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16. Abstract In this study, RAP was blended with recycling emulsions and conventional maintenance mixtures in attempts to improve its field performance as a maintenance mixture. RAP was also mixed with stabilizers and used as a base material in maintenance projects. Several field experiments were constructed throughout the state, and this report documents their performance. In general, most of the field experiments performed well and much better than district personnel anticipated at the onset of the study. It was determined that RAP could be used successfully as a maintenance mix for routine maintenance treatments by cold-mixing the RAP with recycling agents or by blending the RAP with conventional, stockpiled maintenance mixtures. RAP was also used successfully as a stabilized base material on maintenance projects. Results of this study were used to develop <i>Guidelines on the Use of RAP in Routine Maintenance Activities</i> as referenced in this report.					
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**FIELD PERFORMANCE OF MAINTENANCE TREATMENTS
CONSTRUCTED WITH RECLAIMED ASPHALT PAVEMENT (RAP)**

by

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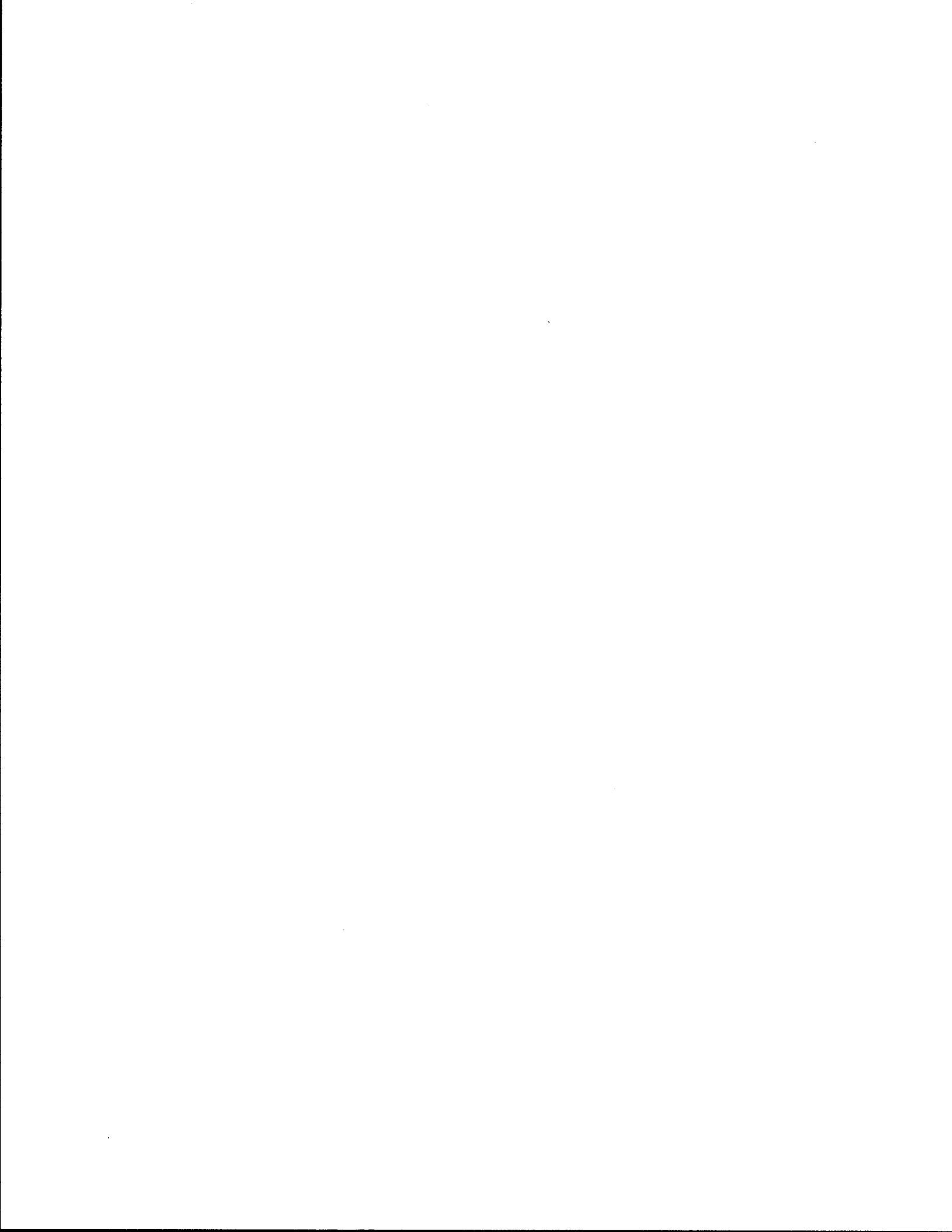
Research Report 187-24
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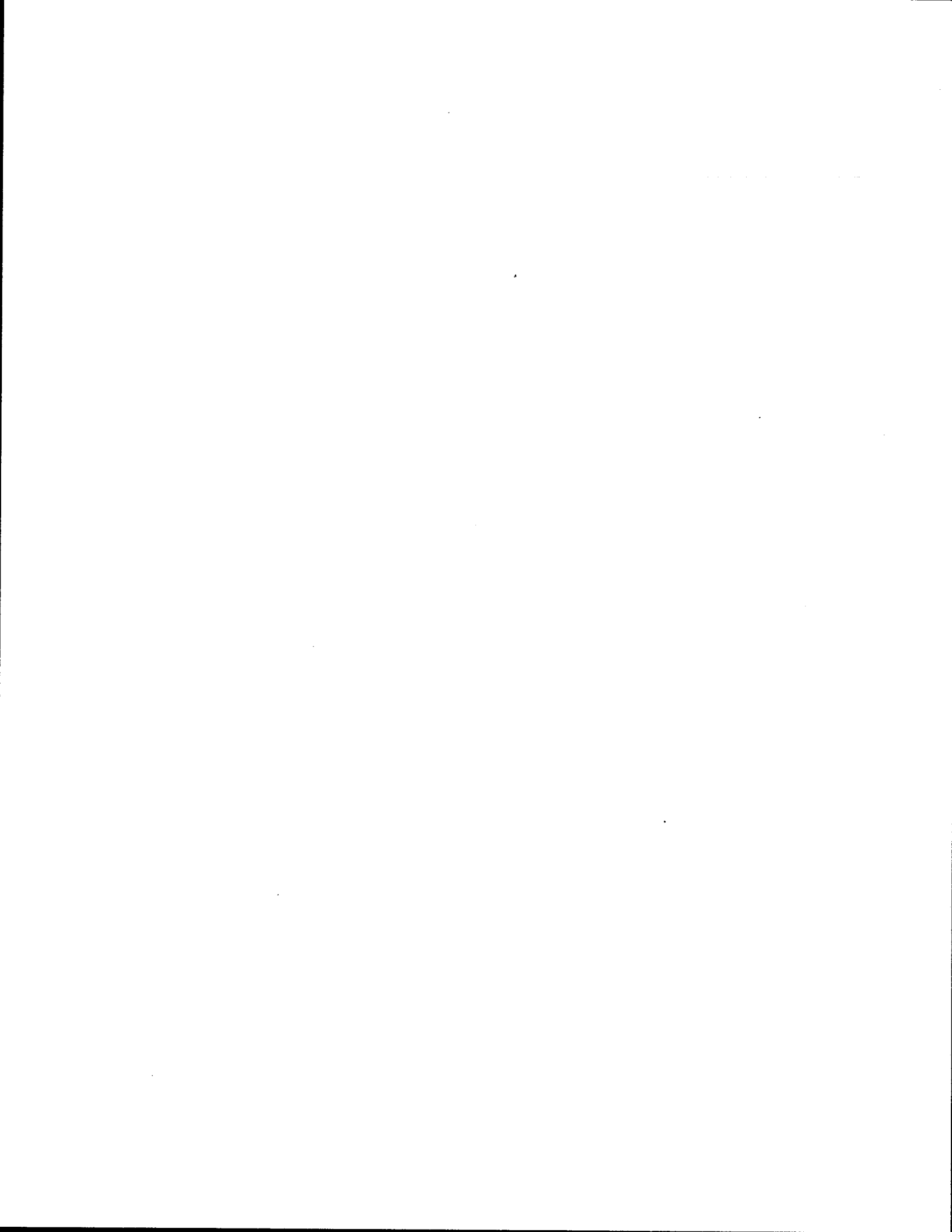


IMPLEMENTATION STATEMENT

Due to concerns for protection of the environment and conservation of natural resources, government agencies must strive to utilize waste materials to the greatest extent possible. With this in mind, implementation of the findings of this research have national significance. The findings are capable of immediate implementation by the Texas DOT and all other highway agencies. With appropriate mixture design and modification techniques, milled RAP can alleviate the problem highway agencies sometimes experience in procuring maintenance mixes of sufficient quantity to meet their needs.

Results presented in this report were used to develop *Guidelines on the Use of RAP in Routine Maintenance Activities* by Estakhri and Bohuslav (1993). These guidelines provide maintenance personnel with direction on using stockpiled RAP in routine maintenance operations, with minimal to no laboratory testing and minimal material processing and handling. Minimizing the testing and processing should keep the cost of the recycled mix well below that of new maintenance mixes.

The final outcome of the field experiments presented in this report document and further endorse the recommendations as outlined in the guidelines (Estakhri and Bohuslav 1993).



DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes.

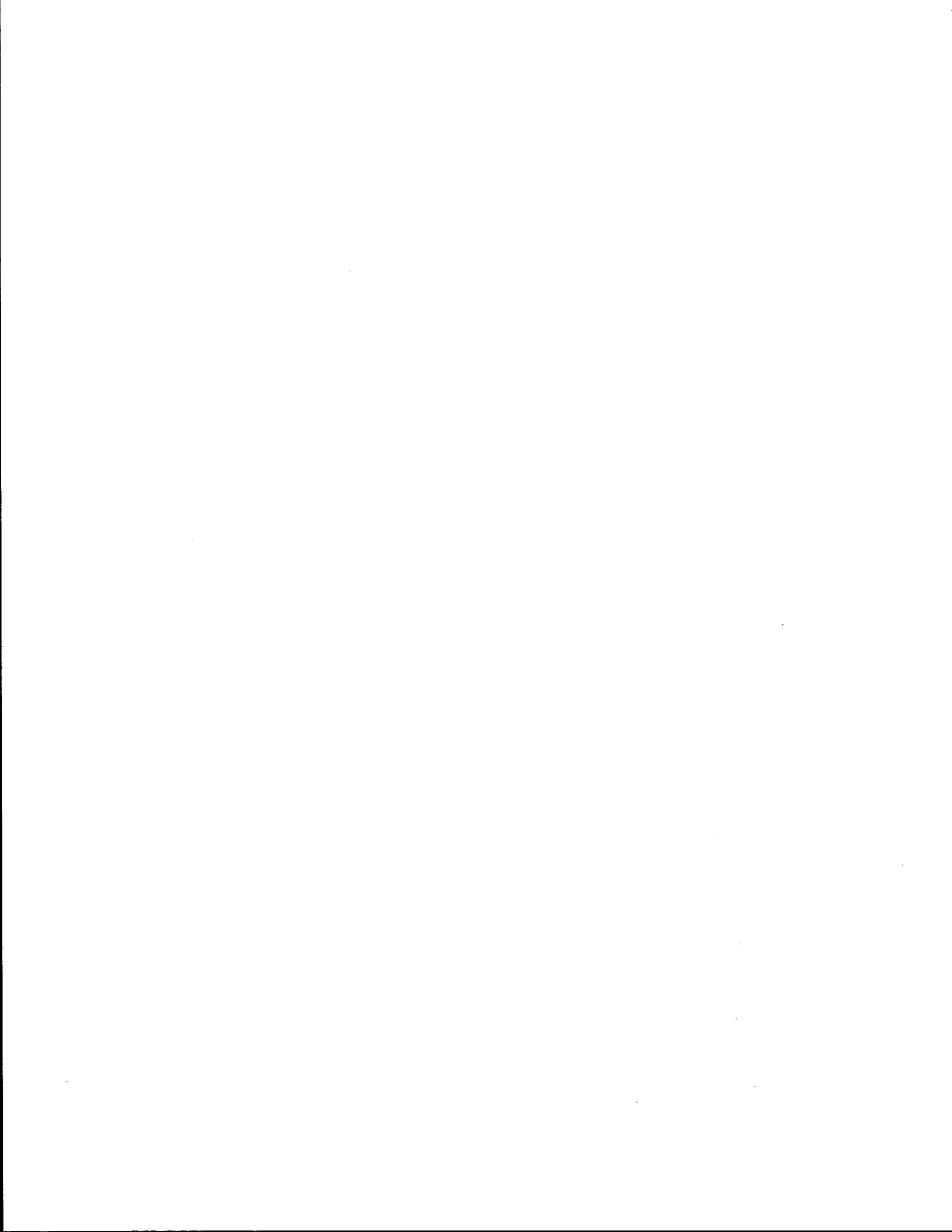


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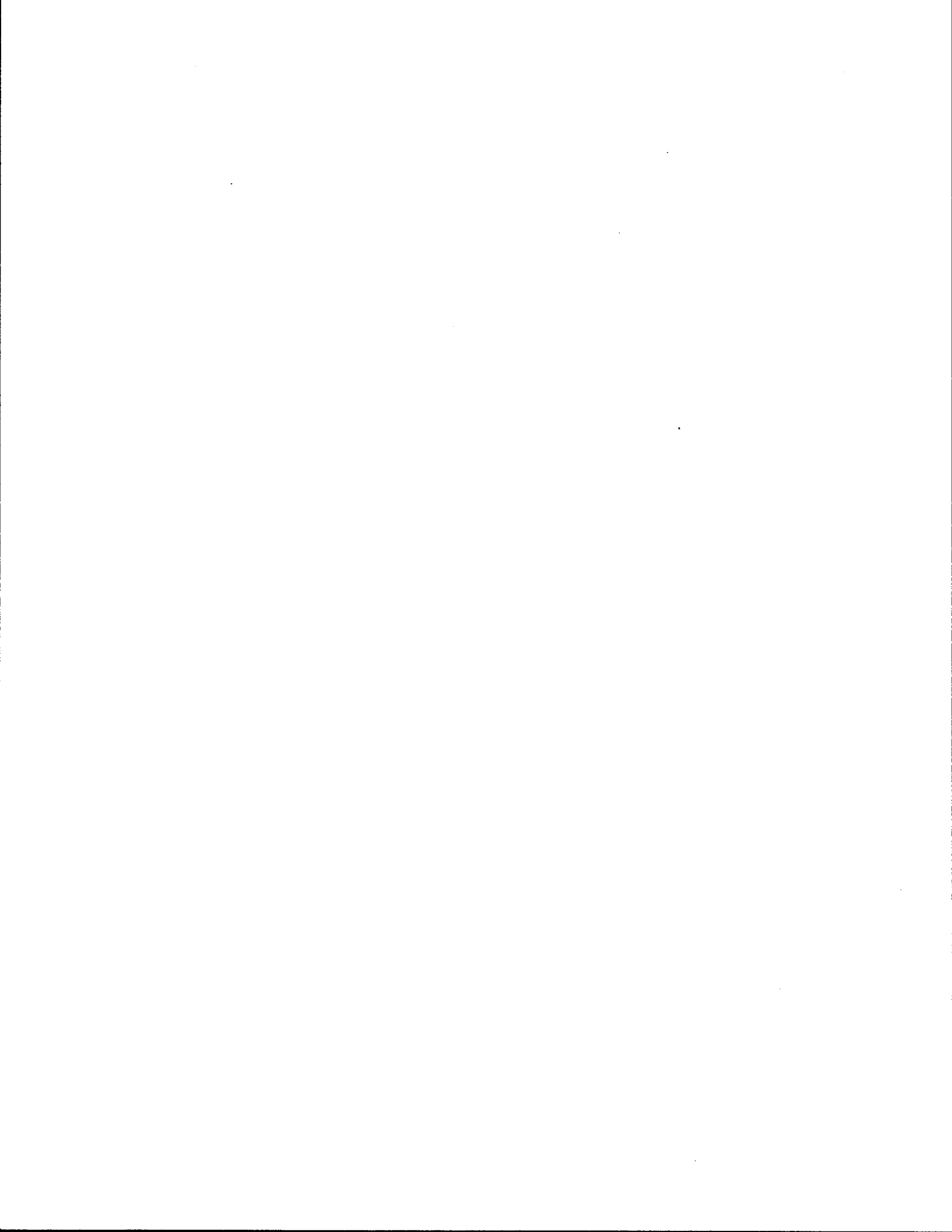
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SUMMARY

The objective of this research study was to monitor and document the performance of RAP test sections which were constructed under a previous research study: 0-1272, "Routine Maintenance Uses for Milled Reclaimed Asphalt Pavement (RAP)". The field experiments were designed to focus on improving the quality of RAP for use in maintenance applications by cold mixing the RAP with recycling agents or by blending it with conventional, stockpiled maintenance mixes. Three of the experiments were designed to evaluate the use of RAP in or as base material.

Several recycling agents were cold-mixed with RAP and evaluated in terms of the mixture's field performance. AES-300RP was determined to be the most cost-effective cold-mix recycling agent for improving the use of RAP as a maintenance mixture with a reasonable stockpile life. However, it was also found that the most common problem when using this recycling agent was the addition of too much AES-300RP, which can lead to early permanent deformation problems in the pavement.

RAP (both treated and untreated) was also blended with conventional maintenance mixtures (hot mix cold laid asphalt concrete pavement - HMCL and limestone rock asphalt pavement - LRA) and evaluated in terms of field performance. The HMCL, which was blended with both treated and untreated RAP, performed very successfully in all of the field trials. LRA was also blended with both untreated and treated RAP. These blends also performed successfully, except for one experiment where severe cracking was observed. The cracking is attributed to a lack of cohesion in the blend. When blending RAP with a conventional maintenance mixture, the most cost-effective blend was found to be HMCL blended with untreated RAP at a 60/40 (HMCL/RAP) ratio.

This study also showed RAP to be successful and cost effective when used as a stabilized base and/or blended with existing base materials.



1

Introduction

Several maintenance treatments were constructed as field experiments with reclaimed asphalt pavement (RAP) under a previous research study: 0-1272, "Routine Maintenance Uses for Milled Reclaimed Asphalt Pavement (RAP)." For most of these projects, researchers collected video footage, field samples, and performed laboratory testing on the field samples. It was essential to the successful completion of research study 1272 that the performance of these field experiments be monitored to determine their success or failure for at least a two-year period. This was accomplished under the study which is documented herein.

1.1 Background and Objectives

Cold milling of asphalt pavements to correct surface irregularities, maintain curblines, or to remove a poor quality layer has become common practice. This milled material is commonly referred to as reclaimed asphalt pavement (RAP). The objective of the parent research study (Study 1272), which preceded the study described in this report, was to determine the most economical and effective maintenance uses for this milled RAP. More specific objectives included: (1) to determine existing, effective uses of milled RAP currently used within the districts and in other states and countries; (2) to determine the effectiveness of new, untried ideas and improvements on existing uses through field experimentation, and (3) to provide the department with a mode of implementation for the research results. The reader is referred to Estakhri and Button (1992) and Estakhri and Bohuslav (1993) for the complete documentation of research

study 1272.

Most of the field experiments constructed in this study attempted to improve the quality of RAP by cold-mixing it with recycling agents or by blending the RAP with conventional maintenance mixtures such as Item 334, Hot Mix-Cold Laid Asphalt Concrete Pavement (HMCL) and Items 330 and 332, Limestone Rock Asphalt Pavement (LRA) as described in the Texas Department of Transportation *Standard Specifications for Construction of Highways, Streets and Bridges 1993*.

The objective of this research study was to monitor and document the performance of the test sections constructed under research study 1272. Field experiments were constructed throughout the state as shown in Figure 1.

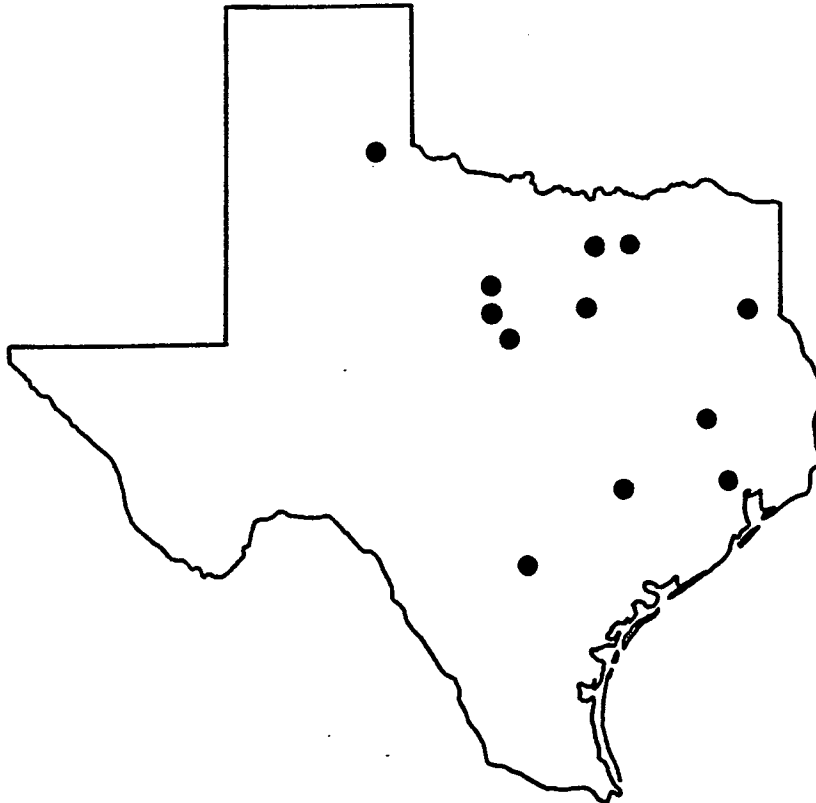


Figure 1. Maintenance Test Section Locations.

The types of maintenance test sections which were constructed by TxDOT maintenance forces included the following:

- County road approach,
- Blade level-up on travel lanes,
- Shoulder reconstruction,
- Base repairs/reconstruction,
- Parking lot construction, and
- Research test sections (thin overlays constructed end-to-end using different materials).

In general, most of the field experiments performed well and much better than district maintenance personnel anticipated at the onset of the study.



Field Experiments and Performance

RAP has been used as is (without improvement) by maintenance personnel in the department for several years as a temporary maintenance treatment where minimal traffic is expected, such as on driveways, mailbox turnouts, and pavement edge repairs. However, with minimal processing RAP can be greatly improved in terms of performance, life, workability, and appearance. When properly blended with recycling emulsions, it can be stockpiled and used as any other maintenance mix with some limitations.

The field experiments described in this chapter were designed to focus on improving the quality of RAP by cold mixing the RAP with recycling agents or by blending it with conventional, stockpiled maintenance mixes. Most of these experiments were constructed in 1991 and 1992 and their performance was monitored semi-annually in 1993 and 1994. Researchers and department personnel agreed that a two-year monitoring period was sufficient to assess the success or failure of a particular RAP blend when used as a maintenance treatment.

Each project is described below along with a discussion of the field performance. Also included in the discussion are results of Hveem stability data which were obtained in study 1272 at the time of field construction. Several other laboratory tests were performed in study 1272; however, it was concluded that the Hveem stability test appeared to be the best test for characterizing RAP and RAP blends in terms of expected performance.

2.1 Dallas District - McKinney Test Sections

Description of Experiment

Beginning on March 26, 1992, the Dallas district participated in an experiment to evaluate the performance of RAP and treated RAP blended with other commonly used maintenance mixes. The following materials were used in this experiment:

- RAP (untreated),
- Treated RAP (RAP which had been blended in a pugmill with AES-300RP three months prior to this experiment),
- HMCL: hot mix-cold laid asphalt concrete pavement, Item 350, Type D (*Standard Specifications for Construction of Highways, Streets and Bridges 1982*), and
- LRA: limestone rock asphalt, Item 330, Type C (*Standard Specifications for Construction of Highways, Streets and Bridges 1982*).

Six overlay test sections were constructed using these materials and combinations of these materials on FM 1461 in Collin County near McKinney, Texas. These six test sections were constructed end-to-end across both lanes of FM 1461. Each test section was 220 meters (700 feet) in length and about 25 to 40 millimeters (1 to 1½ inches) thick. The test sections were constructed as follows:

1. HMCL,
2. HMCL blended with untreated RAP (started with a 45/55 blend of RAP and HMCL, and later increased to 55 percent HMCL and 45 percent RAP and finally to 70 percent HMCL and 30 percent RAP),
3. HMCL blended with treated RAP (50/50 blend),
4. LRA blended with untreated RAP (60 percent LRA and 40 percent RAP),
5. LRA blended with treated RAP (50/50 blend), and
6. LRA.

Construction of Test Sections

Prior to construction of the test sections, the surface of FM 1461 was observed to be a seal coat which was moderately ravelled. There was also slight to moderate rutting on the existing pavement. Air temperature during construction ranged from 10 to 18°C (50 to 65°F).

The HMCL used for the construction of these test sections was freshly mixed and hauled directly from the plant to the jobsite where it was placed while still warm. The temperature of the mix at the time of placement was approximately 77°C (170°F). This provided for a better-than-average maintenance mix and may not be a fair comparison to a hot mix-cold laid mixture which has been stockpiled for several months and placed at ambient temperature. A tack coat consisting of about 0.5 liters per square meter (0.1 gallons per square yard) of RC-250 was sprayed prior to the placement of each test section. The first material blend applied was HMCL mixed with untreated RAP. Trucks dumped HMCL onto the westbound lane of FM 1461 for a length of 120 meters (400 feet). Untreated RAP was then dumped on top of the HMCL. The two materials were then blade-mixed in the westbound lane while traffic was diverted into the eastbound lane. This blend was about 45 percent HMCL and 55 percent RAP.

District personnel thought the blend looked too dry and the surface appeared too rough. Therefore the remainder of the test section in the westbound lane (90 meters or 300 feet) was constructed with about 55 percent HMCL and 45 percent RAP. Maintenance personnel were still not pleased with the appearance of this blend and constructed the eastbound lane of the test section with 70 percent HMCL and 30 percent RAP.

The finished surface of all three HMCL/RAP blends was somewhat rough due to large clumps of material present in the RAP. While most of these larger clumps can be removed by the motor grader operator, it is impossible to remove all of them.

Blade-mixing two materials on the pavement proved very time consuming. Therefore, beginning with test section 4, preliminary blending was accomplished at the

stockpile location using a front-end loader. The loader operator piled one material on top of another in the desired proportions. Mixing was accomplished by scooping material from the bottom of the pile to the top until a uniform blend was achieved. Final mixing was accomplished with a motor grader at the pavement site. This method provided a uniform blend of material and reduced the time of construction activity on the road.

Laboratory Test Results

Hveem stability values for the RAP mixtures used in the McKinney test sections were obtained soon after construction on laboratory molded samples. These values are shown below in Figure 2.

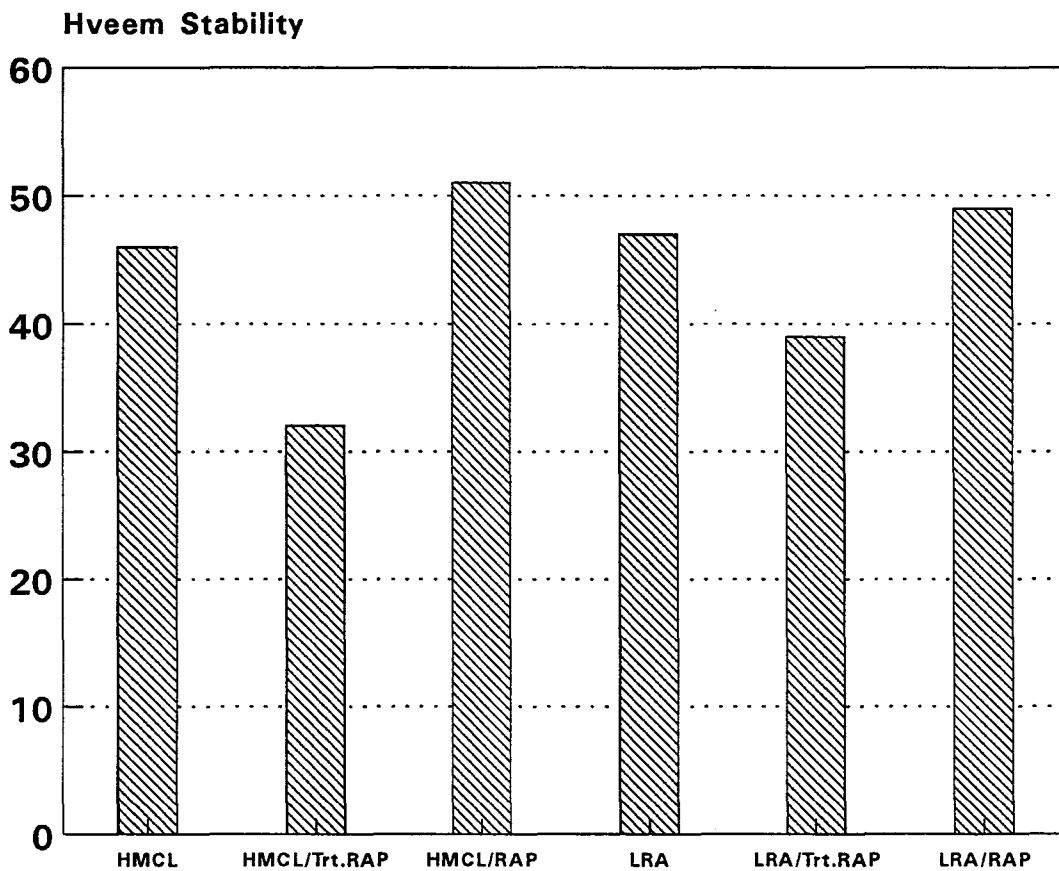


Figure 2. Hveem Stability Data for McKinney Test Section Materials.

While the Hveem stability test is not sensitive to binder viscosity, it is sensitive to binder content. The higher binder contents in the treated RAP blends probably caused the reduction in Hveem stability. The raw RAP blended with the LRA and HMCL have the highest values. This may be because the raw RAP blends had more crushed aggregate, resulting in greater interparticle friction within the mix.

Field Performance

All six test sections performed well throughout this study. All test sections were surfaced with a chip seal in the summer of 1994 as part of a routine chip seal program; therefore, the test section surfaces were exposed to traffic for more than 2 years prior to the chip seal. Any distress which was evident in the test sections by the spring of 1994 is noted below. All of the test sections exhibited slight rutting (less than 12 millimeters or 1/2 inch); however, this is not attributed to the experimental materials but to the underlying pavement which was slightly rutted prior to application of the test sections.

Test Section 1: HMCL

This section was in excellent condition with the exception of one 2.5 square meter (25 square foot) area which was exhibiting slight bleeding. A photograph of this section is shown in Figure 3.

Test Section 2: HMCL/Untreated RAP Blend

As discussed previously, this test section was constructed using several proportions of the HMCL and untreated RAP. The first load of material placed in this test section was a blend composed of about 45 percent HMCL and 55 percent RAP. District personnel thought the blend looked too dry and the surface appeared too rough. Therefore the remainder of the test section in the westbound lane was constructed with about 55 percent HMCL and 45 percent RAP. Maintenance personnel were still not pleased with the appearance and constructed the eastbound lane of the test section with 70 percent HMCL and 30 percent RAP.

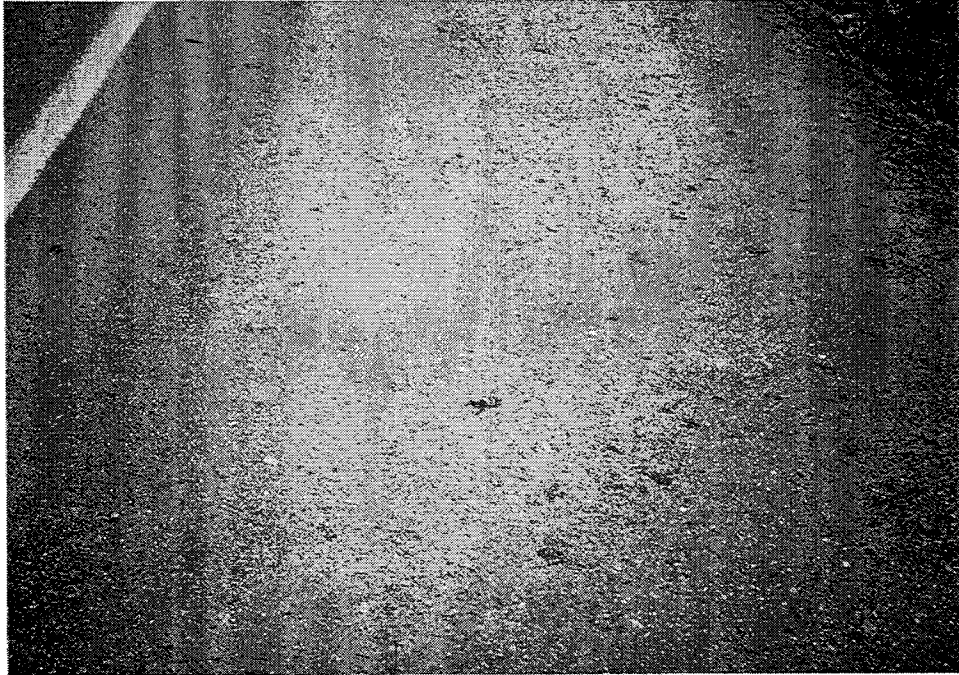


Figure 3. McKinney Test Section No. 1: HMCL.



Figure 4. McKinney Test Section 2: Close-up of HMCL/Untreated RAP, 45/55 Ratio.

The portion with the highest RAP percentage 45/55 ravelled quite severely within the first 24 hours after construction. Surprisingly, however, this raveling did not progress any further throughout the monitoring period. See Figure 4.

The 55/45 blend and the 70/30 blend of HMCL/Untreated RAP were in good condition; only slight raveling was evident. The surface texture was somewhat rough but not particularly detectable by a subjective ride quality assessment. There was almost no discernable difference between the 55/45 blend and the 70/30 blend. Figure 5 shows this test section. The 45/55 HMCL/Untreated RAP blend is shown in the foreground of the left lane in Figure 5. The 55/45 blend is in the background portion of the photo of the left lane and the 70/30 HMCL/Untreated RAP is shown in the right lane of Figure 5.



Figure 5. McKinney Test Section 2: HMCL/Untreated RAP Blend.

Test Section 3: HMCL/Treated RAP Blend

This test section was composed of a 50/50 blend of HMCL and RAP

which had been treated with AES-300RP. This section was in very good condition with slight raveling noted. This section was not particularly better than the previous section which had 55/45 HMCL/Untreated RAP. The HMCL/Treated RAP test section is shown below in Figure 6.

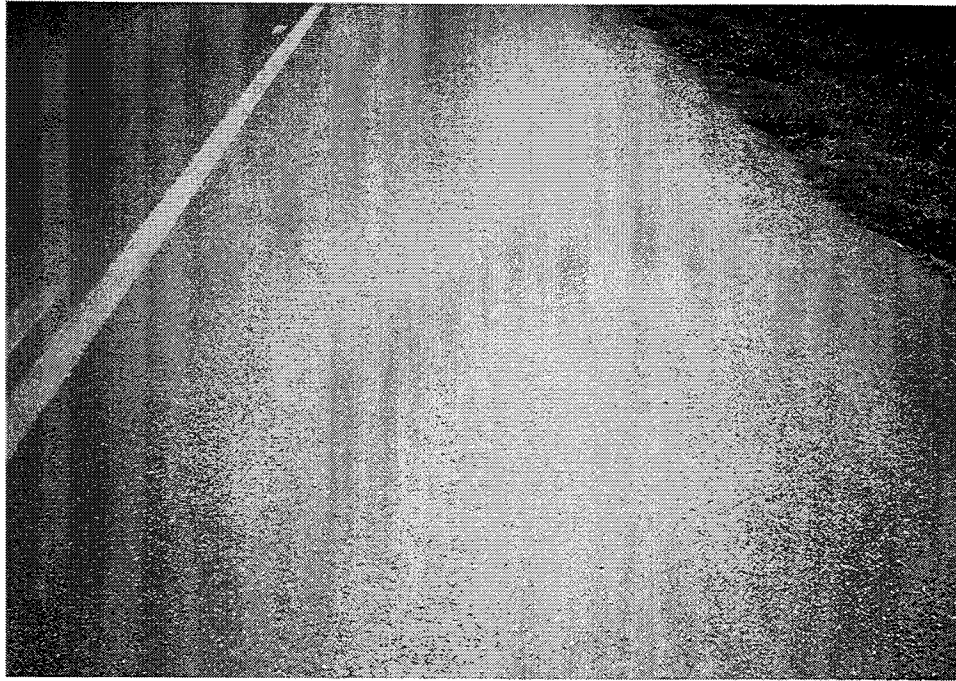


Figure 6. McKinney Test Section 3: HMCL/Treated RAP Blend.

Test Section 4: LRA/Untreated RAP Blend

This test section was constructed with a blend of 60 percent LRA and 40 percent untreated RAP. This test section performed relatively well throughout the monitoring period. It appeared to be slightly more ravelled than test section 3 and exhibited some slight cracking as shown in Figure 7. It also contained a very small pothole (100 millimeters or 4 inches in diameter).



Figure 7. McKinney Test Section 4: LRA/Untreated RAP Blend.

Test Section 5: LRA/Treated RAP Blend

The material blend used to construct this test section was composed of 50 percent LRA and 50 percent RAP treated with AES-300RP. This test section performed very well with no distress noted. A photograph of this section is shown in Figure 8.

Test Section 6: LRA

This test section served as a control section and was constructed with 100 percent LRA. This test section performed very well with no distress noted (see Figure 9).



Figure 8. McKinney Test Section 5: LRA/Treated RAP Blend.



Figure 9. McKinney Test Section 6: LRA.

In summary, all six of the McKinney test sections performed well. There was very little difference in the performance of the test sections containing treated versus untreated RAP when blended with conventional maintenance mixtures; therefore, it would seem cost-effective to use untreated RAP when blending with a conventional maintenance mixture.

The maintenance supervisor was asked to subjectively evaluate the six different test sections based on general appearance and ride quality (at 18 months of service). He ranked the six test sections as follows (the best is listed first):

1. HMCL,
2. HMCL/Untreated RAP (55/45 and 70/30 blend),
3. LRA,
4. HMCL/Treated RAP,
5. LRA/Untreated RAP, and
6. LRA/Treated RAP.

2.2 Fort Worth District - Cleburne Test Sections

Description of Experiment

On April 29, 1992, the Fort Worth District (Cleburne Maintenance Section) began construction of five research test sections to evaluate RAP. The following materials were used in the experiment:

- RAP (untreated),
- Treated RAP (RAP blended with one percent MS-1),
- HMCL: hot mix-cold laid ACP, Item 350, Type FF (*TxDOT Standard Specifications for Highways, Streets and Bridges 1982*), and
- LRA: limestone rock asphalt, Item 330, Type CC (*TxDOT Standard Specifications for Highways, Streets and Bridges 1982*).

Five overlay test sections were constructed using these materials on FM 1902 in Johnson County near Joshua, Texas. These test sections were constructed end-to-end across both lanes of FM 1902. Each test section was 150 meters (500 feet) in length

and the material was placed about 25 millimeters (one inch) thick. The test sections were constructed as follows:

1. HMCL,
2. HMCL blended with untreated RAP (70 percent HMCL and 30 percent RAP),
3. HMCL blended with treated RAP (50/50 blend),
4. LRA, and
5. LRA blended with treated RAP (50/50 blend).

Construction of Test Sections

Prior to construction of the test sections, the surface of FM 1902 was observed to be a plant mix seal which was badly ravelled in places and had some large patches. Air temperature during construction ranged from 15 to 30°C (60 to 85°F).

The treated RAP was blade-mixed at the stockpile with one percent MS-1 the day it was placed on the pavement. Combinations of mixtures were blended at the stockpile using a front-end loader and then hauled to the jobsite for placement. The material was spread and placed using a motor grader and then compacted with a steel-wheel roller.

Laboratory Test Results

Hveem stability data for the Cleburne test sections are shown in Figure 10 below. These tests were performed on laboratory molded samples obtained soon after construction. The addition of RAP and treated RAP to the HMCL and LRA had little effect on Hveem stability.

Field Performance

As stated previously, these test sections were constructed in the spring of 1992. Their performance was monitored in this study through August of 1994 (for 2½ years). A description of the performance of each test section is shown below.

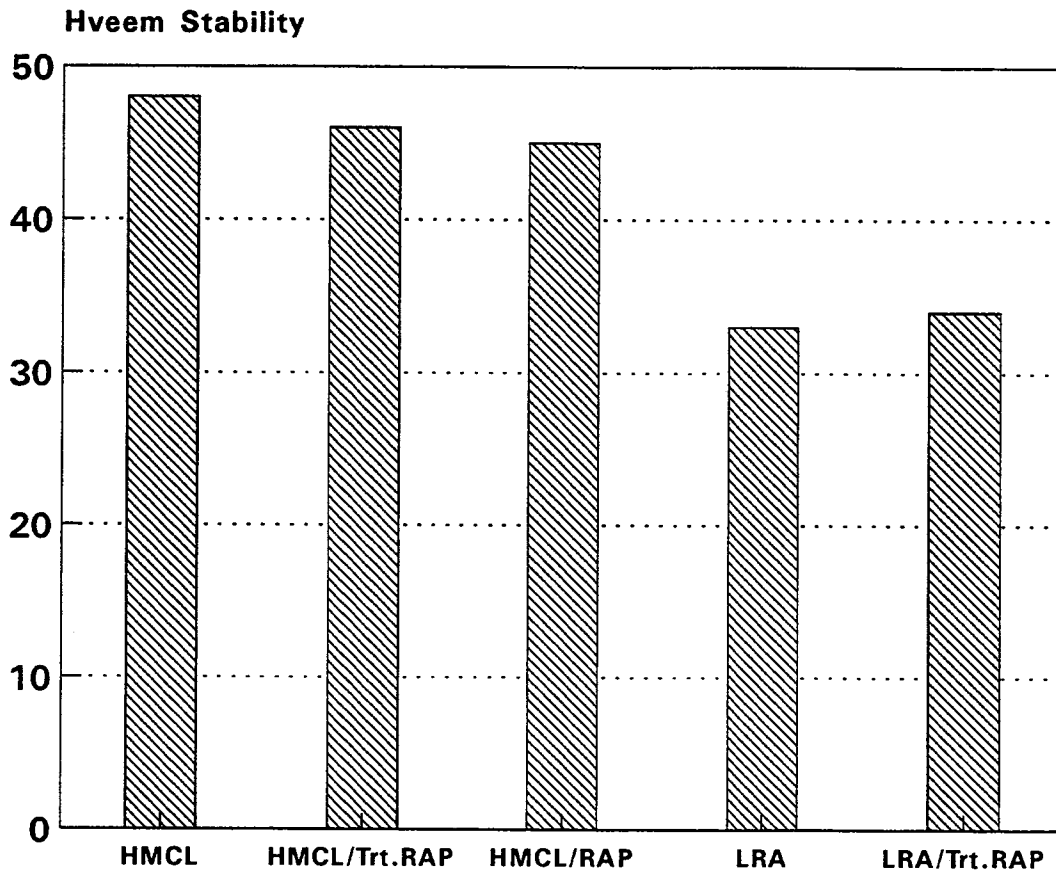


Figure 10. Hveem Stability Data for Cleburne Test Section Materials.

Test Section 1: HMCL

This section served as a control material and was constructed using 100% HMCL. It performed very well throughout the study and showed no signs of any distress. This test section performed better than any of the other four in this Cleburne experiment. A photo of this section is shown in Figure 11.

Test Section 2: HMCL/Untreated RAP Blend

This test section was constructed with a blend of 70 percent HMCL and 30 percent RAP. This section was in very good condition with the exception of some slight ravelling. Most of this ravelling occurred immediately after construction. This test section is shown in Figure 12.



Figure 11. Cleburne Test Section 1: HMCL.



Figure 12. Cleburne Test Section 2: HMCL/Untreated RAP Blend.

Test Section 3: HMCL/Treated RAP Blend

This test section was constructed with a blend of 50 percent HMCL and 50 percent treated RAP. This section was in very good condition throughout the study with the exception of some ravelling. Again, this ravelling occurred immediately after construction and did not progress throughout the monitoring period (see Figure 13 below).

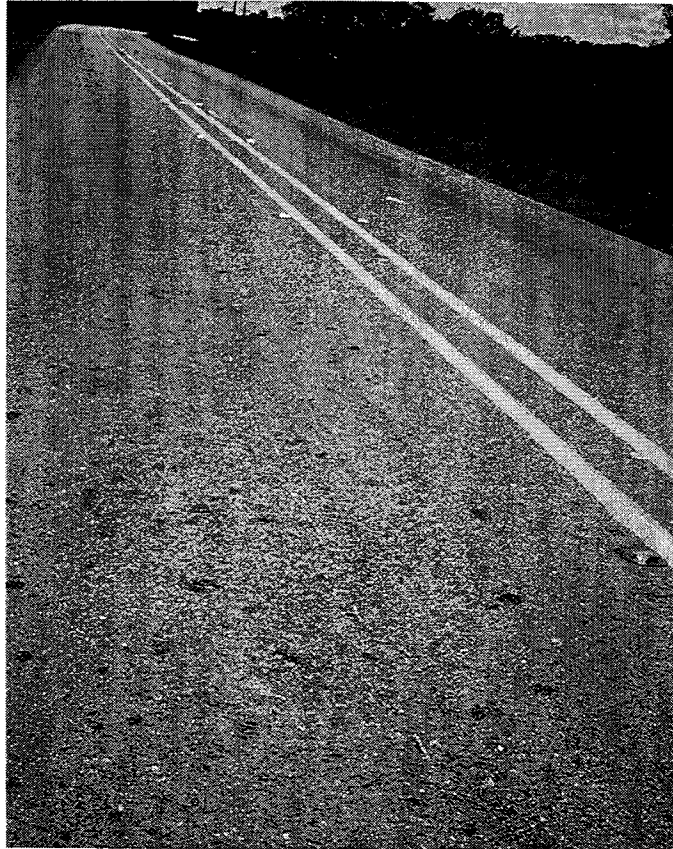


Figure 13. Cleburne Test Section 3: HMCL/Treated RAP Blend.

Test Section 4: LRA.

This test section served as a control material and was constructed of 100% LRA. This section exhibited severe longitudinal cracking as shown below in Figure 14 and significantly more ravelling than sections 1 through 3. Typically, this type of pavement failure evidenced in the surface would be associated with a subgrade failure. However, in this case it appears the cracking is

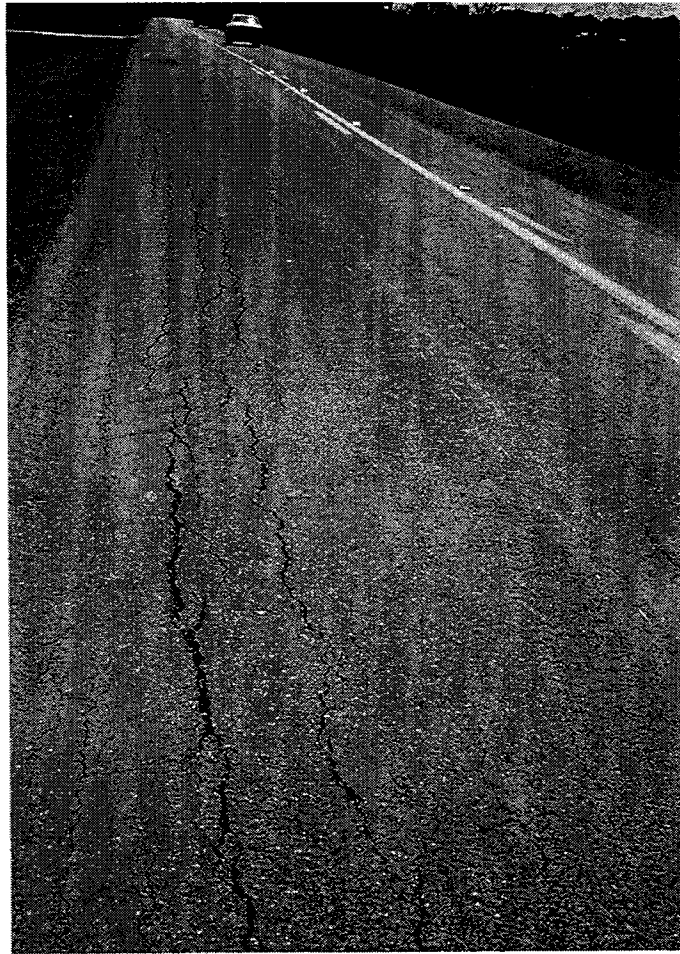


Figure 14. Cleburne Test Section 4: LRA.

occurring in the surface material only. The surface overlay is very thin (25 mm or 1 inch) and in some places the cracks were wide enough to see the underlying pavement layer which was not cracked. It was also noted that beyond the experimental sections, the pavement was not exhibiting this type of distress. The researchers believe that there is slippage between the surface layer and underlying pavement which is causing these types of cracks to appear. This particular section (Number 4) is the worst of the 5 sections in Cleburne.

Test Section 5: LRA/Treated RAP Blend

Test section 5 was constructed with a blend of LRA and treated RAP at a 50/50 ratio. This test section also exhibited a significant amount of ravelling and cracking; however, it was not as severe as that in section 4. In this particular

case, it appears that the addition of the treated RAP to the LRA actually improved its performance. Perhaps the addition of emulsion to the RAP increased the overall binder content of the blend, thereby improving its cohesive properties. This section is shown below in Figure 15.



Figure 15. Cleburne Test Section 5: LRA/Treated RAP Blend.

In summary, the three test sections constructed with HMCL, HMCL/Untreated RAP and HMCL/Treated RAP performed well. Neither the LRA nor LRA/Treated RAP sections performed acceptably, the primary distress of concern being the significant cracking. It appears that this cracking will progress to a level at which the surface must be removed. In general, it seems that LRA is a "drier" mix than HMCL; therefore, this type of "slippage" cracking would be more likely to occur under these particular pavement conditions. Perhaps a heavier tack coat would have improved the performance of the LRA test sections.

2.3 San Antonio District - Pleasanton Test Sections

Description of Experiment

On September 1, 1992, the San Antonio District began construction of five research test sections to evaluate RAP. The following materials were used in the experiment:

- RAP (untreated),
- Treated RAP (RAP blended with AES-300RP),
- HMCL: hot mix-cold laid ACP, Item 350, Type D (*TxDOT Standard Specifications for Highways, Streets and Bridges 1982*), and
- LRA: limestone rock asphalt, Item 330, Type CC (*TxDOT Standard Specifications for Highways, Streets and Bridges 1982*).

Five overlay test sections were constructed using these materials on SH 97 about 3 miles east of I-37 (near Pleasanton). These test sections were constructed across both lanes of SH 97. Each test section was 150 meters (500 feet) in length and the material was placed about 25 millimeters (one inch) thick. The test sections were constructed as follows:

1. HMCL blended with untreated RAP (60 percent HMCL and 40 percent RAP),
2. HMCL,
3. LRA blended with treated RAP (50/50 blend),
4. LRA, and
5. HMCL blended with treated RAP (50/50 blend).

Construction Details

The treated RAP was blended with AES-300RP by the maintenance forces. The RAP material was windrowed and emulsion was sprayed with a distributor onto the RAP. Mixing was accomplished with a pulver mixer and motor grader.

Laboratory Test Results

Hveem stability tests were performed on laboratory molded samples of some of the test section material for the Pleasanton test sections. These data are shown in Figure 16.

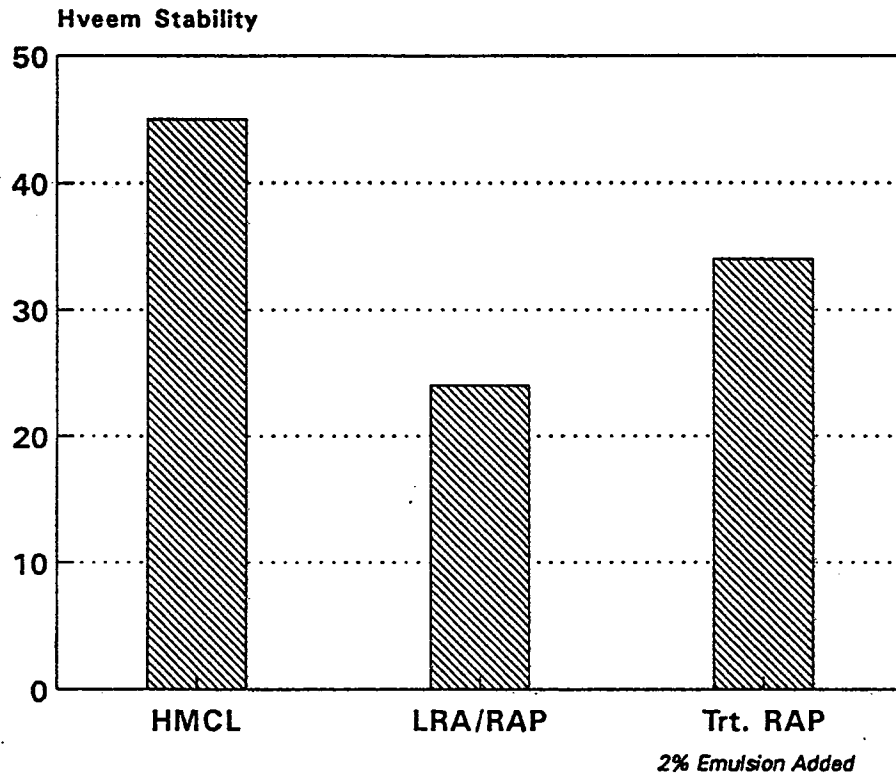


Figure 16. Hveem Stability Data for Pleasanton Test Section Materials.

The treated RAP blend had a stability of more than 30 which was better than most of the materials tested in this study which had been treated with AES-300RP. The HMCL had a stability of 45 and the LRA/RAP blend had a Hveem stability of about 25.

Field Performance

All five test sections performed very well throughout this 2-year monitoring study. The sections were scheduled for a routine chip seal shortly after the final evaluation which was made in August of 1994. A discussion of their performance is summarized below.

Test Section 1: HMCL/Untreated RAP

This test section was constructed with a blend of 60 percent HMCL and 40 percent RAP. It performed very well throughout the study with the exception of minor ravelling. This test section is shown in Figure 17.

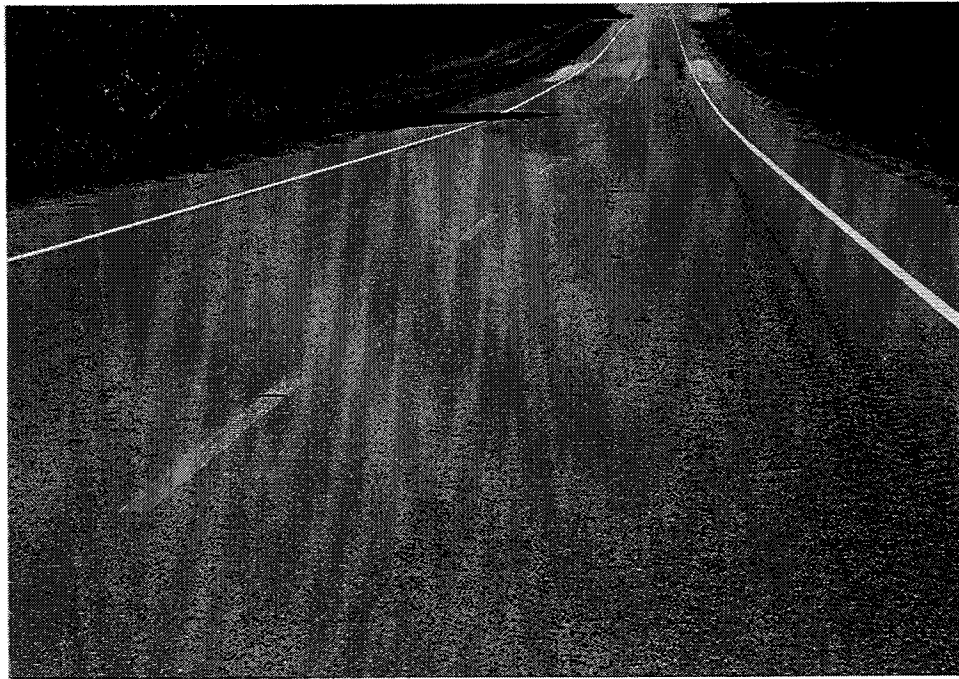


Figure 17. Pleasanton Test Section 1: HMCL/Untreated RAP.

Test Section 2: HMCL

Test section 2 was built as a control section and was constructed of 100% HMCL. It performed very well throughout the study and showed no signs of distress. See Figure 18.

Test Section 3: LRA/Treated RAP

This test section was constructed using LRA blended with treated RAP at a 50/50 ratio. This section showed more distress than any of the other five test sections: the primary distress was longitudinal cracking. However, the cracking did not cover an extensive area and the cracks themselves could be considered slight in severity. See Figure 19 below.



Figure 18. Pleasanton Test Section 2: HMCL.



Figure 19. Pleasanton Test Section 3: LRA/Treated RAP.

Test Section 4: LRA

Test section 4 was constructed as a control section using 100% LRA. This test section performed very well but showed very minor signs of ravelling. See Figure 20 below.



Figure 20. Pleasanton Test Section 4: LRA.

Test Section 5: HMCL/Treated RAP

This section was constructed as a 50/50 blend of HMCL and treated RAP. This section performed very well with only minor signs of ravelling. See Figure 21.

In summary, all of the Pleasanton test sections performed well. The only section showing any signs of distress to warrant concern is the LRA/Treated RAP section. Cracking in this section was fairly minor; however, it is conceivable that the cracking could progress to unacceptable levels. It is not certain that the cracking in this section

exists only in the surface material; however, it is assumed so since this type of distress was not evident in any of the other sections of pavement. The HMCL control section showed the least signs of distress and the remaining three sections all performed equally well: LRA, HMCL/Treated RAP, and HMCL/Untreated RAP.



Figure 21. Pleasanton Test Section 5: HMCL/Treated RAP.

2.4 Tyler District - Kilgore Test Sections

Description of Experiment

In September of 1992, the Tyler district constructed two thin overlays to be evaluated as test sections in this study. Two 150 meter (500 foot) test sections were placed on FM 2011 in Rusk County near Kilgore. Lake Cherokee crosses FM 2011 halfway between SH 322 and FM 1716. The test sections are located immediately east of the lake crossing. These test sections were constructed by district maintenance

forces as follows:

- Treated RAP (RAP blended with 2 percent AES-300RP) and
- HMCL: hot mix-cold laid ACP, Item 350, Type D (*TxDOT Standard Specifications for Highways, Streets and Bridges 1982*).

Construction of Test Sections

In June of 1992, the district contracted to have several stockpiles of RAP pugmill-blended with AES-300RP. These stockpiles were located throughout the district and the pugmill was transported to each location. Approximately two percent, by weight, AES-300RP was blended with the RAP at an average cost of \$17.33 per cubic meter (\$13.00 per cubic yard). Two 150-meter (500-foot) overlay test sections were constructed in September of 1992 by district maintenance forces: one section was built using the treated RAP and the other section was a control section of HMCL. The existing pavement was a chip seal in good condition.

Laboratory Test Results

Hveem stability tests were performed on the laboratory-molded samples of Kilgore RAP treated with AES-300RP as sampled in the field. The Hveem stability value for the treated RAP was so low that it could not be measured. The low stability for this material is attributed to excess binder.

Field Performance

These test sections were constructed in September of 1992 and their performance was monitored in this study through August of 1994 (for 2 years). A description of the performance of these test sections follows.

Test Section 1: Treated RAP

This test section was constructed using RAP which had been treated with AES-300RP as previously described. By the end of the first year, this test section was experiencing serious signs of flushing and rutting in the wheelpaths. By the end of the second year, about 70 percent of the area was flushed and ruts were as deep as 25 millimeters (1 inch). See Figures 22 and 23.



Figure 22. Kilgore Test Section 1: Treated RAP (Flushing Distress).



Figure 23. Kilgore Test Section 1: Treated RAP (Rutting Distress).

Test Section 2: HMCL

Test section 2 was constructed as a control using HMCL. This test section performed well except for some flushing in the wheelpaths of the eastbound lane as shown below in Figure 24.

In summary, the treated RAP test section performed poorly as might have been predicted by the extremely low Hveem stability laboratory values. The poor performance is attributed to excess binder added to the RAP. The HMCL test section performed acceptably despite some minor flushing.



Figure 24. Kilgore Test Section 2: HMCL.

2.5 Childress District - Childress Test Section

Description of Experiment

Using the pugmill-blending process, RAP was mixed with four different emulsions in August of 1992: AES-300RP, CRR-60, ARE-68, and MS-1. TxDOT specifications for AES-300RP and the manufacturer's specifications for CRR-60 and ARE-68 are included in Research Report 1272-1 (Estakhri and Button 1992). Specifications for MS-1 are in the 1982 TxDOT Standard Specifications, Item 300. As described previously, AES-300RP is a high-float, anionic recycling emulsion for use with RAP which is to be stockpiled. CRR-60 is a cationic recycling emulsion which can be mixed with RAP and stockpiled for long-term use (6 to 12 months). ARE-68 is also a cationic recycling emulsion that can be blended with RAP, but for short-term use. It provides a stockpile life of approximately 90 days.

Originally, it was intended that each of the 4 blends would be placed as thin overlays on US 287; however, district personnel elected to place only the ARE-68 blend as a test section on US 287 (traffic level 6400 ADT, 17% trucks) and thus, this blend was the only one monitored in this study. The other 3 blends were used in routine maintenance throughout the district.

Construction of Test Sections

A total of 4875 cubic meters (6500 cubic yards) of RAP were recycled in this project. The average cost of recycling this entire quantity of RAP was \$24.76 per cubic meter (\$18.57 per cubic yard). Approximate quantities and costs for the different recycled materials used on this job are listed below in Table 1.

The manufacturer of the ARE-68 recommended that the blended material be used within 2 to 90 days after mixing; therefore, this material was placed soon after mixing. The RAP treated with ARE-68 was placed in the northbound lanes of US 287 between Estelline and Memphis in Hall County. It was placed in one lift approximately 50 millimeters (2 inches) thick.

Table 1. Quantities and Costs for Childress RAP Blends.

Type Emulsion Used	Quantity of Emulsion, % by wt. of RAP	Quantity of RAP Recycled, m ³ (yd ³)	Cost of Recycled Material, per m ³ , (yd ³)
AES-300RP	2½	2201 (2935)	\$20.28 (\$15.21)
CRR-60	3 - 3½	836 (1115)	\$32.36 (\$24.27)
ARE-68	3 - 3½	836 (1115)	\$33.09 (\$24.82)
MS-1	3 - 3½	1001 (1335)	\$22.80 (\$17.10)

One of the problems in the mixing process noted by district personnel was in controlling the quantity of emulsion mixed with the RAP. The target quantity was estimated based on the amount of emulsion being metered into the pugmill (gallons per minute) and by knowing the amount of time needed to fill up a truck with the recycled material. District personnel report that in the future, a belt scale at the plant will be specified. This will provide more accurate control of the emulsion quantity.

Maintenance forces reported that the AES-300RP blend appeared to provide the best maintenance mix. Only 2½ percent AES-300RP was needed to achieve the desired mix, while 3 to 3½ percent of the other three emulsions was required.

Laboratory Test Results

Hveem stability results for the four different Childress blends are shown below in Figure 25. The AES-300RP-modified RAP had the lowest stability of the four materials tested. It is also very low when compared to other RAPs modified with the same emulsion evaluated in Study 1272. The MS-1-modified RAP had the highest stability; however, one would not expect it to provide extended stockpile life.

Field Performance

The ARE-68 treated RAP began to exhibit rutting soon after construction. By the end of two years, the rutting in the wheel paths was about 12 to 19 millimeters (1/2 to 3/4 inches) deep. District personnel attribute the rutting to inadequate density achieved in the compacted mixture; however, some signs of flushing indicate there may have been excessive binder in the mix. See Figure 26.

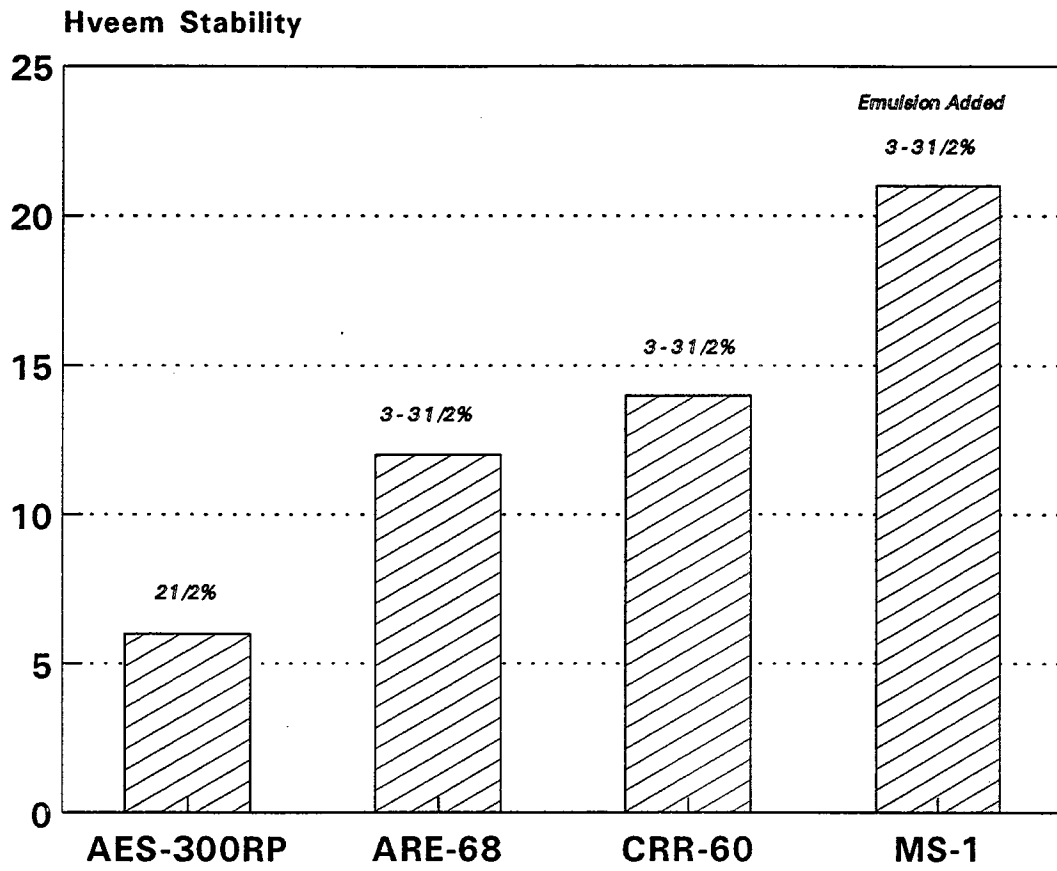


Figure 25. Hveem Stability Data for Childress Test Section Materials.



Figure 26. Childress Test Section - ARE/68 RAP Blend.

2.6 Brownwood District - Routine Maintenance Treatments

Description of Experiment

In July of 1991, TTI observed the construction of three routine maintenance treatments using RAP which had been treated with AES-300RP:

- the intersection to a county road,
- a level-up to correct a pavement dip, and
- a base repair.

The county road approach is located on SH 67 about 8 km (5 miles) north of Breckenridge. The base repair is about 8 km (5 miles) north of Gorham on FM 8 (near county road 506) and the level-up section is on FM 2247 about 1.6 km (1 mile) south of FM 587.

Construction Details

In November of 1990, the Brownwood District blended RAP with AES-300RP using a pugmill. Approximately 6000 cubic meters (8000 cubic yards) of RAP were blended with three percent AES-300RP. The emulsion and pugmill were provided by the contractor and district personnel operated the pugmill. It should be noted that district personnel reported that, due to their lack of experience in operating the pugmill, they recommend that the contractor also should provide an operator for the pugmill on future projects such as this.

The cost of purchasing the AES-300RP, renting the pugmill, and mixing the RAP was \$20.48 per cubic meter (\$15.36 per cubic yard) for the mixed RAP. New HMCL cost about \$28 per cubic meter (\$21 per cubic yard) at the time of this project.

In July of 1991, TTI observed the construction of three routine maintenance operations using this treated RAP: the intersection to a county road, a level-up to correct a pavement dip, and a base repair. District personnel felt the treated RAP contained excessive asphalt binder; therefore, for the base repair, the treated RAP was blended with one-third untreated RAP prior to placement.

Laboratory Test Results

The Brownwood RAP blend had a Hveem stability of 18. Based on the visual characteristics of the blend, it appeared to have excess binder; therefore, the treated RAP was blended with one-third raw RAP for the base repair. Laboratory tests were not performed on the treated RAP/RAP blend.

Field Performance

The performance of these test sections was observed for a period of three years. The county road intersection performed well with only some slight ravelling. The level up and base repair were surfaced with a chip seal within the first year of the monitoring study; however, they both performed well with no signs of distress. See Figures 27 through 29 below for a recent view of their performance.



Figure 27. Brownwood County Road Approach.



Figure 28. Brownwood Base Repair.



Figure 29. Brownwood Level-up Repair.

2.7 Dallas District - Denton Routine Maintenance Treatment

Description of Experiment

This experiment was conducted to evaluate the RAP blended with AES-300RP as it performed in a routine maintenance treatment. The treated RAP was used to repave a short section of the shoulder on Interstate 35.

Construction Details

On June 16, 1992, maintenance forces used treated RAP to repave 150 meters (500 feet) of an interstate shoulder. This job was located in Denton, Texas on Interstate 35W between FM 2449 and FM 407. The main travel lanes of this interstate are continuously reinforced concrete pavement; however, the shoulders are of a "sandwich" design. The shoulders are constructed of six inches of hot mix ACP, eight inches of flexible base, and surfaced with a chip seal.

Maintenance personnel had reported numerous failures on these shoulders which they attribute to moisture trapped in the flexible base layer. This particular section of shoulder exhibited cracking, ravelling, and shoving at the time of repair.

The existing shoulder was removed down to the hot-mix layer. Two hundred millimeters (8 inches) of treated RAP were placed on the shoulder in one lift and compacted with a pneumatic roller.

The RAP material had been blended in a pugmill in January of 1992 with 2½ percent AES-300RP. The treated RAP appeared to contain excessive binder and exhibited tenderness under the weight of the roller.

Laboratory Test Results

The Denton RAP treated with AES-300RP had a Hveem stability value of 1. Based on its visual characteristics, it also had too much binder. It was also noted to be very tender under the weight of the pneumatic rollers during construction.

Field Performance

Even though the mixture appeared to have excess binder, maintenance personnel believed that it might perform suitably on the inside shoulder with little traffic. However, excessive rutting and shoving occurred in the mix and it was removed from the pavement within six months of construction.

In summary, this Denton RAP blend performed very poorly, exhibiting unacceptable levels of permanent deformation. It appeared to have excess binder in the mix as might have been predicted by the very low Hveem stability values.

2.8 Yoakum District - Base Repair

Description of Experiment

On July 6, 1992, maintenance personnel in the Yoakum District used RAP in the repair of a base failure on FM 609 in Fayette County. The cross section of pavement repaired was as follows:

90 mm (3½ inches) of Hot-Mix ACP

150 mm (6 inches) of crushed stone base

60 mm (2½ inches) of ACP

Construction Details

A pavement recycler was used to repair this base failure. This equipment is capable of pulverizing the asphalt concrete pavement and mixing the pulverized RAP with the existing base material. The recycler went down the full 300 millimeters (12 inches) to get both layers of hot-mix. Some new base material was also added so that

a more gradual slope could be provided at the edge of the pavement for better side support. Lime was used to stabilize the pulverized mixture. A seal coat was constructed over the compacted base repair.

The cost for this repair is tabulated below.

Labor

Fayette County Labor - 7 men x 4 hours @ 16.52 per hr	\$462.56
District Labor - 1 man x 4 hours @ 16.71 per hr	<u>\$ 66.84</u>
	\$529.40

Equipment

Recycling Equipment - 4 hours at \$85.00 per hour	\$340.00
Other Equipment	<u>\$346.85</u>
	\$686.85

Material

Lime - 155 sacks at \$2.16 per sack	\$334.80
Base Material - 23 m ³ (30 yd ³)	
at \$2.28 per m ³ (\$1.75 per yd ³)	<u>\$52.50</u>
	387.30

TOTAL \$1603.55

Base Repair Area = 480 m² (567.11 yd²)

TOTAL UNIT COST **\$3.41/m² or** **\$2.83/yd²**

The statewide average for fiscal year 1992 base repair is as follows:

Base Removal and Replacement	\$6.30/m ² or \$5.23/yd ² (State Forces)
	\$9.44/m ² or \$7.84/yd ² (Contract)
Base In-place Repair	\$2.16/m ² or \$1.79/yd ² (State Forces)
	\$6.84/m ² or \$5.68/sy (Contract)

Laboratory Test Results

No laboratory tests were performed on this material.

Field Performance

This base repair performed very well throughout this study with no visible signs of distress. The surface was sealed after one year as part of a routine chip seal operation.

2.9 Bryan District - Base Reconstruction

Description of Experiment

State forces in the Bryan district used untreated RAP to repair a base failure on FM 980 at Riverside, Texas 16 km (10 miles) east of Huntsville in May of 1992. The total length of the project was 3 kilometers (2 miles). There are two limestone quarries serviced by FM 980 which likely contributed to this base failure.

Construction Details

The existing pavement appeared to be a series of chip seals over a thin base. The objective of the project was to scarify and pulverize the existing pavement structure and mix in some additional RAP to increase the bearing capacity and provide a more moisture resistant base material. The pavement section was then primed and surfaced with a chip seal.

The following equipment was used in the project:

- Pulver-mixer,
- (2) Motor graders,
- 3636 to 4545 kilogram (8,000 to 10,000 pound) pneumatic roller,
- Water truck, and
- Self-propelled broom.

The existing pavement was initially broken up using the rippers on the motor grader. The pulver-mixer worked the broken pavement for several passes to reduce the maximum particle size and to mix the existing base with the pulverized surface. Motor graders were then used to windrow the mix.

Untreated RAP was hauled to the job from a stockpile location and mixed into

the existing material at the rate of one truckload of RAP per 30 meters (100 feet) (3.8 meter- or 12-foot lane). Water was added to the mix as needed to enhance compaction. Care was taken to insure the RAP material was uniformly distributed along the entire length of pavement.

Laboratory Test Results

No laboratory tests were performed on this material. Laboratory tests were performed on maintenance mixes only.

Field Performance

This pavement performed very well throughout this study. There was a small area near the intersection of FM 980 and SH 19 that exhibiting some rutting and shoving. The remainder of the pavement had minor rutting (less than 6 mm or 1/4 inch) but overall performed very well.

2.10 Houston District - Base Construction

Description of Experiment

On October 12, 1992, the Houston District used stabilized RAP to construct the base of a parking lot at the district office.

Construction Details

The RAP material was stockpiled near the district office where it was blade-mixed with Type II cement by maintenance personnel. Cement was added at the rate of 1½ sacks per 0.76 cubic meter (1 cubic yard) of RAP and approximately 50 to 60 liters per cubic meter (10 to 12 gallons per cubic yard) of water were added. About 60 cubic meters (80 cubic yards) of material could be mixed at one time.

The cement-stabilized RAP was then hauled to the parking lot jobsite where it was placed and compacted in three lifts for a total thickness of eight inches. It was then surfaced with Item 340, Type D, hot-mix asphalt concrete pavement.

The maintenance supervisor reported that if the base had not been constructed with the RAP, the material of choice would have been Item 292, asphalt-stabilized base. The cost of labor, equipment and materials for construction of the RAP base was \$9,330 (\$24.55 per cubic meter or \$18.66 per cubic yard). The estimated cost of labor, equipment and materials to construct the parking lot base using Item 292 was \$11,644 (\$30.64 per cubic meter or \$23.29 per cubic yard).

Laboratory Test Results

No laboratory tests were performed on this material. Laboratory tests were performed on maintenance mixes only.

Field Performance

A large part of this parking lot around the perimeter appears to be used for storage of materials such as pipes, drums of paint, and 5-gallon cans of patching material. In these areas, particularly under the stored materials, some minor cracks have developed as shown below in Figure 30. Overall, however, the parking lot is performing very well.



Figure 30. Houston District - Base Construction.

3

Conclusions and Recommendations

In this study, RAP was blended with recycling emulsions and conventional maintenance mixtures in attempts to improve its field performance as a maintenance mixture. RAP was also mixed with stabilizers and used as a base material in maintenance projects. These field experiments were monitored for a period of two years to evaluate their performance. A summary of the results is shown in Table 2. Performance of the experiments is classified as success or failure for each maintenance treatment evaluated. A treatment was considered successful if it showed no or little distress and was functioning as generally intended. A treatment was considered a failure if the distress was severe enough to warrant removal and replacement.

3.1 Conclusions

Based on the results of this study, the following conclusions were developed.

- The most common problem with treated RAP was the addition of too much recycling emulsion.
- AES-300RP appears to be the recycling emulsion most preferred by maintenance personnel to improve the properties of RAP as a stockpiled maintenance mix. The data also indicated that it provides the best performance and is the most cost-effective recycling emulsion of those evaluated in this study (but only when the proper amount is used).

Table 2. Summary of Cost, Laboratory Properties, and Performance of Field Experiments.

<i>Field Experiment</i>	<i>Materials Used</i>	<i>Cost of Finished Mixture</i>	<i>Hveem Stability Value</i>	<i>Performance Evaluation</i>
McKinney Test Sections	LRA/Treated RAP (50/50)	\$29.33/m ³ (\$22.00/cy)	39	Success
	LRA/Untreated RAP (60/40)	\$25.33/m ³ (\$19.00/cy)	49	Success
	LRA (Control)	\$40.00/m ³ (\$30.00/cy)	47	Success
	HMCL/Treated RAP (50/50)	\$20.00/m ³ (\$15.00/cy)	32	Success
	HMCL/Untreated RAP (60/40)	\$14.13/m ³ (\$10.60/cy)	51	Success
	HMCL (Control)	\$21.33/m ³ (\$16.00/cy)	46	Success

Table 2. Continued.

<i>Field Experiment</i>	<i>Materials Used</i>	<i>Cost of Finished Mixture</i>	<i>Hveem Stability Value</i>	<i>Performance Evaluation</i>
Cleburne Test Sections	LRA/Treated RAP (50/50)	Not Available	34	Failure (Cracking)
	LRA (Control)		33	Failure (Cracking)
	HMCL/Treated RAP (50/50)		46	Success
	HMCL (Control)		48	Success
	HMCL/Untreated RAP (70/30)		45	Success

Table 2. Continued.

<i>Field Experiment</i>	<i>Materials Used</i>	<i>Cost of Finished Mixture</i>	<i>Hveem Stability Value</i>	<i>Performance Evaluation</i>
Pleasanton Test Sections	HMCL/Untreated RAP (60/40)	Not Available	Not Available	Success
	HMCL (Control)		45	Success
	LRA/Treated RAP (50/50)		24	Success
	LRA (Control)		Not Available	Success
	HMCL/Treated RAP (50/50)		Not Available	Success
Kilgore Test Sections	RAP with 2½% AES-300RP	Not Available	0	Failure (Rutting)
	HMCL	\$17.33/m ³ (\$13.00/cy)	Not Available	Success

Table 2. Continued.

<i>Field Experiment</i>	<i>Materials Used</i>	<i>Cost of Finished Mixture</i>	<i>Hveem Stability Value</i>	<i>Performance Evaluation</i>
Childress Test Sections	RAP with 2½% AES-300RP	\$20.28/m ³ (\$15.21/cy)	6	NA
	RAP with 3 - 3½% CRR-60	\$32.36/m ³ (24.27/cy)	14	NA
	RAP with 3 - 3½% ARE-68	\$33.09/m ³ (\$24.82/cy)	12	Marginal Success (Rutting)
	RAP with 3 - 3½% MS-1	\$22.80/m ³ (\$17.10/cy)	21	NA
Brownwood Routine Maintenance Treatments	RAP with 2% AES-300RP	\$20.48/m ³ (\$15.36/cy)	18	Success

Table 2. Continued.

<i>Field Experiment</i>	<i>Materials Used</i>	<i>Cost of Finished Mixture</i>	<i>Hveem Stability Value</i>	<i>Performance Evaluation</i>
Denton Shoulder Repave	RAP with 2½% AES-300RP	\$16.20/m ³ (\$12.15/cy)	1	Failure (Rutting)
Yoakum Base Repair	Lime Stabilized RAP	\$3.41/m ² (\$2.83/sy) In-place cost	Not Applicable	Success
Bryan Base Reconstruct	RAP Blended with Existing Base	Not Available	Not Applicable	Success
Houston Base Construction	Cement Stabilized RAP	\$24.88/m ³ (\$18.66/cy) In-place Cost	Not Applicable	Success

- RAP (both treated and untreated) blended with HMCL was consistently successful in the 6 applications placed throughout the state.
- Untreated RAP was blended with HMCL at ratios of 60/40 (HMCL/Untreated RAP). Treated RAP was blended with HMCL at ratios of 50/50. There was no appreciable difference in performance between the untreated and treated RAP when blended with HMCL. It is more cost-effective to use a blend of HMCL/Untreated RAP (60/40) than a blend of HMCL/Treated RAP (50/50).
- RAP (both treated and untreated) blended with LRA was generally successful in most of the field experiments except those in Cleburne which exhibited severe cracking. LRA has a history of being a superior maintenance mix particularly for winter use and can generally be considered a "drier" mix than HMCL. When blending LRA with an even "drier" RAP, there may be insufficient binder in the blend to provide adequate cohesion for certain maintenance uses.
- The RAP maintenance mixtures evaluated in this study which had Hveem stability values greater than 24 performed successfully. (Note that the Brownwood RAP had a value of 18 and performed successfully; however, it was thought to have too much binder and prior to field use in a base repair, it was blended with raw RAP). Those blends having Hveem stability values of 12 and under failed due to permanent deformation under traffic.
- RAP (treated or untreated) blended with HMCL provided the most consistently successful performance as a maintenance mix. This type of blend also seems less sensitive to "operator error" such as when too much recycling agent is added to RAP. This type of blend, however, is not recommended for long-term stockpiling. It should be blended and then used on the road soon thereafter.
- RAP when used as a stabilized base and/or blended with existing base materials was shown to be a successful use in this study. It is also quite cost-effective.

3.2 Recommendations

- The recommendations made in Estakhri and Bohuslav's (1993) *Guidelines on the Use of RAP in Routine Maintenance Activities* were developed in part as a result of this research study and are now endorsed based on the final outcome of these field experiments.

References

Estakhri, C.K. and J.W. Button, 1992. *Routine Maintenance Uses for Milled Reclaimed Asphalt Pavement (RAP)*. Research Report TTI 1272-1, Texas Transportation Institute, Texas A&M University, College Station.

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