Department of Transport and Main Roads

Technical Note 150

Testing of Materials for Foamed Bitumen Stabilisation

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Queensland Government

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1 Introduction

The purpose of this Technical Note is to outline a mix design procedure which allows the optimum foamed bitumen content and secondary stabilising agent content (lime or cement) for the stabilisation of soils which are compatible with foamed bitumen. This note provides guidelines, design criteria and test procedures for characterising the host soil and measuring the properties of the treated soil. This notes supports the application of the following departmental technical specifications:

- MRTS07C *Insitu Stabilised Pavements using Foamed Bitumen*
- MRTS09 *Plant-Mixed Pavement Layers Stabilised using Foamed Bitumen.*

The three stages of the testing guideline are as follows:

- Section 3 - Sampling and characterisation of the host material
- Section 4 - Mix design procedure
- Section 5 - Field testing.

All test methods referenced in this document with the prefix “Q” are published by the Department of Transport and Main Roads[#1] and those with a prefix “AS” are published by Standards Australia.

2 Background

Foamed bitumen stabilisation is the process of mixing bitumen (in a foamed state) as the primary stabilising agent and a secondary stabilising agent usually hydrated lime and sometimes blended cement. The purpose of the bitumen is to achieve a strong yet flexible pavement layer compared to other stabilisation treatments.

Generally the aim is to provide a modified material with the following properties:

- initial modulus > 500 to 700 MPa, to provide enough strength for early trafficking
- three day cured modulus > 2500 to 4000 MPa, to provide a strong but flexible pavement
- three day soaked modulus > 1500 to 2000 MPa, to provide a strong but flexible pavement able to withstand inundation
- retained modulus > 0.5, to provide a strong flexible pavement that does not lose greater than 50% of strength when inundated.

For more details refer to Section 4.9.8 of the *Pavement Rehabilitation Manual*[#2, 5]. For specific design limits refer to Tables 4.13 to 4.15 of the *Pavement Rehabilitation Manual*[#2, 5].

The *Pavement Rehabilitation Manual*, Technical Specifications and Test Methods take precedence over this Technical Note in the event of a conflict.

2.1 Insitu stabilised material

The following tables contain the design limits for insitu stabilised material from the *Pavement Rehabilitation Manual*[#2, 5].

Table 2.1(a) – Initial modulus mix design limits for a foamed bitumen stabilised material

Average daily ESA in design year of opening	Minimum initial modulus (MPa)*
< 100	500**
≥ 100	700**

* Initial sample curing time of three hours at 25°C required prior to initial resilient modulus testing being completed.

** Initial modulus values below those in Table 2.1(a) may be accepted provided advice is obtained from Director (Pavement Rehabilitation).

Table 2.1(b) – Cured modulus mix design limits for a foamed bitumen stabilised base

Average daily ESA in design year of opening	Minimum three day 'cured' MATTA modulus (MPa)	Minimum three day 'soaked' MATTA modulus (MPa)	Minimum retained modulus*
< 100	2500	1500	0.4
100-1000	3000	1800	0.45
> 1000	4000	2000	0.5

Note: Base is defined as a stabilised pavement layer with a bituminous seal surfacing or less than 100 mm of asphalt overlaying it.

*Retained modulus ratio = 'three day soaked' modulus divided by the 'three day cured' modulus.

Table 2.1(c) – Cured modulus mix design limits for a foamed bitumen stabilised sub-base

Average daily ESA in design year of opening	Minimum three day 'cured' MATTA modulus (MPa)	Minimum three day 'soaked' MATTA modulus (MPa)	Minimum retained modulus*
< 100	2500	1500	0.4
100-1000	2500	1500	0.45
> 1000	2500	1500	0.5

Note: Base is defined as a stabilised pavement layer with at least 100 mm of asphalt overlaying it.

* Retained modulus ratio = 'three day soaked' modulus divided by the 'three day cured' modulus.

2.2 Plant-mixed materials

As per Clause 7.3.1 of Technical Specification MRTS09, a laboratory mix design trial must be undertaken prior to production plant mix trials. These laboratory test results should comply with the requirements of tables in Section 2.1 above. These complying mix design proportions are termed as the nominated mix design proportions.

As per Clause 7.3.2 of Technical Specification MRTS09, the nominated mix design proportions shall then be used in manufacturing the plant mix foamed bitumen stabilised material. This production mix shall comply with the requirements of Table 2.2 below. Table 2.2 contains the design limits for production plant-mixed material from the *Pavement Rehabilitation Manual*[#2].

Table 2.2 – Soaked modulus mix design limits for a production plant mix foamed bitumen stabilisation

Average daily ESA in design year of opening	Minimum three day 'soaked' MATTA modulus (MPa)	Minimum seven day 'soaked' MATTA modulus (MPa)	Minimum 14 day 'soaked' MATTA modulus (MPa)	Minimum retained modulus*
All	1000	1400	1800	0.45

Note: * Retained modulus ratio = three day 'soaked' modulus divided by the three day 'cured' modulus.

3 Sampling and characterisation

The section under consideration must be sampled at regular intervals in order to identify material types and changes within any material. For characterisation bulk samples of 10 – 50 kg will be required, depending on the maximum particle size of the material. For mix designs an additional bulk sample of 70 – 90 kg will be required. For more information refer to the departmental publications for *Pavement Design*[#3, 4] and *Pavement Rehabilitation*[#2].

It is important that each material type is sampled (AS 1289.1.2.1) and tested at regular intervals in order to establish the range of material properties. Sampling will usually be performed using a machine excavated trench. Use of a soil classification system such as the unified soils classification system can assist in identifying the soil types[#6].

Any material to be used for plant-mixed stabilisation or imported to add to the pavement for insitu stabilisation will be sampled at its source, usually a quarry, to obtain a representative sample (Q060) of the material to be used.

Where material is to be mixed with an insitu stabiliser it may be necessary to sample the pavement in a manner that simulates both the mixing and the disruption caused by using up to three passes of a stabiliser (Q061). This is usually performed using a bobcat or excavator fitted with a profiling/milling head. A lateral trench is milled using three passes and all the material is retained for the sample. This material may not be tested as part of the characterisation of the pavement, but will need to be retained as the material to be used in the mix design in Section 4.

During construction some materials may be excluded from the works, such as sprayed surfacing, asphalt or stabilised patches. Before commencing any sampling, clarification should be sought on which materials are to be excluded from the samples.

Table 3(a) – Test methods used to sample materials

Property	Test Method	Title
Sampling – machine excavated pit or trench	AS 1289.1.2.1	Sampling and preparation of soils – disturbed samples
Sampling from stockpile	Q060	Representative sampling of soils, crushed rock and aggregates
Sampling for stabilisation testing – plant excavation	Q061	Spot sampling of soils, crushed rock and aggregates

Host soil characterisation tests are as follows:

Table 3(b) – Test methods used to classify materials

Property	Test Method	Title
Particle Size Distribution (Grading)	Q103A	Particle size distribution of soil - wet sieving
	Q103C	Particle size distribution of soil – hydrometer
Atterberg limits (Liquid limit, plastic limit, plasticity index and linear shrinkage)	Q104A or D	Liquid limit of soil
	Q105	Plastic limit and plasticity index of soil
	Q106	Linear shrinkage of soil

3.1 Classification

Initially, classification tests including particle size distribution and Atterberg limits should be undertaken[5]. Depending on the variation in material properties as indicated by the particle size and Atterberg limit tests, either undertake further testing on samples representing material extremes, or where properties are similar, test the highest percentage passing the 0.075 mm sieve. Generally materials that are suitable for stabilisation are:

- comply with material requirements of MRTS05 *Unbound Pavements* for Type 2 materials
- may include limited quantities of RAP
- comply with the ‘C’ or 'Mod C' particle size distribution requirements of MRTS05
- not include any previously stabilised materials
- Table 4.12 of *Pavement Rehabilitation Manual*[#2], and
- have a low plasticity PI ≤ 10 or LS ≤ 6.

Refer to Table 4.6 and Section 4.9 of the *Pavement Rehabilitation Manual*[#2] for more details.

3.2 Deleterious materials

This is usually not an issue for materials obtained from quarries or existing pavement materials originally obtained from quarries. However materials need to be free of organic or other deleterious materials. The water soluble sulfate content must not exceed 1.9 g of sulfate (expressed as SO_3) per litre.

4 Mix design

This stage of the procedure is to establish the suitability of stabilising the host material with foamed bitumen. This is usually performed with samples prepared at 70% OMC, with 3.0% bitumen and 2.0% lime. Once it has been established the host material is suitable it may for larger projects be appropriate to perform further testing to optimise the bitumen and lime contents.

Design test procedures are as follows:

Table 4 – Test methods used for design

Property	Test Method	Title
Resilient modulus	Q139	Resilient modulus of stabilised material – indirect tensile method
	Q138	Preparation and compaction of foamed bitumen stabilised material
Compacted density and moisture content	Q147B	Compacted density of stabilised material – vacuum saturation
Optimum moisture content	Q142A	Dry density-moisture relationship (standard compaction)
Available lime	AS 4489.6.1	Lime index – available lime
Dynamic viscosity	AS 2341.2	Determination of dynamic (coefficient of shear) viscosity by flow through a capillary tube
Sulfate content of groundwater	AS 1289.4.2.1	Determination of the sulfate content of a natural soil and the sulfate content of the groundwater

4.1 Lime

Hydrated lime, complying with the requirements of AS 1672.1: Hydrated lime, is to be used exclusively in laboratory testing. The hydrated lime should be sourced directly from suppliers. Bagged supplies from hardware stores/building suppliers should not be used as the age and condition of the lime is not known. Instructions for the storage and use of lime are included in Appendix 1.

A certificate with the available lime (AL_x) (AS 4489.6.1) should be obtained from the supplier for the batch of lime. As an alternative the lime may be sampled and forwarded to a laboratory to determine the AL_x.The AL_x value should be forwarded along with other results of testing for the mix design procedure. If a different source of lime is used for construction the quantity of lime ordered and spread rates on site may need to be adjusted for a lime that is more or less reactive than the lime used for the design procedure.

Quicklime is not to be used in the laboratory because of safety concerns.

4.2 Cement and supplementary cementitious materials

Cement, complying with the requirements of AS 3972: General purpose and blended cements, is to be used exclusively in laboratory testing. The cement should be sourced directly from suppliers. Bagged supplies from hardware stores/building suppliers should not be used as the age and condition of the cement is not known. Instructions for the storage and use of cement are included in Appendix 1.

Supplementary cementitious materials (fly-ash, slag, silica fume and so on) should be sourced directly from suppliers. They should be kept dry in air tight containers. While they do not deteriorate with age they should be discarded after 12 months as the sample may no longer represent the materials currently supplied.

4.3 Bitumen

Class 170 bitumen is to be used exclusively for all foamed bitumen designs. Each batch of bitumen should be checked for viscosity (AS 2341.2) before use. A sample of the batch should be foamed and the foaming apparatus adjusted to provide expansion ratio of at least 10 and a half-life of at least 20 seconds. This will usually require a foaming water content of 3.0%, however this should be optimised for each batch of bitumen.

4.4 Water

Potable water (fit for human consumption) free from organics and with a sulfate content (AS 1289.4.2.1) less than 0.05% is the preferred mixing water. Where possible, the actual water source to be used in the field should also be used for the laboratory testing programme. While water high in soluble salts is suitable for mixing and curing, they can cause a build-up of salts which may migrate to the surface of the pavement. Excess concentration of salts can interface with the adhesion of seal coats.

4.5 Resilient modulus

The resilient modulus is determined by performing an indirect tensile test (Q139) on a minimum of three specimens prepared at a single lime and bitumen content. These are usually prepared at 70% OMC, with 3.0% bitumen and 1.5 to 2.0% lime[#5].

The lime/soil mixture should be conditioned using short term conditioning, that is, where the lime/soil mixture is allowed to condition in an air-tight container for 45 minutes before further mixing, addition of foamed bitumen and compaction.

A standard curing and testing regime is undertaken as detailed in Q139 as follows:

- Initial modulus – Three specimens, to be stored in the environmental cabinet at 25 ± 0.5°C after compaction for 3 ± 0.5 hours then test to determine initial modulus (Q139).
- Three day cured modulus – Three specimens, retained after the determination of initial modulus, to be stored at 40 ± 5.0°C for 72 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for two hours then test to determine the three day cured modulus (Q139).
- Three day soaked modulus – Three specimens, retained after the determination of three day cured modulus, to be placed in a container and covered with potable water at 25 ± 0.5°C. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes. After the vacuum soaking remove the specimens from the water and remove excess water (pat dry) then test to determine soaked modulus (Q139). The compacted density and moisture content of the specimens may be determined if required (Q147B).

4.6 Analysis

If the results obtained from the resilient modulus testing comply with the specific design limits from Tables 4.13 to 4.15 of the *Pavement Rehabilitation Manual*[#2] then the host material can be stabilised using 3.0% C170 bitumen and 2.0% hydrated lime.

4.7 Optimisation

For large projects it may be worthwhile to adjust the bitumen and lime contents to find an optimal bitumen/lime content.

5 Field testing

Field testing is undertaken to ensure compliance with the specification for properties such as bitumen content, hydrated lime content and relative compaction are achieved. It is also undertaken to verify that particular design parameters, such as resilient modulus are achieved and where necessary fine tune the design and production processes.

Table 5(a) – Test methods used for compliance

Property	Test Method	Title
Spread rate	Q719	Field spread rate of solid stabilising agents - fabric mat
Bitumen content	Q118	Bitumen content of stabilised material
Mixing uniformity (lime/cement content)	Q134*	Stabilising agent content - heat of neutralisation
	AS 5101.3.2*	Lime or cement content of stabilised pavement materials (EDTA method)
Compacted density	Q141A	Compacted density of soils and crushed rock (nuclear gauge)
	Q141B	Compacted density of soils and crushed rock (sand replacement)
Reference density	Q142A	Dry density-moisture relationship (standard compaction)
	Q144A	Assignment of maximum dry density and optimum moisture content for soils and crushed rock
Relative Compaction	Q140A	Relative compaction of soils and crushed rock
Relative moisture ratio	Q250	Relative moisture content of soils and crushed rock
Nominated working time limit	Q136	Working time for stabilised materials

Table 5(b) – Test methods used for verification

Property	Test Method	Title
Mixing uniformity (lime/cement content)	Q134*	Stabilising agent content - heat of neutralisation
	AS 5101.3.2*	Lime or cement content of stabilised pavement materials (EDTA method)
Field modulus (compaction)	Q138	Preparation and compaction of foamed bitumen stabilised material
Resilient modulus	Q139	Resilient modulus of stabilised material – indirect tensile method

* These tests measure lime content.

5.1 Lime/cement content and mixing uniformity

For insitu stabilisation a simple mat test (Q719) is used to monitor stabilising agent content and distribution. One or more 1 m² mats are placed so as to catch the discharge from the spreader.

While modern high performance equipment is capable of providing uniform mixing, the need arises from time to time to measure mixing efficiency. The cement content can be readily measured anywhere within the stabilised soil profile using one of two tests. The Heat of Neutralisation test (Q134) is a field test while the EDTA Titration method (Q117A) – is an analytical test which is normally performed in a specialised laboratory. Samples of both the unstabilised material and the stabilising agent are required prior to performing either of these tests.

5.2 Bitumen content

The bitumen content can be readily measured using a solvent extraction method (Q118). The testing is normally performed in a specialised laboratory.

5.3 Moisture content of feed stockpiles and stabilised materials

Monitoring and adjustment of the moisture content of the feed stockpiles, stabilised material stockpiles and the material delivered for placement is critical to the performance of the final pavement.

The moisture ratio of the feed stockpile must be determined prior to incorporation of stabilising agents. It should be in the range of 40 - 55%. After incorporation of stabilising agents the stabilised material in stockpile should be in the range of 60 - 80%.

The moisture ratio of the stabilised material after spreading but before compaction should be in the range of 60 - 80%.

5.4 Compacted density and reference density – insitu stabilisation

The inherent variability of insitu stabilised materials usually means that a testing regime of one for one testing must be employed. Such testing involves taking a sample from each insitu density location and determining a reference density.

The sand replacement test is the accepted test for measuring insitu density. A nuclear gauge technique can be used for foamed bitumen stabilised materials and has the potential to be a rapid, low cost alternative to sand replacement provided a wet density and moisture content bias is determined as detailed in the *Nuclear Gauge Testing Manual*[#7].

The reference density is measured using the traditional dry density – moisture relationship test. It is important that the reference density sample is taken and compacted before the allowable working time for lime has elapsed.

The Hilf density ratio is not applicable for on-site compaction control. The Hilf method assumes the insitu density is determined at the same time the reference density is sampled and that both specimens are at the same moisture content. For insitu stabilisation the reference density is sampled from uncompacted material and then insitu density is determined later in the compacted material. The moisture content of the material can change significantly during the time between sampling and testing.

5.5 Compacted density and reference density – plant mixed stabilisation

The plant mixed material should be more uniform and the use of assigned values for maximum dry density and optimum moisture content should be achievable. Samples for this testing must be obtained from the production stockpile. However, if this is not possible, then a testing regime of one for one testing must be employed. Such testing involves taking a sample of uncompacted material from each insitu density location and determining a reference density.

The sand replacement test is the accepted test for measuring insitu density. A nuclear gauge technique can be used for foamed bitumen stabilised materials and has the potential to be a rapid, low cost alternative to sand replacement provided a wet density and moisture content bias is determined as detailed in the *Nuclear Gauge Testing Manual*[#7].

The reference density is measured using the traditional dry density – moisture relationship test. It is important that the reference density sample is taken and compacted before the allowable working time for lime has elapsed.

5.6 Field modulus – insitu mixed

The resilient modulus test provides additional information on expected field performance relative to design. The field mixed material is moulded at field moisture content. Moulded specimens are then cured under standard conditions prior to testing. The sampling, compaction, curing and testing of field modulus specimens is detailed in test methods Q138 and Q139.

The typical curing and testing regime undertaken for field mixed specimens is as follows:

- Initial modulus – three specimens, to be stored in the environmental cabinet at 25 ± 0.5°C after compaction for 3 ± 0.5 hours then test to determine initial modulus (Q139).
- Three day cured modulus – three specimens, retained after the determination of initial modulus, to be stored at 40 ± 5.0°C for 72 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for two hours then test to determine the three day cured modulus (Q139).
- Three day soaked modulus – three specimens, retained after the determination of three day cured modulus, to be placed in a container and covered with potable water at 25 ± 0.5°C. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes. After the vacuum soaking remove the specimens from the water and remove excess water (pat dry) then test to determine soaked modulus (Q139). The compacted density and moisture content of the specimens may be determined if required (Q147B).

When sampling and making resilient modulus specimens in the field it is assumed the insitu moisture content will be close to the target moisture content of the material. If not then the achieved dry density and dry density ratio will vary from the design. Therefore care is required in interpreting these results.

5.7 Field modulus - plant mixed

The resilient modulus test provides additional information on expected field performance relative to design. The plant mixed material is moulded at production moisture content. Moulded specimens are then cured under standard conditions prior to testing. The sampling, compaction, curing and testing of field modulus specimens is detailed in test methods Q138 and Q139.

The typical curing and testing regime undertaken for plant mixed specimens is as follows:

- Initial modulus – three specimens, to be stored in the environmental cabinet at 25 ± 0.5°C after compaction for 3 ± 0.5 hours then test to determine initial modulus (Q139).
- Three day cured modulus – three specimens, retained after the determination of initial modulus, to be stored at 40 ± 5.0°C for 72 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for two hours then test to determine the three day cured modulus (Q139).
- Three day soaked modulus – three specimens, retained after the determination of three day cured modulus, to be placed in a container and covered with potable water at 25 ± 0.5°C. Place in the vacuum chamber and apply a partial vacuum of 13 kPa or less absolute pressure for 10 minutes. After the vacuum soaking remove the specimens from the water and remove excess water (pat dry) then test to determine soaked modulus (Q139). The compacted density and moisture content of the specimens may be determined if required (Q147B).
- Seven day cured modulus – three specimens to be stored at 40 ± 5.0°C for 168 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for two hours then test to determine the seven day cured modulus (Q139).
- Seven day soaked modulus – three specimens, retained after the determination of seven day cured modulus, to be tested using the same procedure as the three day soaked modulus specimens.
- Fourteen day cured modulus – three specimens to be stored at 40 ± 5.0°C for 336 ± 2.0 hours. Remove specimens from the oven and allow them to equilibrate to the test temperature in the environmental cabinet at 25 ± 0.5°C for two hours then test to determine the fourteen day cured modulus (Q139).
- Fourteen day soaked modulus – three specimens, retained after the determination of fourteen day cured modulus, to be tested using the same procedure as the three day soaked modulus specimens.

When sampling and making resilient modulus specimens in the field it is assumed the insitu moisture content will be close to the target moisture content of the material. If not then the achieved dry density and dry density ratio will vary from the design. Therefore care is required in interpreting these results.

5.8 Working time limit

Currently for foamed bitumen materials the working time is nominated in the relevant Technical Specification. For plant mixed foamed bitumen, testing may be undertaken to determine if the working time limit for the actual materials and additive proportions (for example, host materials with 3% Bitumen and 2% hydrated lime) approved in MRTS09 Hold Point 1, exceed that of the 8 hour working time nominated in the Plant Mixed Foamed Bitumen Technical Specification.

Testing for varying the working time limit shall be undertaken as follows:

A foamed bitumen sample with the actual materials and proportions is manufactured in accordance with Q138. A three day soaked resilient modulus test in accordance with Q139 is performed to establish a reference three day soaked modulus value (0 hour delay). As a variation to the Q138 test method, further specimens are manufactured and compacted with a delay between mixing and compaction which for foamed bitumen will be typically 8, 10, 12, 14 and 16 hours.

Due to the delays between mixing and compaction, the soaked resilient modulus values tend to reduce. This is due to the lime hydrating and reacting with the host materials, reducing the moisture content and increasing the friction between particles. In addition, these effects inhibit the reorientation of particles during compaction and therefore reduce the achieved (MDD) Maximum Dry Density. The higher air voids and lower density also reduces the achieved soaked resilient modulus values.

The working time limit is defined as the delay time that produces a 20% reduction in achieved reference three day soaked modulus (that is, 100% to 80%).

A plot of the three day soaked resilient modulus versus time delay should be established and a horizontal line from the vertical modulus axis should be drawn from 80% of the reference soaked modulus value. The horizontal intercept between this horizontal line and the plot is considered as the working time.

An Administrator may consider any increase of the working time beyond the specified 8 hours provided there is consistent supporting resilient modulus test results. Tests should be carried out beyond 8 hours up to the proposed working time. If the resilient modulus values obtained either equals or exceeds the project specific structural design modulus values (adopted by the pavement designer) consideration may be given for increase in working time. In any event extension of working time will be such that the total working time shall not exceed 16 hours.

Further advice can be obtained from the Director (Pavement Rehabilitation).

5.9 Future developments

Since 2010 amendments to the *Materials Testing Manual* have allowed major changes in the testing of foamed bitumen stabilised materials through the publication of test methods Q138 and Q139. These methods have been further amended to allow compaction and testing of field sampled materials and cores.

There are some issues to be addressed in future amendments/edition of the *Materials Testing Manual* and departmental Technical Specifcations[1], including:

- use of ignition oven for determining bitumen content
- use of delay factors for compaction control.

Some of these issues still require significant research to be performed.

6 References

1. *Materials Testing Manual*, Queensland Department of Transport and Main Roads, Edition 4, 2014.
2. *Pavement Rehabilitation Manual*, Queensland Department of Transport and Main Roads, April 2012.
3. *Guide to Pavement Technology,* Part 2: Pavement Structural Design, AustRoads, 2012
4. *Pavement Design Supplement*, Supplement to “Part 2: Pavement Structural Design of *AustRoads Guide to Pavement Technology*, Queensland Department of Transport and Main Roads, November 2013.

5. *Foamed Bitumen Stabilisation – The Queensland experience*, 20th ARRB conference, Martin Kendall; Bruce Baker; Peter Evans and Jothi Ramanujan, 19 - 21 March 2001.
6. *Geotechnical Site Investigations*, Standards Australia, AS 1726-1993, Appendix A – Description and classification of soils and rocks for geotechnical purposes.
7. "*Nuclear Gauge Testing Manual*", Queensland Department of Transport and Main Roads, Edition 3, April 2016.
8. TN149 *Testing of materials for cement or cementitious blend stabilisation*, Technical Note, Queensland Department of Transport and Main Roads, 2016.

Appendix 1 – Storage of lime/cement in the laboratory

Importance of proper storage

Cement and lime will react with products in the atmosphere and degenerate with age. With proper handling, the degeneration can be held to a minimum. It is important to keep all cement dry and in airtight containers.

Storage

1. It is best to obtain no more than a 1 - 2 month supply of cement/lime at a time.
2. Upon receipt, the total supply should be transferred from bags into airtight “stock” containers, Ergotainers are recommended. The date received should be marked on each container.
3. It is helpful to “tap” the full containers on the ground to achieve some degree of cement/lime settling. This compaction will help limit atmospheric exposure of the cement/lime below the surface.
4. A smaller “lab” container is needed to hold the cement/lime used in day-to-day testing.
5. The lab container must also be airtight and should hold a 1 - 2 week supply. The use of a lab container avoids exposing the cement/lime supply to the atmosphere and limits the number of times a stock container must be opened. The stock container only needs to be opened a couple of times a month rather than daily.
6. Cement/lime in the stock container should be discarded 12 weeks after it is received.

Use/sampling

1. Each time cement/lime is transferred from the stock container to a lab container the top 10 - 20 mm of cement/lime in the stock container should be discarded. When cement/lime is added to the lab container the date should be marked on the container.
2. Before each testing job, the top 10 - 20 mm of cement/lime should be discarded from the lab container.
3. Prior to transferring cement/lime from the stock container to the lab container, all cement/lime remaining in the lab container should be discarded.
4. No container should be left open when not being used. If the lab container is to be unused for more than 10 minutes, close it tight.
5. Cement/lime in the lab container should be discarded if it has been in the lab container for more than 14 days.
6. If care is taken to follow these storage methods, and stock is rotated often, the cement/lime quality should remain at acceptable levels.