The Direct Science of Granular Pavement Layer Compaction

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Plateau Density Testing

Acknowledgement

Jason Heap - Higgins

Agenda

- Background to Pavement Layer Density
- Target Density and Plateau Density Testing
- PP2O Trials and resulting project requirements
- Waka Kotahi's – Test Method and Notes

Pavement Layer Density

- Granular and Modified Granular are stress dependent layers and therefore get stiffer with increasing stress – any deficiency in density at the time of construction will likely result in early life rutting
- Bound granular subbase layers develop their strength and hence their fatigue characteristics with increasing density – note that we generally don't model the fatigue phase but it is still imperative that we achieve as high a density as possible
- NZTA B-Series specifications require the following in terms of Density:

Degree of compaction	Sub-base pavement layer	Basecourse pavement layer
Mean value	≥95%	≥98%
Minimum value	≥92%	≥95%

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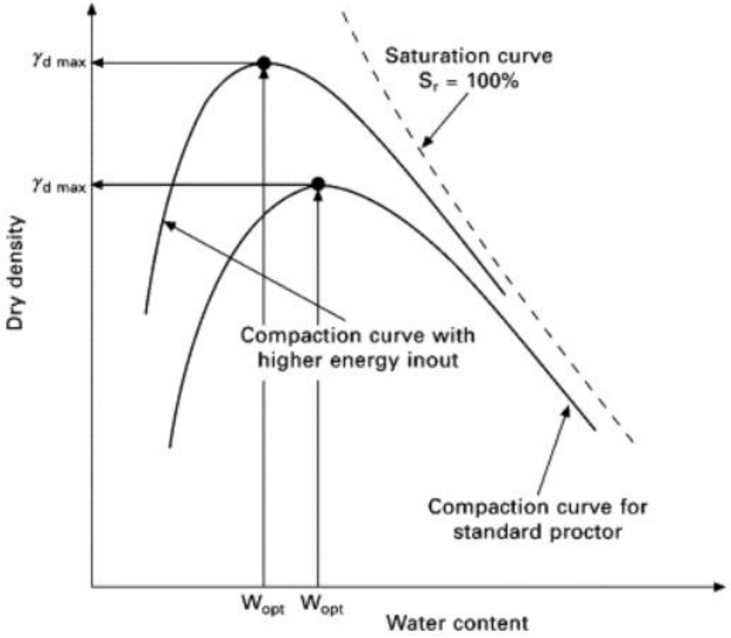
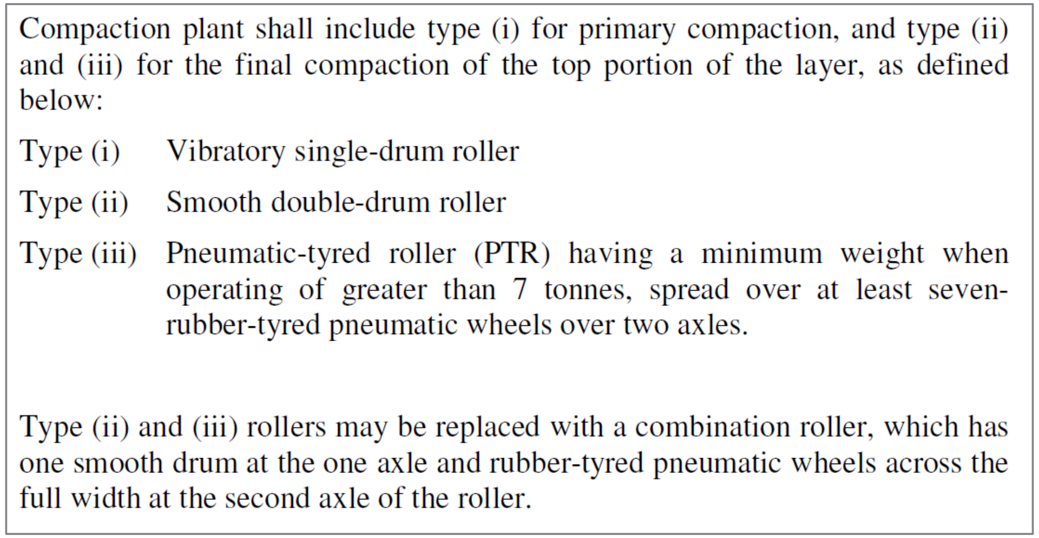
Target MDD



Laboratory derived MDD

Plateau Density test

Plateau Density Testing


Compaction plant shall include type (i) for primary compaction, and type (ii) and (iii) for the final compaction of the top portion of the layer, as defined below:

Type (i)	Vibratory single-drum roller
Type (ii)	Smooth double-drum roller
Type (iii)	Pneumatic-tyred roller (PTR) having a minimum weight when operating of greater than 7 tonnes, spread over at least seven-rubber-tyred pneumatic wheels over two axles.

Type (ii) and (iii) rollers may be replaced with a combination roller, which has one smooth drum at the one axle and rubber-tyred pneumatic wheels across the full width at the second axle of the roller.

- Vibratory Single-Drum Roller – Weight ? Amplitude ?
- Smooth Drum Roller – Weight? Width? Double drum or Three Pin?
- PTR > 7 tonne & ≥ 7 tyres over two axles
- If the laboratory MDD can't be achieved => Get approval from The Engineer to use the Plateau Density derived target.
- No standard test method for the Plateau Density Test!

Plateau Density Testing – NPTG TAN

NPTG draft Plateau Density Testing Guide => Waka Kotahi NZTA TAN started early 2020

The number of roller passes to achieve the optimum density can be influenced by the following main factors:

- Compaction Equipment (mass at the compaction drum(s), drum type, vibratory amplitudes and frequencies)
- Material type, grading, shape, maximum size and layer thickness
- Material's moisture content (MC) relative to the Optimum compaction Moisture Content (OCMC)
- The anvil provided by the strength of the underlying layer(s)
- Method of density testing (Backscatter vs Direct Transmission)

Plateau Density Testing – NPTG TAN

- Guidance regarding lift thicknesses for various aggregate sizes
- Roller widths and Centrifugal Force for various aggregate sizes

Widening or trench width (m)	Max. Aggregate Size (mm)	Lift thickness (min to max)	Typical roller width (m) and Centrifugal force (kN)
< 1.2m	20	40 to 80	0.8m to 1.2m 15 kN to 30 kN
1.2 to 2.5m	40	80 to 160	1.2m to 2.0m 50 kN to 100 kN
> 2.5m	65	130 to 260	> 2.0m 150 kN to 250 kN

Table 1: Pavement layer thickness relative to maximum particle size

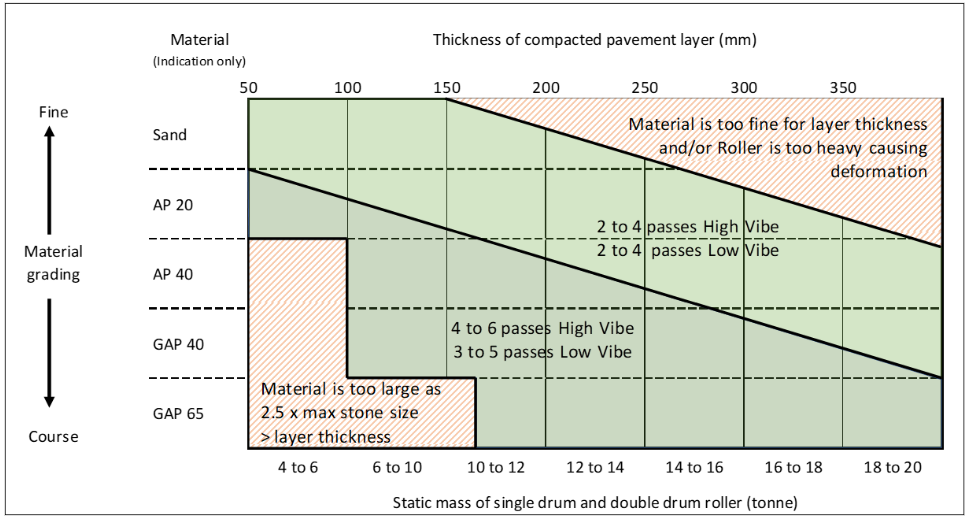


Figure 1 Guide to determine the appropriate primary compaction plant

Plateau Density Testing – NPTG TAN

Plateau Density Test Procedure

The recommended procedure for the plateau density test is as follows:

1) Lay down specified aggregate and condition to optimum compaction moisture content (see notes below) within a planned, daily production length (Figure 2).
2) Mark two test areas (one called A, the other called B) by placing the NDM on the surface to be compacted and marking the test perimeters with a spray can. These two test areas are generally between 10 and 20m apart along the same line (say in between the stabiliser's wheel paths in the case of in-situ stabilisation) and are used to check that the densities are in the same "ball park", remembering that the NDM tolerance is ± 50kg/m3 or 0.050 t/m3.

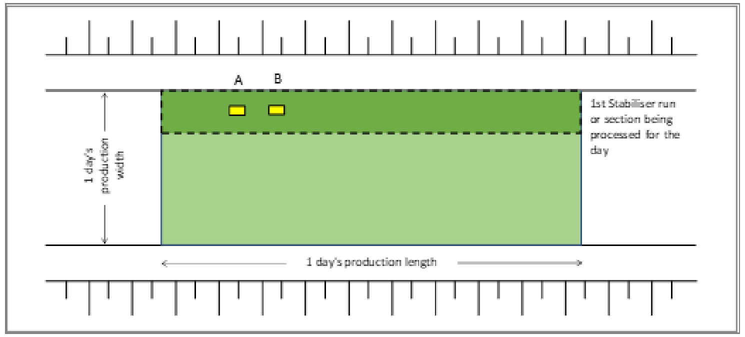


Figure 2 The layout of a Plateau Test. The yellow boxes represent where the NDM will sit during testing

3) Determine and record the bulk density, dry density and moisture content by placing the NDM on patch A and B before compaction and reference these as Loose-WD-A & B, Loose-DD-A & B and Loose-MC-A & B respectively. Calculate and record the average Loose-DD. Refer to Notes below regarding the most appropriate test specification to be used (Backscatter vs Direct Transmission).
4) Perform 1st pass of the vibrating (primary) roller at high vibe: VH = high amplitude / low frequency setting
5) Determine and record the bulk density, dry density and moisture content by placing the NDM on patch A and B and reference these as VH1-WD-A & B, VH1-DD-A & B and VH1-MC-A & B respectively (VH1 = first pass of the vibrating roller at high vibe). Calculate and record the average VH1-DD.
6) Perform 2nd pass of the vibrating (primary) roller @ VH = high amplitude / low frequency setting
7) Determine and record the bulk density, dry density and moisture content by placing the NDM on patch A and B. Reference these as VH2-WD-A & B, VH2-DD-A & B and VH2-MC-A & B respectively (VH2 = second pass of the vibrating roller at high vibe). Calculate and record the average VH2-DD.
8) Continue this sequence until the dry density measurements hover or drop slightly as shown in Figure 3 - this is the high vibe cut off.
9) Change the primary roller to low vibe (VL = low amplitude / high frequency setting) and repeat steps 4 to 8 recording as VL1-DD, VL2-DD, etc. until reaching the low vibe cut off.
10) Change the roller to static or replace with secondary rollers. With the static roller(s) carry out sets of 5 or 10 passes and record the dry density in patch A and B again, this time assign the numbers as S5, S10, etc. (S10 = ten static roller passes).

11) Continue secondary rolling with passes in groups of 5 or 10 until the dry density appears to plateau. Record as the Plateau Density target.

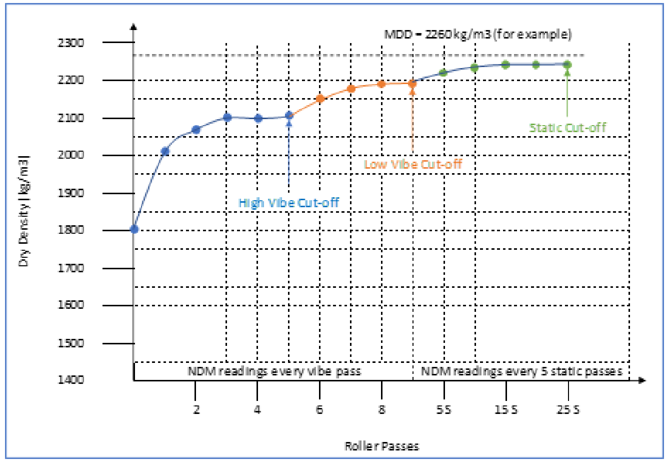


Figure 3: Plateau Density test – results presentation and compaction cut-off points

Reporting of results:

Over and above the NZS 4407:2015 reporting requirements, the following items should be reported:

- Material description
- Layer thickness / In-situ mixing depth
- If applicable binder(s) type and content
- If applicable time lapse from time of mixing with binder(s)
- NDM manufacturer and model
- Compaction equipment description
- Weather conditions
- Anvil – underlying layer description (if known) – ideally some for of deflection testing (Benkelman beam or FWD) will provide insight into this
- Optimum moisture content and maximum dry density (target)
- Test depth(s) if direct transmission is used

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PP2O Stabilisation Trials

PP2O Expressway Cement Bound Subbase

- Met all PRs regarding Density (the way we have been testing to date – Backscatter)
- Issue with cores not able to extract to the full depth

Extensive Trials to investigate various factors:

- Fines migration: Slurry vs No Slurry
- Particle Grading and Shape
- Compaction equipment
- Mixing energy
- Mixing Rotor (Wirtgen vs Bomag)

} Paper being drafted for future publication

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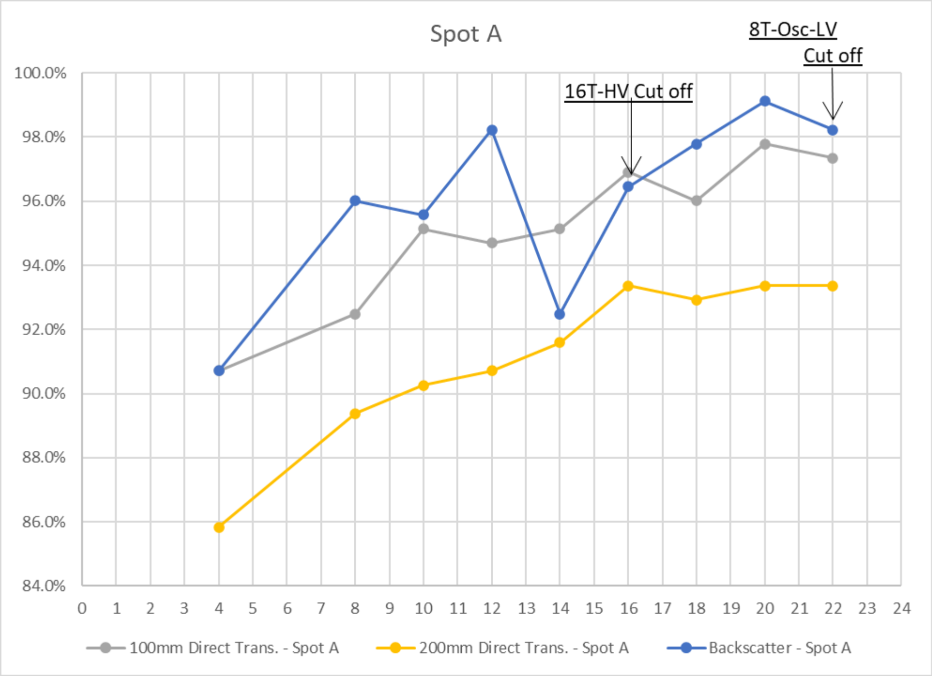
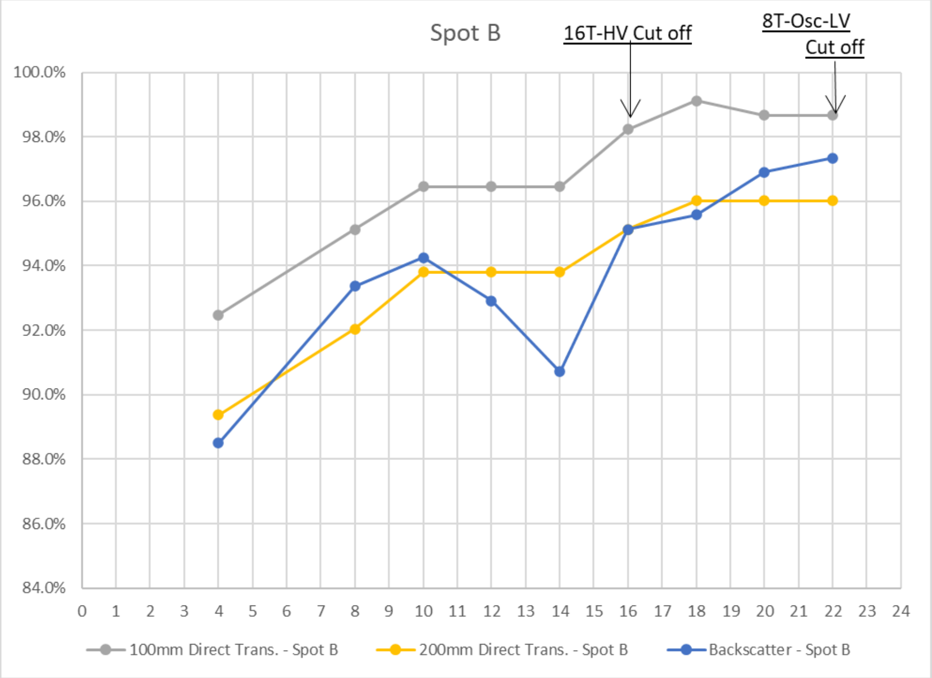
PP2O Stabilisation Trials





Typical Plateau Density Test using Direct Transmission

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PP2O Stabilisation Trials

Changes made:

- Substantial increase in the compaction energy –
  - 4HV passes with 14T HAMM to
  - 16HV passes with 16T Bomag Vario Roller
- No Padfoot (this needs to be slightly amended in NZTA B/6)
- Coring machine from electric to hydraulic driven unit

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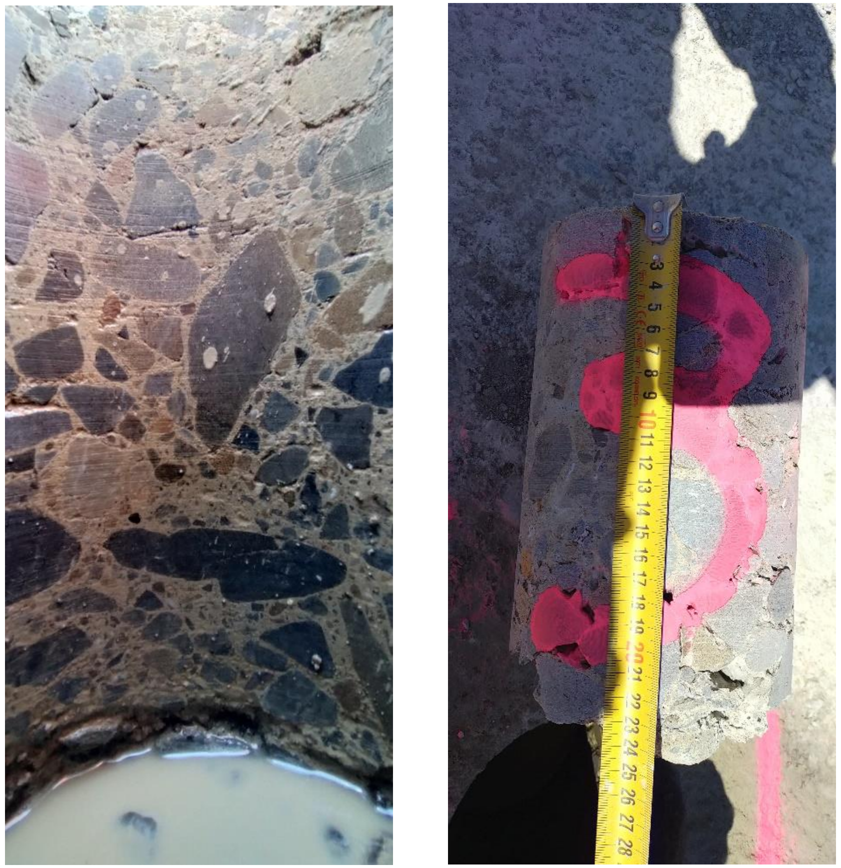
PP2O Stabilisation Trials

Typical Density Results for a lot achieved with revised methodology that was driven by Direct Transmission Plateau density testing

CoV				3.95%				1.11%				2.95%
Position	Backscatter				100mm DT				200mm DT			
	WD	DD	MC	DoC	WD	DD	MC	DoC	WD	DD	MC	DoC
Pos.1	2.39	2.23	6.8	98.9%	2.33	2.17	7.4	96.1%	2.36	2.21	6.8	97.8%
Pos.2	2.38	2.25	6.0	99.4%	2.36	2.25	5.3	99.4%	2.26	2.13	6.1	94.4%
Pos.3	2.32	2.19	6.1	96.8%	2.35	2.21	6.1	98.0%	2.34	2.19	6.8	96.9%
Pos.4	2.38	2.25	5.9	99.4%	2.39	2.25	6.1	99.6%	2.29	2.15	6.6	95.0%
Pos.5	2.24	2.13	6.1	94.2%	2.34	2.21	5.8	97.9%	2.24	2.12	5.8	93.7%
Pos.6	2.27	2.13	6.6	94.4%	2.35	2.20	6.9	97.3%	2.37	2.21	7.3	97.6%
Pos.7	2.42	2.28	6.1	101.0%	2.39	2.27	5.6	100.2%	2.33	2.18	6.9	96.4%
Pos.8	2.36	2.20	7.5	97.5%	2.36	2.21	6.7	97.8%	2.40	2.21	7.9	97.6%
Pos.9	2.36	2.18	8.1	96.5%	2.36	2.20	7.2	97.5%	2.38	2.22	7.3	98.2%
Pos.10	2.29	2.14	7.3	94.6%	2.37	2.22	6.4	98.2%	2.35	2.22	6.1	98.2%
Pos.11	2.31	2.15	7.5	95.2%	2.36	2.19	8.0	96.8%	2.40	2.25	6.6	99.6%
Pos.12	2.36	2.20	7.3	97.3%	2.37	2.22	6.6	98.4%	2.32	2.17	7.1	96.0%
Pos.13	2.33	2.17	7.4	96.1%	2.34	2.20	6.9	97.3%	2.38	2.25	6.6	99.5%
Pos.14	2.33	2.19	6.5	96.9%	2.36	2.20	7.2	97.4%	2.36	2.21	6.9	97.7%
Pos.15	2.20	2.15	7.1	95.0%	2.37	2.22	6.6	98.3%	2.29	2.15	6.3	95.2%
Average				96.9%				98.0%				96.9%
10th %-ile				94.5%				97.0%				94.6%
Minimum				94.2%				96.1%				93.7%

PP2O Stabilisation Trials

Original rolling pattern (Plateau using Backscatter) – Note conforming Density check using Backscatter



Typical Core using new rolling pattern (Plateau using Backscatter, DT100 and DT200)

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PP2O Stabilisation Trials

Recommendation by Project's-PTG after 3 months of trials was to change the PRs as follows:

- Continue with current mixing equipment (Wirtgen)
- Plateau Density test using BS, D100 & D200
- Density requirements for BS, D100 & D200 set at 95% Mean / 92% Min (usual Subbase requirements)

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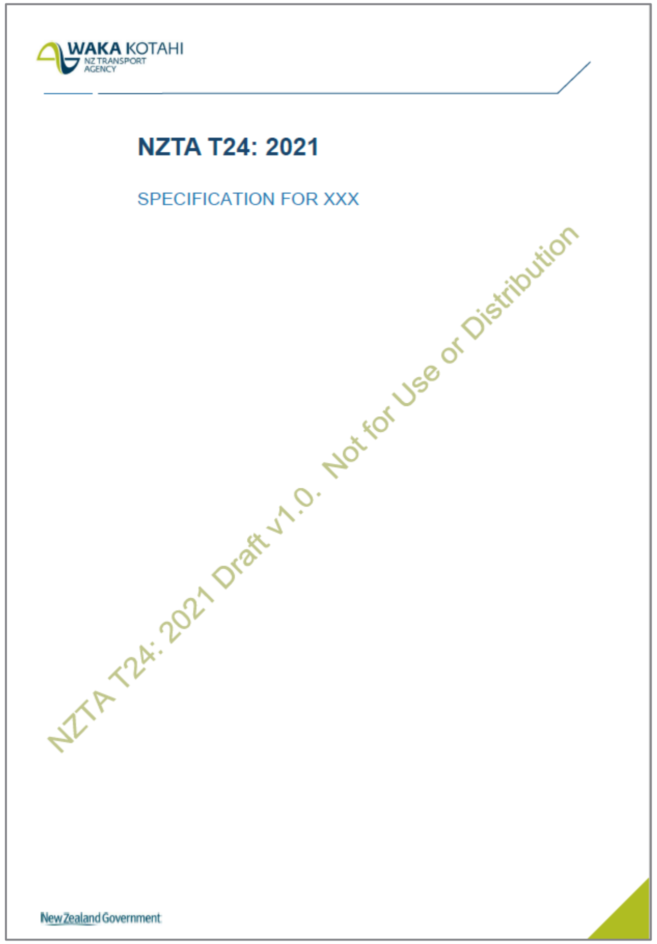
The Way Forward

Waka Kotahi NZTA Specification and Notes

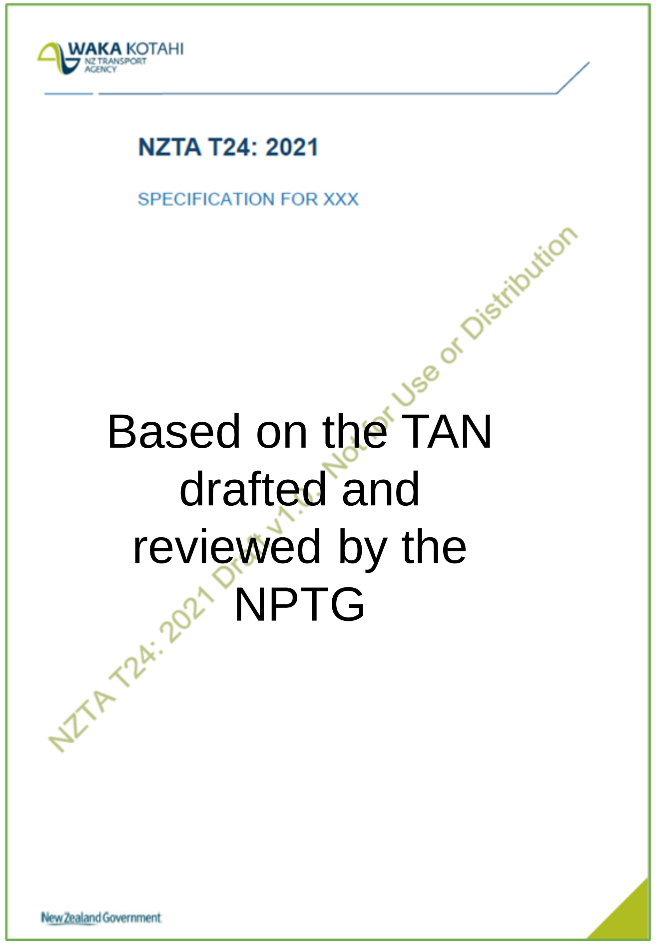

WAKA KOTAHI NZ TRANSPORT AGENCY

NZTA T24: 2021

SPECIFICATION FOR XXX

NZTA T24: 2021 Draft v1.0. Not for Use or Distribution

New Zealand Government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Based on the TAN drafted and reviewed by the NPTG

The Way Forward

Civil Contractors (CCNZ) pavement committee recommendation

- T/24 Test Method should be a process of how to do the plateau density test / direct transmission
- T/24 Notes - Interpretation for the technicians and/or the engineer
- Degree of compaction requirements incorporated into the revisions of the B-series specs
- Keep it simple – i.e. DoC limits for DT and BS as per B-series specifications
- Plateau Test is there to establish rolling pattern – not compliance
- Needs to be IANZ endorsed
- Release T/24 as Pilot Test Method and Notes for one season to collect data
- Waka Kotahi and LGAs realisation that there will be an additional cost