June

Reclaimed Asphalt Pavement

This packet provides information about how and why to use reclaimed asphalt pavement (RAP) in roadway construction and maintenance projects.

Research Summary	RAP Variability in Hot-Mix Asphalt
Case Study #1	Use of Cold Recycle RAP Base, Limestone County
Case Study #2	RAP Use in Superpave
TxDOT Experience	Summary of TxDOT experience using reclaimed asphalt pavement in various applications
Material Availability	Map and table listing companies that generate reclaimed asphalt pavement
Material Processors	Map and table listing companies that process reclaimed asphalt pavement
Specifications	Draft Special Specification: Cold Processed-Recycled Paving Material (RPM) for Use as Aggregate Base Course

If you have questions or comments regarding this packet, contact:

Rebecca Davio, TxDOT's recycling coordinator
(512) 416-2086 or rdavio@mailgw.dot.state.tx.us

Material Brief

According to the National Asphalt Pavement Association (NAPA), 20 years of industry experience has proven that hot-mix asphalt (HMA) can be recycled for use in roadways time after time.

Forms of asphalt recycling date back as far as 1915. However, interest in HMA recycling grew significantly in response to inflated construction costs during OPEC's oil embargo in the mid-1970s.

A Federal Highway Administration (FHWA) report on pavement recycling indicates that long-term pavement performance of recycled HMA that is designed and controlled during production performs comparably to conventional HMA. In fact, it can improve material properties of the existing pavement layer.

Research has proven that recycled pavements offer the same durability as pavements constructed with 100 percent virgin materials.

Asphalt pavement recycling has many advantages, including

- reduced cost of construction,
- conservation of aggregate and binders,

• preservation of existing pavement geometrics,
• preservation of environment, and
• conservation of energy.

A review of current literature shows the use of hot-mix, hot in-place and cold in-place recycling achieves material and construction savings of up to 40, 50 and 67 percent, respectively. In addition, significant user-cost savings are realized due to reduced interruption in traffic flow when compared with conventional rehabilitation techniques.

An estimated 45 million tons of RAP are produced each year in the U.S., with approximately 33 percent used in HMA production.

Research indicates that in 1992 less than 20 percent of the HMA produced in Texas contained RAP. The first recycled Texas highway was a 15-mile section of State Highway 36 in Burleson County in 1967.

Overview

According to FHWA, the majority of RAP is used in construction and maintenance applications, including

• hot in-place recycling,
• cold in-place recycling,
• full-depth reclamation,
• roadbase aggregate,
• shoulder surfacing and widening, and
• various maintenance uses.

Cold In-Place Recycling: The pavement is removed by cold planing to a depth of 3 in. to 4 in. The material is pulverized, sized and mixed with an additive. Virgin aggregate may be added to modify RAP characteristics. An asphalt emulsion or a recycling agent is added; then the material is placed and compacted. An additional layer is optional, such as a chip seal or 1 in. to 3 in. of hot-mix asphalt.

A 3-piece "train" may be used, consisting of a cold-planing machine, a screening and crushing unit, a mixing device, and conventional laydown and rolling equipment. This "train" occupies only one lane, thus maximizing traffic flow.

Cost savings range from 20 to 40 percent more than conventional techniques. Because heat is not used, energy savings can be from 40 to 50 percent.

Cold-Mix Asphalt (Central Processing Facility): RAP processing requirements for cold-mix recycling are similar to those for recycled hot mix. However, the graded RAP produced is incorporated into cold-mix asphalt paving mixtures as an aggregate substitute.

Hot Recycling: At a central plant, RAP is combined with hot new aggregate, and asphalt or a recycling agency to produce asphalt concrete (AC), using a batch or drum plant. The RAP is usually obtained from a cold-planing machine, but could also be from a ripping or crushing operation.

Hot In-Place Recycling: The pavement is softened by heating, and is scarified or hot milled and mixed to a depth or 0.75 in. to 1.5 in. New hot-mix material and/or a recycling agent is added in a single pass of the machine. A new wearing course may also be added with an additional pass after compaction.

Full-Depth Reclamation: All of the asphalt pavement section and a portion of the underlying materials are processed to produce a stabilized base course. The materials are crushed, and additives are introduced; the materials are then shaped and compacted, and a surface or wearing course is applied.

Embankment or Fill: FHWA's "User Guidelines for Waste and By-product Materials in Pavement Construction" allows stockpiled RAP material to be used as a granular fill or base for embankment or backfill construction. However, this application is not widely used and does not represent the highest and most suitable use for RAP. RAP as an embankment base may be a practical alternative for material stockpiled for a considerable time period, or that has been commingled from several project sources.

Tips for Success with RAP

• Consider recycling as an option during design stages of all rehabilitation projects.

• Evaluate RAP and report its composition in plans, specifications and estimates to successfully use greater percentages of RAP in HMA mixtures.

• Perform enough pavement sampling to estimate variability of material properties.

• Decrease the handling and hauling of RAP to maximize its value.

• Separate and identify by source large quantities of RAP obtained from different sources.

• Produce a homogenous RAP product from a "composite" pile by first blending it thoroughly with a front-end loader or bulldozer. Then crush the largest RAP stone size to one smaller than the top-size in the hot mix being produced (e.g., 0.625 in. for a 0.75 in. top-size mix). This ensures the asphalt bond is broken as much as possible and eliminates oversized stones.

• Avoid low, horizontal RAP piles, which have a tendency to hold water. Large cone-shaped stockpiles, originally thought to cause re-agglomeration, are now thought to be better. Experience has proven that RAP tends to form a crust over the exterior that is eight to 10 inches thick.

• Avoid driving front-end loaders and bulldozers directly on RAP stockpiles to minimize compaction.

• Cover RAP stockpiles when feasible because RAP doesn't shed water or drain like other aggregates. However, tarps should not be used because they cause condensation.

• Place RAP on a solid paved surface to improve drainage and reduce soil contamination during loading.

References

National Asphalt Pavement Association, "Recycling Hot Mix Asphalt Pavements," Information Series #123, 1996.

"Pavement Recycling Executive Summary and Report," FHWA-SA-95-060, 1996.

"Pavement Recycling Guidelines for State Governments," FHWA-SA-97, 1997.

"Department Use of Reclaimed Asphalt Pavement (RAP) during FY 1992," TxDOT, December 1992.

"User Guidelines for Waste and By-product Materials in Pavement Construction" FHWA Report RD 97-148.

"Asphalt Pavement Recycling," Construction and Demolition Recycling Program. California Integrated Waste Management Board. Fact Sheet #431-95-067 April 3, 1996.

Research Summary

RAP Variability in Hot-Mix Asphalt

Problem Statement

The Florida Department of Transportation (FDOT) is a national leader in the use of RAP in HMA paving construction. RAP is a part of all FDOT structural hot-mix asphalt concrete (HMAC) and sometimes represents as much as 50 percent of the aggregate component in the mix. This study examined the variability of RAP and its effect on the variability of HMAC for FDOT mixtures. Data were analyzed for 33 hot-mix designs, which incorporated a total of 19 different RAP stockpiles from 13 HMA contractors located throughout the state.

Objectives

The International Center for Aggregates Research (ICAR) prepared Research Report ICAR-401-1, "Recycled Hot-Mix Asphalt Concrete in Florida: A Variability Study," for FDOT and the Florida Limerock and Aggregate Institute to compare variability data as reported in the literature with FDOT mixtures.

These data included standard deviations from the mean on Marshall stability, air voids, extracted aggregate gradation and extracted asphalt content. In general, the variability of the recycled FDOT mixtures was comparable to variabilities reported by other agencies for HMAC.

Two types of statistical parameters were used in the variability analysis: coefficient of variation and chi-squared measure of spread. Using these statistical values, an analysis was performed to address two important questions:

- Does the amount of RAP in a mix cause an increase in the variability of that mix?
- What is the variability of RAP compared to the variability of virgin aggregates? How do these variabilities compare with the variability of HMAC?

Findings

Results of this analysis generally indicate

- The variability of RAP is not statistically different from that of the stockpiled virgin aggregates at the asphalt plant site;
- when looking at 75 percent of the data, RAP and virgin aggregate (based on data from quarry or pit) are not statistically different, but when including all of the data (the maximum absolute deviation), RAP is significantly more variable than virgin aggregate;
- the variability of virgin aggregate at the point of production is generally lower than that of the stockpiled virgin aggregate at the asphalt plant site; and
- RAP (as analyzed under the restrictions in this study does not show an adverse effect on the variability of HMAC.

There are several limitations to the research performed in this study. This was intended to analyze variability of RAP and its effect on HMAC. The only measure of variability that could be used in the analysis was aggregate gradation. Therefore, conclusions regarding variability are based on gradation only. Yet there are certainly other important material properties that could also be used to characterize variability.

The contents of this summary are reported in detail in the Research Report ICAR-401-1, "Recycled Hot-Mix Asphalt Concrete in Florida: A Variability Study," Cindy Estakhri, Cliff Spiegelman, Byron Gajewski, Guiquin Yang and Dallas Little, revised November 1998. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of ICAR. This report does not constitute a standard, specification or regulation.

Case Study #1

Use of Cold-Recycle RAP Base, Limestone County

Project Overview

This maintenance project was let in June of 1998 to install a 4 in. overlay of cold processed RAP base (CRRB) using two different emulsified recycling agents (ERA), referred to in this case study as "immediate use." This case study also included preparation of three different blends of maintenance mix, referred to as "stockpiled mix."

Immediate Use: The roadway selected for this project, FM 2838, runs from US 84 west of Mexia to SH 171 northwest of Mexia. The average daily traffic (ADT) on the roadway is estimated at 710 vehicles. There is a moderate amount of 18-wheel truck traffic, predominately gravel trucks hauling material from quarries located south of US 84. This roadway is typical of the low- to medium-volume FMs in the area and is a good location for testing the performance of cold-processed RAP.

This project, originally let in spring 1997, was re-let with changes, summarized below, to make the use of RAP more economical.

1. Test sections were approximately five mi. from the RAP stockpile location.

2. The contractor was allowed to waste oversize stockpile material so that the portable rock crusher was not required.

3. Two different ERA were used to evaluate their performance (Cyclogen-ME and Prime-ERA-25).

4. Separate bid items for mobilization and traffic control were ordered in the plans so these costs would not affect the bid price of the mix.

- Test Section #1
Approximately one-third of the plan quantity of Cyclogen-ME and RAP mix.

- Test Section #2
Approximately one-third of the plan quantity of Prime-ERA-25 and RAP mix.

- Test Section #3
Approximately one-third of the plan quantity of Prime-ERA-25 and "RAP-blend" mix. The RAP blend consisted of the original RAP with 15 in. plus particles scalped off, with the balance of material separated into 1 in., 0.625 in. and minus 0.625 in. The portion of the RAP between 1 in. and 1.5 in. was not used.

The initial rolling pattern was one pass with a 25-ton vibratory steel wheel, two passes with a 25-ton static steel wheel, and passes with a 30-ton pneumatic. Excessive shoving and cracking of the mix and an unanticipated yet required compactive effort required the rolling pattern revision to one pass with a 25-ton static steel wheel followed by eight to 10 passes of a 30-ton pneumatic.

Stockpiled Mix: Additionally, during this project, quantities of three types of "maintenance mix" were stockpiled as shown below.

Table 1. Stockpiled Mix

MIX TYPE	QUANTITY (tons)
Cyclogen-ME	220
Prime-ERA-25	25
AES 300RP	160

Specifications

A "Cold-Recycle RAP Base" Special Specification (attached) was used on this project.

Test Data

- Moisture analysis of the RAP taken just prior to mixing showed a total moisture content of 6.7 percent (average of multiple samples).
- The HVEEM stability of laboratory molded specimens of all three mixes ranged from 35 to 44.
- The road density of the different types of mix, as determined by TxDOT nuclear density thin-lift gauge, were as shown in Table 2.

Approximately one month after construction, the roadway was cored with a 6 in. wet-core barrel. The cores crumbled before they could be removed from the hole. Approximately two months after construction, the roadway was successfully cored with a 12 in. dry core barrel.

Results:

Immediate Use: The project, completed almost a year ago, is holding up very well. This confirms that the use of RAP as a rehabilitation technique has potentially good value to TxDOT for low- to medium-volume FM roadways as a strength course. (One of the ERAs also indicated potential as a surface course.)

Table 2. Road Density

MIX TYPE	DENSITY (#/cf)	
	Date Constructed	*After approximately one month under traffic*
Cyclogen-ME/RAP	115 - 126	132 - 133
Prime-ERA-25/RAP	120 - 128	127 - 129
Prime-ERA-25/RAP Blend	125 - 126	129 - 131

The CRRB process can be used if the project has the following.

- A source of fair to good quality RAP close to the job site;
- A RAP stockpile location that is suitable for proper handling of the material;
- A quantity of mix required for the project large enough to ensure adequate competition for the work and, more specifically, the ERA; and
- A low- to medium-volume roadway.

The importance of maintaining clean aggregate throughout the CRRB process cannot be emphasized enough. In hot-mix or hot-recycle processes, small quantities of contaminant are usually vaporized and dispersed in the heater or drying drum. This is not the case in this cold-recycle process. Even a seemingly insignificant quantity of wet soil or grass will result in a defect on the roadway.

On this project, the RAP stockpile seemed to be in an ideal location. The material was stockpiled along the center of a 20 ft-wide abandoned concrete roadway. The mixing plant was set up in the center of the abandoned roadway at the end of the stockpile. The processed material, both in front of and behind the mixer, was belt-fed directly onto the concrete pavement. Even with these conditions, contaminated material was introduced into the mix when material was loaded from the bottom of a pile at the edge of the roadway. It was also tracked onto the concrete pavement from the loader tires. This contaminated material in the mix led to problems on the roadway.

The significant differences between the two ERAs tested in this project were in appearance and texture only. When first delivered to the roadway, the mixes looked very much alike. As one of the mixes was worked, it became drier but maintained a somewhat “greasy” feel and a smooth texture, demonstrating potential for use as a possible surface course. The other mix became dry and crusty, appearing and feeling similar to untreated RAP. The texture was more open and appeared more likely to damage in rain prior to sealing.

Stockpiled Mix: The quantities of "maintenance mix" sat undisturbed in the stockpile for approximately 30 days before use by Limestone County and Falls County maintenance forces. The material was laid with a blade and used for FM base failure cutouts and FM level-up. The maintenance supervisors using the mixes reported that they handled like other TxDOT requisition "trap mix" and performed moderately well. Based on observations, laying and even mixing this material with a blade are feasible. This procedure, however, is probably more appropriate for low-volume roadways.

This project has increased interest in the potential for the use of RAP and an ERA in the production of a stockpile maintenance mix. It seems the maintenance mix products performed as well as most "virgin" mixtures now used. This may very well be one of the more practical uses for the RAP produced by TxDOT construction projects. As a direct result of the CRRB project, the Waco District is going out for bids to have 10,000 tons of this RAP plant mixed with an ERA to produce stockpile maintenance mix.

Based on projected prices, the cost for future projects is estimated as follows:

- Cold-recycle RAP Base (Plantmix/Laydown Machine) $20–32/ton

- Cold-recycle RAP Base (Roadmix/Blade Laid) $14-25/ton

Table 3. Project Contacts

Name	Organization	Phone
Jeff Kennedy, P.E.	TxDOT-Waco District (Asst. Area Engineer)	(254) 883-3302
Richard Stimmel	TxDOT-Waco District (Maintenance Supv.)	(254) 562-2900
Barry Dunn	Viking Construction (Contractor)	(512) 385-5777
Gene Bridges	Bridges Asphalt Products, Inc. (Supplier)	(972) 487-2118
Bill O'Leary	Prime Materials and Supply Corp.	(281) 821-1482

Special thanks to Jeff Kennedy, P.E., the assistant area enginner at the Marlin Area Office, for preparing this case study.

Case Study #2

RAP Use in Superpave

Introduction

Connecticut Department of Transportation (ConnDOT) specifications allow the routine use of RAP in HMA pavement at less than 15 percent by mass of the mix. Higher amounts can also be utilized with approval of the Materials Testing Division. A few of Connecticut's HMA contractors have used RAP in conventional Marshall mix designs.

With the pending implementation of the Superpave system of mix design, ConnDOT officials felt that RAP must be allowed in these mixes. Since the original research did not address the use of RAP in Superpave mixes, ConnDOT wanted to proceed with the use of RAP in Superpave mixes on a trial basis. A research project was developed to monitor and evaluate a Superpave mix which included 20 percent RAP on the westbound travel lanes of a 40-km-long four-lane pavement overlay project.

Project Overview

Connecticut's first large-scale Superpave project was constructed on a 10-km section of State Route 2 extending from exit #21 to exit #23 and traversing sections of the townships of Colchester, Lebanon and Bozrah in southeastern Connecticut between May and October 1997.

The construction project involved removal of the existing top 50 mm of an HMA overlay placed in 1986, the placement of 25 mm of a standard ConnDOT Class 2 leveling course meeting Marshall criteria, and the placement of a 63-mm Superpave surface layer. Traditional Class I mixes were used for control purposes. Six mixes–four Superpave and two conventional–were utilized for the surface layer. C was used for the design. Average annual melted precipitation in Colchester is 1220 mm, with approximately 750 mm of snow.

State Route 2 is a four-lane median-divided highway functionally classified as a principal arterial. It carries from 15,000 to 18,000 vehicles per day, with 10 percent trucks. It was originally constructed in 1970 as a full-depth HMA pavement and subsequently overlaid in 1986. For the Superpave system, a 15-year design life of between one and three million 80-kN ESALs was calculated with a maximum seven-day air temperature of 39°C.

Materials Information

The RAP used in the project was material that was milled off the existing roadway. The 1986 pavement was composed of basaltic coarse aggregate with a maximum size of 25 mm, natural fine aggregate, and 5.2 percent AC-20 asphalt cement. ConnDOT's conventional approach for testing extracted asphalt from RAP for viscosity and penetration was used. Additional tests performed on the RAP by the design consultant included specific gravity of aggregate, gradation, coarse aggregate angularity and fine aggregate angularity.

Mixture Design

Two Superpave mixtures with RAP and one conventional pavement with RAP were designed for the westbound direction of the project. In addition, three sections using virgin materials (two Superpave and one conventional design) were placed in the eastbound direction. Both Superpave RAP mixes had the same aggregate gradation but different Superpave binder grades. The mix design called for the final Superpave binder grade, after addition of RAP and new asphalt, to conform to PG 64-28 and PG 64-22 requirements, which correspond to 98 percent and 50 percent reliability, respectively. In order to meet the final Superpave binder requirements, a PG 58-34 with a modifier and an anti-strip agent was used to obtain a PG 64-28, while an unmodified PG 58-28 with anti-strip agent was used to achieve a PG 64-22. The anti-strip agent was required for both Superpave mixes after the result of AASHTO T-283 showed the potential for moisture susceptibility. This was an unexpected finding since the same aggregates have been used for many years in Connecticut with minimal stripping problems. The anti-strip agent was mixed at a rate of 0.375 percent of binder.

The method used by the designer for determining the PG grade of binder that would be added to the RAP to obtain the required PG 64-28 and PG 64-22 was empirical. In the past, an asphalt cement equivalent to an AC-10 was typically used with RAP mixes in Connecticut. An AC-10 is approximately equal to a PG 58-28. After blending, the extracted asphalt cement from the RAP with the virgin PG 58-28 asphalt, a PG 76-22 resulted, which was deemed acceptable for the project. To meet the resultant PG 64-28 for the other section, it was decided to drop the low and high end one binder grade and use a PG 58-34 based upon guidance from the FHWA Superpave Mixtures Expert Task Group.

As many as 13 trial blends were made in order to meet the criteria for voids, Nini and field compaction. The final aggregate gradation of the two mixes passed below the restricted zone on the 0.45 power gradation chart. The final mix design was 20 percent RAP; 5.0 percent total asphalt (4 percent virgin); 3.9 percent voids; 14.3 percent VMA; 72.8 percent VFA; dust/asphalt ratio of 0.7; Gmm at Nini=87.2 percent; and Gmm at Nmax=97.4 percent.

Construction

Milling of the existing pavement began on April 29, 1997. Paving of the Class 2 leveling course began May 14, 1997. The first surface layer placed was a conventional Class I mix without RAP in the eastbound direction. Placement of the first Superpave RAP section occurred August 11, 1997, after all the virgin mixes were completed. All paving was completed by September 10, 1997. A total of 13290 megagrams of Superpave with RAP were placed. Total tonnage of all mixes placed was 38823 megagrams.

The contractor used a 3.6 megagram Cedar Rapids batch plant located in Montville, Conn. On some days, the mixes were stored in silos before being transported to the project site. The batch plant was modified to allow the RAP to be incorporated into the pugmill. The RAP was loaded via front-end loader from the stockpile to aggregate bins at prevailing moisture. It was sieved through a 50-mm scalper screen and then transferred to the weigh hopper via aggregate conveyor belts, the virgin aggregate finally entering the batch plant mixing chamber at between 215° to 230 °C.

The asphalt fed to the plant already contained the anti-strip agent, and for one mix, the modifier. All blending of the asphalt cement with the anti-strip and asphalt modifier took place at the asphalt supplier in Rhode Island. At the job site, which was 15 to 25 km from the plant, conventional paving methods were used for placement of all the mixes. After application of a tack coat at 0.09 to 0.18 L/m^2, a Blaw-Knox PF 180-H paver was used for paving. An 11-megagram Hyster

C766A double-drum vibratory roller was generally used for breakdown rolling. During some periods, a 12-megagram Caterpillar CB 614 vibratory roller was used for intermediate rolling. A 14-megagram Hyster C350C roller in the static mode was used for final compaction. The contractor was responsible for all quality control, which included the laboratory tests on molds from the Superpave gyratory compactor and monitoring of field density. ConnDOT also monitored density and performed laboratory tests for quality assurance.

Evaluations

This project is a participant in FHWA's LTPP SPS 9A project, *Verification of SHRP Asphalt Specification and Mix Design.* As such, an extensive amount of monitoring is scheduled for at least four years. Pavement cores 150 mm in diameter are scheduled to be taken at intervals of 6, 12, 18, 24 and 48 months. These cores will be tested for maximum specific gravity, bulk specific gravity, asphalt content, aggregate gradation and volumetric properties, as well as tests on the recovered asphalt cement for penetration, viscosity, dynamic shear, creep stiffness and direct tension. Performance surveys will be performed annually for skid resistance, rideability rutting, deflections and visual distress. Continuous traffic and weather conditions will also be monitored via a weigh-in-motion system and a Roadway Weather Information System installed at the project in Lebanon.

Lessons Learned

Overall, the pavements were placed without problems. However, achieving field density of greater than 92 percent maximum theoretical required more attention than the conventional mixes. Compaction appeared to be dependent on air and mix temperatures. The Superpave RAP mixes were more easily compacted when the ambient air temperature was below 24 °C. The mix became tender when the mat temperature was between 93 °C and 126 °C.

Note: On some Superpave mixes without RAP, a tender zone corresponding to mat temperatures between 93 °C and 115 °C (temperature range varies from mix to mix) has been found.

This tender Superpave mix can be satisfactorily compacted above and below the tender temperature zone. The preferred compaction method is to obtain density before entering the tender temperature zone by adding additional rollers and increasing the compactive effort or changing the rolling technique.

Another alternative would be to use a steel-wheel vibratory roller above the tender temperature zone, stop compaction efforts while the mat temperature is within the tender zone, and then finish the rolling process before the mat temperature reaches 80 °C.

There is concern that blindly reducing the PG grade by one level on both the high and low end as recommended by the FHWA Superpave Mixtures Expert Task Group could lead to performance problems. The source, and particularly the age, of the RAP should ultimately determine the proper grade of virgin asphalt to be used. However, using blending charts and determining the PG grade of extracted asphalt cements proved difficult on this project.

In the past, stripping was deemed a problem only at isolated locations in Connecticut. There was some question on this project about the reliability of the AASHTO T-283 test for detecting moisture susceptibility.

For more information on this project, please contact Mr. Timothy Lewis of FHWA at (202) 366-4657, or Mr. Keith Lane, director of Research and Materials at ConnDOT, at (860) 258-0371.

TxDOT Experience

This table provides information about TxDOT's experience using reclaimed asphalt pavement in various applications.

District Name	Construction	Material	Results	Installed	Spec	Location	Additional Comments
Abilene	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1992	292, 340, 3063	District-wide	
Abilene	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1992	247	District-wide	
Amarillo	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Excellent	1994	3063, 3022, 3000	Numerous	Very good uses District-wide. Contractors are all set-up to use RAP.
Amarillo	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1967		Gray - US 60	We have used salvage base with RAP on all roads.
Atlanta	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good - Poor	1990	Standard	District-wide	>20% Poor <20% So-So
Atlanta	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1987	Maint.	District-wide	Mailbox turnouts and low shoulder work
Atlanta	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1995	Contract Special Spec	Panola	Added emulsion for stabilized sub-base
Austin	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1993	No	District-wide	
Austin	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1994	No	Travis County	
Austin	Embankments & Backfill	Reclaimed Asphalt Pavement	Unknown	1995	No	Travis County	

Beaumont	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Unknown	1996	3553	IH-10 - Jefferson	In place recycling
Beaumont	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1992	340	Hardin	
Beaumont	Paving Materials-Portland Cement Concrete (PCC)	Reclaimed Asphalt Pavement	Good	1994	NA	Chambers	various needed
Beaumont	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good		276	SH 05	Cement Stabilized Base
Beaumont	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Excellent	1995	None	SH 87	Used with PCC to create base for add on lane.
Beaumont	Embankments & Backfill	Reclaimed Asphalt Pavement	Good	1987	NA	Liberty	
Beaumont	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement		1987		US 90	Used in shoulder washouts, etc.
Beaumont	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Excellent	1987		Jasper	
Beaumont	Paving Materials-Portland Cement Concrete (PCC)	Reclaimed Asphalt Pavement	Excellent	1987		Jasper	
Beaumont	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Excellent	1987		Jasper	
Beaumont	Embankments & Backfill	Reclaimed Asphalt Pavement	Excellent	1987		Jasper	
Beaumont	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Unknown	1996	3063	IH-10-Jefferson, Chambers	

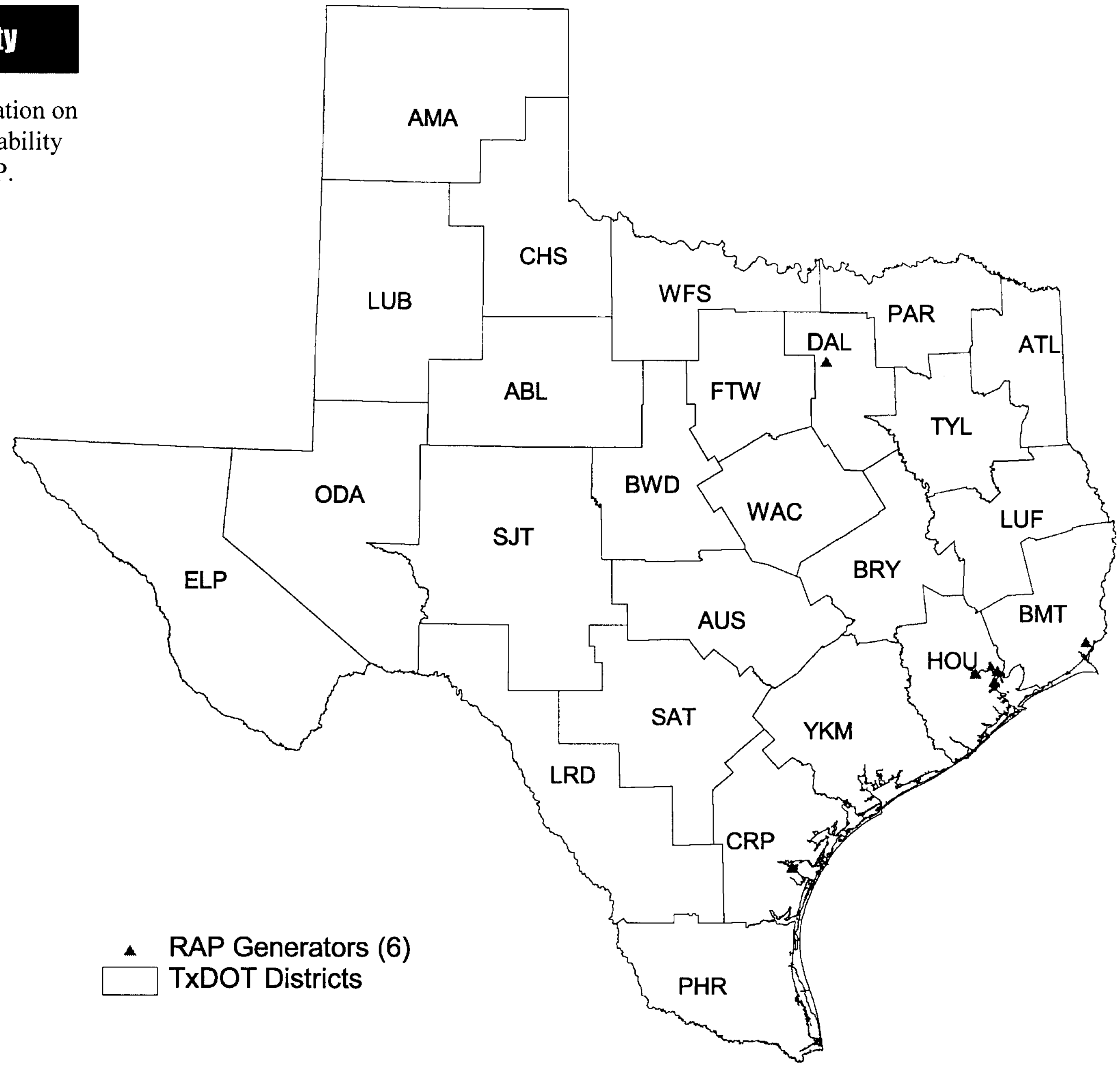
Brownwood	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good		Item 247	FM 570-Eastland	Pore-out base - 20% RAP, 80% virgin base.
Brownwood	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good		State Maint. Forces	FM driveways	Emulsion / water laying with grader
Brownwood	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Poor			District-wide	Recycled various RAP stockpiles with AES 300R used as patching material on driveways and mailbox turnouts.
Brownwood	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good		249	FM 570, CSJ 1027-1-8	Mixed 74% base with 26% millings by volume.
Bryan	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1986	340-003-999	US 290 W	
Bryan	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Unknown	1996		Various	
Bryan	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Excellent	1987	Item 260, 262, 275	Various	
Bryan	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Unsatisfactory	1995	Spec 2008, 1995	Walker, Brazos	
Bryan	Embankments & Backfill	Reclaimed Asphalt Pavement	Excellent	1996	Item 132	SH 21 Brazos River	Mixed soils with sized RAP to stabilize low area
Childress	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1992	340	Donley Co. US 287	10% RAP used
Childress	Paving Materials-Portland Cement Concrete (PCC)	Reclaimed Asphalt Pavement	Good	1987	247	Briscoe (SH 86), Childress (US 287), Hall (US 287)	
Corpus Christi	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1987	251	Various	Incorporated into flexible base

El Paso	Embankments & Backfill	Reclaimed Asphalt Pavement		1993	132	El Paso	Used in embankment and as a stabilizer for shoulder surface.
Fort Worth	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1987	340,3007,3834,3778, 3063,3116, 3022	Fort Worth District	Only allowed in asphalt bases
Houston	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1992	Item 340	District-wide	RAP was used in level-up (under-layers) in most cases. It was used for surface mixes on 2 or 3 projects.
Houston	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1992	Item 276	District-wide	Used as an admixture (percent of aggregate) and as a complete replacement for the aggregate.
Laredo	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1995	3063	Webb	TxDOT owned RAP
Lubbock	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Unknown	1992		Garza	
Lubbock	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Poor		Item 3297	US 62/82-Terry	Recycled ACP in 1982, used in ASB with new ACP placed on top.
Lubbock	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1994	Item 3063	Garza, Lubbock Co.	Okay if used in moderation, <20%
Lufkin	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Excellent	1985		District-wide	
Odessa	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1993	292 & 345	Andrews, Midland, & Martin	Found to be a successful way to use RAP when stabilized base is required. We have found we need to use ordinary compaction instead of density control when RAP is used.
Odessa	General Comments	Reclaimed Asphalt Pavement			Item 345		Item 345 limits the amount of RAP to 30% unless testing of the extracted binder is done to insure that the RAP has not degraded the overall mix. This is an important requirement that should be kept.
Pharr	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1985		District-wide	QC/QA and non QC/QA hot mix specs. with general notes.

Pharr	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Excellent		251, 260, 262	District-wide	Mix with subgrade or salvage base to improve strength. Long time District practice.
San Angelo	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Unknown	1996	None	Tom Green County US 87	RAP was used in embankment
San Antonio	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Excellent	1992	Standard	Bexar, etc.	RAP material has been used in HMAC, as Premix, as Base Admixture, and as Stabilized Embankment.
Tyler	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1993	358 & 3063, etc.	Numerous Projects	
Tyler	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good		Special Specs.	FM 344, FM 3226 - Smith Co.	Mixed with existing Flex Base and added lime.
Waco	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Good	1993	Item 340	US 84 in McGregor	Base Course
Waco	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Good	1995	275	SH 171 - Limestone Co.	30-35% by weight + cement stabilized.
Wichita Falls	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement		1987	TxDOT Standard Spec.	Wichita, Clay, Montague, Cooke	We've used RAP and virgin mix. Also used Hot in-place recycling with 20-30% new material. Also thru plant at 60% virgin mat. w/ 40% RAP, and 70% virgin mat. w/ 30% RAP.
Yoakum	Paving Materials-Asphaltic Concrete	Reclaimed Asphalt Pavement	Unknown	1995	Items 3007 and 3063	District-wide	RAP in level up HMAC only.
Yoakum	Paving Materials-Base/Sub-base	Reclaimed Asphalt Pavement	Unknown	1995	N/A	District-wide	
Amarillo	Paving Materials-Asphaltic Concrete	Recycled PCC	Good		N/A	Lipscomb - US 60	One time job.
Bryan	Paving Materials-Asphaltic Concrete	Recycled PCC	Good	1986	340-003-999	US 290 W	
Waco	Paving Materials-Asphaltic Concrete	Rejuvinated RAP	Unknown	1996		FM 3047 - McLennan Co.	Koch Materials CMS-2S was added to RAP to produce a stockpile material. Reclamite was added to (1) test batch. Material could not be kept in stockpile. Came out of base failure cut-outs when used to repair failures.

Material Availability

The map and table provide information on companies that have expressed an ability and/or willingness to generate RAP.

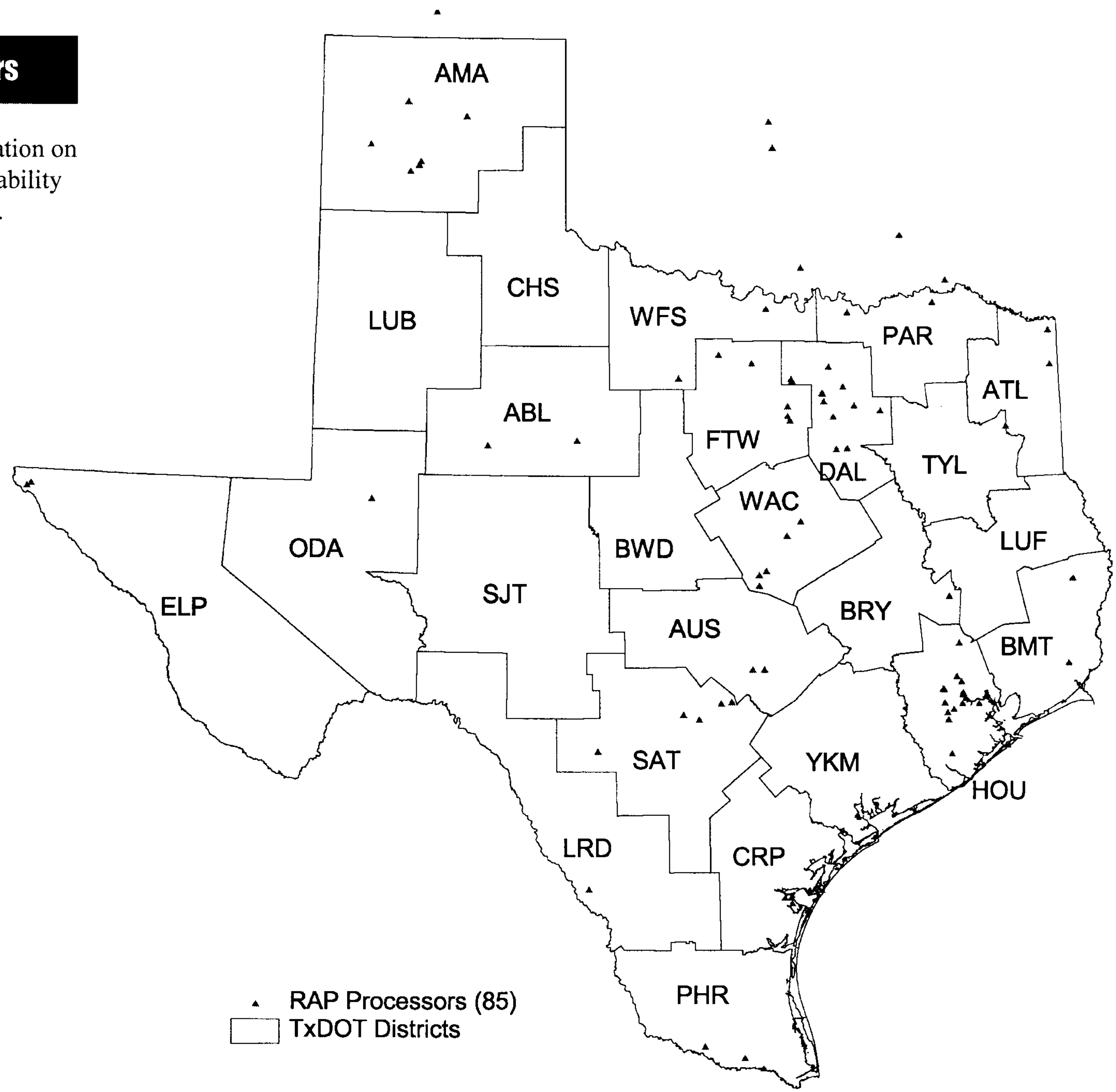


Companies with Ability and/or Willingness to Generate RAP

COMPANY	PLANTNAME	ADDRESS	CITY	ST	ZIPCODE	MAINPHONE	ONHAND	1999	2000	2001	2002	2003	RAP
Huntsman Petrochemical Corporation	Port Neches	2101 Park Street/2701 Spur 136	Port Neches	TX	77651-3500	(409) 723-3636	0	150	150	150	150	150	x
Valero Refining	Houston Refinery	9701 Manchester Street	Houston	TX	77012-2408	(713) 923-3432	0	10	10	10	10	10	x
FMC Corporation	Bayport Hydrogen Plant	12000 Bay Area Boulevard	Pasadena	TX	77507-1310	(281) 474-8759	50000						x
Coastal Refining & Marketing Inc.	Corpus Christi Refinery	1300 Cantwell Lane	Corpus Christi	TX	78407-	(512) 887-4103	0	90	90	90	90	90	x
Wellmark International	Dallas Pesticides	12200 Denton Drive	Dallas	TX	75234-7239	(972) 888-8689	0	0	0	0	0	500	
Exxon Chemical Americas - BTCP	Baytown Chemical Plant	5000 Bayway Drive	Baytown	TX	77522-	(281) 834-1969	0	1	1	1	0	0	x

Material Processors

The map and table provide information on companies that have expressed an ability and/or willingness to process RAP.



Companies with Ability and/or Willingness to Process RAP

COMPANY	PLANTNAME	ADDRESS	CITY	ST	ZIPCODE	MAINPHONE	ONHAND	1999	2000	2001	2002	2003	RAP
Huntsman Petrochemical Corporation	Port Neches	2101 Park Street/2701 Spur 136	Port Neches	TX	77651-3500	(409) 723-3636	0	150	150	150	150	150	x
Valero Refining	Houston Refinery	9701 Manchester Street	Houston	TX	77012-2408	(713) 923-3432	0	10	10	10	10	10	x
FMC Corporation	Bayport Hydrogen Plant	12000 Bay Area Boulevard	Pasadena	TX	77507-1310	(281) 474-8759	50000						x
Coastal Refining & Marketing Inc.	Corpus Christi Refinery	1300 Cantwell Lane	Corpus Christi	TX	78407-	(512) 887-4103	0	90	90	90	90	90	x
Wellmark International	Dallas Pesticides	12200 Denton Drive	Dallas	TX	75234-7239	(972) 888-8689	0	0	0	0	0	500	
Exxon Chemical Americas - BTCP	Baytown Chemical Plant	5000 Bayway Drive	Baytown	TX	77522-	(281) 834-1969	0	1	1	1	0	0	x

DRAFT

RAP can be used in a number of TxDOT Statewide Specifications, as well as in cold process recycled pavement materials. A draft specification was provided in the May-Miscellaneous Soils packet.

SPECIAL SPECIFICATION
COLD PROCESSED - RECYCLED PAVING MATERIAL (RPM)
FOR USE AS AGGREGATE BASE COURSE

Description: This item, Cold Processed - Recycled Paving Material (RPM), shall govern the construction of base course, sub-base course or foundation course, each course being composed of a compacted mixture of emulsified asphalt cement, aggregate, which may include non-hazardous recycled materials mixed cold in a central mixing plant, or on site, in accordance with the details as shown on the plans and the requirements set forth herein.

Materials: The Contractor shall furnish materials to the project meeting the following requirements prior to mixing. Additional test requirements, affecting the quality of individual materials, may be required based on the plans, at the discretion of the Engineer, and in accordance with requirements established in Item 6.

(1) Coarse Aggregate: Coarse aggregate shall be composed of naturally occurring gravels, crushed stone, crushed concrete or other non-hazardous recycled materials processed recycled asphalt pavements, bottom ash, foundry slag, glass, recycled crumb rubber so as to produce a composite mixture conforming to the grading requirements listed below or as shown on plans:

COLD PROCESSED RECYCLED PAVING MATERIALS
AGGREGATE BASE GRADING REQUIREMENTS
(Percent Passing by Weight)

Sieve Size

1 3/4-inch	100
No. 4	* 60 maximum
No. 40	* 50 maximum

* These percentages may be adjusted as per the discretion of the Engineer; however, the stabilized base course must conform to the minimum strength and stability requirements of this item or as shown on the plans.

(2) Asphaltic Materials: The asphaltic material for this item shall be of the grade shown on the plans or as approved by the Engineer and shall meet the applicable requirements of Item 300, “Asphalt, Oils and Emulsions”. The Contractor shall notify the Engineer of the source of the asphaltic material prior to design of the stabilized base course. This source shall not be changed during production without the authorization of the Engineer.

(3) Pozzolans such as fly ash, bottom ash, lime or portland cement may be added to the processed base course mixture to improve mixing and workability properties.

Mixture Design: The Contractor shall furnish the Engineer with a mixture design formulated to comply with the following properties prior to production:

- Specified gradation or as approved by the Engineer as determined by test method Tex-200.

- Minimum compressive strength of 35 psi for secondary roads and streets and 50 psi for primary highways, major arteries and heavy wheel load traffic areas, as defined by the project engineer, when tested in accordance with test method Tex-126-E as modified in "Test Procedures" section.

- Minimum Hveem stability value of 35 when tested in accordance with Tex-208-F as modified in the "Test Procedures" section.

The mixture design shall be adjusted or redesigned as necessary to accommodate changes in the materials or to ensure compliance with the specifications.

Mandatory Trial Batch: To substantiate the original design and/or any changes and adjustments necessary for field production, a mandatory test production of a minimum of 100 tons shall be batched and tested using all of the proposed project materials and equipment, prior to any placement. The Engineer may waive trial mixtures if similar designs with the same materials have proven satisfactory.

Tolerances: Gradation approval may be based on unstabilized stockpile samples of the processed coarse aggregate and environmentally affected recyclable materials. Other methods of proven accuracy such as cold feed belt samples may be used. The gradation of the processed unstabilized base course shall not vary from the grading established for the mix design by more than (±) 10 percent for the No. 4 and No. 40 sieves as long as the strength and stability specifications are met.

The emulsified asphalt content shall not vary by more than (±) 1.0 percent from the design asphalt content, unless authorized by the Engineer, when tested in accordance with Tex-210-F, or Tex-236-F. In any event, regardless of the asphalt content tolerances, the Contractor is still responsible for producing a final product conforming to the minimum test requirements.

Test Procedures: Test procedures used to develop the design mixture and evaluate the mixture quality during production will be modified as follows:

Tex-126-E: The stabilized mixture shall be molded at room temperature (77º ± 5ºF) and allowed to cure for 72 ± 4 hours at room temperature prior to compressive strength testing.

Tex-208-F: The stabilized mixtures shall be molded at room temperature (77º ± 5ºF) and allowed to cure 72 ± 4 hours at room temperature prior to 3 1/2 to 4 hours of oven curing at 140ºF for Hveem stability determination.

Equipment General: All equipment for the handling of all materials, mixing, placing and compacting of the mixture shall be maintained in good repair and operating condition and subject to the approval of the Engineer. Any equipment found to be defective and potentially having a negative effect on the quality of the base material mixture will not be allowed. When permitted by the Engineer, equipment other than that specified herein which will consistently produce satisfactory results may be used.

(1) Mixing Plants: Mixing plants may be the weigh-batch type, the modified weigh-batch type or continuous pug mill mixer type. All plants shall be equipped with the necessary equipment to consistently produce stabilized base course conforming to the design mixture proportions.

The Contractor is responsible for state certified accuracy verification of all weighing and metering devices utilized in the production of the product. Such certification shall be provided to the Engineer prior to commencement of production. Additional or subsequent certifications may be required during production or at the discretion of the Engineer. The accuracy of the weighing and metering devices shall conform to the tolerances established in Item 520, "Weighing and Measuring Equipment".

The Contractor shall provide safe and accurate means to enable inspection forces to take all required samples and to provide for a means of checking the accuracy of metering devices and to perform calibration and weight checks as required by the Engineer.

Recording devices to indicate the date, project identification number, vehicle identification, total weight of the load, tare weight of the vehicle, the net weight of the mixture in each load in units established by the plans, and the load number for the day will be furnished by the Contractor unless otherwise shown on the plans or waived by the Engineer.

(2) Motor Grader: The motor grader, when used, shall be a self propelled power motor grader and shall be equipped with smooth thread pneumatic tired wheels unless directed otherwise by the Engineer.

(3) In-Place Road Mixer/Pulverizers must be used for in-place mixing when required. The degree of pulverization and mixing shall be sufficient to ensure encapsulation by the emulsified asphalt of the fine and coarse aggregate to produce a final product conforming to the minimum requirements established in this specification or as shown on the plans. The environmentally affected recyclable material of the mixture shall be pulverized to the extent that a minimum of 80 percent by weight of the particles pass the 3/8-inch sieve or as approved by the Engineer.

(4) Rollers: Rollers used for the compaction of this item shall be pneumatic, vibratory steel wheeled, tandem roller or any combination of these types providing the necessary compactive effort throughout the entire depth of the lift as required in the “Compaction” section of this item or as determined by the Engineer.

Construction Methods:

General: It shall be the responsibility of the Contractor to produce, procure, transport, mix, place and compact the specified base material in accordance with these requirements.

(1) Stockpiling of Base Material: Prior to stockpiling of materials, the area shall be cleaned of trash, weeds, grass and shall be relatively smooth and well drained. The stockpiling shall be done in a manner that will minimize aggregate degradation, segregation and preclude contamination by foreign materials. Feeding from a stockpile shall be done so as to avoid any contamination from underlying in-place materials not intended for use as base course.

(2) Preparation of In-Place Subgrade of Existing Road Bed: Prior to delivery of the Cold Processed - RPM, the subgrade of existing roadbed shall be shaped to conform to the typical sections shown on the plans or established by the Engineer. The Contractor shall proof-roll the roadbed in general accordance with Item 216, “Rolling (Proof)”. Soft spots shall be corrected as directed by the Engineer.

(3) First, Succeeding or Finish Courses: Cold Processed - RPM will be spread uniformly and shaped the same day as delivered. Should inclement weather or other unforeseen circumstances render this impractical, the material shall be shaped as soon as practical. All segregated material shall be corrected as directed by the Engineer.

(4) Compaction: The Cold Processed - RPM shall be compacted to the extent necessary to provide no less than 98 percent density as determined by Tex-113-E for primary highways and a minimum of 95 percent density for secondary roadways and measured in place by Test Method Tex-115-E, Part II. A minimum of one density test for each 10,000 sq.ft. of Cold Processed - RPM placed and compacted shall be taken. In-place moisture content shall be within 2.0 percent of the optimum moisture content established by Tex-113-E. Additional tests shall be taken if directed bythe Engineer. If the material fails to meet the density requirements, or it loses the required stability, density or finish before the next course is placed or the project is completed, it shall be reworked and retested until the compaction requirements are met. The Quality Control shall be performed by an independent testing firm or agency, approved by the Engineer, at the expense of the Contractor, unless otherwise directed by the Engineer.

(5) Grade and Thickness Tolerances: In areas on which surfacing is to be placed, any deviation in excess of 1/4-inch in cross section or 1/4-inch in a length of 16-ft measured longitudinally, as referenced in Item 247, shall be corrected by loosening, adding or removing material, reshaping and recompacting. Any area of base where

thickness' are deficient by more than 1/16-inch per inch, the deficiency shall be corrected by scarifying, adding material as required, reshaping, recompacting and refinishing at the Contractor's expense.

(6) Plant Production Quality Control: Cold Processed - RPM mixtures produced at the plant shall be tested for the requirements established in the "Strength and Stability" section of this item for every 800 tons of stabilized base course produced for a given project. The 800-ton lot sample shall be composed of a composite of four sub-samples obtained at 200-ton intervals. A minimum of one compressive strength test, Tex-126-E, and one set of Hveem stability specimens, Tex-208-F, shall be tested on days that production exceeds 200 tons. If production does not exceed 200 tons, that day's production will be included into the following day's production. The Quality Control shall be performed by an independent testing firm or agency, approved by the engineer, at the expense of the Contractor, unless other wise directed by the project specifications.

(7) Moisture Content: Moisture content of the mixture, prior to addition of the emulsified asphalt, shall be continually monitored in order to produce a uniformly mixed and stabilized final product. Moisture contents shall be performed at a minimum frequency of 1 per 200 tons.

(8) Environmental Regulations: The Contractor is responsible to ensure that all aspects of production of cold processed-RPM must be managed to comply with requirements of this Special Specification, Standard Specification Item 6 and related Special Provision, and all environmental remediation requirements established by the Texas National Resources and Conservation Commission and/or other environmental regulatory agencies.

Measurement: This item will be measured by the composite weight or composite volumetric method.

(1) Composite Weight Method: This item will be measured by the ton of 2000 pounds of the composite mixture used in the completed and accepted work in accordance with the plans and specifications for the project. The composite mixture is hereby defined as the asphalt, aggregates, recycled materials and additives as noted in the plans and/or approved by the Engineer.

(2) Composite Volumetric Method: This item will be measured by cubic yard of materials measured by the average-end-area method in the stockpile or in haul vehicles or by the square yard in its original position.

Payment: The work performed in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid per cubic yard or square yards or tons as applicable for "Cold Processed-Recycled Materials". This price shall be full compensation for furnishing all materials, additives, freight involved and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.