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PUBLISHED PROJECT REPORT PPR1017

Highways England 2018 National Dynamic Plate Test device Accreditation Trial

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Report details

Report prepared for:	Highways England		
Project/customer reference:	SPATS: 1-657		
Copyright:	© TRL Limited		
Report date:	11/03/2022		
Report status/version:	1.0		
Quality approval:			
Cathy Booth (Project Manager)	Cathy Booth	Brian Ferne (Technical Reviewer)	Brian Ferne

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Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Reviewer
1.0	11/03/2022	Converted to published report for historic continuity	SB	BF

Table of Contents

Executive Summary

The 2018 UK Dynamic Plate Test device (DPT) accreditation trial was held on the Twin Straights on the Horiba-MIRA proving ground, between 25th and 27th September 2018. This was the twentieth mandatory DPT accreditation trial to be held in the UK with the objective being to assess the performance of all DPT devices likely to be operating on the Highways England Strategic Road Network (SRN). DPT devices include Falling Weight Deflectometers (FWDs), Heavy Weight Deflectometers (HWDs) and Super Heavy Weight Deflectometers (SHWDs).

The performance of individual machines was assessed by examining and monitoring the results from the machines operating on specified test sections. Only machines that can demonstrate satisfactory performance in the accreditation trial may subsequently be approved for use on the SRN.

A total of twenty-five machines took part in the trial, consisting of:

- Thirteen trailer-mounted Dynatest FWDs
- Seven trailer mounted Dynatest HWDs
- Two trailer mounted Grontmij FWDs
- One trailer mounted Grontmij HWD
- One trailer mounted PaveTesting HWD
- One trailer mounted Rincent HWD

The trials followed a similar format to that which was used successfully in previous mandatory trials carried out since 1999. The Trial is split into 3 days with machine inspections, distance calibration, and initial testing held on the first day. The main testing is then held on the second day, and the third day is used for contingency in case of bad weather or other unforeseen circumstances. The tests undertaken this time comprised the following:

- Repeatability of deflection measurement (a mandatory test)
- Reproducibility of deflection measurement (a mandatory test)
- Accuracy of measurement of elapsed distance against an independent reference (a mandatory test)
- Accuracy of temperature measurement devices (non-mandatory test)
- Accuracy of measurement of pavement temperature (at 100mm and surface temperature) against an independent reference (a non-mandatory test)
- Accuracy of 3-dimensional positional data where fitted (a non-mandatory test)

The deflection tests and associated acceptance criteria are based on but not identical to those published by the CROW standards organisation in the Netherlands. In August 2011 CROW issued an updated version of their recommendations (CROW, 2011) to include the repeatability test.

Based on the results from this trial and previous trials, it is recommended that the temperature at depth criteria is transformed into a mandatory criterion for future trials.

At a future date the surface temperature criteria should also transition to mandatory criteria. However, it is worth noting that surface temperature measurement equipment is only fitted to some of the devices, so it would only be mandatory for those wishing to supply surface temperature measurements. Following anticipated changes in HD29, at future trials there may be some devices being assessed for only the measurement of temperature at depth, and some devices for only the surface temperature measurement (and some for both).

At the completion of the trial it was identified that:

- Twenty-one of the twenty-five machines met the mandatory criteria of the trial.
- 3-dimensional position data was supplied by eleven of the test machines. This data was provided in lat/long/height format. After conversion of the data by TRL into the OSGR format, six machines achieved a high rating, three a medium and two a low rating. The contractor’s coordinate transformation to OSGR format was not assessed.
- Twenty four machines provided a full set of temperature measurements at depth. Thirteen machines achieved a high rating, three a medium rating, six a low rating and two were identified as not suitable.
- Eleven machines provided surface temperature measurements. The assessment of this data was not carried out due to problems establishing a reference dataset.
- Fifteen machines provided air temperature measurements. Although air temperature measurements from the DPTs do not form part of the updated test method, it seemed prudent to review the data supplied. Using the surface temperature criteria, twelve machines achieved a High performance level, one a Medium, and two a Low.

The surface temperature assessment was undertaken using thermocouples set up in the path adjacent to the test lane (to avoid damage from the test vehicles) and periodic measurements using a handheld IRT. Both of these datasets were significantly different from the values collected by the sensors fitted to the DPT devices. In addition there was a wide scatter of the results from the sensors fitted to the DPT devices. It is therefore recommended that additional details on the set-up and configuration of these devices is obtained and additional investigation into these devices is undertaken (both by the survey contractors and the auditor) between now and the next trial. In addition consideration should be given to improving the reference data collected (for both the surface and air temperature measurements) at the next trial.

1 Introduction

Current advice on the use of Dynamic Plate Test devices, provided in HD29/08 (where they are referred to as FWDs) of the Design Manual for Roads and Bridges (DMRB 7.3.2), requires that all of these devices be tested and approved at an annual FWD accreditation trial before being accredited for operating on the Highways England Strategic Road Network (SRN). A similar requirement has also been in place for side force skid resistance devices and Deflectographs for many years, and forms part of a system to ensure that consistent, high quality data is obtained from condition surveys of the SRN in England. In addition, Defence Estates' Design and Maintenance Guide 27, "A Guide to Airfield Pavement Design and Evaluation" requires that FWDs be approved at an annual accreditation trial before they may be permitted to survey on MoD airfields.

As satisfactory performance at an accreditation trial is required for subsequent accreditation for use on the SRN, the trial is henceforward referred to as an accreditation trial. In addition, as the trial covers FWD, HWD and SHWD, the trial is also referred to as a DPT trial rather than an FWD trial.

The objectives of the 2018 DPT Accreditation trial were:

- To ensure that all measuring systems appear to be maintained and in good mechanical order by conducting an inspection of each machine at the trial.
- To ensure consistent performance of individual machines and the reproducibility of all machines, including any supporting measurements (e.g. temperature).
- To monitor and seek improvements in performance over the longer term.

The twentieth mandatory UK DPT accreditation trial was held between 25th and the 27th September 2018 on behalf of Highways England. The trial followed the basic format that was used successfully in the previous mandatory trials carried out since 1999. The 2018 trial included the following mandatory checks:

- Reproducibility
- Repeatability
- Distance measurement

And the following non-mandatory checks

- Temperature measurement devices/probes calibration check
- Temperature measurement at 100mm, air and surface
- OSGR data (obtained from 3-dimensional positional systems)

These tests and associated acceptance criteria are broadly based on those published by the CROW Standards organisation in the Netherlands. In August 2011 CROW issued an updated version of their recommendations (CROW, 2011) which has been used to guide the design of the tests incorporated in this trial.

From 1999 to April 2010 the trials were conducted on the Small Roads System at TRL. The trial was then conducted at the Horiba-MIRA Proving grounds in Warwickshire in November

2010 and October 2011. Due to programming issues the trial returned to the Small Roads System at TRL for the November 2012 trial. The 2013 trial and subsequent trials have all been held on the proving grounds at Horiba-MIRA. This report describes the conduct and findings of the September 2018 accreditation trial and presents the details of the machines that took part in the trial.

2 Trial Format

2.1 Participants

Twenty-five machines (all trailer-mounted) took part in the 2018 Highways England DPT accreditation trial, comprising sixteen FWDs and nine HWDs. A total of fifteen owning organisations took part, with the machines in attendance shown in Table 2.1.

Table 2.1: DPT devices attending the trial

Company	Devices brought to trial
AECOM	3×Dynatest 8002 FWD, 2×Dynatest 8082 HWD
ALC (MoD)	Dynatest 8082 HWD
Atlas Geophysical Limited	Grontmij Primax 2100 FWD
Balfour Beatty	Dynatest 8002 FWD
CET	Dynatest 8002 FWD
Dynatest	Dynatest 8012 FWD, Dynatest 8082 HWD
James Fisher Testing Services Ltd.	Grontmij Primax 2500 HWD
Milestone Pavement Technologies	Grontmij Primax 1500 FWD
PaveTesting	PaveTesting FWD150
PMS Ltd. (Eire)	2 × Dynatest 8002 FWD and 1 x Dynatest 8082 HWD
PTS Ltd.	1 × Dynatest 8002 FWD and 3 x Dynatest 8082 HWD
Pulse Surveying Ltd.	Dynatest 8002 FWD
SOCOTEC	RINCENT HeavyDyn
Stanger Testing Services	Dynatest 8002 FWD
TRL	Dynatest 8002 FWD

More details of the attending machines are provided in Appendix A and example photographs are given in Appendix B.

In this report the individual machines are referred to by the running numbers assigned to them for the trial. For ease of comparison, machines usually retain the same running number year-on-year.

2.2 Preparation of vehicles

All operators were provided detailed instructions for the trial and asked to prepare their machines for testing under standard conditions prior to their arrival at the trial, as follows:

- Positions of deflection sensors: 0, 300, 600, 900, 1200, 1500 and 2100 mm. Note: this is the flexible and flexible-composite set-up described in HD29/08 and is different from the positions used for trials before 2013.
- Standard loading plate, diameter 300mm.

- Data storage in standard metric output (".F20" or ".F25" format).

For the repeatability testing the following were also specified:

- Load 50kN (fixed height, seek may not be used).
- Configured for 12 drops at each test station.

For the reproducibility testing the following were also specified:

- Load 50kN (fixed height or seek).
- Configured for 5 drops at each test station.

Operators were also advised to have the peak smoothing function, if available, activated.

2.3 Inspection of vehicles

Operators were requested to provide details of the latest manufacturer's calibration and their own dynamic calibrations and stack/tower consistency checks prior to the start of the trial. The machines were subsequently checked by a TRL inspector before testing began to ensure that the machines were set up correctly and configured as required for the trial. The findings are summarised in Appendix A.

2.4 Location of Trial

Four test sections were used for the trial; each with different constructions and associated deflection levels, and located on the Twin Straights on the Horiba-MIRA proving ground. Each section contained three test stations (12 stations in total) which were clearly marked out using road paint (see Figure 2.1 below) and swept clear of debris prior to the trial. An additional station (number 13) is located on a concrete section and this station (along with 2, 5 and 8) is used in the repeatability testing. Two additional test lengths were set up; one to allow operators to undertake distance calibrations and one for the odometer test. Nominal construction details for the four main test sections can be found in Appendix C. Crews were instructed that the loading plate should be placed completely within the marked box for testing.

Figure 2.1: Test station marked by a painted box

2.5 Temperature monitoring

The temperatures were measured throughout the trial using two sets of temperature sensors and data loggers. Each set contained thermocouples to measure the 40mm and 100mm pavement temperatures and also the air and pavement surface temperatures. One set was located near station 2 and the other near station 11. The loggers connected to the sensors were set to record the temperature measurement once every minute.

2.6 Test Programme

Detailed instructions were provided to the participants regarding the conduct of the trial. An outline of the programme is provided below.

2.6.1 Day 1 – Inspection and Repeatability testing

Day 1 is used to conduct machine inspections, a familiarisation lap and repeatability tests. The familiarisation lap is designed to give new operators the chance to familiarise themselves with the course, and to seek to highlight any obvious problems with machines that would otherwise delay progress during the trial.

TRL staff members were available during testing to assist crews with positioning at test stations.

The familiarisation lap followed the same format as used for day 2 (reproducibility testing) with five replicate drops at each of the standard twelve test stations. The peak values of load and deflection were recorded as well as time histories. For this testing operators are recommended to activate the load “Seek” setting (if available).

Four stations (2, 5, 8 and 13) were selected for the repeatability testing. For this testing two laps of twelve replicate drops at each station was required, with peak values of load and deflection recorded as well as time histories. For the repeatability testing the load “Seek” setting is switched off.

During this day the crews were also asked to perform a distance calibration using a marked out length (400m).

The operators’ temperature probes were compared using a stabilised environment to provide a simple check on the calibration of these devices.

2.6.2 Day 2 – Reproducibility testing

Reproducibility tests were conducted on day 2. As with day 1, TRL staff members were available during testing to assist crews with positioning at test stations.

Five replicate drops were made at the twelve test stations, with peak values of load and deflection recorded as well as time histories. Each complete set of 12 test stations is referred to as a lap.

The first lap was treated as a warm-up lap, and then followed by two test laps. After completing each lap, the data was handed over to TRL staff before beginning the next lap, and any anomalies reported by operators were recorded. Real-time data processing enabled summary results of each lap to be available to the TRL inspectors soon after each lap was completed.

During each lap the crews were asked to make temperature measurements using pre-drilled holes (the same ones used for the temperature loggers to measure the 100mm depth). In addition, on returning to the start of the test site the operators were asked to measure a predefined length to provide an assessment of the odometers fitted to the equipment.

2.6.3 Day 3 – Contingency day

Day 3 is reserved for contingency for bad weather or other unforeseen circumstances. This day was used in the 2018 trial to further investigate three machines.

3 Assessment criteria

The accreditation trial criteria are specified in “Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices” (TRL, 2016). The specification is a live document (i.e. is subject to change) and the July 2016 version of the document was used for the trial. The relevant sections of the document are reproduced verbatim below in blue text (section 3.1 and 3.2). Note that the appendices referred to in section 3.1 and 3.2 are not included in this report.

Note that 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 load measurement system, 3-dimensional position system, distance 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.

3.1 Mandatory Trial criteria from the Accreditation and QA document

E4.2 Repeatability testing – Mandatory Requirement

E4.2.1 Repeatability testing will be conducted on a series of test stations identified by the Auditor. The requirements for these test stations are given in Appendix C.

E4.2.2 Repeatability testing will use a test procedure typical of general usage on the network. The test procedure will include a minimum of two seating drops and ten measurement drops at each test station. The specific details of the test procedure for Repeatability testing (including nominal peak load and number of drops) will be communicated by the Auditor prior to the trial.

E4.2.3 It is noted that some Equipment have drop height variation functionality which varies the drop height based on the load measured on the previous drops (sometime referred to as “seek” mode). This functionality may not be used for the repeatability testing.

E4.2.4 The following must be achieved with regards to the load applied on each station:

- The mean load applied shall be within 10% of the target load.
- The standard deviation of the load recorded shall be less than, or equal to two percent of the mean of the recorded values.

E4.2.5 In the event that these load requirements are not achieved the data will be disregarded and additional tests will be undertaken. If the Equipment does not meet the load requirements given above in subsequent tests then it is deemed to be unable to undertake the assessment and have failed the Repeatability criteria.

E4.2.6 The valid Repeatability data will be collected and the Equipment will pass the Repeatability test if it meets the criteria given in Table 1. A worked example of the analysis process is given in App D.1.

Table 1 – Deflection Repeatability Criteria

Parameter	Acceptability Limit
Standard deviation of load corrected deflections	95% of the data less than or equal to 2µm or the sum of 1µm and 0.75% of the mean of the recorded normalised values (whichever is greater)

E4.3 Reproducibility testing – Mandatory Requirement

E4.3.1 Reproducibility testing will be based on at least two test sets conducted on a series of test stations identified by the Auditor. The requirements for these test sets and test stations are given in Appendix C.

E4.3.2 To be classified as a valid Reproducibility test the 100mm pavement temperature must not change by more than ±3°C between tests conducted by the different Equipment on the same test station in each test set. If the temperature varies by more than this then this is likely to introduce additional variation to the Survey Data of the Equipment and should be disregarded. Additional test sets should then be undertaken in order to obtain the required amount of Survey Data within the required temperature range.

E4.3.3 Reproducibility testing will use a test procedure typical of general usage on the network. The test procedure will include a minimum of one seating drop and four measurement drops at each test station. The specific details of the test procedure (including nominal peak load and number of drops) will be communicated by the Auditor prior to the trial.

E4.3.4 The Field Calibration Factor (FCF) and the Standard Deviation of the Deviation Ratio (SDDR) are used as the basis for the assessment of Reproducibility.

E4.3.5 For each deflection sensor the reference deflection divided by the Equipment's mean deflection, averaged over all test stations, is defined as the FCF for that sensor. The overall FCF for each Equipment is calculated by averaging the FCF values for the individual sensors. The FCF therefore indicates, on average, how well the deflections recorded by each Equipment relate to the reference deflection basins.

E4.3.6 The difference between the deflection measured by each sensor at each test point and that of the reference deflection basin, expressed as a fraction of the reference deflection is defined as the Deviation Ratio. For each Equipment, the SDDR is calculated over all test stations and gives an indication of the consistency with which the Equipment tends to over-read or under-read over the set of test stations.

E4.3.7 The FCF and SDDR statistics will be calculated for each test set. The Equipment will pass the Reproducibility test if the criteria in Table 2 are met for each test set. A worked example of the analysis process is given in App D.2.

Table 2 - Deflection Reproducibility Criteria

Parameter		Maximum	Minimum
FCF	Mean for all sensors	1.05	0.95
	Individual sensor value	1.10	0.90
SDDR	Mean for all sensors	0.05	N/A
	Individual sensor value	0.07	N/A

E4.3.8 Occasionally, Equipment will produce isolated anomalous sensor readings which may result in FCF or SDDR values falling outside the acceptable limits. To compensate for this the accreditation procedure allows for the measurement from a single sensor from one test station to be removed from the analysis of each lap of the test site if required.

E4.4 Location Referencing Testing (Distance) – Mandatory Requirement

E4.4.1 Accreditation of an Equipment's ability to measure distance is carried out by comparing its measurements of a test length with the Reference Data. The test is carried out at least four times. All of the test measurements must be within the criteria given in Table 3.

Table 3 - Acceptance Criteria for Location Reference Measurement

Parameter	Acceptability Limit
Elapsed chainage versus Reference Data	± 2m or 1% (whichever is greater)

3.2 Additional test criteria from the Accreditation and QA document

E5.2 Location reference – OSGR coordinates

E5.2.1 For Equipment undertaking this test, the difference in position (as the horizontal error) between the reported OSGR coordinates from each test station and the reference OSGR coordinates will be calculated. A minimum of 18 stations will be used to undertake this test (either 18 different test stations or a lower number of test stations using multiple laps). The criteria for the assessment of OSGR coordinates are given in Table 4.

Table 4 - Acceptance Criteria for OSGR data

Performance	Criteria
High	75% of the data is within 2m of the Reference Data
Medium	75% of the data is within 5m of the Reference Data
Low	75% of the data is within 10m of the Reference Data
Not suitable	Otherwise

E5.3 Temperature measurement – temperature sensor for measurement at depth (within the pavement)

E5.3.1 If undertaking this test, the Contractor will be required to collect at least eight measurements in the pre-drilled holes (100mm depth) during the course of the test laps. The criteria for the assessment of temperature measurement at depth are given in Table 5.

Table 5 - Acceptance Criteria for temperature measurement at depth

Performance	Criteria
High	80% of the data is within 1˚C of the Reference Data
Medium	60% of the data is within 1˚C of the Reference Data
Low	25% of the data is within 1˚C of the Reference Data
Not suitable	Otherwise

E5.3.2 The Re-accreditation trial may also incorporate a check on the calibration of the temperature Systems via measurement of a static sample of known temperature (e.g. ice).

E5.4 Temperature measurement – temperature sensor for surface measurement

E5.4.1 If undertaking this test the Contractor will be required to collect at least eight measurements of the pavement surface at defined points during the course of the test laps. The criteria for the assessment of temperature measurement of the pavement surface are given in Table 6.

Table 6 - Acceptance Criteria for temperature measurement of pavement surface

Performance	Criteria
High	80% of the data is within 1˚C of the Reference Data
Medium	60% of the data is within 1˚C of the Reference Data
Low	25% of the data is within 1˚C of the Reference Data
Not suitable	Otherwise

4 Results – Day 1

4.1 Machine set-up and configuration

The machine check on the first day of the trial ran efficiently due largely to the vehicle inspection check sheets being sent to participants and completed prior to the trial, ensuring that most of the machines arrived correctly set up and configured with only minor checks required by TRL staff.

Appendix A itemises the configuration of the various machines, while Table 4.1 summarises the findings of the inspection with regards to certain key parameters that either affect operation or are requested in the trial documentation.

Table 4.1: Summary of DPT configurations on arrival

Checklist item	Number compliant (out of 25)
Completed Check list returned to TRL before trial	16
Date of last tower calibration	24
Date of last dynamic calibration	24
Date of last manufacturer's calibration	25
All seven geophones in correct positions	10

Following the 2006 accreditation trial, it had been agreed with the DPT operators that routine dynamic and tower calibration records should be made available for viewing at the 2007 and subsequent accreditation trials. The dates supplied by the contractors for their latest calibrations (regardless of whether evidence of the calibration was supplied) is shown in Appendix A.

4.2 Day 1 familiarisation lap

A familiarisation lap is conducted on Day 1 to familiarise operators with the test procedure and to provide early data to highlight any obvious problems with the survey machines to allow corrective action to be undertaken prior to the main testing. If any machines undergo any corrective action during the trial then additional testing (if required) is undertaken to make sure there is a suitable set of data for all of the assessments (i.e. reflective of the current condition and configuration of the device).

The data from the familiarisation lap is shown in Figure 4.1 and Figure 4.2 below. In these figures the circle and square show the mean FCF and SDDR respectively for the machine on the lap. The error bars show the range of the FCF and SDDR values for each geophone. In the full assessment the machines would be deemed suitable if the mean FCFs are within the mean limit (i.e. between 0.95 and 1.05), the individual FCFs within the individual limit (i.e. between 0.90 and 1.10), and the SDDR mean and individual values are below their corresponding limits (0.05 and 0.07 respectively).

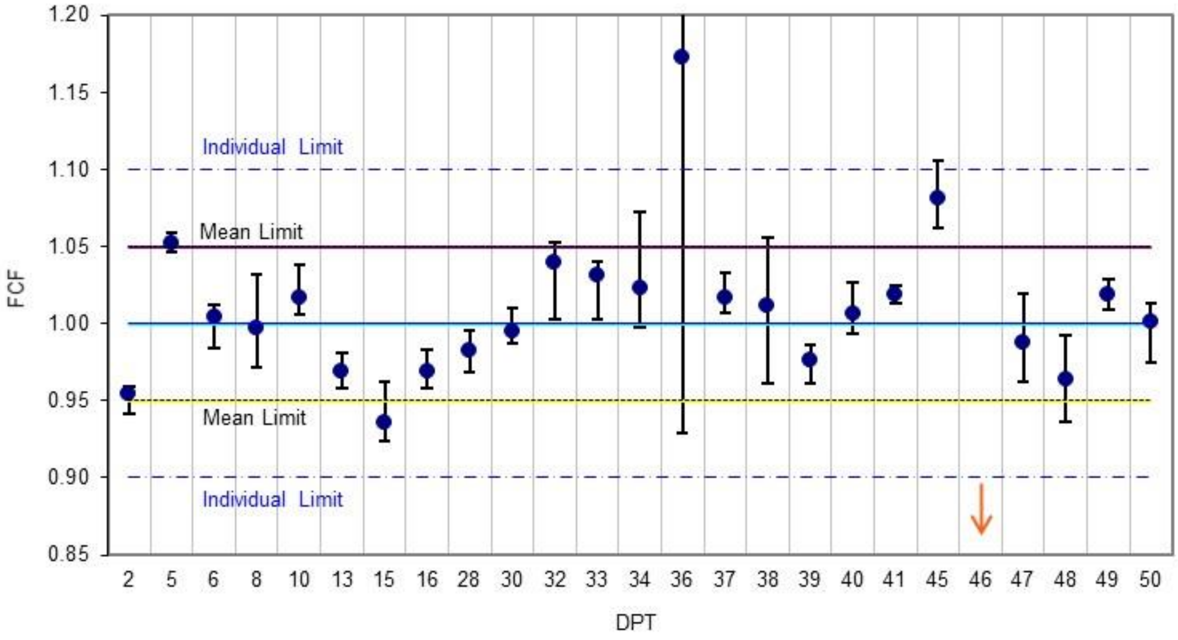

Figure 4.1: FCF (familiarisation lap – full dataset)

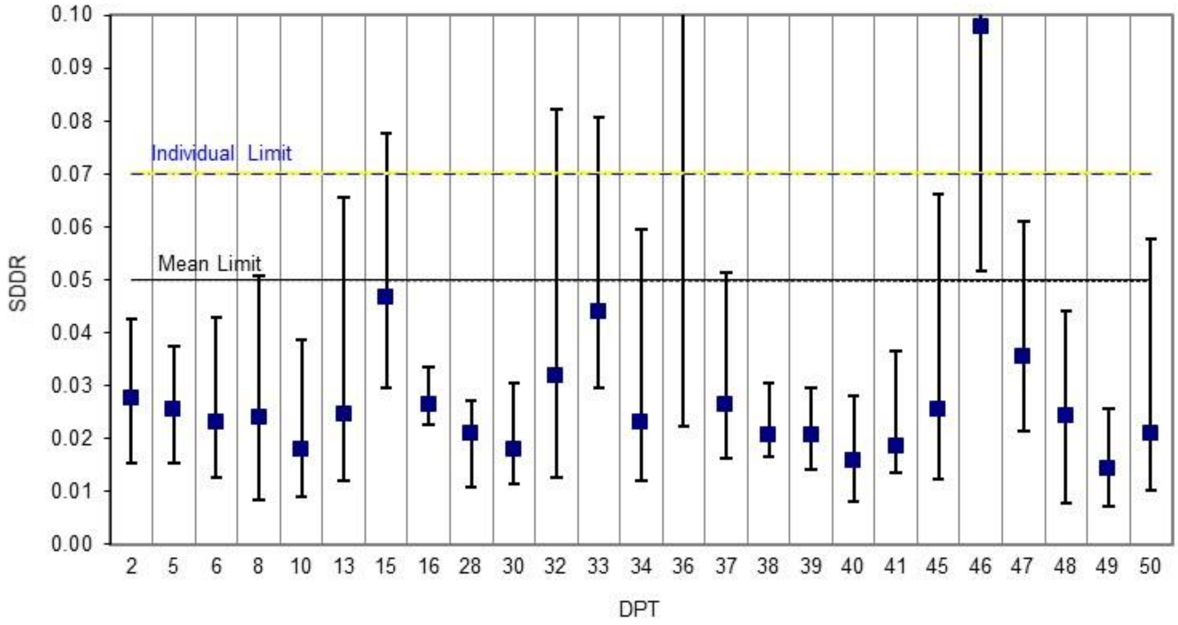

Figure 4.2: SDDR (familiarisation lap – full dataset)

On examination of the familiarisation lap data it was found that Machines 5, 15, 36, 45 and 46 exceeded the limits for mean FCF (machine 46 was off the graph with a mean FCF of 0.823) in addition Machines 36, 45 and 46 exceeded the limits for individual geophones

Machines 36 and 46 exceeded the limits for the mean SDDR, and Machines 15, 32, 33, 36 and 46 exceeded the limits for the individual SDDR limit.

However, due to the chances of isolated anomalous sensor readings, the accreditation criteria allows for the removal of the measurement from a single sensor from one test station to be removed from the analysis lap if required. The results after removing these points (for machines which didn't originally meet the criteria) are shown in Figure 4.3 and Figure 4.4.

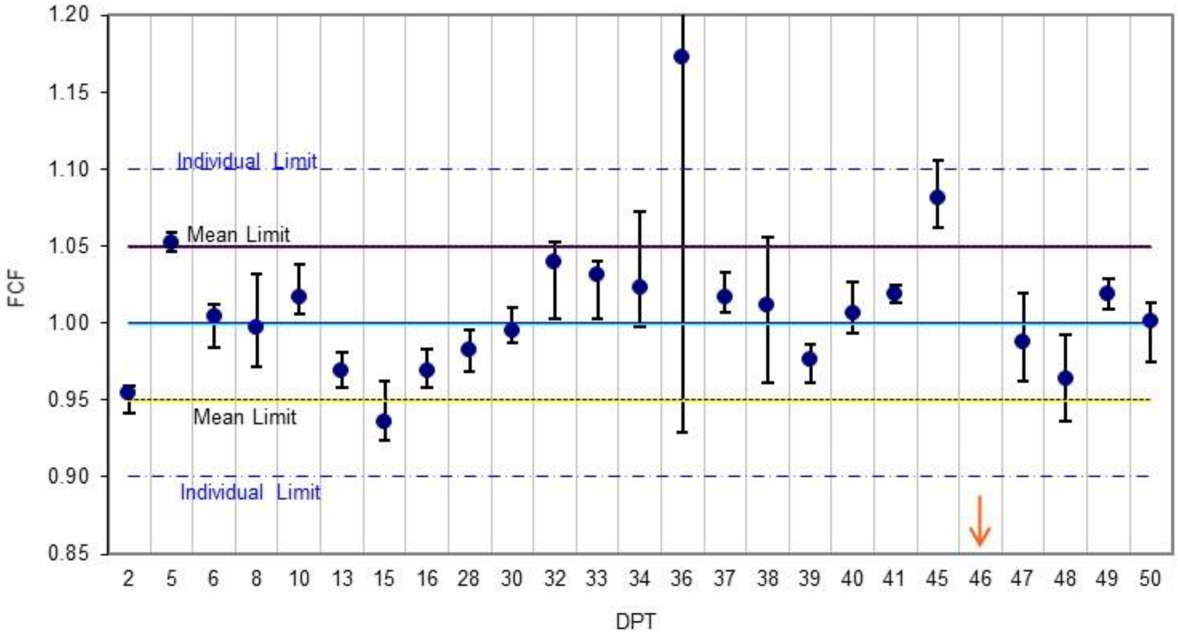

Figure 4.3: FCF (familiarisation lap- single data point removed)

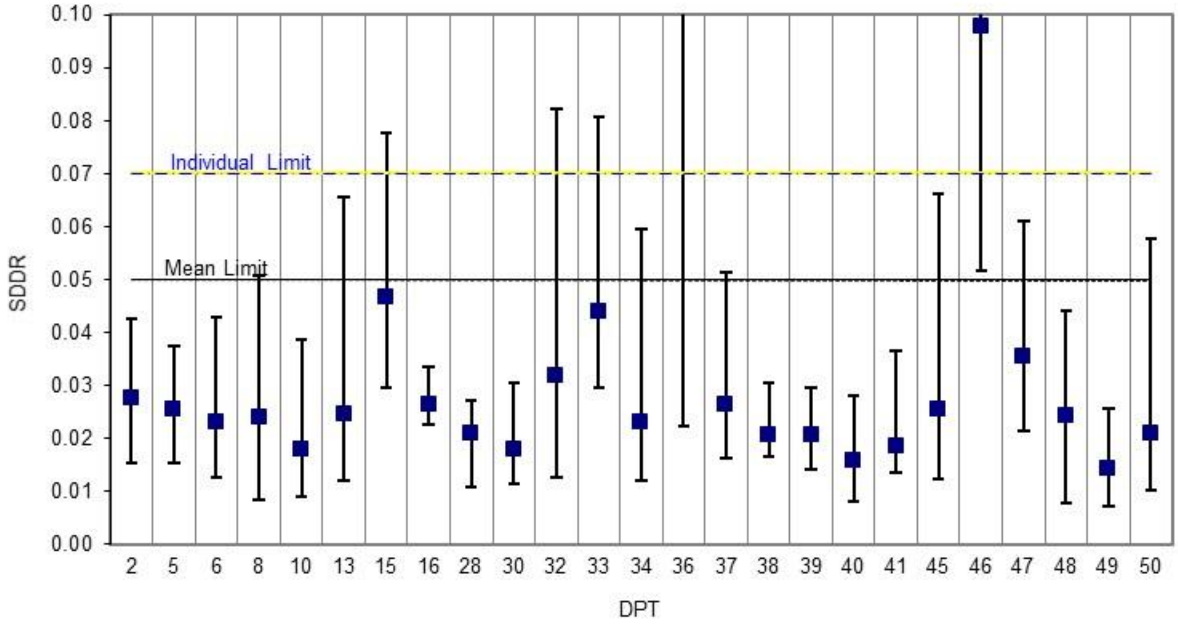

Figure 4.4: SDDR (familiarisation lap- single data point removed)

It can be seen from this data that Machines 5, 15, 36, 45 and 46 still did not meet the mean FCF criteria following the removal of a data point. Machines 36 and 46 were still outside of the FCF criteria for individual geophones, however Machine 45 now met this criteria.

Following removal of a data point, Machines 36 and 46 still exceeded the limits for the mean SDDR and Machines 15, 36 and 45 still exceeded the SDDR limits for individual geophones. Machines 32 and 33 were now within the limits.

Therefore based on the familiarisation lap (after removal of a data point) the following machines were identified as having a potential issue Machines 5, 15, 36, 45 and 46. The operators of these machines were notified of these issues so that they could investigate their machines before the testing on day two.

4.3 Repeatability tests

Repeatability tests were also conducted on day 1 using stations 2, 5, 8 and 13 and were assessed using the test criteria in section 3.1. Some machines underwent alterations during the trial (see section 5.2 for more details) and as such repeated the repeatability tests after these changes. Table 4.2 shows the summary of the final results for the repeatability assessment for all machines, including those which did not undertake the testing on day 1. The full details of each repeatability test (including the load values obtained) can be found in Appendix D.

Table 4.2: Repeatability assessment

ID	Count of failure to meet SD of normalised deflections criteria							Percentage met criteria	Status
	D1	D2	D3	D4	D5	D6	D7		
2	1	0	0	0	0	0	0	98.2	Pass
5	1	0	0	0	0	0	0	98.2	Pass
6	0	0	0	0	0	0	0	100.0	Pass
8	0	0	0	0	0	0	0	100.0	Pass
10	0	0	0	0	0	0	0	100.0	Pass
13	0	0	0	0	0	0	0	100.0	Pass
15	1	1	0	0	0	0	0	96.4	Pass
16	0	0	0	0	0	0	0	100.0	Pass
28	0	0	0	0	0	0	0	100.0	Pass
30	0	0	0	0	0	0	0	100.0	Pass
32	0	0	0	0	0	0	0	100.0	Pass
33	0	0	0	0	0	0	0	100.0	Pass
34	0	0	0	0	0	0	0	100.0	Pass
36	0	0	0	1	0	0	0	98.2	Pass
37	0	0	0	0	0	0	0	100.0	Pass
38	2	0	0	0	0	0	0	96.4	Pass
39	1	0	0	0	0	0	0	98.2	Pass
40	0	0	0	0	0	0	0	100.0	Pass

ID	Count of failure to meet SD of normalised deflections criteria							Percentage met criteria	Status
	D1	D2	D3	D4	D5	D6	D7		
41	0	0	0	0	0	0	0	100.0	Pass
45	0	0	0	0	0	0	0	100.0	Pass
46	1	2	0	0	0	0	0	94.6	Fail
47	0	0	0	0	0	0	0	100.0	Pass
48	0	0	0	0	0	0	0	100.0	Pass
49	0	0	0	0	0	0	0	100.0	Pass
50	2	0	0	0	0	0	0	96.4	Pass

All machines achieved the required load criteria for a valid test. All but one machine (Machine 46) failed to meet the Repeatability criteria. It is believed that this machine failed in part due to the fact the machine was recording much higher deflections raising the variability of the results.

4.4 Temperature Probes

During the inspection day the operators’ temperature probes were compared to the data-loggers using a stabilised environment (a container of water). From this testing it was found that the probes were broadly speaking consistent, with one probe providing slightly different results. The owner of this probe was notified.

5 Results – Day 2

5.1 Temperature variation

The maximum permitted change in the 100mm depth pavement temperature during a test lap is 3°C. The aim of this limit is to minimise changes in deflections due to temperature changes within the pavement construction in each test lap.

On day 2, pavement temperatures were recorded at 40 and 100mm depths near stations 2 and 11. The 100mm temperatures steadily increased over the day as shown in Figure 5.1. The air and surface temperatures were also collected at stations 2 and 11 and the data is shown in Figure 5.2.

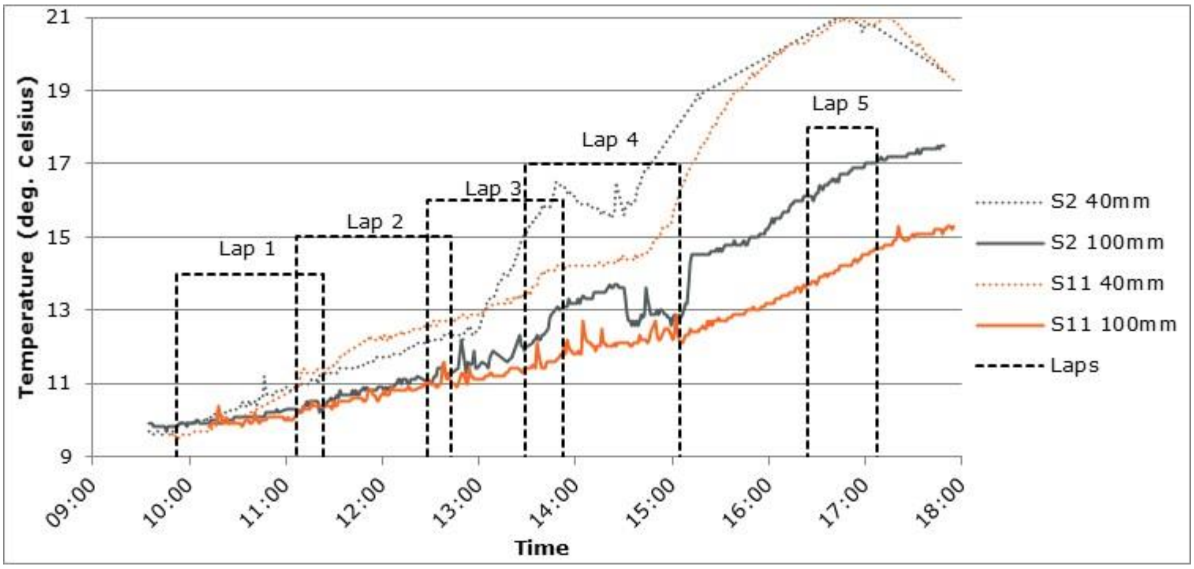

Figure 5.1: Pavement temperatures during main trial day (Day 2)

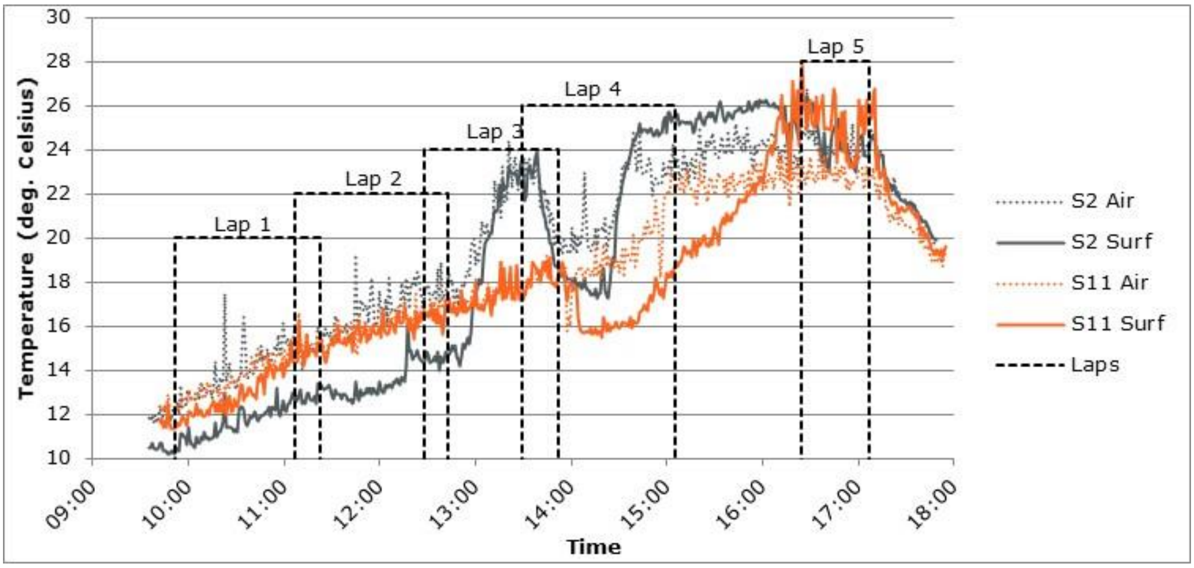

Figure 5.2: Air and surface temperatures during main trial day (Day 2)

Summaries of the pavement temperature measurements for each test lap are given in Table 5.1 and

Table 5.2 for stations 2 and 11 respectively.

Table 5.1: Pavement temperatures for each lap during Day 2, near station 2

Lap	Start of Lap			End of Lap			Lap Duration (Hours:mins)	Temperature difference during lap (˚ C)	
	Time	Temperature (˚C)		Time	Temperature (˚C)				
		40mm	100mm		40mm	100mm		40mm	100mm
1	09:52	9.8	9.8	11:23	11.3	10.3	01:31	1.5	0.5
2	11:07	11.0	10.3	12:43	12.3	11.2	01:36	1.3	0.9
3	12:28	12.1	11.2	13:52	16.4	13.0	01:24	4.3	1.8
4	13:29	15.1	12.0	15:05	16.8	12.8	01:36	1.7	0.8
5	16:24	18.9	16.1	17:07	20.8	17.0	00:43	1.9	0.9

Table 5.2: Pavement temperatures for each lap during Day 2, near station 11

Lap	Start of Lap			End of Lap			Lap Duration (Hours:mins)	Temperature difference during lap (˚ C)	
	Time	Temperature (˚C)		Time	Temperature (˚C)				
		40mm	100mm		40mm	100mm		40mm	100mm
1	09:52	9.6	9.8	11:23	11.4	10.4	01:31	1.8	0.6
2	11:07	9.9	10.2	12:43	12.7	11.0	01:36	2.8	0.8
3	12:28	12.6	10.9	13:52	14.2	11.7	01:24	1.6	0.8
4	13:29	13.5	11.4	15:05	16.3	12.1	01:36	2.8	0.7
5	16:24	20.4	13.7	17:07	20.9	14.7	00:43	0.5	1.0

It can be seen that the differences in 100mm depth temperatures between the start and end of laps ranged between 0.5˚C and 1.8˚C, significantly below the 3.0˚C limit.

5.2 Reproducibility results from test laps

In order to evaluate the performance of each machine two laps are chosen from the test set: these laps are denoted lap i and lap ii. In general, the laps chosen for i and ii were laps 3 and 4 respectively (Note: the data from the warm up lap [lap 1] is always discarded). However, in some instances e.g. software failure, missed stations or machine alterations have resulted in different laps being selected. In some cases the machines took part in an additional lap (lap 5) along with some of the other machines to act as reference. These instances where laps 3 and 4 were not used and actions taken are discussed below:

- **Machine 5** After the testing on the inspection day (FCF was not within the criteira) this machine was investigated and the load cell gain was altered. During lap 3 this machine was found to be just outside of the mean FCF criteria (at 1.054). It was further examined and additional alterations were undertaken prior to lap 4. This machine then also took part in the lap 5. As such laps 4 and 5 were used for laps i and ii.
- **Machine 33** During lap 3 this machine was found to be just outside of the mean FCF criteria (also at 1.054). It was examined and alterations were undertaken prior to lap

4. This machine then also took part in the lap 5. As such laps 4 and 5 were used for laps i and ii.

- **Machine 34** During lap 4 the operator for this machine did not test point 10. Therefore the data from laps 2 and 3 were used for laps i and ii.
- **Machine 36** During laps 2 and 3 this machine was found to be producing a low mean FCF and was failing the SDDR criteria for geophone 7. It was examined and it was found that the not all of the geophones were selected for the output and as such the incorrect data was selected for the analysis. This was rectified prior to lap 4 and this machine then also took part in the lap 5. As such laps 4 and 5 were used for laps i and ii.
- **Machine 40** During lap 3 the operator for this machine did not test point 10. Therefore the data from laps 2 and 4 were used for laps i and ii.
- **Machine 45** During the test laps it was found that this machine was exceeding the SDDR criteria for geophone 7. The last alteration on this machine was undertaken prior to lap 4 and this machine did not take place in lap 5. Therefore only lap 4 is shown in the analysis below (i.e. there was not a full dataset collected for this machine).
- **Machine 46** During the testing on the inspection day it was found that this machine was producing significantly higher deflection values relative to the other machines resulting in lower FCF values (see section 4.2). To ascertain if the differences with this machine was due to calibration issues the crew were notified of the average difference between their machine and the fleet so that a correction could be applied prior to the main trial day to test this. During the test laps on the main trial day it was found that this machine was exceeding the SDDR criteria for geophones 5, 6 and 7 and for the mean of the geophones. The last alteration on this machine was undertaken prior to lap 4 and this machine did not take place in lap 5. Therefore only lap 4 is shown in analysis below (i.e. there was not a full dataset collected for this machine).

The FCF and SDDR values derived from each machine's laps are given in Appendix E, Table E.1. The laps chosen for assessment (lap i and ii) were laps 3 and 4 for most machines apart for the exceptions discussed above, as shown in Table 5.3.

Table 5.3: Machines for which laps 2 and 3 were not used for the assessment

Machine	Lap i	Lap ii
5	Lap 4	Lap 5
33	Lap 4	Lap 5
34	Lap 2	Lap 3
36	Lap 4	Lap 5
40	Lap 2	Lap 4
45	-	Lap 4
46	-	Lap 4

5.2.1 *Plots of FCF and SDDR (prior to geophone removal)*

The results from laps i and ii (prior to the removal of individual geophone readings) are shown graphically in Figure 5.3 for FCF and Figure 5.4 for SDDR. The vertical bars in these figures indicate the range of values from individual sensors and the filled circles/squares indicate the mean value for all seven sensors.

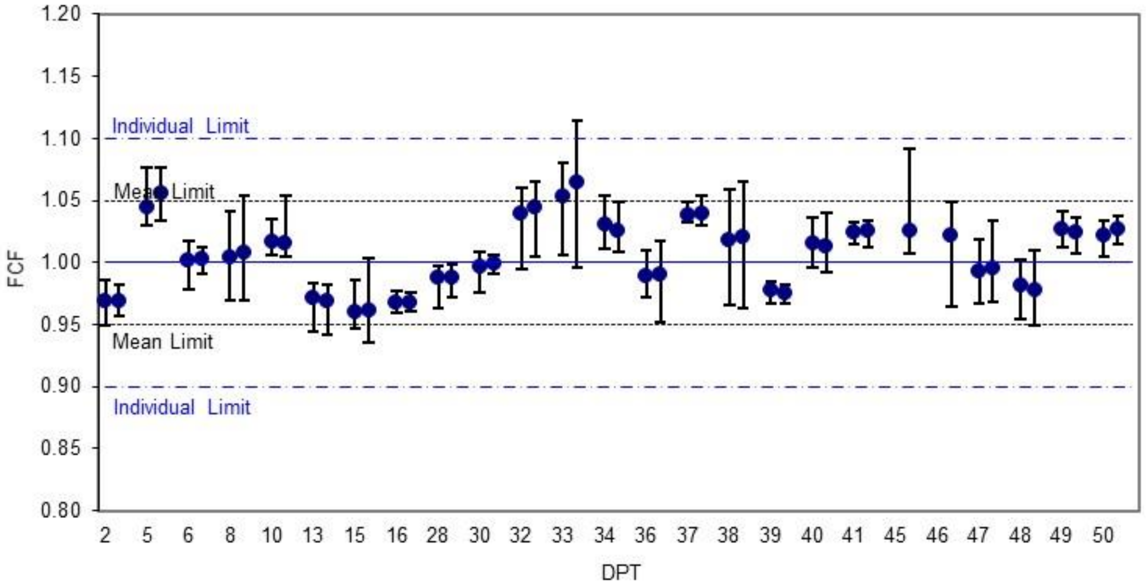

Figure 5.3: FCF for each DPT (main trial day for laps i and ii – full data set)

It can be seen from Figure 5.3 that two machines (Machine 5 and 33) fail to meet the mean Field Calibration Factor (FCF) criteria using the full data set from the two chosen test laps. In addition one machine (Machine 33) fails to meet the trial requirements for the individual geophone FCF values using the full set of data.

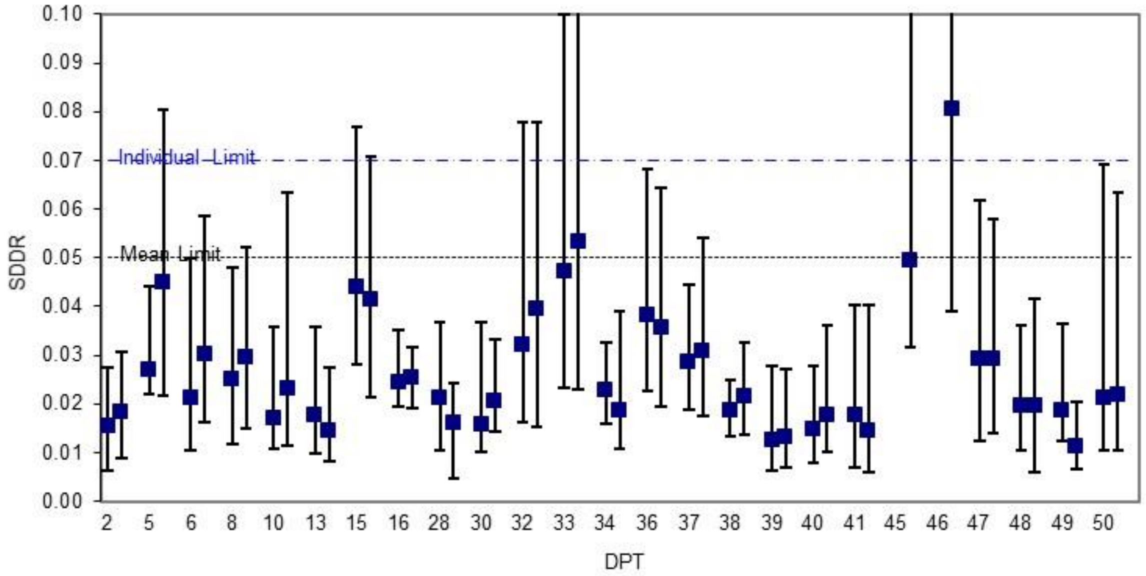

Figure 5.4: SDDR for each DPT (main trial day for laps i and ii – full dataset)

Two machines (Machine 33 and 46) failed to meet the criterion for the mean SDDR using the full set of data. Six machines (Machines 5, 15, 32, 33, 45 and 46) failed to meet the individual SDDR criterion using the full set of data.

5.2.2 *Plots of SDDR (after geophone removal)*

The results from laps i and ii (after geophone removal for identified machines) are shown graphically in Figure 5.5 for FCF and Figure 5.6 for SDDR.

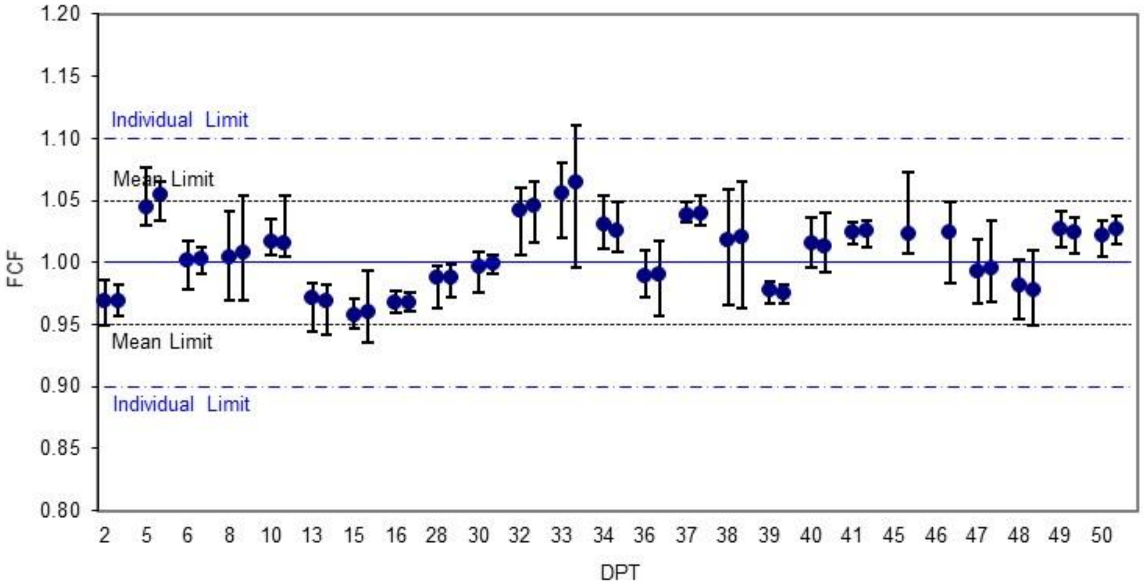

Figure 5.5: FCF for each DPT (main trial day for laps i and ii – single data point removed)

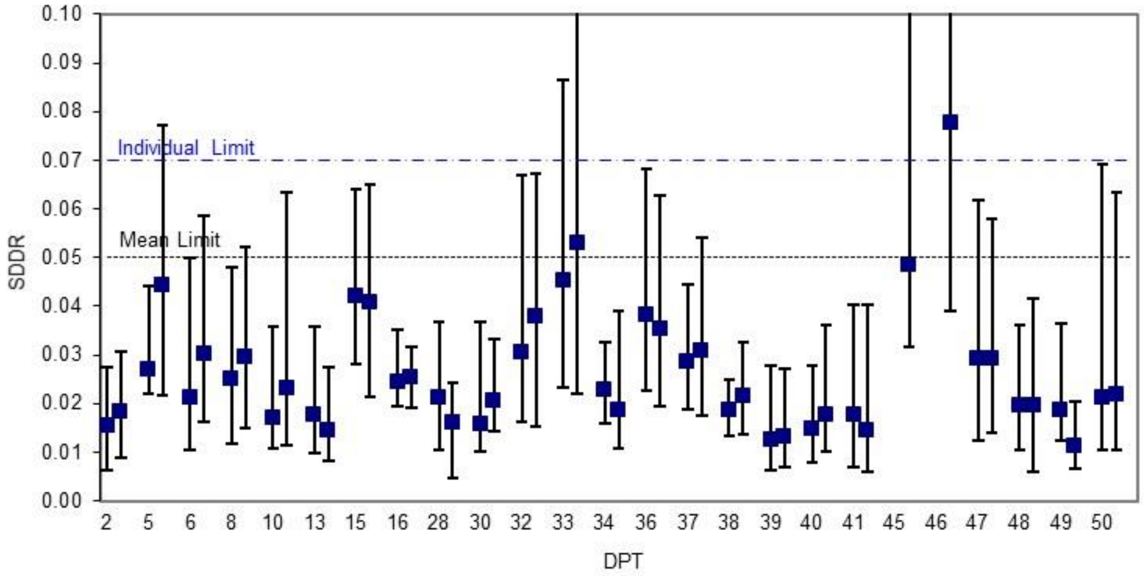

Figure 5.6: SDDR for each DPT (main trial day for laps i and ii – single data point removed)

Following the removal of a single geophone reading from one station on each lap it can be seen that Machines 5 and 33 still fail to meet the mean FCF criteria. In addition Machine 33 still fails to meet the individual FCF criteria.

Even after removal of a single geophone reading from one station on each lap it can be seen that Machines 33 and 46 do not meet the mean SDDR criteria. In addition Machines 5, 33, 45 and 46 still fail to meet the individual SDDR criteria. Machines 15 and 32 now meet the individual SDDR criteria.

Therefore, in summary, 4 of the 25 machines (Machines 5, 33, 45 and 46) fail to meet the reproducibility criteria after the test laps on the main trial day.

5.3 Distance measurement tests

In order to assess the measurement of distance, the operators were asked to provide distance measurements on four laps. The reference length was 512.1m and the criteria applied to this data are described in section 3.1. The differences between the trial data and the reference are given in Table 5.4 (negative denotes the operator recorded a shorter length). In this table the data is shown in grey if the difference measured was within or equal to 1m of the reference, and highlighted in bold and red font if the difference measured was greater than the tolerance (1% i.e. 5.1m). A machine would fail this test if it could not supply all four measured lengths within the criteria.

Table 5.4: Difference between operators' measured values and reference

Machine	Difference between measured distance and reference (m)				Performance
	Lap a	Lap b	Lap c	Lap d	
2	-0.1	-0.1	-0.1	-0.1	Pass
5	0.3	0.2	0.1	0.0	Pass
6	0.2	0.0	-0.1	-0.1	Pass
8	-1.1	-2.1	-0.1	-0.1	Pass
10	0.9	-0.1	-0.1	-0.1	Pass
13	-0.1	-1.1	-0.1	-1.1	Pass
15	0.9	0.5	0.5	0.9	Pass
16	0.9	-0.1	0.9	0.9	Pass
28	0.9	0.9	0.9	0.9	Pass
30	-1.1	-1.3	-1.1	-1.1	Pass
32	-0.1	-0.1	-0.1	-0.1	Pass
33	-0.1	-0.1	-0.1	-0.1	Pass
34	0.9	-0.1	-0.1	-0.1	Pass
36	0.9	0.9	0.9	0.9	Pass
37	1.3	1.1	1.0	0.9	Pass
38	0.9	0.9	0.9	0.9	Pass
39	0.4	0.3	0.1	0.1	Pass
40	-2.6	-2.7	-2.7	-2.7	Pass
41	-0.1	-0.1	-0.1	-0.1	Pass
45	1.9	0.9	0.9	0.9	Pass
46	2.9	2.9	2.9	2.9	Pass

Machine	Difference between measured distance and reference (m)				Performance
	Lap a	Lap b	Lap c	Lap d	
47	0.3	0.1	0.0	-0.1	Pass
48	0.9	-0.1	-0.1	-0.1	Pass
49	-0.1	-0.1	-0.1	-0.1	Pass
50	3.0	2.9	2.8	2.6	Pass

It can be seen from this table that all machines met the trial criteria. In addition, 77% of the measurements were within 1m of the reference distance.

5.4 OSGR measurements (from 3-dimensional position data)

3-dimensional position data was supplied by 11 of the 25 machines at the trial. These devices all provide the data in lat/long/height format. Therefore the data has been converted to OSGR format (eastings and northings) by TRL before assessment against the criteria (given in section 3.2). It is worth noting that other survey devices that operate on the Highways England network provide their data in OSGR format and as such consideration should be given to imposing the requirement of providing the data in OSGR format.

The percentage of the data within 2m, 5m and 10m for each of the machines that supplied positional data is given in Table 5.5. This data is highlighted in bold and red text if the percentage is below 75% for any of the criteria.

Table 5.5: Assessment of positional data

Machine	Percentage of data that is within x m of the reference (horizontally)			Performance band
	2m	5m	10m	
6	100%	100%	100%	High
28	94%	100%	100%	High
30	**54%**	**71%**	75%	Low
36	**58%**	100%	100%	Medium
38	**2%**	**58%**	91%	Low
39	80%	100%	100%	High
40	90%	100%	100%	High
47	**63%**	100%	100%	Medium
48	96%	100%	100%	High
49	100%	100%	100%	High
50	**10%**	100%	100%	Medium

5.5 Operator temperature measurements

The DPT operators were asked to use their own equipment to record temperatures from two pre-drilled holes so that the accuracy of temperature collection could be assessed. These holes are drilled to 100mm depth and located near stations 2 and 11. The temperatures recorded by the operators are plotted against the data recorded from the temperature data logger (located in the same hole) in Figure 5.7 and Figure 5.8.

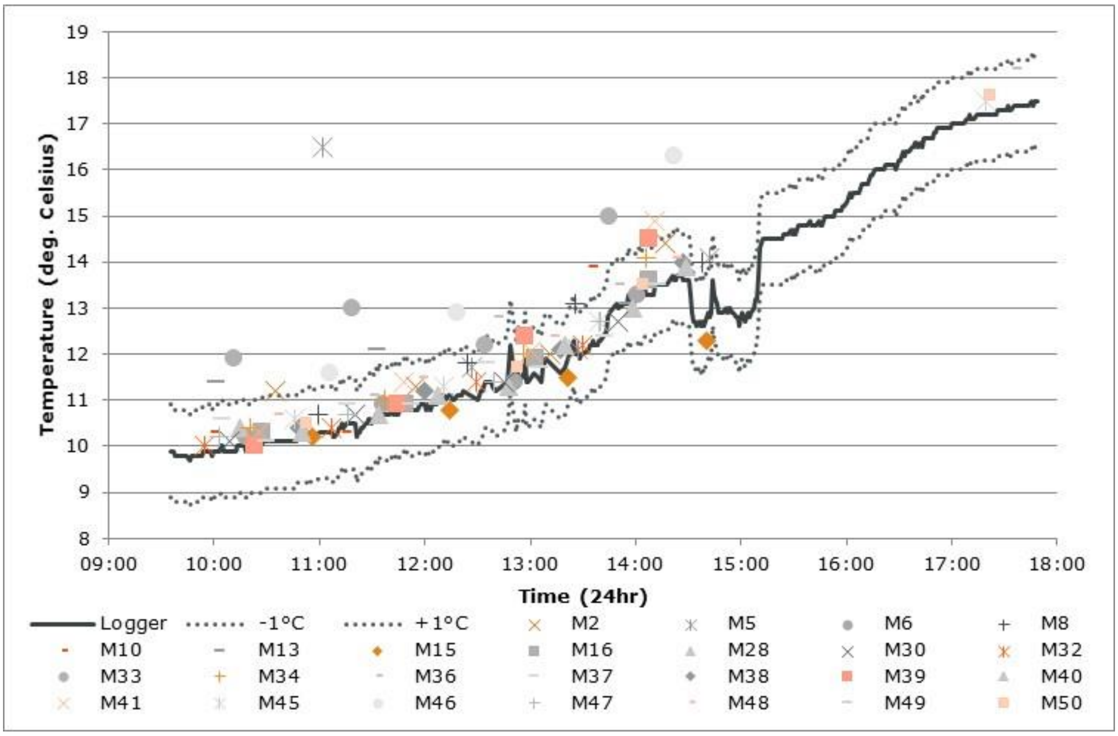

Figure 5.7: Comparison of operator's temperatures and logger temperatures (day 2 near station 2, 100mm depth)

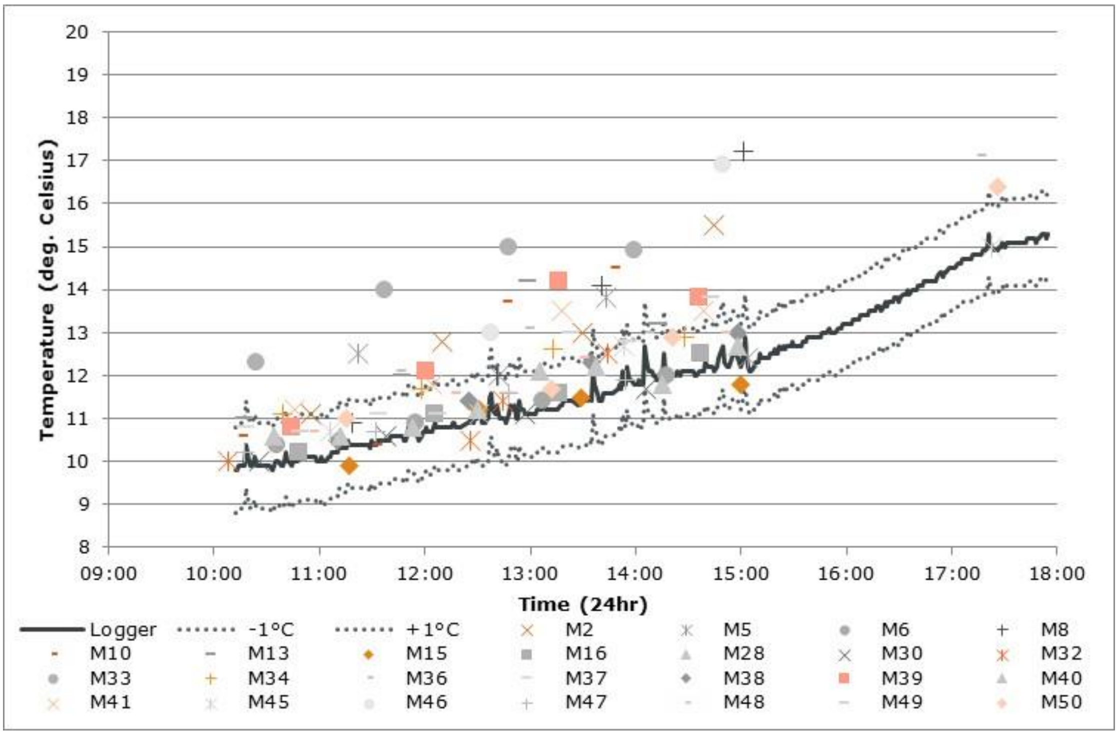

Figure 5.8: Comparison of operator's temperatures and logger temperatures (day 2 near station 11, 100mm depth)

It can be seen from these two plots that the operators' measurements are generally consistent with the logger measurement. However, there is a noticeable difference in the performance seen on station 2 in comparison to station 11. It is not known what the causes for these differences are however this difference was also observed in the 2017 trial. It could be due to differences in the holes drilled (the holes could be smaller at station 11 reducing the depth measured by some probes), differences in the test procedure applied by the operators (station 2 is near the start where they are queued up waiting to test and therefore have more time to take care with the measurement) or some other cause. This should be further investigated at the next trial to try and identify the cause.

The test criteria for temperature measurement at depth are given in section 3.2, and the machines were assessed using data from four laps. The differences and ratings given are presented in Table 5.6. In the table values are highlighted in bold and red font if the value was more than 1˚C away from the reference. Machine 46 did not complete a full set of tests and therefore this machine was not provided a performance rating.

Table 5.6: Assessment of operators' temperature measurement at depth (stations 2 & 11)

Machine	Difference between operators' measurement and reference data (˚C)								Percentage within 1˚C	Rating
	Lap a		Lap b		Lap c		Lap d			
	2	11	2	11	2	11	2	11		
2	**1.10**	1.00	0.50	**2.00**	0.10	**1.60**	0.90	**3.40**	50%	Low
5	**6.20**	**2.10**	0.50	0.90	0.10	**2.20**	**1.30**	0.20	50%	Low
6	0.30	0.40	0.20	0.20	-0.80	0.10	0.10	-0.10	100%	High
8	0.50	0.50	0.60	0.70	**1.10**	**2.70**	**1.30**	**4.90**	50%	Low
10	0.50	0.70	-0.10	0.00	0.80	**2.70**	**1.70**	**2.90**	63%	Medium
13	**1.50**	**1.10**	**1.50**	**1.40**	**11.60**	**3.10**	-0.20	**1.20**	13%	Not Suitable
15	0.00	-0.50	-0.30	0.20	-0.20	0.10	-0.40	-0.40	100%	High
16	0.30	0.20	0.10	0.20	0.30	0.40	0.30	0.40	100%	High
28	0.40	0.70	-0.10	0.00	-0.10	0.90	-0.20	-0.20	100%	High
30	0.20	0.10	0.20	0.10	0.20	0.00	-0.30	-0.70	100%	High
32	0.11	0.01	0.10	-0.50	0.20	0.40	0.20	0.90	100%	High
33	**2.00**	**2.40**	**2.50**	**3.50**	0.80	**3.90**	**2.10**	**3.10**	13%	Not Suitable
34	0.40	**1.20**	0.30	**1.10**	0.40	**1.40**	0.80	0.80	63%	Medium
36	0.60	**1.50**	**1.60**	**2.00**	0.40	0.60	0.80	**2.30**	50%	Low
37	0.60	0.40	0.40	0.60	0.40	0.50	0.10	0.60	100%	High
38	0.20	0.30	0.30	0.50	0.50	0.90	0.40	0.60	100%	High
39	0.00	0.90	0.20	**1.30**	0.50	**3.00**	**1.20**	**1.70**	50%	Low
40	0.10	0.30	0.20	0.20	0.50	0.40	0.30	0.30	100%	High
41	0.30	**1.20**	0.50	**1.10**	0.66	**2.20**	**1.40**	**1.40**	38%	Low
45	0.50	0.60	0.20	0.10	0.40	0.60	0.30	0.00	100%	High
46	**1.30**	**1.40**	**1.80**	.	**2.70**	**4.20**	.	.	0%	Not assessed
47	0.30	0.30	0.20	0.30	0.10	0.50	0.40	0.10	100%	High
48	0.60	0.60	0.60	0.70	0.50	1.00	0.50	0.30	100%	High
49	0.00	0.60	0.10	0.30	0.20	**1.60**	0.00	**1.60**	75%	Medium
50	0.30	0.70	0.10	0.50	0.20	0.90	0.40	**1.50**	88%	High

It can be seen from this table that thirteen machines achieved the high performance rating, three machines achieved a medium performance and six machines achieved a low performance. In addition two machines were identified as not suitable and one machine did not complete the test (it was found that the temperature probe was too big for the hole drilled for the purpose).

5.5.1 *Contactless surface and air temperature measurements*

A methodology for estimating the temperature at 100mm has been developed but is not formally implemented. This method uses the surface temperature at the time of the survey (collected using on board IRT sensors on the DPT) and the average air temperature for the previous day (acquired from a weather station). Due to this new methodology a number of contractors have fitted sensors for the automatic measurement of air and surface temperatures to their survey devices.

5.5.1.1 *Contactless surface temperature measurements*

Of the twenty-five machines which took part in the trial, eleven machines (32, 34, 37, 38, 39, 40, 45, 47, 48, 49 and 50) had surface temperatures in their datasets which changed during testing (i.e. not fixed default values). The surface temperature data from station 2 and 11 for these machines is shown along with surface temperature data from the logger in Figure 5.9 and Figure 5.10 respectively.

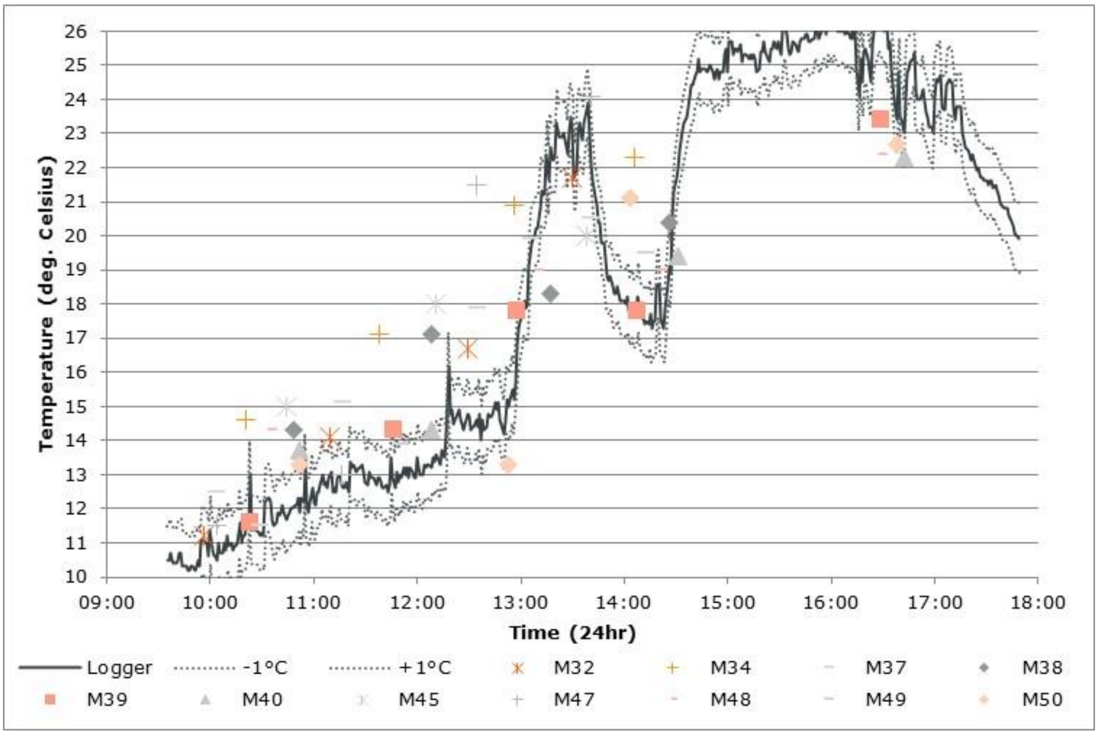

Figure 5.9: Comparison of surface temperatures recorded by DPTs and reference logger measurements (day 2 near station 2)

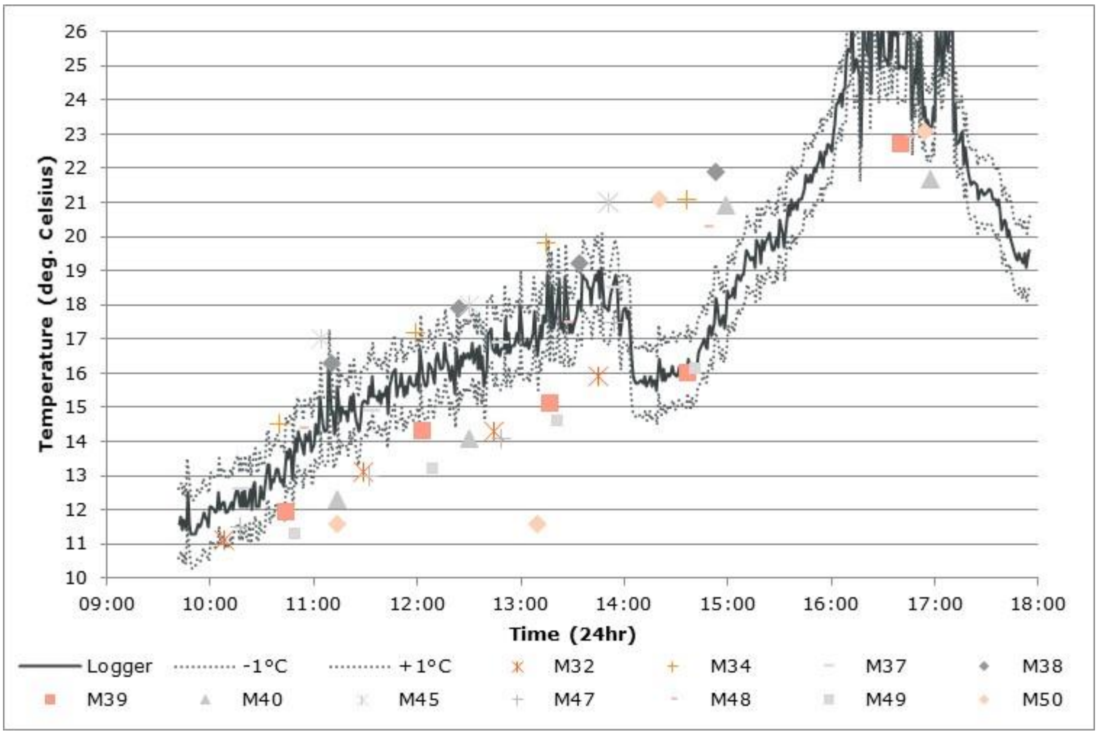

Figure 5.10: Comparison of surface temperatures recorded by DPTs and reference logger measurements (day 2 near station 11)

It can be seen from these graphs (Figure 5.9 and Figure 5.10) that there is not a good match between the survey contractor surface measurements and the data logger. In addition there is quite a large spread between the results provided by the survey contractors.

The test criteria for surface temperature measurement are given in section 3.2, and the machines were assessed using the data from 4 laps. The differences and ratings given are presented in Table 5.7. In the table values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Table 5.7: Assessment of operators' surface temperature measurement against logger

Machine	Difference between operators' measurement and reference data (˚C)								Percentage within 1˚C	Rating
	Lap A		Lap B		Lap C		Lap D			
	2	11	2	11	2	11	2	11		
32	0.10	**-1.10**	**1.20**	**-2.10**	**1.90**	**-2.40**	**-1.40**	**-3.10**	13%	Not Suitable
34	**3.20**	**1.50**	**4.20**	**1.50**	**5.70**	**2.20**	**4.60**	**5.10**	0%	Not Suitable
37	**2.00**	0.10	**2.50**	-1.00	**3.50**	0.20	**-1.60**	-0.40	50%	Low
38	**2.30**	**1.50**	**3.90**	**2.00**	**-4.30**	**1.10**	**1.30**	**3.70**	0%	Not Suitable
39	**-1.40**	**-1.80**	**1.40**	**-1.60**	1.00	**-2.20**	-0.40	-0.40	38%	Low
40	**1.80**	**-3.30**	**1.10**	**-2.30**	.	.	**-2.60**	**3.20**	0%	Not Suitable
45	**3.30**	**1.70**	**4.40**	**1.60**	**-3.70**	**3.20**	**-3.70**	**3.20**	0%	Not Suitable
47	1.00	-0.60	0.30	**-2.60**	**6.90**	**-2.60**	**2.00**	**-1.20**	38%	Low
48	**2.00**	0.40	.	.	**-1.20**	**-1.30**	0.40	**3.50**	33%	Low
49	0.30	**-2.80**	1.00	**-2.70**	0.10	**-3.20**	**2.00**	0.00	50%	Low
50	**1.40**	**-4.00**	.	.	**-1.70**	**-4.90**	**3.30**	**4.70**	0%	Not Suitable

The results given above would initially suggest that the majority of the operators' surface temperature measurement systems are not suitable for use and the remainder are achieving a low performance. However, it seems unlikely that none of the operators' devices would be able to achieve at least a medium performance. This suggests that the reference data collected for this test may be unsuitable. On the inspection day all of the thermocouples for the temperature loggers were compared against each other and the operators' temperature probes (the water bucket test). This found that the thermocouples were all reading consistently. Therefore the issue is likely due to the position of the thermocouples (they are located to the side of the track where as the operator's devices measure in the test lane), the contact with the pavement surface or differences in the measurement principles (the DPT devices use IRT sensors).

As this issue also occurred during the 2017 DPT trial additional measurements were taken using a handheld IRT on the path at the side of the track (where the thermocouples were located) and in the test lane (lane 1). This data is shown against the logger data in Figure 5.11 and Figure 5.12.

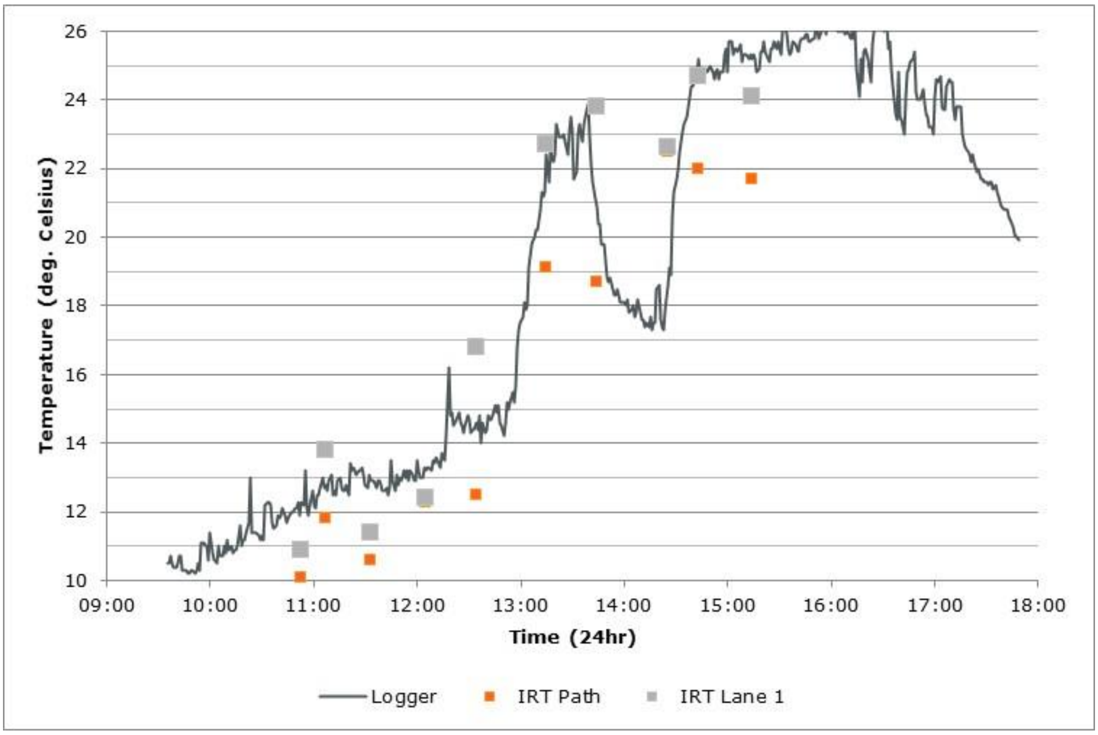

Figure 5.11: Comparison of handheld IRT and reference logger measurements of surface temperature (day 2 near station 2)

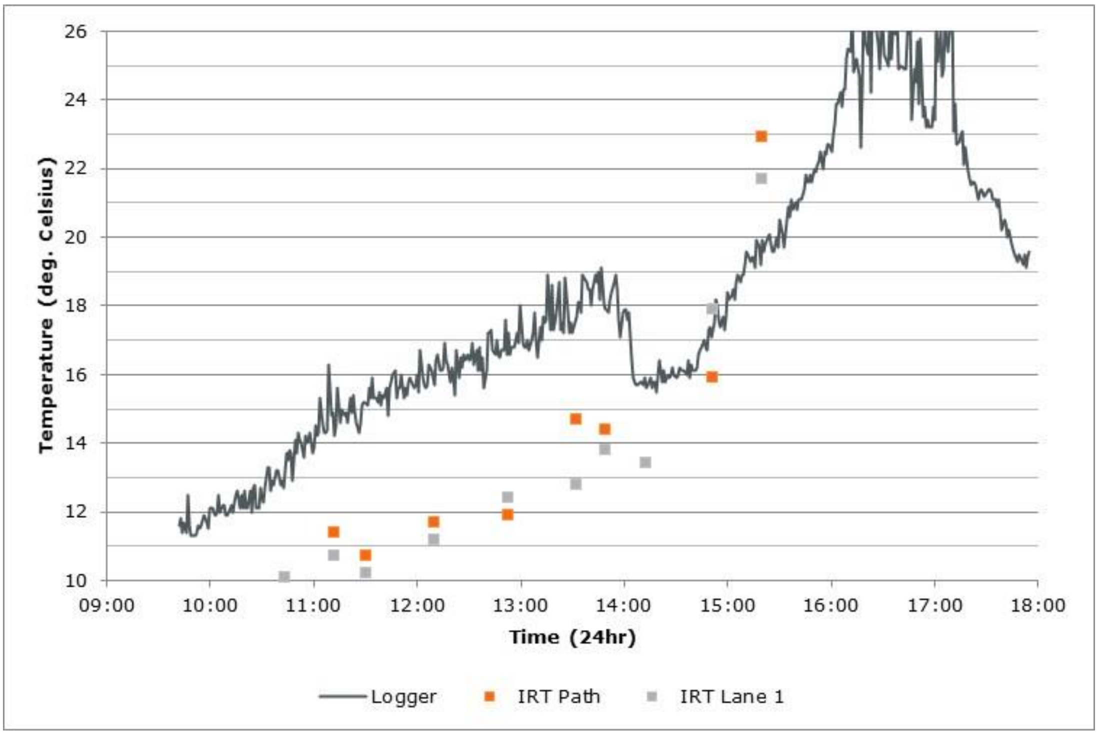

Figure 5.12: Comparison of handheld IRT and reference logger measurements of surface temperature (day 2 near station 11)

From these graphs (Figure 5.11 and Figure 5.12) it can be seen that there are differences between the handheld IRT measurements and the logger measurements, however the differences are not consistent between the two stations. In addition the data from station 2 suggests a difference between the path and the test lane, whereas the same does not appear to be true for station 11. It is worth noting that if we plot a curve through the IRT measurements for the test lane, and use this data to assess the devices then the performance of the devices is very similar to the earlier assessment (i.e. mostly “not suitable” and a few “low”).

Where there is uncertainty in the auditor’s collected references, we would typically use the average of the fleet as the reference. However, given the wide scatter of the results from the operators (see Figure 5.9 and Figure 5.10) this is not a suitable choice and would only marginally improve the performances awarded. This suggests that there is a significant number of the devices producing a poor performance, however with the reference data collected it is not possible to determine which machines these are (assuming that at least some are providing a good performance). It is therefore recommended that additional details on the set-up and configuration of these devices is obtained and additional investigation into these devices is undertaken (both by the survey contractors and the auditor) between now and the next trial. In addition consideration should be given to improving the reference data collected at the next trial.

5.5.1.2 Air temperature measurements

Fifteen machines (6, 30, 32, 34, 36, 37, 38, 39, 40, 45, 46, 47, 48, 49 and 50) provided air temperatures in their datasets which changed during testing. The air temperature data from station 2 and 11 for these machines is shown along with air temperature data from the logger in Figure 5.13 and Figure 5.14 respectively.

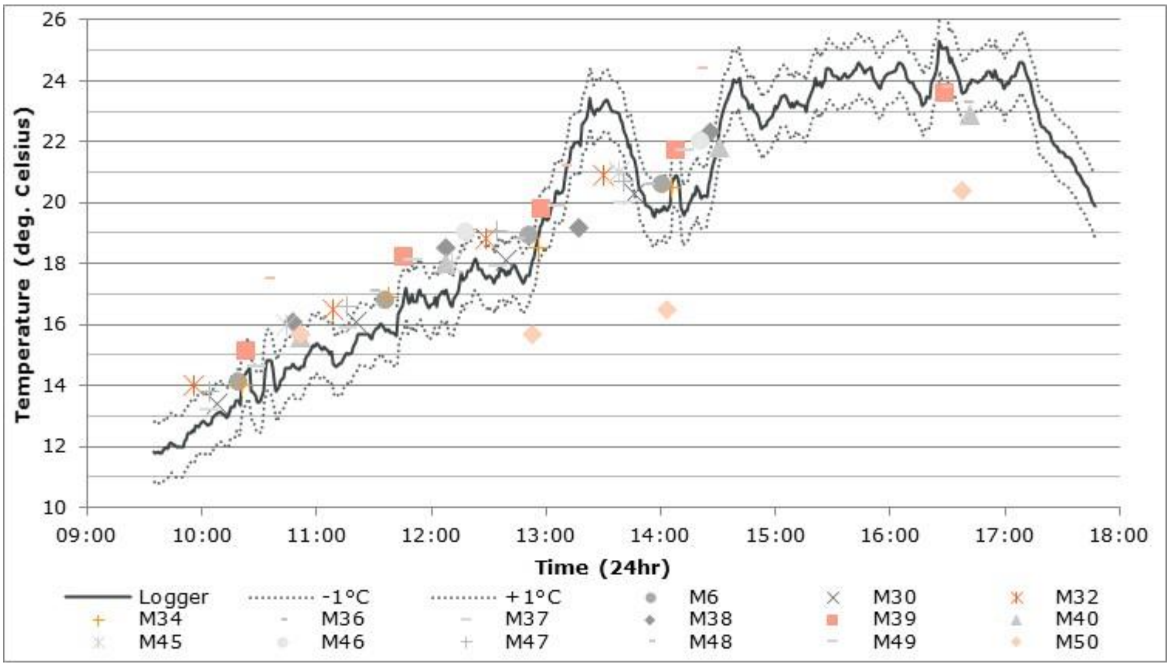

Figure 5.13: Air temperatures recorded by DPTs and reference logger measurements (day 2 near station 2)

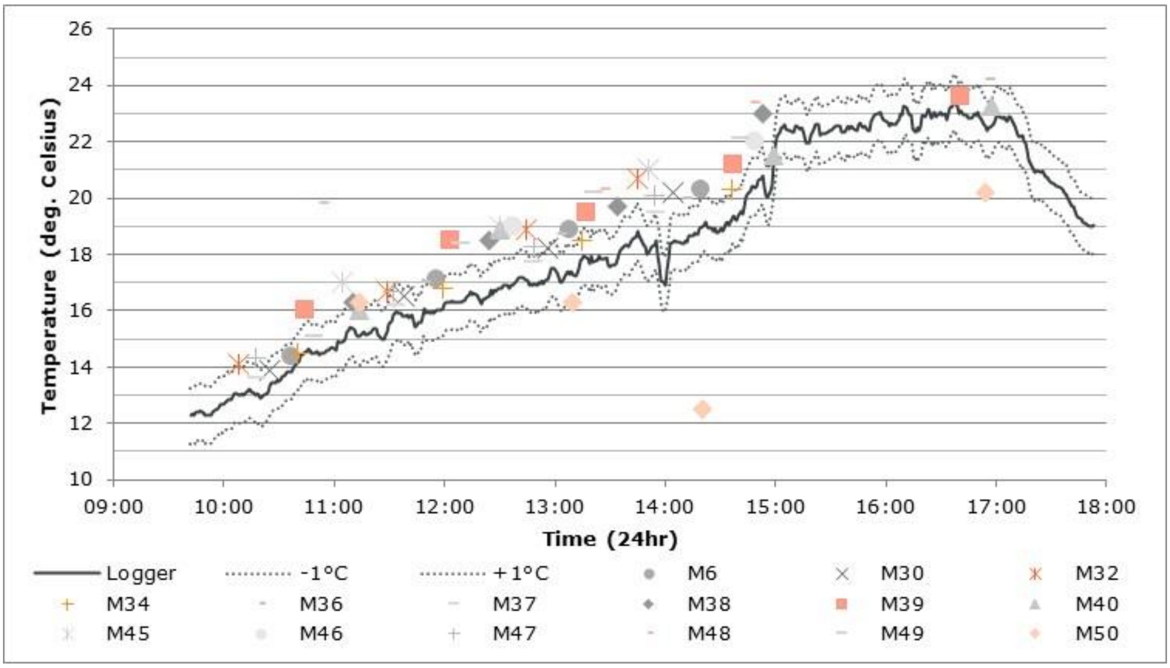

Figure 5.14: Air temperatures recorded by DPTs and reference logger measurements (day 2 near station 11)

Although same day air temperature measurements from DPTs do not form part of the updated test method it seemed prudent to assess the data supplied. However from the graphs above (Figure 5.13 and Figure 5.14) it can be seen that there is an offset between the logger and the average of the fleet. This is likely due to the fact that the logger was not shaded from the sun and protected from wind-chill. Therefore the data (as the data from the survey contractors were consistent) was assessed against the fleet average for the each station. This data is graphed in Figure 5.15 and Figure 5.16.

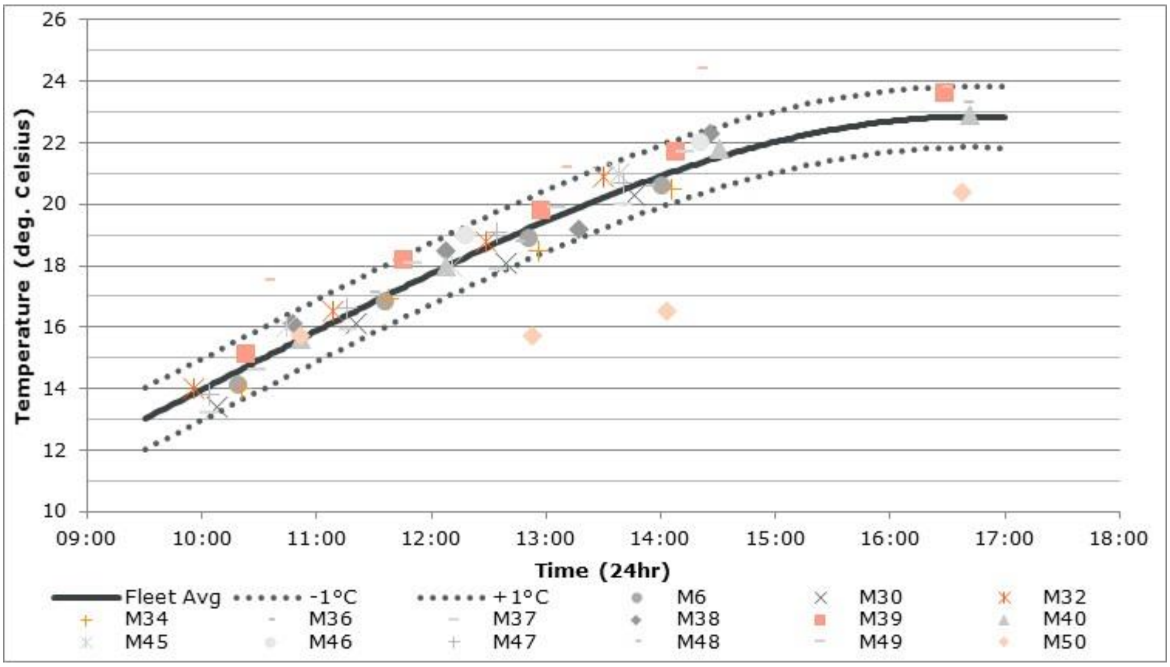

Figure 5.15: Air temperatures recorded by DPTs and fleet average (day 2 near station 2)

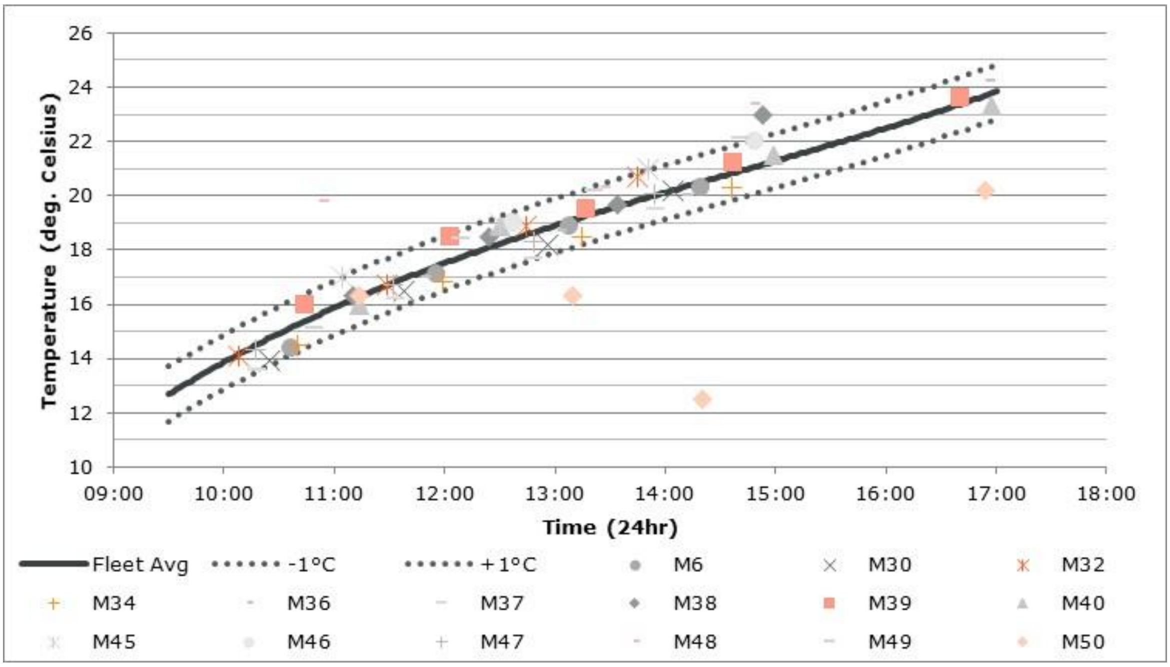

Figure 5.16: Air temperatures recorded by DPTs and fleet average (day 2 near station 11)

As air temperature measurements from DPTs do not form part of the updated test method there is no formal criteria set for this measurement. As such the data has been assessed against the surface temperature measurement criteria (given in section 3.2), and the machines were assessed using the data from 4 laps. The differences between the data and the fleet average, and the ratings given are presented in Table 5.7. In the table values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Table 5.8: Assessment of operators' air temperature measurement

Machine	Difference between operators' measurement and reference data (˚C)								Percentage within 1˚C	Rating
	Lap A		Lap B		Lap C		Lap D			
	2	11	2	11	2	11	2	11		
6	-0.44	-0.72	-0.21	-0.32	-0.28	-0.17	-0.31	-0.17	100%	High
30	-0.82	-0.82	-0.41	-0.45	-0.75	-0.62	-0.30	0.00	100%	High
32	0.22	-0.06	0.36	0.02	0.23	0.35	0.68	0.89	100%	High
34	-0.61	-0.75	-0.17	-0.67	-0.85	-0.70	-0.54	-0.52	100%	High
36	0.34	-0.21	-0.22	-0.24	-0.14	-0.32	0.45	0.51	100%	High
37	-0.90	-0.85	-0.49	-0.64	-0.84	-0.94	-0.46	-0.51	100%	High
38	0.60	0.19	0.52	0.40	-0.67	0.09	0.85	**1.87**	88%	High
39	0.43	0.62	0.88	0.93	0.40	0.26	0.61	0.38	100%	High
40	0.03	-0.29	0.02	0.66	0.28	0.25	0.05	-0.44	100%	High
45	0.63	**1.00**	-0.04	0.76	0.59	**1.07**	0.59	**1.07**	63%	Medium
46	.	.	0.72	0.58	.	.	0.67	0.95	100%	High
47	-0.30	-0.15	0.21	-0.09	0.36	-0.34	0.24	0.09	100%	High
48	**2.51**	**4.17**	**1.53**	0.85	**3.07**	**2.38**	0.97	**3.19**	25%	Low
49	-0.26	-0.41	0.66	0.68	0.29	0.88	0.53	**1.20**	88%	High
50	0.13	0.01	**-3.54**	**-2.81**	**-4.46**	**-8.01**	**-2.45**	**-3.44**	25%	Low

From these results it can be seen that 12 machines meet the high performance level, one meet the medium performance level and two meet the low performance level.

6 Results – Contingency day

By the end of the main trial day four machines were identified as having not met the deflection criteria. Of these three machines (Machines 5, 33 and 45) were identified as being close to passing the criteria and were given the opportunity to investigate their machines and re-test on the contingency day. A selection of devices (Machines 8, 10, 16, 34 and 39) which met the criteria were also present to provide reference data. The following changes were made to the devices being assessed on the contingency day:

- **Machine 5** Altered trigger height
- **Machine 33** Increased trigger time by 3ms and greased nylon guide blocks.
- **Machine 45** No additional alterations, attending to provide a full data set following the last change on the main trial day.

On the contingency day three reproducibility test laps (a warm-up and two assessment laps) were undertaken followed by two repeatability test laps. The machines being assessed were excluded from the calculation of the reference for the calculation of FCF and SDDR. During the warm-up lap Machine 45 identified an issue which would not be resolvable during the timescale of the testing, and pulled out of the remaining testing.

The FCF and SDDR results from the two assessment laps are shown in Figure 6.1.

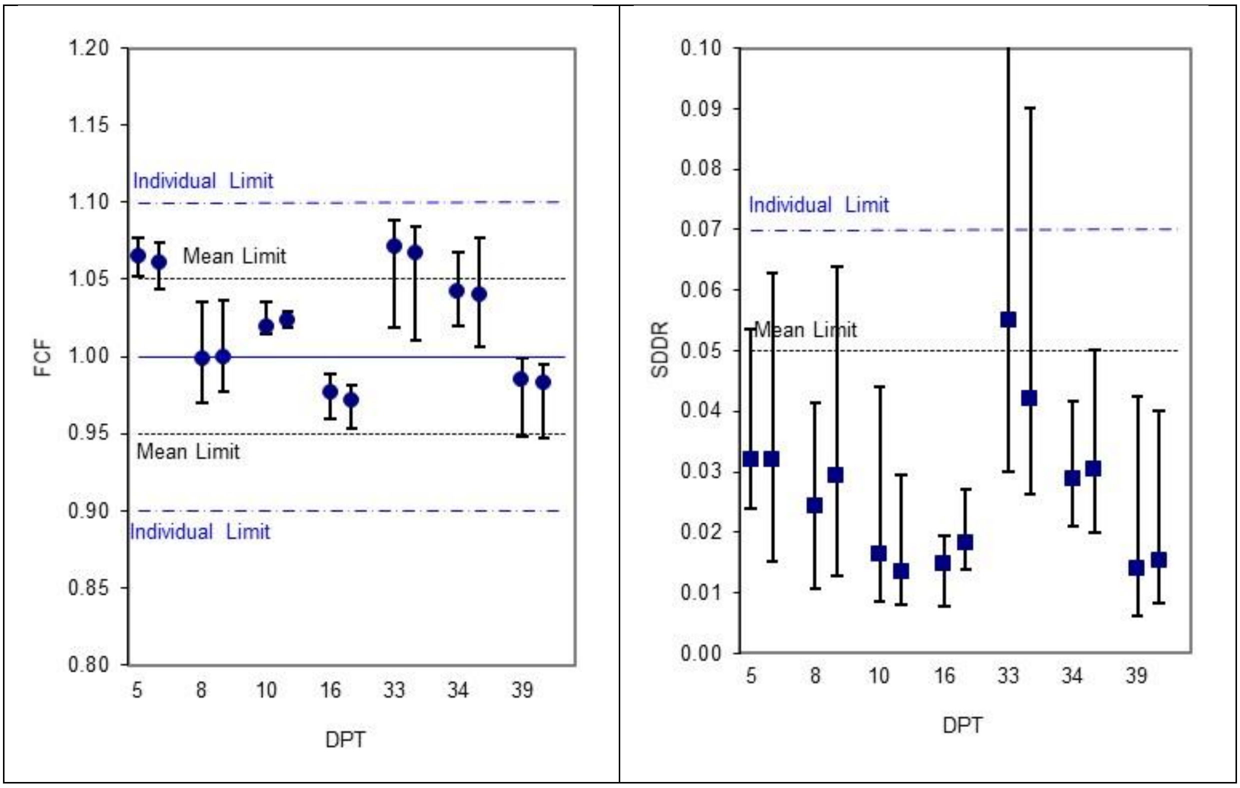

Figure 6.1: FCF and SDDR results from the contingency day

From this data it can be seen that both Machines 5 and 33 exceed the mean FCF crtieria and Machine 33 also exceeds the mean and individual SDDR criteira. It is possible that the selected reference machines have produced a reference which would be different if the entire fleet was present and therefore slightly alter the FCF values. To investigate this ratio of the FCFs calculated for the reference machines between the two days was compared and this was used to estimate the FCF values for Machines 5 and 33 if they operated in this condition with the whole fleet. This analysis found that the FCF values reduced slightly but still remained outside of the criteria.

7 Summary of trial findings

The 2018 UK DPT accreditation trial was held at Horiba-MIRA between the 25th and 27th September 2018. Twenty-five machines took part in the trial.

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

(i) Repeatability of Deflections

- Twenty-four of the twenty-five machines met the trial requirements for the Repeatability assessment.

(ii) Reproducibility of Deflections

- Twenty-three of the twenty-five machines met the trial requirements for the mean Field Calibration Factor (FCF).
- All twenty-five machines met the trial requirements for the individual geophone Field Calibration Factors (FCF).
- Twenty-two of the twenty-five machines met the trial requirements for the mean Standard Deviation of the Deviation Ratio (SDDR).
- Twenty-two of the twenty-five machines met the trial requirements for the individual Standard Deviation of the Deviation Ratio (SDDR).

(iii) Distance measurement

- All twenty-five machines met the trial requirements for distance assessment.

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

(iv) OSGR Co-ordinates

- Eleven machines provided 3-dimensional position data in lat/long/height format. After conversion of the data into OSGR format (by TRL), six machines were identified as having achieved a High performance level, three a medium performance level and two a Low performance level. The contractors' coordinate transformation to OSGR format was not assessed.

(v) Temperature measurement at depth (100mm)

- Twenty four of the twenty five machines provided a full set of temperature measurements of the 100mm pavement temperature. Thirteen machines achieved a High performance level, three a Medium, six a Low and two not suitable.

(vi) Surface temperature measurement

- Eleven machines provided surface temperature measurements. The assessment of this data was not carried out due to problems establishing a reference dataset.

(vii) Air temperature measurement

- Fifteen machines provided air temperature measurements. Using the surface temperature criteria (and assessing against the fleet mean), twelve machines achieved a High performance level, one a Medium, and two a Low.

In summary, twenty-one of the twenty-five machines that participated in the 2018 accreditation trial fully met the mandatory requirements of the trial.

The outcome of the trial for each machine, against both the mandatory and non-mandatory criteria, is summarised in Appendix G.

The surface temperature assessment was undertaken using thermocouples set up in the path adjacent to the test lane (to avoid damage from the test vehicles) and periodic measurements using a handheld IRT. Both of these datasets were significantly different from the values collected by the sensors fitted to the DPT devices. In addition there was a wide scatter of the results from the sensors fitted to the DPT devices. It is therefore recommended that additional details on the set-up and configuration of these devices is obtained and additional investigation into these devices is undertaken (both by the survey contractors and the auditor) between now and the next trial. In addition consideration should be given to improving the reference data collected (for both the surface and air temperature measurements) at the next trial.

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Acknowledgements

The author wishes to thank the operators of the DPT devices for their co-operation in the accreditation process. The author is also grateful to Brian Ferne who carried out the technical review of this report, and to Francesca Danelon, Darius Singfield, Chris Torkington and Patrick Werro for their assistance with the trial.

Appendix A Machine details table

ID	Owner	Make, model and serial number	Trailer or vehicle mounted?	No of weights / buffers per side	Plate type	Date of last tower calibration	Date of last dynamic calibration	Date of last manufacturer calibration
2	AECOM Ltd.	Dynatest FWD 8002 SN 102	Trailer	6/3	Solid plate	16/08/2018	24/09/2018	09/2018
5	AECOM Ltd.	Dynatest HWD 8082 SN 050	Trailer	4/5	2-way segmented	31/05/2018	24/09/2018	05/09/2018
6	PMS Ltd.	Dynatest HWD 8082 SN 018	Trailer	0/5	Solid plate	06/2018	08/2018	09/2018
8	AECOM Ltd.	Dynatest FWD 8002 SN 028	Trailer	6/3	2-way segmented	16/08/2018	24/09/2018	22/08/2018
10	AECOM Ltd.	Dynatest FWD 8002 SN 192	Trailer	6/3	2-way segmented	15/08/2018	24/09/2018	23/09/2018
13	AECOM Ltd.	Dynatest HWD 8082 SN 029	Trailer	4/5	Solid plate	23/05/2018	24/09/2018	08/2018
15	CET Infrastructure	Dynatest FWD 8002 SN 203	Trailer	6/3	2-way segmented	06/2018	06/2018	06/2018
16	PTS	Dynatest FWD 8002 SN 214	Trailer	5/2	2-way segmented	10/09/2018	17/09/2018	03/08/2018
28	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 271	Trailer	4/2	Solid plate	14/05/2018	18/09/2018	22/06/2018
30	PMS Ltd.	Dynatest FWD 8002 SN 173	Trailer	5/2	Solid plate	26/06/2018	14/08/2018	13/03/2018

ID	Owner	Make, model and serial number	Trailer or vehicle mounted?	No of weights / buffers per side	Plate type	Date of last tower calibration	Date of last dynamic calibration	Date of last manufacturer calibration
32	PTS	Dynatest HWD 8082 SN 069	Trailer	0/4	Solid plate	12/09/2018	16/09/2018	18/07/2018
33	PTS	Dynatest HWD 8082 SN 070	Trailer	0/4	Solid plate	11/09/2018	18/09/2018	08/08/2018
34	PTS	Dynatest HWD 8082 SN 108	Trailer	0/2	2-way segmented	10/09/2018	17/09/2018	30/04/2018
36	Testconsult Ltd.	Grontmij PRI 2500 0608-303	Trailer	3/4	4-way segmented	05/2018	24/09/2018	16/07/2018
37	Stanger Testing Services	Dynatest FWD 8002 SN 352	Trailer	6/3	4-way segmented	01/09/2018	01/09/2018	07/08/2018
38	Milestone Pavement Technologies	Grontmij PRI 1500 1111-448	Trailer	3/4	4-way segmented	13/09/2018	13/09/2018	13/09/2018
39	TRL	Dynatest FWD 8002 SN 388	Trailer	6/3	2-way segmented	07/08/2018	17/09/2018	06/07/2018
40	Dynatest	Dynatest FFWD 8012 SN 002	Trailer	4/2	4-way segmented	08/08/2018	08/08/2018	08/08/2018
41	ALC (MoD)	Dynatest HWD 8082 SN 145	Trailer	0/4	4-way segmented	12/12/2017	12/12/2017	12/12/2017
45	Atlas Geophysical	Grontmij Carlbro PRI2100 0903-088	Trailer	6/6	Solid plate	17/09/2018	17/09/2018	17/09/2018
46	PaveTesting	PaveTesting FWD150 107PT0218	Trailer	18/4	4-way segmented	14/09/2018	14/09/2018	14/09/2018

ID	Owner	Make, model and serial number	Trailer or vehicle mounted?	No of weights / buffers per side	Plate type	Date of last tower calibration	Date of last dynamic calibration	Date of last manufacturer calibration
47	PMS Ltd.	Dynatest FWD 8002 SN 452	Trailer	4/2	4-way segmented	06/2018	06/2018	09/2018
48	Balfour Beatty	Dynatest FWD 8002 SN 424	Trailer	4/2	Not provided	Not provided	Not provided	11/12/2017
49	Dynatest	Dynatest FWD 8082 SN 146	Trailer	0/4	4-way segmented	30/08/2018	12/09/2018	17/04/2018
50	SOCOTEC	RINCENT HeavyDyn HVY-101A	Trailer	10/4	Solid	20/07/2018	03/09/2018	17/08/2018

Appendix B Example photographs

Figure B.1: Dynatest 8002 FWD

Figure B.2: Dynatest 8082 FWD

Figure B.3: Grontmij Primax 2100 HWD

Figure B.4: Grontmij Primax 1500 HWD

Appendix C Construction details for Highways England reference site at Horiba-MIRA proving ground

Table C.1: Design construction of Highways England reference site

Section	Test points	Nominal construction details and material type (mm)				
		Surface course	Binder course	Base	Total asphalt thickness [mm]	Sub-base
1	1-3	30 TSC	235 EME2		270	200mm C8/10 HBM
2	4-6	35 TSC	170 DBM		200	250mm 6F1 granular capping material
3	7-9	30 TSC	170 EME2		200	200 Type 1 granular material
4	10-12	35 TSC	35 Axo	230 JRC	70	150-175 Hoggin
Notes	TSC = Cl 942 Thin Surface Course EME2 = Enrobé à Module Élevé, DBM = Dense Bitumen Macadam, Axo = Axoshield, HBM = Hydraulically Bound Material, JRC = Jointed reinforced concrete, 6F1 = Selected granular capping.					

Table C.2: Construction details of Highways England reference site from cores

Section	Test points	Post Construction Results from cores (mm)			
		Surface course	Binder/ Binder+ base courses	Total asphalt thickness [mm]	Base/Sub-base (mm)
1	1-3	42 TSC	228	270	217 (HBM sub-base)
2	4-6	37 TSC	158	192	-
3	7-9	35 TSC	191	226	-
4	10-12	30 TSC	36 Axo	66	194 (JRC base)
Notes	TSC = Cl 942 Thin Surface Course , HBM = Hydraulically Bound Material, JRC = Jointed reinforced concrete, Axo= Axoshield				

Table C.3: Construction details of Highways England reference site from GPR

Section	Test points	Post Construction layer information results from GPR (in mm)			
		Minimum	Average	Maximum	Material
1	1-3	192	242	272	Asphalt
		166	188	215	HBM
		388	431	468	Total bound thickness
2	4-6	167	192	240	Asphalt
3	7-9	167	199	240	Asphalt
4	10-12	47	65	76	These results are for the bitumen-bound surfacing. No lower GPR trace due to steel reinforcement.
Notes	HBM = Hydraulically Bound Material				

Appendix D Repeatability trial data

Data is highlighted in bold red text if it does not meet the criteria (for a valid test or for the assessment). Laps not used in the assessment are shown in italics and grey text (apart from the data points which exceed the criteria).

D.1 Machine 2

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	697.9	0.2%	79	65	57	49	43	36	25	1.0	1.2	0.9	0.3	0.3	0.4	0.7
	5	676.1	0.1%	521	410	260	154	91	53	33	1.5	0.8	0.5	0.5	0.5	0.1	0.3
	8	681.7	0.3%	243	213	174	130	96	69	37	**4.8**	0.6	1.3	0.6	0.5	0.7	0.9
	13	689.6	0.1%	131	114	98	82	69	55	33	0.5	0.2	0.1	1.0	1.0	0.9	0.5
2	*2*	*697.6*	*0.1%*	*78*	*63*	*56*	*50*	*42*	*34*	*24*	*0.5*	*1.6*	*1.4*	*1.1*	*0.7*	*1.1*	*0.8*
	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	2	695.7	0.4%	81	66	58	51	45	36	25	1.0	0.5	0.8	0.7	0.8	0.7	0.5
	5	674.1	0.1%	556	435	270	153	86	49	35	0.9	1.0	1.0	0.5	0.9	1.2	0.7
	8	684.3	0.2%	265	227	184	137	99	69	35	1.7	0.8	1.1	0.5	0.7	0.7	0.6
	13	693.8	0.2%	122	113	99	82	68	55	30	0.6	0.2	0.4	0.3	0.4	0.3	0.6

D.2 Machine 5

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	*2*	*733.8*	*0.2%*	*69*	*57*	*52*	*45*	*38*	*31*	*18*	*0.7*	*0.1*	*0.6*	*0.5*	*0.3*	*0.1*	*0.7*
	5	*725.6*	*0.3%*	*492*	*388*	*252*	*149*	*89*	*54*	*34*	*0.7*	*0.9*	*0.6*	*0.5*	*0.4*	*0.6*	*0.4*
	8	*727.9*	*0.3%*	*221*	*195*	*158*	*120*	*88*	*63*	*31*	*0.8*	*0.3*	*0.4*	*0.6*	*0.4*	*0.2*	*0.4*
	13	*720.2*	*0.3%*	*115*	*104*	*90*	*75*	*61*	*48*	*28*	*1.0*	*0.4*	*0.5*	*0.4*	*0.3*	*0.6*	*1.0*
2	*2*	*713.8*	*0.1%*	*70*	*58*	*52*	*45*	*39*	*32*	*21*	*0.3*	*0.9*	*0.5*	*0.4*	*0.1*	*0.7*	*0.4*
	5	*712.2*	*0.2%*	*495*	*392*	*251*	*151*	*87*	*54*	*34*	*2.2*	*1.9*	*0.7*	*0.7*	*0.3*	*0.1*	*1.0*
	8	*716.1*	*0.2%*	*226*	*201*	*163*	*123*	*90*	*65*	*33*	*1.3*	*0.9*	*0.8*	*0.7*	*0.5*	*0.8*	*0.4*
	13	*706.1*	*0.4%*	*118*	*104*	*92*	*74*	*61*	*49*	*32*	*0.7*	*0.9*	*0.4*	*0.6*	*0.2*	*0.2*	*0.1*
3	*2*	*727.6*	*0.2%*	*76*	*59*	*53*	*46*	*40*	*33*	*21*	*0.5*	*0.3*	*0.3*	*0.4*	*0.1*	*0.1*	*0.2*
	5	*720.7*	*0.1%*	*536*	*429*	*267*	*154*	*89*	*54*	*34*	*1.0*	*0.5*	*0.3*	*0.3*	*0.4*	*0.2*	*0.7*
	8	*724.5*	*0.3%*	*243*	*214*	*170*	*127*	*92*	*64*	*34*	*1.4*	*0.6*	*0.4*	*0.7*	*0.4*	*0.3*	*0.2*
	13	*707.8*	*0.2%*	*117*	*108*	*93*	*78*	*65*	*52*	*29*	*0.3*	*0.3*	*0.5*	*0.4*	*0.5*	*0.4*	*0.8*
4	*2*	*720.1*	*0.5%*	*73*	*60*	*53*	*46*	*39*	*32*	*19*	*1.2*	*0.1*	*0.2*	*0.2*	*0.1*	*0.2*	*0.7*
	5	*712.6*	*0.3%*	*545*	*426*	*267*	*152*	*87*	*53*	*36*	*1.2*	*1.2*	*0.9*	*1.1*	*0.7*	*0.5*	*0.2*
	8	*720.9*	*0.2%*	*246*	*212*	*170*	*126*	*93*	*65*	*33*	*0.4*	*1.0*	*0.4*	*0.7*	*0.2*	*0.2*	*0.2*
	13	*710.9*	*0.2%*	*121*	*109*	*95*	*79*	*65*	*51*	*32*	*0.2*	*0.3*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*
5	2	738.7	0.3%	67	57	51	45	38	32	22	**2.2**	0.4	0.1	0.4	0.4	0.1	0.5
	5	730.6	0.3%	453	379	247	151	91	57	34	1.4	0.6	0.4	0.3	0.4	0.3	0.9
	8	734.6	0.5%	226	200	162	122	91	65	32	0.6	0.6	0.4	0.5	0.7	0.5	0.8
	13	727.0	0.2%	117	105	91	76	62	49	31	0.5	0.6	0.4	0.4	0.1	0.3	0.5
6	2	746.6	0.4%	69	57	51	45	39	32	23	0.3	0.2	0.3	0.4	0.3	0.1	0.4
	5	736.9	0.3%	466	372	242	147	89	54	33	1.5	0.4	0.6	0.5	0.4	0.2	0.4
	8	727.4	0.4%	227	197	160	119	89	64	33	0.7	0.6	0.6	0.4	0.7	0.5	0.5
	13	726.7	0.2%	116	104	90	75	62	48	29	0.4	0.3	0.4	0.3	0.4	0.4	0.5

D.3 Machine 6

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	690.6	0.7%	64	50	45	40	34	30	20	0.3	0.4	0.3	0.2	0.5	0.2	0.5
	5	653.7	0.6%	467	363	237	144	85	55	34	2.0	1.8	1.0	0.7	0.5	0.5	0.5
	8	671.0	0.5%	204	177	146	112	82	60	31	1.0	0.9	0.7	0.6	0.6	0.5	0.8
	13	732.7	0.4%	93	84	74	61	50	41	24	0.9	0.3	0.2	0.1	0.2	0.3	0.2
2	2	684.6	0.6%	62	50	46	40	34	29	20	0.3	0.5	0.2	0.5	0.6	0.7	0.4
	5	647.4	0.3%	471	364	234	144	86	56	33	1.8	1.2	0.8	0.6	0.6	0.5	0.7
	8	656.7	0.5%	209	182	148	113	83	61	31	1.3	0.6	0.8	0.5	0.4	0.8	0.5
	13	727.3	0.4%	100	88	76	62	48	41	24	0.5	0.5	0.5	0.3	0.3	0.8	0.7

D.4 Machine 8

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	736.1	0.3%	77	63	56	49	42	35	24	0.6	0.3	0.3	1.0	0.3	0.1	0.3
	5	713.3	0.2%	526	401	251	149	84	49	28	1.4	0.9	0.7	0.9	0.2	0.4	0.5
	8	727.9	0.5%	240	210	169	128	94	66	33	1.0	0.7	0.8	0.6	0.8	0.5	0.4
	13	734.2	0.3%	125	114	98	83	68	54	32	0.6	0.5	0.3	0.3	0.3	0.4	0.3
2	2	739.2	0.3%	76	62	56	49	42	35	24	0.4	0.3	0.2	0.3	0.1	0.1	0.1
	5	717.5	0.4%	516	403	252	150	85	50	27	2.2	1.5	1.2	0.8	0.5	0.5	0.3
	8	729.0	0.5%	244	213	171	130	94	67	33	1.0	0.6	0.6	0.7	0.3	0.5	0.3
	13	739.0	0.2%	125	114	99	82	66	53	34	0.5	0.4	0.2	0.5	0.4	0.1	0.4

D.5 Machine 10

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	707.4	0.3%	73	61	54	47	41	34	23	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	5	683.9	0.2%	515	396	252	149	87	53	32	0.5	0.6	0.3	0.3	0.2	0.2	0.2
	8	697.5	0.3%	232	204	165	126	92	66	34	0.3	0.2	0.2	0.2	0.2	0.1	0.3
	13	702.0	0.3%	119	109	95	80	65	52	31	1.3	0.2	0.1	0.3	0.3	0.1	0.6
2	2	706.4	0.2%	69	60	54	47	40	33	23	0.2	0.1	0.1	0.1	0.1	0.2	0.1
	5	683.2	0.2%	510	387	251	147	84	52	26	0.7	0.4	0.3	0.2	0.4	0.1	0.6
	8	695.1	0.3%	237	210	168	129	94	66	34	0.8	0.1	0.1	0.1	0.1	0.1	0.1
	13	699.9	0.3%	122	110	96	81	66	53	34	0.2	0.1	0.2	0.1	0.2	0.1	0.1

D.6 Machine 13

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	703.2	0.4%	80	63	56	50	42	34	24	0.6	0.5	0.5	0.4	0.4	0.6	0.6
	5	697.6	0.5%	523	417	264	159	91	57	33	1.2	0.9	0.7	0.8	0.7	0.5	0.6
	8	697.7	0.4%	244	213	173	133	96	69	36	1.1	1.0	0.9	0.4	0.8	0.5	0.5
	13	684.8	0.7%	128	114	100	83	67	54	33	0.7	1.0	0.6	0.6	0.5	0.3	0.6
2	2	695.7	0.3%	78	64	57	50	43	35	25	0.7	0.3	0.5	0.6	0.6	0.3	0.5
	5	694.4	0.2%	521	412	262	158	92	56	35	1.8	1.6	1.2	1.1	0.7	0.4	0.7
	8	689.7	0.3%	245	213	173	133	94	69	36	0.5	0.6	0.4	0.5	0.8	0.7	0.7
	13	695.1	0.5%	134	122	106	87	72	57	41	1.0	0.5	0.5	0.7	0.8	0.4	0.8

D.7 Machine 15

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	*2*	*736.7*	*1.0%*	*82*	*66*	*60*	*53*	*45*	*38*	*26*	*1.0*	*0.9*	*0.8*	*0.6*	*0.5*	*0.5*	*0.4*
	5	*722.7*	*1.0%*	*517*	*413*	*267*	*160*	*88*	*52*	*30*	*4.7*	*3.9*	*2.6*	*1.5*	*0.8*	*0.5*	*0.3*
	8	*733.8*	*0.9%*	*255*	*223*	*182*	*138*	*100*	*71*	*36*	*2.0*	*1.9*	*1.6*	*1.1*	*0.8*	*0.7*	*0.4*
	13	*738.0*	*0.8%*	*132*	*120*	*104*	*87*	*72*	*53*	*30*	*1.1*	*1.1*	*1.0*	*0.6*	*0.8*	*0.5*	*0.6*
2	*2*	*749.2*	*1.1%*	*78*	*66*	*60*	*53*	*44*	*38*	*25*	*0.9*	*0.8*	*0.7*	*0.8*	*0.6*	*0.9*	*1.0*
	5	*733.7*	*0.8%*	*522*	*416*	*265*	*159*	*88*	*52*	*30*	*3.8*	*3.0*	*2.0*	*1.1*	*0.6*	*0.4*	*0.5*
	8	*738.4*	*1.0%*	*254*	*221*	*179*	*136*	*98*	*70*	*35*	*2.3*	*2.2*	*1.6*	*1.1*	*1.0*	*0.8*	*0.2*
	13	*746.1*	*0.9%*	*133*	*119*	*103*	*86*	*69*	*56*	*36*	*1.3*	*1.1*	*0.9*	*0.7*	*1.0*	*0.8*	*0.4*
3	2	750.5	0.9%	85	67	60	52	45	38	25	0.8	0.6	0.5	0.5	0.5	1.1	0.9
	5	725.9	0.9%	561	437	273	156	82	48	30	**5.3**	**5.0**	2.7	1.4	0.9	0.6	0.2
	8	733.5	0.6%	275	239	191	142	100	71	34	1.8	1.6	1.4	0.9	1.2	1.3	0.4
	13	739.7	0.7%	131	119	106	85	69	51	33	0.9	1.1	1.4	0.5	0.6	1.1	0.3
4	2	741.8	1.2%	85	67	60	53	45	38	25	1.0	0.8	0.7	0.6	0.5	0.5	0.4
	5	723.8	0.7%	552	426	268	154	84	48	30	4.5	3.4	2.1	1.3	0.9	0.5	0.4
	8	737.3	0.8%	272	236	188	140	99	69	34	2.0	1.7	1.3	1.0	0.8	0.6	0.4
	13	744.7	0.7%	131	117	101	84	68	54	31	0.9	0.8	0.6	0.5	0.4	0.7	0.7

D.8 Machine 16

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	720.1	0.3%	75	62	56	49	44	34	24	0.3	0.2	0.4	0.3	0.4	0.6	0.5
	5	700.9	0.3%	510	409	258	155	89	55	33	0.8	1.0	0.7	0.5	0.5	0.2	0.1
	8	710.6	0.2%	237	209	169	129	95	68	35	0.6	0.5	0.5	0.4	0.4	0.1	0.1
	13	709.2	0.1%	120	112	98	83	67	54	32	0.2	0.4	0.5	0.5	0.5	0.3	0.4
2	2	716.9	0.2%	77	64	58	49	43	36	25	0.1	0.4	0.4	0.5	0.1	0.5	0.3
	5	696.5	0.2%	528	402	259	151	89	55	32	0.7	0.7	0.4	0.5	0.2	0.5	0.5
	8	706.2	0.2%	244	215	175	132	96	68	35	0.8	0.3	0.5	0.5	0.3	0.3	0.4
	13	707.3	0.2%	128	114	101	84	70	55	36	1.0	0.5	0.5	0.5	0.4	0.5	0.7

D.9 Machine 28

Lap	Station	Load		Mean of the normalised deflection(μm)							Standard deviation of the normalised deflections (μm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	707.7	0.1%	73	63	55	48	43	35	24	0.5	0.3	0.6	0.4	0.5	0.3	0.0
	5	687.4	0.1%	517	416	257	153	88	55	31	0.6	1.0	0.4	0.3	0.8	0.5	0.5
	8	700.2	0.1%	237	210	168	128	94	67	34	0.5	0.4	0.4	0.5	0.4	0.3	0.4
	13	701.1	0.2%	121	109	99	81	67	53	31	0.3	0.6	0.8	0.3	0.4	0.7	0.4
2	2	715.3	0.1%	72	63	54	48	42	35	23	0.1	0.5	0.5	0.3	0.3	0.0	0.5
	5	697.2	0.1%	517	405	260	153	90	53	31	1.1	1.0	1.0	0.4	0.5	0.5	0.4
	8	707.4	0.2%	240	215	169	129	95	67	34	0.4	0.8	0.9	0.3	0.8	0.9	0.5
	13	707.4	0.2%	122	107	93	83	68	51	34	0.5	0.4	0.4	0.5	0.4	0.4	0.3

D.10 Machine 30

Lap	Station	Load		Mean of the normalised deflection(μm)							Standard deviation of the normalised deflections (μm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	665.7	0.3%	73	58	53	46	40	34	23	0.2	0.1	0.3	0.1	0.3	0.2	0.3
	5	640.7	0.2%	480	384	251	149	89	53	36	2.2	1.4	1.0	0.3	0.8	0.3	0.9
	8	654.5	0.2%	222	193	159	123	88	63	38	0.6	0.6	0.3	0.3	0.6	0.7	1.5
	13	677.0	0.4%	109	105	85	75	61	48	29	0.5	0.5	0.6	0.4	0.3	0.3	0.5
2	2	665.1	0.3%	70	59	52	46	39	33	22	0.2	0.3	0.1	0.2	0.6	0.1	0.3
	5	640.2	0.3%	485	380	243	144	87	53	35	1.3	1.1	0.8	0.8	0.3	0.3	0.7
	8	654.4	0.3%	227	198	160	124	91	65	34	0.4	0.4	0.2	0.3	0.3	0.2	0.3
	13	677.7	0.3%	112	102	88	74	61	49	28	0.4	0.2	0.2	0.2	0.2	0.1	0.7

D.11 Machine 32

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	687.4	0.7%	71	58	52	45	38	32	22	0.3	0.3	0.2	0.5	0.2	0.1	0.2
	5	692.6	0.3%	497	387	251	148	88	57	37	1.1	1.2	1.6	2.0	0.3	0.3	0.4
	8	681.1	0.2%	222	196	159	119	87	64	34	0.2	0.3	0.3	0.4	0.2	0.3	0.3
	13	692.4	0.2%	113	102	90	74	60	48	28	0.4	0.1	0.2	0.6	0.1	0.2	0.7
2	2	694.6	0.4%	72	57	52	45	38	32	22	0.2	0.5	0.3	0.4	0.2	0.3	0.3
	5	694.3	0.2%	486	379	249	147	87	58	39	1.5	1.0	1.0	1.9	0.4	0.7	0.4
	8	681.2	0.3%	227	198	162	122	89	64	35	0.6	0.3	0.3	0.5	0.8	0.3	0.4
	13	691.4	0.3%	118	103	88	72	57	46	28	0.5	0.3	0.2	0.9	0.7	0.4	1.1

D.12 Machine 33

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	744.8	0.4%	70	57	51	44	38	31	21	0.8	0.4	0.3	0.2	0.4	0.6	0.4
	5	718.0	1.0%	490	404	256	155	92	62	38	0.6	0.8	0.5	0.5	0.4	0.3	0.3
	8	730.2	0.2%	223	197	160	121	90	63	34	0.7	0.5	0.6	0.5	0.3	0.4	0.5
	13	731.8	0.2%	110	101	88	73	58	46	29	0.4	0.3	0.3	0.2	0.4	0.5	0.3
2	2	732.2	0.3%	70	57	52	45	38	32	22	0.6	0.5	0.3	0.1	0.1	0.4	0.4
	5	719.6	0.5%	498	393	252	152	92	60	41	0.8	0.5	0.5	0.6	0.6	0.8	0.2
	8	730.8	0.2%	223	198	161	123	90	64	34	0.6	0.4	0.4	0.3	0.5	0.2	0.5
	13	739.6	0.2%	114	104	89	73	58	44	27	0.7	0.4	0.3	0.1	0.5	0.1	0.3
3	2	746.0	0.3%	71	58	52	45	38	32	21	**2.0**	0.2	0.1	0.2	0.4	0.3	0.1
	5	738.1	0.2%	542	418	261	150	84	56	40	1.3	0.5	0.3	0.4	0.4	0.2	0.3
	8	738.2	0.4%	237	208	168	125	90	63	33	0.6	0.1	0.1	0.1	0.1	0.1	0.3
	13	731.1	0.1%	117	104	90	75	60	48	30	0.6	0.1	0.1	0.2	0.2	0.1	0.1
4	2	739.5	0.3%	72	57	52	45	38	31	22	1.0	0.1	0.1	0.1	0.2	0.2	0.1
	5	736.9	0.2%	529	411	257	149	86	55	37	1.3	0.7	0.4	0.2	0.2	0.1	0.2
	8	734.7	0.2%	237	208	167	124	90	63	33	**3.3**	0.1	0.2	0.3	0.2	0.2	0.3
	13	731.1	0.3%	113	102	88	73	59	46	29	0.6	0.1	0.1	0.1	0.2	0.1	0.1
5	2	703.9	0.5%	64	56	50	44	39	31	20	0.4	0.3	0.3	0.4	0.5	0.2	0.4
	5	698.5	0.7%	459	376	243	149	90	58	37	0.8	0.4	0.2	0.6	0.2	0.4	0.2
	8	704.8	0.2%	222	196	158	120	88	63	33	0.6	0.1	0.2	0.2	0.1	0.2	0.4
	13	714.7	0.1%	111	101	89	74	60	47	30	0.5	0.2	0.3	0.1	0.3	0.1	0.4
6	2	708.0	0.4%	65	56	50	44	38	31	21	0.9	0.3	0.1	0.1	0.2	0.1	0.1
	5	701.2	0.1%	461	374	243	148	89	60	36	0.7	0.7	0.4	0.2	0.1	0.5	0.3
	8	698.9	0.1%	220	197	160	121	89	63	33	0.8	0.2	0.1	0.1	0.1	0.2	0.2
	13	690.6	0.3%	109	101	88	74	60	48	29	0.3	0.2	0.2	0.2	0.8	0.9	0.8

D.13 Machine 34

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	671.5	0.1%	69	58	52	47	39	33	23	0.3	0.2	0.1	0.2	0.1	0.2	0.4
	5	661.2	0.1%	490	397	256	153	90	56	31	1.4	0.6	0.3	0.3	0.2	0.2	0.3
	8	656.0	0.5%	228	199	164	124	91	66	32	0.4	0.3	0.2	0.3	0.2	0.3	0.3
	13	642.8	0.2%	120	104	94	77	64	51	28	0.8	0.5	0.2	0.5	0.2	0.3	0.8
2	2	714.2	0.2%	71	59	53	46	40	34	21	0.2	0.3	0.2	0.2	0.2	0.2	0.5
	5	712.1	0.2%	484	391	254	152	90	56	32	0.4	0.3	0.1	0.1	0.1	0.2	0.2
	8	709.6	0.1%	230	202	166	126	92	67	32	0.8	0.4	0.3	0.3	0.2	0.4	0.2
	13	694.7	0.1%	124	109	97	79	67	53	33	0.2	0.4	0.3	0.5	0.2	0.2	0.2

D.14 Machine 36

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	706.4	0.9%	81	64	59	51	44	37	26	0.2	0.2	0.2	0.3	0.2	0.1	0.2
	5	711.5	0.6%	481	407	260	149	80	48	30	1.0	0.7	0.6	0.4	0.2	0.3	0.2
	8	708.9	0.8%	268	221	182	135	96	68	35	1.2	0.5	0.3	0.7	0.3	0.1	0.1
	13	703.3	1.0%	144	112	100	84	67	54	33	0.6	0.2	0.2	0.6	0.4	0.3	0.2
2	2	706.6	1.0%	81	65	59	51	44	37	26	0.6	0.1	0.1	0.4	0.1	0.1	0.1
	5	704.3	0.9%	483	412	262	147	81	48	31	1.2	1.1	0.7	2.5	0.3	0.2	0.3
	8	701.3	1.2%	258	220	181	134	95	68	35	0.6	0.5	0.3	0.6	0.4	0.2	0.2
	13	709.4	0.9%	142	110	97	81	66	52	32	1.3	0.6	0.5	0.7	0.6	0.4	0.6

D.15 Machine 37

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	747.6	0.3%	69	57	52	46	39	32	21	0.3	0.7	0.3	0.4	0.1	0.2	0.1
	5	715.8	0.2%	514	406	257	156	89	57	34	1.1	0.5	0.2	0.2	0.2	0.4	0.2
	8	731.0	0.2%	227	200	162	125	90	64	34	1.5	0.4	0.4	0.6	0.6	0.2	0.4
	13	742.5	0.2%	115	104	90	75	59	47	28	0.3	0.3	0.3	0.2	0.2	0.2	0.2
2	2	746.1	0.3%	69	58	52	46	39	33	22	0.4	0.1	0.2	0.2	0.2	0.2	0.2
	5	714.3	0.2%	519	388	249	153	88	57	35	0.8	0.4	0.2	0.3	0.4	0.6	0.2
	8	731.2	0.1%	230	203	164	126	90	65	34	0.8	1.1	0.2	0.3	0.2	0.4	0.1
	13	746.0	0.2%	118	105	90	74	58	45	27	0.2	0.3	0.2	0.1	0.3	0.1	0.1

D.16 Machine 38

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	724.7	0.8%	68	58	52	48	41	36	22	0.3	0.2	0.3	0.3	0.3	0.2	0.3
	5	712.4	1.0%	511	385	252	155	92	59	32	1.4	1.2	1.1	0.7	0.6	0.6	0.9
	8	717.3	0.7%	223	197	162	126	93	68	33	0.9	0.8	0.7	0.5	0.5	0.4	0.5
	13	698.7	0.4%	119	108	94	80	66	54	31	0.4	0.4	0.3	0.3	0.4	0.2	0.2
2	2	723.6	0.9%	66	58	52	48	41	36	22	2.9	0.3	0.2	0.2	0.4	0.2	0.3
	5	713.4	0.8%	512	390	254	156	93	59	32	5.6	2.0	1.3	0.9	0.6	0.4	0.8
	8	713.4	1.2%	226	200	164	127	94	69	33	1.0	0.8	0.7	0.6	0.6	0.4	0.4
	13	686.4	1.0%	128	116	100	87	71	60	39	0.7	0.7	0.6	0.5	0.5	0.3	0.3

D.17 Machine 39

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	701.5	0.2%	73	64	52	49	42	35	24	2.2	0.3	0.8	0.4	0.5	0.3	0.3
	5	681.8	0.4%	507	404	259	158	90	55	37	1.0	2.4	0.8	1.1	1.0	0.4	1.2
	8	683.9	0.2%	241	207	167	129	94	68	37	1.7	0.3	0.4	0.4	0.4	0.3	0.9
	13	702.7	0.2%	129	114	94	82	69	54	33	0.7	0.2	1.0	0.9	0.8	0.6	1.5
2	2	705.4	0.1%	79	62	56	50	42	35	24	0.8	0.4	0.3	1.5	0.4	0.2	1.0
	5	680.3	0.3%	517	412	261	158	90	55	34	1.4	0.5	0.4	0.2	0.6	0.9	1.5
	8	694.6	0.2%	245	212	171	131	95	68	36	0.7	0.5	0.3	0.7	0.6	0.1	0.6
	13	702.3	0.2%	127	111	94	80	64	52	32	1.2	0.7	0.9	0.7	0.9	0.8	0.8

D.18 Machine 40

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	710.0	0.2%	73	60	55	49	41	34	23	0.2	0.3	0.5	0.8	0.4	0.3	0.3
	5	702.1	0.1%	507	398	254	149	85	52	33	0.6	0.5	0.3	0.4	0.3	0.2	0.1
	8	705.4	0.3%	235	207	167	126	92	65	33	0.4	0.2	0.2	0.1	0.2	0.2	0.2
	13	704.1	0.4%	122	109	94	79	63	50	30	0.3	0.4	0.4	0.5	0.4	0.6	0.6
2	2	711.1	0.3%	72	60	54	47	40	33	23	0.2	0.6	0.2	0.4	0.2	0.2	0.2
	5	701.2	0.2%	503	392	253	150	86	52	32	1.0	0.8	0.3	0.2	0.4	0.3	0.1
	8	706.9	0.2%	235	207	167	127	92	65	33	0.3	0.2	0.2	0.3	0.2	0.2	0.2
	13	706.7	0.3%	122	109	94	78	62	49	32	0.2	0.2	0.4	0.2	0.4	0.3	0.2

D.19 Machine 41

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	724.6	0.1%	72	59	53	46	40	33	22	0.2	0.1	0.1	0.1	0.1	0.1	0.2
	5	718.0	0.1%	514	380	242	144	86	52	33	0.4	0.2	0.2	0.4	0.3	0.2	0.5
	8	722.0	0.2%	230	202	163	124	91	65	33	0.3	0.2	0.3	0.2	0.2	0.2	0.3
	13	728.8	0.3%	118	105	92	77	63	50	32	0.2	0.1	0.1	0.4	0.3	0.4	0.2
2	2	730.2	0.1%	72	59	53	46	39	34	22	0.2	0.2	0.1	0.2	0.1	0.3	0.2
	5	718.7	0.3%	497	403	253	150	88	57	35	0.7	0.3	0.2	0.2	0.2	0.4	0.3
	8	729.0	0.1%	232	203	164	124	91	66	34	0.2	0.2	0.1	0.1	0.1	0.2	0.3
	13	729.6	0.1%	126	114	97	81	66	53	35	0.2	0.2	0.2	0.2	0.2	0.1	0.3

D.20 Machine 45

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	*2*	*703.5*	*0.2%*	*68*	*57*	*51*	*45*	*39*	*33*	*23*	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*	*0.1*	*0.5*
	5	*695.7*	*0.3%*	*462*	*367*	*235*	*144*	*84*	*49*	*27*	*1.3*	*0.9*	*0.6*	*0.4*	*0.7*	*0.1*	*0.4*
	8	*709.0*	*0.2%*	*216*	*192*	*154*	*119*	*87*	*61*	*31*	*0.7*	*0.7*	*0.4*	*0.6*	*0.3*	*0.4*	*0.1*
	13	*717.4*	*0.5%*	*112*	*101*	*86*	*72*	*59*	*48*	*30*	*0.9*	*0.6*	*0.6*	*0.5*	*0.6*	*0.2*	*0.5*
2	*2*	*717.2*	*0.3%*	*75*	*62*	*56*	*50*	*42*	*35*	*24*	*0.4*	*0.2*	*0.2*	*0.4*	*0.3*	*0.3*	*0.1*
	5	*706.8*	*0.2%*	*479*	*378*	*240*	*145*	*82*	*47*	*26*	*1.6*	*1.3*	*0.8*	*0.5*	*1.0*	*0.6*	*0.5*
	8	*711.4*	*0.2%*	*233*	*206*	*164*	*126*	*93*	*64*	*32*	*1.4*	*0.8*	*0.9*	*0.6*	*1.0*	*0.5*	*0.3*
	13	*713.2*	*0.2%*	*121*	*109*	*93*	*78*	*65*	*53*	*33*	*0.5*	*0.2*	*0.4*	*0.3*	*0.5*	*0.4*	*0.1*
3	2	704.0	0.3%	76	63	56	49	42	35	23	0.5	0.2	0.3	0.5	0.5	0.3	0.5
	5	706.8	0.4%	524	410	251	149	82	45	24	2.5	2.3	1.3	1.2	0.8	0.6	0.9
	8	713.9	0.5%	248	218	172	130	93	64	32	1.3	1.1	0.9	0.7	0.9	0.3	0.4
	13	701.8	0.5%	121	109	93	79	64	52	29	0.8	0.6	0.7	0.4	0.7	0.2	0.3
4	2	700.8	0.3%	78	63	56	50	43	36	23	0.3	0.5	0.5	0.1	0.1	0.1	0.5
	5	698.5	0.5%	525	411	251	148	84	47	25	3.1	1.9	1.2	0.8	0.7	0.2	0.1
	8	694.8	0.2%	251	219	173	131	94	65	32	0.3	0.5	0.4	0.3	0.2	0.4	0.5
	13	693.9	0.2%	124	111	95	80	66	54	32	0.3	0.2	0.2	0.3	0.1	0.4	0.1

D.21 Machine 46

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	728.3	0.6%	84	69	62	53	46	38	23	0.5	0.5	0.6	0.6	0.6	0.4	0.4
	5	669.3	0.7%	662	497	328	199	129	88	55	5.0	3.9	2.6	1.0	0.7	0.6	0.7
	8	703.2	0.4%	292	255	203	152	115	83	44	3.2	**16.1**	1.4	1.1	0.8	1.0	1.2
	13	728.3	0.6%	145	127	109	89	71	55	34	1.1	0.6	0.6	0.8	0.6	0.6	0.3
2	2	728.3	0.5%	85	69	63	54	47	38	24	1.8	0.4	0.5	0.3	0.4	0.2	0.1
	5	669.1	0.4%	663	515	331	203	132	88	56	**6.6**	**6.9**	3.3	1.6	1.0	0.6	0.9
	8	704.4	0.5%	290	247	203	152	115	83	42	2.8	2.1	1.8	1.3	1.4	1.2	0.8
	13	728.8	0.6%	153	132	115	93	74	57	38	1.2	0.7	0.6	0.5	0.7	0.6	0.3

D.22 Machine 47

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	692.1	0.2%	76	63	57	50	43	36	24	0.2	0.3	0.2	0.1	0.1	0.4	0.2
	5	678.9	0.1%	511	397	251	144	83	48	30	0.7	0.4	0.5	1.0	0.2	0.5	0.2
	8	684.8	0.1%	237	211	168	128	94	67	34	0.2	0.2	0.2	0.1	0.2	0.2	0.1
	13	686.4	0.2%	124	114	97	81	66	53	30	0.2	0.3	0.1	0.1	0.1	0.8	0.6
2	2	695.3	0.3%	77	64	56	51	43	35	24	0.1	0.2	0.1	0.2	0.2	0.3	1.2
	5	680.7	0.1%	531	411	252	150	85	51	30	1.3	0.8	0.4	0.3	0.1	0.2	0.1
	8	685.9	0.2%	241	214	171	129	94	67	34	0.2	0.2	0.2	0.2	0.1	0.2	0.2
	13	686.0	0.2%	124	110	97	81	66	52	31	0.5	1.6	0.5	0.7	0.7	0.7	0.9

D.23 Machine 48

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	747.0	0.2%	76	62	58	49	42	36	24	1.4	0.3	0.4	0.1	0.1	0.3	0.5
	5	731.5	0.3%	521	413	255	154	88	54	31	1.7	0.6	0.5	0.4	0.2	0.4	0.5
	8	735.8	0.3%	242	215	171	130	95	67	35	0.7	0.6	0.5	0.4	0.2	0.3	0.2
	13	734.1	0.3%	128	116	98	82	67	53	33	1.1	0.4	0.4	0.2	0.2	0.1	0.1
2	2	741.4	0.3%	76	64	56	50	43	36	24	1.5	0.2	0.2	0.2	0.2	0.2	0.2
	5	727.1	0.3%	528	423	258	154	89	52	31	2.4	1.4	0.8	0.4	0.3	0.2	0.2
	8	732.3	0.3%	243	216	172	131	95	68	35	0.9	0.6	0.5	0.3	0.3	0.2	0.3
	13	732.6	0.2%	130	117	99	83	68	54	35	1.0	0.3	0.2	0.1	0.2	0.3	0.3

D.24 Machine 49

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	722.6	0.2%	72	60	54	46	40	33	22	0.3	0.2	0.1	0.1	0.2	0.2	0.3
	5	712.7	0.1%	485	379	247	144	86	53	32	1.1	0.6	0.2	0.2	0.4	0.4	0.2
	8	716.9	0.1%	229	198	162	121	90	64	34	0.2	0.1	0.1	0.1	0.2	0.1	0.5
	13	717.2	0.3%	118	105	93	77	63	50	30	0.2	0.2	0.2	0.2	0.2	0.3	0.3
2	2	708.7	0.1%	74	61	55	47	41	34	23	0.1	0.1	0.1	0.1	0.4	0.2	0.2
	5	713.5	0.1%	506	391	252	148	85	53	30	0.8	0.4	0.2	0.2	0.3	0.1	0.3
	8	713.6	0.2%	231	201	165	123	91	65	34	0.5	0.2	0.3	0.2	0.2	0.2	0.2
	13	713.9	0.1%	120	106	92	75	61	49	30	0.2	0.2	0.2	0.1	0.1	0.1	0.1

D.25 Machine 50

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	712.9	0.3%	70	59	52	47	40	34	22	0.8	0.1	0.1	0.1	0.1	0.9	0.2
	5	699.7	0.3%	508	396	252	153	86	54	33	2.3	1.2	0.5	0.5	0.4	0.9	0.5
	8	711.9	0.3%	229	200	162	126	91	66	34	1.1	0.4	0.3	0.3	0.3	1.1	0.4
	13	720.5	0.3%	121	104	91	77	62	50	30	**4.9**	0.3	0.1	0.2	0.2	1.0	0.3
2	2	720.5	0.4%	77	58	52	47	40	34	22	1.7	0.2	0.3	0.2	0.3	1.0	0.3
	5	705.7	0.4%	504	395	249	153	89	54	32	4.0	1.2	0.7	0.7	0.4	1.3	0.5
	8	718.3	0.3%	233	201	162	126	91	66	34	1.7	0.4	0.3	0.3	0.4	1.2	0.3
	13	724.4	0.2%	123	106	91	78	62	50	33	**2.8**	0.2	0.1	0.3	0.1	1.2	0.3

Appendix E Reproducibility trial data

Note: In the tables below bold red text indicates that the value is outside of acceptable limits. Data from laps disregarded in the accreditation analysis are shown in grey italics (accept where the value is outside of acceptable limits).

Table E.1: All trial data during the main trial day (all laps - full dataset)

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
2	*1*	*N*	*0.954*	*0.960*	*0.960*	*0.971*	*0.956*	*0.968*	*0.962*	*0.962*	*0.016*	*0.013*	*0.015*	*0.015*	*0.015*	*0.026*	*0.026*	*0.018*
	2	*N*	*0.955*	*0.966*	*0.968*	*0.976*	*0.964*	*0.989*	*0.950*	*0.967*	*0.017*	*0.006*	*0.021*	*0.011*	*0.022*	*0.049*	*0.029*	*0.022*
	3	Y	0.950	0.968	0.968	0.980	0.964	0.986	0.969	0.969	0.017	0.008	0.006	0.009	0.016	0.025	0.027	0.016
	4	Y	0.957	0.966	0.964	0.974	0.964	0.983	0.971	0.968	0.020	0.009	0.013	0.014	0.019	0.023	0.031	0.018
5	*1*	*N*	*1.042*	*1.037*	*1.035*	*1.047*	*1.030*	*1.045*	*1.080*	*1.045*	*0.017*	*0.015*	*0.019*	*0.021*	*0.022*	*0.030*	*0.041*	*0.024*
	2	*N*	*1.041*	*1.039*	*1.043*	*1.052*	*1.041*	*1.058*	*1.070*	*1.049*	*0.028*	*0.025*	*0.023*	*0.023*	*0.020*	*0.030*	*0.055*	*0.029*
	3	*N*	*1.040*	*1.043*	*1.045*	*1.050*	*1.041*	*1.071*	*1.090*	***1.054***	*0.026*	*0.023*	*0.026*	*0.022*	*0.027*	*0.029*	*0.068*	*0.031*
	4	Y	1.032	1.037	1.040	1.048	1.030	1.051	1.076	1.045	0.028	0.023	0.022	0.022	0.022	0.026	0.044	0.027
	5	Y	1.061	1.065	1.059	1.063	1.036	1.034	1.077	**1.056**	0.022	0.026	0.033	0.043	0.046	0.064	**0.080**	0.045
6	*1*	*N*	*0.992*	*1.019*	*1.017*	*1.019*	*1.016*	*0.995*	*1.022*	*1.012*	*0.031*	*0.011*	*0.012*	*0.012*	*0.017*	*0.022*	*0.027*	*0.019*
	2	*N*	*0.995*	*1.025*	*1.023*	*1.028*	*1.030*	*0.997*	*1.022*	*1.017*	*0.028*	*0.016*	*0.013*	*0.016*	*0.023*	*0.032*	*0.038*	*0.024*
	3	Y	0.978	1.015	1.013	1.015	1.018	0.992	0.984	1.002	0.028	0.011	0.011	0.013	0.016	0.020	0.052	0.022
	4	Y	0.993	1.012	1.011	1.012	1.011	0.991	0.990	1.003	0.025	0.016	0.019	0.024	0.027	0.041	0.059	0.030
8	*1*	*N*	*0.971*	*0.985*	*0.989*	*0.989*	*0.995*	*1.013*	*1.028*	*0.996*	*0.017*	*0.011*	*0.017*	*0.018*	*0.022*	*0.031*	*0.048*	*0.023*
	2	*N*	*0.960*	*0.982*	*0.992*	*0.993*	*1.005*	*1.025*	*1.042*	*1.000*	*0.023*	*0.013*	*0.015*	*0.021*	*0.027*	*0.036*	*0.053*	*0.027*
	3	Y	0.969	0.989	0.994	0.996	1.009	1.030	1.041	1.004	0.018	0.012	0.015	0.019	0.027	0.037	0.048	0.025
	4	Y	0.970	0.989	0.999	1.000	1.012	1.035	1.053	1.008	0.017	0.015	0.019	0.025	0.035	0.043	0.052	0.030
	5	*N*	*0.969*	*0.994*	*0.992*	*0.988*	*0.999*	*1.011*	*1.041*	*0.999*	*0.025*	*0.010*	*0.015*	*0.018*	*0.023*	*0.039*	*0.068*	*0.028*
10	*1*	*N*	*0.995*	*1.000*	*1.003*	*1.006*	*1.008*	*1.002*	*1.059*	*1.011*	*0.037*	*0.014*	*0.010*	*0.014*	*0.018*	*0.013*	*0.069*	*0.025*
	2	*N*	*1.003*	*1.003*	*1.011*	*1.009*	*1.009*	*1.009*	*1.035*	*1.011*	*0.035*	*0.012*	*0.009*	*0.009*	*0.006*	*0.014*	*0.046*	*0.019*
	3	Y	1.018	1.006	1.010	1.012	1.010	1.023	1.034	1.016	0.018	0.011	0.012	0.012	0.015	0.016	0.036	0.017
	4	Y	1.014	1.005	1.009	1.012	1.006	1.010	1.054	1.016	0.017	0.015	0.011	0.014	0.018	0.022	0.063	0.023
	5	*N*	*1.008*	*1.012*	*1.011*	*1.009*	*1.010*	*1.007*	*1.002*	*1.008*	*0.018*	*0.012*	*0.013*	*0.012*	*0.023*	*0.020*	*0.033*	*0.019*

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
13	1	N	0.971	0.983	0.978	0.975	0.981	0.978	0.951	0.974	0.034	0.013	0.008	0.011	0.010	0.013	0.021	0.016
	2	N	0.970	0.985	0.980	0.978	0.988	0.974	0.941	0.974	0.024	0.010	0.009	0.004	0.011	0.019	0.023	0.014
	3	Y	0.971	0.984	0.976	0.971	0.982	0.974	0.945	0.972	0.021	0.013	0.014	0.015	0.015	0.010	0.036	0.018
	4	Y	0.963	0.981	0.969	0.971	0.982	0.970	0.942	0.968	0.016	0.015	0.008	0.008	0.015	0.011	0.028	0.014
15	1	N	0.943	0.948	0.948	0.948	0.959	0.960	0.979	0.955	0.038	0.029	0.025	0.026	0.036	0.044	0.062	0.037
	2	N	0.934	0.934	0.937	0.939	0.956	0.959	0.973	**0.948**	0.034	0.022	0.025	0.029	0.045	0.058	0.067	0.040
	3	Y	0.946	0.949	0.946	0.951	0.970	0.969	0.986	0.960	0.037	0.028	0.030	0.032	0.053	0.051	**0.077**	0.044
	4	Y	0.936	0.945	0.946	0.950	0.969	0.980	1.003	0.961	0.033	0.022	0.025	0.032	0.047	0.062	**0.071**	0.042
16	1	N	0.969	0.967	0.962	0.964	0.965	0.967	0.955	0.964	0.026	0.017	0.020	0.024	0.029	0.028	0.021	0.023
	2	N	0.964	0.953	0.957	0.956	0.962	0.962	0.954	0.958	0.023	0.020	0.020	0.023	0.028	0.031	0.031	0.025
	3	Y	0.970	0.966	0.961	0.970	0.967	0.977	0.960	0.967	0.022	0.019	0.021	0.021	0.028	0.035	0.026	0.025
	4	Y	0.975	0.965	0.961	0.966	0.964	0.975	0.966	0.968	0.029	0.027	0.021	0.019	0.021	0.028	0.032	0.025
28	1	N	0.995	0.977	0.981	0.980	0.967	0.985	0.989	0.982	0.016	0.016	0.021	0.016	0.029	0.028	0.038	0.023
	2	N	0.991	0.982	0.987	0.985	0.981	0.998	0.995	0.988	0.020	0.016	0.021	0.016	0.016	0.020	0.023	0.019
	3	Y	0.996	0.964	0.998	0.985	0.976	0.998	0.998	0.988	0.010	0.037	0.021	0.017	0.016	0.026	0.022	0.021
	4	Y	0.998	0.972	0.986	0.986	0.981	0.994	0.997	0.988	0.005	0.024	0.021	0.009	0.018	0.019	0.016	0.016
30	1	N	1.001	0.998	0.993	0.991	0.988	0.984	0.987	0.992	0.015	0.013	0.012	0.011	0.015	0.018	0.019	0.015
	2	N	1.009	1.007	1.006	0.999	0.996	0.993	0.997	1.001	0.024	0.014	0.008	0.007	0.009	0.012	0.023	0.014
	3	Y	1.008	1.005	1.000	1.000	0.994	0.995	0.975	0.997	0.014	0.011	0.010	0.010	0.010	0.019	0.037	0.016
	4	Y	1.007	1.005	1.004	0.999	0.995	0.995	0.991	0.999	0.025	0.015	0.014	0.017	0.019	0.019	0.033	0.020
32	1	N	1.047	1.056	1.053	1.071	1.065	1.049	1.019	**1.052**	0.029	0.015	0.018	0.020	0.029	0.041	**0.072**	0.032
	2	N	1.067	1.061	1.057	1.069	1.070	1.057	1.010	**1.056**	0.027	0.019	0.021	0.027	0.032	0.051	**0.083**	0.037
	3	Y	1.038	1.050	1.042	1.054	1.060	1.040	0.994	1.040	0.016	0.017	0.018	0.016	0.030	0.049	**0.078**	0.032
	4	Y	1.041	1.057	1.045	1.066	1.059	1.035	1.004	1.044	0.048	0.015	0.020	0.025	0.033	0.057	**0.078**	0.039
33	1	N	1.077	1.057	1.051	1.059	1.044	1.040	1.003	1.047	0.023	0.019	0.023	0.027	0.036	0.048	**0.092**	0.038
	2	N	1.079	1.057	1.057	1.062	1.047	1.039	0.999	1.049	0.018	0.017	0.021	0.027	0.042	0.050	**0.088**	0.038
	3	N	1.080	1.066	1.060	1.070	1.050	1.054	0.996	**1.054**	0.041	0.024	0.028	0.035	0.043	0.062	**0.110**	0.049
	4	Y	1.081	1.066	1.059	1.067	1.050	1.045	1.006	**1.053**	0.037	0.023	0.026	0.035	0.045	0.063	**0.100**	0.047
	5	Y	**1.114**	1.091	1.075	1.079	1.060	1.037	0.996	**1.065**	0.023	0.027	0.034	0.042	0.053	**0.088**	**0.105**	**0.053**

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
34	1	N	1.041	1.027	1.015	1.017	1.007	1.004	1.066	1.025	0.017	0.013	0.014	0.017	0.020	0.028	0.024	0.019
	2	Y	1.047	1.033	1.022	1.028	1.019	1.011	1.054	1.031	0.028	0.016	0.018	0.017	0.021	0.033	0.027	0.023
	3	Y	1.038	1.031	1.015	1.026	1.016	1.008	1.049	1.026	0.016	0.011	0.012	0.014	0.019	0.039	0.020	0.019
	4	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	1	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	N	0.922	0.960	0.933	0.943	0.938	0.945	0.923	**0.938**	0.060	0.030	0.033	0.029	0.042	0.047	**0.079**	0.046
	3	N	0.907	0.942	0.913	0.926	0.917	0.926	**0.900**	**0.919**	0.047	0.027	0.029	0.028	0.036	0.045	**0.072**	0.041
	4	Y	0.989	1.009	0.979	0.991	0.985	0.993	0.973	0.988	0.053	0.024	0.023	0.026	0.032	0.042	0.068	0.038
	5	Y	1.016	1.018	0.985	0.989	0.988	0.981	0.952	0.990	0.054	0.023	0.022	0.019	0.026	0.041	0.064	0.036
37	1	N	1.054	1.043	1.041	1.035	1.042	1.034	1.037	1.041	0.025	0.020	0.024	0.027	0.029	0.041	0.053	0.031
	2	N	1.055	1.038	1.039	1.033	1.042	1.038	1.040	1.041	0.017	0.018	0.020	0.027	0.028	0.038	0.047	0.028
	3	Y	1.049	1.039	1.034	1.032	1.038	1.036	1.035	1.038	0.020	0.020	0.019	0.026	0.028	0.045	0.043	0.029
	4	Y	1.054	1.037	1.037	1.030	1.040	1.038	1.045	1.040	0.018	0.022	0.023	0.027	0.028	0.043	0.054	0.031
38	1	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	N	1.052	1.032	1.027	0.997	0.995	0.967	1.055	1.018	0.026	0.016	0.018	0.015	0.016	0.014	0.011	0.017
	3	Y	1.059	1.037	1.028	1.001	0.992	0.966	1.044	1.018	0.025	0.013	0.017	0.015	0.021	0.022	0.018	0.019
	4	Y	1.065	1.036	1.031	0.999	0.993	0.963	1.057	1.020	0.032	0.014	0.021	0.016	0.024	0.024	0.019	0.021
39	1	N	0.988	0.977	0.983	0.975	0.975	0.975	0.959	0.976	0.007	0.011	0.011	0.008	0.013	0.019	0.022	0.013
	2	N	0.978	0.969	0.978	0.969	0.981	0.979	0.962	0.974	0.010	0.006	0.006	0.005	0.008	0.014	0.031	0.011
	3	Y	0.981	0.976	0.980	0.972	0.982	0.985	0.966	0.978	0.016	0.011	0.006	0.008	0.008	0.011	0.028	0.013
	4	Y	0.982	0.972	0.979	0.969	0.977	0.981	0.967	0.975	0.013	0.010	0.012	0.011	0.007	0.012	0.027	0.013
	5	N	0.997	0.982	0.979	0.970	0.972	0.964	0.950	0.974	0.017	0.010	0.010	0.017	0.021	0.012	0.036	0.018
40	1	N	0.999	0.999	1.002	1.011	1.009	1.027	1.017	1.009	0.008	0.012	0.008	0.011	0.012	0.020	0.023	0.013
	2	Y	0.996	0.999	1.009	1.018	1.022	1.036	1.029	1.016	0.017	0.015	0.015	0.008	0.012	0.009	0.028	0.015
	3	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	Y	0.995	0.992	1.001	1.011	1.016	1.040	1.038	1.013	0.016	0.010	0.011	0.010	0.014	0.024	0.036	0.018
	5	N	1.012	1.010	1.008	1.016	1.016	1.015	1.021	1.014	0.010	0.006	0.007	0.007	0.007	0.011	0.022	0.010

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
41	*1*	*N*	*1.022*	*1.024*	*1.027*	*1.034*	*1.028*	*1.025*	*1.026*	*1.026*	*0.012*	*0.011*	*0.009*	*0.010*	*0.014*	*0.016*	*0.037*	*0.016*
	2	*N*	*1.024*	*1.021*	*1.025*	*1.035*	*1.036*	*1.028*	*1.018*	*1.027*	*0.012*	*0.011*	*0.012*	*0.012*	*0.016*	*0.021*	*0.035*	*0.017*
	3	Y	1.015	1.023	1.023	1.033	1.030	1.030	1.015	1.024	0.016	0.014	0.007	0.009	0.015	0.023	0.040	0.018
	4	Y	1.013	1.017	1.024	1.034	1.033	1.026	1.029	1.025	0.014	0.006	0.008	0.006	0.008	0.019	0.040	0.015
45	*1*	*N*	*0.993*	*0.998*	*1.006*	*1.001*	*1.002*	*1.029*	*1.099*	*1.018*	*0.036*	*0.032*	*0.035*	*0.038*	*0.042*	*0.064*	***0.115***	***0.052***
	2	*N*	*0.980*	*0.985*	*0.999*	*0.990*	*0.998*	*1.031*	*1.099*	*1.012*	*0.030*	*0.028*	*0.031*	*0.034*	*0.043*	*0.067*	**0.124**	**0.051**
	3	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	Y	1.010	1.011	1.018	1.007	1.012	1.027	1.091	1.025	0.035	0.032	0.032	0.033	0.040	0.053	**0.121**	0.049
46	*1*	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	Y	1.023	1.012	1.049	1.036	1.035	1.031	0.964	1.021	0.058	0.039	0.045	0.052	**0.083**	**0.119**	**0.167**	**0.080**
47	*1*	*N*	*0.980*	*0.967*	*0.983*	*0.991*	*0.990*	*0.997*	*1.013*	*0.988*	*0.019*	*0.019*	*0.019*	*0.025*	*0.028*	*0.044*	*0.055*	*0.030*
	2	*N*	*0.987*	*0.970*	*0.987*	*0.992*	*0.990*	*1.001*	*1.012*	*0.991*	*0.016*	*0.018*	*0.022*	*0.026*	*0.027*	*0.035*	*0.050*	*0.028*
	3	Y	0.980	0.967	0.983	0.996	0.993	1.010	1.018	0.993	0.012	0.015	0.021	0.023	0.031	0.041	0.062	0.029
	4	Y	0.984	0.969	0.985	0.995	0.991	1.012	1.033	0.995	0.014	0.014	0.023	0.024	0.034	0.039	0.058	0.029
48	*1*	*N*	*0.973*	*0.958*	*0.976*	*0.978*	*0.980*	*0.989*	*0.991*	*0.978*	*0.010*	*0.011*	*0.011*	*0.016*	*0.019*	*0.031*	*0.032*	*0.019*
	2	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	Y	0.969	0.955	0.977	0.980	0.985	1.002	1.002	0.981	0.012	0.013	0.011	0.013	0.023	0.029	0.036	0.019
	4	Y	0.962	0.950	0.972	0.976	0.981	0.995	1.010	0.978	0.011	0.006	0.008	0.015	0.027	0.029	0.042	0.020
	5	*N*	*0.977*	*0.965*	*0.978*	*0.974*	*0.977*	*0.976*	*0.974*	*0.974*	*0.012*	*0.007*	*0.009*	*0.008*	*0.014*	*0.025*	*0.027*	*0.015*
49	*1*	*N*	*1.014*	*1.021*	*1.011*	*1.033*	*1.025*	*1.023*	*1.018*	*1.021*	*0.011*	*0.012*	*0.009*	*0.010*	*0.014*	*0.015*	*0.027*	*0.014*
	2	*N*	*1.005*	*1.013*	*1.002*	*1.026*	*1.016*	*1.016*	*1.007*	*1.012*	*0.021*	*0.018*	*0.020*	*0.023*	*0.031*	*0.029*	*0.043*	*0.026*
	3	Y	1.020	1.025	1.012	1.041	1.031	1.035	1.022	1.027	0.021	0.012	0.013	0.014	0.018	0.016	0.037	0.019
	4	Y	1.014	1.018	1.007	1.036	1.027	1.033	1.033	1.024	0.010	0.007	0.007	0.007	0.016	0.012	0.021	0.011

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
50	*1*	*N*	*1.005*	*1.017*	*1.032*	*1.008*	*1.014*	*1.010*	*1.017*	*1.015*	*0.040*	*0.026*	*0.012*	*0.013*	*0.019*	*0.023*	*0.038*	*0.024*
	2	*N*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
	3	Y	1.005	1.032	1.034	1.015	1.022	1.017	1.024	1.022	0.069	0.012	0.012	0.012	0.010	0.014	0.020	0.021
	4	Y	1.025	1.033	1.037	1.015	1.028	1.019	1.029	1.027	0.063	0.011	0.011	0.010	0.014	0.014	0.029	0.022
	5	*N*	*1.020*	*1.042*	*1.041*	*1.012*	*1.018*	*0.996*	*1.003*	*1.019*	*0.046*	*0.015*	*0.015*	*0.021*	*0.027*	*0.025*	*0.045*	*0.028*

Table E.2: All trial data during the main trial day (analysed laps – single data point removed where appropriate)

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophone and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
2	3	0.950	0.968	0.968	0.980	0.964	0.986	0.969	0.969	0.017	0.008	0.006	0.009	0.016	0.025	0.027	0.016	
	4	0.957	0.966	0.964	0.974	0.964	0.983	0.971	0.968	0.020	0.009	0.013	0.014	0.019	0.023	0.031	0.018	
5	4	1.032	1.037	1.040	1.048	1.030	1.051	1.076	1.045	0.028	0.023	0.022	0.022	0.022	0.026	0.044	0.027	
	5	1.061	1.065	1.059	1.063	1.036	1.034	1.066	**1.055**	0.022	0.026	0.033	0.043	0.046	0.064	**0.077**	0.044	Station 10 D7
6	3	0.978	1.015	1.013	1.015	1.018	0.992	0.984	1.002	0.028	0.011	0.011	0.013	0.016	0.020	0.050	0.021	
	4	0.993	1.012	1.011	1.012	1.011	0.991	0.990	1.003	0.025	0.016	0.019	0.024	0.027	0.041	0.059	0.030	
8	3	0.969	0.989	0.994	0.996	1.009	1.030	1.041	1.004	0.018	0.012	0.015	0.019	0.027	0.037	0.048	0.025	
	4	0.970	0.989	0.999	1.000	1.012	1.035	1.053	1.008	0.017	0.015	0.019	0.025	0.035	0.043	0.052	0.030	
10	3	1.018	1.006	1.010	1.012	1.010	1.023	1.034	1.016	0.018	0.011	0.012	0.012	0.015	0.016	0.036	0.017	
	4	1.014	1.005	1.009	1.012	1.006	1.010	1.054	1.016	0.017	0.015	0.011	0.014	0.018	0.022	0.063	0.023	
13	3	0.971	0.984	0.976	0.971	0.982	0.974	0.945	0.972	0.021	0.013	0.014	0.015	0.015	0.010	0.036	0.018	
	4	0.963	0.981	0.969	0.971	0.982	0.970	0.942	0.968	0.016	0.015	0.008	0.008	0.015	0.011	0.028	0.014	
15	3	0.946	0.949	0.946	0.951	0.970	0.969	0.971	0.957	0.037	0.028	0.030	0.032	0.053	0.051	0.064	0.042	Station 5 D7
	4	0.936	0.945	0.946	0.950	0.969	0.980	0.993	0.960	0.033	0.022	0.025	0.032	0.047	0.062	0.065	0.041	Station 5 D7
16	3	0.970	0.966	0.961	0.970	0.967	0.977	0.960	0.967	0.022	0.019	0.021	0.021	0.028	0.035	0.026	0.025	
	4	0.975	0.965	0.961	0.966	0.964	0.975	0.966	0.968	0.029	0.027	0.021	0.019	0.021	0.028	0.032	0.025	

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophone and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
28	3	0.996	0.964	0.998	0.985	0.976	0.998	0.998	0.988	0.010	0.037	0.021	0.017	0.016	0.026	0.022	0.021	
	4	0.998	0.972	0.986	0.986	0.981	0.994	0.997	0.988	0.005	0.024	0.021	0.009	0.018	0.019	0.016	0.016	
30	3	1.008	1.005	1.000	1.000	0.994	0.995	0.975	0.997	0.014	0.011	0.010	0.010	0.010	0.019	0.037	0.016	
	4	1.007	1.005	1.004	0.999	0.995	0.995	0.991	0.999	0.025	0.015	0.014	0.017	0.019	0.019	0.033	0.020	
32	3	1.038	1.050	1.042	1.054	1.060	1.040	1.006	1.041	0.016	0.017	0.018	0.016	0.030	0.049	0.067	0.031	Station 5 D7
	4	1.041	1.057	1.045	1.066	1.059	1.035	1.016	1.046	0.048	0.015	0.020	0.025	0.033	0.057	0.067	0.038	Station 5 D7
33	4	1.081	1.066	1.059	1.067	1.050	1.045	1.020	**1.055**	0.037	0.023	0.026	0.035	0.045	0.063	**0.087**	0.045	Station 5 D7
	5	**1.111**	1.091	1.075	1.079	1.060	1.037	0.996	**1.064**	0.022	0.027	0.034	0.042	0.053	**0.088**	**0.105**	**0.053**	Station 2 D1
34	2	1.047	1.033	1.022	1.028	1.019	1.011	1.054	1.031	0.028	0.016	0.018	0.017	0.021	0.033	0.027	0.023	
	3	1.038	1.031	1.015	1.026	1.016	1.008	1.049	1.026	0.016	0.011	0.012	0.014	0.019	0.039	0.020	0.019	
36	4	0.989	1.009	0.979	0.991	0.985	0.993	0.973	0.988	0.053	0.024	0.023	0.026	0.032	0.042	0.068	0.038	
	5	1.016	1.018	0.985	0.989	0.988	0.981	0.957	0.990	0.054	0.023	0.022	0.019	0.026	0.041	0.063	0.035	Station 2 D7
37	3	1.049	1.039	1.034	1.032	1.038	1.036	1.035	1.038	0.020	0.020	0.019	0.026	0.028	0.045	0.043	0.029	
	4	1.054	1.037	1.037	1.030	1.040	1.038	1.045	1.040	0.018	0.022	0.023	0.027	0.028	0.043	0.054	0.031	
38	3	1.059	1.037	1.028	1.001	0.992	0.966	1.044	1.018	0.025	0.013	0.017	0.015	0.021	0.022	0.018	0.019	
	4	1.065	1.036	1.031	0.999	0.993	0.963	1.057	1.020	0.032	0.014	0.021	0.016	0.024	0.024	0.019	0.021	
39	3	0.981	0.976	0.980	0.972	0.982	0.985	0.966	0.978	0.016	0.011	0.006	0.008	0.008	0.011	0.028	0.013	
	4	0.982	0.972	0.979	0.969	0.977	0.981	0.967	0.975	0.013	0.010	0.012	0.011	0.007	0.012	0.027	0.013	
40	2	0.996	0.999	1.009	1.018	1.022	1.036	1.029	1.016	0.017	0.015	0.015	0.008	0.012	0.009	0.028	0.015	
	4	0.995	0.992	1.001	1.011	1.016	1.040	1.038	1.013	0.016	0.010	0.011	0.010	0.014	0.024	0.036	0.018	
41	3	1.015	1.023	1.023	1.033	1.030	1.030	1.015	1.024	0.016	0.014	0.007	0.009	0.015	0.023	0.040	0.018	
	4	1.013	1.017	1.024	1.034	1.033	1.026	1.029	1.025	0.014	0.006	0.008	0.006	0.008	0.019	0.040	0.015	
45	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	4	1.010	1.011	1.018	1.007	1.012	1.027	1.073	1.023	0.035	0.032	0.032	0.033	0.040	0.053	**0.115**	0.049	Station 5 D7
46	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	4	1.023	1.012	1.049	1.036	1.035	1.031	0.983	1.024	0.058	0.039	0.045	0.052	**0.083**	**0.119**	**0.148**	**0.078**	Station 6 D7
47	3	0.980	0.967	0.983	0.996	0.993	1.010	1.018	0.993	0.012	0.015	0.021	0.023	0.031	0.041	0.062	0.029	
	4	0.984	0.969	0.985	0.995	0.991	1.012	1.033	0.995	0.014	0.014	0.023	0.024	0.034	0.039	0.058	0.029	

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophone and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
48	3	0.969	0.955	0.977	0.980	0.985	1.002	1.002	0.981	0.012	0.013	0.011	0.013	0.023	0.029	0.036	0.019	
	4	0.962	0.950	0.972	0.976	0.981	0.995	1.010	0.978	0.011	0.006	0.008	0.015	0.027	0.029	0.042	0.020	
49	3	1.020	1.025	1.012	1.041	1.031	1.035	1.022	1.027	0.021	0.012	0.013	0.014	0.018	0.016	0.037	0.019	
	4	1.014	1.018	1.007	1.036	1.027	1.033	1.033	1.024	0.010	0.007	0.007	0.007	0.016	0.012	0.021	0.011	
50	3	1.005	1.032	1.034	1.015	1.022	1.017	1.024	1.022	0.069	0.012	0.012	0.012	0.010	0.014	0.020	0.021	
	4	1.025	1.033	1.037	1.015	1.028	1.019	1.029	1.027	0.063	0.011	0.011	0.010	0.014	0.014	0.029	0.022	

Appendix F Reproducibility trial data – contingency day

Note: In the tables below bold red text indicates that the value is outside of acceptable limits. Data from laps disregarded in the accreditation analysis are shown in grey italics (accept where the value is outside of acceptable limits).

Table F.1: All trial data during the contingency day (all laps - full dataset)

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
5	*6*	*N*	*1.064*	*1.065*	*1.061*	*1.069*	*1.053*	*1.068*	*1.072*	***1.065***	*0.024*	*0.029*	*0.034*	*0.041*	*0.043*	*0.048*	*0.058*	*0.040*
	7	Y	1.077	1.066	1.063	1.069	1.052	1.055	1.071	**1.065**	0.024	0.027	0.026	0.028	0.030	0.035	0.053	0.032
	8	Y	1.069	1.056	1.061	1.059	1.044	1.066	1.073	**1.061**	0.015	0.022	0.026	0.027	0.031	0.041	0.063	0.032
8	*6*	*N*	*0.968*	*0.984*	*0.987*	*0.990*	*0.998*	*1.015*	*1.038*	*0.997*	*0.028*	*0.016*	*0.019*	*0.019*	*0.028*	*0.032*	*0.065*	*0.030*
	7	*N*	*0.970*	*0.987*	*0.990*	*0.992*	*1.000*	*1.013*	*1.036*	*0.998*	*0.026*	*0.011*	*0.015*	*0.015*	*0.027*	*0.035*	*0.041*	*0.024*
	8	*N*	*0.977*	*0.987*	*0.994*	*0.991*	*0.998*	*1.016*	*1.037*	*1.000*	*0.024*	*0.013*	*0.016*	*0.017*	*0.033*	*0.038*	*0.064*	*0.029*
10	*6*	*N*	*1.015*	*1.013*	*1.017*	*1.017*	*1.016*	*1.030*	*1.022*	*1.019*	*0.020*	*0.010*	*0.010*	*0.010*	*0.013*	*0.008*	*0.017*	*0.013*
	7	*N*	*1.017*	*1.015*	*1.017*	*1.019*	*1.016*	*1.020*	*1.036*	*1.020*	*0.016*	*0.009*	*0.013*	*0.012*	*0.008*	*0.013*	*0.045*	*0.017*
	8	*N*	*1.022*	*1.018*	*1.021*	*1.024*	*1.020*	*1.029*	*1.029*	*1.023*	*0.012*	*0.008*	*0.012*	*0.008*	*0.013*	*0.011*	*0.028*	*0.013*
16	*6*	*N*	*0.988*	*0.982*	*0.976*	*0.980*	*0.982*	*0.983*	*0.965*	*0.979*	*0.017*	*0.014*	*0.015*	*0.012*	*0.016*	*0.018*	*0.030*	*0.017*
	7	*N*	*0.989*	*0.980*	*0.979*	*0.980*	*0.974*	*0.977*	*0.959*	*0.977*	*0.018*	*0.013*	*0.013*	*0.008*	*0.015*	*0.019*	*0.018*	*0.015*
	8	*N*	*0.982*	*0.975*	*0.974*	*0.974*	*0.973*	*0.972*	*0.953*	*0.972*	*0.027*	*0.015*	*0.015*	*0.014*	*0.018*	*0.020*	*0.018*	*0.018*
33	*6*	*N*	*1.085*	*1.085*	*1.076*	*1.083*	*1.068*	*1.069*	*1.021*	***1.069***	*0.021*	*0.029*	*0.030*	*0.037*	*0.041*	*0.053*	***0.084***	*0.042*
	7	Y	1.088	1.089	1.081	1.087	1.074	1.064	1.019	**1.072**	0.030	0.036	0.036	0.041	0.046	0.065	**0.131**	**0.055**
	8	Y	1.081	1.085	1.078	1.083	1.068	1.067	1.010	**1.068**	0.032	0.026	0.027	0.032	0.039	0.047	**0.090**	0.042
34	*6*	*N*	*1.046*	*1.046*	*1.032*	*1.034*	*1.030*	*1.023*	*1.051*	*1.037*	*0.022*	*0.020*	*0.023*	*0.024*	*0.033*	*0.049*	*0.044*	*0.031*
	7	*N*	*1.047*	*1.054*	*1.035*	*1.042*	*1.033*	*1.020*	*1.068*	*1.043*	*0.030*	*0.025*	*0.021*	*0.025*	*0.026*	*0.033*	*0.042*	*0.029*
	8	*N*	*1.044*	*1.051*	*1.032*	*1.041*	*1.026*	*1.007*	*1.077*	*1.040*	*0.035*	*0.022*	*0.020*	*0.024*	*0.020*	*0.041*	*0.050*	*0.030*
39	*6*	*N*	*0.996*	*0.994*	*0.996*	*0.988*	*0.995*	*0.990*	*0.956*	*0.988*	*0.005*	*0.007*	*0.007*	*0.010*	*0.009*	*0.006*	*0.038*	*0.012*
	7	*N*	*0.999*	*0.994*	*0.994*	*0.983*	*0.997*	*0.980*	*0.948*	*0.985*	*0.006*	*0.010*	*0.008*	*0.012*	*0.006*	*0.014*	*0.042*	*0.014*
	8	*N*	*0.995*	*0.989*	*0.992*	*0.981*	*0.994*	*0.984*	*0.947*	*0.983*	*0.017*	*0.012*	*0.010*	*0.011*	*0.009*	*0.008*	*0.040*	*0.015*

Table F.2: All trial data during the contingency day (analysed laps – single data point removed where appropriate)

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophone and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
5	7	1.077	1.066	1.063	1.069	1.052	1.055	1.064	**1.064**	0.024	0.027	0.026	0.028	0.030	0.035	0.054	0.032	Station 1 D7
	8	1.069	1.056	1.061	1.059	1.044	1.066	1.064	**1.060**	0.015	0.022	0.026	0.027	0.031	0.041	0.061	0.032	Station 12 D7
33	7	1.088	1.089	1.081	1.087	1.074	1.064	1.006	**1.070**	0.030	0.036	0.036	0.041	0.046	0.065	**0.131**	**0.055**	Station 1 D7
	8	1.076	1.085	1.078	1.083	1.068	1.067	1.010	**1.067**	0.029	0.026	0.027	0.032	0.039	0.047	**0.090**	0.042	Station 12 D1

Appendix G Accreditation trial – Trial results

ID	Make, model and serial number	Repeatability	Reproducibility				Elapsed distance	Temperature			OSGR (Horizontal)
			FCF		SDDR			100mm	Surface	Air	
			Mean	Individual	Mean	Individual					
2	Dynatest FWD 8002 SN 102	Pass	Pass	Pass	Pass	Pass	Pass	Low	*No data*	*No data*	No data
5	Dynatest HWD 8082 SN 050	Pass	Fail	Pass	Pass	Pass	Pass	Low	*No data*	*No data*	No data
6	Dynatest HWD 8082 SN 018	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	High	High
8	Dynatest FWD 8002 SN 028	Pass	Pass	Pass	Pass	Pass	Pass	Low	*No data*	*No data*	*No data*
10	Dynatest FWD 8002 SN 192	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	*No data*
13	Dynatest HWD 8082 SN 029	Pass	Pass	Pass	Pass	Pass	Pass	Not Suitable	*No data*	*No data*	*No data*
15	Dynatest FWD 8002 SN 203	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
16	Dynatest FWD 8002 SN 214	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
28	Dynatest FWD 8002 SN 271	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	High
30	Dynatest FWD 8002 SN 173	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	High	Low
32	Dynatest HWD 8082 SN 069	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	*No data*
33	Dynatest HWD 8082 SN 070	Pass	Fail	Pass	Fail	Fail	Pass	Not Suitable	*No data*	*No Data*	*No data*
34	Dynatest HWD 8082 SN 108	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not assessed	High	*No data*
36	Grontmij PRI 2500 0608-303	Pass	Pass	Pass	Pass	Pass	Pass	Low	*No data*	High	Medium
37	Dynatest FWD 8002 SN 352	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	*No data*
38	Grontmij PRI 1500 1111-448	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	Low
39	Dynatest FWD 8002 SN 388	Pass	Pass	Pass	Pass	Pass	Pass	Low	Not assessed	High	High
40	Dynatest FWD 8012 SN 002	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	High
41	Dynatest HWD 8082 SN 145	Pass	Pass	Pass	Pass	Pass	Pass	Low	*No data*	*No Data*	*No data*
45	Grontmij Carlbro PRI2100 0903-088	Pass	Pass[1]	Pass[1]	Fail	Fail	Pass	High	Not assessed	Medium	*No data*
46	PaveTesting FWD150 107PT0218	Fail	Pass	Pass	Fail	Fail	Pass	Not assessed	*No data*	High	*No data*

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[1] This machine met the criteria for FCF but only completed one lap in its final configuration.

ID	Make, model and serial number	Repeatability	Reproducibility				Elapsed distance	Temperature			OSGR (Horizontal)
			FCF		SDDR						
			Mean	Individual	Mean	Individual		100mm	Surface	Air	
47	Dynatest FWD 8002 SN 452	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	Medium
48	Dynatest FWD 8002 SN 424	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Low	High
49	Dynatest HWD 8082 SN 146	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not assessed	High	High
50	RINCENT HeavyDyn HVY-101A	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Low	Medium

Highways England 2018 National Dynamic Plate Test device 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 Dynamic Plate test devices (FWD and HWD) supported by ongoing QA for the devices. In order to undertake accredited surveys, the devices are required to meet the mandatory criteria of the trial.

This report covers the 2018 trial run by TRL and held on the Horiba-MIRA proving ground between 25th and 27th September 2018.

Other titles from this subject area

PPR944	Highways England 2017 National Dynamic Plate Test device Accreditation Trial. S Brittain. 2020
PPR945	Highways England 2016 National Dynamic Plate Test device Accreditation Trial. S Brittain. 2020
PPR946	Highways Agency 2015 National Dynamic Plate Test device Accreditation Trial. S Brittain, M Militzer. 2020
PPR947	Highways Agency 2014 National Falling Weight Deflectometer Accreditation Trial. S Brittain. 2020

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ISSN 2514-9652

ISBN 978-1-915227-01-0

PPR1017