TA7
W34m
no.
GL-92-30

FEAP-UG-92/13
September 1992

MP GL-92-30

FEAP

FACILITIES ENGINEERING
APPLICATIONS PROGRAM

USER'S GUIDE

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

by

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

Innovative Ideas for the Operation, Maintenance, & Repair of Army Facilities

2805-4547

TA7 W34m no.GL-92-30

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1992

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
User's Guide: Cold-Mix Recycling of Asphalt Concrete Pavements

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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3909 Halls Ferry Road
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8. PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper GL-92-30

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers
Engineering and Housing Support Center
Bldg. 2593
Fort Belvoir, VA 22060-5516

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
FEAP-UG-92/13

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This guide provides the technical information required to implement the application of cold-mix recycling of asphalt concrete pavements. Included are details on areas on application, benefits/advantages, limitations/disadvantages, and costs associated with this technology. Information is provided on two demonstration sites at Fort Gillem, Georgia, and Fort Leavenworth, Kansas. Also provided is information concerning funding, procurement, maintenance, and performance monitoring. A fact sheet on recycling, contract specification example, and references are provided in the appendixes.

14. SUBJECT TERMS
See reverse

15. NUMBER OF PAGES
29

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

14. (Concluded).

Asphalt pavement recycling	Emulsified asphalt cement
Cold milling	In-place cold-mix asphalt recycling
Cold-mix asphalt recycling	Recycling of asphalt

CONTENTS

COLD-MIX RECYCLING OF ASPHALT CONCRETE PAVEMENTS

PART I: INTRODUCTION

Description

1. Asphalt pavement recycling involves reusing the asphalt concrete pavement material to rehabilitate and/or strengthen the pavement structure. The cold-mix recycling process involves first breaking up and pulverizing the pavement in-place or removing the recyclable asphalt pavement (RAP) to a central plant for crushing. Second, the RAP material is modified by the addition of emulsified asphalt, water, and/or aggregates as required. The RAP material is then placed and compacted to the specified density. The construction equipment required is readily available within the pavement construction industry.

Application

2. The use of cold-mix recycled asphalt concrete is applicable to any pavement structure. Cold-mix recycled pavements have the capability to decrease or minimize reflective cracking. A cold-mix recycled asphalt mixture should be used as an intermediate course, requiring a wearing course or surface treatment over it for most pavement applications. However, it can be used as a surface course on low volume roads and similar applications. Areas with load related pavement distress can be repaired prior to recycling or in conjunction with the cold-mix recycling, provided the cause for the distress is corrected.

Benefits

3. Cold-mix recycling allows the reuse of existing pavement materials resulting in the conservation of existing resources. The resources conserved include aggregate and petroleum resources, and fuels from reduced transportation and processing requirements (no heating of materials required). The reuse of the existing asphalt concrete pavement materials also eliminates the

problem of disposal which can be an environmental as well as an economic concern.

Limitations

4. A cold-mixed recycled pavement should, in most instances, have a wearing surface applied to it. The recycled pavement will normally require form 3 to 30 days to cure before a wearing surface or another recycled layer is placed on top. The strength developed in the cold-mix recycled pavement will typically be slightly less than that of a conventional new asphalt concrete pavement.

Costs

5. There is usually a cost savings associated with cold-mix recycling versus conventional virgin asphalt concrete. Cost savings encountered have ranged from 10 to 30 percent. The effective useful life of cold-mix recycled asphalt pavements and those reconstructed with new materials should be almost equal. The majority of the cost savings are achieved during the construction process as fuel and material savings.

Recommendations for Use

6. Cold-mix recycling of asphalt concrete pavements is recommended for use in any location where an existing asphalt pavement requires reconstruction. It should be considered for both its environmental benefits and the cost benefit advantage. The available Corps of Engineers 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:

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b. US Army Engineering and Housing Support Center:

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8. Points of contact at Fort Gillem, Georgia; Fort Leavenworth, Kansas; and Fort Benjamin Harrison, Indiana where the Facilities Engineering Applications Program (FEAP) cold-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
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b. Chief, Engineering Division, DEH
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c. Commander
US Army Soldier Support Center
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Building 28
Fort Benjamin Harrison, IN 46216-5450
Telephone: 317-549-5417

PART II: PREACQUISITION

Description of Cold-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 pavement materials to increase.

10. With the significant increase in the cost of pavement materials and a growing shortage of good 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 pavement recycling 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. The US Air Force specifies or allows as an alternative, recycling techniques to rehabilitate and/or strengthen its pavements. The 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. This document also states that the recycling evaluation must be included in the "Decision Analysis" document submitted for MACOM or DA approval.

12. Cold-mix recycling involves reusing most or all of the existing bituminous pavement structure by reducing it to a maximum particle size of 1 to 1 1/2 in. blending with virgin materials, if needed, and using the mixture as a pavement material. Appendix B contains a fact sheet describing pavement recycling.

Application

13. Cold-mix recycling should be considered when a pavement has deteriorated to a point where its use is more economical than a conventional overlay or where an overlay is prohibited by existing grades. Cold-mix recycling can be used as a surface course on secondary roads and as a base course for high quality pavements.

Limitations/Disadvantages

14. In most cases, cold-mix recycling will require or at least benefit from the application of a wearing surface on top of the recycled material. The wearing surface will prevent the recycled surface from raveling or eroding under traffic or water drainage. The quality of the recycled mixture will depend on the type and quality of the asphalt pavement and aggregates making up the mixture.

15. Weather conditions such as temperature, humidity, and potential rainfall are factors to consider when scheduling a cold-mix recycling paving project. Another important consideration is the relatively long disruption to the normal traffic flow during construction. Limited trafficking on a recycled pavement during the cure period (usually 5 to 7 days) may be possible.

FEAP Demonstration/Implementation Sites

Installation	Date	Remarks
Fort Gillem, GA	FY84	Flankers Road, a two-lane road 24 ft wide by 2,500 ft long serves as a commercial vehicular truck entrance. It was cold mix recycled to a depth of 8 in. Surfaced with 2 in. of hot mix asphalt concrete 6 months after completion of recycling.
Fort Gillem, GA	FY85	Recreation roads and warehouse roads were cold-mix recycled and surfaced with a double bituminous treatment.

Installation	Date	Remarks
Fort Leavenworth, KS	FY86	5th Artillery Road had 4 in. of asphalt concrete removed by cold-milling in two 2-in. lifts. The remaining pavement structure was then cold-mix recycled. The pavement was then surfaced with 2 in. of hot-mix asphalt concrete.

Life-Cycle Costs and Benefits

16. 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. Cold-mix recycling is accomplished by the in-place recycling process or by removing the old pavement materials and transporting to a central plant for processing. The in-place process has the advantage that minimal transportation of the material is required and greater cost savings are produced, whereas the advantage of the central plant process is that a more consistent mix is obtained. Both procedures have been used with success.

17. A tangible benefit of using the in-place cold-mix recycling process is that a recycled quality base course can be produced which will be stronger and more durable than the original. Also, by using the in-place recycling process, the cracks in the old pavement are removed, reducing the possibility of reflective cracking in the newly constructed pavement.

18. An intangible benefit of both processes is the elimination of disposal of the old pavement in the local landfill. Another intangible benefit is the conservation of natural resources by reusing the old pavement in the construction of the new pavement.

Costs

19. The cost reduction or savings involved in cold-mix recycling will vary with the location, materials, and contractor involved in the project. A cost comparison of cold-mix recycling a structurally failed pavement versus removal and replacement with a new asphalt concrete pavement was developed for the cold-mix recycling demonstration at Fort Gillem, Georgia. The cost for the recycling option included cold-mix recycling 6 in. of asphalt concrete

pavement and base course material and overlaying with 4 in. of new hot mix for $12.36 per sq yd. The cost for removing the low quality base course material and providing a high quality 6 in. base course with a 4-in. new hot mix overlay was $15.55 per sq yd. This resulted in a savings of $3.19 per sq yd or a 21 percent cost savings, using the cold-mix recycling option.

Advantages/Benefits

20. Some tangible benefits of using the cold-mix recycling process include eliminating or minimizing the possibility of reflective cracking, reestablishing the pavement surface to the desired grade, and minimal transportation of materials. The intangible benefits included the elimination of dumping 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

21. Typically, installations fund the implementation of pavements and railroads technologies from their annual budgets. However, the installations annual budget is usually underfunded, and the pavement and railroad 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

22. Components of the technology which must be procured for the use of cold-mix recycling of asphalt concrete pavement are section design (may be in-house or contracted out) to include plans and specifications and a contractor to perform all phases of the recycling process. Cold-mix recycling utilizes equipment which is widely available in the pavement construction industry. Cold milling machines, graders, and rollers are widely available. Many cold-mix recycling operations use portable pulvermixing units which are used to break up and mix the recycled material with any added materials. The units are manufactured by several equipment makers and are widely available. Many contractors have had at least some experience with some form of cold-mix recycling. The Corps of Engineers has guide specifications and design and construction manuals covering (TM 5-822-8 and TM 5-822-10) (Headquarters, Departments of the Army and the Air Force 1987, 1988) the use of cold-mix recycling of asphalt concrete pavement.

Procurement Documents

23. Applicable Specifications are listed below:

- a. CEGS-02552, Bituminous Binder and Wearing Courses (Central Plant Cold-Mix), August 1982.
- b. CEGS-02554, Bituminous Road-Mix Surface Course, March 1983.
- c. CEGS-02591, Cold Mix Recycling, September 1984.
- d. CEGS-02598, Cold Milling of Bituminous Pavements, September 1984.

24. GSA Listing:

None

25. Vendors List and Recent Prices:

Local contractors who have the capability.

Procurement Scheduling

26. 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 to 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

27. The equipment required for cold-mix recycling will depend on the method used to remove/loosen, process, and place the recycled material. The equipment used to remove/loosen the existing pavement can be either a cold milling machine, pulvermixer, or conventional equipment used for ripping and crushing the recyclable asphalt pavement (RAP). Processing and placement equipment can include various combinations of central plants, mix-in-place traveling plants, conventional pavers, graders, and pulvermixers. Conventional paving equipment that is normally used with any method of recycling includes water trucks, distributors, haul trucks, brooms, rollers, and front end loaders.

Materials

28. The materials required for cold-mix recycling will vary according to project conditions. The amount of each material required will depend on the amount of RAP material to be used and final material properties desired in the recycled pavement. Additional asphalt cement is normally added in the form of an emulsified asphalt, although a cutback asphalt cement may be used. Additional aggregates may be added, if required, with the gradation of the aggregates added based on the final gradation desired for the recycled pavement. The final gradation should meet the requirements given in TM 5-822-8 (Headquarters, Departments of the Army and the Air Force 1987) according to pavement usage.

Personnel

29. Personnel involved in the construction of a cold-mix recycled asphalt pavement will be the same as those normally involved in conventional asphalt concrete pavement construction. The only additional personnel that are used to produce and place a recycled mix versus a conventional virgin mix are those employed on a milling machine or those on a break-up and crush operation along with transportation, when appropriate, to a central asphalt concrete plant. The quality control required for the recycling can be easily handled by any commercial testing laboratory qualified for conventional asphalt concrete testing. For the FEAP demonstrations, the quality control

testing was performed by personnel from the US Army Engineer Waterways Experiment Station.

Procedure

30. Given the need for pavement rehabilitation, the option of cold-mix recycling should be based on consideration of 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 asphalt concrete overlay.

b. Existing curb and gutter system which can be maintained with the use of cold-mix recycling.

c. Need to reestablish drainage pattern on roadways and around structures.

d. Pavement structure containing isolated or extensive areas of base failure.

e. A weathered/oxidized pavement surface that is experiencing raveling.

f. The need to provide increased load-carrying capacity to a distressed pavement.

g. The quality of the existing pavement material is lower than that required for hot recycling.

31. With one or more of these conditions existing, the option of cold-mix recycling may be a cost effective method of rehabilitation. The selection of recycling versus a new asphalt concrete mix should be based on providing pavement structures of equal capabilities with regard to preventing reflective cracking and maintaining existing structures and drainage systems.

32. Cold-mix recycling can either be accomplished by in-place processing or by removing the existing pavement and taking it to a central plant for processing. Within these two methods there are various procedures and equipment used to accomplish the same task.

33. The in-place cold-mix recycling method will involve the following construction procedures:

a. The asphalt pavement can be broken up with a pulvermixer or cold milled and left in place.

b. Any additives such as water, asphalt (normally emulsified asphalt), or additional aggregates should then be added to the RAP. These additives should be thoroughly combined, usually with a pulvermixer or by blading with a grader.

c. The RAP material is then final graded as required and compacted.

34. The central plant cold-mix recycling method will involve the following construction procedures:

- a. The asphalt pavement can be broken up as stated above or with a dozer and ripper blade and then transported to a central plant.
- b. If required, the RAP is reduced to the required particle size by passing it through a crusher. The required additives are then combined in the mixing plant and the material is transported back to the jobsite.
- c. The RAP material is then placed at final grade with a paver or with a grader as required and compacted.
- d. The central plant should be used when large amounts (more than 10 percent) of new aggregates are required for the RAP mixture.

35. The mix design will be based on the properties of the RAP material, additional binder required, and additional aggregates, if required. The mix design involves first determining the total asphalt content required for the recycled mix, when tested as a conventional asphalt hot mix. The additional asphalt required is then the total required minus the existing amount in the RAP. The final determination is the amount of water required to achieve the highest possible density. The water contained in the emulsified asphalt added to the mix must be considered as part of the water added or existing in the recycled mixture.

36. The quality control and quality assurance methods used for cold-mix recycled asphalt are different from that of other asphalt mixes in the following ways:

- a. The maximum theoretical density (MTD) is determined by the use of ASTM D 2041. The field density required is based on a percentage of this MTD. The percent MTD required will normally range from 84 to 90 percent, depending on the recycled mixture and the pavement usage.
- b. There is normally a curing period involved with a cold-mix recycled pavement. This curing period will vary with the material properties of the mix and the climatic conditions present during the curing period. The curing period can vary from 3 to 30 days. This curing period should be completed before the pavement is overlaid or sealed.
- c. Obtaining field cores for density determination with a standard coring drill may not be possible as the samples will tend to fall apart. A nuclear gage can be used, provided that it has been calibrated for the recycled material with a series of sand cone or water balloon density tests. It may be possible to dry cut block samples of the pavement for a density determination.

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

Operation and Maintenance

38. Operations and maintenance over a cold-mix recycled asphalt pavement are no different than those over a pavement constructed on conventional asphalt concrete intermediate courses. This is true in instances where the recycled pavement is overlaid or receives a surface treatment.

39. Cold-mix recycled pavements used on low volume roads do not always require an overlay. However, these pavements, depending on the materials used, may be more susceptible to raveling from traffic and weather effects.

40. Cold-mix recycled pavements generally gain strength as they cure and can produce strong and stable pavements. The material will provide a base course material with improved properties over a conventional crushed stone base course or a low volume road surface with lower maintenance requirements than that of conventional aggregate surfaces.

41. Cold-mix recycled pavements can be trafficked until a wearing surface can be applied. Minor maintenance may be required depending on traffic levels and weather conditions.

Service and Support Requirements

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

Performance Monitoring

43. Installation personnel can monitor and measure the performance of the cold-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

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 the Air Force. 1988 (Aug). "Standard Practice for Pavement Recycling," Technical Manual TM 5-822-10/AFM 88-6, Chap. 6, Washington, DC.

__________. 1987 (Jul). "Bituminous Pavements Standard Practice," Technical Manual TM 5-822-8/AFM 88-6, Chap. 9, Washington, DC.

Lynch, L. N. and Lewandowski, L. H. 1991 (Apr). "In-Place Cold Mix Recycling of Asphalt Pavements," Video Report GL-91-2, 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,
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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 FTAT 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. Vollor 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 Mix Recycling

Applicable publications

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

a. Military Standards (MIL. STD.):

MIL-STD-620A	Test Methods for Bituminous Paving Materials

b. American Society for Testing and Materials (ASTM) Publications:

D 140-70 (R 1981)	Sampling Bituminous Materials
D 977-80	Emulsified Asphalt
D 2041-78	Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures
D 2397-79	Cationic Emulsified Asphalt

Mixing plant

48. The mixing plant (travel or fixed) shall be designed, coordinated, and operated to produce mixture within the JMF. The plant shall be equipped with positive means to control the amount of additional asphalt, water, and time of mixing. Time of mixing shall be the interval between the time the bituminous material and/or water is spread on the aggregate and the time the same aggregate leaves the mixing unit.

Weather limitations

49. A recycled cold mix course shall not be constructed in rain or on a layer which contains free water either within the layer or on its surface. Recycled cold mix course shall not be placed when the air temperature is less than 50°F.

Grade control

50. The finished and completed surface shall conform within 0.05 ft to lines, grades, cross section, and dimensions shown. Lines and grades, as indicated, will be maintained by means of line and grade stakes placed by the contractor at site of the work.

Surface-smoothness requirements

51. The surface of the finished pavement shall be checked longitudinally and transversely with a 10-ft straightedge. The straightedge shall be placed parallel to the center line of each lane paved, at intervals over the

width of the surface. The straightedge shall also be placed perpendicular to the center line of each lane paved, at intervals over the length of the surface. The finished surface of the pavement shall not deviate more than 3/8 in. from the 10-ft straightedge. Surface irregulars exceeding this tolerance shall be corrected without additional cost to the Government.

Straightedge

52. The contractor shall furnish and maintain at the site, in good condition, one straightedge for each bituminous paver, 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.

Sampling pavements and mixtures

53. Type, size, number, and location of samples will be determined by the contracting officer. The contractor shall furnish all tools, labor, and materials for obtaining samples and refilling sample locations. All tests necessary to determine conformance to specified requirements will be conducted by the contracting officer.

Access to plant and equipment

54. The contracting officer shall have access at any time to all parts of the paving plant for checking adequacy of equipment in use; inspecting operation of plant; and verifying weights, proportions, and character of material.

Measurement

55. Cold-mix recycling paid for will be the number of square yards of accepted work. When bituminous material is used, the unit of measurement shall be the gallon as specified in the schedule. Gallonage paid for shall be the number of gallons of bituminous material used in the accepted work. Gallonage shall be determined either by measuring material at a temperature of 60°F or by correcting gallonage measured at another temperature to gallons at 60°F, using a coefficient of expansion of 0.00025 per deg Fahrenheit for emulsified asphalt. The yardage of approved new aggregate to be paid for shall be the number of cubic yards used in the completed and accepted surface course.

Payment

56. The quantities of bituminous materials and paving mixtures, determined as provided above, will be paid for at respective contract unit prices

per square yard for bituminous mixture, per gallon for bituminous materials, and per cubic yard for new aggregate. Payment shall constitute full compensation for preparing or reconditioning existing pavement; furnishing all materials, plant equipment, and tools; improving unsatisfactory areas; and labor and incidentals necessary to complete work required. If deficiencies in the finished product exceed requirements specified, no payment will be made for such areas of pavement until the defective areas are corrected.

Products

Aggregates

57. Aggregates shall consist of a mixture of aggregates salvaged from the roadbed and of new material as directed by the contracting officer.

Aggregate quality and gradation

58. Aggregates for bituminous mixture shall be of such size that the material can be spread to the desired thickness and compacted to meet the specified smoothness, grade, and density requirements. The reclaimed material shall be handled in such a manner to prevent segregation and degradation.

Bituminous materials

59. Bituminous materials shall be asphalt Type SS-1 or type CSS-1 conforming to ASTM D977 or ASTM D2397. Sampling and testing of bituminous materials shall be the responsibility of the contractor. Sampling shall be in accordance with ASTM D 140 for bituminous material, unless otherwise directed. Tests shall be performed on each batch of bituminous material to ensure that materials meet specified requirements. Copies of test results shall be furnished to the contracting officer.

Job-mix formula

60. No cold recycled mixture shall be produced until a JMF has been given the contractor by the contracting officer. The formula will indicate a definite percentage of water and asphalt to be added to the mixture. The JMF will be allowed an asphalt content tolerance of 0.4 percent. The asphalt content may be adjusted by the contracting officer to improve paving mixture, without adjustment in contract unit price. When asphalt is added, the optimum asphalt content will be selected to provide the following properties when samples are compacted at 250°F with 50 blows of standard Marshall hammer on each side of the specimen.

Property	Requirement
Voids in total mix, percent	3-5
Voids filled with asphalt, percent	75-85
Stability, pounds	500 minimum
Flow, 0.01 inch	20 maximum

The water content will be selected to provide maximum density when samples are prepared at the optimum asphalt content and compacted with 50 blows of Marshall hammer at ambient temperature.

Execution

Preparation of bituminous mixtures

61. Aggregates, asphalt emulsion, and water shall be mixed as necessary to thoroughly coat all particles with bituminous material.

Placing

Layer thickness and curing

62. Each layer of compacted mixture shall be no more than 3 in. in compacted thickness; each layer shall be allowed to cure for at least 5 days before placing a succeeding layer.

Spraying of contact surfaces of structures

63. Contact surfaces of previously constructed pavement, curbs, manholes, and similar structures shall be sprayed with a thin coat of bituminous material.

Use of mechanical spreader

64. The cold recycled mixture shall be spread so that the surface of the course being laid will be smooth and continuous and of such depth that, when compacted, the surface will conform to the grade, density, and smoothness requirements. The contractor shall establish and place lines parallel to the center line of the area to be paved for the spreading machine to follow. Placing of mixture shall be as nearly continuous as possible.

Shoveling, raking, and
tamping after spreading

65. A sufficient number of shovelers and rakers shall follow the spreading machine raking and adding mixture as required to obtain a course that, when completed, will conform to all specified requirements. Broadcasting or fanning of mixture over areas being compacted will not be permitted. When segregation occurs in the mixture during placement, the spreading operation shall be suspended until the cause is determined and corrected. After trimming, edges of the course shall be thoroughly compacted by tamping laterally with a metal lute. Distortion of the course during tamping will not be permitted.

Hand spreading in
lieu of machine spreading

66. In areas where use of machine spreading is impractical, mixture shall be spread by hand. Mixture will be dumped, distributed into place, and spread with rakes in a uniformly loose layer of such thickness that, when compacted, will conform to the required grade, density, and thickness. During hand spreading, each shovelful of mixture shall be carefully placed by turning the shovel over in a manner to prevent segregation. In no case shall mixture be placed by throwing or broadcasting.

Compaction of mixture

67. Compaction of the mixture shall be conducted such that density, grade, and smoothness requirements are satisfied. For bituminous mixtures rolling shall continue until all roller marks are eliminated and a density of at least 86 percent of the theoretical maximum density (MIL-STD-620, Method 101 or ASTM D 2041) has been obtained. Laboratory test specimens are to be prepared from uncompacted mix taken from the pavement immediately prior to field compaction. Samples of mix will be heated and compacted at 250°F with 50 blows on each side of the specimen to evaluate the satisfactoriness of the mixture. Minimum rolling equipment required includes a 10-ton steel-wheel roller and a 15-ton rubber-tire roller capable of tire inflation pressures of 90 psi.

a. Operation of rollers and tampers. The speed of the rollers shall be slow enough at all times to avoid displacement of mixture. Displacement of the mixture occurring as the result of reversing the direction of the roller, or from any other cause, shall be corrected by the use of rakes and fresh mixture applied or removed, where necessary. Alternate trips of the roller shall be of slightly different lengths. During rolling, wheels of steel-wheeled and rubber-tired rollers shall be moistened, if necessary, to prevent adhesion of the mixture to the wheels, but excess water will not be permitted. The contractor shall furnish additional rollers or improve rolling techniques if the pavement density specified is not obtained. Rollers shall be operated by competent and experienced operators. Rollers will not be permitted to stand on finished courses until courses have been cured 5 days. In all places not accessible to rollers, the mixture shall be thoroughly compacted with hand tampers as specified herein.

b. Correcting deficient areas. Mixture that becomes contaminated with foreign material or is defective in any way shall be removed. Skin patching of an area that has been rolled will not be permitted. Holes of the full thickness of the course shall be cut so that the sides are perpendicular and parallel to the direction of traffic and the edges are vertical. Fresh paving mixture shall be placed in holes in sufficient quantity so that the finished surface will conform to grade and smoothness requirements. Paving mixtures shall be aerated, if necessary, and shall be compacted to the density specified herein. The contractor shall provide competent workmen capable of performing all work incidental to the correction of deficiencies and defects.

Joints

68. Joints shall present the same texture, density, and smoothness as other sections of the course. Joints between old and new pavements or between successive days' work shall be made carefully to ensure continuous bond between old and new sections of the course.

a. Transverse joints. The roller shall pass over the unprotected end of freshly laid mixture only when laying of the course has been discontinued. The edge of the previously laid course shall be cut back to expose even, vertical surface for the full thickness of the course. The fresh mixture shall be raked against the joints, thoroughly tamped, and then rolled.

b. Longitudinal joints. When edges of the longitudinal joints are irregular, honeycombed, or poorly compacted, the joint shall be cut back to expose an even, vertical surface for the full thickness of the course.

Edges of pavement

69. Edges of pavement shall be straight and true to required lines. After final rolling, excess material shall be cut off square and disposed of as directed.