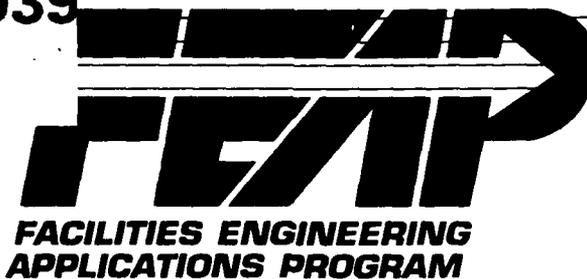


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May 1993

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USER'S GUIDE

# USER'S GUIDE: HOT-MIX RECYCLING OF ASPHALT CONCRETE PAVEMENTS

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by

James E. Shoenberger  
US Army Engineer Waterways Experiment Station  
Vicksburg, MS 39180-6199

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U.S. Army Engineering and Housing Support Center  
Fort Belvoir, VA 22060-5516

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# User's Guide: Hot-Mix Recycling of Asphalt Concrete Pavements

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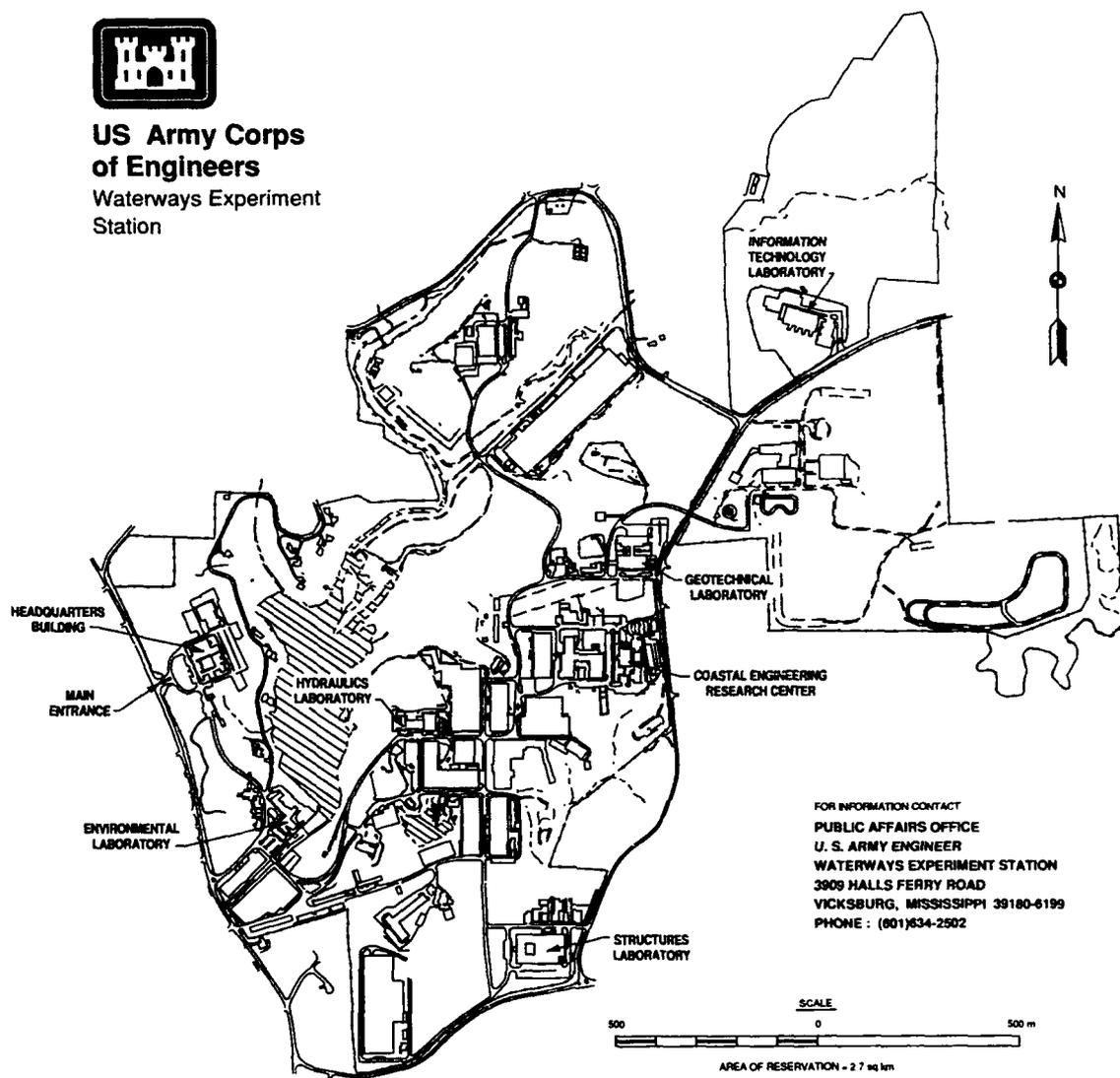
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## USER'S GUIDE: HOT-MIX RECYCLING OF ASPHALT CONCRETE PAVEMENTS

### PART I: EXECUTIVE SUMMARY

#### Description

1. Asphalt pavement recycling involves reusing the in-place pavement material to rehabilitate and/or strengthen the asphalt pavement structure. The recycling process involves removing the asphalt pavement materials of the pavement structure, usually by cold milling, and after adding new materials, reheating the recycled mixture and placing it with the same methods as used for conventional virgin asphalt concrete. Minimal adaptation of existing pavement construction equipment or new equipment purchases are required for hot-mix recycling. The proportions of old material to new material in the blending process will be governed by the material properties of the old asphalt concrete and the specification requirements for the recycled mix.

#### Application

2. The use of hot-mix recycled asphalt concrete is applicable to any pavement where the use is cost effective. Hot-mix recycled pavements have the capability to decrease or minimize reflective cracking. A recycled asphalt mixture can be used for both intermediate and surface applications. Load related distresses in pavements can not be corrected by hot-mix recycling. The base should be repaired prior to or in conjunction with the recycling.

#### Benefits

3. Hot-mix recycling allows the reuse of existing pavement materials resulting in the conservation of existing resources. The resources conserved include fuels from reduced transportation and processing requirements, and also aggregate and petroleum resources. Hot-mix recycling provides an improved pavement without requiring changes in existing utilities, curbs and gutters, and overhead clearance requirements. Recycling of old asphalt

pavement, in situations where the pavement requires removal, eliminates the potential disposal problem of the removed asphalt concrete material.

#### Limitations

4. Some questions remain about the long-term durability of hot-mix recycling with recycling agents versus using soft asphalts. In the past, the existing technology, in the form of existing asphalt plants, limited the practical range of recyclable asphalt pavement (RAP) usage to 15 to 40 percent. Currently new technology is being developed and evaluated to increase this to 100 percent. The RAP material, depending on its final intended use, must be of a quality suitable for modification to meet the intended specification requirements.

#### Costs

5. There is usually a cost savings associated with hot-mix recycling versus conventional virgin asphalt concrete. Cost savings normally range from 10 to 30 percent, with savings of 50 percent encountered. The effective life cycle costs of recycled and virgin asphalt pavements should be almost equal. Cost savings are achieved during the construction process due to lower fuel and material costs.

#### Recommendations for Use

6. Hot-mix recycling of asphalt concrete pavements is recommended for use in any location where an asphalt concrete pavement is required. It should be considered for its environmental benefits and the cost benefit advantage. The available guide specifications should be followed closely, and quality construction methods should be followed at all times.

Points of Contact

7. Points of contact regarding this technology are:

a. Technical:

Director  
US Army Engineer Waterways Experiment Station  
ATTN: CEWES-GP-Q (Mr. James E. Shoenberger)  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199  
Telephone: 601-634-3553  
Facsimile: 601-634-3020

b. US Army Engineering and Housing Support Center:

Commander  
US Army Engineering and Housing Support Center  
ATTN: CEHSC-FB-P (Mr. Joseph Sicuranza)  
Fort Belvoir, VA 22060-5516  
Telephone: 703-704-1574  
Facsimile: 703-780-5935

8. Points of contact at Fort Gillem, Georgia; Fort Leavenworth, Kansas; and Fort Benjamin Harrison, Indiana; where the hot-mix recycling demonstrations occurred are:

a. Director of Engineering and Housing  
ATTN: Mr. Grady Simms, Road Foreman  
Fort Gillem  
Forest Park, GA 30050-5000  
Telephone: 404-363-5771  
Facsimile: 404-363-5631

b. Chief, Engineering Division, DEH  
ATTN: Mr. Bob Mullen  
Fort Leavenworth, KS  
Telephone: 800-567-8262

c. Commander  
US Army Soldier Support Center  
ATTN: ATZI-FEP (Mr. Gene Springer)  
Building 28  
Fort Benjamin Harrison, IN 46216-5450  
Telephone: 317-549-5417

## PART II: PREACQUISITION

### Description of Hot-Mix Recycling

9. Pavement recycling involves reusing the in-place pavement material to rehabilitate the pavement structure. The feasibility of pavement recycling has been recognized for years, but its development and use greatly increased after the 1973 oil embargo. The primary reason for this increase is economics. During and after the embargo, the price of oil increased significantly causing the price of oil products such as asphalt cement, gasoline fuels, and diesel fuels to increase. These and other cost increases caused the cost of producing and hauling aggregate materials to increase.

10. With the significant increase in the cost of pavement materials and a growing shortage of quality aggregates in some parts of the country, recycling of pavements became a cost-effective alternative to be considered when rehabilitating a pavement structure. Even if recycling of a pavement structure is found not to be cost-effective, recycling should be considered because of potential intangible benefits such as conservation of natural resources, energy conservation, and preservation of the environment.

11. Recycling of asphalt concrete pavement has proven itself as a cost-effective means of rehabilitating all or part of the pavement structure. As a result, the acceptability of the recycling processes is growing rapidly. Most states already specify reclamation of existing asphalt pavements or allow recycling as a contract alternative. The US Air Force specifies or allows as an alternative recycling techniques to rehabilitate and/or strengthen its pavements. Headquarters, US Army Corps of Engineers has published an Army Policy Letter on Asphaltic Concrete Pavement Recycling (Headquarters, Department of the Army 1984) (see Appendix A) dated 11 September 1984 which, in summary, states that recycling will be evaluated on all pavement projects which involve overlays, replacement of asphalt concrete, or corrections of the pavement cross-section. Also, this Army policy letter states that the evaluation be included in the "Decision Analysis" document submitted for MACOM or DA approval.

12. Hot-mix recycling involves the removal of the in-place asphalt concrete and mixing the removed material with new aggregate and binder using

heat. The hot-mix procedure can produce a hot asphalt concrete which meets US Army Corps of Engineers specifications for intermediate courses, and both high and low tire pressure surface courses. A properly designed and mixed recycled hot-mix is considered the equivalent of a new asphalt concrete mix. Appendix B contains a fact sheet describing pavement recycling.

#### Application

13. Hot-mix recycling should be considered for the rehabilitation of any asphalt concrete pavement. The cost-effectiveness of hot-mix recycling is normally the deciding factor in the selection of hot-mix recycling over conventional virgin hot-mix. The cost-effectiveness is based in part on material costs, environmental considerations, and other site specific considerations. Hot-mix recycling can be effective in reducing reflective cracking and can eliminate the need to raise or adjust existing curbs and gutters and other utility structures located in the pavement. Hot-mix recycling will also allow for resurfacing of overpasses without an increase in dead weight load.

#### Limitations/Disadvantages

14. In nearly all cases, hot-mix recycling requires additional aggregate and asphalt cement or a recycling agent. These requirements for additional material are normally based on limitations in the heating process and also in mixture requirements. The amount of RAP used in a recycled mix usually varies between 15 and 40 percent, with approximately 60 percent being the maximum percentage possible, even with the newest drum mix plants. There currently is a new microwave heating process available which has the capacity to heat and recycle 100 percent RAP material. The use of this process has been limited and should probably be confined to intermediate courses or low volume road applications until more information on performance is available. An investigation (Brown 1984) has shown that there may be some long term lowering of pavement performance with the use of recycling agents versus the use of a softer asphalt in the recycling process. The use of soft asphalts versus recycling agents is also a limitation on the percentage of RAP material

that is used. As the percentage of RAP material in the recycled mixture increases the need for the use of a recycling agent versus a soft asphalt cement also increases. Normally the use of 50 percent RAP material or more will require at least the partial use of a recycling agent.

FEAP Demonstration/Implementation Sites

<u>Installation</u>	<u>Date</u>	<u>Remarks</u>
Fort Gillem, GA	FY84	Hood Avenue is a four-lane asphalt pavement approximately 2,500 feet long serving as main entrance and thoroughfare at Fort Gillem. Four inches of asphalt pavement was removed and two inches of recycled mix was replaced. Forty percent RAP material was used for the hot-mix recycled asphalt concrete.
Fort Gillem, GA	FY85	Approximately 1.5 miles of warehouse roads surfaced with 2.5 to 3.5 inches of hot mix were used to demonstrate the hot mix recycling process. Two inches of asphalt pavement were removed and replaced with 2 inches of recycled mix. Forty percent RAP material was used for the hot-mix recycled asphalt concrete.
Fort Leavenworth, KS	FY86	Approximately 0.75 miles of roads (Kansas Ave., 6th Infantry Road, and 5th Infantry Road) surfaced with 3 to 4 inches of hot-mix asphalt concrete which was used to demonstrate hot-mix recycling. The old asphalt concrete was milled off to within approximately 1/2 inch of the base. Base repairs were made where necessary, and 2 inches of recycled hot mix were placed as the surface course. Forty one percent RAP material was used for the hot-mix recycled asphalt concrete.

<u>Installation</u>	<u>Date</u>	<u>Remarks</u>
Fort Benjamin Harrison, IN	FY87	Shafter Road approximately 2.0 miles in length was the site of the FY87 demonstration project for hot-mix asphalt concrete recycling. The existing pavement contained random transverse and longitudinal cracks. Four inches of existing asphalt concrete were removed by cold milling and replaced with two recycled hot mix courses. A 2-1/2 inch intermediate course and a 1-1/2 inch surface course were placed. Thirty two percent RAP material was used for the hot-mix recycled asphalt concrete.

#### Life-Cycle Costs and Benefits

15. Pavement recycling provides a pavement rehabilitation or construction procedure which allows the optimum use of money and materials. The optimum use of money and materials will often result in a significant cost savings in the range of 10 to 30 percent. Hot-mix recycling involves the reuse of the existing pavement structure by removing the old asphalt concrete pavement, crushing it if needed, adding virgin aggregate, asphalt and/or recycling agent, mixing the heated materials, and placing it using the same procedures as those for conventional hot-mix asphalt concrete pavement.

16. Asphalt pavement recycling is a relatively new pavement rehabilitation process. Improvements in construction techniques and recycling equipment are ongoing. The processes of recycling asphalt pavement being used today are proving to be cost-effective as well as producing quality pavements.

#### Costs

17. The economical benefits of hot-mix recycling depend on the cost and availability of pavement materials in the area. At Fort Gillem, the cost savings derived when hot-mix recycling Hood Avenue were as follows:

- a. Recycle. Cold mill off 4 inches of old asphalt pavement and replace with 2 inches of hot-mix recycled asphalt concrete pavement. Recycling would restore grade for existing concrete curb and gutters. The unit cost was \$9.42 per square yard.
- b. Overlay new mix. Replace existing curb and gutters and overlay existing pavement with 2 inches of hot-mix asphalt concrete. The unit cost was \$11.20 per square yard.

18. The use of hot-mix recycling provided a cost savings of 16 percent over the conventional overlay method.

#### Advantages/Benefits

19. Some tangible benefits of using the hot-mix recycling process include retarding the process of reflective cracking, re-establishing the pavement surface to the elevation of the concrete gutters, and providing a smooth transition at intersections between the old and new pavements. The intangible benefits included the elimination of waste disposal of the old pavement in local dumps and the conservation of natural resources and energy by reusing the old pavement in the rehabilitation of a new recycled pavement.

## PART III: ACQUISITION/PROCUREMENT

### Potential Funding Sources

20. Typically, installations fund the implementation of pavements and railroads technologies from their annual budgets. However, the installations annual budget is usually under-funded and the pavements and railroads projects do not compete well with other high visibility or high interest type projects. As a result, it is prudent to seek out additional funding sources when the project merits the action. Listed below are some sources commonly pursued to fund projects.

- a. Productivity program. See AR 5-4, Department of the Army Productivity Improvement Program for guidance to determine if the project qualifies for this type of funding.
- b. Facilities Engineering Applications Program (FEAP). In the past, a number of pavement and railroad maintenance projects located at various installations were funded with FEAP demonstration funds. At that time, emphasis was placed on demonstrating new technologies to the Directorate of Engineering and Housing (DEH) community. Now that these technologies have been demonstrated, the installations will be responsible for funding their projects through other sources. However, emphasis concerning the direction of FEAP may change in the future; therefore, one should not rule out FEAP as a source of funding.
- c. Special programs. Examples of these are as follows:
  - (1) FORSCOM mobilization plan which may include rehabilitation or enlargement of parking areas and the reinforcement of bridges.
  - (2) Safety program which may include the repair of unsafe/deteriorated railroads at crossings and in ammunition storage areas.
  - (3) Security upgrade which may include the repair or enlargement of fencing.
- d. Reimbursable customer. Examples of this source are roads to special function areas such as family housing or schools and airfield pavements required to support logistical operations.
- e. Special requests from MACOMS.

- f. Year end funds. This type of funding should be coordinated with the MACOMS to ensure that the funds will not be lost after a contract is advertised.
- g. Operations and Maintenance Army. These are the normal funds used for funding pavement and railroad projects.

#### Technology Components and Sources

21. Components of the technology which must be procured for the use of hot-mix recycling of asphalt concrete pavements are section design (may be in-house or contracted out) and a contractor to perform all phases of the recycling process. Hot-mix recycling utilizes equipment which is widely available in the pavement construction industry. Cold milling machines are widely available, and most plants can be adapted for recycling if that technology is not already built into the plant. Many contractors have had at least some experience in hot-mix recycling. The Corps of Engineers has guide specifications and design and construction manuals (TM 5-822-8 and TM 5-822-10) (Headquarters, Departments of the Army and Air Force 1987, 1988) covering the use of hot-mix recycling of asphalt concrete pavement.

#### Procurement Documents

22. Applicable Specifications are listed below:
- a. CEGS-02590, Recycled Asphalt Concrete Intermediate and Wearing Courses for Airfields, Heliports, and Heavy Duty Pavements (Central Plant Hot-Mix), May 1984.
  - b. CEGS-02551, Bituminous Intermediate and Surface Courses for Roads, Streets, and Open Storage Areas (Central Plant Hot-Mix), September 1984.
  - c. CEGS-02598, Cold Milling of Bituminous Pavements, September 1984.
23. GSA Listing:
- There are no GSA listings.
24. Vendors List and Recent Prices:
- This list includes local contractors who have the capability.

### Procurement Scheduling

25. Normal construction contract schedules should be established that allow adequate design and plan preparation time, design and review and approval, contract preparation, advertising and award, and construction time. A typical pavement project is designed 1-2 years before it is constructed; however, relatively small projects that require limited plans and specifications can be prepared and ready to go within a few months.

## PART IV: POST ACQUISITION

### Initial Implementation

#### Equipment

26. Conventional asphalt mixing and paving equipment can be used to produce, place, and compact hot-mix recycled asphalt concrete pavement. A cold milling machine is normally used to remove the RAP material; however, the asphalt pavement can be broken up and removed to a crusher to obtain the desired maximum size RAP material for recycling. Screening operations can be used, with or without a crusher, to obtain the desired material size. Many drum mix plants have a recycling capability built in; however, the capability to recycle pavement can be added to almost any asphalt concrete mixing plant.

#### Materials

27. The materials required for hot-mix recycling will vary according to project conditions. The amount of each material required will depend on the amount of RAP material which can be used and the final material properties desired in the recycled pavement. The addition of an asphalt cement or a recycling agent is normally required. Additional aggregates are normally required and the gradation of the aggregates added is based on the final gradation desired for the recycled pavement. The final gradation should meet the requirements given in TM 5-822-8 "Bituminous Pavements Standard Practice" (Headquarters, Departments of the Army and Air Force 1987) according to pavement usage.

#### Personnel

28. The personnel normally required for the construction of a conventional virgin asphalt concrete pavement are the same as those needed for construction of a hot-mix recycled pavement. The only additional personnel required to produce and place a recycled mix are a milling machine crew and those personnel on the break-up and crush operation along with the transportation to the central asphalt concrete plant. Milling machines were employed to remove the RAP at all of the hot-mix recycle demonstration sites. The quality control required for the recycling can be easily handled by any commercial testing laboratory qualified for conventional asphalt concrete

testing. The quality control testing at the demonstration projects was performed by personnel from the US Army Engineer Waterways Experiment Station.

#### Procedure

29. Given the need for pavement rehabilitation, the option of hot-mix recycling is technically appropriate based on the following pavement conditions:

- a. Extensive or large cracks in the existing asphalt concrete pavement which would result in reflective cracking within 6 to 18 months of a conventional virgin asphalt concrete overlay.
- b. Existing curb and gutter system which can be maintained with the use of hot-mix recycling.
- c. Need to re-establish drainage pattern on roadways and around structures.
- d. Pavement structure containing isolated areas of base failure or a weathered/oxidized pavement surface that is experiencing raveling.

30. With one or more of these conditions existing the option of recycling should be a cost effective method of rehabilitation. The selection of a recycled versus a virgin mix should be based on cost effectiveness and environmental benefits.

31. The first step in hot-mix recycling is the removal of the existing RAP. This is usually accomplished by milling, although the pavement can be broken-up and removed to a crusher for processing to a usable size or gradation. However the pavement is removed; the RAP material, as it is stockpiled, should be monitored and tested for asphalt content and aggregate gradation. Keeping records and charting the test results will provide the information necessary to obtain a high quality recycled asphalt pavement. A recycled asphalt mix design will need to be developed before the RAP can be used in a recycled asphalt pavement. This is usually accomplished on the stockpiled RAP material; however, it can be accomplished on samples taken from the pavement prior to removal. Adjustments to the mix design may be needed due to the possible generation of fines during the milling operation. The amount of adjustment required will depend upon the type of aggregate in the milled pavement.

32. The type of recycled asphalt mix design used will depend on the intended application of the pavement. There are different requirements for

high pressure (airfield and some primary roads) versus low pressure tire (road) mixtures. The requirements for each type are given in TM 5-822-8/AFM 88-6, Chap 9 (Headquarters, Departments of the Army and Air Force 1987) and in the respective guide specifications for airfield and road applications.

33. The asphalt mix suppliers mixing plant will have to be able to handle a recycled mix. Many drum mix plants have this capability or can be adapted by the addition of a cold bin and conveyor to add the RAP material to the drum. Batch plants can also be used, although they are not normally adapted for this application.

34. A recycled asphalt mixture is placed in the same manner as any other asphalt mixture.

35. The quality control and quality assurance methods used for recycled asphalt pavement construction are very similar to conventional virgin asphalt pavement construction. The main difference is in the requirement to control or assure the correct properties of the recycled asphalt cement by recovering the asphalt cement and testing it for the proper range of penetration values. Meeting the penetration requirement and obtaining the other requirements specified will result in a pavement structure equal to that obtainable with new materials.

36. Appendix C contains an example of a specification used to hot-mix recycle at Fort Gillem, Georgia.

#### Operation and Maintenance

37. Operations and maintenance on a hot-mix recycled asphalt concrete pavement are no different than that of any asphalt concrete pavement. The life expectancy of a hot-mix recycled pavement should be about the same as that of a conventional virgin asphalt concrete pavement. Many pavements have been recycled over the last 15 to 20 years with no obvious decrease in performance noted between recycled and nonrecycled pavements. The amount and type of maintenance required for a recycled pavement should be about the same as that of a virgin asphalt concrete pavement.

### Service and Support Requirements

38. No special services or support is required to implement or maintain this technology.

### Performance Monitoring

39. Installation personnel can monitor and measure the performance of the hot-mix recycled asphalt concrete pavement by making periodic inspections of the pavement for signs of distress (cracking, rutting, etc.). This monitoring of performance would be no more than that required for any asphalt concrete pavement. The performance monitoring can be adjusted to fit into existing pavement management systems. Unusual traffic or climatic conditions could adversely affect performance and should be noted.

APPENDIX A: REFERENCES

Brown, E. R. 1984 (Feb). "Evaluation of Properties of Recycled Asphalt Concrete Hot Mix," Technical Report GL-84-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Headquarters, Department of the Army. 1984 (Sep). "Army Policy on Asphaltic Concrete Pavement Recycling," Army Policy Letter, Office of the Chief of Engineers, Washington, DC.

Headquarters, Departments of the Army and Air Force. 1988 (Aug). "Standard Practice for Pavement Recycling," TM 5-822-10/AFM 88-6, Chapter 6, Headquarters, Departments of the Army and the Air Force, Washington, DC.

\_\_\_\_\_. 1987 (Jul). "Bituminous Pavements Standard Practice," TM 5-822-8/AFM 88-6, Chapter 9, Headquarters, Departments of the Army and the Air Force, Washington, DC.

Lynch, L. N. and Lewandowski, L. H. 1991 (Apr). "Hot Mix Recycling of Asphalt Pavements," Video Report GL-91-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Vollor, T. W. 1986 (May). "Pavement Recycling: Facilities Technology Application Tests (FTAT) Demonstration, FY84, Fort Gillem, Georgia," Technical Report GL-86-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

\_\_\_\_\_. 1986 (Feb). "Asphalt Pavement Recycling Primer," Miscellaneous Paper GL-86-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

APPENDIX B: FACT SHEET



US Army Corps  
of Engineers

Office of the Chief  
of Engineers

# FTAT Projects

For Information on FTAT Projects

Contact Information Manager,

Dr. Robert M. Dinnat or Mr. Jeffrey J. Walaszek

USA-CERL, P.O. Box 4005,

Champaign, Ill. 61820-1305 217-373-6700 or 217-373-7216

December 1987

## PAVEMENT RECYCLING

Description of Technology. Pavement recycling has proven to be an acceptable, cost-effective construction technique to be considered when rehabilitating pavements. Even when recycling is not the most cost-effective method it should always be considered because of potential intangible benefits. These benefits include the conservation of natural resources and energy and the preservation of the environment. Bituminous pavement recycling is normally divided into three categories--surface, cold-mix and hot-mix recycling. Surface recycling should be considered anytime a surface distress on a structurally sound pavement requires correction such as to increase skid resistance, decrease permeability to air and water, improve properties of the asphalt binder, or improve rideability of the pavement.

Cold-mix recycling should be considered anytime a pavement has deteriorated to a point where it is more economical to recycle than use a conventional overlay, where an overlay is prohibited by existing grades, and when the pavement structure requires strengthening. Cold-mix recycling reuses part or all of the existing stabilized base course or an intermediate course material for the rehabilitated pavement structure. Cold-mix recycling can be designed to blend new material with the old materials or to use the old materials without the use of new materials. Under certain conditions, it is used as a surface course material on secondary roads; however, raveling should be expected.

Hot-mix recycling is used to reconstruct the asphalt concrete portion of the pavement structure. To hot-mix recycle, the existing asphalt concrete is removed to the desired depth, crushed if needed, and mixed in a hot-mix asphalt plant with new aggregate, asphalt cement, and recycling agent if needed. Recycling agents should be used only when required to soften the old asphalt cement to desired penetration. Hot-mix recycled mixes can be designed for use as intermediate courses or surface courses in the pavement structure.

Portland cement concrete (PCC) recycling should be considered when good aggregates are not available or when new aggregates are not cost-effective when compared to recycled PCC aggregate. PCC pavement recycling involves removing the existing pavement and crushing and resizing the removed PCC for use as aggregate in new PCC, asphalt concrete, cement-treated base, or aggregate base course.

Status of Demonstration. The 1984 and 1985 field pavement recycling demonstration projects have been completed at Fort Gillem, Georgia. The 1986 pavement recycling demonstration project has been completed at Fort Leavenworth, Kansas. The 1987 pavement recycling demonstration project has been completed at Fort Benjamin Harrison, Indiana. At present, there are no plans for additional pavement recycling projects.

Notebook articles, videotapes, and technical reports will be prepared on the recycling techniques demonstrated.

Benefits of Technology. Pavement recycling provides a pavement rehabilitation or construction procedure which allows the optimum use of money and materials. This often results in a significant cost savings in the range of 10 to 30 percent. The cost savings calculated on the PTAT demonstration projects were approximately 16 percent for hot-mix recycling and approximately 21 percent for cold-mix recycling.

These cost savings were computed by comparing to alternate methods of rehabilitating the pavements. By reusing parts or all of the materials in the existing pavement structure to produce the rehabilitated pavement, depletion of natural materials was reduced. Also, the need of a permanent dump site for the removed old pavement was eliminated. The reoccurrence of reflective cracking was minimized or eliminated. The pavement structure was strengthened. Old drainage facilities and systems which were still functioning were saved.

Points of Contact. Mr. T. W. Vollar or Mr. Randy Ahlrich, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180-0631, 601-634-2206.

APPENDIX C: CONTRACT SPECIFICATION EXAMPLE

## Cold Milling of Pavements

### Applicable publication

1. The American Society for Testing and Materials (ASTM) publication listed below forms a part of this specification to the extent referenced. The publication is referred to in the Appendix by the basic designation only.

C 136-81

Sieve Analysis of Fine and  
Coarse Aggregates

### Equipment, tools, and machines

2. Items used in the performance of the work shall be maintained in a satisfactory working condition.

- a. Cold-milling machine. The cold-milling machine shall be a self-propelled machine capable of milling the pavement to a specified depth and smoothness. The machine shall have the ability to remove the millings or cuttings from the pavement and load them into a truck. The milling machine shall not cause damage to any part of the pavement structure that is not to be removed.
- b. Cleaning equipment. All cleaning equipment shall be suitable for removing and cleaning loose material from the pavement surface.
- c. Straightedge. The contractor shall furnish and maintain at the site, in good condition, one 10-ft straightedge or other suitable device for testing the finished surface. Each straightedge shall be constructed of aluminum or other lightweight metal with flat bottom adequately reinforced to ensure rigidity and accuracy.

### Grade and Surface-Smoothness Requirements

#### Grade

3. The finished surfaces shall vary not more than 0.06 ft from the plan grade line and elevation indicated. Finished surfaces at a juncture with other pavements shall coincide with the finished surfaces of the abutting pavements. The deviations from the plan grade line and elevation will not be permitted in areas of pavements where closer conformance with planned grade and elevation is required for the proper functioning of appurtenant structures involved.

#### Surface smoothness

4. The finished surfaces shall not deviate from the testing edge of a 10-ft straightedge more than 3/8 in.

#### Testing

#### Grade-conformance tests

5. The finished surface of the pavement will be tested for conformance with the plan-grade requirements. The finished surface of each pavement area will be tested for acceptance by the contracting officer. The contractor shall correct variations from the designated grade line and elevation in excess of the plan-grade requirements, as directed, without additional cost to the Government. Skin patching for correcting low areas will not be permitted.

#### Surface-smoothness tests

6. After completion of the final milling, the finished surface will be tested by the Government with a straightedge. Surface irregularities that depart from the testing edge by more than the 3/8-in. tolerance shall be corrected by the contractor at no additional cost to the Government.

#### Method of Measurement

7. The area of removed pavement will be determined by the contracting officer by measuring the length and width of material removed within the specified work area. Measurement to determine the area will be the closest inch for width and the closest foot for length.

#### Basis of Payment

8. The basis of payment will be to the nearest square yard. The payment will include cold milling and hauling the removed material to the stockpile and shall constitute full compensation for all operations necessary to complete the work as specified herein. No payment will be made for milling below depths shown on the drawings or for milling outside the specified area of work.

## Execution

### Preparation of surface

9. When removed material is to be recycled, the pavement surface shall be cleaned of excessive dirt, clay, or other foreign material immediately prior to milling the pavement.

### Milling operation

10. Sufficient passes shall be made so that the designated area has been milled to the grade and cross sections indicated. The milling shall proceed with care and in-depth increments that will not damage the pavement below the designated finished grade. Any items, such as manholes, valve boxes, and utility lines, damaged or any pavement that is torn, cracked, gouged, broken, or undercut shall be repaired or replaced by the contractor at no additional cost to the Government. Removed material that is to be recycled shall have a minimum of 95 percent by weight passing a 1 1/2 in. sieve when tested in accordance with ASTM C 136-82.

### Removal of milled material

11. Material that is removed shall be stockpiled in a manner to prevent segregation or contamination.

## Recycled Asphalt Concrete (AC) Pavement (Hot-Mix)

### Applicable publications

12. The publications listed below form a part of this specification to the extent referenced. The publications are referred to by the basic designation only.

- a. Military Standard (MIL. STD.):
  - MIL-STD-620A                      Test Methods for Bituminous Paving  
& Notice 1                              Materials
- b. US Army Corps of Engineers, Handbook for Concrete and Cement:
  - CRD-C 119-53                      Flat and Elongated Particles in Coarse  
Rev. June 63                              Aggregate
- c. American Society for Testing and Materials (ASTM) Publications:
  - C 29-78                              Unit Weight and Voids in Aggregate
  - C 127-81                              Specific Gravity and Absorption of  
Coarse Aggregate

C 128-79	Specific Gravity and Absorption of Fine Aggregate
C 131-31	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact of the Los Angeles Machine
C 136-82	Sieve Analysis of Fine and Coarse Aggregate
C 183-78	Sampling Hydraulic Cement
D 5-73 (R 1978)	Penetration of Bituminous Materials
D 75-82	Sampling Aggregates
D 140-70 (R 1981)	Sampling Bituminous Materials
D 242-70 (R 1980)	Mineral Filler for Bituminous Paving Mixtures
D 946-82	Penetration-Graded Asphalt Cement for Use in Pavement Construction
D 1250-80	Petroleum Measurement Tables
D 1856-79	Recovery of Asphalt from Solution by Abson Method
D 2041-78	Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures
D 2172-81	Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
D 2216-80	Laboratory Determination of Moisture Content of Soil
D 3381-81	Viscosity-Graded Asphalt Cement for Use in Pavement Construction
D 3515-81	Hot-Mixed, Hot-Laid Bituminous Paving Mixtures

#### Mixing Plants

13. The mixing plant shall be an automatic or semiautomatic controlled commercially manufactured unit designed, coordinated, and operated to consistently produce a mixture within the job mix formula (JMF).

#### Weather limitations

14. Recycled asphalt courses shall be constructed only when the base course or existing pavement has no free water on the surface. Unless otherwise directed, recycled asphalt courses shall not be constructed when temperature of the surface of the existing pavement or base course is below 40°F.

Protection of pavement

15. After final rolling, no vehicular traffic of any kind shall be permitted on the pavement until pavement has cooled to 140°F.

Grade and surface-smoothness requirements

16. Finished surface of pavements, when tested as specified below, shall conform to elevations shown and to surface smoothness requirements specified.

- a. Plan grade. Finished surfaces shall not vary not more than 0.04 ft from the plan gradeline or elevation established and approved at site of work. Finished surfaces at juncture with other pavement shall coincide with finished surfaces of abutting pavements. The 0.04-ft deviations from the plan gradeline will not be permitted in areas of pavements where closer conformance with planned elevation is required for the proper functioning of drainage and other appurtenant structures involved.
- b. Surface smoothness. Finished surfaces shall not deviate from the testing edge of a 10-ft straightedge more than 1/4 in.
- c. Straightedge. The contractor shall furnish and maintain at the site, in good condition, one 10-ft straightedge for use of the contracting officer in testing finished surface. Straightedges shall be constructed of aluminum and shall have blades of box or box-girder cross section with flat bottom reinforced to ensure rigidity and accuracy.

Access to plant and equipment

17. The contracting officer shall have access at all times to all parts of the bituminous plant for checking adequacy of equipment in use; inspecting operation of plant; verifying weights, proportions, and character of materials; and checking temperatures maintained in preparation of mixtures.

Waybills and delivery tickets

18. Waybills and delivery tickets shall be submitted to the contracting officer during progress of the work. Before the final statement is allowed, the contractor shall file with the contracting officer certified waybills and certified delivery tickets for all aggregates, reclaimed asphalt pavement, and bituminous materials actually used in construction covered by the contract.

## Measurement

### Recycled asphalt concrete tonnage

19. The amount paid for will be the number of tons (2,000 pounds) of recycled asphalt mixture used in the accepted work. Recycled asphalt mixture shall be weighed after mixing, and no deduction will be made for weight of bituminous materials incorporated herein.

### Bituminous materials

20. Bituminous materials to be paid for will be the number of tons (2,000 pounds) used in the accepted work.

## Payment

21. Quantities of recycled AC mixtures and bituminous materials, determined as specified above, will be paid for at respective contract unit prices. Payment shall constitute full compensation for preparing and/or reconditioning base course of existing pavement; for furnishing all materials, equipment, plant, and tools; and for all labor and other incidentals necessary to complete work required by this section.

## Products

### Testing

22. The contracting officer will conduct all tests necessary to ensure conformance with the specification requirements.

### Recycled AC

23. Recycled AC shall consist of reclaimed asphalt pavement, coarse aggregate, fine aggregate, mineral filler, asphalt cement, recycling agent, and approved additives, if required, of the qualities and in the proportions required.

## Properties of Aggregates, Bituminous Materials, and Recycled Asphalt Concrete

### New aggregates

24. Samples of each new aggregate to be used in the project will be furnished to the contracting officer at least 15 days prior to start of work.

Aggregates shall consist of aggregate contained in the reclaimed asphalt pavement and also include crushed stone, crushed gravel, crushed slag, screening, sand, and mineral filler, as required. The portion of materials retained on the No. 4 sieve shall be known as coarse aggregate, the portion passing the No. 4 sieve and retained on the No. 200 sieve fine aggregate, and the portion passing the No. 200 sieve as mineral filler. Aggregate gradation of the recycled mixture shall conform to gradation specified in Table A1.

Table A1  
Aggregate Gradation

<u>Sieve Size</u>	<u>Percent Passing</u>
3/4	100
1/2	80 - 98
3/8	73 - 91
No. 4	57 - 75
No. 8	44 - 62
No. 16	32 - 50
No. 30	22 - 40
No. 50	13 - 29
No. 100	7 - 19
No. 200	2 - 8

25. Coarse aggregate shall consist of clean, sound, durable particles meeting the following requirements:

- a. Percentage of loss shall not exceed 40 after 500 revolutions, as determined in accordance with ASTM C 131.
- b. The dry weight of crushed slag shall not be less than 75 pcf, as determined in accordance with ASTM C 29.
- c. Crushed gravel retained on the No. 4 sieve and each coarser sieve listed in Table A1 shall contain at least 75 percent by weight of crushed pieces having two or more fractured faces with the area of each face equal to at least 75 percent of the smallest midsectional area of piece. When two fractures are contiguous, angle between planes of fractures shall be at least 30 deg to count as two fractured faces.

- d. Particle shape of crushed aggregates shall be essentially cubical. Quantity of flat and elongated particles in any sieve size shall not exceed 20 percent by weight, when determined in accordance with CRD-C 119.

26. Fine aggregate shall consist of clean, sound, durable, angular particles produced by crushed stone, slag, or gravel that meet requirements for wear and soundness specified for coarse aggregate. Fine aggregate produced by crushing gravel shall have at least 90 percent by weight of crushed particles having two or more fractured faces in the portion retained on the No. 30 sieve. This requirement shall apply to material before blending with natural sand when blending is necessary. Quantity of natural sand to be added to the wearing- and intermediate-course mixtures shall not exceed 25 percent by weight of new aggregate added to the recycled mixture. Natural sand shall be clean and free from clay and organic matter.

#### Reclaimed Asphalt Pavement

27. Samples will be taken by the contracting officer to ensure the RAP can be met. The amount of reclaimed asphalt pavement used in the recycled mixture shall be between 40 and 50 percent.

#### Bituminous Materials

28. Samples of bituminous materials shall be obtained by the contractor; sampling shall be in accordance with ASTM D 140. Tests necessary to determine conformance with requirements specified herein will be performed by the contracting officer without cost to the contractor. Sources where bituminous materials are obtained shall be selected in advance of time when materials will be required in the work, and samples of the asphalt cement selected by the contractor shall be submitted for approval not less than 15 days before such material is required for use in the work. The asphalt cement selected shall meet the requirements of ASTM D 3381.

#### Asphalt Cement from Recycled Mixture

29. Asphalt cement recovered from the recycled asphalt mixture shall have a penetration of  $55 \pm 10$  (ASTM D 1856 and ASTM D 5).

## Recycled Asphalt Mixture

30. Sampling and testing will be accomplished by the contracting officer. Bituminous mixtures shall conform to requirements contained in paragraphs 32 through 35.

### Additives

31. The use of additives such as antistripping and antifoaming agents is subject to approval of the contracting officer representative.

### Proportioning of Mixture

#### General

32. The JMF for the bituminous mixture will be furnished the contractor by the contracting officer. No payment will be made for mixtures produced prior to the approval of the JMF. The formula will indicate the percentage of each aggregate and mineral filler, the percentage of reclaimed asphalt pavement, the percentage of bitumen, and the temperature of the completed mixture when discharged from the mixer. Tolerances are given in Table A2 for asphalt content, temperature, and aggregate grading for tests conducted on the mix as discharged from the mixing plant. The JMF may be adjusted by the contracting officer during construction to improve paving mixtures without adjustment in the contract unit prices.

Table A2  
Job-Mix Tolerances

<u>Material</u>	<u>Tolerance, Plus or Minus</u>
Aggregate passing No. 4 sieve or larger	5 percent
Aggregate passing Nos. 8, 16, 30, and 50 sieves	4 percent
Aggregate passing Nos. 100 and 200 sieves	2 percent
Bitumen	0.30 percent
Temperature of mixing	25° F

Test properties of recycled asphalt mixtures

33. Finished mixture shall meet requirements described below when tested in accordance with MIL-STD-620. All samples will be compacted with 50 blows of specified hammer on each side of sample. When recycled mixtures fail to meet the requirements specified below, the paving operation shall be stopped until the cause for noncompliance is determined and corrected.

34. Requirements for stability, flow, and voids are shown in Table A3 for nonabsorptive aggregates.

Table A3  
Nonabsorptive-Aggregate Mixture

	<u>Wearing Course</u>
Stability minimum, pounds	500
Flow maximum, 1/100-inch units	20
Voids total mix, percent	3-5
Voids filled with bitumen, percent	75-85

The apparent specific gravity or ASTM D 2041 will be used in computing voids total mix and voids filled with bitumen, and the mixture shall meet requirements in Table A3.

The contracting office may permit deviation from limits specified for voids filled with bitumen in the wearing course in order to stay within limits for percent voids total mix.

35. The index of retained stability must be greater than 75 percent as determined by MIL-STD-620, Method 104. When the index of retained stability is less than 75, the aggregate stripping tendencies may be countered by the use of hydrated lime or by treating the bitumen with an approved antistripping agent. The hydrated lime is considered as mineral filler and should be considered in the gradation requirements. The amount of hydrated lime or antistripping agent added to the bitumen shall be sufficient to produce an index of retained stability of not less than 75 percent. No additional

payment will be made to the contractor for addition of antistripping agent required.

## Execution

### Conditioning of existing pavement

36. Damage to in-situ material caused by the milling operation or any damage occurring after the milling operation shall be repaired prior to placement of recycled mixture.

### Grade control

37. Lines and grades shown on contract drawings for each pavement category of contract shall be established and maintained by means of line and grade stakes placed at site of work by the contractor in accordance with the special provisions. Elevations of bench marks used by the contractor for controlling pavement operations at the site of work will be determined, established, and maintained by the Government. Finished pavement elevations shown shall be established and controlled at the site by work by the contractor in accordance with bench mark elevations furnished by the contracting officer.

### Preparation of bituminous mixtures

38. Aggregates, reclaimed asphalt pavement, mineral filler, bitumen, and recycling agent shall be conveyed into the mixer in proportionate quantities required to meet the JMF. Particles larger than 2 in. shall be removed from the reclaimed asphalt pavement prior to being added to the mixer. Mixing time shall be as required to obtain a uniform coating of the aggregate with the bituminous material. Temperature of aggregate and mineral filler in the mixer shall not exceed 325° F when bitumen is added. Overheated and carbonized mixtures or mixtures that foam shall be rejected.

### Water content of aggregates

39. Drying operations shall reduce the water content of mixture to less than 0.75 percent. Water content test will be conducted in accordance with ASTM D 2216; weight of sample shall be at least 500 grams.

### Storage of bituminous paving mixture

40. Storage of bituminous paving mixture shall conform to the applicable requirements of ASTM D 3515; however, in no case shall the mixture be stored for more than 4 hours.

Transportation of  
recycled asphalt mixture

41. Transportation from paving plant to site shall be in trucks having tight, clean, smooth beds lightly coated with an approved releasing agent to prevent adhesion of mixture to truck bodies. Excessive releasing agent shall be drained prior to loading. Each load shall be covered with canvas or other approved material of ample size to protect mixture from weather and prevent loss of heat. Loads that have crusts of cold, unworkable material or have become wet will be rejected. Hauling over freshly placed material will not be permitted.

Placing

42. Recycled asphalt mixtures shall not be placed without ample time to complete spreading and rolling during daylight hours, unless approved satisfactory artificial lighting is provided.

- a. Surface preparation of underlying course. Prior to placing the recycled mixture, the underlying course shall be cleaned of all foreign or objectionable matter with power brooms and hand brooms.
- b. Spraying contact surfaces of structures. Contact surfaces of previously constructed pavement, curbs, manholes, and similar structures shall be sprayed with a thin coat of bituminous material conforming to Bituminous Tack Coat.
- c. General requirements for use of mechanical spreader. Range of temperatures of mixtures, when dumped into the mechanical spreader, shall be as determined by the contracting officer. Unless otherwise specified, mixtures having temperatures less than 225°F when dumped into the mechanical spreader will be rejected. The mechanical spreader shall be adjusted and the speed regulated so that the surface of the course being laid will be smooth and continuous without tears and pulls, and of such depth that, when compacted, the surface will conform to the cross section indicated. Placing of mixture shall be as nearly continuous as possible, and speed of placing shall be adjusted, as directed, to permit proper rolling. When segregation occurs in the mixture during placing, the spreading operation shall be suspended until the cause is determined and corrected.
- d. Placing strips succeeding initial strips. In placing each succeeding strip after initial strip has been spread and compacted as specified below, the screed of the mechanical spreader shall overlap the previously placed strip 2 to 3 in. and be sufficiently high so that compaction produces a smooth dense joint. Mixture placed on edge of previously placed strip by the mechanical spreader shall be pushed back to the edge of the strip being placed by use of a lute. Excess mixture shall be removed and wasted.

- e. Handspreading in lieu of machine spreading. In areas where use of the machine spreading is impractical, the mixture shall be spread by hand. Spreading shall be in a manner to prevent segregation. The mixture shall be spread uniformly with hot rakes in a loose layer of thickness that, when compacted, will conform to required grade, density, and thickness.

#### Compaction of mixture

43. Sufficient rollers (size, type, and number) shall be furnished to obtain the specified compaction. Rolling shall begin as soon after placing as mixture will bear roller without undue displacement. Delays in rolling freshly spread mixture will not be permitted. After initial rolling, preliminary tests of crown, grade, and smoothness shall be made by the contractor. Deficiencies shall be corrected so that finished course will conform to requirements for grade and smoothness specified herein. After the contractor assures himself of meeting crown, grade, and smoothness requirements, rolling shall be continued until a density of 95 to 100.0 percent of density of laboratory-compacted specimens of the same mixture is obtained. Places inaccessible to rollers shall be thoroughly compacted with hot hand tampers. Minimum rolling equipment required includes a 10-ton steel wheel roller and a 15-ton rubber tire roller capable of the inflation pressures of 90 psi.

- a. Testing of mixture. At the start of plant operation, a quantity of mixture shall be prepared sufficiently to construct a test section at least 50 ft long and two spreader widths wide. Mixture shall be placed, spread, and rolled with equipment to be used in the project and in accordance with requirements specified above. This test section shall conform to all specified requirements. If test results are satisfactory, the test section may remain in place as part of the completed pavement. If tests indicate that the pavement does not conform to specification requirements, necessary adjustments to plant operations and rolling procedures shall be made. Additional test sections, as required, shall be constructed and sampled for conformance to specification requirements. In no case shall the contractor start full production of recycled asphalt mixture without approval.
- b. Correcting deficient areas. Mixtures that become contaminated or are defective shall be removed to the full thickness of course. Edges of the area to be removed shall be cut so that sides are perpendicular and parallel to direction of traffic and so that edges are vertical. Edges shall be sprayed with bituminous materials meeting the requirements for SS-1 or CSS-1 in ASTM D 977 or D 2397. Fresh paving mixture shall be placed in the excavated areas in sufficient quantity so that finished surface will conform to grade and smoothness requirements. Paving mixture shall be compacted to the density specified

herein. Skin patching of an area that has been rolled shall not be permitted.

## Joints

### General

44. Joints between old and new pavements or between successive days' work, or joints that have become cold (less than 175°F) shall be made to ensure continuous bond between old pavement or previous paving lane and the new paving lane. All joints shall satisfy grade and smoothness requirements specified for pavement. Contact surfaces of previously constructed pavements coated by dust, sand, or other objectionable material shall be cleaned by brushing or shall be cut back as directed. The surface against which new material is placed shall be sprayed with a thin, uniform coat of bituminous tack coat material. Material shall be applied far enough in advance of placement of fresh mixture to ensure adequate curing. Care shall be taken to prevent damage or contamination of the sprayed surface.

### Transverse joints

45. The roller shall pass over the unprotected end of a strip of freshly placed material only when placing is discontinued or delivery of mixture is interrupted to the extent that material in place may become cold. In all cases, prior to continuing placement, the edge of previously placed pavement shall be cut back to expose an even vertical surface for the full thickness of the course. In continuing placement of strip, the mechanical spreader shall be positioned on the transverse joint so that sufficient hot mixture will be spread to obtain a joint after rolling that conforms to required density and smoothness specified herein.

### Longitudinal joints

46. Edges of a previously placed strip shall be prepared such that the pavement in and immediately adjacent to the joint between this strip and the succeeding strip meets the requirements for grade, smoothness, and density.

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