NZTA T24 Notes: 2025

Notes to the Determination of the Plateau Dry Density for Pavement Layers

1 Scope

1.1 General

The notes supplement the procedure for determining the Plateau Dry Density for pavement layers, excluding subgrades and subgrade improvement layers.

Various rollers, including Static Steel-Wheel Rollers, Vibratory Rollers, and Pneumatic-Tyre Rollers, are used in the Plateau Density Test (PDT) in order to determine the target dry density for compliance. The success of the test lies in the choice of the roller or roller combination for the combination of pavement materials, pavement thickness, and the underlying surface. These notes provide background to the factors affecting the choice of equipment, including both type and static mass. The Plateau Density Test (PDT) should take about an hour and should match the primary compaction specifications.

For layers incorporating stabilizing agents, laboratory Maximum Dry Density (MDD) using the T28 test method should be carried out on-site or nearby.

Intelligent compaction, while mentioned, is not covered as the determination of the relevant pavement response is determined using equipment specific methodologies.

1.2 Collaborative Partnership

These notes explain the roles and responsibilities of both the contractor and an IANZ accredited laboratory during the Plateau Density Test, emphasizing collaboration and accountability to ensure quality construction processes.

It is essential that both parties, contractor and laboratory, engaged in the plateau test maximize the values of ownership and partnership throughout the testing process. Ownership involves establishing a strong foundation of trust between the contractor and the laboratory, enabling the exchange of opinions and advice to achieve the best possible outcome. Each team member should take pride in their contributions, aiming for continuous improvement of processes.

2 Referenced Documents

No notes.

3 Definitions

No notes.

4 Quality Management Requirements

No notes.

5 Apparatus

5.1 Test equipment

The test methods for determining the bulk density, moisture content and calculated dry density using a nuclear moisture-density gauge are:

(a) NZS 4407:2015 Test 4.2 for full-depth direct transmission

Waka Kotahi NZTA now require the use of the full-depth direct transmission test when the layer thickness ≥ 100mm, which provides a more accurate density measure.

This method involves drilling a hole in the compacted granular layer and inserting the NDM probe to the full depth of the layer for testing.

Trials during the development of T24 show that using direct transmission tests significantly the compaction efficiency through improved the choice of rolling equipment, and the rolling pattern. This method also provides a better indication of the density to the full depth of the layer.

(b) NZS 4407:2015 Test 4.3 for backscatter mode.

The backscatter mode measures the bulk density to a depth of approximately 70 mm to 90mm and that the moisture content sensor measures to a depth of approximately 75 mm depth.

As such only the moisture readings from the initial density readings at the beginning of the T24 are not used for the analysis.

Backscatter may be used on pavement layers less than 100 mm thick.

5.2 Compaction equipment

5.2.1 Factors influencing compaction

Road building aggregates can be compacted well as there are smaller particles which move into the voids between the larger particles during the compaction process and vibratory effects leading to a higher bearing capacity. This increased bearing capacity maximises at around the MDD and OMC for any given material type and compaction effort.

Compaction reduces the air voids making it more difficult for water to flow through soil and can prevent the build-up of large water pressures that cause soil to liquefy during earthquakes.

There are several factors that need to be understood when compacting soils:

(a) MDD and OMC are not absolute

The MDD and OWC vary with the weight and efficiency of the compaction process and material type, as shown in Figure 1.

The ultimate maximum dry density therefore depends on the applied compaction energy rather than just the aggregate characteristic.

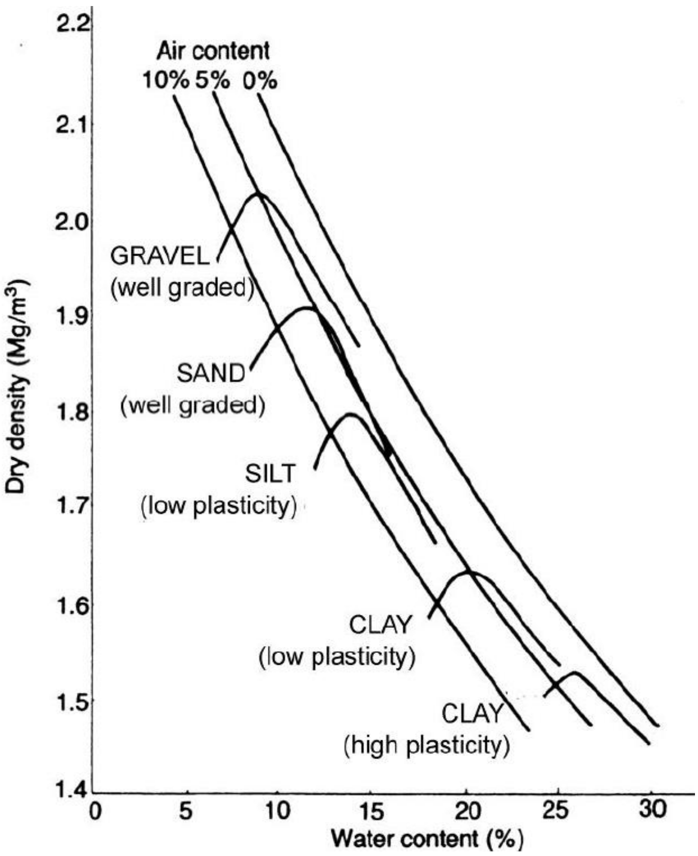

Figure 1: Density variation due to material type compacted under similar conditions. (Soil Compaction, Dr. P McMahon)

(b) Aggregate type

When selecting compaction equipment, the compaction effort required is influenced by the material characteristics, including:

Key considerations compaction include:

- *Particle size distribution*: Well-graded aggregates compact better, have higher MDD and lower OWC, and generally have higher load-bearing capacity.
- *Clay content*: Higher clay content materials require kneading rollers for efficient compaction.

Soil and aggregate materials are classified into two main categories, granular and cohesive based on these characteristics.

- *Granular soils* consist mainly of sand and gravel. The particles are coarse and large enough to see with the naked eye. These soils are best compacted with vibrating rollers as the vibratory action reduces the frictional forces at the contact surfaces, allowing particles to fall freely under their own weight.
- *Cohesive soils*, composed of silts and clays, have small grains that feel smooth. They compact best with a combination of impact force and kneading using tools like tamping rollers or sheepsfoot rollers to expel air voids and excess water.

(c) Moisture

Moisture is a crucial factor affecting soil. Moisture plays a critical role in soil compaction.

The right amount of moisture, called Optimum Water Content (OWC), is necessary for effective compaction as illustrated in Figure 2.

Too little moisture will result in the particles not adhering to each other and difficult to compact. Too much water causes particles to displace easily.

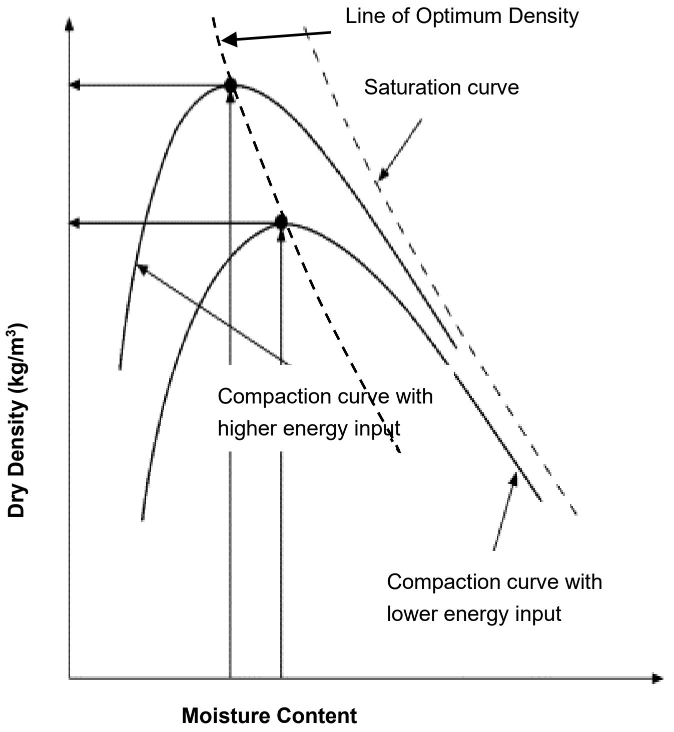

Figure 2: Improvement of density due to higher energy input, e.g. heavier compaction equipment.

Note the OWC reduces with increase in MDD.

However, the Optimum Compaction Water Content (OCWC) can vary based on the type of aggregate, compaction equipment, and stabilizing agents used. Typically, OCWC is slightly lower than OWC for low stabiliser contents but can be higher than OWC with high cement contents. Compaction at OCWC also helps attain maximum strength characteristics like CBR, UCS, or ITS.

5.3 Intelligent compaction (IC)

Intelligent compaction (IC) is a growing technology being adopted in pavement material compaction. Agencies use specifications for IC in earthwork construction, including calibrating IC strips for quality assurance. Waka Kotahi is working with industry to implement IC technology.

6 Procedure

6.1 General

Compaction involves using rollers with adequate static and dynamic mass and matching the compaction methodology at all stages.

The B-series specifications state that no compacted layer should exceed approximately five times its maximum nominal size (see B02 for details). Table 1 shows typical roller mass for different combinations of materials and layer thicknesses.

Table 1: Typical combinations of roller masses, material types, and layer thickness.

Compacted layer thickness (mm)	Aggregate material type			
	AP 20	AP 40	AP 65	AP 100
<100	8t	10t	N/A as less than 2.5 x Max size	
100-200	12t	12t - 14t		
200-250	N/A – too thick for pavement layers	14t-16t		
250-300			Generally ≥16t	
No compacted pavement layers to be >300mm				

It should however be noted that these values are not absolute as new technology rollers, such as Bomag's vario-control rollers, reportedly offer higher compaction performance (m³/h) and compact to greater depths per unit mass than standard vibratory rollers.

Table 2, extracted from SAPEM 2014, gives recommended compaction equipment for various material types.

Table 2: Selection of compaction equipment

Type of compaction equipment	Rock fill	Sand and gravel		Silt and clayey material		Clay		Surface seals	Asphalt	Stab. layers
		Well graded	Poorly graded	Silty sand silty gravel	Clayey sand clayey gravel	Weak	Strong			
Flat wheel roller		✓	✓					✓	✓	✓
Pneumatic tyred roller[1]		✓	✓	✓✓	✓✓	✓		✓✓	✓	✓
Impact roller	✓	✓✓	✓✓	✓✓	✓✓	✓				
Grid roller	✓	✓	✓	✓	✓	✓	✓			
Vibrating roller	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		✓✓	✓✓
Padfoot roller				✓✓	✓✓	✓✓	✓✓			

Legend

✓✓	Recommended
✓	Can be used

Notes

1. Pneumatic tyred rollers should not be used on Stone Mastic Asphalt layers. They can damage the surface of the layer.

6.2 Test Section location

The approximately 50m Test Section must fulfil the specified requirements, including being part of the permanent contract works, excluding previous PDT locations, avoiding transition or tie-in areas, and representing the test Lot as specified, and meeting the construction specifications for materials and layer thickness.

The test positions shown in Figure 1 and Figure 2 of the T24 specification, located ±5 meters apart, were selected to accurately represent the placed material with minimal variance from either material properties or the underlying anvil. It is acknowledged that variations will occur, particularly in maintenance rehabilitation contracts where both the underlying material and its response can be highly variable, resulting in differing compaction density outcomes.

6.3 Mixing, preconditioning and sampling

The preconditioning of the layer is a vital part of the test procedure. The layer should be prepared as close as possible to the final levels, taking bulking into account. Water should be added so as to achieve on the dry side, but close to OWC. In the field it is sometimes difficult to determine this as the laboratory may not be available with their NDM.

6.3.1 Hand Squeeze Test

The hand squeeze test is a good indicator of the OWC and will generally provide you with a moisture content that is within 0.5% of the OWC.

Proceed as follows to perform the hand squeeze test:

- Take a handful sample of material.
- Remove all particles greater than 5mm (the water generally held by the fines / sand fraction).
- Squeeze the sample in your hand as hard as you can.
- Observe the material;
    - If its dull and falls apart = TOO DRY
    - If its shiny and falls apart = TOO WET
    - If it’s slightly dull but sticks together = JUST RIGHT

Figure 3: Take a handful sample of material and remove all particles greater than 5mm as the water generally held by the fines / sand fraction. Squeeze the sample in your hand. If it holds together well, the material is close to OWC.

There are some exceptions to the rule - non-cohesive gravel or mostly sandy soils, and pure clays. As an example, NZTA M04 is difficult to carry this test on, with the hand-compacted material falling apart easily. In this event, observe one of the larger stones from deep inside the stockpile. If the fines are sticking to the larger stones, then chances are you’re close to OWC.

6.3.2 Pre-rolling

Once the material has been placed, mixed and levelled, a single or 2 roller passes should be carried out to allow the sampling and testing to be carried out and to assess the levels and any segregation that may be in effect.

The Hold Point has been put in place to ensure that a robust check of these is carried out prior to completion of the PDT.

6.3.3 Sampling and testing

Layer material samples for MDD and bearing capacity tests (CBR, UVS or ITS) should be sampled from a single point to get the most representative sample of the PDT. However, in practice this may extend the PDT significantly and samples for these tests may be staggered across the entire Lot. All sub-samples must be mixed together prior to testing so that the T28 MDD and CBR may be carried out on homogeneous materials. Individual sub-samples may be used for the compaction of the ITS or UCS at insitu moisture conditions so that laboratory compaction is carried out within the specified time limits.

Samples for the moisture content, however, must be taken from directly under, or adjacent to the NDM test points so that the moisture correction is as accurate as possible.

6.3.4 Addition of water

On very hot and windy days, the surface may not knit together well during the plateau test. This might be due to loss of cohesion at the surface, which will need to be remedied by a light sprinkle of water to dampen the surface. This may however affect the density readings, and any addition of water during the plateau density test should be recorded on the plateau density test sheet.

6.4 Compaction and Testing Procedure

A key objective of the PDT is to establish the most efficient compaction procedure for ensuring a uniform density is achieved to the full depth of the layer. Compaction plant must be appropriate for the material and thickness combination. Compaction plant too light results in the lower portion of the layer incompletely compacted, even though the layer appears compliant to the B-series specifications. Under traffic this is quickly consolidated, resulting in 'shake-down', or rather rapid rutting occurring in the first few years, after which the rut rate per annum reduced to a relative constant. This is one of the main reasons why the PDD is compared to the Laboratory MDD, and the full-depth direct transmission NDM dry density testing is now specified.

To achieve the maximum density possible, a robust technically sound and practical process is needed. The T24 can be completed within ±1 hour, with all three compaction stages completed, if needed.

Each compaction stage follows a similar process for simplicity, but with differences in compaction equipment and/or vibratory mode.

At the initial stages of each process, the compaction is rapid, and testing at test position X0 can be carried out at greater intervals. As the density develops, however, the number of passes before testing must be reduced to ensure that the change in density per pass on the graph is sufficiently large. This is so that the 'plateau' may be identified more accurately for each of the stages.

At times during the compaction and testing process, a false peak is achieved, identified by a sudden drop in density. This might be the result of poor material grading, lack of moisture or several other factors. It is easily identified as such by inspecting the large aggregate for crushing or fracturing, which both happen during the final stages of compaction. With the presence of the above, a false peak can be assumed and the test continued as normal.

Once the true peak has been established for each stage, all three test positions are tested to see if the test section is uniformly compacted over the full 20 m section, i.e. the anvil and material are not significantly different to the central test position X0.

6.5 PDD Validation

Each compaction stage recognises that the dry density variance between the test positions changes, and the allowable variance reduces for each stage. These limits are set from the analysis of a number of PDTs and multiple project compliance testing where both backscatter and full-depth transmission were carried out. These limits therefore may appear quite generous. The test results of 3 consecutive tests show that often the variance may be greater than the limits placed in Tables 3 and 4.

This is due to the small sample size within the PDT Lot. The Principal or their agent must take note of this when comparing the laboratory MDD and the PDD for identifying the Target Dry Density.

6.6 Setting the Target Dry Density

The Target Dry Density (TDD) is considered to be the higher of the laboratory MDD and the PDD. At times however, the laboratory MDD may be unachievable in the field due some of the factors mentioned previously. A general rule to identify this is, if the Degree of Compaction (DoC) results consistently fall 3% - 6% above or below the Target Dry Density (TDD), the TDD might be too high or too low.

Contractors must inform the Principal if the laboratory MDD cannot be achieved so that they may evaluate the results and give instructions for adjusting the Target DD or for a new PDT before constructing the next layer or applying a surfacing.

The PDT may reveal that the MDD from the laboratory cannot be achieved due to one or a combination of factors, including:

- Inadequate subgrade or subbase resistance (anvil) leading to a lower plateau density and inadequate compaction of the Lot when compared to the laboratory MDD. Testing with Benkelman beam or FWD may help identify if this is the cause.
- The laboratory MDD target might be incorrect. Differences in lab tests can cause different MDD results, e.g NZS 4407 heavy hammer vs NZTA T28 vibratory hammer. Laboratory tests generally alter the aggregate grading slightly as they only test the minus 26.5mm or 37.5mm fraction. Most test methods allow for correcting this, and there is a small chance that the corrected laboratory MDD for these larger aggregates may be higher, and not achievable in the field. Comparisons done during the T28 vibratory hammer test method development, however, did not show a statistically significant difference.
- The field compaction equipment (roller combination) may be too light, with the laboratory MDD test showing where maximum density could be reached if in-field compaction conditions were similar. The Principal may then instruct the contractor to dig a few test pits in the pavement layer to ensure that the full layer has visually been compacted. If not, they should instruct the contractor to halt the PDT and redo it.

6.7 Nuclear Densometer Water Correction Factor

The taking of moisture correction samples from the compacted base layer has been controversial for many years because neither contractors nor clients want a test hole dug into their newly compacted pavement layer. The test method to which the laboratory is accredited, however requires that the moisture correction sample shall be taken directly under the tested areas. This has led to laboratories then using estimates for the moisture correction. This is not an acceptable practice as it may lead to approval of non-compliant layers or rejection of compliant layers. NZTA requires the moisture correction to be undertaken during the PDT, and while it is accepted that there is a degree of inaccuracy, it is more representative of the layer than an estimate.

The laboratories must note that the above is a client-specified change to the New Zealand Standard test method and should record it as such on the test report and compliance test reports, where used.

6.8 Monitoring of Visual Condition

During the test procedure the Laboratory and Contractor must monitor the Test Section surface for signs of mobilisation of the underlying layer, or over-compaction of the layer.

During final compaction, it is important to inspect for biscuit layers, caking, or thin interlayers. Compacted layers of fine aggregate form during rolling, especially with slushing during final finishing. It is critical that these are removed by means of a mechanical broom during the compaction process. If left to dry, they'll harden like concrete, making brooming ineffective, even after several days of running course and trafficking. It will result in a surface that has a very fine surface mosaic, with few large stones visible.

If left in place and the road is sealed, infiltration water and the binder diluents tend soften them up, with flushing or potholes following. There have been several projects where this has resulted in a total rejection of the Lot, at significant cost to the contractor.

Table 3 below gives some guidance for visual monitoring during the PDT.

<table>
<tr><th colspan="2">Table 3: Visual monitoring during the Plateau Density Test</th></tr>
<tr><td>Segregation</td><td>Layer appears variable with loose or segregated i.e. boney or fine areas.</td></tr>
<tr><td colspan="2"> 
Segregation in a pavement layer refers to the uneven distribution of aggregate sizes throughout the thickness or surface of the layer. It can be identified by a rough, uneven surface texture, with areas of coarser or finer aggregate than the surrounding area, as noted in the above pictures. Notice areas where the surface appears to have more large aggregate particles or, conversely, areas where the surface is smoother due to a lack of larger particles. Segregation can sometimes cause color variations, with areas containing more fines appearing darker.
This can lead to reduced pavement strength, increased susceptibility to cracking and potholes, and ultimately, premature pavement failure.</td></tr>
<tr><td>Biscuit layers, or caking</td><td>Compacted thin layers of fine aggregate which are delaminating from the layer and in limited areas. Known as caking, interlayers or biscuit layers.</td></tr>
<tr><td>
Fines on surface shear off in thin layers under final rolling, especially when roller turns.</td><td>
Typical thin layers on top of aggregate matrix at pr-seal inspection caused by slurry layer not being removed and drying out.</td></tr>
</table>

<table>
<tr><th colspan="2">Table 3: Visual monitoring during the Plateau Density Test</th></tr>
<tr><td>
Note the texture variations in the base course mosaic.</td><td>
Small ‘pop-outs’ showing the solid layer below.</td></tr>
<tr><td colspan="2">
The biscuit layer portrayed in the above pictures shows what the mosaic looked like before removing the very thick biscuit interlayer in the right hand picture. This is probably the worst case scenario, with the layer being in the region of 15mm thick. A good indicator is a low Clegg reading, even though the DD is high, however a low Clegg may also just mean a high DOS.</td></tr>
<tr><td colspan="2">A "biscuit interlayer" or “caking” in a pavement layer refers to a weak or poorly bonded layer, often appearing as a thin, brittle layer that separates from the surrounding pavement material. It can be identified by a variable rough and fine texture, and through:
• Scabbing, areas where the pavement surface appears to be lifting or flaking off, revealing a distinct layer underneath.
• Delamination, areas where the pavement layers are separating or peeling apart, indicating a weak bond.
• Surface Texture, areas of unusual textures or irregularities.
• Caking can sometimes be accompanied by cracking, as the weakened surface becomes more susceptible to further damage. Interlayer shear failure can lead to cracks that propagate along the weak layer.</td></tr>
</table>

It is very important that the observations obtained from the visual inspection are recorded.

7 Reporting

7.1 Test Method

Reporting is an important part of the test, and the laboratory test report should bear the IANZ logo with a sentence limiting the accreditation to:

- NZS 4407 Test 4.3: Backscatter (60 seconds) moisture content, with a caveat for the moisture correction samples taken adjacent to the test position; and
- NZS 4407 Test 4.2: Direct Transmission (60 seconds), with a caveat for the moisture content correction.

7.2 Observations

At times the laboratory will be required to note observations or other issues identified during the execution of the PDT on the test report.

Laboratory staff are not always comfortable reporting these as they are opinion-based or subjective. NZS ISO/IEC 17025 clause 7.8.7, *Reporting opinions and interpretations*, allows for such observations by accredited organisations, and is quoted below for clarity.

> ***"7.8.7.1*** *When opinions and interpretations are expressed, the laboratory shall ensure that only personnel authorized for the expression of opinions and interpretations release the respective statement. The laboratory shall document the basis upon which the opinions and interpretations have been made.*
>
> *NOTE It is important to distinguish opinions and interpretations from statements of inspections and product certifications as intended in ISO/IEC 17020 and ISO/IEC 17065, and from statements of conformity as referred to in 7.8.6.*
>
> ***7.8.7.2*** *The opinions and interpretations expressed in reports shall be based on the results obtained from the tested or calibrated item and shall be clearly identified as such.*
>
> ***7.8.7.3*** *When opinions and interpretations are directly communicated by dialogue with the customer, a record of the dialogue shall be retained."*

For further clarity, an observation is defined as "*the act or process of closely observing, monitoring, or noticing something to make a judgment or inference, and making a record of the resulting information. A written or spoken report, or description of something noticed or studied, and reported*".

8 References

The following references were used in writing the T24 test procedure:

i. ATT-58/96 DENSITY TEST, Control Strip Method', part of Quality assurance testing and reporting, Transportation Test procedures, Test procedure index, including Alberta Transportation Tests (ATT) and transportation laboratory tests (TLT), for road construction material. Available from: https://www.alberta.ca/alberta-transportation-test-att-procedures.

ii. Field Determination of Target Density for Plant Produced Asphalt Mix by Use of the Control Strip Technique, SCDOT Standard Method SC-T-65 (5/10), SCDOT Form No. 400.0, from the SCDOT Construction Manual and the SCDOT Laboratory Procedures Manual. Available from: https://www.scdot.org/business/materials-testprocedures.html.

iii. MDT MT 219 Controlling Compaction Using a Control-Strip test, Montana Department of Transportation (MDT) (.gov). Available from: https://www.mdt.mt.gov/other/webdata/external/materials/materials_manual/219.pdf

iv. General Specification G4 - Compaction Assessment March 1995, Department Of Infrastructure, Energy And Resources, Tasmania, available from: https://www.transport.tas.gov.au/?a=107782

v. Amendment to OPSS.MUNI 501 (Nov 2014) – Construction Specification for Compaction TS 501 – September 2017. Available from https://www.toronto.ca/wp-content/uploads/2022/09/8eaf-ecs-specs-roadas-TS-501-Sep2017.pdf.

vi. Chapter 8 Roller Patterns, Control Strips, And Test Sections, VDOT Soils and Aggregate Compaction 2016 v1.0. Virginia Department of Transportation (.gov). Available from https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/materials/VTMs_Updated_250305_acc.pdf

vii. M. C. ANDAY and C. S. HUGHES, Compaction Control of Granular Base Course Materials by Use of Nuclear Devices And a Control Strip Technique, Virginia Highway Research Council, Charlottesville. Available from https://onlinepubs.trb.org/Onlinepubs/hrr/1967/177/177-009.pdf

viii. NETTERBERG, F and DE BEER, M. Weak interlayers in flexible and semi-flexible road pavements: Part 1. *J. S. Afr. Inst. Civ. Eng.* [online]. 2012, vol.54, n.1 [cited 2025-07-10], pp.31-42. Available from: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-20192012000100004&lng=en&nrm=iso. ISSN 2309-8775.