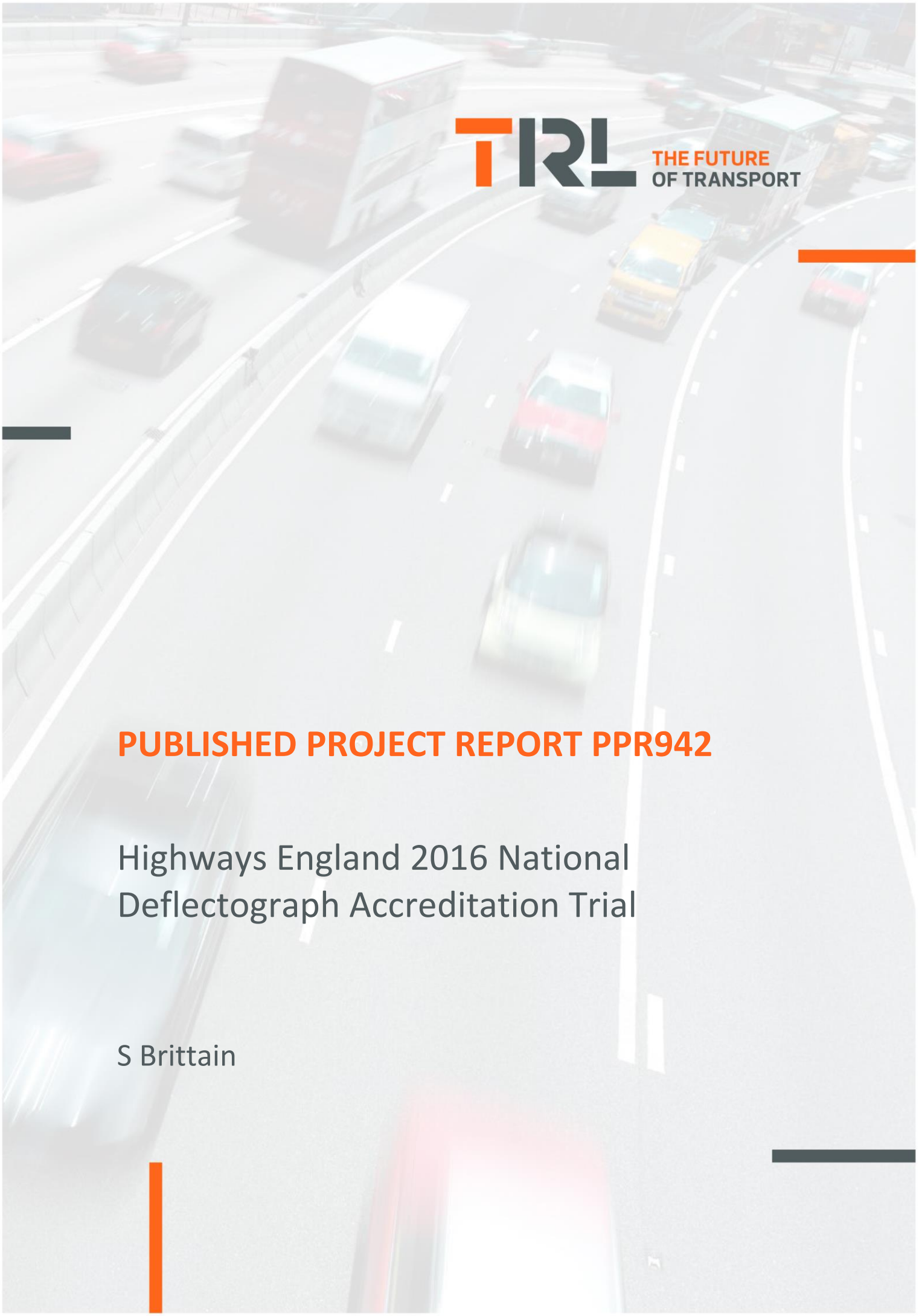

THE FUTURE OF TRANSPORT

PUBLISHED PROJECT REPORT PPR942

Highways England 2016 National Deflectograph Accreditation Trial

S Brittain

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Executive summary

Deflectograph accreditation trials are held annually by TRL on behalf of Highways England. The objective is to monitor the performance of all Deflectographs operating on UK trunk roads. By examining and monitoring the results from the machines operating on specified test sections of the reference site, the performances of:

- individual machines, and
- the whole UK fleet,

are assessed.

The 2016 trials were held during the period 1st to 3rd March 2016. The site used was the twin horizontal straights of the MIRA proving ground. This was the twenty-first year in which TRL took full responsibility for the planning and running of the trials. Ten machines attended the trial.

The format of the 2016 trial was broadly consistent with that of recent years, comprising two scheduled days of testing and one contingency day. The 2016 trial included checks on the distance calibration first added to the 2012 trial. The first day of the trial was dedicated to static inspections and calibration checks, with the second day used for the main running trials. The reserve day was used for additional assessments.

After some additional testing, all ten machines that participated in the March 2016 accreditation trial met the mandatory requirements of the trial and can therefore be considered for approval to survey Highways England's strategic road network.

All ten machines provided temperature data and these were found to be of acceptable quality.

Six machines had front axle weights that exceeded the published limits. This excess weight (on the front axle) seems to have shown no measurable effect over a number of accreditation trials. This matter was reviewed by TRL and HA following the 2004 trial. It was decided that, while revising the standard tolerances may be considered at an appropriate point in the future, for the time being the weight difference would be noted but the machines would continue to be regarded as acceptable.

One machine exceeded the rear wheel limits for the rear OS wheel. This was resolved after the trial and supplementary testing showed that the machine performed consistently before and after the change in weight.

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

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

Contents

1 Introduction

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

- individual machines, and
- the whole UK fleet,

are assessed.

The 2016 trials were held during the period 1st to 3rd March 2016. The site used was the twin horizontal straights of the MIRA proving ground which is further discussed in section 2. This was the twenty-first year in which TRL took full responsibility for the planning and running of the trials but was the fourth full trial at MIRA. Ten machines attended the trial.

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

2 Test site

2.1 Details of the test site

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

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

The trial process and the criteria used for the 2016 trial are discussed in sections 3 and 4 respectively.

2.2 Variability of NS deflections on HECP_02

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

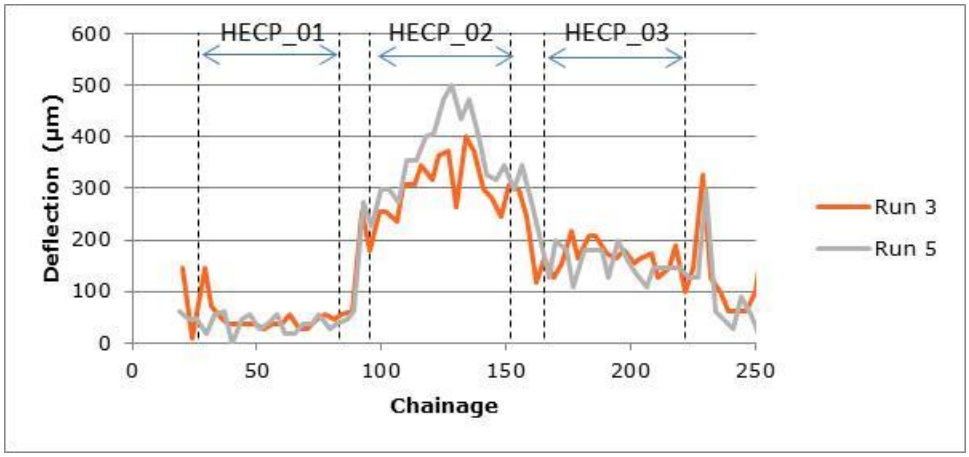

Figure 2.1 Example plot of nearside deflections for MIRA test sections observed during the transitional trial

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

Figure 2.2 Image illustrating cone positons during testing

During the analysis of the 2013 trial it was found that this approach reduced the variability of the deflections for the NS wheel path of section 2. It was therefore decided that these cones will be placed along HECP_02 for future trials in order to reduce this variability.

3 Trial format

The format of the 2016 trial was kept broadly the same as that of recent years, with two scheduled days of testing and one contingency day. The review of the accreditation trial procedure following the transitional trial recommended that checks on the distance calibrations of the machines should be included. This was incorporated into the 2012 trial and repeated in the trials since.

Each crew carried out a machine inspection in advance of the trials and a certified checklist was submitted before the machine could be included in the running trials. The advance inspections were supplemented by a spot-check inspection of one or more machines by TRL staff during the trials.

3.1 Day 1

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

On arrival, each machine was inspected followed by a measurement of the machine's wheel weights. The wheel weight values are then used in the trial software to allow corrections for rear wheel weight to be applied to the deflection data.

The operators' thermometers are collected up so that they can be compared against each other in a stabilised environment.

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

3.2 Day 2 and day 3

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

After completion of the first lap the crew are asked to perform a static calibration (the first lap of day 2 is always disregarded and is used to warm-up the machines). The machines are then cleared to conduct the main running trials. After completion of the main running trials the crews are asked to perform another static calibration.

Deflection measurements are made over the three test sections, and temperature measurements are collected from two pre-drilled holes (40mm depth) located near sections 1 and 3. The distance check involves the crews surveying a length between two cones (separated by more than 400m) and comparing the resulting data to the reference measurement of the cone separation.

The machine running order is randomly determined before testing begins, with all machines running in convoy to cover all the sections in a single circuit. Each machine is required to complete a minimum of five measurement runs. Data from the survey machines is handed

in after each run and real-time data processing enables collated measurements to be available for review as the trials proceed.

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

The Design Manual for Roads and Bridges in HD29/08 (The Highways Agency et al, 2008b) sets a maximum rate of temperature increase of 2.5ºC per hour at 40mm for deflection testing. This requirement is intended to ensure that temperature corrections used to correct deflections to a standard temperature of 20ºC stay within the validity of the equations.

Although temperature corrections are not carried out in analysing data from the accreditation trial, the temperature is monitored for sections HECP_01 and HECP_03 at 40 and 100mm depths to inform any conclusions drawn. Automatic data-loggers are used to provide a record every minute during the running period.

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

4 Criteria for acceptability and the transitional trial

4.1 Wheel weights

The running weight of a Deflectograph inevitably varies during a period of testing depending on the amount of fuel carried and the number (and weight) of crew members on board. For this reason, crews are asked to arrive with the fuel tank approximately half full and the machines are weighed with the crew who normally work the machine in their usual positions on the vehicle. The wheel weights were measured simultaneously on all four wheels using calibrated weigh-pads. The permitted weights for the vehicle plus crew are stipulated in HD 29/08 (Design Manual for Roads and Bridges, 2008) as 4275kg-4725kg on the front axle and 2857kg-3493kg on each of the rear wheel assemblies.

4.2 Deflection criteria

As discussed previously, the criteria used for the assessment of Deflectographs were reviewed during the transitional trial held in September 2011. A primary focus of this review was to determine accreditation criteria which could be used for all three of the test sections (rather than for just on the reference section as in previous trials).

These test sections cover a range of deflections, and it was found that the coefficient of variation (CoV is calculated by dividing the standard deviation by the mean) varied considerably between the sections. Therefore the approach used in previous years for the assessment of fleet variability, based on the CoV of one section with medium deflections, was not suitable for use on three test sections with a range of deflections.

Analysis of the data from the transitional trial suggested that a criterion which varied with deflection level and was based on the between Equipment standard deviation (BESD) should be used.

The criteria used for the identification of outliers used in previous years were found to be suitable for use with multiple test sections and did not need to be modified.

Therefore, the following criteria were used for this accreditation trial:

1. In order to limit the overall variability of the fleet, a restriction is placed upon the maximum between Equipment standard deviation (BESD) allowed on the three test sections (HACP_01, HACP_02 and HACP_03). The maximum BESD is dependent on the fleet mean deflection level for the section and is given in equation 4.1 below. This criterion must be met on both wheel paths of all three test sections.
2. Individual machines must fall within three times the BESD criteria of the overall mean on both wheel paths of all three test sections (HACP_01, HACP_02 and HACP_03). Any that lie between 2 and 3 times the BESD criteria will be investigated in detail to see whether their mean result was affected by any external factor, such as an inconsistent run.

$$Maximum\ BESD(\mu m) = 0.0257 \times Fleet\ mean\ deflection(\mu m) + 9.88 \qquad 4.1$$

It will be necessary to keep the criteria under review and to apply them in full consideration of the data for a particular trial and in the light of experience over several trials. There may also be circumstances when it is clear that a minor infringement on one of the section wheel paths is clearly a statistical random error not reflected as a general bias shown on other sections.

4.3 Distance criteria

The distance check is not a formal requirement for accreditation. However the need for the check had been identified during the transitional trial as a means of assisting in aligning the data and to provide an additional diagnostic tool in the event of unexpected variations in the measured deflections on the trial sections. The procedure involves setting out a marked length and asking the Deflectograph crews to record the length using their Deflectograph.

In Deflectograph data, markers are attached to the nearest deflection reading (rather than recording the elapsed distance between the starting of the recorder and the marker point). Deflection readings are spaced between three and four metres apart and therefore an error of up to 4m could be expected. The criteria used to assess the machines are given in Table 4.1.

Table 4.1 Distance Criteria

	Test Criteria
High	80% within 5m of reference
Medium	80% within 7.5m of reference
Low	80% within 10m of reference
Very Low	Otherwise

4.4 Temperature criteria

The Deflectograph operators are asked to record temperatures from pre-drilled holes on each survey lap so that the quality of their temperature data can be assessed. The pre-drilled holes are on section HACP_01 and HACP_03 and are 40mm deep.

This data is assessed by comparing the results to the reference. The criteria used to assess the machines are given in Table 4.2.

Table 4.2 Temperature Criteria

	Test Criteria
High	80% of the measurement are within 1˚C of the reference
Medium	50% of the measurement are within 1˚C of the reference
Low	15% of the measurement are within 1˚C of the reference
Very Low	Otherwise

5 Results – Inspection day (1st March 2016)

5.1 Inspections

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

5.2 Wheel weights

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

Table 5.1 Deflectograph weight distributions from 3 March 2015

Machine	Weight distribution including crew (kg)						
	Front NS	Front OS	Total Front	Rear NS	Rear OS	Total rear	Total Machine
2	2480	2630	**5110***	3055	3375	6430	11540
3	2355	2450	**4805***	3405	3380	6785	11590
5	2400	2405	**4805***	3320	3340	6660	11465
8	2220	2420	4640	3485	3240	6725	11365
9	2420	2410	**4830***	3290	3055	6345	11175
10	2335	2415	**4750***	3255	**3580***	6835	11585
12	2195	2320	4515	3430	3195	6625	11140
14	2310	2380	4690	3205	3465	6670	11360
15	2360	2580	**4940***	3420	3340	6760	11700
16	2280	2270	4550	3295	3270	6565	11115

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

Machines 2, 3, 5, 9, 10 and 15 exceeded the published front axle limits. Machines 2 and 15 have exceeded the published limit since their introduction into the fleet. However, ever since Machine 2 (and, subsequently Machine 15) was introduced, there has been no measurable effect from the heavier front axle weight. This matter was reviewed by TRL and Highways England following the 2004 trials. It was concluded that, while consideration may be given to revising the specification limits at an appropriate point in the future, for the time being the differences will be noted but the affected machines would continue to be regarded as acceptable provided that they performed satisfactorily in the dynamic tests.

Machine 10 also exceeded the published rear wheel limits for the rear OS wheel. As the rear wheels are used to apply the load to the road for the test the crew was asked to try and move weight around the Deflectograph to meet the weight limits. It was uncovered that it was not possible to rectify this issue at the trial. It was therefore decided that the machine would take part in the trial in its current (over weight) configuration and temporarily extend the load correction formula to allow for this weight. If the machine performed suitably in the main running trials (for deflection measurements) then it would be issued with a certificate stating that it had met the Deflection criteria but it is outside of the weight tolerances and therefore not suitable for testing under HD29.

The operator of Machine 10 would then be given the opportunity to amend the weight shortly after the trial and provide before and after measurements from their QA site (along

with another machine which had met the Deflection criteria at the trial). If this data (with the appropriate load corrections applied) showed consistency before and after the change in weight then an updated certificate would be issued stating that it had met the Deflection criteria and was suitable for testing under HD29 (assuming the other results are suitable).

5.3 Warm-up lap

Following the processing of data from the warm-up lap it was found that the spread of machine results was larger than the criteria. However this is typically the case when there is only data from one lap available. Bearing this in mind there was no cause to do any additional testing on this day or notify the operators of any anomalies.

5.4 Temperature probes

The operator's thermometers were collected up and the probes allowed to stabilise at the same temperature (using a bucket of water). From this testing it was identified that all but one device was within ±0.5˚C of the average (this remaining probe was within 0.6˚C of the average).

6 Results – Main trial day (2nd March 2016)

6.1 Calibrations

After the warm-up lap on the main trial day each crew carried out a static calibration of their machine. A further calibration was carried out following the main running trials. No machines were identified to TRL as not meeting the limits specified in HD29/08.

6.2 Distance check

A distance check length was set up on the track to assess the distance measurement systems on the machines. The reference length used was 406.3m. The difference between the measured length from each machine and the reference, along with the overall performance are given in Table 6.1. The differences are highlighted to indicate the performance bands given in section 4.3.

Table 6.1 Distance checks

Machine	Difference between measured length and the reference (m)					Performance band
	1	2	3	4	5	
2	0.7	2.7	1.7	0.7	0.7	High
3	0.7	1.7	1.7	1.7	0.7	High
5	2.7	3.7	2.7	2.7	4.7	High
8	-3.3	-5.3	-1.3	-2.3	-2.3	High
9	-3.3	-2.3	-2.3	-2.3	-1.3	High
10	-0.3	-1.3	-1.3	-2.3	-2.3	High
12	-0.3	-0.3	-0.3	0.7	0.7	High
14	2.7	2.7	1.7	2.7	4.7	High
15	3.7	3.7	0.7	4.7	1.7	High
16	-3.3	-2.3	-3.3	-2.3	-2.3	High

On examination of Table 6.1 it can be seen that all 10 machines achieved the high performance criterion for distance measurement.

6.3 Temperatures

6.3.1 Temperature pattern shown by the data loggers

An issue with the temperature loggers meant that automatic recording of the data was not achieved during the majority of the main trial day. To mitigate the effects of a failure of the logging equipment, manual records of the temperatures recorded by the data logging system are made roughly every hour during the trial. This is not comprehensive enough to perform the assessment of the data collected by the operators, but does provide independent data on the variation of temperatures during the course of the day.

To assess the data collected by the operators they have been compared to the average of the fleet.

As discussed in section 3.2 HD29/08 sets a maximum rate of temperature increase of 2.5ºC per hour at 40mm for deflection testing. The temperature measurements recorded and the corresponding rate of change per hour are given in Table 6.2 and Table 6.3.

Table 6.2 Manual record of data logger measurements at 40mm

HECP_01			HECP_03		
Time	˚C	Rate of change per hour	Time	˚C	Rate of change per hour
11:45	3.6	-	11:46	3.2	-
12:45	4.0	0.40	12:50	4.0	0.75
13:57	7.1	2.58	13:57	7.1	2.78
15:46	6.2	-0.50	15:46	5.0	-1.16
17:30	4.7	-0.58	17:31	4.3	-0.40

Table 6.3 Manual record of data logger measurements at 100mm

HECP_01			HECP_03		
Time	˚C	Rate of change per hour	Time	˚C	Rate of change per hour
11:45	3.6	-	11:46	3.5	-
12:45	4.1	0.50	12:50	4.2	0.66
13:57	6.4	1.92	13:57	6.5	2.06
15:46	5.5	-0.50	15:46	4.5	-1.10
17:30	4.5	-0.58	17:31	4.6	0.06

It can be seen that the rate of temperature change with time at 40mm just exceeds the suggested limit at one point during testing (between 12:45 and 13:57).

6.3.2 Temperatures recorded by operators

The Deflectograph crews made measurements of temperature from sections HECP_01 and HECP_03 at a 40mm depth. This data is shown below in Figure 6.1 and Figure 6.2.

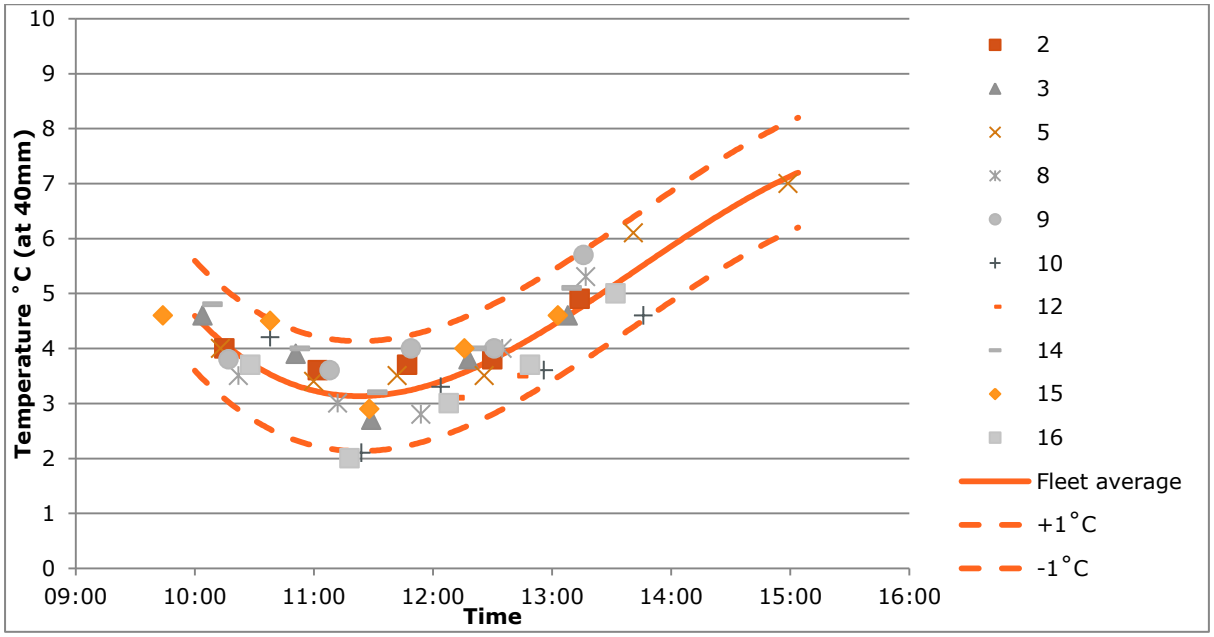

Figure 6.1 Comparison of crew's measurements against reference – Section HECP_01 main trial day

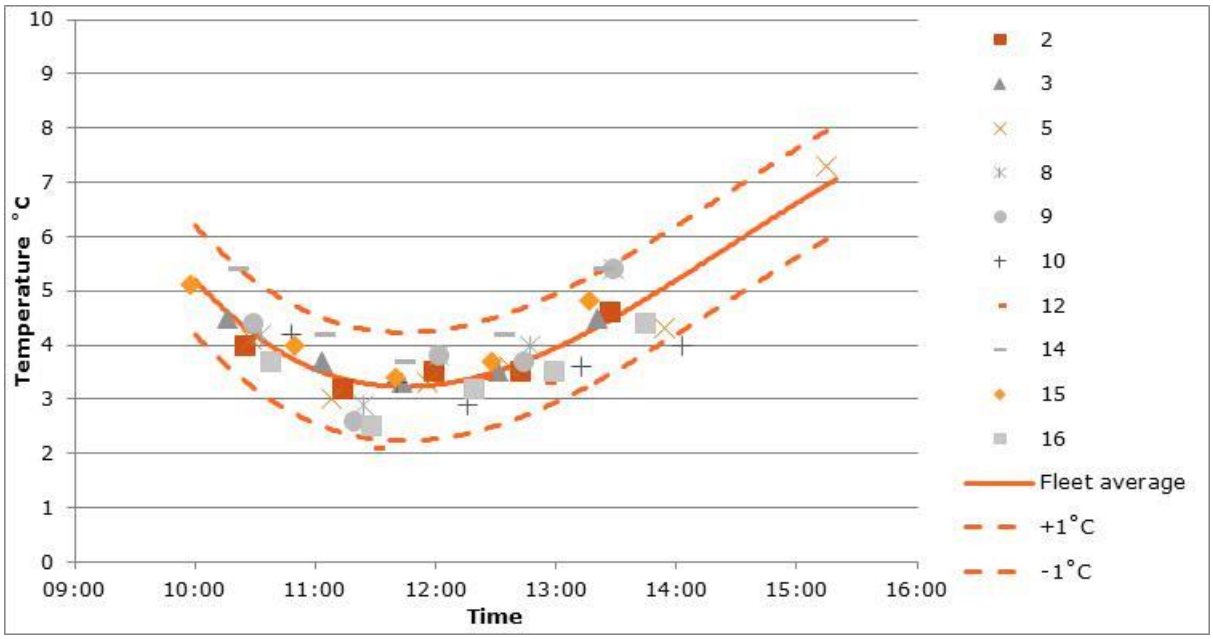

Figure 6.2 Comparison of crew's measurements against reference – Section HECP_03 main trial day

The difference between the operators measured values and the reference are shown in Table 6.4. If the value is more than 1˚C away then it is highlighted in bold red text.

Table 6.4 Difference between operators measured values and the reference on HACP_01 and HACP_03

Machine	Difference between measured temperature and reference (˚C)										Percentage within 1˚C
	Test 1		Test 2		Test 3		Test 4		Test 5		
	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	
2	-0.1	-0.3	0.4	-0.2	0.5	0.2	0.0	-0.2	0.2	0.1	100
3	0.2	-0.1	0.6	0.2	-0.4	0.1	0.2	0.0	0.0	0.2	100
5	-0.1	-0.1	0.2	-0.4	0.3	0.0	-0.2	0.0	0.7	-0.8	100
8	-0.4	0.1	-0.2	-0.4	-0.5	0.5	0.1	0.3	0.5	0.9	100
9	-0.2	0.2	0.4	-0.7	0.8	0.5	0.2	0.0	0.9	0.9	100
10	0.7	0.4	**-1.0**	0.1	-0.1	-0.5	-0.7	-0.6	-0.9	**-1.3**	80
12	0.0	-0.2	**-1.0**	**-1.2**	-0.4	0.0	-0.6	-0.6	0.0	-0.3	80
14	0.5	1.0	0.7	0.7	0.1	0.5	0.3	0.6	0.5	1.0	100
15	.	.	**1.0**	0.3	-0.2	0.2	0.4	0.2	0.1	0.5	88
16	0.0	-0.3	**-1.1**	-0.8	-0.5	-0.2	-0.5	-0.4	-0.2	-0.5	90

In order to meet the high performance criteria (given in section 4.4) 80% of the measurements need to be within 1 ºC of the reference. We can see that although there are a few instances where the data is more than 1 ºC away from the reference, all of the machines met this criterion.

6.4 Deflection readings – Main trial day

On the main trial day the first lap (lap 0) is always disregarded as it is used to warm-up the machines prior to undertaking a beam calibration check.

During the initial laps Machine 5 was found to be reading too high relative to the fleet for the NS measurements. The operator of this machine was notified and given the opportunity to investigate their machine. They replaced the NS measuring box but this did not improve the results. Then they changed the winch drum. This still did not have the desired effect. They then changed the NS measuring box again and recalibrated. This appeared to improve the results however by this point it was not possible to obtain a full set of five runs with this machine. It was therefore decided that testing would resume on the reserve day to assess this machine (using a selection of the other devices to act as a reference).

Therefore in the remainder of this section machine 5 is excluded from the results.

6.4.1 Between run standard deviation for deflection values

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

Table 6.5 Between run standard deviation (runs 1-5) for main running day (day 2)

Machine number	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
2	2.0	1.8	11.8	8.0	7.4	6.2
3	1.0	1.6	5.8	6.7	2.1	5.1
8	1.5	3.2	7.6	5.7	8.9	7.8
9	5.1	2.4	14.6	3.7	2.2	4.2
10	2.5	2.7	12.3	8.5	12.9	10.2
12	5.5	3.4	13.2	9.9	14.1	8.6
14	3.3	2.8	10.3	5.4	12.6	7.8
15	6.7	3.5	10.8	11.0	8.6	4.7
16	2.0	1.5	8.7	13.9	4.5	7.4

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

6.4.2 Mean deflection values

Table 6.6 shows the mean deflections recorded on each section (for runs 1 to 5), together with summary statistics. Instances where the BESD is within the criterion are highlighted in green and instances where the criterion is not met in red. Table 6.7 shows the deviations from the overall mean and these are highlighted if further than 2 or 3 times the BESD criteria (orange and red respectively), for each of the three sections.

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

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	58	49	218	170	150	127	142	115
3	40	38	180	138	114	102	112	93
8	41	40	186	164	119	126	115	110
9	40	37	208	154	137	116	128	102
10	50	47	221	180	140	132	137	120
12	43	37	203	163	130	117	126	106
14	62	50	225	179	149	135	145	121
15	54	53	204	178	139	141	132	124
16	53	53	220	179	141	137	138	123
Mean	49	45	207	167	136	126	131	113
BESD	8.3	6.8	15.8	14.2	12.3	12.3	11.6	10.8
BESD criterion	11.1	11.0	15.2	14.2	13.4	13.1	13.2	12.8
CoV	16.9%	15.2%	7.6%	8.5%	9.0%	9.8%	8.9%	9.5%

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

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	9.0	4.1	11.0	3.0	14.9	1.1	11.6	2.7
3	-8.8	-6.7	-27.4	-28.8	-21.0	-23.8	-19.1	-19.8
8	-8.1	-5.4	-21.2	-3.4	-16.7	0.4	-15.3	-2.8
9	-9.1	-7.9	0.8	-13.4	1.9	-10.0	-2.1	-10.4
10	0.8	2.4	13.4	12.5	4.2	6.0	6.1	7.0
12	-5.6	-7.7	-4.2	-4.5	-5.2	-9.1	-5.0	-7.1
14	13.4	5.3	17.5	11.7	13.1	9.4	14.7	8.8
15	4.5	8.2	-2.8	11.0	3.8	14.9	1.8	11.4
16	4.0	7.7	13.0	11.9	5.1	11.1	7.3	10.2
2x BESD criterion	22.3	22.1	30.4	28.4	26.7	26.2	26.5	25.5
3x BESD criterion	33.4	33.1	45.6	42.5	40.1	39.3	39.7	38.3

It can be seen from these two tables that criteria for the spread of mean deflection values is not met on the NS wheel path for HECP_02. This would typically mean that we would look to remove an outlier to improve the distribution of the fleet so that these criteria are met on all sections and all wheel paths (see section 4.2). However, when examining the deviations (Table 6.7) it can be seen that no machine is more than 2 x BESD away from the fleet mean on this section and wheel path (it is noted that machine 3 is just outside 2 times the BESD criterion on the OS path for this section). On further examination of the distributions of the machines (more clearly seen in the figures in Appendix B) it can be seen that the fleet, like in 2015, is more spread out than in earlier years rather than containing specific outliers. Considering this, in combination with the fact that the machines meet the criteria for the average of the sections, means these nine machines are considered as meeting the trial criteria for deflection measurement. However as noted in section 5.2 Machine 10 would need to undergo additional testing (due to their non-compliant wheel weights) before being approved for testing under HD29. This additional testing is discussed in section 7.2.

7 Results – Additional testing

7.1 Deflection readings – Reserve day

As discussed in section 6.4, Machine 5 was found to be reading too high relative to the fleet for the NS measurements during the test laps. After several attempts at resolving this issue the operator managed to conduct one lap at the end of the main trial day which suggested that they may have resolved this issue. It was therefore decided that the reserve day would be utilised to reassess this machine. A selection of other machines was also held back to allow for comparison between Machine 5 and the fleet.

For this testing Machines 3, 8, 9, 10, 12 and 16 were used to provide reference data. Due to other commitments and driver hours constraints Machine 3 was only able to take part in two laps on this day. In addition due to the track time available it was only possible to obtain 4 of the 5 laps with machine 10. Therefore in the discussion below machines 3 and 10 will be excluded from parts of the analysis where appropriate.

7.1.1 Between run standard deviation

As noted in section 6.4.1 there are no criteria set relating to the between run standard deviation of each machine. It is, however, useful to consider this aspect when investigating anomalies in the behaviour of machines. The between-run standard deviation (for the machines which undertook 5 laps on this day) is shown in Table 7.1.

Table 7.1 Between run standard deviation (runs 1-5) for the reserve day (day 3)

Machine number	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
5	4.8	3.1	10.0	3.2	7.8	6.1
8	3.5	2.6	10.5	6.8	3.3	6.8
9	1.9	3.0	18.2	12.8	8.1	8.1
12	4.7	11.7	6.1	7.1	15.2	12.4
16	2.7	3.8	3.7	6.7	9.3	12.3

These results are broadly similar to the levels seen on the main running day.

7.1.2 Mean deflection values – Reserve day

Table 7.2 shows the mean deflections recorded on each section (for the reserve day), together with summary statistics. The results from Machines 3 and 10 are shown in italics as they are not formed from a full data set (i.e. 5 runs). Table 7.3 shows the deviations from the overall mean and these are highlighted if further than 2 or 3 times the BESD criteria, for each of the three sections. As with the mean deflections table machines 3 and 10 are shown in italics as they are not formed from a full data set.

Table 7.2 Mean deflection (µm) by section: Reserve day (day 3)

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
3	*39*	*38*	*180*	*137*	*100*	*99*	*106*	*91*
5	62	41	193	154	148	121	134	105
8	38	39	181	160	116	120	112	107
9	38	38	208	150	130	114	125	100
10	*47*	*46*	*214*	*165*	*144*	*132*	*135*	*114*
12	43	49	195	153	129	121	123	108
16	48	53	211	179	143	138	134	123
Mean	45	43	197	157	130	121	124	107
BESD	8.6	6.0	14.0	13.0	17.3	12.6	11.6	10.0
BESD criterion	11.0	11.0	15.0	13.9	13.2	13.0	13.1	12.6
CoV	19.0%	13.7%	7.1%	8.3%	13.3%	10.4%	9.3%	9.4%

Table 7.3 Deviation (µm) from overall mean deflection by section: Reserve day (day 3)

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
3	*-6.5*	*-4.9*	*-17.2*	*-19.9*	*-30.2*	*-21.7*	*-18.0*	*-15.5*
5	17.2	-2.8	-4.2	-2.5	17.7	0.3	10.2	-1.6
8	-6.6	-4.2	-16.9	3.5	-14.2	-0.5	-12.6	-0.4
9	-6.7	-5.6	10.0	-7.0	0.4	-7.0	1.2	-6.6
10	*1.7*	*2.2*	*16.6*	*8.3*	*14.0*	*11.2*	*10.7*	*7.2*
12	-1.7	5.6	-2.1	-3.9	-0.6	0.2	-1.5	0.6
16	2.7	9.8	13.9	21.6	13.1	17.4	9.9	16.3
2x BESD criterion	22.1	22.0	29.9	27.8	26.4	26.0	26.1	25.3
3x BESD criterion	33.1	33.0	44.9	41.7	39.7	38.9	39.2	37.9

It can be seen from these two tables that the criteria for the spread of mean deflection is met on all sections and wheel paths apart from the NS on HECP_03. This would initially suggest that Machine 5 should be accepted with regards to Deflection readings. However, this is a reduced set of the fleet and if we exclude Machine 3 then all of the machines come from a single survey contractor. Therefore the reference set of data is not strictly compliant with the requirements in the Accreditation and QA specification:

> *"A reference dataset will comprise measurements from at least three other Equipment, supplied by a minimum of two different Owners."*

This clause (two different Owners) is included to make sure that a bias between different Owners/Operators does not form over time. Therefore to fully assess Machine 5 it will be necessary to combine and compare this data to the data collected on the main trial day.

7.1.3 Mean deflection values – Combined dataset

In order to combine the data from the two days the average deflection values for the machines that acted as the reference on the reserve day (8, 9, 12 and 16) was calculated for each section and wheel path on each day. The ratio between the two days was then calculated and applied to the data from Machine 5 collected on the reserve day, to estimate

the likely measurements it would have achieved if it operated in its new configuration on the main trial day.

The average from each day for the machines acting as reference and the calculated ratio is shown in Table 7.4.

Table 7.4 Reference data values and estimation ratio

	HECP_01		HECP_02		HECP_03	
	NS	OS	NS	OS	NS	OS
Average day 2	44	42	204	165	132	124
Average day 3	42	45	199	160	130	123
Ratio	1.06	0.93	1.03	1.03	1.02	1.01

From this data it can be seen that on the whole the deflection values were consistent between the two days (ratios close to 1). In addition further examination of the data found that the machines appeared to be performing consistently between each of the days relative to each other.

Table 7.5 shows the mean deflections recorded on each section for the combined dataset. Table 7.6 shows the deviations from the overall mean. In both of these tables Machine 5 is in blue italic text to highlight that it is an estimate.

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

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	58	49	218	170	150	127	142	115
3	40	38	180	138	114	102	112	93
5 (estimate)	*66*	*38*	*199*	*159*	*150*	*122*	*138*	*106*
8	41	40	186	164	119	126	115	110
9	40	37	208	154	137	116	128	102
10	50	47	221	180	140	132	137	120
12	43	37	203	163	130	117	126	106
14	62	50	225	179	149	135	145	121
15	54	53	204	178	139	141	132	124
16	53	53	220	179	141	137	138	123
Mean	51	44	206	166	137	125	131	112
BESD	9.5	6.8	15.2	13.6	12.4	11.7	11.2	10.4
BESD criterion	11.2	11.0	15.2	14.2	13.4	13.1	13.3	12.8
CoV	18.6%	15.5%	7.3%	8.2%	9.1%	9.3%	8.5%	9.2%

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

Machine number	HECP_01		HECP_02		HECP_03		Average	
	NS	OS	NS	OS	NS	OS	NS	OS
2	7.3	4.8	11.8	3.8	13.4	1.5	10.8	3.4
3	-10.5	-6.0	-26.6	-28.0	-22.5	-23.4	-19.8	-19.1
5 (estimate)	*15.1*	*-6.4*	*-7.7*	*-7.7*	*13.1*	*-3.7*	*6.9*	*-5.9*
8	-9.8	-4.7	-20.4	-2.5	-18.1	0.8	-16.1	-2.1
9	-10.8	-7.2	1.7	-12.6	0.4	-9.6	-2.9	-9.8
10	-0.9	3.1	14.2	13.4	2.7	6.5	5.4	7.7
12	-7.3	-6.9	-3.4	-3.6	-6.7	-8.7	-5.8	-6.4
14	11.7	6.0	18.4	12.6	11.6	9.8	13.9	9.5
15	2.8	9.0	-2.0	11.9	2.4	15.3	1.1	12.0
16	2.3	8.4	13.8	12.7	3.6	11.5	6.6	10.9
2x BESD criterion	22.4	22.0	30.4	28.3	26.8	26.2	26.5	25.5
3x BESD criterion	33.6	33.1	45.5	42.5	40.2	39.3	39.8	38.3

It can be seen from these two tables that the criteria for the spread of mean deflection values is met on all sections and wheel paths. Therefore following the alterations undertaken to the machine during the main running trial day, Machine 5 should be considered as meeting the trial criteria for deflection measurement.

7.2 Before and after testing for overweight machine

As noted in section 5.2, Machine 10 was outside the specified tolerances for the rear wheel limits for the rear OS wheel. However, it was decided that this machine could still take part in the main running trials and the results assessed by extending the load correction formula. If the machine performed acceptably then a certificate would be issued for the machine which states that it have met the deflection criteria but was outside the weight tolerances and therefore did not meet the criteria for HD29 surveys. The operator was notified that if the following methodology was undertaken (and suitable results obtained) then they would be issued an updated certificate:

1. Conduct a survey of their QA site with machine 10 in its current configuration along with at least one of the operator's other machines.
2. Reduce the weight of machine 10 so that it meets the requirements
3. Re-weigh machine 10 and obtain weight values for each wheel with the crew on board
4. Repeat the survey of their QA site with the same machines as in step 1 (with machine 10 in its new configuration)
5. Supply all of the above data to TRL so that TRL can confirm that the machine is performing as expected

This process was undertaken and the data collected showed that Machine 10 provided consistent results (after load correction) before and after the change in weight.

Therefore an updated certificate was issued for Machine 10 showing the new compliant weight values for the machine. These weight values are provided in Table 7.7.

Table 7.7 Amended weight values for Machine 10

Machine	Weight distribution including crew (kg)						
	Front NS	Front OS	Total Front	Rear NS	Rear OS	Total rear	Total Machine
10	2360	2400	**4760***	3055	3375	6430	11540

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

8 Conclusions

The 2016 National Deflectograph accreditation trials were held on the MIRA proving grounds by TRL on behalf of the Highways England in March 2016. Ten of the machines in the current UK fleet attended the trial.

Following additional testing all ten of the machines that participated in the March 2016 accreditation trial met the requirements of the Highways England's annual accreditation trial with regards to deflection results and can therefore be considered for approval to survey Highways England's strategic road network. It should be noted that this report may not be representative of the current accreditation position of the UK Deflectograph fleet. Changes may occur in accreditation status due to additional trials or machine failure since the time of the trials reported here.

All ten machines achieved a high performance rating for the measurement of distance.

All ten machines provided temperature data and the results were found to be within acceptable limits.

Machines 2, 3, 5, 9, 10 and 15 had front axle weights over the limits defined in the DMRB. Following a review of this matter in 2004, machines exceeding the front axle weight limits are regarded as acceptable provided that they perform satisfactorily in the dynamic tests.

At the trial Machine 10 exceeded the rear wheel weight limit for the rear OS wheel. This was corrected after the trial and supplementary testing showed that the performance with the new compliant weight measurements was acceptable.

References

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

Design Manual for Roads and Bridges. (2008, May). *Volume 7 Section 3, HD29/08, Data for surface assessment*. London: The Stationery Office.

Appendix A Machine identification

Table A.1 Machine identification

ID	Operator at trial date	Registration number	Performance achieved		
			Deflection	Temperature	Distance
2	PTS Ltd	L697 BKR	Pass	High	High
3	TRL Ltd	B180 FBL	Pass	High	High
5	WDM Ltd	D962 JRU	Pass	High	High
8	WDM Ltd	BYW 80V	Pass	High	High
9	WDM Ltd	VGV 182X	Pass	High	High
10	WDM Ltd	F569 JBB	Pass	High	High
12	WDM Ltd	EOU 230W	Pass	High	High
14	Lincolnshire County Council	B195 CFW	Pass	High	High
15	DoE Northern Ireland	ACZ 3268	Pass	High	High
16	WDM Ltd	B880 XOU	Pass	High	High

Appendix B Mean deflections on reference sections – Main trial day

B.1 HECP_01

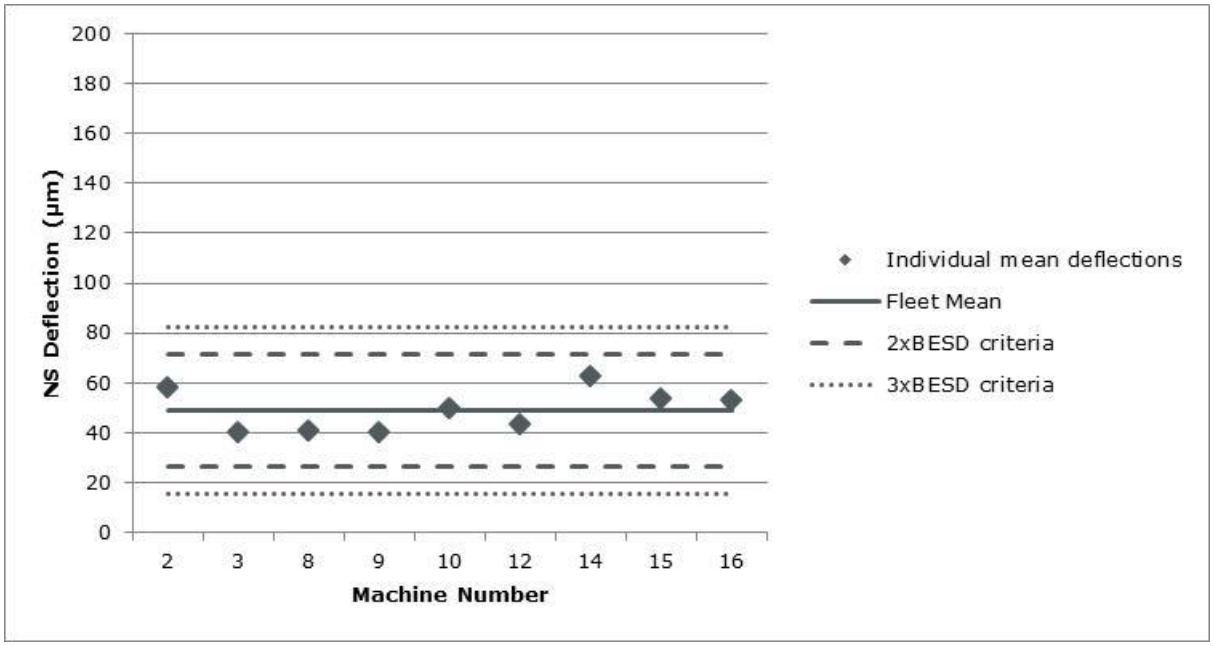

Figure B.1 NS mean deflections for Individual machines and the fleet mean for HECP_01 on the main trial day

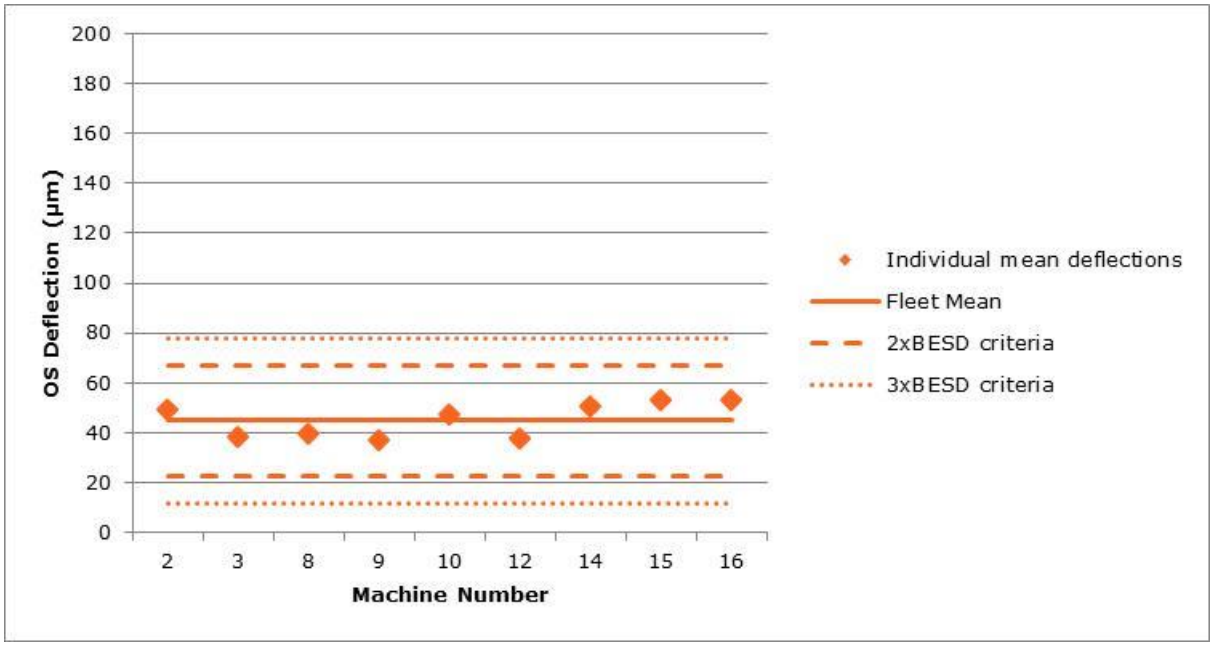

Figure B.2 OS mean deflections for Individual machines and the fleet mean for HECP_01 on the main trial day

B.2 HECP_02

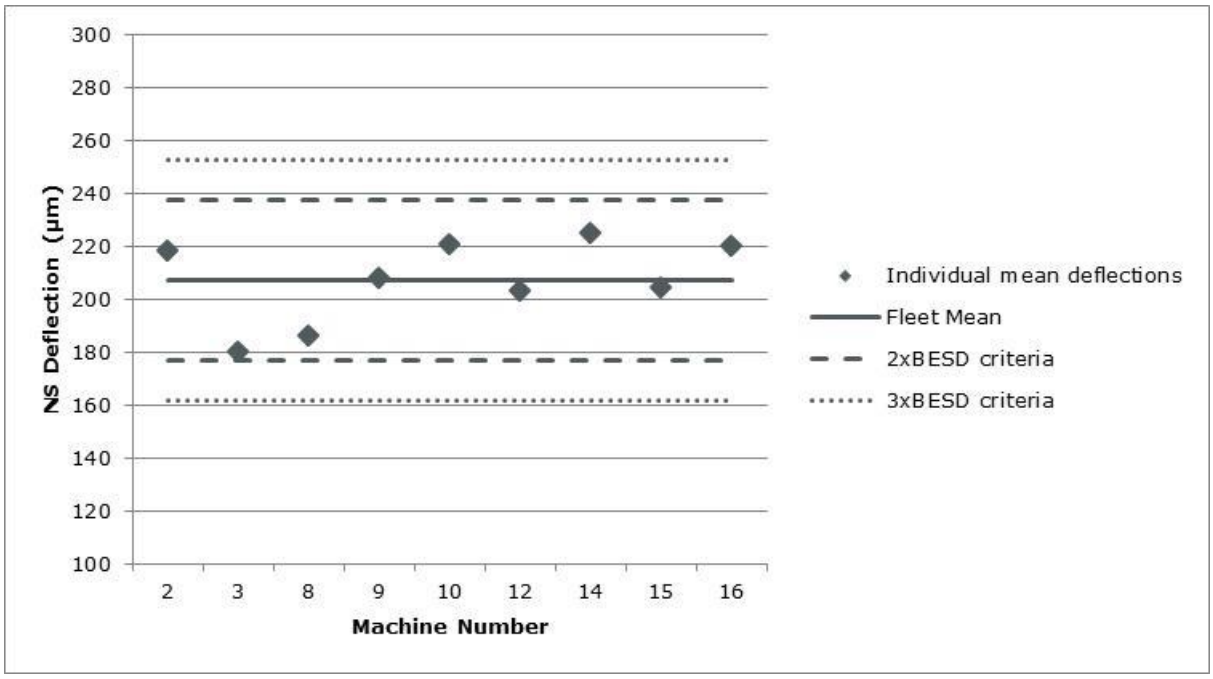

Figure B.3 NS mean deflections for Individual machines and the fleet mean for HECP_02 on the main trial day

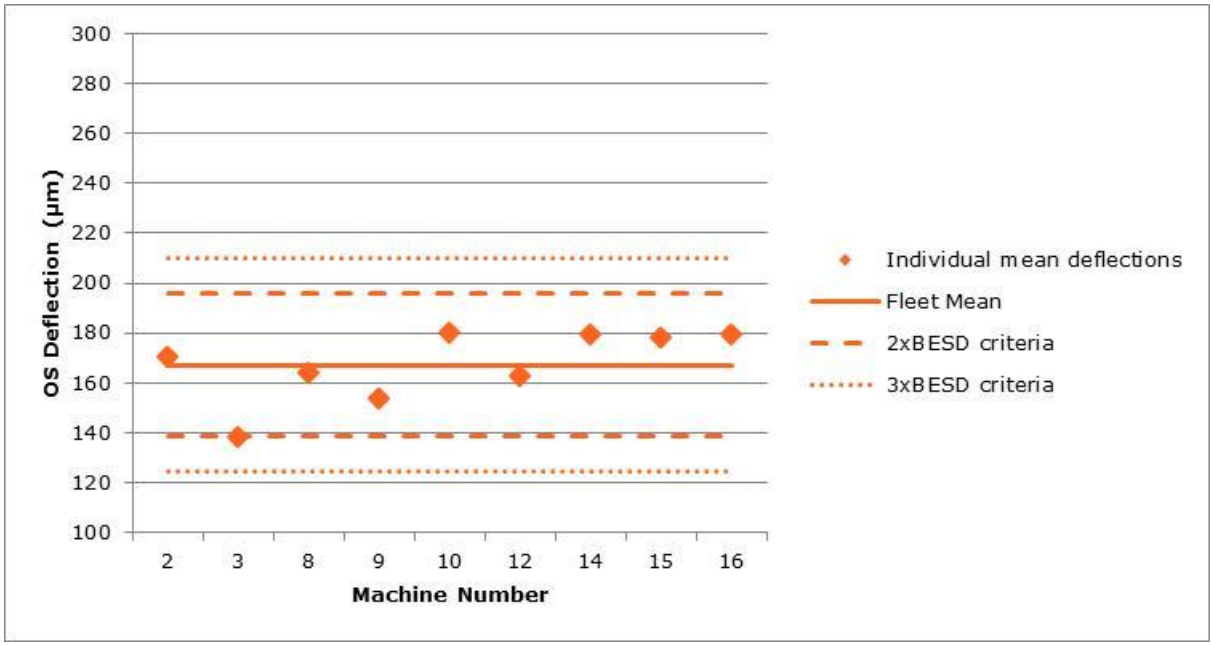

Figure B.4 OS mean deflections for Individual machines and the fleet mean for HECP_02 on the main trial day

B.3 HECP_03

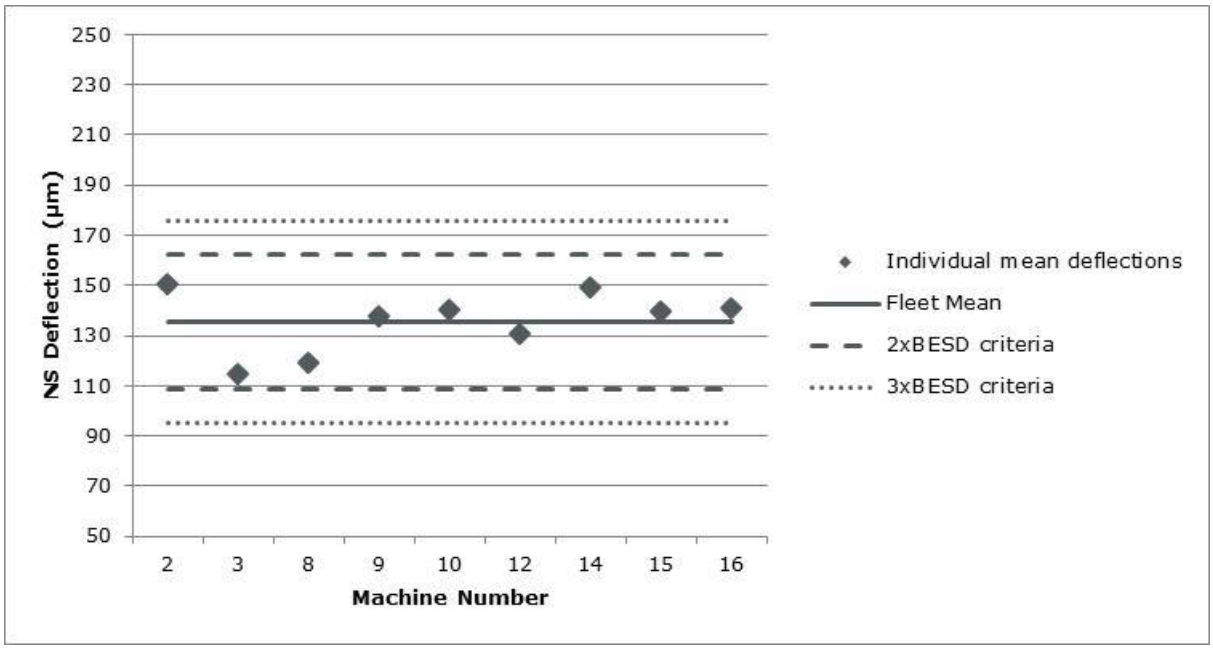

Figure B.5 NS mean deflections for Individual machines and the fleet mean for HECP_03 on the main trial day

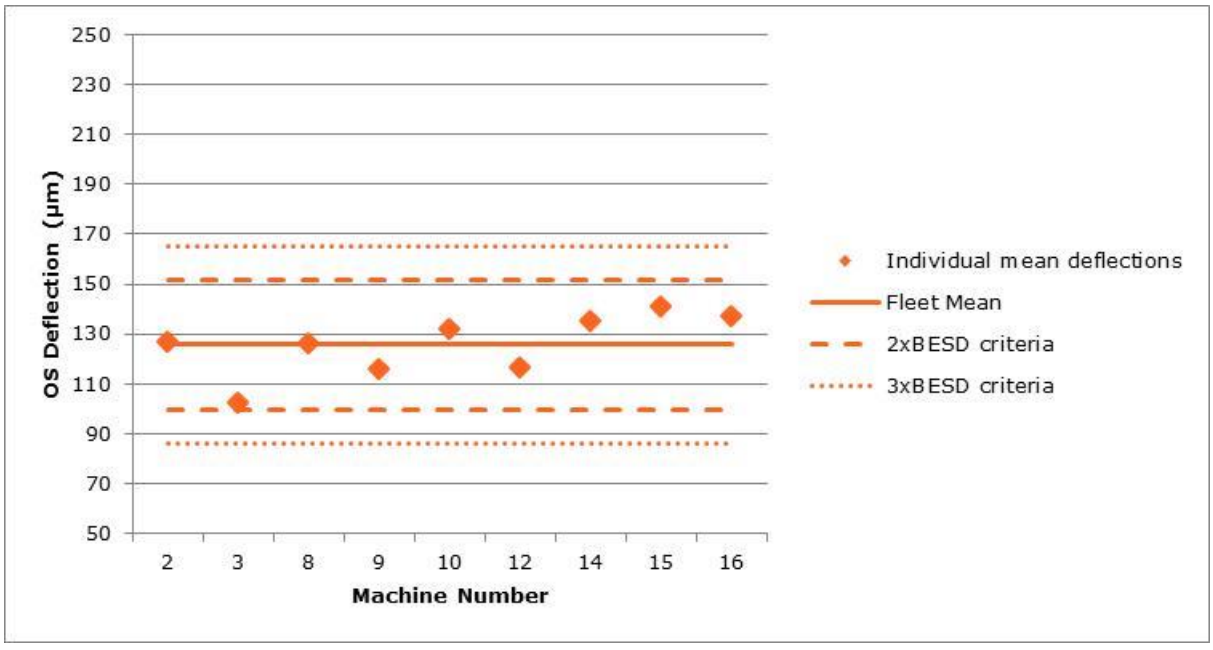

Figure B.6 OS mean deflections for Individual machines and the fleet mean for HECP_03 on the main trial day

Appendix C Mean deflections on reference sections – Reserve day

C.1 HECP_01

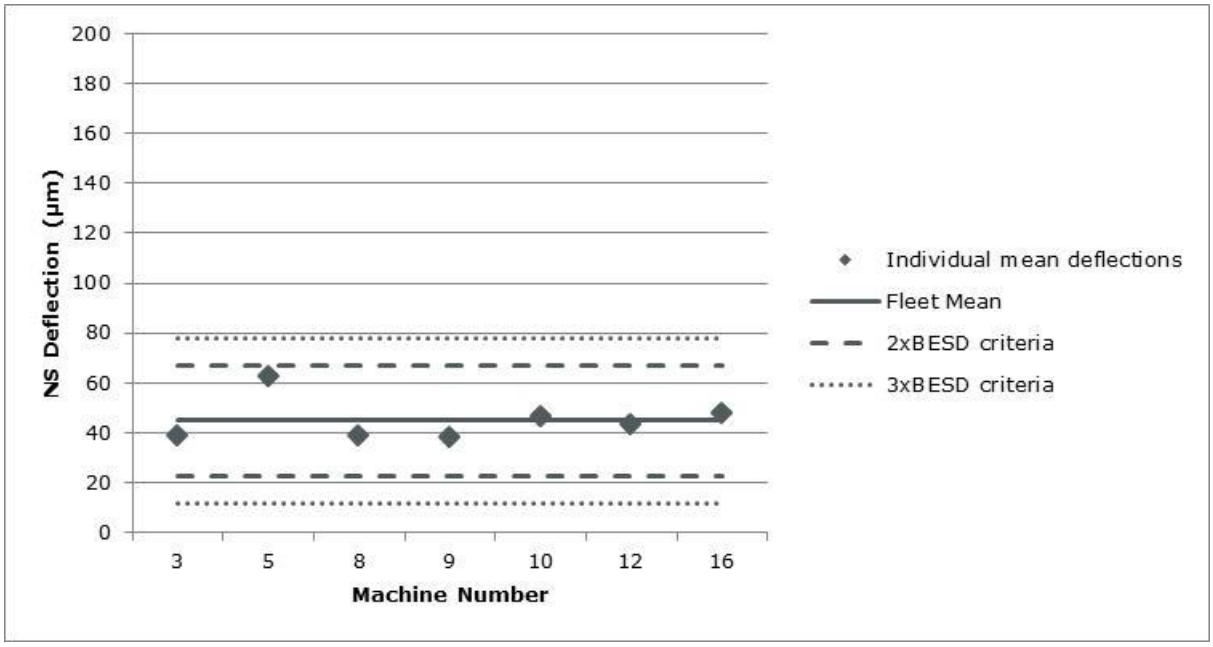

Figure C.1 NS mean deflections for Individual machines and the fleet mean for HECP_01 on the reserve day

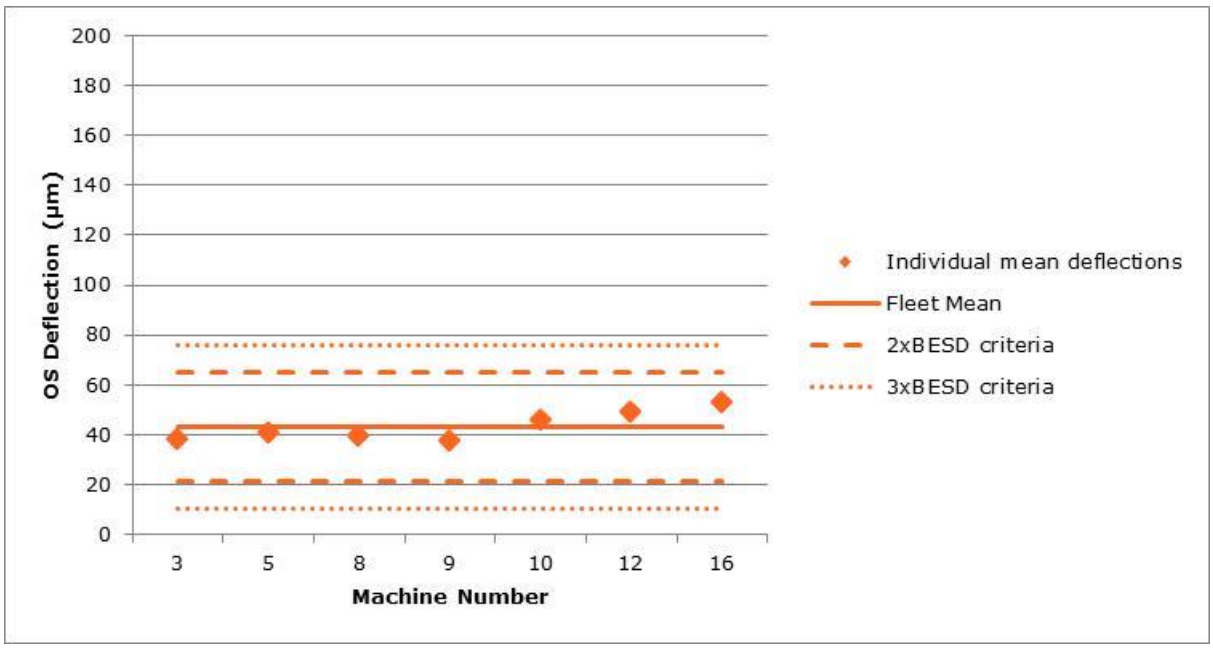

Figure C.2 OS mean deflections for Individual machines and the fleet mean for HECP_01 on the reserve day

C.2 HECP_02

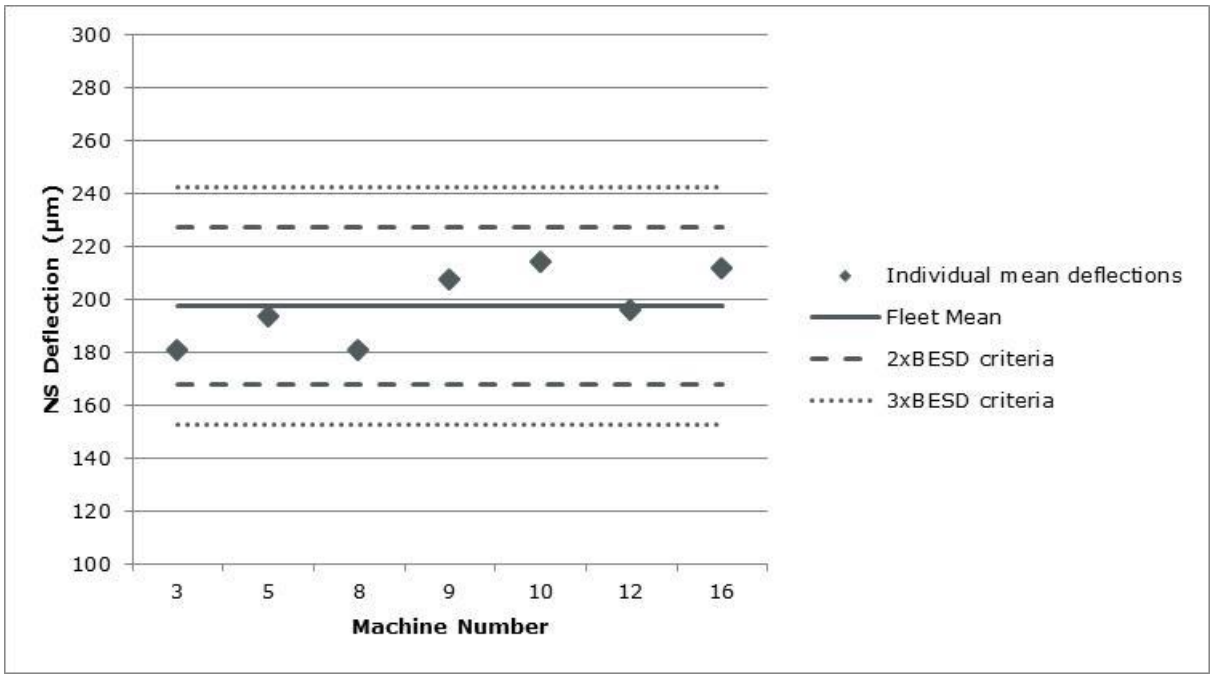

Figure C.3 NS mean deflections for Individual machines and the fleet mean for HECP_02 on the reserve day

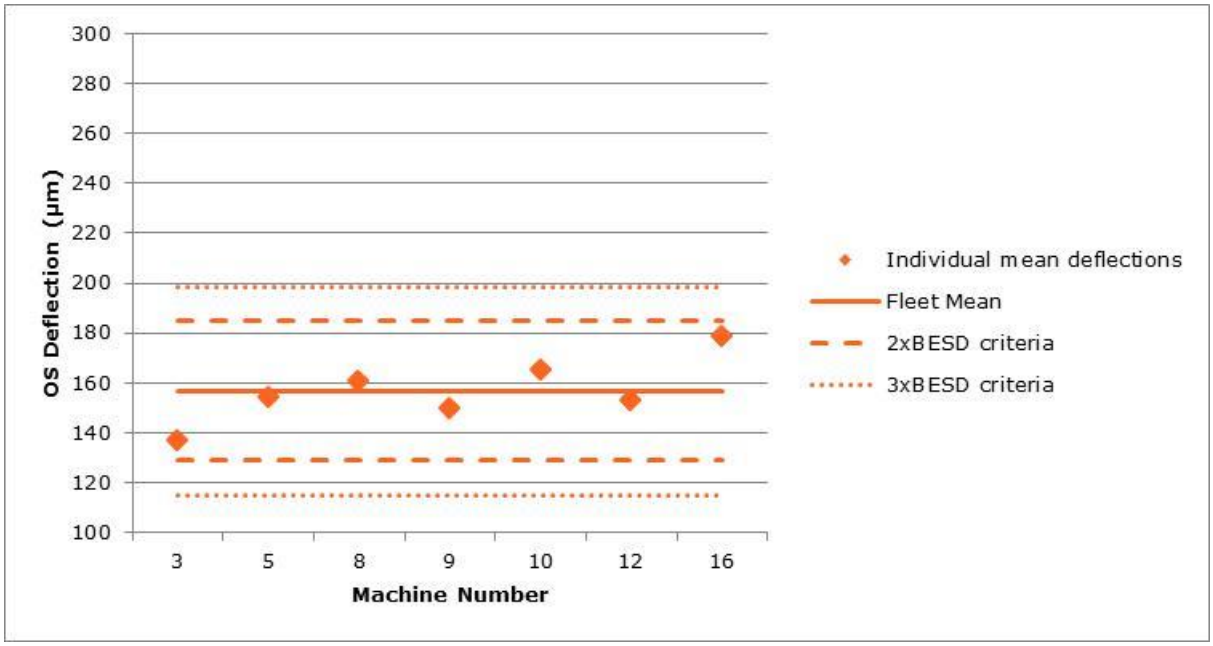

Figure C.4 OS mean deflections for Individual machines and the fleet mean for HECP_02 on the reserve day

C.3 HECP_03

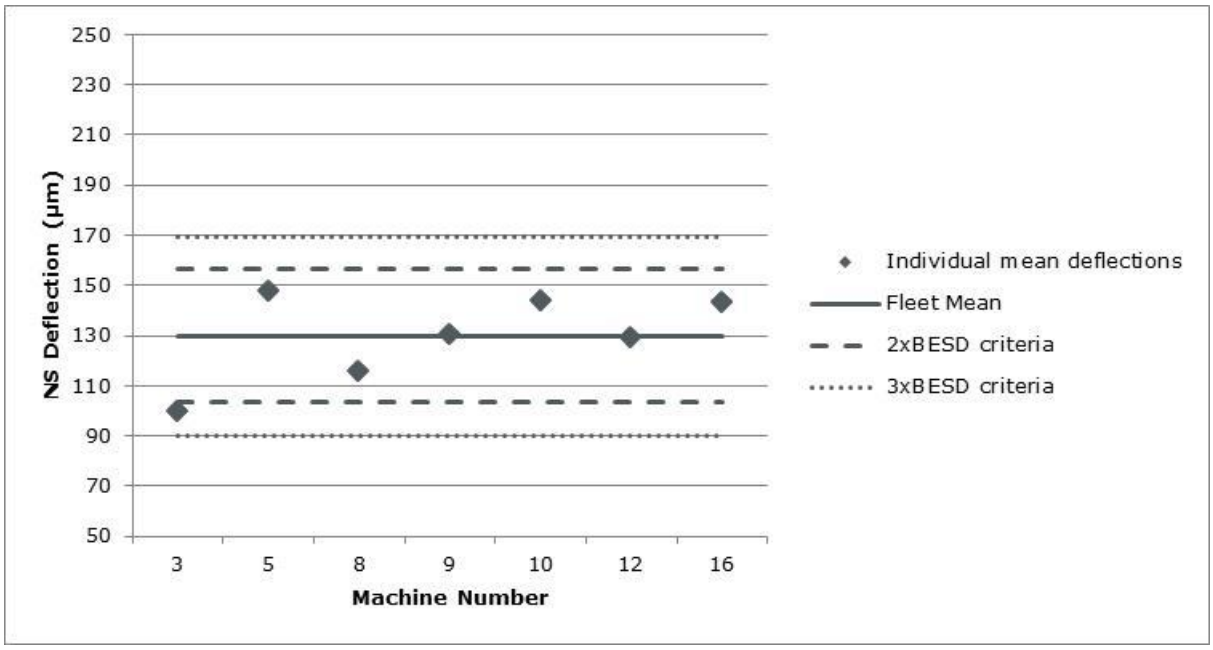

Figure C.5 NS mean deflections for Individual machines and the fleet mean for HECP_03 on the reserve day

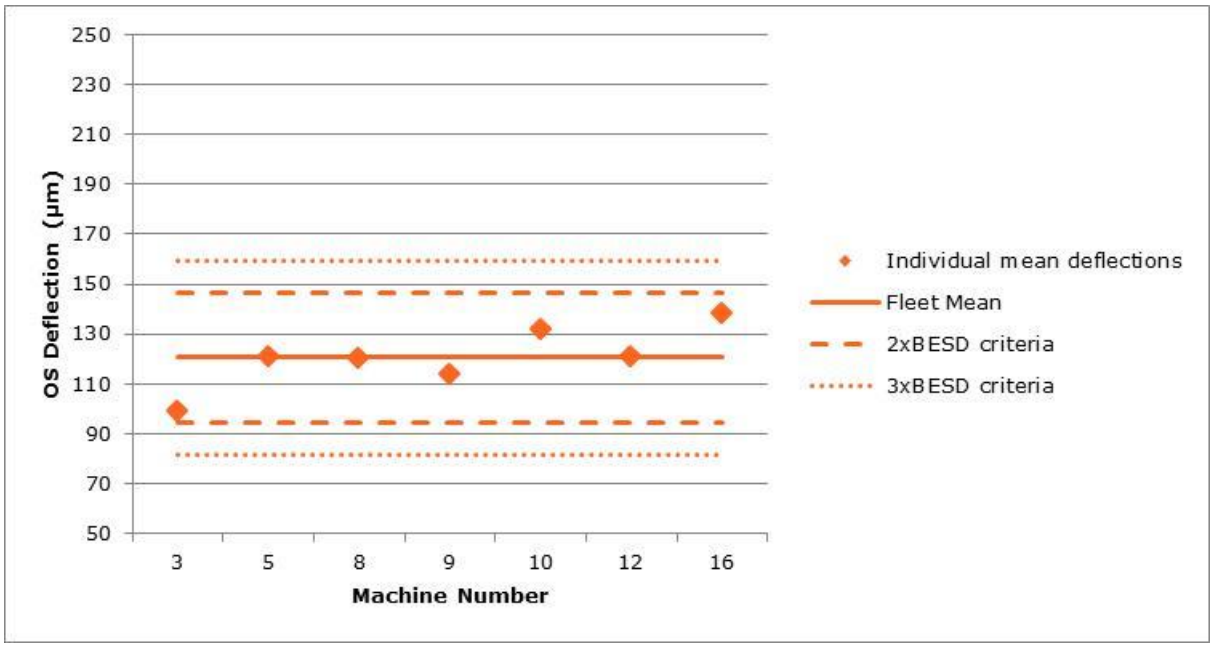

Figure C.6 OS mean deflections for Individual machines and the fleet mean for HECP_03 on the reserve day

Appendix D Layout of test sections at MIRA

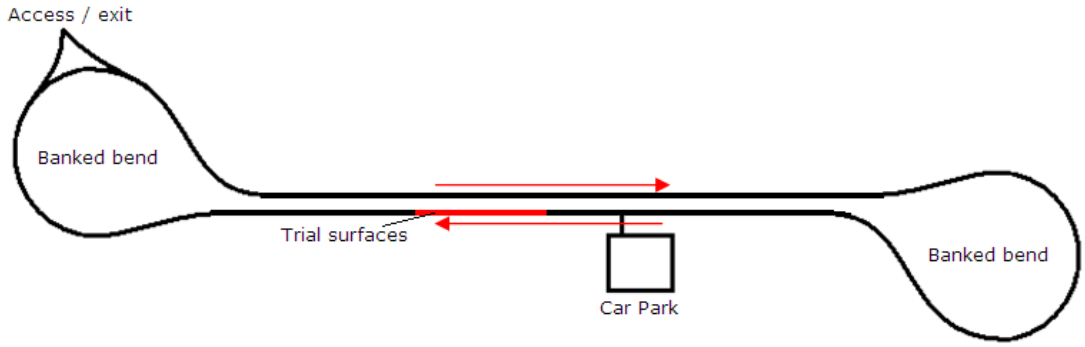

Figure D.1 Test route on the MIRA twin straights

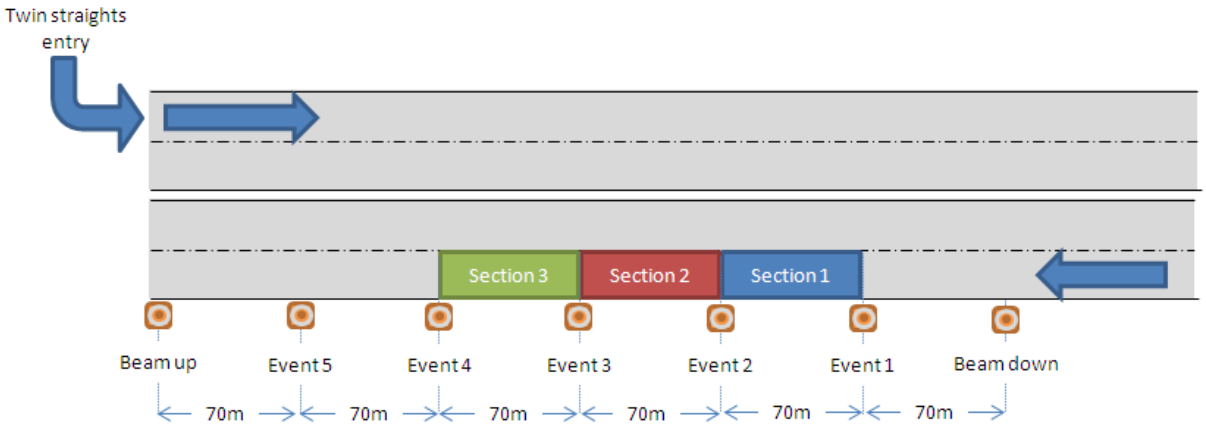

Figure D.2 Location of marker cones and test sections on MIRA twin straights

Appendix E Construction details for MIRA test sections

Table E.1 Design construction of MIRA site

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

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

Table E.2 Construction details for MIRA site from cores

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

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

Table E.3 Construction details for MIRA site from GPR

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

Notes: HBM = Hydraulically Bound Material

Highways England 2016 National Deflectograph Accreditation Trial

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

This report covers the 2016 accreditation trial run by TRL and held on the Horiba-MIRA proving ground between 1st and 3rd March 2016.

Other titles from this subject area

PPR 943	Highways England 2015 National Deflectograph Accreditation Trial. S Brittain. 2020
CPR 1845	Highways England 2014 National Deflectograph Accreditation Trial. S Brittain. 2014
CPR 1619	Highways Agency 2013 National Deflectograph Accreditation Trial. S Brittain. 2013
CPR 1449	Highways Agency 2012 National Deflectograph Accreditation Trial. S Brittain. 2012

TRL
Crowthorne House, Nine Mile Ride,
Wokingham, Berkshire, RG40 3GA,
United Kingdom
T: +44 (0) 1344 773131
F: +44 (0) 1344 770356
E: enquiries@trl.co.uk
W: www.trl.co.uk

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