The use of continues compaction control (CCC) for pavement construction quality control.

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CETANZ Conference Rotorua Aug 2021

WAKA KOTAHI
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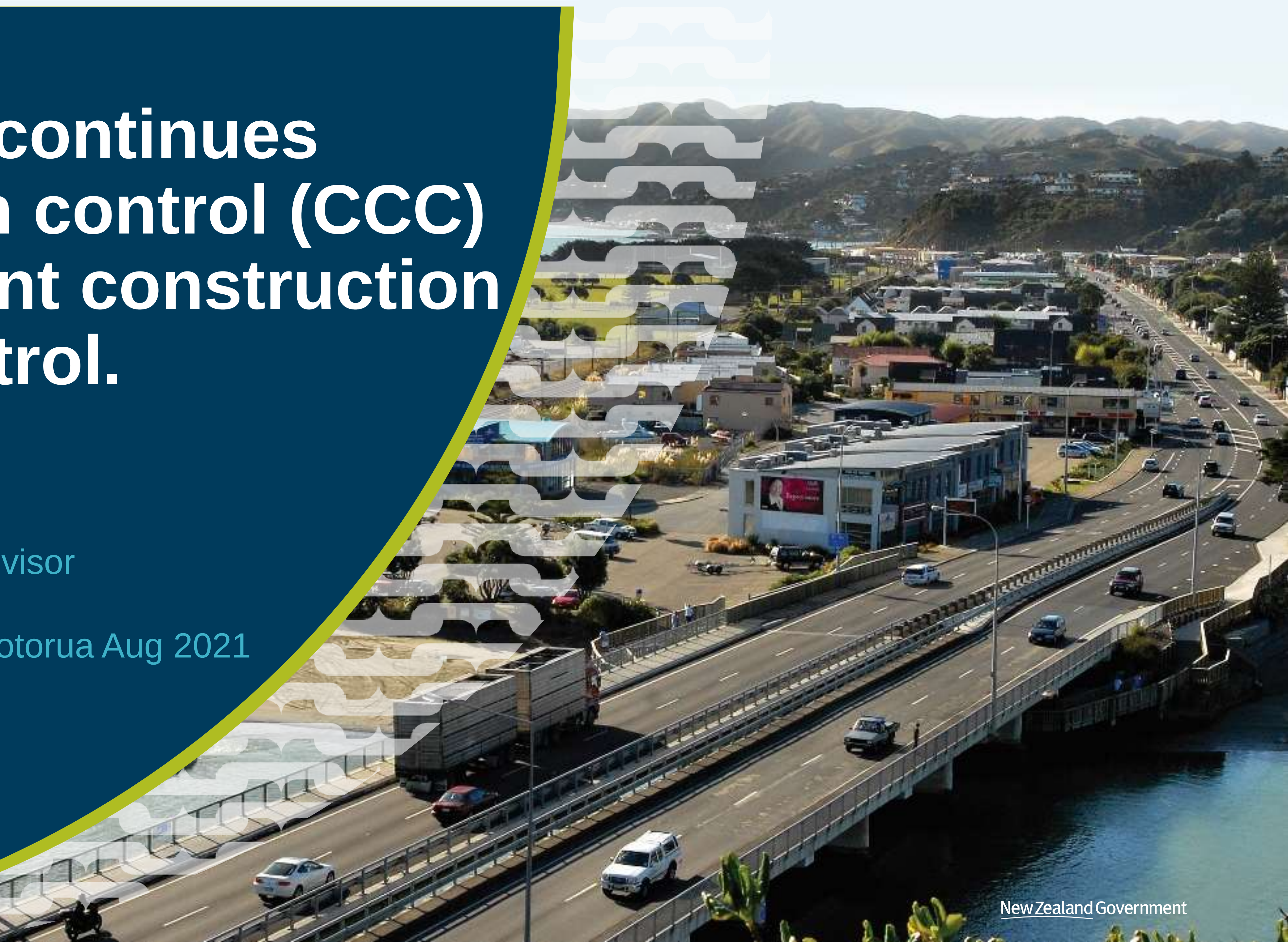


New Zealand Government

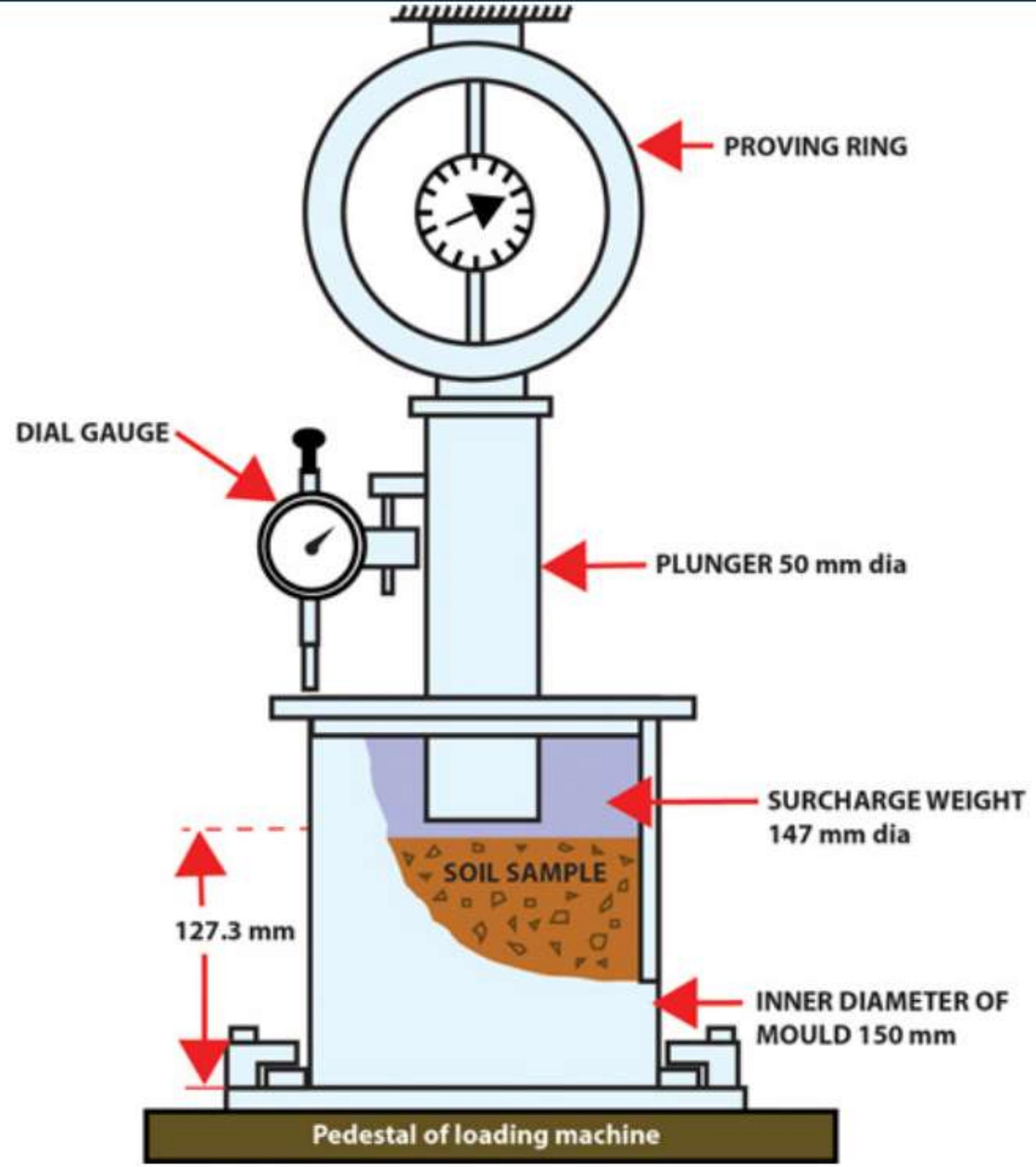
Case Study

Define, specify, report and monitor the bearing strength of subgrade - and subgrade "improvement" layers.

California Bearing Ratio (CBR)

Developed around the 1930 with a CBR value = 100% based on high quality crushed aggregate

- 1.25mm/minute penetration rate.
- Record load at 2.5mm and 5mm.
- CBR = total load/standard load 100%.
- CBR at 2.5mm load is reported, if greater than 5mm load.
- If CBR at 5mm load is greater repeat test.

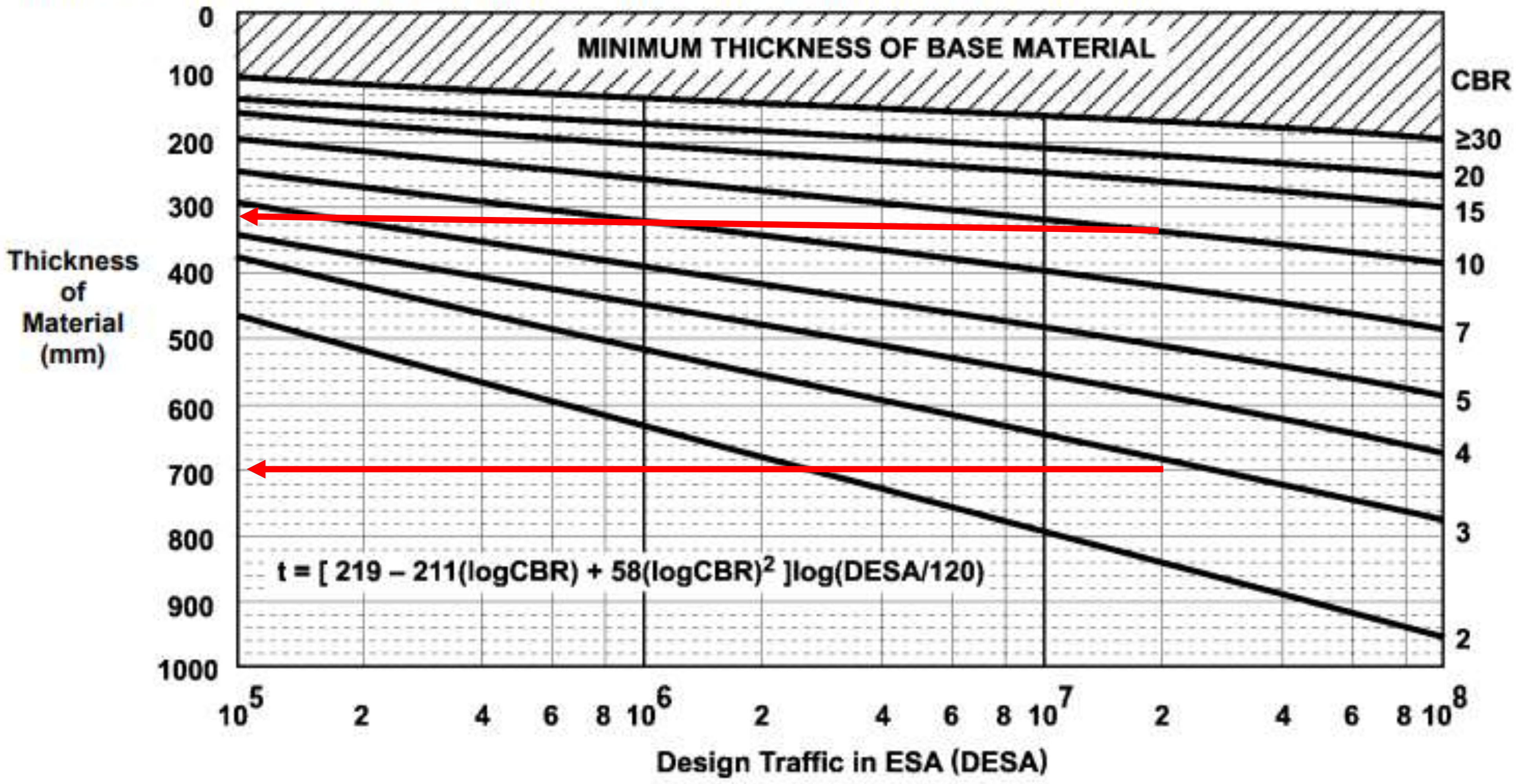


Limitations of CBR Values used in Pavement Designs

- Limited to laboratory and/or in-situ testing.
- Specific samples and/or test locations.
- Time consuming.
- Converting CBR to design modulus (E).
  E= 10 x CBR ????
- Correlation between CBR vs Scala (fine grained cohesive soils Austroads).
- Correlation between CBR vs BB deflections.
- Test results are specific test condition (moisture content/density e.g. draught)

Figure 8.4 Assigned CBR = Pavement Design Thickness

Figure 8.4: Design chart for granular pavements with thin bituminous surfacing



Case Study

Earthworks Construction

- Scala 5 blows per 100mm (first 200mm) and 6 blows/100mm next 250mm depth. ***CBR = 2 x number blows/100mm ???***

- Pavement design based on soaked/in-situ CBR ≥ 12

- BB deflection 95th % >1.85mm and 2.0mm max

What is the impact on the test criteria, if construction takes place in a 60 year draught ???

Case Study

Contract specifications for subgrade

Test	Frequency	Criteria
Proof Roll	100% Subgrade	Substantial Deflections/Designers approval
Benkelmen Beams	10 metre intervals each lane	95%ile of 1.85 mm & Max. of 2.00 mm
Scala Penetrometer	1 test to 450mm below Subgrade level every 100 m^2	CBR >12.5 (5 blows/100mm) in the top 200mm >6 in the next 250mm
Nuclear Densometer	20 metre intervals each lane	Various for dry density, moisture content, air voids etc.
In-Situ CBR	1 test every 1000 m^3	Design based on CBR = 12
Soaked CBR	1 test every 3000 m^3	**Design based on CBR = 12**

Case Study

Laboratory Soaked CBR Test Results

- All samples were compacted at **optimum moisture content** using **heavy compaction.**
- **All samples passes soaked CBR (in-situ completed at surface level)**

L	M	N	O
Subgrade - CBR's			
Northbound		Southbound	
Soaked	In-situ	Soaked	In-situ
	60.00		20.00
85.00	85.00	85.00	85.00
	35.00		135.00
	55.00		95.00
45.00	45.00		

Sample	Soaked CBR	Wet Density	Dry Density
1	12	1.81 t/m^3	1.38 t/m^3
2	31	1.83 t/m^3	1.34 t/m^3
3	30	1.80 t/m^3	1.29 t/m^3
4	23.5	1.88 t/m^3	1.39 t/m^3
5	25	1.76 t/m^3	1.26 t/m^3
6	23	1.74 t/m^3	1.20 t/m^3

Case Study

Soaked CBR on in-situ Field Samples (field density/moisture content)

Field vs Laboratory CBR

Sample	Soaked CBR	Wet Density	Dry Density
I	1.5	**1.76 t/m³**	**1.22 t/m³**
II	11	**1.69 t/m³**	**1.24 t/m³**
III	5	**1.67 t/m³**	**1.30 t/m³**
IV	17	1.78 t/m³	1.26 t/m³
V	30	1.87 t/m³	1.42 t/m³
VI	9	**1.70 t/m³**	**1.28 t/m³**
VII	9	**1.68 t/m³**	**1.24 t/m³**
VIII	25	1.84 t/m³	1.46 t/m³
IX	11	**1.78 t/m³**	**1.26 t/m³**
X	7	**1.82 t/m³**	**1.32 t/m³**
Average	**12.55**	**1.76 t/m³**	**1.30 t/m³**

Sample	Soaked CBR	Wet Density	Dry Density
1	12	1.81 t/m³	1.38 t/m³
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3	30	1.80 t/m³	1.29 t/m³
***4**	**23.5**	**1.88 t/m³**	**1.39 t/m³**
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6	23	1.74 t/m³	1.20 t/m³

Case Study

Scala (DCP) Subgrade Testing for Construction Compliance

	Northbound										Southbound										
Chainage	100	200	300	400	500	600	700	800	900	1000	100	200	300	400	500	600	700	800	900	1000	1
720	30	20	23	23	15	25	18	13	15	8											
730	113	15	25	20	8	13	10	10	8	13	18	18	10	8	8	6	10	10	13	10	
740	20										18	18	10	8	8	6	10	10	13	10	
750	20	28	33	18	8	15	20	13	13	13	25	18	13	8	10	6	15	13	18	18	
760	25	20	13	13	13	10	15	18	13	8	52	75	15	6	6	10	10	20	20	15	
770	28	23	13	13	8	10	13	10	10	15	15	18	20	13	15	15	10	13	18	15	
780	44	58	38	25	18	15	18	20	13	15	38	25	10	10	10	8	10	8	8	13	
790	13	15	20	20	8	18	10	20	13	10	50	20	20	13	8	8	18	18	18	13	
800	36	25	28	28	20	15	15	10	13	15	28	15	8	6	6	8					
810	13	15	15	18	20	13	10	10	18	15	30	20	10	8	8	8	10	18	13	13	
820	25	18	18	15	18	13	13	20	15	10	10	20	25	8	10	8	10	10	10	8	
830	18	18	15	8	6	6	10	10	20	20	20	13	8	8	8	6	6	15	36	28	
840	18	23	15	8	13	13					15	13	20	15	18	15	15	20	13	151	
850	23	18	8	23	20	10					28	18	10	6	8	8	15	10	10	13	
860	18	13	25	15	10	10					13	15	151	151	20	13	20	8	10	18	
870	20	20	25	15	10	6					38	13	8	10	6	25	18	28	20	20	
880	20	18	13	25	23	15					15	10	25	20	10	15	13	13	10	6	
890	23	15	15	18	20	20					33	13	15	18	13	6	10	18	18	28	
900	25	15	10	20	18	13					20	13	10	6	13	13					
910	28	20	13	15	8	13					15	15	8	13	18	15					
920	23	18	10	20	15	13					20	20	28	10	20	6					
930	18	30	23	15	15	10					36	25	13	15	13	8					
940	13	18	15	8	8	6					23	20	13	15	20	13					
950	20	15	15	10..35	18	18					30	13	15	15	23	15					
960	18	18	30	23	8	15					23	18	10	20	28	18					
970	25	20	10	13	8	6					15	13	13	20	8	8					
980	13	15	13	10	10	6					33	13	10	15	20	18					
990	23	23	18	10	10	6					20	23	23	8	15	10					
1000	18	13	10	30	20	23					20	20	18	23	15	15					


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MCP21
Fulton Hogan

Case Study

- Understanding the behaviour of materials under dynamic loading.
- Finding alternative test methods to describe/measure bearing strength under dynamic loading.
- Measure compaction and density.


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Case Study

Bearing Plate Test

Test data shows a strong correlation between the following test equipment:

Ev1 ≈ Evd (LFWD)

Ev2 ≈ Evib (roller)

Ø-Plate : 300 mm

Record number : 1

Weather/Temp : Sunny to overcast, cool to warm

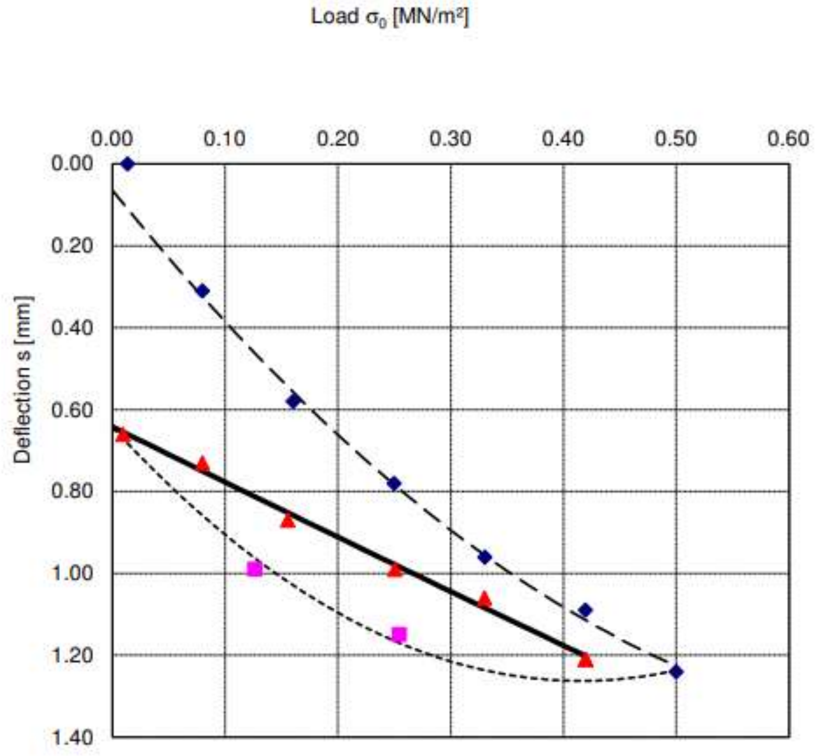
Previous day : Sunny to overcast, cool to warm

Results	a_1	a_2	σ_{0max} [MN/m²]	Measured
Strain modulus E_{v1} [MN/m²]	3.4312	-2.2139	0.4997	**96.8**
Strain modulus E_{v2} [MN/m²]	1.3615	-0.0642	0.4192	**169.3**
Ratio E_{v2}/E_{v1}				**1.75**

Modulus of subgrade reaction (d=2,22), ks [MN/m3] : 211

Remarks : Evib = 162

Test No.	Load σ_0 [MN/m²]	Deflection s [mm]
First loading		
1	0.013	0.00
2	0.080	0.31
3	0.160	0.58
4	0.250	0.78
5	0.330	0.96
6	0.420	1.09
7	0.500	1.24
Unloading		
8	0.254	1.15
9	0.126	0.99
Second loading		
10	0.009	0.66
11	0.080	0.73
12	0.156	0.87
13	0.250	0.99
14	0.330	1.06
15	0.420	1.21
16	0.419	1.21

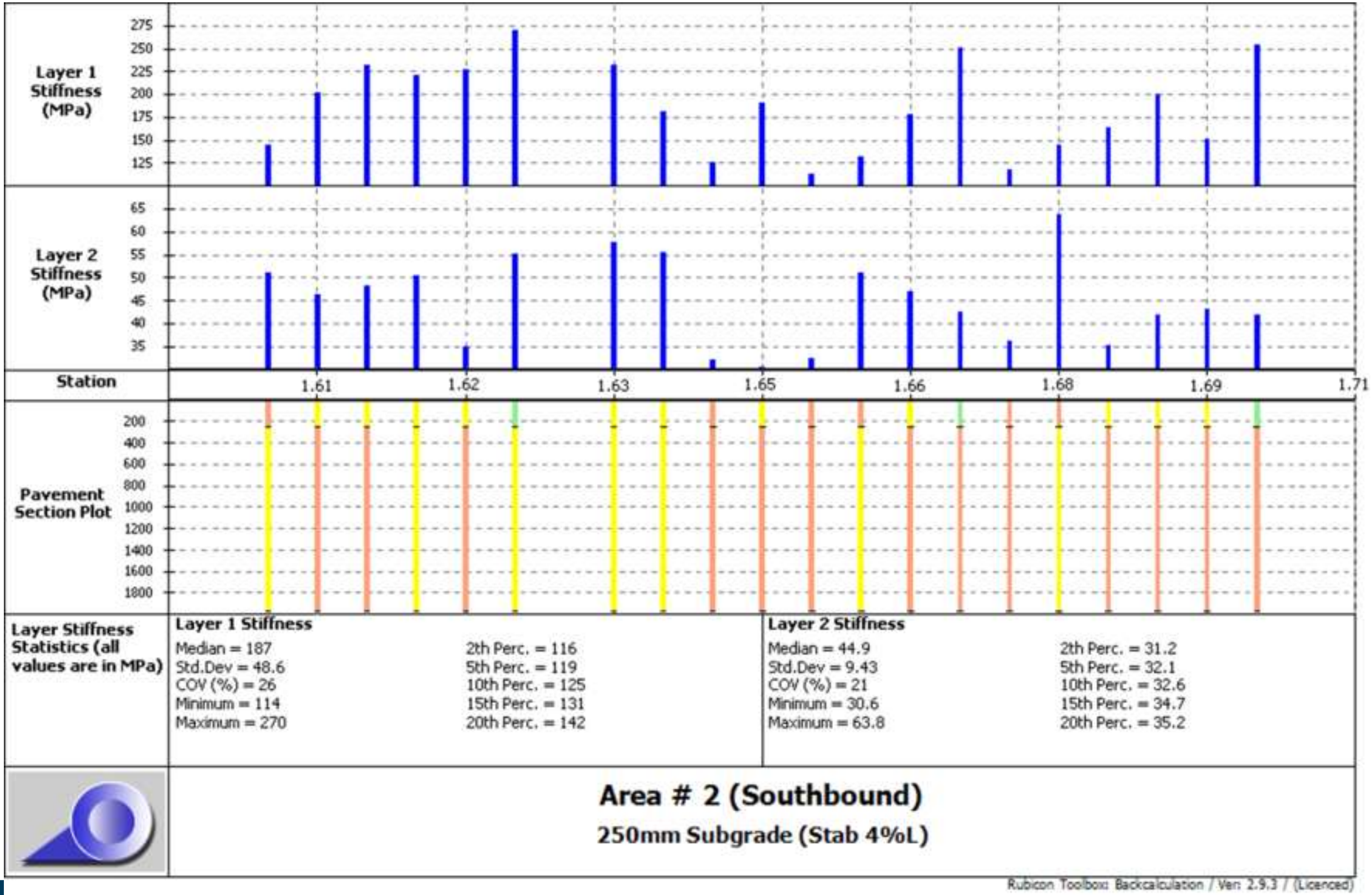


Test Method	Notes
DIN 18134:2012-04 : Static Plate Bearing Test	This report replaces report number HA7495-1, dated 11/06/21.

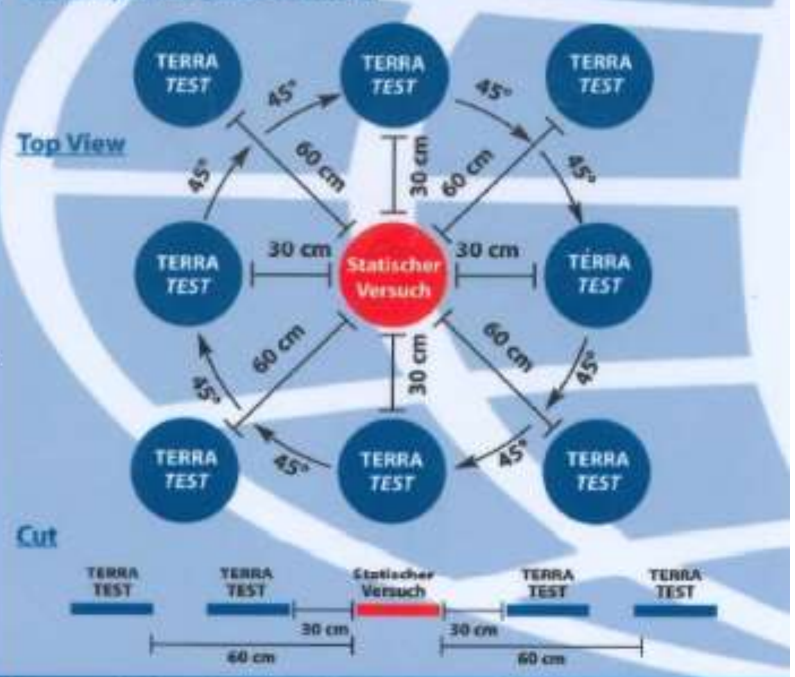

TERRATEST

Case Study

FWD back-calculations on silty/clay subgrade shows E = 35MPa (80th %)



Calibration of Bearing Plate and LFWD



Proposal for Correlation

After having determined the correlation values in this way, you can perform all other tests with the Light Weight Deflectometer, as long as the foundation soil remains the same. The correlation procedure should be performed by contractor and client, so that they can collectively agree on using the Light Weight Deflectometer as their standard test method.

The dynamic plate load test with the Light Weight Deflectometer does not replace your domestic test method as defined in local standards.

Schematic depiction for correlation static/dynamic plate load test

For general information only! All indications are subject to change.

Case Study

Lightweight FWD

- Strong correlation between Evd and Ev1
- Static vs Dynamic Loading

Test Results:

Plate Bearing and FWD Testing: Huntly WEX D0 CH 11500-11850m NB CBR5 Brown Rock (40

CH 11500m CL (LFG 1.0)		CH 11550m SL (LFG 1.0)		CH 11600m FL (LFG 1.0)	
Test	E_{vd} (MN/m^2)	Test	E_{vd} (MN/m^2)	Test	E_{vd} (MN/m^2)
1	43.6	1	51.7	1	54.3
2	42.6	2	48.8	2	55.6
3	42.9	3	53.6	3	56.8
4	46.3	4	54.9	4	51.7
5	61.8	5	42.7	5	47.2
6	60.6	6	40.6	6	49.2
7	58.7	7	48.9	7	42.6
8	44.3	8	56.7	8	48.5
Average E_{vd}	50.1	Average E_{vd}	49.7	Average E_{vd}	50.7
E_{v1} (MN/m^2)	50.0	E_{v1} (MN/m^2)	38.4	E_{v1} (MN/m^2)	52.6
E_{v2} (MN/m^2)	134.3	E_{v2} (MN/m^2)	138.9	E_{v2} (MN/m^2)	116.2
E_{v2}/E_{v1}	2.7	E_{v2}/E_{v1}	3.6	E_{v2}/E_{v1}	2.2
Ks (MN/m^3)	83.0	Ks (MN/m^3)	69.0	Ks (MN/m^3)	86.0

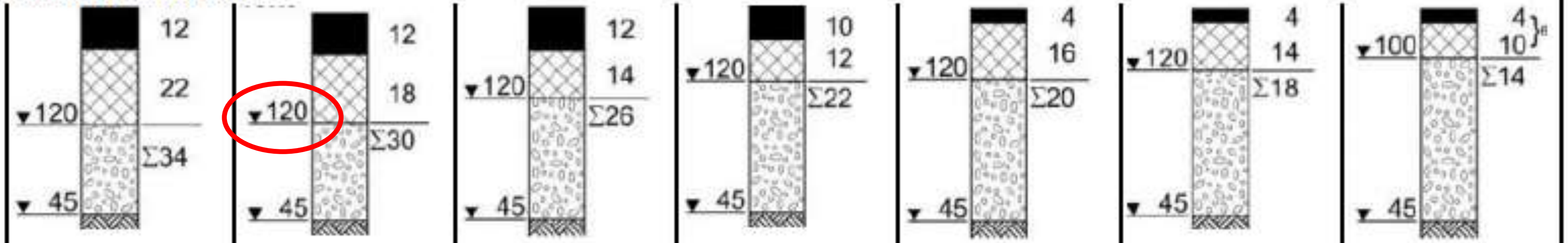
German Catalogue Pavement Design Approach

RStO 12 Draft

Chart 1 Construction methods with bitumen macadam on F2- and F3-subgrade/substructure

(thickness in cm; ▼ E_{V2} minimum values in MN/m²)

Line	Construction class	Bk_{100}				Bk_{32}				Bk_{10}				$Bk_{3.2}$				$Bk_{1.8}$				$Bk_{1.0}$				$Bk_{0.3}$			
	B [million]	> 32				> 10-32				> 3.2 – 10				> 1.8 – 3.2				> 1.0 – 1.8				> 0.3 – 1.0				≤ 0.3			
	Thickness of frost-resistant superstructure[1)]	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	35	45	55	65	35	45	55	65
	Asphalt base course on frost blanket course																												
1	Bitumen macadam Asphalt base course Frost blanket course																												
	Thickness of frost blanket course	-	31[2)]	41	51	25[3]	35	45	55	29[3]	39	49	59	-	33[2]	43	53	25[3]	35	45	55	17[2]	27	37	47	21	31	41	51



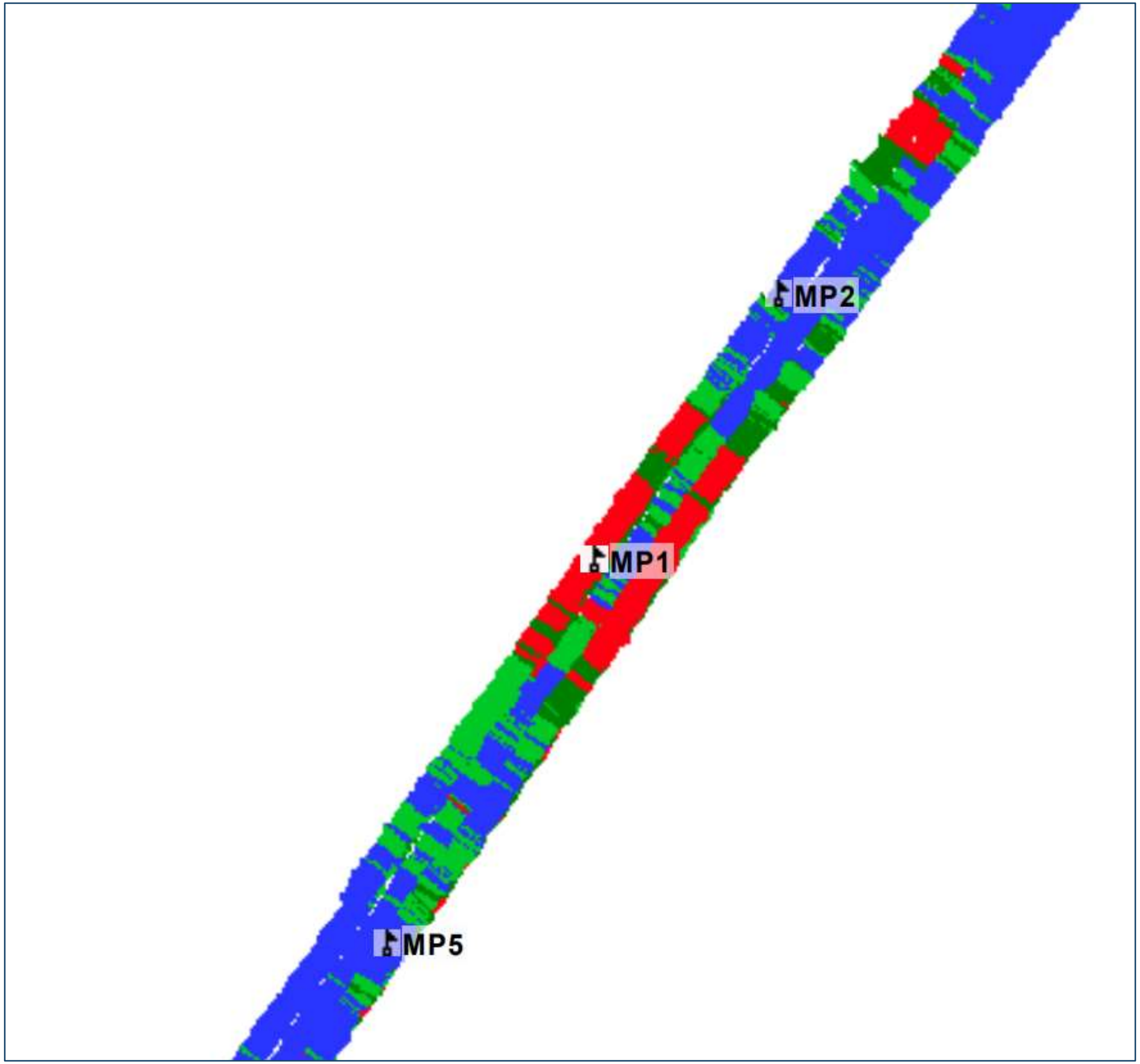
Case Study

CCC roller specified in contracts as a compliance/performance test.

- Compliance Criteria
- Evib > 130MN/m2 (95^{th}%)

(No value < 120MN/m2)

- Test full project area.



CCC - Documentation GPS-Planview

FULTON HOGAN

Waikoto Expressway
Hamilton Construction

Description

Project	**SH1 Hamilton Bypass**
Client	
Contractor	
Lot	**Hamilton Bypass**
Client	
Contractor	
Layer	**900 mm sand 14 May**
Number of layer	1
Field	**proof rolling 14 May 1**

Roller parameters

Model /Serial No.

BW 213 BVC-5 / 101 586 74 1005

Filter

Pass	Last pass
Pass type	dynamic

Stored data

Processed surface 1093 m²

documented from - until 15.05.2019 23:43:43 - 16.05.2019 00:52:27

	AVG	Min	Max
EVIB [MN/m²]	**147**	**63**	**214**
Amplitude [mm]	1.1	0.6	1.4
Frequency [Hz]	27	26	29
Velocity [km/h]	2.4	1.6	3.3

Statistic data

	EVIB [MN/m²]	
	> 150	45 %
	141 - 150	23 %
	130 - 140	17 %
	< 130	15 %
Σ	130 - 150	40 %

AVG-value	147	MN/m²
Increase	4	%
Standard deviation	19	

N

N
815075
14900
14880
14860
0 5 10 15 20 25 m
815132
396095
-201
-162
-123
-84
-45
90°
Field
Zone 1
EVIB
150 MN/m²
0 50 100 150 200 250 300 350
2,8 km/h
0,0 mm
0 Hz
North S 815101,5 m
East Z 396116,5 m
Elevation 44,4 m
GPS Quality 2
No of satellites 18
PDOP 0,7
Stop
F1
F2
F3
F4
F5
Fn
EVIB
BCM
BOMAG
FAYAT GROUP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Summary/Conclusion

- CCC roller bearing capacity response of ***full pavement area***.
- CCC roller bearing capacity response from materials at depth > 600mm.
- CCC roller testing under ***dynamic loading*** simulate traffic loading.
- Calibration process with multiple other criteria e.g. Bearing Plate, light-weight FWD, BB deflections, soaked CBR, density NDM (probe/direct transmission), Scala penetrometer.
- Contract specification to minimum CCC roller response for pavement layers e.g. 120MN/m2 for lower subbase layers.