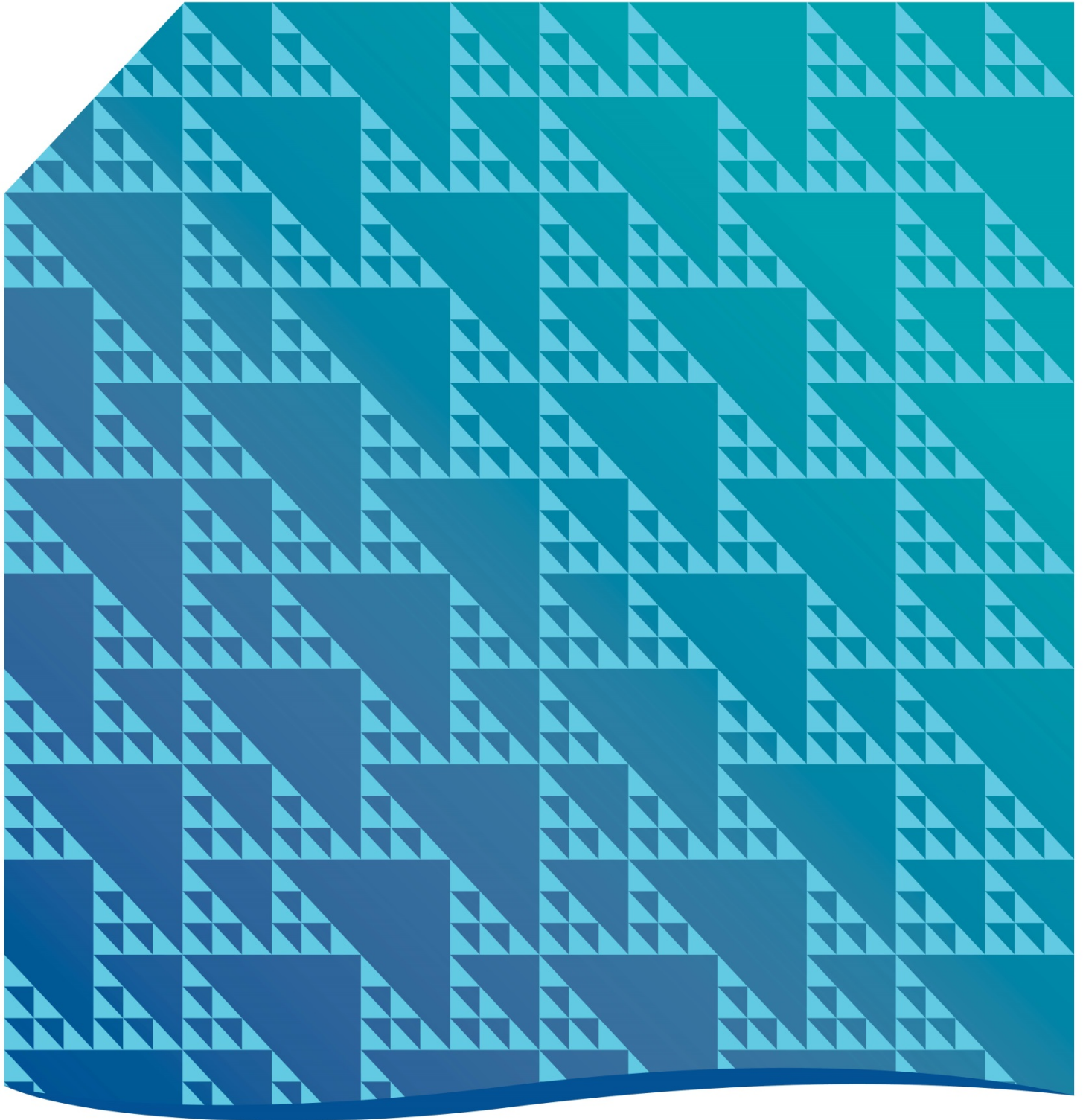


ENR40 Pavement Base and Subbase  
*Explanatory Notes*  
Date: July 2014  
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# Roadworks Specification



**REVISION REGISTER**

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## ENR40.1 SCOPE AND INTENT

### ENR40.1.1 *These Notes*

These notes explain the background and reasoning behind *Standard Specification R40*. Its focus is mainly on the quality control system. It is intended to assist contractors and contract supervisors. These Notes do not form part of a specification.

### ENR40.1.2 *Specification R40*

In addition to defining the required properties, the specification puts an emphasis on quality control and documentation. Documents are to be concise and readily accessible to both the Contactor and Superintendent.

The specification is directed towards achieving uniformity of materials and processes. It defines quality control regimes and requires the use of control charts. These provisions serve the mutual interest of both the Contractor and Department of State Growth by lessening their particular risks.

The Contractor benefits because:

- uniformity in materials permits uniform construction processes which in turn facilitate the progress of work.
- control charts provide a means for the early detection of changes in the quality of incoming supply and in the Contractor's achievements. Problems can be detected and eliminated early, reducing the necessity for re-work and retests.

Department of State Growth benefits because:

- level of service (smoothness) of pavements depends on uniformity of products and processes;
- tight quality control within a process is the most effective means of ensuring the quality of outcomes.

The quality control system of *Standard Specification R40* is closely linked to the quality systems of two other specifications.

- *G6 Production Of Aggregates and Rock Products*
- *G4 Compaction Assessment*

It is prudent to treat the three specifications as an integrated system; one intended to assist in the oversight and control of materials from their origin in a quarry to their place in the pavement.

The various elements of the system and their potential usage are discussed in the following.

## ENR40.2 BACKGROUND

The primary interest of the Principal is that the pavement remains functionally adequate over an extended period of time. There are limited opportunities to frame a specification in this way. The compromise is to specify the characteristics of the constructed product, with the expectation that these characteristics will produce the required performance of the pavement. This involves the specification of a range of required properties, including:

- Material quality
- In place condition (eg moisture and density)
- Dimensions and shape

Material quality is specified in terms of classification/ characterisation tests, such as particle size, Atterberg Limits, durability, CBR etc., on the basis that materials falling within the specified ranges have given adequate performance.

### ENR40.3 RESPONSIBILITIES AND INTERESTS OF CONTRACTOR

The specification generally avoids reference to construction procedures, for these are the Contractor's responsibility.

The Contractor is responsible for the quality of the completed pavement. While the specification allows the Contractor to use control test data from a *Standard Specification G6* compliant source as evidence of compliance, the Contractor is still fully responsible for the quality of the product supplied to the job. The prudent Contractor will keep a close eye on the quality of the incoming product and on the supplier's test data, as will the vigilant supervisor.

The specification defines an acceptable range of properties of the in-place products. Within this specified range there will be a range in the handling, raveling and ease of placement and compaction characteristics, some good and some not so good. It is the Contractor's responsibility to choose materials suitable to the particular task, bearing in mind such matters as:

- if road traffic will be running over the works;
- urban or rural;
- previous experience with product
- compatibility with plant and skills;
- time of year/climate;
- specified layer thickness;
- price compared to ease of handling, placing, cost of control, reliability of supply etc.

### ENR40.4 QUALITY CONTROL ELEMENTS OF THE SPECIFICATION

The following provides comment on the various parts of the specification that relate to the control of quality.

#### ENR40.4.1 Lots

The common effect of not meeting the requirements of homogeneity of a parcel of work is an increase in the measured standard deviation and in the risk of non-compliance. Non-uniformity in materials and moisture content will markedly increase the risk of non-compliance in compacted density.

Note that the definition of a lot refers to a single production unit, produced by the same work process and brought to completion at the same time. The lot size for compaction will often be a single days work. On the other hand, the process that produced the pavement materials is basically continuous and for this reason an arbitrary lot size is stated. Ref Clause *R40.6.3 (a)*.

While large lot sizes might appear attractive because of a reduction in the cost of testing, this attractiveness is lost when the lot fails, because the deficiency will apply to a larger area.

#### ENR40.4.2 Assigned Value and Test Frequency

Because of inherent variability within a product and within test procedures a single test result will often not provide a reliable picture of true quality. The assigned value approach requires that the assessment of quality is based on a number (generally 5) of the most recent test results.

The assigned value for durability, Flakiness Index, Soaked CBR is essentially the lower or upper 15 to 20%ile (characteristic) value. **This means that 15 to 20% of results of a just complying product may fall outside of the specified limits.** It is calculated from the following equation:

$$\text{Assigned Value} = \bar{x} \pm s$$

Where:

- $\bar{x}$  is the average of the five (5) most recent test results
- 's' is the sample standard deviation of the five (5) most recent test results.

The assigned value applies to an essentially homogenous product, that is one without obvious changes in properties, whether or not these properties are directly related to the particular property in question. This qualification also applies to a lot. This qualification about homogeneity is very important. The mixing of data from different populations will inevitably lead to poor decisions. If the appearance of materials has changed or if there are unexpected changes in the control charts, investigate the cause.

While testing based on a small number of samples might indicate that a product complies with a specification, further testing might show that the product does not comply. This uncertainty about compliance is lessened when the gap between the assigned and specified values increases. In consequence the specification offers a reduced level of testing when the test data indicates that the particular quality is well within compliance limits.

#### **ENR40.4.3 Sampling Procedures**

Control of the quality of incoming material is exercised through testing for particle size distribution and properties of fines. The specified frequency is three tests per lot. Maximum lot sizes are defined in R40.6.3.

#### **ENR40.4.4 Target Grading**

The specification sets the target grading for Base Class A. For the other materials it allows the Contractor to nominate a target particle size distribution within a range, provided that the material meets other criteria, such as soaked CBRs.

The target grading should be based on the median grading determined from past experience. Failure to set a target grading consistent with the median value will substantially increase the probability of non-compliance and may require a change to the target. Ref Clause R40.6.3 (d).

**The specified particle grading refers to the particle size distribution after compaction. There should be a clear distinction between test data applying to products tested prior to compaction and tests after compaction. Compliance should not be assessed on pre-compaction test data unless full account is taken of potential breakdown. R40.6.3(c).**

Testing for compliance of the in-place material has many drawbacks. The detection of defective material after it is in place and compacted can be extremely disruptive to the construction program. Testing prior to compaction can be quite misleading where significant breakdown of particles occurs during placement and compaction.

The specification (Clause R40.6.3) permits the Contractor to submit production control data (prior to placement and compaction) provided full account is taken of expected breakdown from compaction. (Refer to R40.6.3 (b) and Appendix B1)

Changes to the placement and compaction procedures, such as compaction in excess of that used in the trial may invalidate the results of the trial and the target grading.

##### *(i) Base Class A*

The target grading for the Base Class A is a maximum density grading; one intended to provide an ideal packing of the various particle sizes with resulting good interlock of particles and in consequence, high strength.

*Note: The stability of materials with maximum density grading is often quite sensitive to relatively small changes in the percentage and plasticity of fines and moisture content. The limits placed on the percentage passing the 0.075mm sieve relative to the percentage the 0.425mm sieve is an attempt to ensure that the fines are not under or over represented.*

##### *(ii) Other Courses*

Experience has shown that a wide variety of particle grading can fulfil the functions of Base Class B, Subbase 1 & 2. The approach adopted in the specification is to set quite wide limits

for the target grading requirements for these other courses (Refer Appendix A) but to control uniformity by setting limits on variability. Limits are also set on grading ratios (quotient of the percentage passing two identified sieve sizes). The ratios ensure that particular particle sizes are not under or over represented in the product.

*(iii) Deviation Limits and Causes of Variability*

The deviation limits given in the "A" series appendices define the acceptable variation of:

- lot mean;
- test results of each and every sample

from around the target grading.

The aim of the limits is to control variability consistent with material behaviour, good production practice and commensurate with the product's exposure and function within the pavement. Wider limits are set for the lower, less heavily stressed courses.

*Note: The major components of measured variability in the quality and compactness of in-place materials are associated with variabilities in:*

- *incoming products and moisture content;*
- *processes and plant used in placing and compaction;*
- *repeatability and reproducibility of sampling and testing.*

*Variability arising from the above is inescapable and due allowance for normal variabilities are provided for in the deviation limits.*

*Variabilities associated with the repeatability and reproducibility of sampling and testing are relatively fixed. These types of variabilities are unbiased (not favouring the Contactor or Principal in the long term), though from time to time they may cause an incorrect decision to be made about a particular lot, in situations where the true quality of the lot is close to acceptance level.*

*Systematic errors that arise from incorrect sampling and test procedures or from an out-of-calibration meter are always biased. They may result in continuing wrong decisions. The detection and elimination of systematic error should be a primary aim of both the Contractor and Superintendent.*

*Control charts can be particularly useful in distinguishing between a statistical blimp or a systematic error.*

*(iv) Quality Control Documentation*

There are two broad requirements concerning the documentation of quality during the construction operations:

- traceability between the test data and the location of the tested material in the pavement
- control charting of material quality information

The Contractor is required to provide " *traceability between the location of the material in the pavement and the production quality testing*". There is also a requirement in G4.8.1 that the Contractor must provide " *A longitudinal section (schematic) of the works identifying the precise location of all lots tested*"

Control charts relating to the supply and placement of material under R40 include:

- Maximum density and characteristic density for the various lots and courses (G4.8)
- Durability (Wet Strength and Wet Dry Strength Variation WDSV) and Flakiness Index in G 6.9
- Particle Size Distribution, Properties of Fines and CBR, R40.6.3 (e)

Control charts, assist in the:

- early detection of changes in material properties. These changes can be expressed by changes in particle size distribution, Atterberg Limits or Maximum Dry Density;
- determination of causes as to why the Contractor fails to achieve the specified compaction requirements;
- delineation between longer term trends and an aberrant result, statistical outlier, etc.
- detection of systematic error/bias in test data
- reduction in the volume of paper required to manage and document the contract, including the completion report.

Test results should be entered on the charts without delay. The charts should have a prominent position.

Results plotted on the control charts should have a clear linkage to the position/lot within the pavement. The number of points on a chart should match the required test frequency and amount of work completed.

*Appendix 1 includes illustrations of control charts. Software which can be used to develop and operate the charts is available from [documents.rpt@stategrowth.tas.gov.au](mailto:documents.rpt@stategrowth.tas.gov.au).*

*(v) Nomination of Materials R40.5*

This stage in the process offers both the Contractor and Superintendent the opportunity to assess the properties of the intended material/s.

(1) Contractor's Obligations

The required information involves:

- geological origin and physical properties of the proposed material/s;
- the proposed target grading and the control limits that will apply;
- evidence of compliance with the specification with respect to properties and variability.

The sample if required by the Superintendent may be used to:

- verify compliance with the specified properties;
- hold as a reference sample in order to compare with the supply.

*Note: Suppliers of base and subbase 1 materials are required to have production control systems that comply with Spec G6 Quarried Materials. The Contractor has obligations under clause G2.8.1 to supply evidence of compliance with G6 in the Contract Management Plan. The Contractor may have other obligations concerning material sources with respect to G1.6.2 and G2.2.2.2.*

(2) Contractor's Interests

The Contractor needs to ensure that the nominated material:

- has appropriate placement and handling characteristics;
- is likely to be stable under the prevailing traffic and site conditions;
- has site compatible drainage characteristics.

*(vi) Non Compliance*

In the event of non-compliance of a lot the Contractor is required to treat the matter as defective work under *Clause G2.4.6*. This will involve a Hold Point and the submission of a Notice of Non-Compliant Work. The Notice must identify the proposed method of rectification. *Clause G2.4.6* does not apply where "conformance is to be achieved by continuation of the original process". Compaction might fall within this exclusion, however the Contractor should be cautious about continuation without a clear understanding of the reasons for non-compliance.



Re-tests must include only fresh tests at the specified number for the lot. **None of the original tests for the lot should be included in the re-test.**

## **ENR40.5 MATERIAL QUALITY**

### ***ENR40.5.1 General***

Pavement materials are required to come from a *Standard Specification G6* compliant source. Such a source is required to have control systems managing both durability and particle shape and may also be testing for grading and Atterberg Limits. The following provides comment on two aspects of material quality, stone durability and soaked CBR.

### ***ENR40.5.2 Stone Durability***

Aggregates, particularly those in the base, need to have:

- Sufficient strength so that they do not crush or fret under traffic action. The Department of State Growth has adopted the measures of Wet Strength and Wet/Dry Strength Variation
- Resistance to weathering and chemical break-down while in the pavement. This property is called "soundness". The Department of State Growth has adopted Secondary Mineral Content (SMC) for basic igneous rock. The SMC is used to determine whether the stone is sound, marginal and unsound. No specific measures have been adopted for other rock sources at this stage.

By and large the available range of durability tests are limited to particle sizes 2.36mm and above. In consequence there is no adequate criterion that covers the durability of the smaller sizes. The specification attempts to get around this difficulty by requiring "*the properties of materials crushed to produce fines for blended products shall satisfy the durability requirements for coarse aggregate.*"

In general particles of pure quartz can be considered to be durable to the extent that they are unlikely to break down into plastic clay sized particles though they may breakdown into non-cohesive sand sizes.

A reduction in the durability in fine particles is likely to be expressed by:

- An increased content of fine sands, silts and clays and possibly increased instability during compaction particularly for maximum density graded products, such as Base Class A.
- reduction in MDD. If this reduction is not detected and accounted for it will lead to an overestimation of achieved compaction
- increased plasticity of fines and potentially increased instability.

### ***ENR40.5.3 Plasticity***

The Plasticity Index (PI) can have a very significant effect on the performance of granular materials. It is determined on the portion of the material passing the 0.0425mm sieve and is the difference between the Liquid Limit (LL) and the Plastic Limit (PL). In consequence, the reliability of its estimation is determined by the reliability of the estimates of the LL and PL.

It is known that both the LL and the PL have better repeatability than reproducibility. In essence this means that while a single operator within a laboratory or sometimes a laboratory as a whole are able to reproduce a consistent result (repeatability), quite different values might be determined by another laboratory (reproducibility). In consequence the true value of the PI is never known.

There is no entirely satisfactory answer to the above, though in addition to the usual vigilance with data oversight, the following may help:

- small changes in plasticity are often evident through visual inspection, particularly with dense graded products. Contractors and supervisors should keep a sample of the nominated material and representative samples at stages of the works for reference.
- an occasional non-compliance in PI is not likely to be a problem if the product of the PI and percent passing the 0.425mm sieve is within the defined limits for this particular criteria. When this product exceeds the specified limits there are increased chances of instability and shear failure.
- a PI above the specified limit for Class A base in conjunction with a fines content above the specified limit is undesirable.

A degree of plasticity is likely to be helpful in providing cohesion to the pavement both during construction (particularly when the works are open to traffic) and in the long term after dry back. It may also improve workability and reduce segregation. A base with plastic fines is likely to have a lower permeability than a base with non-plastic fines and this can be of advantage.

#### **ENR40.5.4 Permeability**

The specification does not set limits on permeability. The following should be borne in mind:

- bases should be relatively impermeable in order to keep water out of the pavement
- lower layers should be more permeable than the base in order that water entering the base is able to drain below.

#### **ENR40.5.5 Soaked CBRs**

The soaked CBR test is the primary control on the strength/stiffness of the product. Pavement designs are based on the CBR.

The specification requires soaked CBR tests on Base Class A and B, Subbase1 and Subbase 2, *R40.6.3(b)*. The compaction requirements are included in the "A" series appendices. Base Class A is not included because any product that satisfies the other specified requirements of Base Class A will satisfy the conventional soaked CBR requirement.

As a result of the wide limits set for grading and to plasticity there is a potential for a very wide range of soaked CBRs within the acceptance limits, some materials far exceeding the required limit for CBR and some failing to comply. The specification includes a range of testing frequencies. The higher frequencies apply to just complying products. It should be noted that CBR tests do not have good repeatability or reproducibility.

CBR tests are undertaken on material passing the 19mm sieve, though quite coarse stone (passing 100mm sieve) is permitted for use in some pavement courses. The coarse stone will generally increase strength and stiffness but not in a predictable manner. There is no universally accepted means of accounting for the retained on 19mm material. The specification contains a provision that gives some recognition to the effects of the coarse material ie

*"Material retained on the 19mm sieve may be replaced by an equal portion by mass of the material passing the 19mm sieve but retained on the 4.75mm sieve. The amount of replaced material, on a dry mass basis, shall not exceed 25% of the portion passing the 19mm sieve."*

### **ENR40.6 CONSTRUCTION**

#### **ENR40.6.1 General**

The Contractor is required, under Clause *G2.4.4* to " *detail procedures and/or work instructions for construction processes under the contract in the Contractor's Contract Management Plan.*" The Contractor's choice of materials and plant will have a considerable bearing on the achieved evenness of dimensions and surface shape.

**ENR40.6.2 Layer Thickness**

The limits placed on layer thickness, R40.7.3 are intended to reduce:

- the chance of unacceptably low densities at the bottom of compacted layers.
- variability in layer thickness and surface evenness. It is generally recognised, but not included that the minimum thickness of a layer should be 2.5 times the nominal size of the material.

**ENR40.6.3 Moisture Control**

Control of moisture content is critical to effective compaction. Too much or too little moisture inhibits compaction. Moisture contents close to the Optimum moisture content will generally facilitate compaction and as well provide the best finish and relatively low permeability. Poor moisture control will increase variability in density (standard deviation). This in turn will:

- create unevenness in the road surface
- reduce the chances of compliance in density by decreasing the characteristic DDR.

*Note: Standard Specification G4, Clause G4.4.2, requires that "nuclear density estimates are checked by oven dried estimates for at least 20% of field test sites". This is an important requirement because it provides a continuing check on the moisture calibration. A systematic error in the moisture channel of a nuclear meter will lead to a systematic error in the DDR.*

**ENR40.6.4 Compaction**

Failure to meet the specified compaction levels can result in a major disruption to a Contract, particularly when the cause of non-compliance is not obvious. It is not wise to continue rolling, because of the potential for continuing breakdown of particles, without having determined that the problem lies with the amount of compaction and not some other cause. Breakdown in Base Class A may cause the material to fall out of specification and necessitate its removal. These other causes might include:

- An unaccounted for reduction in the MDD due to a change in material compaction properties. The evidence of this might lie in the grading control charts and in the most recent MDD test. An unaccounted for increase in MDD will mean that non complying work may be accepted, erroneously.
- Incorrect calibration or application of the nuclear density meter. The moisture channel calibration is a potential source of error. As discussed above, it is important that the moisture calibration is confirmed by oven dried moisture contents

The control chart requirements of this specification and *Standard Specification G4* can be used to identify and potential causes of non-compliance. Another useful device is to plot the field moisture and density data on a plot of the laboratory data that includes the zero air voids line. However in this matter and in matters concerning the reliability of a meter's calibration, it may be prudent to seek expert advice early.

*Note: The moisture channel of most nuclear meters is housed within the base of the instrument. This limits the effective depth of vision to 75 to 100mm.*

**ENR40.6.5 Moisture Control Prior to Sealing**

The stability of base courses under traffic is highly dependent on the moisture condition. Premature failure of the surfacing and base will occur at high moisture contents. The provisions in Clause R40.7.5 set a limit on the maximum moisture content in the base prior to sealing by tying measured moisture contents to the corrected OMC.

It should also be noted that there are other requirements under Clause R51.5.7 concerning Ball Penetration Tests. The embedment depth measured in the test will have a bearing on the binder application rate and may determine if sealing should proceed at the particular time.

These quantitative provisions only apply to uniform pieces of work, without wet and damp spots, effectively brought to completion at the same time (i.e., the area has been subjected to similar moisture control and drying). Surfacing should not be allowed to proceed where there are wet and damp spots.

### **ENR40.7 COMPLETED SURFACE**

The provisions recognise that tight dimensional tolerances are not necessary in the lower pavement courses but are at and near the pavement surface. However any lack of good level and shape control in the lower courses is likely to reflect on the final shape and levels.

The base course layers have two shape requirements:

- the maximum gap under a 1.2m straight edge. This type of provision is important where roughness surveys are not required, such as where work is not undertaken in the full lane width, the road length is too short, or the survey is impractical such as a roundabout;
- the shape (roughness) of the surface profile after the placement of the seal and/or asphalt surfacing. A payment adjustment scheme may apply to this measure either in Spec R55 (new work of 250mm depth and full carriageway) or in the project specification where different limits and payment adjustments might apply.

*Note: The roughness (International Roughness Index, Lane IRI<sub>qc</sub>) is determined by an established calculation method from the surface profile of the two wheel path tracks in each lane. The surface profile of each wheel path is measured by a laser profilometer.*

The Contractor should ensure that the surface is clear of all loose material, ridges etc., prior to commissioning the survey.

The basis of the payment adjustment system is that:

- the level of service (quality of ride, fuel and vehicle operating costs) are significantly affected by roughness
- the serviceable life of a pavement is affected by the initial roughness. A high initial roughness reduces the potential life whereas a low initial roughness prolongs potential life.

The payment adjustment can be positive or negative.

The characteristic roughness is set at the upper 85%ile level of the average of three runs. The multiple runs reduce the impact of test variability on the result. The lane with the highest roughness in any carriageway applies. The Contractor is permitted to subdivide the lane with the highest roughness readings into lots, provided that all but one are longer than 0.5km and that no lot is less than 0.3km.

The payment adjustment applies only to that portion of the pavement that is surfaced. This is consistent with its level of service basis.

## **APPENDIX ENR40.A – CONTROL CHART SOFTWARE**

### **Control Chart Software**

Available From [documents.rpt@stategrowth.tas.gov.au](mailto:documents.rpt@stategrowth.tas.gov.au).



Department of State Growth

GPO Box 536

Hobart TAS 7001 Australia

Transport Infrastructure Services

Phone: 1300 135 513

Email: [info@stategrowth.tas.gov.au](mailto:info@stategrowth.tas.gov.au)

Web: [www.stategrowth.tas.gov.au](http://www.stategrowth.tas.gov.au)

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