Technical
Note 71

Coarse asphalt aggregate

The requirements of AS 2758.5 - 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:

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

This technical note provides background knowledge of the requirements used when supplying coarse aggregates for asphalt.

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 2758.5 sets out the requirements for the quality of a material source and the properties required of the coarse asphalt aggregate.

It should be noted that this Standard sets out the required criteria as known at the time of publishing and should not be regarded as a stand-alone material works specification. Most Australian State Road Authorities have their own specification for aggregates supply into asphalt works. These State specifications will, in most instances, show material attributes that are either the same as or similar to those designated in the Australian Standard AS 2758.5.

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2.0 Asphalt types

The range of asphalt types includes:

- Dense Graded Asphalt (DGA)
- Open Graded Asphalt (OGA)
- Stone Mastic Asphalt (SMA)
- Cold Mixed Asphalt (CMA)
- Fine Gap Graded Asphalt (FGGA)
- Coloured Surface Coatings

The required aggregate attributes vary from type to type and will depend on pavement and traffic conditions.

Figure 1: Typical asphalt placement and completed layers

3.0 Mix design considerations

Asphalt is a mixture of bituminous binders, aggregate and fillers produced in a hot mixing plant. It is delivered to site, spread, levelled and compacted in its hot state. The environmental conditions at this time generally dictate spreading and compaction processes.

Coarse aggregate size selection is a function of layer thickness, the nominal aggregate size is generally 20-25% of the layer thickness specified.

The function of the uppermost asphalt course is to provide a final wearing surface that is even, has good ride quality and results in low tyre noise. It should provide a surface that is suitable for the traffic volume and speed limits set for the project. Asphalt is also used as a filling or levelling course prior to placing the wearing course.

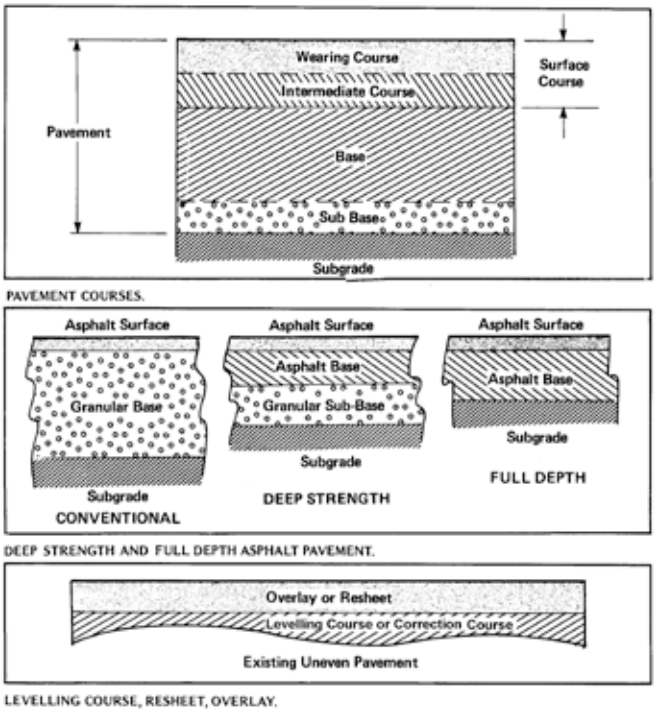

Figure 2: Shows some examples of the use of asphalt

A number of considerations will be taken into account when selecting the type of asphalt to be used, in most cases the relevant road authority will have its own guidelines. Some of the desirable pavement properties taken into consideration are:

- Durability
- Fatigue resistance
- Stability
- Workability
- Skid resistance

Asphalt mix design is based on providing a well-graded mix of coarse and fine aggregates and binders to give the desired characteristics for the selected asphalt type. This will involve:

- Selection of suitable materials
- Identification of a suitable grading
- Availability of suitable aggregate
- Compaction test confirmation
- Volumetric and mechanical testing

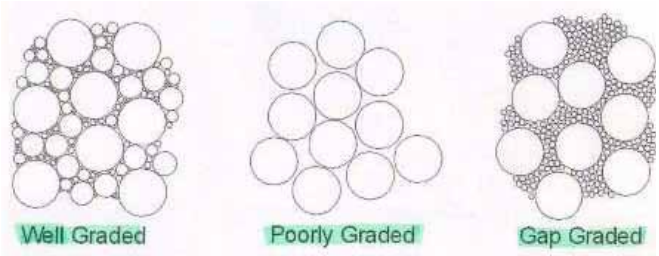

Figure 3: Combined aggregate grading in asphalt

In the case of asphalt, the binding agent is bitumen.

The selection of aggregate is based on being able to have a supply that meets the property requirements set out in AS 2758.5.

Consideration is given to:

- Appropriate particle size distribution (grading)
- Resistance to abrasion and crushing under traffic
- Angularity of particles
- Resistance to weathering and ability to withstand exposure to the elements
- Adhesion of aggregate to binder
- Resistance to polishing and texturally rough
- Low permeability to minimise bitumen absorption

Some of these requirements may be mutually exclusive. For example, a strong aggregate, which is resistant to crushing, could have poor frictional qualities, due to its fine grain structure or mineralogy, etc.

The best coarse aggregates for asphalt tend to be crushed stone, crushed gravel or crushed slag, which are generally strong, irregular/angular in shape, with roughened surface texture. These particles tend to pack together well under compaction or consolidation and remain in place under sustained load due to their ability to interlock.

The crushed aggregates can make the asphalt mix somewhat difficult to place. To improve the workability, mixes may contain both angular and round particles. Typical asphalt mixes contain crushed coarse aggregate particles, and a combination of crushed and natural fine aggregate particles (natural sand). AS 2758.5 specifies in detail the requirements for coarse crushed materials. Fillers, adhesion agents and bitumen are used to coat all the particles and provide lubrication for improving compaction during placement.

Reclaimed Asphalt Pavement (RAP) material is often used in asphalt mixes as it provides a range of economic, environmental and engineering benefits. In general, the use of up to 15% RAP does not have a major impact on the mix design.

4.0 Aggregate properties and the test methods specified in AS 2758.5

4.1 General

AS 2758.5 outlines the test requirements for coarse aggregate for asphalt. Each aggregate property is covered in a separate section of the Standard as follows:

- Section 7 covers Dimensional requirements designated as grading, shape (either by Misshapen Particle test or Flakiness Index test), and crushed particles.
- Section 8 covers Durability requirements designated as Wet Strength and Wet/Dry Strength Variation, Los Angeles Value, Sodium Sulfate Soundness and Unsound and Marginal Stone content and are either a singular test procedure or a combination of tests.
  Note: Each Road Authority has, over time, adopted a test or series of tests for the aggregates available in its particular areas. These have been based on test results and observed durability of aggregate in service.
- Section 9 outlines the requirement for weak particles
- Section 10 covers resistance to stripping requirements
- Section 11 covers frictional characteristics and refers to notes in Appendix A
- Section 12 covers requirements for particle density and water absorption

All tests referred to in AS 2758.5 are covered in the AS 1141 series of Standards. In some work specifications or Road Authority supply documents, the test methods stipulated may be from the Road Authority's own set of test methods. In general, however, these methods will be very similar to those specified in AS 1141.

4.2 Test methods and their purpose

4.2.1 Dimensional Requirements (AS 2758.5 section 7)

The ideal coarse asphalt aggregate would consist of hard and durable material free from dust or deleterious matter and excess amounts of flat or elongated particles. This aggregate should pack efficiently and when combined with other constituents in a well-designed and consistently supplied mix will form the rock skeleton of the asphalt.

AS 2758.5 specifies limits on aggregate grading, shape and proportion of crushed particles, and how these properties are to be measured.

Grading (Clause 7.1)

Grading or Particle Size Distribution (PSD) is determined when a sample is tested in accordance with AS 1141.11.1, AS 1141.11.2 and/or AS 1141.12 (as appropriate). The grading limits for coarse asphalt aggregate specified in AS 2758.5 are based on the results of a "nominated grading" from the supplier and the limits of deviation from that grading. Table 1 gives the allowable deviations from the "nominated grading" for each coarse aggregate size supplied.

The test for grading of the larger fractions (greater than 75µm) is carried out by sieving a sample in accordance with the requirements of AS 1141.11.1 or AS 1141.11.2. This process is where a sample is shaken through a nest of sieves from largest down to smallest. The result is generally reported as the percentage passing each individual sieve size. The test can be performed in either a dry state (a 'dry grading') or by wetting and washing (a 'wash grading').

For the 75µm size the test is performed by wetting and agitating the sample to loosen and separate the very fine material from the bulk. The sample is subsequently washed over a 75µm sieve that, due to the delicacy of the sieve cloth, is protected during the test by the use of a larger sized sieve (normally 1.18mm). This test can be either part of the AS 1141.11.1 test or as an individual test in accordance with AS 1141.12.

Figure 4: Combined aggregate and sand sample graded into its individual sizes

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 segments. For asphalt works, the grading is an important property of the aggregate, as this will influence how well the asphalt mix will combine under compaction to form the overall combined aggregate skeleton of the mix. Variations in grading outside the allowable tolerances can affect the voids content within the asphalt and its ability to sustain loads which may lead to defects such as rutting in the asphalt over time.

Shape (Clause 7.2)

The two methods specified for evaluating shape are:

Particle Shape by Proportional Caliper samples are tested in accordance with AS 1141.14 which expresses the result as a Percentage Misshapen Particle for a given ratio on the caliper 2:1 or 3:1. 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 purpose-made caliper device that can measure the comparative width, thickness or length of an individual aggregate and then calculations are carried out to determine the various relationships of those pieces. The test determines those particles that are; Flat, Elongated or Flat and Elongated by measuring each piece: Length to Width and Width to Thickness. The measure of shape is stipulated by the relationship of either a 3:1 or 2:1 ratio of these pieces.

The standard sets a requirement of less than 10% for a ratio of 3:1 and less than 35% for a ratio of 2:1.

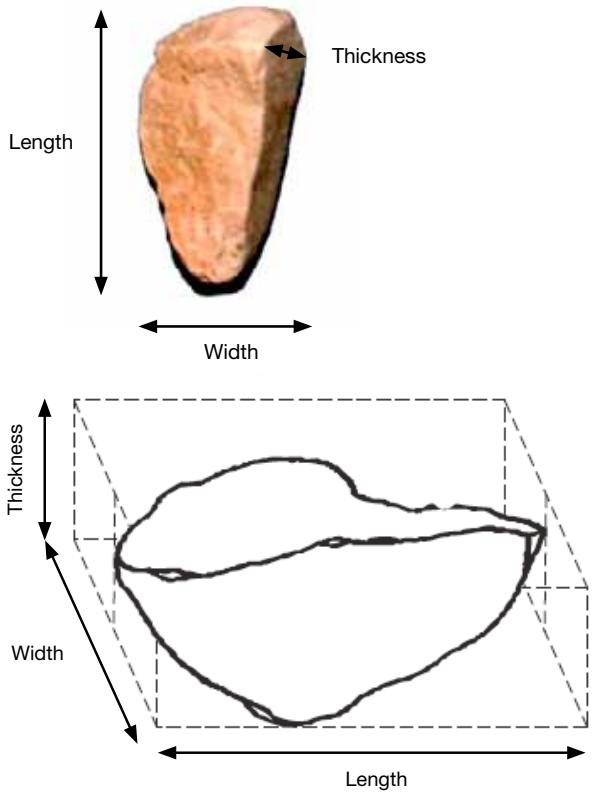

Figure 5: Standard stone dimensions

Flakiness Index in accordance with AS 1141.15. In this test, various fractions of the sample are tested provided they represent a particular fraction of 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 ether passed through or retained. The result is based on a combined calculation of that which passes through the slots v's those retained on the gauge.

The Standard sets a level of less than 35% of Flaky particles.

Figure 6: The Flakiness Index test gauge and Flakiness Index slotted sieves

Crushed Particles (Clause 7.3)

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 for use in sealing projects.

The test is performed to ensure that these types of aggregate have been mechanically altered by means of crushing to have a sufficient number of aggregate pieces, within a sample, with broken surfaces to promote interlock in the matrix and increase the surface roughness of the asphalt wearing courses. In wet or moist conditions, these broken faces and the increased roughness provide better skid resistance than wearing coarses using uncrushed rounded river gravel aggregates.

AS 2758.5 stipulates that at least 75% of particles (by mass) are to have at least two crushed faces.

Figure 7: Examples of river gravel uncrushed and with crushed faces

4.2.2 Durability Requirements (AS 2758.5 Section 8)

General

Asphalt as a flexible wearing course has a life expectancy of 15 to 20 years, and has to remain in place and continue to perform its role for this entire life span. The aggregates used in the asphalt mix must therefore be durable enough to tolerate the long-term loading while maintaining their physical, mechanical and chemical properties under various climatic conditions.

This includes the wetting and drying cycles that occur during the life of the pavement and flexing of the pavement due to traffic and to sub-pavement movement.

AS 2758.5 has a range of durability tests included that either singularly or in combination, provides some confidence of material integrity.

The Standard notes that the three sets of tests nominated, represent those most commonly used in Australia. Of special note is the indication in the Standard that only one of the durability test methods is needed to classify aggregate durability in any works specification.

It should also be noted that the chosen aggregate durability method should be one that most suits the local experience for the particular rock source selected. It has been a common error by specifiers to select several of the test sets, which over complicates the durability classification and in turn under-values the use of the most correct method.

The method sets within the AS 2758.5:

a) Wet strength and Wet/Dry Strength Variation (AS 1141.22)

b) Los Angeles value (AS 1141.23) and Sodium Sulfate Soundness (AS 1141.24)

c) Los Angeles value (AS 1141.23) and Unsound and Marginal Stone Content (AS 1141.30.1)

Wet Strength and Wet/Dry Strength Variation (Clause 8.2)

This test is performed in accordance with AS 1141.22 and is an aggregate crushing test. A measured quantity of sized aggregate is placed within a dedicated restraining ring, a plunger placed onto aggregate and the sample subjected to a force to produce 10% fines in 10 minutes. The test is performed on aggregate in both the wet and dry conditions which identifies if the aggregate in question is water sensitive and likely to maintain its strength over time in a wet or dry environment.

Figure 8: Wet/Dry strength test equipment and compression machine

The 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 sample of exactly the same size as for the dry test but the test portion is soaked for 24 hours to allow an understanding of the change in strength when moist.

For coarse asphalt aggregate, AS 2758.5 requires the wet strength to be “not less than 150 kN” for aggregate intended for use in Open Grade mixes and “not less than 100 kN” for all other mixes. The wet/dry variation “shall not exceed 35%” for all cases.

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. This test can be affected by the shape of the individual aggregate as better shaped aggregates in general pack more efficiently and are less likely to have edges broken off during loading, producing a higher strength for 10% fines.

Los Angeles Value and Sodium Sulfate Soundness (Clause 8.3)

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 loaded with steel balls. A bar across the drum interrupts the flow structure of the steel balls and ensures they perform a crushing process and do not just flow. The drum is rotated for 500 revolutions and this action produces fine particles which are removed and measured as a percentage of the initial mass. A high value means the material has poor resistance to abrasion.

Figure 9: LA machine and test sample

Table 2 in AS 2758.5, gives a range of acceptable LA test results based on rock type. Some aggregate types can lose whole crystals during the test (it has been known to happen with some granites). Care is therefore needed when interpreting results for those aggregates.

Sodium Sulfate Soundness

The Sodium Sulfate Soundness (SSS) test is performed in accordance with AS 1141.24 and is used to determine the aggregate's ability to resist weathering. This test accelerates the normal weathering process by increasing the frequency and severity of the aggregate's exposure to the elements.

This test is performed by placing aggregate samples in a salt water solution and then drying the sample in an oven. The process is repeated 5 times in 5 days and allows salt crystals to enter any cracks or micro-cracks present in an aggregate and as the salt crystals grow, they expand and break down the aggregate. Poor quality material will disintegrate into grain-sized particles and will show the degree of weathering that can be expected.

This test is a good indicator of potential aggregate durability when the material is to be exposed to ground water or near salt water such as areas within the coastal zone.

The maximum allowable weighted average loss is 12% for all coarse aggregate.

Los Angeles Value and Unsound and Marginal Stone Content (Clause 8.4)

Los Angeles Value

The LA test is performed in accordance with AS 1141.23 as described in the previous section.

Unsound and Marginal Stone Content

This test is performed in accordance with AS 1141.30.1 and uses visual examination of aggregate against known reference specimens. It is necessary that the unsound rock has been defined and is quite distinguishable from sound rock within the same deposit. The difference may be according to colour or texture. AS 1141.30.2 gives the procedure for preparation of the reference specimens used for the comparison.

The test is performed on a sample of aggregate retained on a 4.75mm sieve. The sample is checked firstly for soft material. The remainder of material is then washed and the sample is visually examined and compared to the reference specimens and any unsound particles are separated from the rest of the sample. Their mass is expressed as a percentage of the total sample mass. Samples are generally then kept so they can be used at a deposit for visual comparison with future production.

Table 2 in AS 2758.5, gives a range of acceptable LA test results based on rock type. A maximum of 5% is specified for unsound stone content. The maximum for unsound and marginal stone content is 10%.

4.2.3 Weak Particle (AS 2758.5 Section 9)

The weak particle test is performed in accordance with AS 1141.32. The test involves soaking a sample of aggregate for a period of time, removing any visual clay lumps and then, by using finger pressure on each individual piece, checking for pieces that are easily crushed or broken.

Once separated, the percentage of weak particles can be determined.

The purpose of the test is to ensure the coarse aggregate integrity during the early life of the pavement, ie to minimise the chance of material breakdown during production, delivery and placement of the asphalt, thus ensuring the mix design integrity.

AS 2758.5 specifies that there shall not be more than 1% of weak particles in coarse aggregate.

4.2.4 Resistance to Stripping (AS 2758.5 Section 10)

This test is performed in accordance with AS 1141.50 and is used to assess the adhesion between the selected aggregates and bituminous binders. The aggregate is tested with or without an appropriate adhesion agent and is generally performed on a 14mm aggregate.

The test is carried out using Class 170 Binder conforming to AS 2008 as the standard bitumen. The binder used should be from the source proposed for the project and, if required, may include appropriate adhesion agents.

The aggregate from the source shall be tested in the "as received (untreated) but dried to constant mass" condition.

The test involves heating a sample of bitumen and spreading a film onto a roughened dedicated metal plate and allowing it to cool. Aggregate particles are then embedded into it, orientated in a way similar to how they would place on the pavement. After curing at temperature and cooling in water for a period, each particle is pulled from the plate and checked for adhering binder. Depending on the visual amount of adhering binder on the aggregate a decision is made as to whether the aggregate particle is "completely stripped, partly stripped or not stripped".

The results are weighted and a total % stripped figure is reported.

Figure 10: Photo showing the loss of bond between aggregate and binder leading to the commencement of asphalt stripping within this core hole

AS 2758.5 sets a limit of "not more than 10% stripped particles" when tested in the "as received (untreated) but dried to constant mass" condition.

This test is used as an indicator of bituminous binder/aggregate interaction and adhesion and is not as important with asphalt aggregates as it is with sealing aggregates. The choice of asphalt fillers and adhesion agents added to the mix can have a significant effect on aggregate/binder adhesion.

4.2.5 Frictional Characteristics (AS 2758.5 Section 11)

This section of AS 2758.5 provides no specification details, it only points to a guidance note in Appendix A of the standard.

This property is only considered for coarse aggregate intended for use in an asphalt wearing course and is not relevant for construction or correction courses.

Frictional characteristics of aggregate are expressed as the aggregate's ability to resist polishing compared to a standard reference aggregate (currently Panmure Basalt). This is determined by testing an aggregate sample by the method described in AS 1141.40, AS 1141.41 and AS 1141.42. The result is reported as a Polished Aggregate Friction Value (PAFV) or a Polished Stone Value (PSV) .

The tests involve preparing sample plates of aggregate that are then subjected to continual passes of rubber tyres that simulate traffic movement, wear and loading. The sample plates of aggregate are also subjected to the addition of an abrasive material to simulate wear on the aggregate.

After the period of polishing is completed, the plates are removed and subjected to a frictional pendulum test to ascertain the final frictional characteristic value and polishing resistance. The test results are compared to a known standard aggregate test result.

AS 2758.5 does not give a specified value for this test as there is a wide range of factors that influence the requirement, including road geometry, traffic speed and traffic volumes. In most situations the particular road authority designates the specific requirement for polishing value.

Figure 11: Horizontal bed polishing machine

Figure 12: Vertical wheel polishing machine

Figure 13: Friction Pendulum

4.2.6 Water Absorption and Particle Density (AS 2758.5 Section 12)

Testing for these attributes is not mandatory but is at the option of the purchaser.

The particle density test is performed in accordance with AS 1141.6.1 by taking a sample of aggregate and determining its mass by displacing a mass of water, or in accordance with AS 1141.6.2 by Pycnometer method. The result is the ratio of the density of the substance to the density of water. The particle density represents the mass of the rock in a quarry face or a solid 1m^3 of material. It is reported in the Apparent, Dry and Saturated Surface Dry conditions (SSD).

Note: Bulk Density is defined in AS 1141.4 as the mass per unit volume of the material in loose and compacted forms and represents aggregates in a stockpile, truck or rail wagon in different states of compaction.

Water absorption testing is performed in conjunction with the particle density determination, and is reported as a percentage.

This water absorption value is very important in asphalt and must be kept constant as it is used to determine the amount of bituminous binder required in the asphalt mix. Increases in water absorption values can indicate an increase in binder requirement and thus an increase in the cost of the mixes. The quantity of effective bitumen within the asphalt mix is affected by how much is absorbed into the aggregate itself, as shown in Figure 14.

As solid as aggregate particles may appear to the naked eye, they contain voids, ie natural pores, that are filled with air or water. These voids or pores influence the particle density and water absorption of the aggregate materials. In this way the porosity of the aggregate and its water absorption are related.

The voids within an aggregate particle should not be confused with the voids between particles in an aggregate mass. The voids between the particles influence the design of hot mix asphalt. Refer to diagram below.

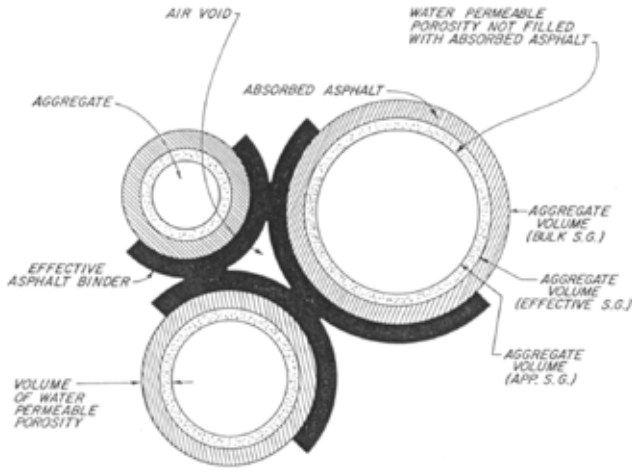

Figure 14: Effective bitumen content

Appendix A of AS 2758.5 - 2009 provides guidance on susceptibility of aggregate to polishing.

5.0 Conclusion

Aggregates that satisfy requirements of AS 2758.5 - 2009 are likely to be suitable for use as coarse aggregate within asphalt applications.