AGGREGATES

1 INTRODUCTION

Aggregates are used in both asphalt and sealing application. The following notes refer primarily to asphalt aggregates but generally apply to sprayed sealing aggregates, except where specifically noted.

1.1 Asphalt aggregates

Asphalt is a mixture of coarse and fine aggregates, and filler, bound with a bituminous binder.

Aggregates form up to 96% by mass (85% by volume) of an asphalt mix. The function of the aggregate is to:

- impart stability to the mix by the interlock of aggregate particles through their frictional resistance to displacement;
- provide a rough surface texture which will maintain skid resistant properties and not polish excessively under traffic;
- form a durable, abrasion-resistant material which will withstand environmental degradation and accommodate imposed loads without failure;
- spread the wheel loads to the lower layers of the pavement.

Coarse aggregate is that portion retained on a 4.75 mm sieve and fine aggregate is that portion passing a 4.75 mm sieve.

Filler is mineral matter substantially passing a 0.075 mm sieve, and includes rock dust derived from coarse and fine aggregate fractions and any other materials such as hydrated lime, fly ash or cement kiln dust added to supplement the quantity and properties of filler in the mix.

1.2 Sprayed sealing aggregates

Aggregate is the load-bearing and wearing component of most sprayed seals. The functions of an aggregate are to:

- Spread the wheel loads to the underlying pavement
- Provide a skid-resistant surface
- Provide surface drainage during wet weather
- Provide a durable, abrasion-resistant surface that will withstand traffic and weathering
- Interlock and impart stability to the treatment.

2 SOURCES OF AGGREGATE

2.1 General

Aggregate may be produced from:

- crushed and screened quarry products
- natural sands and gravels
- manufactured aggregates
- recycled materials.

Igneous rocks are the most common source of processed quarry aggregate, and may include basalt, dolerite, andesite, granite, porphyry, rhyolite, diorite, etc.

Acknowledgement: The text for this section of notes has been adapted substantially from the Austroads *Asphalt Guide*, AP–G66/02

Metamorphic rocks such as hornfels, schists, gneisses and quartzites are also used as asphalt aggregates.

Sedimentary rocks (especially bedded) and low grade (foliated) metamorphic rocks are often precluded as they possess planes of weakness or are of inadequate hardness.

Natural sands and gravels may be crushed and screened, washed and screened, or obtained as untreated bank run or pit sand.

Manufactured aggregates may be either the by-products of an industrial process, such as industrial slag, calcined bauxite, or products especially manufactured for use as aggregates.

Recycled materials include reclaimed asphalt pavement (RAP) and recycled concrete.

Table 1 gives broad guidelines for rock types commonly used as aggregates in asphalt and sprayed seals.

Table 1 Typical Aggregates (from NAASRA 1982)

Rock Group	**Rock type used most commonly as aggregate**	**Other types having similar properties**
Fine/medium grained basic igneous rock	Basalt	Dolerites
Fine/medium grained intermediate igneous rock	Andesite	Microdiorite, Microsyenite, Trachyte
Fine/medium grained acid igneous rock	Rhyolite, Dacite	Microgranite, Aplite, Obsidian
Coarse grained igneous rock	Granite	Granodiorite, Diorite
Regional metamorphics	Slate	Schist, Gneiss
Contact metamorphics	Hornfels	Certain Quartzites, contact-altered volcanic Breccia
Sedimentary and low grade metamorphic rocks	Quartzite, Limestone	Certain sandstones
Sedimentary rocks of volcanic association	Breccia	Agglomerate
Arenaceous sediments	River gravel	Conglomerate
Artificial rock	Blast-furnace slag, steel slag	Copper slag

2.2 Igneous Rocks

Igneous rocks are formed from molten materials either at or below the earth's surface.

Igneous rocks are classified in terms of grain size and composition. Coarse crystal grains are larger than 2 mm and fine grains are smaller than 0.2 mm. Classification by composition is either acidic, intermediate or basic, as shown in Table 2 and Figure 1.

The surface charge of the rock (ie. either acidic or basic) affects the affinity for bitumen, which although mostly bi-polar, may be slightly acidic. As a result, better adhesion is generally achieved with basic (positively charged) aggregate while acidic (negatively charged) rocks may exhibit poorer adhesion characteristics.

Table 2 Classification of Igneous Rocks by Composition (from Roberts et al)

Property	Acidic	Intermediate	Basic
Free silica %	66	52 – 66	< 52
Specific Gravity	< 2.75	-	2.75
Colour	Light	-	Dark
Free Quartz	Yes	-	No

Basalt is a dense, fine-grained, basic rock, dark in colour.

It is usually hard, tough and dense with good resistance to wear and good shape on crushing, although it can sometimes exhibit a vesicular structure.

Very hard basalts may have a tendency to polish, and vesicular basalt may have a weak structure that is likely to break down under traffic.

Basalts need to be examined for the influence of secondary minerals that break down rapidly on exposure to weathering.

Dolerite is a fine to medium-grained basic rock containing minerals similar to basalt.

It is generally hard and tough, although not as dense as basalt. Like basalt, it usually has a good affinity for bitumen, but generally does not polish rapidly.

Andesite is a dense rock, lighter in colour than basalt, and intermediate in composition between basalt and granite.

Affinity for bitumen can be poor and tests should be carried out to evaluate this property.

Granite is the principal coarse-grained igneous rock. It is acidic and contains quartz, feldspar and mica, or hornblende. Diorite is another representative of this group.

Granite has a brittle and crystalline structure and possesses fair to good resistance to abrasion. Sound granite is durable and resistant to weathering. Its shape when crushed is generally not as satisfactory as finer grained rocks, particularly for mechanical interlock.

Affinity for bitumen may be poor, requiring careful choice of filler or other additives to ensure good field performance.

Granite has a reduced tendency to polishing, as grains continually break off under the action of traffic, exposing fresh faces. Breakdown during crushing and screening can result in higher fines content than harder aggregate types.

Porphyry is intermediate in grain size between basalt and granite. It is hard and durable and may have poor affinity for bitumen, similar to that of granite.

Rhyolite is an acidic rock, usually light coloured. It corresponds in chemical composition to granite and quartz-porphyry.

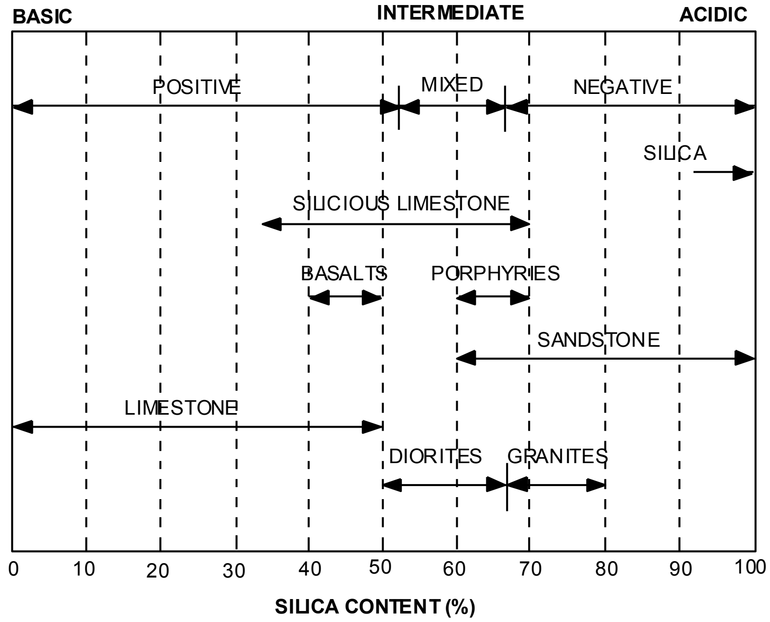

Figure 1 Classification of rocks by silica content and surface charge (from Roberts et al.)

2.3 Metamorphic Rocks

Metamorphic rocks are formed from pre-existing rocks by the action of heat and/or pressure from the earth's crust. The mineral compositions of metamorphic rocks are highly variable depending on the degree of metamorphism and composition of the parent material.

Hornfels and Greywacke can provide good quality, polish resistant asphalt aggregates from suitable sources.

Quartzite is a hardened sedimentary rock (eg. an altered sandstone). It is hard and tough, but may have poor affinity for bitumen.

2.4 Sedimentary Rocks

Sedimentary rocks are formed at the earth's surface by the accumulation and consolidation of the products of weathering and erosion of other rocks and minerals. The sediments usually harden by cementation or compaction over long periods of time. Limestone, sandstone, shales and chert are examples of sedimentary rocks.

Limestone is the principal member of the calcareous group of rocks, which generally result from the decomposition of calcium carbonate.

A wide variety of textures and hardness exist, from very fine-grained, tough materials to soft, sugary or coarse textured calcretes.

Limestone has generally good resistance to weathering and generally very good affinity for bitumen. While it usually yields a well-shaped aggregate, it sometimes tends to polish quickly, resulting in the formation of a slippery pavement.

Sandstone is a variable material composed of water-worn grains of sand cemented together by one of the following:

- carbonate of lime
- oxide of lime
- silica
- clay.

Due to its weak structure and variable nature, sandstone is generally unsuitable for use in either asphalt or sprayed seals.

2.5 Natural Sands and Gravels

Natural sands and gravels are found widely distributed throughout Australia.

Deposits include:

Stream beds, the most satisfactory source of natural aggregate. Particles are normally rounded in shape, clean and strong due to weak materials and fines having been removed by erosion.

Dunes formed by the action of wind. These sands tend to be single-sized and fairly fine.

Alluvial deposits formed on flood plains and riverbeds. Such deposits may contain a range of rock and stone types depending on the source of parent rocks.

Marine deposits formed at the edges and bottom of seas and lakes.

Natural sands generally contain a predominance of quartz grains.

River gravels may be a mixture of quartz, quartz porphyry, basalt, etc, and metamorphic rocks. They are generally hard and durable but may contain a proportion of soft and absorbent pieces.

River gravels tend to have a high proportion of quartz, resulting in low affinity to bitumen. They may be polish resistant but can contain rounded faces that may make them unsuitable for asphalt mixes requiring a high degree of aggregate interlock to maintain stability under heavy traffic loading.

2.6 Industrial Slag and Other Manufactured Aggregates

Both steel furnace and blast furnace slags have been used successfully as aggregates in asphalt and sprayed seals.

Crushed slag varies considerably, and usually consists of a mixture of stony, vesicular and glassy pieces. The former is reasonably hard and tough, but the vesicular pieces are somewhat softer and the glassy pieces are brittle.

Steel furnace slags produce asphalt mixes that display low creep characteristics and high resilient moduli. In general, steel furnace slags may be used for all asphalt applications, including heavily trafficked roads and high stress areas such as roundabouts (Australasian Slag Association 1999). They may also be used as polish-resistant aggregates for sprayed seal work.

Slag materials should be weathered before use as asphalt aggregate. This generally requires stockpiling for at least 6 months.

Steel furnace slag is typically 20% heavier than traditional materials whereas, depending on the size fraction, blast furnace slags are lighter than most traditional materials.

Both steel furnace and blast furnace slags, when crushed, consistently produce a cubical shaped particle with a high percentage of fractured faces.

Blast furnace slag generally has a lower particle strength than steel furnace slag (Australasian Slag Association, 1993), making it more applicable to:

- lightly trafficked roads
- lower asphalt layers
- car parks.

Steel furnace slags have a higher frictional value than most other commonly used aggregates while blast furnace slags tend to have medium friction values. Typical values for Polished Aggregate Friction Value (PAFV) are 58–63 for steel furnace slag and 50 for blast furnace slag.

Steel and iron slag aggregates are basic and therefore have a good affinity for bitumen in the clean dry state.

Aggregates produced from calcined bauxite are usually highly resistant to both wear and polishing. They are sometimes used as high performance, skid resistant, sprayed seal treatments but are considered to be too expensive to be cost-effective as an asphalt aggregate.

Attempts have also been made from time to time to use other manufactured materials, such as ceramics, as aggregates in asphalt to impart specific properties such as low density, light colour or resistance to polishing. Again, the aggregates have been largely considered too expensive for commercial application.

2.7 Reclaimed Asphalt Pavement (RAP)

Reclaimed asphalt pavement (RAP) may be used in asphalt production and should be encouraged.

RAP may be used as a component in the manufacture of hot mix asphalt, in combination with new aggregates and binder, to produce asphalt mixes that are indistinguishable from mixes produced entirely with virgin materials. RAP may also be used in the manufacture of cold recycled mixes.

The composition of the RAP depends on the type and origin of the material, as well as the method of reclaiming. Additional processing in terms of crushing and screening is generally required before use.

In general terms, the quality of the components in the RAP should be comparable with normal virgin materials for the appropriate application.

Not all RAP material is suitable for asphalt manufacture, including:

- asphalt containing crumb rubber and some polymer modified bitumens;
- asphalt with low quality aggregates.

2.8 Recycled Concrete

In view of the increasing pressure on the supplies of natural aggregates, there is potential for using coarse aggregate produced from recycled concrete, in asphalt production.

Recycled concrete aggregate should be clean, hard, uniform in quality and dimensionally stable with changes in moisture content.

The density of recycled aggregate is somewhat lower than the density of the original aggregate and water absorption may be much higher, resulting in greater bitumen absorption.

3 AGGREGATE PRODUCTION

The production of aggregate for asphalt and sprayed seals must be adequately controlled to produce a final product that has the required properties.

Aggregate production from hard rock quarries generally involves crushing followed by screening.

The range and distribution of particle sizes, and shape of aggregate from crushing, are largely determined by the relationship between the rock type, crusher types and crusher settings.

4 AGGREGATE PROPERTIES

4.1 General

The properties of aggregates may be considered in two groups:

- properties primarily dependent on the type of material used, ie:
  - toughness (strength, hardness and resistance to wear)
  - soundness
  - density
  - porosity (water absorption)
  - surface texture
  - resistance to polishing
  - affinity for bitumen.
- properties which can be partly controlled (as a direct result of processing), i.e:
  - shape
  - particle size distribution (grading)
  - cleanliness (silt, clay and organic matter content).

The suitability of aggregates for use in asphalt and sprayed seals is evaluated by a series of tests that are described in Australian Standard AS 1141 “Method for Sampling and Testing Aggregates”. Typical limits for the range of tests are given in State Road Transport Agency specifications and in Australian Standard AS 2758.5 “Aggregates and Rocks for Engineering Purposes – Asphalt Aggregate”.

Table 3 summarises typical properties that are characteristic of aggregates obtained from various rock sources.

4.2 Toughness

Coarse aggregate should have a high resistance to crushing and abrasion during manufacture, placing and compaction, and in service.

AS 1141.21 – Aggregate Crushing Value test or a modification of that test known as the Wet-Dry Strength Variation (AS 1141.22) may be used to determine the strength of the aggregate in terms of crushing force.

Aggregates having higher abrasion losses may be used in lower pavement layers where they are not subject to high stresses caused by traffic.

The Los Angeles test (AS 1141.23) measures wear and abrasion of aggregate.

4.3 Soundness

The aggregate should be sound (not susceptible to degradation) and free from planes of weakness (normally associated with sedimentary and foliated metamorphic rocks).

Tests available for assessing soundness include:

- Sodium sulfate soundness test (AS 1141.24)
- Degradation factor (AS 1141.25)
- Wet/dry strength variation (AS 1141.22)
- Secondary minerals content in basic igneous rocks (AS 1141.26).

The sodium sulfate soundness test subjects the aggregate to alternative wetting in a solution of sodium sulfate in water, and drying. The process causes the growth of sulfate crystals in the pores of aggregate particles. This is intended to reproduce the destructive forces of freezing water.

The degradation factor test is performed on samples of rock taken from quarry spalls or core samples and crushed and screened to specific sizes. It is used to categorise the fines produced by self-abrasion in the presence of water. Most of the experience with the test has been with basic igneous rocks, although it may also be applied to other rock types.

In the wet/dry strength variation test, the forces required to produce 10% fines for an aggregate in both a dry and a saturated surface dry condition are measured. The variation is the decrease in force required to produce 10% fines for wet aggregate expressed as a percentage of force required for dry aggregate.

The secondary mineral content determination involves petrological examination of a thin section of rock and the use of a point counting procedure of the identified secondary minerals.

Aggregate should also be free of contamination with unsound particles. This can be evaluated by testing for unsound particles (AS 1141.30) or weak particles (AS 1141.32). The unsound particles (Clay lumps, weak particles) are those which, when wet, will deform under finger pressure. These particles are removed and the loss of such particles is reported as a percentage by mass of the original test portion. The test portion is the aggregate fraction retained on the 4.75 mm sieve.

4.4 Density

Accurate determination of aggregate particle density is an important element of asphalt mix design, as small variations have a significant effect on calculation of volumetric properties .

The density of coarse aggregates is determined by AS1141.6 and fine aggregates by AS1141.5.

The test methods provide for three measures of particle density.

Particle density on a dry basis is the mass per unit volume of particles where the volume includes both the permeable and impermeable voids inherent in the particles. It is determined from the ratio of mass

of an oven dry sample to the volume of water displaced by the sample mass in a saturated surface dry condition.

Apparent particle density is the mass per unit volume of the impermeable portion of the aggregate particles (inaccessible to water by 24 hour soaking). It is determined from the ratio of the mass of an oven-dried sample to the volume of water displaced by that sample after 24 hour soaking.

Particle density on a saturated surface dry basis is the mass per unit volume including both the permeable and impermeable voids. It is determined from the ratio of the mass of a saturated surface dry sample to the volume of water displaced by that saturated surface dry sample.

For determination of the volumetric properties of asphalt, particle density on a dry basis is generally used.

The particle density of most common aggregates used in asphalt will generally exceed 2.3 t/m^3. Lower values may be an indicator of inferior materials and subject to further investigation.

4.5 Porosity

Good quality asphalt aggregates should be dense and have low porosity. The porosity of an aggregate is generally indicated by the amount of water it absorbs. The water absorption of aggregates should ideally be less than 2%.

The absorption of binder into porous aggregates must be allowed for in asphalt mix design to ensure adequate remaining effective binder content. Allowance for absorptive aggregates is also made in sprayed seal design.

Water absorption is determined by testing in accordance with AS 1141.5 or 1141.6 (See 4.4) and is the ratio of mass of water held in the permeable voids of the aggregate particles brought to the saturated surface dry condition to the oven dry mass of material.

4.6 Surface Texture

Like particle shape, the surface texture of aggregate particles influences the stability of the asphalt mix, and its workability. Rough textured aggregate particles may increase the mix stability but may require additional binder.

The use of vesicular (honeycombed) aggregates with larger surface area may assist binder adhesion, while very smooth-surfaced aggregates may make binder adhesion more difficult.

An indication of typical surface texture obtained from different source rock types is shown in Table 4.

The surface texture of aggregates (micro-texture) is also a factor in skid resistance of the pavement. In that case surface texture is evaluated after polishing to simulate the effect of traffic (See 4.7).

4.7 Resistance to Polishing

All aggregates polish under traffic. The degree of polishing depends on the type of aggregate, traffic conditions and road geometry.

There are a number of methods for preparation of laboratory samples to simulate polishing of aggregate under traffic. These include:

- Laboratory polishing of coarse aggregate using the vertical road-wheel machine (AS 1141.40);
- Laboratory polishing of aggregate using the horizontal bed machine (AS 1141.41);
- Laboratory polishing of coarse aggregate using the vertical road-wheel machine (British Standard BS 812: Part 114).

The Pendulum Friction Test (AS 1141.42) is used to determine the friction of a laboratory polished specimen. It measures the loss of energy when a rubber slider, mounted on the tip of a pendulum, is propelled across the wet surface of a polished aggregate specimen. The test is repeated four times and the friction value is the mean value from the last three tests.

Friction value is expressed as Polished Aggregate Friction Value (PAFV) for samples prepared in accordance with AS1141.40 or AS1141.41, or as Polished Stone Value (PSV) for samples prepared in accordance with BS 812:114. For most practical purposes, results from the different laboratory preparation procedures are considered interchangeable.

There is no direct correlation between polishing tests on an aggregate and the skid resistance of the corresponding pavement but it does allow the ranking of polishing characteristics.

In general, aggregates produced from hard, fine-grained rocks tend to polish more readily than others do, although that may vary depending on composition and state of weathering. Aggregates with particularly good resistance to polishing include some scoria, rhyolite and microgranite sources.

It is desirable for aggregates from each source to be tested to ensure that requirements for resistance to polishing are met.

Generally a minimum PAFV or PSV of 48 is specified for coarse aggregate in wearing course mixes and sprayed seals on medium and heavily trafficked roads, although higher values may be specified for particular application where greater levels of friction are required, such as approaches to traffic light controlled intersections, pedestrian/school crossings, rail level crossings, tight curves and roundabouts.

4.8 Affinity for Bitumen

Adhesion between aggregates and binder is a factor in resistance to stripping. Stripping occurs when moisture causes binder to detach from aggregates in an asphalt mix or sprayed seal.

Stripping in asphalt mixes is a complex mechanism that can be influenced by environment, construction standards, pavement layering, binder and filler type, and condition of aggregates as well as the natural affinity between aggregates and bitumen. Moisture sensitivity of asphalt mixes can be improved with the use of lime fillers or adhesion agents that change the surface chemistry of the aggregate and improve resistance to effects of moisture.

Adhesion of sprayed sealing aggregates in the presence of moisture can be improved by the use of adhesion agents in aggregate precoating materials or bitumen binder.

Table 5 indicates a classification of rocks in terms of their relative affinity for bitumen.

4.9 Particle Shape

Particle shape of processed aggregates is dependent on:

- nature of the rock
- the crushing process.

The shape of aggregate particles can influence the stability of an asphalt mix by virtue of the amount of mechanical interlock. Best interlock is generally obtained with wholly crushed angular particles having sharp corners. Spherical (rounded) particles may have poor mechanical interlock.

A description of particle shape characteristics is provided in Table 6.

Particle shape also influences the workability or ability to compact an asphalt mix. Rounded particles, particularly the incorporation of a proportion of natural sand in the fine aggregates, can provide more workable and more readily compacted mixes.

Particle shape of coarse aggregates may be evaluated using the Flakiness Index test (AS 1141.15) or Proportional Calliper test (AS 1141.14)

Well-shaped aggregates are those with a Flakiness Index of less than 15%, although values of between 25% and 35% may be acceptable for many applications.

Where shape is specified in terms of the proportional calliper test, typical maximum values for the proportion of flat or misshapen particles retained on a 9.50 mm AS sieve are 10% using a 3:1 ratio, and 35% for a 2:1 ratio.

A further factor in the shape of aggregates for asphalt is the presence of fractured faces. This is particularly relevant to natural gravels that may contain a proportion of rounded particles. Generally, at least 75% of particles retained on a 4.75 mm AS sieve should have at least two fractured faces. 90% of these particles should have at least one fractured face. The area of the fractured face(s) should also be a significant proportion of the total surface area of the particles.

The higher the design traffic, the greater the proportion of fractured faces desirable for stability and resistance to deformation of asphalt mixes.

4.10 Particle Size Distribution (Grading)

The grading of coarse aggregate particles is determined by dry sieving using the method described in AS 1141.11 “Particle size distribution by sieving”.

Consistent particle size distribution of aggregates is essential.

The particle size distribution of the coarse and fine aggregates should be such that, when combined with the mineral filler (if added), the resultant particle size distribution will meet the design requirements of the asphalt mix.

4.11 Cleanliness

The surfaces of the aggregate should be clean and free from coatings such as clay or dust, which impair the adhesion of the binder to the aggregate (See also Section 4.8). Washing at the source of supply may free aggregate of such coatings.

Table 3 Relative Properties of Rocks for Asphalt and Sprayed Seals

Rock Type	Mechanical strength	Durability	Chemical Stability	Surface Characteristics	Hardness Toughness	Surface Texture	Crushed Shape
Igneous							
Granite	Good	Good	Good	Good	Fair	Fair	Fair
Syenite	Good	Good	Good	Good	Good	Fair	Fair
Dolerite	Good	Good	Good	Good	Good	Fair	Good
Basalt	Good	Good	Good	Good	Good	Good	Good
Diabase	Good	Fair	Questionable	Good	Good	Good	Good
Periodite	Good	Fair	Questionable	Good	Good	Good	Good
Metamorphic							
Gneiss, schist	Good	Good	Good	Good	Fair	Good	Good
Quartzite	Good	Good	Good	Good	Good	Good	Fair
Marble	Fair	Good	Good	Good	Poor	Fair	Fair
Serpentine	Fair	Fair	Good	Fair to poor	Good	Good	Good
Hornfels	Good	Good	Good	Good	Good	Good	Good
Amphibolite	Good	Good	Good	Good		Fair	Fair
Slate	Good	Good	Good	Poor	Good	Fair	Fair
Sedimentary							
Limestone/ dolomite	Good	Fair	Good	Good	Poor	Good	Poor
Sandstone	Fair	Fair	Good	Good	Fair	Good	Good
Chert	Good	Poor	Poor	Fair	Good	Poor	Good
Conglomerate/ breccia	Fair	Fair	Good	Good			
Shale	Poor	Poor	Poor	Good	Poor	Fair	Fair

Table 4 Surface Texture of Aggregates

Surface Texture	**Characteristics**
Glassy	Conchoidal fracture
Smooth	Water-worn, or smooth due to fracture of laminated or fine-grained rock
Granular	Fracture showing more or less uniform grains
Rough	Rough fracture of fine-grained or medium-grained rock containing no easily visible crystalline constituents
Crystalline	Containing easily visible crystalline constituents
Honeycombed or vesicular	With visible pores and cavities

Table 5 Relative Affinity of Aggregate Rock Types for Bitumen

Good	Moderate	Poor
Igneous Rocks		
Gabbro Basalt Greenstone (basalt) Quartz Dolerite Diabase Scoria, Slag Peridotite	Biotite Granite Basalt Olivine Dolerite w/Analcyte Quartz Diorite Andesite Diabase	Granite Biotite Granite Aplite Granite Pegmatite Granite Soda Granite Granite Porphyry Granodiorite Obsidian Albitised Olivine-Diorite Diorite Rhyolite Trachyte Pumice Dacite Syenite
Metamorphic Rocks		
Siliceous River Sand Siliceous Sand w/Iron Oxide Coat Serpentine	Biotite Feldspar Gneiss Feldpathic Quartz-Sercite Gneiss Granitic Quartz-Feldspar Gneiss Biotite-Muscovite Schist Diabase-Hornfels Biotite Schist	Quartzite Granitic Gneiss Quartz-Sericite Schist Felspathic-Quartzite Biotite Schist Muscovite Schist
Sedimentary Rocks		
Limestone Dolomite Greywacke Limerock	Limestone Dolomite Limerock Reef Coral Calcareous Sandstone	Iron Oxide-rich Arkose Chert Flint Breccia Feldspathic Sandstone Sandstone Chalk Oolitic Limestone Argillaceous Sandstone

(After Stuart, 1990)

Table 6 Aggregate Particle Shape

Classification	Description
Rounded	Fully water-worn (completely shaped by attrition)
Irregular	Naturally irregular, or partly shaped by attrition and having rounded edges
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces
Flaky	Materials in which the thickness is small relative to the other two dimensions
Elongated	Materials, usually angular, in which the length is considerably larger than the other two dimensions
Flaky and Elongated	Materials having the length considerably larger than the width, and the width considerably larger than the thickness

5 COARSE AGGREGATE FOR ASPHALT

Coarse aggregate is that portion of aggregate retained on a 4.75 mm sieve. Coarse aggregates for asphalt are usually produced as one-sized materials with nominal sizes of 7, 10, 14, 20, 28 and 40 mm, although the two largest sizes may not always be available from some quarries.

The desirable properties of coarse aggregates have been largely covered in Section 4.

6 FINE AGGREGATE FOR ASPHALT

Fine aggregate is that portion of aggregate consisting of particles passing a 4.75 mm AS sieve.

Fine aggregate may consist of natural sands, crusher dust, crushed slag or gravel, recycled aggregate, crushed glass or any blend of these.

The functions of fine aggregate are to:

- reduce the voids in the coarse aggregate, reducing permeability and improving durability
- impart stability to the mix by the interlocking of particles.

The shape and texture of fine aggregate can also influence the workability of the asphalt mix.

The required properties of fine aggregate, particularly those pertaining to fine aggregates obtained from crushing of quarried materials, have been largely covered in Section 4.

Additional properties that are specific to fine aggregate include cleanliness of natural sands, particle shape and texture, and particle size distribution.

Some natural sand deposits contain silt and/or clay particles that should be removed by washing. Care should be taken to avoid use of sand that is subject to secondary cementation and formation of lumps that may not break up during asphalt manufacture, but which may disintegrate with weathering in service.

The particles of fine aggregate should generally be sharp and angular. Angular particles are usually the result of crushing and contribute to greater stability in the mix. In some mixes, the inclusion of natural sand with rounded grains may be required to improve workability and compaction, but some loss of deformation resistance may be expected.

Natural sand may be classified as coarse, medium or fine according to the particle size distribution. Generally, medium sand is required in asphalt mixes, however blending of sands (and other fine aggregates) may be necessary to produce the target particle size distribution, especially if the sand is single-sized.

It is essential that the particle size distribution(s) of the fine aggregate supplied be consistent. The mix design cannot be met if large variations occur in the fine aggregate particle size distribution.

7 AGGREGATES FOR SPRAYED SEALS

Aggregate sizes ranging from sand up to 20 mm are used in sprayed seals.

Aggregate sizes up to 14 mm are common in single/single seals. 10 mm and 14 mm aggregate are usually used where there is sufficient traffic volume to warrant the use of large sized aggregates. For lower traffic volume roads and low speed environments, the use of 7 mm aggregate is often more appropriate.

16 mm and 20 mm are occasionally used in single/single seals but have the following disadvantages:

- high tyre/road noise
- increased risk of damage to vehicles from flying loose aggregate particles on new work
- higher binder application rates
- increased cost.

The primary use of 16 and 20 mm aggregates is in combination with a smaller sized aggregate in double/double or single/double seals. Normal combinations of aggregate in double/double and single/double seals are:

- 10 mm with a 5 mm aggregate
- 14 or 16 mm with a 5 or 7 mm,
- 20 mm with a 7 or 10 mm aggregate.

5 mm and 7 mm aggregate sizes may be used:

- as a second application on top of a size 10, 14, 16 or 20 mm seal
- as a surfacing treatment for very lightly trafficked pavement, or for pavements where a fine surface texture is required
- as part of a temporary treatment to waterproof and cure the pavement after construction before trafficking, e.g. new construction which will not be opened to traffic for some time
- as part of a "scatter coat" (usually without the application of bitumen), (sometimes referred to as a “rack-in” seal or as a "pin down" seal) or "blinding" treatment to a large sized seal, where the points of the aggregate from the original seal form the running surface
- for corrective treatments prior to resurfacing.

8 FILLER

8.1 General

Mineral filler is that portion of mineral matter passing a 0.075 mm sieve. Filler includes rock dust derived from coarse and fine aggregate fractions and other materials such as lime, portland cement, cement kiln dust, or fly ash, added to supplement the quantity and properties of filler in the mix. In dense graded mixes, the proportion of filler is generally in the range of 4 to 6% by mass of the aggregates with a ratio by mass of filler to binder of between 0.6 and 1.2.

The function of the mineral filler portion of the asphalt mix is to:

- add stiffness to the binder, and stability to the mix;
- maximise binder content (increased volume in mastic form);
- affect the voids in the total aggregate, depending on the particle size distribution of the mineral filler.

The mineral filler can function:

- as part of the aggregate and overall particle size distribution of the mix;
- in a state of suspension in the liquid binder (ie. mastic) and be considered to increase the volume of the binder.

The particle size distribution (fineness) of the filler will largely determine the extent to which filler performs these dual roles.

Sources of mineral filler include:

Natural fillers

- rock dust derived from coarse and fine aggregates
- baghouse or cyclone dust.

Imported (commercially available) fillers

- hydrated lime
- Portland cement
- ground limestone
- cement kiln dust
- granulated ground blast-furnace slag
- fly ash.

The choice of filler will be determined by availability and cost together with the need to impart specific qualities such as improved stiffness or reduced moisture sensitivity.

Most of the commercially available materials used as added filler are produced to standards that reflect their primary use for other applications, or are by-products of other processes. The standard previously used for mineral fillers for asphalt (AS 2357) has now been withdrawn and filler requirements are included in relevant asphalt specifications. Requirements for fillers and characteristics are described below.

8.2 Properties

Important characteristics of all mineral fillers include:

- particle size distribution
- dry compacted voids content
- moisture content
- particle density.

Additional properties that may apply to certain types of material include:

- chemical composition
- water solubility
- loss on ignition
- presence of clay or other contaminants.

Particle size distribution and dry compacted voids

Particle size distribution is a key factor in the performance of an asphalt filler. In practice, voids in dry compacted filler is used as an indicator of the fineness of the filler material and hence the basic test for characterising filler performance. A high value of voids in dry compacted filler (AS 1141.17) indicates a fine material that will take up a high proportion of binder in filling the voids in the filler and hence a greater stiffening effect on the binder in the asphalt mix. This stiffening can improve deformation resistance and decrease moisture susceptibility.

A typical minimum value for dry compacted voids in the combined filler component of an asphalt mix is 38%. Higher values may be sought for particular applications and increases in voids may be obtained by blending materials with high values of dry compacted voids.

Any materials used as added filler should substantially comprise filler sized particles. Generally such materials should have a minimum of 75% passing the 0.075 mm sieve and 95 to 100% passing the 0.300 mm sieve.

Moisture content

Fillers must be dry and free from lumps to allow accurate feeding and dispersion into the asphalt mix.

Generally a maximum of 3% moisture content applies to all filler materials.

Particle density

A knowledge of particle density of filler is required in determining volumetric properties during asphalt mix design. Density is determined by AS 1141.7 “Apparent particle density of filler”.

Chemical composition

Certain fillers, particularly hydrated lime, Portland cement and cement kiln dust, contain a significant proportion of active lime that changes the surface chemistry of aggregates to improve bitumen adhesion and reduce moisture sensitivity of asphalt mixes.

Active lime materials can also be used to counter the influence of clay particles from stone dust filler on the moisture sensitivity of asphalt mixes.

Water solubility

Water solubility is undesirable in asphalt fillers. Materials that can exhibit solubility include some sources of cement kiln dust. Most other materials used as fillers have negligible solubility.

The water soluble fraction should not exceed 20% when determined by AS 1141.8 - “Water-soluble fraction of filler”.

Loss on ignition

Loss on ignition is used to characterise some fly ash materials (see below).

Clay contaminants

Clay materials are deleterious to asphalt, as they can induce high rates of water absorption and increase moisture sensitivity of the mix. Clay contaminants can occur in the filler portion of some aggregate sources. Where clay contaminants are considered to be relevant, the presence of clay can be identified using a solution of Methylene Blue and reporting values as either Methylene Blue Value (MBV) or Clay Index.

Plasticity Index (PI) is also sometimes specified for mineral fillers although the test is often unreliable for fine materials with low plasticity. A further alternative test for clay materials in fine aggregates is the sand equivalent test or “Clay and fine silt (settling method)”, AS 1141.33.

8.3 Sources and Requirements

Rock dust

Rock dust forms a portion of coarse and fine aggregates and can also include materials from bag-houses or other dry collection systems.

Generally dust from sources complying with the relevant requirements for aggregate quality is satisfactory although certain rock types (e.g. some river gravels and natural sands) may contain clay contaminants that may lead to the need for further treatment at the source, or addition of lime filler.

Hydrated lime

Hydrated lime is one of the most valued added filler materials due to very high voids content (typically 58%) and high proportion of active lime for improved bitumen adhesion.

Hydrated lime should be produced to AS 1672 – Limes and limestones – Lime for building. Tests that are relevant to its application as an asphalt filler are voids in dry compacted filler, sieve residue and moisture content.

Active lime content may also be relevant if being used to promote binder adhesion and counteract clay materials.

Portland cement

Portland cement provides high voids in dry compacted filler as well as improved resistance to moisture sensitivity in asphalt mixes. Cost, however, is generally higher than other available filler types and it is not commonly used.

Portland cement should be produced to AS 3972 Portland and blended cements. Tests that are relevant to its application as an asphalt filler are voids in dry compacted filler and moisture content.

Ground limestone

Ground limestone can be variable and relatively low in dry compacted voids. It does not contain any "active" lime so does not significantly contribute to the performance of asphalt mixes.

Tests that are relevant to its application as an asphalt filler are grading, voids in dry compacted filler and moisture content.

Cement kiln dust

Cement kiln dust is solid material extracted from the flue gases in the manufacture of Portland cement. It can be an economical, but sometimes variable, material with reasonably high dry compacted voids and active lime content.

There are no particular standards applicable to cement kiln dust. Tests that are relevant to its application as an asphalt filler are grading, voids in dry compacted filler, moisture content, water solubility and active lime content.

Granulated ground blast furnace slag

Ground slag is another material with high voids in dry compacted filler.

Material should be produced to AS 3582.2 Slag – Ground granulated iron blast-furnace. Tests that are relevant to its application as an asphalt filler are voids in dry compacted filler and moisture content.

Fly ash

Fly ash is obtained from some coal burning power stations.

Materials should comply with AS 3582.1 Fly ash. The grade to be used is Table 1, Fine grade, which should have a maximum loss on ignition of 4%. Tests that are relevant to its application as an asphalt filler are grading, voids in dry compacted filler, moisture content and loss on ignition.

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AUSTRALASIAN SLAG ASSOCIATION, "A Guide to the Use of Slag in Roads", (1993).

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Australian standards

AS 1141 Methods of sampling and testing aggregates.

AS 1141.3 Sampling
AS1141.5 Particle density and water absorption of fine aggregate
AS1141.6 Particle density and water absorption of coarse aggregate
AS1141.7 Apparent particle density of filler
AS 141.8 Water-soluble fraction of filler
AS1141.11 Particle size distribution by sieving
AS1141.14 Particle shape, by proportional calliper
AS1141.15 Flakiness Index
AS1141.21 Aggregate crushing value
AS1141.22 Wet/dry strength variation
AS1141.23 Los Angeles value
AS1141.24 Aggregate soundness – Evaluation by exposure to sodium sulfate solution
AS1141.25 Degradation factor
AS1141.26 Secondary mineral content in basic igneous rocks
AS1141.30 Coarse aggregate quality by visual comparison
AS1141.32 Weak particles (including clay lumps, soft and friable particles) in coarse aggregate
AS 1141.33 Clay and fine silt (settling method)
AS 1141.40 Polished aggregate friction value – Vertical road-wheel machine
AS 1141.41 Polished aggregate friction value – Horizontal bed machine
AS 1141.42 Pendulum friction test

AS 1672 Limes and limestones – Lime for building

AS 2758.2 Aggregates and rocks for engineering purposes – Part 2: Aggregates for sprayed bituminous surfacings.

AS 2758.2 Aggregates and rocks for engineering purposes – Part 5: Asphalt aggregates.

AS 3582 Supplementary cementitious materials for use with portland and blended cement

AS 3582.1 Fly ash
AS3582.2 Slag–Ground granulated iron blast-furnace
AS 3972 Portland and blended cements.