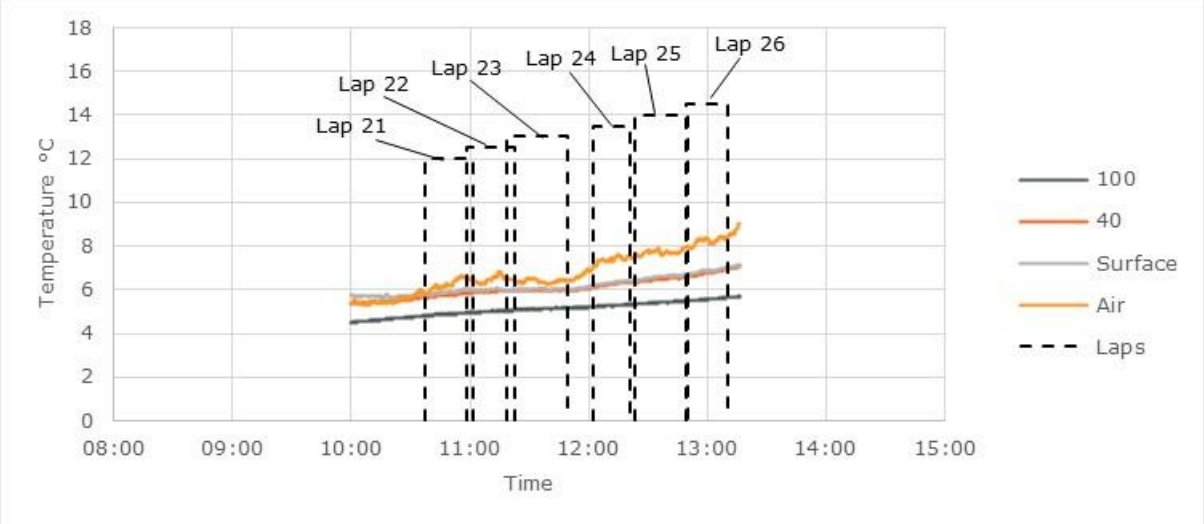

Figure 7.1: Temperature measurements from station 1 (before test sections) on day 3

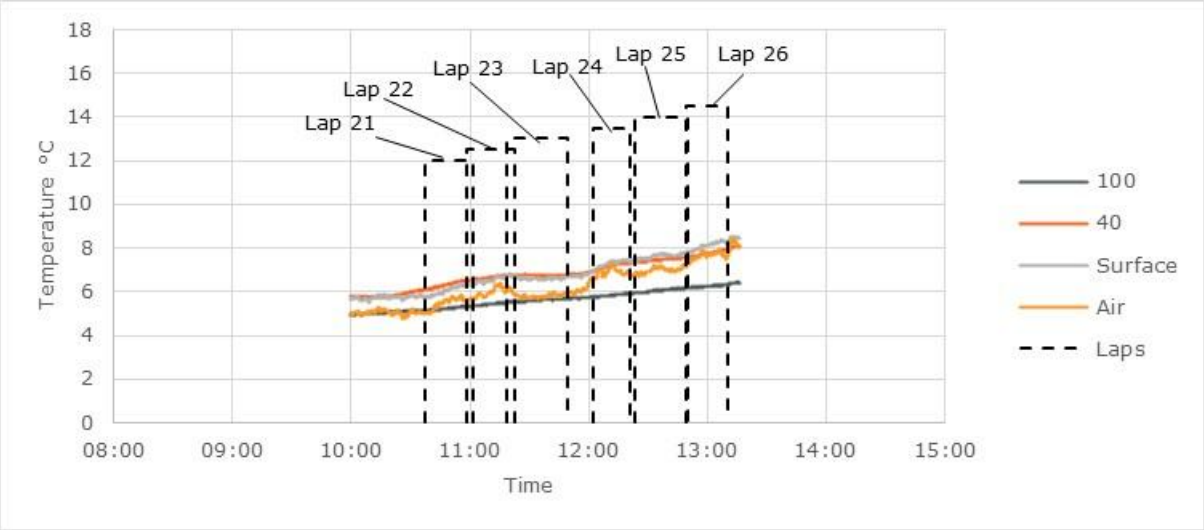

Figure 7.2: Temperature measurements from station 2 (before test sections) on day 3

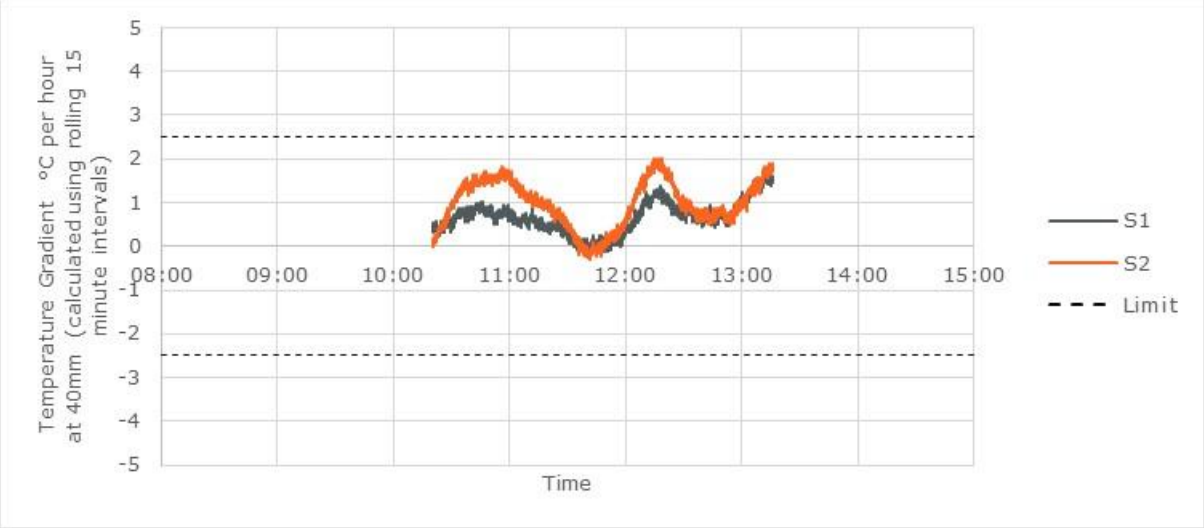

Figure 7.3: 40mm depth temperature changes day 3 (stations 1 and 2)

It can be seen from Figure 7.1 and Figure 7.2 that the temperatures on day 3 followed a gentle upward trend. It can also be seen (from Figure 7.3) that the rate of change in temperature remained within the limits during all of the testing on day 3.

7.3 Deflection readings

The between run standard deviation for laps 22 to 26 for the machines that took part in all of these laps is shown in Table 7.1.

Table 7.1: Between-run standard deviation for day 3 (laps 22 to 26)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
2	5.0	1.4	7.8	5.9	5.8	10.4
3	0.8	2.0	4.5	7.5	5.3	6.5
5	3.2	3.5	9.6	9.3	6.1	8.7
9	1.7	6.0	11.0	3.2	14.3	15.0
16	2.6	3.6	7.1	8.8	14.5	15.5

It can be seen from Table 7.1 that no machine was obviously more variable than the others.

The mean deflections recorded on each section together with summary statistics for laps 22 to 26 for these machines are shown in Table 7.2. The deviations from the overall mean are shown in Table 7.3.

Table 7.2: Mean deflection (µm) by section: day 3 (laps 22-26)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	57	51	270	218	157	154	161	141
3	38	43	233	195	131	130	134	123
5	56	48	256	206	163	143	158	132
9	63	69	282	242	168	175	171	162
16	49	49	243	208	149	145	147	134
Mean	53	52	257	214	153	149	154	138
BESD	9.4	10.0	19.8	17.6	14.6	16.7	14.2	14.7
BESD criterion	11.2	11.2	16.5	15.4	13.8	13.7	13.8	13.4
CoV	17.8%	19.1%	7.7%	8.2%	9.5%	11.2%	9.2%	10.6%

Table 7.3: Deviation (µm) from overall mean deflection by section: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	4.6	-0.9	13.1	4.3	3.4	4.8	7.0	2.7
3	-14.4	-8.9	-24.0	-18.5	-22.5	-19.8	-20.3	-15.7
5	3.0	-3.9	-0.9	-8.0	9.2	-6.0	3.8	-6.0
9	10.1	17.1	25.3	28.0	14.9	25.5	16.8	23.5
16	-3.4	-3.4	-13.5	-5.8	-4.9	-4.5	-7.3	-4.6
2x BESD criterion	22.5	22.4	33.0	30.8	27.6	27.4	27.7	26.9
3x BESD criterion	33.7	33.7	49.4	46.1	41.5	41.2	41.5	40.3

From Table 7.2 it can be seen that the BESD criterion is not met for the average of the site in either wheel path. As the other machines in this testing have performed suitably previously in the trial, this would initially suggest that Machine 3 has not met 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. In addition, it is known that meeting the BESD criteria is typically harder with fewer machines. Therefore, it is necessary to combine this data with the data from day 2 before making the 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. laps

12 to 16 and 22 to 26). The ratio between these values was then applied to the data from Machine 3 (for laps 22 to 26) to provide an estimate of the likely deflections that this machine would have measured if it had operated in its day 3 configuration during the testing on day 2.

The average deflections from the two datasets for the machines acting as reference and the calculated ratios are shown in Table 7.4.

Table 7.4: Reference data values and estimation ratio

	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
Average laps 12 to 16	50	49	270	229	151	147
Average laps 22 to 26	56	54	263	219	159	154
Ratio	0.89	0.91	1.03	1.05	0.95	0.95

The mean deflections recorded on each section together with summary statistics for the combined dataset are provided in Table 7.5. The deviations from the overall mean are shown in Table 7.6. In both of these tables, Machine 3 is denoted in blue italic text to highlight that it is a predicted value.

Table 7.5: Mean deflection (µm) by section: Combined dataset

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	54	50	276	234	152	150	161	145
3	*34*	*39*	*239*	*205*	*125*	*124*	*133*	*123*
5	51	44	267	216	158	138	159	133
8	49	50	277	235	152	152	159	146
9	46	54	275	238	149	156	157	150
10	57	52	278	237	154	150	163	147
12	52	47	289	233	160	150	167	143
14	64	55	279	233	167	156	170	148
15	53	54	271	234	151	149	159	145
16	50	49	262	228	146	144	153	140
Mean	51	49	271	229	152	147	158	142
BESD	7.6	4.9	13.5	10.8	11.3	9.7	10.2	8.3
BESD criterion	11.2	11.2	16.9	15.8	13.8	13.7	13.9	13.5
CoV	15.0%	10.0%	5.0%	4.7%	7.4%	6.6%	6.4%	5.8%

Table 7.6: Deviation (µm) from overall mean deflection by section: Combined dataset

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	3.1	0.9	4.6	4.3	0.6	3.5	2.8	2.9
3	*-16.8*	*-10.1*	*-32.2*	*-24.6*	*-26.9*	*-23.3*	*-25.3*	*-19.3*
5	-0.3	-5.4	-4.7	-13.6	6.9	-8.5	0.6	-9.2
8	-2.1	0.6	6.1	5.9	0.7	5.1	1.6	3.9
9	-4.6	4.6	3.8	9.2	-2.7	9.3	-1.2	7.7
10	5.7	2.9	6.7	8.0	2.3	3.5	4.9	4.8
12	0.7	-2.7	18.0	3.8	8.8	2.8	9.1	1.3
14	12.9	5.6	7.3	3.2	15.9	9.1	12.0	6.0
15	2.6	4.1	-0.3	5.0	-0.1	1.7	0.7	3.6
16	-1.1	-0.4	-9.3	-1.2	-5.3	-3.2	-5.2	-1.6
2x BESD criterion	22.4	22.3	33.7	31.5	27.6	27.3	27.9	27.1
3x BESD criterion	33.6	33.5	50.6	47.3	41.3	41.0	41.8	40.6

It can be seen from Table 7.5 that the BESD criterion is met for the average of the site for both the NS and OS wheel paths (and for each individual section). In addition, no machines were more than 2 times the BESD criterion away from the fleet mean for any section and wheel path combination. Therefore, following the additional testing, all of the machines are considered as meeting the trial criteria for deflection measurement.

8 Conclusions

The 2024 National Deflectograph accreditation trials were held on the Horiba-MIRA proving grounds by TRL on behalf of National Highways in the week beginning the 4th March 2024. Ten machines, which is thought to constitute the whole of the current UK fleet of Deflectographs, attended the trial.

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

(I) Wheel Weights

All ten machines that participated in the trial were within the wheel and axle limits (following the redistribution of on-board weight by one machine).

(II) Deflection measurement

All ten machines that participated in the trial met the criteria for deflection measurement (following the replacement of a winch by one machine).

(III) Distance measurement

All ten machines that participated in the trial met the criteria for distance measurement (following the recalibration of two machines).

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

(IV) Temperature measurement – measurement at depth

Eight of the ten operators achieved a high performance with regards to the measurement of temperature at depth. Two machines achieved a medium.

(V) Temperature measurement – surface temperature

Surface temperature data from five machines was supplied at this trial. Four machines achieved a high performance, and one achieved a medium.

(VI) Temperature measurement – air temperature

Air temperature data from five machines was supplied at this trial. All five machines achieved a high performance.

A summary of the machines that attended the 2024 accreditation trial and the criteria that they met/performance achieved can be found in Appendix A.

References

Brittain, S., & Sanders, P. (2012). *Deflectograph accreditation transitional trial (CPR1299).* Crowthorne: TRL.

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. (2020). *Accreditation and Quality Assurance of Deflectograph Survey Devices [online]. [Accessed 22nd February 2021].* https://ukrlg.ciht.org.uk/ukrlg-home/guidance/road-condition-information/data-collection/deflectograph/.

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Appendix A Machine identification

Table A.1: Machine identification

ID	Operator at trial date	Registration number	Deflection	Distance	Temperature at 40mm	Surface temperature	Air temperature
2	PTS Ltd	L697 BKR	Pass	Pass	High	No data	No data
3	TRL Ltd	B180 FBL	Pass	Pass	Medium	No data	No data
5	WDM Ltd	D962 JRU	Pass	Pass	High	Medium	High
8	WDM Ltd	BYW 80V	Pass	Pass	High	High	High
9	WDM Ltd	VGV 182X	Pass	Pass	High	High	High
10	WDM Ltd	F569 JBB	Pass	Pass	High	High	High
12	WDM Ltd	EOU 230W	Pass	Pass	Medium	No data	No data
14	Lincolnshire County Council	B195 CFW	Pass	Pass	High	No data	No data
15	DFI Roads	ACZ 3268	Pass	Pass	High	No data	No data
16	WDM Ltd	B880 XOU	Pass	Pass	High	High	High

Appendix B Layout of test sections at Horiba-MIRA

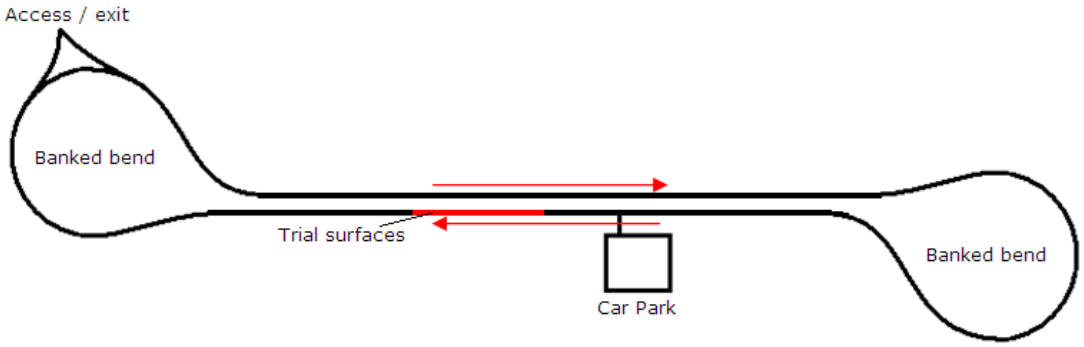

Figure B.1: Test route on the Horiba-MIRA twin straights

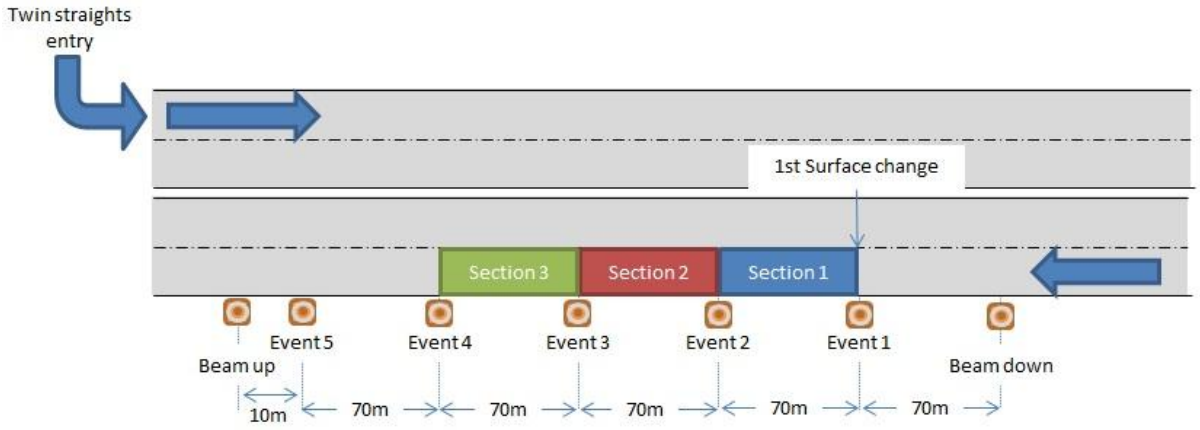

Figure B.2: Location of marker cones and test sections on Horiba-MIRA twin straights

Appendix C Construction details for Horiba-MIRA test sections

Table C.1: Nominal construction details for design construction of Horiba-MIRA site

Section	Surface course (mm)	Binder course (mm)	Total asphalt thickness (mm)	Sub-base (mm)
NHCP_01	30 TSC	235 EME2	270	200mm C8/10 HBM
NHCP_02	35 TSC	170 DBM	200	250mm 6F1 granular capping material
NHCP_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: Post construction details for Horiba-MIRA site from cores

Section	Surface course (mm)	Binder/ Binder+ base courses (mm)	Total asphalt thickness (mm)	Base (mm)
NHCP_01	42 TSC	228	270	217 (HBM)
NHCP_02	37 TSC	158	192	-
NHCP_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 (mm)

Section	Minimum	Average	Maximum	Material
NHCP_01 (Asphalt)	192	242	272	Asphalt
NHCP_01 (HBM)	166	188	215	HBM
NHCP_01 (Total bound thickness)	388	431	468	Total bound thickness
NHCP_02	167	192	240	Asphalt
NHCP_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 (June 2020) version of the document was used for the trial. The relevant section of the document is reproduced verbatim (including the corresponding section labels in the document) 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%

[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.

E3.4 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.

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.

National Highways 2024 Deflectograph Accreditation Trial

A key element for the successful maintenance of a road network is accurate, reliable and consistent survey data. To this aim, National Highways 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 2024 accreditation trial run by TRL and held on the HORIBA-MIRA proving ground between 5th and 7th of March 2024.

Other titles from this subject area

PPR2040	National Highways 2023 Deflectograph Accreditation Trial. S Brittain. 2026
PPR2039	National Highways 2022 Deflectograph Accreditation Trial. S Brittain. 2026
PPR1019	Highways England 2021 National Deflectograph Accreditation Trial. S Brittain. 2022
PPR977	Highways England 2020 National Deflectograph Accreditation Trial. S Brittain. 2022

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