Australian Asphalt Pavement Association

Reclaimed Asphalt Pavement (RAP) Management Plan

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Preface

This Reclaimed Asphalt Pavement (RAP) Management Plan has been prepared for use by AAPA members involved in the processing of asphalt millings from the cold milling process, returned asphalt and plant waste. The primary aim of this document is to set a standard for control of quality and consistency in the winning of RAP and the delivery of the processed RAP for the reuse in asphalt mixes.

Acknowledgements

As with all AAPA publications, this document was the result of a collaborative effort between AAPA members. AAPA gratefully acknowledges the input to this document provided by various representatives of road agencies and asphalt producers. The AAPA National Technology and Leadership Committee would especially like to thank the Queensland Department of Transport and Main Roads, the Australian Road Research Board and the AAPA NTLC Asphalt Subcommittee for their contributions.

1. Introduction

Asphalt is 100% recyclable and the most reused construction material in the world. AAPA and its members strongly support the principles of reuse both from a sustainability and a cost efficiency perspective. Reuse of asphalt will reduce the demand for imported bitumen and need for newly crushed high-quality aggregates. The value of RAP is maximised by reusing it in asphalt pavements as it replaces expensive new raw materials. Wherever possible RAP should not be downcycled to lower value applications

There is a widely held perception that material properties in RAP stockpiles are highly variable and that using RAP, especially at high proportions, will negatively affect consistency of the asphalt product. This perception is unfounded. Published research shows that, provided that RAP stockpiles are properly managed, the grading of the aggregate in the RAP will be at least as consistent as that of virgin sources, binder content and binder properties of the RAP can be expected to be consistent as well. Compliance with this RAP management plan will ensure a homogeneous RAP product.

2. Selection of Materials Suitable to be Processed into RAP

Incoming loads shall be inspected to ensure that the material is suitable to be processed into RAP and free from any contaminants. Contaminants that may be encountered in RAP include:

- Concrete
- Geo-fabric/textiles
- Plastics
- Bricks
- Wood
- Road base
- Vegetation
- Clay
- Metal
- Tar

Some of these contaminants can be screened out after which the RAP can be processed. In all other cases contaminated materials should be stockpiled separately from RAP that will be used in asphalt mixes. Contaminated RAP shall not be used in asphalt mix.

AAPA members are not aware of any historic use of asbestos in Australian asphalt pavements. Since processed RAP should be free of contaminants and only contain asphalt profilings and asphalt plant returns, there should be limited concern around the presence of asbestos in the final asphalt that includes processed RAP. Care should be taken however not to inadvertently accept asphalt profilings from an unknown source. Details such as the source of the asphalt profilings e.g. road, plant returns, etc. shall be recorded.

Sites likely to contain coal tar shall be tested for its presence. Such sites include airport aprons where tar historically was applied to provide a fuel resistant membrane. Tests can be conducted on material cored from the site using Roads and Maritime Services Test method T542. Material can also be tested on site by applying a thin coating of white enamel paint (Note – a yellow-brown tinge to the applied paint indicates the potential of the asphalt to contain coal tar). Millings containing coal tar are not to be included in processed RAP.

The presence of polymer modified binder (e.g. SBS or crumb rubber) in the RAP does not necessitate changes to the RAP processing procedures in this document. Only in cases where a stockpile contains a high proportion of asphalt with polymer modified binder this needs to be appropriately managed. In such cases keeping RAP that contains modified binder separate from the other RAP may be a consideration.

3. Reclaiming and Processing RAP

3.1. Milling

The process of milling the asphalt pavement breaks the original aggregate and so a new material is generated with its own gradation. Ideally, the asphalt millings are stockpiled separately to returned asphalt and plant returns. Care should be taken during profiling to ensure that the RAP is not contaminated with crushed rock from the granular base course. This might require that the old asphalt surface is profiled in two passes to ensure a good quality uniform RAP is obtained for reuse in asphalt. The two-pass milling operation may also be economical when the cost of new friction aggregates is very high and the project specifications allow the surface-course RAP to be used in new surface layers.

3.2. Plant returns

Plant returns is the binder coated aggregate from the start up and end of production runs that is re-directed to waste. Generally. the amount of plant returns generated will be greater for a continuous mixing plant and more frequently that the mix type being produced is changed. Plant returns also include asphalt returned to the plant from due to overordering.

3.3. Processing

Feedstock materials shall be processed to enable a consistent, free flowing RAP to be obtained.

The processing shall include:

1. Blending of feedstock
2. Crushing - the process of passing large slabs of RAP material through an appropriate crusher to create a continuously graded RAP material
3. Screening the RAP profilings over a grizzly to remove oversized material before fractionating the RAP into single or multiple sized fractions (e.g. 0/20 mm, 0/10 mm, etc)
4. Crushing the oversized RAP retained on the screen so it can be fractionated into smaller sizes.
5. Final stockpile

Blending of the RAP feedstock material is required to ensure the formation of a homogeneous stockpile for asphalt production. A bulldozer, excavator, or similar equipment should be used to blend materials from different locations in the multiple-source RAP stockpile as it is fed into the screening and crushing operation. Blending is required due to the multiple combinations of different site profilings, plant waste and plant returns. Careful blending of the feedstock is a critical part of the recycling operation to achieve consistency in the RAP with regard to particle size distribution and binder content. If a large portion of plant waste and returned asphalt needs to be recycled compared to RAP then consideration to adding a small portion of crusher dust should be blended with the fresh asphalt to prevent it from becoming tacky should be undertaken. It is also important to only process sufficient RAP to meet the plant demand to limit stockpile height, so it does not consolidate under its own weight and with high ambient temperatures.

4. Stockpiling of Processed RAP

The processed RAP is stockpiled separately away from incoming asphalt millings, plant waste and returned asphalt.

Each stockpile lot shall not exceed 1,000 tonnes, or the typical weekly usage of RAP at a particular plant, whichever is greater.

Any processed RAP that has been left unused for too long such that it has hardened into lumps is to be re-processed. To prevent compaction of the completed stockpile, heavy equipment such as front-end loaders, shall not travel on the stockpile.

Processed RAP stockpiles should be walled and covered to reduce the impact of moisture during the mixing in the pugmill or mixing drum with hot aggregates. Where this cannot be done then:

- The stockpile shall be formed on a sloped pad so that the water drains away from the loading end
- Stockpile shall be shaped so that the water drains off the sides and the angle of sides not to be too steep to reduce the potential for segregation
- Stockpile height should be controlled to prevent consolidation of the RAP
- Adequate separation to eliminate the potential for contamination with other aggregates
- Appropriate signage such as lot number, product description, approval for release, etc.

If segregation occurs, or consolidation occurs, a front-end loader can be used to re-mix the stockpile. Where consolidation results in large lumps, additional crushing of the material may be required.
Stockpile lots are tested for binder content, moisture content and particle size distribution prior to being released for use. Characterisation testing on the RAP binder may also be required as discussed in Section 5.

5. Testing of the RAP

5.1. Sampling

Samples shall be taken from each stockpile to allow characterisation of the RAP material and to verify homogeneity of the stockpile. Representative RAP samples shall be taken in accordance with AS1141.3.1 by a competent person. A minimum of three samples shall be taken using this procedure from each stockpile.

5.2. General characterisation tests

For each of the samples from the stockpiled lot, the following properties shall be recorded:

- Bitumen content determined in accordance with AS/NZS2891.3.1, AS/NZS2891.3.2 or AS/NZS2891.3.3
- Aggregate gradation determined in accordance with AS/NZS2891.3.1, AS/NZS2891.3.2 or AS/NZS2891.3.3
- Moisture content determined in accordance with AS/NZS2891.10

5.3. Aggregate density

There are various methods available to determine the density of aggregate in RAP. Each method has known advantages and disadvantages. Aggregate recovery through ignition oven may lead to damaged aggregate. The accuracy of back-calculating aggregate from the RAP maximum density by subtracting the binder is highly dependent on the assumed amount of absorbed binder. It is also possible to determine aggregate density after solvent binder extraction, this method however is not often used in Australia due to the large aggregate sample required for density testing.

5.3.1. Ignition oven method

Extract the binder by means of ignition oven method (AGPT/T236) and determine aggregate density in accordance with AS1141.5 for fine aggregate and AS 1141.6.2 for coarse aggregate.

5.3.2. Back-calculation from maximum density

To estimate the density of the combined aggregate in the RAP ($\rho_{a(RAP)}$):

1. Determine maximum density ($\rho_{max(RAP)}$) of the RAP in accordance with AS/NZS2891.7.1
2. Calculate the apparent density of the RAP aggregate ($\rho_{ae(RAP)}$) from Equation 1, where P_b is the percentage binder in the RAP and ρ_b is the assumed density of that binder.

$$\rho_{ae(RAP)} = \frac{100 - P_{b(RAP)}}{\left(\frac{100}{\rho_{\max(RAP)}}\right) - \left(\frac{P_{b(RAP)}}{\rho_b}\right)} \qquad (1)$$

3. Calculate $\rho_{a(RAP)}$ from Equation 2, where P_{ba} is the assumed binder absorption.

$$\rho_{a(RAP)} = \frac{\rho_{ae(RAP)}}{\left(\frac{P_{ba} \times \rho_{ae(RAP)}}{100 \times \rho_b} + 1\right)} \qquad (2)$$

5.4. RAP binder properties

Unless otherwise specified, the properties of the binder in the RAP shall be characterised where more than 15% RAP by mass of total mix is added to asphalt mixes. Binder characterisation shall be performed on a minimum of three samples from each stockpile. There are a number of suitable methods in use for both the recovery of the binder and the measurement of binder viscosity or similar rheological properties.

5.4.1. Binder recovery

Binder can be recovered by means of centrifuge in accordance with Austroads AGPT/T191, Rotary Evaporator in accordance ASTM D5404, or the Abson method in accordance with ASTM D1856.

5.4.2. Binder characterisation

The binder can be characterised using one of the following methods

- Viscosity at 60 °C measured by means of dynamic shear rheometer (DSR) in accordance with AGPT/T192
- Dynamic Viscosity at 60 °C, AS/NZS 2341.3

It is also possible to characterise the binder properties with the following methods, however these are not compatible with the viscosity target ranges presented in Section 8 and an alternative suitable method would therefore have to be established to control the binder blend.

- Sliding plate viscosity at 45 °C, AS/NZS 2341.5
- The combination of penetration and softening point in accordance with AS 2341.12 and AS 2341.18 respectively

6. Delivery and Stockpiling of Processed RAP at the Asphalt Plant

The processed RAP lot is delivered to the asphalt plant site in such a way that there is no segregation or contamination of the processed RAP material. The deliveries of processed RAP should be tipped to ensure the distribution of aggregate in the stockpile is visually homogeneous.

The constituent proportions and binder type (or amount of rejuvenator if added) may need to be amended in the asphalt plant control system for any change in the binder content, binder properties, aggregate gradation and moisture contents prior to use of any new lot of processed RAP.

All processed RAP from each bin must be used to prevent the build-up of lumps and to ensure that the processed RAP remains free flowing. An air cannon or offset oscillating vibratory motor can be installed on the RAP hopper to prevent RAP build up.

If a rain event of sufficient intensity to impact on the moisture content of the RAP occurs between the time the RAP stockpile was tested and when the RAP is to be used the moisture content shall be retested.

7. Incorporation of RAP into the Asphalt Mix

At the asphalt plant the processed RAP shall be stored in stockpiles or cold aggregate storage bins that are covered with a permanent roof and protected from the direction of prevailing weather by permanent walls.

The aggregates are heated sufficiently to ensure that the binder in the processed RAP is activated sufficiently for the RAP to be thoroughly incorporated in the asphalt. The heating process should not involve exposing the RAP to a direct flame. Care shall be taken not to heat the aggregate to an excessive temperature that will damage the virgin binder and the binder of the RAP. The difference in temperatures between the binder and the aggregate (including RAP) shall be maintained so that it does not exceed 30 ^{o}C.

The processed RAP is thoroughly mixed so that there is no apparent physical or temperature segregation in the mix or increased variability in the resulting asphalt production test results.

8. Mix design for asphalt mixes containing RAP

8.1. General

Asphalt mixes incorporating RAP should be designed to meet the same performance criteria as asphalt mixes without RAP.

8.2. Binder content

The binder content of the RAP shall be determined as described in Section 5.2. All the binder in the RAP contributes to the binder content of the final asphalt mix. The binder content of the mix design is therefore equal to the binder content of the RAP proportion plus the virgin binder added to the mix.

8.3. Aggregate grading

The maximum nominal size of the RAP shall be not greater than the maximum nominal aggregate size of the asphalt mix the RAP will be used in.

The process of developing a target grading for an asphalt mix containing RAP is like that for a mix without RAP. The grading of the aggregate in the RAP shall be determined in accordance with the procedures in Section 5.2. The RAP aggregate is considered as an aggregate fraction on the mix design sheet. The aggregate density may be determined using an appropriate method described in Section 5.3.

8.4. Volumetrics

To calculate volumetric properties such as binder volume and voids in mineral aggregate, the bulk density of the RAP aggregate determined in accordance with Section 5.3 may be used, provided that the known limitations of the methods are understood.

8.5. Accounting for RAP binder properties

Inclusion of RAP in asphalt mixes has a stiffening effect on the binder, as the RAP binder has a higher viscosity than virgin bitumen. This effect can be turned into an advantage if the intention is to create a mix with a higher modulus than would be achieved by using virgin binder only. Within the current specification framework the aim of asphalt mix design containing RAP will be to create a mix that has properties equivalent to that of a mix containing virgin binder only.

8.5.1. Mix designs containing up to 15% of RAP

For mixes containing up to 15% RAP by mass of total mix no intervention is required to correct for the stiffening influence of the RAP binder.

8.5.2. Mix designs containing more than 15% of RAP

Including RAP above 15% will produce asphalt that provides performance equivalent to non-RAP mixes provided that measures are taken to correct for the stiffening effect of the RAP binder on the viscosity of the total binder blend in the mix. At RAP contents between 15% and 30% it will usually suffice to use a softer virgin class binder to correct the viscosity. At percentages RAP greater than 30%, it may be necessary to introduce a rejuvenator to control the viscosity of the overall binder in the mix.
RAP binder characterisation or other means of performance assessment shall be undertaken to assess the need to use a lower viscosity binder or a rejuvenator to achieve the desired resultant binder.

The following procedure may be used to design a binder blend to a specified viscosity value. A worked example of a binder blend calculation for a mix containing two RAP fractions, a virgin binder and a rejuvenator is provided in Appendix A.

1. Collect a representative sample of the RAP as described in Section 5.1
2. Determine the binder content of the RAP as described in Section 5.2.
3. Extract a representative sample of RAP binder using one of the methods listed in Section 5.4.1.
4. Determine the viscosity of the extracted RAP binder, the virgin binder and/or rejuvenator (where applicable) using one of the test methods listed in Section 5.4.2.
5. Calculate the proportion of RAP binder, virgin binder and/or rejuvenator by mass of total binder. Note that this is an iterative process, the proportion of virgin binder / rejuvenator required to produce a conforming blend may have to be assumed. Also note that the proportion of RAP binder in the binder blend generally differs from the percentage of RAP by mass of total mix.
6. Predict the viscosity of the binder blend from Equation 3 below
7. If the predicted viscosity is outside the desired range for the design, adjust the proportion of the binder blend components iteratively.

$$VBI_i = \frac{3 + log\vartheta_i}{6 + log\vartheta_i}$$

$$VBI_\beta = \sum_{i=1}^{n} x_i \cdot VBI_i \qquad (3)$$

$$\mu = 10^{\left(\frac{3VBI_\beta}{1-VBI_\beta} - 3\right)}$$

where:

ϑ_i	=	viscosity of i^{th} component (in Pa.s)
VBI_i	=	viscosity blending index of i^{th} component
VBI_β	=	viscosity blending index of the blend
x_i	=	volume fraction of i^{th} component
μ	=	viscosity of the blend (in Pa.s)

To design a binder blend with a viscosity equivalent to AS2008 bitumen classes the following viscosity ranges apply:

Table 1: Viscosity ranges

Target Binder Class	Viscosity Range (Pa.s)
Class 320	320 to 500
Class 450	450 to 680
Class 600	600 to 880

Note that these viscosity ranges are set to produce a binder blend with a viscosity no lower than the midrange viscosity of the target binder class.

9. Warm Mix Asphalt and RAP Mixes

The use of warm mix asphalt technologies is strongly recommended by AAPA. Also, for mixes including RAP. The use of warm mix technology will help reduce the virgin binder ageing during mixing thus reducing the viscosity of the comingled binder.

10. Using RAP in Mix Designs Containing PMBs

The use of RAP in mix designs containing polymer modified binders shall be limited to 15% RAP unless a concentrated PMB blend is used which has been designed to achieve the desired resultant binder properties.

11. RAP process control

A robust system of process control shall be implemented to ensure a consistent end asphalt is produced from the addition of processed RAP. The system shall include an Inspection and Test Plan (ITP) to clearly document all relevant testing and acceptance criteria, including the following:

- Binder content
- Aggregate Grading
- Moisture content
- Binder properties (for mixes including more than 15% RAP)

11.1. RAP grading and binder content

A target grading and binder content shall be established for the RAP and a tolerance applied as shown in the table below:

Table 2: RAP Grading and Binder Content Tolerances

Description	Tolerance
Passing 26.5 mm AS sieve and larger	± 10
Passing 4.75 mm to 19.0 mm AS sieve	± 8
Passing 1.18 mm and 2.36 mm	± 6
Passing 0.300 mm and 0.600 mm	± 5
Passing 0.150 mm	± 3
Passing 0.075 mm	± 2
Binder Content (%)	±0.5

11.2. Moisture content

The contractor shall nominate the acceptable maximum value for moisture content appropriate for the asphalt plant. The process control documentation shall include a detailed process describing the management of fluctuations in RAP moisture content in the asphalt production process. The variation of the RAP moisture content shall be monitored based on the samples taken from the stockpile.

If a rain event of sufficient intensity to impact on the moisture content of the RAP occurs between the time the RAP stockpile was tested and when the RAP is to be used the moisture content shall be retested. Any change in moisture content for the lot, where it will have an impact on the final asphalt product, is to be input into the asphalt plant control system. An increase in moisture content will limit the amount of RAP that can be used as it will affect the operation of the bag house extraction system and the safe operation of the plant.

11.3. Binder properties

For mixes containing more than 15% RAP, the viscosity result for the RAP in each stockpile shall be used to verify that the calculated viscosity for the binder blend is within the target range for the binder nominated in the mix design (as per Table 1).

Alternatively, binder blend properties may be monitored using sliding plate viscosity or the combination of penetration and softening point, but the procedure is not presented in this guideline.

11.4. Non-conforming RAP

Where the RAP, or the RAP binder blend does not comply with the requirements, an assessment of the impact of the resultant properties on the asphalt shall be undertaken. It may be necessary to change the relative proportions of RAP and virgin product in the mix, within the limits of the relevant asphalt material specification. The total RAP content of the altered mix shall not exceed the RAP content on the mix design certificate. The decision to use or reject the RAP shall form the disposition for this non-conformance.

References

Austroads 2013. *Maximising the re-use of reclaimed asphalt pavement: Binder blend Characterisation*, AP-T245-13, Austroads, Sydney.

Austroads 2015. *Maximising the re-use of reclaimed asphalt pavement: Outcomes of Year Two - RAP mix design,* AP-T286-15, Austroads, Sydney.

Austroads 2016. *Maximising the re-use of reclaimed asphalt pavement: Field validation.* AP-R517-16, Austroads, Sydney.

NAPA 2015. *Best Practices for RAP and RAS Management,* Quality Improvement Series 129, National Asphalt Pavement Association, Lanham.

Roads and Maritime Services 2012. Test method T542 Identification of tar or Pitch in asphalt.

Appendix A: Example binder blend calculation

Aim: design a binder blend for a mix containing 35% RAP such that the viscosity of blend meets the target for Class 320 bitumen in Section 8 of this guide (320-380 Pa.s). RAP will be added to the mix in two size fractions (RAP fraction 1 and 2)

Given:
Total RAP content in the asphalt mix: 35%
RAP fraction 1 content in the asphalt mix: 20%
RAP fraction 2 content in the asphalt mix: 15%
RAP fraction 1 binder content: 4.83%
RAP fraction 2 binder content: 3.16%
Asphalt mix total binder content: 4.2%
Viscosity Class 320 binder: 362 Pa.s
RAP fraction 1 binder viscosity: 15580 Pa.s (taken as 15,600 Pa.s as per AGPT/T192)
RAP fraction 2 binder viscosity: 10060 Pa.s (taken as 10,100 Pa.s as per AGPT/T192)
Rejuvenator viscosity: 0.02 Pa.s

Determine proportion of rejuvenator to be added to blend (proportion by mass of virgin binder)
Calculation in accordance with procedure in Section 8.5.2.

Solution

1- Determine the viscosity blending index of the blend components (virgin binder, RAP fractions 1 and 2 and rejuvenator agent

$$VBI_{\text{virgin binder}} = \frac{3 + \log 362}{6 + \log 362} = 0.6495$$

$$VBI_{\text{RAP1 binder}} = \frac{3 + \log 15600}{6 + \log 15600} = 0.7057$$

$$VBI_{\text{RAP2 binder}} = \frac{3 + \log 10100}{6 + \log 10100} = 0.7001$$

$$VBI_{\text{rejuvenator}} = \frac{3 + \log 0.02}{6 + \log 0.02} = 0.3025$$

2- Calculation of volume fraction of the blend components of the two RAP fractions:

$$x_{\text{RAP1}} = \frac{20}{100} \times \frac{4.83}{4.2} = 0.230$$

$$x_{\text{RAP2}} = \frac{15}{100} \times \frac{3.16}{4.2} = 0.113$$

The volume proportion of the rejuvenator is assumed at 6% for this example, if the assumed proportion results in a blend viscosity outside the recommended range, the proportion should be changed in the calculation. For most problems it is also possible to mathematically solve the equation for the desired viscosity. The percentage of virgin binder is determined from the proportions of RAP1 and RAP2 and rejuvenator:

$x_{virgin} = 1 - (0.230+0.113+0.06) = 0.597$

3- The viscosity blending index of the binder blend (VBI_β) can then be calculated:

$$VBI_\beta = \sum_{i=1}^{n} x_i . VBI_i = 0.230×0.7057 + 0.113×0.7001 + 0.597×0.6495 + 0.06×0.3025 = 0.6473$$

4- Once VBI_β is obtained, the viscosity of the binder blend can be calculated

$$\mu = 10^{\left(\frac{3VBI_\beta}{1-VBI_\beta} - 3\right)} = 10^{\left(\frac{3×0.6473}{1-0.6473} - 3\right)} = 321 \text{ Pa.s}$$

This is within the targeted range of 320-380 Pa.s

The final binder composition is as follows:

Rejuvenator = 0.06 × 4.2 = 0.25 % by mass of mix

Virgin binder = 0.597 × 4.2 = 2.51 % by mass of mix

Contributed by RAP1 = 0.23 × 4.2 = 0.96 % by mass of mix

Contributed by RAP2 = 0.11 × 4.2 = 0.47 % by mass of mix