

Technical Note 76

Introduction to roadbase products and testing

1.0 Background to AS 2758

Australian Standards are prepared by committees of industry representatives who contribute their expert knowledge to ensure the information contained in a Standard reflects the best technical, scientific and system knowledge available.

In the case of AS 2758, Aggregates and rock for engineering purposes, a set of Standards has been developed to ensure uniform material compliance is identified and specified, thus minimising the risk of a failure in a project. AS 2758 comprises seven individual standards, viz:

AS 2758.0	Part 0 Definitions and classification
AS 2758.1	Part 1 Concrete aggregates
AS 2758.2	Part 2 Aggregate for sprayed bituminous surfacing
AS 2758.4	Part 4 Aggregate for gabion baskets and wire mattresses
AS 2758.5	Part 5 Coarse asphalt aggregates
AS 2758.6	Part 6 Guidelines for the specification of armourstone
AS 2758.7	Part 7 Railway ballast

It is noted that the Australian Standard series AS 2758, Aggregates and rock for engineering purposes, does not have a section for roadbase. Part 3 of the Standard series was originally allocated for the roadbase specification but due to the wide range of requirements specified state by state, the committee at the time, was of the opinion that it would be in the best interests of the state specifying bodies not to have an Australian Standard for these materials. Therefore, part 3 has not been developed to date.

This document, “roadbase” is prepared by Cement Concrete and Aggregates Australia to give the reader background knowledge of some of the more general requirements used when supplying roadbase to a particular project. The requirements will greatly depend on information contained in the supply contract or the works specification.

Aggregate produced from rock, gravel, metallurgical slag, recycled materials or suitable synthetic materials may be used provided the particular criteria set out for the aggregate is met.

Roadbase is a well graded material, consisting of various sized particles containing coarse and fine aggregate, that when mixed and placed correctly enable compaction of the material into a layer that resists distortion due to weather cycles of wetting and drying as well as deformation due to vehicular mass and movement.

It should be noted that various state specifications for roadbase products set out the required criteria as known at the time of publishing and each of these documents should not be read as stand-alone unless noted as the only material specification in a given works specification.

In some circumstances, the full range of testing shown in the specification is not required to control the ongoing supply of roadbase to a particular project. Separate inspection and test plans may need to be established for that purpose.

Due to the significant number of various state and territory test methods available and specification of specific test methods for use in some cases, this document refers generally to equivalent Australian Standard test methods where possible. In most circumstances, the road authority method for testing is similar if not the same as the Australian Standard procedure.

2.0 Roadbase applications

Due to the wide range of materials that fit into the definition of roadbase, across Australia, this document has not been written to cover the supply of all types of roadbase available. Instead it provides the reader with a brief description of how a pavement is constructed, some detail of the way in which roadbase materials are used and the relevant tests commonly specified to provide confidence of material suitability for the intended application.

Roadbase products, as the name suggests, are often used in the construction of road pavements; which are made up of several layers of material of varying property. Roadbases are generally classified into two main supply categories, as a “sub-base” material and as a “base” material; which when placed at the correct moisture content and compactive effort, form rigid layers able to distribute traffic loading from the pavement surface to the ground beneath. Sub-base material layers tend to be placed deeper within a pavement where loading is less, and as such the quality of the materials within sub-bases may not need to be premium. Significant fines and plasticity (plastic fines) may also be incorporated to assist in the binding nature of the sub-base material required during placement. This is dependent on the pavement design as inundation from a rising water table is always possible and some designs use permeable sub-bases to control this rising water deep within the pavement.

Base courses constructed of quarry products, slag or soil-aggregate mixtures, lie close to the surface; hence, they must possess high resistance to deformation in order to withstand the high loads imposed upon them.

They are usually located directly beneath a surface wearing course of asphalt or sprayed bituminous seal and due to the higher loading, aggregate interlock within the roadbase is key to the load distribution into the underlying layers or subgrade. Later in this document the roadbase properties of grading and shape will be discussed and their important relationship with roadbase interlock.

As pavement systems primarily fail due to repetitious fatigue loading, the damage done to pavement increases with the increase of axle load of the vehicles travelling on it. Accordingly, heavily loaded trucks can do more than 10,000 times the damage done by a normal passenger car. Passenger cars are considered to have no practical effect on a pavement’s service life, from a fatigue perspective.

Other failure modes include aging and surface abrasion. As years go by, the binder in a bituminous wearing course gets stiffer and less flexible. When it gets “old” enough, the surface will start losing aggregates, and as a result the surface macro-texture depth increases dramatically. If no maintenance action is done quickly on the wearing course potholing will take place. If the road is still structurally sound, pot hole repairs or a bituminous surface treatment, such as re-sheeting can prolong the life of the road at low cost.

The science of accurate and reliable pavement design involves a thorough understanding of the properties of roadbase materials and their interactions and as such some road authorities over the years have developed their own rules for pavement construction, while others use design criteria developed by Austroads, (the association of Australian and New Zealand road transport and traffic authorities). Design by either method incorporates the use of a series of different materials of differing property, with one overlaying the previous until the final upper layer under the pavement wearing surface is established.

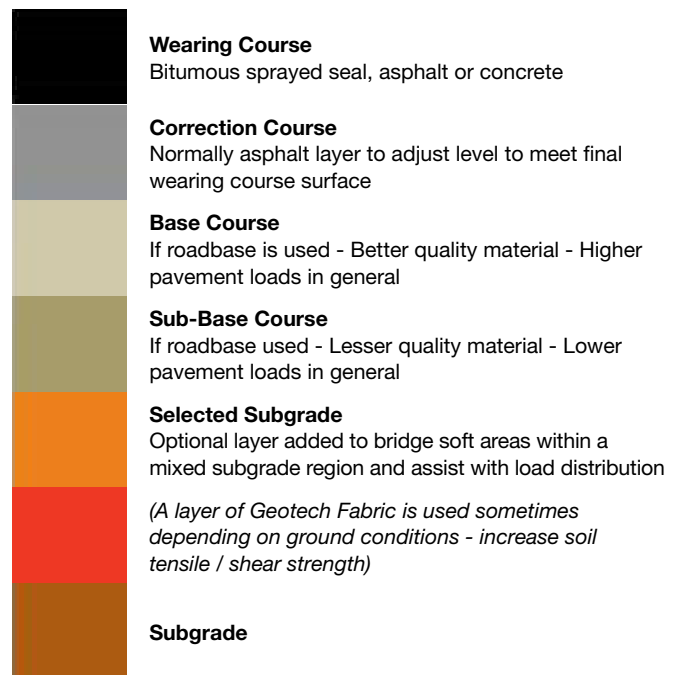


Figure 1: The typical layers within a pavement

Roadbase materials are an integral part of road pavement construction.

The construction process of a rigid or flexible pavement requires up to three layers of quarried products. Each layer is placed, compacted and overlain by the next layer above. The final pavement surface is the wearing course, generally a sealed layer of bitumen and aggregate, either as a single aggregate on bitumen, or a mixture of stone and aggregate known as asphalt. It may also be that the pavement is designed to be rigid and would usually comprise a thin lean mixed concrete sub-base layer overlain by a thicker concrete base layer.

The thickness of each of the layers will vary depending on natural ground conditions, atmospheric conditions, loading mass and frequency of traffic. The pavement design considers these issues and develops a structure to address these actions.

Individual road authorities have developed their own range of roadbase product size criteria based on local experience and local availability of quarry products. They then set out a range of grading (particle size distribution) envelopes which are used to design and produce the roadbase at the quarry to meet those requirements.

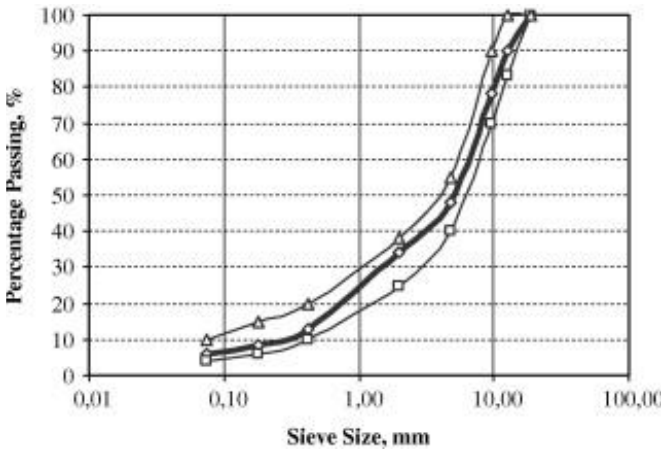


Figure 2: Grading envelope with “upper” and “lower” limits and results in heavier line

The production of roadbase from a manufacturing quarry, involves taking a range of various aggregate sizes, made available during the crushing process, and recombining them into a balanced formula that produces the required properties specific to a given application. The finished product must meet the specified requirements of grading, workability, placeability, strength, density, long-term durability and appearance. For this reason, the supplier needs to clearly understand the properties of the aggregate constituents intended to be used in the roadbase, so repeatable and reproducible measurable engineering properties can be achieved in the final product.

For example, a particular quarry may proportionally mix scalps (a common clay rich fines by-product), 20mm aggregate and other quarry rock fines to make a roadbase that meets the specified requirements of a given road authority specification. Some quarries may use batch cards as a means of clearly communicating the required aggregate mix proportions for a specific roadbase blend. Batch cards may be located within a mixing pug-mill control cabin, in a sophisticated plant, or within a mobile Front End Loader (FEL) where loader mixing on the ground is utilised. As there may be several types of roadbase produced by any one particular quarry the numbering / identification of each batch card and roadbase blend is essential to maintain control of the process.

BATCH CARD No1			(Rev 1/13)
Product to be blended:		DGB20/Class 1	
	20mm Scalps	20mm Single Size Agg.	5mm Crusher Fines
Percentage (%)	22	33	45
Ratio (Buckets)	2	3	4
			Card issued: 6/6/2013
Comments: Have the Laboratory check moisture of components and add sufficient water to be at 2% below Optimum Moisture before dispatch			

Figure 3: Batch card

Even with accurate proportioning of roadbase blends at the manufacturing quarry the material may not perform adequately during placement and compaction on site unless the correct grading is provided, within the given roadbase. For this reason great care should be taken to ensure consistency in all of the constituent aggregate components to produce a consistent roadbase blend.

The performance of a specific roadbase blend is ultimately determined by the achievement of a specified in situ density within a compacted layer in the field. To obtain this required field density full compaction is applied via various pieces of mobile equipment including but not limited to; a pad foot roller, vibrating smooth drum roller, multi-tyred roller, grader and water cart. The correct use of this equipment is essential to ensure a given roadbase has a chance of achieving the required density without breaking down due to over-compaction or being under-compacted due to inadequate operation.

Roadbases bind together by aggregate interlock, plasticity or a combination of both. The properties of grading and shape determine the interlock of the aggregate particles and the presence of plastic (clay) fines assists in binding the rock skeleton tighter. Too many clay-rich fines may make the roadbase water sensitive to shrinkage and swelling and cause other long term performance issues.

3.0 Aggregate properties and the test methods

The quantity of water within a specific roadbase blend is critical to enable the particles to come together, during placement and compaction, in a manner that allows as much air as possible to be removed and only aggregate particles left to fill the voids within the rock skeleton. This will ensure that even distribution of all the particles throughout the mix, has occurred even after compaction has taken place. Too little water within the roadbase during placement and compaction can have the effect of allowing particles to segregate or be broken down and thus in situ density will not be able to be obtained. Too much water and the overwork required to dry back can further breakdown aggregate particles and lead to segregation affecting the ability to obtain proper compaction within that roadbase layer.

Improper compaction can lead to a multitude of issues and ultimately pavement failure in a shorter time than allowed for in the design. One of the main issues arising from under compaction of roadbase layers will be rutting of the surface. This will be due to the movement of particle during cycles of wetting and drying during the life of the pavement.

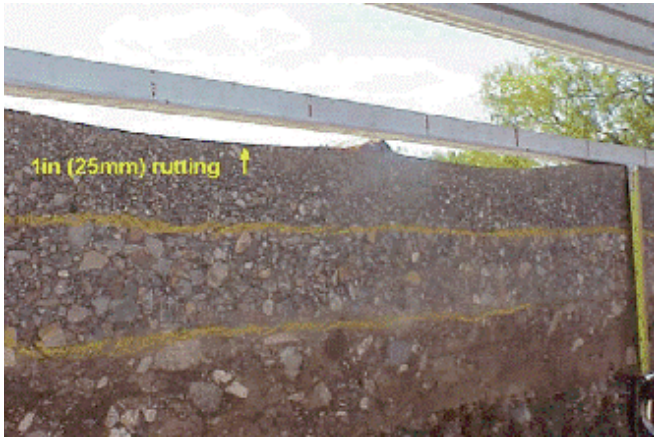


Figure 4: Shows the ruts developed in a pavement as particle move out of their original interlocked position

To obtain the best possible grading for a roadbase, the theoretical Fuller Curve for grading of an idealised material is used as a design tool. In this approach, all particles are to fit together in the densest possible packing. The largest particles are to just touch each other and the next smallest size particles are to fit exactly in the voids between these larger ones without moving them apart. The third sized particles down are to fit in the voids of the second one and so on. In this way the theoretical void spaces between all aggregate particles should be accommodated provided sufficient moisture is present during layer construction to allow the particles to align themselves and form the required rock skeleton needed to distribute traffic loading over time.

3.1 General

State road authorities or local councils tend to develop and specify their own criteria for a range of roadbase products based upon their experience and knowledge of the geography and geology of their area. The products will generally have a specific range of testing requirements gathered over time that designates the desired properties being used for material compliance. Most specifications contain sections related to maximum particle size, particle size distribution (grading), particle shape and particle strength.

Testing for roadbase compliance will generally fit into two main areas. The first being mechanical testing of the components and the blend and the second by physical testing of the shear strength characteristics after standardised compaction of the roadbase. For example the Modified Texas Triaxial test or California Bearing Ratio test are performance based determinations of the likely shear strength developed within a given blend under standard conditions.

In this section, the document will focus on the test methods and not specified limits, as that will depend on the specific State or Local Government specification in use for a particular project. In some cases however, a guide will be given to indicate an acceptable compliance level for a given application.

3.2 Pre-treatment

Prior to performing a range of laboratory tests, some specifications will call for a roadbase sample to be “pre-treated” first. In other cases, roadbase samples retrieved from the completed pavement layer may be “pre-treated”. The purpose of pre-treatment is to subject the sample to a series of known methods that may provide an indication of the likely long term performance of the roadbase during in-service conditions. It is mostly used to indicate if there is likelihood that during placement the materials characteristics will change.

The two most common pre-treatment procedures are, artificial weathering and repeated compaction.

3.2.1 Artificial weathering

This test is done by simply, taking the sample being tested and soaking it for a period of 16 hours, draining the water and then drying out the sample completely. The test is completed after a number of cycles of wetting and drying and it this repetition that provides an insight into any potential issues with long term durability of the roadbase or its components.

Artificial weathering is performed on the sample before other testing. Care is taken not to bake the material as severe heat can alter some materials such as those containing gypsum or organic matter.

3.2.2 Repeated compaction

Repeated compaction is performed on materials that are suspect to breakdown during construction such as shales, siltstones and other soft or laminated rocks.

The test method simulates the breakdown of material under construction equipment and long-term degradation under traffic. If material is too dry or too wet, the degree of breakdown may be different to the desired result. It is important therefore to ensure the moisture content is as close to optimum moisture content as possible when tested. See 3.10.1 of this document.

The test is performed by taking the cured sample and compacting it in a mould with a standard rammer. The height of the layers and the number of blows are dependent on the mould size. Once the entire sample has been compacted, it is removed from the mould and the process repeated.

The number of cycles used to pre-treat the sample is generally three but more may be specified depending on the nature of the quarry products used in the roadbase manufacture.

3.3 Grading

Particle Size Distribution (Grading)

Particle size distribution (also called 'grading') is the most common test performed on the aggregates used in the supply of roadbase. A gradation test is performed on a sample in the laboratory. A typical sieve analysis involves a nested column of sieves with punch plate, woven wire mesh and or cloth screens nested in decreasing order and the sample is shaken through the sieve until no more will pass and the retained portion on each sieve is weighed and recorded. Calculation is commonly performed to represent the results expressed as percentage (%) passing a particular selected sieve. This procedure is normally performed on a sample in the dry state; however wash gradings may also be undertaken where the sample is washed over a 75µm sieve during the grading process.

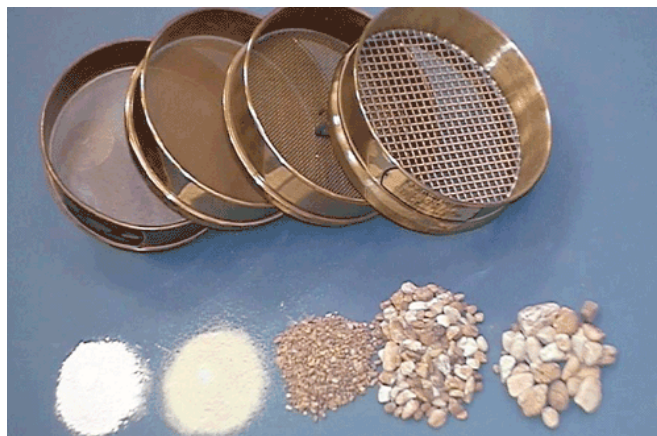


Figure 5: Typical of the sieves used in grading analysis of roadbase materials

The purpose of the grading test is to determine the various amounts of material contained in standard size segments from largest to smallest within a given sample of the aggregate. For roadbase, the individual grading of each aggregate size used and the combination of these is important to the production of the material and its ability to withstand and distribute loads during its time in service.

Grading or Particle Size Distribution (PSD) is determined when a sample is tested in accordance with a method stipulated in a given material supply document or material specification. The method may be one developed by the particular road authority, or others, but it will generally be in line with the procedures contained in AS 1289.3 (grading sections).

To better understand the finer particles (minus 75 micron), within a roadbase, there may be a need to test a portion as per AS 1141.19, "Fine particle size distribution in road materials by sieving and decantation". This involves deliberate segregation of the fine sample into its size ranges by wetting and decanting the very fine materials off using the methodology of Stoke's Law.

For roadbase material, each of the various grades, classes or types of product being supplied will normally have their own limits of compliance specified. These limits will vary and the selected specification will show clearly the required upper and lower requirements for each sieve size specified for each material type.

It is common for established roadbase specifications to contain only some of the standard sieve sizes described in Australian Standard test methods. In some cases they will skip one or two standard sieve sizes to specify a given roadbase product. For example, NSW, Roads and Maritime Services DGB20 (HD) material grading will move from the 2.36mm sieve to the 0.425mm sieve and exclude the two sieve sizes in between.

Note: It is important to ensure that proof sieving is done correctly for material retained on each sieve and no sieves are overloaded during the grading operation as this may skew the results achieved. Given the importance of this test, it is critical that laboratory technicians receive appropriate training on how to perform this and all others in this important Standard.



Figure 6: Shows the actions required when proof sieving to obtain the desired outcome when proof sieving

3.4 Particle shape

There are two established methods used or specified for shape in roadbase. The methods are Particle Shape and Flakiness Index as described below.

a) Particle Shape; Samples are tested in accordance with AS 1141.14, which is referred to as the Misshapen Particle test.

This test is carried out on sample fractions of material larger than 9.5mm and proportions representing fractions of greater than 10% of the sample.

The test is performed using a measuring device such as a purpose made caliper that can measure the comparative width, depth or height of a stone and then calculations are carried out to determine the various relationships of those pieces. The test is conducted by measuring the length to width and width to thickness of each aggregate particle and passing it through both ends of the proportional calliper. The particles are then described as Flat, Elongated or Flat and Elongated depending on whether they can pass through the calliper or are retained.

The measure of shape is normally conducted with the caliper in the 2:1 and 3:1 ratio positions. The result is normally expressed as % misshapen particles when compared to normal shaped, cubical, aggregate pieces.

The limit set when tested at a 2:1 ratio is normally < 35%.

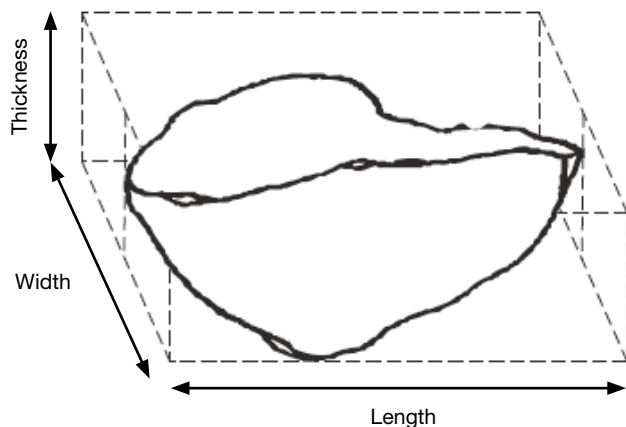


Figure 7: Standard stone dimensions

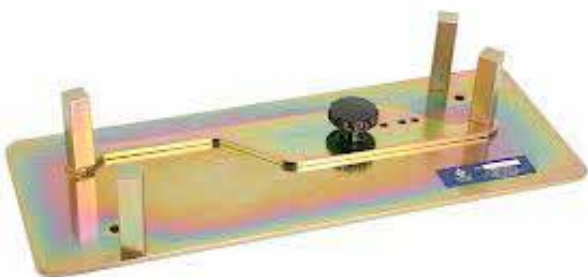


Figure 8: Proportional caliper used to perform the test

b) Flakiness Index; Samples are tested in accordance with AS 1141.15 where, various fractions must represent more than 5% of the sample and the fractional sizes are between 26.0mm and 4.75mm.

The test is performed using a measuring gauge that has standard sized slots through which the sample pieces are either passed through or retained. The result is based on a combined calculation of that which passes through the slots divided by those retained on the gauge.

The various states that use this test set limits of less than 30 to 35% of flaky particles.



Figure 9: The Flakiness Index test gauge and Flakiness Index slotted sieves

3.5 Durability

Durability will normally be selected based on experience and the local knowledge of the material and its ability to withstand breakdown overtime. Some states will use the Wet/Dry variation test (AS 1141.22) to gain this understanding whereas others may use the Los Angeles abrasion test (AS 1141.23). There may be cause from time to time for a specifier to request other durability testing such as Secondary Minerals (AS 1141.26) or Sodium Sulfate Soundness (AS 1141.24).

3.5.1 Wet Dry Strength and Wet/Dry Strength Variation

Roadbase is made up of a range of particles of various sizes. The larger particles are particularly subjected to cycles of wet and dry periods as well as movement sustained due to flexing of the pavement. To ensure these coarse aggregate fractions used in roadbase are durable they are subjected to the Wet/Dry test.

This test is performed in accordance with AS 1141.22 and is a basic aggregate crushing test. The test is performed by taking a measured quantity of sized aggregate and subjecting the sample to a force within a confined space. The test is performed on aggregate in both the wet and dry condition. The aim of the test is to obtain the crushing force required, to produce 10% fines in the sample in the wet and dry states. The percent variation between those conditions is termed the wet/dry strength variation.



Figure 10: Wet/Dry Strength test equipment and compression machine

The dry strength of the aggregate is defined as the crushing force which, when applied to a known mass of the aggregate will produce fines of a particular sizing and amounting to 10% of the mass of the dry test portion. The wet test is performed on a separate portion of the same sample as, the dry test, except that the test portion is soaked for 24 hours then towel dried (SSD), to allow an understanding of the change in strength when moist.

Generally, the smaller sized aggregates produce a higher strength value due to the packing nature and void characteristics of the particles in the test mould.

The requirements for wet strength and the wet/dry variation can be found in the applicable state road authority specification.

Note: Dry strengths tend to be greater than wet strengths in aggregate due to the absence of moisture within the aggregate pores.

3.5.2 Los Angeles Value

The Los Angeles (LA) test is performed in accordance with AS 1141.23 and is a dry abrasion test. The test is performed in a rotating drum container, which is loaded with steel balls and has a bar across the inside of the drum to interrupt the flow structure of the steel balls and ensure they perform a crushing process and not just flow. The drum is rotated for 500 revolutions and this action produces fine particles.

By means of drum rotation and interaction of the steel balls, the test produces fines, which are then weighed to calculate the percentage produced from the initial mass. A high value means the material has poor resistance to abrasion.



Figure 11: LA machine and test sample



Figure 12: LA machine test sample

Some aggregate types can lose whole crystals during the test and care is taken when interpreting results of those aggregates. The normal value specified for LA is a maximum of 35% loss.

3.6 Crushed particles of coarse aggregate

The test for crushed particles is performed in accordance with AS 1141.18 and is a simple visual test used when selecting either river gravels or conglomerates for use in roadbase production.

The test is performed to ensure these types of aggregates have been mechanically altered by means of crushing to have sufficient pieces of aggregate with broken faces to ensure interlock. Should there be too many rounded particles present, the materials may not interlock adequately to distribute loads and due to material movement action, the particles may unravel over time.

The states that use this test set limits ranging from 60% to 85% of particles (by mass) to have at least two crushed faces.

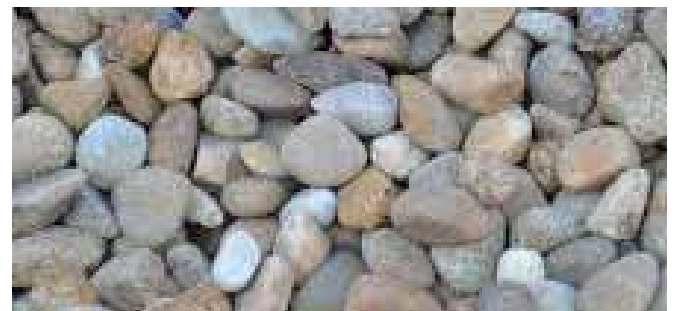


Figure 13: Examples of river gravel with crushed and uncrushed face

3.7 Plasticity

The nature of roadbase is that the material is made up of a range of material sizes and in some cases there is a requirement to test the finer materials in the mix for its nature when wet or dry. The tests mostly performed are Liquid Limit, Plastic Limit, Plastic Index and Linear Shrinkage and are often referred to as Atterberg Limits.

These tests allow the user to understand how the roadbase will act in various conditions and particularly during the placement process. It will also help in the understanding of the material capability to remain stable in wet periods.

In most cases, it is common for the roadbase specification to designate a small amount of plasticity in a product to aid in the compaction of the material and to assist in the surface cohesion of the pavement layer. As there can be traffic movement over a new pavement during construction and as more construction is performed under traffic, a small quantity of plasticity can help to keep the new surface from ravelling. That is allowing segregation of the fines away from the coarse particles.

The Atterberg limits are referred to as a basic measure of the nature of fine-grained materials in roadbase. Depending on the water content of the materials, they can be quantified into four states; these are, solid, semi-solid, plastic and liquid. Each state will affect the consistency and behaviour of the material. It will also affect the engineering properties of these fine materials. The Atterberg limits are used to help distinguish between silt and clay and their quantities in the materials tested.

3.7.1 Liquid Limit

A sample of fine material is placed into a metal cup and a groove is made down its centre with a standardised tool. The cup is repeatedly dropped 10mm vertically onto a special hard rubber base at a rate of 120 blows per minute (2 blows per second), during which the groove closes up gradually as a result of the impact.

The moisture content at which it takes 25 drops of the cup to cause the groove to close over a distance of 13.5 millimetres designates the point of Liquid Limit (LL). Although the procedure can vary, the test is normally run at four moisture contents, and the moisture content, which requires 25 blows to close the groove, can be interpolated from the resulting graph of moisture to blows required to close the gap.



Figure 14: Liquid limit device with sample

3.7.2 Plastic Limit

The plastic limit (PL) is determined by rolling out a thread of sample from the liquid limit test. This is performed using a flat, non-porous surface such as etched glass.

If the soil is plastic, this thread will retain its shape down to a small diameter. As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3mm.

If the material is non-plastic, the sample thread will not be able to be rolled down to 3mm at any moisture level below the liquid limit point.

3.7.3 Plasticity Index

The Plastic Index (PI) is the difference between the Liquid Limit and the plastic limit ($PI = LL - PL$). The plasticity index is the size of the range of water contents where the soil exhibits plastic properties.

Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of zero (non-plastic) tend to have little or no silt or clay.

Examples of PI ranges and their meanings:

0	Non plastic
1-5	Slightly plastic
5-10	Low plasticity
10-20	Medium plasticity
20+	High plasticity

Note: Each material tested will have its own relationship between liquid limit and plastic limit and testing should be done by an experienced operator to obtain meaningful results. Specialised training is required to gain sufficient experience to conduct this test correctly.

3.7.4 Linear Shrinkage

The Shrinkage Limit (SL) of a roadbase is the water content where further loss of moisture will not result in any more volume reduction. The test to determine the shrinkage limit is AS 1289.3.4.1. The shrinkage limit is seldom used as often as the liquid and plastic limit as a means of determining material plasticity and response to moisture.

The test is performed by taking a sample of selected material and mixing it to liquid limit moisture, compacting it into a mould and drying the sample back.

The change in linear volume is classified as the linear shrinkage.

3.8 Permeability

Permeability is a measure of the ability of a porous material (often, a rock or unconsolidated material) to allow fluids to pass through it.

Just as the porosity of a roadbase affects how much water it can hold, it also affects how quickly water can flow through it. The ability of water to flow through a roadbase is referred to as the materials permeability. The permeability of gravel is higher than that of clay.

In grading specifications, limits are placed on the percentage of fines, i.e. material passing the 75µm sieve. In addition, a minimum and maximum value is specified for Plasticity Index (PI). A roadbase that contains sufficient fines to fill all voids between the aggregate particles will still gain its strength from point to point contact but has increased shear resistance. Its density will be sufficient and its permeability low.

The test is performed by timing the flow of water through a compacted sample of the roadbase.



Figure 15: Permeability test apparatus and typical drainage types

For the base course layer in a pavement construction the most common requirement for permeability is 5×10^{-8} . This means the material is impermeable and not free draining.

It has been found that unless there are sufficient fine material ($<75\mu\text{m}$) in the product, this level of permeability is difficult to obtain.

3.9 Recycled materials

Most specifying bodies will allow the use of recycled materials as a portion of roadbase manufacture.

The table below from the New South Wales Roads and Maritime Services (RMS) gives some indication of the limits that may be in place. Specifications from each specifying body should be consulted to understand the requirements fully before using these materials in a roadbase application.

RMS Limits on Use of Recycled and Manufactured Materials as Constituent Materials

Recycled Material	Unbound or Modified Base & Subbase	Bound Base & Subbase
Iron & Steel slag	100%	100%
Crushed Concrete	100%	100%
Brick	20%	10%
RAP	40%	40%
Fly Ash	10%	10%
Furnace Bottom Ash	10%	10%
Crushed Glass Fines	10%	10%

There are also limits of Undesirable Materials within Recycled and Manufactured Materials.

3.10 Shear strength characteristics

Shear strength characteristics may be used as an acceptable alternative to the commonly specified mechanical properties or they may be used in conjunction with them to better understand the material long-term ability to withstand deformation.

The most commonly used tests for determination of shear strength in a roadbase are Modified Texas Triaxial and California Bearing Ratio (CBR).

As shear strength testing requires the sample to be fully compacted, the first stage of testing is to gather information regarding the density and moisture needed to obtain the correct compaction required on a test sample. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are determined in laboratory testing and it is these results that are later used in the field to determine if adequate in-situ compaction has been achieved. This is normally expressed as an insitu density of somewhere between 98% to 102% of the lab or assigned MDD. The laboratory determined OMC also becomes essential to ensure roadbases are delivered just below optimum and compaction is conducted close to optimum for the best conditions to achieve full insitu compaction and density.

3.10.1 Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).

For roadbase to obtain its MDD there is a need to add sufficient moisture to the material so that air is removed from the sample and the particles are packed correctly into place to give a maximum density.

To achieve this, a sample is taken and mixed with water to somewhere below OMC and then compacted into a standard mould. The compaction is always the same using a standard compaction rammer. At low moisture contents, not all the air is removed, the ongoing addition of more moisture will allow greater removal of air and thus increased density. As further moisture and compaction is provided, a peak density is met. This effect begins to be counteracted by the saturation of the soil and the density again starts to lower after the addition of further moisture to the material past the peak.

The test is performed in a standard sized mould and compacted with a standard compaction rammer. The mould used for minus 19mm samples is 1 litre in volume and has a diameter of 105mm. The metal rammer used for standard compaction has a 50mm face diameter, a drop mass of 2.7kg and equipped with a suitable device to control the height of drop to a free fall of 300mm.

To achieve “standard compaction” the sample is compacted in three layers with 25 blows of the rammer per layer.

The relationship between the moisture and the density of the material at a given moisture can be graphed and the point of maximum density related to the optimum moisture required to achieve it.

Various test methods show the details required to graph the relationship between MDD and OMC. Shown below is a typical computer generated graph.

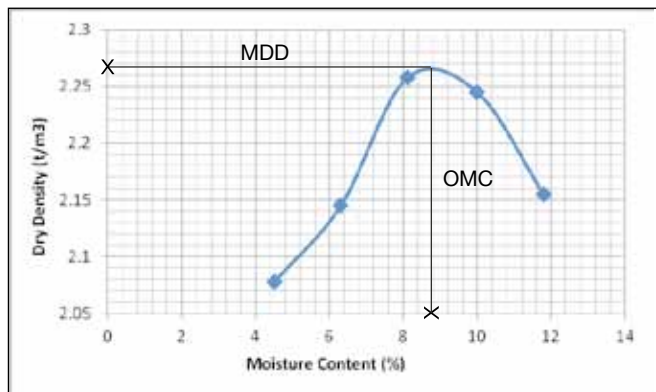


Figure 16: Computer generated graph for MDD/OMC (simple Excel method)

The standard test was firstly developed in the 1930's and since that time, the equipment used in the field for compacting has improved greatly with larger and heavier compaction equipment. In the late 1950's, a further development of the test was implemented with heavier laboratory test equipment and a change to the compaction technique. This test was then called the “modified” method. In the 1980's, the use of this method became more common for field compaction comparisons.

Note: the application of the heavier drop hammer in the modified test allows the max dry density of the roadbase to be achieved at allowed moisture content but can lead to breakdown of the roadbase in the field if over-compaction results from the use of too heavy equipment or too thin a roadbase layer under compaction.

3.10.2 The California bearing ratio (CBR)

The California bearing ratio (CBR) is a penetration test used to evaluate the mechanical strength of subgrade and roadbase materials. It was developed by the California Department of Transportation before World War II.

A sample is compacted into a standard mould using the compaction values obtained from the MDD/OMC test. The compaction value used depends on the requirements of the material being tested and for roadbase the value is either 100% of standard compaction or 100% of modified compaction.

The sample is then cured in water for a designated time under load. The sample is drained and then the penetration is carried out.

The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The pressure required to achieve an equal penetration on a standard crushed rock material then divides the measured pressure.

The CBR rating was developed for measuring the load-bearing capacity of materials used for building roads. The standard material for this test is crushed California limestone, which has a value of 100. The harder the material surface, the higher the CBR value. For comparison sake, the following example gives an indication of values. A CBR of 3 equates to topsoil material, a CBR of 5 equates to moist clay, while moist sand may have a CBR of 10. For high quality crushed rock, it would be expected that a CBR over 80 would be achieved.



Figure 17: Typical CBR test equipment

3.10.3 A modified Texas Triaxial

A modified Texas Triaxial shear test is a common method to measure the shearing resistance of granular materials (shear strength).

Although the name Triaxial test suggests that the stresses would be different in three directions, this is not the case in the test with air as a confining medium and the confining pressures equal in all directions. In a true Triaxial test the stresses in all three directions can be different.

A sample is compacted, in the test, into a special sized mould using the compaction values obtained from the MDD/OMC test. The compaction value used depends on the requirements of the material being tested and for roadbase the value is normally, 100% of standard compaction but the moisture content will be somewhat less than OMC and mostly in the order of 85% of OMC. The sample is removed from the compaction mould, and then confined into the Texas Triaxial mould with the latex sleeve and top and bottom platens.

The sample is placed in the test apparatus. The top platen can then be mechanically driven up or down along the axis of the cylinder to squeeze the material. Using the selected stress, commence compression until the required deformation is achieved. Repeat the test on further samples at selected stress levels. Normal selected stress levels are 10, 30, 60 and 90 kPa.

The distance that the upper platen travels is measured as a function of the force required to move it, as the pressure of the surrounding air is carefully controlled.

The Texas Classification number is obtained by calculation and a comparison made against a standard Texas Triaxial Classification chart.

Depending on either material classification or the particular traffic category selected, there is a minimum Texas Triaxial classification number.



Figure 18: A view of typical Texas Triaxial testing equipment

4.0 Conclusion

Roadbase materials must satisfy the requirements of the selected specification for a given application. Roadbases are most likely suitable for use in pavement construction and related structures provided they are consistently supplied and regular sampling and testing is undertaken to ensure those selected properties remain compliant with the relevant works specifications or industry requirements.

A range of recycled or alternative pavement materials have been shown to be suitable as a roadbase product based on testing for shear strength characteristics not mechanical properties. Should such materials be selected for use, consistency of the selected test processes is important in assuring the laboratory test results are transferred to the in-situ material use. Roadbases are important construction materials and when well designed, produced, placed and compacted can form an important part of our road network or ground support for important structures along with other applications.