Aggregates for Asphalt

Asphalt, a mixture of aggregate, bitumen and at times additives and fillers are used as a structural and surfacing layer in pavements. It has a longer life than most other surfacing or structural layers as it withstands more stress and strain from traffic loadings. The specially formulated product is governed by design practices and often specified to Waka Kotahi's M/10 specification. The components, detailed design, expected performance, manufacturing process and paving technologies results in the product being more costly than other surfacing.

The asphalt system works by creating a skeleton from the aggregates and the bitumen to glue it together. The bitumen allows for some flexibility and aggregates provide the strength to handle the load. This is unlike concrete where the strength is mostly gained by the cement bonds between the aggregate.

Figure 1 Interlocking aggregates

What's the same?

Volumetrically, aggregate is the largest component of a mix and therefore its properties have an influence on mix performance. The design process serves to understand these properties and make allowance for achieving a target but also includes a factor of safety to allow for some natural variability from the aggregate. These design parameters are ring fenced as the mix design. Variation can have an adverse effect on the performance of the final product.

What's changing?

In 2020 Waka Kotahi released a new asphalt design specification M/10 2020. The two biggest changes were the requirement to achieve lower air voids than previously and have tighter controls around field core air voids.

This has resulted in asphalt designs being coarser, with the expectation to meet the same or tighter parameters. **The designs are more sensitive to changes so it is more important than ever to maintain consistency with input materials.**

Why is consistency key?

A target grading is determined to optimise the mix, this has to be within a design envelope. The design envelope, just like an aggregate grading envelope, is governed by the M/10 spec. M/10 specifies the maximum and minimum limits for each asphalt type. For compliance, asphalt is required to comply with aggregate grading envelope, bitumen content and air voids from production and in the field. If the aggregate grading changes this impacts the air voids, even if within the tighter envelope.

Once the target grading is determined, a tighter envelope is applied for asphalt production. For example, the graph below shows the target grading (red line), the design envelope (light blue lines) and the production envelope (dark blue line), which is specifically calculated around the target grading. The table details the design aggregates and data displayed in the graph for an AC14 asphalt design.

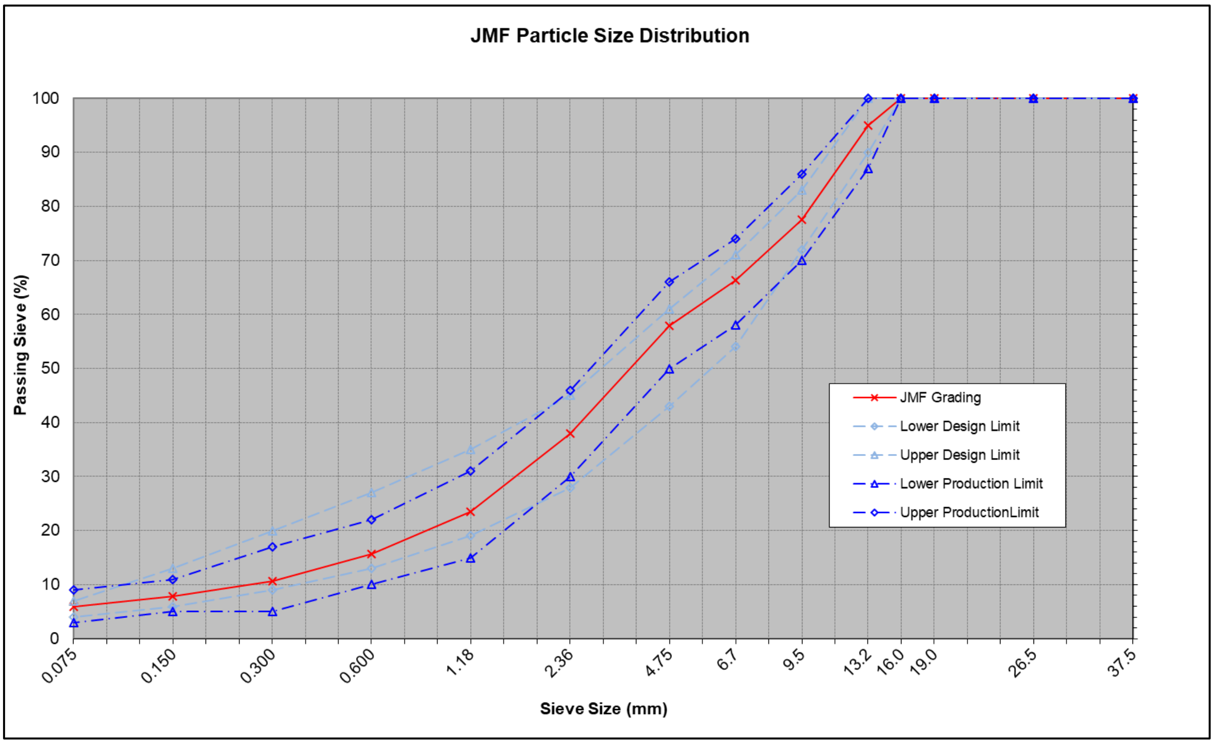

Figure 2 JMF of asphalt design and production envelope

Table 1 Design aggregate ratio

Sieve Size (mm)	16.0mm	13.2mm	9.5mm	6.7mm	PAP	RAP 10	Blend MF Gradin	Specification Lower Design Limit	Upper Design Limit	Lower Production Limit	Upper ProductionLimit
37.5	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
26.5	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
19.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
16.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
13.2	25.0	94.0	100.0	100.0	100.0	100.0	95	90	100	87	100
9.5	0.0	24.0	94.0	100.0	100.0	99.0	78	72	83	70	86
6.7	0.0	1.0	34.0	98.0	100.0	94.0	66	54	71	58	74
4.75	0.0	0.0	2.0	25.0	100.0	83.0	58	43	61	50	66
2.36	0.0	0.0	0.0	0.0	66.0	60.0	38	28	45	30	46
1.18	0.0	0.0	0.0	0.0	39.0	42.0	23	19	35	15	31
0.600	0.0	0.0	0.0	0.0	25.0	31.0	16	13	27	10	22
0.300	0.0	0.0	0.0	0.0	17.0	21.0	11	9	20	5	17
0.150	0.0	0.0	0.0	0.0	13.0	14.0	8	6	13	5	11
0.075	0.0	0.0	0.0	0.0	10.0	10.0	6	4	7	3	9
Ratio	5	22	9	5	44	15	100				

If an aggregate supplied to the asphalt plant were to vary from what was used in the design, the resulting risk of the asphalt grading falling out of the production spec is high, additionally the change can impact a sensitive design, causing out-of-specification air voids and compaction issues in the field.

Table 2 Design aggregate PSD and ratios with a non-compliant aggregate

Sieve Size (mm)	16.0mm	13.2mm	9.5mm	6.7mm	PAP	RAP 10	Blend JMF Grading	Specification Lower Design Limit	Upper Design Limit	Lower Production Limit	Upper ProductionLimit
37.5	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
26.5	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
19.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
16.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100
13.2	25.0	94.0	100.0	100.0	100.0	100.0	95	90	100	87	100
9.5	0.0	24.0	94.0	100.0	100.0	99.0	78	72	83	70	86
6.7	0.0	1.0	34.0	98.0	100.0	94.0	66	54	71	58	74
4.75	0.0	0.0	2.0	25.0	100.0	83.0	58	43	61	50	66
2.36	0.0	0.0	0.0	0.0	83.0	60.0	46	28	45	30	46
1.18	0.0	0.0	0.0	0.0	55.0	42.0	31	19	35	15	31
0.600	0.0	0.0	0.0	0.0	36.0	31.0	20	13	27	10	22
0.300	0.0	0.0	0.0	0.0	24.0	21.0	14	9	20	5	17
0.150	0.0	0.0	0.0	0.0	19.0	14.0	10	6	13	5	11
0.075	0.0	0.0	0.0	0.0	11.0	10.0	6	4	7	3	9
Ratio	5	22	9	5	44	15	100				

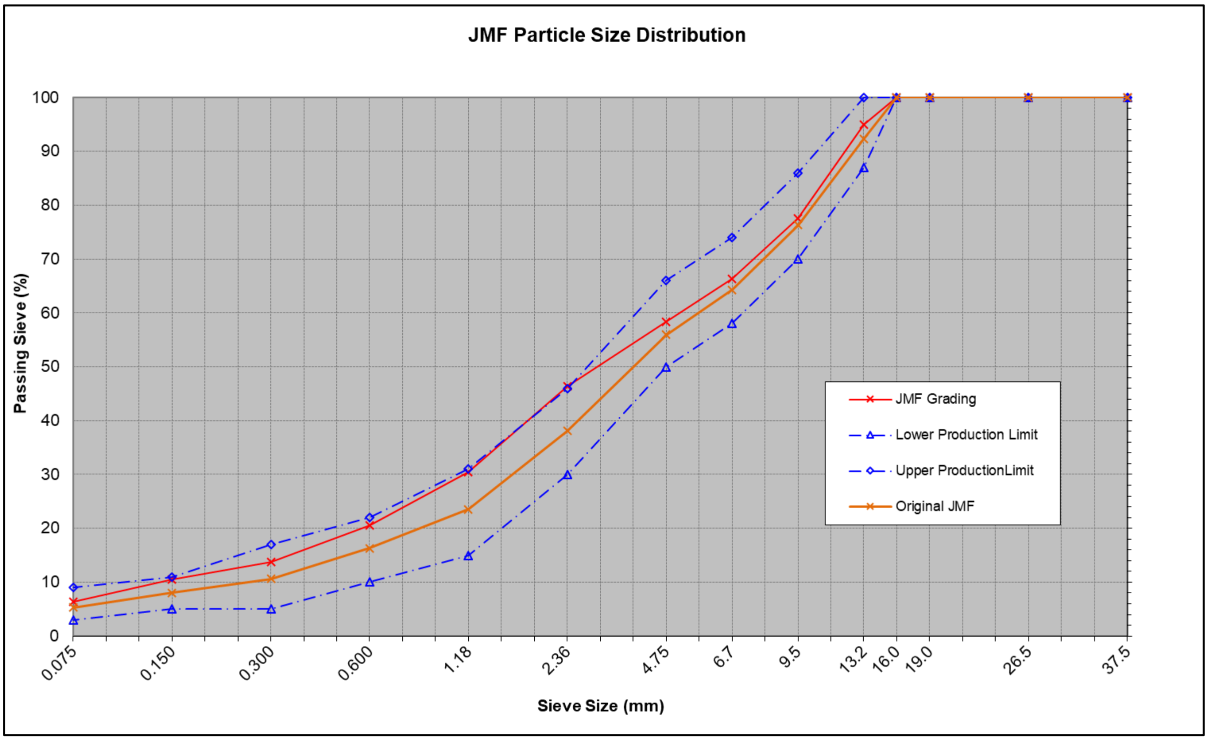

Figure 3 Production particle size distribution vs design JMF

Shape

The aggregate shape has a big impact on how the aggregate particles pack together. The mix relies on particle interaction to develop strength. The ideal shape is a cubical aggregate with sharp defined edges. This shape allows for the best packing arrangement to be achieved.

Figure 4 Aggregate shape difference; flaky, cubic and round

Figure 5 Flaky vs cubic shaped aggregate

Flaky particles should be avoided. They have a lower strength due to their shape. This can lead to particle breakdown during compaction, effectively changing the grading of the mix. This can make the mix unstable. Flaky particles can lead to selective orientation during the compaction. Where this occurs at the asphalt surface this can lead to ravelling and chip loss.

The shape also impacts the compaction of the asphalt, even if it's not flaky. Changing the source of an aggregate, even with the same grading, can have vastly different shapes. This impacts how the aggregates pack together during compaction, affecting the asphalt's volumetrics.

APAS

Additionally all asphalt plants have to submit data to be assessed by APAS – the Asphalt Production Accreditation Scheme. This is an industry-lead initiative to demonstrate continued compliance of asphalt production.

It requires the asphalt production results (binder content and grading) to be compliant and consistent, so not only does the grading have to be within the envelope but the values on each sieve can't vary too much (even if it's in the envelope). This is consistent with M/10. Some contracts require compliance to APAS, if an asphalt plant is non-compliant they can lose their accreditation. This causes contractual compliance issues and ultimately asphalt could be removed after paving even if compliant on the mat or in production.

Asphalt aggregate requires a higher level of oversight of conformance to customer-agreed specifications than most other aggregates. Aggregate variation has been demonstrated through the Asphalt Plant Accreditation Scheme (APAS) as being the single largest input variable. This coupled with other plant variations can produce non-compliant mix. The costs associated with remediation are far and above those associated with ensuring quality during the production stage.

New Zealand aggregate industry has typically offered up sealing chip aggregate as an asphalt aggregate. Asphalt volumes outside of the main centres are small which does not lend to quarries to target the higher levels of conformance required or keep separate product stockpiles. This does not negate the need to provide a quality product. Agreeing acceptance criteria and a process to work through non-conformance is critical to minimising undue costs to either party.

Quality Control

Asphalt aggregates are to be tested in accordance with M/10 2020, M/27 2020, P/11 and P/11e. They detail requirements for both source and production property testing.

In addition, the frequency as to which these tests are to be performed are specified in CCNZ BPG05, this document is available through the CCNZ website. https://civilcontractors.co.nz/Quality-Assurance-of-Aggregates/10902-1d08afaf-5dc2-4b8a-a4c8-2cbab4e0e400/

Aggregate suppliers are to provide these results to demonstrate compliance within the customer's expectations, additionally it is best practice for the asphalt producer to conduct routine testing at the asphalt plant to ensure any variance is captured before manufacture so the mix ratios can be adjusted as necessary. If there are uncommon or new tests required for a project this can be discussed with the quarry as to who will conduct the testing.

Source properties of aggregates are tested yearly or every 10,000 m^3. Typically once a year the quarry will complete source property testing and send to asphalt clients to update mix designs.

Things for aggregate suppliers to focus on:

1. **Consistency is key.**
2. Calibration of cone crushers when setting the Closed Side Setting (CSS). Modern crusher automation packages can perform metal-on-metal calibration and provide setting adjustment. If you have an older style cone, "leading" is still a viable method of establishing the CSS. While power draw under load can be an indicator of work being done, physical setting verification is preferred.
3. Screen wear and tear should be monitored at regular intervals. Where wire screens are installed, wear around the hole should be checked regularly. A limit on wear should be put in place that is acceptable for the customer's process. i.e. concrete production coarse aggregate can tolerate a higher level of variability than a coarse asphalt aggregate, especially when that aggregate represents a high percentage of the mix.
4. Use a crushing process that promotes consistent circuit loading and allows circuit loading to be controlled. The use of surge bins prior to each crusher allows for material surges in the system to be controlled which then assists with product consistency.
5. Stockpile management – when constructing stockpiles, ensure that the aggregate is minimally handled. Overhandling increases the chances of segregation. If constructing a stockpile with a loader, reduce the drop height to minimise the potential for segregation. In addition, ensure load out phases are not contaminated with load in material.

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