ASPHALT RECYCLING

1 INTRODUCTION

The following notes are based on text from the Austroads Asphalt Guide. For further information, reference should be made to the Asphalt Guide and other referenced documents.

This chapter covers the recycling of asphalt with particular reference to insitu recycling, including assessment of suitability of pavements for insitu recycling, selection of recycling method, and selection and assessment of materials. Reference is also made to plant-mixed cold recycling of asphalt.

2 RECYCLING PROCESSES

Asphalt may be recycled in several ways:

- using reclaimed asphalt pavement (RAP) as a component in the manufacture of new hot mix asphalt
- insitu, using hot processes
- insitu, using cold processes
- by cold plant mixing of RAP material.

The manufacture of hot mix asphalt containing RAP has been covered elsewhere in the notes on asphalt manufacture.

Hot insitu recycling involves heating and scarifying or milling of asphalt surface material, mixing with fresh binder or rejuvenator, and re-laying, generally in one operation. Fresh asphalt may also be added during the hot recycling process to improve asphalt properties or supplement layer thickness.

Cold insitu recycling involves milling of insitu asphalt, mixing with fresh binder or rejuvenator, and re-laying. Filler or other additives may also be used to improve mix properties.

Insitu recycling can only correct the asphalt surface layer. The underlying pavement must be sound and likely to remain so for the life of the treatment.

Cold plant recycling is similar to cold insitu recycling except that mixing of RAP, binder, and additional materials is performed in a separate mixing plant. Cold plant recycling is more versatile than insitu recycling as it may use RAP from different sources and provide more control over grading of materials, use of additives and efficiency of mixing.

Asphalt recycling may be used as:

- a rehabilitation/maintenance treatment
- a means of conserving energy and road making material resources.

The selection of asphalt recycling as an appropriate rehabilitation treatment should involve a life cycle costing analysis.

3 ASSESSMENT OF SUITABILITY OF PAVEMENTS FOR INSITU RECYCLING

3.1 General

A preliminary assessment should be carried out on any pavement that is a candidate for insitu recycling. This assessment should involve visual inspection, investigation and testing programs to determine the most appropriate rehabilitation treatment (of which recycling may be one alternative). It should cover:

- structural condition

- pavement type and history
- existing condition of asphalt materials
- subgrade characteristics
- surface conditions.

Project location (urban, rural, mountainous, coastal), road geometry and traffic conditions may also influence the suitability, or otherwise, for insitu recycling.

An essential part of the selection of recycling as a rehabilitation option, and of a specific recycling method, is an assessment of the cost of the various options.

Insitu recycling may be appropriate where there is a need to:

- restore riding quality of the surface where there is no need for structural improvement
- remove ruts from asphalt
- restore surface characteristics (e.g. surface texture and skid resistance)
- rejuvenate the oxidised binders in asphalt
- rehabilitate asphalt layers that have deteriorated due to poor asphalt quality
- add a thin layer of asphalt to an existing pavement
- repair non-structural damage (e.g. after utility patching)
- improve structural capacity at minimal cost.

Insitu recycling of an asphalt pavement should not be used for rehabilitation, if:

- any of the lower courses are not stable
- excessive hardening of the binder has taken place
- there are surface maintenance problems associated with base or drainage problems
- variations in the surface thickness are excessive
- the pavement structure is weak and cannot bear the equipment
- the pavement is excessively wet
- the pavement contains tar, rubber, polymer binder, or geotextile fabric.

Generally, it is more difficult to achieve the same quality control over the insitu and cold recycling processes compared to hot mix asphalt production and placing. Quality of hot in-place and cold recycled materials is generally inferior to that of hot mix asphalt. However, with strict quality control measures, quality recycled materials can be produced with a performance that is cost-effective for appropriate applications.

3.2 Structural Condition

Asphalt recycling is only an option if a pavement is structurally sound or the treatment is cost-effective in the short term. Appropriate deflection testing should be used to determine if the pavement thickness is adequate and has sufficient structural integrity.

3.3 Pavement Type and History

If possible, original construction records should be used to verify thickness and types of materials used. This information, together with the subsequent history of rehabilitation and maintenance treatments, should be used to assist in determining suitability for recycling.

Core samples should be used to confirm this information, or provide these details if records are not available.

3.4 Existing Condition of Pavement Materials

The material properties of the recycled asphalt mix are dependent on the properties of the old bitumen and aggregates, although these properties can be modified with added binder, filler, aggregates and fresh asphalt mix.

Field cores provide information on the properties and existing condition of the asphalt component materials. They also enable assessment of the integrity of the pavement material.

Sufficient core samples should be taken to detect any variation in material properties along a project (say, 500m interval for projects less than 1 km up to 1000m intervals for jobs longer than 3.5 km).

Where the properties of the existing asphalt show significant variation, additional cores (say 10) should be taken to allow a reliable statistical mean to be calculated for assessment and mix design purposes.

The existing asphalt may not be suitable for rejuvenation of the binder (i.e. for recycled asphalt), depending on the rheological properties.

3.5 Subgrade Characteristics

Poor subgrade conditions may preclude insitu asphalt recycling.

3.6 Surface Condition

A visual inspection of the wearing surface should be carried out as part of any assessment. Identification of surface defects can assist in determining the cause of pavement distress and may suggest appropriate corrective action (recycling or otherwise).

Inspection must indicate that deterioration is only in the asphalt layer for recycling to be an appropriate treatment.

3.7 Economics of Recycling

Significant savings may be achieved by recycling asphalt pavements. The savings depend on the selected recycling technology and the quality of the asphalt being recycled.

Direct savings in the use of recycled asphalt materials include:

- aggregate
- binder
- energy
- reduced waste disposal to land fill.

Insitu processes may also provide savings in:

- cartage of materials
- reduced damage to roads and environmental impact of construction traffic.

Further indirect savings in insitu recycling that are more difficult to quantify can include:

- the longer life of adjacent road network due to lack of construction traffic
- reduction of construction time and delays to traffic
- existing surface levels can be maintained
- effectiveness of bond between layers treated by hot in-place recycling.
- correction of mix deficiencies and restoration of functional characteristics of pavement.

When comparing the hot in-place recycling with mill and replace, savings of up to 20% may be achieved depending on the scale of the job.

4 SELECTION OF RECYCLING METHOD

4.1 Hot In-place Asphalt Recycling (HIPAR)

Hot in-place recycling is applicable to replacing wearing courses (usually 30 to 50 mm), with heating and scarifying depth limited to about 60 mm under good conditions.

Situations suitable for hot in-place recycling include:

- asphalt surface courses showing distress due to oxidation or poor mix design
- rectification of surface rutting
- restoration of road shape (crossfall)
- restoration of surface texture and skid resistance.

Hot recycling is not recommended when the road section is short, as it is likely to be uneconomic, or if it has sharp corners that make operation of equipment difficult.

4.2 Cold In-place Recycling

Cold in-place recycling can be an effective process for the rehabilitation of low to medium trafficked roads, in both intermediate and wearing courses.

It is suitable for treatment of existing pavements, where deterioration is limited to the upper pavement structure, including:

- crocodile and thermally cracked pavements
- old oxidised pavements
- rutted and shoved pavements (with appropriate mix design)
- where ride and cross slope need correction.

Some advantages of cold in-place recycling are:

- it causes minimum disruption to traffic and allows the whole roadway to be open to traffic after each day's work
- it is cost effective
  - achieves good production
  - is energy efficient
  - all existing materials are reused with a minimal quantity of new material.

Cold in-place recycling is also suitable for projects that are located far from mixing plants.

Cold in-place recycling is **not** recommended:

- when stripping is apparent
- when rutting has occurred due to unstable, fatty mix.

As moisture is introduced to the recycled mix as part of the cold recycling process, full strength of these materials is generally not obtained until moisture content is reduced and materials are fully cured.

A new surfacing is usually required following cold in-place recycling. The type of surfacing selected depends on the traffic loading. For light traffic, a surface enrichment, sprayed seal, slurry surfacing or cape seal may be suitable. For heavier traffic, an asphalt overlay is recommended.

4.3 Cold Plant Recycling

Cold plant recycled asphalt is suitable for the following applications:

- intermediate or base courses in deep lift pavements
- shoulder surfacing
- asphalt pavement patching.

In environmental and efficiency terms, cold plant recycling provides the following advantages:

- no heating is required
- high production rates can be achieved
- mixes with up to 100% RAP can be produced.

The cartage required for cold plant recycling reduces the otherwise economic advantage of the technology.

5 MATERIALS FOR ASPHALT RECYCLING

The materials used in recycled asphalt production depend on the type of recycling process and include:

- Reclaimed Asphalt Pavement (RAP)
- new aggregate
- new binder
- rejuvenating agent
- new asphalt (as add-mix).

5.1 Reclaimed Asphalt Pavement (RAP)

Generally, RAP for plant mixing consists of millings from deteriorated asphalt pavements.

Other methods of reclamation are:

- heater scarifying/planing
- ripping and crushing.

The RAP is transported to a mixing plant or stockpiled for screening and/or crushing prior to mixing.

The milled RAP is crushed or screened to a maximum size of 14 or 20 mm. Crushing and screening of RAP for cold plant recycling provides better consistency and separation of particles than insitu operations. RAP that is well separated and graded provides maximum surface area for uniform dispersion of the binder or rejuvenating agent. Improved grading also assists placing and achievement of the required compacted density.

New aggregates may be added to correct deficiencies in the particle size distribution, particularly for the coarser material.

Care must be taken to ensure that there is little or no contamination e.g. clay particles, in the RAP.

Stockpiles of RAP should be carefully controlled to:

- identify and keep separate, different quality RAP materials
- be built up in layers to a conical stockpile as large as can be conveniently handled
- avoid moisture retention.

5.2 New Aggregates and Filler

New aggregates and filler used in plant recycling should conform to the same requirements as for new asphalt. New aggregates or filler may be used in recycled production to:

- correct particle size distribution
- improve stiffness of the final mix.

5.3 Binder

The types of binder used in asphalt recycling may include:

- bitumen
- bitumen emulsion
- foamed bitumen
- combination emulsion / rejuvenating agent.

5.4 Rejuvenating Agents

Rejuvenating agents (also called recycling agent or softener), may be used in recycled asphalt to:

- reduce the viscosity of the existing bitumen
- restore the recycled bitumen to its optimum chemical characteristics for durability.

Rejuvenating agents are usually low viscosity oils. They are generally proprietary products and may also consist of blends of bitumen, emulsion or modified bitumen.

Generally, the proprietary materials are composed of selected maltene and asphaltene fractions derived from crude oil and may be supplied in either an emulsified or oil phased non-emulsified form.

5.5 Add-mix

Hot in-place recycling may require additional new asphalt (add-mix, sometimes called beneficiating mix) to supplement the recycled mix.

Add-mix may consist of graded aggregate or fresh asphalt. It is mixed with the existing asphalt during the in-place recycling process to modify the asphalt grading, binder content and/or binder grade.

6 HOT IN-PLACE RECYCLING PROCEDURES

6.1 General

There are four general procedures for hot in-place recycling:

- Reshape
- Repave
- Remix
- Remix Plus.

The procedure selected depends on specific site requirements.

6.2 Reshape Procedure

The existing rutted/deformed asphalt is heated, scarified, re-spread and compacted to restore the surface profile. A rejuvenating agent is usually added, however the properties of the asphalt mix are not otherwise substantially altered.

6.3 Repave Procedure

The existing asphalt is remixed and reshaped, as above, and a thin layer of new asphalt (add-mix) is spread over the reshaped mix, rather than incorporated into the layer. Both layers are compacted together ensuring a better than usual bonding.

6.4 Remix Procedure

The existing asphalt is heated, scarified, modified (with rejuvenating agent and/or fresh mix), re-spread and compacted.

Remixing is used when add-mix (additional aggregate or asphalt) is required to achieve the desired mix composition and performance.

6.5 Remix Plus Procedure

The existing asphalt is heated, loosened, and mixed with a rejuvenating agent and fresh mix. Further fresh mix is placed over the remixed layer without being incorporated into the layer.

Figures 1 to 4 illustrate the four procedures with before and after pavement cross sections.

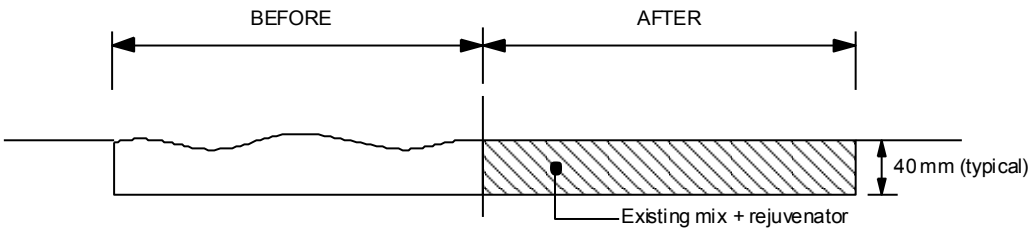

Figure 1 Reshape procedure

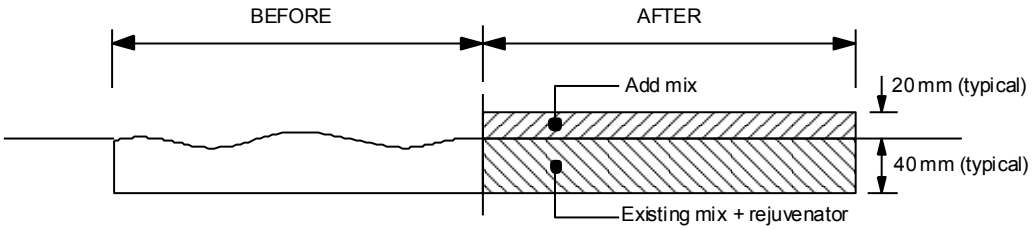

Figure 2 Repave procedure

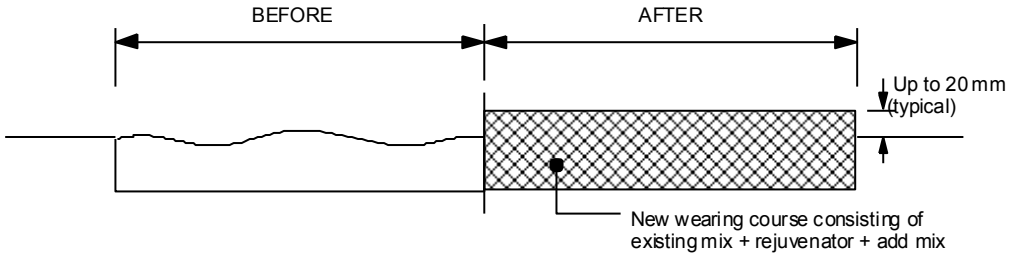

Figure 3 Remix procedure

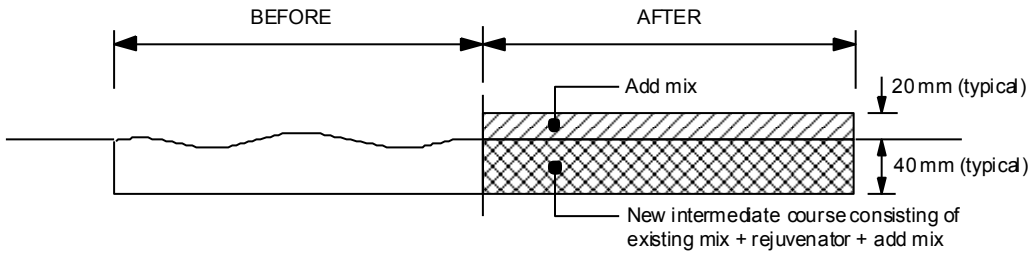

Figure 4 Remix Plus procedure

6.6 Typical Recycling Operation

The hot in-place asphalt recycling (HIPAR) process involves the following steps:

- The existing asphalt surface is heated to between 140°C and 170°C by propane gas-fired infrared preheaters.
- The bituminous binder is softened sufficiently to permit the asphalt to be loosened by scarifiers without binder degradation.
- Rotating scarifiers precisely skim off the loosened material to the required depth. The maximum total thickness of hot in-place recycling, including addition of fresh mix, is normally a total of 60 mm using one heater bank and about 80 mm using two preheating units.

- The asphalt is mixed with binder and/or rejuvenator (and add-mix if required), to restore the desired properties in the asphalt. Mixing the materials may be either in-place or in a pugmill depending on plant used.
- The recycled asphalt is spread to the required profile and compacted. When a thin layer of fresh mix is laid over the recycled mix, the new asphalt forms a thermal bond with the recycled layer.

An average machine speed of 2 to 3 m/min is normal, however for small depths up to 5 m/min is possible.

Typical daily outputs are:

- 3500 to 4000 m^2 at 40 mm depth
- 2000 to 3000 m^2 at 60 mm depth.

A practical average daily output for urban arterial and rural highway work is 3000 m^2 with outputs of 4000 m^2 possible.

Before work commences all pavement failures should be rectified.

Sprayed-on marking may be left but thermoplastic line markings must be removed before recycling commences to avoid fuming.

Sprayed seal surfaces may need to be removed to avoid fuming and excessive binder content. Areas containing excessive crack sealing may also lead to high binder content in finished surface.

Recycling runs should be the full width of traffic lanes, with longitudinal joints located between lanes. The air temperature should be above 10°C

6.7 Plant

The operation is generally completed in a single pass.

A typical recycling train consists of:

- pre-heater(s)
- delivery truck
- main unit
  - receiving hopper for add-mix
  - hoppers for storing materials
  - scarifier
  - pugmill mixer
  - augers and conventional asphalt tamping screed
  - binder / rejuvenator tank
  - distribution auger and screed
- rollers.

For Repave and Remix Plus operations, the recycler is fitted with an additional levelling screed in front of the tamping screed.

6.8 Heating

Heat penetration of the asphalt pavement is adversely affected by:

- low air and pavement temperatures
- moisture in the asphalt
- wind velocity and direction.

Work should be avoided in late autumn or winter or after prolonged rain (water can be held in open graded asphalt for a week or more after rain). Under these conditions the work rate is very slow and there is greater risk of variable texture and quality of the finished product.

Providing wind guards, slowing the recycling operations, lowering the heaters or increasing the heat on the windward side can reduce problems caused by high winds.

More than one pre-heating may be required under adverse conditions.

Heating width should be approximately 100 mm outside the scarified width to ensure a hot joint with the existing pavement.

6.9 Asphalt Temperature

Control of heating of the insitu asphalt is critical to HIPAR.

The surface must be heated to as high a temperature as possible to obtain the desired heat penetration without damaging the binder. The asphalt has to be hot enough to minimise degradation during scarification and to provide for re-compaction.

The maximum surface temperature of the asphalt pavement should not exceed 180°C and the preferred operating range is 140°C to 170°C.

Further heating of the scarified surface with a separate infrared heater bank is generally used to ensure a durable, hot bond with the recycled mix layer.

6.10 Compaction

Primary compaction of the recycled mix is carried out by the paving screed.

The secondary compaction is by rollers using conventional rolling patterns as for virgin asphalt.

Generally, a pass with a steel-wheeled roller in static mode, followed by passes in vibratory mode will achieve the required compaction. Intermediate rolling may be carried out with a rubber tyred roller.

Initial rolling should be completed before the asphalt pavement temperature has dropped below 105°C and final rolling should be completed before the asphalt pavement temperature has dropped below 80°C.

The new pavement should be allowed to cool to below 60°C before it is opened to traffic. Depending on the layer thickness this cooling period could take up to 2 hours.

7 COLD INSITU RECYCLING

7.1 General

The cold in-situ recycling process is carried out at ambient temperatures (i.e. without any heating). In-situ cold recycling is an effective rehabilitation process for low to medium trafficked roads. It involves the following steps:

- reclaiming, by milling, the existing surface and base up to a total depth required. Very hard surfaces may require pre-milling.
- thorough mixing of the materials with the quantity of binder and additive determined by the mix design
- spreading mixed materials and compacting
- applying a surface treatment after curing (usually about 2 weeks).

To accelerate the curing process, gas-heating units from the HIPAR process may be used to accelerate the removal of the free water and stiffen the surface.

Important requirements for the viability of the process are:

- good control of maximum size of material and particle size distribution
- accurate control of depth of material and subsequent additives to be processed
- control over quantity of binder, additives and moisture content

- control of segregation of the mix
- the need to place the recycled material as soon as possible
- achieving a "one pass" operation
- being able to achieve density requirements
- sufficient strength to carry traffic as early as possible after compaction.

7.2 Plant

The plant for cold in-place recycling may include:

- conventional stabilising equipment
- a specialised cold in-place recycler
- compaction equipment.

A typical recycler utilises a modified cutting action whereby milling eliminates the need for separate screening and crushing equipment.

Level controls provide precise control over pavement profile and depth of cut.

A microprocessor-controlled metering and blending system keeps additive/aggregate mix within precise limits, adjusting the flow rate with variations in milling speed.

The process requires the binder tanker to be connected to the recycler to allow the correct amount of binder to be metered during the operation.

Smaller machines commonly recycle a width of 2 m, while larger machines can treat from 3 m to 3.7 m widths.

7.3 Construction Considerations

The cold in-place recycling process should be carried out only in warm, dry weather conditions. The minimum ambient temperature should be 10°C.

The moisture content in cold recycling should be kept to a minimum, consistent with workability and binder coating.

Continuous monitoring is required during the operation to ensure a quality result.

7.4 Compaction

Initial compaction is usually achieved using vibratory steel-wheeled rollers, followed by multi-tyred rolling. Final rolling is achieved by a maximum of two passes of a vibratory roller.

If final density is not achieved, re-rolling the following day may be required. Excessive rolling, before the moisture content has reduced, may cause cracking in the mix, and should be avoided.

The compacted mix should not be opened to traffic for 1.5 to 2 hours to enable sufficient green strength to be achieved in the mix.

7.5 Curing

The new recycled surface should be left for a few weeks without a seal or asphalt overlay to provide maximum opportunity for moisture reduction and curing unless heating units are used to remove the moisture.

Minor shrinkage cracking may occur with loss of moisture. Sealing can cure this problem.

Freshly placed cold recycled mix can have little apparent cohesive strength, but with adequate curing perform similarly to hot mix asphalt. It can take from six to twelve months (or sometimes longer) before full strength is achieved.

Minor ravelling of a freshly laid surface can often result, especially if subject to turning traffic. Treatments such as fog sprays can accelerate curing and protect the new recycled surface. Final treatment can include sprayed seal, slurry seal or asphalt surfacing.

Important factors in cold asphalt recycling include:

- satisfactory pulverisation of the existing asphalt
- careful mix design including the selection of binder type and quantity
- control of moisture content
- accurate and consistent dispersal and mixing of recycled binder
- compacted density
- rate of curing must be suited to traffic requirements.

8 COLD PLANT RECYCLING

Cold plant recycling of asphalt is similar to insitu recycling except that treatment of RAP and mixing is undertaken off site.

Mixing is commonly undertaken in continuous flow type pugmill mixers that can have a capacity in excess of 100 tonnes per hour. Mixing plants generally incorporate facilities for addition of filler and other additives, if required.

REFERENCES

Australian Asphalt Pavement Association Implementation Guide IG2 – *Cold Mix Granular Materials Guide*, 1997

AUSTROADS – *Asphalt Recycling Guide,* 1997

AUSTROADS – *Framework Specifications for Asphalt Recycling,* 2000

AUSTROADS – *Asphalt Guide*, AP-G66/02, 2002

Queensland Transport, *Pavement Rehabilitation Manual*, Pavements and Asset Strategy Branch, June 1992.

Rebbechi, J. and Rootsey, C., *Cold Asphalt Recycling,* Workshop on Pavement Recycling technology, Canberra, October 1994.

RTA of NSW, *Guide to Hot In-place Asphalt Recycling,* Engineering Services, September 1992.