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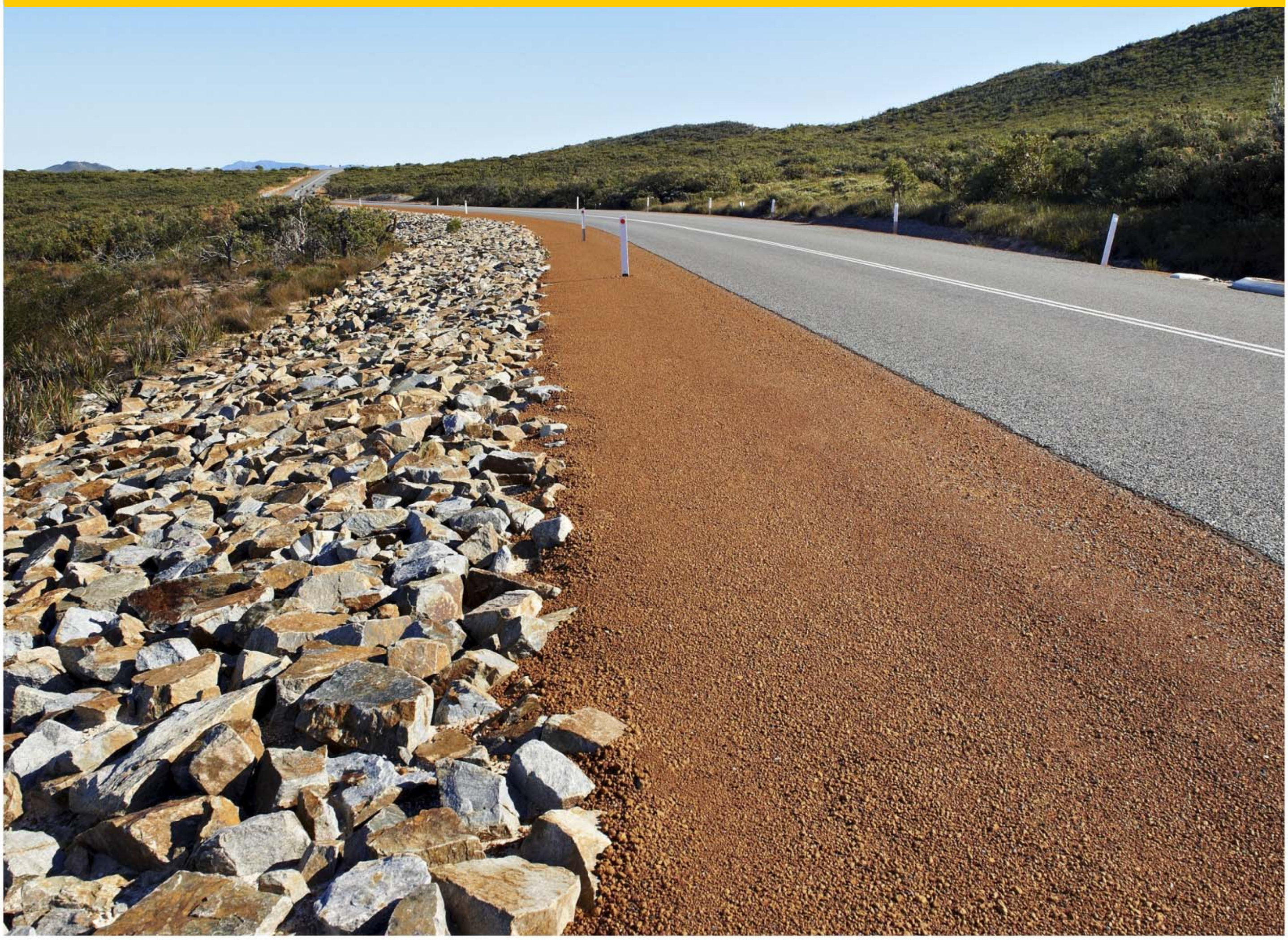
Western Australian Pavement Asset Research Centre

Validation of Proposed Austroads Finite Element Design Model

2011/10



CONTRACT REPORT

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Validation of Proposed Austroads Finite Element Pavement Design Model: Analysis of Kwinana Freeway Trial Sections

Project No:

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for Main Roads Western Australia

TC-423-1-3-2

Validation of Proposed Austroads Finite Element Pavement Design Model: Analysis of Kwinana Freeway Trial Sections

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SUMMARY

Unbound and modified granular materials are widely used in Australia. Most rural pavements and a considerable portion of the urban network comprise granular bases and subbases overlain by thin bituminous surfacing. The current pavement design model adopted by Austroads is linear elastic and does not accurately represent the behaviour of stress-dependent materials, such as granular and modified bases, subbases and subgrades.

The Validation of Proposed Austroads Finite Element Pavement Design Model is an effort by the Western Australian Pavement Asset Research Centre (WAPARC) aimed at evaluating the effectiveness of the proposed finite element analysis (Austroads Pavement Analytical Design Software – APADS) compared to the current methodology (linear elastic model CIRCLY).

The project consisted of characterising the modulus of each material through laboratory repeated load triaxial (RLT) testing, modelling different pavement sections in APADS and CIRCLY, and comparing deflections predicted by these models with measured deflections from falling weight deflectometer (FWD) testing.

The findings were:

- Improved agreement between predicted and measured deflections was achieved when the sand subgrade modulus was not constrained to a modulus 120 MPa, the current presumptive MRWA Engineering Road Note 9 value for the design of new pavements. The finite element modelling indicated a value of 200 MPa provided a better match between predicted and measured deflections.
- From the finite element modelling it was concluded that the Austroads granular characterisation method significantly under-estimates the support provided by crushed limestone subbase. An improved characterisation is warranted and would result in reduced new pavement construction costs across a wide range of Perth pavements.
- With further development in relation to sand and crushed limestone subbase moduli, the linear elastic model has the ability to predict deflections with comparable accuracy to the finite element model considering the limitations of laboratory modulus measurements and assumptions of in situ moisture and densities.
- The project findings were limited by laboratory modulus measurements. Improved methods of measurement of modulus in the repeat load triaxial test are required.

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1 INTRODUCTION

Granular pavement materials are widely used in Australia. Most rural pavements and a considerable portion of the urban network comprise granular bases and subbases overlain by seals and thin asphalt layers. Granular pavement materials, including modified materials, behave as stress-dependent materials. The modulus of elasticity and strength of these materials vary with the stress condition to which they are subjected. Closer to the load, both vertically and horizontally, the elastic modulus is higher.

The current Austroads linear elastic model for pavement analysis and design (Austroads 2012b) does not adequately allow an assessment of the varying modulus of individual unbound and modified granular bases to be considered in the design process. Whilst some allowance is currently made for the variation in modulus with the Austroads sublayering rules, the variation in granular moduli horizontally cannot be provided for in the current linear elastic model. This feature limits the ability of the current Austroads model to predict responses and hence performance of unbound granular pavements, especially thin (<150 mm) bituminous surfaced pavements.

Austroads project TT1452 *Development of pavement design models* has provided an enhanced ability to predict pavement critical strain by means of a non-linear finite element (FE) method (Austroads Pavement Analytical Design Software – APADS). Granular moduli calculated in the model from the repeated load triaxial test results are significantly different from the presumptive values currently used. As a result, the strains calculated from this FE model are considerably different from those currently calculated and used in linear elastic modelling.

This MRWA-funded research project *Validation of Proposed Austroads Finite Element Pavement Design Model* is aimed at evaluating the effectiveness of APADS compared to the current methodology (linear elastic model CIRCLY).

The project consisted of characterising the modulus of each material through laboratory repeated load triaxial (RLT) testing, modelling the different pavement sections in APADS and CIRCLY, and comparing deflections predicted by these models with measured deflections from falling weight deflectometer (FWD) testing. Data from the Kwinana Freeway trial sections were used as they comprised pavements with a variety of granular base types.

2 KWINANA FREEWAY TRIAL SECTIONS

2.1 Introduction

During the construction of the New Perth Bunbury Highway (NPBH) in 2009, Main Roads Western Australia (MRWA) constructed 15 pavement trial sections. The NPBH is a continuous 70.5 km of dual carriageway freeway from Safety Bay Road in Baldivis to Old Coast Road in Lake Clifton (Figure 2.1).

The 32 km section from Safety Bay Road in Baldivis to South Yunderup Road in South Yunderup, is part of Kwinana Freeway. The remainder of the route is part of a rural highway called Forrest Highway. The route was opened to traffic on 20 September 2009.

The approximate limits of the trial sections are shown in Figure 2.2. The details of the pavement sections including surfacing, basecourse and subbase materials, and layer thicknesses are given in Figure 2.3. The pavement layer thicknesses shown in Figure 2.3 are the as-constructed layer thicknesses rather than the nominal design values.

The primary objective of the construction of the trial sections was to evaluate the performance of various granular base types over an extended period of time. However, in this project the data collected was used to investigate whether a nonlinear finite element model (APADS) provides a better match to the measured deflections than a linear elastic model (CIRCLY).

2.2 Composition of the Trial Site Pavements

The various granular base materials used in the Kwinana Freeway trials are listed below:

- CRB – crushed rock base (< 26.5 mm maximum stone size)
- FC – ferricrete
- G1 CRB – crushed rock base (< 37.5 mm)
- HCTCRB – hydrated cement treated crushed rock base (< 26.5 mm)
- BSL – bitumen (2%) stabilised limestone
- CRC – crushed recycled concrete and demolition material.

The sources of the subbase and basecourse materials are as summarised in Table 2.1.

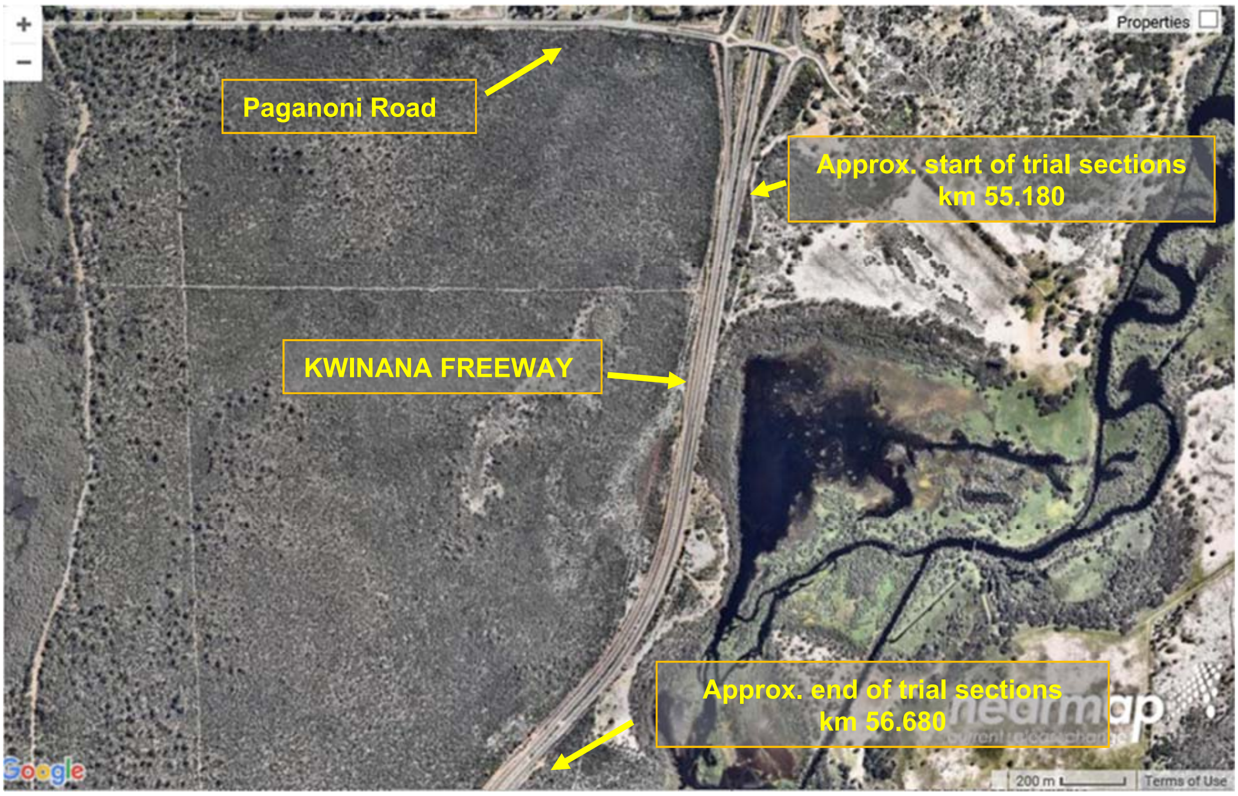
All trial sections include crushed limestone subbase (CLS) and sand subgrade: as shown schematically in Figure 2.3, trial Section 1 was constructed on white/grey (Bassendean) sand, while the remainder of the trial sections were constructed on yellow (Tamala) sand.

This report provides a comprehensive analysis of the data obtained from the Kwinana Freeway trial sections excluding the full-depth asphalt sections. Section 1 was also excluded due to the difficulty of undertaking laboratory modulus testing of the white sand subgrade in this section.

Figure 2.1: NPBH project map

Source: Southern Gateway Alliance – SGA Website.

Figure 2.2: Approximate start and end locations of trial sections



Source: nearmap© (2016), 'WA' map data, nearmap, Perth, WA.

Table 2.1: Base and subbase material sources

Material description	Source of material
Crushed rock base (CRB)	Holcim, Gosnells Quarry
Ferricrete	B&J Catalano (Pty) Ltd., Wagerup Pit
G1 crushed rock base	WA Bluemetal, Byford Quarry
Hydrated cement treated crushed rock (HCTCRB) (hydration age 27 days)	Cemex, Gosnells
Bitumen stabilised limestone (BSL)	WA Limestone, Quarry 9
Crushed recycled concrete (CRC)	All Earth Group (Pty) Ltd.
Crushed limestone subbase (CLS)	WA Limestone, Quarry 9

Source: Rehman (2011).

Figure 2.3: Kwinana Freeway trial sections

		55180	55280	55380	55480	55580	55680	55780	55880	55980	56080	56180
		1	2	3	4	5	6	7	8	9	10	11
SURFACI		30 OGA	30 OGA	30 OGA	30 OGA	30 OGA	30 OGA	30 OGA	30 OGA	A20E OGA	30 OGA	30 OGA
		30 DGA	30 DGA	30 DGA	30 DGA	30 DGA	30 DGA	30 DGA	A15E DGA	A15E DGA	30 DGA	30 DGA
		ES	ES	ES	ES	ES	ES	ES	ES	ES	ES	10S
PAVEMENT		223 HCTCRB	160 CRB	255 CRB	260 FC	255 G1CRB	255 HCTCRB	255 HCTCRB	255 HCTCRB	290 HCTCRB	265 HCTCRB	180 ICA (MRWA)
												88 ICA (MRWA)
		200 CLS	255 CLS	150 CLS	150 CLS	150 CLS	150 CLS	150 CLS	150 CLS	150 CLS	150 CLS	150 CLS
SUBGRADE		WHITE SAND	YELLOW SAND									

ES	Emulsion seal 10mm / 5mm
7S	7mm Class 170 seal
10S	10mm Class 170 seal
10GS	10mm Geotextile reinforced seal on 10/5 emulsion seal
OGA	Open graded asphalt
DGA	Dense graded asphalt (granite compacted to 94% (Rc))
A15E	Polymer modified binder
A20E	Polymer modified binder
SMA	Stone mastic asphalt 7mm
ICA (MRWA)	Intermediate course asphalt (MRWA spec 510), compacted to 95% (Rc)
ICA (SGA)	Intermediate course asphalt (SGA spec 510), compacted to 95% (Rc)
CRB	Crushed rock base, compacted to 98% (Rc)
HCTCRB	Hydrated cement treated crushed rock base (<2
BSL	Bitumen stabilised limestone, compacted to 96%
G1CRB	Crushed rock base (<37.5mm), compacted to 88
FC	Ferricrete basecourse compacted to 98% (Rc)
BCA	Base course asphalt, compacted to 95% (Rc)
CRC	Crushed recycled concrete & demolition waste, c
CLS	Crushed limestone subbase, compacted to 94%
SAND	Minimum CBR 12, compacted to 96% (Rc)

Source: Rehman (2011).

2.3 Construction

The granular bases were constructed and surfaced between May 2009 and August 2009, as summarised in Table 2.2.

Table 2.2: Construction dates

Trial section number	Base material	Base carted	Base compacted	Primed	Emulsion primerseal	Dense graded asphalt
2	Crushed rock base	unknown	8 May 09	29 May 09	15 June 09	26 July 09[3]
3	Crushed rock base	unknown	8 May 09	29 May 09	15 June 09	26 July 09[3]
4	Ferricrete	unknown	14 May 09	9 June 09	15 June 09	26 July 09[3]
5	G1 Crushed rock base	unknown	18 May 09	9 June 09	15 June 09	26 July 09[1][3]
6	HCTCRB	11 May 09	13 May 09	9 June 09	15 June 09[2]	5 August 09
7	HCTCRB	11 May 09	13 May 09	9 June 09	15 June 09	27 August 09
8	HCTCRB	11 May 09	13 May 09	9 June 09	15 June 09	28 August 09
9	HCTCRB	11 May 09	14 May 09	29 May 09	15 June 09	28 August 09
10	HCTCRB	11 May 09	14 May 09	29 May 09	15 June 09	26 July 09[3]
12	Bitumen stabilised limestone (BSL)	20 May 09	27 May 09	9 June 09	15 June 09	26 July 09[3]
13	Crushed recycled concrete (CRC)	21 May 09	23 May 09	9 June 09	15 June 09	26 July 09[3]
14	HCTCRB	11 May 09	14 May 09	9 June 09	15 June 09	26 July 09[3]

1. DGA stopped 35m short of Lot 5 and 6 boundary to allow large working area for GRS.
2. GRS seal was placed on 30/07/09
3. DGA Shoulder was placed on 05/08/09

The base material of each trial section was spread and shaped using a grader. Base materials were compacted using a 15 tonne vibrating smooth drum roller and a 15 tonne multi-wheel rubber tyred roller.

After compaction, the bases were dried back and the following surfacing treatments applied:

- 50/50 (Class 170 bitumen/medium curing cutting oil) prime
- two coat 10 mm/5 mm primerseal
- CRS170/60 emulsion (diluted by 50% water) tack coat
- 30 mm thickness of 10 mm dense graded asphalt placed (except for Section 7 where a stone mastic asphalt layer was used)
- CRS170/60 emulsion (diluted by 50% water) tack coat
- 30 mm thickness of open graded asphalt.

3 MATERIALS TESTING DURING CONSTRUCTION

3.1 Introduction

During construction, materials acceptance testing and construction compliance testing were undertaken. Details of the materials acceptance testing are presented in the Materials Engineering Report No. 2010-13 M (Rehman 2011).

The pavement materials were tested in the laboratory for:

- particle size distribution
- determination of linear shrinkage (LS)
- determination of liquid limit (LL) and plasticity index (PI)
- determination of maximum dry density (MDD)
- optimum moisture content (OMC)
- soaked CBR.

The results are included in Appendix A.

3.2 Field Densities

As part of the quality control testing, in situ density testing was conducted on each trial section. All the bases complied with the minimum characteristic dry density ratio specified for each base material type (Rehman 2011).

The mean dry densities are summarised in Table 3.1.

Table 3.1: Summary of mean field densities measured at construction

Trial section number	Base material	Mean dry density (t/m^3)		
		Base	Crushed limestone subbase	Sand subgrade
2	Crushed rock base	2.32	1.90	1.77
3	Crushed rock base	2.31	1.90	1.77
4	Ferricrete	2.45	1.92	1.75
5	G1 crushed rock base	2.59	1.89	1.77
6	HCTCRB	2.23	1.88	1.80
7	HCTCRB	2.23	1.86	1.80
8	HCTCRB	2.23	1.87	1.74
9	HCTCRB	2.23	1.86	1.76
10	HCTCRB	2.23	1.85	1.76
12	Bitumen stabilised limestone (BSL)	1.90	1.90	1.77
13	Crushed recycled concrete	1.97	1.88	1.81
14	HCTCRB	2.21	N/A	1.85

3.3 In Situ Moisture Content

The deflection data used in this research project were those measured with the FWD after the primerseal was placed and prior to the placement of the asphalt surfacing (Section 4).

The mean moisture contents measured after the primerseal was placed are shown in Table 3.2. The samples for moisture content measurements were obtained by drilling test holes at two chainages in each trial section located between the wheel paths of Lane 2 (outer lane). Detailed test results are provided in MRWA Report No. 2010-13 (Rehman 2011).

It is noted that trial Sections 12 and 13 had higher subbase and subgrade moisture contents than the other sections.

Table 3.2: Summary of field moisture contents

Trial section number	Base material	Date primersealed	Date material sampled	Mean moisture content (%)		
				Base	Crushed limestone subbase	Sand subgrade
2	Crushed rock base	15 June 09	7 August 09	2.8	3.8	2.6
3	Crushed rock base	15 June 09	7 August 09	2.8	4.4	2.5
4	Ferricrete	15 June 09	17 June 09	6.0	4.2	2.5
5	G1 crushed rock base	15 June 09	17 June 09	3.0	3.8	2.1
6	HCTCRB	15 June 09	7 August 09	5.9	4.0	2.4
7	HCTCRB	15 June 09	7 August 09	5.3	3.9	2.1
8	HCTCRB	15 June 09	7 August 09	5.9	3.9	2.4
9	HCTCRB	15 June 09	17 June 09	5.3	4.1	2.4
10	HCTCRB	15 June 09	17 June 09	5.1	3.2	2.0
12	Bitumen stabilised limestone	15 June 09	17 June 09	5.2	6.0	3.9
13	Crushed recycled concrete	15 June 09	17 June 09	10.5	5.6	3.4
14	HCTCRB	15 June 09	3 July 09	5.5	4.0	2.7

3.4 Base and Subbase Thicknesses

During the excavation to obtain samples for moisture content, the base and subbase thicknesses were measured (Rehman 2011). Nominal and measured thicknesses are presented in Table 3.3.

Table 3.3: Layer thicknesses

Trial section number	Base material	Base mean thickness (mm)		Crushed limestone subbase mean thickness (mm)	
		Nominal	Measured	Nominal	Measured
2	Crushed rock base	125	160	255	250
3	Crushed rock base	230	255	150	160
4	Ferricrete	230	260	150	165

Trial section number	Base material	Base mean thickness (mm)		Crushed limestone subbase mean thickness (mm)	
		Nominal	Measured	Nominal	Measured
5	G1 crushed rock base	230	255	150	175
6	HCTCRB	230	255	150	140
7	HCTCRB	230	255	150	160
8	HCTCRB	230	255	150	145
9	HCTCRB	230	290	150	125
10	HCTCRB	230	265	150	155
12	Bitumen stabilised limestone	230	270	150	160
13	Crushed recycled concrete	230	258	150	173
14	HCTCRB	180	220	200	205

Source: Rehman (2011).

4 MEASURED SURFACE DEFLECTIONS

4.1 Introduction

Surface deflections were measured using a FWD testing at nominal contact stresses of 566 kPa and 700 kPa in the outer wheel path of Lane 2 (outer lane) and outer wheel path of Lane 1 (inner lane) of the southbound carriageway. The deflections were measured at 10 m intervals along each trial section. Deflections were measured at the following offsets from the centre of the FWD loading plate: 0 mm, 200 mm, 300 mm, 400 mm, 500 mm, 600 mm, 750 mm, 900 mm and 1500 mm.

The ages of the bases at the time the deflections were measured are listed in Table 4.1. These deflections were measured after the primerseal was placed and prior to the placement of the asphalt surfacing.

As the base moisture contents (Table 3.2) were measured in the outer lane (Lane 2), the analysis undertaken in this research project considers only the outer lane deflections.

Table 4.1: Summary of base ages when FWD testing was undertaken on primerseal surface

Trial section number	Base material	1st set		2nd set		3rd set	
		Date	Age(1)	Date	Age(1)	Date	Age(1)
2	Crushed rock base	18 June 09	41	9 July 09	62	25 July 09	78
3	Crushed rock base	18 June 09	41	9 July 09	62	25 July 09	78
4	Ferricrete	18 June 09	35	9 July 09	56	25 July 09	72
5	G1 crushed rock base	18 June 09	31	9 July 09	52	25 July 09	68
6	HCTCRB	18 June 09	36	9 July 09	57	26 July 09	74
7	HCTCRB	18 June 09	36	9 July 09	57	26 July 09	74
8	HCTCRB	18 June 09	36	9 July 09	57	26 July 09	74
9	HCTCRB	18 June 09	35	9 July 09	56	26 July 09	73
10	HCTCRB	18 June 09	35	9 July 09	56	26 July 09	73
12	Bitumen stabilised limestone	25 June 09	29	9 July 09	43	26 July 09	60
13	Crushed recycled concrete	25 June 09	33	9 July 09	47	26 July 09	64
14	HCTCRB	25 June 09	42	9 July 09	56	26 July 09	73

1. Days since construction of basecourse.

4.2 Results

Deflection bowls measured in the outer lane are detailed in Appendix B .

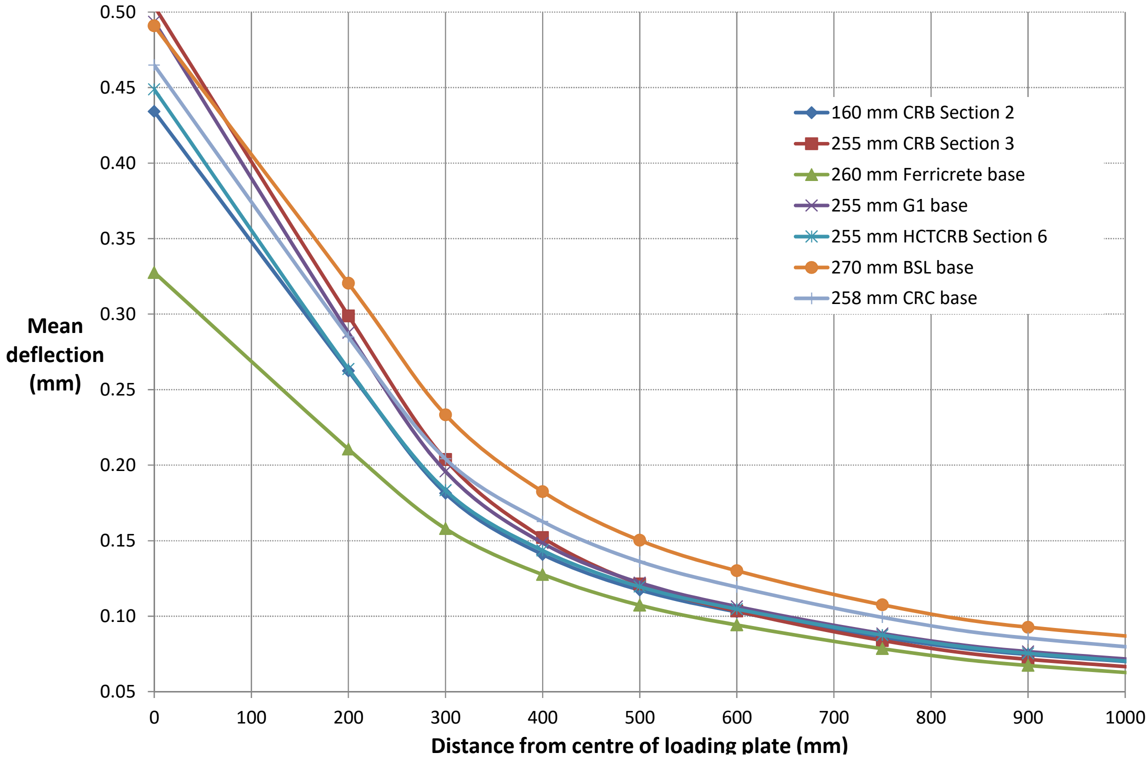
Table 4.2 summarises the mean deflection bowls for each section at the two nominal contact stresses (566 kPa and 700 kPa) based on the tests carried out closest to the date when field moisture contents were determined (Table 3.2): that is 25 and 26 July, 60-78 days after construction.

Figure 4.1 shows mean deflection bowls at a nominal contact stress of 700 kPa for selected sections.

Table 4.2: Summary of mean deflections bowls outer lane (Lane 2)

Trial section number	Date deflections measured	Average contact stress (kPa)	Mean surface deflection (mm)								
			D_0	D_{200}	D_{300}	D_{400}	D_{500}	D_{600}	D_{750}	D_{900}	D_{1500}
Nominal contact stress 566 kPa, 40 kN load											
2	25 July 09	562	0.394	0.229	0.155	0.121	0.097	0.085	0.071	0.061	0.040
3	25 July 09	562	0.443	0.266	0.177	0.130	0.103	0.087	0.070	0.060	0.038
4	18 June 09	588	0.287	0.176	0.130	0.105	0.088	0.078	0.066	0.057	0.035
5	18 June 09	583	0.385	0.204	0.139	0.111	0.094	0.083	0.070	0.061	0.039
6	26 July 09	597	0.389	0.227	0.157	0.122	0.101	0.089	0.074	0.064	0.040
7	26 July 09	593	0.376	0.222	0.156	0.123	0.102	0.090	0.074	0.064	0.039
8	26 July 09	588	0.361	0.216	0.151	0.118	0.099	0.087	0.072	0.062	0.037
9	18 June 09	580	0.373	0.196	0.131	0.105	0.089	0.078	0.066	0.057	0.035
10	18 June 09	582	0.304	0.171	0.122	0.099	0.086	0.077	0.066	0.058	0.039
12	25 June 09	571	0.450	0.274	0.187	0.140	0.114	0.097	0.082	0.072	0.048
13	25 June 09	572	0.444	0.255	0.167	0.127	0.103	0.088	0.075	0.065	0.044
14	9 July 09	614	0.350	0.201	0.138	0.110	0.093	0.082	0.069	0.059	0.039
Nominal contact stress 700 kPa, 50 kN load											
2	25 July 09	682	0.434	0.262	0.181	0.141	0.117	0.103	0.086	0.075	0.049
3	25 July 09	682	0.504	0.299	0.204	0.152	0.121	0.103	0.084	0.071	0.045
4	18 June 09	709	0.345	0.210	0.154	0.124	0.105	0.092	0.078	0.068	0.043
5	18 June 09	706	0.464	0.243	0.166	0.133	0.112	0.099	0.084	0.073	0.047
6	26 July 09	709	0.449	0.264	0.183	0.144	0.120	0.105	0.087	0.075	0.047
7	26 July 09	710	0.424	0.257	0.180	0.143	0.119	0.105	0.088	0.075	0.046
8	26 July 09	708	0.417	0.251	0.177	0.140	0.117	0.103	0.085	0.074	0.045
9	18 June 09	705	0.440	0.225	0.155	0.123	0.105	0.093	0.078	0.068	0.043
10	18 June 09	707	0.367	0.204	0.145	0.120	0.104	0.093	0.080	0.072	0.047
12	25 June 09	710	0.543	0.333	0.228	0.170	0.137	0.118	0.099	0.087	0.058
13	25 June 09	711	0.513	0.303	0.205	0.158	0.130	0.112	0.094	0.081	0.053
14	9 July 09	733	0.403	0.236	0.163	0.131	0.110	0.097	0.082	0.071	0.045

Figure 4.1: Mean deflections measured at a nominal stress of 700 kPa on 25–26 July 2009



In July 2009, the section comprising a ferricrete base (Section 4) had the lowest deflections. An unexpected observation was that the thin (160 mm) crushed rock base (Section 2) had similar deflections to the 255 mm thick HCTCRB section (Section 6). It was also noted that the section with the thicker crushed rock base (Section 3) was higher in deflection than Section 2, suggesting that the crushed limestone subbase can develop higher modulus than the crushed rock base at subbase stress levels. This was later confirmed in the laboratory (Section 5.3.3).

In July 2009 no significant difference in deflections was observed between the section with crushed rock base (Section 3) and the section with G1 crushed rock base (Section 5).

It was noted that in July 2009 the section comprising bitumen stabilised limestone (BSL) base (Section 12) and the section comprising crushed recycled concrete (CRC) base had higher deflections at an offset of 500 mm or more from the centre of the FWD loading plate. This suggests that the limestone subbase and sand subgrade in this region may be lower in modulus than the other sections. This is consistent with the trend in the measured moisture contents of the subbase and subgrade (Table 3.2).

It was observed from the data in Appendix B that deflections varied with time despite the base being surfaced with a primerseal. The sections with crushed rock base (Sections 2 and 3), G1 crushed rock base and the HCTCRB tended to increase slightly (up to about 15%) in deflection. This may have been due to a total rainfall of about 250 mm in June and July 2009 (Rehman 2011). However, the sections with ferricrete, BSL and CRC tended to decrease in deflections. Because of these variations in deflection with time, the deflection values used in the analysis (Section 5.5) were those measured on 25 and 26 July 2009, within two weeks of when the base moisture contents were measured (Table 3.2).

5 LABORATORY MODULUS TESTING

5.1 Introduction

To predict the surface deflections of the trial sections, elastic characterisation of each of the pavement layers and the subgrade is required. This section describes the method used to measure the resilient modulus of the granular bases, crushed limestone subbase and the sand subgrade.

Section 5.2 outlines the current Austroads resilient modulus test method for unbound granular materials. Section 5.3 explains how this was modified to provide more detailed characterisation required for use in the non-linear finite element modelling and the test results for bases and crushed limestone subbase. Section 5.4 investigates the influence of curing time, moisture conditions and specimen size on resilient modulus. Section 5.5 describes the test method and results for the sand subgrade. Section 5.6 summaries the modulus stress-dependency relationships used to predict the deflections (Section 6, Section 7).

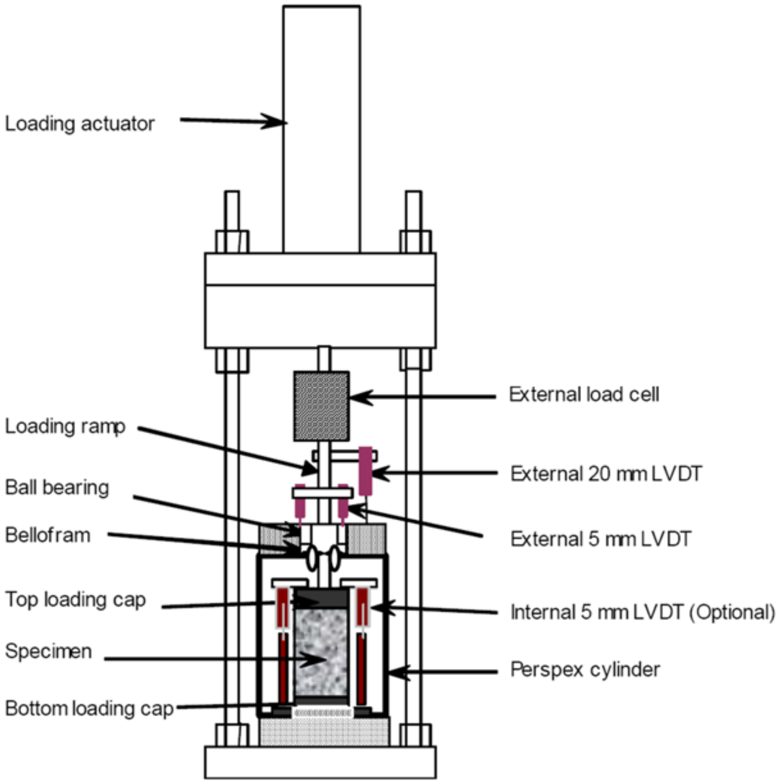
5.2 Austroads Test Method

The Austroads resilient modulus testing procedure (Austroads 2007) for unbound granular materials was developed in response to a need for performance characterisation indices and performance-based specifications for unbound materials.

The test method consists of the determination of resilient modulus of unbound granular basecourse and subbase materials under repeat load triaxial (RLT) testing (Figure 5.1). The test is conducted using cylindrical samples which are 100 mm in diameter and 200 mm height, a size suitable for materials up to 20 mm maximum particle size. For this study, test specimens were compacted to the required density by placing the loose material in the steel mould and using a modified Proctor hammer to compact the material in eight layers. The tests were conducted under drained conditions to avoid pore pressure build up.

The test method provides for the measurements of vertical resilient strain responses over 66 stress conditions using combinations of applied repeated vertical (σ_d) and static lateral confining stresses (σ_3). Table 5.1 details the standard stress states used.

Figure 5.1: Schematic of typical repeat load triaxial apparatus



Source: Austroads (2007).

Table 5.1: Stress levels for resilient modulus testing

Stress stage number	Stress levels		Stress stage number	Stress levels	
	σ_3 (kPa)	σ_d (kPa)		σ_3 (kPa)	σ_d (kPa)
1	10	10	34	40	60
2	15	15	35	60	70
3	10	15	36	40	70
4	60	20	37	30	70
5	50	20	38	15	70
6	40	20	39	60	80
7	30	20	40	40	80
8	20	20	41	30	80
9	15	20	42	20	80
10	10	20	43	40	80
11	20	25	44	60	90
12	15	25	45	40	90
13	60	30	46	20	90
14	50	30	47	60	100
15	40	30	48	40	100

Stress stage number	Stress levels		Stress stage number	Stress levels	
	σ_3 (kPa)	σ_d (kPa)		σ_3 (kPa)	σ_d (kPa)
16	25	30	49	20	100
17	20	30	50	40	100
18	15	30	51	60	120
19	60	40	52	40	120
20	50	40	53	20	120
21	40	40	54	60	140
22	30	40	55	40	140
23	15	40	56	20	140
24	40	40	57	40	140
25	60	50	58	60	160
26	50	50	59	40	160
27	40	50	60	20	160
28	30	50	61	60	180
29	15	50	62	40	180
30	60	60	63	20	180
31	40	60	64	60	200
32	30	60	65	40	200
33	15	60	66	20	200

Source: Austroads (2007)

5.3 Base and Subbase Materials

5.3.1 Test Method

Size of Test Specimens

The Austroads test method is applicable to unbound granular materials with maximum particle size of up to 20 mm. As detailed in Appendix A, the G1 crushed rock base has a maximum particle size of 40 mm and the crushed limestone subbase has a maximum particle size of about 75 mm.

For these materials, testing was conducted using 150 mm diameter and 300 mm high test specimens, which were considered suitable sizes for testing materials with maximum particle size of up to 40 mm.

The crushed limestone had a maximum particle size exceeding 40 mm, with on average, about 16% of the limestone is retained on the 37.5 mm sieve. In this case, the test specimens were prepared after discarding the material retained on the 37.5 mm sieve. To assess whether the mould size had a significant influence on the moduli, a number of size 20 mm limestone samples were tested in both the 100 mm and 150 mm diameter moulds. The testing with 150 mm specimens resulted in an average modulus increase of approximately 7% when compared to the specimens measuring 100 mm in diameter. It was concluded that the mould size had only a minor effect on the modulus on hence for the crushed limestone the moduli were measured using 100 mm diameter specimens.

Dry-back of Compacted Specimens

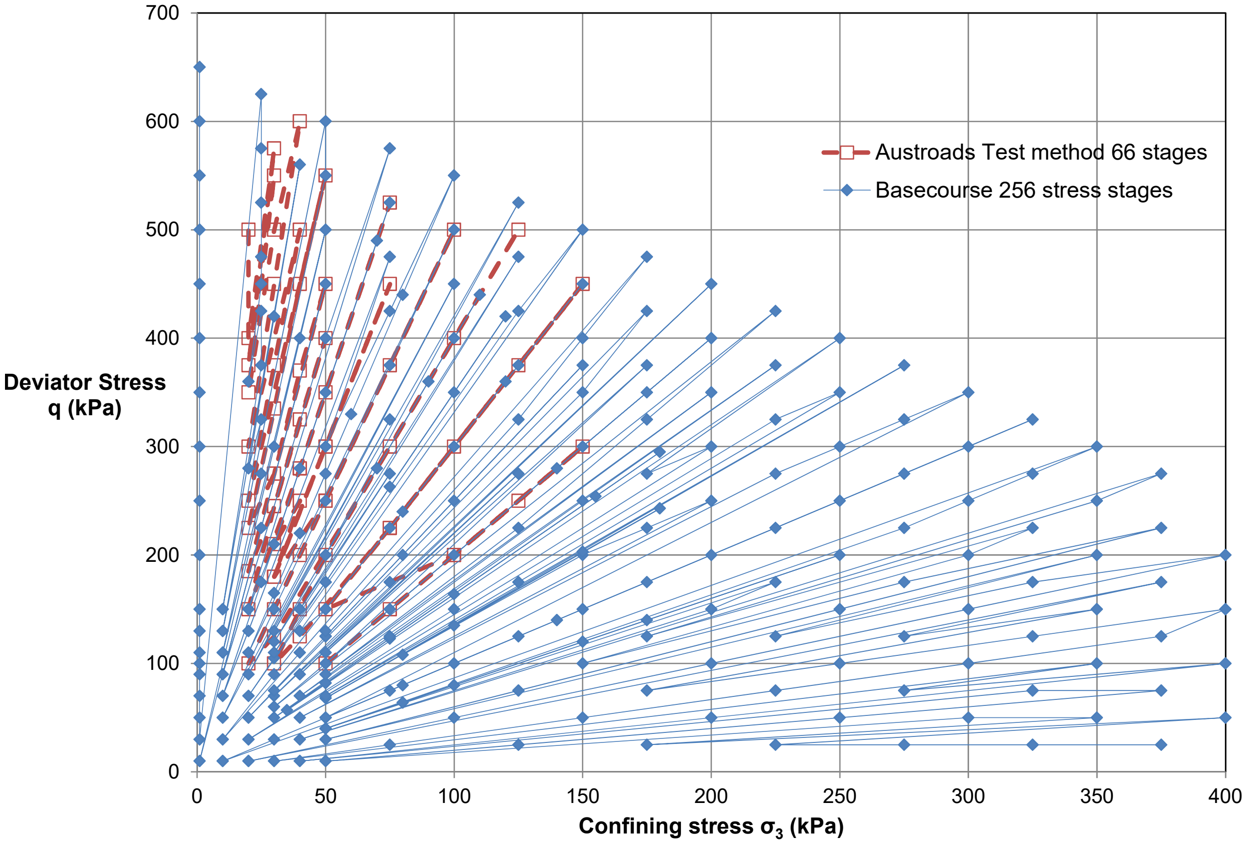
To allow comparison of predicted and measured surface deflections, modulus values were required to be measured on specimens prepared to the field densities and moisture conditions at the time of deflection testing. As the field moisture contents (Table 3.2) were well dry of optimum moisture content (OMC) it was not possible to compact the laboratory specimens to the required densities in these dry states. Consequently, the following process was used to prepare the test specimens:

- Firstly, the test material was wet up to modified Proctor OMC.
- The material was then compacted in the test mould using a modified Proctor drop hammer to the target dry density.
- The following day, the test cylinder was removed from the mould and was then air-dried in the laboratory to the target field moisture content.
- The test cylinder was then sealed and cured. Most of the testing was undertaken after about 28 days curing in accordance with MRWA practice.

Stress states

During the development of the nonlinear finite element response to load model (Austroads 2012a) it was concluded that the 66 stress states specified in the Austroads modulus test method needed to be modified to provide a more comprehensive elastic characterisation. In conjunction with MRWA, more comprehensive sets of stress conditions were developed for testing of basecourse subbase materials, as detailed in Appendix C. A comparison between these stresses and the Austroads test conditions is presented in Figure 5.2. The revised stress states particularly address the need to predict the modulus at low deviator stresses.

Figure 5.2: Base stress stages



5.3.2 Granular Base Moduli

The measured moduli are reported in Appendix C.1. Regression analysis was undertaken to derive the modulus stress-dependency relationship (Equation 1) for each test specimen.

$$E = K_1 \times \left(\frac{\sigma_m}{\sigma_{ref}}\right)^{K_2} \times \left(\frac{\tau}{\sigma_{ref}}\right)^{K_3} \quad (1)$$

where

E	=	resilient modulus (MPa)
σ_m	=	mean normal stress, $(\sigma_1 + 2\sigma_3)/3$, (kPa)
τ	=	octahedral shear stress, $(\sqrt{2}(\sigma_1 - \sigma_3)/3)$, (kPa)
σ_{ref}	=	reference stress (atmospheric pressure = 100 kPa)
K_1, K_2, K_3	=	constants determined from regression analysis

A minimum mean normal stress of 40 kPa was considered in the FE model to take into consideration the residual compaction stress (Austroads 2012). In addition, the FE model predicted that the octahedral shear stresses do not exceed 450 kPa. Consequently, in undertaking the regression analysis, modulus data with a mean stress less than 40 kPa or octahedral shear stress greater than 450 kPa were not included.

The model fits to the data are plotted in Appendix C.1 and the modulus stress-dependency relationships are summarised in Table C 2.

5.3.3 Crushed Limestone Subbase Moduli

The resilient modulus results are included in Appendix C.2.2. It is noted that the limestone samples tested were those prepared after removal of the material retained on the 19 mm sieve. Regression analysis was undertaken to derive the modulus stress-dependency relationship (Equation 1) for each test specimen.

For the crushed limestone subbase, the measured moduli exceeded 1000 MPa in some stress states. For confining pressures above 100 kPa the resilient moduli ranged between 1000 MPa and up to more than 2 000 MPa. It should be noted that the RLT equipment does not use on-specimen measurements and for stiff materials, the resilient modulus measurement can be biased due to machine compliance effects. Machine compliance effects are specific to each testing equipment used. It is considered that the resilient moduli data greater than 1 000 MPa were impacted by this issue and therefore should not be considered reliable. Nevertheless, this data was not excluded in calculating the modulus stress-dependency (Equation 1).

The model fits to the data are plotted in Appendix C.2.2. The modulus stress-dependency parameters are summarised in Table C 4.

5.4 Effect of Specimen Preparation on Base and Subbase Resilient Modulus

During the base and subbase modulus testing, the specimens were subjected to different curing periods and moisture contents. This section explores how each factor influenced the resilient modulus of selected material types.

5.4.1 Effect of Curing Time

MRWA current practice is cure modulus specimens for about 28 days prior to testing.

The specimens were firstly compacted at OMC. Specimens were the placed in a soil oven at a temperature of 35ºC to dry back to the desired moisture content. When the appropriate moisture content (i.e. test conditions) was reached the specimen was sealed (using plastic membrane or stored in a sealed container) and left to 'cure' for a period of time. During this curing period, typically 28 days, the moisture content differences between the drier outer surface and the interior, tend to equalise.

As some granular materials increase in modulus with time, it was of interest to test materials after more than 28 days curing. This was important as the measured FWD deflections used to compare to the predict values were measured about 80 days after construction. It was decided to measure the ferricrete, BSL and CRC base moduli after extended curing. The crushed limestone subbase was also investigated.

Ferricrete

Modulus testing of ferricrete was conducted of samples after four curing periods: 35, 36, 88 and 90 days. Figure 5.3 shows the measured modulus of a specimen based on curing time plotted against a 36-day reference curing period.

Figure 5.3: Ferricrete modulus variation with curing time

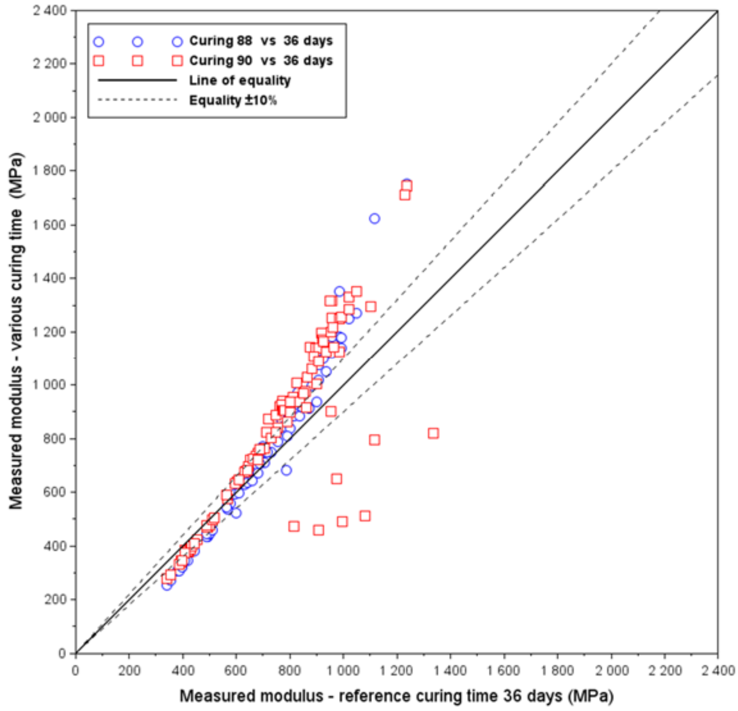


Figure 5.3 indicates that the resilient modulus of ferricrete generally increases with curing time. For example, a 36-day modulus of 880 MPa increases to about 1000 MPa after 90 days curing.

The increase in modulus with curing time is not clear for results lower than about 700 MPa.

Bitumen Stabilised Limestone (BSL)

Modulus testing of BSL was undertaken on samples after three curing periods: 29, 73 and 74 days. The measured modulus of a specimen based on curing time plotted against a 29-day reference curing period is presented in Figure 5.4.

Figure 5.4: BSL modulus variation with curing time

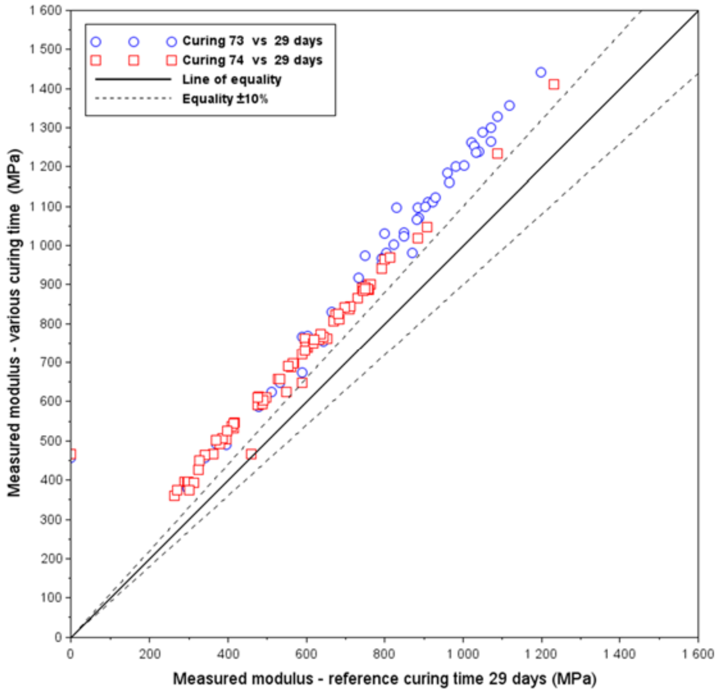


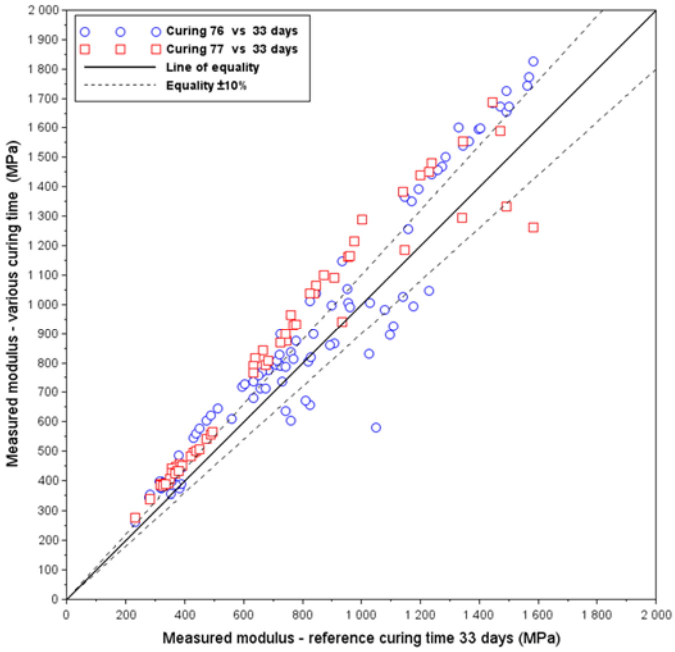
Figure 5.4 indicates that the resilient modulus of BSL generally increases with curing time. For example, a 29-day modulus of 670 MPa increases to about 800 MPa after 74 days curing.

Crushed Recycled Concrete

Modulus testing of crushed recycled concrete was conducted on samples after three curing periods: 33, 76 and 77 days. Figure 5.5 shows the measured modulus of a specimen based on curing time plotted against a 33-day reference curing period.

Figure 5.5 indicates that in general crushed recycled concrete modulus increases with curing time. For example, a 33-day modulus of 680 MPa increases to 800 MPa after 77 days curing.

Figure 5.5: Crushed recycled concrete modulus variation with curing time



Limestone Subbase

Modulus testing of BSL was conducted on samples after six curing periods: 28, 30, 31, 90, 92 and 93 days. The measured modulus of a specimen based on curing time plotted against the 28-day reference curing time period is presented in Figure 5.6 .

Figure 5.6: Crushed limestone subbase modulus variation with curing time

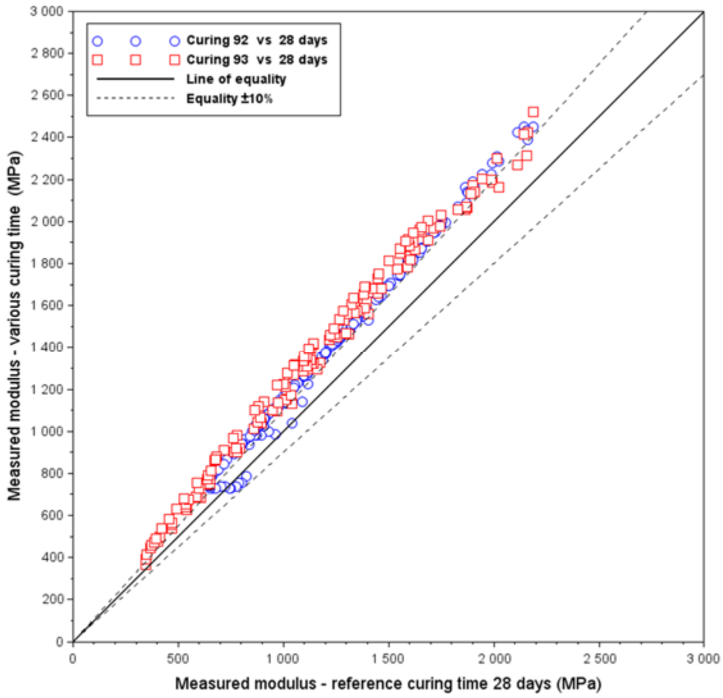


Figure 5.6 indicate that in general crushed limestone subbase modulus increases with curing time. For example, a 28-day value of 500 MPa increases to about 630 MPa after 92 days.

5.4.2 Moisture Content Effect

Testing of crushed rock base and crushed limestone subbase specimens to evaluate the effect of moisture content on modulus.

Crushed Rock Base

Modulus testing of crushed rock base was conducted on both 100 mm diameter and 150 mm diameter specimens.

Figure 5.7 shows the measured moduli of 100 mm diameter specimens measured at 55% of modified Proctor OMC compared to the values at 60% of OMC. Similarly, Figure 5.8 shows the measured moduli of 150 mm diameter specimen at 53% and 62% of OMC against the values at 60% OMC. Clearly if crushed rock base modulus needs to be measured to an accuracy of 10%, the moisture content needs to be known to a high accuracy. For the crushed rock base which had an OMC was 5.3% (Table A 1), to measure the modulus to an accuracy of 20% (e.g. 100 MPa), the moisture content of test specimen needs to be more than 0.2% from the target content.

The effect of moisture content on crushed rock base modulus is discussed further in Section 6.3.2.

Figure 5.7: Crushed rock base modulus variation with moisture content (100 mm diameter specimens)

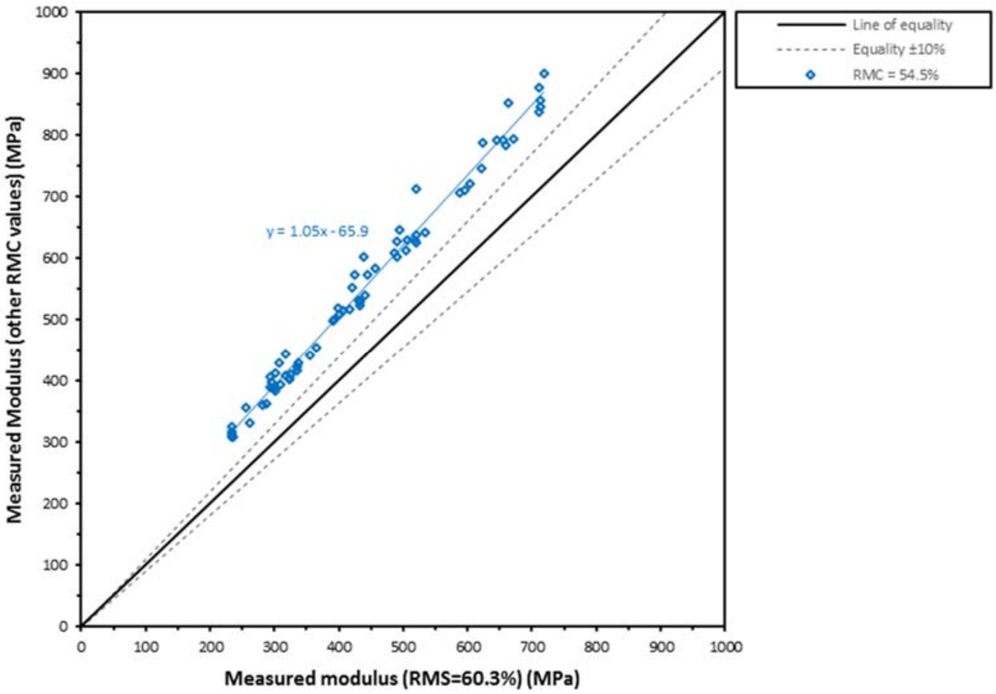
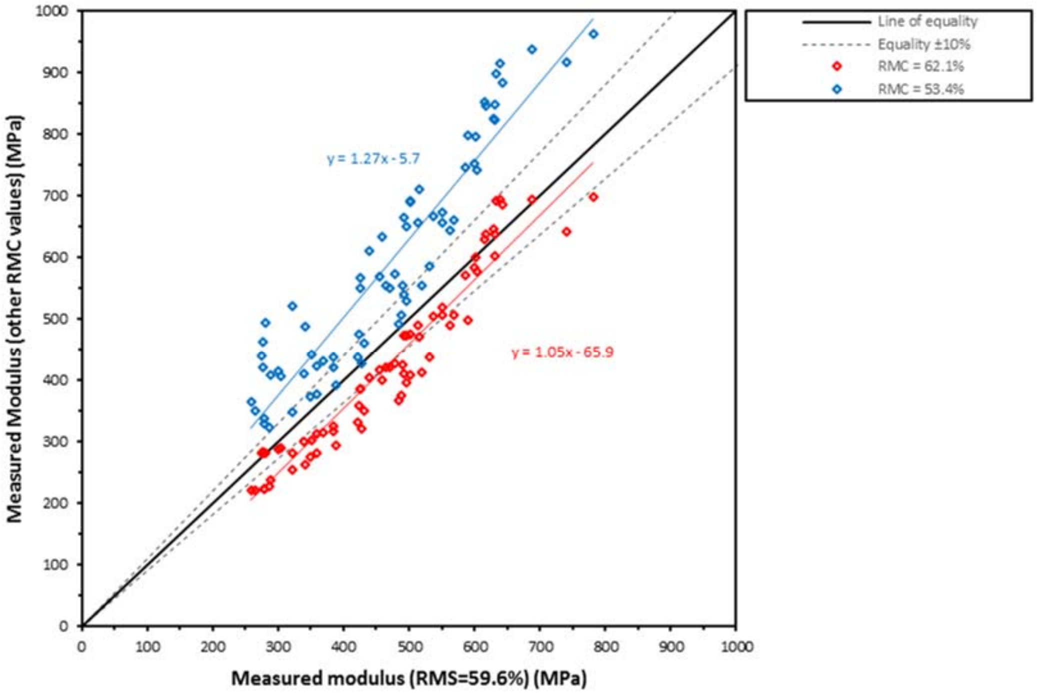


Figure 5.8: Crushed rock base modulus variation with moisture content (150 mm diameter specimens)



Limestone Subbase

Figure 5.9 and Figure 5.10 shows the measured modulus at relative moisture contents of 36% and 42% of OMC. As the OMC of the limestone was 10.5% relative moisture content of 36% and 42% equate to a moisture contents of 3.8% and 4.4%, respectively. When tested after 28 days curing, an increase in moisture content of 0.6% results in about a 20% decrease in modulus. The effect of moisture variation was less after 90 days curing.

Figure 5.9: Crushed limestone modulus variation with moisture content, 28 days curing

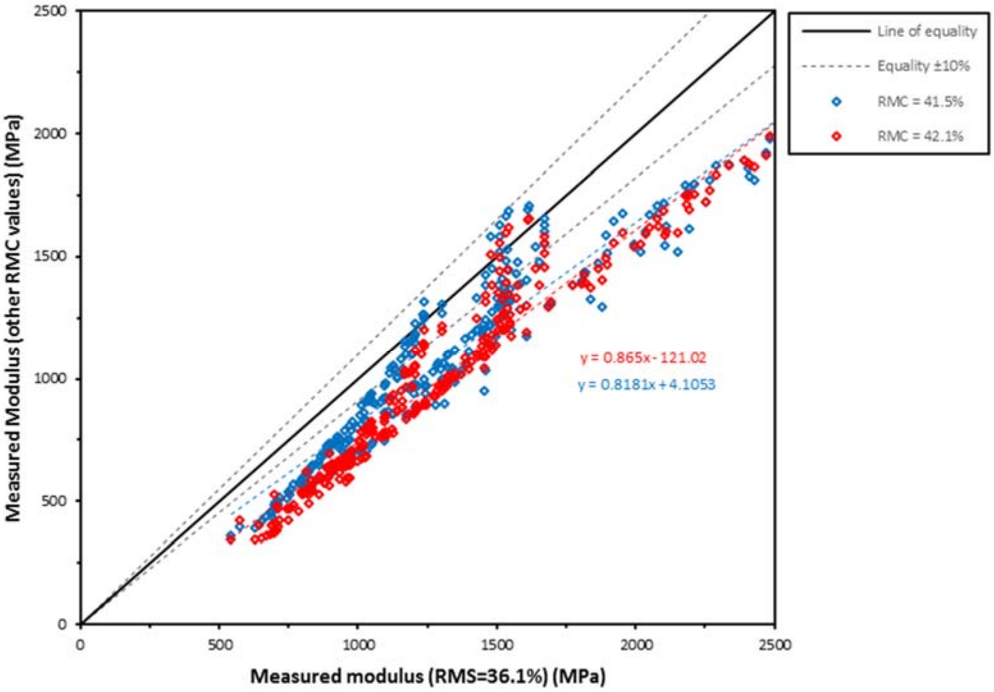
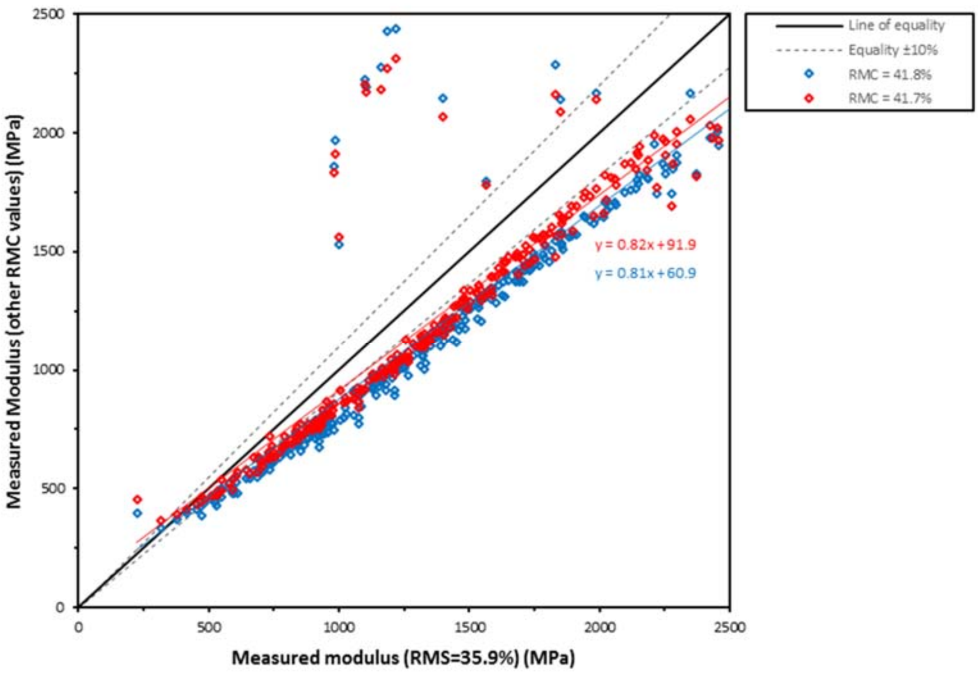


Figure 5.10: Crushed limestone modulus variation with moisture content, 90 days curing



5.5 Sand Subgrade

5.5.1 Test Method

The Austroads test method (Austroads 2007) provides stress stages for testing base and subbase materials. These stress levels exceed the predicted levels in the sand subgrade of the Kwinana Freeway trial sections. For this reason, MRWA and ARRB modified the testing by developing a 66-stress stage test for sand subgrades as detailed in Table C 5.

The stress stages adopted for the sand subgrade testing were considerably lower than applied when testing unbound granular materials using the Austroads test method. The RLT equipment specified in the Austroads method was not developed to apply low load levels. Preliminary testing of 100 mm diameter specimens indicated difficulty in reliably applying the required stress states. Therefore, it was decided to increase the specimen size to measure the modulus of 150 mm diameter and 300 mm high specimens, as this allowed higher loads to be applied for a given stress state and thus provided a more reliable test with the available equipment.

5.5.2 Modulus Results

The measured resilient moduli of the sand subgrade are given in Appendix C.3. Regression analysis was undertaken to derive the modulus stress-dependency relationship (Equation 1) for each test specimen. The model fits to the data are plotted in Appendix C.

As seen from Table 3.2, the in situ sand moisture contents ranged from 2.1% to 3.9%. Although it was possible to prepare and test a specimen at a moisture content of 2.3%, the low cohesion of the sand did not enable preparation and testing of a specimen at 3.9% moisture content. Despite a number of attempts, the sand samples collapsed when removed from the compaction mould.

The modulus stress-dependency parameters are summarised in Table C 6.

5.6 Laboratory Test Results Used to Predict Pavement Deflections

To predict pavement deflections to compare the measured deflections (Section 6), the measured moduli at conditions (density and moisture content) closest to the field conditions were selected (Table 5.2).

As seen from Figure 5.11, for some base materials the test specimen dry densities were much lower than the field densities (Table 3.1). Of particular concern, the HCTCRB modulus specimens were about 5% lower in density than the mean field density. Consequently, the HCTCRB moduli at the field densities would have been considerably higher: the example results in AGPT02 (Austroads 2012b) suggest that a 5% reduction in density results in a halving of crushed rock base modulus. In addition, as seen from Figure 5.12 the crushed limestone subbase modulus specimens were generally lower than mean field value (Table 3.1) again leading to an under-estimation of the modulus.

All the testing was undertaken with curing times around 28 days except for the crushed recycled concrete which was cured for 76 days as MRWA did not test is materials after about 28 days curing. Details of the selected conditions are provided in (Table D 1 for the base materials and Table D 2 for subbase material).

Note that the measured deflections used to compare against the predictions were those measured on 25 and 26 July 2009, which was 60-78 days after construction (Table 4.1). In contrast the laboratory measured moduli used in the predictions were those after about 28 days (except for crushed recycled concrete). Although the 28 days curing reflects MRWA current practice, as discussed in Section 6 close agreement between the measured and predicted deflections may have occurred if the curing periods were the same.

Using the modulus-stress dependency relationships, the base moduli were calculated at a mean normal stress of 240 kPa and an octahedral shear stresses of 120 kPa and are presented in Table 5.2. The resilient moduli of the crushed limestone subbase was also calculated for comparison purposes. It was concluded that at the in service density and moisture conditions the crushed limestone subbase has a higher modulus than the base materials.

Table 5.2: Material universal model parameters used for the deflection predictions

Base or subbase	Material	Trial section no.	Lab specimen number	Cure time (days)	Test moisture content (%)	Test dry density (t/m³)	k1 (MPa)	k2	k3	Resilient modulus(1) (MPa)
Base	Crushed rock base	2 - 3	09M276AF	28	2.8	2.27	383	1.00	-0.44	850
	Ferricrete	4	09M283A1	35	6.0	2.43	522	0.71	-0.14	950
	G1 crushed rock base	5	09M260A1	32	3.1	2.51	332	0.81	-0.22	650
	HCTCRB	6 - 7 - 8	Lot120 70%-A	28	5.8	2.11	473	0.69	-0.20	840
	HCTCRB	9 - 10 -14	Lot120 70%-B	29	5.8	2.11	465	0.83	-0.27	920
	Bitumen stabilised limestone	12	09M262A	29	5.2	1.91	326	0.88	-0.27	671
	Crushed recycled concrete	13	09M304A5	76	10.6	1.91	440	0.76	-0.31	808
Subbase	Crushed limestone	4,10,12	12M7B	30	3.8	1.82	860	0.58	-0.18	1385
		2,5,6-9,14	12M7C	31	3.8	1.82	860	0.57	-0.27	1346
		13	12M7G	28	4.4	1.82	605	0.71	-0.28	1071
		3	Combined 12M7G+12M7I	28	4.4	1.82	646	0.68	-0.23	1125
Subgrade	sand	2-4, 6,8,9,12, 13,14	12M212B	28	2.3	1.80	292	0.33	-0.10	
		5,7,10	12M212A	28	2.3	1.73	245	0.77	-0.42	

(1) Predicted resilient modulus using Equation 1 for mean normal stress = 240 kPa and octahedral shear stress = 120 kPa

Figure 5.11: Base modulus specimen dry densities relative to field values

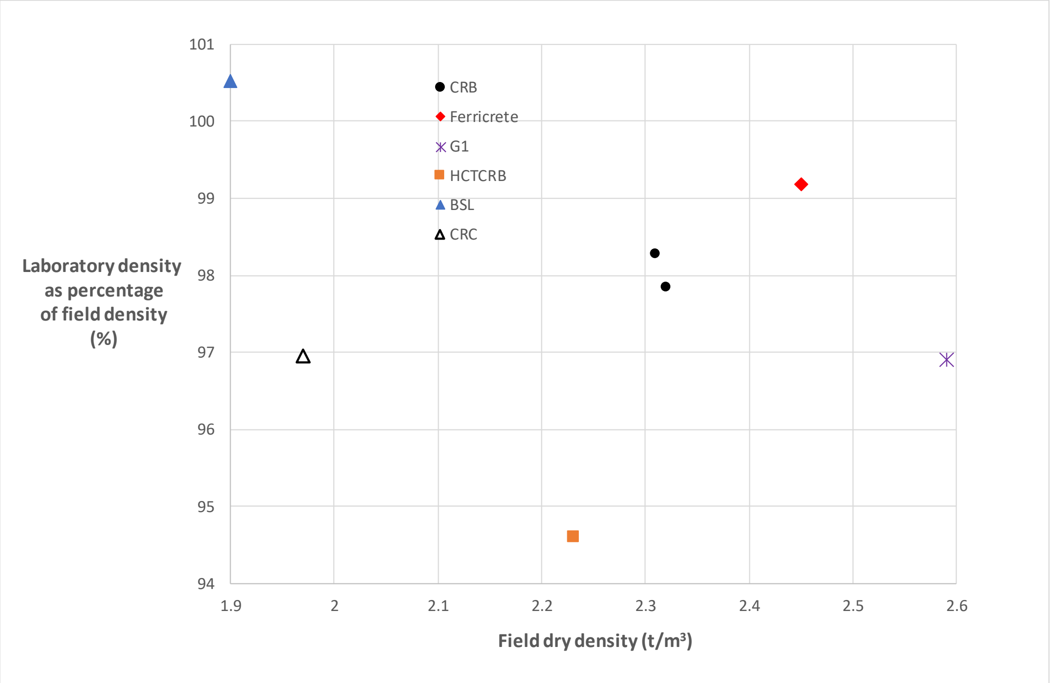
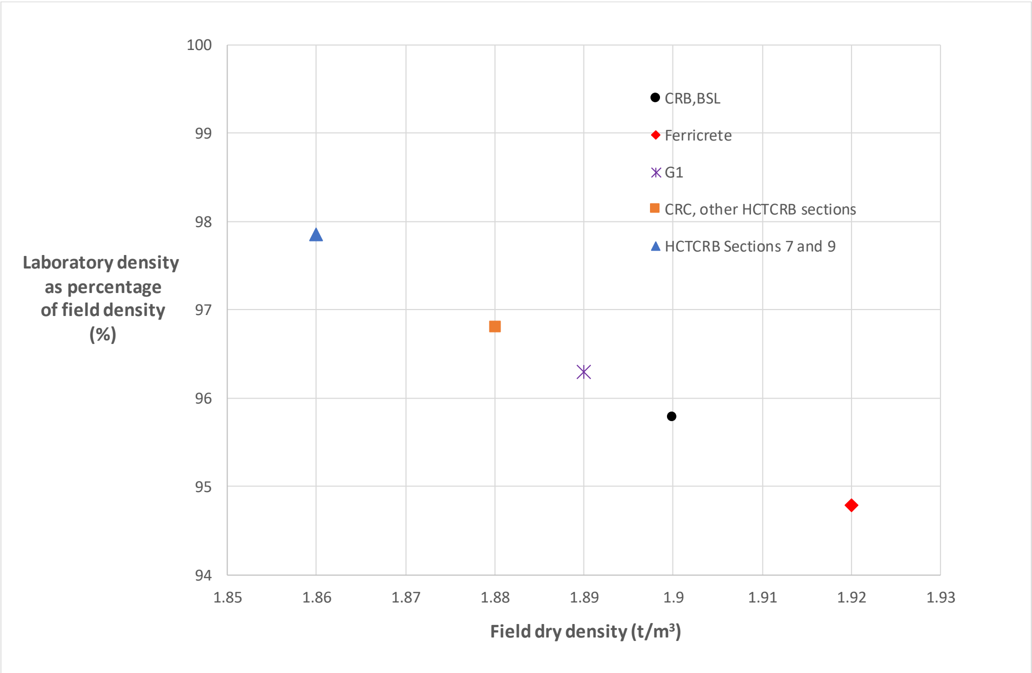


Figure 5.12: Limestone subbase modulus specimen dry densities relative to field values



6 PREDICTED DEFLECTIONS USING FE MODEL AND MEASURED MODULUS

6.1 Introduction

The primary objective of the *Validation of Proposed Austroads Finite Element Design* project was to determine if predicting pavement surface deflections using a non-linear finite element (FE) model (APADS) with laboratory measured modulus results is in better agreement with the measured surface deflections than those obtained using a linear elastic model such as CIRCLY.

This section describes how APADS was used to predict deflections for each trial section and compares the predicted deflections with the measured values. Section 7 describes findings when a linear elastic model is used to predict deflections.

It should be noted that the conclusions that can be drawn from this analysis were limited due to the measured moduli of about half the bases (Figure 5.11) and the crushed limestone subbase (Figure 5.12) being under-estimated as the specimen densities were more than 2% below the field values.

6.2 Finite Element Analysis (APADS)

6.2.1 Model inputs

The APADS model is a FE model that is capable of simulating the stress-dependent behaviour of granular and subgrade materials under an applied load. APADS provides an automated mesh generator that is tailored for multi-layered pavement structures and adopts the modulus stress-dependency relationship to account for the effect of both confining and shear stresses on the unbound granular material resilient modulus, this model is presented in Equation 1. The parameters were determined using the RLT test results, as discussed in Section 5. It is noted that the current non-linear approach used in APADS assumes that the granular material behaviour is isotropic, whereas the current Austroads method assumes it is anisotropic with a degree of anisotropy of two (the vertical modulus is twice the horizontal modulus).

The laboratory moduli used in the predictions were selected to be those with dry densities and moisture contents as close as possible to the field values during the deflection measurements. As discussed in Section 5.6, the laboratory-measured moduli used in the predictions were those after about 28 days (except for crushed recycled concrete). The selected test results for the bases, subbase and subgrade specimens are presented in Appendix D Table D 1 , Table D 2 and Table D 3, respectively.

The FE input data for each trial section is summarised in Table D 4. The base and subbase resilient moduli were limited to a minimum of 50 MPa and a maximum of 1000 MPa. The subgrade resilient moduli was limited to a minimum of 10 MPa and a maximum of 150 MPa. The minimum and maximum moduli values were selected from the presumptive values decided when the FE model framework was developed (Austroads 2012a).

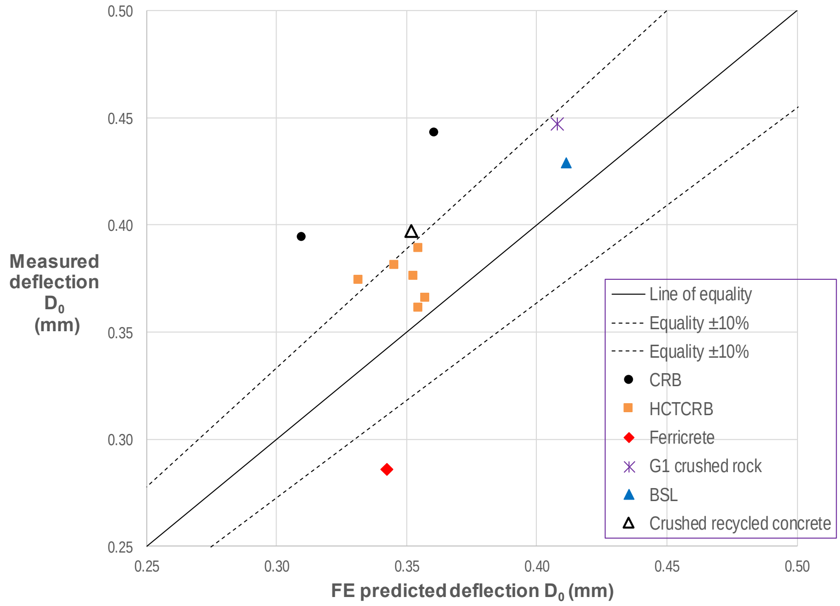
6.2.2 Results

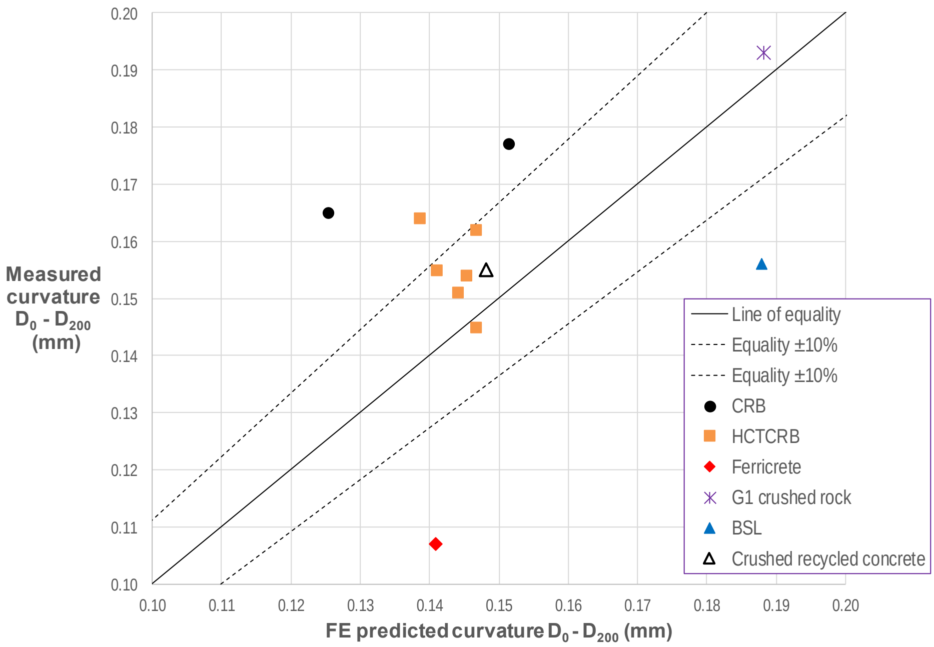
The measured maximum deflections (D_0) and curvatures ($D_0 – D_{200}$) were compared to the deflections predicted using APADS. Plots showing measured and calculated deflection bowls for each section are included in Appendix E.

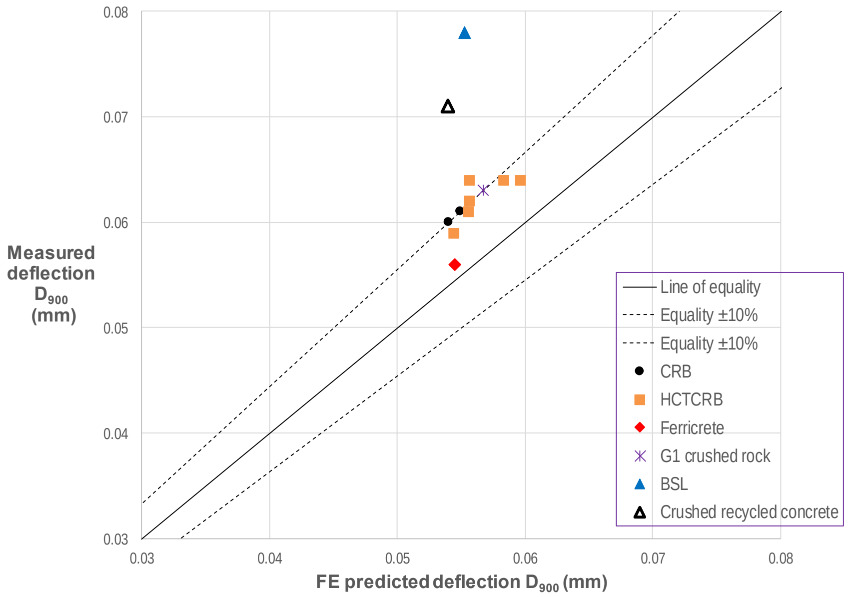
Figure 6.1 shows the predicted APADS maximum deflection (D_0), the deflection 900 mm from the load (D_{900}) and curvature ($D_0 - D_{200}$) values of each section plotted against the mean measured values for a FWD contact stress of 566 kPa.

As discussed in Section 5.6, for some materials the predicted deflections were based on modulus measurements of test specimens significantly different from the field values. For example, the HCTCRB test specimens were about 5% lower density than the mean field density. As such the HCTCRB moduli used in the deflection predictions underestimated appropriate values for comparison against the measured deflections. For HCTCRB, more appropriate moduli may have been twice the value used which would have significantly reduced the predicted D_0 and D_0-D_{200} and hence lessened the degree to which the predictions agreed with the measured values.

Figure 6.1: Comparison of FE model deflection predictions with measured deflections







6.3 Calculated Moduli

6.3.1 Base Moduli

Further to the discussion in Section 6.2.2, Table 6.1 shows the granular base moduli at a depth of 100 mm and under the centre of the loading plate, calculated from the laboratory measured moduli and the stresses calculated in the finite element modelling under 40 kN and 50 kN FWD loading.

Table 6.1: Calculated base modulus under the loading plate at depth of 100 mm

Trial section number	Base material	Base thickness (mm)	Curing period (days)	Base moduli(1) (MPa)	
				40 kN FWD load	50 kN FWD load
2	Crushed rock base	160	28	902	982
3	Crushed rock base	255	28	758	816
4	Ferricrete	260	35	950	1000
5	G1 crushed rock base	255	32	638	702
6	HCTCRB	255	28	822	889
7	HCTCRB	255	28	825	892
8	HCTCRB	255	28	823	890
9	HCTCRB	290	29	872	949
10	HCTCRB	265	29	879	956
12	Bitumen stabilised limestone	270	29	631	693
13	Crushed recycled concrete	258	76	761	811
14	HCTCRB	220	29	913	996

(1) Under the centre of the load at depth of 100 mm

Note that Section 2 had a higher modulus than Section 3 even though both sections had the same crushed rock base material. The key difference between these two sections is that Section 2 has a thinner base thickness than Section 3 (i.e. Section 2 = 160 mm, Section 3 =255 mm). Due to the very high modulus of crushed limestone subbase, the stresses at 100 mm below the surface increases as the base thickness reduces and as a consequence the modulus increases.

It was of interest to compare Section 3 crushed rock moduli with the HCTRCB values in Sections 6, 7, 8 and 10 as their base thicknesses were similar. The HCTCRB moduli were only marginally higher than the crushed rock base. Several factors may have contributed this unexpected finding:

- HCTRCB laboratory specimens were 5-6% lower in density than the field values whereas a lesser discrepancy (2% lower) applied for the crushed rock base. Had the HCTCRB modulus specimens been compacted to same relative compaction as the crushed rock base specimens, the HCTCRB moduli would have been well in excess of crushed rock base values.
- The in situ moisture content of the crushed rock base was low (about 2.8%, which is less than 50% of modified Proctor OMC). As discussed in Section 6.3.2, in this dry state the modulus is high. If such dry moisture contents could be maintained in crushed rock base, the benefits of using HCTCRB would reduce.
- HCTCRB laboratory specimens were cured for 28 days prior to modulus measurement. Had they been cured for a longer period the moduli are likely to have increased.

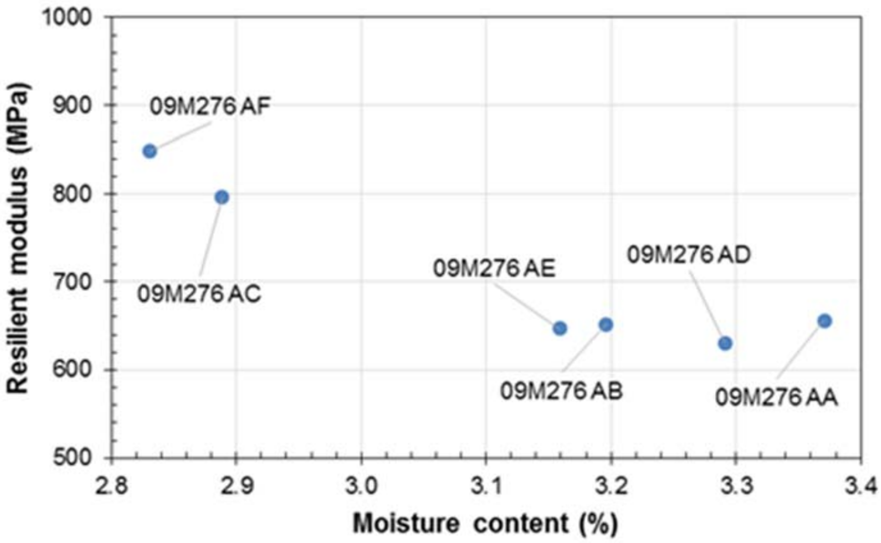
The BSL modulus when tested after 29 days curing was unexpected low compared to crushed rock base. As shown in Section 5.4.1, had the BSL been cured for 77 days prior to laboratory testing the modulus would have been similar to dry crushed rock base. As seen from Table 5.2, the BSL modulus was also low compared to crushed limestone subbase without the bitumen emulsion when both materials were tested after about 29 days curing. Additional research is required to assess the whether the lower modulus was due to its higher moisture content and the influence of the bitumen.

6.3.2 Impact of the Crushed Rock Base Moisture Content

Given the above-mentioned high modulus of the crushed rock base at the field moisture contents of the trial sections, it was of interest to investigate the modulus sensitivity to moisture content.

Figure 6.2 shows the very significant influence of moisture content on modulus: increasing the moisture content from 2.8% to 3.2% results in the modulus decreasing from about 840 MPa to about 640 MPa. It is apparent that to compare predicted and measured deflections, crushed rock base moisture contents need to be known to high accuracy.

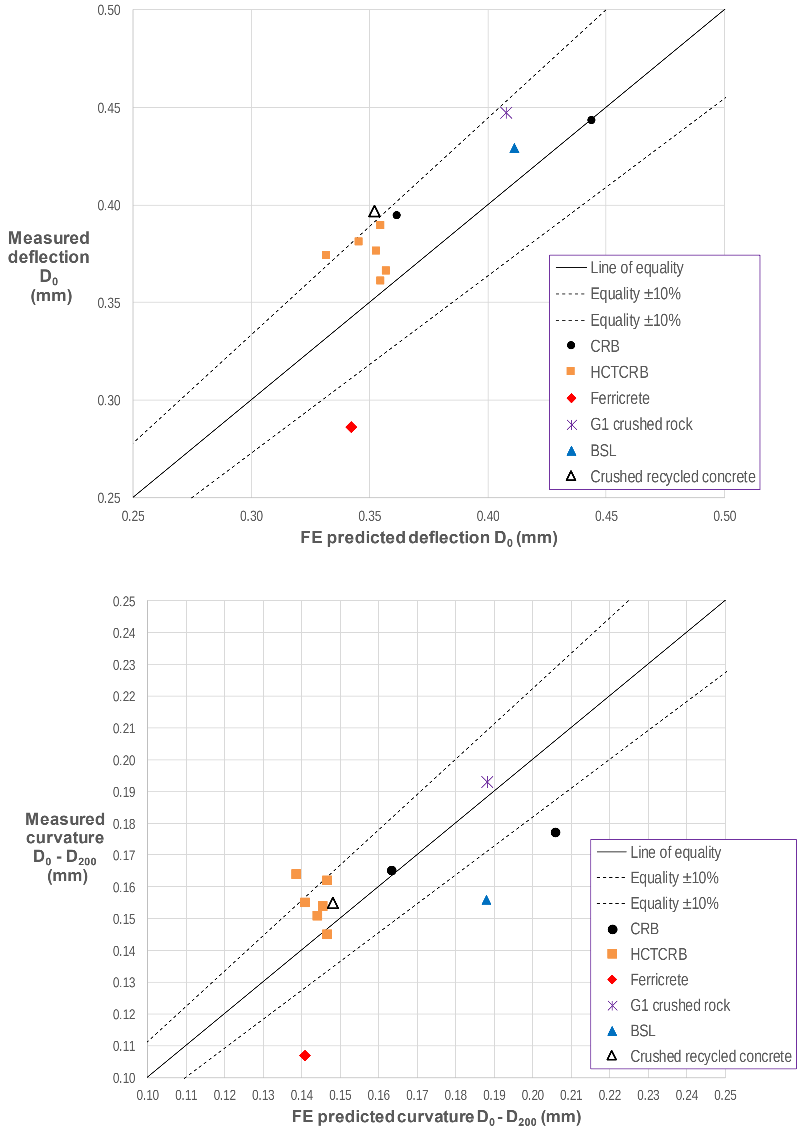
Figure 6.2: Effect of moisture content on the resilient modulus of the crushed rock base (CRB) material



In Figure 6.3, the predicted deflections and curvatures for crushed rock base at a moisture content of 3.3% are compared with the measured values (results for other bases are unchanged from Figure 6.1).

Using the crushed rock base moduli obtained in slightly wetter conditions (3.3% vs 2.8%) led to a better agreement with the measured deflections. This observation raises the question of additional complexity of finite element model is warranted for design of new pavements given the accuracy to which moisture contents can be estimated.

Figure 6.3: Finite element model deflection predictions using a crushed rock base moisture content of 3.3%



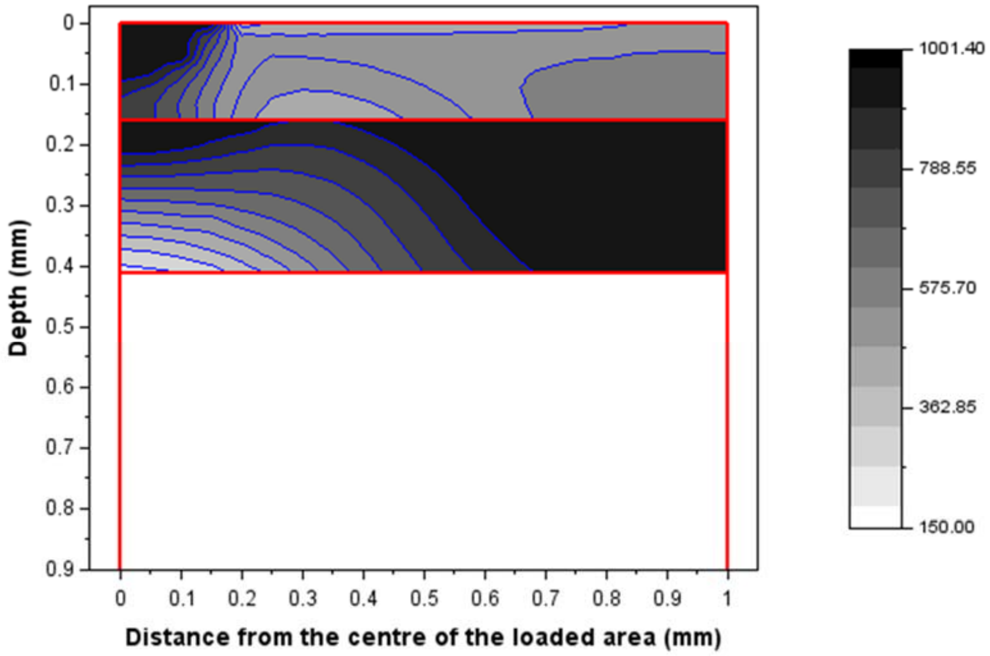
6.3.3 *Sand subgrade modulus*

Figure 6.4 shows the contour plot of the FE calculated modulus under the FWD load (contact stress 566 kPa) for trial Section 2 which had crushed rock base. It can be seen that the sand subgrade (depth > 405 mm) modulus was 150 MPa, this was the maximum value elected to be for the sand modelling. When no maximum value was assigned to the subgrade, a sand subgrade modulus of 200 MPa was calculated.

It was concluded the sand subgrade has a higher moduli than the presumptive value of 120 MPa generally assumed for this type of subgrade in Western Australia.

As discussed in Section 5.5.2, it was not possible to measure the sand modulus at a moisture content similar to the higher in situ values (Table 3.2) of the BSL and the crushed recycled concrete sections. Therefore the same sand modulus characterisation was used for these two trials sections as the others. This explains why the predicted D_{900} values of the BSL and crushed recycled concrete sections exceeded the measured values (Figure 6.1). Had a more appropriate sand modulus been used in the analysis both D_0 and D_{900} would have increased and there would have been a minor increase in D_0-D_{200}.

Figure 6.4: Tangent modulus from the non-linear analysis (Section 2)



6.3.4 *Crushed limestone modulus*

Figure 6.5 shows the profile with depth of the calculated moduli under the centre of the loading plate for pavement Section 2 which had a crushed rock base.

Of particular interest is the very high crushed limestone modulus particularly at low stress levels. Figure 6.5 shows the calculated in the middle of crushed limestone subbase (depth 285 mm). The modulus values are lower underneath the loaded area with 640 MPa under the centre of the load. Further away from the load the modulus increases until it reached the maximum modulus value or base and subbase material (E_{max} = 1000 MPa).

The crushed limestone subbase has a substantially higher modulus than the crushed rock base at any pavement stress state, including at base stresses (Table 5.2). This was despite the relative low densities to which the limestone specimens were compacted (Figure 5.12).

It is noted that the Austroads granular materials modulus characterisation was developed not based on subbases like the high modulus Perth’s crushed limestone. It was concluded that an improved mechanistic design method for characterising limestone modulus is required as the support provided by crushed limestone subbase is currently underestimated. Such an improvement needs to be undertaken in conjunction with a review of sand subgrade moduli (Section 6.3.3).

Figure 6.5: Section 2 tangent modulus profiles

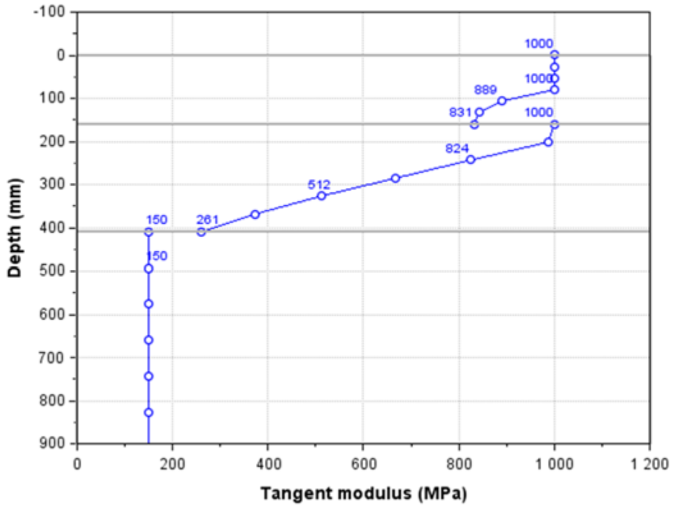
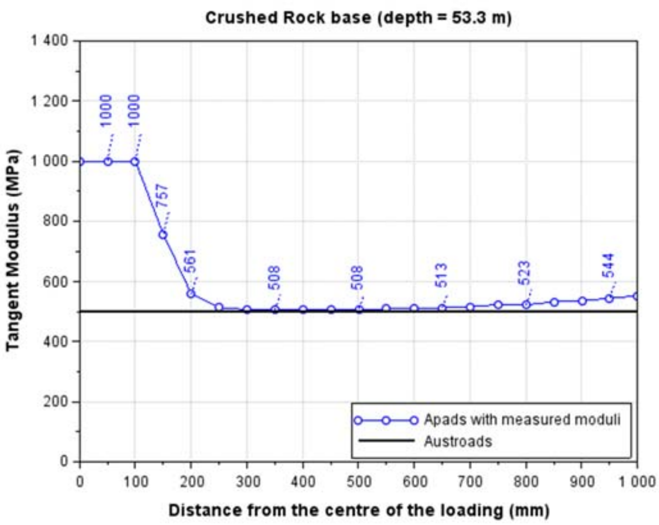
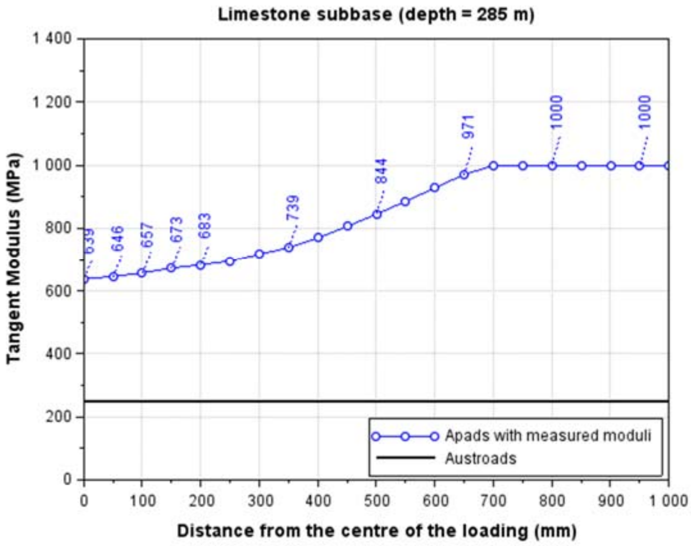


Figure 6.6: Predicted modulus variation with horizontal distance from the centre of loading





6.4 Discussion

The deflections predicted using the FE model with moduli measured at field conditions were in reasonable agreement with the measured deflections (Figure 6.1). However, limited conclusions can be drawn from the analysis as for some materials (e.g. HCTCRB, crushed limestone subbases) the moduli used in the predictions were based on test specimens that were prepared at densities which were more than 3% lower than the field densities (Figure 5.11, Figure 5.12). Had specimens been tested at appropriate densities, the predicted D_0 and D_0-D_{200} of the HCTCRB sections would be lower than indicated in Figure 6.1.

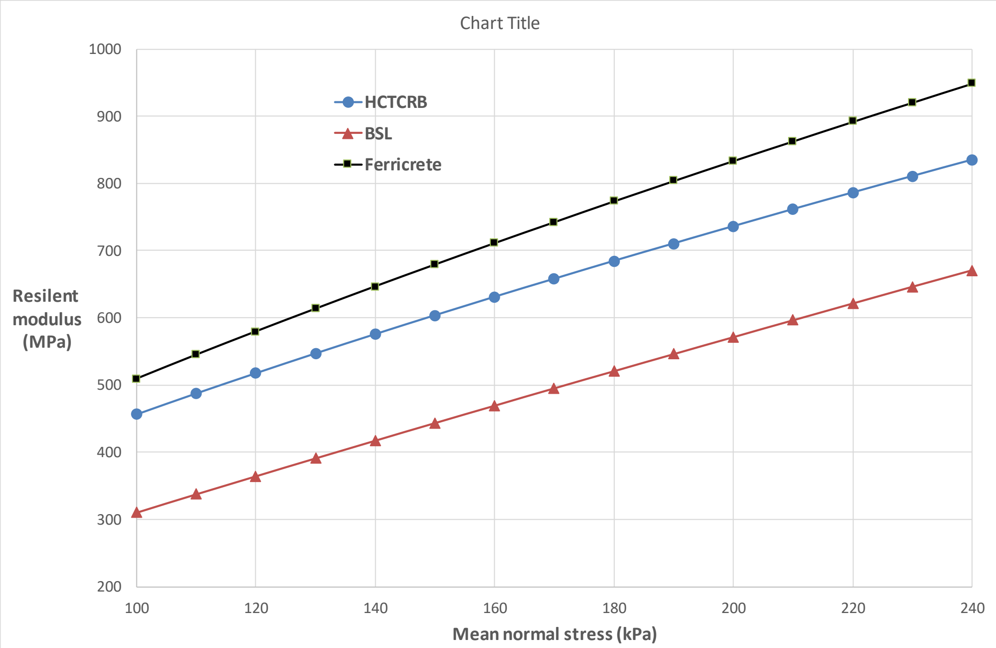
As seen from Figure 6.1, the predicted curvatures of different base types and different pavement structures were not closely correlated with the measured values. In particular, the ferricrete and BSL predictions significantly over-estimated the measured values.

In terms of the BSL predictions, the BSL trial section (Section 12) had a similar pavement structure to three of the HCTRCB trial sections (Sections 6, 7 and 8). The mean measured curvature on this BSL section was similar to that of these HCTCRB sections, suggesting the BSL modulus should be similar to HCTCRB.

The laboratory measured BSL modulus was significantly less than the HCTCRB (Figure 6.7) despite the fact the HCTCRB specimens tested were about 5% lower in density than the field density (Figure 5.11). If the procedure for measuring BSL moduli cannot be modified to provide values similar to HCTCRB, the way forward maybe to use of the same presumptive modulus as HCTCRB.

The measured curvatures of ferricrete trial (Section 4) were clearly the lowest (Figure 6.1). Although the ferricrete laboratory measured moduli were higher than HCTCRB moduli (Figure 6.7), the measured moduli did not appear to reflect the very high in situ values as a consequence the curvatures were over-predicted. Note however, the HCTCRB laboratory moduli were measured at densities well below the field density (Section 5.6) and hence the moduli were under-estimated.

Figure 6.7: Comparison base laboratory measured moduli



7 PREDICTED DEFLECTIONS USING LINEAR ELASTIC ANALYSIS

7.1 Introduction

The primary objective of the *Validation of Proposed Austroads Finite Element Design* project was to determine if predicting pavement surface deflections using a non-linear finite element model (APADS) with laboratory measured modulus results is in better agreement with the measured surface deflections than using a linear elastic model.

This section describes the use of linear elastic modelling to predict deflections for each trial section and compares the predicted deflections with the measured values.

It should be noted that the conclusions that can be drawn from this analysis were limited due to the measured moduli of about half the bases (Figure 5.11) and the crushed limestone subbase (Figure 5.12) being underestimated as the specimen densities were more than 2% below the field values.

7.2 Model inputs

Five cases of input modulus parameters were used in the analysis carried out with the linear elastic model (CIRCLY) to allow a comprehensive evaluation of the difference between the current Austroads design method with and without incorporating laboratory derived modulus, and the finite element analysis method. Unlike the FE modelling, granular and subgrade materials were considered cross-anisotropic with horizontal modulus half the vertical modulus. These cases are summarised below:

- CIRCLY Case 0: Typical design for granular pavement according to the Austroads Guide Pavement Technology Part 2 (Austroads 2012b). The basecourse, subbase and subgrade modulus are based on typical presumptive values currently used in design (Austroads 2012b). The subgrade vertical modulus of E_v = 120 MPa (E_H = 0.5 Ev) was used. The full depth of granular materials (base and subbase) was divided in five sublayers and each sublayer modulus calculated using the Austroads process. The maximum base layer vertical modulus was set to the typical high quality value of 500 MPa for all pavement sections regardless of the material.
- CIRCLY Case 1: basecourse, subbase and subgrade modulus values based on typical presumptive values currently used in design in Western Australia (e.g. subgrade vertical modulus 120 MPa). The full depth of granular materials (base and subbase) was divided in five sublayers with a maximum vertical modulus as shown in Table 7.1.
- CIRCLY Case 2: similar to Case 1 except for the maximum vertical modulus derived from RLT modulus data for mean normal and octahedral stresses respectively equal to 240 kPa and 120 kPa. Table 7.1 lists the vertical modulus of the top granular sublayer. The subgrade was modelled as per Cases 0 and 1.
- CIRCLY Case 3: similar to Case 2 except for the subgrade model. The subgrade was modelled with the vertical modulus equal to 150 MPa rather than 120 MPa.

Table 7.1: Maximum granular base vertical modulus

Base type	Vertical modulus (MPa)		
	Case 0	Case 1	Cases 2 and 3
Crushed rock base	500	600	848
Ferricrete	500	800	950
G1	500	500	646
HCTCRB	500	1000	831/914
Crushed recycled concrete	500	1000	807
Bitumen stabilised limestone	500	500	670

For Cases 2 and 3. the stress states used to determine the maximum vertical modulus from measured values were consistent with the MRWA Engineering Road Note 9 (MRWA 2013). ERN9 requires that the minimum octahedral shear stress and the maximum mean normal stress used in the determination of the vertical modulus of the top sublayer of the base from laboratory RLT testing are, respectively, 120 kPa and 240 kPa. For all cases the base, subbase and subgrade materials were considered to be cross-anisotropic with the horizontal modulus half the vertical modulus.

The input parameters for each cases are listed in Table D 5.

7.3 Comparison Measured and Predicted Deflections

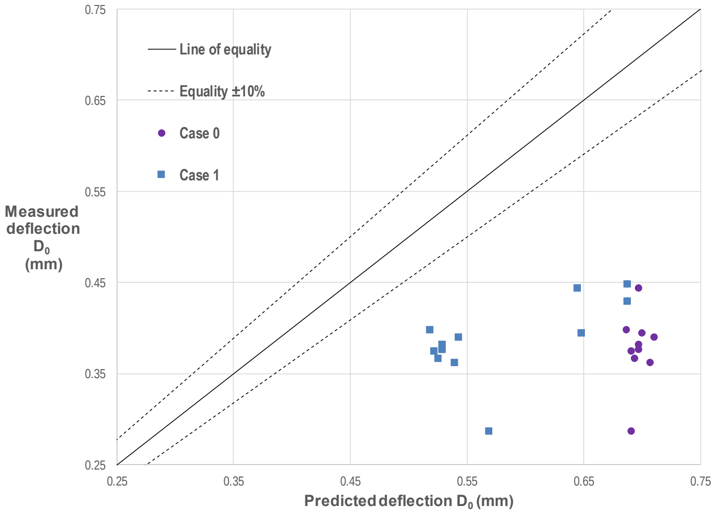
Plots showing measured and predicted deflection bowls for each section are listed in Appendix E.

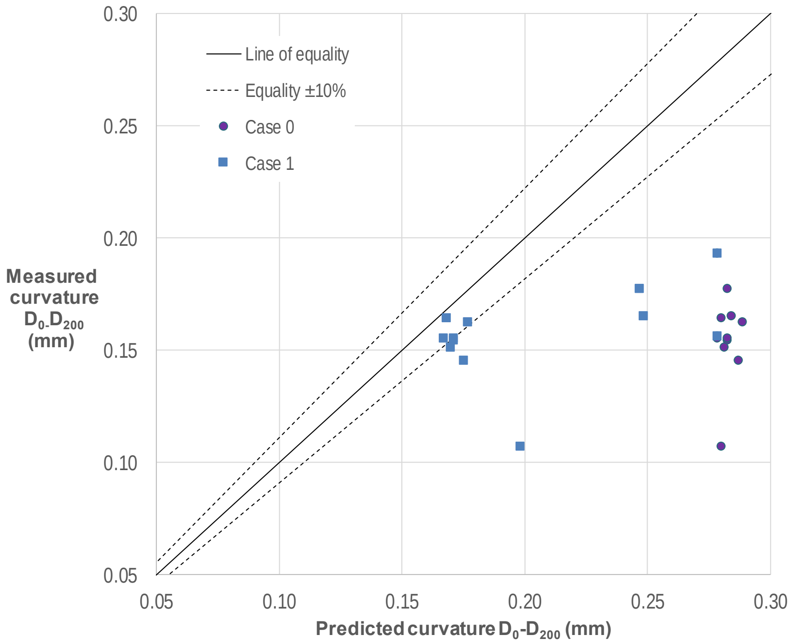
7.3.1 Cases 0 and 1

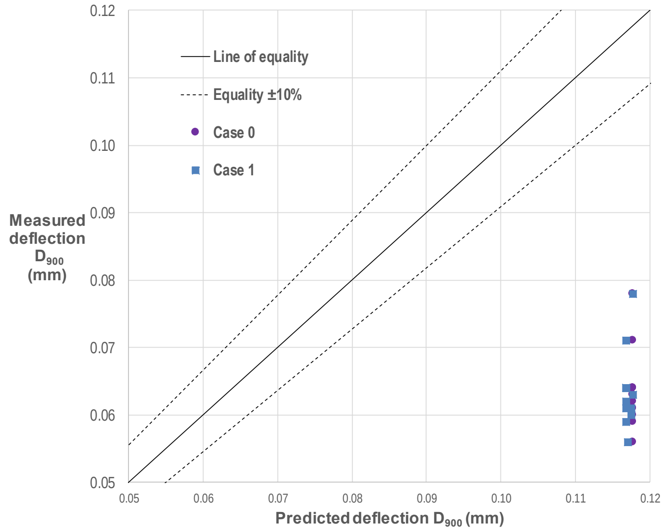
For Cases 0 and 1, Figure 7.1 compares the measured D_0, D_0-D_{200} and D_{900} values normalised to a contact stress of 566 kPa with the predicted deflections.

Results plotted in Figure 7.1 indicate that the use of Austroads presumptive base moduli (Case 0) leads to significant over-estimation of pavement deflections. Predictions made using the MRWA presumptive base moduli (Case 1) are a much closer with the measured values. However, it is noted that using a sand subgrade modulus of 120 MPa results in the predicted D_{900} being about twice the measured values. Had a higher maximum subgrade modulus been used the predicted D_0 and D_{900} values would have been in closer agreement with the measured values.

Figure 7.1: Comparison of Case 0 and Case 1 predictions with measured values







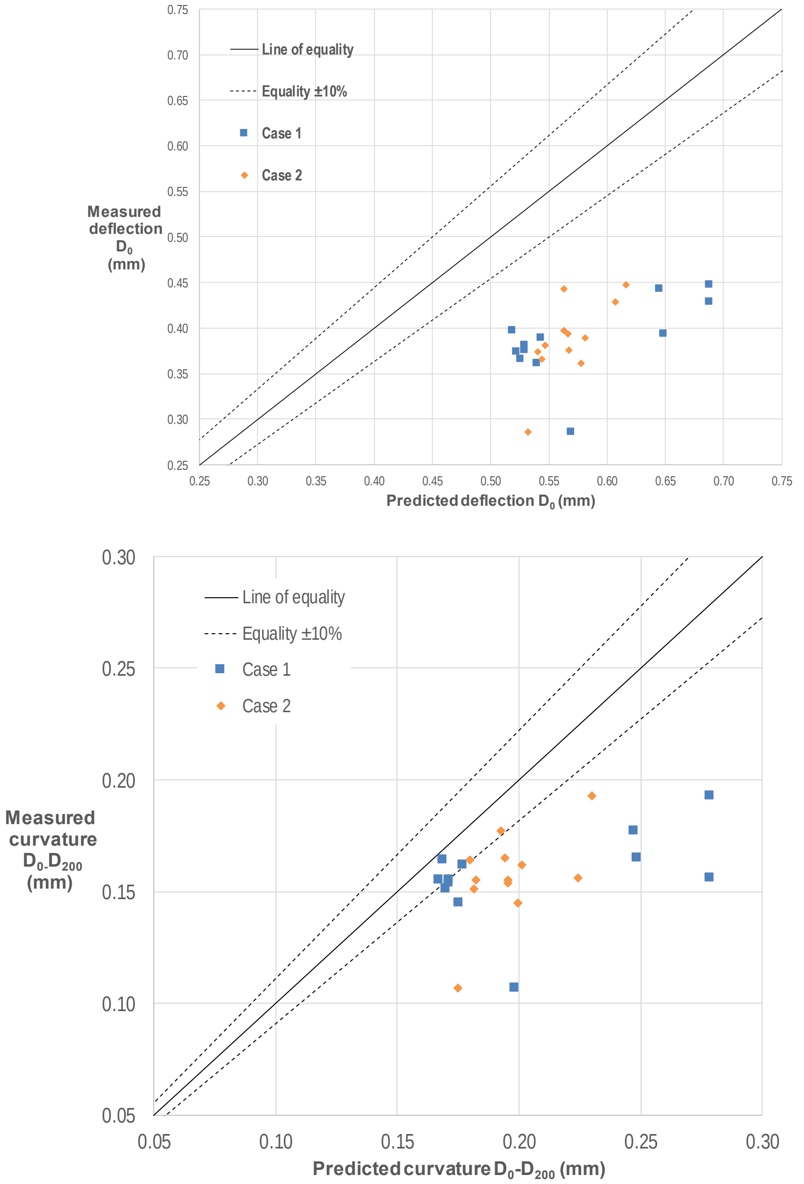
7.3.2 *Cases 1 and 2*

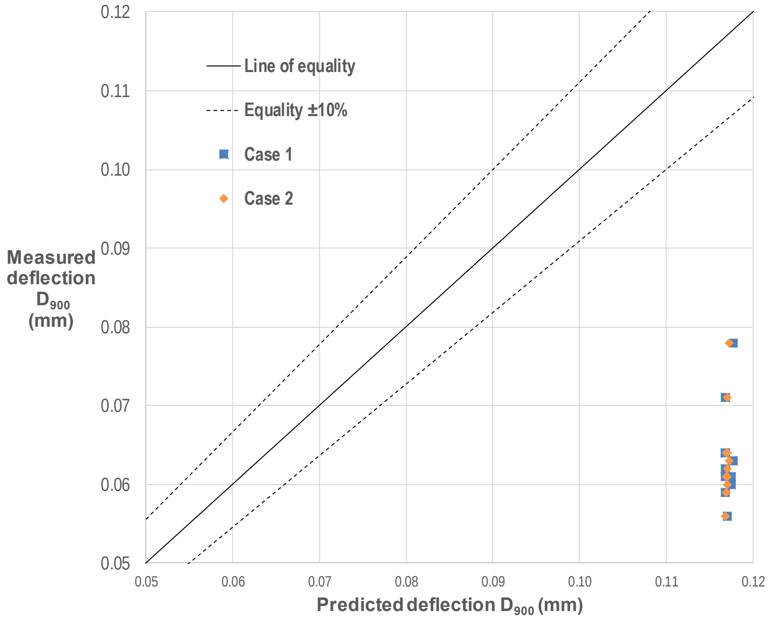
As described in Section 7.2, Case 2 differs from Case 1 in that the maximum base moduli (Table 7.1) were derived from measured results at densities, moisture contents and ages which were intended to be similar to the conditions in situ at the time the deflections were measured. However, as mentioned in Section 7.1, the laboratory specimen densities for most materials were more than 2% below the field values.

As seen from Table 7.1 , the moduli used for HCTCRB and crushed recycled concrete were significantly lower the Case 1 MRWA presumptive values. The low HCTCRB moduli are likely to be due to the specimen densities being low.

For Cases 1 and 2, Figure 7.2 compares the measured D_0, D_0-D_{200} and D_{900} values normalised to a contact stress of 566 kPa in which the predicted deflections. It was concluded that the use of the measured base moduli at the field conditions generally provided better agreement with the measured D_0-D_{200} values, but that again the D_0 and D_{900} values were over-predicted due to limiting the subgrade modulus to a maximum of 120 MPa.

Figure 7.2: Comparison of Case 1 and Case 2 predictions with measured values

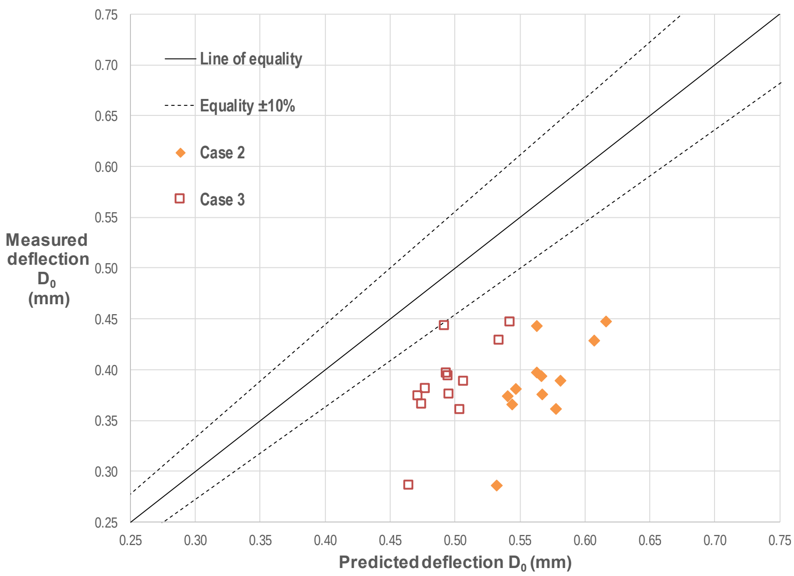


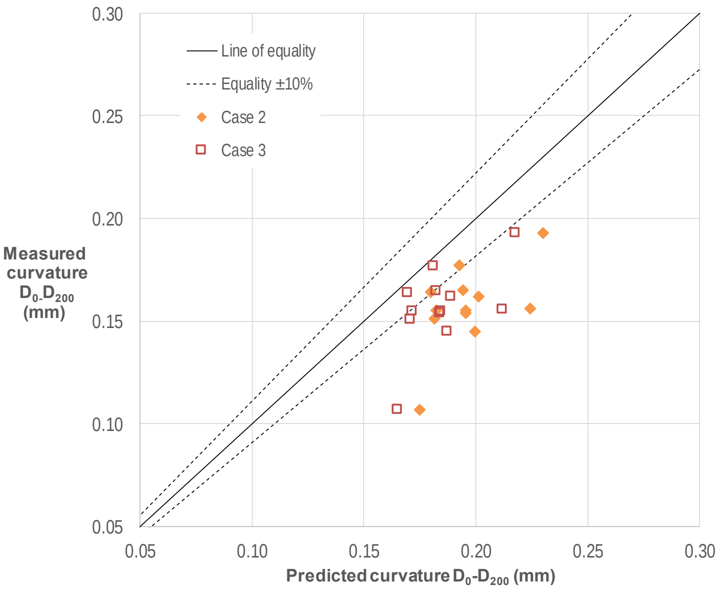


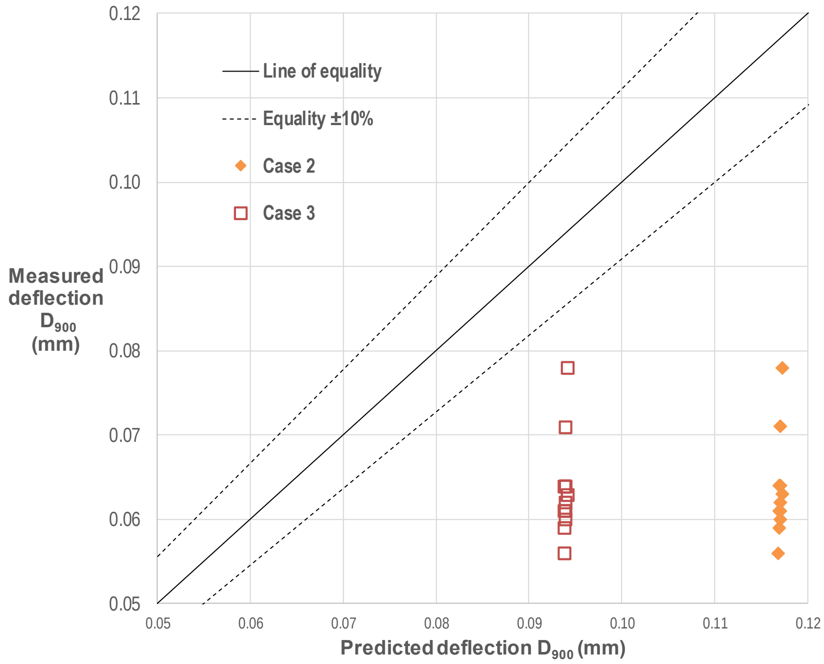
7.3.3 Cases 2 and 3

As described in Section 7, Case 3 uses the same elastic characterisation as Case 2 except that the vertical modulus of the subgrade was increase to 150 MPa, the same as the maximum value used in the FE modelling (Section 6.2). As seen Figure 7.3, the use of the high sand modulus significantly improved the agreement between the measured and predicted deflections.

Figure 7.3: Comparison of Case 2 and Case 3 predictions with measured values







7.4 Summary of findings

It was concluded that:

- The Austroads presumptive modulus for high quality crushed rock base (500 MPa) does not adequately consider the support to thin asphalt surfaced pavements provided by the granular materials available for use by MRWA in Perth.

- The MRWA presumptive modulus for sand subgrade (120 MPa) is conservative and if used in the linear elastic deflection predictions results in over-estimation of measured deflections. Consistent with the findings of the predictions using the FE model, a sand subgrade modulus in excess of 150 MPa is required to provide closer agreement with measured deflections.
- The predictions using the linear elastic model could be further improved if the Austroads sublayering method was adjusted to more fully reflect the high degree of support provided by the crushed limestone subbase. As discussed in Section 6.3.4, the crushed limestone subbase modulus greatly exceeded that for crushed rock base across a wide range of stress states.
- The analysis investigated the extent to which the agreement between predicted and measured deflections was improved by determining the top granular sublayer modulus from the laboratory measured modulus at the ERN9 design stresses (i.e. mean normal stress of 240 kPa, octahedral shear stress of 120 kPa). Although the results suggest an improvement using the measured moduli, unfortunately the conclusions that can be drawn from this analysis were limited due to the measured moduli of about half the bases (Figure 5.11) and the crushed limestone subbase (Figure 5.12) being underestimated as the specimen densities were more than 2% below the field values.

8 SUMMARY AND CONCLUSIONS

The current Austroads linear elastic model for pavement analysis and design does not adequately allow an assessment of the varying modulus of individual unbound and modified granular bases to be considered in the design process. Whilst some allowance is currently made for the variation in modulus with the Austroads sublayering rules, the variation in granular moduli horizontally cannot be provided for in the current linear elastic model. This feature limits the ability of the current Austroads model to predict responses and hence performance of unbound granular pavements.

Austroads project TT1452 *Development of pavement design models* has provided an enhanced ability to predict pavement critical strain by means of a non-linear finite element (FE) method (APADS). Granular moduli assumed in the FE model are calculated from the laboratory RLT results as a function of stress conditions, which means that the modulus values in the model can vary horizontally and vertically within the pavement structure.

This report presents the validation of APADS by comparison of FWD deflection bowls measured on the Kwinana Freeway trial sections with deflections predicted using APADS and the current Austroads pavement response to load model (CIRCLY).

The methodology involved the following:

- Laboratory resilient moduli testing on the pavement materials under RLT conditions intended to be similar to the field densities and moisture contents measured at the time of deflection testing.
- Fitting the stress-dependency relationship for use in the nonlinear finite element model.
- Calculating the predicted deflections using APADS using the nonlinear parameters fitted on the laboratory measured resilient moduli for the different pavement and subgrade layers.
- Calculation using the current Austroads pavement response to load were undertaken for comparison.

General conclusions drawn based on the investigation conducted are as follows:

- Improved methods of measurement of modulus in the repeat load triaxial test are required. The conclusions that can be drawn from this project were limited due to the measured moduli of about half the bases (Figure 5.11) and the crushed limestone subbase (Figure 5.12) being underestimated as the specimen densities were more than 2% below the field values. In addition, the analysis was also hindered by the fact that modulus testing was not undertaken for all materials after the same curing period as the field deflection measurements selected for the analysis. As the modulus of some of the trial bases and the crushed limestone subbase increased with curing time, this was a further factor limiting the study findings.
- Improved agreement between predicted and measured deflections was achieved when the sand subgrade modulus was not constrained to a modulus 120 MPa (the current presumptive MRWA Engineering Road Note 9 value for the design of new pavements). The FE modelling indicated a value of 200 MPa provided a better match between predicted and measured deflections.
- From the FE modelling it was concluded that the Austroads granular characterisation method significantly under-estimates the support provided by crushed limestone subbase. An improved characterisation is warranted and would result in reduced new pavement construction costs across a wide range of Perth pavements.

- With further development in relation to sand and crushed limestone subbase moduli, the linear elastic model has the ability to predict deflections with comparable accuracy to the FE model considering the limitations of laboratory modulus measurements and assumptions about in situ moistures and densities.
- Vuong et al. (1998) describe the limitation of measuring modulus using the repeat load triaxial test, particularly when testing materials with a modulus of 1000 MPa or more. Given that many granular materials of interest to MRWA have moduli well in excess of 500 MPa it is recommended that a detailed investigation be undertaken as the suitability of the MRWA equipment for such use in determining design moduli. It may be necessary to use on-sample strain measurement to reliability measure modulus. In addition, curing periods in excess of 28 days maybe warranted for some materials.

9 RESEARCH RECOMMENDATIONS

The project has highlighted research needs for further research related to a number of issues.

- To design thin asphalt surfaced pavements with high modulus bases it is critical that laboratory modulus measurements are reliable. There are doubt about the suitability of the Australian repeat load triaxial test method for high modulus granular materials described by Vuong et al. (1998). It is recommended that MRWA investigate whether their existing equipment provides reliable modulus values.

- The measured modulus of the crushed limestone subbase was about twice that the bitumen stabilised limestone. In part this may have been due to the high moisture content of the bitumen stabilised limestone. Further testing of these two materials is required to understand the reason(s) for this modulus difference.

- The measured modulus of the crushed limestone subbase greatly exceeded the modulus values currently used in mechanistic design. Further testing of the limestone from a range of quarries is required to assess modulus variability and if possible identify the properties that cause the modulus to vary. It is envisaged that a new method of elastic characterisation of crushed limestone subbase will need to be developed for use in mechanistic pavement design.

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APPENDIX A MATERIALS TESTING DURING CONSTRUCTION

A.1 Introduction

This Appendix summarises materials test results of granular base and subbase materials used in the Kwinana Freeway trials, as reported by Rehman (2011).

A.2 Granular Base Materials

A.2.1 Crushed Rock Base

The crushed rock base was sourced from HOLCIM Gosnells Quarry. The samples were collected from site. The test results are summarised in Table A 1. The results generally comply with Southern Gateway Alliance (SGA) specifications.

Table A 1: Crushed rock base test results

Particle size distribution (PSD)			
Sieve size (mm)	**SGA CRB Specification passing %**	**Sample 09M276 (2) passing (%)**	**Sample 09M276 (1) passing (%)**
26.5	100	–	–
19.0	95–100	100	100
13.2	70–90	86	88
9.5	60–80	70	72
4.75	40–60	52	52
2.36	30–45	39	38
1.18	20–35	27	28
0.600	13–27	19	20
0.425	11–23	15	16
0.300	8–20	12	14
0.150	5–14	9	10
0.075	5–11	7	8
Other tests	**SGA CRB specification %**	**Sample 09M276 (2) passing (%)**	**Sample 09M276 (1) passing (%)**
LS	2.0 max.	0.4	0.4
MDD (t/m^3)	–	–	2.29
OMC (%)	–	–	5.3
CBR Soaked (%)	100 min	270	290
MDCS (MPa)	1.7 MPa min	3.59	3.62
LA Abrasion (%)	35 max	–	20
FI (%)	30 max	–	21

Notes:

LS: Linear Shrinkage WA123.1, MDCS: Max. Dry Compressive Strength WA140.1, MDD: Max. Dry Density WA 133.1, OMC: Optimum Moisture Content WA133.1, LA: Los Angeles Abrasion WA220.1, FI: Flakiness Index WA216.1

Source: Rehman (2011).

A.2.2 Ferricrete

The ferricrete was sourced from B&J Catalano Pty Ltd, Wagerup pit. The samples were taken from the material delivered to the trial site, the test results are summarised in Table A 2.

Table A 2: Ferricrete test results

Particle size distribution (PSD)						
Sieve size (mm)	SGA ferricrete specification	Sample No: BY08 1944 stockpile W2 passing (%)	Sample No: BY08 1947 stockpile W3 passing (%)	Sample No: BY08 1950 stockpile W4 passing (%)	Sample No: BY08 1953 stockpile W5 passing (%)	Sample No: BY08 1978 combined samples passing (%)
37.5	100	100	100	100	100	–
19.0	72–100	87	91	87	86	–
9.5	50–78	61	71	65	67	–
4.75	36–-58	44	50	45	51	–
2.36	25–44	33	36	32	38	–
1.18	18–35	26	27	24	30	–
0.600	13–28	22	23	19	25	–
0.425	11–25	20	20	17	21	–
0.300	9–22	17	17	14	18	–
0.150	6–17	11	11	9	11	–
0.075	4–13	8	7	6	8	–
0.0135	2–9	4	3	3	4	–
Other tests						
LS (%)	2.0 max.	1.6	0.8	0.4	0.8	–
LL (%)	25 max.	22	NO	NO	21	–
PI (%)	–	NP	NP	NP	NP	–
MDCS (MPa)	2.3 MPa min	5.64	3.54	2.44	3.62	–
MDD (t/m^3)	2.0	–	–	–	–	2.29
OMC (%)	–	–	–	–	–	8.2
CBR (%)	80 min	–	–	–	–	260

Notes:

PSD: Particle Size Distribution WA115.1, LS: Linear Shrinkage WA123.1, LL: Liquid Limit WA120.2, PI: Plasticity Index WA122.1, MDCS: Max. Dry Compressive Strength WA140.1, MDD: Max. Dry Density WA 133.1, OMC: Optimum Moisture Content WA133.1, CBR (Soaked 4 days @98% of MDD and 100% of OMC) WA141.1

Source: Rehman (2011).

A.2.3 G1 Crushed Rock Base

G1 CRB for the project was sourced from WA Bluemetal, Byford quarry. The G1 test results are summarised in Table A 3. The results generally comply with SGA specifications.

Table A 3: G1 crushed rock base test results

Particle size distribution (PSD)				
Sieve size (mm)	**SGA CRB specification passing (%)**	**Sample No: P09/506 passing (%)**	**Sample No: P09/507 passing (%)**	**Sample No: P09/508 passing (%)**
37.5	–	100	100	-
26.5	100	94*	94*	–
19.0	95–100	83*	84*	–
13.2	70–90	73	74	–
9.5	60–80	62	64	–
6.7	–	53	56	–
4.75	40–60	46	50	–
2.36	30–45	33	35	–
1.18	20–35	24	25	–
0.600	13–27	17	17	–
0.425	11–23	15	15	–
0.300	8–20	13	13	–
0.150	5–14	10	10	–
0.075	5–11	7	8	–
0.0135	–	3	3	–
Other tests				
LS (%)	2.0 max.	NA	0.8	0.8
LL (%)	25 max.	NA	NA	21.0
FI (%)	30 max.	24.4		

Notes:
LS: Linear Shrinkage WA123.1, LL: Liquid Limit WA120.2, FI: Flakiness Index WA216.1
*Values in red indicate non-compliance
Source: Rehman (2011).

A.2.4 Hydrated Cement Treated Crushed Rock Base

HCTCRB for the project was sourced from Cemex, Gosnells. The summary of test results performed on the rock base samples by Cemex Gosnells laboratory are given in Table A 4.

The HCTCRB used in trial sections 1, 6, 10 and 14 was tested for resilient modulus and unconfined compressive strength (UCS) at the MRWA Materials Engineering Branch laboratory at the time of construction. The test results are summarised in Table A 5.

Table A 4: HCTCRB test results

Particle size distribution (PSD)							
Sieve size (mm)	**SGA specification passing (%)**	**Client sample ID: Lot 97 #1) passing (%)**	**Client sample ID: Lot 97 #2) passing (%)**	**Client sample ID: Lot 97 #3) passing (%)**	**Client sample ID: Lot 100 #1) passing (%)**	**Client sample ID: Lot 100 #2) passing (%)**	**Client sample ID: Lot 100 #3) passing (%)**
26.5	100	100	100	100	100	100	100
19.0	95–100	100	100	100	100	100	100
16.0	–	97	97	97	98	97	98
13.2	70–90	88	88	87	89	89	88
9.5	60–80	71	72	71	69	70	70
6.7	–	59	60	60	55	54	57
4.75	40–60	51	52	52	47	46	50
2.36	30–45	39	40	40	35	35	38
1.18	20–35	29	29	29	25	26	26
0.600	13–27	21	21	22	20	19	19
0.425	11–23	17	17	18	18	17	16
0.300	8–20	14	14	15	15	14	14
0.150	5–14	10	10	11	13	10	10
0.075	5–11	7	8	8	9	7	7
0.0135	–	5	6	6	5	5	5
Tests							
LS (%)	2.0% max.	1.2	–	–	1.6	–	–
LL (%)	25% max.	22.7	–	–	22	–	–
PI (%)	6.0% max.	NP	–	–	NP	–	–
FI (%)	30% max.	26	23	25	25	22	24
MDD (t/m^3)	–	2.26	–	–	2.29	–	–
OMC (%)	–	6.7	–	–	6.6	–	–
FM	–	4.7	4.6	4.6	4.8	4.8	4.7

Notes:

LS: Linear Shrinkage WA123.1, LL: Liquid Limit WA120.2, PI: Plasticity Index WA122.1, FI: Flakiness Index WA216.1, MDD: Max. Dry Density WA 133.1, OMC: Optimum Moisture Content WA133.1, FM: Fineness Modulus WA115.1.

Source: Rehman (2011).

Table A 5: Summary of HCTCRB modulus and strength results

Sample number	Trial section number	Moisture ratio (%)	Density ratio (%)	UCS (MPa)	Resilient modulus (MPa)
09RB005A	1,6,7,8	87	99.5	–	682
09RB005B	1,6,7,8	77	99.5	–	926
09RB005C	1,6,7,8	71	99.7	–	1192
09RB007A	9,10,14	83	99.6	–	832
09RB007B	9,10,14	80	99.4	–	896
09RB007C	9,10,14	74	99.6	–	1023
09RB004	1,6,7,8	–	–	0.68	–
09RB006	9,10,14	–	–	0.88	–

Source: Rehman (2011).

A.2.5 Bitumen Stabilised Limestone (BSL)

The crushed limestone used in the BSL was sourced from WA limestone. The crushed limestone was stabilised with 2.0% bituminous emulsion. The test results are summarised in Table A 6.

Table A 6: Bitumen stabilised limestone test results

Particle size distribution (PSD)				
Sieve size (mm)	**MRWA Specification 501 passing (%)**	**Sample No:20090148 passing (%)**	**Sample No:20090149 passing (%)**	**Sample No: P09/504 passing (%)**
19.0	90-100	100	100	100
6.7	–	77	84	–
4.75	60-90	73	80	73
1.18	35-75	58	64	59
0.300	–	29	31	32
0.075	–	5	6	9
Other tests				
Bitumen content (%)	2.0 min. 2.2 max.	2.1	2.3	–

Source: Rehman (2011).

A.2.6 Crushed Recycled Concrete

The CRC sample was sourced from All Earth Group Pty Ltd. The test results are summarised in Table A 7.

Table A 7: Crushed recycled concrete test results

Particle size distribution (PSD)			
Sieve size (mm)	**MRWA Specification 501 passing (%)**	**Sample No: 7149 passing (%)**	**Sample No: 7042 passing (%)**
26.5	100	100	100
19.0	95–100	100	99
9.5	59–80	61	73
4.75	41–60	42	52
2.36	29–45	32	40
1.18	20–35	26	33
0.600	13–27	20	25
0.425	10–23	15	19
0.300	8–20	11	13
0.150	5–14	6	7
0.075	3–11	4	4
Other tests			
LL (%)	35 max.	–	35
LS (%)	3.0 max.	–	0.4
CBR (%)	100 max.	150%	–
Los Angeles Abrasion value (%)	40 max.	Sample A4360 = 37	–
Unconfined Compressive Strength (UCS)	1.0 MPa max.	Sample P09/752 = 0.3 MPa	Sample P09/753 = 0.18 MPa
Foreign material-high density materials (brick, glass etc)	Max. % retained by mass on 4.75mm sieve=10%	Sample No: 7149= 5.1	–
Foreign material-low density Material (plastic, plaster etc)	Max. % retained by mass on 4.75mm sieve=2%	Sample No: 7149= 0	–
Foreign material- (wood and other vegetable matter)	Max. % retained by mass on 4.75mm sieve=0.5%	Sample No: 7149=0.1	–
Foreign material (asbestos)	Max. % retained by mass on 4.75mm sieve=0%	Sample No: 7149=0	–

Notes:

PSD: Particle Size Distribution WA115.1, LS: Linear Shrinkage WA123.1, LL: Liquid Limit WA120.2, Max. Dry Density WA 133.1, OMC: Optimum Moisture Content WA133.1, CBR (Soaked 4 days at 98% of MDD and 100% of OMC) WA141.1, LA Abrasion: Los Angeles Abrasion WA220.2, UCS: WA143.1.

Source: Rehman (2011).

A.3 Crushed Limestone Subbase

The limestone subbase samples were sourced from WA limestone, Quarry 9. The test results are summarised in Table A 8 and comply with SGA limestone subbase specifications.

Table A 8: Crushed limestone subbase test results

Particle size distribution (PSD)					
Sieve size (mm)	**SGA Specification passing (%)**	**Sample P08/1525 passing (%)**	**Sample P08/1526 passing (%)**	**Sample P08/1527 passing (%)**	**Sample P08/1529 passing (%)**
105.0	100	100	100	100	100
75.0	88–100	97	100	96	100
53.0	–	95	99	83	95
37.5	–	85	87	75	88
26.5	–	76	83	68	79
19.0	55–85	70	77	63	74
9.5	–	61	72	56	65
4.75	–	55	63	51	58
2.36	35–65	51	51	47	53
0.425	–	36	32	32	37
0.075	–	8	8	8	8
0.0135	–	5	5	5	5
Other tests	**SGA Specification**	**Sample P08/1525**	**Sample P08/1526**	**Sample P08/1527**	**Sample P08/1529**
$CaCO_3$ Content (%)	60 min	86	84	78	86
LS (%)	<1.0	0	0	0	0
LA Abrasion (%)	20–60	–	–	–	32
CBR (%)	>50				100

Notes:

PSD: Particle Size Distribution WA115.1, CaCO Content: Calcium Carbonate Content WA915.1, LS: Linear Shrinkage WA123.1, CBR (Soaked 4 days @94% of MDD and 100% of OMC) WA141.1, LA Abrasion: Los Angeles Abrasion WA220.2.

Source: Rehman (2011).

APPENDIX B MEASURED SURFACE DEFLECTIONS

B.1 Section 2 – Crushed Rock Base

Table B 1: Section 2 measured FWD deflections at a nominal applied stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	41	55.119	12.1	588	0.315	0.185	0.131	0.108	0.091	0.080	0.069	0.061	0.040
		55.128	12.1	590	0.323	0.183	0.129	0.104	0.089	0.077	0.067	0.059	0.038
		55.137	12.1	590	0.326	0.192	0.134	0.106	0.090	0.079	0.068	0.059	0.042
		55.146	12.2	587	0.351	0.194	0.132	0.105	0.089	0.078	0.067	0.059	0.040
		55.155	12.2	590	0.318	0.183	0.130	0.103	0.087	0.077	0.066	0.058	0.038
		55.164	12.2	590	0.340	0.195	0.135	0.106	0.089	0.078	0.066	0.057	0.037
		55.173	12.2	591	0.334	0.189	0.129	0.102	0.086	0.076	0.065	0.056	0.036
		55.182	12.2	585	0.351	0.195	0.132	0.105	0.088	0.077	0.065	0.056	0.036
		55.191	12.2	592	0.317	0.187	0.128	0.103	0.088	0.078	0.066	0.057	0.036
		55.200	12.2	588	0.355	0.184	0.131	0.106	0.089	0.079	0.067	0.058	0.037
			Average	**589**	**0.333**	**0.189**	**0.131**	**0.105**	**0.089**	**0.078**	**0.066**	**0.058**	**0.038**
	62	55.119	13.1	611	0.330	0.213	0.146	0.115	0.098	0.086	0.073	0.064	0.044
		55.128	13.2	613	0.344	0.208	0.144	0.116	0.099	0.088	0.074	0.065	0.043
		55.137	13.1	610	0.385	0.198	0.140	0.112	0.097	0.087	0.073	0.063	0.043
		55.146	13.4	610	0.356	0.204	0.143	0.115	0.096	0.083	0.070	0.063	0.041
		55.155	13.3	615	0.369	0.216	0.150	0.116	0.097	0.087	0.073	0.064	0.042
		55.164	13.4	615	0.403	0.198	0.139	0.111	0.094	0.084	0.071	0.061	0.040
		55.173	13.5	615	0.371	0.215	0.146	0.113	0.094	0.084	0.070	0.061	0.040
		55.182	13.5	612	0.363	0.217	0.147	0.115	0.096	0.084	0.071	0.061	0.040
		55.191	13.5	614	0.355	0.212	0.146	0.116	0.096	0.085	0.072	0.061	0.039
		55.200	13.6	611	0.439	0.209	0.148	0.118	0.098	0.084	0.070	0.060	0.039
			Average	**613**	**0.371**	**0.209**	**0.145**	**0.115**	**0.096**	**0.085**	**0.072**	**0.062**	**0.041**
	78	55.119	22.2	567	0.382	0.213	0.148	0.117	0.097	0.086	0.074	0.064	0.043
		55.128	22	566	0.367	0.236	0.159	0.142	0.100	0.088	0.075	0.063	0.043
		55.137	22.5	567	0.401	0.234	0.158	0.121	0.101	0.088	0.074	0.065	0.043
		55.146	22.3	560	0.403	0.234	0.159	0.118	0.097	0.085	0.072	0.062	0.041
		55.155	21.8	564	0.425	0.247	0.159	0.120	0.098	0.084	0.072	0.061	0.041
		55.164	21.7	558	0.385	0.227	0.151	0.116	0.095	0.083	0.069	0.060	0.038
		55.173	21.6	561	0.383	0.224	0.151	0.115	0.096	0.083	0.069	0.059	0.038
		55.182	21.6	558	0.396	0.220	0.152	0.117	0.096	0.084	0.070	0.060	0.038
		55.191	22.1	559	0.414	0.218	0.152	0.120	0.098	0.086	0.073	0.060	0.036
		55.2	22.1	562	0.389	0.235	0.158	0.119	0.094	0.083	0.068	0.059	0.039
			Average	**562**	**0.394**	**0.229**	**0.155**	**0.121**	**0.097**	**0.085**	**0.071**	**0.061**	**0.040**

Table B 2: Section 2 measured FWD deflections at a nominal applied stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	41	55.119	16.4	707	0.396	0.217	0.159	0.127	0.107	0.095	0.082	0.072	0.048
		55.128	16.5	709	0.389	0.220	0.158	0.127	0.108	0.095	0.081	0.074	0.047
		55.137	16.3	692	0.413	0.231	0.158	0.126	0.106	0.094	0.080	0.071	0.048
		55.146	16.4	712	0.385	0.224	0.156	0.127	0.107	0.095	0.080	0.071	0.047
		55.155	16.5	705	0.369	0.222	0.157	0.124	0.106	0.093	0.080	0.070	0.047
		55.164	16.5	707	0.413	0.227	0.158	0.126	0.106	0.092	0.078	0.068	0.044
		55.173	16.6	708	0.402	0.219	0.151	0.123	0.104	0.091	0.078	0.067	0.044
		55.182	16.6	706	0.403	0.234	0.160	0.127	0.106	0.094	0.078	0.068	0.044
		55.191	16.7	706	0.410	0.236	0.159	0.128	0.106	0.093	0.079	0.069	0.043
		55.200	16.7	711	0.437	0.234	0.161	0.129	0.108	0.094	0.079	0.069	0.044
			Average	**706**	**0.402**	**0.226**	**0.158**	**0.126**	**0.107**	**0.094**	**0.079**	**0.070**	**0.046**
	62	55.119	20.6	733	0.421	0.230	0.165	0.134	0.115	0.102	0.087	0.077	0.052
		55.128	20.1	734	0.417	0.229	0.166	0.135	0.115	0.102	0.087	0.077	0.052
		55.137	20.3	738	0.394	0.248	0.173	0.137	0.116	0.102	0.087	0.075	0.051
		55.146	20.4	741	0.397	0.249	0.175	0.138	0.117	0.103	0.087	0.076	0.051
		55.155	20.4	733	0.400	0.244	0.169	0.135	0.113	0.101	0.085	0.075	0.051
		55.164	20.4	740	0.400	0.244	0.170	0.136	0.114	0.102	0.086	0.076	0.051
		55.173	20.6	738	0.444	0.267	0.179	0.138	0.114	0.101	0.085	0.075	0.051
		55.182	20.6	741	0.439	0.266	0.180	0.139	0.115	0.101	0.086	0.075	0.051
		55.191	20.1	734	0.438	0.320	0.169	0.134	0.112	0.099	0.085	0.074	0.050
		55.200	20.4	734	0.436	0.236	0.168	0.134	0.112	0.099	0.085	0.074	0.050
			Average	**737**	**0.419**	**0.253**	**0.171**	**0.136**	**0.114**	**0.101**	**0.086**	**0.075**	**0.051**
	78	55.119	16.400	687	0.429	0.255	0.182	0.140	0.119	0.105	0.089	0.077	0.053
		55.128	16.700	683	0.444	0.263	0.181	0.143	0.120	0.106	0.088	0.077	0.051
		55.137	17.200	682	0.431	0.258	0.182	0.143	0.118	0.104	0.087	0.076	0.050
		55.146	17.400	678	0.447	0.271	0.184	0.142	0.118	0.103	0.087	0.076	0.051
		55.155	16.700	688	0.436	0.280	0.189	0.145	0.119	0.104	0.088	0.077	0.050
		55.164	16.900	679	0.440	0.262	0.178	0.138	0.116	0.101	0.084	0.073	0.047
		55.173	16.800	682	0.438	0.259	0.180	0.138	0.115	0.100	0.083	0.072	0.047
		55.182	16.800	679	0.441	0.258	0.178	0.141	0.116	0.103	0.084	0.073	0.047
		55.191	16.800	679	0.401	0.260	0.181	0.142	0.118	0.103	0.086	0.073	0.046
		55.200	16.800	683	0.435	0.257	0.179	0.138	0.116	0.100	0.083	0.072	0.047
			Average	**682**	**0.434**	**0.262**	**0.181**	**0.141**	**0.117**	**0.103**	**0.086**	**0.075**	**0.049**

Figure B 1: Section 2 measured deflections at a nominal applied stress of 566 kPa

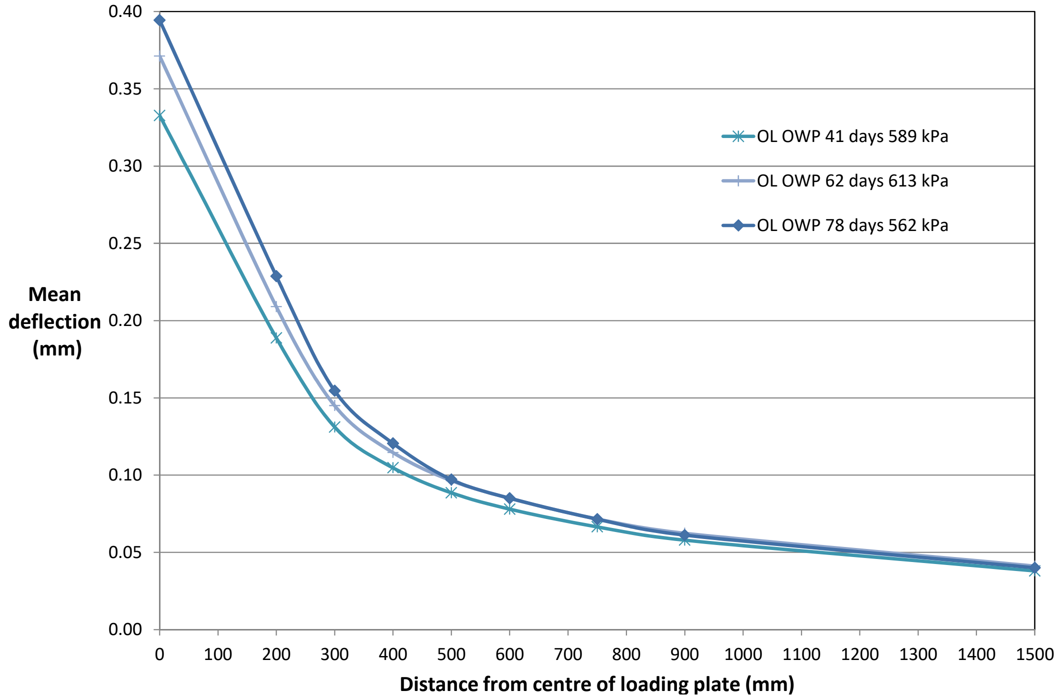
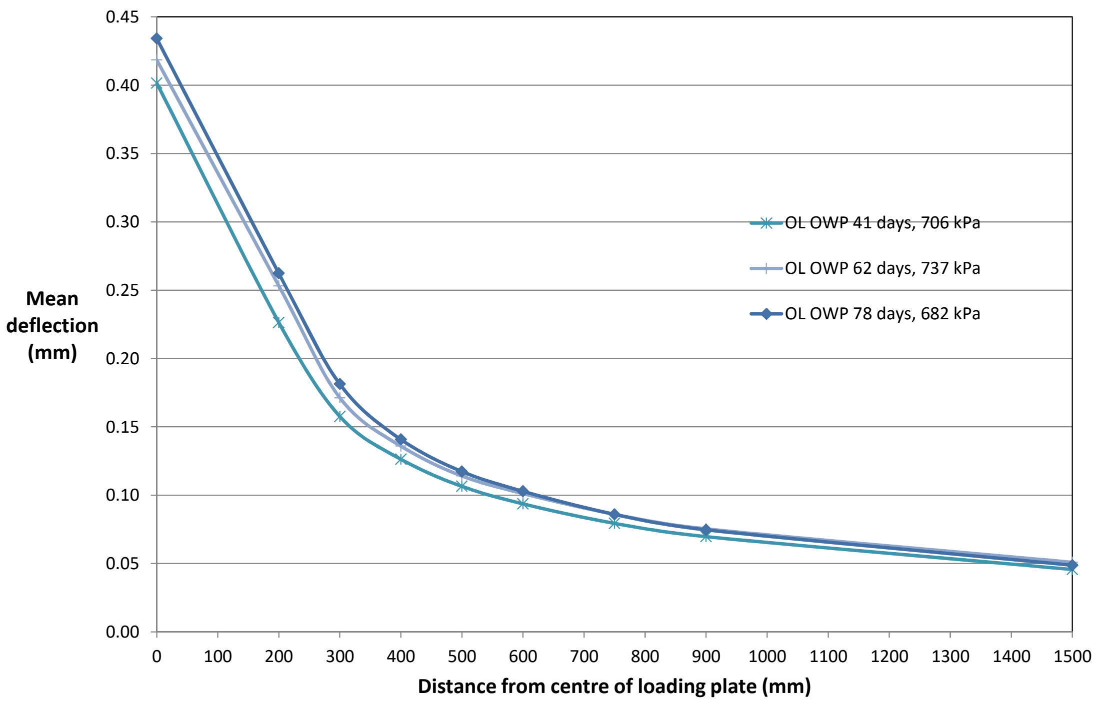


Figure B 2: Section 2 measured deflections at a nominal stress of 700 kPa



B.2 Section 3 – Crushed Rock Base

Table B 3: Section 3 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	41	55.219	12.2	583	0.439	0.244	0.162	0.119	0.096	0.082	0.067	0.058	0.036
		55.228	12.2	589	0.460	0.251	0.163	0.117	0.094	0.080	0.066	0.056	0.035
		55.237	12.3	582	0.404	0.235	0.155	0.114	0.092	0.077	0.066	0.056	0.035
		55.246	12.5	588	0.409	0.228	0.148	0.111	0.090	0.077	0.064	0.054	0.034
		55.255	12.5	588	0.414	0.232	0.151	0.114	0.091	0.079	0.065	0.055	0.035
		55.264	12.5	592	0.424	0.243	0.158	0.117	0.094	0.080	0.066	0.057	0.036
		55.273	12.5	591	0.415	0.241	0.156	0.115	0.094	0.080	0.066	0.056	0.035
		55.282	12.6	592	0.426	0.224	0.150	0.113	0.092	0.079	0.066	0.056	0.035
		55.291	12.6	588	0.384	0.221	0.145	0.109	0.089	0.078	0.065	0.056	0.035
		55.300	12.6	585	0.381	0.219	0.147	0.112	0.090	0.078	0.065	0.056	0.035
			Average	**588**	**0.416**	**0.234**	**0.153**	**0.114**	**0.092**	**0.079**	**0.066**	**0.056**	**0.035**
	62	55.219	13.8	610	0.453	0.253	0.173	0.126	0.102	0.085	0.069	0.060	0.038
		55.228	13.9	606	0.438	0.247	0.168	0.125	0.101	0.086	0.070	0.060	0.041
		55.237	14.0	613	0.427	0.256	0.172	0.129	0.102	0.087	0.071	0.060	0.038
		55.246	14.0	609	0.419	0.253	0.171	0.127	0.102	0.092	0.071	0.061	0.039
		55.255	13.8	612	0.413	0.246	0.169	0.125	0.101	0.086	0.070	0.060	0.038
		55.264	13.9	606	0.391	0.239	0.169	0.127	0.103	0.088	0.072	0.061	0.039
		55.273	13.9	613	0.416	0.241	0.165	0.125	0.101	0.088	0.072	0.061	0.039
		55.282	13.8	614	0.406	0.237	0.168	0.124	0.099	0.087	0.071	0.063	0.038
		55.291	13.8	615	0.374	0.224	0.157	0.120	0.098	0.085	0.071	0.060	0.038
		55.300	13.8	612	0.396	0.233	0.163	0.123	0.098	0.086	0.071	0.060	0.037
			Average	**611**	**0.413**	**0.243**	**0.168**	**0.125**	**0.101**	**0.087**	**0.071**	**0.061**	**0.038**
	78	55.219	21.4	564	0.450	0.276	0.180	0.131	0.103	0.086	0.070	0.060	0.039
		55.228	21.4	562	0.439	0.272	0.182	0.130	0.102	0.086	0.070	0.059	0.037
		55.237	21.2	561	0.453	0.277	0.182	0.131	0.103	0.086	0.069	0.059	0.037
		55.246	20.7	565	0.456	0.269	0.180	0.131	0.103	0.087	0.070	0.059	0.037
		55.255	20.4	564	0.469	0.270	0.177	0.132	0.104	0.087	0.071	0.059	0.038
		55.264	20.6	558	0.424	0.271	0.178	0.133	0.106	0.090	0.072	0.061	0.038
		55.273	20.4	560	0.452	0.271	0.178	0.130	0.103	0.087	0.071	0.061	0.038
		55.282	20.5	563	0.450	0.264	0.177	0.127	0.103	0.089	0.072	0.061	0.038
		55.291	20.4	559	0.418	0.238	0.165	0.126	0.098	0.085	0.069	0.059	0.039
		55.300	20.3	559	0.419	0.254	0.171	0.127	0.101	0.086	0.070	0.059	0.037
			Average	**562**	**0.443**	**0.266**	**0.177**	**0.130**	**0.103**	**0.087**	**0.070**	**0.060**	**0.038**

Table B 4: Section 3 measured FWD deflections at nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	41	55.219	16.9	704	0.505	0.294	0.193	0.141	0.114	0.097	0.079	0.068	0.043
		55.228	16.6	704	0.539	0.302	0.190	0.142	0.112	0.096	0.080	0.068	0.042
		55.237	16.9	711	0.507	0.277	0.184	0.138	0.110	0.094	0.078	0.067	0.042
		55.246	17.2	710	0.501	0.276	0.180	0.134	0.109	0.094	0.078	0.066	0.042
		55.255	17.2	709	0.484	0.293	0.182	0.138	0.110	0.096	0.078	0.067	0.043
		55.264	17.4	705	0.485	0.286	0.188	0.138	0.113	0.097	0.079	0.069	0.042
		55.273	17.5	703	0.499	0.277	0.182	0.135	0.111	0.095	0.080	0.068	0.043
		55.282	17.6	702	0.463	0.271	0.178	0.137	0.110	0.095	0.079	0.069	0.046
		55.291	17.6	706	0.448	0.256	0.169	0.130	0.105	0.091	0.077	0.066	0.042
		55.300	17.6	709	0.438	0.253	0.170	0.130	0.107	0.093	0.076	0.067	0.041
			Average	**706**	**0.487**	**0.278**	**0.182**	**0.136**	**0.110**	**0.095**	**0.078**	**0.067**	**0.043**
	62	55.219	20.9	725	0.521	0.282	0.190	0.144	0.115	0.099	0.082	0.071	0.046
		55.228	20.4	728	0.520	0.281	0.191	0.145	0.116	0.100	0.083	0.071	0.046
		55.237	20.0	731	0.518	0.295	0.199	0.145	0.115	0.099	0.081	0.070	0.046
		55.246	19.0	729	0.516	0.293	0.198	0.145	0.115	0.099	0.081	0.070	0.046
		55.255	18.7	736	0.512	0.286	0.198	0.147	0.116	0.099	0.082	0.069	0.045
		55.264	18.7	736	0.506	0.285	0.197	0.147	0.116	0.100	0.082	0.070	0.045
		55.273	18.4	741	0.522	0.314	0.203	0.149	0.120	0.103	0.084	0.071	0.045
		55.282	18.1	741	0.516	0.311	0.201	0.149	0.120	0.103	0.084	0.071	0.045
		55.291	18.6	740	0.492	0.311	0.203	0.149	0.120	0.102	0.084	0.072	0.046
		55.300	18.4	740	0.484	0.307	0.203	0.150	0.120	0.102	0.084	0.072	0.046
			Average	**735**	**0.511**	**0.297**	**0.198**	**0.147**	**0.117**	**0.101**	**0.083**	**0.071**	**0.046**
	78	55.219	18.5	686	0.502	0.315	0.210	0.153	0.122	0.103	0.083	0.071	0.045
		55.228	18.5	681	0.517	0.305	0.205	0.151	0.122	0.104	0.083	0.071	0.045
		55.237	18.7	684	0.520	0.317	0.212	0.156	0.123	0.104	0.084	0.070	0.045
		55.246	18.4	681	0.526	0.303	0.207	0.150	0.120	0.103	0.083	0.071	0.044
		55.255	18.3	678	0.522	0.279	0.198	0.149	0.119	0.102	0.084	0.072	0.046
		55.264	18.2	685	0.512	0.312	0.210	0.156	0.123	0.105	0.085	0.072	0.045
		55.273	18.3	681	0.513	0.306	0.204	0.155	0.123	0.105	0.086	0.073	0.045
		55.282	18.2	680	0.486	0.295	0.200	0.153	0.122	0.104	0.085	0.073	0.045
		55.291	18.3	681	0.480	0.278	0.197	0.148	0.119	0.101	0.083	0.070	0.045
		55.300	18.5	678	0.462	0.279	0.194	0.148	0.120	0.102	0.083	0.071	0.046
			Average	**682**	**0.504**	**0.299**	**0.204**	**0.152**	**0.121**	**0.103**	**0.084**	**0.071**	**0.045**

Figure B 3: Section 3 measured deflections at a nominal applied stress of 566 kPa

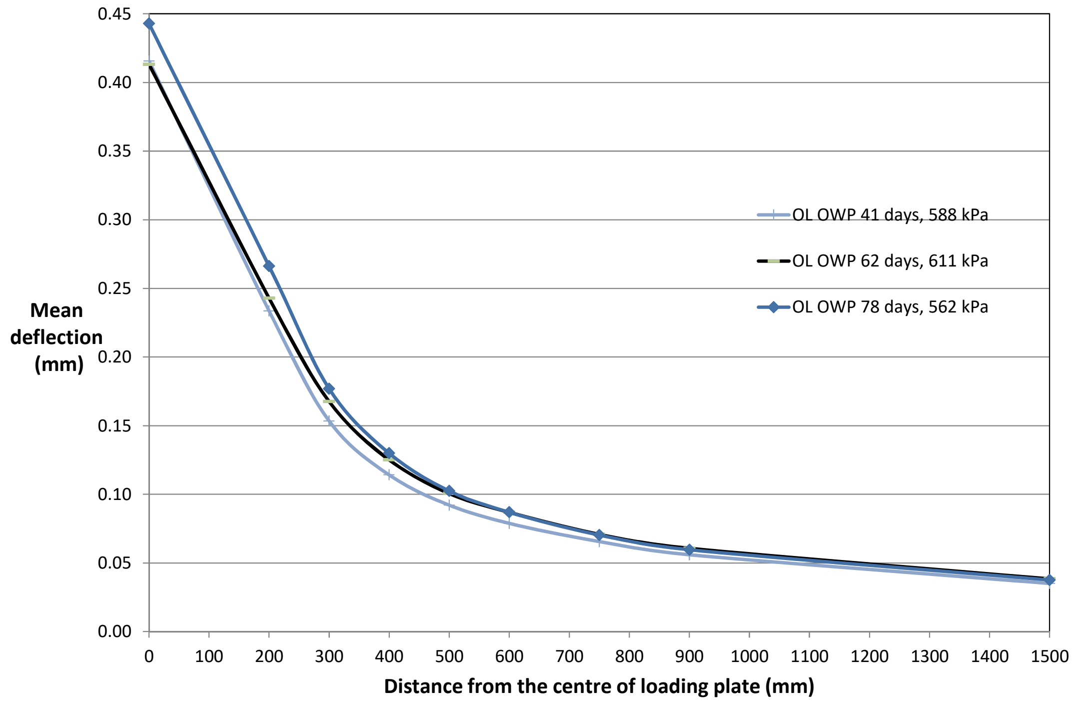
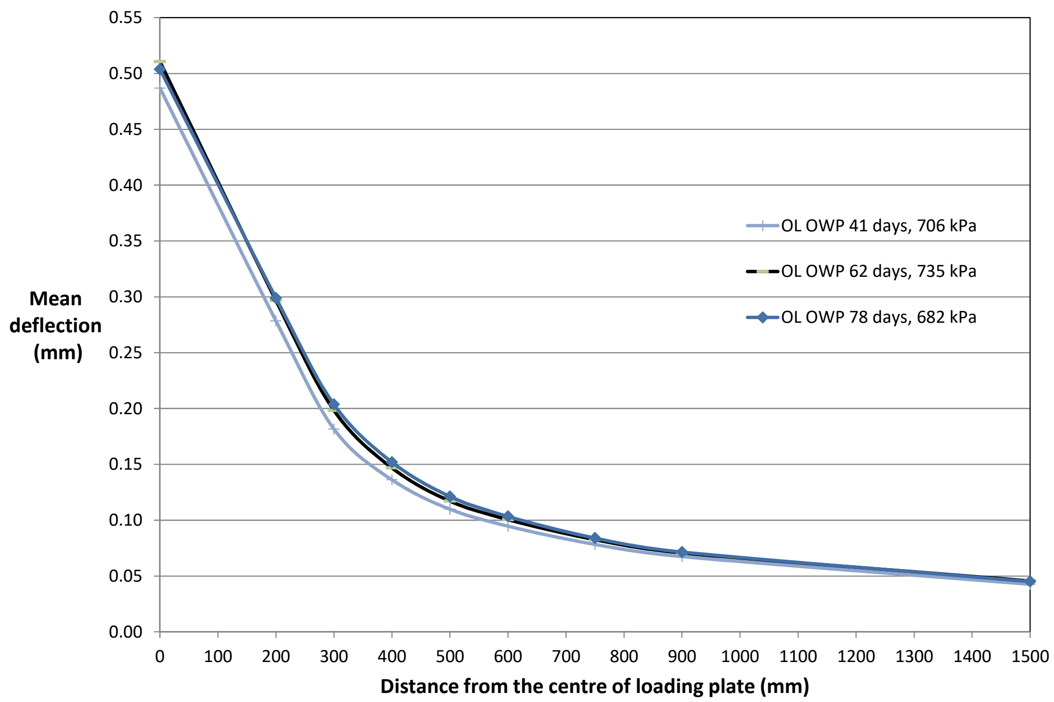


Figure B 4: Section 3 measured deflections at a nominal stress of 700 kPa



B.3 Section 4 – Ferricrete

Table B 5: Section 4 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	35	55.319	12.5	584	0.309	0.171	0.125	0.100	0.085	0.075	0.063	0.054	0.034
		55.328	12.5	589	0.291	0.180	0.131	0.106	0.090	0.079	0.066	0.057	0.036
		55.337	12.5	587	0.289	0.183	0.135	0.108	0.091	0.080	0.067	0.059	0.037
		55.346	12.5	588	0.298	0.183	0.134	0.107	0.091	0.080	0.067	0.059	0.036
		55.355	12.5	588	0.306	0.192	0.140	0.110	0.093	0.081	0.068	0.059	0.036
		55.364	12.6	589	0.296	0.181	0.135	0.110	0.092	0.080	0.068	0.058	0.036
		55.373	12.6	591	0.272	0.172	0.127	0.104	0.088	0.078	0.065	0.057	0.035
		55.382	12.5	589	0.260	0.163	0.123	0.102	0.087	0.078	0.067	0.059	0.038
		55.391	12.5	589	0.304	0.181	0.136	0.112	0.095	0.085	0.073	0.064	0.041
		55.400	12.5	589	0.242	0.155	0.118	0.088	0.070	0.063	0.052	0.044	0.027
			Average	**588**	**0.287**	**0.176**	**0.130**	**0.105**	**0.088**	**0.078**	**0.066**	**0.057**	**0.035**
	56	55.319	13.8	609	0.306	0.190	0.140	0.110	0.091	0.080	0.068	0.057	0.035
		55.328	13.9	613	0.304	0.189	0.141	0.111	0.093	0.082	0.067	0.058	0.037
		55.337	13.9	618	0.308	0.197	0.144	0.116	0.095	0.085	0.071	0.060	0.038
		55.346	13.9	613	0.299	0.191	0.140	0.114	0.096	0.084	0.071	0.061	0.037
		55.355	14.0	609	0.293	0.192	0.141	0.115	0.097	0.085	0.070	0.060	0.038
		55.364	13.9	608	0.273	0.182	0.140	0.112	0.095	0.083	0.068	0.059	0.037
		55.373	13.9	607	0.267	0.187	0.138	0.112	0.093	0.082	0.069	0.059	0.037
		55.382	13.9	612	0.267	0.175	0.132	0.109	0.093	0.082	0.070	0.060	0.039
		55.391	13.9	611	0.298	0.202	0.150	0.122	0.102	0.091	0.078	0.068	0.044
		55.400	13.8	614	0.283	0.177	0.128	0.099	0.079	0.067	0.052	0.043	0.025
			Average	**611**	**0.290**	**0.188**	**0.139**	**0.112**	**0.093**	**0.082**	**0.068**	**0.058**	**0.037**
	72	55.319	21.1	579	0.273	0.176	0.132	0.106	0.089	0.078	0.065	0.056	0.035
		55.328	20.8	569	0.263	0.165	0.124	0.101	0.084	0.075	0.064	0.055	0.034
		55.337	20.4	570	0.273	0.164	0.125	0.102	0.087	0.077	0.065	0.057	0.036
		55.346	20.3	576	0.290	0.177	0.132	0.108	0.091	0.081	0.068	0.058	0.035
		55.355	20.4	571	0.285	0.177	0.133	0.109	0.091	0.081	0.067	0.058	0.035
		55.364	20.4	573	0.290	0.182	0.133	0.107	0.092	0.081	0.067	0.058	0.034
		55.373	20.7	575	0.314	0.187	0.139	0.110	0.092	0.080	0.066	0.056	0.034
		55.382	20.9	572	0.322	0.201	0.149	0.115	0.096	0.084	0.068	0.058	0.036
		55.391	21.2	577	0.270	0.182	0.136	0.109	0.093	0.082	0.069	0.061	0.039
		55.400	20.8	566	0.280	0.174	0.128	0.098	0.081	0.071	0.056	0.048	0.028
			Average	**573**	**0.286**	**0.179**	**0.133**	**0.107**	**0.090**	**0.079**	**0.065**	**0.056**	**0.035**

Table B 6: Section 4 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	35	55.319	17.6	707	0.350	0.208	0.148	0.120	0.101	0.089	0.076	0.065	0.041
		55.328	17.6	708	0.337	0.213	0.153	0.124	0.105	0.094	0.078	0.068	0.042
		55.337	17.6	711	0.363	0.211	0.154	0.124	0.105	0.092	0.079	0.068	0.044
		55.346	17.6	712	0.357	0.221	0.159	0.130	0.109	0.096	0.081	0.070	0.044
		55.355	17.6	709	0.348	0.223	0.165	0.131	0.110	0.095	0.080	0.070	0.044
		55.364	17.6	711	0.342	0.218	0.161	0.128	0.108	0.094	0.079	0.069	0.043
		55.373	17.5	711	0.325	0.200	0.149	0.123	0.105	0.093	0.077	0.067	0.041
		55.382	17.5	703	0.319	0.192	0.146	0.120	0.105	0.093	0.079	0.069	0.045
		55.391	17.1	704	0.375	0.228	0.169	0.137	0.116	0.104	0.089	0.077	0.050
		55.400	17.2	711	0.330	0.189	0.135	0.105	0.086	0.074	0.061	0.052	0.033
			Average	**709**	**0.345**	**0.210**	**0.154**	**0.124**	**0.105**	**0.092**	**0.078**	**0.068**	**0.043**
	56	55.319	18.3	725	0.369	0.237	0.170	0.134	0.112	0.098	0.081	0.069	0.045
		55.328	17.9	727	0.368	0.236	0.172	0.134	0.112	0.098	0.081	0.070	0.044
		55.337	18.0	724	0.381	0.241	0.172	0.139	0.116	0.102	0.085	0.074	0.046
		55.346	18.0	729	0.378	0.240	0.169	0.140	0.116	0.103	0.086	0.074	0.046
		55.355	17.9	733	0.389	0.259	0.183	0.144	0.120	0.104	0.086	0.075	0.046
		55.364	17.9	735	0.385	0.257	0.182	0.145	0.120	0.105	0.087	0.075	0.047
		55.373	17.7	733	0.370	0.242	0.177	0.143	0.119	0.104	0.087	0.075	0.048
		55.382	18.2	738	0.367	0.241	0.178	0.144	0.120	0.105	0.088	0.076	0.047
		55.391	18.4	736	0.358	0.231	0.173	0.139	0.117	0.103	0.086	0.074	0.046
			Average	**731**	**0.374**	**0.243**	**0.175**	**0.140**	**0.117**	**0.102**	**0.085**	**0.073**	**0.046**
	72	55.319	18.8	694	0.336	0.209	0.157	0.126	0.107	0.094	0.078	0.067	0.042
		55.328	18.9	689	0.307	0.198	0.151	0.122	0.103	0.091	0.077	0.066	0.041
		55.337	19.0	687	0.310	0.195	0.147	0.123	0.104	0.092	0.078	0.067	0.042
		55.346	18.5	685	0.312	0.207	0.155	0.127	0.109	0.095	0.081	0.069	0.043
		55.355	18.9	687	0.327	0.211	0.158	0.129	0.110	0.097	0.081	0.070	0.043
		55.364	19.2	687	0.318	0.209	0.160	0.130	0.110	0.097	0.082	0.070	0.042
		55.373	19.0	689	0.343	0.225	0.166	0.133	0.110	0.096	0.078	0.067	0.040
		55.382	19.2	686	0.370	0.233	0.174	0.137	0.115	0.099	0.081	0.070	0.044
		55.391	18.8	687	0.332	0.217	0.163	0.132	0.111	0.099	0.084	0.073	0.047
		55.400	18.9	687	0.321	0.202	0.148	0.117	0.096	0.082	0.066	0.055	0.033
			Average	**688**	**0.328**	**0.211**	**0.158**	**0.128**	**0.107**	**0.094**	**0.078**	**0.067**	**0.042**

Figure B 5: Section 4 measured deflections at a nominal applied stress of 566 kPa

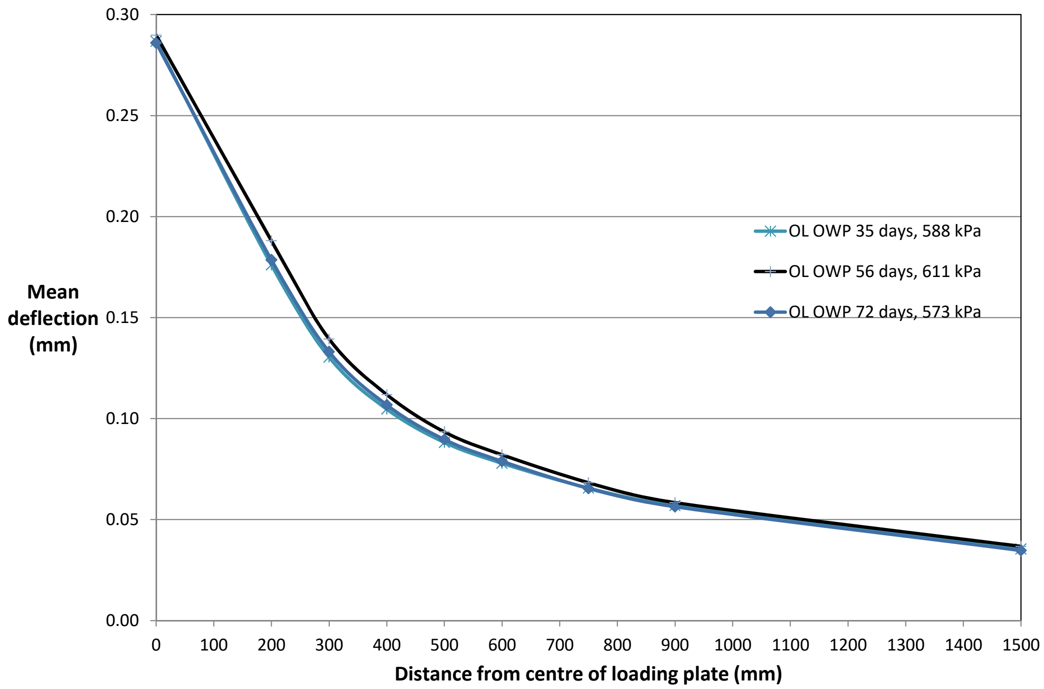
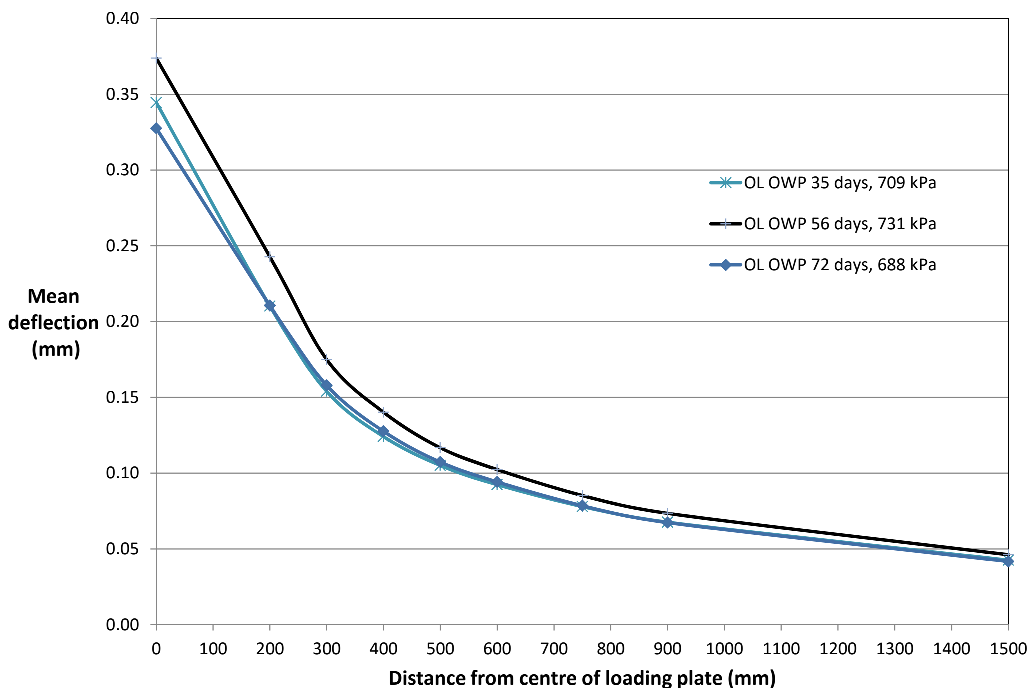


Figure B 6: Section 4 measured deflections at a nominal stress of 700 kPa



B.4 Section 5 – G1 Crushed Rock Base

Table B 7: Section 5 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	31	55.419	12.5	579	0.408	0.226	0.155	0.123	0.104	0.091	0.077	0.067	0.043
		55.428	12.6	585	0.381	0.208	0.146	0.116	0.098	0.085	0.071	0.061	0.040
		55.437	12.7	582	0.396	0.203	0.143	0.115	0.097	0.084	0.070	0.061	0.039
		55.446	12.7	586	0.414	0.226	0.149	0.116	0.096	0.084	0.069	0.059	0.038
		55.455	12.7	584	0.387	0.214	0.140	0.111	0.093	0.083	0.069	0.060	0.039
		55.464	12.7	583	0.391	0.182	0.125	0.103	0.087	0.077	0.066	0.057	0.037
		55.473	12.7	581	0.346	0.194	0.133	0.107	0.091	0.081	0.068	0.060	0.039
		55.482	12.7	584	0.388	0.197	0.132	0.107	0.092	0.082	0.070	0.061	0.039
		55.491	12.7	588	0.383	0.202	0.137	0.111	0.094	0.084	0.071	0.061	0.039
		55.500	12.6	582	0.354	0.186	0.130	0.105	0.091	0.081	0.069	0.060	0.038
			Average	**583**	**0.385**	**0.204**	**0.139**	**0.111**	**0.094**	**0.083**	**0.070**	**0.061**	**0.039**
	52	55.419	13.9	606	0.421	0.241	0.167	0.130	0.108	0.095	0.079	0.068	0.044
		55.428	13.9	612	0.509	0.250	0.167	0.127	0.105	0.090	0.075	0.065	0.042
		55.437	13.9	611	0.443	0.259	0.169	0.126	0.101	0.088	0.074	0.065	0.043
		55.446	13.9	609	0.457	0.247	0.165	0.125	0.103	0.089	0.073	0.063	0.041
		55.455	13.9	612	0.413	0.237	0.160	0.123	0.101	0.089	0.073	0.064	0.041
		55.464	14.0	611	0.402	0.220	0.147	0.116	0.100	0.086	0.072	0.064	0.040
		55.473	14.1	613	0.393	0.225	0.154	0.122	0.102	0.091	0.076	0.066	0.043
		55.482	14.2	619	0.429	0.234	0.155	0.121	0.102	0.090	0.076	0.066	0.043
		55.491	14.4	610	0.419	0.237	0.163	0.126	0.104	0.091	0.076	0.066	0.043
		55.500	14.3	615	0.369	0.226	0.157	0.123	0.104	0.092	0.078	0.064	0.043
			Average	**612**	**0.425**	**0.238**	**0.160**	**0.124**	**0.103**	**0.090**	**0.075**	**0.065**	**0.042**
	68	55.419	20.3	563	0.456	0.265	0.174	0.133	0.108	0.094	0.078	0.067	0.044
		55.428	20.4	554	0.443	0.270	0.169	0.123	0.100	0.086	0.070	0.061	0.040
		55.437	19.6	560	0.470	0.263	0.171	0.127	0.102	0.089	0.072	0.063	0.041
		55.446	20.0	565	0.436	0.268	0.170	0.126	0.103	0.086	0.070	0.061	0.040
		55.455	20.4	556	0.469	0.251	0.165	0.123	0.098	0.085	0.071	0.061	0.040
		55.464	20.3	560	0.450	0.237	0.159	0.119	0.099	0.086	0.071	0.063	0.041
		55.473	20.3	563	0.416	0.243	0.161	0.124	0.102	0.089	0.074	0.064	0.041
		55.482	20.3	553	0.437	0.247	0.167	0.126	0.103	0.089	0.075	0.065	0.041
		55.491	20.2	555	0.457	0.263	0.171	0.130	0.105	0.092	0.075	0.065	0.041
		55.500	20.0	558	0.437	0.236	0.161	0.124	0.104	0.090	0.075	0.065	0.041
			Average	**559**	**0.447**	**0.254**	**0.167**	**0.125**	**0.102**	**0.088**	**0.073**	**0.063**	**0.041**

Table B 8: Section 5 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	31	55.419	17.5	698	0.479	0.275	0.188	0.146	0.121	0.108	0.090	0.078	0.050
		55.428	17.5	702	0.488	0.264	0.177	0.139	0.116	0.101	0.084	0.073	0.047
		55.437	17.4	707	0.494	0.247	0.172	0.138	0.114	0.101	0.084	0.073	0.047
		55.446	17.5	705	0.491	0.264	0.177	0.137	0.115	0.100	0.084	0.072	0.045
		55.455	17.4	701	0.488	0.254	0.164	0.131	0.111	0.098	0.083	0.071	0.046
		55.464	17.3	707	0.447	0.222	0.153	0.124	0.106	0.094	0.081	0.071	0.046
		55.473	17.1	710	0.431	0.230	0.160	0.129	0.110	0.097	0.082	0.072	0.047
		55.482	17.1	708	0.467	0.221	0.157	0.128	0.110	0.098	0.083	0.074	0.048
		55.491	17.3	708	0.472	0.233	0.162	0.131	0.112	0.100	0.084	0.074	0.048
		55.500	17.4	709	0.380	0.221	0.154	0.127	0.109	0.097	0.084	0.073	0.048
			Average	**706**	**0.464**	**0.243**	**0.166**	**0.133**	**0.112**	**0.099**	**0.084**	**0.073**	**0.047**
	52	55.419	19.2	727	0.513	0.298	0.208	0.157	0.130	0.113	0.095	0.082	0.054
		55.428	18.6	728	0.505	0.297	0.209	0.158	0.131	0.114	0.095	0.083	0.054
		55.437	18.2	729	0.588	0.320	0.201	0.149	0.121	0.104	0.087	0.075	0.050
		55.446	18.0	730	0.573	0.315	0.202	0.151	0.122	0.105	0.087	0.075	0.049
		55.455	18.4	730	0.539	0.324	0.201	0.147	0.119	0.102	0.086	0.075	0.053
		55.464	18.5	736	0.530	0.318	0.202	0.149	0.120	0.103	0.086	0.075	0.053
		55.473	18.7	729	0.517	0.301	0.199	0.148	0.120	0.104	0.086	0.074	0.049
		55.482	19.0	730	0.512	0.298	0.199	0.149	0.120	0.105	0.087	0.076	0.049
		55.491	19.1	726	0.505	0.264	0.182	0.139	0.115	0.101	0.085	0.074	0.049
		55.500	18.9	733	0.499	0.264	0.183	0.141	0.116	0.102	0.085	0.074	0.049
			Average	**730**	**0.528**	**0.300**	**0.199**	**0.149**	**0.121**	**0.105**	**0.088**	**0.076**	**0.051**
	68	55.419	17.7	680	0.479	0.307	0.208	0.155	0.128	0.111	0.093	0.081	0.052
		55.428	17.8	676	0.479	0.290	0.194	0.145	0.119	0.103	0.086	0.074	0.049
		55.437	17.5	678	0.526	0.295	0.199	0.149	0.120	0.104	0.087	0.075	0.049
		55.446	17.5	685	0.496	0.300	0.202	0.152	0.122	0.104	0.086	0.074	0.048
		55.455	17.8	679	0.515	0.292	0.197	0.148	0.121	0.104	0.087	0.075	0.049
		55.464	17.9	679	0.496	0.274	0.184	0.143	0.119	0.104	0.087	0.075	0.050
		55.473	18.0	688	0.468	0.277	0.186	0.145	0.121	0.107	0.090	0.078	0.050
		55.482	18.0	671	0.487	0.278	0.189	0.146	0.121	0.108	0.090	0.078	0.051
		55.491	17.8	676	0.510	0.292	0.201	0.154	0.127	0.110	0.091	0.079	0.049
		55.500	17.5	681	0.480	0.273	0.200	0.150	0.124	0.109	0.091	0.078	0.049
			Average	**679**	**0.494**	**0.288**	**0.196**	**0.148**	**0.122**	**0.106**	**0.089**	**0.077**	**0.050**

Figure B 7: Section 5 measured deflections at a nominal applied stress of 566 kPa

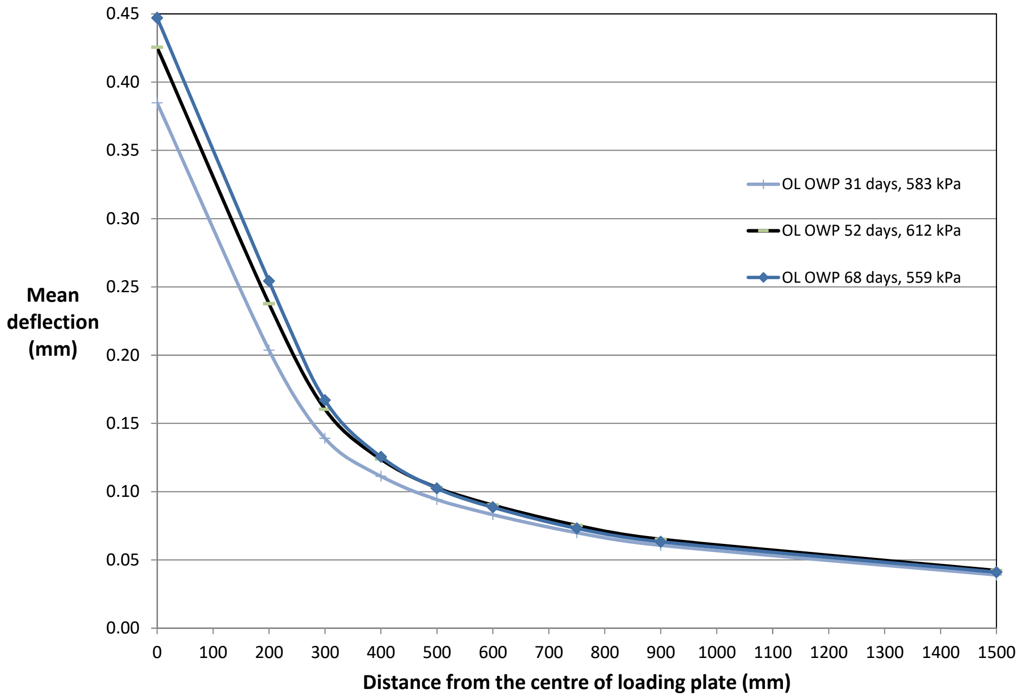
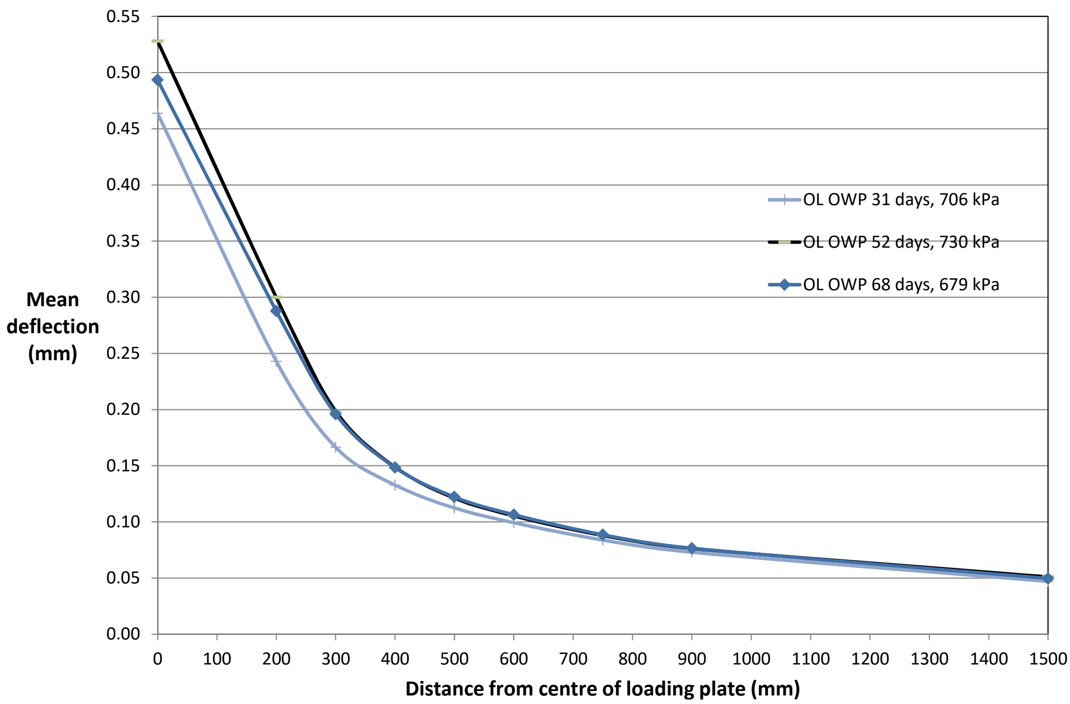


Figure B 8: Section 5 measured deflections at a nominal stress of 700 kPa



B.5 Section 6 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Table B 9: Section 6 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	36	55.519	12.6	583	0.302	0.170	0.125	0.104	0.090	0.081	0.070	0.061	0.039
		55.528	12.7	587	0.322	0.173	0.129	0.104	0.088	0.077	0.064	0.055	0.035
		55.537	12.7	583	0.326	0.202	0.139	0.111	0.094	0.084	0.071	0.062	0.039
		55.546	12.7	585	0.342	0.176	0.122	0.097	0.084	0.074	0.063	0.055	0.034
		55.555	12.7	583	0.351	0.194	0.134	0.106	0.091	0.081	0.069	0.060	0.038
		55.564	12.7	586	0.328	0.187	0.127	0.101	0.086	0.076	0.065	0.056	0.035
		55.573	12.7	582	0.307	0.181	0.128	0.101	0.087	0.078	0.067	0.059	0.036
		55.582	12.7	586	0.333	0.194	0.131	0.104	0.089	0.079	0.067	0.059	0.037
		55.591	12.7	579	0.395	0.209	0.145	0.114	0.096	0.084	0.071	0.061	0.037
		55.600	12.7	583	0.327	0.185	0.136	0.111	0.094	0.083	0.071	0.061	0.037
			Average	**584**	**0.333**	**0.187**	**0.131**	**0.105**	**0.090**	**0.080**	**0.068**	**0.059**	**0.037**
	57	55.519	14.4	612	0.326	0.192	0.138	0.113	0.096	0.086	0.073	0.064	0.041
		55.528	14.3	611	0.332	0.179	0.131	0.105	0.092	0.082	0.070	0.061	0.039
		55.537	14.3	619	0.376	0.204	0.145	0.115	0.097	0.086	0.073	0.063	0.040
		55.546	14.5	612	0.350	0.195	0.130	0.104	0.085	0.075	0.063	0.056	0.036
		55.555	14.6	618	0.367	0.222	0.141	0.109	0.091	0.080	0.067	0.059	0.038
		55.564	14.6	612	0.377	0.217	0.142	0.108	0.089	0.079	0.067	0.058	0.037
		55.573	14.6	620	0.383	0.217	0.143	0.111	0.094	0.084	0.070	0.061	0.038
		55.582	14.7	612	0.367	0.211	0.146	0.114	0.095	0.084	0.071	0.061	0.038
		55.591	14.9	616	0.415	0.218	0.156	0.123	0.101	0.088	0.073	0.063	0.039
		55.600	14.8	547	0.393	0.232	0.160	0.123	0.101	0.088	0.073	0.062	0.038
			Average	**608**	**0.369**	**0.209**	**0.143**	**0.113**	**0.094**	**0.083**	**0.070**	**0.061**	**0.038**
	74	55.519	13.1	596	0.385	0.205	0.147	0.119	0.101	0.090	0.077	0.067	0.043
		55.528	13.4	595	0.352	0.197	0.143	0.115	0.097	0.086	0.073	0.063	0.039
		55.537	13.3	592	0.375	0.224	0.159	0.122	0.103	0.090	0.077	0.065	0.041
		55.546	13.3	596	0.365	0.205	0.143	0.111	0.094	0.082	0.068	0.059	0.037
		55.555	13.1	597	0.382	0.230	0.155	0.121	0.100	0.088	0.074	0.064	0.040
		55.564	12.9	601	0.401	0.236	0.156	0.116	0.095	0.084	0.069	0.060	0.037
		55.573	12.9	597	0.385	0.226	0.155	0.120	0.100	0.089	0.074	0.064	0.039
		55.582	12.9	597	0.421	0.240	0.163	0.127	0.103	0.090	0.076	0.065	0.040
		55.591	12.9	596	0.415	0.271	0.181	0.137	0.112	0.096	0.079	0.067	0.041
		55.600	13.1	598	0.408	0.240	0.167	0.129	0.108	0.093	0.076	0.065	0.039
			Average	**597**	**0.389**	**0.227**	**0.157**	**0.122**	**0.101**	**0.089**	**0.074**	**0.064**	**0.040**

Table B 10: Section 6 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	36	55.519	17.9	700	0.369	0.201	0.151	0.125	0.108	0.097	0.084	0.073	0.047
		55.528	17.6	712	0.365	0.217	0.153	0.123	0.104	0.091	0.077	0.066	0.042
		55.537	17.9	707	0.486	0.244	0.163	0.130	0.112	0.099	0.084	0.073	0.045
		55.546	18.4	706	0.395	0.209	0.146	0.116	0.100	0.089	0.076	0.066	0.041
		55.555	18.7	709	0.378	0.220	0.155	0.126	0.107	0.096	0.082	0.072	0.046
		55.564	18.7	708	0.417	0.224	0.151	0.121	0.104	0.091	0.077	0.067	0.042
		55.573	18.9	711	0.379	0.221	0.152	0.122	0.104	0.092	0.079	0.069	0.043
		55.582	19.0	711	0.403	0.232	0.158	0.126	0.108	0.095	0.081	0.071	0.045
		55.591	18.8	698	0.422	0.242	0.173	0.139	0.118	0.104	0.086	0.075	0.045
		55.600	19.0	702	0.395	0.239	0.169	0.135	0.115	0.101	0.084	0.075	0.046
			Average	**706**	**0.401**	**0.225**	**0.157**	**0.126**	**0.108**	**0.096**	**0.081**	**0.071**	**0.044**
	57	55.519	19.0	723	0.384	0.228	0.165	0.134	0.114	0.102	0.087	0.075	0.048
		55.528	19.2	726	0.379	0.228	0.165	0.135	0.115	0.102	0.086	0.075	0.049
		55.537	19.0	733	0.413	0.237	0.169	0.134	0.112	0.098	0.083	0.071	0.045
		55.546	19.0	735	0.411	0.236	0.169	0.134	0.112	0.099	0.083	0.071	0.045
		55.555	18.5	728	0.475	0.256	0.181	0.141	0.119	0.106	0.089	0.077	0.049
		55.564	18.4	731	0.470	0.257	0.182	0.142	0.120	0.106	0.089	0.078	0.049
		55.573	18.4	729	0.413	0.219	0.157	0.124	0.106	0.093	0.078	0.069	0.043
		55.582	18.8	728	0.408	0.218	0.157	0.124	0.106	0.093	0.078	0.069	0.042
		55.591	18.3	732	0.417	0.245	0.174	0.138	0.115	0.101	0.085	0.073	0.046
		55.600	18.9	734	0.415	0.246	0.174	0.138	0.115	0.101	0.085	0.074	0.046
			Average	**730**	**0.418**	**0.237**	**0.169**	**0.134**	**0.114**	**0.100**	**0.084**	**0.073**	**0.046**
	74	55.519	13.8	707	0.393	0.247	0.174	0.141	0.121	0.108	0.091	0.080	0.050
		55.528	13.9	705	0.418	0.250	0.178	0.141	0.119	0.105	0.087	0.075	0.046
		55.537	14.0	705	0.472	0.264	0.186	0.146	0.123	0.108	0.091	0.078	0.050
		55.546	14.1	708	0.416	0.251	0.170	0.132	0.110	0.096	0.080	0.070	0.044
		55.555	14.2	710	0.455	0.261	0.181	0.141	0.118	0.103	0.087	0.075	0.047
		55.564	14.2	707	0.441	0.265	0.182	0.140	0.116	0.101	0.083	0.071	0.044
		55.573	14.2	714	0.465	0.250	0.175	0.138	0.117	0.102	0.086	0.074	0.046
		55.582	14.2	709	0.463	0.268	0.184	0.144	0.118	0.102	0.085	0.074	0.047
		55.591	14.2	711	0.501	0.291	0.203	0.158	0.128	0.112	0.092	0.079	0.048
		55.600	14.4	711	0.464	0.290	0.201	0.155	0.127	0.111	0.092	0.078	0.047
			Average	**709**	**0.449**	**0.264**	**0.183**	**0.144**	**0.120**	**0.105**	**0.087**	**0.075**	**0.047**

Figure B 9: Section 6 measured deflections at a nominal applied stress of 566 kPa

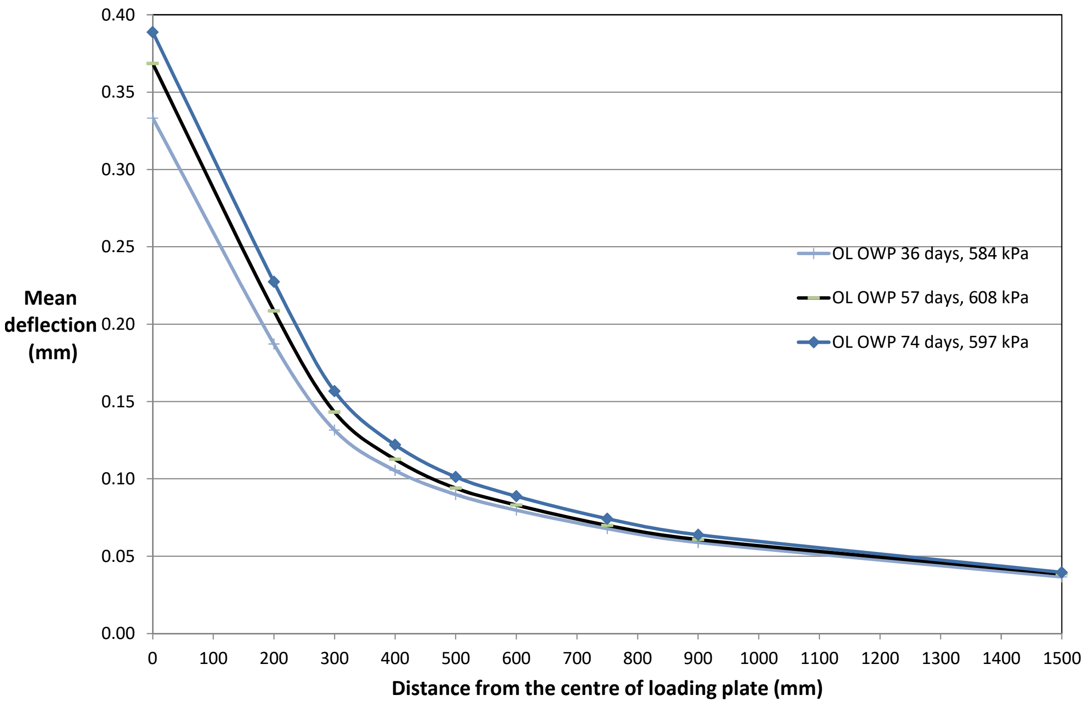
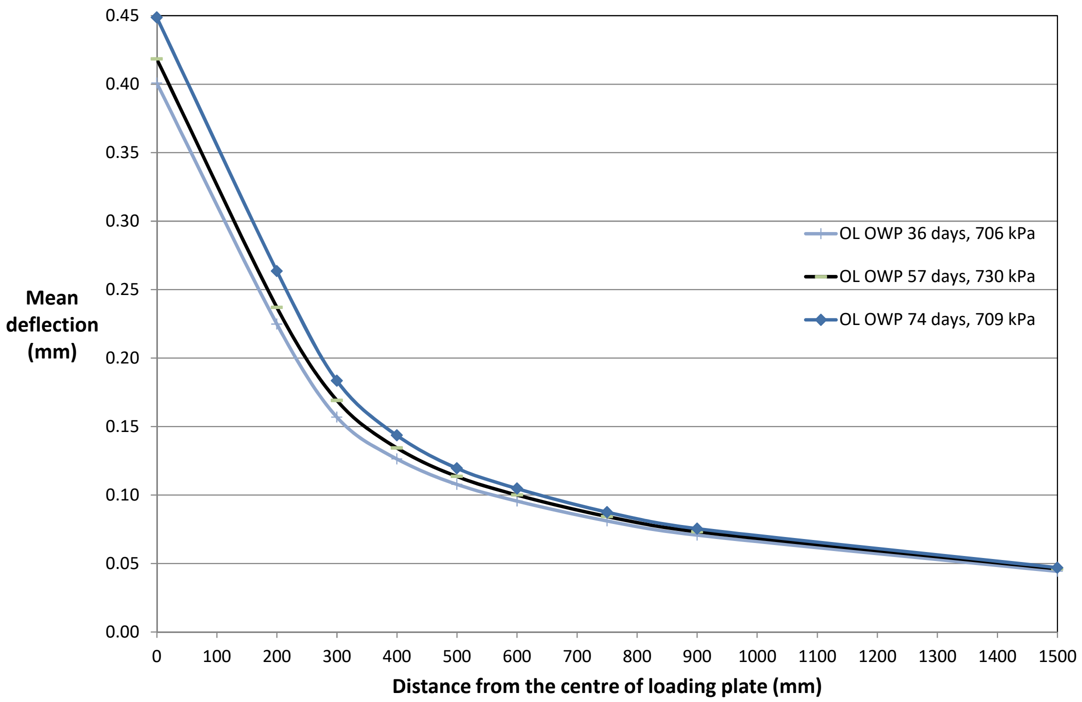


Figure B 10: Section 6 measured deflections at a nominal stress of 700 kPa



B.6 Section 7 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Table B 11: Section 7 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	36	55.619	12.8	580	0.346	0.196	0.145	0.113	0.096	0.085	0.072	0.063	0.040
		55.628	12.8	584	0.328	0.207	0.144	0.115	0.096	0.084	0.071	0.061	0.037
		55.637	12.9	582	0.405	0.204	0.141	0.110	0.093	0.082	0.068	0.059	0.035
		55.646	12.8	588	0.346	0.194	0.131	0.106	0.089	0.082	0.070	0.060	0.035
		55.655	12.9	579	0.343	0.188	0.132	0.105	0.090	0.080	0.069	0.060	0.038
		55.664	12.8	580	0.294	0.170	0.127	0.102	0.088	0.079	0.067	0.058	0.036
		55.673	12.9	582	0.296	0.170	0.122	0.099	0.085	0.076	0.065	0.057	0.035
		55.682	12.9	586	0.305	0.164	0.118	0.096	0.083	0.074	0.063	0.055	0.034
		55.691	12.8	581	0.293	0.167	0.117	0.093	0.081	0.072	0.062	0.054	0.034
		55.700	12.8	582	0.296	0.163	0.113	0.092	0.079	0.071	0.061	0.053	0.033
			Average	**582**	**0.325**	**0.182**	**0.129**	**0.103**	**0.088**	**0.078**	**0.067**	**0.058**	**0.036**
	57	55.619	14.9	611	0.399	0.225	0.159	0.123	0.103	0.091	0.076	0.066	0.042
		55.628	14.9	613	0.390	0.217	0.154	0.121	0.102	0.088	0.073	0.062	0.040
		55.637	15.0	610	0.369	0.226	0.152	0.119	0.100	0.093	0.073	0.062	0.037
		55.646	15.0	617	0.372	0.198	0.141	0.114	0.097	0.085	0.070	0.060	0.038
		55.655	15.1	608	0.362	0.204	0.142	0.112	0.095	0.084	0.071	0.061	0.038
		55.664	15.2	616	0.370	0.206	0.144	0.113	0.096	0.085	0.072	0.062	0.038
		55.673	15.2	614	0.342	0.199	0.139	0.112	0.094	0.083	0.069	0.060	0.038
		55.682	15.2	605	0.335	0.201	0.138	0.108	0.092	0.081	0.069	0.059	0.037
		55.691	15.4	614	0.344	0.198	0.133	0.106	0.091	0.080	0.068	0.058	0.036
		55.700	15.5	613	0.314	0.180	0.130	0.104	0.088	0.078	0.066	0.057	0.035
			Average	**612**	**0.360**	**0.205**	**0.143**	**0.113**	**0.096**	**0.085**	**0.071**	**0.061**	**0.038**
	74	55.619	13.1	592	0.407	0.251	0.176	0.136	0.112	0.098	0.081	0.070	0.043
		55.628	13.1	591	0.403	0.236	0.168	0.131	0.108	0.094	0.077	0.066	0.040
		55.637	13.0	595	0.390	0.222	0.161	0.127	0.107	0.093	0.076	0.064	0.039
		55.646	13.1	595	0.377	0.222	0.156	0.123	0.102	0.090	0.075	0.064	0.039
		55.655	13.3	593	0.357	0.227	0.159	0.125	0.105	0.092	0.076	0.066	0.040
		55.664	13.3	591	0.395	0.219	0.155	0.122	0.103	0.090	0.075	0.065	0.039
		55.673	13.3	592	0.364	0.210	0.148	0.117	0.098	0.087	0.072	0.063	0.039
		55.682	13.1	599	0.368	0.217	0.149	0.119	0.099	0.087	0.073	0.063	0.038
		55.691	13.2	588	0.341	0.213	0.144	0.114	0.096	0.084	0.070	0.060	0.037
		55.700	13.3	589	0.355	0.207	0.144	0.112	0.093	0.082	0.069	0.059	0.037
			Average	**593**	**0.376**	**0.222**	**0.156**	**0.123**	**0.102**	**0.090**	**0.074**	**0.064**	**0.039**

Table B 12: Section 7 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	36	55.619	19.4	697	0.428	0.246	0.173	0.143	0.117	0.104	0.088	0.077	0.048
		55.628	19.2	699	0.393	0.227	0.166	0.136	0.115	0.102	0.084	0.074	0.045
		55.637	19.4	697	0.377	0.222	0.161	0.129	0.112	0.100	0.082	0.072	0.044
		55.646	19.8	707	0.397	0.233	0.156	0.125	0.107	0.095	0.082	0.071	0.044
		55.655	19.7	706	0.379	0.214	0.154	0.127	0.109	0.097	0.082	0.071	0.044
		55.664	19.7	709	0.376	0.210	0.149	0.122	0.104	0.098	0.081	0.072	0.044
		55.673	19.7	709	0.376	0.218	0.148	0.122	0.105	0.093	0.079	0.069	0.043
		55.682	19.7	709	0.353	0.199	0.143	0.115	0.100	0.090	0.075	0.066	0.043
		55.691	19.6	710	0.342	0.191	0.137	0.111	0.096	0.086	0.074	0.065	0.040
		55.700	19.8	707	0.332	0.196	0.138	0.111	0.095	0.085	0.073	0.064	0.040
			Average	**705**	**0.375**	**0.216**	**0.152**	**0.124**	**0.106**	**0.095**	**0.080**	**0.070**	**0.043**
	57	55.619	19.5	727	0.454	0.278	0.190	0.148	0.123	0.109	0.091	0.079	0.050
		55.628	19.3	728	0.452	0.307	0.190	0.148	0.124	0.110	0.092	0.080	0.050
		55.637	18.8	729	0.427	0.251	0.177	0.142	0.119	0.106	0.087	0.074	0.046
		55.646	19.0	729	0.427	0.249	0.177	0.143	0.119	0.106	0.087	0.075	0.046
		55.655	19.6	729	0.411	0.240	0.171	0.138	0.119	0.105	0.087	0.075	0.045
		55.664	19.3	731	0.409	0.239	0.171	0.138	0.119	0.105	0.088	0.075	0.045
		55.673	19.3	729	0.366	0.242	0.168	0.134	0.113	0.100	0.084	0.072	0.044
		55.682	19.3	733	0.364	0.240	0.169	0.135	0.114	0.100	0.084	0.072	0.045
		55.691	19.0	725	0.397	0.241	0.168	0.135	0.117	0.105	0.087	0.073	0.046
		55.700	19.1	728	0.392	0.240	0.169	0.135	0.117	0.106	0.087	0.073	0.046
			Average	**729**	**0.410**	**0.253**	**0.175**	**0.139**	**0.118**	**0.105**	**0.087**	**0.075**	**0.046**
	74	55.619	14.5	706	0.464	0.298	0.204	0.158	0.125	0.116	0.095	0.082	0.052
		55.628	14.3	712	0.455	0.290	0.193	0.153	0.127	0.111	0.092	0.077	0.047
		55.637	14.3	715	0.416	0.270	0.188	0.148	0.125	0.108	0.090	0.078	0.047
		55.646	14.3	711	0.447	0.252	0.178	0.141	0.118	0.104	0.086	0.074	0.046
		55.655	14.3	708	0.414	0.249	0.180	0.144	0.121	0.106	0.089	0.076	0.047
		55.664	14.5	699	0.418	0.239	0.176	0.142	0.119	0.105	0.088	0.076	0.046
		55.673	14.7	708	0.413	0.243	0.173	0.138	0.118	0.103	0.087	0.073	0.046
		55.682	14.8	709	0.401	0.243	0.170	0.136	0.114	0.102	0.085	0.074	0.045
		55.691	14.8	715	0.401	0.244	0.171	0.138	0.113	0.101	0.085	0.072	0.043
		55.700	14.9	712	0.409	0.237	0.167	0.133	0.112	0.095	0.083	0.072	0.044
			Average	**710**	**0.424**	**0.257**	**0.180**	**0.143**	**0.119**	**0.105**	**0.088**	**0.075**	**0.046**

Figure B 11: Section 7 measured deflections at a nominal applied stress of 566 kPa

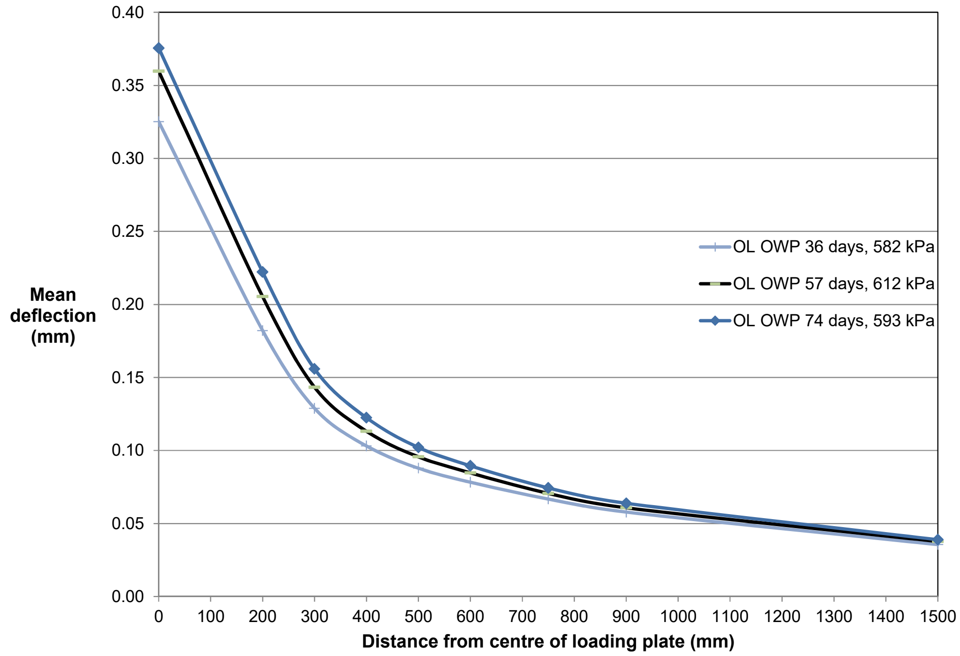
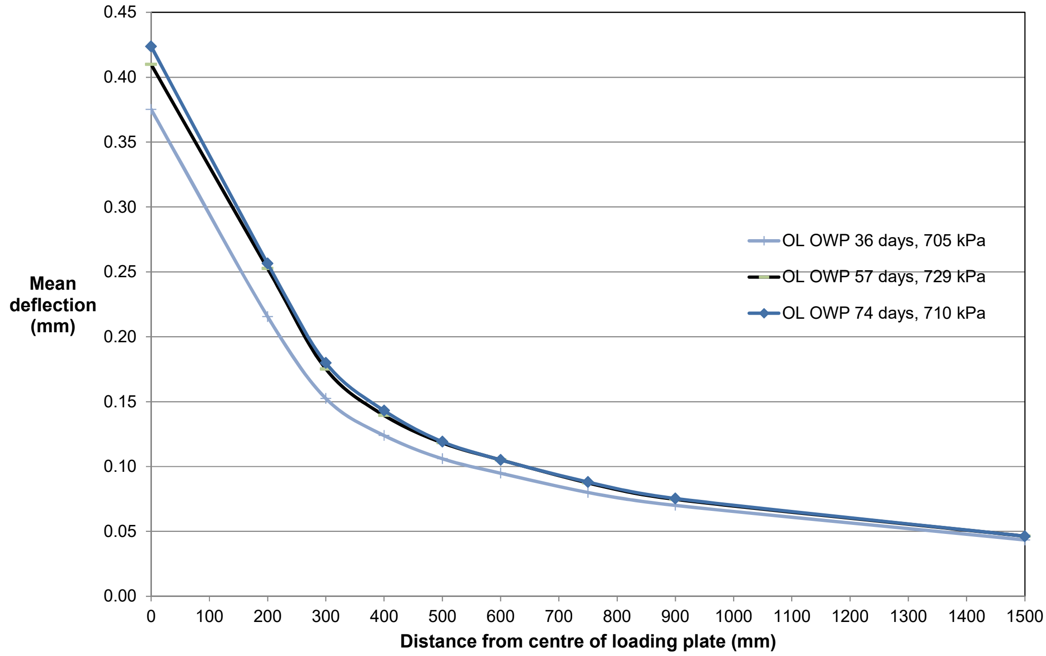


Figure B 12: Section 7 measured deflections at a nominal stress of 700 kPa



B.7 Section 8 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Table B 13: Section 8 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	36	55.719	12.8	578	0.333	0.172	0.122	0.098	0.085	0.076	0.064	0.056	0.035
		55.728	12.8	582	0.310	0.178	0.124	0.099	0.084	0.075	0.064	0.055	0.034
		55.737	12.8	582	0.316	0.175	0.120	0.097	0.083	0.074	0.063	0.055	0.034
		55.746	12.9	583	0.313	0.184	0.128	0.101	0.086	0.076	0.065	0.057	0.035
		55.755	12.9	581	0.325	0.186	0.130	0.104	0.088	0.078	0.067	0.059	0.035
		55.764	13.0	581	0.339	0.184	0.129	0.104	0.087	0.077	0.066	0.057	0.036
		55.773	13.0	583	0.361	0.191	0.135	0.108	0.092	0.081	0.069	0.059	0.035
		55.782	13.1	581	0.340	0.199	0.133	0.108	0.093	0.082	0.069	0.058	0.035
		55.791	13.1	579	0.307	0.181	0.128	0.104	0.089	0.080	0.068	0.059	0.036
		55.800	13.1	584	0.358	0.181	0.129	0.105	0.089	0.079	0.067	0.058	0.036
			Average	**581**	**0.330**	**0.183**	**0.128**	**0.103**	**0.088**	**0.078**	**0.066**	**0.057**	**0.035**
	57	55.719	15.8	609	0.346	0.200	0.140	0.109	0.092	0.081	0.068	0.059	0.036
		55.728	15.7	610	0.353	0.204	0.140	0.109	0.092	0.082	0.067	0.059	0.036
		55.737	15.8	610	0.328	0.192	0.137	0.109	0.091	0.080	0.068	0.057	0.036
		55.746	15.9	611	0.337	0.206	0.143	0.113	0.095	0.083	0.069	0.060	0.037
		55.755	16.0	614	0.339	0.200	0.141	0.111	0.093	0.082	0.068	0.059	0.036
		55.764	16.0	615	0.350	0.194	0.141	0.112	0.095	0.082	0.069	0.060	0.037
		55.773	16.1	615	0.340	0.217	0.151	0.117	0.098	0.086	0.071	0.061	0.038
		55.782	16.2	614	0.378	0.204	0.144	0.114	0.097	0.087	0.071	0.062	0.038
		55.791	16.1	615	0.355	0.195	0.143	0.114	0.101	0.086	0.070	0.060	0.037
		55.800	16.0	615	0.369	0.192	0.134	0.108	0.091	0.081	0.068	0.058	0.036
			Average	**613**	**0.349**	**0.200**	**0.141**	**0.112**	**0.094**	**0.083**	**0.069**	**0.059**	**0.037**
	74	55.719	12.3	590	0.348	0.211	0.148	0.115	0.096	0.084	0.070	0.061	0.037
		55.728	12.2	587	0.346	0.207	0.144	0.114	0.094	0.083	0.069	0.060	0.036
		55.737	12.0	593	0.329	0.214	0.149	0.116	0.097	0.086	0.071	0.061	0.038
		55.746	12.3	591	0.357	0.214	0.150	0.118	0.097	0.086	0.072	0.062	0.037
		55.755	12.4	590	0.379	0.216	0.152	0.118	0.099	0.087	0.073	0.063	0.038
		55.764	12.4	584	0.384	0.207	0.150	0.119	0.100	0.087	0.072	0.062	0.038
		55.773	12.1	584	0.366	0.227	0.158	0.123	0.103	0.089	0.073	0.063	0.038
		55.782	12.4	586	0.362	0.222	0.156	0.124	0.104	0.090	0.076	0.064	0.039
		55.791	12.1	589	0.380	0.224	0.158	0.122	0.102	0.089	0.074	0.065	0.038
		55.800	11.9	582	0.360	0.217	0.149	0.116	0.097	0.085	0.071	0.061	0.037
			Average	**588**	**0.361**	**0.216**	**0.151**	**0.118**	**0.099**	**0.087**	**0.072**	**0.062**	**0.037**

Table B 14: Section 8 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	36	55.719	19.8	703	0.371	0.209	0.143	0.116	0.098	0.089	0.075	0.066	0.041
		55.728	19.6	703	0.349	0.203	0.145	0.117	0.100	0.089	0.076	0.065	0.041
		55.737	19.5	707	0.319	0.195	0.138	0.115	0.097	0.088	0.073	0.066	0.040
		55.746	19.4	710	0.346	0.214	0.153	0.123	0.104	0.092	0.080	0.068	0.042
		55.755	19.4	706	0.376	0.211	0.151	0.121	0.104	0.092	0.077	0.068	0.042
		55.764	19.2	706	0.355	0.196	0.143	0.121	0.102	0.092	0.078	0.068	0.042
		55.773	19.1	709	0.385	0.225	0.156	0.130	0.111	0.096	0.081	0.073	0.046
		55.782	19.1	708	0.399	0.225	0.157	0.130	0.111	0.100	0.082	0.072	0.043
		55.791	19.1	707	0.378	0.209	0.156	0.126	0.109	0.097	0.082	0.070	0.043
		55.800	19.1	710	0.425	0.223	0.148	0.121	0.104	0.093	0.079	0.068	0.043
			Average	**707**	**0.370**	**0.211**	**0.149**	**0.122**	**0.104**	**0.093**	**0.078**	**0.068**	**0.042**
	57	55.719	19.0	726	0.414	0.236	0.163	0.130	0.109	0.096	0.081	0.070	0.043
		55.728	19.1	727	0.411	0.232	0.162	0.130	0.109	0.096	0.081	0.070	0.043
		55.737	19.2	729	0.375	0.236	0.164	0.129	0.108	0.095	0.080	0.069	0.043
		55.746	19.3	727	0.372	0.234	0.165	0.129	0.109	0.095	0.080	0.070	0.043
		55.755	19.4	732	0.395	0.217	0.158	0.126	0.107	0.095	0.079	0.069	0.043
		55.764	19.4	735	0.397	0.217	0.158	0.126	0.108	0.095	0.079	0.069	0.043
		55.773	19.4	732	0.381	0.233	0.168	0.132	0.111	0.098	0.082	0.071	0.043
		55.782	19.5	731	0.378	0.231	0.168	0.132	0.111	0.099	0.082	0.071	0.044
		55.791	18.9	731	0.379	0.223	0.162	0.130	0.110	0.098	0.083	0.071	0.043
		55.800	18.5	734	0.380	0.224	0.162	0.131	0.110	0.098	0.083	0.071	0.044
			Average	**730**	**0.388**	**0.228**	**0.163**	**0.129**	**0.109**	**0.096**	**0.081**	**0.070**	**0.043**
	74	55.719	12.8	708	0.382	0.247	0.176	0.139	0.116	0.101	0.085	0.076	0.046
		55.728	13.1	703	0.399	0.239	0.170	0.135	0.114	0.100	0.083	0.072	0.044
		55.737	13.1	710	0.424	0.232	0.169	0.135	0.114	0.101	0.084	0.072	0.045
		55.746	13.2	710	0.415	0.264	0.182	0.141	0.118	0.103	0.085	0.075	0.046
		55.755	13.0	709	0.407	0.244	0.175	0.139	0.116	0.102	0.085	0.073	0.045
		55.764	13.6	704	0.410	0.258	0.176	0.139	0.116	0.101	0.085	0.074	0.045
		55.773	13.2	712	0.450	0.280	0.191	0.151	0.123	0.108	0.088	0.076	0.045
		55.782	13.3	708	0.425	0.254	0.180	0.144	0.121	0.106	0.088	0.075	0.045
		55.791	13.1	705	0.430	0.253	0.181	0.144	0.120	0.105	0.087	0.075	0.046
		55.800	13.0	709	0.425	0.243	0.168	0.136	0.114	0.104	0.083	0.070	0.044
			Average	**708**	**0.417**	**0.251**	**0.177**	**0.140**	**0.117**	**0.103**	**0.085**	**0.074**	**0.045**

Figure B 13: Section 8 measured deflections at a nominal applied stress of 566 kPa

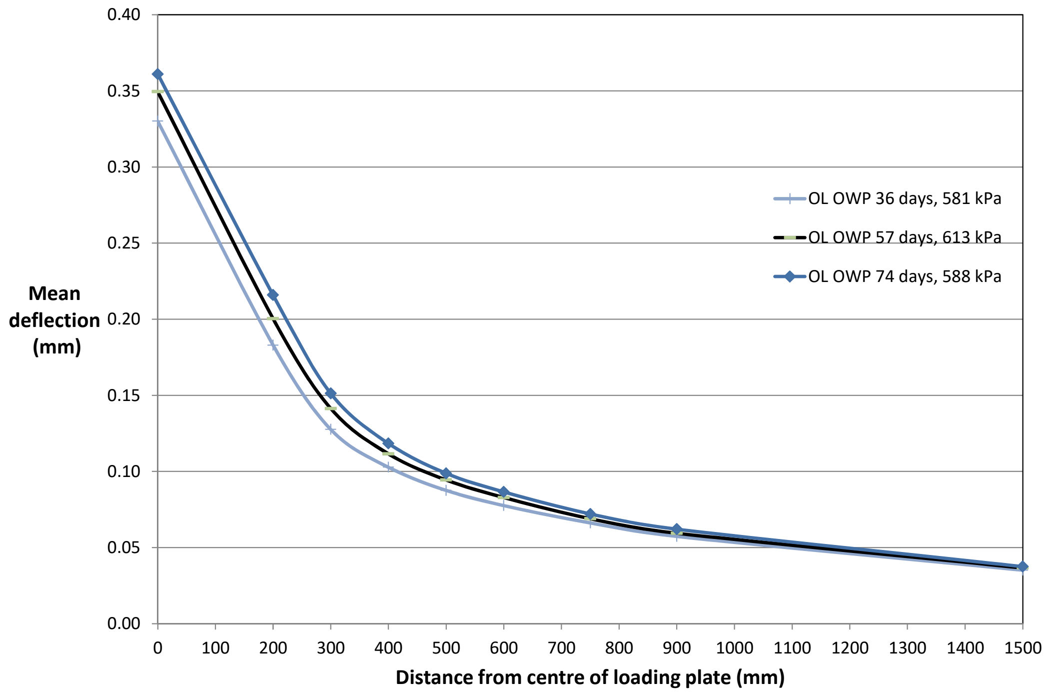
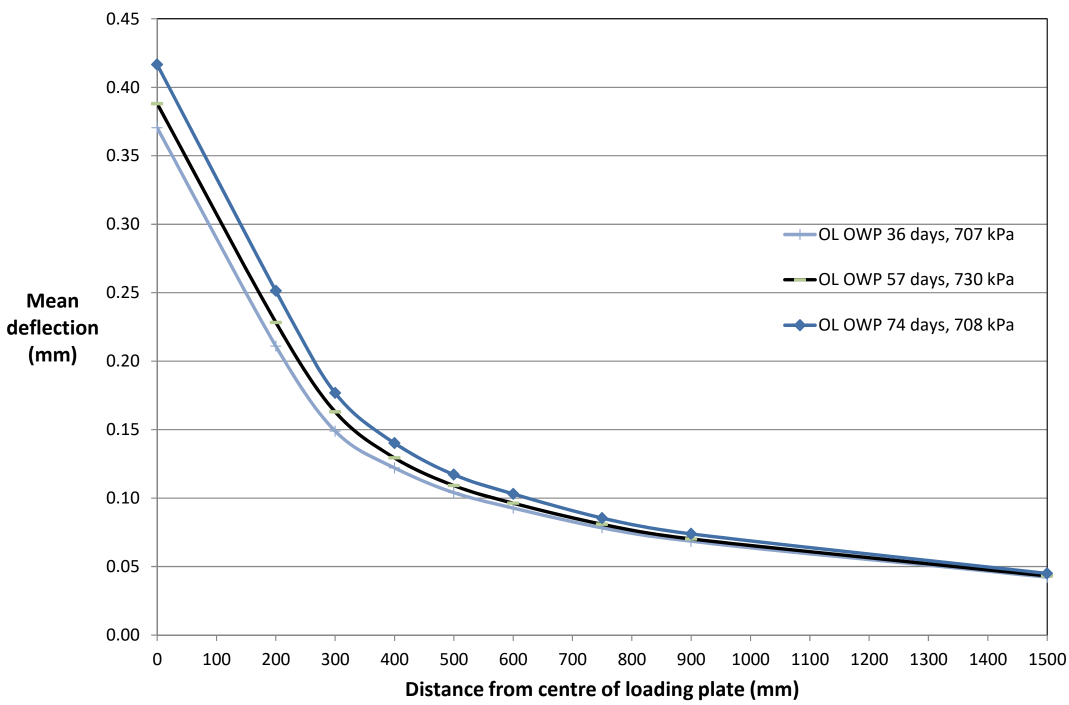


Figure B 14: Section 8 measured deflections at a nominal stress of 700 kPa



B.8 Section 9 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Table B 15: Section 9 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	35	55.819	13.2	579	0.365	0.190	0.127	0.103	0.090	0.077	0.064	0.056	0.035
		55.828	13.2	582	0.395	0.193	0.130	0.103	0.087	0.077	0.065	0.056	0.034
		55.837	13.2	583	0.424	0.226	0.136	0.107	0.089	0.078	0.065	0.056	0.034
		55.846	13.3	578	0.413	0.205	0.133	0.104	0.087	0.077	0.065	0.054	0.034
		55.855	13.3	583	0.361	0.194	0.131	0.105	0.088	0.078	0.065	0.056	0.033
		55.864	13.2	578	0.391	0.203	0.135	0.107	0.089	0.078	0.065	0.056	0.035
		55.873	13.2	582	0.394	0.202	0.134	0.104	0.088	0.077	0.063	0.057	0.036
		55.882	13.3	578	0.373	0.188	0.131	0.104	0.088	0.077	0.065	0.056	0.036
		55.891	13.3	577	0.311	0.173	0.124	0.101	0.087	0.077	0.066	0.057	0.037
		55.900	13.3	581	0.309	0.184	0.135	0.113	0.097	0.087	0.075	0.065	0.040
			Average	**580**	**0.373**	**0.196**	**0.131**	**0.105**	**0.089**	**0.078**	**0.066**	**0.057**	**0.035**
	56	55.819	15.9	612	0.380	0.214	0.142	0.113	0.094	0.082	0.068	0.059	0.038
		55.828	15.9	614	0.401	0.207	0.143	0.110	0.093	0.082	0.069	0.059	0.037
		55.837	16.0	615	0.406	0.229	0.147	0.112	0.093	0.082	0.067	0.058	0.037
		55.846	16.0	610	0.378	0.205	0.142	0.110	0.092	0.080	0.066	0.055	0.036
		55.855	16.0	615	0.351	0.203	0.142	0.112	0.095	0.081	0.068	0.058	0.037
		55.864	15.9	616	0.406	0.202	0.141	0.112	0.092	0.081	0.068	0.058	0.037
		55.873	16.1	609	0.401	0.210	0.146	0.113	0.095	0.083	0.069	0.060	0.037
		55.882	16.1	609	0.360	0.208	0.144	0.112	0.093	0.082	0.069	0.060	0.039
		55.891	16.2	615	0.345	0.210	0.144	0.112	0.093	0.083	0.070	0.060	0.039
		55.900	16.1	613	0.363	0.216	0.155	0.124	0.106	0.094	0.079	0.068	0.041
			Average	**613**	**0.379**	**0.210**	**0.145**	**0.113**	**0.095**	**0.083**	**0.069**	**0.060**	**0.038**
	73	55.819	13.5	580	0.378	0.220	0.154	0.122	0.101	0.087	0.072	0.061	0.037
		55.828	13.5	590	0.371	0.225	0.157	0.121	0.100	0.087	0.072	0.061	0.037
		55.837	13.5	583	0.385	0.222	0.154	0.120	0.098	0.086	0.071	0.061	0.037
		55.846	13.6	591	0.391	0.224	0.155	0.121	0.099	0.086	0.071	0.060	0.037
		55.855	13.6	585	0.389	0.220	0.150	0.118	0.097	0.084	0.070	0.059	0.037
		55.864	13.6	587	0.383	0.232	0.156	0.119	0.097	0.085	0.069	0.060	0.037
		55.873	13.6	587	0.369	0.231	0.155	0.118	0.097	0.084	0.069	0.059	0.038
		55.882	13.6	584	0.388	0.218	0.155	0.118	0.098	0.086	0.071	0.058	0.037
		55.891	13.7	589	0.367	0.226	0.153	0.118	0.097	0.084	0.070	0.061	0.039
		55.900	13.6	585	0.386	0.242	0.169	0.132	0.108	0.095	0.079	0.069	0.046
			Average	**586**	**0.381**	**0.226**	**0.156**	**0.121**	**0.099**	**0.086**	**0.071**	**0.061**	**0.038**

Table B 16: Section 9 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	35	55.819	19.8	698	0.471	0.223	0.151	0.123	0.104	0.093	0.079	0.068	0.041
		55.828	19.7	706	0.423	0.233	0.156	0.124	0.106	0.093	0.078	0.068	0.043
		55.837	19.7	706	0.465	0.232	0.152	0.119	0.102	0.090	0.076	0.066	0.042
		55.846	19.8	707	0.444	0.232	0.152	0.122	0.103	0.092	0.076	0.066	0.042
		55.855	20.0	707	0.503	0.227	0.154	0.121	0.103	0.090	0.077	0.067	0.042
		55.864	20.1	703	0.455	0.237	0.162	0.126	0.106	0.093	0.079	0.069	0.043
		55.873	19.8	706	0.448	0.234	0.160	0.126	0.106	0.093	0.078	0.068	0.043
		55.882	19.8	703	0.417	0.212	0.152	0.122	0.104	0.091	0.078	0.068	0.044
		55.891	19.8	706	0.373	0.210	0.150	0.120	0.103	0.092	0.079	0.069	0.044
		55.900	20.0	705	0.400	0.214	0.157	0.127	0.110	0.099	0.084	0.072	0.046
			Average	**705**	**0.440**	**0.225**	**0.155**	**0.123**	**0.105**	**0.093**	**0.078**	**0.068**	**0.043**
	56	55.819	18.4	724	0.413	0.227	0.165	0.132	0.111	0.098	0.081	0.070	0.044
		55.828	19.1	726	0.411	0.225	0.164	0.132	0.111	0.098	0.082	0.070	0.043
		55.837	19.1	729	0.403	0.234	0.172	0.135	0.113	0.100	0.083	0.071	0.044
		55.846	19.3	731	0.397	0.234	0.171	0.135	0.113	0.099	0.083	0.071	0.045
		55.855	19.1	730	0.448	0.249	0.172	0.133	0.111	0.098	0.081	0.070	0.044
		55.864	19.6	732	0.442	0.248	0.172	0.133	0.111	0.097	0.081	0.070	0.043
		55.873	19.8	729	0.446	0.243	0.167	0.132	0.110	0.097	0.081	0.069	0.044
		55.882	19.9	732	0.446	0.241	0.166	0.132	0.111	0.098	0.080	0.070	0.044
		55.891	20.0	730	0.434	0.249	0.168	0.131	0.109	0.095	0.080	0.069	0.044
		55.900	19.8	733	0.435	0.249	0.169	0.131	0.110	0.096	0.080	0.069	0.044
			Average	**730**	**0.427**	**0.240**	**0.169**	**0.133**	**0.111**	**0.097**	**0.081**	**0.070**	**0.044**
	74	55.819	15.0	705	0.472	0.248	0.177	0.142	0.120	0.105	0.087	0.074	0.045
		55.828	15.1	701	0.446	0.258	0.178	0.141	0.117	0.103	0.085	0.073	0.045
		55.837	15.1	708	0.486	0.270	0.180	0.139	0.116	0.102	0.083	0.072	0.044
		55.846	15.1	703	0.471	0.275	0.186	0.141	0.115	0.101	0.084	0.072	0.045
		55.855	15.1	708	0.469	0.258	0.179	0.138	0.114	0.099	0.081	0.070	0.045
		55.864	15.3	706	0.452	0.264	0.177	0.138	0.115	0.101	0.084	0.072	0.045
		55.873	15.3	704	0.492	0.267	0.179	0.138	0.114	0.099	0.084	0.072	0.046
		55.882	15.3	709	0.469	0.264	0.180	0.137	0.114	0.099	0.083	0.072	0.046
		55.891	15.3	707	0.446	0.253	0.176	0.136	0.113	0.100	0.084	0.074	0.047
		55.900	15.4	702	0.459	0.269	0.192	0.154	0.129	0.113	0.094	0.080	0.049
			Average	**705**	**0.466**	**0.263**	**0.180**	**0.140**	**0.117**	**0.102**	**0.085**	**0.073**	**0.045**

Figure B 15: Section 9 measured deflections at a nominal applied stress of 566 kPa

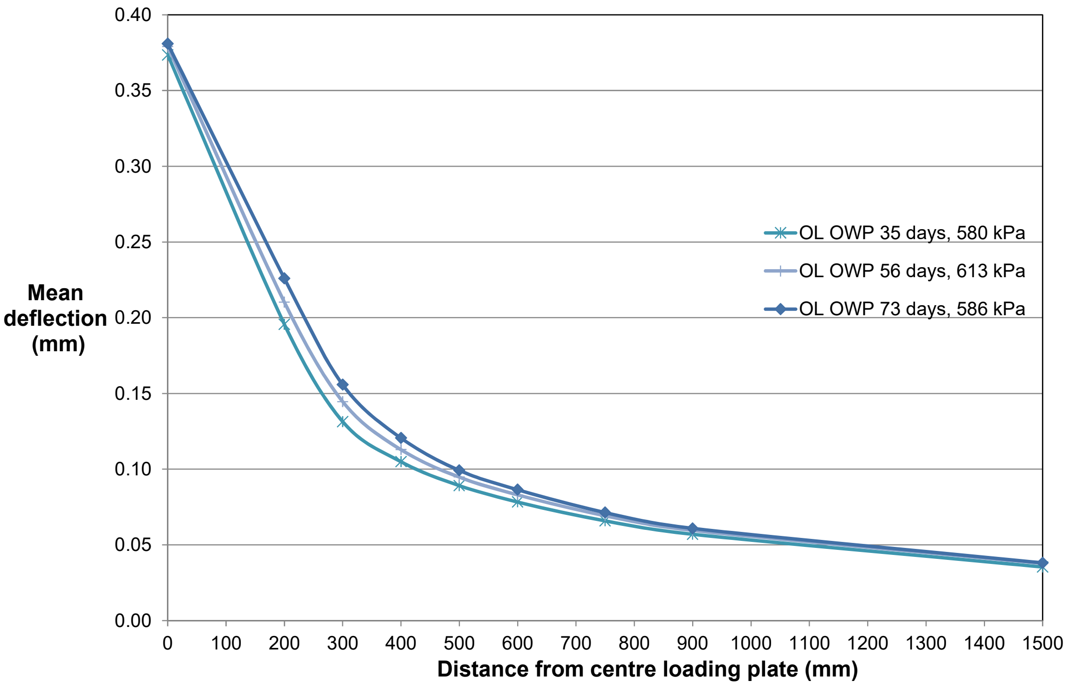
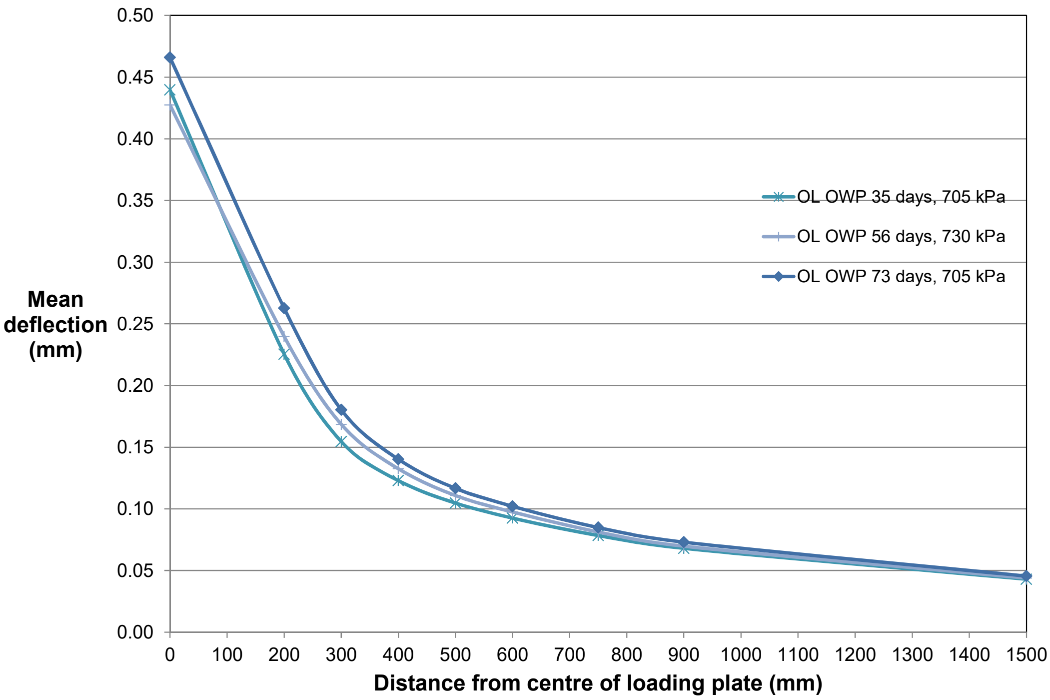


Figure B 16: Section 9 measured deflections at a nominal stress of 700 kPa



B.9 Section 10 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Table B 17: Section 10 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	35	55.919	13.3	583	0.302	0.180	0.121	0.099	0.085	0.075	0.065	0.057	0.037
		55.928	13.4	578	0.338	0.177	0.123	0.099	0.085	0.075	0.064	0.057	0.037
		55.937	13.4	584	0.322	0.182	0.125	0.102	0.087	0.080	0.067	0.059	0.039
		55.946	13.4	580	0.289	0.165	0.120	0.099	0.087	0.078	0.067	0.058	0.039
		55.955	13.4	583	0.324	0.166	0.122	0.099	0.086	0.077	0.066	0.059	0.039
		55.964	13.4	580	0.316	0.167	0.125	0.099	0.086	0.077	0.067	0.060	0.040
		55.973	13.4	582	0.282	0.164	0.119	0.098	0.086	0.077	0.067	0.059	0.040
		55.982	13.4	583	0.279	0.158	0.114	0.094	0.082	0.074	0.065	0.057	0.039
		55.991	13.3	581	0.270	0.164	0.118	0.096	0.084	0.075	0.065	0.058	0.040
		56.000	13.2	584	0.317	0.183	0.129	0.104	0.089	0.080	0.069	0.061	0.041
			Average	**582**	**0.304**	**0.171**	**0.122**	**0.099**	**0.086**	**0.077**	**0.066**	**0.058**	**0.039**
	56	55.519	16.1	610	0.339	0.194	0.136	0.108	0.090	0.081	0.068	0.060	0.039
		55.928	16.1	612	0.324	0.194	0.136	0.108	0.091	0.081	0.068	0.060	0.040
		55.937	16.1	616	0.338	0.195	0.138	0.109	0.093	0.082	0.070	0.062	0.043
		55.946	16.2	614	0.330	0.192	0.139	0.112	0.094	0.083	0.070	0.064	0.043
		55.955	16.1	613	0.388	0.196	0.140	0.114	0.095	0.085	0.072	0.064	0.043
		55.964	16.0	611	0.341	0.206	0.143	0.114	0.097	0.085	0.073	0.064	0.044
		55.973	16.0	615	0.329	0.204	0.142	0.113	0.096	0.085	0.072	0.064	0.044
		55.982	16.0	615	0.324	0.201	0.140	0.112	0.095	0.085	0.073	0.064	0.044
		55.991	15.9	609	0.355	0.200	0.141	0.113	0.095	0.085	0.073	0.064	0.043
		56.000	15.7	611	0.348	0.212	0.149	0.118	0.098	0.087	0.074	0.066	0.044
			Average	**613**	**0.341**	**0.199**	**0.140**	**0.112**	**0.095**	**0.084**	**0.071**	**0.063**	**0.043**
	73	55.919	13.8	577	0.379	0.204	0.146	0.114	0.095	0.083	0.070	0.063	0.040
		55.928	13.8	586	0.380	0.217	0.148	0.116	0.096	0.084	0.070	0.061	0.040
		55.937	13.8	583	0.366	0.213	0.146	0.116	0.098	0.086	0.073	0.063	0.042
		55.946	14.0	582	0.366	0.212	0.148	0.116	0.097	0.086	0.072	0.063	0.042
		55.955	14.0	581	0.344	0.221	0.149	0.118	0.098	0.086	0.073	0.064	0.043
		55.964	14.2	587	0.368	0.214	0.153	0.119	0.100	0.088	0.074	0.066	0.044
		55.973	14.2	581	0.362	0.212	0.149	0.117	0.097	0.086	0.074	0.064	0.043
		55.982	14.1	580	0.374	0.216	0.151	0.118	0.100	0.088	0.075	0.066	0.045
		55.991	14.1	586	0.361	0.218	0.157	0.122	0.101	0.090	0.077	0.067	0.045
		56.000	14.2	593	0.359	0.229	0.162	0.125	0.103	0.091	0.076	0.066	0.044
			Average	**584**	**0.366**	**0.215**	**0.151**	**0.118**	**0.098**	**0.087**	**0.073**	**0.064**	**0.043**

Table B 18: Section 10 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	35	55.919	20.5	699	0.350	0.202	0.143	0.117	0.103	0.091	0.078	0.069	0.045
		55.928	20.0	708	0.379	0.219	0.145	0.119	0.103	0.091	0.078	0.069	0.046
		55.937	20.3	705	0.366	0.205	0.146	0.122	0.104	0.092	0.080	0.075	0.047
		55.946	20.3	708	0.359	0.214	0.150	0.122	0.105	0.094	0.081	0.071	0.048
		55.955	20.6	710	0.378	0.207	0.145	0.119	0.103	0.093	0.081	0.072	0.049
		55.964	20.6	707	0.370	0.202	0.145	0.119	0.103	0.094	0.081	0.072	0.049
		55.973	20.3	708	0.346	0.199	0.144	0.120	0.106	0.095	0.080	0.077	0.048
		55.982	20.6	705	0.361	0.186	0.136	0.114	0.099	0.090	0.079	0.070	0.048
		55.991	20.6	709	0.374	0.196	0.141	0.119	0.103	0.093	0.080	0.071	0.046
		56.000	20.2	706	0.386	0.207	0.152	0.125	0.109	0.096	0.084	0.074	0.049
			Average	**707**	**0.367**	**0.204**	**0.145**	**0.120**	**0.104**	**0.093**	**0.080**	**0.072**	**0.047**
	56	55.919	20.9	723	0.377	0.232	0.159	0.126	0.107	0.095	0.080	0.070	0.046
		55.928	20.7	724	0.377	0.230	0.158	0.127	0.107	0.095	0.081	0.070	0.047
		55.937	20.6	728	0.388	0.242	0.164	0.129	0.109	0.096	0.081	0.072	0.048
		55.946	20.3	731	0.386	0.240	0.164	0.130	0.110	0.097	0.082	0.073	0.048
		55.955	20.4	728	0.405	0.223	0.161	0.128	0.110	0.098	0.084	0.074	0.049
		55.964	20.7	731	0.402	0.222	0.161	0.129	0.111	0.098	0.084	0.074	0.049
		55.973	20.4	729	0.395	0.232	0.163	0.131	0.110	0.098	0.084	0.073	0.050
		55.982	20.5	733	0.395	0.231	0.164	0.131	0.111	0.098	0.085	0.073	0.050
		55.991	20.8	730	0.416	0.233	0.165	0.132	0.112	0.099	0.086	0.075	0.051
		56.000	20.7	731	0.410	0.233	0.165	0.132	0.112	0.099	0.085	0.075	0.051
			Average	**729**	**0.395**	**0.232**	**0.162**	**0.130**	**0.110**	**0.097**	**0.083**	**0.073**	**0.049**
	73	55.919	15.6	696	0.420	0.242	0.170	0.133	0.112	0.100	0.084	0.073	0.049
		55.928	15.8	707	0.423	0.245	0.173	0.136	0.113	0.100	0.083	0.073	0.048
		55.937	15.8	705	0.412	0.252	0.172	0.135	0.113	0.101	0.087	0.077	0.051
		55.946	15.7	699	0.416	0.249	0.175	0.137	0.115	0.101	0.086	0.076	0.051
		55.955	15.8	699	0.395	0.246	0.173	0.138	0.116	0.103	0.088	0.077	0.052
		55.964	15.7	703	0.433	0.249	0.173	0.137	0.117	0.104	0.089	0.078	0.054
		55.973	15.6	696	0.411	0.249	0.177	0.138	0.117	0.104	0.088	0.083	0.053
		55.982	15.9	703	0.430	0.256	0.180	0.141	0.118	0.105	0.090	0.080	0.053
		55.991	15.8	712	0.438	0.258	0.183	0.146	0.123	0.108	0.092	0.081	0.054
		56.000	15.8	711	0.456	0.255	0.182	0.144	0.122	0.107	0.091	0.080	0.054
			Average	**703**	**0.423**	**0.250**	**0.176**	**0.138**	**0.116**	**0.103**	**0.088**	**0.078**	**0.052**

Figure B 17: Section 10 measured deflections at a nominal applied stress of 566 kPa

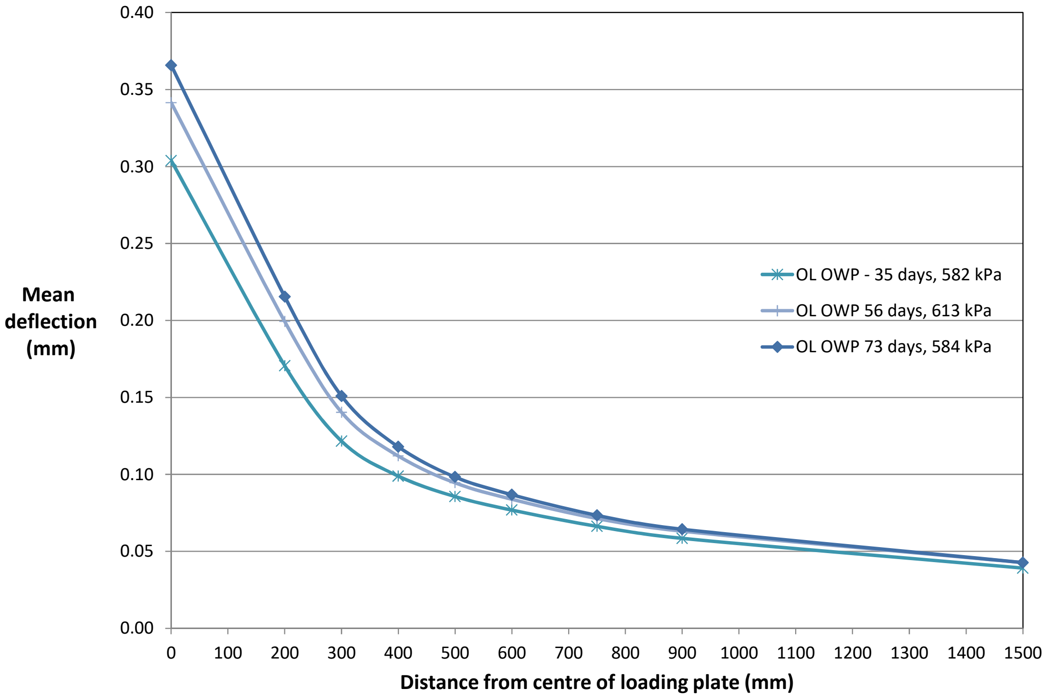
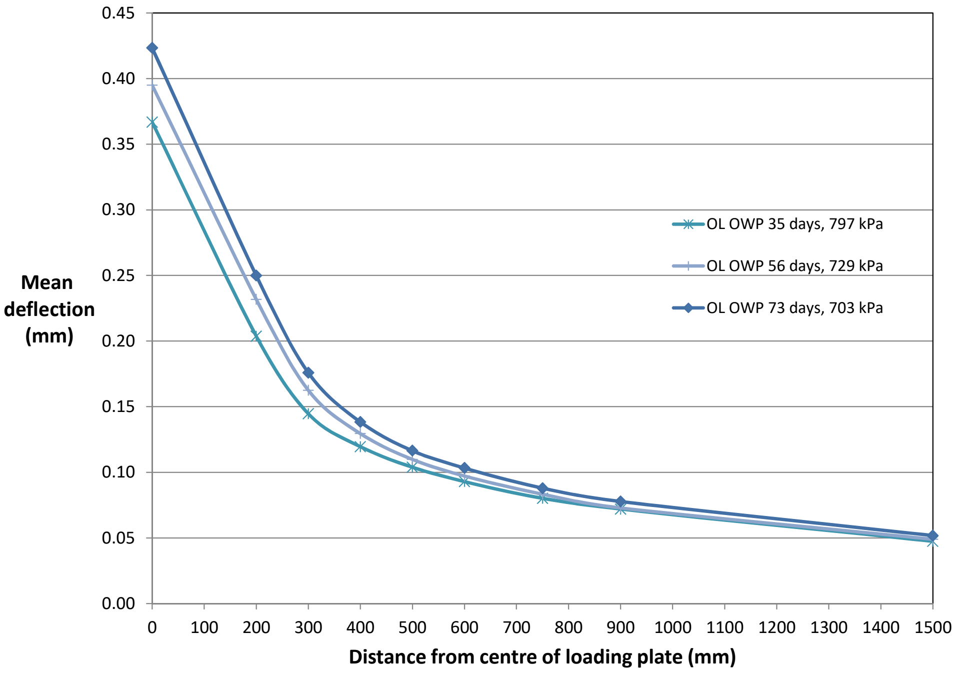


Figure B 18: Section 10 measured deflections at a nominal stress of 700 kPa



B.10 Section 12 – Bitumen Stabilised Limestone Base

Table B 19: Section 12 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	29	56.119	19.8	578	0.430	0.268	0.189	0.143	0.118	0.101	0.087	0.077	0.058
		56.128	19.8	568	0.465	0.278	0.188	0.148	0.120	0.103	0.087	0.078	0.053
		56.137	20.0	571	0.431	0.279	0.190	0.143	0.116	0.099	0.083	0.075	0.049
		56.146	19.9	572	0.454	0.274	0.188	0.139	0.114	0.098	0.083	0.073	0.050
		56.155	20.2	571	0.459	0.280	0.187	0.141	0.114	0.099	0.083	0.074	0.049
		56.164	19.9	570	0.457	0.283	0.195	0.146	0.117	0.101	0.086	0.075	0.050
		56.173	19.5	569	0.457	0.280	0.190	0.142	0.115	0.098	0.081	0.071	0.046
		56.182	19.6	569	0.446	0.263	0.178	0.133	0.109	0.092	0.076	0.066	0.044
		56.191	19.5	570	0.456	0.278	0.183	0.135	0.108	0.091	0.075	0.066	0.042
		56.200	19.6	569	0.445	0.261	0.183	0.136	0.109	0.093	0.078	0.068	0.044
			Average	**571**	**0.450**	**0.274**	**0.187**	**0.140**	**0.114**	**0.097**	**0.082**	**0.072**	**0.048**
	43	56.119	15.5	612	0.427	0.252	0.183	0.142	0.118	0.105	0.088	0.078	0.054
		56.128	15.8	611	0.387	0.267	0.190	0.148	0.123	0.108	0.092	0.081	0.055
		56.137	15.7	612	0.405	0.262	0.188	0.147	0.122	0.107	0.090	0.079	0.052
		56.146	15.8	616	0.411	0.257	0.187	0.145	0.120	0.107	0.089	0.078	0.052
		56.155	15.7	609	0.387	0.251	0.183	0.145	0.119	0.106	0.089	0.078	0.052
		56.164	15.9	609	0.411	0.255	0.186	0.147	0.122	0.107	0.090	0.078	0.053
		56.173	15.8	608	0.429	0.267	0.193	0.149	0.123	0.108	0.090	0.079	0.053
		56.182	15.8	608	0.417	0.264	0.183	0.142	0.117	0.102	0.083	0.073	0.047
		56.191	16.0	610	0.407	0.266	0.189	0.146	0.118	0.102	0.085	0.074	0.047
		56.200	15.9	613	0.430	0.258	0.185	0.145	0.119	0.104	0.086	0.075	0.048
			Average	**611**	**0.411**	**0.260**	**0.187**	**0.146**	**0.120**	**0.105**	**0.088**	**0.077**	**0.051**
	60	56.119	19.9	578	0.436	0.272	0.196	0.153	0.126	0.111	0.092	0.080	0.055
		56.128	19.7	577	0.421	0.269	0.198	0.155	0.129	0.112	0.094	0.082	0.054
		56.137	20.1	577	0.409	0.274	0.199	0.157	0.127	0.111	0.092	0.079	0.051
		56.146	20.0	581	0.421	0.270	0.199	0.154	0.127	0.110	0.092	0.079	0.051
		56.155	20.1	582	0.429	0.268	0.198	0.157	0.126	0.110	0.095	0.081	0.053
		56.164	19.9	584	0.435	0.274	0.201	0.158	0.131	0.114	0.094	0.082	0.054
		56.173	20.0	581	0.438	0.279	0.202	0.157	0.128	0.111	0.090	0.077	0.048
		56.182	20.1	580	0.430	0.271	0.197	0.153	0.124	0.107	0.087	0.074	0.047
		56.191	19.9	580	0.437	0.271	0.196	0.150	0.122	0.105	0.085	0.073	0.046
		56.200	19.9	578	0.433	0.279	0.199	0.155	0.126	0.108	0.090	0.076	0.048
			Average	**580**	**0.429**	**0.273**	**0.199**	**0.155**	**0.127**	**0.110**	**0.091**	**0.078**	**0.051**

Table B 20: Section 12 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	29	56.119	19.2	705	0.539	0.327	0.225	0.172	0.140	0.120	0.102	0.091	0.063
		56.128	19.6	715	0.546	0.333	0.229	0.176	0.143	0.123	0.105	0.093	0.063
		56.137	19.6	713	0.538	0.336	0.233	0.172	0.138	0.119	0.101	0.088	0.060
		56.146	18.8	709	0.539	0.337	0.230	0.169	0.135	0.118	0.099	0.087	0.060
		56.155	19.4	706	0.518	0.327	0.228	0.172	0.138	0.120	0.101	0.090	0.059
		56.164	19.3	709	0.537	0.335	0.232	0.172	0.140	0.120	0.102	0.090	0.061
		56.173	18.9	706	0.553	0.345	0.228	0.171	0.136	0.118	0.095	0.083	0.054
		56.182	19.2	709	0.547	0.329	0.225	0.164	0.133	0.114	0.094	0.083	0.054
		56.191	19.5	712	0.559	0.326	0.221	0.163	0.132	0.112	0.093	0.082	0.053
		56.200	19.2	712	0.557	0.338	0.233	0.174	0.139	0.119	0.099	0.085	0.055
			Average	**710**	**0.543**	**0.333**	**0.228**	**0.170**	**0.137**	**0.118**	**0.099**	**0.087**	**0.058**
	43	56.119	22.1	721	0.480	0.313	0.222	0.172	0.142	0.125	0.105	0.093	0.065
		56.128	22.1	725	0.472	0.311	0.221	0.174	0.143	0.126	0.106	0.094	0.065
		56.137	21.8	730	0.478	0.308	0.220	0.173	0.145	0.128	0.107	0.095	0.066
		56.146	22.0	728	0.470	0.306	0.219	0.173	0.145	0.128	0.108	0.095	0.066
		56.155	21.9	715	0.459	0.308	0.216	0.168	0.140	0.123	0.103	0.091	0.061
		56.164	21.8	729	0.460	0.310	0.220	0.171	0.143	0.125	0.106	0.093	0.063
		56.173	21.7	722	0.502	0.295	0.215	0.169	0.142	0.125	0.106	0.093	0.062
		55.182	21.8	730	0.500	0.295	0.216	0.170	0.144	0.126	0.107	0.094	0.064
		55.191	21.7	714	0.455	0.305	0.220	0.173	0.143	0.125	0.105	0.091	0.061
		56.200	21.5	730	0.455	0.307	0.222	0.176	0.145	0.128	0.107	0.093	0.062
			Average	**724**	**0.473**	**0.306**	**0.219**	**0.172**	**0.143**	**0.126**	**0.106**	**0.093**	**0.064**
	60	56.119	20.5	703	0.492	0.311	0.229	0.180	0.150	0.131	0.109	0.095	0.065
		56.128	20.4	701	0.490	0.318	0.234	0.181	0.151	0.131	0.110	0.098	0.065
		56.137	20.4	708	0.490	0.318	0.234	0.183	0.152	0.131	0.110	0.095	0.063
		56.146	20.4	703	0.489	0.316	0.230	0.181	0.148	0.129	0.106	0.092	0.062
		56.155	20.3	706	0.472	0.328	0.236	0.186	0.152	0.133	0.110	0.095	0.063
		56.164	20.4	702	0.503	0.325	0.238	0.185	0.153	0.133	0.111	0.096	0.064
		56.173	20.4	703	0.488	0.322	0.237	0.188	0.151	0.131	0.108	0.092	0.059
		56.182	20.4	707	0.495	0.323	0.229	0.181	0.151	0.127	0.104	0.087	0.056
		56.191	20.4	705	0.482	0.313	0.226	0.174	0.143	0.124	0.100	0.086	0.054
		56.200	20.3	703	0.508	0.331	0.240	0.185	0.152	0.131	0.107	0.091	0.058
			Average	**704**	**0.491**	**0.320**	**0.233**	**0.182**	**0.150**	**0.130**	**0.108**	**0.093**	**0.061**

Figure B 19: Section 12 measured deflections at a nominal applied stress of 566 kPa

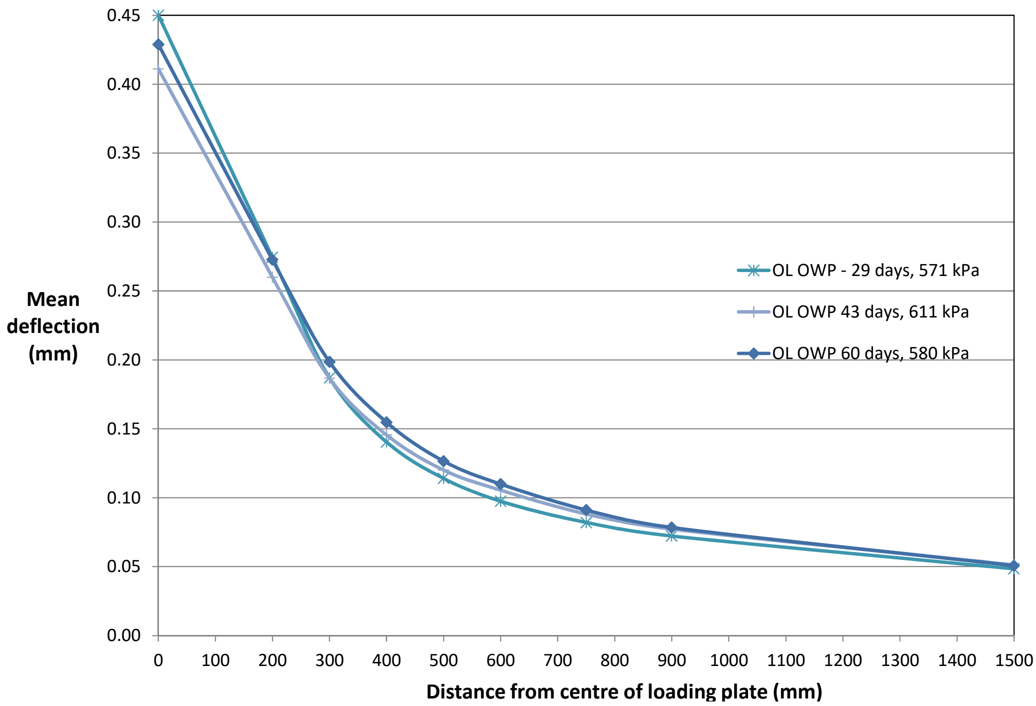
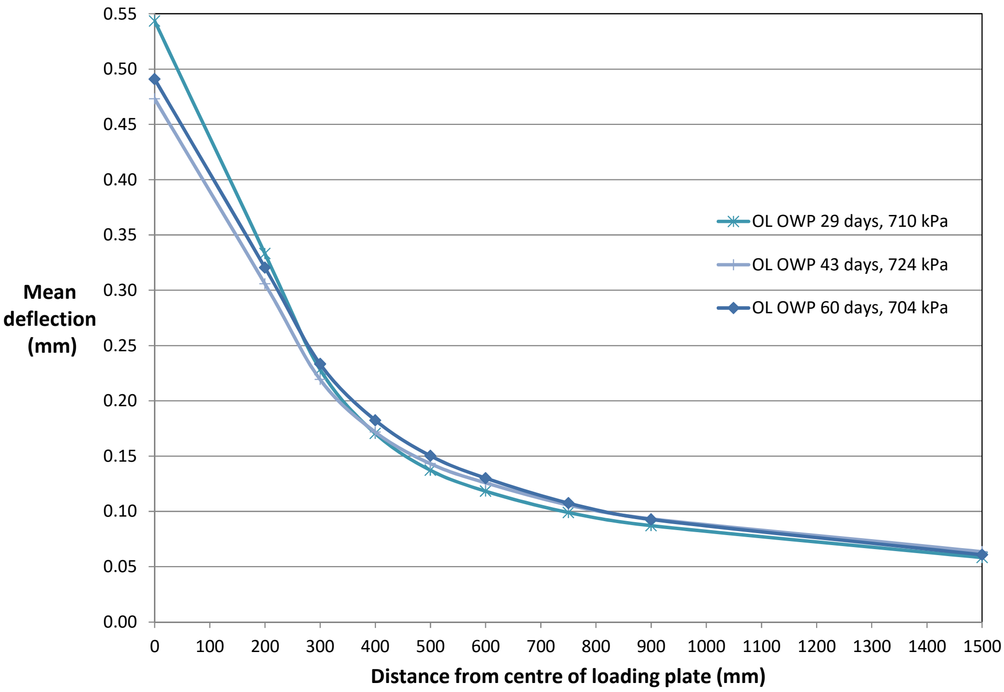


Figure B 20: Section 12 measured deflections at a nominal stress of 700 kPa



B.11 Section 13 – Crushed Recycled Concrete Base

Table B 21: Section 13 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	33	56.219	19.5	568	0.425	0.239	0.162	0.122	0.099	0.084	0.069	0.060	0.038
		56.228	19.2	565	0.437	0.234	0.159	0.122	0.099	0.086	0.073	0.064	0.042
		56.237	18.9	573	0.463	0.257	0.162	0.122	0.098	0.085	0.077	0.062	0.045
		56.246	19.3	577	0.399	0.254	0.165	0.125	0.102	0.089	0.076	0.067	0.046
		56.255	19.5	575	0.450	0.250	0.168	0.128	0.107	0.094	0.080	0.071	0.048
		56.264	19.4	572	0.434	0.249	0.167	0.133	0.103	0.088	0.074	0.067	0.046
		56.273	19.7	572	0.456	0.253	0.167	0.128	0.105	0.091	0.077	0.067	0.044
		56.282	19.7	576	0.449	0.274	0.175	0.131	0.104	0.088	0.073	0.062	0.041
		56.291	19.4	573	0.444	0.258	0.167	0.128	0.104	0.089	0.074	0.063	0.046
		56.300	19.2	568	0.488	0.287	0.182	0.133	0.105	0.089	0.073	0.063	0.041
			Average	**572**	**0.444**	**0.255**	**0.167**	**0.127**	**0.103**	**0.088**	**0.075**	**0.065**	**0.044**
	47	56.219	15.7	611	0.359	0.210	0.157	0.127	0.106	0.094	0.079	0.069	0.044
		56.228	15.7	610	0.408	0.219	0.155	0.123	0.102	0.090	0.075	0.065	0.042
		56.237	15.8	610	0.408	0.229	0.162	0.128	0.106	0.094	0.079	0.068	0.044
		56.246	16.2	610	0.398	0.240	0.166	0.131	0.110	0.097	0.083	0.076	0.049
		56.255	16.0	613	0.383	0.215	0.159	0.129	0.109	0.097	0.083	0.073	0.049
		56.264	16.0	613	0.381	0.233	0.165	0.129	0.109	0.096	0.082	0.071	0.048
		56.273	15.9	613	0.382	0.231	0.159	0.125	0.105	0.092	0.077	0.067	0.045
		56.282	15.9	615	0.393	0.239	0.169	0.132	0.109	0.096	0.080	0.069	0.044
		56.291	15.9	614	0.408	0.261	0.188	0.149	0.124	0.109	0.090	0.077	0.046
		56.300	15.9	613	0.404	0.245	0.170	0.133	0.109	0.095	0.078	0.067	0.043
			Average	**612**	**0.392**	**0.232**	**0.165**	**0.131**	**0.109**	**0.096**	**0.080**	**0.070**	**0.045**
	64	56.219	19.4	578	0.395	0.242	0.173	0.134	0.111	0.096	0.079	0.068	0.041
		56.228	19.3	580	0.379	0.232	0.169	0.134	0.113	0.100	0.083	0.072	0.045
		56.237	19.2	582	0.410	0.237	0.168	0.132	0.110	0.097	0.082	0.071	0.045
		56.246	19.2	582	0.371	0.226	0.164	0.131	0.111	0.097	0.082	0.072	0.048
		56.255	19.4	580	0.397	0.248	0.172	0.136	0.115	0.101	0.085	0.074	0.048
		56.264	19.5	582	0.389	0.230	0.166	0.132	0.112	0.101	0.083	0.072	0.047
		56.273	19.5	581	0.392	0.240	0.170	0.138	0.117	0.103	0.086	0.074	0.046
		56.282	19.6	584	0.406	0.253	0.178	0.139	0.116	0.100	0.081	0.069	0.042
		56.291	19.6	585	0.396	0.246	0.176	0.140	0.117	0.101	0.083	0.070	0.042
		56.300	19.4	586	0.436	0.264	0.183	0.139	0.115	0.099	0.082	0.069	0.042
			Average	**582**	**0.397**	**0.242**	**0.172**	**0.136**	**0.114**	**0.099**	**0.083**	**0.071**	**0.045**

Table B 22: Section 13 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	33	56.219	18.9	707	0.523	0.301	0.202	0.156	0.127	0.109	0.089	0.076	0.049
		56.228	19.0	705	0.484	0.288	0.194	0.152	0.126	0.109	0.092	0.080	0.053
		56.237	19.2	706	0.527	0.303	0.201	0.154	0.128	0.111	0.092	0.080	0.053
		56.246	19.3	709	0.473	0.296	0.202	0.158	0.130	0.113	0.099	0.086	0.058
		56.255	19.0	711	0.476	0.284	0.197	0.157	0.133	0.117	0.099	0.088	0.059
		56.264	18.6	706	0.490	0.289	0.197	0.153	0.128	0.112	0.094	0.083	0.056
		56.273	18.5	719	0.524	0.308	0.205	0.162	0.135	0.117	0.098	0.087	0.056
		56.282	18.8	714	0.526	0.317	0.216	0.162	0.132	0.113	0.093	0.080	0.049
		56.291	18.7	717	0.516	0.306	0.211	0.161	0.132	0.111	0.090	0.080	0.049
		56.300	18.7	715	0.591	0.334	0.222	0.162	0.128	0.108	0.088	0.077	0.049
			Average	**711**	**0.513**	**0.303**	**0.205**	**0.158**	**0.130**	**0.112**	**0.094**	**0.081**	**0.053**
	47	56.219	19.4	711	0.373	0.240	0.180	0.146	0.124	0.109	0.092	0.079	0.051
		55.228	19.7	722	0.379	0.245	0.184	0.147	0.125	0.110	0.094	0.080	0.051
		56.237	19.7	702	0.444	0.262	0.185	0.145	0.119	0.104	0.087	0.075	0.049
		56.246	19.8	714	0.446	0.265	0.188	0.148	0.122	0.106	0.089	0.076	0.050
		56.255	20.1	723	0.463	0.284	0.189	0.150	0.124	0.109	0.091	0.078	0.051
		56.264	20.0	739	0.471	0.290	0.194	0.153	0.127	0.111	0.093	0.080	0.052
		56.273	19.9	726	0.465	0.272	0.190	0.150	0.127	0.112	0.095	0.084	0.057
		56.282	19.8	741	0.471	0.276	0.193	0.154	0.130	0.115	0.097	0.085	0.058
		56.291	19.7	723	0.417	0.264	0.187	0.150	0.127	0.113	0.097	0.085	0.059
		56.300	19.6	741	0.428	0.269	0.191	0.154	0.130	0.116	0.099	0.087	0.059
			Average	**724**	**0.436**	**0.267**	**0.188**	**0.150**	**0.125**	**0.111**	**0.093**	**0.081**	**0.054**
	64	56.219	19.9	700	0.444	0.280	0.201	0.159	0.132	0.115	0.095	0.081	0.051
		56.228	19.7	710	0.437	0.263	0.194	0.156	0.133	0.116	0.099	0.085	0.054
		56.237	19.8	705	0.475	0.280	0.203	0.158	0.132	0.116	0.097	0.084	0.054
		56.246	19.9	705	0.453	0.274	0.198	0.159	0.132	0.116	0.098	0.085	0.057
		56.255	20.0	699	0.464	0.282	0.201	0.164	0.139	0.122	0.103	0.090	0.059
		56.264	20.2	703	0.458	0.273	0.200	0.162	0.136	0.119	0.100	0.087	0.057
		56.273	20.1	710	0.450	0.292	0.209	0.166	0.141	0.126	0.105	0.091	0.058
		56.282	20.0	711	0.480	0.301	0.210	0.167	0.139	0.121	0.098	0.084	0.051
		56.291	19.8	707	0.463	0.290	0.208	0.166	0.139	0.121	0.099	0.084	0.052
		56.300	19.8	712	0.523	0.313	0.219	0.170	0.140	0.122	0.099	0.084	0.050
			Average	**706**	**0.465**	**0.285**	**0.204**	**0.163**	**0.136**	**0.119**	**0.099**	**0.085**	**0.054**

Figure B 21: Section 13 measured deflections at a nominal applied stress of 566 kPa

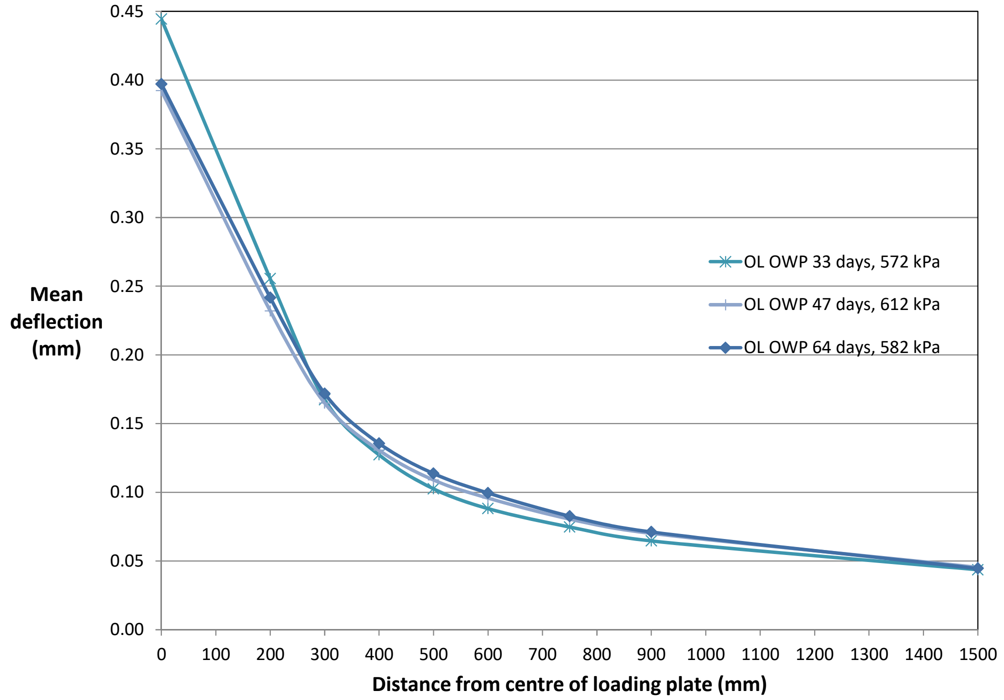
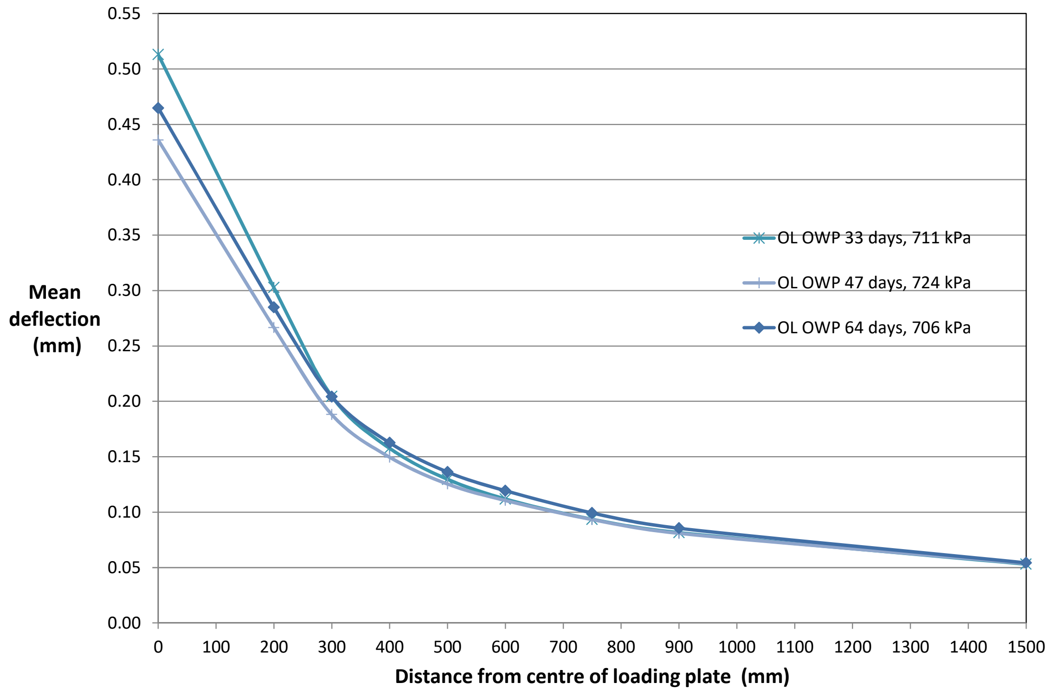


Figure B 22: Section 13 measured deflections at a nominal stress of 700 kPa



B.12 Section 14 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Table B 23: Section 14 measured FWD deflections at a nominal stress of 566 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	42	56.319	19.2	573	0.346	0.206	0.149	0.113	0.094	0.082	0.069	0.060	0.038
		56.328	19.2	573	0.359	0.196	0.133	0.104	0.088	0.076	0.064	0.055	0.037
		56.337	19.2	575	0.341	0.190	0.129	0.101	0.084	0.073	0.061	0.052	0.035
		56.346	19.1	578	0.313	0.183	0.127	0.100	0.084	0.074	0.062	0.054	0.035
		56.355	19.0	576	0.308	0.193	0.137	0.112	0.096	0.085	0.072	0.063	0.041
		56.364	19.1	577	0.366	0.195	0.133	0.105	0.088	0.076	0.064	0.054	0.035
		56.373	19.0	569	0.366	0.201	0.125	0.098	0.082	0.071	0.059	0.051	0.033
		56.382	18.9	572	0.396	0.194	0.129	0.099	0.083	0.072	0.061	0.052	0.034
		56.391	18.9	573	0.349	0.184	0.127	0.100	0.083	0.073	0.060	0.053	0.035
		56.400	19.0	569	0.371	0.201	0.129	0.100	0.091	0.075	0.063	0.055	0.036
			Average	**574**	**0.351**	**0.194**	**0.132**	**0.103**	**0.087**	**0.076**	**0.063**	**0.055**	**0.036**
	56	56.319	15.5	617	0.365	0.215	0.151	0.121	0.102	0.090	0.075	0.065	0.040
		56.328	15.5	615	0.335	0.205	0.143	0.112	0.095	0.083	0.070	0.060	0.038
		56.337	15.7	619	0.298	0.178	0.130	0.106	0.089	0.079	0.064	0.056	0.036
		56.346	15.5	614	0.319	0.186	0.129	0.103	0.088	0.079	0.066	0.056	0.037
		56.355	15.5	611	0.337	0.191	0.133	0.108	0.092	0.082	0.069	0.060	0.040
		56.364	15.4	612	0.338	0.209	0.144	0.112	0.100	0.082	0.069	0.059	0.039
		56.373	15.5	609	0.361	0.216	0.141	0.107	0.090	0.078	0.066	0.057	0.037
		56.382	15.7	614	0.402	0.201	0.141	0.111	0.092	0.080	0.067	0.057	0.038
		56.391	15.7	616	0.365	0.205	0.140	0.112	0.095	0.084	0.077	0.063	0.043
		56.400	15.9	617	0.378	0.200	0.132	0.105	0.090	0.080	0.068	0.059	0.039
			Average	**614**	**0.350**	**0.201**	**0.138**	**0.110**	**0.093**	**0.082**	**0.069**	**0.059**	**0.039**
	73	56.319	19.3	573	0.381	0.219	0.157	0.126	0.105	0.092	0.076	0.065	0.040
		56.328	19.2	579	0.368	0.206	0.145	0.116	0.096	0.083	0.069	0.059	0.038
		56.337	19.1	581	0.344	0.191	0.138	0.110	0.091	0.079	0.065	0.056	0.035
		56.346	19.1	580	0.383	0.201	0.137	0.108	0.091	0.080	0.067	0.057	0.037
		56.355	19.1	575	0.347	0.199	0.140	0.113	0.095	0.084	0.070	0.061	0.039
		56.364	19.0	579	0.406	0.201	0.144	0.112	0.094	0.082	0.068	0.058	0.036
		56.373	18.8	578	0.372	0.214	0.143	0.112	0.093	0.081	0.067	0.058	0.041
		56.382	19.0	580	0.410	0.237	0.153	0.117	0.096	0.082	0.067	0.057	0.036
		56.391	19.3	583	0.344	0.225	0.147	0.117	0.097	0.085	0.071	0.062	0.041
		56.400	19.4	586	0.381	0.203	0.138	0.110	0.093	0.083	0.069	0.061	0.039
			Average	**579**	**0.374**	**0.210**	**0.144**	**0.114**	**0.095**	**0.083**	**0.069**	**0.059**	**0.038**

Table B 24: Section 14 measured FWD deflections at a nominal stress of 700 kPa

Location	Age	Station	Surface temp.	Contact stress	Deflection (mm) at various distances from loading plate								
	Days	(km)	(°C)	(kPa)	0 mm	200 mm	300 mm	400 mm	500 mm	600 mm	750 mm	900 mm	1500 mm
Outer lane, outer wheel path	42	56.319	18.5	702	0.485	0.251	0.174	0.140	0.116	0.104	0.086	0.076	0.047
		56.328	18.5	713	0.440	0.237	0.165	0.130	0.109	0.094	0.080	0.070	0.053
		56.337	18.7	721	0.403	0.221	0.155	0.126	0.104	0.091	0.076	0.065	0.042
		56.346	18.9	709	0.393	0.227	0.156	0.122	0.104	0.089	0.075	0.065	0.043
		56.355	18.9	716	0.404	0.235	0.163	0.132	0.112	0.100	0.085	0.075	0.048
		56.364	18.6	709	0.404	0.242	0.163	0.130	0.110	0.095	0.080	0.068	0.045
		56.373	18.8	702	0.417	0.226	0.152	0.119	0.100	0.087	0.074	0.063	0.043
		56.382	19.0	715	0.403	0.226	0.161	0.125	0.106	0.092	0.077	0.066	0.043
		56.391	19.0	717	0.429	0.230	0.156	0.124	0.106	0.092	0.077	0.068	0.045
		56.400	19.2	708	0.438	0.216	0.150	0.118	0.102	0.091	0.078	0.069	0.045
			Average	**711**	**0.422**	**0.231**	**0.160**	**0.127**	**0.107**	**0.093**	**0.079**	**0.068**	**0.045**
	56	56.319	19.5	713	0.449	0.247	0.174	0.139	0.118	0.103	0.087	0.074	0.047
		56.328	19.6	730	0.454	0.249	0.175	0.141	0.120	0.105	0.088	0.076	0.047
		56.337	19.4	717	0.392	0.236	0.168	0.134	0.113	0.099	0.083	0.072	0.046
		56.346	19.4	718	0.391	0.237	0.168	0.135	0.113	0.100	0.083	0.072	0.046
		56.355	19.4	740	0.394	0.248	0.162	0.130	0.108	0.095	0.082	0.072	0.044
		56.364	19.4	741	0.391	0.247	0.162	0.129	0.108	0.095	0.081	0.070	0.044
		56.373	19.6	744	0.386	0.223	0.156	0.126	0.106	0.094	0.081	0.067	0.043
		56.382	19.7	744	0.384	0.222	0.157	0.127	0.107	0.094	0.081	0.067	0.043
		56.391	19.8	742	0.394	0.228	0.157	0.125	0.106	0.092	0.078	0.068	0.045
		56.400	19.7	741	0.396	0.227	0.156	0.125	0.106	0.092	0.078	0.068	0.045
			Average	**733**	**0.403**	**0.236**	**0.163**	**0.131**	**0.110**	**0.097**	**0.082**	**0.071**	**0.045**
	73	56.319	19.8	697	0.468	0.258	0.184	0.148	0.125	0.110	0.092	0.079	0.049
		56.328	19.8	707	0.448	0.242	0.173	0.140	0.118	0.102	0.085	0.074	0.046
		56.337	19.9	706	0.401	0.235	0.166	0.134	0.111	0.097	0.080	0.069	0.043
		56.346	19.8	703	0.412	0.230	0.162	0.131	0.109	0.095	0.080	0.069	0.044
		56.355	19.9	706	0.397	0.238	0.167	0.135	0.114	0.101	0.086	0.075	0.048
		56.364	19.9	703	0.431	0.248	0.177	0.141	0.116	0.101	0.084	0.072	0.046
		56.373	19.7	704	0.450	0.254	0.174	0.135	0.113	0.099	0.082	0.070	0.046
		56.382	19.6	705	0.486	0.280	0.182	0.142	0.116	0.100	0.081	0.074	0.045
		56.391	19.9	699	0.443	0.254	0.176	0.136	0.113	0.100	0.084	0.072	0.049
		56.400	19.9	708	0.463	0.249	0.167	0.132	0.111	0.099	0.084	0.074	0.048
			Average	**704**	**0.440**	**0.249**	**0.173**	**0.137**	**0.115**	**0.100**	**0.084**	**0.073**	**0.046**

Figure B 23: Section 14 measured deflections at a nominal applied stress of 566 kPa

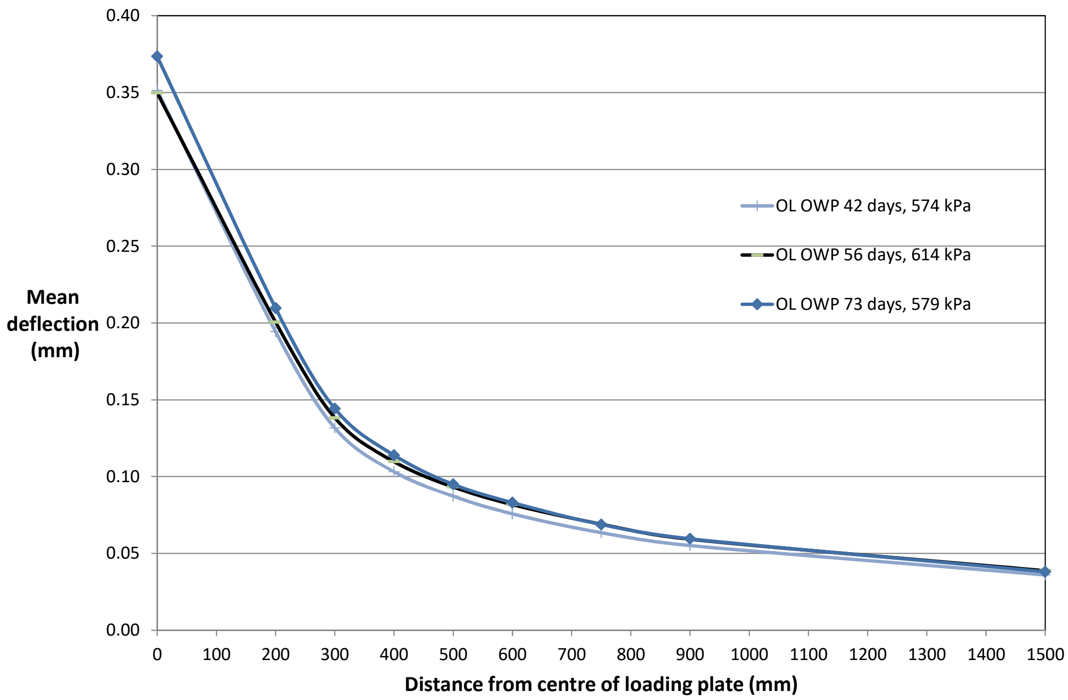
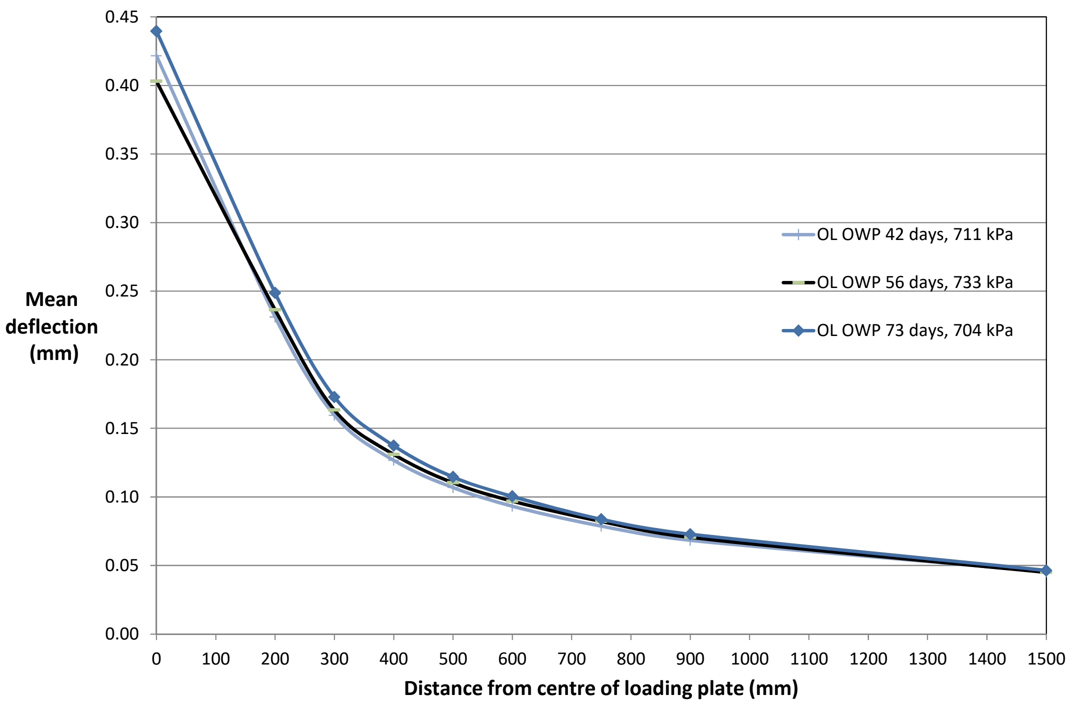


Figure B 24: Section 14 measured deflections at a nominal stress of 700 kPa



APPENDIX C RESILIENT MODULUS RESULTS

C.1 Base Materials

C.1.1 Stress stages

Table C 1 lists the stress stages used in repeat load triaxial modulus testing of the base materials.

Table C 1: Stress stages used in the base modulus tests

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (°)
1	375	25	0.067	383	0.0652	0.0323	1.8
2	325	25	0.077	333	0.0750	0.0370	2.1
3	275	25	0.091	283	0.0882	0.0435	2.5
4	225	25	0.111	233	0.1071	0.0526	3.0
5	400	50	0.125	417	0.1200	0.0588	3.4
6	175	25	0.143	183	0.1364	0.0667	3.8
7	350	50	0.143	367	0.1364	0.0667	3.8
8	300	50	0.167	317	0.1579	0.0769	4.4
9	50	10	0.200	53	0.1875	0.0909	5.2
10	125	25	0.200	133	0.1875	0.0909	5.2
11	250	50	0.200	267	0.1875	0.0909	5.2
12	375	75	0.200	400	0.1875	0.0909	5.2
13	325	75	0.231	350	0.2143	0.1034	5.9
14	40	10	0.250	43	0.2308	0.1111	6.4
15	200	50	0.250	217	0.2308	0.1111	6.4
16	400	100	0.250	433	0.2308	0.1111	6.4
17	275	75	0.273	300	0.2500	0.1200	6.9
18	350	100	0.286	383	0.2609	0.1250	7.2
19	30	10	0.333	33	0.3000	0.1429	8.2
20	75	25	0.333	83	0.3000	0.1429	8.2
21	150	50	0.333	167	0.3000	0.1429	8.2
22	225	75	0.333	250	0.3000	0.1429	8.2
23	300	100	0.333	333	0.3000	0.1429	8.2
24	375	125	0.333	417	0.3000	0.1429	8.2
25	400	150	0.375	450	0.3333	0.1579	9.1
26	325	125	0.385	367	0.3409	0.1613	9.3
27	250	100	0.400	283	0.3529	0.1667	9.6
28	175	75	0.429	200	0.3750	0.1765	10.2
29	350	150	0.429	400	0.3750	0.1765	10.2
30	275	125	0.455	317	0.3947	0.1852	10.7
31	375	175	0.467	433	0.4038	0.1892	10.9
32	20	10	0.500	23	0.4286	0.2000	11.5
33	100	50	0.500	117	0.4286	0.2000	11.5
34	200	100	0.500	233	0.4286	0.2000	11.5
35	300	150	0.500	350	0.4286	0.2000	11.5
36	400	200	0.500	467	0.4286	0.2000	11.5
37	325	175	0.538	383	0.4565	0.2121	12.2
38	225	125	0.556	267	0.4688	0.2174	12.6

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (°)
39	350	200	0.571	417	0.4800	0.2222	12.8
40	50	30	0.600	60	0.5000	0.2308	13.3
41	125	75	0.600	150	0.5000	0.2308	13.3
42	250	150	0.600	300	0.5000	0.2308	13.3
43	375	225	0.600	450	0.5000	0.2308	13.3
44	275	175	0.636	333	0.5250	0.2414	14.0
45	150	100	0.667	183	0.5455	0.2500	14.5
46	300	200	0.667	367	0.5455	0.2500	14.5
47	325	225	0.692	400	0.5625	0.2571	14.9
48	175	125	0.714	217	0.5769	0.2632	15.3
49	350	250	0.714	433	0.5769	0.2632	15.3
50	375	275	0.733	467	0.5893	0.2683	15.6
51	40	30	0.750	50	0.6000	0.2727	15.8
52	200	150	0.750	250	0.6000	0.2727	15.8
53	225	175	0.778	283	0.6176	0.2800	16.3
54	50	40	0.800	63	0.6316	0.2857	16.6
55	80	64	0.800	101	0.6316	0.2857	16.6
56	100	80	0.800	127	0.6316	0.2857	16.6
57	150	120	0.800	190	0.6316	0.2857	16.6
58	175	140	0.800	222	0.6316	0.2857	16.6
59	250	200	0.800	317	0.6316	0.2857	16.6
60	50	40	0.800	63	0.6316	0.2857	16.6
61	275	225	0.818	350	0.6429	0.2903	16.9
62	300	250	0.833	383	0.6522	0.2941	17.1
63	325	275	0.846	417	0.6600	0.2973	17.3
64	350	300	0.857	450	0.6667	0.3000	17.5
65	10	10	1.000	13	0.7500	0.3333	19.5
66	30	30	1.000	40	0.7500	0.3333	19.5
67	50	50	1.000	67	0.7500	0.3333	19.5
68	75	75	1.000	100	0.7500	0.3333	19.5
69	80	80	1.000	107	0.7500	0.3333	19.5
70	100	100	1.000	133	0.7500	0.3333	19.5
71	125	125	1.000	167	0.7500	0.3333	19.5
72	140	140	1.000	187	0.7500	0.3333	19.5
73	150	150	1.000	200	0.7500	0.3333	19.5
74	175	175	1.000	233	0.7500	0.3333	19.5
75	200	200	1.000	267	0.7500	0.3333	19.5
76	225	225	1.000	300	0.7500	0.3333	19.5

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (°)
77	250	250	1.000	333	0.7500	0.3333	19.5
78	275	275	1.000	367	0.7500	0.3333	19.5
79	300	300	1.000	400	0.7500	0.3333	19.5
80	325	325	1.000	433	0.7500	0.3333	19.5
81	50	50	1.000	67	0.7500	0.3333	19.5
82	300	350	1.167	417	0.8400	0.3684	21.6
83	275	325	1.182	383	0.8478	0.3714	21.8
84	250	300	1.200	350	0.8571	0.3750	22.0
85	225	275	1.222	317	0.8684	0.3793	22.3
86	40	50	1.250	57	0.8824	0.3846	22.6
87	200	250	1.250	283	0.8824	0.3846	22.6
88	175	225	1.286	250	0.9000	0.3913	23.0
89	150	200	1.333	217	0.9231	0.4000	23.6
90	80	108	1.350	116	0.9310	0.4030	23.8
91	100	135	1.350	145	0.9310	0.4030	23.8
92	180	243	1.350	261	0.9310	0.4030	23.8
93	150	203	1.353	218	0.9326	0.4036	23.8
94	50	68	1.360	73	0.9358	0.4048	23.9
95	275	375	1.364	400	0.9375	0.4054	23.9
96	50	70	1.400	73	0.9545	0.4118	24.3
97	125	175	1.400	183	0.9545	0.4118	24.3
98	250	350	1.400	367	0.9545	0.4118	24.3
99	225	325	1.444	333	0.9750	0.4194	24.8
100	20	30	1.500	30	1.0000	0.4286	25.4
101	100	150	1.500	150	1.0000	0.4286	25.4
102	200	300	1.500	300	1.0000	0.4286	25.4
103	175	275	1.571	267	1.0313	0.4400	26.1
104	250	400	1.600	383	1.0435	0.4444	26.4
105	35	57	1.629	54	1.0556	0.4488	26.7
106	75	123	1.640	116	1.0603	0.4505	26.8
107	100	164	1.640	155	1.0603	0.4505	26.8
108	155	254	1.639	240	1.0598	0.4504	26.8
109	180	295	1.639	278	1.0599	0.4504	26.8
110	50	82	1.640	77	1.0603	0.4505	26.8
111	30	50	1.667	47	1.0714	0.4545	27.0
112	75	125	1.667	117	1.0714	0.4545	27.0
113	150	250	1.667	233	1.0714	0.4545	27.0
114	225	375	1.667	350	1.0714	0.4545	27.0

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (°)
115	40	70	1.750	63	1.1053	0.4667	27.8
116	200	350	1.750	317	1.1053	0.4667	27.8
117	50	90	1.800	80	1.1250	0.4737	28.3
118	125	225	1.800	200	1.1250	0.4737	28.3
119	175	325	1.857	283	1.1471	0.4815	28.8
120	225	425	1.889	367	1.1591	0.4857	29.1
121	30	60	2.000	50	1.2000	0.5000	30.0
122	50	100	2.000	83	1.2000	0.5000	30.0
123	75	150	2.000	125	1.2000	0.5000	30.0
124	100	200	2.000	167	1.2000	0.5000	30.0
125	140	280	2.000	233	1.2000	0.5000	30.0
126	150	300	2.000	250	1.2000	0.5000	30.0
127	175	350	2.000	292	1.2000	0.5000	30.0
128	200	400	2.000	333	1.2000	0.5000	30.0
129	50	100	2.000	83	1.2000	0.5000	30.0
130	175	375	2.143	300	1.2500	0.5172	31.1
131	50	110	2.200	87	1.2692	0.5238	31.6
132	125	275	2.200	217	1.2692	0.5238	31.6
133	40	90	2.250	70	1.2857	0.5294	32.0
134	200	450	2.250	350	1.2857	0.5294	32.0
135	30	70	2.333	53	1.3125	0.5385	32.6
136	75	175	2.333	133	1.3125	0.5385	32.6
137	150	350	2.333	267	1.3125	0.5385	32.6
138	175	425	2.429	317	1.3421	0.5484	33.3
139	20	50	2.500	37	1.3636	0.5556	33.7
140	30	75	2.500	55	1.3636	0.5556	33.7
141	50	125	2.500	92	1.3636	0.5556	33.7
142	80	200	2.500	147	1.3636	0.5556	33.7
143	100	250	2.500	183	1.3636	0.5556	33.7
144	150	375	2.500	275	1.3636	0.5556	33.7
145	50	125	2.500	92	1.3636	0.5556	33.7
146	50	130	2.600	93	1.3929	0.5652	34.4
147	125	325	2.600	233	1.3929	0.5652	34.4
148	150	400	2.667	283	1.4118	0.5714	34.8
149	175	475	2.714	333	1.4250	0.5758	35.2
150	40	110	2.750	77	1.4348	0.5789	35.4
151	10	30	3.000	20	1.5000	0.6000	36.9
152	30	90	3.000	60	1.5000	0.6000	36.9

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (º)
153	50	150	3.000	100	1.5000	0.6000	36.9
154	75	225	3.000	150	1.5000	0.6000	36.9
155	80	240	3.000	160	1.5000	0.6000	36.9
156	100	300	3.000	200	1.5000	0.6000	36.9
157	120	360	3.000	240	1.5000	0.6000	36.9
158	125	375	3.000	250	1.5000	0.6000	36.9
159	150	450	3.000	300	1.5000	0.6000	36.9
160	50	150	3.000	100	1.5000	0.6000	36.9
161	40	130	3.250	83	1.5600	0.6190	38.2
162	150	500	3.333	317	1.5789	0.6250	38.7
163	125	425	3.400	267	1.5938	0.6296	39.0
164	20	70	3.500	43	1.6154	0.6364	39.5
165	30	105	3.500	65	1.6154	0.6364	39.5
166	50	175	3.500	108	1.6154	0.6364	39.5
167	75	263	3.507	163	1.6168	0.6368	39.6
168	100	350	3.500	217	1.6154	0.6364	39.5
169	120	420	3.500	260	1.6154	0.6364	39.5
170	50	175	3.500	108	1.6154	0.6364	39.5
171	30	110	3.667	67	1.6500	0.6471	40.3
172	75	275	3.667	167	1.6500	0.6471	40.3
173	40	150	3.750	90	1.6667	0.6522	40.7
174	125	475	3.800	283	1.6765	0.6552	40.9
175	30	120	4.000	70	1.7143	0.6667	41.8
176	50	200	4.000	117	1.7143	0.6667	41.8
177	70	280	4.000	163	1.7143	0.6667	41.8
178	90	360	4.000	210	1.7143	0.6667	41.8
179	100	400	4.000	233	1.7143	0.6667	41.8
180	110	440	4.000	257	1.7143	0.6667	41.8
181	50	200	4.000	117	1.7143	0.6667	41.8
182	125	525	4.200	300	1.7500	0.6774	42.6
183	30	130	4.333	73	1.7727	0.6842	43.2
184	75	325	4.333	183	1.7727	0.6842	43.2
185	20	90	4.500	50	1.8000	0.6923	43.8
186	100	450	4.500	250	1.8000	0.6923	43.8
187	10	50	5.000	27	1.8750	0.7143	45.6
188	30	150	5.000	80	1.8750	0.7143	45.6
189	50	250	5.000	133	1.8750	0.7143	45.6
190	75	375	5.000	200	1.8750	0.7143	45.6

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (°)
191	100	500	5.000	267	1.8750	0.7143	45.6
192	20	110	5.500	57	1.9412	0.7333	47.2
193	30	165	5.500	85	1.9412	0.7333	47.2
194	40	220	5.500	113	1.9412	0.7333	47.2
195	50	275	5.500	142	1.9412	0.7333	47.2
196	60	330	5.500	170	1.9412	0.7333	47.2
197	80	440	5.500	227	1.9412	0.7333	47.2
198	100	550	5.500	283	1.9412	0.7333	47.2
199	75	425	5.667	217	1.9615	0.7391	47.7
200	50	300	6.000	150	2.0000	0.7500	48.6
201	75	475	6.333	233	2.0357	0.7600	49.5
202	20	130	6.500	63	2.0526	0.7647	49.9
203	10	70	7.000	33	2.1000	0.7778	51.1
204	25	175	7.000	83	2.1000	0.7778	51.1
205	30	210	7.000	100	2.1000	0.7778	51.1
206	40	280	7.000	133	2.1000	0.7778	51.1
207	50	350	7.000	167	2.1000	0.7778	51.1
208	70	490	7.000	233	2.1000	0.7778	51.1
209	75	525	7.000	250	2.1000	0.7778	51.1
210	30	210	7.000	100	2.1000	0.7778	51.1
211	20	150	7.500	70	2.1429	0.7895	52.1
212	75	575	7.667	267	2.1563	0.7931	52.5
213	50	400	8.000	183	2.1818	0.8000	53.1
214	10	90	9.000	40	2.2500	0.8182	54.9
215	25	225	9.000	100	2.2500	0.8182	54.9
216	50	450	9.000	200	2.2500	0.8182	54.9
217	1	10	10.000	4	2.3077	0.8333	56.4
218	30	300	10.000	130	2.3077	0.8333	56.4
219	40	400	10.000	173	2.3077	0.8333	56.4
220	50	500	10.000	217	2.3077	0.8333	56.4
221	10	110	11.000	47	2.3571	0.8462	57.8
222	25	275	11.000	117	2.3571	0.8462	57.8
223	50	550	11.000	233	2.3571	0.8462	57.8
224	50	600	12.000	250	2.4000	0.8571	59.0
225	10	130	13.000	53	2.4375	0.8667	60.1
226	25	325	13.000	133	2.4375	0.8667	60.1
227	20	280	14.000	113	2.4706	0.8750	61.0
228	30	420	14.000	170	2.4706	0.8750	61.0

Stress stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean stress p (kPa)	M = q/p	Sinf	f (º)
229	40	560	14.000	227	2.4706	0.8750	61.0
230	10	150	15.000	60	2.5000	0.8824	61.9
231	25	375	15.000	150	2.5000	0.8824	61.9
232	25	425	17.000	167	2.5500	0.8947	63.5
233	20	360	18.000	140	2.5714	0.9000	64.2
234	25	450	18.000	175	2.5714	0.9000	64.2
235	25	475	19.000	183	2.5909	0.9048	64.8
236	25	525	21.000	200	2.6250	0.9130	65.9
237	25	575	23.000	217	2.6538	0.9200	66.9
238	25	625	25.000	233	2.6786	0.9259	67.8
239	1	30	30.000	11	2.7273	0.9375	69.6
240	1	50	50.000	18	2.8302	0.9615	74.1
241	1	70	70.000	24	2.8767	0.9722	76.5
242	1	90	90.000	31	2.9032	0.9783	78.0
243	1	100	100.000	34	2.9126	0.9804	78.6
244	1	110	110.000	38	2.9204	0.9821	79.2
245	1	130	130.000	44	2.9323	0.9848	80.0
246	1	150	150.000	51	2.9412	0.9868	80.7
247	1	200	200.000	68	2.9557	0.9901	81.9
248	1	250	250.000	84	2.9644	0.9921	82.8
249	1	300	300.000	101	2.9703	0.9934	83.4
250	1	350	350.000	118	2.9745	0.9943	83.9
251	1	400	400.000	134	2.9777	0.9950	84.3
252	1	450	450.000	151	2.9801	0.9956	84.6
253	1	500	500.000	168	2.9821	0.9960	84.9
254	1	550	550.000	184	2.9837	0.9964	85.1
255	1	600	600.000	201	2.9851	0.9967	85.3
256	1	650	650.000	218	2.9862	0.9969	85.5

C.1.2 Measured moduli of crushed rock base

Figure C 1: Crushed rock base sample 09M276AB moduli variation with stress

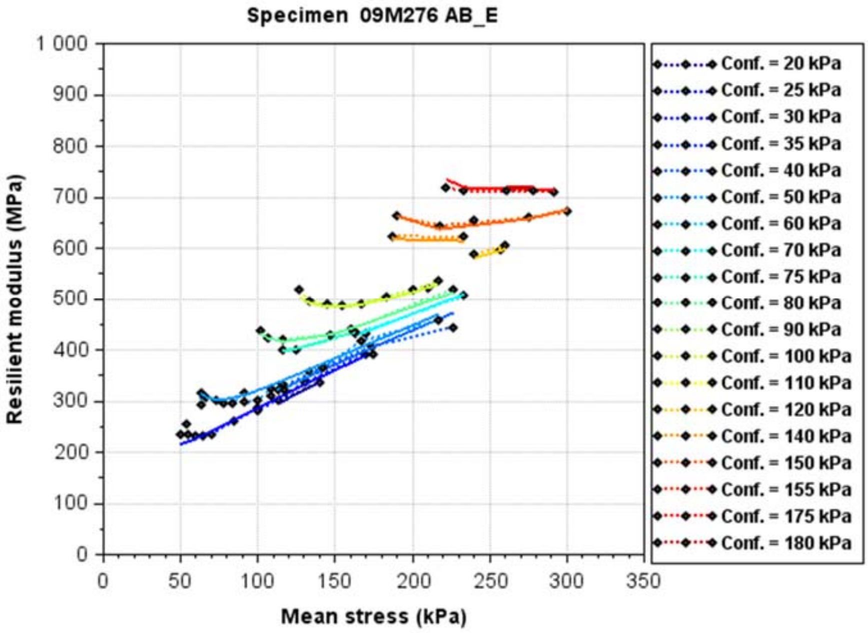


Figure C 2: Crushed rock base sample 09M276AB modulus prediction relationship and fit to the measured data

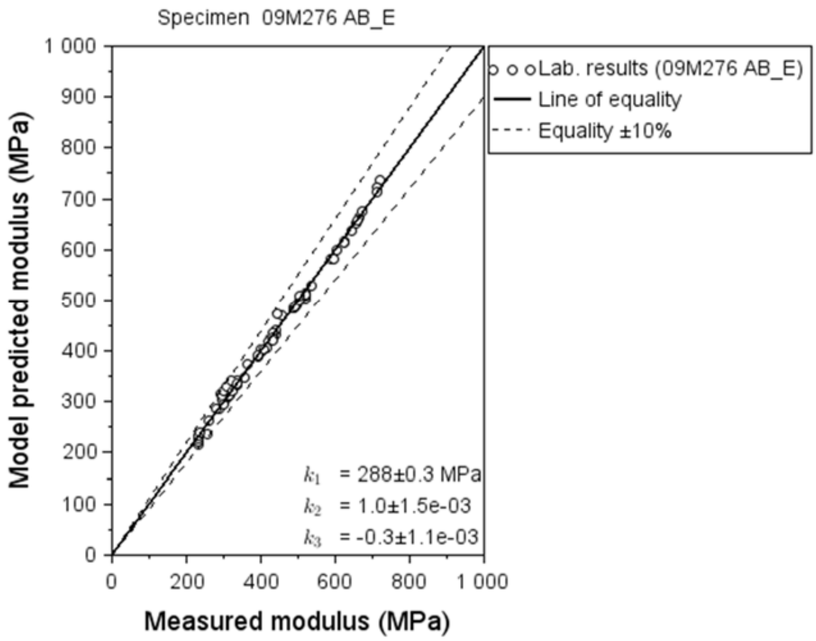


Figure C 3: Crushed rock base sample 09M276AC moduli variation with stress

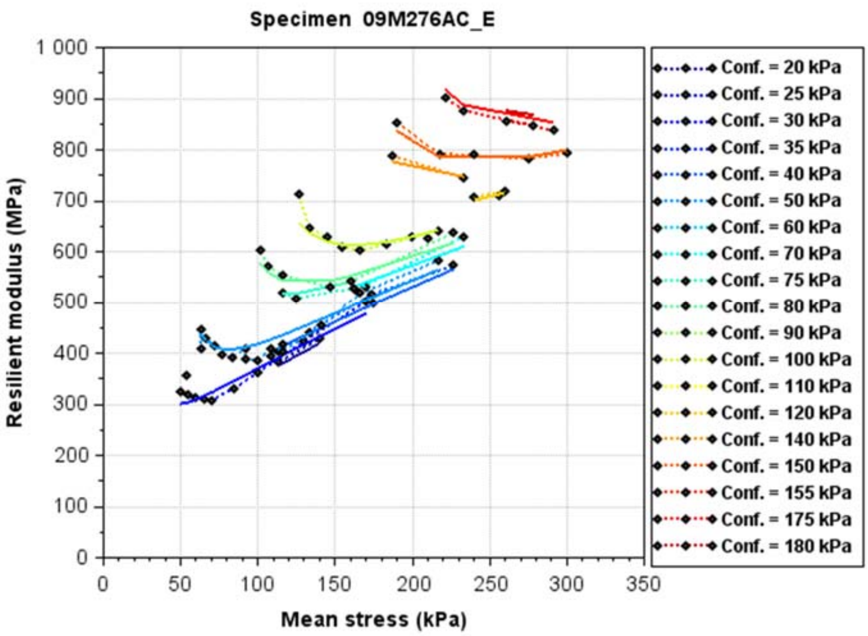


Figure C 4: Crushed rock base sample 09M276AC modulus prediction relationship and fit to the measured data

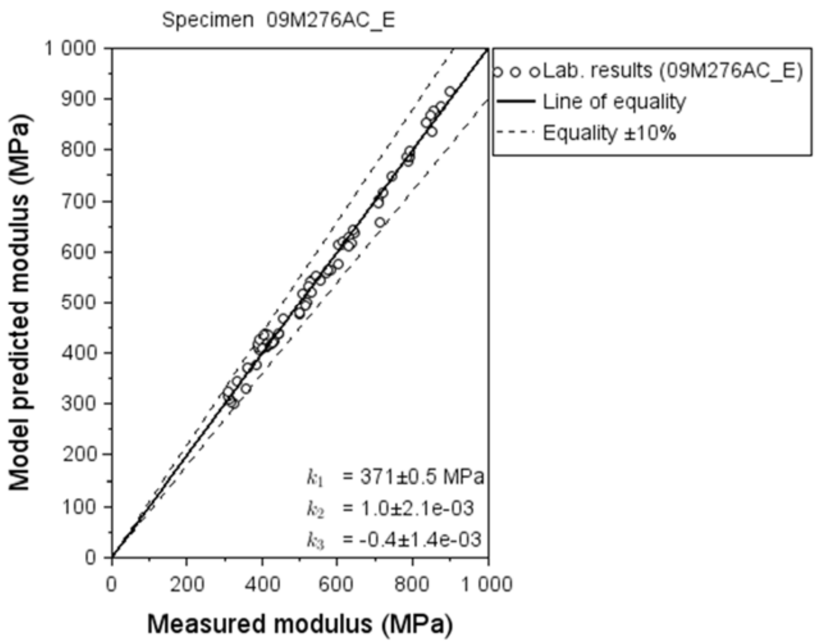


Figure C 5: Crushed rock base sample 09M276AD moduli variation with stress

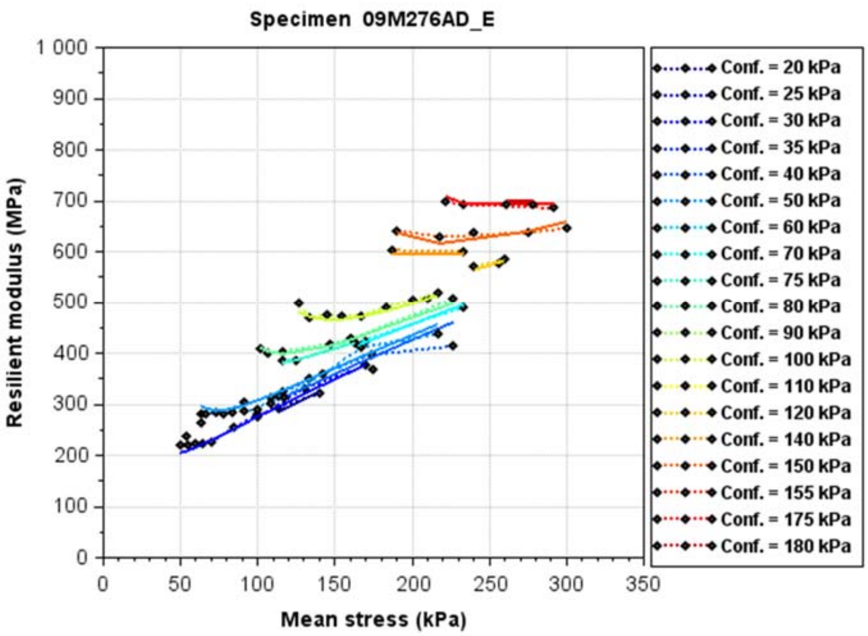


Figure C 6: Crushed rock base sample 09M276AD modulus prediction relationship and fit to the measured data

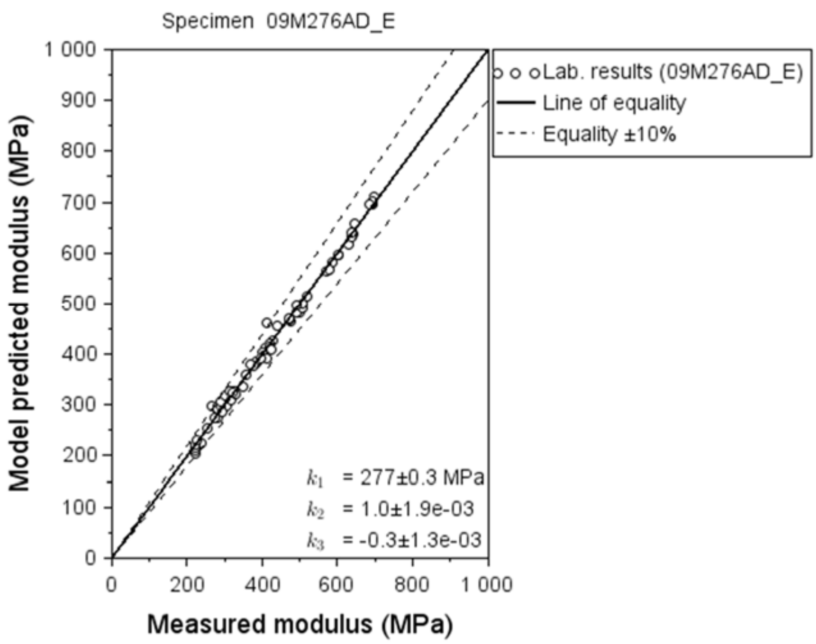


Figure C 7: Crushed rock base sample 09M276AE moduli variation with stress

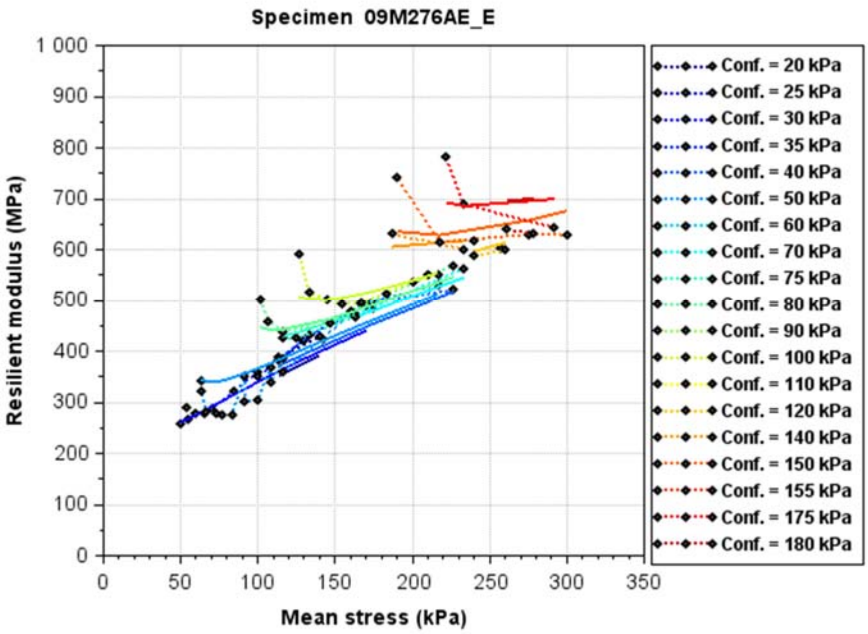


Figure C 8: Crushed rock base sample 09M276AE modulus prediction relationship and fit to the measured data

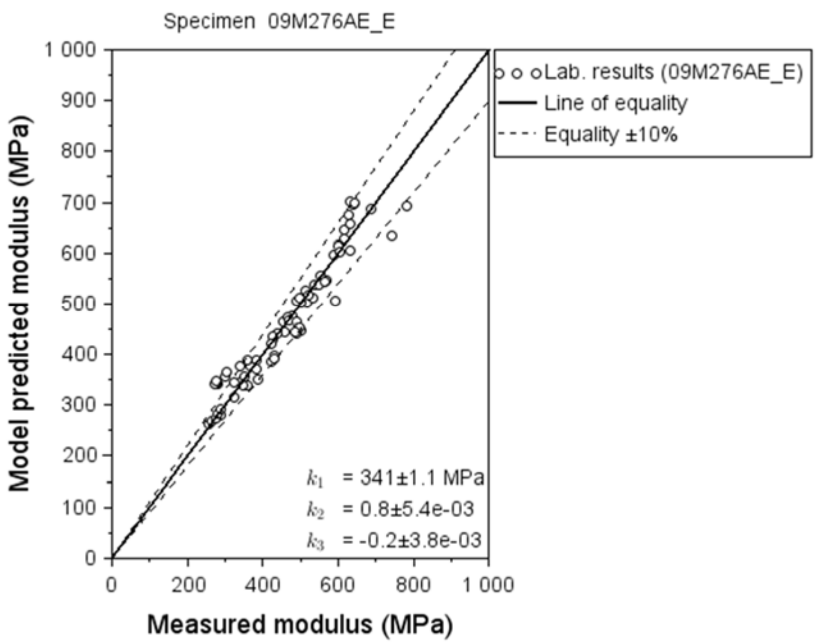


Figure C 9: Crushed rock base sample 09M276AF moduli variation with stress

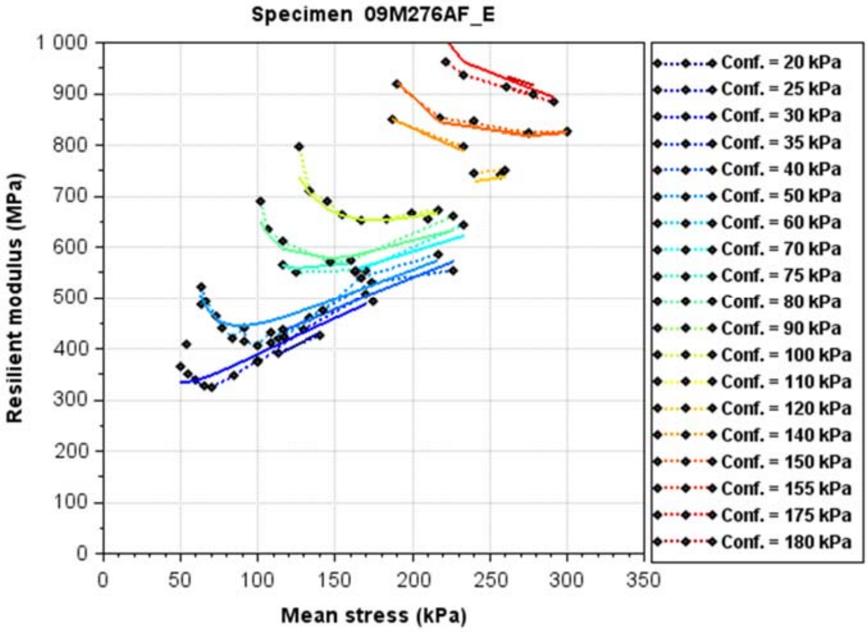
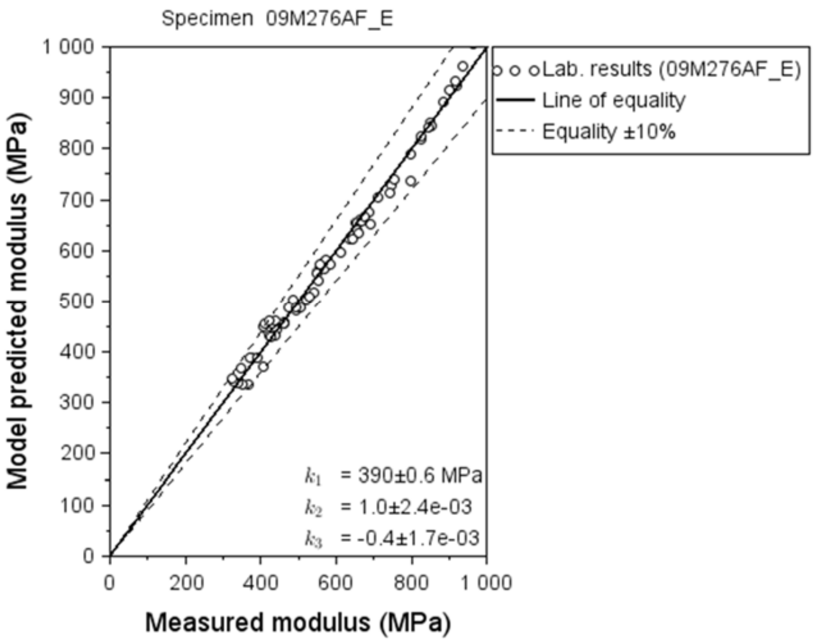


Figure C 10: Crushed rock base sample 09M276AF modulus prediction relationship and fit to the measured data



C.1.3 Measured moduli of ferricrete

Figure C 11: Ferricrete sample 09M283A1 moduli variation with stress

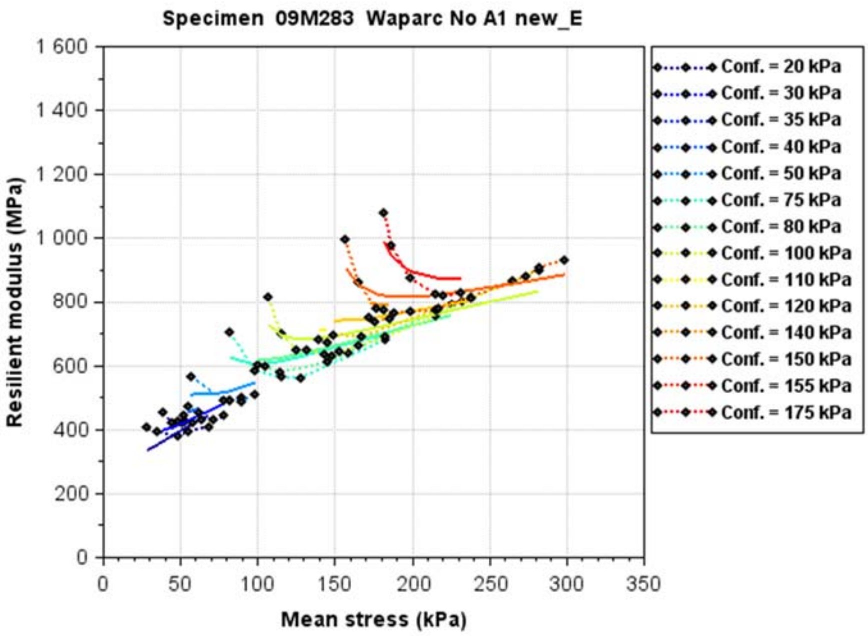


Figure C 12: Ferricrete sample 09M283A1 modulus prediction relationship and fit to the measured data

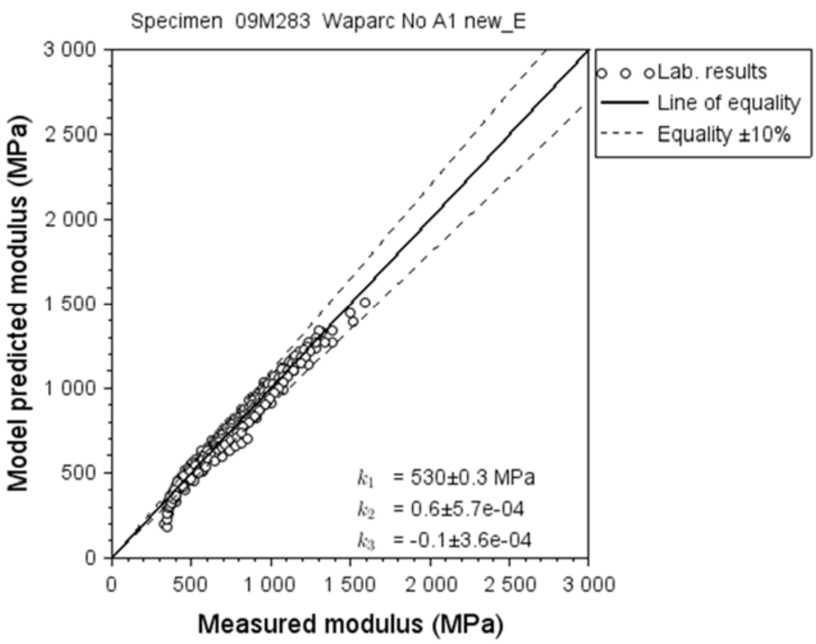


Figure C 13: Ferricrete sample 09M283A3 moduli variation with stress

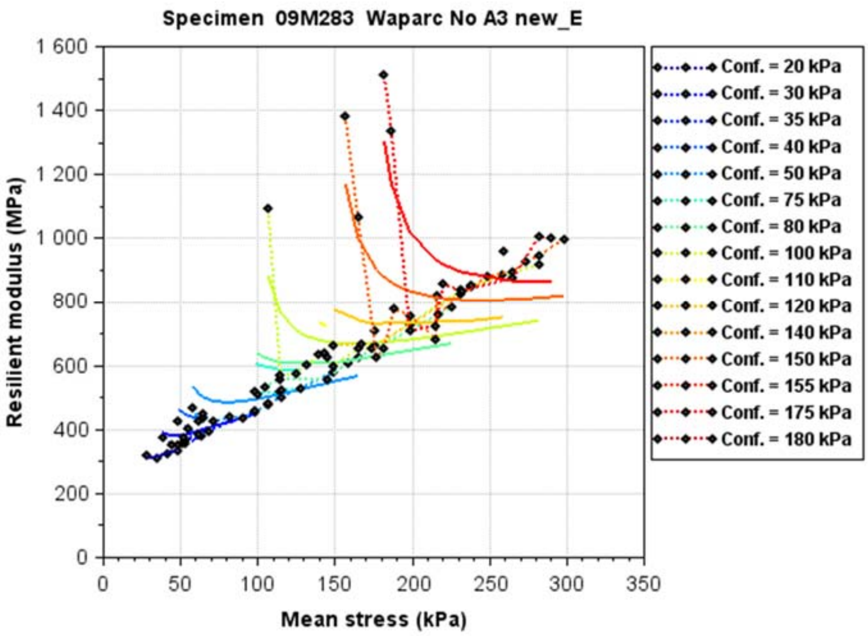


Figure C 14: Ferricrete sample 09M283A3 modulus prediction relationship and fit to the measured data

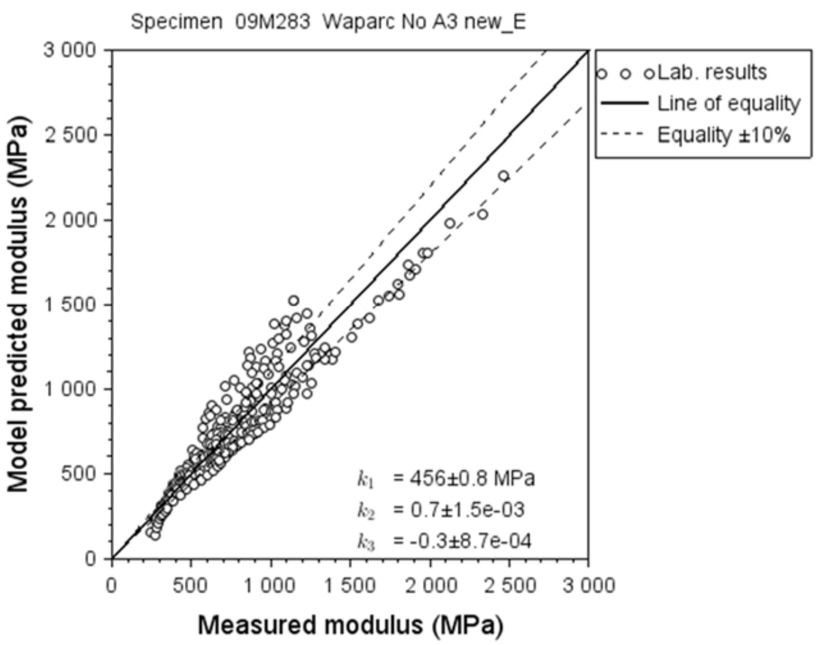


Figure C 15: Ferricrete sample 09M283A5 moduli variation with stress

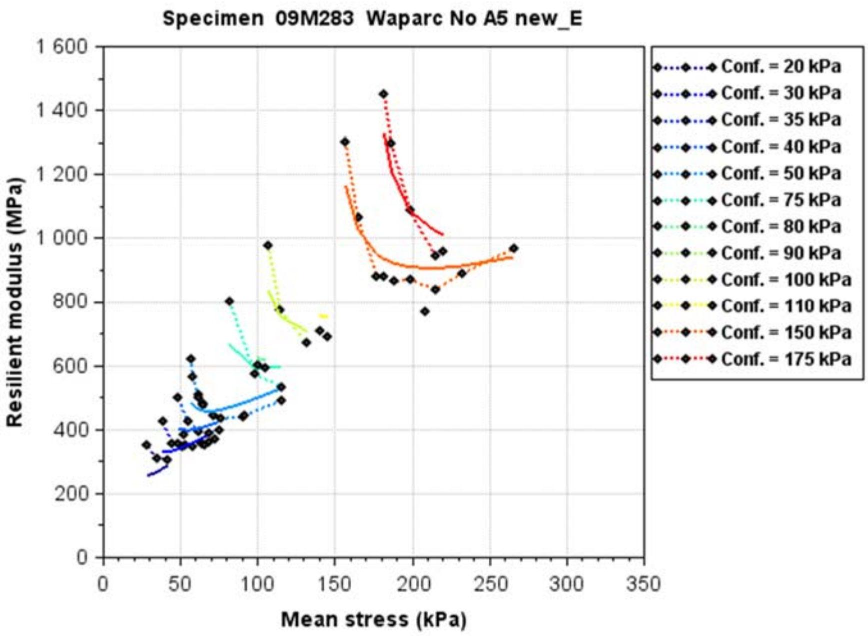


Figure C 16: Ferricrete sample 09M283A5 modulus prediction relationship and fit to the measured data

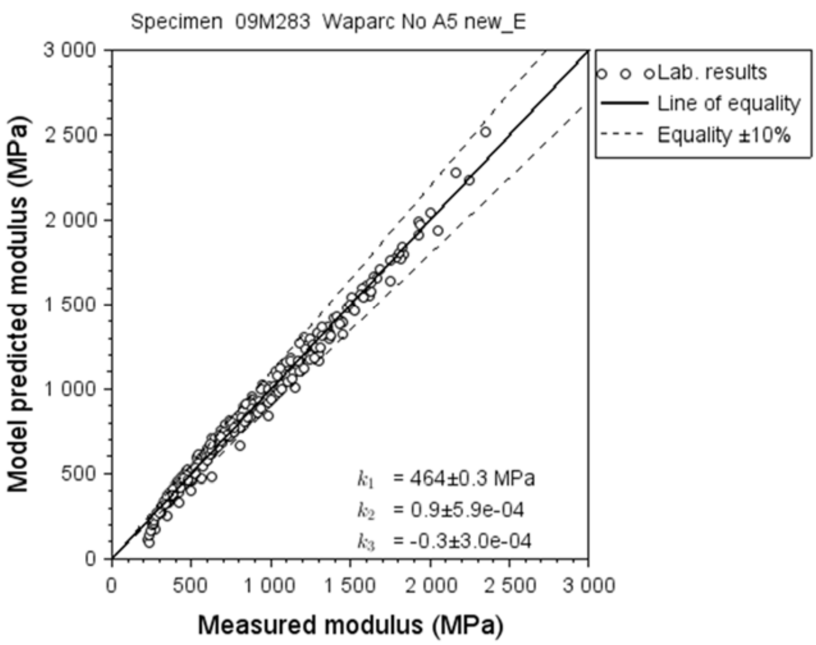


Figure C 17: Ferricrete sample 09M283A4 moduli variation with stress

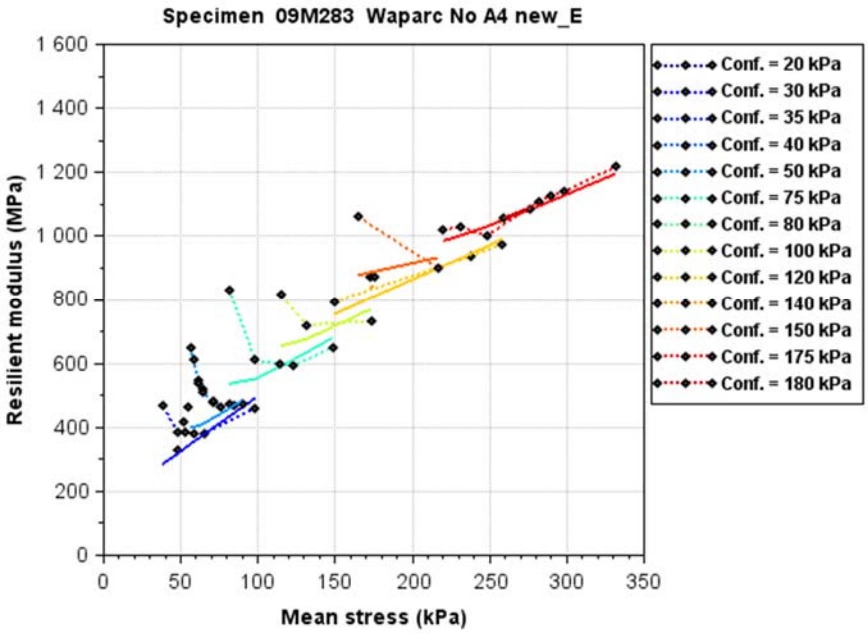
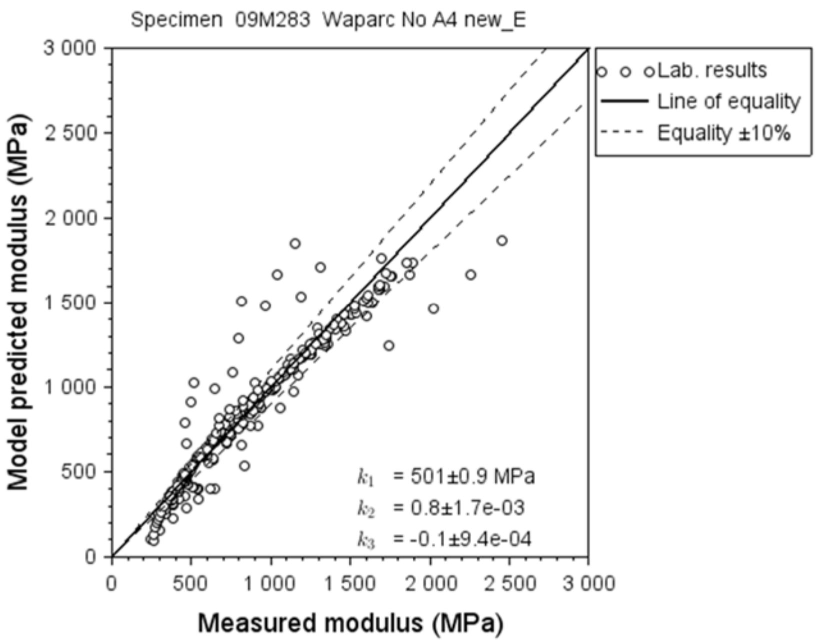


Figure C 18: Ferricrete sample 09M283A4 modulus prediction relationship and fit to the measured data



C.1.4 Measured moduli of G1 crushed rock base

Figure C 19: G1 crushed rock base sample 09M260A1 moduli variation with stress

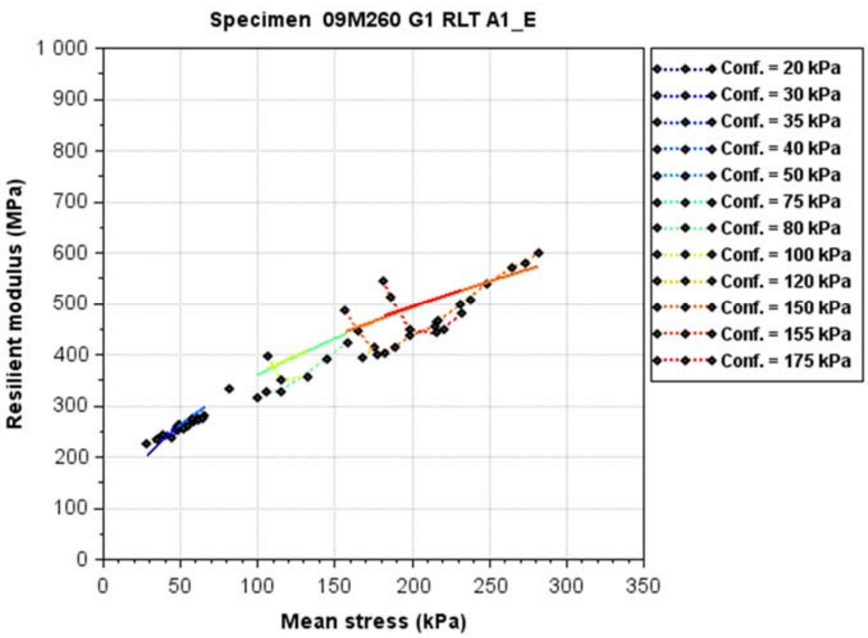


Figure C 20: G1 crushed rock base sample 09M260A1 modulus prediction relationship and fit to the measured data

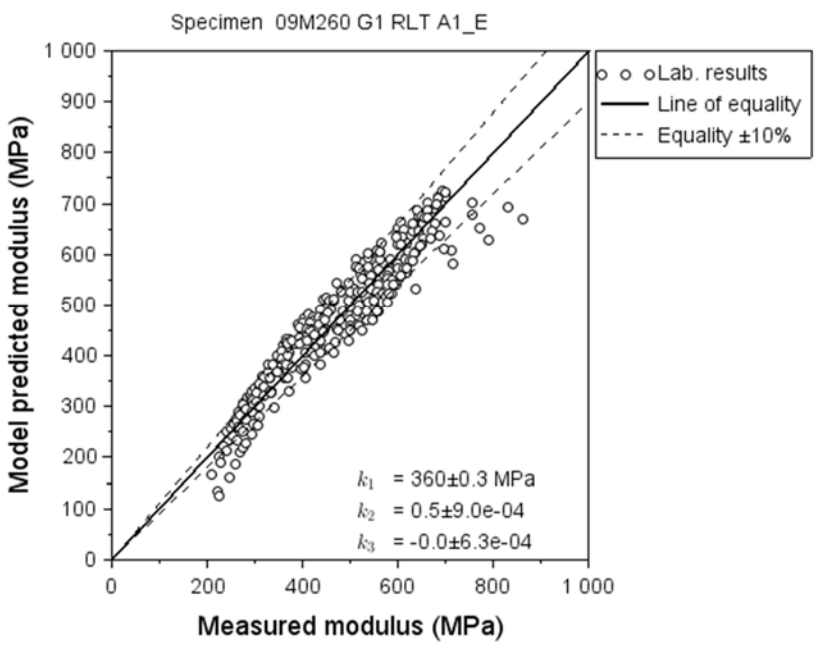


Figure C 21: G1 crushed rock base sample 09M260A2 moduli variation with stress

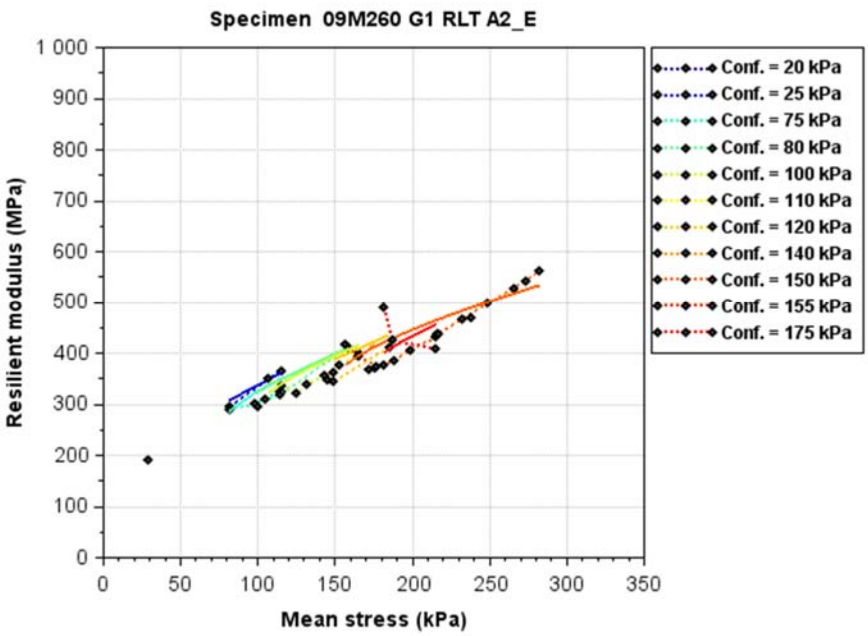


Figure C 22: G1 crushed rock base sample 09M260A2 modulus prediction relationship and fit to the measured data

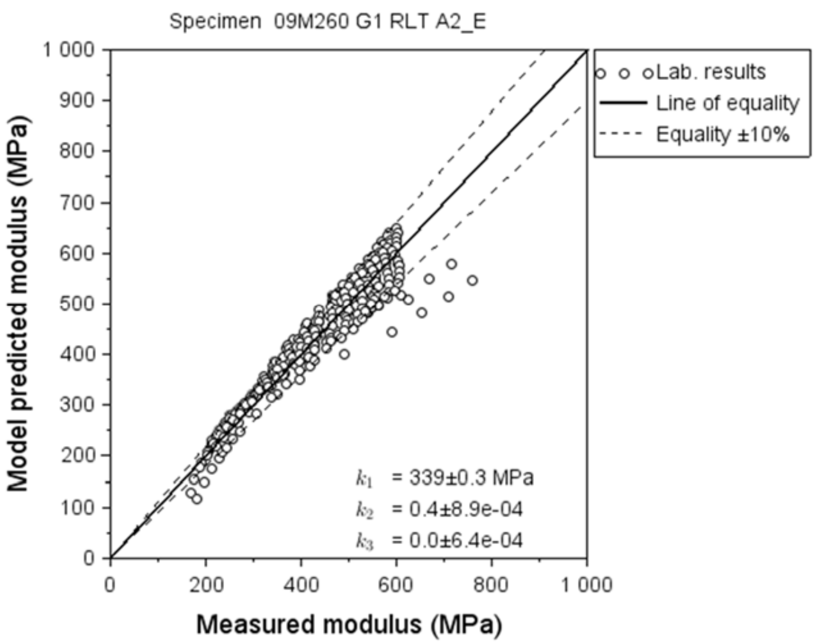


Figure C 23: G1 crushed rock base sample 09M260A5 moduli variation with stress

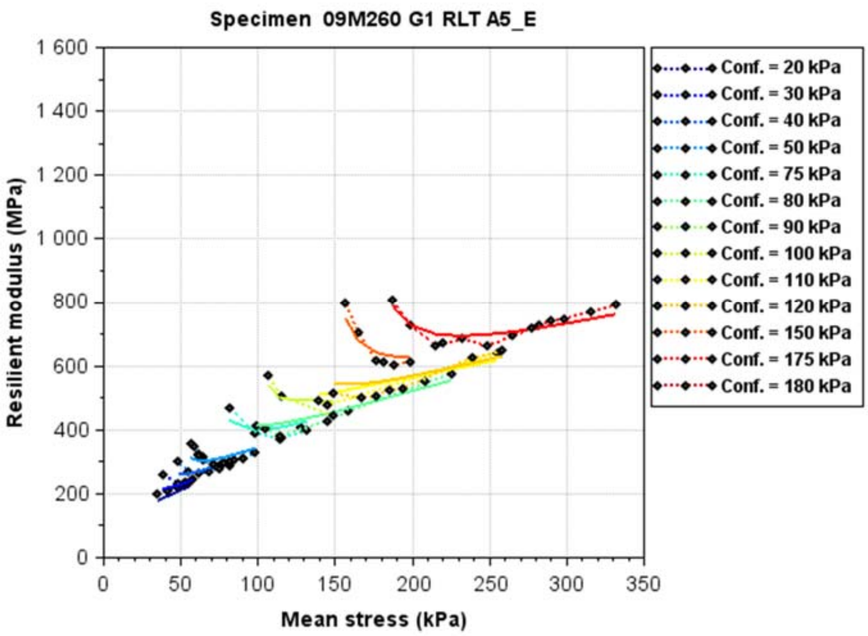
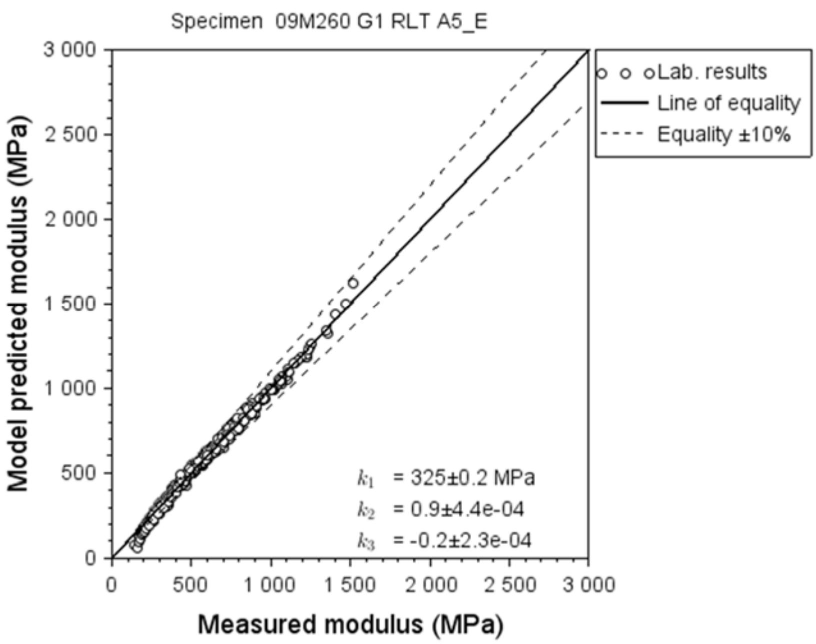


Figure C 24: G1 crushed rock base sample 09M260A5 modulus prediction relationship and fit to the measured data



C.1.5 Measured moduli of hydrated cement treated crushed rock base (HCTCRB)

Figure C 25: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 120 70% A moduli variation with stress

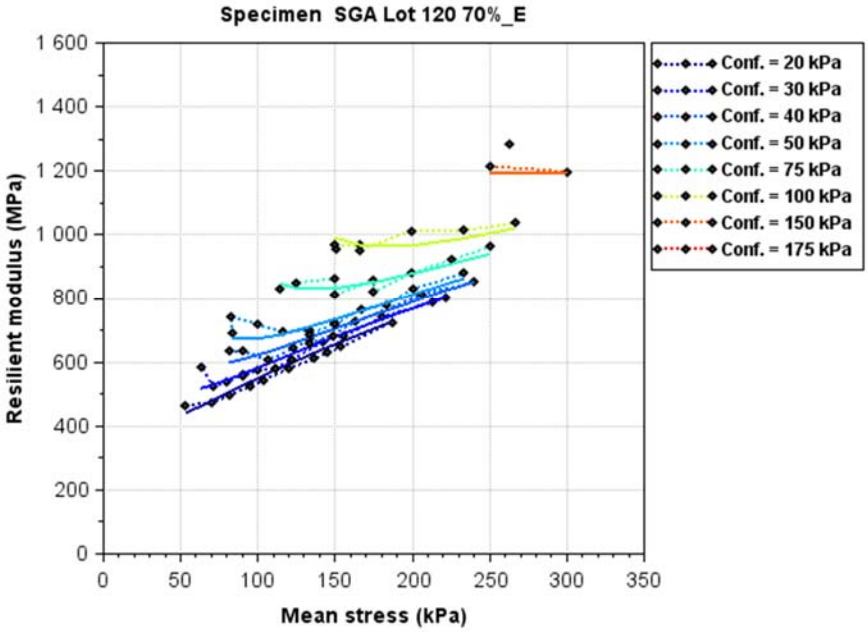


Figure C 26: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 120 70% A modulus prediction relationship and fit to the measured data

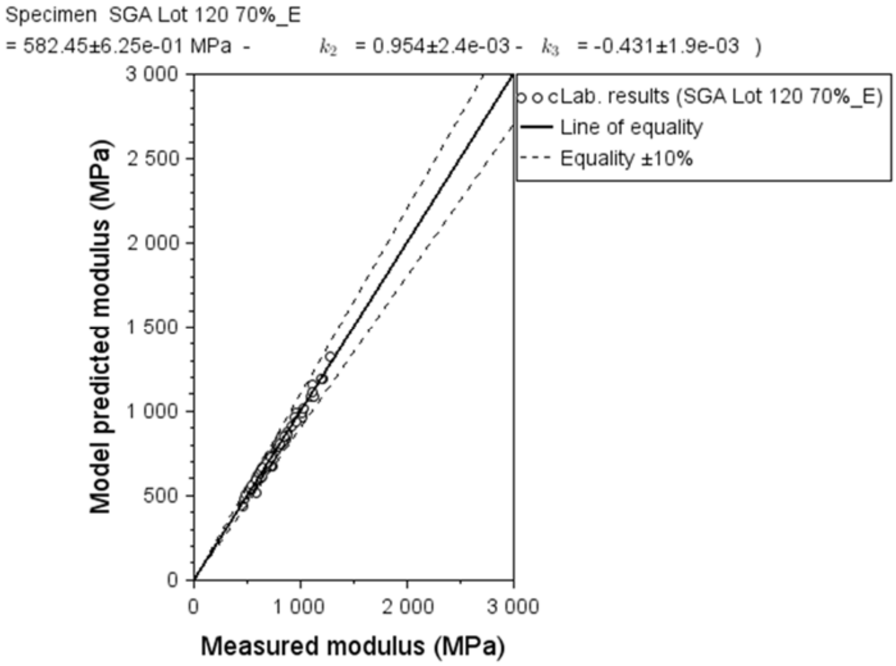


Figure C 27: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 120 80% A moduli variation with stress

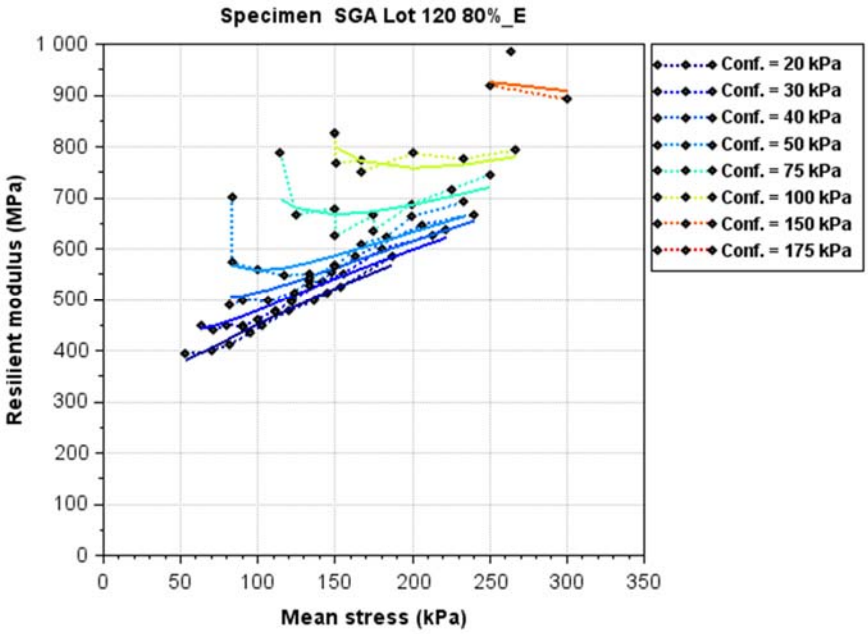


Figure C 28: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 120 80% A modulus prediction relationship and fit to the measured data

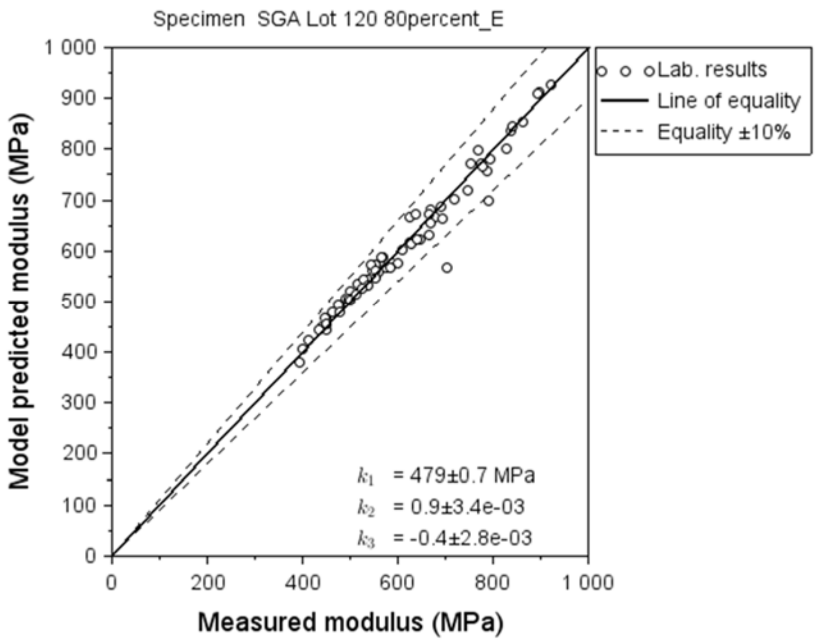


Figure C 29: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 120 90% B moduli variation with stress

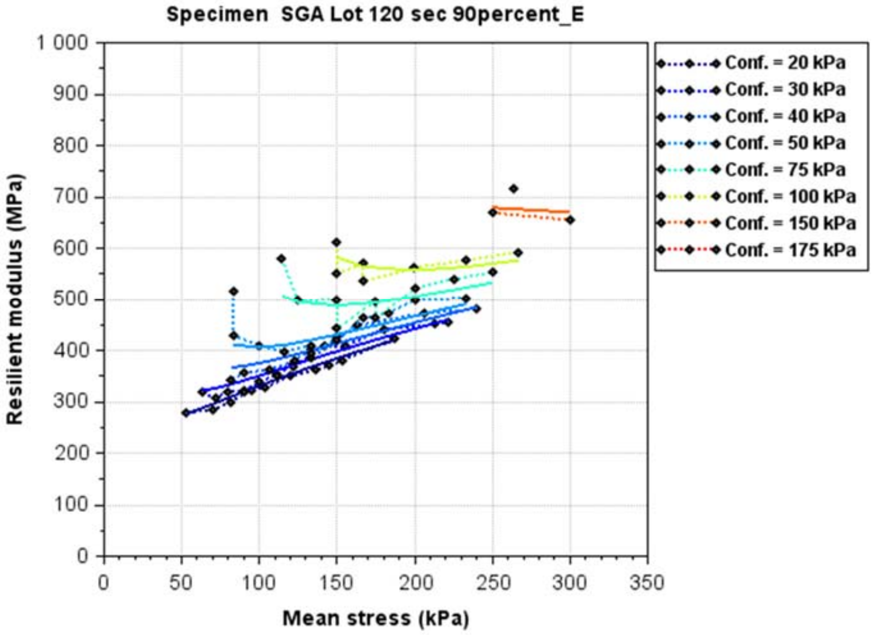


Figure C 30: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 120 90% B modulus prediction relationship and fit to the measured data

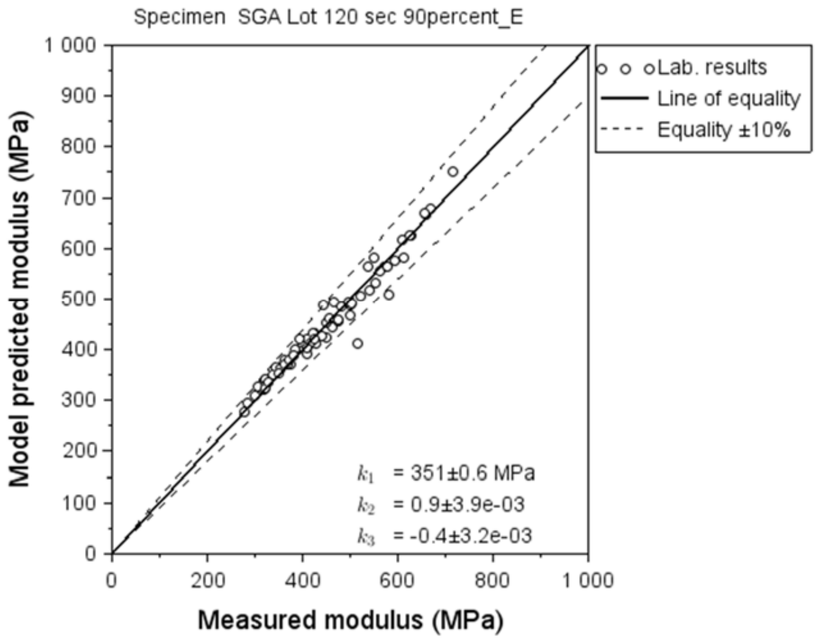


Figure C 31: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 121 70% B moduli variation with stress

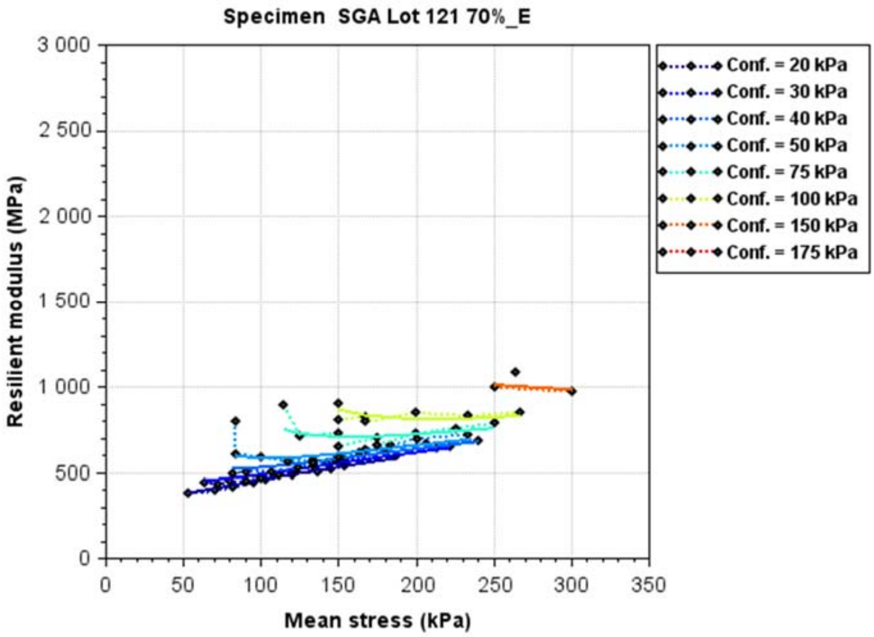


Figure C 32: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 121 70% B modulus prediction relationship and fit to the measured data

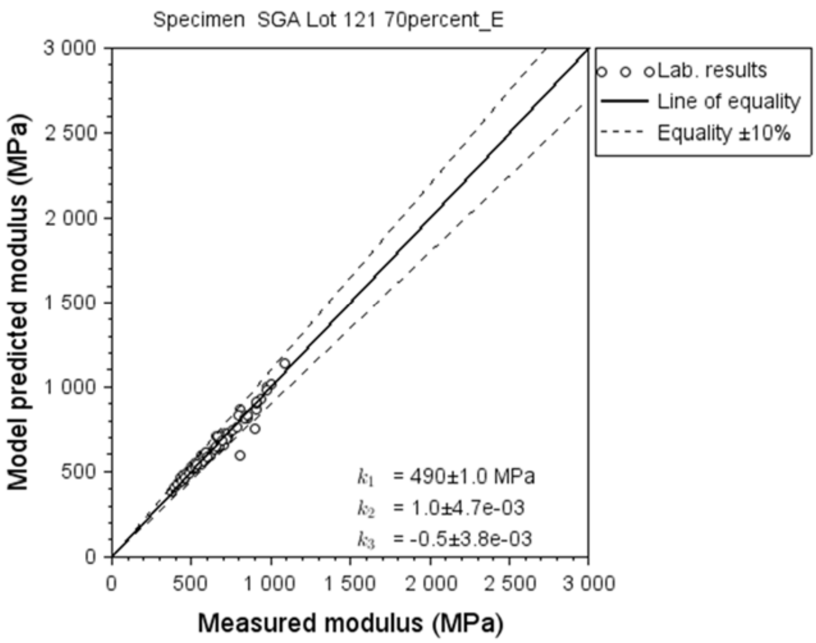


Figure C 33: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 121 80% B moduli variation with stress

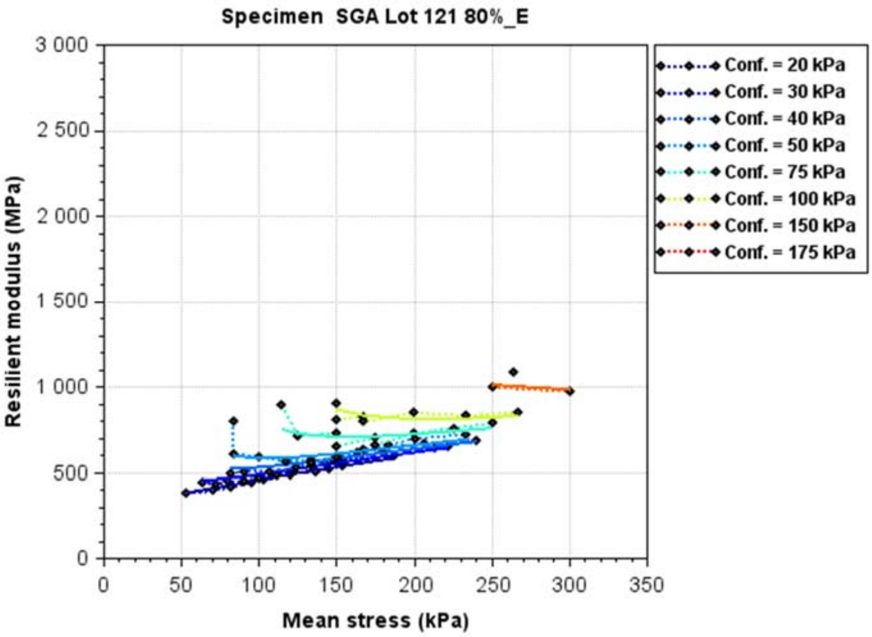


Figure C 34: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 121 80% B modulus prediction relationship and fit to the measured data

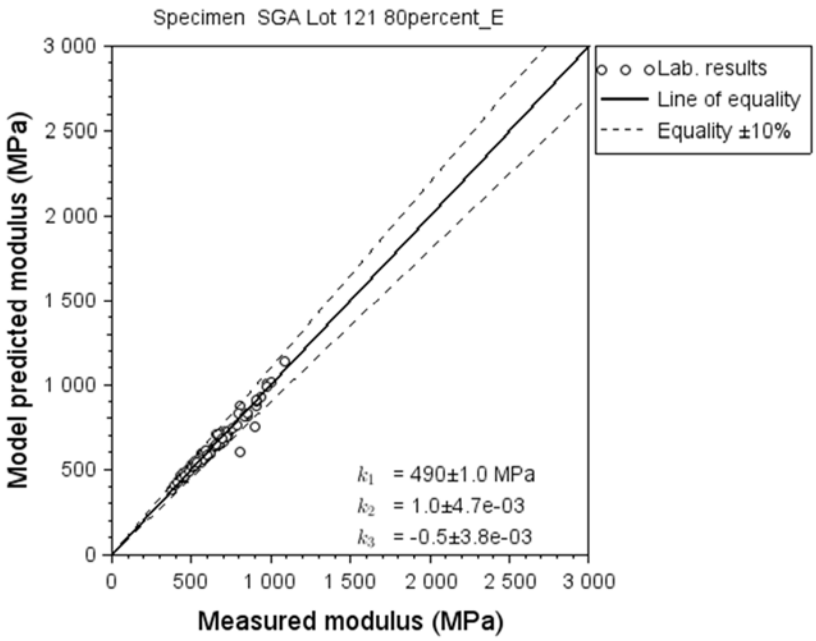


Figure C 35: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 121 90% B moduli variation with stress

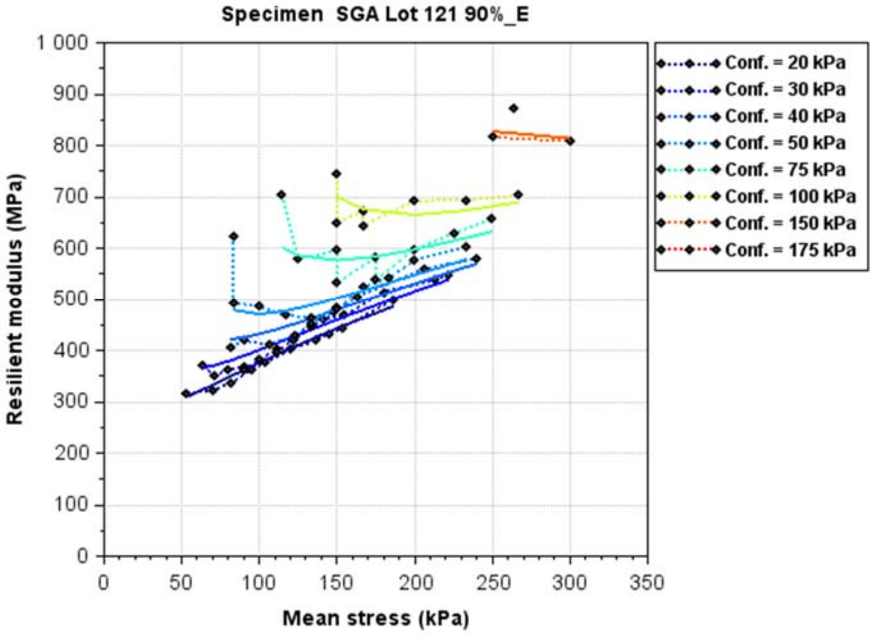
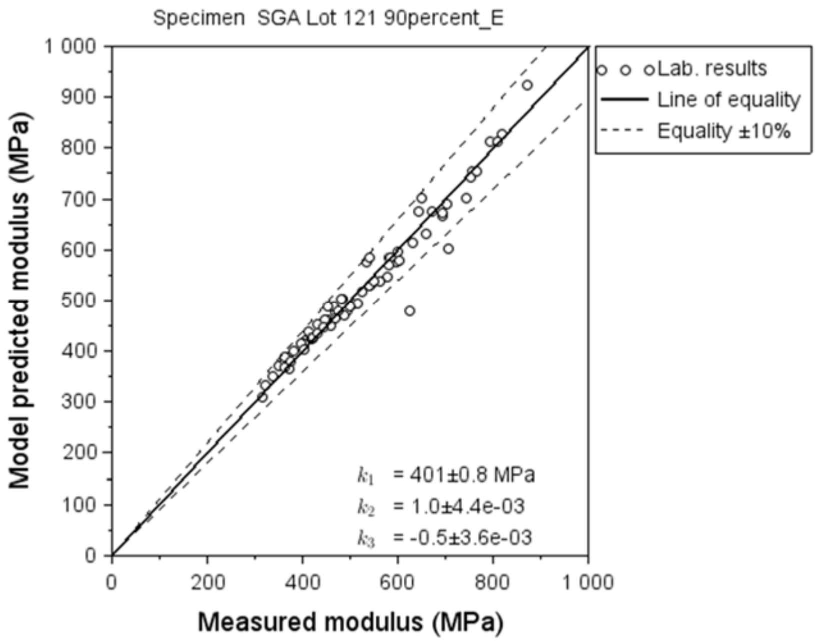


Figure C 36: Hydrated cement treated crushed rock base (HCTCRB) sample Lot 121 90% B modulus prediction relationship and fit to the measured data



C.1.6 Measured moduli of bitumen stabilised limestone (BSL)

Figure C 37: Bitumen stabilised limestone (BSL) sample 09M262A moduli variation with stress

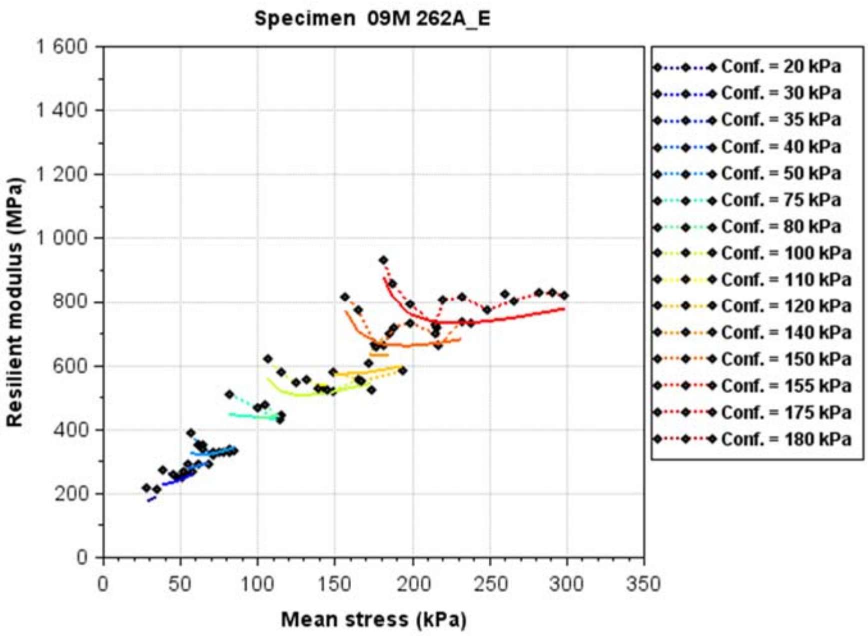


Figure C 38: Bitumen stabilised limestone (BSL) sample 09M262A modulus prediction relationship and fit to the measured data

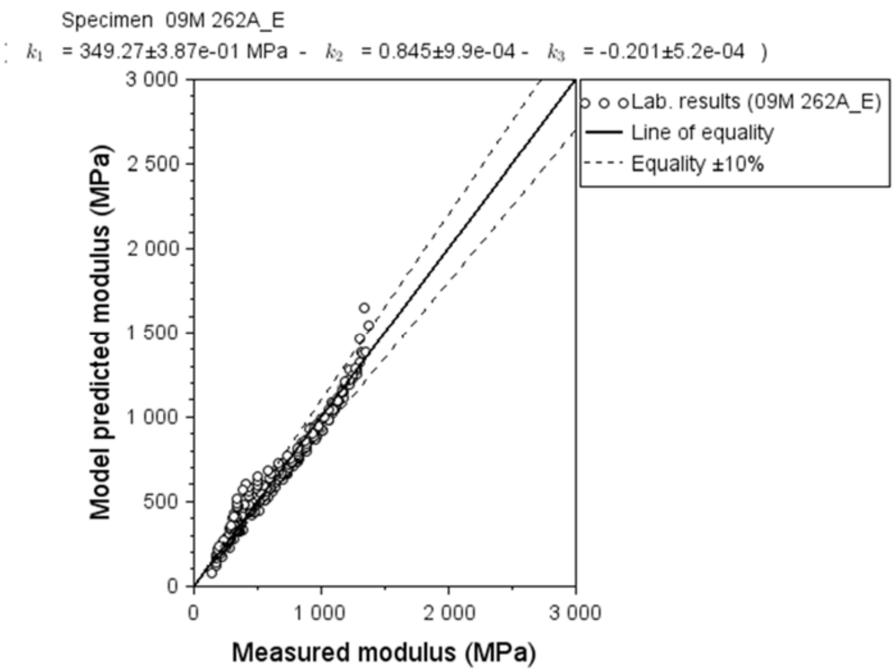


Figure C 39: Bitumen stabilised limestone (BSL) sample 09M262B moduli variation with stress

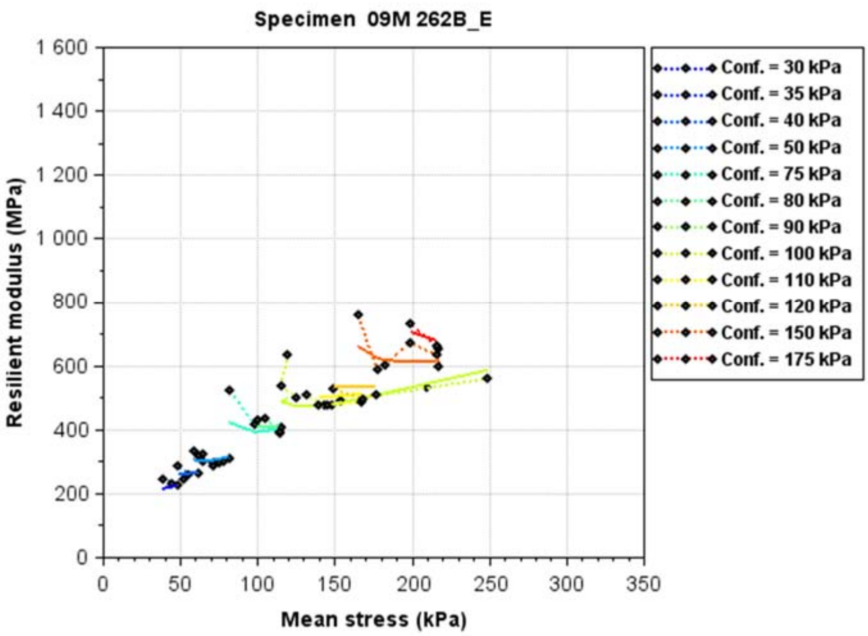


Figure C 40: Bitumen stabilised limestone (BSL) sample 09M262B modulus prediction relationship and fit to the measured data

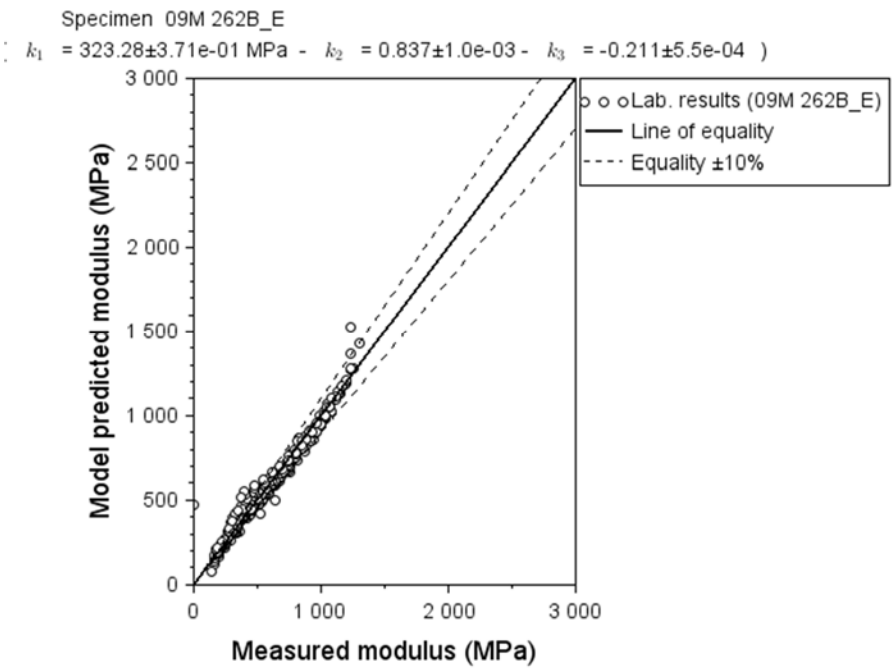


Figure C 41: Bitumen stabilised limestone (BSL) sample 09M262D moduli variation with stress

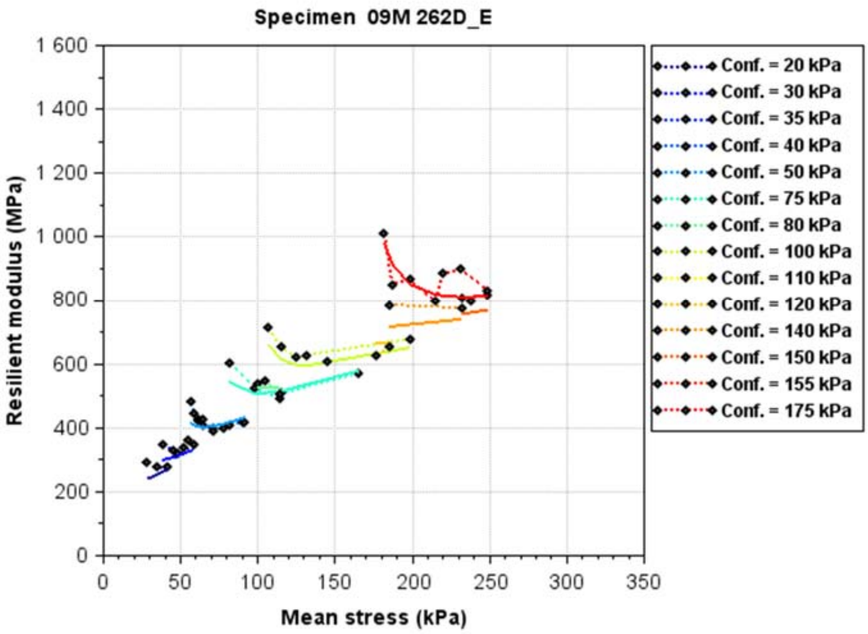


Figure C 42: Bitumen stabilised limestone (BSL) sample 09M262D modulus prediction relationship and fit to the measured data

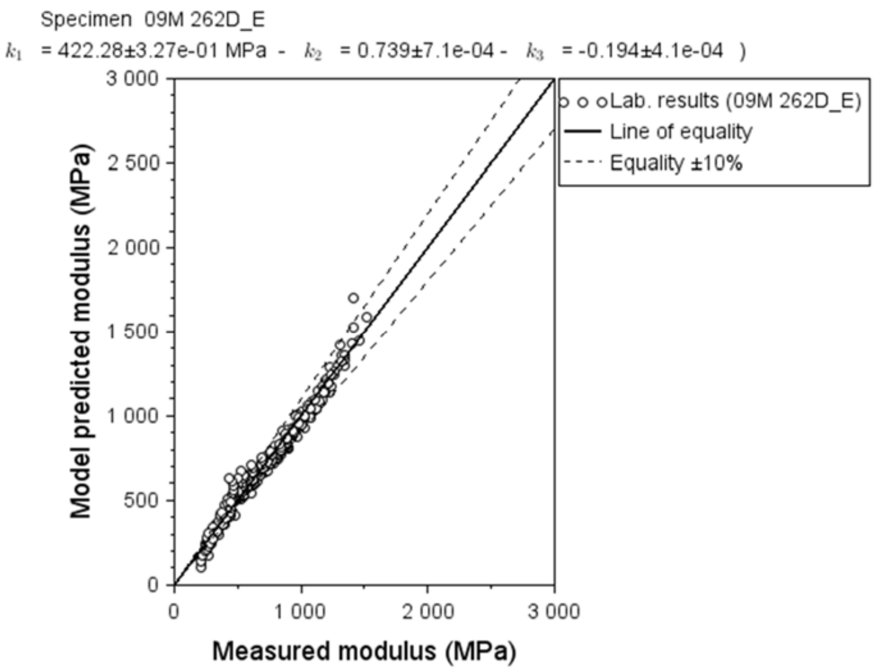


Figure C 43: Bitumen stabilised limestone (BSL) sample 09M262F moduli variation with stress

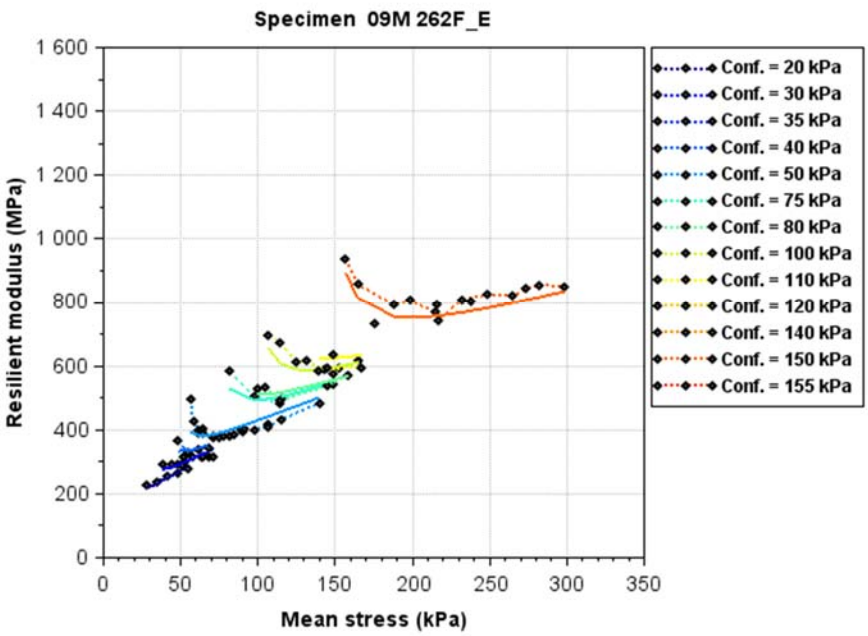
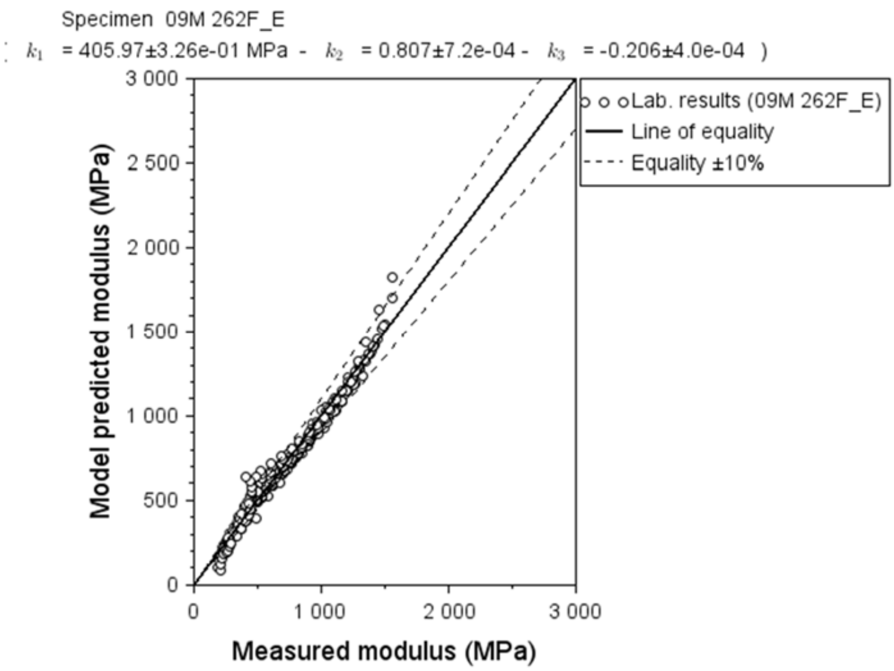


Figure C 44: Bitumen stabilised limestone (BSL) sample 09M262F modulus prediction relationship and fit to the measured data



C.1.7 Measured moduli of crushed recycled concrete (CRC)

Figure C 45: Crushed recycled concrete (CRC) sample 09M304A1 moduli variation with stress

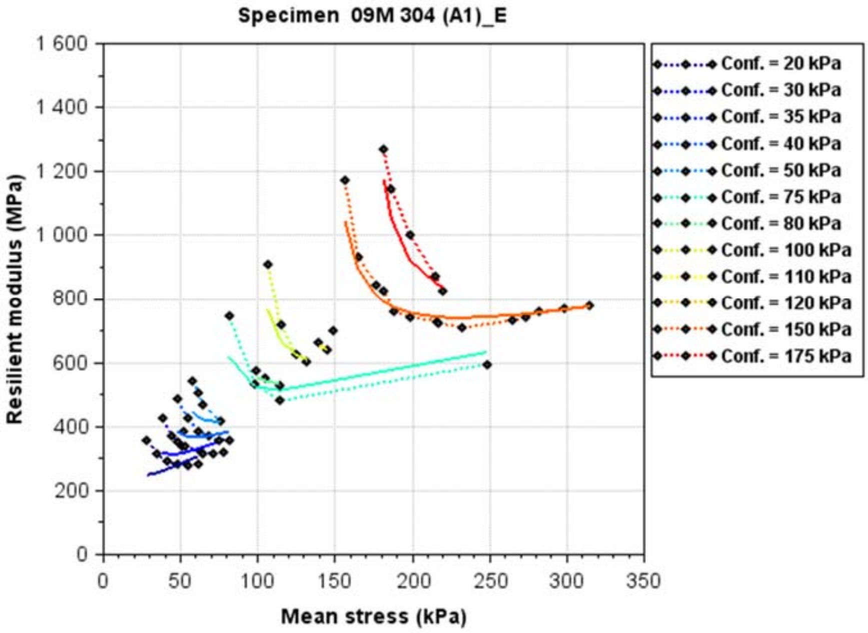


Figure C 46: Crushed recycled concrete (CRC) sample 09M304A1 modulus prediction relationship and fit to the measured data

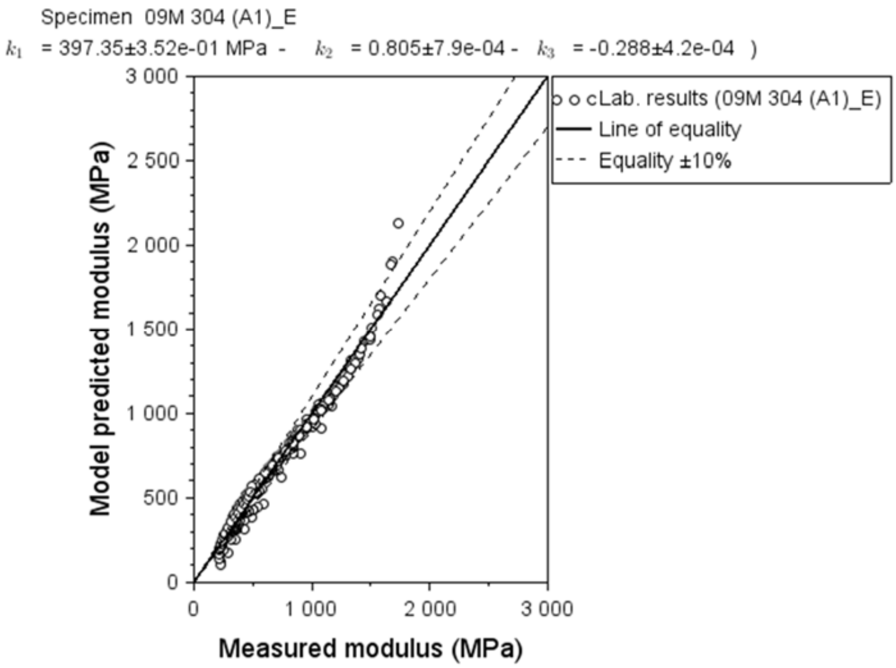


Figure C 47: Crushed recycled concrete (CRC) sample 09M304A2 moduli variation with stress

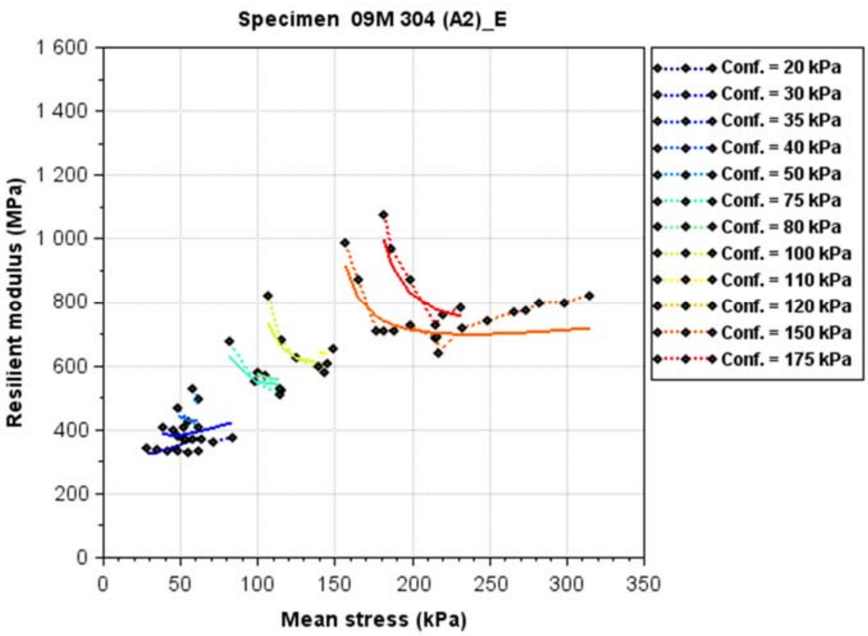


Figure C 48: Crushed recycled concrete (CRC) sample 09M304A2 modulus prediction relationship and fit to the measured data

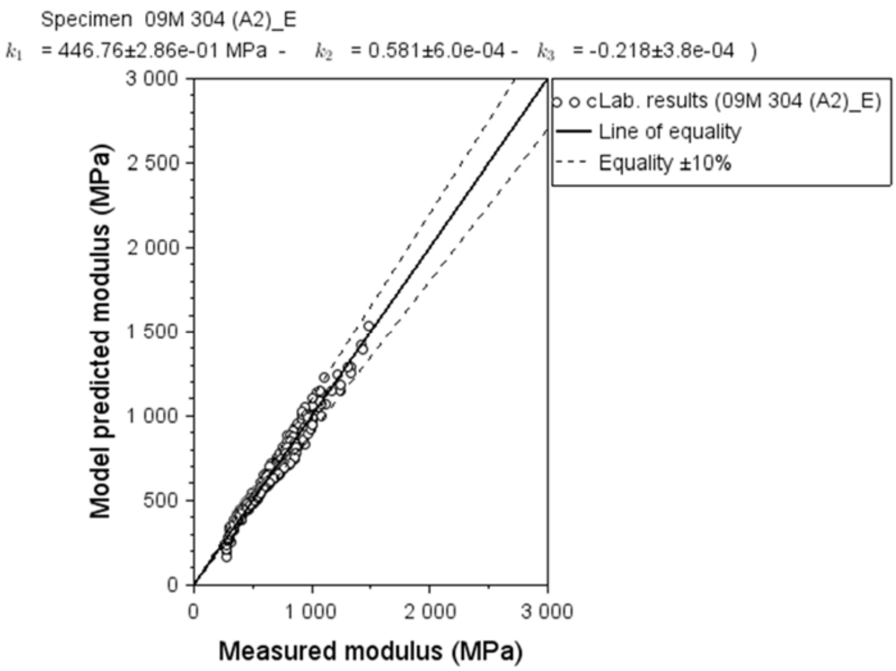


Figure C 49: Crushed recycled concrete (CRC) sample 09M304A4 moduli variation with stress

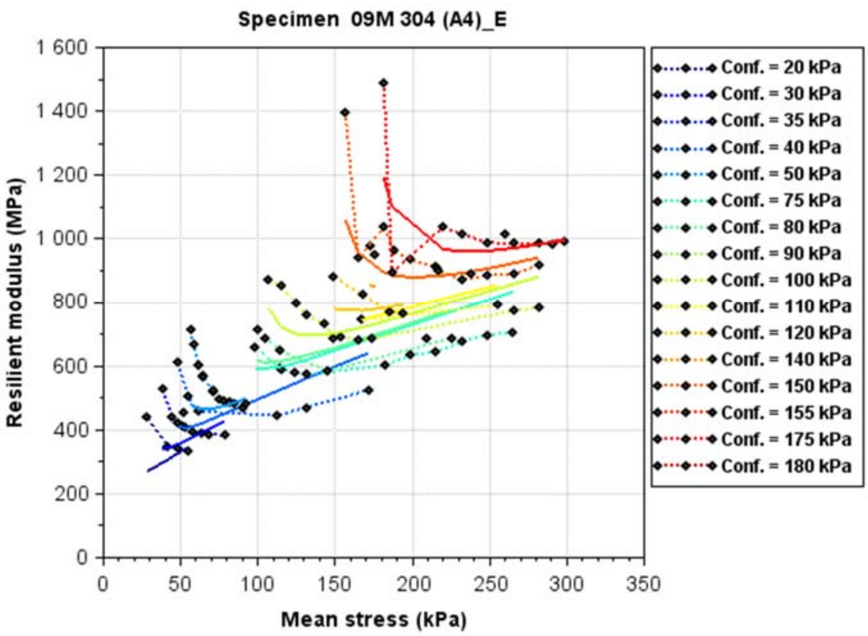


Figure C 50: Crushed recycled concrete (CRC) sample 09M304A4 modulus prediction relationship and fit to the measured data

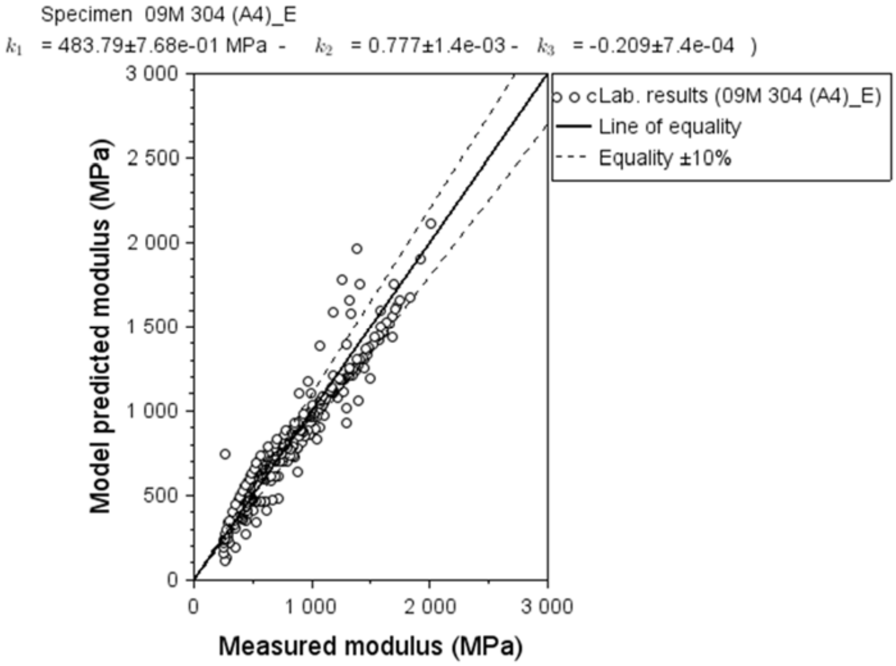


Figure C 51: Crushed recycled concrete (CRC) sample 09M304A5 moduli variation with stress

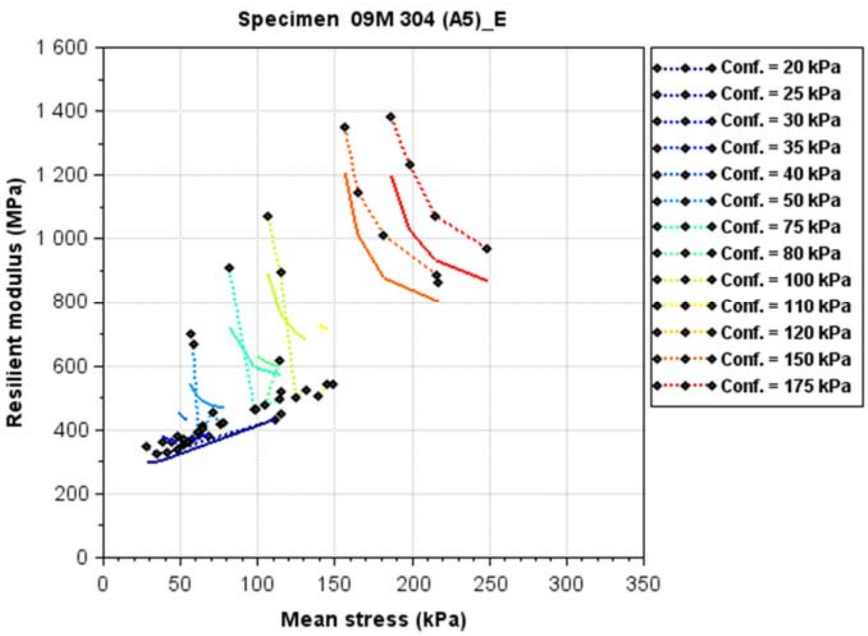
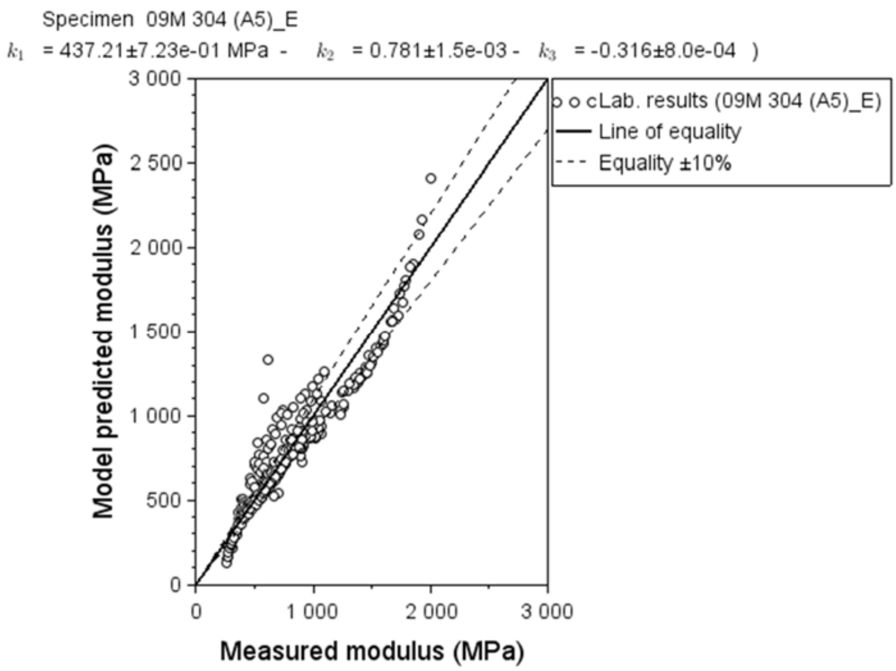


Figure C 52: Crushed recycled concrete (CRC) sample 09M304A5 modulus prediction relationship and fit to the measured data



C.1.8 Summary of granular base modulus stress-dependency relationships

Table C 2: Modulus stress-dependency relationships

Material	Laboratory number	Curing period out of mould (days)	Test density (t/m³)	Test moisture content (%)	Stress-dependency parameter		
					K_1	K_2	K_3
Crushed rock base	09M276AA	28	2.27	3.4	291.1	1.003	–0.361
	09M276AB	28	2.28	3.2	285.6	1.012	–0.337
	09M276AC	28	2.27	2.9	367.1	0.961	–0.366
	09M276AD	28	2.27	3.3	275.8	1.011	–0.319
	09M276AE	28	2.26	3.2	338.2	0.781	–0.191
	09M276AF	28	2.27	2.8	383.1	0.999	–0.438
Ferricrete	09M283A1	36	2.43	6.0	533.8	0.539	–0.132
	09M283A3	35	2.42	6.0	473.3	0.685	–0.201
	09M283A5	88	2.43	6.0	464.7	0.829	–0.272
	09M283A4	90	2.43	6.0	522.0	0.712	–0.135
G1 crushed rock base (passing 20 mm fraction)	09M260A1	32	2.51	3.1	365.1	0.418	0.016
	09M260A2	32	2.51	3.1	336.1	0.412	0.048
	09M260A5	85	2.51	3.1	331.9	0.807	–0.222
Hydrated cement treated crushed rock base (HCTCRB)	Lot120 90%-A	28	2.11	7.5	345.2	0.921	–0.449
	Lot120 80%-A	28	2.11	6.6	474.0	0.914	–0.460
	Lot120 70%-A	28	2.11	5.8	579.1	0.968	–0.455
	Lot120 90%-B	29	2.11	7.5	394.4	1.012	–0.501
	Lot120 80%-B	29	2.11	6.6	407.2	1.059	–0.509
	Lot120 70%-B	29	2.11	5.8	481.2	1.025	–0.528
Bitumen stabilised limestone (BSL)	09M262A	29	1.91	5.2	326.2	0.880	–0.274
	09M262B	29	1.91	5.2	306.2	0.867	–0.262
	09M262D	74	1.91	5.2	452.2	0.684	–0.173
	09M262F	73	1.91	5.2	442.0	0.747	–0.179
Crushed recycled concrete (CRC)	09M304A1	33	1.89	10.6	381.3	0.804	–0.356
	09M304A2	33	1.89	10.6	437.6	0.589	–0.222
	09M304A4	76	1.9	10.6	472.1	0.755	–0.248
	09M304A5	76	1.91	10.6	439.6	0.760	–0.314

C.2 Crushed Limestone Subbase

C.2.1 Stress stages

Table C 3 lists the stress stages used in repeated load triaxial testing of the crushed limestone subbase.

Table C 3: Stress stages used in the crushed limestone subbase tests

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (°)
1	375	25	0.067	383	0.0652	0.0323	1.8
2	325	25	0.077	333	0.0750	0.0370	2.1
3	275	25	0.091	283	0.0882	0.0435	2.5
4	225	25	0.111	233	0.1071	0.0526	3.0
5	400	50	0.125	417	0.1200	0.0588	3.4
6	175	25	0.143	183	0.1364	0.0667	3.8
7	350	50	0.143	367	0.1364	0.0667	3.8
8	300	50	0.167	317	0.1579	0.0769	4.4
9	50	10	0.200	53	0.1875	0.0909	5.2
10	125	25	0.200	133	0.1875	0.0909	5.2
11	250	50	0.200	267	0.1875	0.0909	5.2
12	375	75	0.200	400	0.1875	0.0909	5.2
13	325	75	0.231	350	0.2143	0.1034	5.9
14	40	10	0.250	43	0.2308	0.1111	6.4
15	200	50	0.250	217	0.2308	0.1111	6.4
16	400	100	0.250	433	0.2308	0.1111	6.4
17	275	75	0.273	300	0.2500	0.1200	6.9
18	350	100	0.286	383	0.2609	0.1250	7.2
19	30	10	0.333	33	0.3000	0.1429	8.2
20	75	25	0.333	83	0.3000	0.1429	8.2
21	150	50	0.333	167	0.3000	0.1429	8.2
22	225	75	0.333	250	0.3000	0.1429	8.2
23	300	100	0.333	333	0.3000	0.1429	8.2
24	375	125	0.333	417	0.3000	0.1429	8.2
25	400	150	0.375	450	0.3333	0.1579	9.1
26	325	125	0.385	367	0.3409	0.1613	9.3
27	250	100	0.400	283	0.3529	0.1667	9.6
28	175	75	0.429	200	0.3750	0.1765	10.2
29	350	150	0.429	400	0.3750	0.1765	10.2
30	275	125	0.455	317	0.3947	0.1852	10.7
31	375	175	0.467	433	0.4038	0.1892	10.9
32	20	10	0.500	23	0.4286	0.2000	11.5
33	50	25	0.500	58	0.4286	0.2000	11.5
34	75	38	0.507	88	0.4335	0.2021	11.7
35	100	50	0.500	117	0.4286	0.2000	11.5
36	130	65	0.500	152	0.4286	0.2000	11.5
37	200	100	0.500	233	0.4286	0.2000	11.5
38	300	150	0.500	350	0.4286	0.2000	11.5

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (°)
39	400	200	0.500	467	0.4286	0.2000	11.5
40	100	50	0.500	117	0.4286	0.2000	11.5
41	325	175	0.538	383	0.4565	0.2121	12.2
42	225	125	0.556	267	0.4688	0.2174	12.6
43	350	200	0.571	417	0.4800	0.2222	12.8
44	50	30	0.600	60	0.5000	0.2308	13.3
45	80	48	0.600	96	0.5000	0.2308	13.3
46	100	60	0.600	120	0.5000	0.2308	13.3
47	125	75	0.600	150	0.5000	0.2308	13.3
48	140	84	0.600	168	0.5000	0.2308	13.3
49	250	150	0.600	300	0.5000	0.2308	13.3
50	375	225	0.600	450	0.5000	0.2308	13.3
51	50	30	0.600	60	0.5000	0.2308	13.3
52	275	175	0.636	333	0.5250	0.2414	14.0
53	150	100	0.667	183	0.5455	0.2500	14.5
54	300	200	0.667	367	0.5455	0.2500	14.5
55	325	225	0.692	400	0.5625	0.2571	14.9
56	50	35	0.700	62	0.5676	0.2593	15.0
57	80	56	0.700	99	0.5676	0.2593	15.0
58	100	70	0.700	123	0.5676	0.2593	15.0
59	150	105	0.700	185	0.5676	0.2593	15.0
60	175	123	0.703	216	0.5694	0.2600	15.1
61	175	125	0.714	217	0.5769	0.2632	15.3
62	350	250	0.714	433	0.5769	0.2632	15.3
63	375	275	0.733	467	0.5893	0.2683	15.6
64	40	30	0.750	50	0.6000	0.2727	15.8
65	200	150	0.750	250	0.6000	0.2727	15.8
66	225	175	0.778	283	0.6176	0.2800	16.3
67	50	40	0.800	63	0.6316	0.2857	16.6
68	80	64	0.800	101	0.6316	0.2857	16.6
69	100	80	0.800	127	0.6316	0.2857	16.6
70	150	120	0.800	190	0.6316	0.2857	16.6
71	175	140	0.800	222	0.6316	0.2857	16.6
72	250	200	0.800	317	0.6316	0.2857	16.6
73	50	40	0.800	63	0.6316	0.2857	16.6
74	275	225	0.818	350	0.6429	0.2903	16.9
75	300	250	0.833	383	0.6522	0.2941	17.1
76	325	275	0.846	417	0.6600	0.2973	17.3

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (º)
77	350	300	0.857	450	0.6667	0.3000	17.5
78	10	10	1.000	13	0.7500	0.3333	19.5
79	30	30	1.000	40	0.7500	0.3333	19.5
80	50	50	1.000	67	0.7500	0.3333	19.5
81	75	75	1.000	100	0.7500	0.3333	19.5
82	80	80	1.000	107	0.7500	0.3333	19.5
83	100	100	1.000	133	0.7500	0.3333	19.5
84	125	125	1.000	167	0.7500	0.3333	19.5
85	140	140	1.000	187	0.7500	0.3333	19.5
86	150	150	1.000	200	0.7500	0.3333	19.5
87	175	175	1.000	233	0.7500	0.3333	19.5
88	200	200	1.000	267	0.7500	0.3333	19.5
89	225	225	1.000	300	0.7500	0.3333	19.5
90	250	250	1.000	333	0.7500	0.3333	19.5
91	275	275	1.000	367	0.7500	0.3333	19.5
92	300	300	1.000	400	0.7500	0.3333	19.5
93	325	325	1.000	433	0.7500	0.3333	19.5
94	50	50	1.000	67	0.7500	0.3333	19.5
95	300	350	1.167	417	0.8400	0.3684	21.6
96	275	325	1.182	383	0.8478	0.3714	21.8
97	250	300	1.200	350	0.8571	0.3750	22.0
98	225	275	1.222	317	0.8684	0.3793	22.3
99	40	50	1.250	57	0.8824	0.3846	22.6
100	200	250	1.250	283	0.8824	0.3846	22.6
101	175	225	1.286	250	0.9000	0.3913	23.0
102	150	200	1.333	217	0.9231	0.4000	23.6
103	80	108	1.350	116	0.9310	0.4030	23.8
104	100	135	1.350	145	0.9310	0.4030	23.8
105	150	203	1.353	218	0.9326	0.4036	23.8
106	180	243	1.350	261	0.9310	0.4030	23.8
107	275	375	1.364	400	0.9375	0.4054	23.9
108	50	68	1.360	73	0.9358	0.4048	23.9
109	50	70	1.400	73	0.9545	0.4118	24.3
110	125	175	1.400	183	0.9545	0.4118	24.3
111	250	350	1.400	367	0.9545	0.4118	24.3
112	225	325	1.444	333	0.9750	0.4194	24.8
113	20	30	1.500	30	1.0000	0.4286	25.4
114	100	150	1.500	150	1.0000	0.4286	25.4

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (°)
115	200	300	1.500	300	1.0000	0.4286	25.4
116	175	275	1.571	267	1.0313	0.4400	26.1
117	250	400	1.600	383	1.0435	0.4444	26.4
118	35	57	1.629	54	1.0556	0.4488	26.7
119	75	123	1.640	116	1.0603	0.4505	26.8
120	100	164	1.640	155	1.0603	0.4505	26.8
121	155	254	1.639	240	1.0598	0.4504	26.8
122	180	295	1.639	278	1.0599	0.4504	26.8
123	50	82	1.640	77	1.0603	0.4505	26.8
124	30	50	1.667	47	1.0714	0.4545	27.0
125	75	125	1.667	117	1.0714	0.4545	27.0
126	150	250	1.667	233	1.0714	0.4545	27.0
127	225	375	1.667	350	1.0714	0.4545	27.0
128	40	70	1.750	63	1.1053	0.4667	27.8
129	200	350	1.750	317	1.1053	0.4667	27.8
130	50	90	1.800	80	1.1250	0.4737	28.3
131	125	225	1.800	200	1.1250	0.4737	28.3
132	175	325	1.857	283	1.1471	0.4815	28.8
133	225	425	1.889	367	1.1591	0.4857	29.1
134	30	60	2.000	50	1.2000	0.5000	30.0
135	50	100	2.000	83	1.2000	0.5000	30.0
136	75	150	2.000	125	1.2000	0.5000	30.0
137	100	200	2.000	167	1.2000	0.5000	30.0
138	140	280	2.000	233	1.2000	0.5000	30.0
139	150	300	2.000	250	1.2000	0.5000	30.0
140	175	350	2.000	292	1.2000	0.5000	30.0
141	200	400	2.000	333	1.2000	0.5000	30.0
142	100	200	2.000	167	1.2000	0.5000	30.0
143	50	100	2.000	83	1.2000	0.5000	30.0
144	175	375	2.143	300	1.2500	0.5172	31.1
145	50	110	2.200	87	1.2692	0.5238	31.6
146	125	275	2.200	217	1.2692	0.5238	31.6
147	40	90	2.250	70	1.2857	0.5294	32.0
148	200	450	2.250	350	1.2857	0.5294	32.0
149	30	70	2.333	53	1.3125	0.5385	32.6
150	75	175	2.333	133	1.3125	0.5385	32.6
151	150	350	2.333	267	1.3125	0.5385	32.6
152	175	425	2.429	317	1.3421	0.5484	33.3

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (º)
153	20	50	2.500	37	1.3636	0.5556	33.7
154	30	75	2.500	55	1.3636	0.5556	33.7
155	50	125	2.500	92	1.3636	0.5556	33.7
156	80	200	2.500	147	1.3636	0.5556	33.7
157	100	250	2.500	183	1.3636	0.5556	33.7
158	150	375	2.500	275	1.3636	0.5556	33.7
159	50	125	2.500	92	1.3636	0.5556	33.7
160	50	130	2.600	93	1.3929	0.5652	34.4
161	125	325	2.600	233	1.3929	0.5652	34.4
162	150	400	2.667	283	1.4118	0.5714	34.8
163	175	475	2.714	333	1.4250	0.5758	35.2
164	40	110	2.750	77	1.4348	0.5789	35.4
165	10	30	3.000	20	1.5000	0.6000	36.9
166	30	90	3.000	60	1.5000	0.6000	36.9
167	50	150	3.000	100	1.5000	0.6000	36.9
168	75	225	3.000	150	1.5000	0.6000	36.9
169	80	240	3.000	160	1.5000	0.6000	36.9
170	100	300	3.000	200	1.5000	0.6000	36.9
171	120	360	3.000	240	1.5000	0.6000	36.9
172	125	375	3.000	250	1.5000	0.6000	36.9
173	150	450	3.000	300	1.5000	0.6000	36.9
174	50	150	3.000	100	1.5000	0.6000	36.9
175	40	130	3.250	83	1.5600	0.6190	38.2
176	150	500	3.333	317	1.5789	0.6250	38.7
177	125	425	3.400	267	1.5938	0.6296	39.0
178	20	70	3.500	43	1.6154	0.6364	39.5
179	30	105	3.500	65	1.6154	0.6364	39.5
180	50	175	3.500	108	1.6154	0.6364	39.5
181	75	263	3.507	163	1.6168	0.6368	39.6
182	100	350	3.500	217	1.6154	0.6364	39.5
183	120	420	3.500	260	1.6154	0.6364	39.5
184	50	175	3.500	108	1.6154	0.6364	39.5
185	30	110	3.667	67	1.6500	0.6471	40.3
186	75	275	3.667	167	1.6500	0.6471	40.3
187	40	150	3.750	90	1.6667	0.6522	40.7
188	125	475	3.800	283	1.6765	0.6552	40.9
189	30	120	4.000	70	1.7143	0.6667	41.8
190	50	200	4.000	117	1.7143	0.6667	41.8

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (º)
191	70	280	4.000	163	1.7143	0.6667	41.8
192	90	360	4.000	210	1.7143	0.6667	41.8
193	100	400	4.000	233	1.7143	0.6667	41.8
194	110	440	4.000	257	1.7143	0.6667	41.8
195	50	200	4.000	117	1.7143	0.6667	41.8
196	125	525	4.200	300	1.7500	0.6774	42.6
197	30	130	4.333	73	1.7727	0.6842	43.2
198	75	325	4.333	183	1.7727	0.6842	43.2
199	20	90	4.500	50	1.8000	0.6923	43.8
200	100	450	4.500	250	1.8000	0.6923	43.8
201	10	50	5.000	27	1.8750	0.7143	45.6
202	30	150	5.000	80	1.8750	0.7143	45.6
203	50	250	5.000	133	1.8750	0.7143	45.6
204	75	375	5.000	200	1.8750	0.7143	45.6
205	100	500	5.000	267	1.8750	0.7143	45.6
206	20	110	5.500	57	1.9412	0.7333	47.2
207	30	165	5.500	85	1.9412	0.7333	47.2
208	40	220	5.500	113	1.9412	0.7333	47.2
209	50	275	5.500	142	1.9412	0.7333	47.2
210	60	330	5.500	170	1.9412	0.7333	47.2
211	80	440	5.500	227	1.9412	0.7333	47.2
212	100	550	5.500	283	1.9412	0.7333	47.2
213	75	425	5.667	217	1.9615	0.7391	47.7
214	50	300	6.000	150	2.0000	0.7500	48.6
215	75	475	6.333	233	2.0357	0.7600	49.5
216	20	130	6.500	63	2.0526	0.7647	49.9
217	10	70	7.000	33	2.1000	0.7778	51.1
218	25	175	7.000	83	2.1000	0.7778	51.1
219	50	350	7.000	167	2.1000	0.7778	51.1
220	75	525	7.000	250	2.1000	0.7778	51.1
221	20	150	7.500	70	2.1429	0.7895	52.1
222	75	575	7.667	267	2.1563	0.7931	52.5
223	50	400	8.000	183	2.1818	0.8000	53.1
224	10	90	9.000	40	2.2500	0.8182	54.9
225	25	225	9.000	100	2.2500	0.8182	54.9
226	50	450	9.000	200	2.2500	0.8182	54.9
227	1	10	10.000	4	2.3077	0.8333	56.4
228	50	500	10.000	217	2.3077	0.8333	56.4

Stress Stage	Confining stress (kPa)	Deviator stress q (kPa)	Ratio	Mean Stress p (kPa)	M = q/p	Sinf	f (º)
229	10	110	11.000	47	2.3571	0.8462	57.8
230	25	275	11.000	117	2.3571	0.8462	57.8
231	50	550	11.000	233	2.3571	0.8462	57.8
232	50	600	12.000	250	2.4000	0.8571	59.0
233	10	130	13.000	53	2.4375	0.8667	60.1
234	25	325	13.000	133	2.4375	0.8667	60.1
235	10	150	15.000	60	2.5000	0.8824	61.9
236	25	375	15.000	150	2.5000	0.8824	61.9
237	25	425	17.000	167	2.5500	0.8947	63.5
238	25	475	19.000	183	2.5909	0.9048	64.8
239	25	525	21.000	200	2.6250	0.9130	65.9
240	25	575	23.000	217	2.6538	0.9200	66.9
241	25	625	25.000	233	2.6786	0.9259	67.8
242	1	30	30.000	11	2.7273	0.9375	69.6
243	1	50	50.000	18	2.8302	0.9615	74.1
244	1	70	70.000	24	2.8767	0.9722	76.5
245	1	90	90.000	31	2.9032	0.9783	78.0
246	1	100	100.000	34	2.9126	0.9804	78.6
247	1	110	110.000	38	2.9204	0.9821	79.2
248	1	130	130.000	44	2.9323	0.9848	80.0
249	1	150	150.000	51	2.9412	0.9868	80.7
250	1	200	200.000	68	2.9557	0.9901	81.9
251	1	250	250.000	84	2.9644	0.9921	82.8
252	1	300	300.000	101	2.9703	0.9934	83.4
253	1	350	350.000	118	2.9745	0.9943	83.9
254	1	400	400.000	134	2.9777	0.9950	84.3
255	1	450	450.000	151	2.9801	0.9956	84.6
256	1	500	500.000	168	2.9821	0.9960	84.9
257	1	550	550.000	184	2.9837	0.9964	85.1
258	1	600	600.000	201	2.9851	0.9967	85.3
259	1	650	650.000	218	2.9862	0.9969	85.5

C.2.2 Measured Moduli on Crushed Limestone Subbase

Figure C 53: Crushed limestone subbase sample 12M7B moduli variation with stress

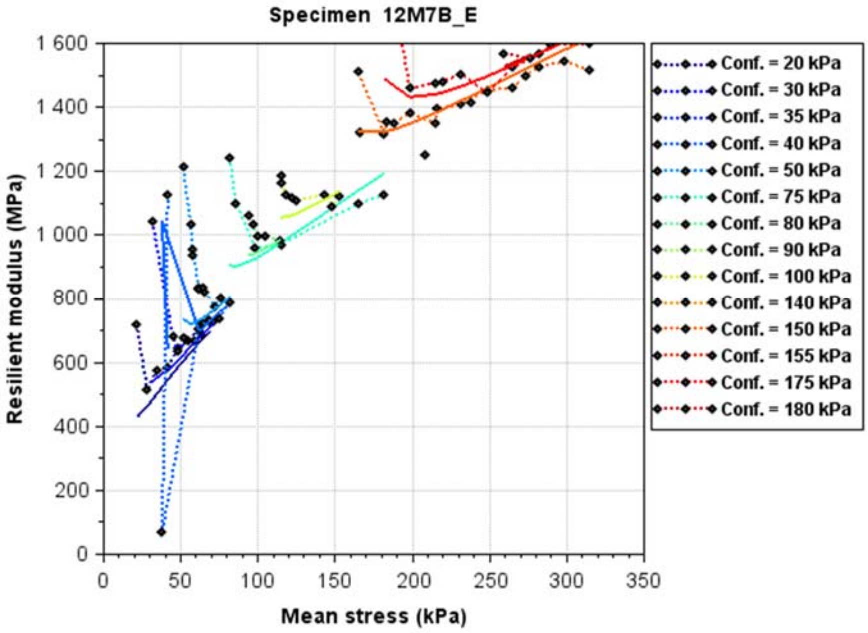


Figure C 54: Crushed limestone subbase sample 12M7B modulus prediction relationship and fit to the measured data

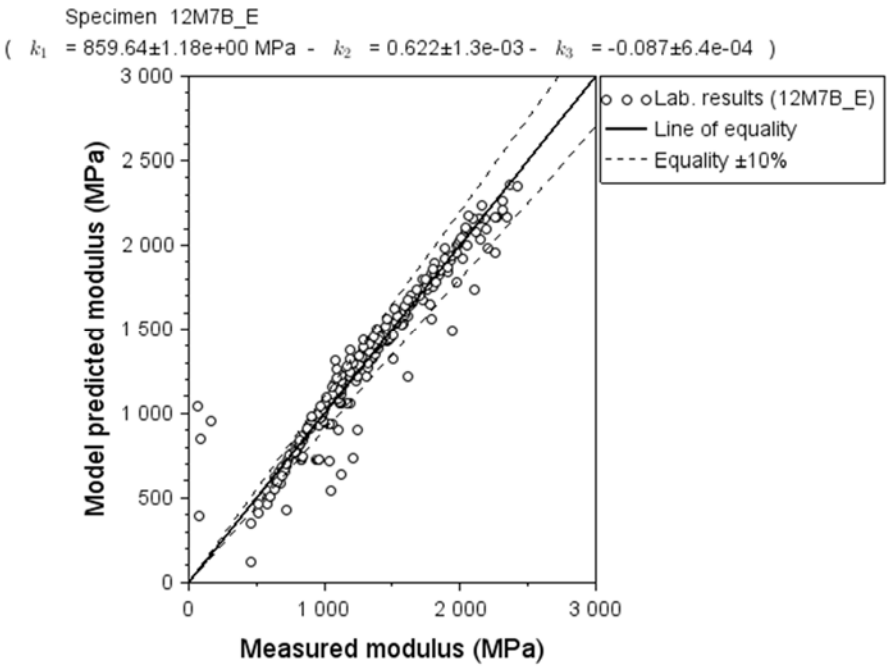


Figure C 55: Crushed limestone subbase sample 12M7C moduli variation with stress

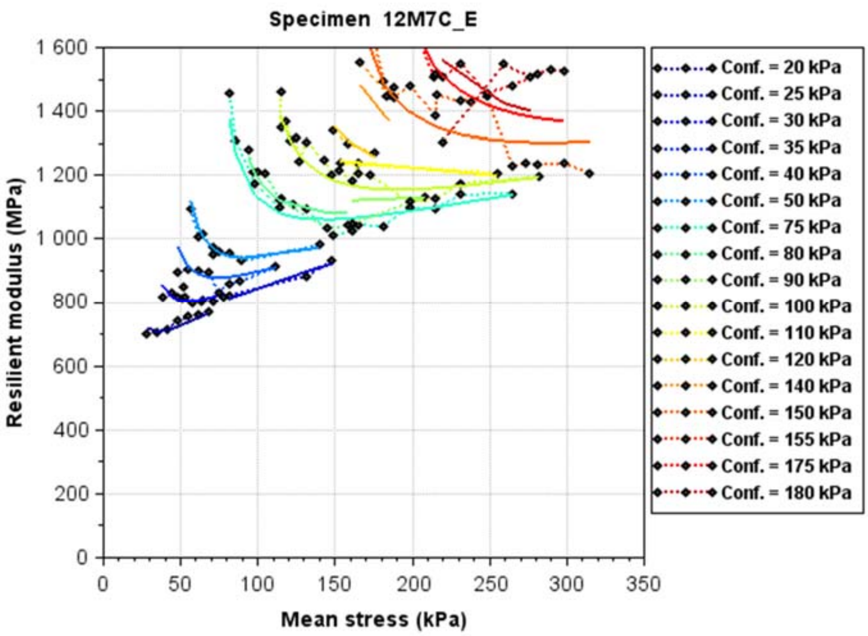


Figure C 56: Crushed limestone subbase sample 12M7C modulus prediction relationship and fit to the measured data

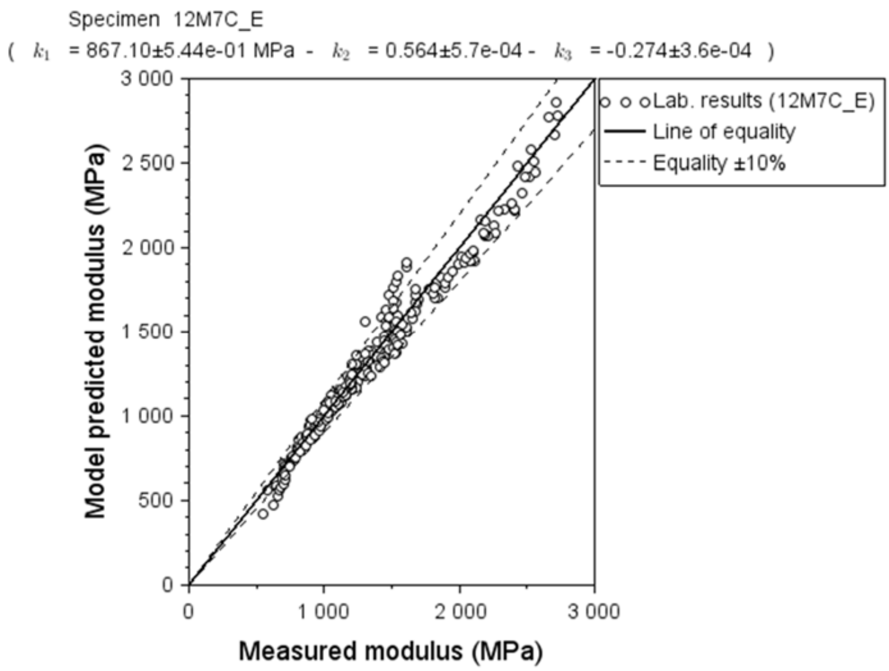


Figure C 57: Crushed limestone subbase sample 12M7D moduli variation with stress

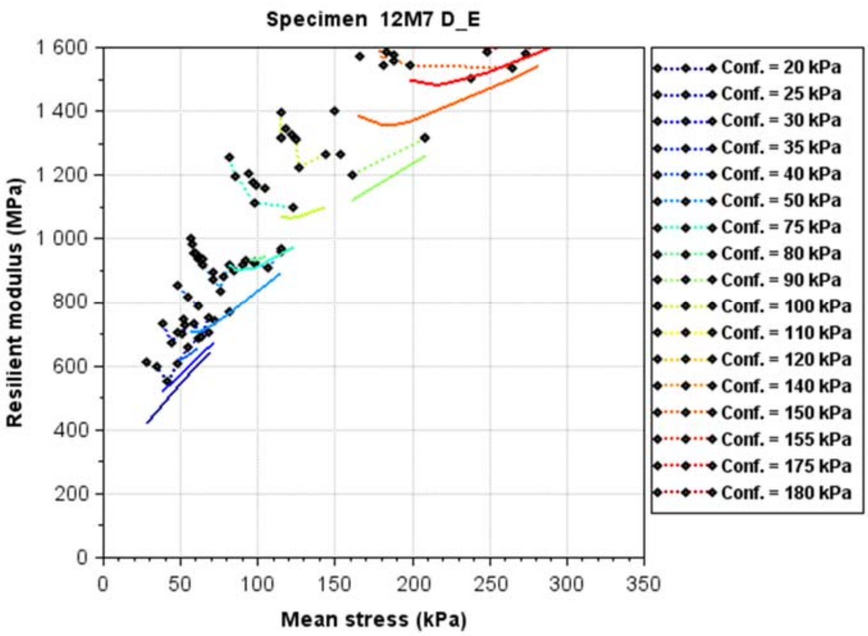


Figure C 58: Crushed limestone subbase sample 12M7D modulus prediction relationship and fit to the measured data

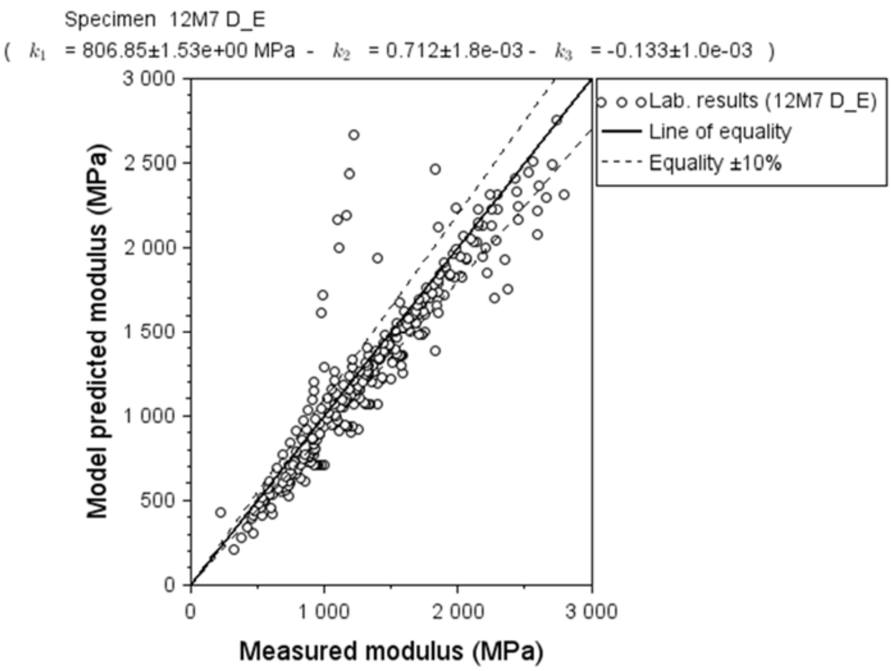


Figure C 59: Crushed limestone subbase sample 12M7G moduli variation with stress

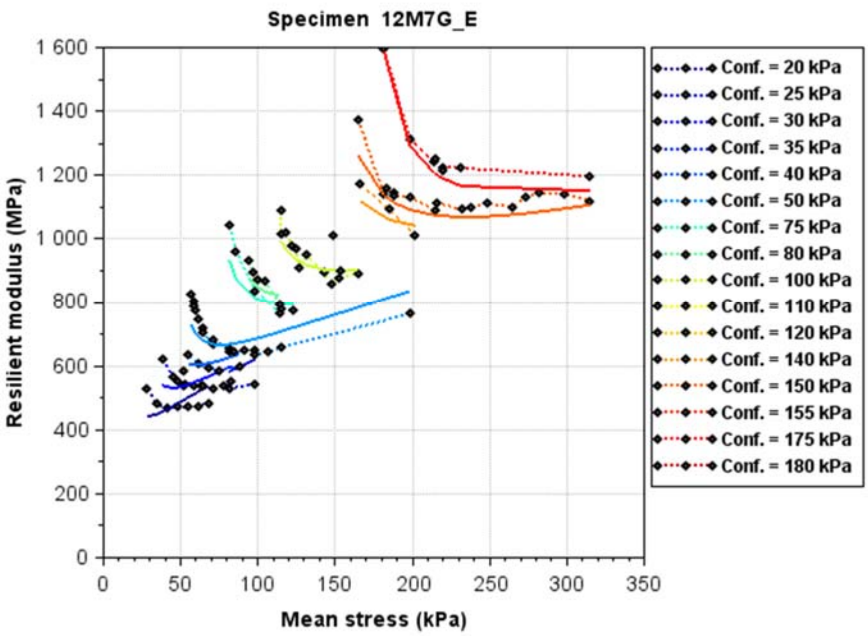


Figure C 60: Crushed limestone subbase sample 12M7G modulus prediction relationship and fit to the measured data

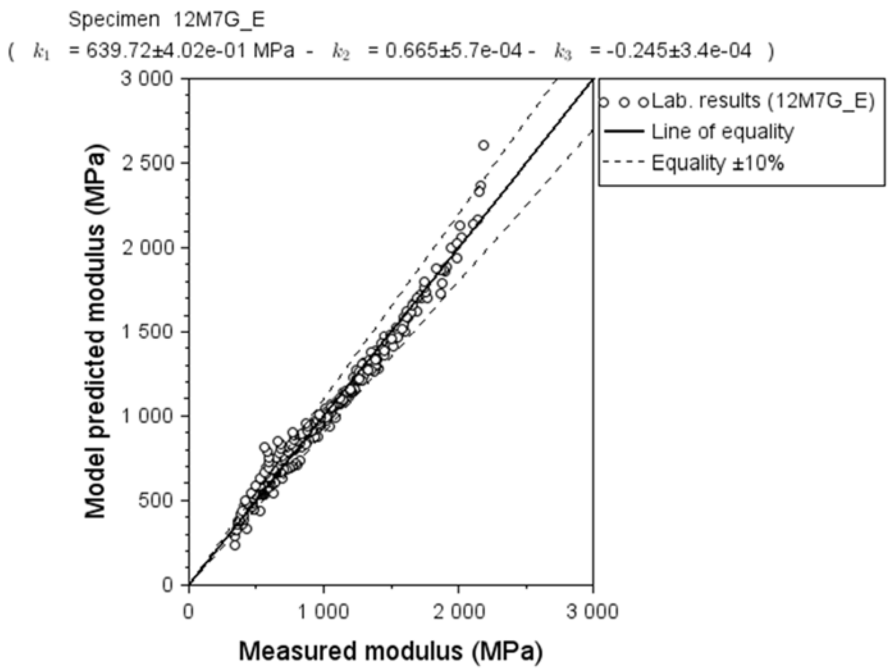


Figure C 61: Crushed limestone subbase sample 12M7l moduli variation with stress

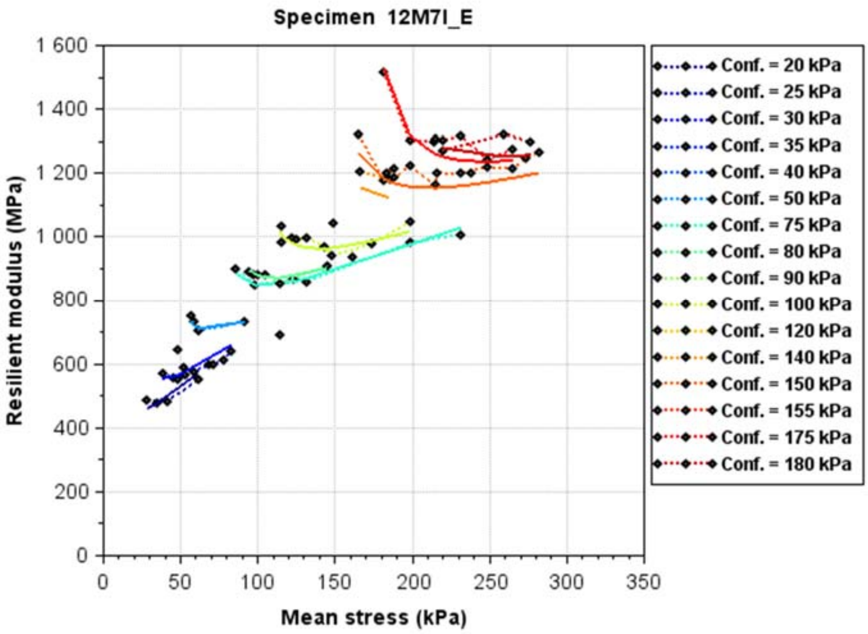


Figure C 62: Crushed limestone subbase sample 12M7l modulus prediction relationship and fit to the measured data

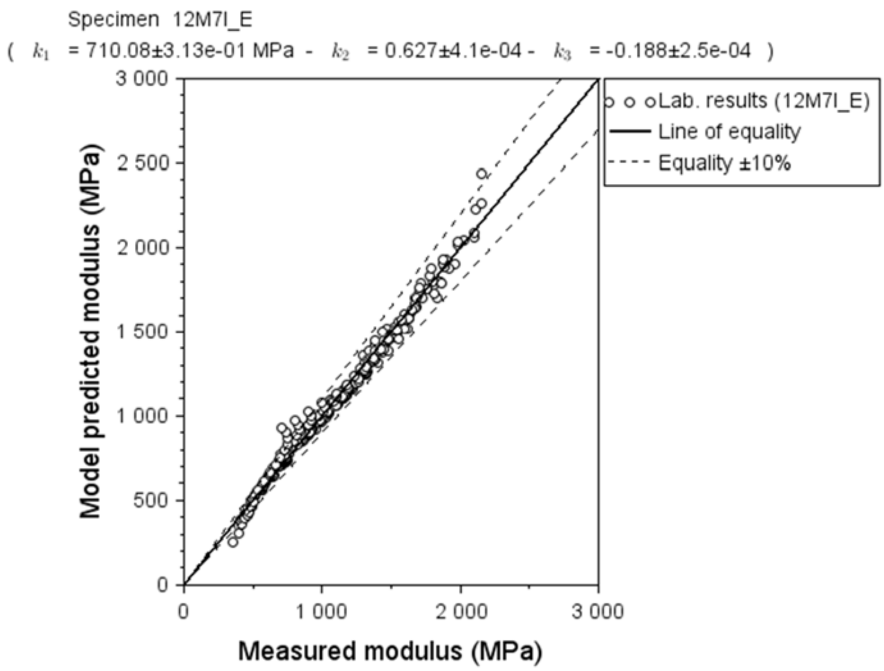


Figure C 63: Crushed limestone subbase sample 12M7J moduli variation with stress

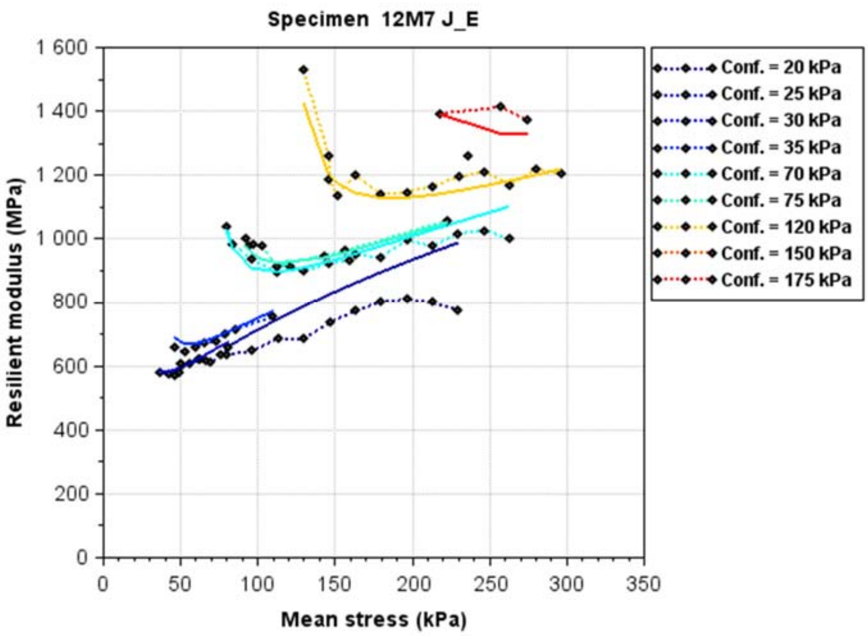


Figure C 64: Crushed limestone subbase sample 12M7J modulus prediction relationship and fit to the measured data

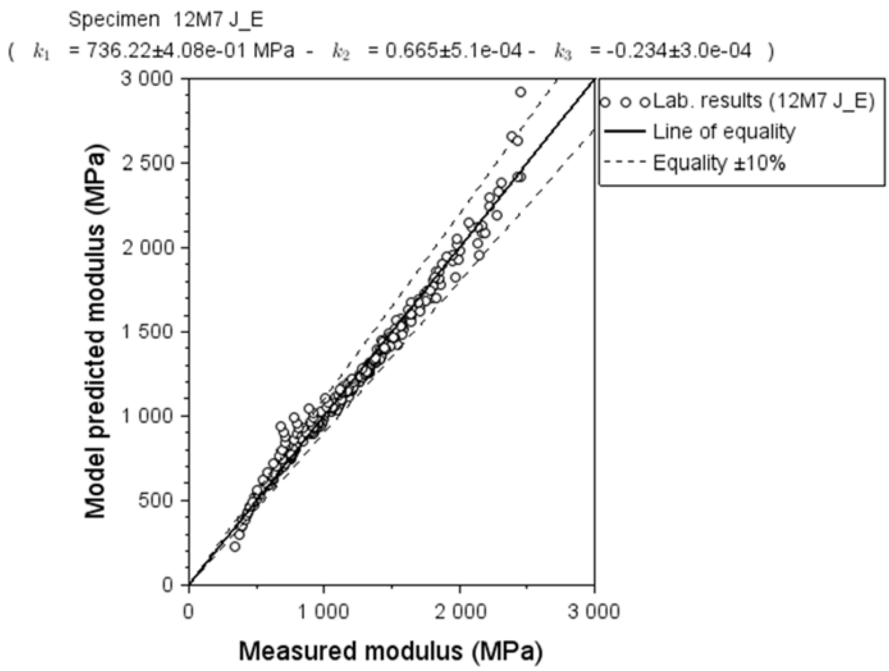


Figure C 65: Crushed limestone subbase sample 12M7L moduli variation with stress

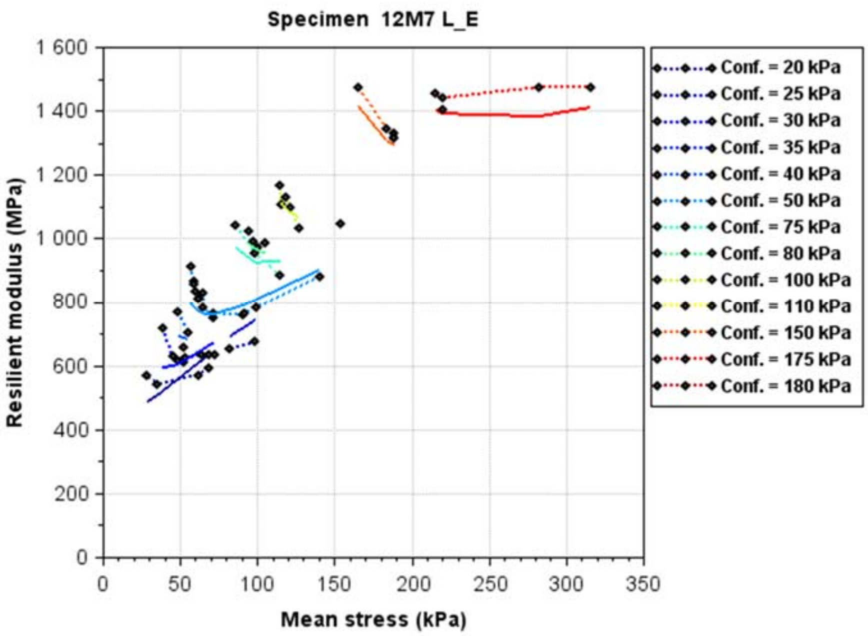
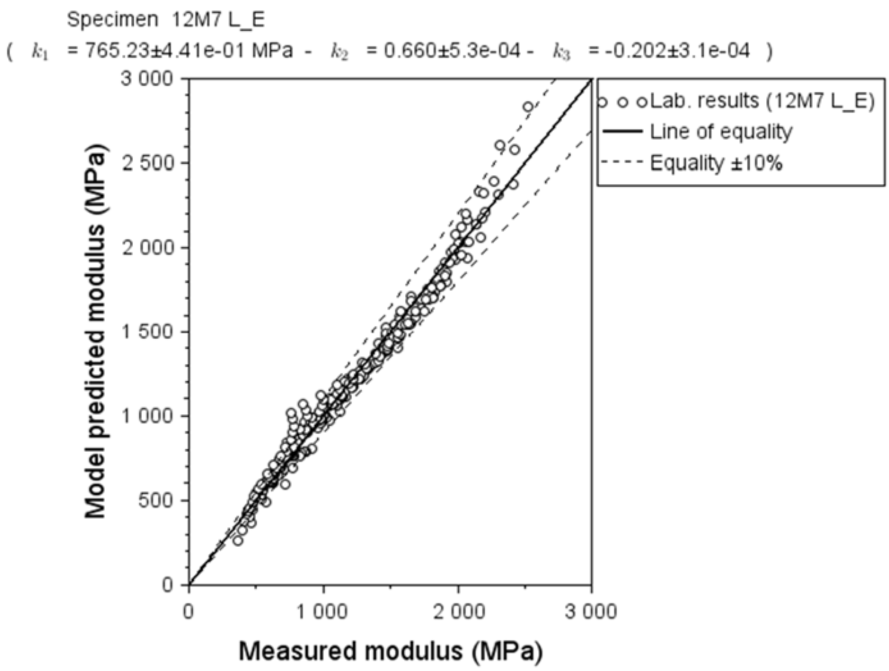


Figure C 66: Crushed limestone subbase sample 12M7L modulus prediction relationship and fit to the measured data



C.2.3 Summary of modulus stress-dependency relationships for the limestone subbase

Table C 4: Crushed limestone subbase modulus stress-dependency relationships

Maximum particle size (mm)	Laboratory number	Curing period out of mould (days)	Test density (t/m³)	Test moisture content (%)	Stress-dependency parameter		
					K_1	K_2	K_3
20 mm	12M7B	30	1.82	3.8	859.6	0.583	–0.184
	12M7C	31	1.82	3.8	871.5	0.522	–0.271
	12M7D	90	1.82	3.8	885.3	0.625	–0.109
	12M7G	28	1.82	4.4	605.5	0.696	–0.294
	12M7I	28	1.82	4.4	690.8	0.639	–0.204
	12M7J	92	1.82	4.4	691.3	0.707	–0.261
	12M7L	93	1.82	4.4	738.0	0.679	–0.235

C.3 Sand Subgrade

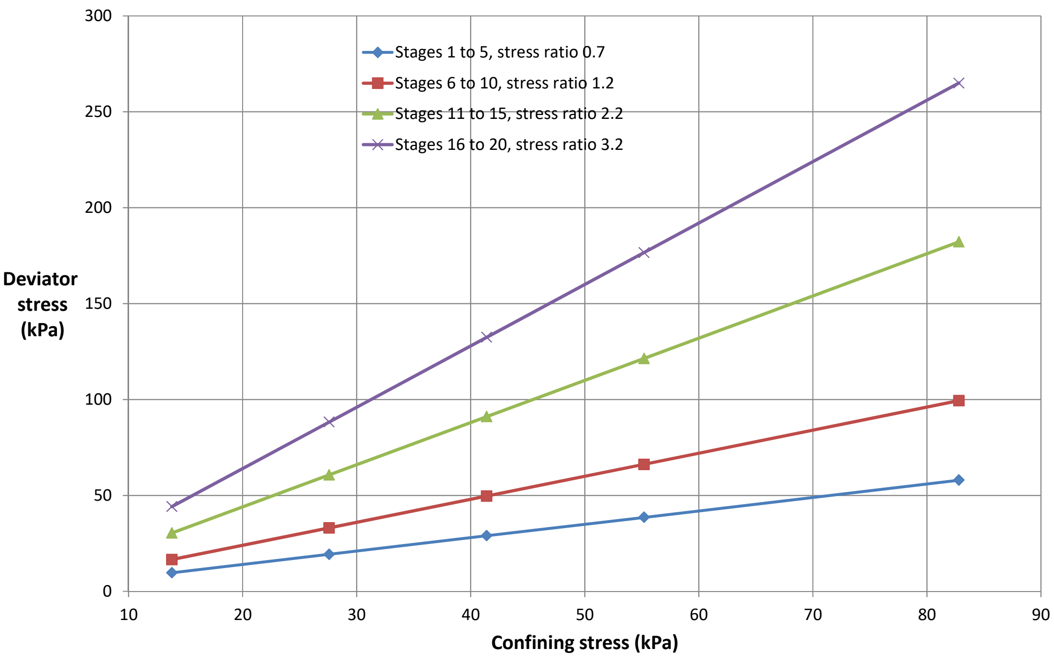
C.3.1 Introduction

As the current Austroads method for resilient modulus (Austroads 2007) is not applicable to subgrade materials a testing procedure needed to be developed for the sand subgrade.

In developing the procedure cognisance was taken of NCHRP Project 1-28A *Harmonized test methods for laboratory determination of resilient modulus for flexible pavement design* (NCHRP 2004). Key features of interest were:

- 1000 cycles of pre-conditioning at confining stress of about 30 kPa and deviator stress of about 60 kPa
- Followed by measurement of modulus by applying 100 cycles of loading at each of 20 stress states as illustrated in Figure C 67.

Figure C 67: NCHRP stress states for granular subgrades



Source: developed from data in NCHRP (2004)

C.3.2 Preconditioning and Stress stages

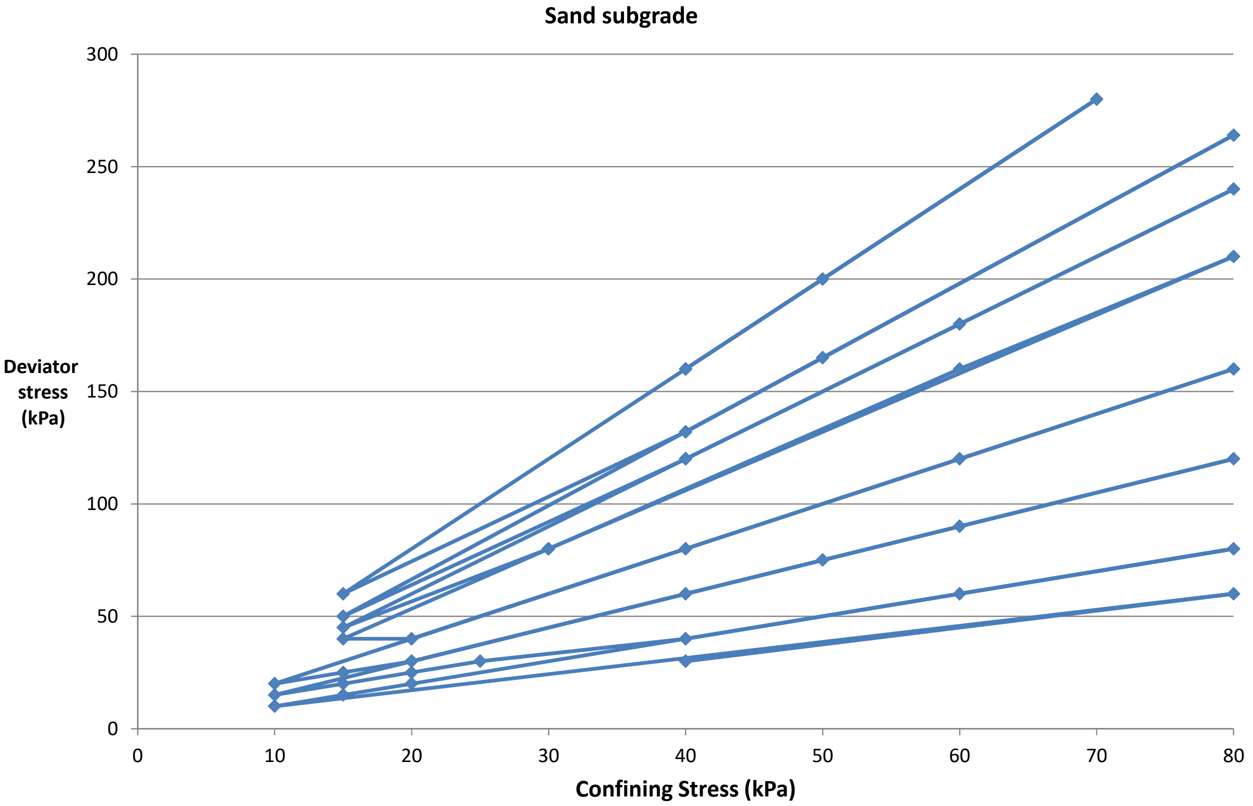
The pre-conditioning consisted of 1000 cycles at a deviator stress of 50 kPa and confining pressure of 50 kPa. This is same confining stress as in the Austroads test method (Austroads 2007) for basecourse and subbase materials, but the deviator stress is half the Austroads value.

The resilient modulus was then measured by applying 50 cycles of loading at each of 45 stress states listed in Table C 5 as illustrated in Figure C 68 . Whilst the range of deviator stresses and confining stresses applied are similar to the NCHRP values (Table C 5), the stress stages were extended to include a higher stress ratio (σ_d/σ_3) in later stages.

Table C 5: Stress stages used for sand subgrade

Stress stage number	Stress levels			Stress stage number	Stress levels		
	Confining stress σ_3 (kPa)	Deviator stress σ_d (kPa)	σ_d/σ_3		Confining stress σ_3 (kPa)	Deviator stress σ_d (kPa)	σ_d/σ_3
1	40	30	0.75	24	60	120	2.0
2	80	60	0.75	25	80	160	2.0
3	10	10	1.0	26	20	40	2.0
4	15	15	1.0	27	15	40	2.67
5	20	20	1.0	28	30	80	2.67
6	40	40	1.0	29	60	160	2.67
7	60	60	1.0	30	80	210	2.63
8	80	80	1.0	31	30	80	2.67
9	40	40	1.0	32	15	45	3.0
10	25	30	1.20	33	40	120	3.0
11	20	25	1.25	34	60	180	3.0
12	15	20	1.33	35	80	240	3.0
13	10	15	1.50	36	40	120	3.0
14	20	30	1.50	37	15	50	3.3
15	40	60	1.50	38	50	165	3.3
16	60	90	1.50	39	80	264	3.3
17	80	120	1.50	40	40	132	3.3
18	50	75	1.50	41	15	60	4.0
19	20	30	1.50	42	40	160	4.0
20	15	25	1.67	43	70	280	4.0
21	10	20	2.0	44	50	200	4.0
22	20	40	2.0	45	40	160	4.0
23	40	80	2.0				

Figure C 68: Sand subgrade modulus testing stress states



C.3.3 Sample size

The available repeat load triaxial test equipment met the requirements specified in Austroads test method for basecourse and subbase materials (Austroads 2007). The lowest deviator stress applied in this test is 100 kPa. For a 100 mm diameter specimen, a load of 800 N is required. MRWA have reported difficulty in obtaining a stable stress level at these low deviator stresses.

As the minimum applied deviator stress for the sand subgrade is considerably lower (10 kPa), it was decided to increase the diameter of the specimens to 150 mm, allowing the equipment to operate at more than twice the load level required for 100 mm diameter specimens.

C.3.4 Measured moduli of sand subgrade

Figure C 69: Sand subgrade sample 12M212-A moduli variation with stress

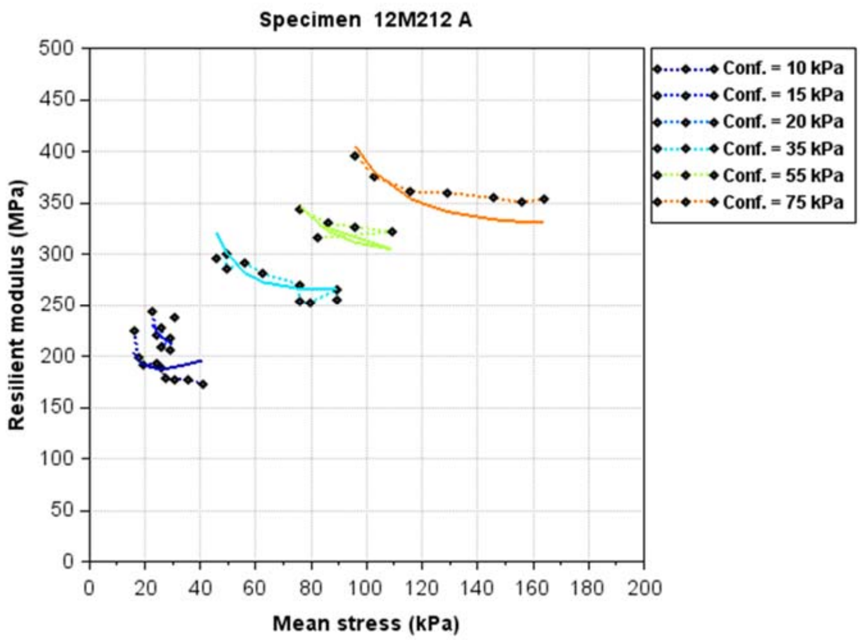
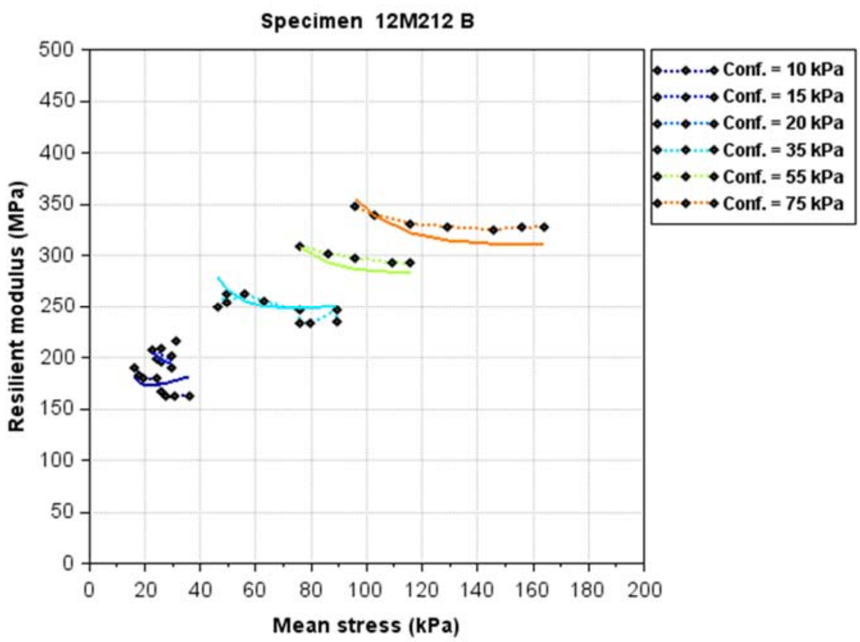


Figure C 70: Sand subgrade sample 12M212-B moduli variation with stress



C.3.5 Summary of modulus stress-dependency relationships for sand subgrade

Table C 6: Sand subgrade modulus stress-dependency relationships

Laboratory number	Curing period out of mould (days)	Test density (t/m^3)	Test moisture content (%)	Stress-dependency parameter		
				K_1	K_2	K_3
12M212A	28	1.73	2.28	244.8	0.766	–0.418
12M212B	28	1.80	2.33	291.2	0.330	–0.10

APPENDIX D ANALYIS INPUT VALUES

D.1 Finite Element Analysis (APADS) Inputs

Table D 1: Base specimen selected for predictions

Trial section No.	In situ condition			Closest lab sample				k1	k2	k3
	Material	Mean moisture content (%)	Mean dry density (t/m^3)	Sample No.	Cure time (days)	Test moisture content (%)	Test dry density (t/m^3)			
2	Crushed rock base	2.8	2.32	09M276AF	28	2.8	2.27	383.1	1.000	–0.438
3	Crushed rock base	2.8	2.31	09M276AF	28	2.8	2.27	383.1	1.000	–0.438
4	Ferricrete	6.0	2.45	09M283A1	35	6.0	2.43	522.0	0.712	–0.14
5	G1 crushed rock base	3.0	2.59	09M260A1	32	3.1	2.51	331.9	0.81	–0.22
6	HCTCRB	5.9	2.23	Lot120 70%-A	28	5.8	2.11	473.3	0.69	–0.20
7	HCTCRB	5.3	2.23	Lot120 70%-A	28	5.8	2.11	473.3	0.69	–0.20
8	HCTCRB	5.9	2.23	Lot120 70%-A	28	5.8	2.11	473.3	0.69	–0.20
9	HCTCRB	5.3	2.23	Lot120 70%-B	29	5.8	2.11	464.7	0.83	–0.27
10	HCTCRB	5.1	2.23	Lot120 70%-B	29	5.8	2.11	464.7	0.83	–0.27
12	Bitumen stabilised limestone	5.2	1.90	09M262A	29	5.2	1.91	326.2	0.88	–0.27
13	Crushed recycled concrete	10.5	1.97	09M304A5	76	10.6	1.91	439.6	0.76	–0.31
14	HCTCRB	5.5	2.21	Lot120 70%-B	29	5.8	2.11	464.7	0.83	–0.27

Table D 2: Crushed limestone subbase selected specimen for predictions

Trial section no.	In situ condition		Closest lab sample				k1	k2	k3
	Mean moisture content (%)	Mean dry density (t/m³)	Sample No.	Cure time (days)	Test moisture content (%)	Test dry density (t/m³)			
2	3.8	1.90	12M7C	31	3.8	1.82	859.9	0.569	–0.274
3	4.4	1.90	Combined 12M7G+12M7I	28	4.4	1.82	645.5	0.683	–0.234
4	4.2	1.92	12M7B	30	3.8	1.82	859.6	0.583	–0.184
5	3.8	1.89	12M7C	31	3.8	1.82	859.9	0.569	–0.274
6	4.0	1.88	12M7C	31	3.8	1.82	859.9	0.569	–0.274
7	3.9	1.86	12M7C	31	3.8	1.82	859.9	0.569	–0.274
8	3.9	1.87	12M7C	31	3.8	1.82	859.9	0.569	–0.274
9	4.1	1.86	12M7C	31	3.8	1.82	859.9	0.569	–0.274
10	3.2	1.85	12M7B	31	3.8	1.82	859.9	0.569	–0.274
12	6.0	1.90	12M7B	28	4.4	1.82	605.0	0.710	–0.278
13	5.6	1.88	12M7G	28	4.4	1.82	605.0	0.710	–0.278
14	4.0	na	12M7C	31	3.8	1.82	859.9	0.569	–0.274

Table D 3: Sand subgrade specimens selected for predictions

Trial section no.	Sand subgrade		Closest lab sample				k1	k2	k3
	Mean moisture content (%)	Mean dry density (t/m^3)	Sample No.	Cure time (days)	Test moisture content (%)	Test dry density (t/m^3)			
2	2.6	1.77	12M212B	28	2.3	1.80	291.2	0.330	–0.104
3	2.5	1.77	12M212B	28	2.3	1.80	291.2	0.330	–0.104
4	2.5	1.75	12M212B	28	2.3	1.80	291.2	0.330	–0.104
5	2.1	1.77	12M212A	28	2.3	1.73	244.8	0.766	-0.418
6	2.4	1.80	12M212B	28	2.3	1.80	291.2	0.330	–0.104
7	2.1	1.80	12M212A	28	2.3	1.73	244.8	0.766	–0.418
8	2.4	1.74	12M212B	28	2.3	1.80	291.2	0.330	–0.104
9	2.4	1.76	12M212B	28	2.3	1.80	291.2	0.330	–0.104
10	2.0	1.76	12M212A	28	2.3	1.73	244.8	0.766	–0.418
12	3.9	1.77	12M212	28	2.3	1.80	291.2	0.330	–0.104
13	3.4	1.81	12M212	28	2.3	1.80	291.2	0.330	–0.104
14	2.7	1.85	12M212	28	2.3	1.80	291.2	0.330	–0.104

Table D 4: Finite element input data

Trial section number	Material	Thickness (mm)	Bulk density (t/m³)	Modulus stress dependency			Emin (MPa)	Emax (MPa)	Poisson's ratio	Residual compaction stress (kPa)
				K1 (MPa)	K2	K3				
2	Crushed rock base	160	2.27	383.1	1.000	-0.438	50	1000	0.35	40
	Limestone subbase	250	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.330	-0.104	10	150	0.35	0
3	Crushed rock base	255	2.27	383.1	1.000	-0.438	50	1000	0.35	40
	Limestone subbase	160	1.82	645.5	0.683	-0.234	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.330	-0.104	10	150	0.35	0
4	Ferricrete	260	2.43	522.0	0.712	-0.135	50	1000	0.35	40
	Limestone subbase	165	1.82	859.6	0.583	-0.184	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.330	-0.104	10	150	0.35	0
5	G1 base	255	2.51	331.9	0.810	-0.220	50	1000	0.35	40
	Limestone subbase	175	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.73	244.8	0.776	-0.418	10	150	0.35	0
6	HCTCRB	255	2.11	473.3	0.690	-0.200	50	1000	0.35	40
	Limestone subbase	140	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.330	-0.104	10	150	0.35	0
7	HCTCRB	255	2.11	473.3	0.690	-0.200	50	1000	0.35	40
	Limestone subbase	160	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	244.8	0.766	-0.418	10	150	0.35	0
8	HCTCRB	255	2.11	473.3	0.690	-0.200	50	1000	0.35	40
	Limestone subbase	145	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.330	-0.104	10	150	0.35	0
9	HCTCRB	255	2.11	464.7	0.830	-0.270	50	1000	0.35	40

Trial section number	Material	Thickness (mm)	Bulk density (t/m^3)	Modulus stress dependency K1 (MPa)	K2	K3	Emin (MPa)	Emax (MPa)	Poisson's ratio	Residual compaction stress (kPa)
	Limestone subbase	145	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.330	-0.104	10	150	0.35	0
10	HCTCRB	290	2.11	464.7	0.830	-0.270	50	1000	0.35	40
	Limestone subbase	125	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	244.8	0.766	-0.418	10	150	0.35	0
12	BSL	265	2.11	326.2	0.880	-0.274	50	1000	0.35	40
	Limestone subbase	155	1.82	859.6	0.583	-0.184	50	1000	0.35	40
	Sand subgrade	0	1.73	291.2	0.330	-0.104	10	150	0.35	0
13	Crushed concrete	270	1.91	439.6	0.760	-0.314	50	1000	0.35	40
	Limestone subbase	160	1.82	605.0	0.710	-0.278	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.323	-0.104	10	150	0.35	0
14	HCTCRB	258	1.91	464.7	0.830	-0.270	50	1000	0.35	40
	Limestone subbase	173	1.82	859.9	0.569	-0.274	50	1000	0.35	40
	Sand subgrade	0	1.74	291.2	0.323	-0.104	10	150	0.35	0

D.2 Linear Elastic Analysis (CIRCLY) Inputs

Table D 5: CIRCLY input data – Case 0 to 3

Trial section no.	Material	Contact stress (kPa)	Thickness (mm)	Case 0 – AGPT Part 2 (2012) presumptive granular modulus, subgrade modulus 120 MPa			Case 1 – MRWA presumptive granular modulus, subgrade modulus 120 MPa			Case 2 – measured granular modulus, subgrade modulus 120 MPa			Case 3 – measured granular modulus, subgrade modulus 150 MPa		
				Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)
2	Crushed rock base Limestone subbase	566/700	410	500 (sublayered)	0.35	370	600 (sublayered)	0.35	444	848 (sublayered)	0.35	628	848 (sublayered)	0.35	628
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
3	Crushed rock base Limestone subbase	566/700	415	500 (sublayered)	0.35	370	600 (sublayered)	0.35	444	848 (sublayered)	0.35	628	848 (sublayered)	0.35	628
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
4	Ferricrete Limestone subbase	566/700	425	500 (sublayered)	0.35	370	800 (sublayered)	0.35	593	950 (sublayered)	0.35	704	950 (sublayered)	0.35	704
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
5	G1 base Limestone subbase	566/700	430	500 (sublayered)	0.35	370	500 (sublayered)	0.35	370	646 (sublayered)	0.35	478	646 (sublayered)	0.35	478

Trial section no.	Material	Contact stress (kPa)	Thickness (mm)	Case 0 – AGPT Part 2 (2012) presumptive granular modulus, subgrade modulus 120 MPa			Case 1 – MRWA presumptive granular modulus, subgrade modulus 120 MPa			Case 2 – measured granular modulus, subgrade modulus 120 MPa			Case 3 – measured granular modulus, subgrade modulus 150 MPa		
				Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
6	HCTCRB	566/700													
	Limestone subbase		395	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	831 (sublayered)	0.35	616	831 (sublayered)	0.35	616
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
7	HCTCRB	566/700													
	Limestone subbase		415	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	831 (sublayered)	0.35	616	831 (sublayered)	0.35	616
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
8	HCTCRB	566/700													
	Limestone subbase		400	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	831 (sublayered)	0.35	616	831 (sublayered)	0.35	616
	Sand Subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
9	HCTCRB	566/700													
	Limestone subbase		415	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	914 (sublayered)	0.35	677	914 (sublayered)	0.35	677
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111

Trial section no.	Material	Contact stress (kPa)	Thickness (mm)	Case 0 – AGPT Part 2 (2012) presumptive granular modulus, subgrade modulus 120 MPa			Case 1 – MRWA presumptive granular modulus, subgrade modulus 120 MPa			Case 2 – measured granular modulus, subgrade modulus 120 MPa			Case 3 – measured granular modulus, subgrade modulus 150 MPa		
				Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)	Vertical modulus (MPa)	Poisson's ratio	f (shear)
10	HCTCRB	566/700	420	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	914 (sublayered)	0.35	677	914 (sublayered)	0.35	677
	Limestone subbase														
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
12	BSL	566/700	430	500 (sublayered)	0.35	370	500 (sublayered)	0.35	370	670 (sublayered)	0.35	497	670 (sublayered)	0.35	497
	Limestone subbase														
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
13	Crushed concrete	566/700	431	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	807 (sublayered)	0.35	598	807 (sublayered)	0.35	598
	Limestone subbase														
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111
14	HCTCRB	566/700	425	500 (sublayered)	0.35	370	1000 (sublayered)	0.35	741	914 (sublayered)	0.35	677	914 (sublayered)	0.35	677
	Limestone subbase														
	Sand subgrade		NA	120	0.35	89	120	0.35	89	120	0.35	89	150	0.35	111

APPENDIX E DEFLECTION RESULTS

E.1 Section 2 – Crushed Rock Base

Figure E 1: Deflection comparisons 566 kN load - Section 2

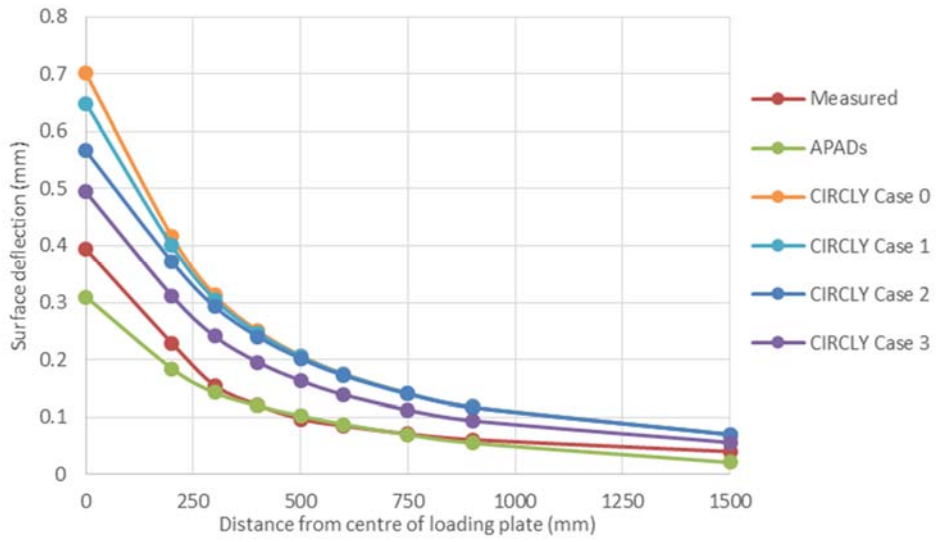
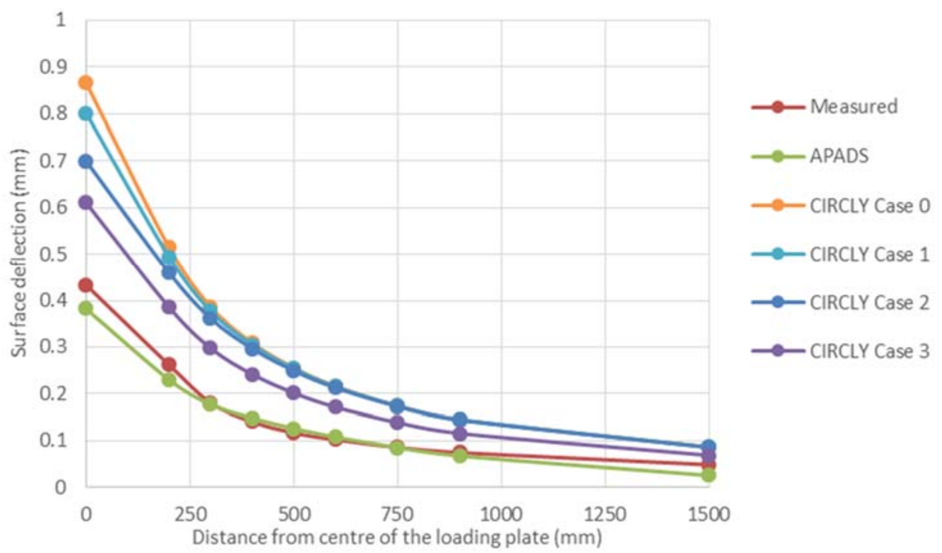


Figure E 2: Deflection comparisons 700 kN load - Section 2



E.2 Section 3 – Crushed Rock Base

Figure E 3: Deflection comparisons 566 kN load - Section 3

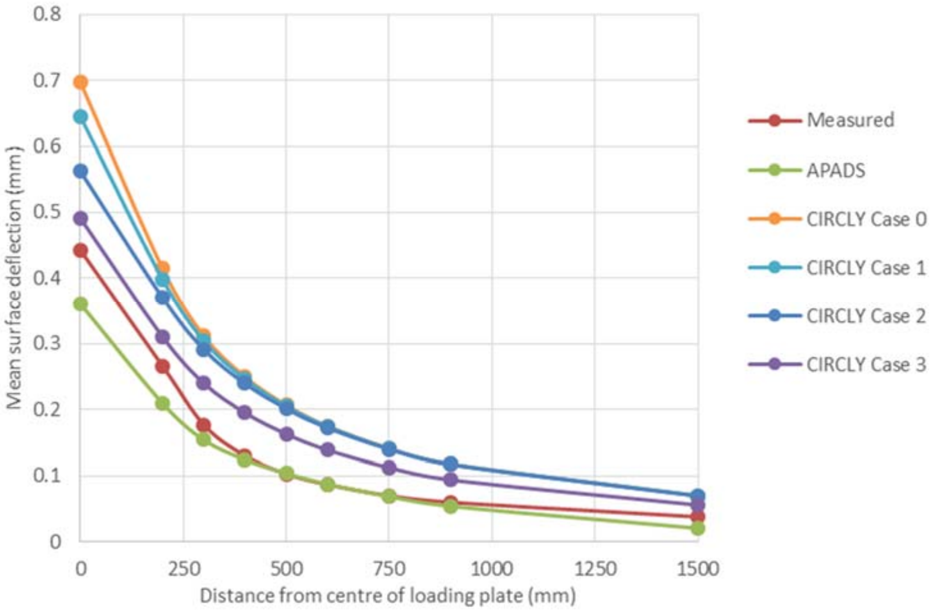
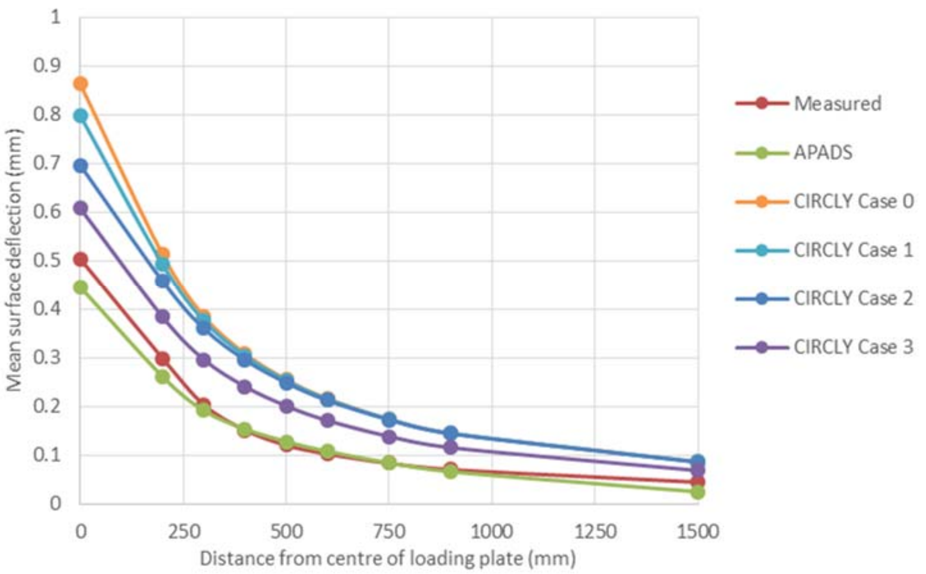


Figure E 4: Deflection comparisons 700 kN load - Section 3



E.3 Section 4 – Ferricrete

Figure E 5: Deflection comparisons 566 kN load - Section 4

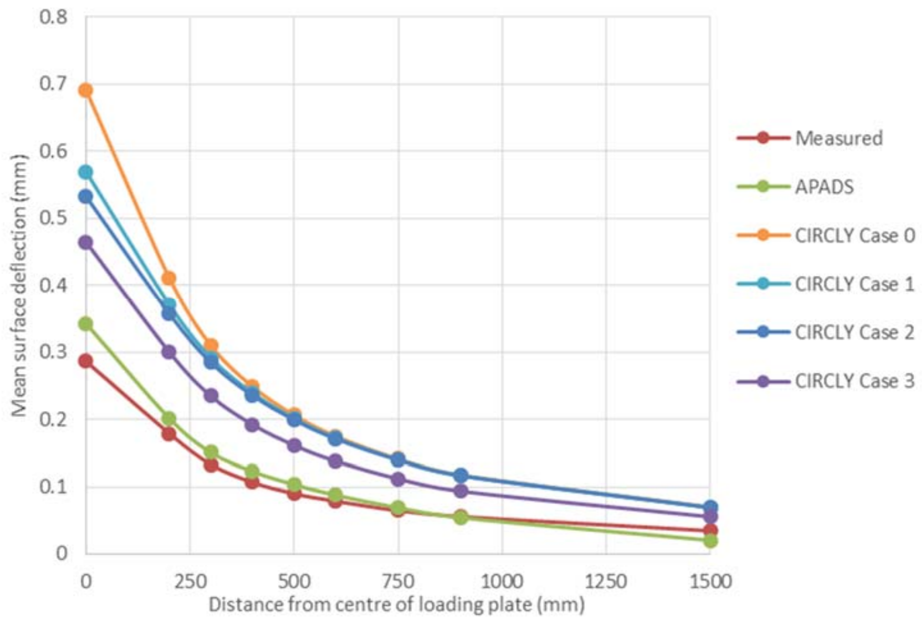
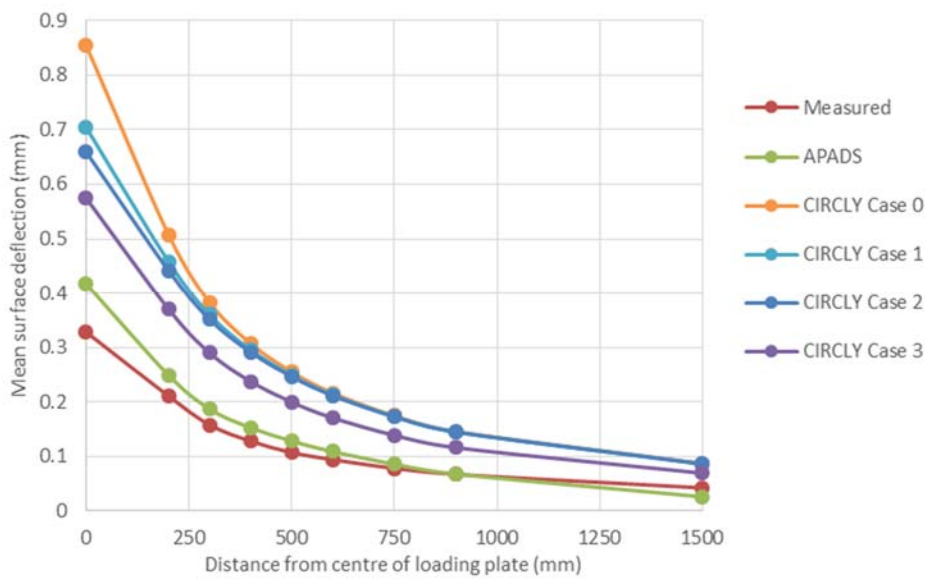


Figure E 6: Deflection comparisons 700 kN load - Section 4



E.4 Section 5 – G1 Crushed Rock Base

Figure E 7: Deflection comparisons 566 kN load - Section 5

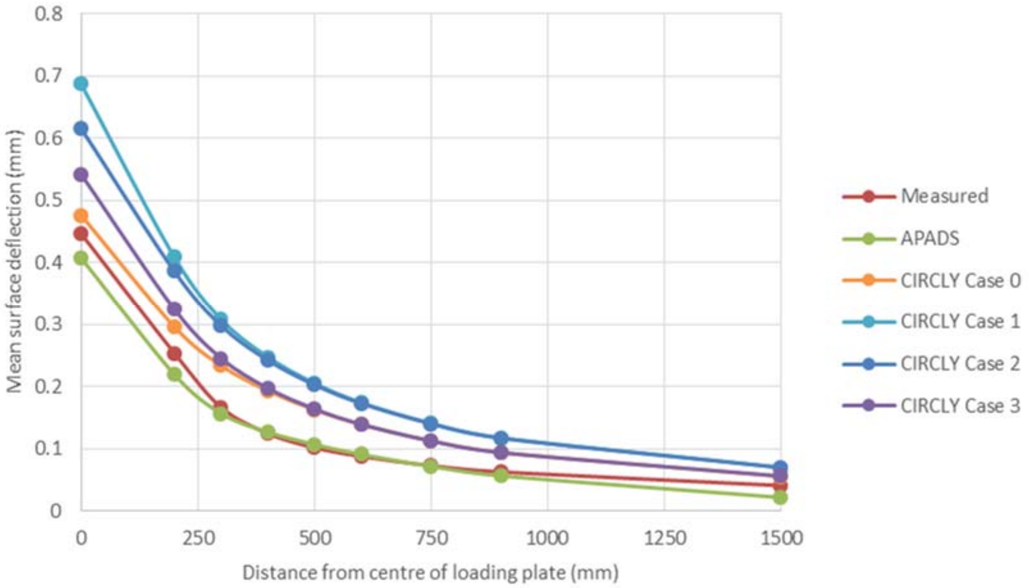
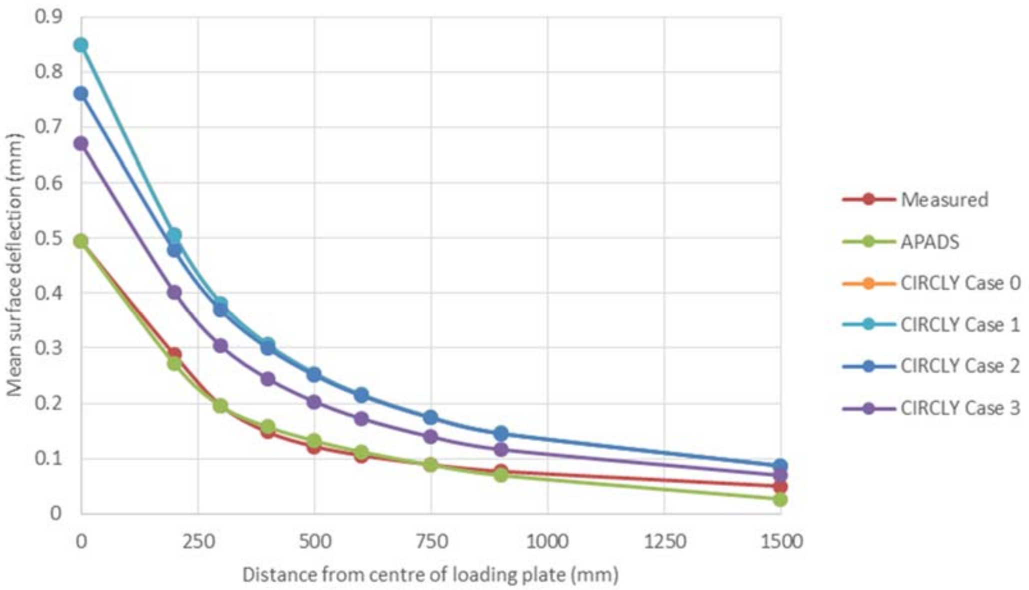


Figure E 8: Deflection comparisons 700 kN load - Section 5



E.5 Section 6 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Figure E 9: Deflection comparisons 566 kN load - Section 6

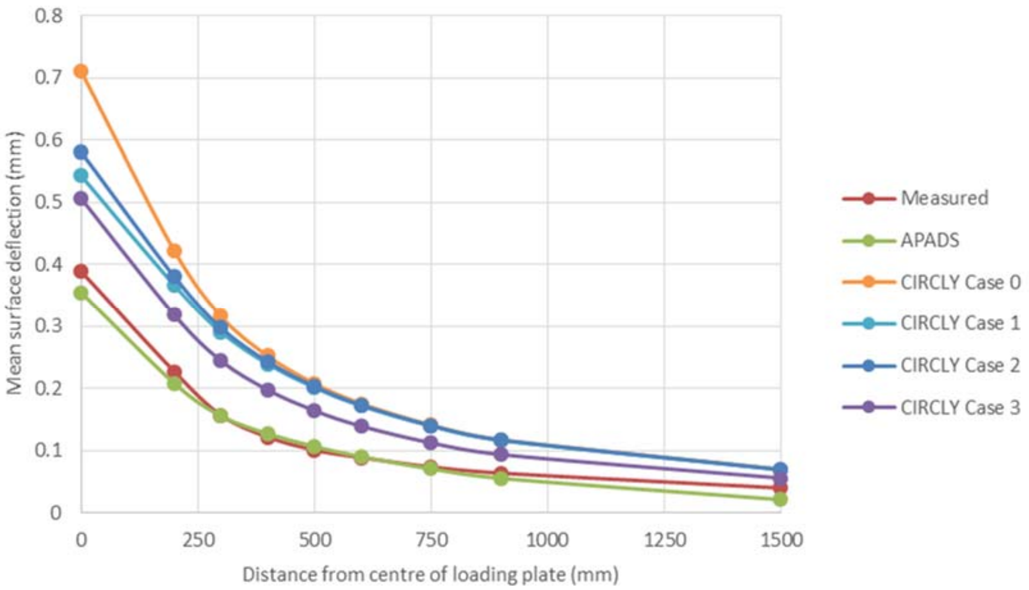
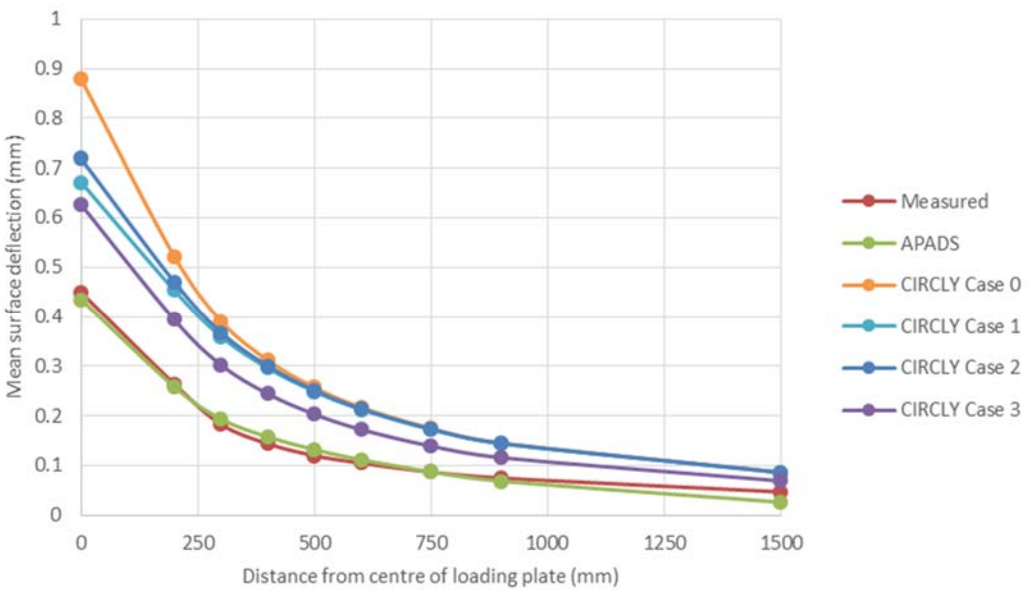


Figure E 10: Deflection comparisons 700 kN load - Section 6



E.6 Section 7 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Figure E 11: Deflection comparisons 566 kN load – Section 7

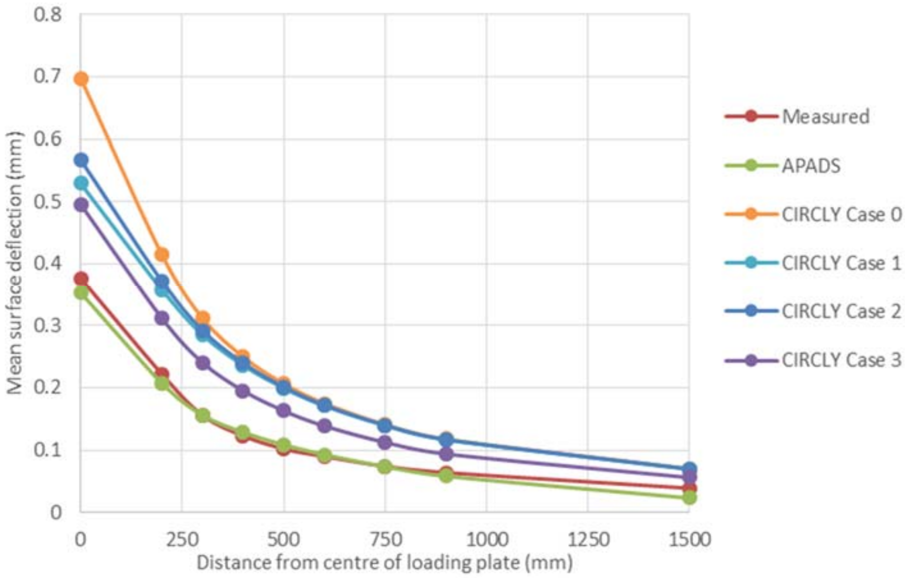
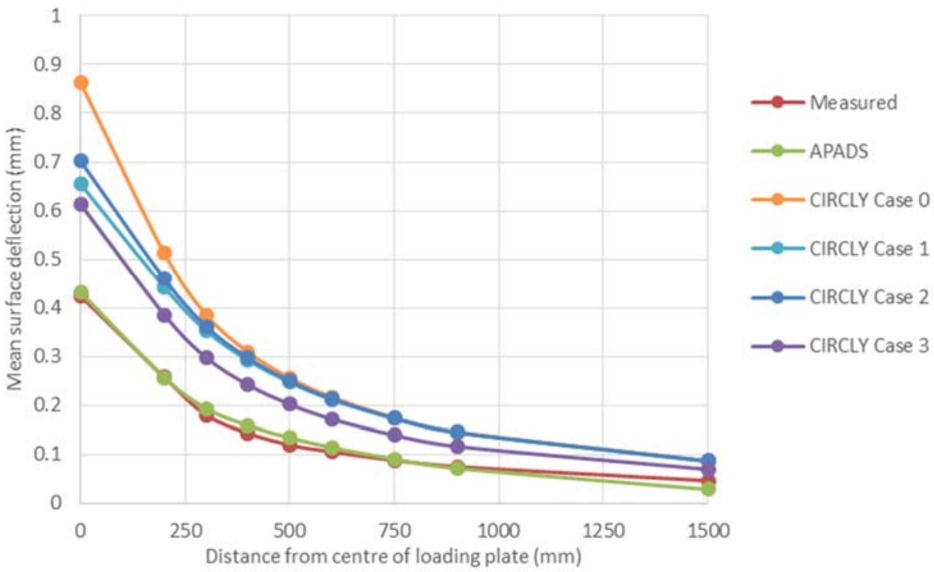


Figure E 12: Deflection comparisons 700 kN load - Section 2



E.7 Section 8 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Figure E 13: Deflection comparisons 566 kN load - Section 8

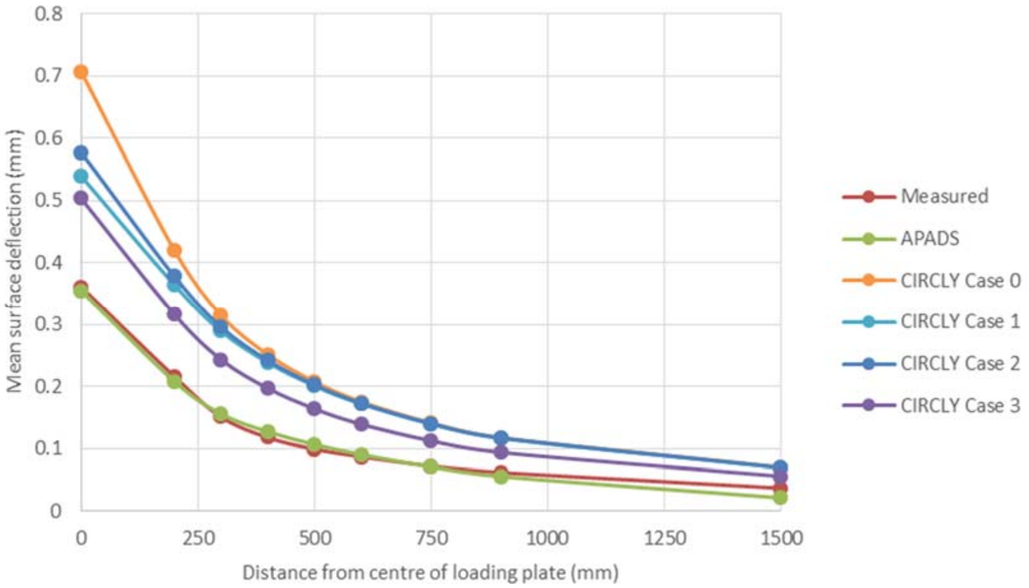
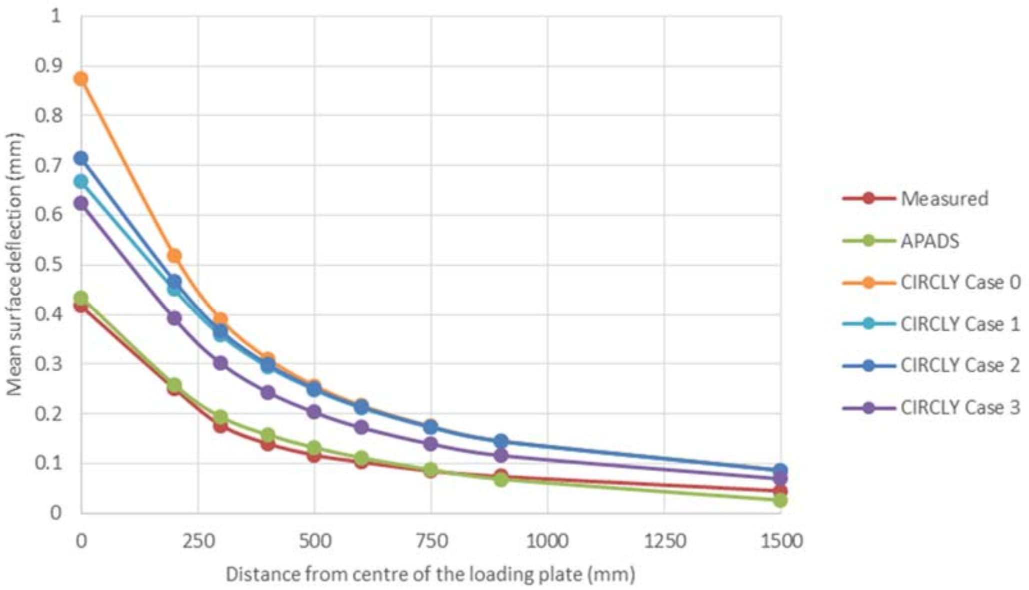


Figure E 14: Deflection comparisons 700 kN load - Section 8



E.8 Section 9 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Figure E 15: Deflection comparisons 566 kN load - Section 9

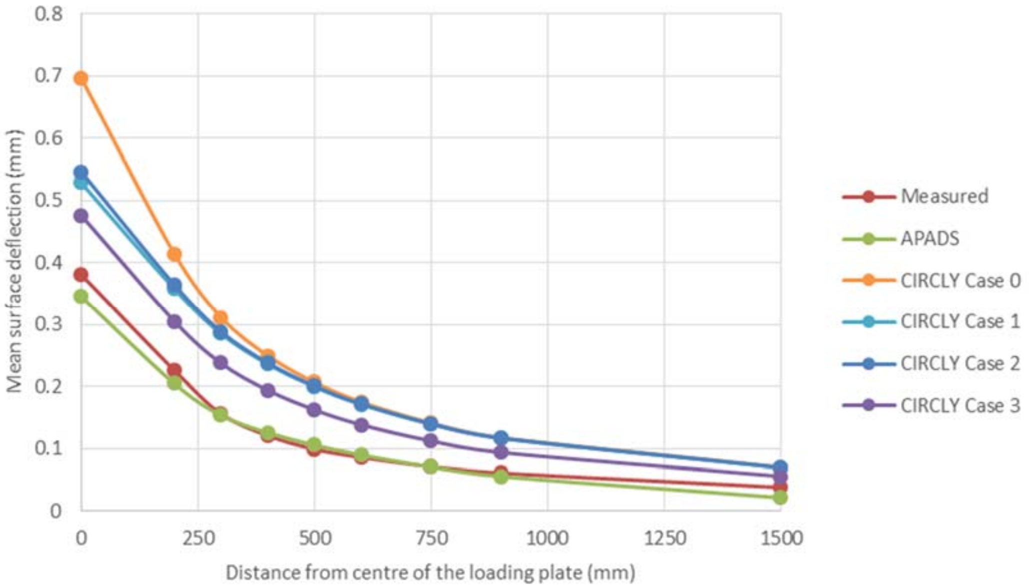
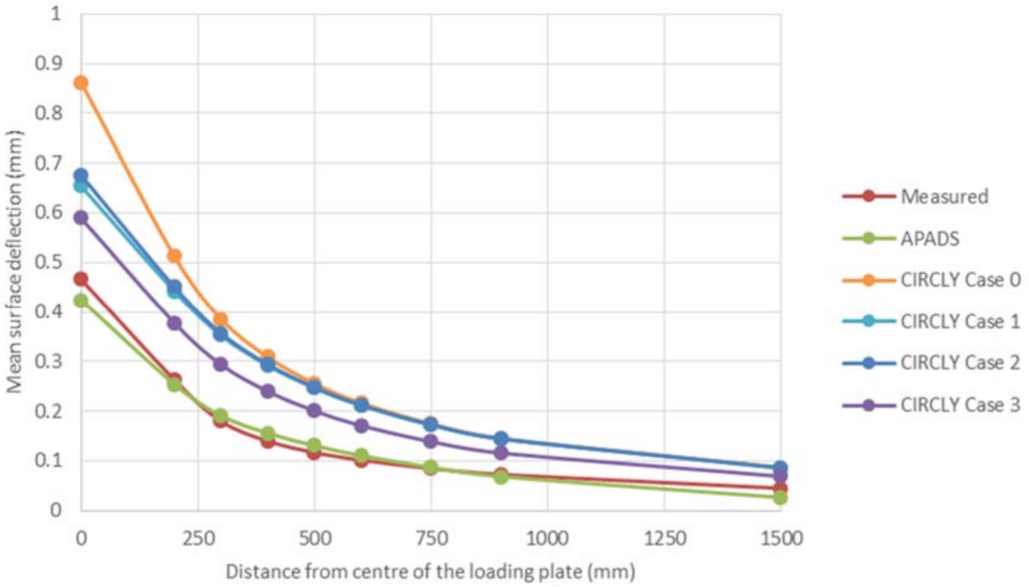


Figure E 16: Deflection comparisons 700 kN load - Section 9



E.9 Section 10 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Figure E 17: Deflection comparisons 566 kN load - Section 10

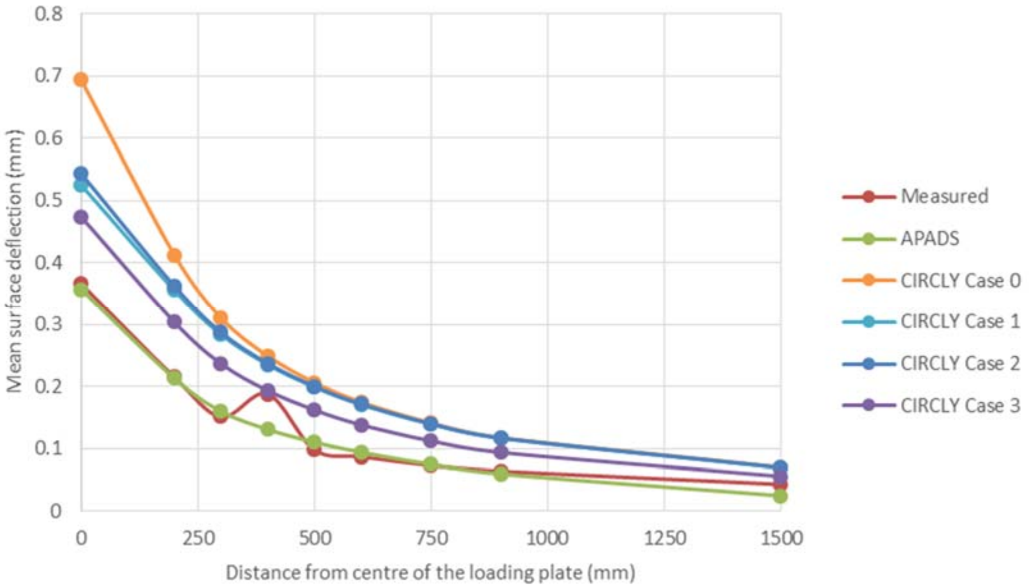
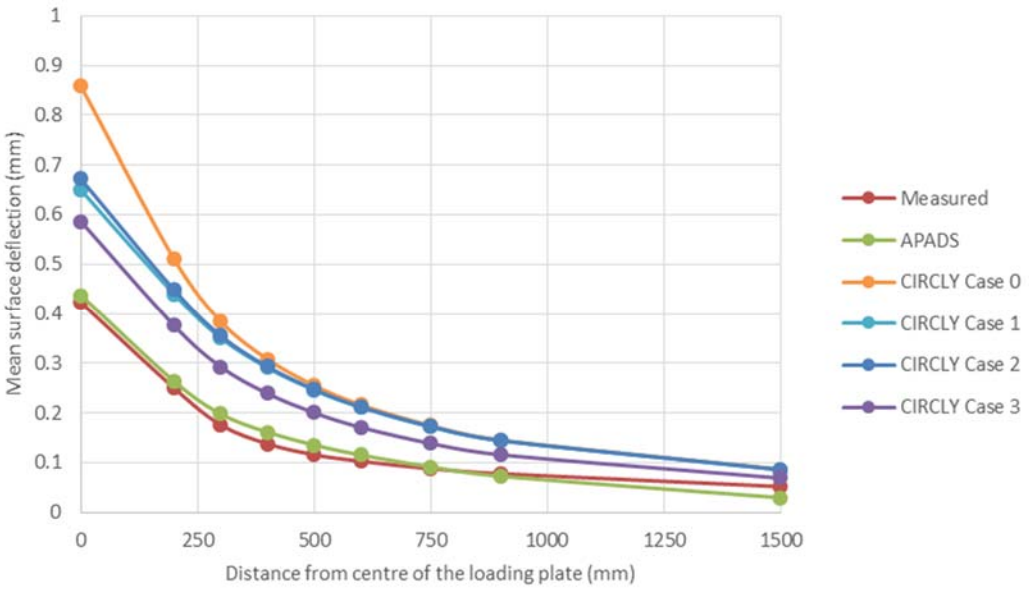


Figure E 18: Deflection comparisons 700 kN load - Section 10



E.10 Section 12 – Bitumen Stabilised Limestone Base

Figure E 19: Deflection comparisons 566 kN load – Section 12

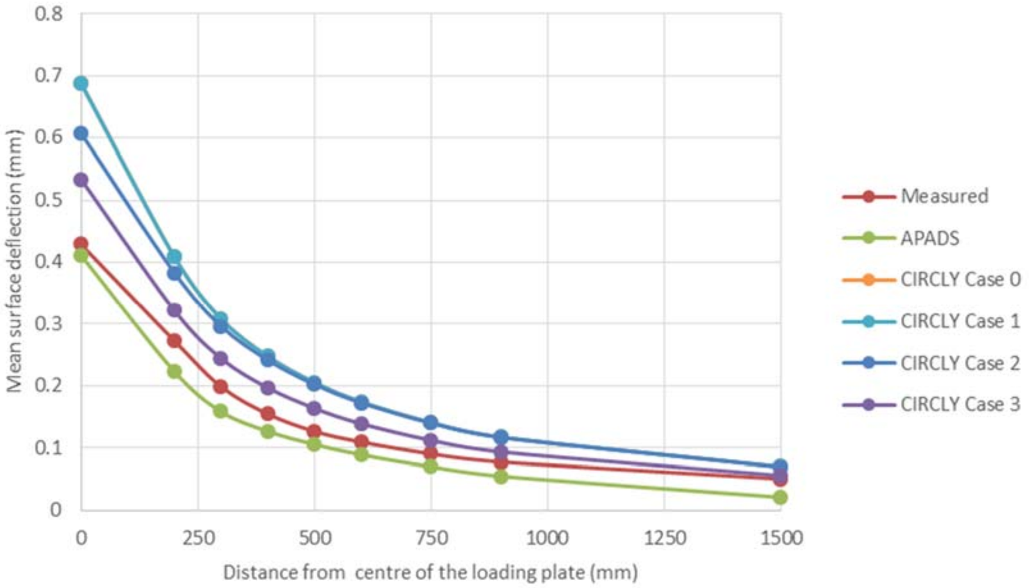
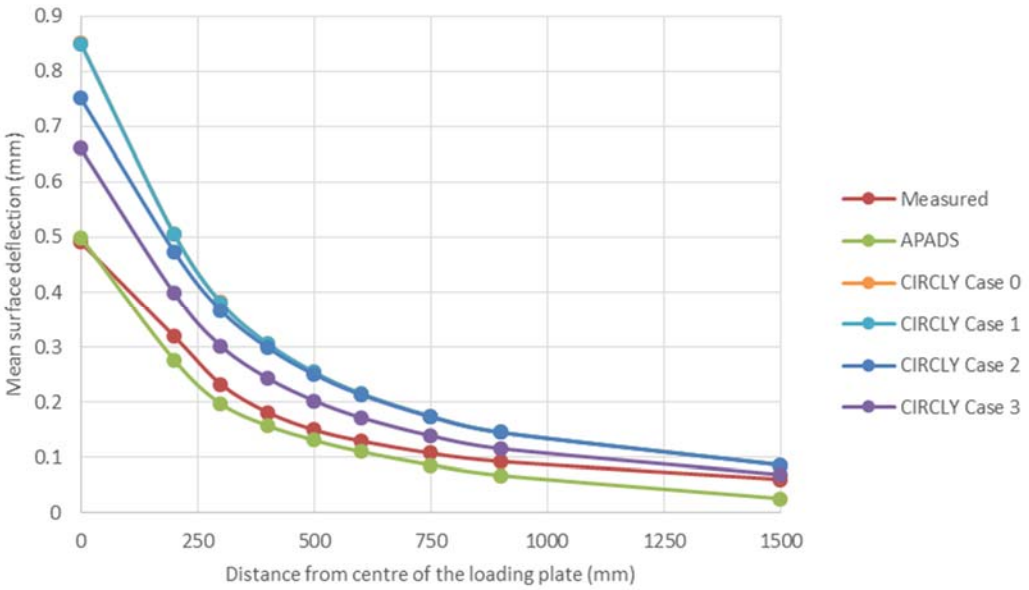


Figure E 20: Deflection comparisons 700 kN load - Section 12



E.11 Section 13 – Crushed Recycled Concrete

Figure E 21: Deflection comparisons 566 kN load - Section 13

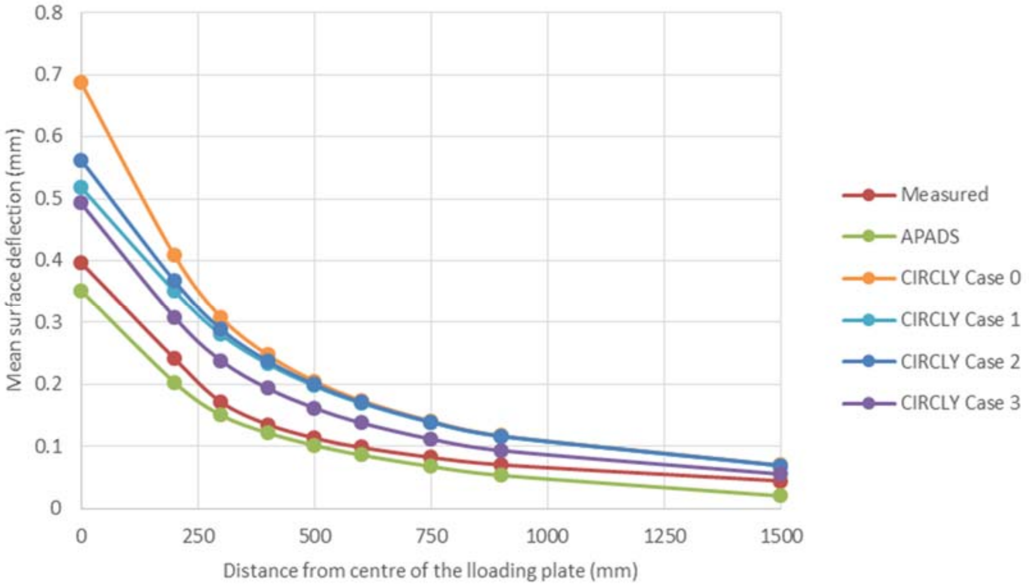
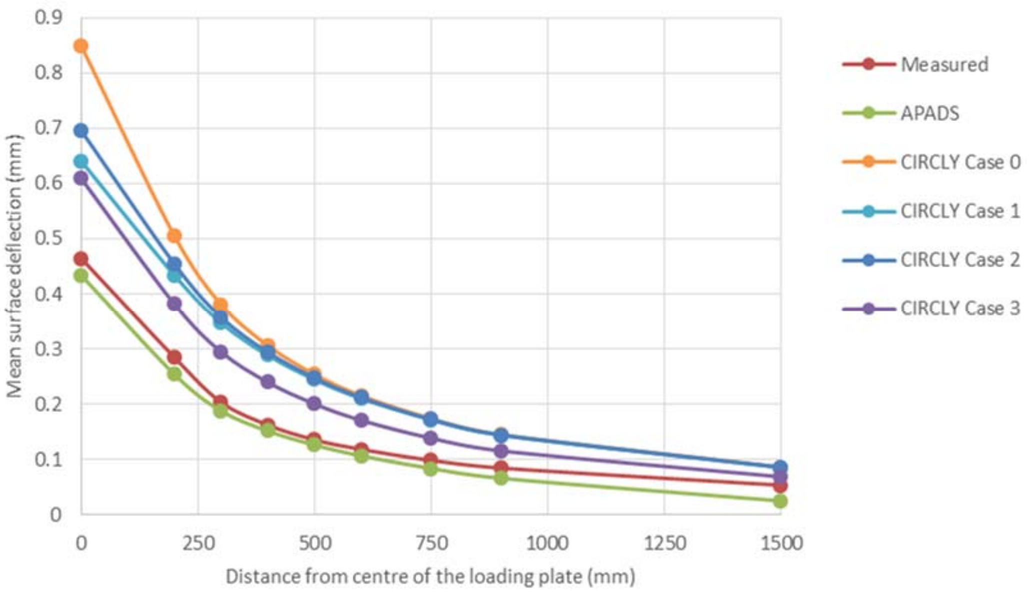


Figure E 22: Deflection comparisons 700 kN load - Section 13



E.12 Section 14 – Hydrated Cement Treated Crushed Rock Base (HCTCRB)

Figure E 23: Deflection comparisons 566 kN load - Section 14

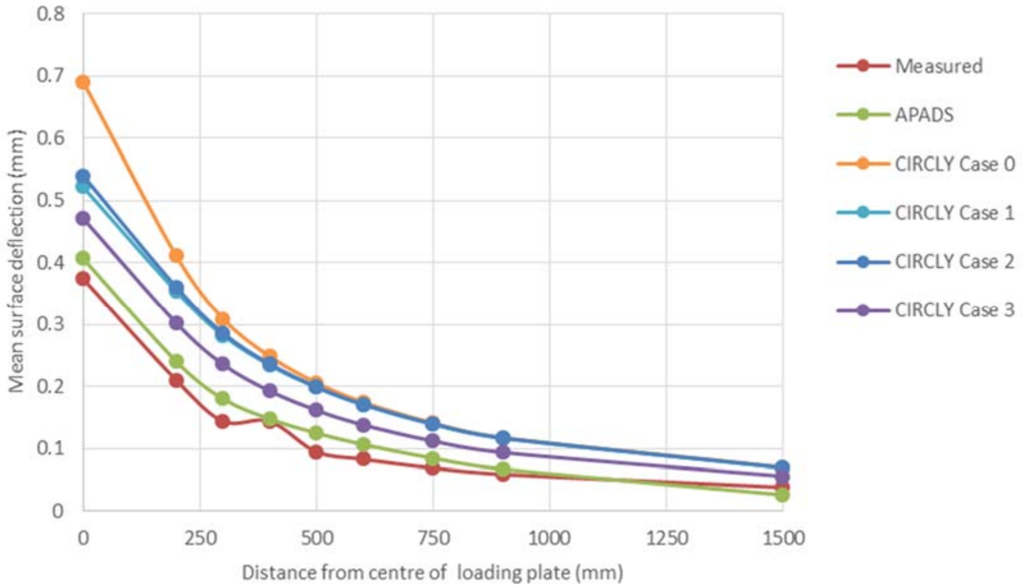
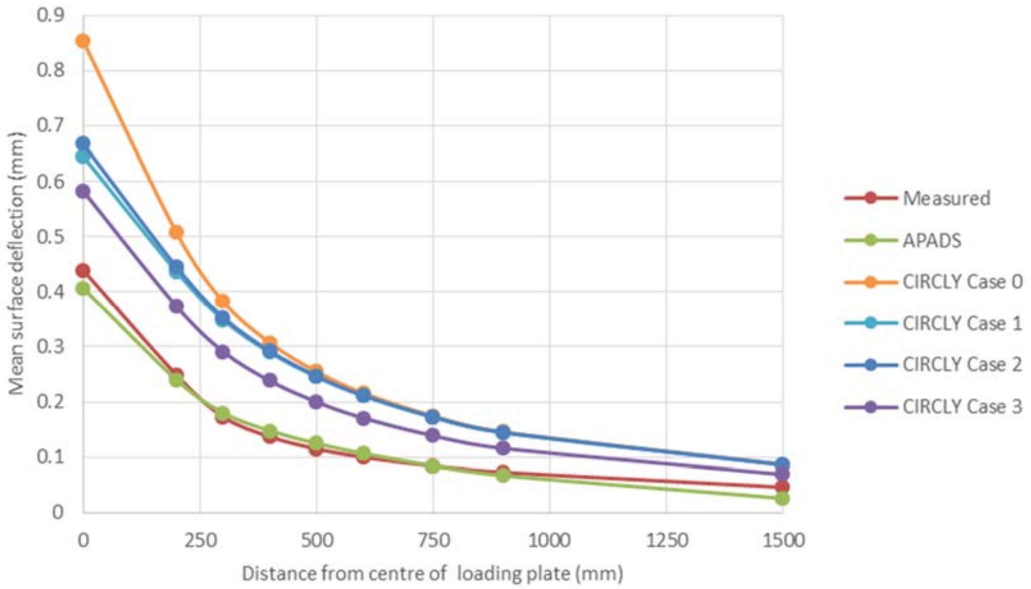


Figure E 24: Deflection comparisons 700 kN load - Section 14



E.13 Summary of Measured and Calculated Deflection and Curvature Values

Table E 1: Measured FWD deflections and curvatures – 566 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.394	0.229	0.155	0.121	0.097	0.085	0.071	0.061	0.040	0.165
Section 3	0.443	0.266	0.177	0.130	0.103	0.087	0.070	0.060	0.038	0.177
Section 4	0.286	0.179	0.133	0.107	0.090	0.079	0.065	0.056	0.035	0.107
Section 5	0.447	0.254	0.167	0.125	0.102	0.088	0.073	0.063	0.041	0.193
Section 6	0.389	0.227	0.157	0.122	0.101	0.089	0.074	0.064	0.040	0.162
Section 7	0.376	0.222	0.156	0.123	0.102	0.090	0.074	0.064	0.039	0.154
Section 8	0.361	0.216	0.151	0.118	0.099	0.087	0.072	0.062	0.037	0.145
Section 9	0.381	0.226	0.156	0.121	0.099	0.086	0.071	0.061	0.038	0.155
Section 10	0.366	0.215	0.151	0.188	0.098	0.087	0.073	0.064	0.043	0.151
Section 12	0.429	0.273	0.199	0.155	0.127	0.110	0.091	0.078	0.051	0.156
Section 13	0.397	0.242	0.172	0.136	0.114	0.099	0.083	0.071	0.045	0.155
Section 14	0.374	0.210	0.144	0.144	0.095	0.083	0.069	0.059	0.038	0.164

Table E 2: Measured FWD deflections and curvatures – 700 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.434	0.262	0.181	0.141	0.117	0.103	0.086	0.075	0.049	0.172
Section 3	0.504	0.299	0.204	0.152	0.121	0.103	0.084	0.071	0.045	0.205
Section 4	0.328	0.211	0.158	0.128	0.107	0.094	0.078	0.067	0.042	0.117
Section 5	0.494	0.288	0.196	0.148	0.122	0.106	0.089	0.077	0.050	0.206
Section 6	0.449	0.264	0.183	0.144	0.120	0.105	0.087	0.075	0.047	0.185
Section 7	0.424	0.257	0.180	0.143	0.119	0.105	0.088	0.075	0.046	0.167
Section 8	0.417	0.251	0.177	0.140	0.117	0.103	0.085	0.074	0.045	0.166
Section 9	0.466	0.263	0.180	0.140	0.117	0.102	0.085	0.073	0.045	0.203
Section 10	0.423	0.250	0.176	0.138	0.116	0.103	0.088	0.078	0.052	0.173
Section 12	0.491	0.320	0.233	0.182	0.150	0.130	0.108	0.093	0.061	0.171
Section 13	0.465	0.285	0.204	0.163	0.136	0.119	0.099	0.085	0.054	0.180
Section 14	0.440	0.249	0.173	0.137	0.115	0.100	0.084	0.073	0.046	0.191

Table E 3: Deflections and curvatures calculated using APADS – 566 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.310	0.184	0.142	0.120	0.102	0.088	0.069	0.055	0.021	0.125
Section 3	0.361	0.209	0.154	0.124	0.104	0.088	0.069	0.054	0.021	0.151
Section 4	0.342	0.201	0.151	0.123	0.103	0.088	0.069	0.055	0.021	0.141
Section 5	0.408	0.220	0.157	0.127	0.107	0.091	0.072	0.057	0.022	0.188
Section 6	0.355	0.208	0.156	0.127	0.107	0.090	0.071	0.056	0.021	0.147
Section 7	0.353	0.207	0.156	0.129	0.109	0.093	0.074	0.058	0.023	0.145
Section 8	0.355	0.208	0.156	0.127	0.107	0.090	0.071	0.056	0.021	0.147
Section 9	0.346	0.205	0.154	0.126	0.106	0.090	0.071	0.056	0.021	0.141
Section 10	0.357	0.213	0.160	0.131	0.110	0.094	0.075	0.060	0.025	0.144
Section 12	0.411	0.223	0.159	0.127	0.106	0.090	0.070	0.055	0.021	0.188
Section 13	0.352	0.204	0.151	0.122	0.102	0.087	0.068	0.054	0.021	0.148
Section 14	0.332	0.193	0.145	0.119	0.101	0.086	0.069	0.054	0.021	0.139

Table E 4: Deflections and curvatures calculated using APADS – 700 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.382	0.230	0.178	0.149	0.127	0.108	0.086	0.068	0.026	0.152
Section 3	0.446	0.262	0.192	0.154	0.129	0.108	0.085	0.067	0.025	0.184
Section 4	0.417	0.249	0.187	0.153	0.128	0.109	0.085	0.067	0.026	0.168
Section 5	0.494	0.272	0.195	0.157	0.132	0.112	0.088	0.070	0.027	0.223
Section 6	0.435	0.258	0.194	0.158	0.132	0.112	0.088	0.069	0.026	0.176
Section 7	0.431	0.257	0.193	0.159	0.134	0.114	0.090	0.071	0.028	0.175
Section 8	0.435	0.258	0.194	0.158	0.132	0.112	0.088	0.069	0.026	0.176
Section 9	0.424	0.254	0.191	0.156	0.131	0.111	0.087	0.069	0.027	0.170
Section 10	0.437	0.264	0.198	0.161	0.136	0.116	0.092	0.073	0.030	0.174
Section 12	0.500	0.277	0.197	0.158	0.131	0.111	0.087	0.068	0.026	0.223
Section 13	0.434	0.254	0.188	0.152	0.127	0.107	0.084	0.067	0.026	0.180
Section 14	0.407	0.240	0.180	0.148	0.125	0.107	0.085	0.067	0.026	0.167

Table E 5: Deflections and curvatures calculated using CIRCLY Case 0 – 566 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.701	0.416	0.313	0.250	0.207	0.175	0.141	0.118	0.070	0.284
Section 3	0.697	0.415	0.312	0.250	0.207	0.175	0.141	0.118	0.070	0.283
Section 4	0.691	0.411	0.310	0.249	0.206	0.175	0.141	0.118	0.070	0.280
Section 5	0.688	0.409	0.309	0.248	0.206	0.175	0.141	0.118	0.070	0.279
Section 6	0.711	0.422	0.316	0.252	0.208	0.176	0.141	0.118	0.070	0.289
Section 7	0.697	0.415	0.312	0.250	0.207	0.175	0.141	0.118	0.070	0.283
Section 8	0.707	0.420	0.315	0.252	0.208	0.176	0.141	0.118	0.070	0.287
Section 9	0.697	0.415	0.312	0.250	0.207	0.175	0.141	0.118	0.070	0.283
Section 10	0.694	0.413	0.311	0.249	0.206	0.175	0.141	0.118	0.070	0.282
Section 12	0.688	0.409	0.309	0.248	0.206	0.175	0.141	0.118	0.070	0.279
Section 13	0.687	0.409	0.308	0.248	0.206	0.175	0.141	0.118	0.070	0.279
Section 14	0.691	0.411	0.310	0.249	0.206	0.175	0.141	0.118	0.070	0.280

Table E 6: Deflections and curvatures calculated using CIRCLY Case 0 – 700 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.867	0.515	0.387	0.310	0.256	0.217	0.175	0.146	0.087	0.352
Section 3	0.863	0.513	0.386	0.309	0.256	0.217	0.175	0.146	0.087	0.350
Section 4	0.855	0.508	0.383	0.307	0.255	0.216	0.175	0.146	0.087	0.346
Section 5	0.851	0.506	0.382	0.307	0.255	0.216	0.175	0.146	0.087	0.345
Section 6	0.879	0.522	0.391	0.312	0.257	0.217	0.175	0.146	0.087	0.357
Section 7	0.863	0.513	0.386	0.309	0.256	0.217	0.175	0.146	0.087	0.350
Section 8	0.875	0.520	0.390	0.311	0.257	0.217	0.175	0.146	0.087	0.355
Section 9	0.863	0.513	0.386	0.309	0.256	0.217	0.175	0.146	0.087	0.350
Section 10	0.859	0.511	0.384	0.308	0.255	0.216	0.175	0.146	0.087	0.348
Section 12	0.851	0.506	0.382	0.307	0.255	0.216	0.175	0.146	0.087	0.345
Section 13	0.850	0.506	0.381	0.307	0.254	0.216	0.175	0.146	0.087	0.344
Section 14	0.855	0.508	0.383	0.307	0.255	0.216	0.175	0.146	0.087	0.346

Table E 7: Deflections and curvatures calculated using CIRCLY Case 1 – 566 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.649	0.400	0.306	0.247	0.205	0.174	0.141	0.118	0.070	0.249
Section 3	0.645	0.398	0.305	0.246	0.205	0.174	0.141	0.118	0.070	0.247
Section 4	0.569	0.371	0.291	0.239	0.201	0.172	0.140	0.117	0.070	0.198
Section 5	0.688	0.409	0.308	0.248	0.206	0.175	0.141	0.118	0.070	0.279
Section 6	0.544	0.367	0.291	0.240	0.202	0.172	0.140	0.117	0.069	0.177
Section 7	0.529	0.358	0.285	0.236	0.200	0.171	0.140	0.117	0.069	0.171
Section 8	0.540	0.364	0.289	0.239	0.201	0.172	0.140	0.117	0.069	0.175
Section 9	0.529	0.358	0.285	0.236	0.200	0.171	0.140	0.117	0.069	0.171
Section 10	0.526	0.356	0.284	0.235	0.199	0.171	0.140	0.117	0.069	0.170
Section 12	0.688	0.409	0.308	0.248	0.206	0.175	0.141	0.118	0.070	0.279
Section 13	0.518	0.351	0.281	0.234	0.198	0.170	0.139	0.117	0.069	0.167
Section 14	0.522	0.354	0.283	0.235	0.199	0.171	0.139	0.117	0.069	0.169

Table E 8: Deflections and curvatures calculated using CIRCLY Case 1 – 700 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.802	0.495	-0.378	0.305	0.254	0.216	0.174	0.145	0.087	0.307
Section 3	0.798	0.492	0.377	0.305	0.254	0.215	0.174	0.145	0.087	0.306
Section 4	0.704	0.459	0.360	0.296	0.249	0.213	0.173	0.145	0.086	0.245
Section 5	0.850	0.506	0.381	0.307	0.254	0.216	0.175	0.146	0.087	0.345
Section 6	0.672	0.453	0.360	0.296	0.249	0.213	0.173	0.145	0.086	0.219
Section 7	0.654	0.443	0.353	0.292	0.247	0.212	0.173	0.145	0.086	0.212
Section 8	0.668	0.451	0.358	0.295	0.249	0.213	0.173	0.145	0.086	0.217
Section 9	0.654	0.443	0.353	0.292	0.247	0.212	0.173	0.145	0.086	0.212
Section 10	0.650	0.440	0.351	0.291	0.246	0.212	0.173	0.144	0.086	0.210
Section 12	0.850	0.506	0.381	0.307	0.254	0.216	0.175	0.146	0.087	0.345
Section 13	0.641	0.434	0.348	0.289	0.245	0.211	0.172	0.144	0.086	0.207
Section 14	0.646	0.437	0.349	0.290	0.246	0.211	0.172	0.144	0.086	0.209

Table E 9: Deflections and curvatures calculated using CIRCLY Case 2 – 566 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.566	0.372	0.293	0.240	0.202	0.173	0.140	0.117	0.070	0.194
Section 3	0.563	0.370	0.291	0.240	0.201	0.172	0.140	0.117	0.070	0.193
Section 4	0.532	0.357	0.285	0.236	0.199	0.171	0.140	0.117	0.070	0.175
Section 5	0.616	0.386	0.298	0.243	0.203	0.173	0.140	0.117	0.070	0.230
Section 6	0.582	0.380	0.298	0.243	0.203	0.173	0.140	0.117	0.070	0.201
Section 7	0.567	0.372	0.292	0.240	0.202	0.172	0.140	0.117	0.070	0.195
Section 8	0.578	0.378	0.296	0.242	0.203	0.173	0.140	0.117	0.070	0.200
Section 9	0.547	0.364	0.289	0.238	0.201	0.172	0.140	0.117	0.070	0.182
Section 10	0.544	0.362	0.287	0.237	0.200	0.172	0.140	0.117	0.070	0.181
Section 12	0.607	0.383	0.297	0.242	0.203	0.173	0.140	0.117	0.070	0.224
Section 13	0.563	0.368	0.289	0.238	0.201	0.172	0.140	0.117	0.070	0.195
Section 14	0.540	0.360	0.286	0.236	0.200	0.171	0.140	0.117	0.070	0.180

Table E 10: Deflections and curvatures calculated using CIRCLY Case 2 – 700 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.700	0.461	0.362	0.297	0.250	0.213	0.173	0.145	0.086	0.240
Section 3	0.696	0.458	0.360	0.296	0.249	0.213	0.173	0.145	0.086	0.238
Section 4	0.659	0.442	0.352	0.291	0.246	0.212	0.173	0.145	0.086	0.217
Section 5	0.762	0.478	0.369	0.300	0.251	0.214	0.173	0.145	0.086	0.284
Section 6	0.719	0.470	0.368	0.301	0.252	0.214	0.173	0.145	0.086	0.249
Section 7	0.702	0.460	0.361	0.297	0.249	0.213	0.173	0.145	0.086	0.242
Section 8	0.715	0.468	0.366	0.300	0.251	0.214	0.173	0.145	0.086	0.247
Section 9	0.676	0.451	0.357	0.294	0.248	0.213	0.173	0.145	0.086	0.226
Section 10	0.672	0.448	0.355	0.293	0.248	0.212	0.173	0.145	0.086	0.224
Section 12	0.751	0.474	0.367	0.299	0.251	0.214	0.173	0.145	0.086	0.277
Section 13	0.696	0.455	0.358	0.294	0.248	0.213	0.173	0.145	0.086	0.242
Section 14	0.668	0.446	0.354	0.292	0.247	0.212	0.173	0.145	0.086	0.223

Table E 11: Deflections and curvatures calculated using CIRCLY Case 3 – 566 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.494	0.312	0.241	0.196	0.163	0.139	0.113	0.094	0.056	0.182
Section 3	0.492	0.311	0.240	0.195	0.163	0.139	0.112	0.094	0.056	0.181
Section 4	0.465	0.300	0.235	0.192	0.161	0.138	0.112	0.094	0.056	0.165
Section 5	0.542	0.325	0.246	0.198	0.164	0.140	0.113	0.094	0.056	0.218
Section 6	0.507	0.318	0.245	0.198	0.164	0.140	0.113	0.094	0.056	0.189
Section 7	0.496	0.312	0.241	0.196	0.163	0.139	0.113	0.094	0.056	0.184
Section 8	0.504	0.317	0.244	0.197	0.164	0.139	0.113	0.094	0.056	0.187
Section 9	0.477	0.306	0.238	0.194	0.162	0.139	0.112	0.094	0.056	0.171
Section 10	0.474	0.304	0.237	0.193	0.162	0.138	0.112	0.094	0.056	0.170
Section 12	0.534	0.322	0.245	0.197	0.164	0.139	0.113	0.094	0.056	0.212
Section 13	0.493	0.309	0.239	0.194	0.162	0.139	0.112	0.094	0.056	0.184
Section 14	0.472	0.302	0.236	0.193	0.162	0.138	0.112	0.094	0.056	0.169

Table E 12: Deflections and curvatures calculated using CIRCLY Case 3 – 700 kPa

Trial section no.	Deflection (mm) at various distances from loading plate									Curvature
	D0	D200	D300	D400	D500	D600	D750	D900	D1500	
Section 2	0.611	0.386	0.298	0.242	0.202	0.172	0.139	0.116	0.069	0.225
Section 3	0.608	0.384	0.297	0.241	0.202	0.172	0.139	0.116	0.069	0.224
Section 4	0.575	0.371	0.290	0.238	0.200	0.171	0.139	0.116	0.069	0.204
Section 5	0.671	0.402	0.304	0.245	0.203	0.173	0.139	0.116	0.069	0.269
Section 6	0.627	0.394	0.302	0.245	0.203	0.173	0.139	0.116	0.069	0.233
Section 7	0.613	0.386	0.298	0.242	0.202	0.172	0.139	0.116	0.069	0.227
Section 8	0.623	0.392	0.301	0.244	0.203	0.172	0.139	0.116	0.069	0.232
Section 9	0.590	0.378	0.294	0.240	0.201	0.171	0.139	0.116	0.069	0.212
Section 10	0.587	0.376	0.293	0.239	0.200	0.171	0.139	0.116	0.069	0.211
Section 12	0.660	0.399	0.303	0.244	0.203	0.172	0.139	0.116	0.069	0.262
Section 13	0.610	-0.382	0.295	0.240	0.201	0.171	0.139	0.116	0.069	0.228
Section 14	0.583	0.374	0.292	0.238	0.200	0.171	0.139	0.116	0.069	0.209