

PUBLISHED PROJECT REPORT PPR944

Highways England 2017 National Dynamic
Plate Test device Accreditation Trial

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Report details

Report prepared for:	Highways England		
Project/customer reference:	SPATS: 1-123		
Copyright:	© TRL Limited		
Report date:	14/01/2020		
Report status/version:	1.1		
Quality approval:			
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Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Reviewer
0.1	20/11/2017	Draft for review by Project Sponsor	S Brittain	D Gershkoff
1.0	27/06/2018	Issued version	S Brittain	D Gershkoff
1.1	14/01/2020	Converted to published report for historic continuity	S Brittain	D Gershkoff & P Langdale

Document last saved on:	14/01/2020 17:09
Document last saved by:	Stuart Brittain

Executive Summary

The 2017 UK Dynamic Plate Test device (DPT) accreditation trial was held on the Twin Straights on the Horiba-MIRA proving ground, on the 26th and 27th September 2017. This was the nineteenth 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-two machines took part in the trial, consisting of:

- Twelve trailer-mounted Dynatest FWDs
- Seven trailer mounted Dynatest HWDs
- Two trailer mounted Grontmij FWDs
- One trailer mounted Grontmij 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. The accreditation trial criteria are specified in “Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices” (TRL, 2016).

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-two machines met the mandatory criteria of the trial.
- 3-dimensional position data was supplied by eight of the test machines. This data was provided in lat/long/height format. After conversion of the data by TRL into the OSGR format, five machines achieved a high rating, two a low rating and one was identified as not suitable. The contractor's coordinate transformation to OSGR format was not assessed.
- All twenty-two machines provided temperature measurements at depth. Thirteen machines achieved a high rating, five a medium rating and four a low rating.
- Nine machines provided surface temperature measurements. The assessment of this data was not carried out due to problems establishing a reference dataset.
- Eleven 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, three machines achieved a High performance level, two a Medium, five a Low and one was identified as not suitable.

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). It was found that this reference data set was significantly different to the fleet average. It is possible that these differences are due to differences in the test positions (in lane 1 vs. adjacent to lane 1), the set-up of the thermocouples and/or differences in the measurement methods (IRT vs direct contact measurement). This should be further investigated and monitored at future trials. In the 2017 trial one machine failed to meet the SDDR criteria for D7. This appeared to be due to its performance on stations 4 to 9 which are of fully flexible construction. The specification for the test stations for a trial given in appendix C of the accreditation and QA specification (TRL, 2016) provides the required range of deflections and constructions. This specification should be reviewed to identify if additional criteria should be imposed on the selection of the test site for the accreditation trials.

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

<http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-collection/dynamic-plate-test-devices-dpt/index.cfm>

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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 2017 DPT Accreditation trial were:

- To ensure that all machines are maintained 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 nineteenth mandatory UK DPT accreditation trial was held on the 26th and 27th September 2017 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 2017 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. The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices" (TRL, 2016).

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 2017 accreditation trial and presents the details of the machines that took part in the trial.

2 Trial Format

2.1 Participants

Twenty-two machines (all trailer-mounted) took part in the 2017 Highways England DPT accreditation trial, comprising fourteen FWDs and eight HWDs. A total of thirteen 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
CET Infrastructure	Dynatest 8002 FWD
Dynatest	Dynatest 8012 FWD
Forth Bridge Constructors JV	Dynatest 8002 FWD
James Fisher Testing Services Ltd.	Grontmij Primax 2500 HWD
Milestone Pavement Technologies	Grontmij Primax 1500 FWD
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
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 site.

For the reproducibility testing the following were also specified:

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

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 a pre-drilled hole near one of the temperature loggers. 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, but was not required for the 2017 trial.

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 2 μ m or the sum of 1 μ m 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 $\pm 3^{\circ}\text{C}$ 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 22)
Completed Check list returned to TRL before trial	21
Date of last tower calibration	21
Date of last dynamic calibration	21
Date of last manufacturer's calibration	21
Calibration details correct in field program	22
All seven geophones in correct positions	19

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).

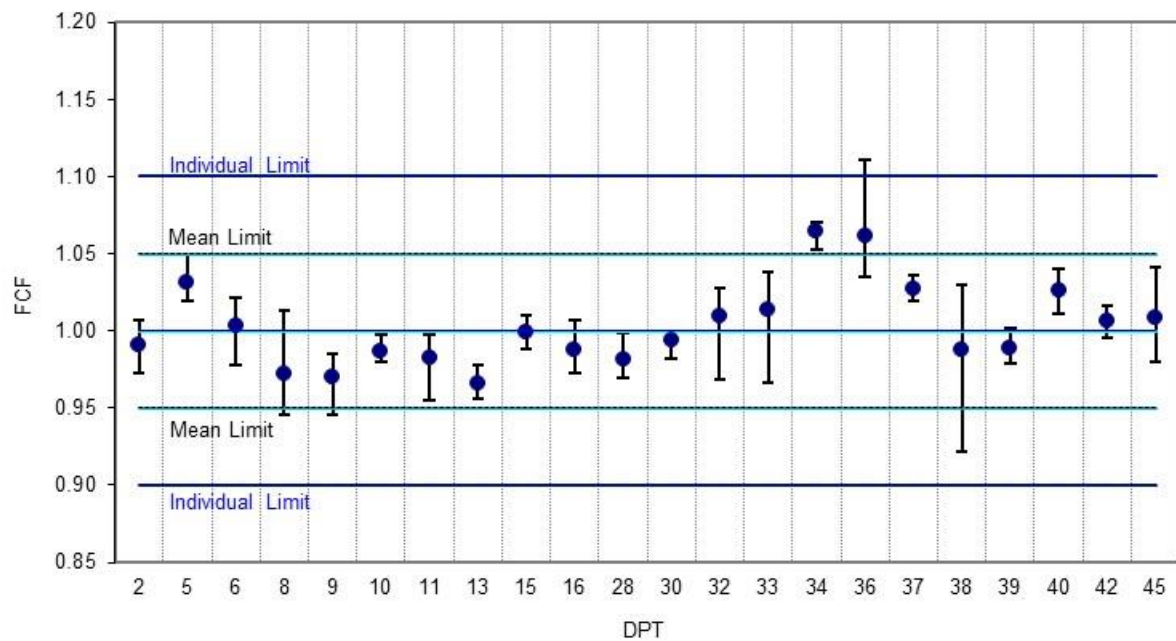


Figure 4.1 FCF (familiarisation lap – full dataset)

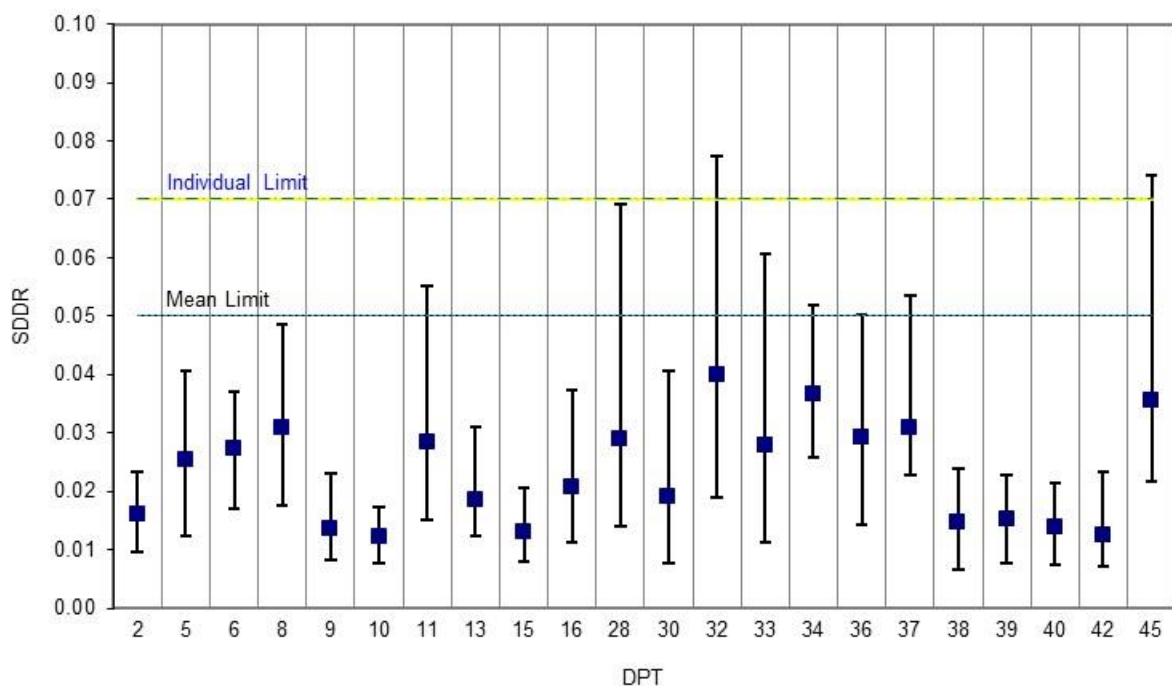


Figure 4.2 SDDR (familiarisation lap – full dataset)

On examination of the familiarisation lap data it was found that Machines 34 and 36 exceeded the limits for the mean FCF. In addition Machine 36 also exceeded the limit for the individual FCF values. All of the machines met the mean SDDR limit, but Machines 32 and 45 did not meet 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.

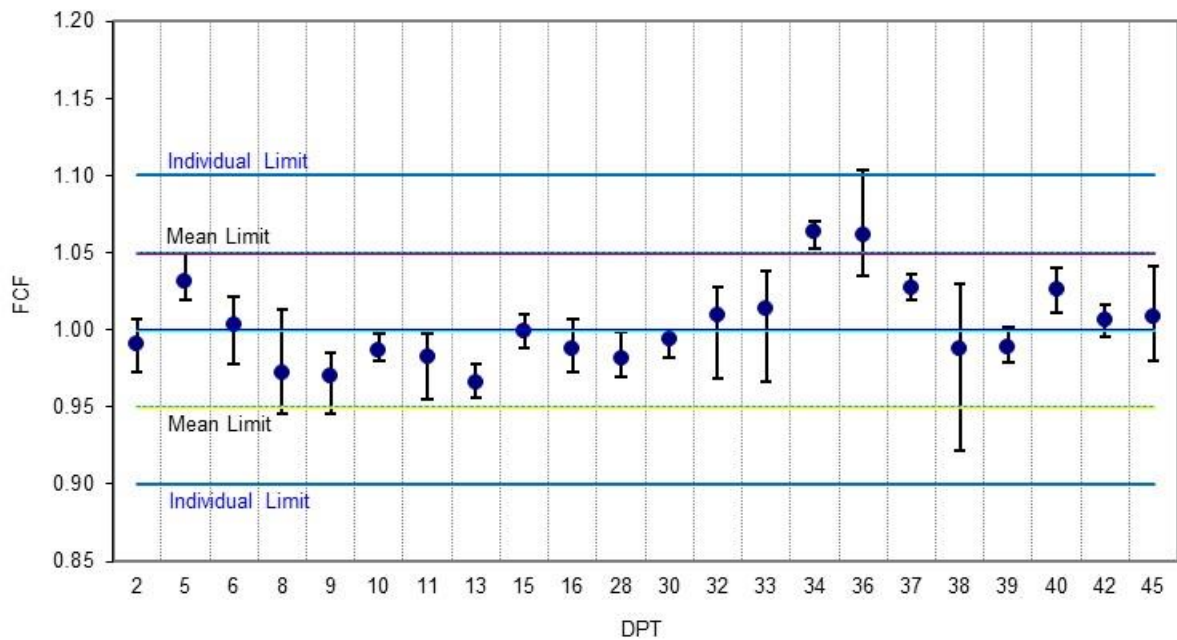


Figure 4.3 FCF (check lap- single data point removed)

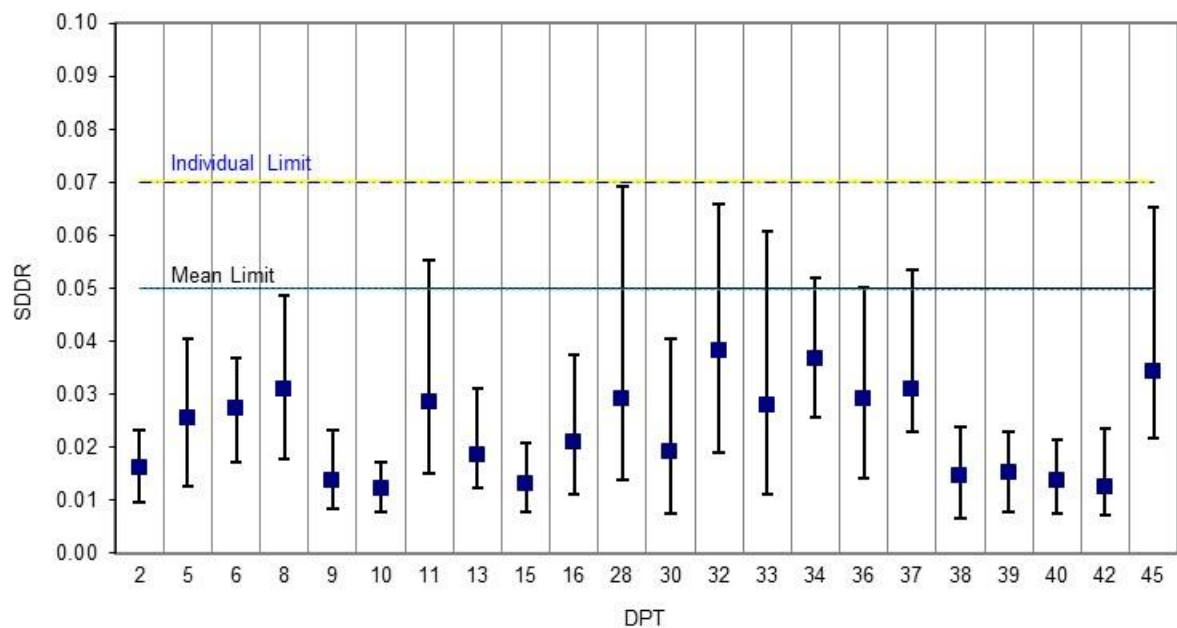


Figure 4.4 SDDR (check lap- single data point removed)

It can be seen from this data that Machines 34 and 36 still did not meet the FCF criteria even after the removal of a data point. 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. All machines achieved the required load criteria for a valid test. One machine (Machine 10) failed to meet the Repeatability criteria. After investigation of their machine the owners identified a contact issue with the cabling for D7 and applied contact spray and retested. This machine (along with 34 and 36 which were being inspected during part of this testing) completed their Repeatability testing on day 2. 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%	Pass
5	0	0	0	0	0	0	0	100%	Pass
6	0	0	0	0	0	0	0	100%	Pass
8	0	0	0	0	0	0	0	100%	Pass
9	0	1	0	0	0	1	0	96%	Pass
10	0	0	0	0	0	0	0	100%	Pass
11	0	0	0	0	0	0	0	100%	Pass
13	0	0	0	0	0	0	0	100%	Pass
15	0	0	0	0	0	0	0	100%	Pass
16	0	0	0	0	0	0	0	100%	Pass
28	0	0	0	0	0	0	0	100%	Pass
30	0	0	0	0	0	0	0	100%	Pass
32	0	0	0	0	0	0	0	100%	Pass
33	0	0	0	0	0	0	0	100%	Pass
34	0	0	0	0	0	0	0	100%	Pass
36	0	0	0	0	0	0	0	100%	Pass
37	0	0	0	0	0	0	0	100%	Pass
38	0	0	0	0	0	0	0	100%	Pass
39	0	0	0	0	0	0	1	98%	Pass
40	0	0	0	0	0	0	0	100%	Pass
42	0	0	0	0	0	0	0	100%	Pass
45	1	0	0	0	0	0	0	98%	Pass

On examination of the data it can be seen that all of the assessed machines meet the repeatability criteria.

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 identified that one probe was providing anomalous readings (20.1°C when the average was 16.7°C). The owner of the machine (Machine 6) was notified and they used a different probe for the 2nd day of the trial.

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.

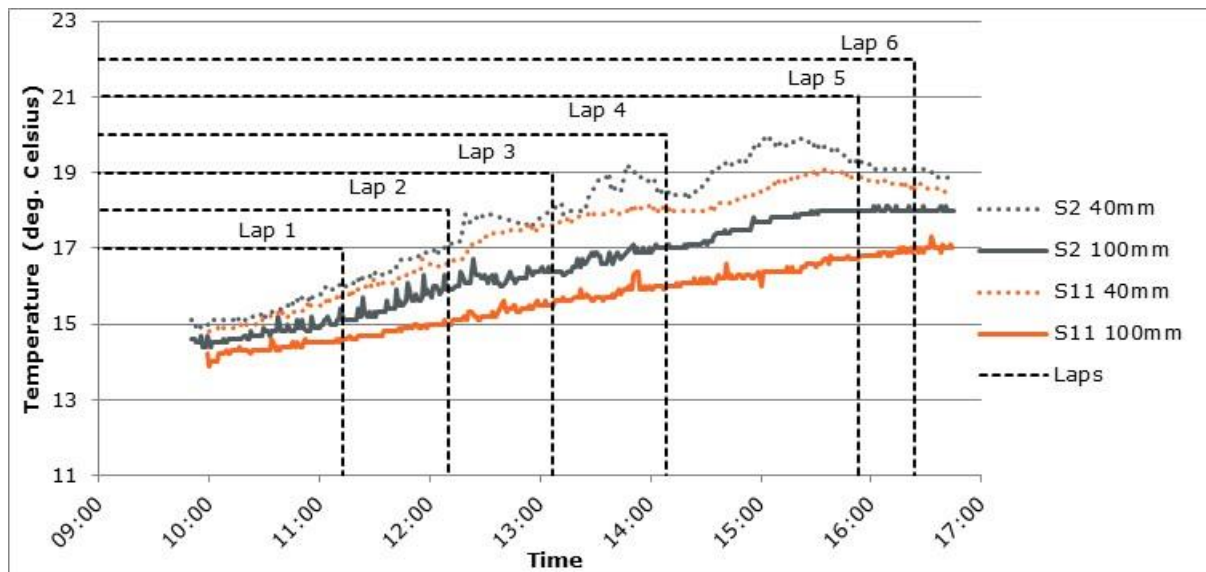


Figure 5.1 Pavement temperatures during main trial day (Day 2)

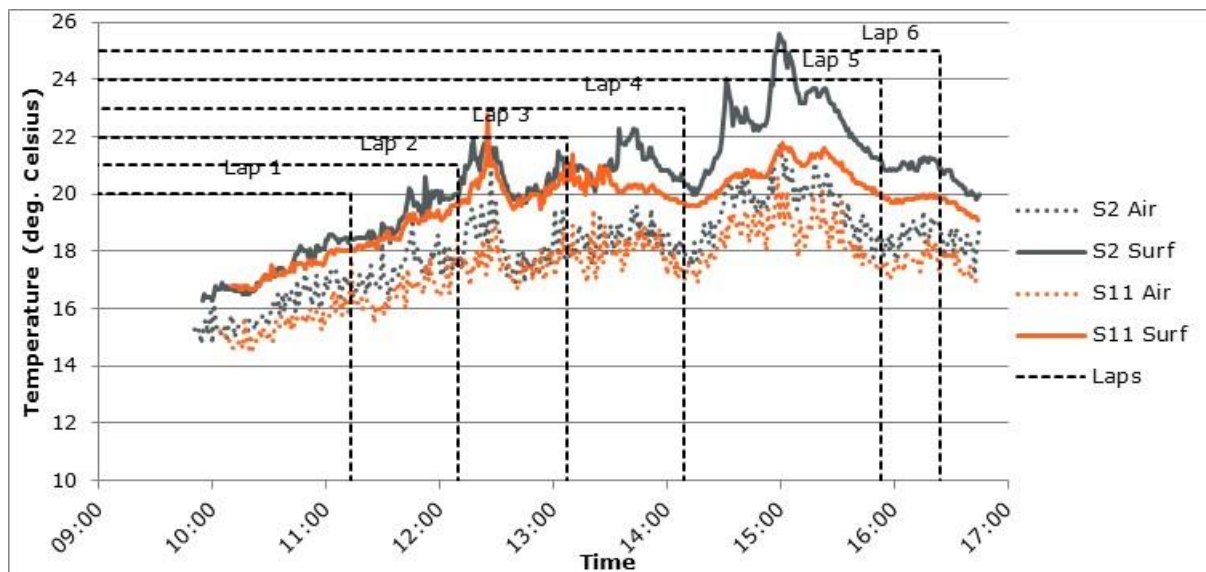


Figure 5.2 Air and surface temperatures during main trial day (Day 2)

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		40mm	100mm
0	09:51	15.1	14.6	11:13	16.1	15.1	01:22	1.0	0.5
1	10:57	15.7	15.0	12:10	17.0	15.9	01:13	1.3	0.9
2	11:54	16.8	15.6	13:07	17.7	16.4	01:13	0.9	0.8
3	12:56	17.6	16.3	14:09	18.4	17.0	01:13	0.8	0.7
4	15:08	19.8	17.8	15:53	19.3	18.0	00:45	-0.5	0.2
5	15:35	19.7	18.0	16:24	19.1	18.0	00:49	-0.6	0.0
6	09:51	15.1	14.6	11:13	16.1	15.1	01:22	1.0	0.5

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		40mm	100mm
0	09:51	14.8	14.2	11:13	15.8	14.6	01:22	1.0	0.4
1	10:57	15.5	14.5	12:10	16.6	15.0	01:13	1.1	0.5
2	11:54	16.4	15	13:07	17.6	15.5	01:13	1.2	0.5
3	12:56	17.5	15.4	14:09	18.0	16.0	01:13	0.5	0.6
4	15:08	18.7	16.4	15:53	18.9	16.7	00:45	0.2	0.3
5	15:35	19.1	16.7	16:24	18.6	17.0	00:49	-0.5	0.3
6	09:51	14.8	14.2	11:13	15.8	14.6	01:22	1.0	0.4

It can be seen that the differences in 100mm depth temperatures between the start and end of laps ranged between 0.0°C and 0.9°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 are laps 2 and 3 respectively (the data from the warm up lap [lap 1] is always discarded). However, when machines do not perform as expected additional laps may be required. A summary of the points raised with the operators and the steps undertaken is discussed below.

- Machine 36 failed to meet the mean FCF criterion (the FCF was too low) on lap 1. During the inspection day this machine had a FCF which was too high. The operators of the machine reinvestigated the machine before undertaking lap 2. It then operated in this final configuration for the rest of the trial.
- Machine 45 failed to meet the SDDR criterion for D7 on lap 1. The machine then achieved the criteria on lap 2 (following removal of a single geophone measurement) without any modifications to the machine. Due to software issues, a full dataset was not provided on lap 3. In lap 4 the SDDR criterion for D7 was not met. This machine

was then investigated before going into lap 5. The criterion was not met on lap 5, and the machine was re-investigated before lap 6. The criterion was still not met. One final lap was completed (with this machine on its own) to test one last theory. Assessing this data against the reference from the previous lap found that the criterion was still not met and it was decided that testing should stop. Although the machine underwent alterations between all of these final laps, laps 5 and 6 are shown in the results below as these are the last two laps for the machine with a set of reference devices.

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 2 and 3 for all machines apart for the exceptions discussed above and 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
45	Lap 5	Lap 6

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.

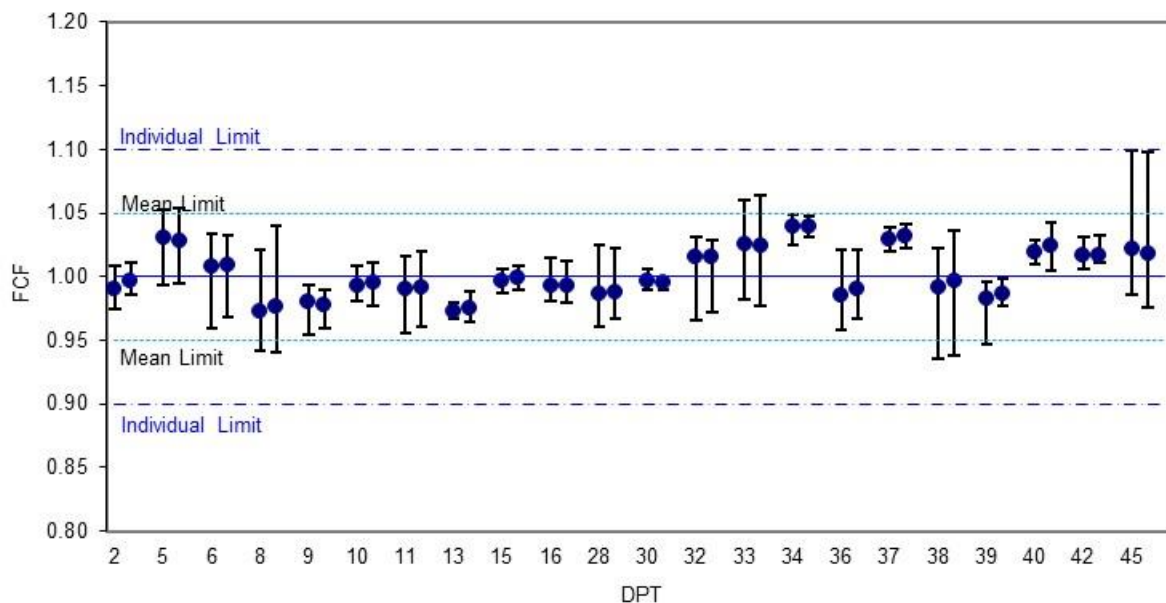


Figure 5.3 FCF for each DPT (main trial day for laps i and ii – full data set)

It can be seen from Figure 5.3 that all twenty-two machines met the trial requirements for mean Field Calibration Factor (FCF) using the full data set from the two chosen test laps. In addition all of the machines met the trial requirements for the individual geophone FCF values using the full set of data.

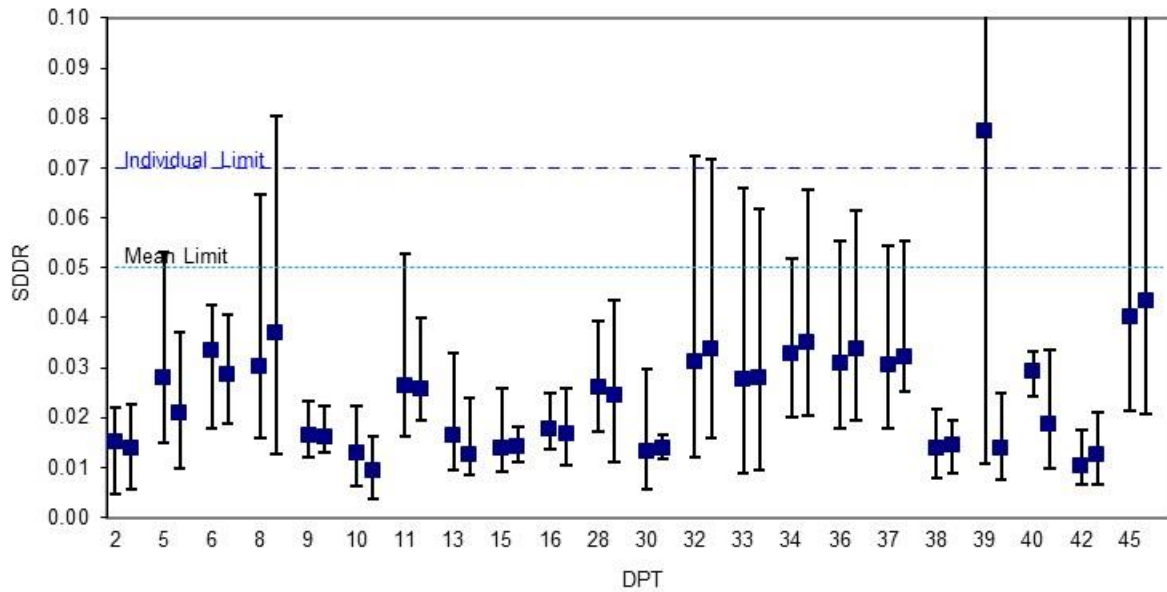


Figure 5.4 SDDR for each DPT (main trial day for laps i and ii – full dataset)

One machine (Machine 39) failed to meet the criterion for the mean SDDR using the full set of data. Four machines (Machines 8, 32, 39 and 45) 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) are shown graphically in Figure 5.5 for SDDR.

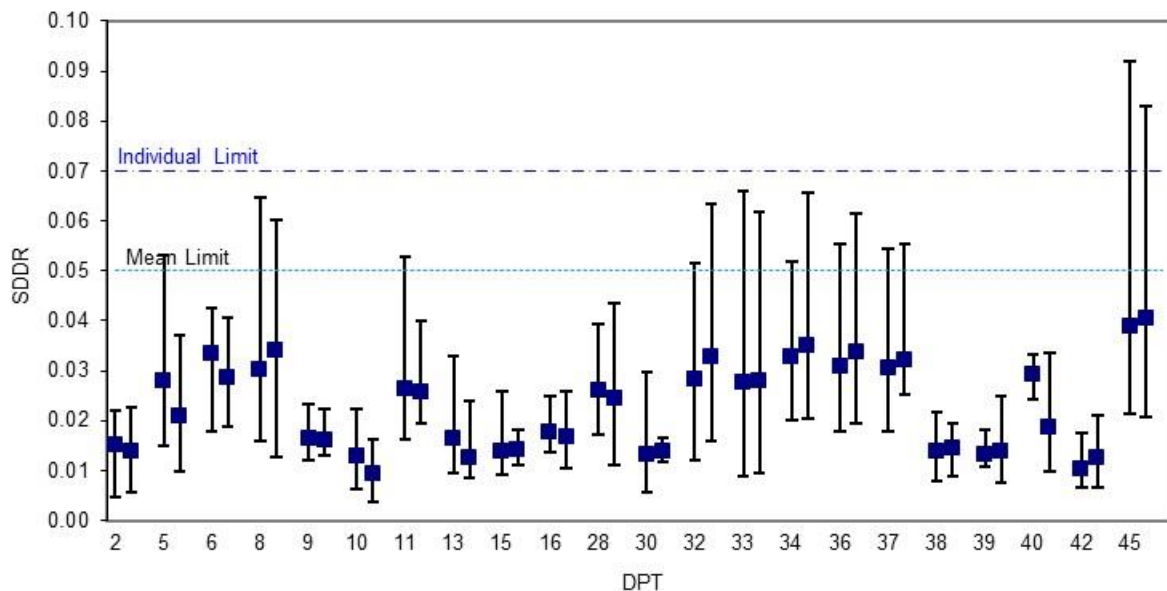


Figure 5.5 SDDR for each DPT (main trial day for laps i and ii – single data point removed)

Following the removal of a single geophone reading from one station on each lap it can be seen that Machines 8, 32 and 39 now meet both of the SDDR criteria. However Machine 45 still does not meet the individual SDDR trial criterion.

5.3 Distance measurement tests

In order to assess the measurement of distance the measurements provided for laps 1, 2, 3 and 4 were used for each machine. The reference length was 419.53m 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. 4.20m). 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 0	Lap 1	Lap 2	Lap 3	
2	-1.5	-1.5	-1.5	-1.5	Pass
5	-1.5	-1.5	-1.6	-1.5	Pass
6	-1.5	-1.5	-1.5	-1.5	Pass
8	-2.5	-2.5	-2.5	-2.5	Pass
9	-1.5	-1.5	-1.5	-1.5	Pass
10	-1.5	-0.5	-1.5	-1.5	Pass
11	-1.5	-1.8	-1.7	-1.9	Pass
13	-3.5	-3.5	-3.5	-3.5	Pass
15	-0.5	-0.5	-0.5	-0.5	Pass
16	0.5	0.5	0.5	0.5	Pass
28	-0.5	-0.5	-0.5	-0.5	Pass
30	-1.5	-1.5	-1.5	-1.5	Pass
32	-1.5	-1.5	-1.5	-1.5	Pass
33	-1.5	-1.5	-1.5	-1.5	Pass
34	-0.5	0.5	-0.5	0.5	Pass
36	-1.5	-1.5	-1.5	-1.5	Pass
37	-2.5	-0.9	-0.8	-0.7	Pass
38	-1.5	-1.5	-1.5	-1.5	Pass
39	-1.5	-1.4	-1.5	-0.9	Pass
40	-0.5	-0.5	-0.5	-0.5	Pass
42	-1.5	-1.5	-1.5	-1.5	Pass
45	-1.5	-1.5	-1.5	-1.5	Pass

It can be seen from this table that all machines met the trial criteria. In addition, 72% 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 8 of the 22 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) before assessment against the criteria (given in section 3.2).

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	98	100	100	High
9	96	98	98	High
15	100	100	100	High
30	33	50	54	Not Suitable
36	27	73	96	Low
38	6	71	100	Low
39	96	100	100	High
40	97	100	100	High

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 5.6 and Figure 5.7.

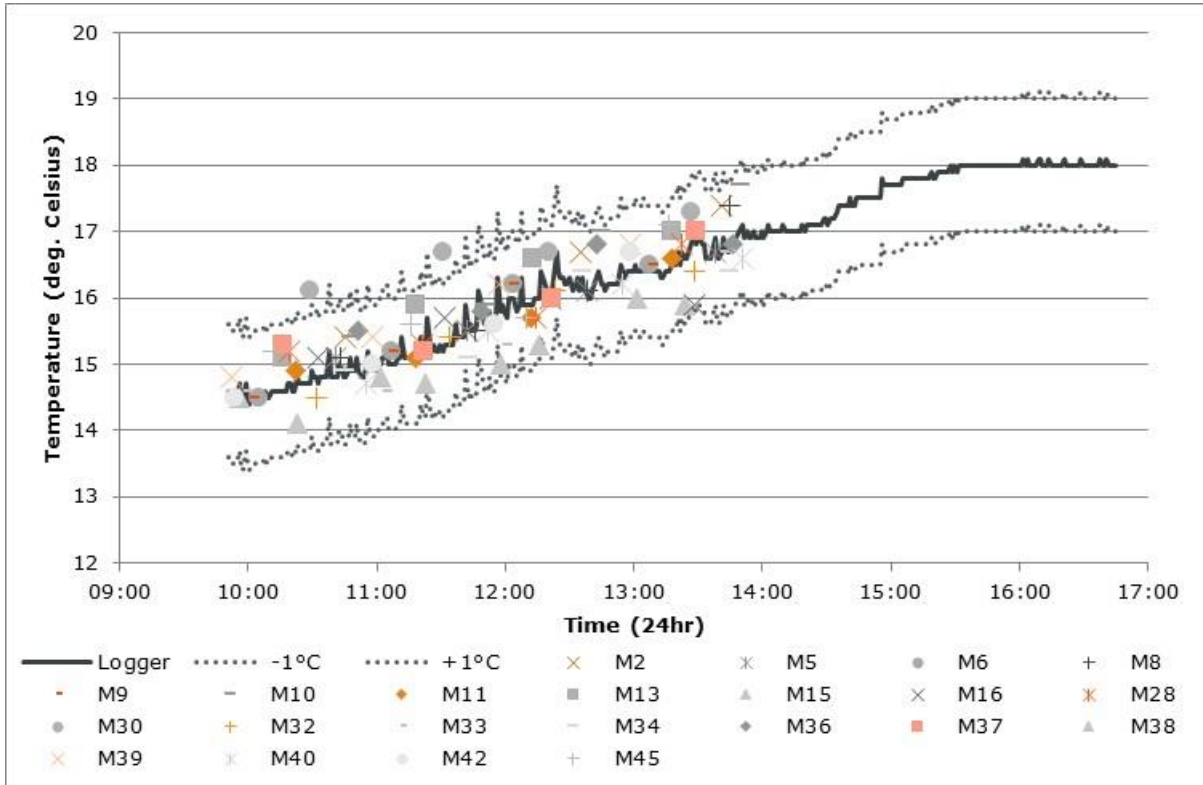


Figure 5.6 Comparison of operator's temperatures and logger temperatures (day 2 near station 2, 100mm depth)

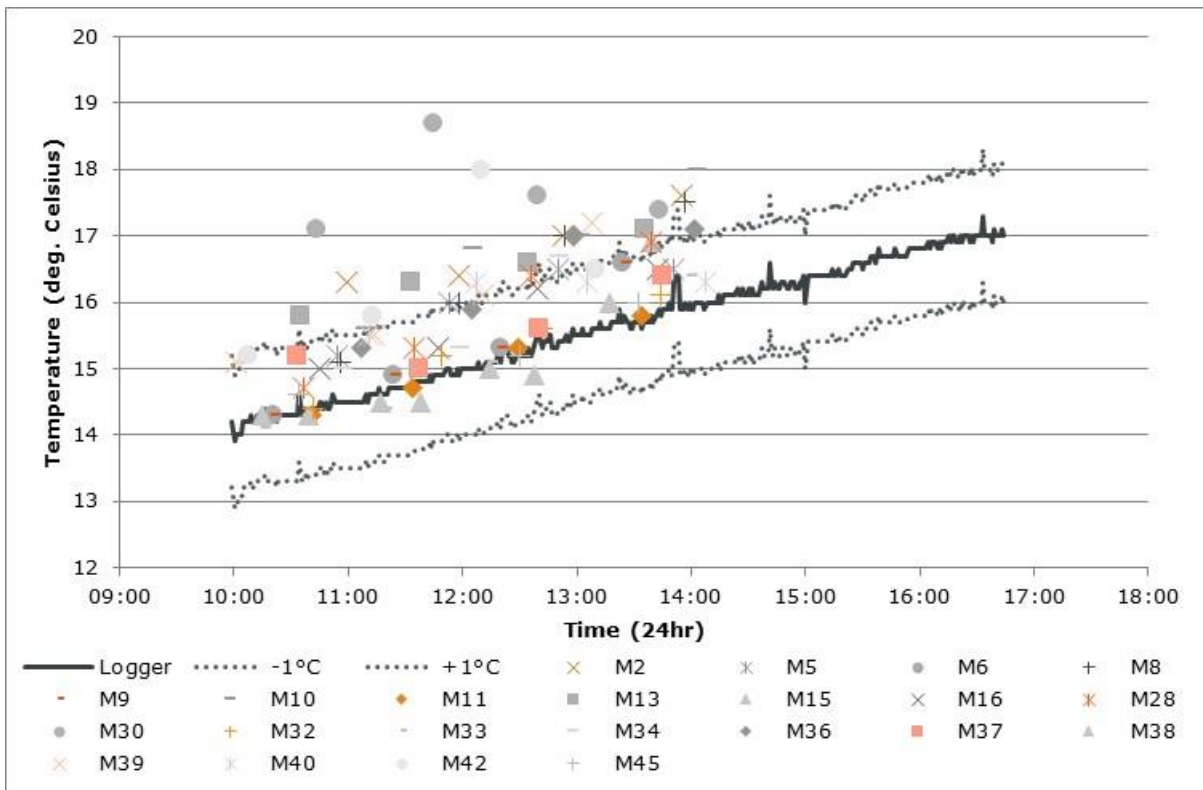


Figure 5.7 Comparison of operator's temperatures and logger temperatures (day 2 near station 11, 100mm depth)

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. It could be due to differences in the holes drilled (the holes could be smaller at station 11 reducing the depth of 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) or some other cause. This should be monitored in future trials especially if the difference between the two stations remains or increases.

The test criteria for temperature measurement at depth are given in section 3.2, and the machines were assessed using the data from laps 1, 2, 3 and 4. 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.

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

Machine	Difference between operators' measurement and reference data (°C)								Percentage within 1°C	Rating
	Lap 0		Lap 1		Lap 2		Lap 3			
	2	11	2	11	2	11	2	11		
2	0.60	1.80	-0.40	1.40	0.60	1.60	0.70	1.70	50%	Low
5	0.30	0.70	-0.40	1.00	0.00	1.20	-0.20	0.60	88%	High
6	0.00	0.00	0.20	0.20	0.20	0.10	0.10	0.90	100%	High
8	0.10	0.60	0.00	1.00	0.00	1.60	0.70	1.60	75%	Medium
9	0.10	0.00	0.20	0.20	0.20	0.10	0.10	0.90	100%	High
10	0.30	1.10	0.30	1.80	0.80	1.50	1.00	2.00	50%	Low
11	0.30	-0.10	0.00	0.00	-0.20	0.10	0.10	0.10	100%	High
13	0.50	1.20	0.80	1.60	0.70	1.40	0.50	1.40	50%	Low
15	-0.70	0.00	-0.50	-0.30	-0.70	-0.30	-0.70	1.20	88%	High
16	0.40	0.60	0.40	0.40	-0.10	1.00	-1.00	0.80	100%	High
28	0.50	0.40	-0.10	0.60	-0.30	1.20	0.30	1.20	75%	Medium
30	1.40	2.70	1.50	3.90	0.60	2.40	0.70	1.70	25%	Low
32	-0.30	0.00	0.10	0.30	0.00	0.20	-0.50	0.20	100%	High
33	0.20	-0.20	-0.50	-0.20	-0.60	0.00	0.00	0.40	100%	High
34	0.10	0.50	-0.40	0.40	0.10	1.30	-0.30	0.60	88%	High
36	0.40	0.80	-0.10	0.90	0.70	1.40	0.10	1.20	75%	Medium
37	0.70	0.90	0.00	0.20	-0.10	0.40	0.20	0.60	100%	High
38	-0.20	0.00	-0.20	-0.20	-0.80	-0.10	-0.50	0.40	100%	High
39	0.20	1.20	0.50	0.90	-0.10	1.10	0.40	1.70	63%	Medium
40	-0.10	1.00	-0.10	1.30	-0.20	0.80	-0.50	0.40	88%	High
42	0.00	1.00	0.10	1.20	0.00	3.00	0.30	0.90	75%	Medium
45	0.60	0.30	0.50	0.30	-0.20	0.00	0.70	0.30	100%	High

It can be seen from this table that fourteen machines achieved the high performance rating. Five machines (Machines 8, 28, 36, 39 and 42) achieved a medium performance. Four machines (Machines 2, 10, 13, and 30) achieved a low performance.

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-two machines which took part in the trial, nine machines (32, 33, 34, 37, 38, 39, 40, 42 and 45) 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 5.8 and Figure 5.9 respectively.

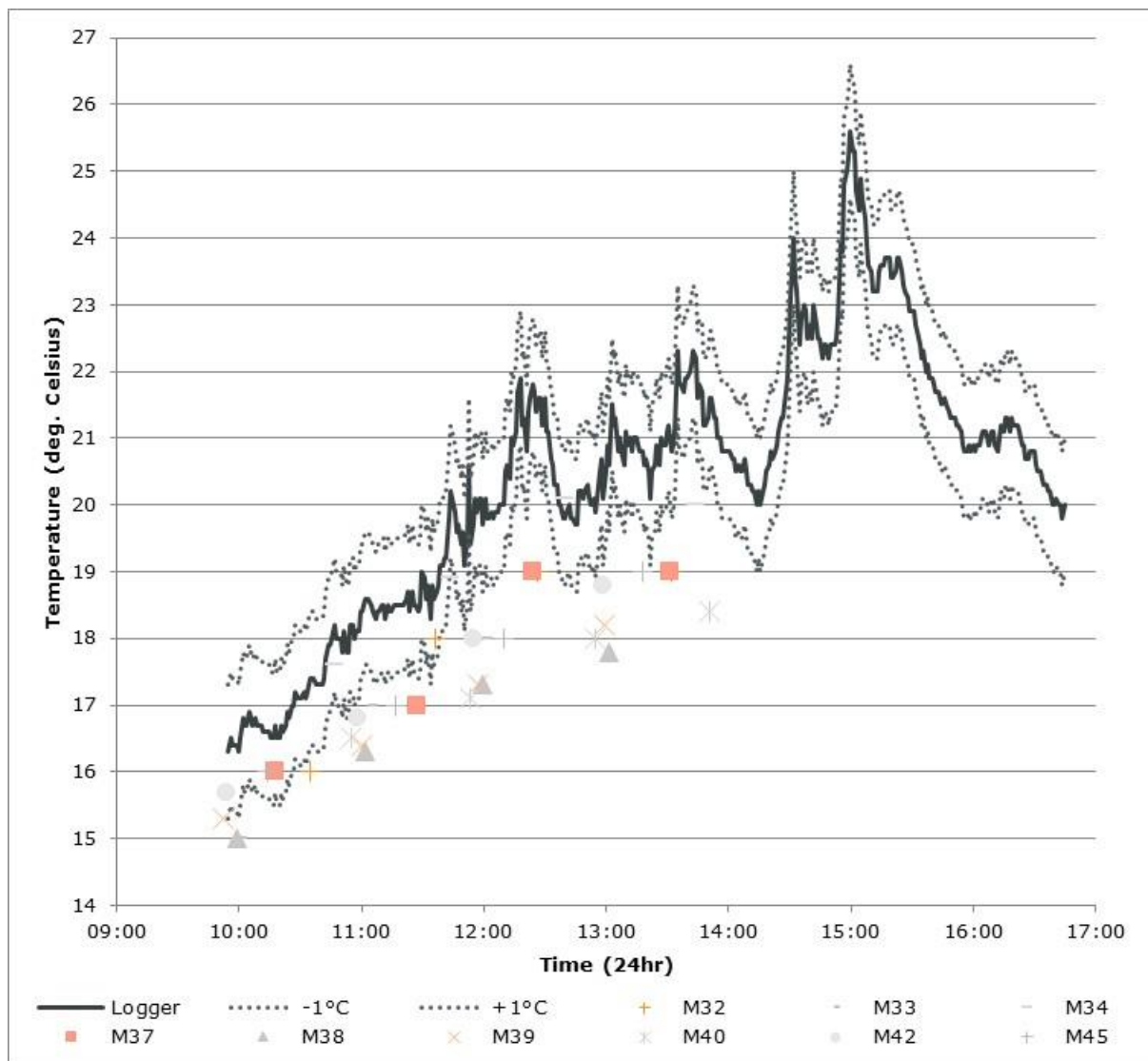


Figure 5.8 Comparison of surface temperatures recorded by DPTs and reference logger measurements (day 2 near station 2)

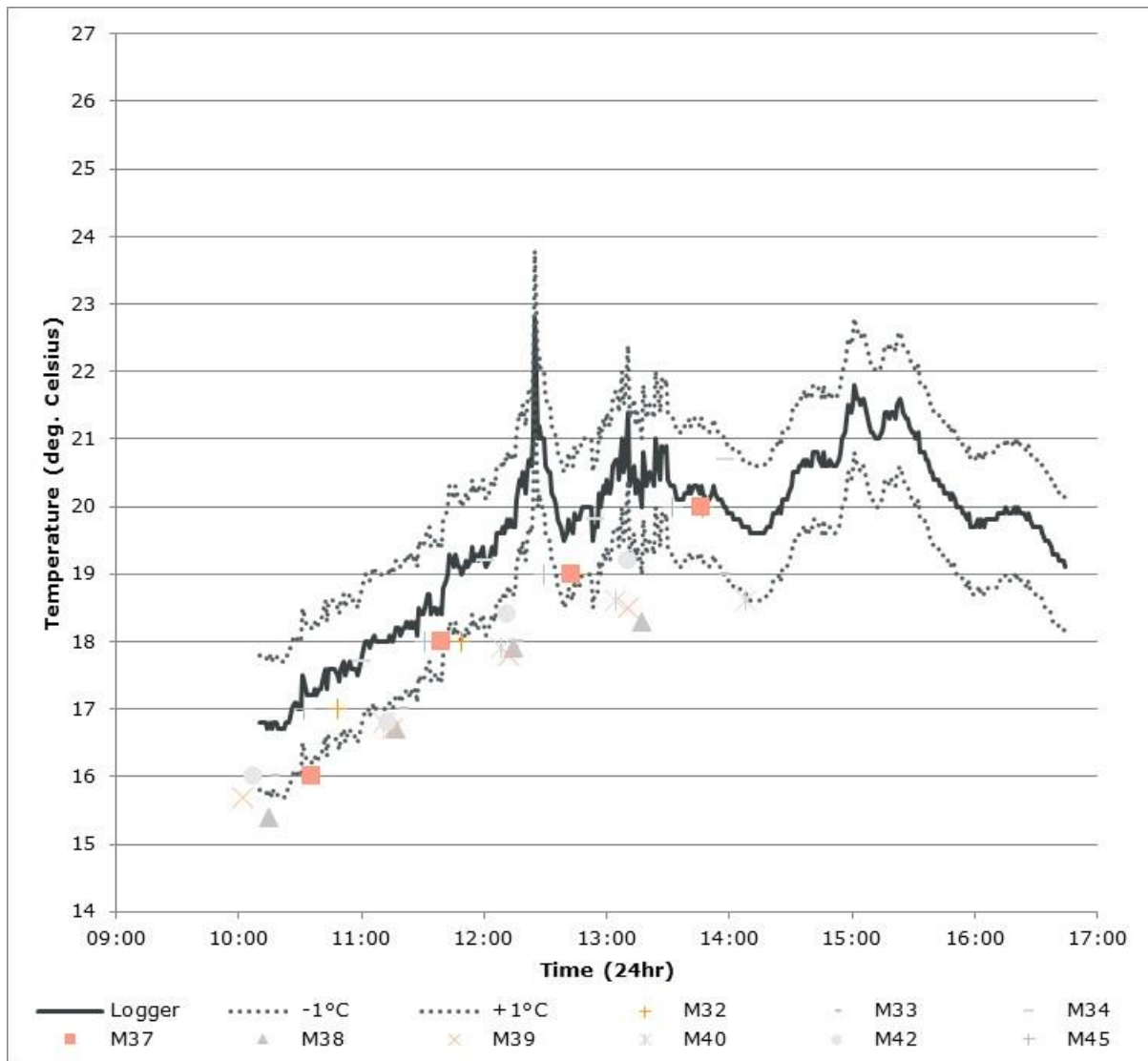


Figure 5.9 Comparison of surface temperatures recorded by DPTs and reference logger measurements (day 2 near station 11)

It can be seen from these graphs (Figure 5.8 and Figure 5.9) that there is not a good match between the survey contractor surface measurements and the data logger.

The test criteria for surface temperature measurement are given in section 3.2, and the machines were assessed using the data from laps 1, 2, 3 and 4. 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

Machine	Difference between operators' measurement and reference data (°C)								Percentage within 1°C	Rating
	Lap 0		Lap 1		Lap 2		Lap 3			
	2	11	2	11	2	11	2	11		
32	-1.40	-0.60	-0.60	-1.10	-2.40	-0.90	-1.80	-0.30	50%	Low
33	-1.30	-0.80	-1.60	-1.20	-1.70	-1.70	-2.10	-1.10	13%	Not Suitable
34	-0.60	0.10	-1.30	0.00	0.30	0.10	-2.20	0.70	75%	Medium
37	-0.70	-1.20	-1.50	-0.50	-2.80	-0.70	-2.20	-0.20	50%	Low
38	-1.40	-1.30	-2.30	-1.40	-2.80	-1.90	-3.10	-1.90	0%	Not Suitable
39	-2.00	-1.80	-2.00	-1.40	-2.60	-2.00	-1.90	-2.10	0%	Not Suitable
40	-1.70	-1.20	-3.50	-1.70	-1.90	-2.00	-3.20	-1.10	0%	Not Suitable
42	-2.00	-1.60	-1.30	-1.20	-1.70	-1.20	-1.90	-1.40	0%	Not Suitable
45	-0.60	-0.50	-1.50	-0.40	-2.00	-2.00	-1.80	-0.30	50%	Low

The results given above would initially suggest that the majority of the operators' surface temperature measurement systems are not suitable for use. However, it seems unlikely for this to be the case, particularly as there was a reasonably good correlation in the results between the operators' devices. This suggests that the reference data collected for this test is 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, the contact with the pavement surface or differences in the measurement principles (the DPT devices use IRT sensors).

The surface thermocouples were located to the side of the track (so as to not be run over by the test vehicles). This meant that the pavement surface they were measuring was rarely in the shade. The operator's temperature sensors are located within the trailer and as such measured the pavement surface in lane 1. This part of the pavement was regularly in shade due to the passing over of survey vehicles. It is therefore possible that this shading effect could cause the lower measurements made by the operators' systems.

Although care was taken to make sure the thermocouples were in contact with the pavement surface it is possible that these were not accurately measuring the surface temperature and were instead measuring the air temperature. However the air temperatures seen on the day were lower than the surface temperatures (see section 5.5.1.2), therefore this does not appear to be a likely cause for the differences.

The IRT sensors used on the DPT vehicles will be dependent in part on the colour of the pavement (as the sensors involve reflecting laser light off the pavement) and as such these devices may inherently give slightly different results to a sensor in contact with the surface.

The differences between the reference surface temperature measurements and the measurements from the DPTs will need to be further investigated and monitored at future trials. Due to this effect, the certificates for these devices have text stating that the surface temperature assessment was not completed due to problems establishing a reference dataset. This was deemed to be a valid approach for this trial as the use of air and surface temperature measurements has not yet been approved for use in surveys.

In future trials consideration should be given to using additional pavement surface thermocouples located in lane 1 (with suitable protection to avoid damage) and/or using IRT sensors to record the pavement temperature. Due to the potential for damage, any sensors located in lane 1 should be duplicated in the current position to the side of the track to serve as a backup.

5.5.1.2 Air measurements

Eleven machines (6, 32, 33, 34, 36, 37, 38, 39, 40, 42 and 45) 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 5.10 and Figure 5.11 respectively.

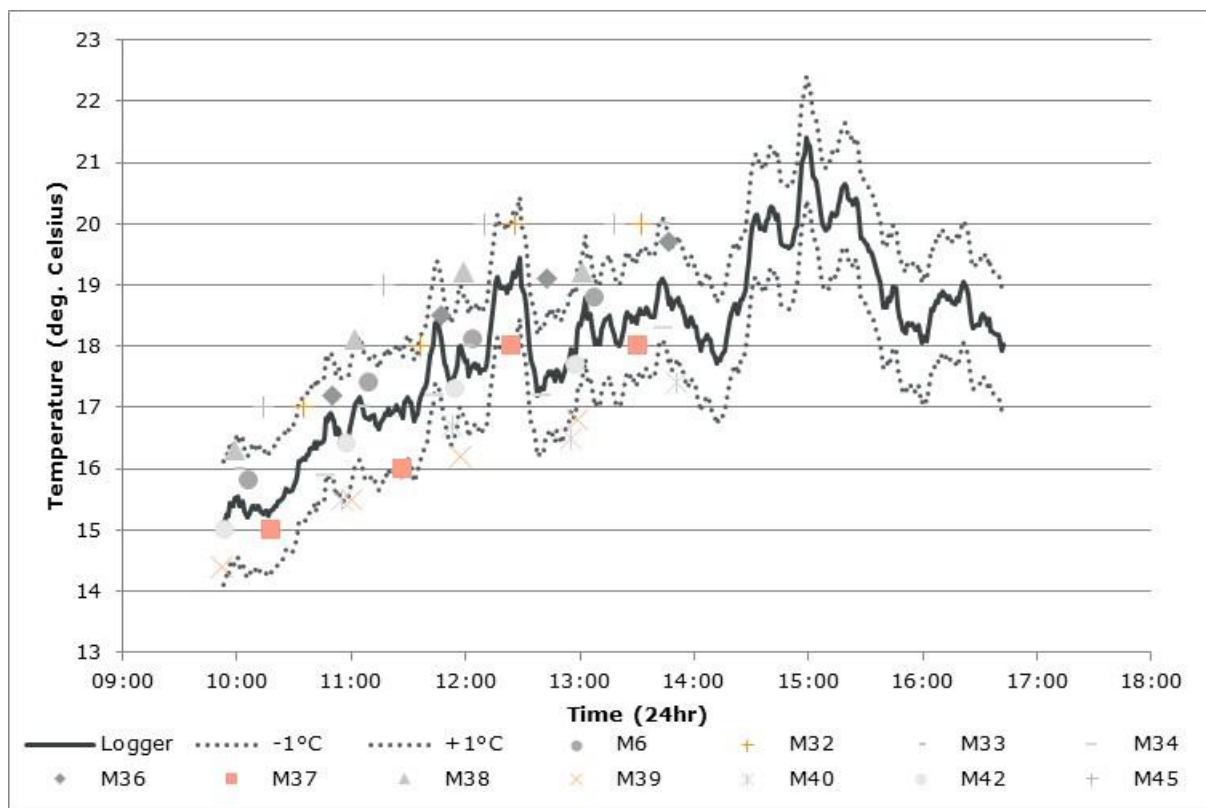


Figure 5.10 Comparison of air temperatures recorded by DPTs and reference logger measurements (day 2 near station 2)

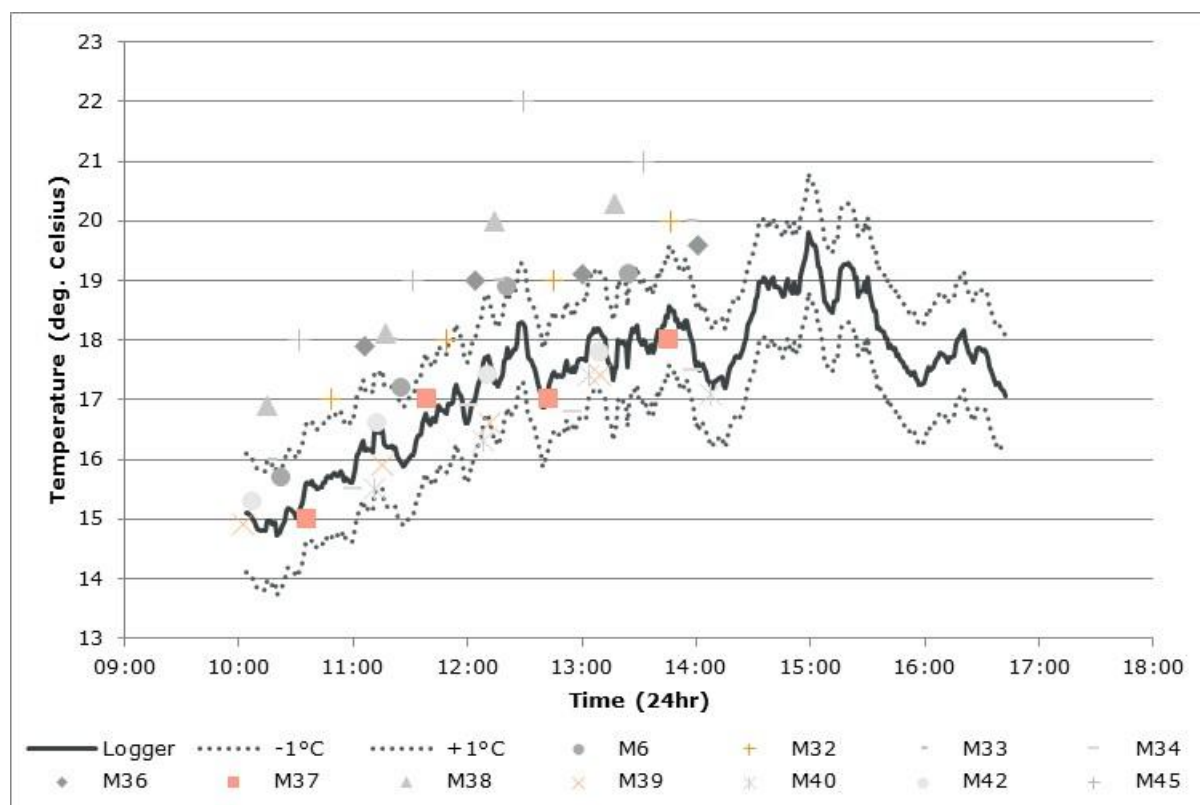


Figure 5.11 Comparison of air temperatures recorded by DPTs and reference logger measurements (day 2 near station 11)

Although air temperature measurements from DPTs do not form part of the updated test method it seemed prudent to assess the data supplied. 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 laps 1, 2, 3 and 4. 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 5.8 Assessment of operators' air temperature measurement

Machine	Difference between operators' measurement and reference data (°C)								Percentage within 1°C	Rating
	Lap 0		Lap 1		Lap 2		Lap 3			
	2	11	2	11	2	11	2	11		
6	0.60	0.92	0.58	1.18	0.40	1.22	0.78	1.54	63%	Medium
32	0.82	1.28	0.94	1.20	0.88	1.60	1.40	1.42	38%	Low
33	0.48	1.02	-0.12	1.80	0.26	1.72	0.98	1.66	50%	Low
34	-0.94	-0.12	-1.18	0.28	-0.12	-0.66	-0.80	-0.58	88%	High
36	0.30	1.58	0.26	2.06	1.60	1.42	1.00	2.04	38%	Low
37	-0.30	-0.58	-0.82	0.22	-0.94	-0.10	-0.52	-0.38	100%	High
38	0.78	2.10	1.06	1.84	1.38	2.58	0.84	2.98	25%	Low
39	-1.00	-0.06	-1.18	-0.54	-1.78	-1.14	-1.48	-0.78	50%	Low
40	-0.98	-0.62	-0.68	-1.10	-1.30	-0.50	-1.34	-0.20	63%	Medium
42	-0.16	0.24	-0.10	0.16	-0.28	-0.28	-0.20	-0.38	100%	High
45	1.74	2.94	2.18	2.92	2.38	3.70	1.80	3.08	0%	Not Suitable

From these results it can be seen that three machines meet the high performance level, two meet the medium performance level, five the low level and one was identified as not suitable.

6 Summary of trial findings

The 2017 UK DPT accreditation trial was held at Horiba-MIRA on the 26th and 27th September 2017. Twenty-two machines took part in the trial.

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

(i) Repeatability of Deflections

- All twenty-two machines met the trial requirements for the Repeatability assessment.

(ii) Reproducibility of Deflections

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

(iii) Distance measurement

- All twenty-two 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

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

(v) Temperature measurement at depth (100mm)

- All twenty two machines provided temperature measurements of the 100mm pavement temperature. Thirteen machines achieved a High performance level, five a Medium and four a Low.

(vi) Surface temperature measurement

- Nine 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

- Eleven machines provided air temperature measurements. Using the surface temperature criteria, three machines achieved a High performance level, two a Medium, five a Low and one was identified as not suitable.

In summary, twenty-one of the twenty-two machines that participated in the 2017 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 F.

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). It was found that this reference data set was significantly different to the fleet average. It is possible that these differences are due to differences in the test positions (in lane 1 vs. adjacent to lane 1), the set-up of the thermocouples and/or differences in the measurement methods (IRT vs direct contact measurement). This should be further investigated and monitored at future trials.

In the 2017 trial one machine failed to meet the SDDR criteria for D7. This appeared to be due to its performance on stations 4 to 9 which are of relatively thin fully flexible construction (200mm asphalt thickness). If these stations were not included in the trial then this machine would be identified as suitable. Therefore it is important that future trials include a suitable range of test stations so as to accurately identify the performance of the devices. The specification for the test stations for a trial given in appendix C of the accreditation and QA specification (TRL, 2016) provides the required range of deflections and constructions. This specification should be reviewed to identify if additional criteria should be imposed on the selection of the test site for the accreditation trials.

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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 David Gershkoff who carried out the technical review of this report, and to Fiona Coyle, Nick Lindley, Pete Sanders and Andrew Stuart 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	06/04/2017	13/09/2017	21/09/2017
5	AECOM Ltd.	Dynatest HWD 8082 SN 050	Trailer	0/5	2-way segmented	31/05/2017	12/09/2017	21/09/2017
6	PMS Ltd.	Dynatest HWD 8082 SN 018	Trailer	0/5	Solid plate	21/07/2017	21/07/2017	22/09/2017
8	AECOM Ltd.	Dynatest FWD 8002 SN 028	Trailer	6/3	2-way segmented	05/04/2017	19/09/2017	21/09/2017
9	PMS Ltd.	Dynatest FWD 8002 SN 136	Trailer	4/2	2-way segmented	26/06/2017	21/07/2017	20/09/2017
10	AECOM Ltd.	Dynatest FWD 8002 SN 192	Trailer	6/3	2-way segmented	05/04/2017	12/09/2017	28/08/2017
11	Forth Crossing Bridge Constructors JV	Dynatest FWD 8002 SN 187	Trailer	6/3	2-way segmented	25/07/2017	25/07/2017	25/07/2017
13	AECOM Ltd.	Dynatest HWD 8082 SN 029	Trailer	4/5	Solid plate	23/05/2017	13/09/2017	17/08/2017
15	CET Infrastructure	Dynatest FWD 8002 SN 203	Trailer	6/3	2-way segmented	06/2017	06/2017	06/2017
16	PTS	Dynatest FWD 8002 SN 214	Trailer	5/2	2-way segmented	11/09/2017	12/09/2017	14/06/2017

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
28	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 271	Trailer	4/2	Solid plate	15/05/2017	23/08/2017	26/06/2017
30	PMS Ltd.	Dynatest FWD 8002 SN 173	Trailer	5/2	Solid plate	26/05/2017	01/08/2017	26/03/2017
32	PTS	Dynatest HWD 8082 SN 069	Trailer	1/2	Solid plate	08/09/2017	08/09/2017	08/09/2017
33	PTS	Dynatest HWD 8082 SN 070	Trailer	1/2	Solid plate	14/09/2017	15/09/2017	27/07/2017
34	PTS	Dynatest HWD 8082 SN 108	Trailer	1/2	4-way segmented	14/09/2017	14/09/2017	27/07/2017
36	Testconsult Ltd.	Grontmij PRI 2500 0608-303	Trailer	3/4	4-way segmented	08/05/2017	01/09/2017	02/06/2017
37	Stanger Testing Services	Dynatest FWD 8002 SN 352	Trailer	6/3	4-way segmented	27/07/2017	27/07/2017	24/08/2017
38	Milestone Pavement Technologies	Grontmij PRI 1500 1111-448	Trailer	3/4	4-way segmented	21/09/2017	20/09/2017	20/09/2017
39	TRL	Dynatest FWD 8002 SN 388	Trailer	6/3	2-way segmented	19/09/2017	20/09/2017	30/05/2017
40	Dynatest	Dynatest FFWD 8012 SN 002	Trailer	4/2	4-way segmented	20/09/2017	20/09/2017	20/09/2017
42	ALC (MoD)	Dynatest HWD 8082 SN 149	Trailer	0/2	4-way segmented	11/07/2017	11/07/2017	11/07/2017

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
45	Atlas Geophysical	Grontmij Carlbro PRI2100 0903-088	Trailer	3/4	4-way segmented	-	-	-

Appendix B Example photographs



Figure B.1 Dynatrest 8002 FWD



Figure B.2 Dynatrest 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 = CI 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 = CI 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	691.8	0.3%	73	62	55	48	41	36	23	0.6	0.4	0.5	0.7	0.7	0.9	0.7
	5	670.1	0.2%	514	417	253	146	82	49	33	1.2	1.2	0.7	0.5	0.5	0.3	0.6
	8	673.6	0.3%	253	224	176	131	92	65	34	1.0	0.5	0.5	0.3	0.7	0.8	0.5
	13	682.4	0.3%	112	113	95	80	64	55	29	0.7	0.5	0.6	0.6	0.5	0.5	0.8
2	2	687.5	0.2%	73	62	55	49	41	35	24	0.4	0.3	0.1	0.2	0.2	0.2	0.2
	5	665.4	0.4%	509	417	255	147	80	48	32	1.2	1.4	0.7	0.6	1.1	1.4	0.4
	8	667.0	0.3%	254	224	177	131	94	66	35	0.6	0.4	0.4	0.3	0.3	0.3	0.2
	13	679.4	0.2%	108	109	94	78	64	51	30	2.1	0.2	0.3	0.4	0.2	0.2	0.9

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	721.5	0.4%	68	59	52	46	40	33	22	0.9	0.2	0.2	0.3	0.4	0.2	0.2
	5	715.9	0.4%	501	404	252	149	86	52	35	1.1	0.7	0.6	0.4	0.3	0.5	0.4
	8	715.4	0.5%	243	214	169	127	92	64	33	0.7	0.4	0.3	0.5	0.1	0.4	0.3
	13	698.5	0.3%	114	102	88	74	61	47	30	0.6	0.4	0.3	0.2	0.2	0.5	0.5
2	2	712.1	0.7%	73	59	53	46	42	33	21	1.5	0.2	0.4	0.3	1.3	0.2	0.6
	5	711.6	0.3%	503	403	252	149	86	54	35	1.4	0.7	0.4	0.4	0.3	1.0	0.7
	8	709.5	0.3%	243	213	169	128	92	65	33	0.8	0.6	0.6	0.5	0.4	0.4	0.5
	13	710.1	0.9%	111	101	87	74	61	47	28	0.8	0.4	0.3	0.5	0.6	0.2	0.2

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	665.0	0.5%	67	52	47	42	36	30	22	0.6	0.3	0.4	0.8	0.2	0.4	1.1
	5	650.4	0.7%	470	373	238	144	87	50	32	1.3	1.0	0.6	0.5	0.3	0.2	0.7
	8	678.1	0.8%	217	188	150	114	83	58	30	1.3	0.5	0.6	0.3	0.4	0.5	0.3
	13	707.2	0.5%	92	83	73	62	51	40	24	0.2	0.3	0.5	0.3	0.5	0.2	1.0
2	2	700.9	0.6%	65	52	47	41	36	30	21	0.8	0.3	0.3	0.7	0.6	0.4	0.6
	5	669.9	0.2%	478	376	239	144	89	52	34	1.7	1.1	0.9	0.7	0.6	0.5	0.5
	8	690.1	0.3%	224	193	154	116	85	58	29	1.3	0.8	0.8	0.7	0.6	0.5	0.4
	13	738.2	0.6%	93	81	71	59	49	40	23	1.2	0.2	0.3	0.2	0.2	0.4	0.5

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	739.3	0.3%	76	65	56	50	44	36	24	0.3	0.3	0.1	0.1	0.3	0.2	0.2
	5	717.5	0.2%	513	419	251	149	81	47	29	0.7	0.5	0.4	0.3	0.3	0.4	0.2
	8	730.0	0.2%	263	228	178	134	94	66	32	0.4	0.4	0.3	0.2	0.2	0.2	0.2
	13	741.2	0.2%	121	110	96	81	64	51	29	0.2	0.2	0.5	0.5	0.1	0.2	0.1
2	2	745.8	0.3%	74	63	56	50	42	35	23	0.5	0.2	0.3	0.9	0.2	0.1	0.5
	5	723.4	0.3%	519	413	251	148	80	48	28	1.3	1.2	0.5	0.4	0.2	0.2	0.2
	8	735.5	0.2%	258	223	175	132	92	65	32	0.7	0.5	0.4	0.7	0.3	0.1	0.3
	13	747.5	0.4%	125	111	95	83	64	52	30	0.3	0.3	0.2	0.6	0.1	0.2	0.3

D.5 Machine 9

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	692.8	0.6%	74	64	56	50	42	35	24	0.5	0.2	0.4	0.3	0.4	0.3	0.2
	5	677.4	0.4%	535	423	253	149	83	51	34	1.9	1.5	0.9	0.6	0.3	0.2	0.3
	8	683.4	0.3%	262	230	177	133	95	67	35	0.5	0.3	0.2	0.2	0.2	0.1	0.1
	13	683.1	0.4%	119	109	95	80	65	50	30	0.5	2.6	0.6	1.3	1.3	2.6	0.2
2	2	689.6	0.2%	75	64	56	50	42	35	24	0.2	0.1	0.2	0.3	0.1	0.2	0.3
	5	678.7	0.5%	534	424	254	150	84	52	34	1.1	0.8	0.4	0.4	0.2	0.1	0.1
	8	681.3	0.9%	259	226	176	132	94	66	35	1.3	1.3	1.3	1.2	0.6	0.4	0.2
	13	691.0	0.3%	123	109	93	78	63	50	30	0.4	0.3	0.3	0.4	0.2	0.1	0.4

D.6 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	700.5	0.3%	71	62	55	49	41	35	23	0.3	0.1	0.2	0.1	0.2	0.1	0.2
	5	675.9	0.3%	533	411	258	147	82	53	30	1.2	2.2	0.2	2.6	1.0	0.9	5.9
	8	687.2	0.3%	256	221	176	132	93	66	34	0.5	0.4	0.4	0.3	0.2	0.2	0.2
	13	694.3	0.2%	121	109	94	79	63	51	28	0.3	0.1	0.1	0.1	0.2	0.2	0.4
2	2	700.7	0.4%	74	62	55	48	42	35	23	0.4	0.2	0.2	1.8	0.8	1.0	0.8
	5	681.6	0.3%	550	413	258	152	83	53	20	0.8	0.8	0.6	0.6	0.5	0.5	12.1
	8	695.3	0.3%	258	223	178	131	90	65	35	0.7	0.5	0.9	1.4	2.0	1.7	0.5
	13	704.9	0.5%	121	108	93	78	61	50	29	0.7	0.5	0.4	0.2	0.5	0.3	0.2
3	2	703.2	0.4%	71	60	54	46	39	34	23	0.2	0.3	0.2	1.3	0.9	0.1	0.6
	5	682.9	0.3%	475	378	242	147	83	54	31	0.7	0.6	0.2	0.3	0.4	0.4	0.2
	8	692.1	0.3%	242	212	170	129	91	66	34	0.5	0.3	0.2	0.2	0.1	0.1	0.1
	13	705.5	0.4%	121	107	91	76	61	49	29	0.2	0.1	0.1	0.1	0.1	0.1	0.1
4	2	707.4	0.4%	73	61	55	48	40	34	23	0.2	0.3	0.3	0.2	0.1	0.1	0.2
	5	681.7	0.4%	520	406	259	152	84	55	32	0.7	0.7	0.6	0.6	0.3	0.4	0.8
	8	695.2	0.4%	258	224	178	134	93	67	33	0.7	0.4	0.2	0.4	0.2	0.6	0.2
	13	696.7	0.6%	123	107	93	79	63	51	29	0.3	0.4	0.2	0.1	0.2	0.2	0.1

D.7 Machine 11

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	770.4	0.2%	76	63	57	50	43	36	24	0.1	0.1	0.4	0.8	0.2	0.2	0.2
	5	749.1	0.2%	530	409	251	147	83	48	31	0.5	0.6	0.3	0.3	0.3	0.3	0.4
	8	759.7	0.1%	262	224	176	132	96	66	33	0.3	0.2	0.3	0.2	0.4	0.1	0.2
	13	771.5	0.2%	125	118	96	80	69	52	29	0.2	0.4	0.1	0.1	0.7	0.2	0.2
2	2	766.7	0.2%	75	64	56	49	42	35	21	0.4	0.2	0.2	0.2	0.3	0.3	0.5
	5	743.3	0.2%	558	418	255	148	84	50	30	0.8	0.9	0.7	0.4	0.6	0.5	0.9
	8	757.7	0.2%	261	225	177	130	93	66	33	0.5	0.6	0.6	0.3	0.4	0.3	0.5
	13	763.3	0.1%	123	111	96	81	66	53	31	0.2	0.2	0.4	0.1	0.5	0.3	0.1

D.8 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	714.1	0.5%	77	64	57	49	43	36	24	0.6	0.3	0.3	0.3	0.2	0.2	0.2
	5	715.6	0.3%	537	415	259	149	85	51	31	4.9	1.6	1.0	0.5	0.5	0.4	0.6
	8	720.7	0.7%	263	226	181	135	97	69	36	1.8	1.5	1.2	0.9	0.7	0.6	0.5
	13	704.7	0.5%	126	112	98	81	66	53	29	0.9	0.6	0.8	0.5	0.4	0.4	0.4
2	2	709.1	0.6%	77	65	58	50	44	36	25	0.3	0.3	0.3	0.3	0.2	0.2	0.1
	5	717.8	0.3%	534	415	263	152	86	49	32	1.4	1.0	0.6	0.5	0.3	0.4	0.6
	8	725.1	0.4%	264	230	182	135	97	68	35	1.5	1.2	1.0	0.7	0.5	0.6	0.4
	13	702.3	0.5%	125	113	97	81	66	52	30	0.7	0.5	0.5	0.5	0.6	0.3	0.3

D.9 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	676.6	0.3%	73	62	55	48	42	34	23	0.4	0.4	0.4	0.3	0.4	0.4	0.4
	5	658.0	0.2%	509	405	254	147	84	50	34	0.6	0.5	0.3	0.3	0.2	0.2	0.3
	8	667.3	0.3%	256	221	175	130	94	65	34	0.3	0.2	0.2	0.2	0.2	0.2	0.2
	13	674.0	0.2%	118	107	92	77	63	50	28	0.2	0.2	0.2	0.2	0.2	0.5	0.3
2	2	680.1	0.2%	71	62	55	48	42	34	23	0.2	0.1	0.1	0.1	0.3	0.2	0.3
	5	660.5	0.3%	505	406	253	149	86	51	33	0.8	0.5	0.3	0.3	0.5	0.2	0.3
	8	669.6	0.2%	255	221	174	129	94	65	33	0.6	0.4	0.2	0.3	0.5	0.1	0.2
	13	678.3	0.2%	121	108	92	76	64	51	30	0.5	0.2	0.2	0.3	0.3	0.4	0.8

D.10 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	712.2	0.2%	72	63	55	49	43	34	23	0.6	0.1	0.5	0.1	0.5	0.1	0.5
	5	691.6	0.1%	582	402	246	142	83	48	31	1.6	0.4	0.6	0.7	0.9	0.1	0.3
	8	700.6	0.1%	260	225	178	132	95	65	34	0.4	0.3	0.6	0.9	1.2	0.4	0.0
	13	704.6	0.1%	120	106	97	81	63	52	30	0.4	0.3	0.3	0.3	0.4	0.6	0.4
2	2	712.6	0.2%	72	64	55	49	42	34	24	0.3	0.5	0.1	0.5	0.1	0.1	0.0
	5	692.3	0.2%	573	410	255	149	84	48	32	1.6	0.6	0.4	0.4	0.9	0.3	0.6
	8	702.2	0.2%	259	225	177	132	94	65	33	0.4	0.3	0.4	0.4	0.2	0.4	0.5
	13	706.5	0.1%	125	112	96	79	64	50	29	0.5	0.5	0.5	0.1	0.3	0.4	0.5

D.11 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	702.4	0.1%	74	64	58	50	44	35	24	1.0	0.9	0.9	0.9	0.8	0.8	0.8
	5	687.1	0.1%	528	420	256	147	86	46	31	0.4	2.2	0.4	0.3	0.6	0.5	1.1
	8	694.7	0.1%	258	224	178	131	95	66	33	0.2	0.4	0.2	0.2	0.1	0.9	0.2
	13	695.7	0.2%	120	111	97	79	64	48	27	0.3	0.3	1.0	0.1	0.5	0.9	0.4
2	2	701.9	0.2%	72	64	57	50	40	36	24	0.2	0.2	0.3	0.4	0.6	0.5	0.3
	5	684.4	0.1%	527	408	253	145	84	47	31	0.3	0.7	0.5	0.4	0.3	0.5	0.5
	8	693.0	0.1%	258	222	177	131	94	64	34	0.2	0.5	0.2	0.2	0.2	0.2	0.5
	13	695.6	0.2%	120	109	95	78	65	50	29	0.2	0.2	0.1	0.2	0.4	0.4	0.6

D.12 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	687.7	0.2%	74	62	57	49	39	36	23	0.1	0.1	0.2	0.1	0.3	0.2	0.2
	5	669.8	0.4%	525	415	254	149	83	51	33	1.1	0.8	0.2	0.7	0.3	0.7	0.3
	8	674.6	0.4%	255	224	177	132	95	66	33	0.3	0.5	0.3	0.1	0.2	0.4	0.2
	13	678.4	0.5%	117	108	93	78	64	50	29	0.2	0.2	0.2	0.2	0.5	0.4	0.3
2	2	681.6	0.7%	72	62	56	49	42	35	22	0.4	0.2	0.2	0.2	0.3	0.2	0.2
	5	665.8	0.4%	537	411	253	148	84	50	33	0.6	0.4	0.3	0.2	0.3	0.1	0.3
	8	674.5	0.3%	253	220	174	129	93	66	33	0.5	0.4	0.3	0.2	0.3	0.4	0.3
	13	677.1	0.6%	119	107	93	77	64	50	29	0.4	0.4	0.1	0.2	0.3	0.1	0.2

D.13 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	703.5	0.2%	74	60	53	47	40	33	23	0.5	0.3	0.3	0.3	0.5	0.5	0.5
	5	696.9	0.2%	511	400	252	151	91	55	40	0.5	1.5	0.9	0.7	0.5	0.5	0.8
	8	690.9	0.2%	247	212	167	126	91	63	35	0.6	0.3	0.4	0.5	0.4	0.3	0.8
	13	698.7	0.3%	115	102	88	75	62	47	28	1.2	0.5	0.5	0.8	0.6	0.6	0.6
2	2	696.0	0.2%	72	59	53	47	40	32	22	0.5	0.3	0.5	0.7	0.7	0.7	0.6
	5	699.6	0.3%	510	406	255	153	91	55	38	1.5	1.6	1.1	0.5	0.8	0.7	0.7
	8	691.2	0.2%	245	216	170	128	92	64	34	0.3	0.2	0.4	0.5	0.5	0.5	0.1
	13	705.9	0.2%	114	102	88	74	61	47	28	0.6	0.5	0.6	1.4	1.7	0.9	0.9

D.14 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	717.7	0.5%	64	59	52	46	40	33	22	1.4	0.5	0.5	0.4	0.2	0.2	0.5
	5	703.8	0.7%	507	403	253	149	87	65	36	3.7	3.0	1.8	1.2	0.6	0.7	0.6
	8	714.9	0.5%	248	214	169	127	92	68	33	2.4	1.1	0.7	0.8	0.5	0.8	0.2
	13	725.8	0.5%	104	104	90	75	62	50	28	1.5	0.5	0.4	0.4	0.3	0.6	0.3
2	2	721.7	0.4%	61	59	52	47	40	33	22	1.0	0.2	0.2	0.2	0.5	0.4	0.1
	5	720.0	0.3%	478	403	245	149	87	58	36	2.0	1.2	0.9	0.5	0.3	0.3	0.3
	8	712.4	1.1%	247	217	172	129	92	67	33	2.7	2.0	1.7	1.3	1.0	1.0	0.4
	13	723.2	0.3%	110	102	87	73	60	48	27	0.5	0.3	0.7	0.2	0.9	1.2	0.4

D.15 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	728.0	0.1%	65	57	51	45	38	31	21	0.8	0.1	0.1	0.1	0.1	0.2	0.2
	5	714.9	0.2%	538	386	241	143	83	55	35	1.1	0.4	0.7	0.5	0.4	0.5	0.2
	8	723.1	0.2%	238	208	165	124	87	62	31	0.8	0.9	0.9	0.7	0.6	0.3	0.2
	13	711.7	0.1%	111	101	87	74	60	47	27	0.5	0.2	0.2	0.3	0.1	0.2	0.3
2	2	706.6	0.2%	67	58	52	46	39	32	21	0.5	0.1	0.1	0.1	0.1	0.1	0.1
	5	697.6	0.2%	527	403	252	151	87	55	35	0.7	0.6	0.2	0.3	0.2	0.2	0.2
	8	705.4	0.2%	243	212	168	127	89	63	32	0.4	0.5	0.5	0.3	0.3	0.2	0.2
	13	694.4	0.3%	113	101	88	75	59	48	28	0.4	0.2	0.4	0.5	0.4	0.1	0.1
3	2	738.8	0.2%	63	55	50	43	37	31	21	0.2	0.2	0.2	0.3	0.1	0.4	0.3
	5	719.7	0.2%	470	376	242	151	90	60	34	1.0	0.4	0.3	0.8	0.3	0.3	1.0
	8	724.6	0.6%	228	200	159	121	86	64	33	0.3	0.5	0.3	0.5	0.4	0.3	0.2
	13	720.0	0.3%	109	99	85	71	57	47	30	0.6	0.6	0.3	0.5	0.7	0.2	0.4

D.16 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	712.2	0.6%	75	68	62	53	46	40	26	0.5	0.4	0.3	0.4	0.4	0.3	0.3
	5	720.6	0.8%	540	430	279	153	91	54	33	1.1	0.7	0.4	0.2	0.2	0.2	0.2
	8	717.3	0.5%	271	237	192	138	103	73	36	1.0	0.6	0.4	0.4	0.3	0.3	0.2
	13	720.5	0.6%	130	117	103	83	70	57	33	0.9	0.2	0.3	0.2	0.4	0.1	0.1
2	2	680.7	0.5%	74	67	60	52	45	39	26	1.1	0.1	0.1	0.2	0.1	0.1	0.1
	5	686.3	0.6%	496	397	263	151	93	56	31	1.4	1.0	0.7	0.4	0.2	0.2	0.2
	8	686.2	0.6%	255	226	185	133	101	72	36	0.5	0.4	0.3	0.3	0.3	0.2	0.1
	13	684.3	0.9%	126	114	101	81	68	56	35	0.3	0.3	0.3	0.3	0.3	0.3	0.2

D.17 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	733.9	0.3%	69	59	53	47	40	33	22	0.2	0.2	0.3	0.1	0.1	0.1	0.1
	5	711.7	0.2%	509	417	258	154	84	52	36	1.1	0.8	0.5	0.5	0.4	0.2	0.2
	8	717.6	0.2%	247	216	172	129	91	63	34	0.6	0.2	0.4	0.2	0.1	0.2	0.1
	13	729.9	0.2%	116	103	89	74	60	47	27	0.7	0.2	0.1	0.2	0.1	0.1	0.1
2	2	734.3	0.2%	71	59	53	46	39	32	22	0.5	0.1	0.2	0.4	0.1	0.1	0.1
	5	712.4	0.2%	502	399	255	152	84	53	36	1.9	0.9	0.8	0.4	0.3	0.3	0.4
	8	720.2	0.3%	245	215	171	128	90	63	33	1.2	1.4	0.2	0.4	0.1	0.2	0.2
	13	730.4	0.2%	120	106	91	75	60	47	25	0.6	0.2	0.2	0.2	0.4	0.5	0.4

D.18 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	702.0	1.3%	72	62	55	50	43	38	22	0.3	0.3	0.2	0.2	0.2	0.2	0.2
	5	696.6	1.0%	525	408	258	156	90	58	33	1.4	0.9	0.5	0.3	0.3	0.5	0.4
	8	696.6	0.7%	251	219	175	134	97	70	33	0.5	0.5	0.4	0.3	0.3	0.2	0.3
	13	682.5	1.5%	120	109	95	82	67	55	29	0.3	0.3	0.2	0.2	0.1	0.1	0.2
2	2	711.4	0.8%	71	62	55	51	43	38	23	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	5	712.0	1.0%	547	414	263	159	92	58	32	1.4	1.0	0.7	0.5	0.5	0.3	0.4
	8	716.1	0.9%	252	220	176	134	97	70	33	0.4	0.4	0.3	0.3	0.3	0.2	0.3
	13	713.1	0.9%	121	109	94	81	66	55	30	0.4	0.3	0.3	0.3	0.3	0.3	0.2

D.19 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	707.7	0.3%	71	62	55	49	41	36	24	0.6	0.4	0.3	0.6	0.2	1.0	0.3
	5	668.3	0.1%	536	390	247	148	85	52	32	1.5	1.4	1.5	2.1	1.9	1.8	2.3
	8	689.3	0.3%	246	216	170	131	92	66	33	0.7	0.5	0.4	0.9	0.6	1.0	0.3
	13	710.8	0.3%	115	102	89	75	59	48	26	1.1	0.3	0.2	0.4	0.4	0.3	0.2
2	2	700.9	0.3%	71	61	54	48	41	35	23	0.4	0.2	0.6	0.4	0.3	0.4	0.4
	5	668.8	0.3%	523	412	259	153	85	53	34	0.9	0.4	0.5	0.3	0.8	0.6	0.5
	8	684.7	0.1%	251	220	173	129	94	66	34	0.6	0.6	0.5	0.3	0.5	0.2	0.4
	13	712.5	0.2%	114	103	89	75	61	49	27	0.5	0.3	0.2	0.5	0.2	0.7	0.7

D.20 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	707.8	0.4%	70	60	54	47	40	33	22	0.5	0.2	0.1	0.1	0.2	0.2	0.1
	5	703.3	0.4%	515	393	243	141	79	47	32	1.4	0.7	0.4	0.4	0.3	0.6	0.5
	8	701.4	0.3%	252	218	172	127	91	63	32	0.5	0.3	0.2	0.3	0.3	0.4	0.4
	13	706.4	0.4%	116	104	90	75	62	49	28	0.9	0.8	0.3	0.3	0.5	0.2	0.3
2	2	712.2	0.3%	71	61	54	47	41	33	23	0.4	0.3	0.2	0.2	0.4	0.2	0.3
	5	702.7	0.2%	492	395	245	143	82	48	31	1.1	0.4	0.3	0.3	0.4	0.4	0.3
	8	706.7	0.3%	251	217	171	126	91	63	32	0.4	0.5	0.3	0.2	0.3	0.3	0.1
	13	708.9	0.4%	121	109	95	78	64	51	30	0.5	0.3	0.3	0.4	0.3	0.4	0.5

D.21 Machine 42

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	710.4	0.1%	72	62	55	48	41	34	23	0.4	0.1	0.2	0.1	0.1	0.2	0.3
	5	703.2	0.1%	509	407	249	145	81	50	32	0.9	0.3	0.1	0.2	0.2	0.2	0.2
	8	705.4	0.1%	252	219	173	129	91	64	32	0.5	0.2	0.2	0.1	0.1	0.1	0.1
	13	709.3	0.1%	119	108	92	77	62	49	28	0.5	0.1	0.2	0.2	0.1	0.2	0.2
2	2	711.4	0.1%	71	62	55	48	40	34	23	0.1	0.1	0.2	0.1	0.3	0.1	0.2
	5	701.6	0.4%	515	409	255	149	82	51	33	0.8	0.5	0.3	0.3	0.3	0.3	0.3
	8	708.0	0.2%	252	220	174	130	92	65	33	0.3	0.2	0.2	0.1	0.1	0.2	0.2
	13	710.9	0.2%	121	110	95	79	63	51	31	0.2	0.1	0.1	0.1	0.1	0.3	0.1

D.22 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	732.6	0.4%	75	63	56	50	43	35	25	0.6	0.3	0.5	0.2	0.2	0.6	0.3
	5	695.2	0.4%	529	396	252	149	83	47	27	1.4	0.8	0.6	0.6	0.6	0.4	0.5
	8	720.6	0.4%	256	220	174	131	93	64	34	0.9	0.5	0.6	0.6	0.3	0.2	1.1
	13	737.5	0.2%	116	102	87	74	61	49	28	0.2	0.4	0.2	0.2	0.1	0.3	0.1
2	2	731.0	0.3%	75	63	56	50	43	36	25	2.1	0.2	0.2	0.2	0.4	0.3	0.1
	5	692.4	0.3%	544	405	258	152	85	48	27	1.3	1.0	0.6	0.5	0.4	0.3	0.1
	8	716.9	0.4%	258	223	176	132	93	66	31	0.7	0.6	0.7	0.6	0.6	0.4	0.5
	13	725.6	0.3%	115	102	87	74	61	48	28	0.5	0.3	0.3	0.3	0.2	0.1	0.1

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	<i>0.994</i>	<i>0.980</i>	<i>0.989</i>	<i>0.997</i>	<i>1.011</i>	<i>0.999</i>	<i>0.988</i>	<i>0.994</i>	<i>0.016</i>	<i>0.009</i>	<i>0.009</i>	<i>0.013</i>	<i>0.020</i>	<i>0.018</i>	<i>0.035</i>	<i>0.017</i>
	2	Y	0.989	0.980	0.992	0.997	1.008	0.995	0.974	0.991	0.016	0.005	0.011	0.012	0.022	0.019	0.022	0.015
	3	Y	0.995	0.985	0.995	0.998	1.011	1.001	0.992	0.997	0.018	0.006	0.011	0.009	0.016	0.015	0.022	0.014
	4	N	<i>0.993</i>	<i>0.982</i>	<i>0.992</i>	<i>1.001</i>	<i>1.008</i>	<i>1.000</i>	<i>0.974</i>	<i>0.993</i>	<i>0.010</i>	<i>0.006</i>	<i>0.010</i>	<i>0.012</i>	<i>0.014</i>	<i>0.022</i>	<i>0.037</i>	<i>0.016</i>
5	1	N	<i>1.053</i>	<i>1.052</i>	<i>1.046</i>	<i>1.040</i>	<i>1.026</i>	<i>1.031</i>	<i>1.035</i>	<i>1.040</i>	<i>0.018</i>	<i>0.019</i>	<i>0.015</i>	<i>0.020</i>	<i>0.023</i>	<i>0.028</i>	<i>0.058</i>	<i>0.026</i>
	2	Y	1.053	1.041	1.045	1.038	1.020	1.021	0.993	1.030	0.015	0.015	0.025	0.025	0.027	0.036	0.053	0.028
	3	Y	1.054	1.036	1.034	1.029	1.016	1.029	0.995	1.028	0.020	0.010	0.013	0.016	0.021	0.029	0.037	0.021
	4	N	<i>1.049</i>	<i>1.039</i>	<i>1.042</i>	<i>1.032</i>	<i>1.023</i>	<i>1.019</i>	<i>1.034</i>	<i>1.034</i>	<i>0.033</i>	<i>0.013</i>	<i>0.018</i>	<i>0.018</i>	<i>0.024</i>	<i>0.035</i>	<i>0.045</i>	<i>0.027</i>
6	1	N	<i>1.015</i>	<i>1.039</i>	<i>1.030</i>	<i>1.030</i>	<i>1.008</i>	<i>1.026</i>	<i>0.973</i>	<i>1.017</i>	<i>0.023</i>	<i>0.018</i>	<i>0.025</i>	<i>0.030</i>	<i>0.034</i>	<i>0.022</i>	<i>0.043</i>	<i>0.028</i>
	2	Y	1.002	1.034	1.022	1.021	1.000	1.019	0.959	1.008	0.018	0.028	0.026	0.035	0.042	0.042	0.044	0.034
	3	Y	1.002	1.032	1.024	1.019	1.002	1.016	0.968	1.009	0.019	0.022	0.023	0.030	0.036	0.029	0.040	0.028
	4	N	<i>1.006</i>	<i>1.032</i>	<i>1.026</i>	<i>1.023</i>	<i>0.997</i>	<i>1.016</i>	<i>0.960</i>	<i>1.009</i>	<i>0.017</i>	<i>0.016</i>	<i>0.019</i>	<i>0.022</i>	<i>0.033</i>	<i>0.031</i>	<i>0.038</i>	<i>0.025</i>
	5	N	<i>1.002</i>	<i>1.026</i>	<i>1.022</i>	<i>1.022</i>	<i>0.997</i>	<i>1.014</i>	<i>0.966</i>	<i>1.007</i>	<i>0.015</i>	<i>0.015</i>	<i>0.014</i>	<i>0.021</i>	<i>0.026</i>	<i>0.017</i>	<i>0.035</i>	<i>0.021</i>
	6	N	<i>0.996</i>	<i>1.019</i>	<i>1.015</i>	<i>1.016</i>	<i>0.992</i>	<i>1.002</i>	<i>0.965</i>	<i>1.001</i>	<i>0.012</i>	<i>0.011</i>	<i>0.011</i>	<i>0.014</i>	<i>0.020</i>	<i>0.023</i>	<i>0.025</i>	<i>0.016</i>
8	1	N	<i>0.955</i>	<i>0.957</i>	<i>0.963</i>	<i>0.956</i>	<i>0.977</i>	<i>0.979</i>	<i>1.017</i>	<i>0.972</i>	<i>0.027</i>	<i>0.010</i>	<i>0.014</i>	<i>0.020</i>	<i>0.028</i>	<i>0.040</i>	<i>0.065</i>	<i>0.029</i>
	2	Y	0.942	0.952	0.966	0.956	0.982	0.989	1.021	0.972	0.024	0.016	0.016	0.022	0.029	0.040	0.065	0.030
	3	Y	0.940	0.955	0.964	0.961	0.982	0.992	1.040	0.976	0.029	0.013	0.022	0.028	0.036	0.050	0.080	0.037
	4	N	<i>0.945</i>	<i>0.958</i>	<i>0.970</i>	<i>0.964</i>	<i>0.989</i>	<i>0.999</i>	<i>1.029</i>	<i>0.979</i>	<i>0.022</i>	<i>0.011</i>	<i>0.015</i>	<i>0.020</i>	<i>0.025</i>	<i>0.043</i>	<i>0.060</i>	<i>0.028</i>
9	1	N	<i>0.973</i>	<i>0.976</i>	<i>0.989</i>	<i>0.985</i>	<i>0.990</i>	<i>0.985</i>	<i>0.956</i>	<i>0.979</i>	<i>0.018</i>	<i>0.008</i>	<i>0.012</i>	<i>0.013</i>	<i>0.013</i>	<i>0.011</i>	<i>0.013</i>	<i>0.012</i>
	2	Y	0.975	0.980	0.990	0.984	0.994	0.984	0.955	0.980	0.022	0.023	0.013	0.014	0.015	0.012	0.014	0.016
	3	Y	0.974	0.970	0.988	0.978	0.989	0.986	0.960	0.978	0.022	0.013	0.013	0.013	0.015	0.015	0.022	0.016
	4	N	<i>0.967</i>	<i>0.972</i>	<i>0.993</i>	<i>0.982</i>	<i>0.995</i>	<i>0.990</i>	<i>0.960</i>	<i>0.980</i>	<i>0.029</i>	<i>0.010</i>	<i>0.011</i>	<i>0.011</i>	<i>0.011</i>	<i>0.011</i>	<i>0.014</i>	<i>0.014</i>

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
10	1	N	0.974	0.990	0.984	0.985	1.006	0.994	1.004	0.991	0.015	0.006	0.008	0.006	0.012	0.013	0.011	0.010
	2	Y	0.981	0.987	0.987	0.987	1.008	0.994	1.006	0.993	0.014	0.006	0.007	0.012	0.007	0.022	0.022	0.013
	3	Y	0.977	0.991	0.988	0.989	1.011	1.000	1.011	0.995	0.013	0.004	0.005	0.006	0.011	0.012	0.016	0.009
	4	N	0.981	0.994	0.992	0.989	1.011	1.000	0.995	0.995	0.012	0.007	0.005	0.006	0.008	0.011	0.011	0.009
	5	N	0.983	0.991	0.990	0.990	1.011	0.987	1.007	0.994	0.010	0.008	0.011	0.011	0.021	0.013	0.020	0.013
	6	N	0.986	0.994	0.993	0.997	1.013	1.000	1.008	0.999	0.013	0.008	0.007	0.013	0.022	0.013	0.024	0.014
11	1	N	0.955	0.984	0.987	0.992	0.991	0.990	1.012	0.987	0.027	0.015	0.018	0.021	0.030	0.026	0.063	0.029
	2	Y	0.956	0.982	0.991	0.993	0.998	0.997	1.016	0.990	0.038	0.016	0.017	0.018	0.019	0.025	0.053	0.026
	3	Y	0.960	0.986	0.990	0.991	0.996	0.996	1.020	0.991	0.026	0.021	0.019	0.021	0.024	0.028	0.040	0.026
	4	N	0.963	0.979	0.986	0.983	0.993	0.988	0.995	0.984	0.026	0.014	0.023	0.025	0.023	0.038	0.058	0.030
13	1	N	0.973	0.978	0.973	0.986	0.981	0.975	0.996	0.980	0.017	0.010	0.007	0.007	0.009	0.012	0.027	0.013
	2	Y	0.968	0.974	0.967	0.980	0.973	0.975	0.975	0.973	0.025	0.012	0.011	0.011	0.009	0.014	0.033	0.016
	3	Y	0.965	0.973	0.965	0.980	0.973	0.981	0.988	0.975	0.014	0.009	0.010	0.011	0.010	0.012	0.024	0.013
	4	N	0.960	0.974	0.969	0.979	0.979	0.982	0.972	0.974	0.016	0.007	0.007	0.010	0.013	0.022	0.032	0.015
15	1	N	1.001	0.996	0.998	0.998	0.984	1.001	0.990	0.995	0.020	0.008	0.009	0.008	0.008	0.009	0.013	0.011
	2	Y	1.002	0.996	0.999	0.999	0.987	1.006	0.988	0.997	0.026	0.014	0.012	0.009	0.009	0.011	0.015	0.014
	3	Y	1.002	0.998	0.999	0.999	0.989	1.008	0.994	0.999	0.018	0.012	0.012	0.011	0.013	0.014	0.018	0.014
	4	N	0.996	0.994	0.998	0.999	0.989	1.008	0.990	0.996	0.012	0.007	0.009	0.009	0.012	0.012	0.022	0.012
16	1	N	0.984	0.982	0.980	0.985	0.993	1.013	0.990	0.990	0.026	0.018	0.013	0.019	0.016	0.028	0.033	0.022
	2	Y	0.987	0.981	0.986	0.988	0.999	1.015	0.990	0.992	0.018	0.016	0.014	0.014	0.019	0.025	0.017	0.018
	3	Y	0.980	0.983	0.984	0.984	0.998	1.012	1.009	0.993	0.013	0.011	0.010	0.015	0.020	0.021	0.026	0.017
	4	N	0.980	0.982	0.987	0.985	1.002	1.017	0.991	0.992	0.046	0.013	0.016	0.021	0.028	0.035	0.030	0.027
28	1	N	0.993	0.964	0.956	0.984	0.977	1.003	1.044	0.989	0.013	0.018	0.028	0.016	0.023	0.035	0.037	0.024
	2	Y	0.993	0.963	0.961	0.983	0.988	0.991	1.025	0.986	0.017	0.021	0.023	0.019	0.025	0.039	0.039	0.026
	3	Y	0.982	0.969	0.966	0.986	0.983	1.003	1.022	0.987	0.011	0.016	0.021	0.018	0.024	0.039	0.043	0.025
	4	N	0.990	0.964	0.960	0.992	0.972	0.997	1.059	0.991	0.016	0.026	0.038	0.007	0.041	0.029	0.044	0.029

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
30	1	N	1.005	0.998	0.996	1.001	1.001	0.998	1.006	1.001	0.010	0.012	0.008	0.007	0.013	0.017	0.018	0.012
	2	Y	0.998	0.993	0.995	0.996	0.999	0.990	1.006	0.997	0.013	0.007	0.006	0.010	0.012	0.015	0.030	0.013
	3	Y	0.990	0.994	0.994	0.996	0.995	0.998	0.997	0.995	0.016	0.013	0.012	0.013	0.014	0.016	0.012	0.014
	4	N	0.995	0.992	0.993	1.000	1.001	1.001	1.014	0.999	0.018	0.009	0.006	0.009	0.010	0.014	0.030	0.014
	5	N	1.002	0.987	0.995	0.996	0.995	0.998	1.006	0.997	0.007	0.013	0.008	0.012	0.014	0.019	0.027	0.014
	6	N	1.008	0.993	0.999	1.001	1.004	0.999	1.019	1.003	0.015	0.006	0.008	0.010	0.013	0.017	0.014	0.012
32	1	N	1.018	1.035	1.037	1.029	1.018	1.030	0.984	1.022	0.048	0.012	0.015	0.017	0.034	0.045	0.067	0.034
	2	Y	1.016	1.027	1.031	1.025	1.013	1.030	0.966	1.015	0.037	0.012	0.013	0.019	0.026	0.039	0.072	0.031
	3	Y	1.019	1.028	1.028	1.021	1.014	1.024	0.972	1.015	0.029	0.016	0.018	0.024	0.035	0.044	0.072	0.034
	4	N	1.016	1.022	1.028	1.018	1.005	1.021	0.964	1.011	0.014	0.020	0.019	0.025	0.038	0.056	0.080	0.036
	5	N	1.025	1.024	1.024	1.020	1.007	1.024	0.986	1.016	0.019	0.012	0.013	0.016	0.026	0.031	0.057	0.025
	6	N	1.022	1.021	1.024	1.019	1.006	1.029	0.987	1.015	0.028	0.012	0.016	0.020	0.032	0.045	0.066	0.031
33	1	N	1.064	1.045	1.038	1.038	1.023	0.983	0.990	1.026	0.033	0.007	0.007	0.009	0.016	0.043	0.057	0.025
	2	Y	1.061	1.044	1.040	1.040	1.024	0.982	0.991	1.026	0.015	0.009	0.013	0.014	0.026	0.066	0.050	0.027
	3	Y	1.064	1.044	1.038	1.035	1.022	0.977	0.991	1.024	0.025	0.013	0.010	0.013	0.020	0.051	0.062	0.028
	4	N	1.051	1.031	1.030	1.028	1.016	0.982	0.981	1.017	0.030	0.008	0.010	0.008	0.019	0.046	0.050	0.025
34	1	N	1.043	1.050	1.049	1.043	1.051	1.037	1.045	1.045	0.052	0.024	0.026	0.026	0.026	0.051	0.054	0.037
	2	Y	1.048	1.045	1.045	1.038	1.042	1.032	1.025	1.039	0.049	0.021	0.020	0.022	0.027	0.038	0.052	0.033
	3	Y	1.048	1.038	1.039	1.034	1.039	1.031	1.048	1.040	0.020	0.023	0.022	0.027	0.032	0.054	0.066	0.035
	4	N	1.051	1.040	1.036	1.034	1.044	1.040	1.036	1.040	0.021	0.022	0.021	0.025	0.033	0.051	0.044	0.031
36	1	N	0.959	0.918	0.901	0.941	0.906	0.898	0.927	0.921	0.029	0.026	0.016	0.032	0.032	0.043	0.063	0.035
	2	Y	1.021	0.983	0.968	1.005	0.972	0.958	0.990	0.985	0.028	0.022	0.018	0.030	0.028	0.036	0.056	0.031
	3	Y	1.022	0.986	0.969	1.006	0.975	0.967	1.004	0.990	0.022	0.025	0.019	0.035	0.027	0.046	0.061	0.034
	4	N	1.020	0.986	0.973	1.009	0.976	0.960	0.992	0.988	0.020	0.020	0.016	0.030	0.026	0.036	0.063	0.030
37	1	N	1.043	1.037	1.030	1.029	1.041	1.036	1.032	1.035	0.020	0.024	0.022	0.029	0.028	0.033	0.047	0.029
	2	Y	1.032	1.029	1.025	1.020	1.038	1.036	1.024	1.029	0.018	0.026	0.024	0.027	0.027	0.039	0.054	0.031
	3	Y	1.039	1.032	1.027	1.022	1.039	1.041	1.025	1.032	0.028	0.025	0.026	0.029	0.027	0.034	0.055	0.032
	4	N	1.028	1.028	1.022	1.020	1.038	1.038	1.008	1.026	0.027	0.024	0.023	0.027	0.023	0.037	0.067	0.032

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
38	1	N	1.018	1.014	1.003	0.973	0.984	0.942	1.034	0.995	0.015	0.011	0.012	0.016	0.016	0.023	0.010	0.015
	2	Y	1.023	1.012	1.006	0.973	0.976	0.935	1.018	0.992	0.015	0.008	0.011	0.012	0.017	0.022	0.013	0.014
	3	Y	1.020	1.018	1.009	0.978	0.979	0.938	1.036	0.997	0.016	0.009	0.012	0.014	0.017	0.019	0.014	0.014
	4	N	1.022	1.016	1.009	0.978	0.975	0.931	1.026	0.994	0.017	0.010	0.012	0.013	0.018	0.024	0.016	0.016
39	1	N	1.001	0.994	0.989	0.988	0.993	0.982	0.974	0.989	0.015	0.013	0.009	0.011	0.011	0.015	0.028	0.014
	2	Y	0.947	0.990	0.991	0.988	0.995	0.982	0.989	0.983	0.464	0.011	0.011	0.011	0.012	0.014	0.018	0.077
	3	Y	0.995	0.983	0.983	0.978	0.988	0.977	0.998	0.986	0.014	0.010	0.007	0.009	0.015	0.016	0.025	0.014
	4	N	0.992	0.977	0.978	0.972	0.981	0.972	0.967	0.977	0.023	0.017	0.015	0.017	0.018	0.015	0.029	0.019
	5	N	1.001	0.982	0.983	0.979	0.992	0.974	0.999	0.987	0.016	0.010	0.005	0.009	0.019	0.019	0.030	0.015
	6	N	0.996	0.978	0.980	0.978	0.993	0.985	1.006	0.988	0.015	0.016	0.007	0.013	0.014	0.017	0.034	0.017
40	1	N	1.019	1.027	1.031	1.033	1.032	1.046	1.046	1.034	0.020	0.010	0.015	0.019	0.016	0.019	0.022	0.017
	2	Y	1.010	1.014	1.022	1.023	1.022	1.029	1.017	1.020	0.028	0.024	0.026	0.030	0.033	0.032	0.031	0.029
	3	Y	1.005	1.017	1.021	1.026	1.026	1.035	1.043	1.025	0.020	0.010	0.013	0.017	0.017	0.020	0.034	0.019
	4	N	1.012	1.023	1.031	1.035	1.036	1.046	1.046	1.033	0.016	0.009	0.011	0.017	0.016	0.017	0.029	0.016
42	1	N	1.017	1.019	1.020	1.026	1.036	1.017	1.019	1.022	0.018	0.005	0.005	0.008	0.012	0.017	0.017	0.012
	2	Y	1.013	1.012	1.016	1.019	1.031	1.015	1.006	1.016	0.012	0.008	0.007	0.008	0.012	0.007	0.017	0.010
	3	Y	1.015	1.012	1.016	1.019	1.033	1.014	1.012	1.017	0.019	0.008	0.007	0.007	0.012	0.013	0.021	0.012
	4	N	1.010	1.009	1.016	1.019	1.033	1.021	1.006	1.016	0.010	0.005	0.007	0.009	0.011	0.011	0.023	0.011
45	1	N	0.984	1.002	0.990	0.995	0.995	1.013	1.069	1.007	0.031	0.021	0.024	0.020	0.030	0.039	0.084	0.036
	2	N	0.973	1.000	1.004	0.995	0.997	1.013	1.049	1.004	0.020	0.027	0.024	0.025	0.032	0.040	0.077	0.035
	3	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	N	0.973	1.006	1.009	1.001	1.003	1.010	1.053	1.008	0.031	0.028	0.026	0.025	0.032	0.041	0.113	0.042
	5	Y	0.986	1.006	1.016	1.009	1.011	1.022	1.099	1.021	0.025	0.026	0.021	0.027	0.033	0.048	0.103	0.040
	6	Y	0.976	1.005	1.010	1.006	1.006	1.027	1.098	1.018	0.021	0.031	0.028	0.030	0.037	0.054	0.103	0.043

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 Geophones and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
2	2	0.989	0.980	0.992	0.997	1.008	0.995	0.974	0.991	0.016	0.005	0.011	0.012	0.022	0.019	0.022	0.015	
	3	0.995	0.985	0.995	0.998	1.011	1.001	0.992	0.997	0.018	0.006	0.011	0.009	0.016	0.015	0.022	0.014	
5	2	1.053	1.041	1.045	1.038	1.020	1.021	0.993	1.030	0.015	0.015	0.025	0.025	0.027	0.036	0.053	0.028	
	3	1.054	1.036	1.034	1.029	1.016	1.029	0.995	1.028	0.020	0.010	0.013	0.016	0.021	0.029	0.037	0.021	
6	2	1.002	1.034	1.022	1.021	1.000	1.019	0.959	1.008	0.018	0.028	0.026	0.035	0.042	0.042	0.043	0.033	
	3	1.002	1.032	1.024	1.019	1.002	1.016	0.968	1.009	0.019	0.022	0.023	0.030	0.036	0.029	0.041	0.029	
8	2	0.942	0.952	0.966	0.956	0.982	0.989	1.021	0.972	0.024	0.016	0.016	0.022	0.029	0.040	0.065	0.030	
	3	0.940	0.955	0.964	0.961	0.982	0.992	1.020	0.973	0.029	0.013	0.022	0.028	0.036	0.050	0.060	0.034	Station 5 D7
9	2	0.975	0.980	0.990	0.984	0.994	0.984	0.955	0.980	0.022	0.023	0.013	0.014	0.015	0.012	0.014	0.016	
	3	0.974	0.970	0.988	0.978	0.989	0.986	0.960	0.978	0.022	0.013	0.013	0.013	0.015	0.015	0.022	0.016	
10	2	0.981	0.987	0.987	0.987	1.008	0.994	1.006	0.993	0.014	0.006	0.007	0.012	0.007	0.022	0.022	0.013	
	3	0.977	0.991	0.988	0.989	1.011	1.000	1.011	0.995	0.013	0.004	0.005	0.006	0.011	0.012	0.016	0.009	
11	2	0.956	0.982	0.991	0.993	0.998	0.997	1.016	0.990	0.038	0.016	0.017	0.018	0.019	0.025	0.053	0.026	
	3	0.960	0.986	0.990	0.991	0.996	0.996	1.020	0.991	0.026	0.021	0.019	0.021	0.024	0.028	0.040	0.026	
13	2	0.968	0.974	0.967	0.980	0.973	0.975	0.975	0.973	0.025	0.012	0.011	0.011	0.009	0.014	0.033	0.016	
	3	0.965	0.973	0.965	0.980	0.973	0.981	0.988	0.975	0.014	0.009	0.010	0.011	0.010	0.012	0.024	0.013	
15	2	1.002	0.996	0.999	0.999	0.987	1.006	0.988	0.997	0.026	0.014	0.012	0.009	0.009	0.011	0.015	0.014	
	3	1.002	0.998	0.999	0.999	0.989	1.008	0.994	0.999	0.018	0.012	0.012	0.011	0.013	0.014	0.018	0.014	
16	2	0.987	0.981	0.986	0.988	0.999	1.015	0.990	0.992	0.018	0.016	0.014	0.014	0.019	0.025	0.017	0.018	
	3	0.980	0.983	0.984	0.984	0.998	1.012	1.009	0.993	0.013	0.011	0.010	0.015	0.020	0.021	0.026	0.017	
28	2	0.993	0.963	0.961	0.983	0.988	0.991	1.025	0.986	0.017	0.021	0.023	0.019	0.025	0.039	0.039	0.026	
	3	0.982	0.969	0.966	0.986	0.983	1.003	1.022	0.987	0.011	0.016	0.021	0.018	0.024	0.039	0.043	0.025	
30	2	0.998	0.993	0.995	0.996	0.999	0.990	1.006	0.997	0.013	0.007	0.006	0.010	0.012	0.015	0.030	0.013	
	3	0.990	0.994	0.994	0.996	0.995	0.998	0.997	0.995	0.016	0.013	0.012	0.013	0.014	0.016	0.012	0.014	
32	2	1.016	1.027	1.031	1.025	1.013	1.030	0.978	1.017	0.037	0.012	0.013	0.019	0.026	0.039	0.052	0.028	Station 5 D7
	3	1.019	1.028	1.028	1.021	1.014	1.024	0.982	1.017	0.029	0.016	0.018	0.024	0.035	0.044	0.063	0.033	Station 5 D7

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophones and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
33	2	1.061	1.044	1.040	1.040	1.024	0.982	0.991	1.026	0.015	0.009	0.013	0.014	0.026	0.066	0.050	0.027	
	3	1.064	1.044	1.038	1.035	1.022	0.977	0.991	1.024	0.025	0.013	0.010	0.013	0.020	0.051	0.062	0.028	
34	2	1.048	1.045	1.045	1.038	1.042	1.032	1.025	1.039	0.049	0.021	0.020	0.022	0.027	0.038	0.052	0.033	
	3	1.048	1.038	1.039	1.034	1.039	1.031	1.048	1.040	0.020	0.023	0.022	0.027	0.032	0.054	0.066	0.035	
36	2	1.021	0.983	0.968	1.005	0.972	0.958	0.990	0.985	0.028	0.022	0.018	0.030	0.028	0.036	0.056	0.031	
	3	1.022	0.986	0.969	1.006	0.975	0.967	1.004	0.990	0.022	0.025	0.019	0.035	0.027	0.046	0.061	0.034	
37	2	1.032	1.029	1.025	1.020	1.038	1.036	1.024	1.029	0.018	0.026	0.024	0.027	0.027	0.039	0.054	0.031	
	3	1.039	1.032	1.027	1.022	1.039	1.041	1.025	1.032	0.028	0.025	0.026	0.029	0.027	0.034	0.055	0.032	
38	2	1.023	1.012	1.006	0.973	0.976	0.935	1.018	0.992	0.015	0.008	0.011	0.012	0.017	0.022	0.013	0.014	
	3	1.020	1.018	1.009	0.978	0.979	0.938	1.036	0.997	0.016	0.009	0.012	0.014	0.017	0.019	0.014	0.014	
39	2	0.947	0.990	0.991	0.988	0.995	0.982	0.989	0.983	0.015	0.011	0.011	0.011	0.012	0.014	0.018	0.013	
	3	0.995	0.983	0.983	0.978	0.988	0.977	0.998	0.986	0.014	0.010	0.007	0.009	0.015	0.016	0.025	0.014	
40	2	1.010	1.014	1.022	1.023	1.022	1.029	1.017	1.020	0.028	0.024	0.026	0.030	0.033	0.032	0.031	0.029	
	3	1.005	1.017	1.021	1.026	1.026	1.035	1.043	1.025	0.020	0.010	0.013	0.017	0.017	0.020	0.034	0.019	
42	2	1.013	1.012	1.016	1.019	1.031	1.015	1.006	1.016	0.012	0.008	0.007	0.008	0.012	0.007	0.017	0.010	
	3	1.015	1.012	1.016	1.019	1.033	1.014	1.012	1.017	0.019	0.008	0.007	0.007	0.012	0.013	0.021	0.012	
45	5	0.986	1.006	1.016	1.009	1.011	1.022	1.077	1.018	0.025	0.026	0.021	0.027	0.033	0.048	0.092	0.039	Station 5 D7
	6	0.976	1.005	1.010	1.006	1.006	1.027	1.071	1.014	0.021	0.031	0.028	0.030	0.037	0.054	0.083	0.040	Station 5 D7

Appendix F 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	Low	No data	No data	No data	
5	Dynatest HWD 8082 SN 050	Pass	Pass	Pass	Pass	Pass	High	No data	No data	No data	
6	Dynatest HWD 8082 SN 018	Pass	Pass	Pass	Pass	Pass	High	No data	Medium	High	
8	Dynatest FWD 8002 SN 028	Pass	Pass	Pass	Pass	Pass	Medium	No data	No data	No data	
9	Dynatest FWD 8002 SN 136	Pass	Pass	Pass	Pass	Pass	High	No data	No data	High	
10	Dynatest FWD 8002 SN 192	Pass	Pass	Pass	Pass	Pass	Low	No data	No data	No data	
11	Dynatest FWD 8002 SN 187	Pass	Pass	Pass	Pass	Pass	High	No data	No data	No data	
13	Dynatest HWD 8082 SN 029	Pass	Pass	Pass	Pass	Pass	Low	No data	No data	No data	
15	Dynatest FWD 8002 SN 203	Pass	Pass	Pass	Pass	Pass	High	No data	No data	High	
16	Dynatest FWD 8002 SN 214	Pass	Pass	Pass	Pass	Pass	High	No data	No data	No data	
28	Dynatest FWD 8002 SN 271	Pass	Pass	Pass	Pass	Pass	Medium	No data	No data	No data	
30	Dynatest FWD 8002 SN 173	Pass	Pass	Pass	Pass	Pass	Low	No data	No data	Not Suitable	
32	Dynatest HWD 8082 SN 069	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Low	No data	
33	Dynatest HWD 8082 SN 070	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Low	No data	
34	Dynatest HWD 8082 SN 108	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	No data	
36	Grontmij PRI 2500 0608-303	Pass	Pass	Pass	Pass	Pass	Medium	No data	Low	Low	
37	Dynatest FWD 8002 SN 352	Pass	Pass	Pass	Pass	Pass	High	Not assessed	High	No data	
38	Grontmij PRI 1500 1111-448	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Low	Low	
39	Dynatest FWD 8002 SN 388	Pass	Pass	Pass	Pass	Pass	Medium	Not assessed	Low	High	
40	Dynatest FWD 8012 SN 002	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Medium	High	
42	Dynatest HWD 8082 SN 149	Pass	Pass	Pass	Pass	Pass	Medium	Not assessed	High	No data	
45	Grontmij Carlbro PRI2100 0903-088	Pass	Pass	Pass	Pass	Fail	Pass	High	Not assessed	Not Suitable	No data

Highways England 2017 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 (FWDs and HWDs) supported by ongoing QA for the devices. In order to undertake accredited surveys, the survey devices are required to meet the mandatory criteria of the trial.

This report covers the 2017 trial run by TRL and held on the Horiba-MIRA proving ground between 26th and 27th September 2017.

Other titles from this subject area

- PPR 945** Highways England 2016 National Dynamic Plate Test device Accreditation Trial. S Brittain. 2020
- PPR 946** Highways England 2015 National Dynamic Plate Test device Accreditation Trial. S Brittain, M Militzer. 2020
- PPR 947** Highways Agency 2014 National Dynamic Plate Test device Accreditation Trial. S Brittain. 2020
- CPR 1712** Highways Agency 2013 National Falling Weight Deflectometer Accreditation Trial. S Brittain. 2013

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ISSN 2514-9652

ISBN 978-1-913246-30-3

PPR944