Exploring the Durability Specification of Coarse Aggregate Used in Airport Asphalt Mixtures

Greg White(✉) and Kayl Fergusson

University of the Sunshine Coast, Sippy Downs, QLD, Australia
gwhite2@usc.edu.au

Abstract. Coarse and fine aggregate constitutes approximately 93% of dense graded airport asphalt and the aggregate properties can affect asphalt surface performance. Despite a general trend towards performance-related specification of asphalt mixtures, prescriptive aggregate properties are generally still retained. This primarily reflects the absence of reliable performance-based laboratory test methods for determining the effect of aggregates on asphalt weathering and erosion. Historical airport asphalt specifications included a broad range of aggregate durability properties and the aggregate supply industry has questioned whether coarse aggregate durability testing can be simplified to combinations of just two properties. To determine whether a reduction in aggregate durability testing is appropriate for Australian airport asphalt, eight sources of aggregate were tested for wet strength, wet-dry strength variation, Los Angeles abrasion, sodium sulphate soundness and water absorption. The different tests were associated with different levels of variability and the correlation between the various tests results was generally low, except for Los Angeles abrasion and wet strength. The industry recommended combinations of aggregate durability testing were found to be inconsistent and ineffective. Consequently, the current range of aggregate durability tests must be retained. The only exception was the potential to omit Los Angeles abrasion when the wet strength is high. Furthermore, there was no significant difference between the results associated with the various coarse aggregate fraction sizes, indicating it may be appropriate to allow only one sized fraction per quarry source to be tested. Further work is required to correlate the various aggregate durability tests to asphalt field performance.

1 Introduction

Flexible airport pavement surfaces are predominantly comprised of dense graded, Marshall designed asphalt. The aggregates are usually fully crushed, newly quarried hard rock and the bituminous binder is usually a premium or modified product. The binder content is high compared to road and highway asphalt, typically 5.4–5.8% by mass of the asphalt mixture. Some jurisdictions and airports have developed alternate airport surface types. However, the USA, Australia, New Zealand, the Middle East and South Africa continue to favour dense graded mixtures designed using the Marshall method (White 1985).

Regardless of the asphalt mixture type, it is clear that asphalt surface performance is critical to the lifecycle cost and efficiency of airport pavement systems (AAA 2017).

H. Shehata and S. El-Badawy (Eds.): *Sustainable Issues in Infrastructure Engineering*, SUCI, pp. 207–224, 2021.
https://doi.org/10.1007/978-3-030-62586-3_13

Generally, the performance requirements for airport asphalt are similar to those associated with road and other pavement surfaces. However, the prioritisation of the necessarily balanced performance properties is skewed to reflect the slow and unstable movement of aircraft on the ground, the importance of skid resistance during take-off and landing operations, as well as the potential for loose stones to damage fragile aircraft engines (Table 1).

Table 1. Airport asphalt performance requirements (White 2018)

Physical requirement	Protects against	Importance
Deformation resistance	Groove closure Rutting Shearing/shoving	High
Fracture resistance	Top down cracking Fatigue cracking	Moderate
Surface friction and texture	Skid resistance Compliance requirement	High
Durability	Pavement generated loose stones Resistance to moisture damage	Moderate

Of the airport asphalt performance properties identified in Table 2, deformation resistance, fracture resistance and surface texture can be tested in the laboratory. Established test methods are directly related to the asphalt mixture performance in the field and these tests form the basis of performance-related specifications (White 2018). For example, wheel tracking at 60 °C is well established as being related to the risk of asphalt shearing, shoving, rutting and groove closure in the field (Jamieson and White 2019). Indirect tests are also well established for moisture damage resistance, such as the loss of indirect tensile modulus upon vacuum soaking asphalt samples with high air voids, known as the Lottman test (Nosler and Beckedahl 2000). In contrast, testing for durability associated with fretting, ravelling and the generation of loose stones (USACE 2009) is not well established.

Fretting, ravelling and other distresses that contribute to pavement generated loose stones are generally a function of age related weathering. The factors that affect the weathering of asphalt surfaces include (Abouelsaad and White 2020):

- Binder properties. The propensity for a particular bituminous binder to harden with age due to oxidation directly effects on embrittlement of the bituminous mastic and the rate of asphalt surface weathering.
- Aggregate properties. The propensity for particular aggregates to absorb the bituminous binder, or to degrade and breakdown, directly effects the loss of the mastic and the rate of weathering.
- Mixture composition. The volumetric composition of the mixture affects the amount and composition of the mastic and the bituminous binder film thickness, consequently affecting the amount of mastic erosion that occurs before ravelling commences.

Table 2. Typical Australian airport asphalt characteristics (Emery 2005)

Asphalt property	Typical value
Bitumen content (% by mix mass)	5.8
Target Marshall air voids (%)	4
Target voids filled with bitumen (%)	75
Filler Content (% by aggregate)	1.5 of hydrated lime
Minimum Marshall Stability (kN)	12
Maximum Marshall Flow (mm)	3
Percentage passing AS sieve (mm)	Target by volume (%)
13.2	100
9.5	82
6.7	70
4.75	60
2.36	44
1.18	33
0.600	25
0.300	16
0.150	10
0.075	5

Construction factors also play a part with sound joint construction and protection from mixture segregation required to reduce the rate of severe weathering in isolated areas. Although significant research on asphalt weathering has focussed on binder properties and the mixture composition, the aggregate properties also play an important role. In particular, the durability of the aggregate is expected to be important and because there is no established performance-related test for asphalt mixture weathering associated with aggregate durability, aggregate durability is generally still specified in a prescriptive manner.

This paper reviews the specification of aggregate durability for airport asphalt mixtures, particularly within the Australian context. A range of diverse aggregate samples were tested for the various aggregate durability properties and the results are explored to consider whether the testing indicates similar or different relative aggregate suitability. The conclusions consider whether there is an opportunity to reduce or omit some, or all, of the aggregate durability testing for airport asphalt in the future.

2 Background

2.1 Airport Asphalt

As stated above, airport asphalt in Australia and many other countries is designed based on the Marshall method (White 1985) with samples compacted by 75 blows of a Marshall hammer. Runway asphalt is generally 14 mm maximum nominal size and is typically constructed in 50–80 mm thick layers. Australian airport asphalt is usually densely graded with a high bitumen content and hydrated lime is often added as an anti-stripping agent (Table 2).

2.2 Aggregate for Asphalt

In practice, the mineral component of airport asphalt mixtures almost always consists of crushed coarse and fine aggregate, natural sand and a hydraulic filler (Zelelew and Papagiannakis 2012). The hydraulic filler is often hydrated lime, although fly ash has also been used from time to time (Liao et al. 2013). The natural sand is usually sourced from rivers or natural sand pits. In practice, 10–15% natural sand is common. Excessive natural sand can lead to deformation prone mixtures while asphalt mixtures with inadequate natural sand are often stiff and unworkable (White 2018).

As detailed above, the aggregate comprises around 93% (by mass) of an airport asphalt mixture. Despite a general focus on the importance of the bituminous binder on airport asphalt performance, the aggregate also plays an important part. However, because most performance related asphalt tests are dominated by the effects of the bituminous binder, aggregate is usually still specified in a prescriptive manner.

Aggregates are routinely characterised by a combination of the consensus properties (angularity, size and shape) as well as their source properties (abrasion resistance, strength, deleterious material content and chemical/mineral composition) (Bessa et al. 2012). The consensus properties are greatly affected by the quarry operation and crushing processes. For example, the shape of aggregate particles can be adjusted by adding tertiary crushing processes. In contrast, the source properties are inherent to the rock and can not be adjusted by processing.

In general, the consensus properties affect how the aggregate fractions are combined to achieve an asphalt mixture with an appropriately graded and interlocking aggregate skeleton, while the source properties are more focussed on the durability of the aggregate and therefore the weathering of the asphalt surface. For example, reactivity to environmentally common chemicals may result in reactions within the aggregate minerals, in turn reducing the asphalt surface life.

2.3 Airport Asphalt Aggregate Specification

Different jurisdictions specify different properties and values for aggregates used in airport asphalt production. However, specifications generally aim to control (CCAA 2009):

- Size and shape.
- Durability.
- Absorptivity.
- Affinity to bitumen.
- Frictional characteristics.
- Contamination.

As stated above, aggregate durability is important to asphalt surface performance, but there is no single and direct test for aggregate durability. Therefore, most jurisdictions use a combination of aggregate properties as indirect indicators of aggregate durability. Table 3 summarises the properties specified for the durability of airport asphalt aggregate in different jurisdictions. Related tests, such as water absorption and plasticity index, are also detailed, although it could be argued that these are not intended to be indicators of aggregate durability. The Australian specification has been criticised by practitioners for containing redundant and excessive durability tests. In fact, in addition to the properties detailed in Table 3, previous versions of the Australian airport asphalt specification also required:

- Unsound and Marginal stone content (AS 1141.30.1). Maximum 1%.
- Methylene blue value, fine aggregate only (AS 1141.66). Maximum 10 mg/g.
- Secondary mineral content (AS 1141.26). Maximum 20%.

The over-specification of airport asphalt aggregate durability in Australia generally reflects the different approaches to road asphalt aggregate specification in each of the Australian States. Each State has its own road asphalt specification and some States prefer different aggregate durability indicators (Table 4). But because the same airport asphalt specification is used across all States, all the durability tests were traditionally included. This contradicts industry advice which recommends any of the following combinations of standard tests to optimise aggregate durability specification (CCAA 2009):

- Wet strength and wet-dry strength variation, or
- Los Angeles abrasion and sodium sulphate soundness, or
- Los Angeles abrasion and unsound/marginal stones.

It is clear that there are various tests and approaches for evaluating the durability of aggregate for asphalt production. It is also clear that some jurisdictions take a significantly more sophisticated approach than recommended by CCAA (2009). What is not clear is whether the various tests provide consistent results. That is, whether a material that is considered unacceptable, or marginal, under one testing regime would also be considered unacceptable, or marginal, under another. Similarly, if a particular aggregate passes one regime but not another, it is not clear whether that material should be accepted, or rejected, or re-tested using an alternate combination of durability indicators.

3 Methods and Results

3.1 Methods

Eight diverse sources of aggregate were sampled and the 10 mm fraction was tested for the Australian airport asphalt specification indicators of course aggregate durability (AAPA 2018):

- Wet strength. According to AS 1141.22.
- Wet-dry strength variation. According to AS 1141.22.

Table 3. Example airport asphalt aggregate durability specifications

Jurisdiction	Specification	Properties	Limit	Test methods
Australia	AAPA (2018)	Los Angeles abrasion	≤30%	AS 1141.23
		Wet strength	≥150 kN	AS 1141.22
		Wet-dry strength variation	≤30%	AS 1141.22
		Sodium sulphate soundness	≤3%	AS 1141.24
		Water absorption	≤2%	AS 1141.6.1
		Plasticity index	Non-plastic (fine only)	AS 1289.3.3.1
United States	FAA (2018)	Los Angeles abrasion	≤40% (course only)	ASTM C131
		Sodium sulphate soundness	≤10/12% (fine/course)	ASTM C88
		Liquid limit	≤25% (fine only)	ASTM D4318
		Plasticity index	≤4% (fine only)	ASTM D4318
United Kingdom	MoD (2009)	Resistance to freeze/thaw	≤18%	BS EN 1367-2
		Los Angeles abrasion	≤30%	BS EN 1097-2
		Water absorption	≤2%	BS EN 1097-6
		Methylene blue value	≤25 km/g (fine only)	BS EN 933-9

- Los Angeles abrasion. According to AS 1141.23.
- Sodium sulphate soundness. According to AS 1141.24.
- Water absorption. According to AS 1141.6.1.

Where available, different sized fractions (7 mm and 14 mm) were tested for the same sources. This allowed the effect of particle size on the test result to be considered. Furthermore, where available, replicate samples of the 10 mm sized fraction were tested, allowing the variability of the testing to be determined.

The sources of aggregate were either used or considered for use in airport asphalt resurfacing projects in Australia (Table 5). The various results were analysed first by looking at the variability of the various tests results for the same aggregate source and nominal fraction size. The difference between the average results for the various nominal sized fractions were also considered, before correlations between the different tests were

Table 4. Australian road asphalt durability specifications

State	Specification	Properties	Limit	Test methods
Victoria	Vicroads (2018)	Degradation factor	Varies with type/use	AS 1141.25.2
		Los Angeles abrasion	Varies with type/use	AS 1141.23
		Unsound/marginal stones	Varies with type/use	AS 1141.30
New South Wales	RMS (2015)	Wet strength	≥150 kN	AS 1141.22
		Wet-dry strength variation	≤35%	AS 1141.22
		Water absorption	≤2.5%	AS 1141.6.1
		Sodium sulphate soundness	≤12%	AS 1141.24
Queensland	TMR (2018)	Degradation factor	≥40%	AS 1141.25.2
		Wet strength	≥150 kN	AS 1141.22
		Wet-dry strength variation	≤35%	AS 1141.22
		Water absorption	≤2.5%	AS 1141.6.1
		Sodium sulphate soundness	≤12%	AS 1141.24
South Australia	DPTI (2018)	Los Angeles abrasion	Project specific	AS 1141.23
		Water absorption	Project specific	AS 1141.6.1
		Sodium sulphate soundness	Project specific	AS 1141.24
		Unsound/marginal stones	Project specific	AS 1141.30
Western Australia	MRWA (2017)	Los Angeles abrasion	≤25%	AS 1141.23
		Wet strength	≥100 kN	AS 1141.22
		Wet-dry strength variation	≤35%	AS 1141.22
		Degradation factor	≥50%	AS 1141.25.2
		Water absorption	≤2%	AS 1141.6.1

Note: Some methods, options and details have been presented in a simplified form.

considered across the various aggregate sources. The results were primarily analysed graphically and using simple statistics, such as mean, standard deviation, coefficient of variation and Student t-tests for differences of means.

Table 5. Aggregate sources

Location	Aggregate type
Alice Springs, Northern Territory	Amphibolite
Archer River, Queensland	Greywacke
Dubbo, New South Wales	Basalt
Mareeba, Queensland	Greywacke
Mildura, Victoria	Basalt
Kununurra, Western Australia	Dolomite
Norfolk Island, New South Wales	Basalt
Rockhampton, Queensland	Greywacke
Proserpine, Queensland	Andesite
Adelaide, South Australia	Dolomite

4 Results

The results for the 10 mm aggregate fractions from each source are summarised in Table 6. The Australian airport asphalt specification limits are also included for reference. The results for the other sized fractions are in Table 7, for the five sources for which data was available. Finally, the replicate 10 mm fraction results are in Table 8, for the three sources for which data was available.

5 Discussion

5.1 Compliance with the Australian Airport Specification

The results for the 10 mm fraction were normalised, such that a value of 1.0 indicated a result at the Australian airport asphalt specification compliance limit and results exceeding 1.0 indicated a source that did not meet the compliance limit. For the aggregate sources considered, wet-dry strength variation, wet strength and water absorption were more likely to result in a source being rejected based on durability indicators (Fig. 1). In fact, all aggregate sources met the Los Angeles abrasion and sodium sulphate soundness requirements. Furthermore, four of the ten aggregate sources met all the Australian airport asphalt durability requirements. This indicates that the sources selected for this research represented the diverse range of materials found in Australia.

Table 6. 10 mm fraction results for all sources

Source	W/D strength (%)	Wet strength (kN)	LA abrasion (%)	SS soundness (%)	Absorption (%)
Specification	≤30	≥150	≤25	≤3	≤2
Alice Springs	45	121	22	0.7	1.6
Archer River	9	147	15	1.3	2.4
Dubbo	23	292	11	0.5	1
Mareeba	21	235	16	1.1	0.8
Mildura	24	133	21	1.9	1.1
Kununurra	13	193	23	0.8	0.3
Norfolk Island	54	139	20	1.1	2.7
Rockhampton	13	376	9	0.2	0.2
Proserpine	15	249	19	0.4	2.5
Adelaide	29	218	20	0.4	2.1

W/D = wet to dry, LA = Los Angeles, SS = Sodium Sulphate.

Table 7. 7 mm and 14 mm fraction results for select sources

Source/Fraction	W/D strength (%)	Wet strength (kN)	LA abrasion (%)	SS soundness (%)	Absorption (%)
Alice Springs					
7	44	111	24	0.2	0.7
14	45	134	19	2.1	1.9
Dubbo					
7	20	354	15	0.9	0.9
14	23	264	13	0.5	1
Mildura					
7	28	134	19	0.5	0.4
14	30	138	13	1.8	1.2
Rockhampton					
7	10	380	17	0.2	0.4
14	11	382	16	0.2	0.2
Proserpine					
7	18	209	13	0.5	0.3
14	15	249	22	0.6	0.9

Table 8. 10 mm replicate fraction results for select sources

Source	W/D strength (%)	Wet strength (kN)	LA abrasion (%)	SS soundness (%)	Absorption (%)
Alice Springs	42	154	19	1.3	0.6
	31	134	18	2.1	0.9
	45	195	18	0.9	0.9
	43	158	23	0.2	0.9
	44	111	24	0.5	0.7
Dubbo	23	264	13	0.5	1
	20	288	15	0.9	0.9
	19	312	9	1.3	1.2
	21	279	14	0.7	1.1
	24	289	16	0.4	0.8
Proserpine	13	262	13	0.8	0.1
	18	244	22	0.9	0.7
	15	266	21	1.0	0.9
	18	239	14	0.7	1.9
	22	209	18	0.5	0.3

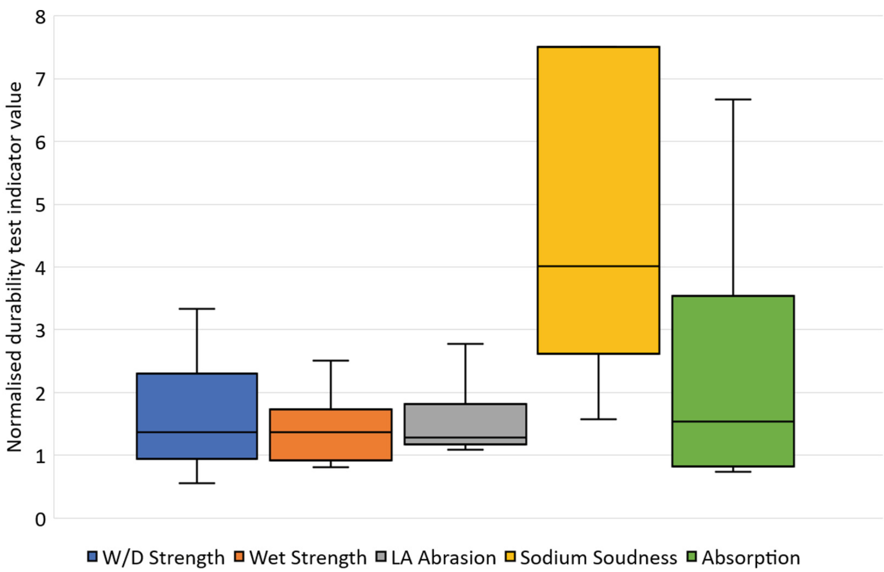

Fig. 1. Normalised 10 mm fractions results

5.2 Variability of Results

The replicate 10 mm fraction results allowed the variability of results for a nominally identical material to be analysed. Table 9 summarises the coefficients of variation for each source and for each durability indicator. Including the results in Table 6, there were a total of six replicate results for each of the three aggregate sources considered. The results indicate that Alice Springs aggregate has greater durability indicator variability than the other sources. However, the Alice Springs Los Angeles abrasion was less variable and the Proserpine water absorption was very high.

Table 9. 10 mm aggregate fraction result coefficients of variation

Source	W/D strength	Wet strength	LA abrasion	SS soundness	Absorption
Alice Springs	12.8%	20.8%	12.9%	71.0%	37.5%
Dubbo	9.1%	5.5%	20.1%	47.0%	14.1%
Proserpine	18.9%	8.3%	20.5%	32.3%	88.3%

Some durability indicator results were significantly different for the different sources, but the variability was generally similar. An example is wet strength, which was significantly lower for Alice Springs than for Dubbo and for Proserpine but with comparable variability (Fig. 2). In contrast, the water absorption results were not significantly different, although the range of the results was much greater for Proserpine than for Alice Springs and for Dubbo (Fig. 3). These contrasts suggest that the expected variability and the average value of the various durability indicators is highly material-specific, supporting the retention of currently specified range of tests.

5.3 Effect of Fraction Size on Results

Despite the durability tests being consensus properties, there are differences in the results for the different fraction sizes presented in Table 7. These differences may simply reflect the natural variation observed within a single fraction size (Table 9) or some other effect associated with relative scale of the aggregate particles compared to the test device, or the imperfections that initiate failures, such as the particle micro-voids that allow water absorption. Although the results varied across the fraction sizes, the differences were generally random. For example, Fig. 4 shows the wet strength being almost uniform across the three fraction sizes for all five aggregate sources. In contrast, the water absorption results were generally consistent for all fraction sizes for Dubbo and Rockhampton, but not for Alice Springs, Mildura and Proserpine (Fig. 5). This indicates that any difference in durability test results associated with the different fraction sizes is more likely to reflect the natural variability in the materials and the testing, rather than some effect of particle size on the test result. However, replicate results for each fraction size are required to allow statistically based conclusions to be drawn.

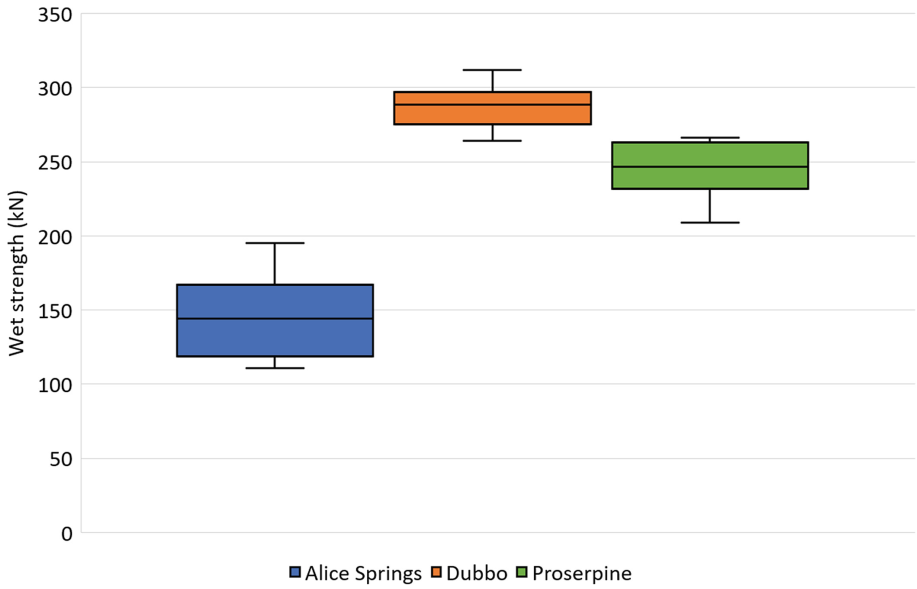

Fig. 2. Distribution of replicate wet strength results

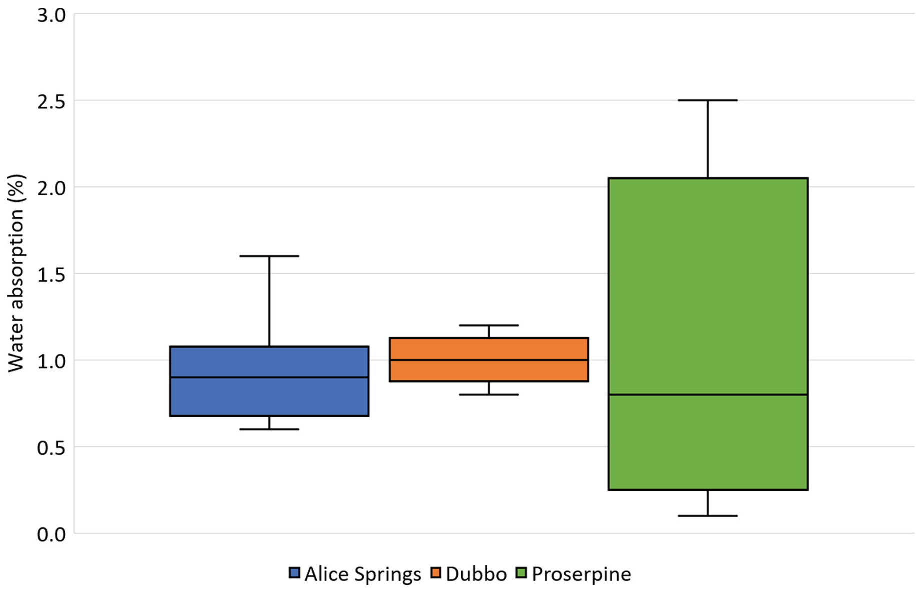

Fig. 3. Distribution of replicate water absorption results

5.4 Relationships Between Durability Indicators

The ability to reduce the range of durability tests for airport asphalt aggregate relies on different indicators providing the same conclusion regarding the suitability of a particular

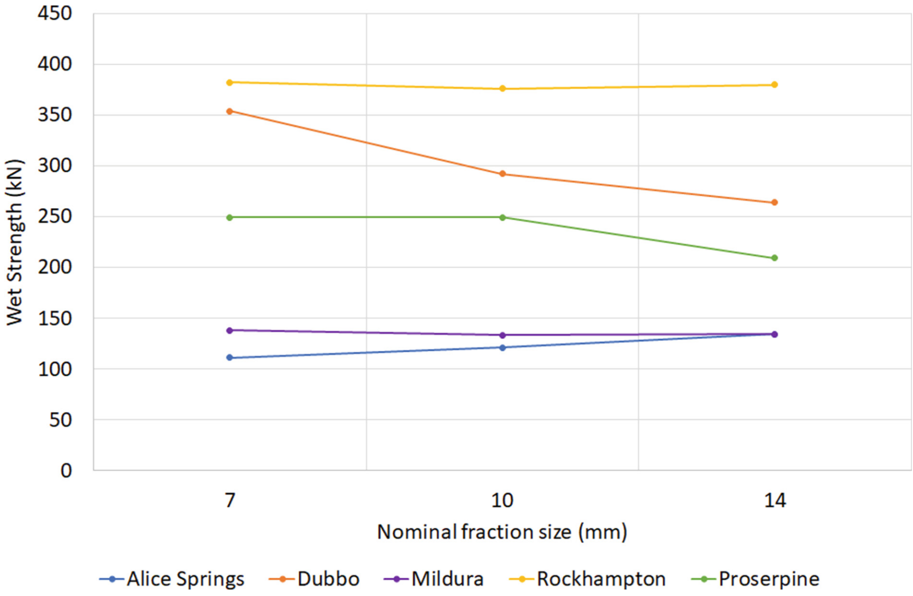

Fig. 4. Wet strength as a function of fraction size

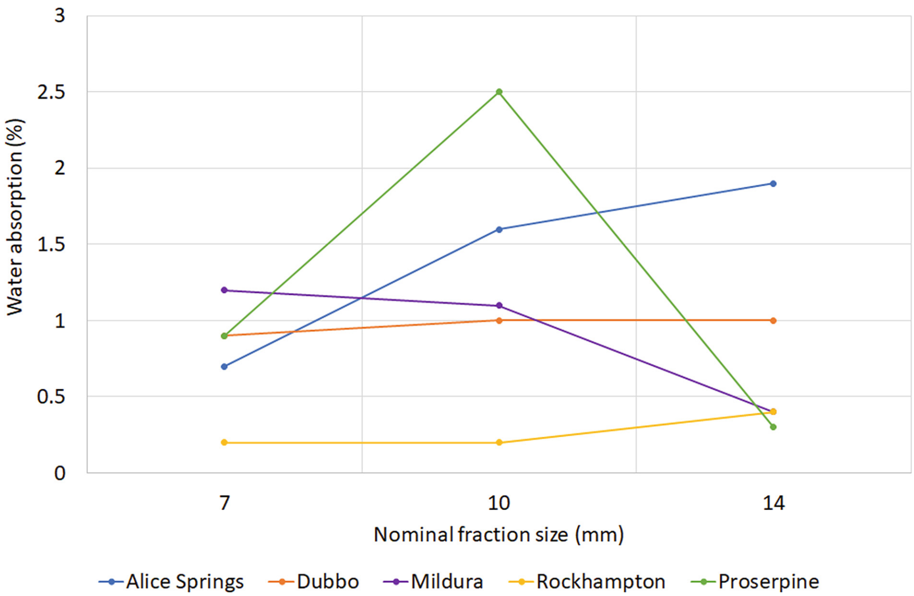

Fig. 5. Water absorption as a function of fraction size

aggregate source. That implies that any redundant tests are highly correlated to each other. Simple linear correlations were developed between the 10 mm fraction results for each durability indicator, across all ten aggregate sources. The resulting coefficients of determination (R^2 values) (Table 10) were less than 0.5, except for the relationship between wet strength and Los Angeles abrasion, which is shown in Fig. 6. In contrast, there was no reportable correlation ($R^2 < 0.01$) between wet-dry strength variation and sodium sulphate soundness (Fig. 7).

Table 10. Coefficients of determination between 10 mm fraction durability test results

Indicator	Wet strength	LA abrasion	SS soundness	Absorption
W/D strength	0.23	0.16	<0.01	0.16
Wet strength	–	0.60	0.49	0.23
LA abrasion	–	–	0.13	0.09
SS Soundness	–	–	–	0.01

All correlations based on first order linear regressions.

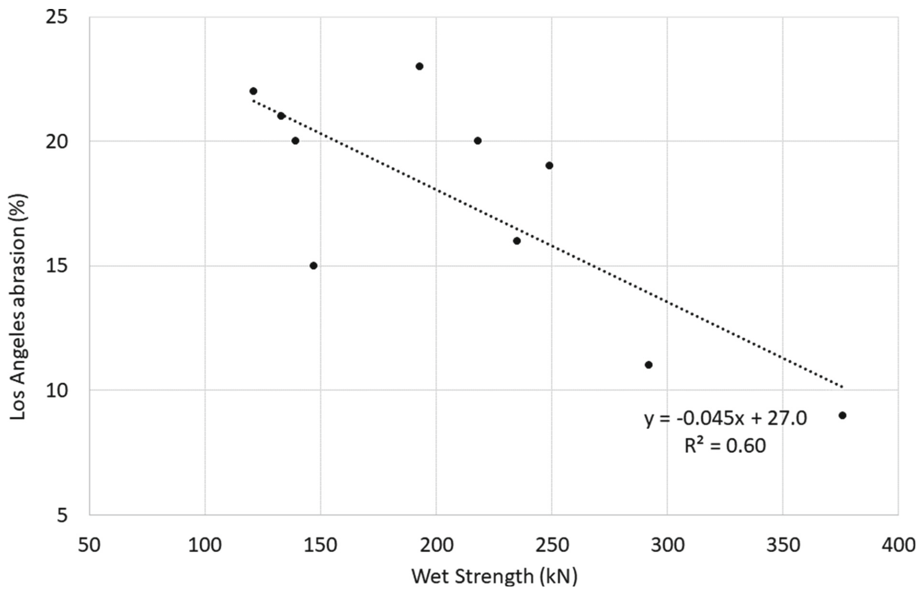

Fig. 6. Relationship between wet strength and LA Abrasion results

The reasonable correlation between wet strength and Los Angeles abrasion is expected to reflect the similar physical mechanisms associated with the two tests. Both involve mechanical damage in the presence of moisture. In contrast, the sodium sulphate test is based on chemical reactivity, while water absorption is a function of the structure of the rock, rather than the minerology of the solid portion of the aggregate particles. It follows that some tests may be redundant and potentially omitted where they test the same physical phenomena, for example mechanical damage in the presence of moisture. However, absorption and chemical reactivity must continue to be tested regardless of the more mechanical test methods.

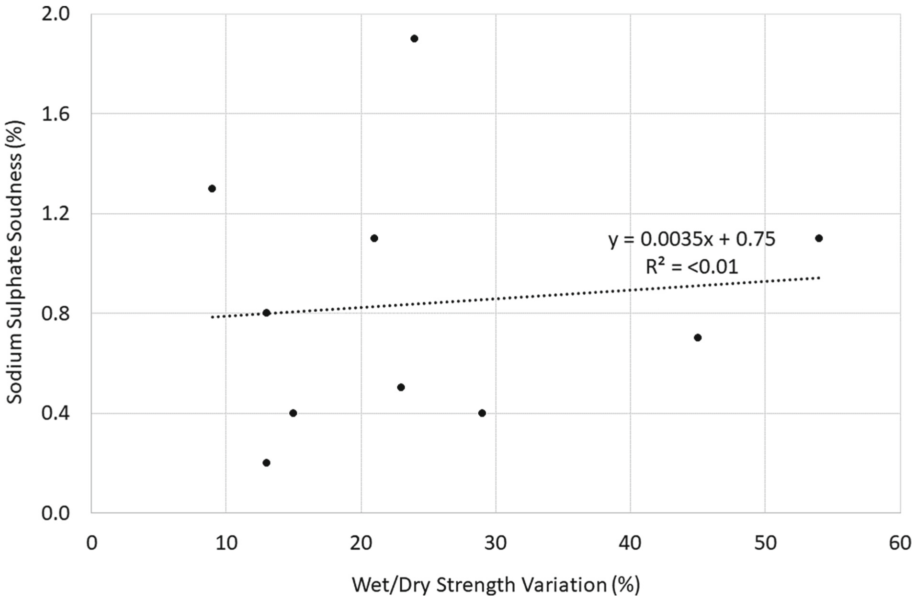

Fig. 7. Relationship between wet-dry strength and sodium sulphate soundness

Water absorption is an interesting test because it is technically not a durability indicator in its own right. However, in practice, high water absorption is anecdotally associated with high wet-dry strength variation. That is because the high absorption allows water to enter the micro-voids within the aggregate particles and this results in reduced mechanical abrasion or crushing resistance. However, very strong aggregates are not affected by the water absorption, as shown in Fig. 8. For example, Proserpine had a high water absorption of 2.5%, but a good wet strength of 249 kN and a wet-dry strength variation of just 15%. Similarly, some aggregates have a low wet strength despite having only modest water absorption, such as Alice Springs, which has 1.6% water absorption but an unacceptable wet strength of just 121 kN and an unacceptable high wet-dry strength variation of 45%.

5.5 Efficacy of Industry Recommended Combinations

As discussed above, industry recommends reducing aggregate durability testing to one of three combinations of durability indicator tests (CCAA 2009). Excluding the combination that includes the percentage of unsound/marginal stones, which is not included in the airport asphalt specification, the recommended combinations are:

- Wet strength and wet-dry strength variation, or
- Los Angeles abrasion and sodium sulphate soundness.

Table 11 summarises the evaluation of each aggregate source against each of the industry recommended combinations. Six sources passed both industry recommended

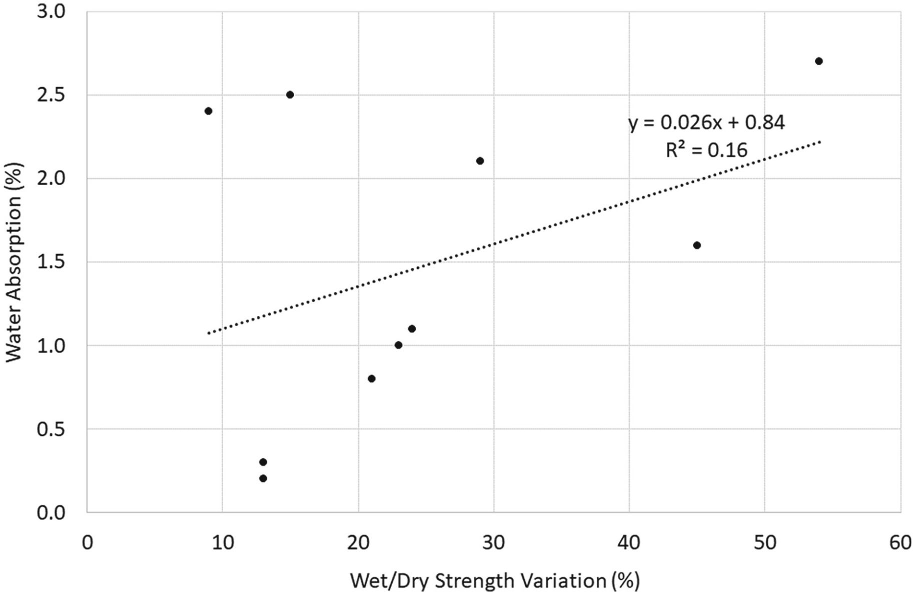

Fig. 8. Relationship between wet-dry strength and absorption

combinations. Of these, two failed the water absorption requirement. Not one source failed on the Los Angeles abrasion and sodium sulphate soundness combination, despite four samples failing the wet strength and wet-dry strength variation combination. This indicates that the Los Angeles abrasion and sodium sulphate soundness combination is not effective and these two industry-recommended combinations are not equivalent. Consequently, the broader combination of durability tests in the current Australian airport asphalt specification can not be replaced by the industry recommended combinations.

Table 11. Acceptance of aggregate based on industry recommended combinations of criteria

Source	Wet strength and wet-dry variation	LA abrasion and SS soundness	Comments
Alice Springs	Fail	Pass	Failed both
Archer River	Fail	Pass	Failed wet strength
Dubbo	Pass	Pass	
Mareeba	Pass	Pass	
Mildura	Fail	Pass	Failed wet strength
Kununurra	Pass	Pass	
Norfolk Island	Fail	Pass	Failed both
Rockhampton	Pass	Pass	
Proserpine	Pass	Pass	
Adelaide	Pass	Pass	

6 Conclusions

It was concluded that wet strength and wet-dry strength variation are the most restrictive of the current aggregate durability requirements in the Australian airport asphalt specification. The different tests are associated with different levels of variability, depending on the aggregate source. Furthermore, the correlation between the various tests results was generally low, except for Los Angeles abrasion and wet strength. The industry recommended combinations of aggregate durability testing were found to be inconsistent and ineffective. Consequently, the current range of aggregate durability tests must be retained. The only exception is the potential to omit Los Angeles abrasion when the wet strength is high. Furthermore, there was no significant difference between the results on the various coarse aggregate fraction sizes and further research is recommended to determine whether acceptable 10 mm fraction results justifies the omission of the testing of the 7 mm and 14 mm fractions from the same source. Further work is required to correlate the various aggregate durability tests to asphalt field performance, although this is expected to be challenging. It would be difficult to isolate the effects of aggregate properties from the overall mixture volumetrics, environmental conditions, traffic loading and bituminous binder properties, when evaluating the field performance of asphalt mixtures. However, a universal, accelerated, laboratory test for the effect of aggregate source properties on the weathering and durability of asphalt mixtures would provide a significant improvement in the future, allowing a more performance-related specification of aggregates for airport asphalt production.

References

AAA: Airfield Pavement Essential, Airport Practice Note 12. Australian Airports Association. Canberra, Australian Capital Territory, Australia, April 2017

Abouelsaad, A., White, G.: Fretting and ravelling of asphalt surfaces for airport pavements: a load or environmental distress? Highways and Airport Pavement Engineering, Asphalt Technology and Infrastructure Conference. Liverpool, England, United Kingdom, 11–12 March 2020

AAPA: Performance-based Airport Asphalt Model Specification. Australian Asphalt Pavement Association. Melbourne, Victoria, Australia, ver. 1.0, January 2018

Bessa, I.S., Branco, V.T.F.C, Soares, J.B.: Evaluation of different digital image processing software for aggregates and hot mix asphalt characterizations. Construct. Build. Mater. **37**, 370–337 (2012)

CCAA: Coarse Asphalt Aggregate: the requirements of AS 2758.5-2009. Cement Concrete and Aggregates Australia. Mascot, New South Wales, Australia (2009)

DPTI: Supply of Pavement Materials, Specification R15. Department of Planning, Transport and Infrastructure. Government of South Australia, July. www.dpti.sa.gov.au/contractor_documents/specifications_-_division_R_roadworks. Accessed 28 Dec 2019

Emery, S.: Asphalt on Australian airports. In: Proceedings AAPA Pavements Industry Conference. Surfers Paradise, Queensland, Australia, 18–21 September 2005

FAA: Standard Specifications for Construction of Airfields. AC 150/5370-10H. Federal Aviation Administration, Department of Transportation. Washington, District of Columbia, USA, 21 December 2018

Jamieson, S., White, G.: Improvements to the Australian wheel tracking protocol for asphalt deformation resistance measurement. Aust. Geomech. **54**(2), 113–121 (2019)

Liao, M.-C., Airey, G., Chen, J.-S.: Mechanical properties of filler-asphalt mastics. Int. J. Pavement Res. Technol. **6**(5), 576–581 (2013)

MoD: Marshall Asphalt for Airports. Specification 13. Defence Estates, Ministry of Defence, August 2009

MRWA: Materials for Bituminous Materials, Specification 511. Main Roads Western Australia, Government of Western Australia. 19 August 2019. www.mainroads.wa.gov.au/BuildingRoads/TenderPrep/Specifications/Pages/500series.aspx. Accessed 28 Dec 2017

Nosler, I., Beckedahl, H.: Adhesion between aggregate and bitumen – performance testing of compacted asphalt specimens by mean of the dynamic indirect tensile test. In: 2nd Eurasphalt and Eurobitume Congress. Barcelona, Spain, 20–22 September 2000

RMS: Aggregates for Asphalt. QA Specification 3152. Roads and Maritime Services, New South Wales Government, 15 July 2015. www.rms.nsw.gov.au/business-industry/partners-suppliers/document-types/specifications/qa/materials.html. Accessed 28 Dec 2019

TMR: Asphalt Pavements, Specification MRS30. Department of Transport and Main Roads, Queensland Government, March 2018. www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Specifications/5-Pavements-Subgrade-and-Surfacing. Accessed 28 Dec 2019

USACE: Asphalt Surface Airfields PAVER Distress Identification Manual. US Army Corps of Engineers. Vicksburg, Mississippi, United States of America, June 2009

Vicroads: Material Sources for the Production of Crushed Rock and Aggregates. Specification Section 801. Vicroads, Victorian Government, July 2018. webapps.vicroads.vic.gov.au/VRNE/csdspeci.nsf/. Accessed 28 Dec 2019

White, T.D.: Marshall procedures for design and quality control of asphalt mixture. Asphalt Pavement Technol. **54,** 265–285 (1985)

White, G.: State of the art: asphalt for airport pavement surfacing. Int. J. Pavement Res. Technol. **11**(1), 77–98 (2018)

Zelelew, H.M., Papagiannakis, A.T.: Interpreting asphalt concrete creep behavior through non-Newtonian mastic rheology. Road Mater. Pavement Des. **13**(2), 266–278 (2012)