THE USE OF RECYCLED ASPHALT PAVEMENT IN TEXAS

DHT-26

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16. Abstract

The Texas State Department of Highways and Public Transportation (SDHPT) has continued to increase the use of recycled and reused pavement as these methods have become more cost effective. In the last twenty years, the SDHPT has recycled over three million tons of pavement. Reclaimed asphaltic concrete pavement (RAP) that is not recycled for base courses or surface courses is reused in many ways, mostly by department maintenance forces. Mailbox turnouts, driveways, shoulders, level-up material for ruts and pavement edges, and slope protection around pipe ends on driveways are some of the common and effective maintenance uses of RAP.

The SDHPT has used several methods to recycle pavement: cold in-place, hot in-place, and plant recycling. Recycling in the plant has yielded the most consistent results over time. Hot in-place recycling has worked extremely well in some cases, but the performance of cold in-place recycling was unsatisfactory.

The availability and quality of the current recycling technology is not consistent enough to always meet the stringent requirements of the SDHPT. Due to these extreme variations, the recycling of pavement remains an engineering and economic decision to be made with careful consideration. As the level of technology meets the level of performance required for durable highways, the use of recycled material will increase from the sizeable quantity used to date.

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Prepared by the

Transportation Planning Division
Research Section

of the

Texas State Department of Highways
and Public Transportation

April 1991

ABSTRACT

The Texas State Department of Highways and Public Transportation (SDHPT) has continued to increase the use of recycled and reused pavement as these methods have become more cost effective. In the last twenty years, the SDHPT has recycled over three million tons of pavement. Reclaimed asphaltic concrete pavement (RAP) that is not recycled for base courses or surface courses is reused in many ways, mostly by department maintenance forces. Mailbox turnouts, driveways, shoulders, level-up material for ruts and pavement edges, and slope protection around pipe ends on driveways are some of the common and effective maintenance uses of RAP.

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DISCLAIMER

LIST OF TERMS USED

Aggregate – crushed stone, sand, and gravel.

Base – the layer or layers of selected material to support a surface course.

Cold In-Place Recycling – process in which the old pavement is milled, crushed and sized, mixed, combined with rejuvenating agents, and placed as pavement.

Flushing (or Bleeding) – identified by a film of asphalt on the pavement that creates a shiny surface.

Hot In-Place Recycling – process in which the old pavement is heated, scarified, remixed, combined with additional fresh aggregate or hot mix asphaltic concrete, and placed as pavement.

Plant recycling – process which occurs inside a batch or drum mix plant in which virgin aggregate is heated and then combined with reclaimed asphaltic concrete pavement prior to placement of new pavement.

RAP – reclaimed asphalt concrete pavement.

Raveling – the wearing away of the pavement surface caused by the dislodging of aggregate particles.

Reclaimed Material– material that has been milled or planed with no heat processing.

Recycled Material – material that has undergone a change in chemical composition, through heat or chemical reaction.

Reflective Cracking – cracks in the top layer of the road caused when existing cracks from lower layers propagate upward.

Rutting – grooves or channels in the wheelpath.

Scarify – to break up and loosen the surface.

Seal Coat – an asphaltic surface of one or more applications of asphalt binder and cover aggregate used to seal an existing paved surface.

Stripping – separation of asphalt films from aggregate particles in the presence of moisture.

Surface Course – the top-most layer of the roadway.

Virgin Material – new, unused material.

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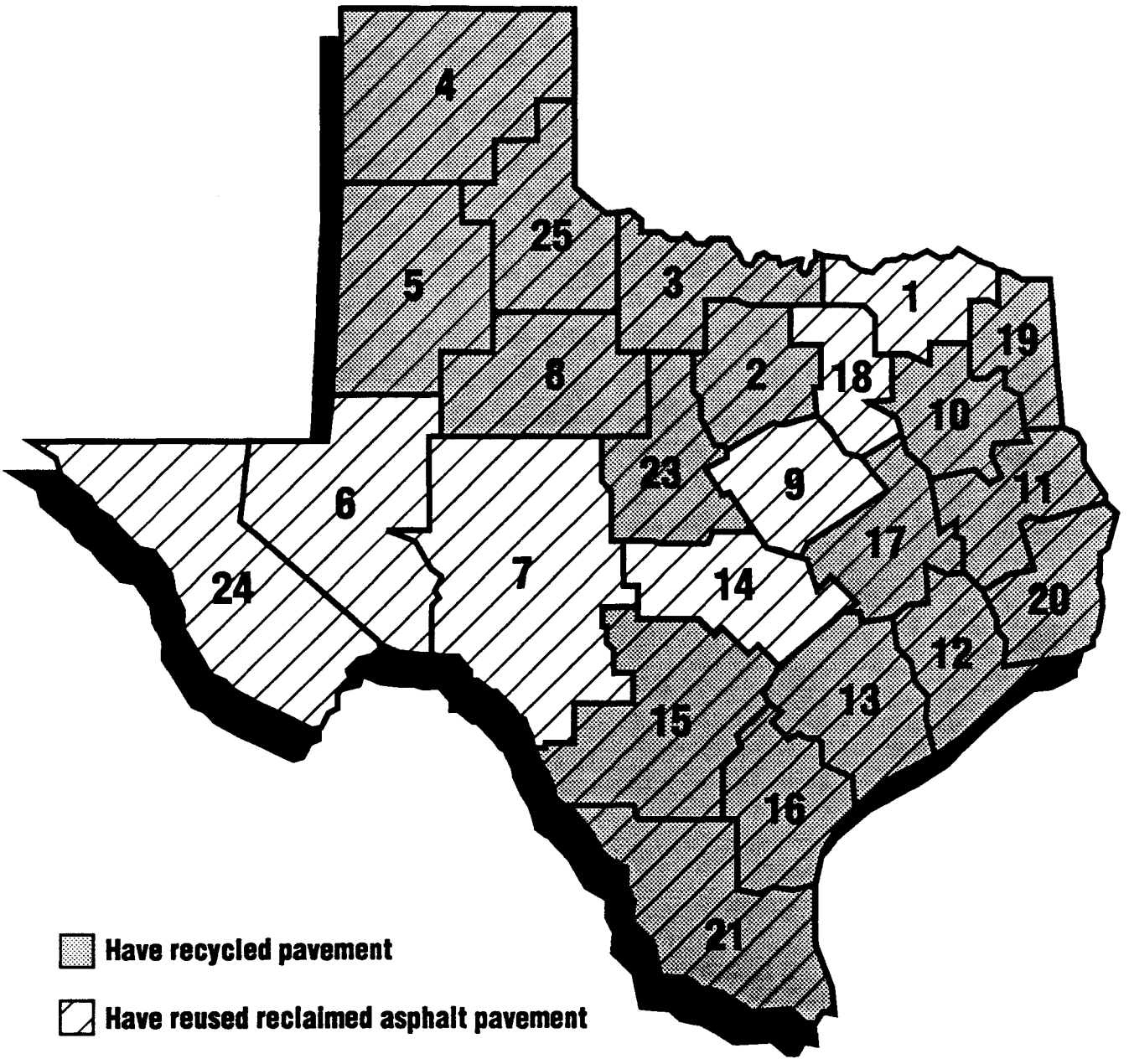


Figure 1. Statewide Usage of Recycled and Reused Pavement.

required for durable highways, the use of recycled material will increase from the large quantity used to date.

The department will continue to optimize its available resources and will continue its role as a technological innovator in this area. A research program funded jointly by the Federal Highway Administration and the department is in progress to determine the most economical and effective uses of milled reclaimed asphaltic pavement. The project is a two year study which will be completed on August 31, 1992. The research is being carried out by the Texas Transportation Institute (TTI) at Texas A&M University.

The information gathered as a result of this project will be important to accurately assess the impact of reusing and recycling pavement across the state.

A brief questionnaire was recently submitted to each district in order to gather more information about the performance of recycled pavements. This report summarizes the results of the questionnaire.

BACKGROUND

There are basically three categories of pavement recycling:

(1) Cold in-place recycling, where the old pavement is milled, crushed and sized, mixed, combined with rejuvenating agents, and placed as pavement;
(2) Hot in-place recycling, where the old pavement is heated, scarified, remixed, combined with additional fresh aggregate or hot mix asphaltic concrete, and placed as pavement; and
(3) Plant recycling, which occurs inside a batch or drum mix plant where virgin aggregate is heated and then combined with reclaimed asphaltic concrete prior to placement of the new pavement.

Cold in-place recycling does not have the expense of transporting new material, but it generally does not give the performance required by the SDHPT. A seal coat is required, and there are often problems with stripping and flushing. Moreover, cold in-place recycling has a tendency to rut.

Hot in-place recycling is more successful at restoring the asphalt and correcting any deficiencies in the existing mix. Additional fuel costs are required to heat the mix. On processes where an open flame was used, seal coats would sometimes ignite; a process using heat radiated from ceramic plates solves this problem but still creates a good deal of smoke. Often, the ride quality of a surface course constructed from this type of recycled pavement is not acceptable and an overlay must placed.

Hot mix plant recycling has increased as technology has improved to control the process of mixing. The plant must be centrally located to avoid the expense of transporting the material from and to the site. A new plant process utilizing microwave technology has been developed. This process has not been used nor tested on a Texas highway as of the publication date of this report.

SUMMARY OF QUESTIONNAIRE RESPONSE

In an effort to compile more information about the amount used and the performance of recycled pavements, a questionnaire was sent to each district (Appendix A). Each district has used RAP for maintenance purposes, but this questionnaire focused on those projects where pavement has been recycled as either a base course or a surface course.

The frequency and amount of recycled asphaltic pavement has increased drastically over the last twenty years (Figure 2). Recycling has become an economic and engineering option that will increase in popularity as the available technology advances to meet the needs of the department's construction and maintenance program.

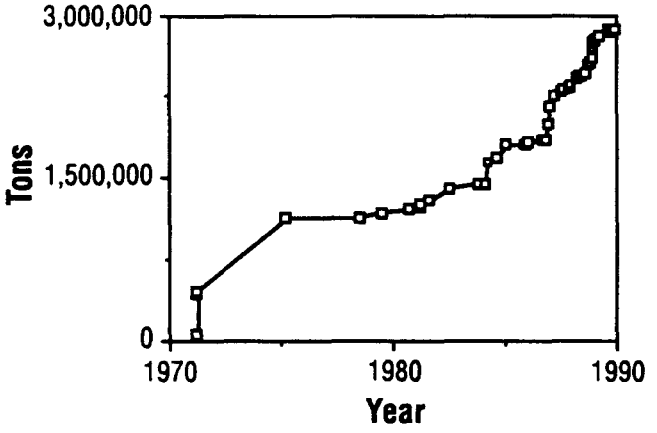


Figure 2. Use of Recycled Pavement in Tons.

Over three million tons (six billion pounds) of recycled asphalt have been used by the department. The amount of RAP used for maintenance purposes was not covered in this questionnaire, but is also very large. Of the total amount of reclaimed asphaltic pavement kept by the SDHPT, 70 percent is of a quality such that it is considered reusable. A large portion of the remainder is sold to local governments for use on lower standard roads.

The performance of recycled pavements has ranged from very poor to excellent. The plant mix recycled ACP performed better in each category than the hot in-place recycled method. The cold in-place method performed very poorly in both projects for which it was used. The overall performance rating on a scale of 1 to 5 for each method is:

- plant mix -4.1;
- hot in-place -3.3;
- cold in-place -2.5.

Because of the poor performance and limited number of cold in-place recycling projects, the remainder of this report will concentrate on the other two methods of pavement recycling. A breakdown of the district rating for each performance category is included in Appendix B.

As a measure of determining the progress of recycling technology, the overall performance, cost effectiveness, and availability versus time is plotted in Figure 3.

The general trend for these criteria is one of improvement. However, the ratings for each of these categories for hot in-place recycling show very little, if any, convergence. Plant recycling does show a reasonable amount of convergence at a score of between 4 and 5, highlighted in gray. This implies that the technology for plant recycling is more reliable and consistent than the technology for hot in-place recycling.

The recycled pavement's performance does not appear to rely solely on the percentage of virgin material added to the mix (Figure 4). The percentage of virgin material added should depend upon the composition of the existing reclaimed roadway. Additionally, adding more virgin material sometimes complicates the control of the mixing and heating processes; this is especially the case for hot in-place recycling.

The decline in the cost per square yard (Figure 5) has improved the cost effectiveness and increased the amount used of recycled pavement. The average cost per square yard per inch of recycled pavement was $2.19 for hot in-place recycling and $2.35 for plant recycled material. Although these figures do not compare favorably with the cost of all new material, the price of recycling in *recent* years is competitive.

For a more detailed examination of the problems encountered in the field and some possible solutions, Appendix C contains the comments from each district (by specification number). Also included is a table of successful uses of milled RAP gathered by the TTI researchers as part of Research Study 1272.

CONCLUSIONS

Recycling pavement has proven itself to be a sound economic and engineering choice under the right conditions. Currently, using recycled pavement is not always the best option. Many factors affect the quality and performance of recycled asphaltic pavement, and it is not always feasible to recycle. Constructing a highway from all new materials is sometimes required to meet the necessary standards. Recycling pavement will become even more common as technology and experience reach the level to meet the demands of highways. The SDHPT will continue to perform engineering and technical analyses on each project in order to effectively use all available resources.

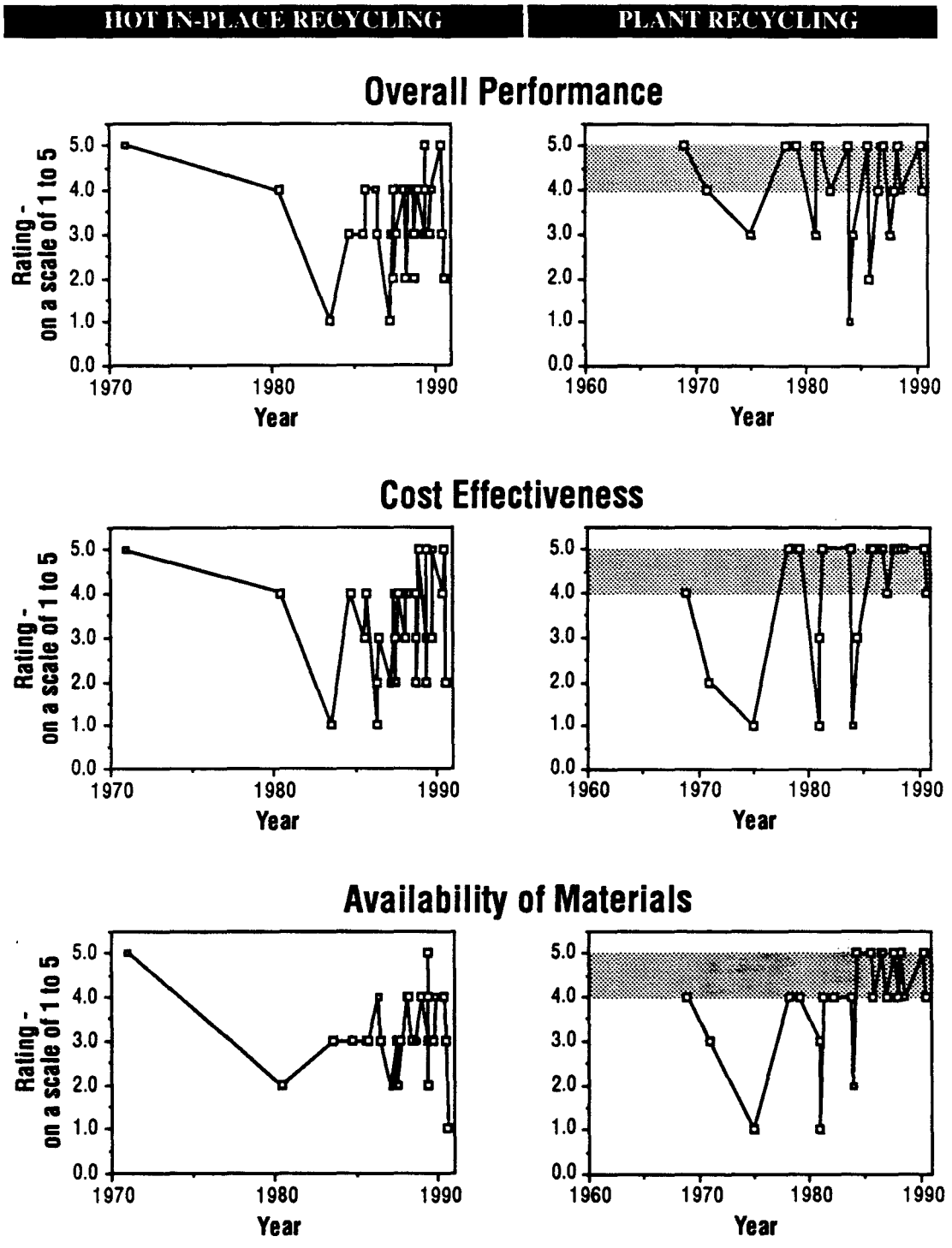


Figure 3. Improvement of Recycling Technology vs. Time.

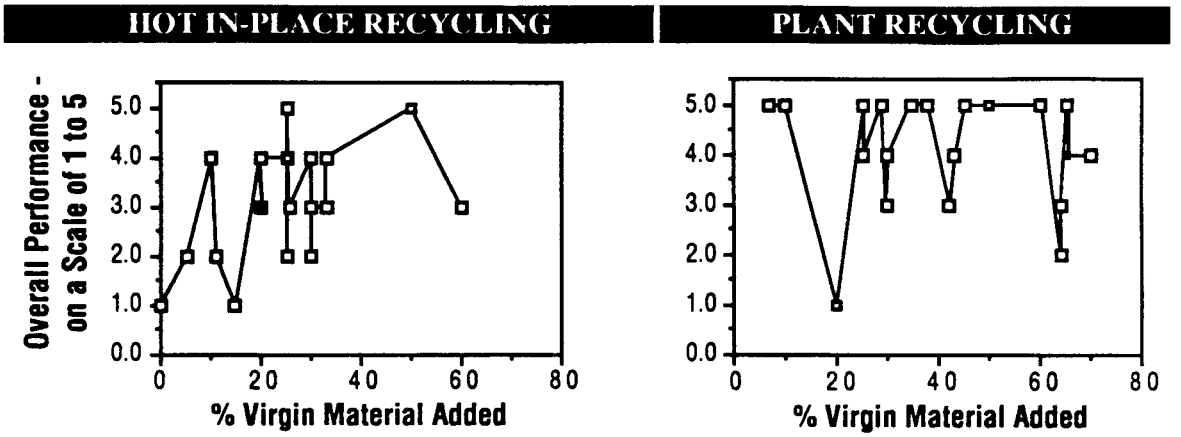


Figure 4. Effect of Virgin Material on the Overall Performance of Recycled Pavement.

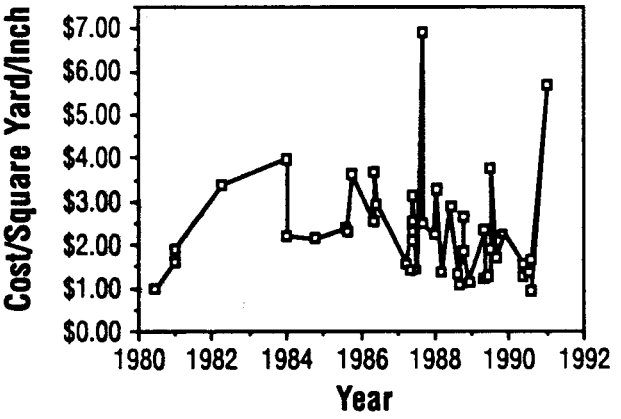


Figure 5. Cost of Recycled ACP in the Past Decade.

REFERENCES

"Producers, Consumers Eager to Take the RAP." *Roads and Bridges* January 1986, pp. 60-67.

HPR Research Study 1272 "Utilization of Milled Reclaimed Asphalt Pavement (RAP)." Texas Transportation Institute sponsored by the Texas State Department of Highways and Public Transportation and the Federal Highway Administration. March 1991.

APPENDIX A
QUESTIONNAIRE

RECYCLED ACP QUESTIONNAIRE

District: County:

PROJECT DESCRIPTION

Highway:_____ # of lanes:_____
Cntrl-Sec or Location Description:

Length of Project:

TRAFFIC DATA

AADT: % Truck Traffic:

Roadway condition before recycled pavement project:

Roadway preparations prior to recycle (if applicable):

Problems with construction and possible solutions:

Are more recycled ACP projects planned? If so, when and where?

TYPE OF RECYCLE:

In-Place: _____	Plant Mixed: _____
Virgin Material Added (%): _____	Virgin Material Added (%): _____
Item Number:	Item Number:
Total Material Used (tons):	Total Material Used (tons):
Cost ($/sq.yd.):	Cost ($/sq.yd.):
Total recycle project cost:	Total recycle project cost:

AGGREGATE	ASPHALT
Type:	Type:
	Grade:
Source:	Additives:
	Source:
	Content (%):

Please Rate the Recycled Pavement for Each Relevant Category

Category	Low				High	
Overall Performance	1	2	3	4	5	N/A
Cost Effectiveness	1	2	3	4	5	N/A
Ease of Installation	1	2	3	4	5	N/A
Availability of Materials/Equipment	1	2	3	4	5	N/A
Rutting Resistance	1	2	3	4	5	N/A
Cracking Resistance	1	2	3	4	5	N/A
Control of Flushing and Bleeding	1	2	3	4	5	N/A
Stripping	1	2	3	4	5	N/A
Ride Quality	1	2	3	4	5	N/A
Skid Resistance	1	2	3	4	5	N/A
Potholes	1	2	3	4	5	N/A
Performance Under Freeze-Thaw Conditions	1	2	3	4	5	N/A
Other	1	2	3	4	5	N/A

Age of recycled pavement (months):

Describe maintenance activities pertaining to this particular pavement:

Would you use this type of recycle pavement again? Please explain.

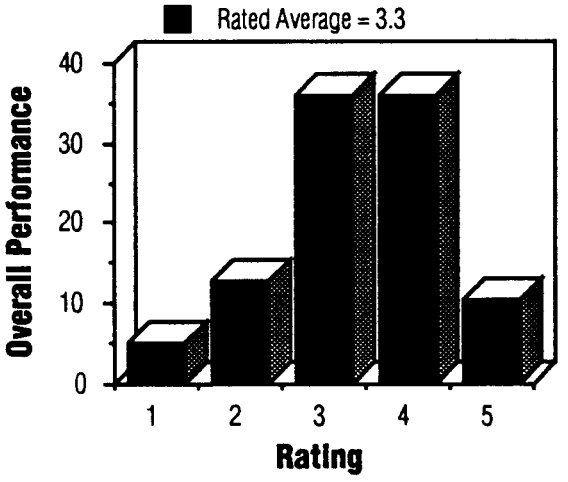
Additional comments or suggestions (special procedures, etc) (use separate page if necessary).

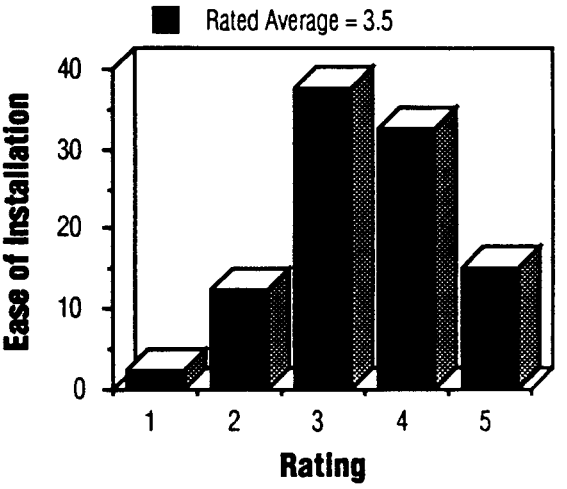
APPENDIX B
QUESTIONNAIRE RESULTS

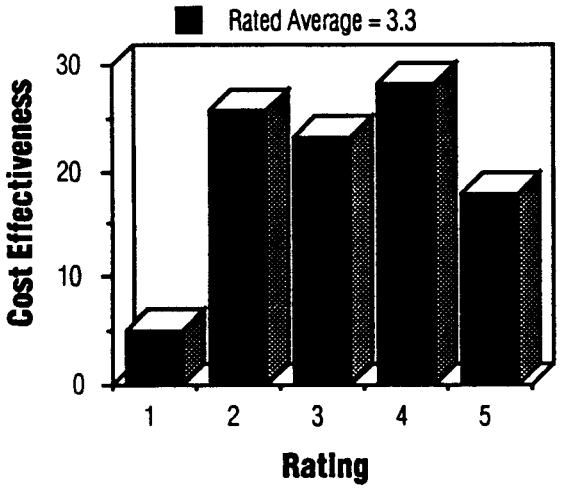
DISTRICT RESPONSE BREAKDOWN OF QUESTIONNAIRE

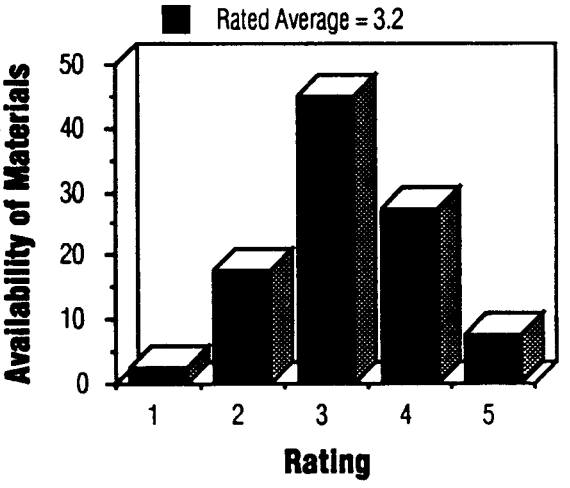
HOT IN-PLACE RECYCLED

These are the results of the questionnaires completed for hot in-place recycling. The districts were asked to rate, on a scale of 1 to 5, the recycled pavement's performance for each category shown. The data presented shows the *percentage* of responses for each score.

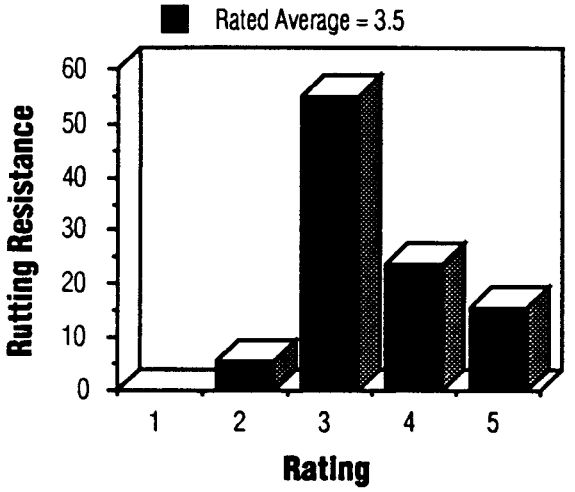


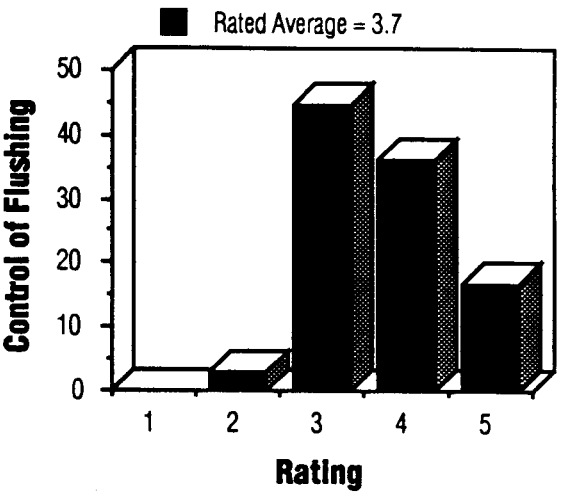


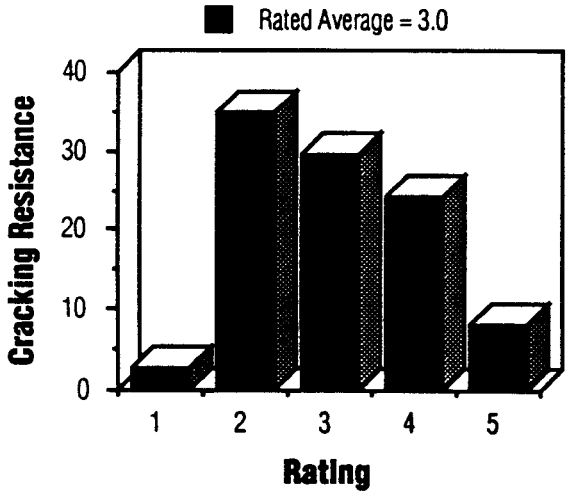


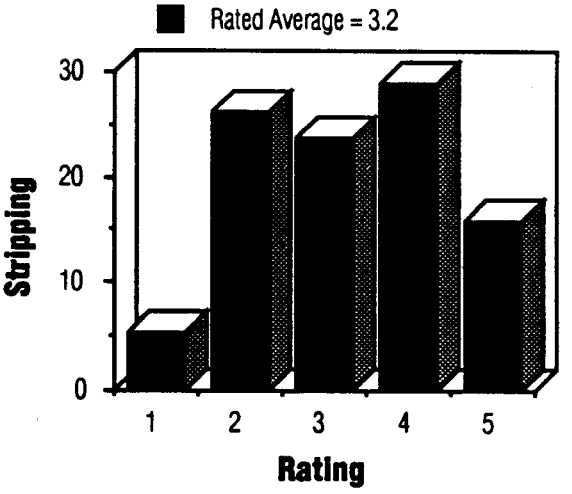


HOT IN-PLACE RECYCLED (CONT.)









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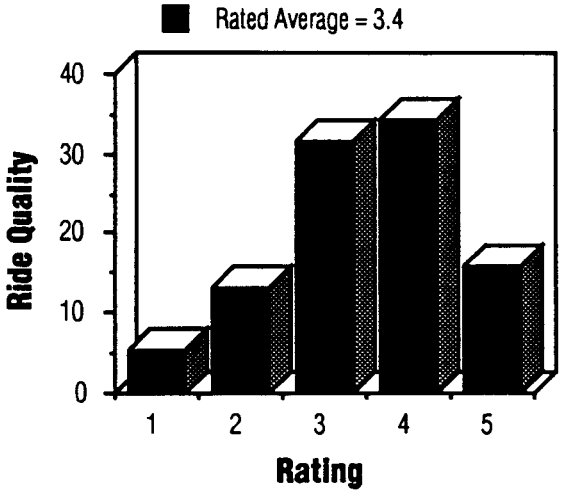

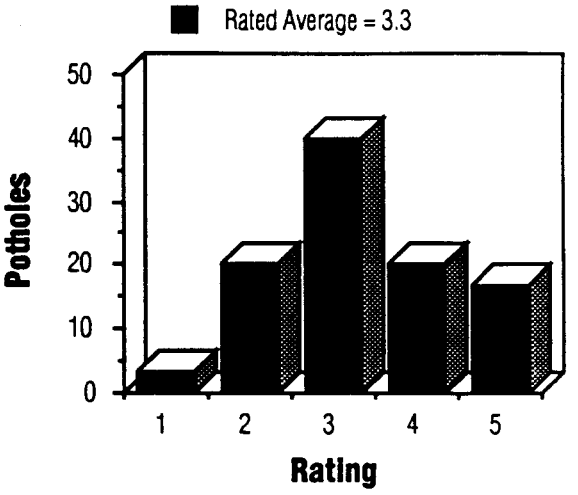

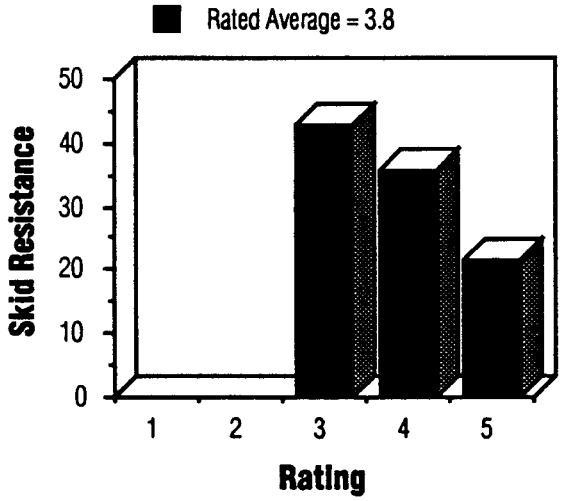

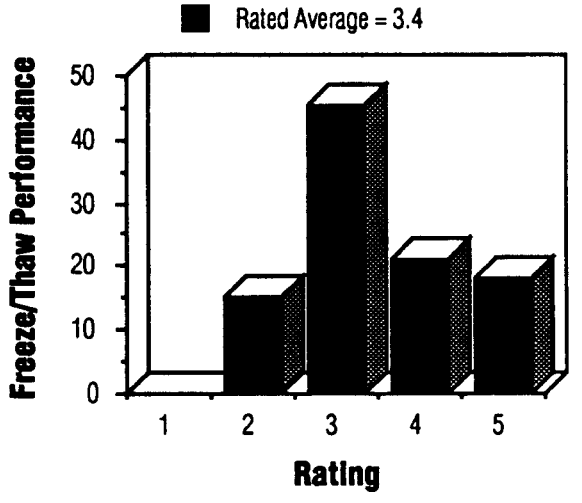

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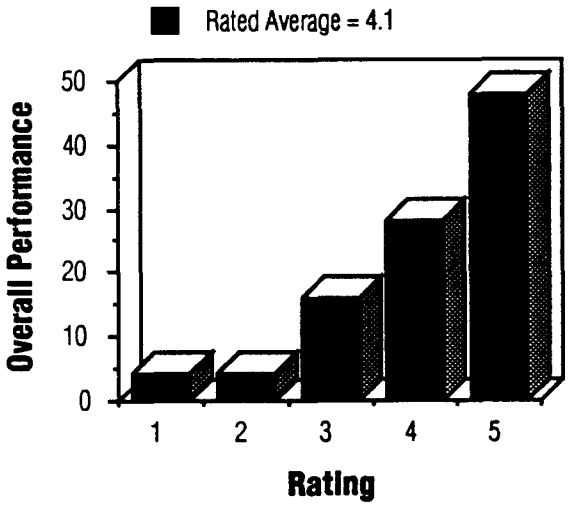

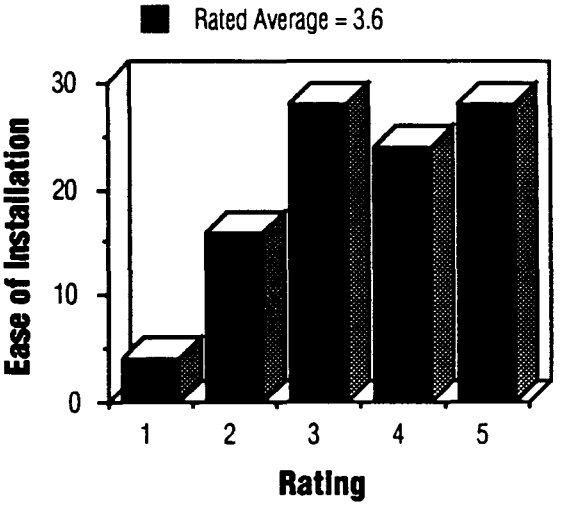

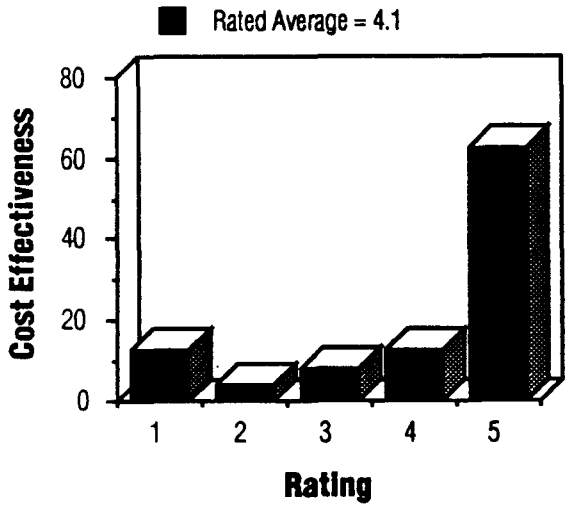

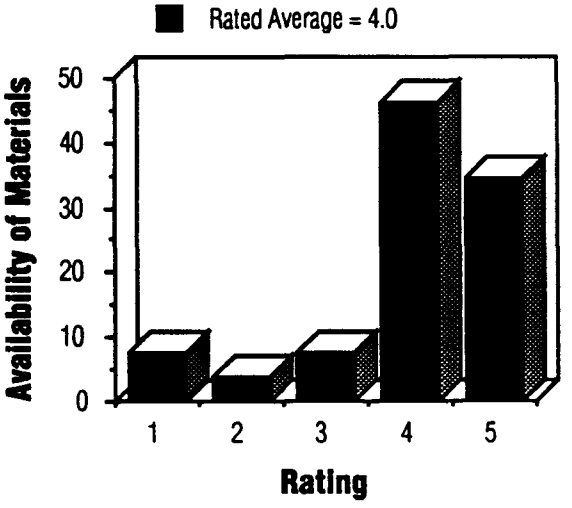

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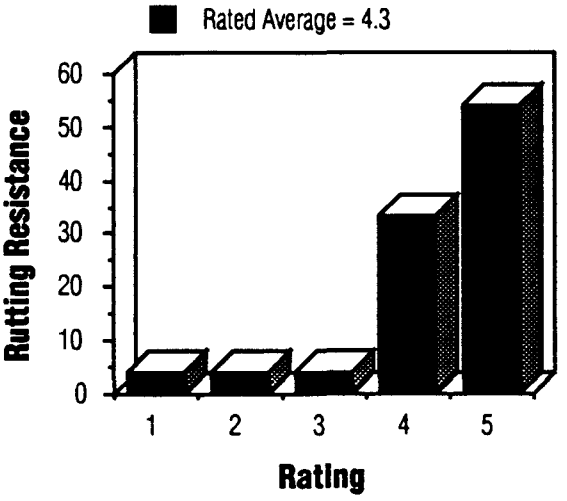

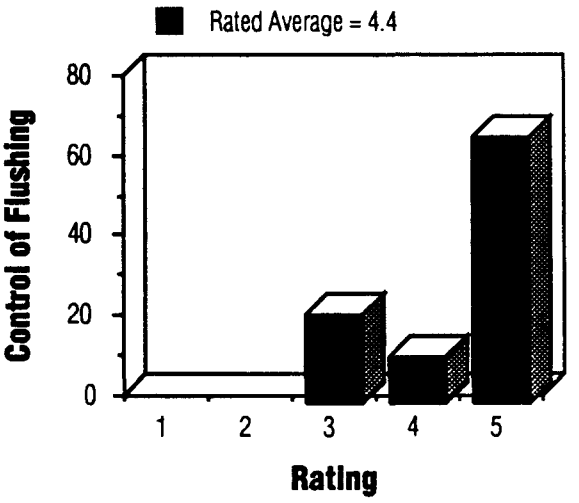

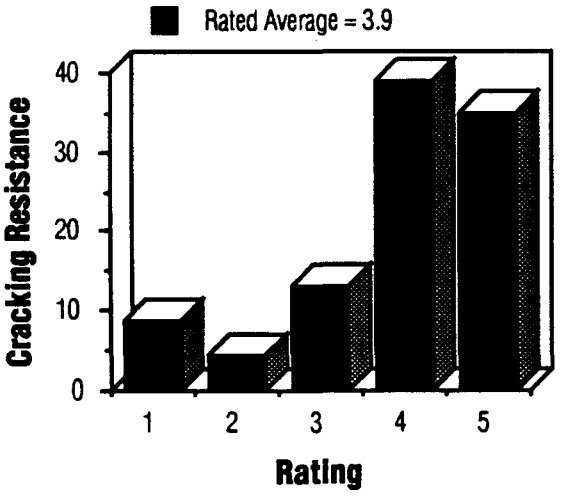

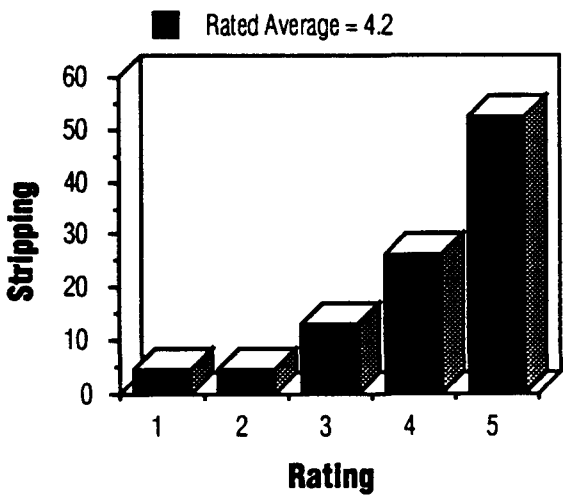

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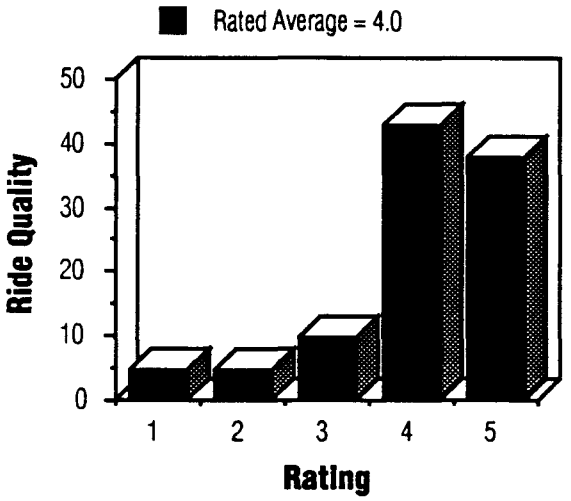

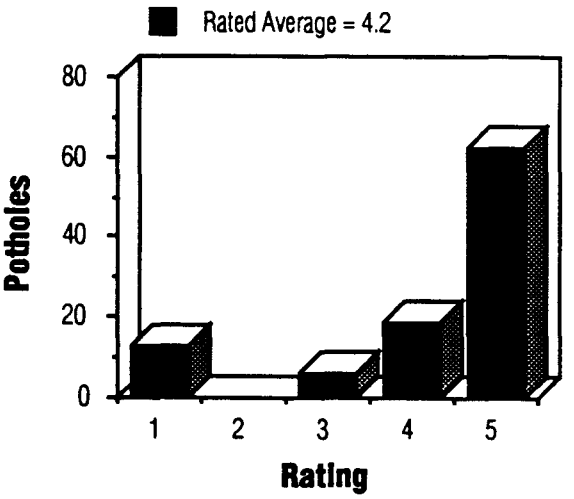

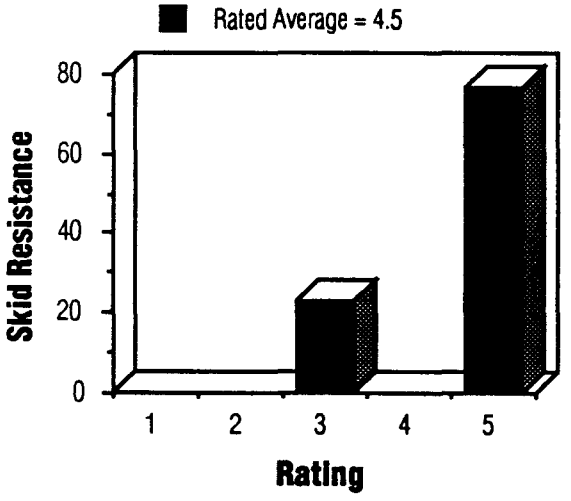

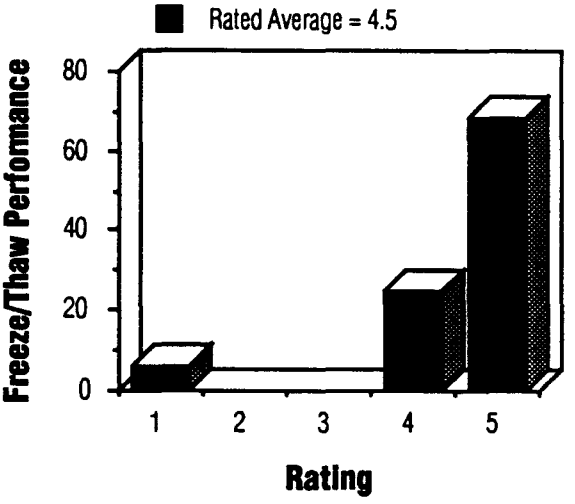

APPENDIX C
DISTRICT COMMENTS AND SUCCESSFUL USES OF MILLED RAP

DISTRICT COMMENTS

DISTRICT 2 - FORT WORTH

Item Number 3386 - (In-Place) Cleaning and Sealing Joints and Cracks

This method received scores of 1 for overall performance and cost effectiveness. This method would not be considered again because it "is inferior to remixing operations."

DISTRICT 3 - WICHITA FALLS

Item Number 3261 - (Plant) Hot-Mix Recycled Bituminous Pavement

"Recycled material was used on 10 foot shoulders. Quality, workability, and performance of pavement was equal to pavement with 100 percent virgin materials. [Would use again] because of cost effectiveness and pavement performance."

Item Number 3553 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"Equipment was too sophisticated for inexperienced personnel... We feel this would have been a very successful project with a capable contractor."

DISTRICT 4 - AMARILLO

Item Number 3351 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"The paver lacked material storage capacity, affecting the ability to maintain grade and obtain a smooth riding surface. A surge bin added to the paving train should solve this problem... [We would use this method again because] costs are reduced and good, available material sources have diminished. Also, with each successive overlay the front slopes become steeper."

DISTRICT 5 - LUBBOCK

Item Number 3292 - (Plant) Waterproofing Pavement Joints and Cracks

This project received an overall performance and cost effectiveness rating of 1. "[We would not use this type again because it is] too costly for the life of the pavement."

DISTRICT 8 - ABILENE

District has spearheaded the development of techniques to use recycled ACP in base courses. For information on the first recycled base course please refer to research report 604-1.

"There has not been any surface recycling or in-place recycling done in this district... These [asphalt stabilized base recycling] projects represent a little over one million tons of asphalt stabilized base."

Special Item 2037 - (Plant) Lime Stabilized Base

"We had some problems with air pollution but the project was completed within Texas Air Control Board Standards. This project has performed exceptionally well."

Special Items 2042, 3089, 3279, 3228, 3326, 3461, and Item 292 -

These have excellent performance.

DISTRICT 10 - TYLER

Item Number 3570-001 - Cold In-Place Recycling of ACP

This item received an overall performance and cost-effectiveness score of 2. "[We would not use this again as] there appears to be no advantage to cold recycle, as a seal is required which flushes rapidly and does not have a good resistance to rutting."

Item Number 3351-005 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"[We would use this again as] the existing material can be used corrected for deficiency, in asphalt content and particle size."

Item Number 340 - (In-Place) Hot Mix Asphaltic Concrete Pavement

This method received an overall performance score of 4 and a cost effectiveness score of 5. "[We would use this method again because it is] cost effective... This method should not be used for pavement problems deeper than 1-1/2 inches."

DISTRICT 11 - LUFKIN

"In place recycling does not lend itself to every project. It works well on ACP pavements that are rutted due to excessive asphalt.

"ACP pavement that is cracked due to weathered asphalt, etc. will soon crack again. Additives are not effective.

"Heavy seal coats need to be milled off before recycling. The heating process cannot penetrate a heavy seal.

"It is very difficult to control the final product. The old ACP can be altered to some extent. The heating process hardens the asphalt a great deal and is somewhat unpredictable. The more virgin material that can be added the better the final product."

Item Number 3199 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"Mixture must be heated to 225 degrees or more for proper coating and compaction... [We would use this method] when [it is the] most economical rehabilitation strategy."

Item Number 3241 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"This should only be used as a short-term solution... [We would use again] when short sections are in need of short-term type repairs."

Item Number 3351 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"Additional patching was required after several years. This solution is only practical for spot repairs."

Item Number 3354 - (In-Place) Backfilling Pavement Edges

"The depth of cracks were noted to be deeper than the 3/4-inch depth of recycled asphaltic concrete. More recycled ACP projects are planned, but not in a thin, cracked asphaltic layer."

Item Number 3241 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"This project was successful and met design life. [You] must hold the temperature of mixture at or above 225 degrees for adequate coating and compaction."

"[We would use again] if the existing seal coat is removed prior to recycling."

Item Number 3351 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"[We would use this method again] when recycling proves to rehabilitate the existing asphaltic concrete, and when a new asphaltic concrete overlay can be placed soon afterward."

"Production rate of recycling equipment was slowed due to existing aggregate being stripped of asphalt, and more heat and mixing was required for a good recoating of aggregates."

"The cracking is reflecting from below."

"Existing seal coats created a problem in heating the mixture below. A substantially higher amount of low asphalt content virgin mixture was added to off-set the excessive amount of asphalt from the seal coats."

Item Number 3553 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"[We would use this type again] if proper repairs to existing base course are made, prior to recycling."

DISTRICT 12 - HOUSTON

"We must report that District 12 has not recycled any asphalt pavement [for surface courses] to date. We do utilize our asphalt pavements in our recycled stabilized bases and we stockpile milled asphalt for maintenance work."

DISTRICT 13 - YOAKUM

"Even though we have not actually recycled too much of this material back into ACP, we have found a good use for this material in our maintenance operations:

- base material to construct shoulders and widen a narrow FM Highway;
- base material to improve quarter-point repairs to low volume highways;
- level-up adjacent to pavement edges, private driveways, mailbox turnouts;
- slope protection around pipe ends on driveways; and
- level-up material in ruts on low volume FM Highways.

We have not and do not intend to dispose of any of this type of material in the future. It has proven to be of significant value, especially to our State Maintenance Forces."

Item Number 3351 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"[No problems with construction, we] even added additional virgin material to allow for improvement to the ride. By adding additional virgin material above that required for the rutting, we were able to improve the characteristics of the ride quality."

"Seal coat previously placed on hot mix surface caught fire during recycling and caused too much asphalt content into the recycled material. Had to have State Maintenance Forces cold mill off seal coat prior to recycling.

DISTRICT 15 - SAN ANTONIO

Roadside Mix of Stockpiled Materials

"[We would use this again] because it is cheap and a good alternative when you can't purchase premix. You need a good finish blade operator to finish roadway with the type of salvaged rotomilled material we used."

Item Number 340-015 - (In-Place) Hot Mix Asphaltic Concrete Pavement

"[We would not use again because it is] more expensive to recycle at this point in time. New material is still more cost effective due to construction methods."

Item Number 3472 - Cold In-Place Recycling of ACP

"[We would not use this again because the] section must be overlaid with ACP and sealed or stripping will occur."

Item Number 3553 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"[We would use this again] but not in a high volume urban area."

DISTRICT 16 - CORPUS CHRISTI

Item Number 3177 - (Plant) Cleaning and Repairing of Longitudinal and Edge Joints

"Too much reclaimed asphaltic pavement used in mix. Unable to add sufficient new AC to coat virgin aggregates and maintain adequate stability. [We would use again] if it is cost competitive."

DISTRICT 17 - BRYAN

"District Seventeen has plans to recycle approximately 31,000 tons of existing Type D Hot Mix this fall or early next year."

Item Number 1222, 340 - (Plant) Hot Mix Asphaltic Concrete Pavement

"The amount of ACP varied in the crushed recycled materials which resulted in fluctuation of asphalt in the completed mix. Problem could be reduced if ACP had been salvaged separate from concrete pavement, crushed and combined back into the mix separately... Would use again whenever old ACP or concrete rubble are available."

"Clay clung to old concrete pavement. Was necessary to wash rubble in log washer and then after crushing it was again washed on a wet deck to remove impurities. Problem would have been much less if contractor had used more care in breaking and picking up old concrete pavement."

Item Number 292 - (Plant) Asphalt Stabilized Base

"[We would use this again as] the rutting that occurred in the surface course was not caused by the asphalt stabilized base layer. We feel the underlying base course should continue to perform for many years."

DISTRICT 19 - ATLANTA

"In the past 10 - 12 years, we have milled a lot of old ACP. To our knowledge, none of it has ended up in a landfill. We keep some of it for our forces to use on mailbox turnouts, driveways, shoulder dropoffs, etc. That which the contractors have kept has been sold as is for driveway material or it has been run through their plants and sold in their commercial mix. We have done numerous rehabilitation projects where the existing ACP is pulverized and mixed with the flexible base.... [R]ecycling should be an engineering and economic decision, not a legislative mandate."

Item Number 3157 - (in-Place) Repairing Existing Pavement Structure

"[We] have not had to go down to the recycled layer for maintenance. [We would use this again because] technology advances in equipment make it more feasible now."

Item Number 292 - (Plant) Asphalt Stabilized Base

"[We would use this method again] with the right combination of existing conditions. The contractor bought a new Cedar Rapids Drum in Drum Plant for the project... Production rate was only 100 tons per hour and a lot of down time. Contractor got into trouble with [the Texas Air Control Board Standards]."

Item Number 3351 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"Used Cutler process which burnt the asphalt... This process [would not be used in the future]... Need to rewrite specification to avoid Cutler process."

"A lower course of ACP has stripped and is apparently causing the rutting."

"Morning side of daily headers have raveled indicating problems with uniform heating and mixing on startup. Work was done...using Wirtgen process. [We have] just let another [contract using this process]."

Item Number 3553 - (In-Place) Asphaltic Concrete Surface Rehabilitation

"This was a curb and gutter street with numerous intersections. Had to mill and inlay the intersections because recycle equipment can't maneuver enough for intersection type work."

Item Number 292 - (Plant) Asphalt Stabilized Base

"We allow it [recycling] as a contractor's option on most projects which require milling an existing surface."

DISTRICT 20 - BEAUMONT

District 20 has recycled pavements along U.S. 69, IH-10, U.S. 90, and S.H. 87. They have had good results (overall performance of 4 and cost effectiveness of 5) and will use recycled ACP again.

DISTRICT 21 - PHARR

Item Number 3336 - (Plant) Hot-Mix Recycled Bituminous Pavement

"Slower mixing process improved the mixing of lime [in recycled material]. Excess planed unused material stockpiled for future use creates unsightly areas. Recycled material placed on surface course also. Dry and loss of fines experienced as well as cracked in different areas. Asphalt rejuvenator applied in 1987 and cracks poured in 1988 and sealed in spots in 1989. [We will use recycled pavement again] but not on the surface course."

Item Number 3456 - (Plant) Hot-Mix Recycled Bituminous Pavement

Will use again in base courses "whenever and wherever possible." The hot mix bid on this project was $28.50/ton and the recycled material bid was $22.50/ton.

Item Number 3533, 3483, 3446 - (Plant) Hot-Mix Recycled Bituminous Pavement

Will use again in base courses "whenever and wherever possible."

DISTRICT 23 - BROWNWOOD

District 23 has milled material from IH 20 to be used as a substitute for pre-mix in maintenance operations. It will be used for leveling, roadway edges and driveways.

DISTRICT 25 - CHILDRESS

Item Number 340 - (Plant) Hot Mix Asphaltic Concrete Pavement

"This material was used as a stabilized base. Surface course used and overlaid at a later date." This material received an overall performance rating of 4 and a cost effectiveness rating of 2.

Item Number 340 - (In-Place) Hot Mix Asphaltic Concrete Pavement

This method probably will not be used again because of very poor ride quality.

Item Number 246 - (In-Place) Foundation Course

This method received ratings of 5 for every applicable category and will be used again. "These projects are in counties with better subgrades. They are performing well... We feel it is very cost effective and structurally advantageous... This method of recycling utilized the HMAC after cold milling and mixing (cold) with flex base."

SUCCESSFUL DISTRICT USES FOR RAP IN BOTH MAINTENANCE AND CONSTRUCTION ACTIVITIES

District	Successful Uses for Milled RAP
1	Filling edge drops, repairing driveways and mailbox turnouts (no additives).
2	Base course: used in HMAC as an aggregate with no additives. Backfilling edge of pavement (untreated). Surfacing driveways (untreated). Pothole patching: added CMS-1 emulsion and rejuvenating agent in pug mill.
3	Used as flex base to build service road (untreated). Used as shoulder material and for mailbox turnouts (untreated).
4	Base for pavement repairs (untreated). Driveway and mailbox turnouts, shoulder dropoffs (untreated).
5	Driveway repair, crossovers, and mailbox turnouts (untreated).
6	Mailbox turnouts, litter barrel turnouts, and for paving maintenance yards (material was blade mixed with an emulsion). Parking lot (untreated).
7	Mailbox turnouts (untreated). On one occasion, material was sprayed with emulsion after it was laid.
8	RAP used in Item 246, Foundation Course in rehabilitation of F.M. highways and frontage roads. RAP was dumped on the existing foundation course and the two materials were mixed with a Bomag and maintainer on the roadway. Water was the only additive. Good results.

(Continued)

District	Successful Uses for Milled RAP
	Used for private driveways and mailbox turnouts. RAP was mixed with MS-l emulsion by maintainer in the maintenance yard and hauled to the job site. The material was used immediately after being mixed. A maintainer and pneumatic roller were used to place material at the job site. Good results. District has used approximately 50,000 tons this way. Used as a part of Item 292, Asphalt Stabilized Base, full depth recycle project. Mixed with Item 249, Flexible Base.
9	No successful uses.
10	RAP was mixed in a pug mill with AES-300 emulsion and used for base repair in both main lanes and paved shoulders. Used for construction and reconstruction of public road and street entrances and for edge and driveway repair.
11	Driveway surfacing and pavement edge repairs. Sometime the RAP is used as is. RAP is sometimes mixed with AE5-300R utilizing a portable Xolberg Mixing Plant and stockpiled for approximately 30 days and then bladed on.
12	Used for shoulder drop offs, mailbox turnouts, park and ride lot, and as a base for full depth concrete repairs. RAP was mixed with AES-3 OOR in recycling plant that heated the material and mixed with the emulsion. It was mixed and stockpiled with a front-end loader at the same location. It was then handled like a hot-mixed, cold-laid material.
13	Used for edge repair, mail box turnouts, minimum level up, and pipe end stabilization. Recently used as a flexible base. RAP was hauled to roadbed, dumped and spread. Approximately 10 percent binder and 1 to 1.3 percent dry bulk lime wag spread over millings, mixed and laid in with maintainers and rollers.
14	Used on driveways and pavement edge dropoffs (no additives).
15	Some of the uses have been edge/shoulder repair, level-up, erosion backfill, mailbox turnouts, ditch liner, hot recycled ACP and substitution for Flex Base in reconstruction of a low volume roadway or repairing base failures. Mainlane usage was usually sealed. Additives have consisted of MS-l, cement and in the case of the hot-recycled ACP, some rejuvenator and virgin AC was used. Most RAP has been stockpiled at a convenient location. Prior to its use, the additive is introduced and mixing is done with a blade. Future plans are to use AES-300RP and mix it with the RAP through the use of a pulver-mixer. A two to three month supply will be stockpiled and used as needed.
16	Used for edge protection, driveways, pot holes, mailbox turnouts, blade on level up, and patches.Mixed with emulsion for blade on.
17	Used for driveways, mailbox turnouts and pavement edges. Two mixing processes have been used: 1. RAP was mixed with 5-6 percent AE5-300R through a pug mill. 2. RAP was mixed with a blade and mixer in windrow with 5-6 percent AES- 300R. After mixing, material is stockpiled and used as needed.

(Continued)

District	Successful Uses for Milled RAP
18	Untreated RAP has been used on low edges, driveways and section yards for a number of years. Have also been successful mixing binders (RC-250, emulsions, etc.) in small quantities for low edges and patching shoulders for a number of years. In 1989, mixed AES-300RP with RAP in pugmill at two locations. Some of this material was used to construct shoulders on an F.M. road which was very successful. The other material was used for low edges, shoulder repair and driveways. District is nearing completion of a contract to mix AES-300RP with RAP in five sections (approximately 60,000 cubic yards). RAP has been used successfully as a percentage of the material for an asphalt base on a large project. A project on IH 45 is set up to use 70 to 100 percent RAP for asphalt base.
19	RAP has been mixed with both cracked fuel oil and AE5-300 and used successfully on low edges, driveways, mailbox turnouts, base repairs and heavy level ups. Has been recycled in Item 292.
20	Untreated RAP has been used in maintenance as a base material, for driveways, turnouts, and shoulder repairs. Untreated RAP has been used also in construction as a base material.
21	RAP has been mixed with rejuvenator and used mostly in edge repair. RAP is also recycled back in new hot mix at a RAP content of approximately 35 percent .
23	Used as a blade level-up. RAP material is windrowed along highway then NS-2 is applied and mixed with maintainer working it back and forth until satisfactory mix is obtained. Used for driveways, turnouts and edge treatment. Tack coat of MS-2 is applied and RAP is spread with maintainer, rolled with pneumatic or flat-wheel roller and finished with application of MS-2, if needed. Recently mixed RAP with AE5-300RP in a pugmill and stockpiled.
24	In construction, RAP has been used as a subbase: Material was hauled from stockpile to roadway, dumped, spread, and grill-rolled to break up consolidated material. Material was then windrowed and placed in a similar manner to a base material. It was then sprinkled lightly with water and compacted. Used approximately 13,000 cubic yards. In maintenance, RAP has been used as a subbase in patches and has also been used to pave small areas. It has also been used as a slope stabilizer along roadways and as a support material behind curbs. Material was sprinkled lightly with emulsion, placed and compacted. In some instances, it was heated in a heating drum and used as a hot-mix patch. Used approximately 1,000 cubic yards.
25	In maintenance, RAP has been mixed 50/50 with fresh hot-mixed, cold-lay material for use in blade patches. In construction, pavement has been milled full depth and mixed with existing flexible base material and relaid.