Aggregate for Railway Ballast

The requirements of AS 2758.7 - 2009

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:

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This technical note provides background knowledge of the requirements used when supplying aggregates for use in Railway Ballast applications.

Aggregate produced from rock, gravel, metallurgical slag or synthetic materials may be used provided the particular criteria set out for the aggregate are met. AS 2758.7 sets out the requirements for the quality of a material source and the properties required of the rock.

This Standard sets out best practice criteria as known at the time of publishing and should not be regarded as a stand-alone material works specification. Most Australian industry procedures will have their own specification for aggregates supply into Rail Ballast works. These specifications will, in most instances, specify material attributes that are either the same as or similar to those designated in the Australian Standard AS 2758.7.
2.0 Railway ballast applications

One of the most demanding applications for crushed aggregate is railway ballast. This product serves as a bed for railroad tracks and provides track stability, drainage, and distribution of the significant loads carried by locomotive engines and railcars into the ground beneath. In addition, it deters the growth of vegetation that might interfere with the track structure and operation and allows track maintenance to be performed more easily.

Railway ballast is packed beneath the train rails to interlock with the capping layer subgrade and provide a uniform support layer. More ballast is also packed between the sleepers and rail itself to lock them in place to resist the high loads from passing trains (Figure 1). Rail ballast must interlock to provide this load transfer and track stability. The properties of rail ballast aggregate are therefore very important to the effective load carrying capacity of the rail structure and the subsequent in-service life of the rail track structure.

![Figure 1: Typical railway track showing good ballast height and width](image)

Ballast is typically made of crushed rock. The term “ballast” comes from a nautical term for the stones used to stabilise a ship during loading and transportation. Good ballast should be strong, hard-wearing, and stable, drain easily, be easy to keep clean or re-clean, workable and resistant to deformation under load.

What is Railway Ballast?

As mentioned earlier in this document railway track ballast provides the required cover for the underlying subgrade and this material is also used to hold the railway tracks in place. Ballast has several functions:

- Distributes the weight of the trains from the track, through the sleepers and ballast rock skeleton to the ground beneath
- Keeps the track from moving under the weight of the trains
- Provides adequate drainage for the track
- Maintains proper track levelling and alignment
- Retards growth of vegetation
- Reduces dust build up which may lead to uneven support to the rail

- Distributes the load of the track and train to prevent over stressing the subgrade and possible rail deflection, temporary or permanent
- Restrains the track laterally, longitudinally, and vertically under dynamic loads imposed by trains and thermal stress induced in the rails by changing temperatures. This is most evident in continuously welded rail which is particularly temperature sensitive and is present in parts of the Australian rail network

If ballast becomes contaminated with other materials, it can lose its ability to do some or all of these jobs. A common problem is fouling of rail ballast by coal spillages or other where the drainage ability of the ballast is affected. This may lead to pressure differences and potential rail loading issues. As such, ballast cleaning is a common practice over time to ensure extended life for the ballast and minimise load concentration on rail, sleepers and track structures.

![Figure 2: Typical construction layout](image)

In Australia there are many and varied owners of the rail network and they may have their own specifications in place but the over-riding specification for supply of railway ballast is AS 2758.7.

The construction of the rail network throughout Australia has had a checkered history, made up with disagreements and State rivalry. This has led to a variety of rail track sizes in service, different specifications and operational policies from one state of Australia to another. Some of the main ones are shown below:

Main gauges (see also Figure 3):

- **Standard gauge**: 1,435mm – with approximately 17,678km of track, mainly New South Wales and the interstate rail network
- **Narrow gauge**: 1,067mm – with approximately 15,160 km of track, mainly Queensland, Western Australia and Tasmania as well as some of South Australia
- **Broad gauge**: 1,600mm – with approximately 4,017km of track, mainly Victoria, some South Australia, some Victorian Railways branch lines extending into southern New South Wales
These differences have led to some unusual constructions to allow trains to accommodate customer needs. The Albury Railway Station is a great example of this (Figure 4). As originally New South Wales and Victoria had different railway gauges, this meant that all travellers in either direction had to change trains at Albury. To accommodate these changes, a very long railway platform was needed; the covered platform is one of the longest in Australia.

Figure 4: Albury Railway Station

Network

Figure 5: Network ownership (may change from time to time)
Construction

In Australian Standards the railway track construction is based on track loading which sets the track classification.

In Section 5 of AS 2758.7 the various classifications are shown as follows:

(a) Class H – Loading in excess of 6 million tonnes per year
(b) Class N – Loading from 1 million tonnes to 6 million tonnes per year
(c) Class L – Loading less than 1 million tonnes per year

The thickness of a layer of track ballast depends on the size and spacing of the sleepers, the amount of traffic expected on the line, and various other factors. An insufficient depth of ballast overloads the underlying subgrade or roadbase materials. In the worst cases, this can cause track deformation and affect the ride and operation of the trains. Slowing trains down on poorly designed or maintained track costs time and money in its operation if the ballast does not have sufficient depth it can lead to vibrations, which in turn can damage nearby infrastructure. It should also be noted that once the required depth of ballast is achieved, more depth of ballast will not necessarily reduce further vibration to surrounding infrastructure.

Rail ballast typically sits on a layer of roadbase type material, which is made of crushed rock to give integrity to that layer of the construction. It gives a solid support for the ballast, and assists to seal out water from the underlying materials.

It is essential for ballast to be placed as high as the sleepers, and for a substantial “shoulder” to be placed at their ends. This is most important, since this ballast shoulder is, for the most part, the only thing restraining lateral movement of the track.

The quality of the rock used and the interaction of rock on rock movement are important features in railway track construction. In AS 2758.7, the requirements for supply of rock for railway track construction particularly relies on size and durability. Should the selected rock have a tendency to breakdown due to weaker particles or have micro internal cracking, this can commence a breakdown of particles and a weakening of the track bed.
Aggregate properties and the test methods specified in AS 2758.7

3.1 General

AS 2758.7 outlines the test requirements for aggregates for Railway ballast. Each aggregate property is covered in a separate section of the Standard as follows:

- Section 8 covers rock density requirements
- Section 9 covers the dimensional requirements including shape and crushed particles
- Section 10 covers durability requirements - designated as Wet Strength and Wet/Dry Strength variation, Los Angeles value, Aggregate Crushing Value and Wet Attrition Value

All tests referred to in AS 2758.7 are covered in AS 1141 series of test methods. In some work specifications or supply documents, the test methods stipulated may be from a specifier's suite of test methods. In general, however, these methods will be very similar to those specified in AS 1141.

3.2 Test methods and their purpose in the Standard

3.2.1 General Requirements (Section 8)

Bulk Density (Clause 8.1)

Bulk Density is carried out in accordance with AS 1141.4. The test gives the density (mass per unit volume) of the material either in stockpile or when loaded into a bulk container for delivery. In the case of ballast the test is used to calculate volumes required as material is mostly delivered to a project by rail cars.

The test is carried out in the loose density or compacted density format. For railway ballast the requirement called for is the compacted bulk density. Material compacts somewhat and settles during the loading and delivery process.

This test is performed by placing a sample of aggregate into a container in layers and compacting each layer with designated number of blows using a rod. After levelling the surface of the sample with the container, the mass of the sample is taken and using the volume of the container a calculation is performed to work out the density of the aggregate.

\[ D = \frac{M}{V} \]

where \( D \) = Density, \( M \) = Mass of sample and \( V \) = Volume of test mould (measured in tonnes/m³).

AS 2758.7 sets the requirement for bulk density at not less than 1200kg/m³

Particle Density (Clause 8.2)

In AS 2758.7, the specification does not require the reporting of the water absorption of the aggregate but it is obtained when testing for particle density. The following information describes both the procedure for particle density and water absorption.

Whereas bulk density is the mass per unit volume of the material and includes the material voids, the particle density test is performed by taking a sample of aggregate and determining its mass by displacing a mass of water. The result is the ratio of the density of the aggregate to the density of water with the air voids removed.

Water absorption testing is performed in conjunction with determining the particle density, both in the dry state and in the Saturated Surface dry Condition (SSD).

The water absorption, which is the amount of water a particle can absorb, can be calculated from the test procedure. There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the particle density and water absorption of the aggregate materials.

The voids within an aggregate particle should not be confused with the void system which makes up the space between particles in an aggregate mass. Refer to Figure 9 below.

3.2.2 Dimensional Requirements (Section 9)

The most ideal aggregate for rail ballast would consist of particles of a selected range of sizes and degree of angularity, made out of a hard and durable stone free from dust or deleterious matter with very few flat or elongated particles. Aggregate with these attributes should have good packing ability.

Grading or Particle Size Distribution (PSD) is determined when a sample is tested in accordance with AS 1141.11.1.

The test for grading is carried out by sieving, where an aggregate sample is shaken through a nest of selected sieve sizes from largest down to smallest. The result is reported as the percentage passing each individual sieve size. This test can be performed in either a dry state (a 'dry grading') or by wetting and washing (a 'wash grading').
Grading of aggregate is the most commonly requested test within this industry. The purpose of the test is to determine the varying amounts of material contained in standard size segment.

AS 2758.7, Table 1 gives the material nominal sizing and acceptable maximum and minimum requirements for percentage passing a standard test sieve size.

**Particle Shape (Clause 9.2)**
Samples are tested in accordance with AS 1141.14, which is 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 whole sample.

The test is performed using a measuring device such as a purpose made calliper 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 determines those particles that are determined to be Flat, Elongated or Flat and Elongated. The measure of shape is stipulated in AS 2758.7 by the relationship of a 2:1 ratio.

**Crushed Particles of Coarse Aggregate (Clause 9.3)**
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.

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 surfaces to ensure interlock.

AS 2758.5 set a limit of at least 75% of particles (by mass) will have at least 2 crushed faces.
3.2.3 Durability Requirements (Section 10)

General

The aggregate used as railway ballast must be durable, as it is exposed to a range of atmospheric, vibration and other cyclic conditions which threaten to break them down while in service. They therefore need to be sufficiently durable to achieve the required wear characteristics specified.

AS 2758.7 suggests a range of test methods that may be used to determine the potential durability of an aggregate. Two options that are most commonly used in Australia are provided for, but only one is required to be included in any given works specification.

The chosen method should be that which most suits local experience for the particular rock source selected.

The recommended durability test options in AS 2758.7 are:

- Aggregate Crushing Value (ACV) and Wet Attrition Value
- Wet Strength and Wet/Dry Strength variation and Los Angeles value

Aggregate Crushing Value (clause 10.3)

The aggregate crushing value test is performed in accordance with test method AS 1141.21.

This test procedure is similar to the wet/dry strength variation test.

The aim of the test is to obtain, by crushing, produced fines, which in turn ascertain the strength of the aggregate. The test is performed by taking a measured quantity of sized aggregate and subjecting the sample to a force within a confined space.

The standard test sample is based on the -13.2mm + 9.5mm fraction of the aggregate sample using a 2.36mm sieve for the separation of the produced fines after crushing. The test is carried out in the dry condition only. There is provision for testing other sizes shown within the test procedure.

For railway ballast, the sample size used is the -26.5mm+19.0mm fraction, with the separation of fines after crushing sieve being the 4.75mm sieve. This is an alternative to the standard test sample size.

The strength of the aggregate is defined by the quantity of fines produced after application of the total force applied in a ten minute time limit. The load is applied evenly in that time. In the case of railway ballast, the designated total force applied is 400kN.

The standard AS 2758.7 set a range of limits for crushing value based on the class of rail track being constructed.

- Class H: 25% maximum
- Class N: 30% maximum
- Class L: 40% maximum

Wet Attrition Value (Clause 10.3)

In addition to testing rail ballast for crushing value, the Standard requires aggregate to be tested for the wet attrition value.

A sample of aggregate sized between 53.0mm and 37.5mm is checked for misshapen particles, which are removed from the test fraction. The misshapen particles are based on a 2:1 caliper ratio. The sample prepared sample is washed and dried. Four test portions of approximately 5kg are taken.

The test is performed in duplicate in both the dry form and in a wet format. The wet format involves placing equal masses of aggregate and water in the test container.

A test portion is placed in the “Deval Attrition” apparatus, which has a container, or containers that are set at 30° to the axis of the rotating shaft of the apparatus. Some machines have more than one container built into them. The sample is then rotated for 10,000 rotations.

After removal of the sample following the test rotations, it is washed and sieved over a 2.36mm separation sieve to ascertain the loss from the test portion.

The standard AS 2758.7 set a range of limits for attrition value based on the class of rail track being constructed.

- Class H: 6% maximum
- Class N: 8% maximum
- Class L: 12% maximum

Wet Strength and Wet/Dry Strength Variation (Clause 10.4)

This test is performed in accordance with AS 1141.22 and is a basic aggregate crushing test. It 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 is to obtain, by crushing, 10% of produced fines in order to ascertain the strength of the aggregate in both wet and dry conditions and to determine the percentage variation between the aggregate’s strength in the two conditions.

![Figure 14: Deval attrition machine](image)
The strength of the aggregate is defined as the crushing force which, when applied to a known mass of the aggregate, will produce fines amounting to 10% of the mass of the dry test portion. The wet test is performed on a sample of the same size as that for the dry test but it is soaked for 24 hours then towel dried to Saturated Surface Dry Condition (SSD), and crushed. This allows an understanding of the change in strength between the dry and wet states, thus identifying any sensitivity to water.

Due to the size of the rock used in railway ballast, the test is carried out on a sample sized -26.5+19.0mm. Testing may be carried out on material from a quarry source that represents that being crushed and supplied to a particular project. Results obtained from normal quarry production can be acceptable should the supply be coming from that area of the quarry.

The standard AS 2758.7 sets a range of wet/dry variation limits based on the class of rail track being constructed.

- **Class H**: 25% maximum
- **Class N**: 30% maximum
- **Class L**: 40% maximum

The standard AS 2758.7 sets a range of limits for wet strength based on the class of rail track being constructed.

- **Class H**: 175kN minimum
- **Class N**: 150kN minimum
- **Class L**: 110kN minimum

### Los Angeles Value (Clause 10.4)

The Los Angeles (LA) test is performed in accordance with AS 1141.23 and is a dry abrasion test. It is performed in a rotating drum loaded with steel balls. A bar across the inside of the drum interrupts the flow structure of the steel balls and ensures they perform a crushing/impact process and do not just roll around the drum during rotation. The drum is rotated for 500 revolutions and through this action, fine particles are generated from the interaction of the steel balls and the aggregate.

After completion of the test, the sample is sieved over a separation sieve and the percentage loss is expressed as a percentage LA Abrasion loss. A high percentage LA abrasion loss may indicate a weak material, which could degrade in service.

For railway ballast, the aggregate size used in the test is -19.0mm +9.5mm and a sample of actual ballast may be crushed to provide the sample.

AS 2758.7 set a range of limits for Los Angeles value based on the class of rail track being constructed.

- **Class H**: 25% maximum
- **Class N**: 30% maximum
- **Class L**: 40% maximum

### Conclusion

Aggregates that satisfy the requirements of AS 2758.7 are likely to be suitable for use in railway track construction, provided they are consistently supplied and regular sampling and testing is undertaken to ensure those properties remain compliant with this Australian Standard document, relevant works specifications or industry requirements.