SECTION 9
ASPHALT PAVEMENT RECYCLING

Recycling is defined as “the reuse, usually after some processing, of a material that already has served its first-intended purpose”. Relative to asphalt pavement recycling, there are several methods available. Therefore, each project being considered for recycling must be carefully evaluated to determine the method most appropriate. The factors should include:

1. Existing pavement condition,
2. Existing pavement material types and thickness,
3. Recycled pavement structural requirements and
4. Availability of recycling additives.

9.1 Types of Recycling

The Asphalt Recycling and Reclaiming Association (ARRA) recognizes five types of asphalt pavement recycling:

- Cold Planing — The asphalt pavement is removed to a specified depth and the surface is restored to a desired grade and cross slope and free of humps, ruts and other surface imperfecections. This pavement removal or “milling” is completed with a self-propelled rotary drum cold planing machine. The reclaimed asphalt pavement (RAP) is transferred to trucks for removal and stockpiled for hot or cold recycling.
- Hot Recycling — RAP is combined with new aggregate and asphalt cement and/or recycling agent to produce hot mix asphalt (HMA). Although batch type hot mix plants are used, drum plants typically are used to produce the recycled mix. Most of the RAP is produced by cold planing but also can be produced from pavement removal and crushing. The mix placement and compacting equipment and procedures are those typical of HMA construction.
- Hot In-Place Recycling — The recycling is performed on-site, in-place and the pavement typically is processed to a depth of from 20 to 40 mm (3/4 to 1-1/2 in.). The asphalt pavement is heated, softened and scarified to the depth specified. An asphalt emulsion or other recycling agent is added, and with one of the processes, new HMA is incorporated as required. The three hot inplace recycling methods are heater-scarification, repaving and remixing.
- Cold Recycling — Although cold recycling is performed using the central or stationary plant process, the method most commonly used is cold in-place recycling (CIR). For CIR, the existing asphalt pavement typically is processed to a depth of from 50 - 100 mm (2 - 4 in.). The pavement is pulverized and the reclaimed material is mixed with an asphalt emulsion or emulsified recycling agent, spread and compacted to produce a base course. Cold recycled bases require a new asphalt

surface. Lower traffic pavements may use an asphalt emulsion surface treatment. Higher traffic pavements may use a modified emulsion surface treatment or an HMA surface.

- Full-Depth Reclamation — With FDR, all of the pavement section, and in some cases a predetermined amount of underlying material, are mixed with asphalt emulsion to produce a stabilized base course. Base problems can be corrected with this construction. Full depth reclamation consists of six basic steps: pulverization, additive and/or emulsion incorporation, spreading, compacting, shaping, and placement of new asphalt surface.

This chapter will describe those methods where asphalt emulsions are most frequently used cold recycling and full depth reclamation.

9.2 Candidates for Recycling

A candidate for recycling is usually an old asphalt pavement, from hot mix asphalt to an aggregate base with surface treatment. Candidate pavements will have severe cracking and disintegration, such as pot holes (**Figure 9-1 Deteriorated Asphalt Pavement and Candidate for Recycling**). Frequently the poor condition is due to the pavement being too thin or weak for the traffic and so it is being over-stressed. Poor drainage can also accelerate the rate and amount of pavement deterioration. All types of asphalt pavements can be recycled: low, medium and high traffic volume highways, county roads, city streets, airport taxiways, runways and aprons, and parking lots. Many asphalt pavements have aggregate bases and some sandy soils for the subgrade, allowing both upgrading and strengthening by stabilization with asphalt emulsion.

Figure 9-1 Deteriorated Asphalt Pavement and Candidate for Recycling

Table 9-1 Materials Evaluation Procedures — Cold Recycling and Full-Depth Reclamation

Characteristics	Method of Test	
	ASTM	AASHTO
Bitumen content of bituminous paving mixture	D 2172	T 164
Recovered asphalt from a bituminous paving mixture	D 1856	T 170
Sieve analysis of fine and coarse aggregates	C 136	T 27
Amount of materials finer than 75 µm (No. 200) sieve in mineral aggregate by washing	C 117	T 11
Liquid limit, plastic limit and plasticity index of soil	D 4318	T 89/90
Sand equivalent value of soil or aggregate	D 2419	T 176
Penetration of bituminous materials	D 5	T 49
Viscosity of asphalt by vacuum capillary viscometer	D 2171	T 202

An essential part of selecting any asphalt pavement rehabilitation method is determining the existing pavement condition. The type and amount of pavement defects need to be evaluated. The strength of the current pavement structure and its materials needs to be determined. The current and future traffic needs must be investigated. Very important to the success of pavement recycling is proper materials sampling and testing. Pavement cores and/or test holes are used to determine the type, thickness and condition of the various pavement layers and to obtain representative samples for

laboratory testing. For asphalt materials, testing typically includes conventional asphalt extraction for both asphalt content and aggregate sieve analysis. For cold recycling, a solvent or “Abson” recovery also may be included to determine the asphalt properties, including penetration at 25°C (77°F) and absolute viscosity at 60°C (140°F). For aggregate bases and subgrade soils, a washed sieve analysis and sand equivalent or plasticity index are normally completed. The typical tests performed are in **Table 9-1 Materials Evaluation Procedures — Cold Recycling and Full-Depth Reclamation**. A mixture design is required to determine the type and amount of asphalt emulsion or emulsified recycling agent, pre-mixing water content (if new aggregate is required), and the stability and strength (modulus) properties of the recycled mixture.

9.3 Advantages

Cold recycling and full depth reclamation of asphalt pavements provide many environmental and other advantages:

- Natural resources are conserved through the reuse/salvaging of aggregate and asphalt in existing pavements.
- Pavement materials disposal is greatly reduced or eliminated.
- Energy is conserved as the construction is completed in-place/on-grade and no fuel is required for heating.
- Reflective cracking can be controlled since it is normally reduced or delayed with CIR and eliminated by FDR.
- Pavement crown and cross slope can be improved or restored.
- Loss of curb reveal can be reduced or eliminated (**Figure 9-2 Loss of Curb Height/Reveal and Drainage Capacity**).
- Pavement maintenance costs can be reduced.

Figure 9-2 Loss of Curb Height/Reveal and Drainage Capacity

9.4 Cold Recycling

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The emulsions typically used are the medium-setting grades of regular MS and CMS, high float HFMS and polymer modified versions of these grades. For some cold recycling, cationic slow-setting grades of CSS-1 and CSS-1h have been used. New aggregate can be added to improve mixture gradation or to reduce the asphalt content if necessary. Also, to increase recycled mixture early strength and resistance to water damage, small amounts of cement or lime can be added (1 to 1.5% by weight of RAP). Cement and lime were initially added dry but now are being added as a slurry (cement or lime and water). Cold recycling can be either by central/stationary plant mixing or mixing in-place/on-grade.

9.4.1 Plant Mixed

When plant mix cold recycling, the reclaimed asphalt pavement is usually obtained by cold planing or milling (**Figure 9-3 Cold Planing/Milling Machine Removing Asphalt Pavement**) and the RAP hauled to the plant site and stockpiled. Cold mixing plants normally consist of:

1. A feed hopper or hoppers
2. Conveyor belts
3. Twin-shaft pugmill mixer
4. Emulsion and water meters, valves, piping and spray bars
5. Emulsion and water tanks or tankers
6. Mix storage bin or silo
7. A power supply (**Figure 9-4 Central/Stationary Plan With RAP Sizing Unit**).

Some mixing plants also may have a screening and crushing unit to reduce any agglomerated, oversized RAP. The cold plant recycled mix is hauled to the paving site in either end or bottom dump trucks. Spreading is with a conventional self-propelled asphalt paver or motor grader and compacting by pneumatic-tired or steel-wheeled rollers (see Chapter 7 Aggregate Mixes). An emulsion surface treatment or HMA surface is required for waterproofing and to provide a wearing course.

Figure 9-3 Cold Planing/Milling Machine Removing Asphalt Pavement

Figure 9-4 Central/Stationary Plan With RAP Sizing Unit

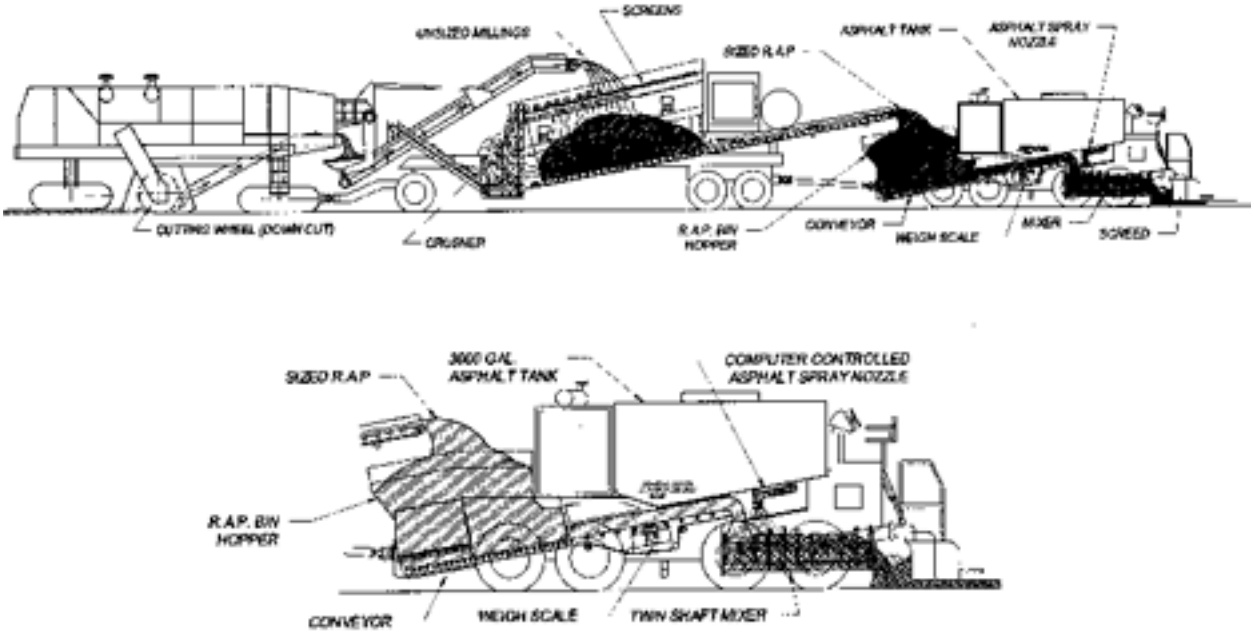

Figure 9-5 Multiple Unit or "Train" for Cold In-Place Recycling

9.4.2 Mixed In-Place

This method of cold recycling has gained widespread acceptance and is the most cost effective because of being completed in-place and on-grade. The existing asphalt pavement is typically recycled by either single unit or multiple unit (train) processing (Figure 9.4-3). With either of these processes, the total gradation of the pulverized pavement is controlled by the maximum particle size.

The first step in CIR is pulverization of the asphalt pavement, usually with a cold planing or milling machine. Water is sprayed on the milling machine cutting head to cool the carbide tipped cutting teeth. The water application rate must also be controlled because it acts as the pre-wetting water in the emulsion mix. The addition and mixing of asphalt emulsion may be by a milling machine with single unit processing or with a travel plant/paver or trailer mounted pugmill for multiple unit processing (**Figure 9-5 Multiple Unit or "Train" for Cold In-Place Recycling**). Although spreading can accomplished with a motor grader, most CIR mix is placed with a conventional self-propelled asphalt paver equipped with automatic screed control to provide the desired depth, cross slope and smoothness.

Proper compaction procedures are required for cold recycled mixes, whether produced by central plant or in-place mixing methods. With an uncompacted lift thickness up to 150 mm (6 in.), a delay in beginning the initial or breakdown rolling usually is required. The time of delay in rolling is dependent upon how rapidly the asphalt emulsion breaks (begins to turn from a brown to black color). Besides the breaking characteristics of the emulsion, the depth of mix and climatic conditions (temperature, humidity and wind) influence when rolling can begin. With thicker lifts, a large pneumatic-tired roller is usually specified. The roller is required to have a mass of 23 - 27 tonnes (25 - 30 tons) and tire pressures of 620 kPa (90 psi). A tandem vibratory steel-wheeled roller nor mally is used for both intermediate and finish rolling, the former with vibration and the latter operated statically.

If the surface of the CIR ravels when opened to traffic, a fog seal of diluted slow setting emulsion should be applied. If raveling occurs, the amount of emulsion in the cold recycled mix may need to be increased. Adequate curing of the cold recycled mixes is required prior to placement of any new asphalt surface course. Inadequate curing can produce high retained moisture contents that increase the possibility of asphalt stripping and slow rates of strength development after the surface is placed.

9.5 Full-Depth Reclamation

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When an asphalt pavement has insufficient structural strength, full depth reclamation with asphalt emulsion may be the solution. The depth of FDR depends upon the existing pavement thickness, subgrade soil conditions and future traffic. The depth typically ranges from 150 - 250 mm (6 - 10 in.). The existing asphalt mix, granular base and sometimes subgrade soil are processed on-grade and inplace, and treated with an asphalt emulsion to produce a new pavement with improved load carrying capability. The process uses 100 percent of the materials and the recycles the complete pavement.

The pulverization of the asphalt pavement and mixing of the asphalt emulsion normally are accomplished with road reclaiming machines (**Figure 9-6 Asphalt Pavement Reclaiming Machine Adding Asphalt Emulsion**). During pulverization, new aggregate or RAP may be added. Asphalt emulsion may be added with an asphalt distributor but will require multiple emulsion applications and mixings. The emulsion typically is add-

ed through a metered liquid system on the reclaiming machine, producing better control of the asphalt content and increased productivity.

Figure 9-6 Asphalt Pavement Reclaiming Machine Adding Asphalt Emulsion

Compaction procedures for full depth reclaimed materials are very similar to those for conventional asphalt emulsion mixes as pneumatic-tired and steel-wheeled rollers are used. Generally the depth of compaction should be limited to 100 mm (4 in.) per lift. However, lifts of 125 to 150 mm (5 to 6 in.) and more in depth have been placed when initial rolling has been with vibratory padfoot rollers that compact from the bottom up.

When a rolling procedure results in cracking or severe displacement of the mix, it should be discontinued until the problem is identified and eliminated. In some instances, the problem may be an underlying wet, weak subgrade. This condition must be corrected by drying or stabilization with cement, fly ash or lime before FDR can proceed.

An important step in the FDR process is the final grading of the surface. This work typically is completed with a motor grader. The final grading is particularly important if the final surface is to be an asphalt emulsion surface treatment. For some highway and airport projects, the finished surface may be established by trimming with a cold planing/milling machine having automatic grade and cross slope control and using a fixed reference or stringline.

As with other types of asphalt emulsion paving, FDR bases require waterproofing and a wearing course. Although HMA is generally used, single or double chip seals, slurry seals or other asphalt surface treatments may be all that is required for low traffic volumes. Also, high quality cold emulsion mixes such as open-graded asphalt emulsion mix, are being placed as the surface course.