

RECYCLING ASPHALT CONCRETE PAVEMENT

RACP Aggregate and Asphalt Requirements and Rheology Design and Pre-Engineering Materials Evaluation

1.0 DEFINITIONS

- 1.1 In this procedure, recycled asphalt concrete pavement (RACP) means asphalt concrete pavement (ACP) containing reclaimed asphalt pavement (RAP).
- 1.2 Rheology refers to the flow characteristics of an asphalt binder. For conventional asphalt, rheology is measured in terms of penetration at 25°C and viscosity at 60°C. For performance grade asphalt cements (PGAC) rheology is tested as per the procedures outlined in AASHTO MP1 and reported in terms of high and low temperature service ratings, i.e. PG 58-34.

2.0 SCOPE

- 2.1 This procedure outlines the aggregate and binder requirements as well as the asphalt binder testing and design methodology for RACP mix design purposes. The use of rejuvenators is also covered.
- 2.2 This procedure also outlines the pre-engineering requirements to assess the characteristics of an ACP material for recycling. This assessment would normally be carried out to assess material characteristics for recycling (e.g. Hot In-Place Recycling (HIR) or mill and inlay).

3.0 APPLICABLE DOCUMENTS

- 3.1 AASHTO MP1 Standard Specification for Performance Graded Asphalt Binder
- 3.2 AASHTO MP2 Standard Specification for Superpave Volumetric Mix Design
- 3.3 AASHTO PP28 Standard Practice for Superpave Volumetric Design for Hot-Mix Asphalt
- 3.4 ASTM C131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- 3.5 ASTM D5 Standard Test Method for Penetration of Bituminous Materials

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- 3.6 ASTM D1856 Standard Test Method for Recovery of Asphalt from Solution by Abson Method
- 3.7 ASTM D2041 Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
- 3.8 ASTM D2171 Standard Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer
- 3.9 [ATT-5](#) Coring
- 3.10 [ATT-12](#) Extraction
- 3.11 [ATT-26](#) Sieve Analysis, 20 000 µm minus
- 3.12 [ATT-37](#) Sampling Mixes
- 3.13 [TLT-107](#) Determination of Detrimental Matter Content in Coarse Aggregate
- 3.14 [TLT-301](#) Mix Design Method for Asphalt Concrete Pavement
- 3.15 [TLT-314](#) Percent Manufactured Fines in Bituminous Mixtures
- 3.16 [TLT-315](#) Visual Inspection of Cores

4.0 RACP AGGREGATE REQUIREMENTS

RAP is suitable for recycling if the final RACP mix meets the mix design requirements of the applicable specification (i.e. [Specification 3.50](#), Asphalt Concrete Pavement – EPS, or [Specification 3.53](#), Asphalt Concrete Pavement – Superpave).

Gradation, % Fractures and % Manufactured Fines are based on the total aggregate (i.e. virgin plus extracted RAP aggregate). Plasticity Index and Clay Content are based on the virgin aggregate component only. Other aggregate properties (Detrimental Matter, L.A. Abrasion, Fine Aggregate Angularity, Elongated Particles) are based on only the virgin aggregate component if the RACP contains 10% or less RAP, and on the total aggregate if the RACP contains greater than 10% RAP.

For Marshall mix designs, the preparation and testing of the RAP aggregate for mix design is covered in [TLT-301](#), section 7.0. For Superpave mix designs, the preparation and testing of the RAP aggregate for mix design is as follows:

- The gradation and asphalt content of the RAP are determined according to the frequencies and test methods in [Specification 3.16](#), table 3.16.3.3 (Notes:

pre-existing RAP stockpiles shall be sampled using a backhoe; if milling is concurrent with paving, RAP samples shall be obtained by coring the pavement prior to milling). A fracture count on each sample is also performed. The average gradation, asphalt content and fracture count of all test results is used as the RAP gradation, asphalt content and % fractures for mix design purposes.

- If no historical records are available indicating an acceptable quality of the extracted RAP aggregate, it is tested for detrimental matter content and L.A. abrasion (if the RACP contains greater than 10% RAP).
- The extracted RAP aggregate and virgin aggregate are combined at the desired gradation and tested for gradation and aggregate angularity (coarse and fine) and elongated particles.

5.0 RACP RHEOLOGY REQUIREMENTS

Rheology testing and design is not required if the RAP to virgin aggregate ratio is 10/90 or less, or as otherwise specified.

At or below this ratio, it is assumed that the effect of the RAP binder on the virgin binder will be limited and the resulting blended binder will have the same rheological characteristics as the virgin binder. Above this ratio, rheology testing and design is required and the blended binder must meet the penetration and viscosity requirements of the specified mix type or, for mixes specified to use PGAC binders, the blended binder must meet the temperature requirements of the specified PGAC.

5.1 RAP rheology testing

To establish the RAP rheology, a minimum of 1 test per 5000 tonnes shall be done on each RAP source. Notwithstanding this requirement, no fewer than 3 tests per source shall be performed.

5.1.1 If the mix design is to use a penetration-viscosity grade asphalt, each RAP sample is tested as follows:

- quantitative extraction of asphalt by centrifuge method bowl extraction ([ATT-12](#), part II, method B), using trichloroethylene and including fines correction by high speed centrifuge
- recovery of asphalt by the Abson method (ASTM D1856)
- penetration at 25°C (ASTM D5)
- absolute viscosity at 60°C (ASTM D2171)
- extracted aggregate gradation ([ATT-26](#)).

5.1.2 If the mix design is to use a PGAC, the RAP binder characteristics are determined according to AASHTO MP2, appendix X1.

However, the extraction and recovery of asphalt may be done according to section 5.1.1. Each RAP sample is tested separately.

5.2 RACP Rheology design

The ratio of RAP to virgin aggregate (R/V) may be restricted by the asphalt rheology, the gradation of the RAP material, or by the amount of material available to be reclaimed.

5.2.1 For penetration-viscosity specified asphalts, the individual penetration and viscosity results are plotted (for an example, see Figure 1). The average penetration and viscosity are adjusted to account for outliers or patching (excessive patching must be treated separately). Judgement is required in determining which test results are representative and which should be excluded. The average penetration and viscosity of the RAP are then plotted along with the penetration and viscosity of the virgin binder¹ (for an example, see Figure 2). A recycle asphalt to virgin asphalt ratio (r/v) is selected that will result in the target asphalt grade for the mix type specified. For mix design purposes, the RAP to virgin aggregate (R/V) ratio is estimated to be equivalent to the r/v ratio.

Once the mix design is complete, the actual r/v ratio must be calculated and replotted to ensure that the actual blended rheology meets the target requirements. A significant change in penetration and viscosity values may occur at high R/V ratios when the asphalt content of the RAP and RACP mix differ significantly. The actual r/v ratio must result in an 'A' grade asphalt within the penetration range required by the mix type. The R/V ratio needs to be adjusted and the mix redesigned until the actual r/v ratio meets target requirements.

Example:

- From blending chart (fig. 2), r/v is 15/85; therefore, R/V assumed to be 15/85
- From testing RAP, asphalt cement content of RAP is 6.1%
- From mix design, design a/c content of RACP is 5.1%
- Based on 1000g of dry aggregate and 15/85 R/V ratio, 150g would be RAP and 850g would be virgin aggregate
- Calculate RAP aggregate mass: $150 \div 1.061 = 141.4\text{g}$
- Calculate RAP a/c mass: $150 - 141.4 = 8.6\text{g}$
- Calculate the total aggregate mass: $141.4 + 850 = 991.4\text{g}$
- Calculate total a/c mass: $991.4 \times 0.051 = 50.6\text{g}$
- Calculate actual r/v ratio: $(8.6 \div 50.6) \times 100 = 17.0$; actual r/v ratio = 17/83
- Determine penetration and viscosity of blended a/c for actual r/v ratio (use equation in example of fig. 2)
 - Actual blended penetration = 161
 - Actual blended viscosity = 87.5
- Verify that actual penetration and viscosity values results in an 'A' grade

¹ Mix designers are to use the average penetration and viscosity values to use for a specific supplier's asphalt cement. These average penetration and viscosity values shall be used as the virgin binder values in Figure 2.

5.2.2 For PGAC specified asphalts, the resulting high, intermediate and low temperature values are adjusted to account for outliers or patching (excessive patching must be treated separately) and are averaged. Judgement is required in determining which test results are representative and which should be excluded. These average high, intermediate and low temperature values are then used to calculate the percentage RAP, which is determined according to AASHTO MP2, appendix X1.

5.3 Use of rejuvenators

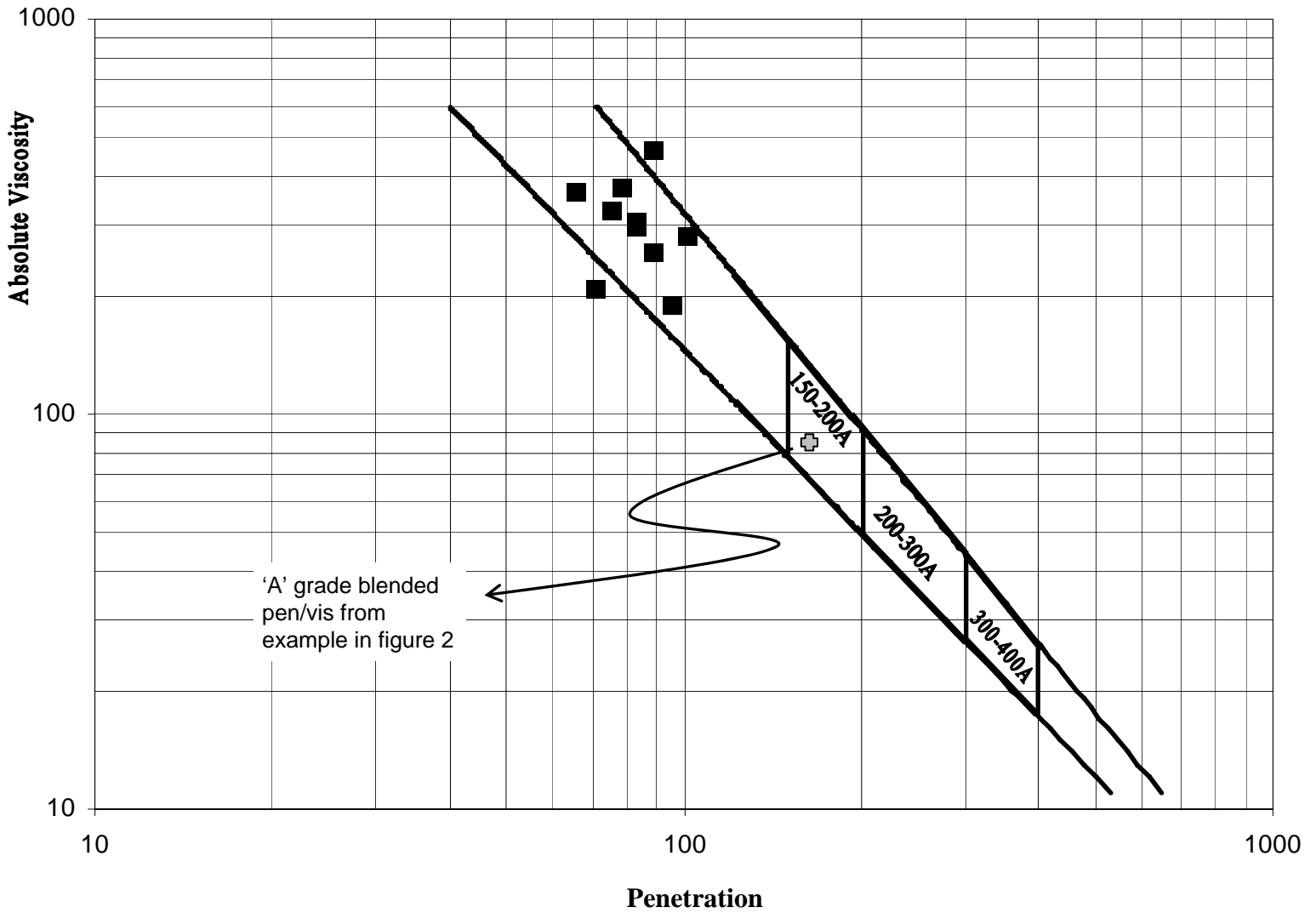
If rejuvenators are used to assist in meeting the design rheology, the manufacturer's nomographs shall be used to determine the rejuvenating effect on the RAP asphalt. The procedures in sections 5.1 and 5.2 must still be followed to design the RACP rheology. The mix design must also incorporate the use of rejuvenator.

5.4 Reporting requirements

When RAP rheological testing and RACP rheology design is required, the following information, along with the required mix design information, must be submitted to the consultant for review:

- the design RACP rheology
- the design r/v ratio and R/V ratios
- all individual asphalt rheology test results
- all blending charts
- all RAP extraction test results
- all extracted RAP aggregate gradations
- rejuvenator nomographs (if used).

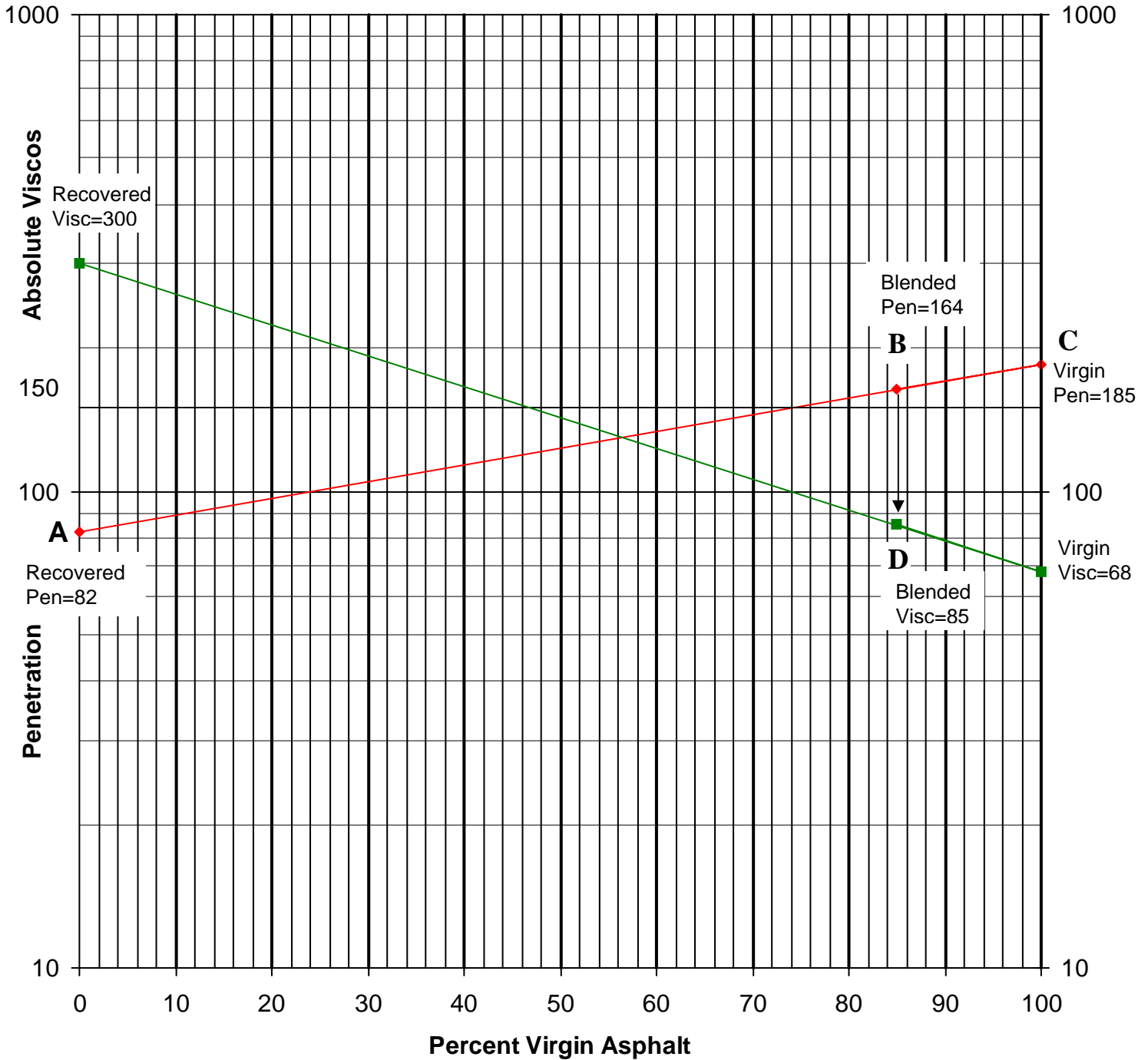
Figure 1
Sample Asphalt Rheology Testing Results



Example:

The average recovered penetration is calculated by averaging the value of all the individual penetration results. In the example, none of the test results are deemed as outliers and therefore the average penetration = $(78 + 95 + 82 + 100 + 88 + 88 + 75 + 65 + 70)/9$
= 82

Figure 2
Sample Asphalt Blending Chart



Example: The average recovered penetration is 82 dmm and is plotted (point A). The average penetration of the virgin binder is 185 dmm (point C). At an r/v ratio of 15/85 (point B), the resultant penetration is 164 dmm [blended penetration = $10^{(85\% \log(185) + 15\% \log(82))}$]. The viscosity at the r/v ratio is then checked (point D) to ensure an 'A' grade blended asphalt cement (see plot on figure 1).

6.0 PRE-ENGINEERING MATERIALS EVALUATION

A pre-engineering materials evaluation is used to assess the viability of in-place ACP for recycling.

6.1 Historical review

A review of historical construction records for the project is carried out based on the construction limits identified. Weekly construction reports are evaluated to ascertain the as-constructed quality of the materials to be reclaimed and to confirm the source of the materials. Project files and/or testing records may provide results of testing on asphalt products.

6.2 Coring

A coring and testing program is conducted to confirm or establish the physical characteristics of the materials to be recycled. The coring program is dependent on the rehabilitation strategy being considered for the project and findings from the historical evaluation. Projects where excessive patching has occurred require a detailed surface area map so that the sampling and testing can be properly proportioned. The following provides a guideline for selecting the appropriate coring program.

6.2.1 Historical records indicate that ACP is unsuitable for recycling

This would generally include materials that do not meet existing specifications or exhibit undesirable characteristics (i.e. gradations with excessive amounts of sand, silt or clay sizes or a 'B' grade asphalt). The department may also have other records, such as notes to file, which could indicate problematic materials.

To validate the historical records, it is recommended that a minimum of 4 (150 mm dia.) cores be obtained from within each of the historical construction project limits. The spacing of these cores is dependent on the project length and condition of the surface (patching). Extensively patched areas require separate treatment.

Note: This coring program is intended only to validate historical records. If the results of this coring and testing indicate a potentially suitable material, additional coring as per section 6.2.2 would be required.

6.2.2 Historical records indicate that the materials may be suitable for either plant mix recycling or Hot In-Place Recycling (HIR)

For projects with 50 mm or more to be reclaimed and plant mixed, obtain one (150 mm dia.) core per kilometre, alternating from lane to lane (this may be modified based on project specific conditions).

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If less than 50 mm is to be reclaimed and plant mixed, two or more cores (150 mm dia.), per kilometre alternating from lane to lane, must be taken at each location in order to recover a sufficient amount of asphalt for testing purposes.

For projects being considered for HIR, two cores (150 mm dia.) per location per kilometre, alternating from lane to lane, are required if a 50 mm depth is specified, and three or more if the depth is less than 50 mm.

Note: A minimum of 6 locations should be cored from within each of the historical construction project limits, with the required number of cores (1 or more) being taken at each location depending on the recycling option.

6.3 Visual Inspection of Cores and Sample Preparation

6.3.1 The visual inspection of cores is carried out on one core from each location in accordance to [TLT-315](#). After lift measurements are taken, cores are trimmed then split vertically to aid visual inspection.

6.3.2 The cores are trimmed to the specified recycling depth as determined by the rehabilitation strategy in order to obtain a representative sample of the material to be reclaimed or HIR.

6.4 Testing

6.4.1 If the final mix design is to use a penetration and viscosity grade asphalt, or if the final mix design is to use an unknown type of asphalt, a minimum 2000 gram sample is obtained from each location and tested according to section 5.1.1.

6.4.2 If the final mix design is to use a PGAC, the asphalt binder characteristics are determined according to section 5.1.2.

6.4.3 If no historical records are available indicating an acceptable quality of the aggregate, the extracted aggregate is tested for detrimental matter content and L.A. abrasion.

6.5 Analysis

6.5.1 Unsuitable material

Unsuitable material would include asphalt cement that has characteristics that can not be modified to result in a compliant grade, gradations with excessive amounts of sand, silt or clay

sizes, or significant amounts of detrimental matter that would result in a non-compliant final product. If at any time during the pre-engineering assessment the proposed material is determined to be unsuitable for recycling, the final report can be prepared without further testing.

6.5.2 Suitable material

6.5.2.1 The results of testing (rheology, gradation, aggregate quality) are reviewed for consistency and analyzed with respect to mix design feasibility. Virgin asphalt, aggregate/admix requirements, air voids, and the use of a rejuvenator are also analyzed with respect to mix design feasibility.

The ACP would be suitable for recycling by plant mixing if the final mix could meet the requirements of [Specification 3.50](#), Asphalt Concrete Pavement – EPS, or the material and mix design requirements of [Specification 3.53](#), Asphalt Concrete Pavement – Superpave.

The ACP would be suitable for HIR if the final mix could produce a desirable gradation as well as meet the requirements of table 1 of specification amendment [amc_s155](#), Hot In-Place Recycled Asphalt Concrete Pavement – EPS. A 'B' grade asphalt cement would not be suitable for recycling unless it could be modified to result in an 'A' grade.

6.5.3 ACP degradation

Milling of ACP results in degradation of the reclaimed aggregate. Experience shows that the gradation of the ACP material will increase in the percent passing on all sieve sizes. The amount of degradation is dependent on many factors, but for estimating purposes the following percent increases, based on core gradation results, can be used:

Cold milling	Sieve Size	% increase
	5 000	5 to 10
	315	about 5
	80	1 to 3
HIR	Sieve Size	% increase
	5 000	2 to 5
	315	1 to 3
	80	1 to 2

6.6 Calculations and report

When the pre-engineering materials evaluation supports the option to recycle, the recommendations shall include the expected types of modifications and material characteristics necessary to ensure that the resultant mix characteristics comply with the specified mix type. These recommendations and supporting documents will form part of the contract special provisions. The pre-engineering report shall contain the following information:

Project description: Highway number, control section, from/to kilometres

Background: Rehabilitation options, coring program

Testing: Sample preparation, testing program

Results: Results of all testing should be presented either in tabular or graphical form. All assumed or estimated values should be included along with supporting documentation.

Analysis: Details of the materials evaluation that resulted in the recommendations including a general assessment of the engineering properties of the pavement in relation to its intended use and applicable specifications.

Recommendations: Based on the analysis of the results the recommendations should include the following details:

- Maximum R/V ratio based on using various virgin binders;
- The use of a rejuvenator and admix;
- Instructions / recommendations on how materials should be stockpiled and processed;
- instructions on what information should be included in the special provisions for contract development should be noted (e.g. individual core results).