STATE OF FLORIDA

Evaluation of Two Hot-In-Place Recycling Projects

Research Report
FL/DOT/SMO/02-455

Gregory A. Sholar
James A. Musselman
Gale C. Page
Patrick B. Upshaw
Howie L. Moseley

July 2002

STATE MATERIALS OFFICE

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ABSTRACT

In 2001, the Florida Department of Transportation constructed two projects utilizing the hot-in-place recycling (remixing) process. This process was utilized in lieu of the conventional milling and resurfacing technique. Historically, the Department has had mixed success with the hot-in-place recycling process and stopped using the process. With the advent of improved hot-in-place recycling equipment, new specifications were drafted and the Department decided to construct two hot-in-place recycling projects, one requiring in-place milling and the other requiring scarification. The hot-in-place recycling project utilizing in-place milling began to crack and delaminate within two weeks of completion. After several more weeks, over 50% of the project experienced cracking and delamination. Subsequently, the project was milled and resurfaced with hot-mix asphalt. Possible causes of the cracking and delamination include: 1) excess dust generated by the milling head, 2) high pavement deflections at the inside wheelpath, 3) in-place milling depth coinciding with the surface of the lower layer, 4) low mixture temperature and 5) inadequate mixture properties (low AC content, high dust content, high binder viscosity). The project utilizing the scarification process was a success in comparative terms, but the ride quality appears to be below that of conventional hot-mix asphalt paving. Should additional hot-in-place recycling projects be constructed, there needs to be better control over mixture properties during construction, a milling depth that does not coincide with an underlying layer should be specified and a warranty should be part of the contract.

INTRODUCTION

In 2001, the Florida Department of Transportation (FDOT) constructed two projects utilizing the hot-in-place recycling (remixing) process. This process was utilized in lieu of the conventional milling and resurfacing technique. Historically, from the 1970's, the Department has had mixed experiences with hot-in-place recycling processes from Jackson's heat and rework process, Cutler's heat/rework/overlay process, to the newer heat and remix process (1, 2, 3). Because of these mixed experiences, the Department stopped using the process, which never was included in the Department's Standard Specifications. Independently, a number of hot-in-place industry representatives convinced the Department that there had been a significant improvement in the technology of the equipment with the inclusion of on-board pugmills, where additional materials could be added as necessary and remixed to result in a more homogenous product.

Beginning in 1996, the Department worked with the hot-in-place recycling industry to develop a specification to incorporate this technology and to attempt to assure a better quality product. The Department utilized NCHRP Synthesis 193, "Hot In-Place Recycling of Asphalt Concrete" (4), as a basis, along with the Department's experience and industry's input in developing this new specification. The final draft was reviewed by all industry partners.

Shortly before identifying a project to be let under these new specifications, a hot-in-place recycling industry representative expressed strong concerns about the specification. The most significant comment was that the specification allowed either in-place milling or scarification of the pre-heated pavement. As a result, the Department decided to let two projects: one requiring in-place milling and the other requiring scarification.

The Department constructed these two projects in order to evaluate the newer hot-in-place recycling process known as "remixing" to determine if it might be a viable alternative for pavement resurfacing projects on lower volume roadways and to determine the performance of in-place milling versus scarification during the recycling process.

The first project was constructed in Putnam County on County Road 315, and the second project was constructed in Lake County on State Road 19. Though both projects utilized the hot-in-place recycling process, the CR-315 project utilized milling heads during the operation, while the SR-19 project utilized scarification. This report will provide a detailed description of each project, including the specific hot-in-place recycling process, construction and performance data, and will provide recommendations on the use of this technology for future applications.

OVERVIEW OF THE HOT-IN-PLACE RECYCLING PROCESS

Hot-in-place recycling, in general terms, is a process used to rework a distressed pavement surface with the result being a rejuvenated distress-free pavement. There are three basic hot-in-place recycling processes. The first process is the "heater-scarification" process, in which the distressed pavement is heated, scarified, rejuvenated, leveled, reprofiled and compacted. The second process is "repaving", in which the distressed pavement is heated, scarified, rejuvenated, leveled, overlaid with new hot mix, reprofiled and compacted, all in the same operation. The third process is the "remixing" process, which was used for the first time by the Department on both of these projects. The remixing process uses heat to soften the existing pavement material, mechanical loosening and removal of the heated pavement material, mixing of the mechanically removed material with new paving materials where necessary, and reapplication of the rejuvenated material to the roadway. Unlike a conventional cold milling/inlay resurfacing project, the recycled pavement material is never removed from the roadway location to an offsite area. Construction is a continual process consisting of pavement heaters, a recycling/paving machine, and compaction equipment (4). In concept, the hot-in-place recycling process offers the following advantages compared to conventional milling and resurfacing: 1) faster construction time, 2) potentially reduced costs, and 3) 100% reuse of the existing pavement materials with the addition of few new raw materials. Drawbacks include: 1) limitations in the quality of the in-service pavement, 2) limited potential to improve the cross-slope and longitudinal profile of the pavement surface, and 3) a lack of established construction specifications/procedures clearly defining the processes. The quality of the finished product is claimed by many in the hot-in-place recycling industry to be dependent on the particular process/equipment used, but is also claimed to be comparable to conventional hot-mix asphalt.

The remainder of this report will be presented in the following manner: 1) description, construction data, and analysis for the CR-315 project, 2) description, construction data, and analysis for the SR-19 project, 3) conclusions, and 4) recommendations.

COUNTY ROAD 315 PROJECT

General Project Information

This project, item 406819-4-52-01, is located in FDOT District 2, Putnam County, on CR-315 between SR-100 to the north and SR-20 to the south. The length of the project was 7.58 miles long (15.16 lane miles and 88,939 sy) with the northbound and southbound ten-foot wide lanes resurfaced to a depth of 1.5 inches. T.R. Remixer, Inc. (herein referred to as Remixer), of Tyler, Texas, was awarded the competitively bid project for a lump sum price of $374,000, or an average unit cost of $24,670 per lane mile or $4.21/sy. Construction began on January 25, 2001 and was completed on March 7, 2001, for a total of 42 days.

By comparison, V. E. Whitehurst and Sons, Inc. also constructed a project containing two segments of CR-315. One segment was to the south and one segment was to the north of the hot-in-place recycling project. The Whitehurst constructed project used conventional milling and resurfacing with Marshall Type S mix 1 ½" thick. The total length of both segments was 13.84 miles (27.68 lane miles and 169,429 sy). Whitehurst was awarded the contract for the lump sum price of $804,879. This equates to an average unit cost of $29,078 per lane mile or $4.75/sy. For this particular comparison, the hot-in-place recycling project was 11.4% less expensive than the conventional milling/resurfacing process on a square yard basis. The average lane width was not the same on the Whitehurst project, therefore, it would not be prudent to compare the hot-in-place recycling project to the Whitehurst project on the basis of cost per lane mile.

Hot-In-Place Recycling Process

The hot-in-place recycling process used by Remixer consisted of an equipment train that heats, mills, mixes, paves, and compacts the pavement (Figure 1). The process starts with three separate pre-heaters in succession that raise the temperature of the existing roadway from ambient temperature to a surface temperature of approximately 425°F. Following the pre-heaters, two additional heaters on the milling/paving machine further raise the pavement temperature from 425°F to approximately 530°F. The milling head then mills the heated pavement to the specified depth and conveys the loosened material to an on-board pugmill, where it is mixed with new asphalt mixture and a rejuvenating agent in small percentages. The recycled mixture is then paved using a conventional paving screed. The compaction equipment used on this project consisted of a steel-wheeled vibratory roller and a rubber-tired roller.

Mixture Design

The mixture was designed per Marshall mixture design criteria (50 blows) to meet the requirements for a Type S-I asphalt mixture. The new materials added to the milled asphalt included 2% by weight of plant-produced Type S-I structural mixture and 0.04% by weight of liquid asphalt rejuvenating agent (AES-300RP). A copy of the mix design is included in the Appendix.

Specification Criteria

All typical FDOT Type S asphalt specification criteria were included for this project. Acceptance criteria included asphalt content and gradation of the as-produced mixture and density and smoothness of the completed pavement surface. In addition to the hot-in-place recycling specifications identified for this project, the specifications also required the use of rotating milling heads for loosening the heated pavement. A copy of the Technical Special Provisions for the project is included in the Appendix.

Construction Test Data

Asphalt Content and Gradation

During construction, the asphalt content and gradation of the as-produced mix was determined in accordance with FM 5-544 and FM 5-545 for both Quality Control and Acceptance purposes. Acceptance and Quality Control tests were performed at a frequency of one test per 1000-ton sublot. Acceptance test data for gradation and asphalt binder content are presented in Table 1. Examination of the average Acceptance values for gradation show that the mixture was consistently finer (higher percent passing) on every sieve as compared to the mix design values, however, the variation was not excessive. Some individual test values for the percent passing the #4, #10, #40 and #200 sieves failed to meet the specified tolerances. The average Acceptance value for asphalt binder content was 0.6% less than the target value as shown on the mix design. Four of the seven asphalt binder content test values failed to meet the specified tolerance.

Viscosity and Penetration

The State Materials Office (SMO) obtained 23 asphalt mixture samples over the duration of the project and recovered the binder from the samples in accordance with FM 5-524 and FM 3-D5404. The absolute viscosity of the recovered binder samples was then determined at 140°F in accordance with FM 1-T 202 and the penetration values were determined at 77°F in accordance with FM 1-T 049. The viscosity and penetration results are presented in Table 2. The average viscosity was 23,508 Poises, with a minimum viscosity value of 11,084 Poises, and a maximum viscosity value of 39,426 Poises. The specified range for viscosity of recycled mixtures is 4,000 to 12,000 Poises. The average penetration value was 26, with a minimum penetration value of 20, and a maximum penetration value of 34. During the project, the Contractor was notified of the high viscosity values and initially attempted to modify the application rate of the liquid rejuvenator in order to reduce the viscosity. These attempts were generally unsuccessful.

Density, Air Voids, Marshall Stability and Flow

Independent Assurance personnel from the FDOT District 2 Materials Office tested the as-produced mix to determine the density, air void content, Marshall stability and flow (Table 3). All test results met specification requirements. It should be noted that the average stability was 2,428 lbs, which is 1,547 lbs. less than the mix design stability value. Flow values for the as-produced mix averaged 9.5 (0.01 inch units), which were slightly higher than the mix design value of 8.0.

Roadway Density

The density requirements for the project were based on Superpave density criteria (for fine graded mixes) using six-inch diameter roadway cores. One core was randomly cut per every 1000 feet long roadway sublot. The density of the roadway cores was determined in accordance with FM 1-T 166. There were 23 roadway LOTs for this project. The roadway density data is shown in Table 4. Theoretical maximum specific gravity (G_{mm}) tests were performed in the field laboratory by Quality Control personnel on the as-produced mix per FM 1-T 209. These results served as the target density. The average roadway density for the project was 92.6% of G_{mm}. The specified minimum density for this project was 92.0% G_{mm}.

Thickness

Thickness measurements were obtained by measuring layer thicknesses from cores cut randomly throughout the length of the northbound and southbound lanes (Table 5). Note: during the project, project personnel changed the method of determining thickness from one core per 200 ft. of roadway [1/400 ft./lane] to just monitoring the thickness through 1) thickness of density cores and 2) probing the new asphalt pavement as it was placed. This was done due to problems encountered in delineating the actual overlay from the underlying material, and also to reduce the number of cores cut from the finished surface. The overall average thickness for the project was 1.52 inches, with a minimum thickness of 1.13 inches and a maximum thickness of 1.94 inches. The specified thickness was 1.5 inches.

Temperature

In addition to temperature measurements made by the Contractor and Department construction personnel, SMO personnel measured temperatures of the roadway surface during the first week of construction. The temperature measurements were taken by using an infrared temperature-measuring device at numerous points longitudinally along the hot-in-place recycling train of heaters and paving equipment. The temperature data is displayed in Figure 2. Of interest is the temperature of the mixture directly behind the screed. The average of the three temperature measurements behind the screed was 241°F. This is lower than normally encountered in conventional hot-mix paving, which is typically in the range of 280 to 300°F.

Bond Strength

An experimental test procedure currently under development by the SMO was used to measure the strength of the bond between the recycled mixture and the underlying surface. The device shears a roadway core at the bond interface between the two layers. Ten cores were tested from various points throughout the project. Five cores were also cut from a nearby section of CR-315, north of the hot in-place recycling project, that had recently been paved using a conventional milling/resurfacing process with hot-mix asphalt. Test results are presented in Table 6. The data shows that the average strengths for both projects were nearly identical. The hot-in-place project had an average strength of 158 psi and the conventional hot-mix project had an average strength of 157 psi. The difference between the two projects is in the standard deviation of the test results. The high standard deviation (90 psi) for the hot-in-place recycling project indicates that there were areas with very high strength bonds and very low strength bonds, as compared to the average. The conventional hot-mix project had a small standard deviation (8 psi) indicating uniformity of the bond strengths of the cores tested. One of the claimed benefits of the hot-in-place recycling process is a stronger thermally bonded interface between the two layers due to the heating process.

Friction

The Pavement Evaluation Section of the SMO conducted ribbed-tire wet friction testing in accordance with ASTM E 274 at various points along the project before and after construction. This data is presented in Table 7. The average friction number for both lanes prior to construction was 42.1 and after construction the friction number was 51.0. Both numbers are considered good.

Ride Rating

The Pavement Evaluation Section also performed a survey of the pavement for roughness, rut depth, and cracking before construction and five days after construction was completed. The roughness values are given in terms of the International Roughness Index (IRI) and Ride Number (RN). The data is presented in Table 8. Examination of the data shows that the ride quality as measured by IRI and RN did not change significantly after construction. However, the pre-construction and post-construction values are considered to be good or better. It should be noted that the road, after construction, did subjectively appear to ride rougher than a new conventionally paved surface. After construction, the rutting had been eliminated and the crack rating was perfect at AA/10.0, both to be expected. AA means there was 0 to 5% cracking in the wheelpaths and outside the wheelpaths, respectively. A 10.0 means there were no point deductions for cracking. However, the pavement soon developed severe cracking and delamination, which will be discussed in the next section.

Pavement Failure Investigation

Within two weeks of the completion of paving, project personnel noticed some cracking and delamination at a number of locations originating in the southbound lane (Figure 3). The cracks seemed to originate at the centerline, progressing approximately three feet towards the edge of the pavement. District 2 Materials and SMO personnel then began coring the project in an effort to determine the cause and extent of the cracking. Over a period of several weeks, the pavement continued to deteriorate at a rapid pace with an increasing number of locations and increasing extent. In addition, the distresses also began to appear in the northbound lane. The distress appeared to be related to the delamination of the top 1.5 inches of recycled pavement from the underlying pavement structure. This delamination extended approximately 4 feet into the lane from the centerline in both northbound and southbound directions. Over 50% of the project experienced this delamination. The following section focuses on the forensic analysis that was conducted and will present several theories regarding the possible causes of the pavement distresses. It should be noted that there does not appear to be any identified single factor that is believed to have caused the pavement distresses but rather a combination of factors that each contributed to the pavement failure. Each contributing factor will be discussed separately below.

Potential Factors Contributing to the Pavement Distress

Excess Dust Generated by Milling Head

During the recycling process, the pavement is heated to a temperature that softens the asphalt to the extent that the "hot" milling operation only has to loosen the material, as opposed to a typical "cold" milling operation, which has to literally cut through the pavement at ambient temperatures when the pavement is very stiff. As such, cold-milling operations typically generate significant amounts of fines (material passing the #200 sieve), which need to be removed from the pavement surface prior to resurfacing, while hot milling operations do not generate the excessive fines and do not necessitate its removal. Since the delamination on this project occurred on the left side of both the northbound and southbound lanes, one possibility is that the pavement heaters on the left side of the recycling operation did not heat the pavement adequately. Consequently, the milling operation on the left side of each lane may have more closely resembled a cold-milling operation resulting in excessive fines being deposited on the left side of the lane. This layer of fines would in all likelihood have an adverse effect on the bond between the remixed layer and the underlying layer. This theory is also backed up by observations of the coring crew that there appeared to be a layer of fines in-between the top and bottom layers. However, it is uncertain if the fines noted by the coring crew originated with the milling operation, or were the result of the water and fines from the coring operation.

It was also noted that the outer two feet on each side of the milling head was not of the same design as the central portion. It is possible that the outer portion on the left side of the milling head was not operating correctly resulting in a slightly different texture and/or milling depth in this area. It is worth noting that the slippage and cracking observed started in this portion of the asphalt mat.

Further contributing to this problem would be that this was the first project constructed by Remixer using native Florida aggregates. Florida limestone materials generate more fines when cold-milled as compared to harder materials from other regions of the country, such as granite. Furthermore, through examination of the delaminated areas, roadway cores and trenches, the resulting milled surface was very smooth and lacked the striations present in a conventional milling operation, which intuitively would help prevent slippage if the striations were present.

Pavement Deflections - Inside Wheelpath

On April 26, 2001, two trenches (one northbound and one southbound) were cut across the full width of the lane in areas of severe pavement distress (Figures 4 and 5). The removed pavement structure from the trench provided a full-depth cross-section of the pavement. Both cross-sections show that the thickness of the asphalt pavement structure is thinner at the inside portion (left wheel path) of each lane. The southbound lane has three inches less total asphalt pavement on the inside of the lane as compared to the outside of the lane (5 in. vs. 8 in.). Figure 6 shows the total pavement thickness versus width for each lane. Note that Figure 6 only shows pavement thickness for a distance of eight feet extending outward from the centerline. This is because the outside two feet of each lane had a pavement thickness of approximately 24 inches or greater, from a previous trench widening. The thinner asphalt pavement structure in the left wheel path could possibly provide less support for vehicle loadings and result in higher pavement deflections, which could cause the top layer to delaminate from the underlying layer.

In-place Milling Depth Coinciding with Surface of Lower Layer

Observations by project personnel during construction indicated that the in-place milled surface appeared to be smoother than a typical milled surface, and that the hot-in-place recycled mixture tended to push or shove slightly during the compaction operations. It was noted that it often appeared that the milling depth was such that the milled surface fell directly on top of the old pavement surface. However, the average depth of the old top layer was 28 mm for the northbound lane and 28 mm for the southbound lane, while the specified milling depth for both lanes was 40 mm. It is possible that there were some areas where the milling depth matched the surface of the underlying layer resulting in a smoother milled surface than normal, but it is unlikely these areas extended throughout the entire length of the distressed areas.

Relatively Lower Mixture Temperature

As mentioned previously, Figure 2 shows the temperatures of the asphalt surface at thirteen points along the heating/paving train. The average temperature of the recycled mixture behind the screed was 241°F. This is approximately 40 to 60°F less than the temperature of typical plant-produced mix. As mentioned previously, if the pavement heaters on the left side of the equipment had not been functioning properly, then the milled surface on the left side of the pavement would have been cooler than on the right side. Applying a recycled mixture at 241°F to a cooler milled surface, that possibly had excess dust present from the in-place milling operation and without using a tack coat, could lead to an inadequate bond between the recycled mixture and the underlying milled surface, resulting in the potential for delamination.

Inadequate Mixture Properties

Acceptance test results for extraction and gradation, as shown in Table 1, indicate that the recycled mixture on average for the project contained a higher dust content and lower asphalt binder content than shown on the mix design. Viscosity test results, as shown in Table 2, indicate that the recycled mixture had an average viscosity of 23,508 Poises, which is higher than the allowable range of 4,000 to 12,000 Poises for conventional plant-produced mix. Forensic testing of four areas that exhibited severe cracking indicates that dust contents and viscosities (Table 9) were even higher than the Acceptance test results. These factors would lead to a stiffer, more brittle mixture that would be more susceptible to cracking.

Rehabilitation

Due to the rapid failure of CR-315, the entire project was milled and resurfaced using conventional hot-mix asphalt during the year 2002.

STATE ROAD 19 PROJECT

General Project Information

This project, item 404126-1-52-01, is located in FDOT District 5, Lake County, on SR-19 between SR 40 to the north and the town of Pittman to the south. The length of the project was 9.725 miles long (171,160 sy) with the northbound and southbound 12-foot wide lanes (plus a three ft. wide shoulder) resurfaced to a depth of 1.5 inches. Angelo Benedetti, Inc. (herein referred to as Benedetti), of Bedford, Ohio, was awarded the competitively bid project for a price of $811,235. Benedetti's unit price for the hot-in-place recycling portion only (excluding maintenance of traffic, utility work, etc.) was $2.30/sy. Construction began on July 11, 2001 and was completed on September 28, 2001, for a total of 80 days.

By comparison, Middlesex Corporation also constructed a project in Lake County using conventional milling and resurfacing with a fine graded Superpave mix 1 ½" thick. Middlesex was awarded the contract for the price of $1,507,666. Middlesex's unit price for milling 1 ½" of pavement and resurfacing with 1 ½" of fine graded Superpave mix was $4.45/sy. For this particular comparison, the hot-in-place recycling project was 48.3% less expensive than the conventional milling/resurfacing process on a square yard basis when comparing the milling and repaving cost portion only.

Hot-In-Place Recycling Process

The hot-in-place recycling process used by Benedetti is similar to that of Remixer in general concept but does differ in some respects. The process starts with two separate pre-heaters in succession that raise the temperature of the existing roadway from ambient temperature to a surface temperature of approximately 325°F as measured on this project. A multi-purpose machine performing three functions follows the two pre-heaters. This machine contains a pre-heater at the front, followed by a scarifier that mechanically removes the top portion of the asphalt surface (to a depth of 1.5 inches in this project) which is then followed by a remixer that mixes the scarified material with new aggregate and a liquid rejuvenating agent. Once the materials are mixed together, this machine places the asphalt mixture into a windrow. The recycled mixture is then paved in a manner similar to a regular paving operation using a paver than can pick up the windrowed material (Figure 7). Finally, the mixture is compacted in a conventional manner. The compaction equipment used on this project consisted of a three-wheeled steel roller and a steel-wheeled tandem roller.

Mixture Design

Just as with the CR-315 project, the mixture for SR-19 was designed per Marshall mixture design requirements. The new materials added to the scarified asphalt included 8% by weight of S-1-B South Florida limestone and 1.5% by weight of liquid asphalt rejuvenating agent (Reclamite). The specifications called for the final pavement to meet all requirements for a type S-I asphalt mixture. A copy of the mix design is included in the Appendix.

Specification Criteria

As with the CR-315 project, all typical FDOT Type S asphalt specification criteria were included for this project. Acceptance criteria included asphalt content and gradation of the as-produced mix, and density and smoothness of the completed pavement surface. In addition to the hot in-place recycling specifications identified for this project, the specifications also required the use of a pavement scarifier for loosening the heated asphalt mat and an auger to convey the loosened material into a windrow ahead of the mixing chamber. A copy of the Technical Special Provisions for the project is included in the Appendix.

Construction Test Data

Asphalt Content and Gradation

During construction, the asphalt content and gradation of the as-produced mix was determined in accordance with FM 5-544 and FM 5-545 for both Quality Control and Acceptance purposes.

Acceptance and Quality Control tests were performed at a frequency of one test per 1000-ton sublot. Acceptance test data for gradation and asphalt binder content are presented in Table 10. Examination of the average Acceptance values show that the gradation is nearly the same as the mix design values for every sieve size except for the #200 sieve, which was an average 1.5% greater than design. Two of the thirteen individual test values for the percent passing the #200 sieve failed to meet the specified tolerance from the target value of the mix design (+/- 2%). The average Acceptance value for asphalt binder content was the same as shown on the mix design (6.2%). No individual test result for asphalt binder content exceeded the allowable tolerance from the target value of the mix design.

Viscosity and Penetration

The State Materials Office (SMO) obtained 28 asphalt mixture samples over the duration of the project and recovered the binder from the samples in accordance with FM 5-524 and FM 3-D5404. The absolute viscosity of the recovered binder samples was then determined at 140°F in accordance with FM 1-T 202 and the penetration values were determined at 77°F in accordance with FM 1-T 049. The viscosity and penetration results are presented in Table 11. The average viscosity was 15,603 Poises, with a minimum viscosity value of 2,804 Poises, and a maximum viscosity value of 45,970 Poises. The specified range for viscosity of recycled mixtures is 4,000 to 12,000 Poises. The average penetration value was 40, with a minimum penetration value of 23, and a maximum penetration value of 72.

Density, Air Voids, Marshall Stability and Flow

Independent Assurance personnel from the FDOT District 5 Materials Office tested the as-produced mix to determine the density, air void content, Marshall stability and flow (Table 12). All test results did not meet specification requirements. One flow value (17.2) exceeded the maximum value (14.0) and the air void contents were 2.6% and 1.1%, which were considerably below the design value of 5.0%. High flow and low air void values are two indicators that the mix may be susceptible to future rutting.

Roadway Density

The density requirements for the project were based on Superpave density criteria (for fine graded mixes) using six-inch diameter roadway cores. One core was randomly cut per every 1000 feet long roadway sublot. The density of the roadway cores was determined in accordance with FM 1-T 166. There were 32 roadway LOTs for this project. The roadway density data is shown in Table 13. Theoretical maximum specific gravity (G_{mm}) tests were also performed in the field laboratory on the as-produced mix by Quality Control personnel per the specifications, and served as the target density. The average roadway density for the project was 94.4% of G_{mm}. The specified minimum density for this project was 92.0% Gmm.

Thickness

Thickness measurements were obtained by measuring layer thicknesses from the roadway density cores that had been cut randomly throughout the length of the northbound and southbound lanes (Table 13). (As with the CR-315 project, the method of determining thickness was changed from one core per 200 ft. of roadway [1/400 ft./lane] to just monitoring the thickness through 1) thickness of density cores and 2) probing the new asphalt pavement as it was placed. This was done due to problems encountered in delineating the actual overlay from the underlying material, and also to reduce the number of cores cut from the finished surface.) Based on the roadway density cores, the overall average thickness for the project was 1.55 inches, with a minimum thickness of 1.33 inches and a maximum thickness of 1.79 inches. The specified thickness was 1.5 inches.

Temperature

In addition to temperature measurements made by the Contractor and Department construction personnel, SMO personnel measured temperatures of the roadway surface during the first week of construction. The temperature measurements were taken by an infrared temperature-measuring device at numerous points along the hot in-place recycling train of heaters and paving equipment. The temperature data is displayed in Figure 7. Like the CR-315 project, the temperature of the mixture directly behind the screed (200°F) was lower than that encountered in conventional hot-mix paving. The typical range encountered in conventional hot-mix paving is 280 to 300°F. Temperature measurements obtained by the roadway inspector throughout the duration of the project are shown in Table 14. It should be noted that each of these temperature measurements is the average of three temperature measurements taken transversely across the width of the mat, which differs from the CR-315 project in that only one measurement was taken transversely. The average temperature measured by the roadway inspector was 213°F, which is similar to that measured by SMO personnel.

Bond Strength

The same experimental test procedure used on the CR-315 project was also used for this project by SMO personnel to measure the strength of the bond between the new recycled mixture and the underlying surface. Eighteen cores were tested form various points throughout the project. Test results are presented in Table 15. The average strength was 190 psi, with a standard deviation of 67 psi.

Friction

The Pavement Evaluation Section of the SMO conducted ribbed-tire wet friction testing in accordance with ASTM E 274 at various points along the project before and after construction. This data is presented in Table 16. The average friction number for both lanes prior to construction was 49.1 and after construction the friction number was 47.8. Both numbers are considered good.

Ride Rating

The Pavement Evaluation Section also performed a survey of the pavement for roughness, rut depth, and cracking before construction and after construction. The roughness values are given in terms of the International Roughness Index (IRI) and Ride Number (RN). The data is presented in Table 17. Examination of the data shows that the ride quality as measured by IRI did not change significantly after construction. The ride quality as measured by RN did increase slightly after construction. Both the pre-construction and post-construction values are considered to be good or better. It should be noted that the road, after construction, does subjectively appear to ride rougher than a new conventionally paved surface. After construction, the rutting had been eliminated and the crack rating was perfect at AA/10.0, both to be expected. AA means there was 0 to 5% cracking in the wheelpaths and outside the wheelpaths, respectively. A 10.0 means there were no point deductions for cracking.

CONCLUSIONS

The following conclusions can be drawn from the two hot-in-place recycling projects and are categorized as follows:

Hot-In-Place Recycling Process

In general concept, the two methods of recycling evaluated on these projects were similar, however, there is one major difference. This difference is that Remixer used a milling process on the CR-315 project and Benedetti used a scarifying process on the SR-19 project to remove the existing asphalt surface. The milling process, as compared to the scarifying process, appears to create a smoother surface texture and has the potential to generate more fine material if the temperatures of the milled surface are not high enough. The evidence of slippage and delamination of the recycled asphalt layer on the CR-315 project indicates that there was a significant problem with the hot in-place recycling process on this project, resulting in an inadequate bond between the new recycled layer and the underlying layer. This could possibly be due to a number of factors such as excessive dust at the interface caused by a low milling temperature, inadequate mix temperature or possibly a malfunction of the milling head.

Furthermore, as a comparison, laboratory shear test results indicate that the scarifying process produced bond strengths 20% greater than the bond strengths for the milling process for these projects.

Construction Material Test Results

Asphalt Content and Viscosity

The average asphalt binder content for the CR-315 project was 0.6% below that stated in the mixture design and the average recovered viscosity was 23,508 Poises. The specified range for recovered asphalt viscosity for recycled mixtures is 4,000 – 12,000 Poises. The combination of a low asphalt content and high viscosity will create a more brittle mixture, possibly resulting in cracking when subjected to traffic loads. Extensive cracking was observed shortly after construction of the CR-315 project was completed. This cracking could quite possibly be due to a combination of a brittle mixture and high pavement deflections. In contrast, the SR-19 project had an average asphalt binder content equal to the mixture design and an average recovered viscosity of 15,603 Poises. No cracking has been observed to date.

Temperature of Asphalt Mat

Both hot-in-place recycling processes resulted in surface temperatures of the asphalt mat in the range of 200 to 240°F directly behind the screed. This range is lower than that normally encountered with conventional hot-mix asphalt paving. With respect to achieving proper compaction at the roadway, this did not present a problem since both projects easily met the specified density requirements.

Friction

With respect to ribbed-tire wet friction values, both hot-in-place recycling processes resulted in good post-construction friction values. The overall average for the CR-315 project was 51.0 and the overall average for the SR-19 project was 47.8. These values were either greater than or equivalent to the pre-construction friction values. However, it should be noted that friction values are a function of aggregate type and traffic volume rather than construction process.

Ride Rating

The post-construction ride quality of the recycled asphalt roadway for both projects, expressed in terms of IRI or RN, was either the equivalent or slightly greater than the pre-construction ride quality values. However, both projects did subjectively appear to ride rougher than a new conventionally paved surface.

RECOMMENDATIONS

1. Two hot-in-place recycling projects have been constructed to different degrees of success. The first project, CR-315, started to fail within several weeks and required rehabilitation within one year. The second project, SR-19, was a success in comparative terms, however, the ride quality appears to be below that of conventional hot-mix asphalt paving. Furthermore, rutting may be a problem in the future due to low air voids and high flow. Even through the use of the improved specifications, the outcome of these two projects appears to be typical of the Department's experience with hot-in-place recycling projects in the past. This process may not be advantageous to the type of high-speed, heavily trafficked roadways typically found on the State Highway System.

2. Should additional hot-in-place recycling projects be constructed, the following areas should be addressed:

a) The recovered asphalt viscosity of the recycled mixture should be controlled by the Contractor to specified levels.

b) Asphalt binder content needs to be monitored and controlled by the Contractor.

c) The air void content of the recycled mixture should be monitored and controlled within the range of 3 – 5% by the Contractor.

d) Periodic inspection of the equipment (i.e., milling heads, heaters) should be routinely conducted by the Contractor.

e) The milling depth should be specified and controlled to not coincide with the interface of any of the underlying pavement layers.

f) A warranty should be part of the contract to ensure against failures such as occurred on CR-315.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Susan Andrews, Frank Suarez, William Dillon, Jason Toole, Aaron Turner, Rick Lloyd and Charles Jones of the State Materials Office for their work in obtaining, preparing and testing samples. The authors also wish to acknowledge Gene Pettyjohn, Bill Craig and Wayne Wilkerson of District 2, Ron Meade of District 5 and Armando Perez, Denise Larkin and Joe Wilson of Tampa Bay Engineering for their assistance and cooperation.

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Table 1 – Acceptance Extraction/Gradation Test Results for CR-315 Project

Sieve Size	FDOT Quality Assurance Data, % Passing, Vacuum Extraction Method								
	LOT 1, Sub 1	LOT 1, Sub 2	LOT 1, Sub 3	LOT 1, Sub 4	LOT 2, Sub 1	LOT 2, Sub 2	LOT 2, Sub 3	Average	Mix Design
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
1/2"	97.6	98.4	98.2	98.1	97.4	96.0	96.7	97.5	97
3/8"	93.2	93.9	94.1	94.3	91.9	92.0	92.1	93.1	90
4	66.3	69.4	71.6	73.9	75.7	67.2	69.5	70.5	68
10	47.9	48.6	51.0	55.6	56.2	50.7	53.2	51.9	50
40	31.1	32.3	29.4	33.9	35.8	33.3	35.2	33.0	29
80	11.5	14.3	15.9	15.4	15.8	15.1	16.1	14.9	14
200	5.7	6.4	7.2	6.3	7.1	6.4	6.7	6.5	5.9
% AC	6.9	6.3	6.6	6.7	6.5	6.5	6.9	6.6	7.2

Table 2 – Recovered Viscosity and Penetration Test Results for CR-315 Project

Date	Viscosity (Poises)	Pen (0.01 in.)
01/25/01	13,946	34
01/26/01	20,930	28
01/29/01	28,234	24
01/30/01	37,293	21
02/03/01	24,011	25
02/05/01	27,452	24
02/06/01	32,708	23
02/07/01	25,786	27
02/08/01	23,526	24
02/09/01	23,551	25
02/12/01	15,746	31
02/13/01	15,300	28
02/14/01	15,990	28
02/15/01	26,051	24
02/16/01	22,073	26
02/19/01	11,084	33
02/20/01	14,963	29
02/21/01	25,709	24
02/23/01	39,426	20
02/26/01	27,089	23
02/28/01	25,748	21
03/01/01	23,968	25
03/02/01	20,096	24
Average	23,508	26

Table 3 – Independent Assurance Test Results for CR-315 Project

Property	Date Sampled			Average	Mix Design	Specification
	1/26/2001	1/29/2001	2/7/2001			
Stability (lbs)	2050	2200	3033	2428	3975	1500 min.
Flow (0.01 in)	9.4	9.4	9.6	9.5	8.0	8 min./14 max.
Density (pcf)	138	140	139	139	140	
% Air Voids	6.5	4.7	5.2	5.5	5.0	2.5 min.

Table 4 – Roadway Density Test Results for CR-315 Project

LOT #	SY	% Gmm	(SY)*(%Gmm)
1	1,681	95.4	160,367
2	2,007	91.7	184,042
3	3,680	92.5	340,400
4	1,928	92.2	177,762
5	3,767	91.1	343,174
6	4,444	91.5	406,626
7	4,117	92.5	380,823
8	4,442	93.1	413,550
9	4,997	93.0	464,721
10	4,356	93.0	405,108
11	3,333	91.5	304,970
12	1,522	94.5	143,829
13	2,271	94.8	215,291
14	3,667	92.2	338,097
15	4,094	93.2	381,561
16	4,444	92.1	409,292
17	6,000	91.1	546,600
18	5,417	93.7	507,573
19	2,972	93.3	277,288
20	3,333	92.1	306,969
21	6,400	92.1	589,440
22	5,078	93.3	473,777
23	4,607	92.6	426,608
Sum	88,557		8,197,868
% Gmm; Weighted Average:			**92.6**

Table 5 – Asphalt Mat Thickness Measurements for CR-315 Project

Northbound			Southbound		
Core #	Station	Thk. (in.)	Core #	Station	Thk. (in.)
1	67+76	1.50	1	400+75	1.94
2	135+58	1.25	2	377+00	1.56
3	158+75	1.69	3	297+00	1.63
4	202+80	1.75	4	276+01	1.50
5	219+50	1.19	5	243+13	1.50
6	234+61	1.25	6	220+42	1.69
7	245+00	1.25	7	192+22	1.50
8	283+51	1.25	8	181+71	1.25
9	340+74	1.13	9	142+19	1.69
10	354+63	1.69	10	139+27	1.56
11	361+04	1.56	11	105+46	1.63
12	375+34	1.56	12	96+90	1.81
13	388+37	1.19	13	83+53	1.50
14	401+28	1.75	14	67+29	1.69
	Average	1.43		Average	1.60
Overall Average		1.52			

Table 6 – Bond Strength Shear Test Results for CR-315 Project

CR 315 Hot-In-Place Project			Conventional Hot-Mix Project		
Test #	Max Load (lbs)	Strength (psi)	Test #	Max Load (lbs)	Strength (psi)
1	3530	281	1	2110	168
2	1406	112	2	1849	147
3	490	39	3	2020	161
4	3030	241	4	1988	158
5	922	73	5	1894	151
6	1166	93	Avg.	1972	157
7	1370	109	Std. Dev.	103	8
8	3000	239			
9	1519	121			
10	3440	274			
Avg.	1987	158			
Std. Dev.	1135	90			

Table 7 – Ribbed-Tire Wet Friction Test Results for CR-315 Project

Direction	Milepost	Before Construction	After Construction
		Avg. FN	Avg. FN
Northbound	10.425 - 11.400	26.3	43.7
	11.400 - 13.200	33.2	51.1
	13.200 - 17.718	49.2	51.2
	17.718 - 17.997	41.2	48.1
	Weighted Average	41.1	49.7
Southbound	10.425 - 11.400	30.2	47.7
	11.400 - 13.200	34.4	52.4
	13.200 - 17.718	50.6	53.3
	17.718 - 17.997	35.1	44.3
	Weighted Average	43.4	52.1
Weighted Average (both directions)		**42.1**	**51.0**

Table 8 – Pavement Condition Survey Test Results for CR-315 Project

Direction	Survey Type	Before Construction	After Construction
Northbound	IRI	72	67
	Ride Number	4.27	4.25
	Rut Depth (in.)	0.12	0.00
	Crack Rating	CG/6.5	AA/10.0
Southbound	IRI	64	66
	Ride Number	4.29	4.28
	Rut Depth (in.)	0.11	0.01
	Crack Rating	BG/7.5	AA/10.0

Table 9 – Forensic Test Results for Cracked Areas for CR-315 Project

Sieve Size	Percent Passing; Reflux Extraction Method				
	Site 1	Site 2	Site 3	Site 4	Mix Design
3/4"	100	100	100	100	100
1/2"	99	98	98	98	97
3/8"	92	93	93	92	90
4	69	72	75	72	68
10	51	53	55	56	50
40	33	34	33	35	29
80	16	18	18	17	14
200	8.8	10.5	10.8	9.0	5.9
% AC	6.5	6.4	6.4	5.9	7.2
Viscosity	34,007	31,666	34,601	26,916	4 to 12 k

Table 10 – Acceptance Extraction/Gradation Test Results for SR-19 Project

Sieve Size	FDOT Quality Assurance Data, % Passing, Vacuum Extraction Method							
	LOT 1, Sub 1	LOT 1, Sub 2	LOT 1, Sub 3	LOT 1, Sub 4	LOT 2, Sub 1	LOT 3, Sub 1	LOT 3, Sub 2	LOT 3, Sub 3
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	99.4	97.8	96.1	97.8	97.9	98.9	99.0	97.9
3/8"	93.7	91.8	89.1	91.7	92.9	93.6	91.7	90.6
4	57.0	58.0	57.3	57.6	57.7	60.9	60.5	61.6
10	41.9	40.8	44.7	45.1	45.3	46.7	44.3	43.8
40	27.0	26.1	26.7	28.2	27.0	29.7	28.1	30.0
80	12.2	13.2	11.4	11.6	11.4	12.1	11.8	12.9
200	7.1	7.1	7.1	6.8	7.0	6.7	6.3	6.4
% AC	6.0	6.5	6.0	5.8	6.2	5.9	6.0	6.0

Sieve Size	LOT 3, Sub 4	LOT 4, Sub 1	LOT 4, Sub 2	LOT 4, Sub 3	LOT 4, Sub 4	Average	Mix Design
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	100
1/2"	98.9	97.3	98.2	98.9	98.3	98.2	98
3/8"	93.8	89.4	93.0	94.1	91.9	92.1	93
4	63.7	58.3	57.3	61.4	57.4	59.1	60
10	46.0	43.6	41.7	44.6	39.7	43.7	42
40	28.7	27.3	26.3	28.3	26.4	27.7	27
80	12.2	11.7	10.3	13.0	12.5	12.0	10
200	7.1	8.3	7.2	7.5	8.4	7.1	5.6
% AC	6.3	6.4	6.3	6.6	5.9	6.2	6.2

Table 11 – Recovered Viscosity and Penetration Test Results for SR-19 Project

Date	Viscosity (Poises)	Pen (0.01 in.)
07/11/01	18,029	34
07/11/01	11,753	40
07/12/01	3,061	72
07/13/01	2,804	72
08/01/01	6,506	45
08/07/01	11,036	40
08/08/01	8,572	47
08/09/01	10,771	42
08/10/01	43,630	23
08/11/01	24,305	33
08/13/01	26,674	28
08/15/01	26,153	29
08/21/01	45,970	26
08/23/01	27,089	28
08/28/01	31,657	28
09/05/01	12,096	39
09/06/01	22,690	31
09/07/01	12,956	35
09/08/01	24,567	32
09/10/01	11,605	35
09/11/01	11,403	35
09/12/01	5,750	50
09/13/01	8,177	42
9/18/2001	6642	46
9/19/2001	7773	41
9/20/2001	3855	60
9/22/2001	4736	50
9/28/2001	6620	40
Average	15,603	40

Table 12 – Independent Assurance Test Results for SR-19 Project

Property	Date Sampled			Average	Mix Design	Specification
	7/12/2001	8/24/2001	9/18/2001			
Stability (lbs)	2775	3296	3340	3137	2569	1500 min.
Flow (0.01 in)	12.5	11.5	17.2	13.7	12.0	8 min./14 max.
Density (pcf)	142.4	141.7	143.8	142.6	137.6	
% Air Voids	NA	2.6	1.1	1.9	5.0	2.5 min.

Table 13 – Roadway Density Test Results and Thickness Measurements for SR-19 Project

LOT #	Direction	SY	Roadway Density		Thickness	
			% Gmm	(SY)*(%Gmm)	Meas. Thk.	Thk * SY
1	Southbound	6,117	95.5	584,174	1.63	9940
2	Southbound	7,317	94.8	693,871	1.73	12622
3	Southbound	1,367	92.4	126,311	1.42	1937
4	Southbound	1,200	92.5	111,000	1.38	1652
5	Southbound	3,300	94.9	313,170	1.42	4676
6	Southbound	6,967	92.1	641,661	1.65	11509
7	Southbound	5,783	95.1	550,021	1.79	10323
8	Southbound	6,783	91.9	623,358	1.64	11124
9	Southbound	6,500	93.9	610,090	1.60	10368
10	Southbound	6,533	92.7	605,478	1.63	10636
11	Southbound	6,217	92.6	575,756	1.78	11085
12	Southbound	6,833	93.9	641,824	1.68	11452
13	Southbound	6,750	94.3	636,390	1.48	9963
14	Southbound	6,533	91.5	597,574	1.35	8787
15	Southbound	7,380	96.0	708,775	1.63	12000
16	Northbound	3,830	96.0	367,527	1.42	5439
17	Northbound	6,250	95.4	596,438	1.69	10550
18	Northbound	2,542	93.9	238,795	1.55	3932
19	Northbound	1,208	94.5	114,120	1.71	2069
20	Northbound	1,250	93.9	117,425	1.42	1775
21	Northbound	7,000	94.7	662,620	1.71	11942
22	Northbound	8,533	92.4	788,279	1.33	11374
23	Northbound	4,050	93.6	379,242	1.55	6290
24	Northbound	5,583	95.4	532,451	1.43	7984
25	Northbound	1,917	92.9	178,089	1.44	2766
26	Northbound	7,333	94.6	693,922	1.56	11403
27	Northbound	5,000	94.8	474,000	1.54	7685
28	Northbound	8,833	95.1	840,107	1.33	11748
29	Northbound	4,917	96.5	474,491	1.39	6849
30	Northbound	5,500	96.3	529,650	1.54	8487
31	Northbound	6,533	97.0	633,766		
32	Northbound	5,833	96.8	564,459	1.37	7980
	Sum	171,692		16,204,832		256,346
				% Gmm; Weighted Average:	**94.4**	
				Overall thickness (in.); Weighted Average:	**1.55**	

Table 14 – Temperature Measurements for SR-19 Project

Station	Temperature, F	
	Northbound	Southbound
50+50	198	216
100+00	216	214
150+00	214	238
200+00	252	202
249+00	229	195
300+00	195	210
351+00	180	201
400+00	213	202
450+00	215	230
500+00	226	215
Averages	214	212
Overall Average		213

Table 15 – Bond Strength Shear Test Results for SR-19 Project

Test #	Max Load (lbs)	Strength (psi)
1	3080	277
2	2320	210
3	1197	108
4	1650	148
5	3020	271
6	1372	124
7	2750	247
8	1631	147
9	1194	108
10	1209	109
11	3020	273
12	1762	159
13	1649	149
14	1508	135
15	1964	175
16	3410	308
17	2690	240
18	2520	229
Avg.	2108	190
Std. Dev.	745	67

Table 16 – Ribbed-Tire Wet Friction Test Results for SR-19 Project

Before Construction		
Direction	Milepost	Average FN
Northbound	0.569 - 1.846	43
	1.846 - 9.725	49
	Weighted Average	48.4
Southbound	0.569 - 1.846	48
	1.846 - 9.725	50
	Weighted Average	49.8
Weighted Average (both directions)		49.1
After Construction		
Direction	Milepost	Average FN
Northbound	0.569 - 0.790	47
	0.790 - 1.448	31
	1.448 - 2.200	45
	2.200 - 9.000	50
	9.000 - 9.310	51
	9.310 - 9.725	48
	Weighted Average	47.7
Southbound	0.569 - 0.790	42
	0.790 - 1.448	47
	1.448 - 2.200	50
	2.200 - 9.000	50
	9.000 - 9.310	37
	9.310 - 9.725	33
	Weighted Average	47.9
Weighted Average (both directions)		47.8

Table 17 – Pavement Condition Survey Test Results for SR-19 Project

Direction	Survey Type	Before Construction	After Construction
Northbound	IRI	76	63
	Ride Number	4.02	4.26
	Rut Depth (in.)	0.23	0.00
	Crack Rating	LK/1.0	AA/10.0
Southbound	IRI	69	67
	Ride Number	4.09	4.23
	Rut Depth (in.)	0.22	0.00
	Crack Rating	LL/0.0	AA/10.0

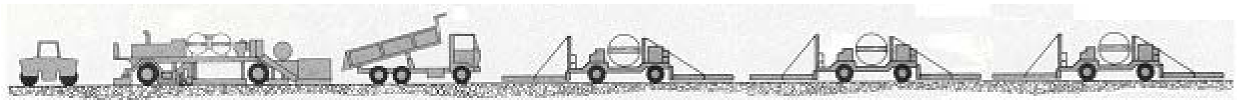
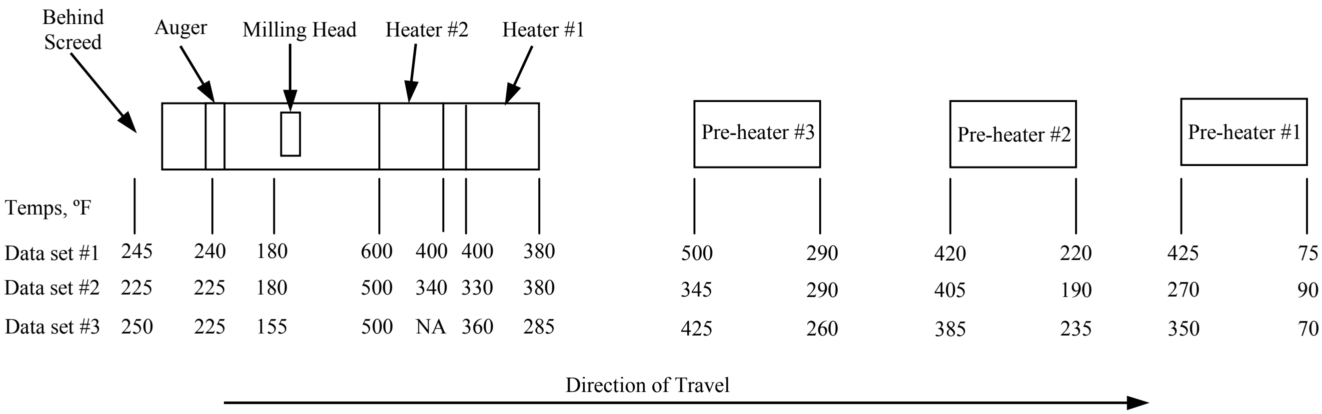


Figure 1 – Remixer Hot In-Place Recycling Process for CR-315 Project



Notes:

1. Temperatures were measured with an infrared thermometer on three different days within a one-week period by three different people.

2. At any given location, temperatures varied by more than 30ºF within a few feet transversely across the mat. Therefore, temperatures were measured in the outside wheelpath for consistency.

3. Temperatures measured at the pre-heaters were measured approximately 3 ft. in front of and behind the pre-heater to avoid measuring the temperature of the exposed flames.

4. The steel-wheeled roller was approximately 200 ft. behind the paver. The temperature of the asphalt at the first pass was 180ºF for Data Set #1.

Figure 2 – Temperature Measurements Along Remixer Paving Train for CR-315 Project

Figure 3 – Cracking and Delamination Damage for CR-315 Project

Figure 4 – Northbound Trench at Pavement Failure Area of CR-315 Project

Figure 5 – Southbound Trench at Pavement Failure Area of CR-315 Project

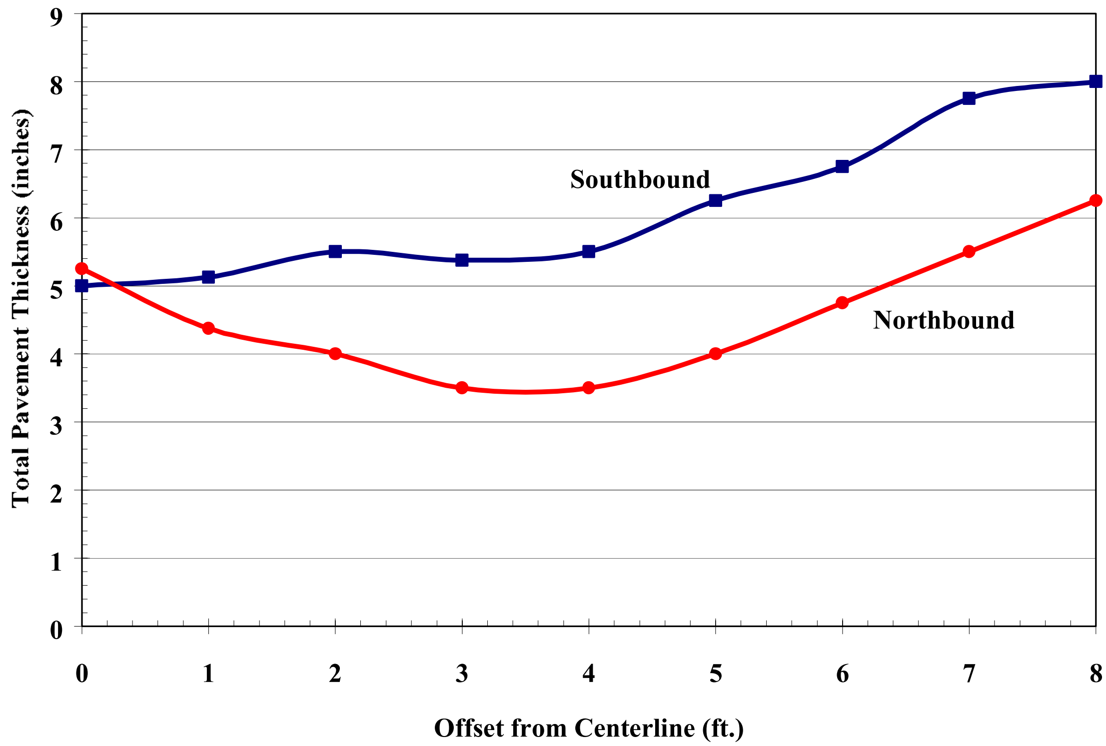
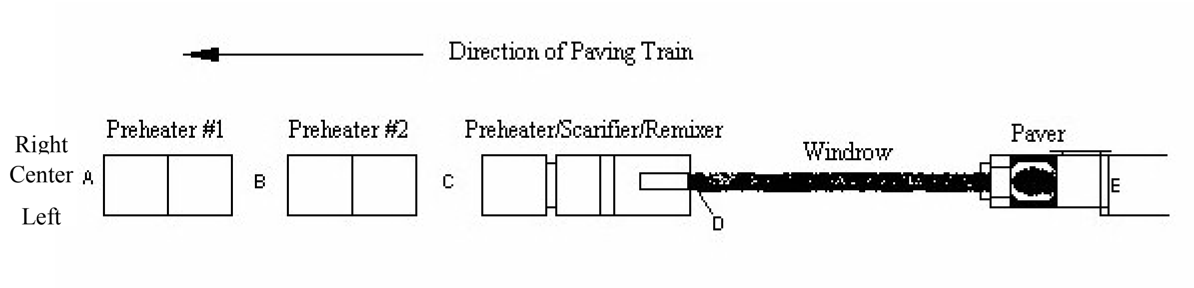


Figure 6 – Total Pavement Thickness vs. Offset from Centerline for CR-315 Project



Location	Temperature, °F		
	Left	Center	Right
A	110	109	108
B	400	320	320
C	310	320	345
D		240	
E	200	200	200

Notes:

1. Temperatures were measured with an infrared thermometer at five locations (A, B, C, D, E).

2. The temperatures measured at locations A, B, C, E were taken at the left side, center, and right side of the heated/paved area.

3. Temperature measurements for locations B and C were taken at the midpoint between the two pieces of equipment.

Figure 7 – Temperature Measurements Along Benedetti Paving Train for SR-19 Project

Appendix A

Mix Design for CR-315 Project

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
STATEMENT OF SOURCE OF MATERIALS AND JOB MIX FORMULA FOR BITUMINOUS CONCRETE

SUBMIT TO THE STATE MATERIALS ENGINEER, CENTRAL BITUMINOUS LABORATORY, 2006 NORTHEAST WALDO ROAD., GAINESVILLE, FLA. 32609

Contractor T. R. Remixer, Inc. Address P. O. Box 5090, Tyler, Texas 75712

Phone No. (903) 595-6755 Fax No. (903) 595-6790 E-mail

Submitted By Cal-Tech Testing, Inc. Type Mix S-I Recycle Intended Use of Mix Structural

TYPE MATERIAL	F.D.O.T. CODE	PRODUCER	PIT NO.	DATE SAMPLED
1. Milled Material		406819-4-52-01 Top 1.6"/40mm EB & WB MP 10.420 - 19.997 / KmP 16.770 - 28.963	Roadway	09 / 19 / 2000
2. QA 00-9846A (TS-I)		V. E. Whitehurst & Sons		09 / 19 / 2000
3. AES-300RP		Koch Materials		
4.				
5.				
6.				

PERCENTAGE BY WEIGHT TOTAL AGGREGATE PASSING SIEVES

	Blend	98%	2%					JOB MIX	GRADATION
	Number	1	2	3	4	5	6	FORMULA	DESIGN RANGE
SIEVE SIZE	1" 25.0mm								
	3/4" 19.0mm	100	100					100	100
	1/2" 12.5mm	97	95					97	88 - 98
	3/8" 9.5mm	90	89					90	75 - 93
	No. 4 4.75mm	68	72					68	47 - 75
	No. 10 2.0mm	50	47					50	31 - 53
	No. 40 425μm	29	25					29	19 - 35
	No. 80 180μm	14	7					14	7 - 21
	No. 200 75μm	6.0	2.4					5.9	2 - 6
	Sp. Gr.	2.585	2.623					2.586	

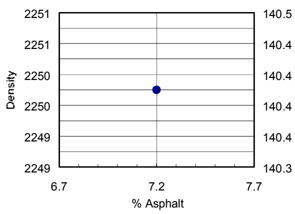
The mix properties of the Job Mix Formula have been conditionally verified, pending successful final verification during production at the assigned plant, the mix design is approved subject to F.D.O.T. specifications

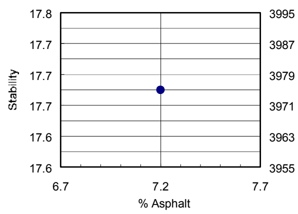
LD 00-2504A (TS-I)

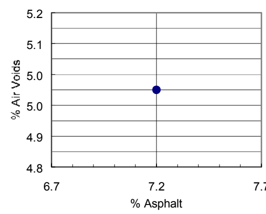
HOT MIX DESIGN DATA SHEET

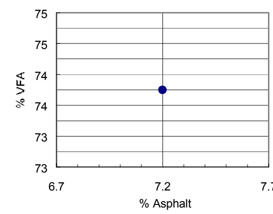
LD 00-2504A (TS-I)

Percent A.C. Total Wt. of Mix	Bulk Specific Gravity (Gmb)	Max. Measured Spec. Grav. (Gmm)	Air Voids Percent	%VMA	%VFA	Effective Asphalt Content	Dust to Effective AC Ratio	Stability (English)	Stability (Metric)	Flow Average (English)	Flow Average (Metric)
7.2	2.250	2.368	5.0	19.3	74	6.5	0.9	3975	17.7	8.0	2.0









Optimum Asphalt 7.2 %

V.M.A. 19.3 %

Mixing Temperature 300 °F 149 °C

Lab. Density 140.4 Lbs/Ft³ 2250 Kg/m³

Air Voids 5.0 %

Additives Antistrip 0.5 % ______ %

Stability 3975 Lbs 17.7 kN

NCAT Oven Calibration Factor -0.24 %
(+To Be Added)/(-To Be Subtracted)

Optimum Asphalt	=	7.20%
Asphalt using 98% Milled Material @ 7.2%	=	7.06%
Asphalt using 02% QA 00-9846A @ 5.6%	=	0.11%
AES-300RP to be added	=	0.04%

Appendix B

Technical Special Provisions For Hot-In-Place Asphalt Recycling CR-315 Project

TECHNICAL SPECIAL PROVISIONS

FOR

HOT IN-PLACE ASPHALT RECYCLING

CR-315 PROJECT

FINANCIAL PROJECT NUMBER: 406819-4-52-01

Prepared By: ______________________
James A. Musselman, P.E.

Date: ______________________
Pages: ______________________

SECTION 324
HOT IN-PLACE ASPHALT RECYCLING

324-1 Description.

The work specified in this section consists of furnishing all labor, equipment, materials, and performing all operations in connection with heating, in-place recycling, applying recycling agent, adding new raw materials or hot mix asphalt, mixing, redistributing and compacting the recycled asphalt material.

324-2 Equipment.

324-2.1 General Requirements: The equipment used to recycle the existing asphalt surface shall be designed and built for this specific purpose. The equipment shall be capable of a continuous single pass, multi-step operation that includes; multi-step heating, milling, introducing recycling agent and virgin materials or hot mix asphalt, mixing the new material with the reclaimed material in a separate on-board chamber (pugmill/drum mix plant), redistributing the recycled material, leveling, and compacting.

The equipment will be on site in good operating condition sufficiently in advance of the reworking operation to allow full evaluation. As required by the Engineer, the Contractor shall demonstrate that the machine proposed for this purpose meets all the requirements specified herein.

324-2.2 Pavement Preheaters: Preheaters shall be capable of heating the existing pavement to a temperature high enough to allow dislodging of the material to the desired depth without fracturing aggregate particles, without charring the existing asphalt, and without producing undesirable pollutants. The heaters shall be adjustable in width. The heating mechanism shall be so equipped that heat shall be under an enclosed or shielded hood as to prevent damage to adjacent property.

324-2.3 Pavement Recyclers: The pavement recyclers shall be capable of uniformly loosening the pavement to the depth specified in the plans. Recycling shall be accomplished using rotating milling heads. The entire system shall be continuously operating and in contact with the preheated asphalt surface at all times. The system shall be flexible in order to process the entire area with minimum monitoring of the system. Tooth spacing of the milling heads shall be such as to allow material to pass without excessive retention. The equipment shall be capable of raising and lowering sections of the milling heads in order to recycle the material around manholes and other obstacles. Scarification tines may be used in lieu of milling heads in these areas.

324-2.4 Rejuvenator Application System: A metering system will be used for adding and uniformly applying a recycling agent with the hot, loosened material. The application of the recycling agent and new raw materials shall be synchronized with the machine speed to provide a proportional application at the predetermined application rate. The rejuvenator shall be added after milling has taken place to provide a uniform application and absorption of recycling agent during the mixing of the recycled material.

324-2.5 Milling Head/Auger: The equipment shall be equipped with either a milling head or an auger that is capable of gathering the heated and loosened asphalt concrete pavement. The milling head/auger(s) shall be operated in such a manner as to minimize aggregate degradation. The milling heads shall be capable of windrowing the material ahead of the mixing chamber.

324-2.6 Mixing Chamber: The equipment shall be equipped with an on-board mixing chamber (either a pugmill or drum mix plant) that is capable of thoroughly mixing the heated, reworked material with new materials. This unit shall be completely enclosed and configured such that the materials are lifted from the roadway surface to allow for complete blending without segregation or coking of the materials.

324-2.7 Screed: The equipment shall be equipped with a heated, vibratory screed system, which is capable of distributing the blended mixture, without segregation, evenly over the area being processed. The screed shall be equipped with a longitudinal grade control system (either the skid or traveling stringline type) with a minimum length of 25 feet [7.5 m].

324-3 Materials

324-3.1 General Specifications: The materials used shall conform with the requirements specified in Division III of the Standard Specifications. Specific references are as follows:

(1) Asphalt Cement/Recycling Agent . . . . .916-1 and 916-2
(2) Coarse Aggregate 901
(3) Fine Aggregate 902

324-3.2 Mix Design: Prior to the commencement of any recycling operations, the Contractor shall submit a proposed mix design and corresponding materials to the State Materials Office. The proposed mix design shall include the information required in 331-4.3. The Contractor shall determine the amount of new material to be added to the existing material such that the gradation meets the requirements for a Type S-I structural mix as specified in Table 331-1. In addition, the mix shall meet the Marshall Design properties for a Type S-I mix as shown in Table 331-2. Modifications to the Marshall Design Method, such as mixing time and compaction temperature shall be shown on the proposed mix design. The Department will have two weeks from the date of receiving the design and materials to either verify or reject the mix as designed.

324-4 Environmental Regulations.

Special attention is directed to the fact that local environmental and other regulations governing the operation of this type of equipment may vary considerably from place to place. It shall be the Contractor's responsibility to become familiar with and comply with all such local regulations, as well as State and Federal rules, and to obtain all necessary permits.

324-5 Construction.

324-5.1 General Requirements: Prior to commencing construction operations, all major defective portions of the existing pavement are to be repaired as indicated in the plans or as directed by the Engineer.

The minimum ambient temperature required to begin recycling shall be 50^{o}F [10^{o}C] and rising.

The pavement shall be cleaned so as to be reasonably free from sand, dirt, and other deleterious substances that would affect the quality of the reworked mix. Specialized equipment, such as vacuum or street sweepers, may be necessary in urban areas with curb and gutters so as to prevent excessive amounts of material from entering storm drains. Cleaning shall also include removing existing raised reflective pavement markers (RPM) and thermoplastic paint markings prior to recycling.

324-5.2 Heating and Recycling: The pavement surface shall be evenly heated and recycled to the widths and depths as shown in the plans. Heating shall be controlled to assure uniform heat penetration without causing differential softening of the pavement. The Contractor shall make all efforts to protect all adjacent landscape from heat damage, and will be responsible for such damage.

324-5.3 Rejuvenating, Mixing, and Placing: The reclaimed materials shall be blended with the recycling agent and new raw materials, then automatically fed into the mixing chamber. The type and quantity of new material and reclaimed material shall be as specified on the mix design. All materials shall then be thoroughly mixed while maintaining the minimum temperature as shown on the mix design.

Virgin materials (asphalt concrete or aggregate) shall be added prior to the mixing operation in order to allow for complete blending. All virgin asphalt concrete shall be added after heating as to prevent damage.

Following the remixing process, the recycled material shall be distributed and leveled in such a manner as to produce a uniform cross-section in conformance with the plan thickness and as specified below. The recycled asphalt pavement shall have a minimum temperature of 225^{o}F [105 ^{o}C] measured directly behind the screed.

324-5.4 Compaction: The Contractor will select the compaction equipment and rolling sequences necessary to meet the density specifications as set forth below. All equipment shall meet the criteria established in 320-6.3. All compaction operations shall be completed before the pavement surface temperature reaches 150^{o}F [65 ^{o}C].

324-6 Contractor's Quality Control.

324-6.1 General: The Contractor shall furnish and maintain a Quality Control System that will provide reasonable assurance that all materials and products submitted to the Department for acceptance conform to the contract requirements, whether manufactured or processed by the Contractor or procured from suppliers or subcontractors. The Contractors Quality Control procedures, inspection, and tests shall be documented and that information made available for review by the Department throughout the life of the contract. These documents shall become the property of the Department at the end of the project.

The Contractor shall furnish a fully equipped asphalt laboratory (permanent or portable) within 25 miles [40 km] of the project site, meeting the requirements defined in 6-8.4.

The Contractor shall submit a proposed Quality Control (QC) Plan outlining all necessary Quality Control activities, prior to the commencement of construction. As a minimum the proposed QC Plan should contain the following:

1. Determination of asphalt content and gradation – 1/500 tons [1/450 metric tons]
2. Determination of gradation of incoming virgin aggregate - 1/500 tons [1/450 metric tons]
3. Determination of asphalt content and gradation of incoming hot mix asphalt – 1/500 tons [450 metric tons]
4. Determination of pavement temperature – 1/100 feet [1/30 m]
5. Determination of maximum specific gravity – 1/day
6. Depth determination – 1/50 feet [1/15 m]
7. Visual inspection – continual

324-6.2 Corrective Actions: The Contractor shall take prompt action to correct any errors, equipment malfunctions, process changes, or other assignable causes which have resulted or could result in the submission of materials, products, and completed construction which do not conform to the requirements of the specifications.

324-6.3 Quality Control of Binder Viscosity: The Engineer will monitor the viscosity and penetration of the asphalt binder during production. The viscosity of the asphalt material in the bituminous mixture, determined by the Engineer in accordance with FM 1-T 202, shall be in the range of from 4,000 – 12,000 poises [400 – 1200 Pa-s] or as approved by the Engineer. The Engineer reserves the right to request reasonable changes throughout the construction duration. This determination will be made on samples obtained by the Department on a random basis at a frequency of approximately one per 2000 tons [1800 metric tons] of mix.

324-7 Acceptance Requirements.

324-7.1 Extraction/Gradation Analysis of the Mix: The recycled asphalt mixture will be accepted with respect to asphalt content and gradation as specified in 331-5. Samples shall be obtained randomly from behind the paver prior to compaction.

324-7.2 Density Requirement: The pavement will be accepted with respect to density in accordance with 334-5.4, meeting the requirements for a fine mix.

324-7.3 Straightedge and Thickness: The bituminous mixture will be accepted with respect to surface tolerance and thickness in accordance with 330-12 and 330-15 respectively.

324-7.4 Finished Pavement: The finished pavement at time of completion shall meet the following requirements. Areas failing to meet these criteria shall be corrected as approved by the Engineer.

324-7.4.1 The finished pavement shall be free of all types of disintegration, (including, but not limited to, mix delamination, potholes, and raveling) and excessive asphalt cement (flushing).

324-7.4.2 At all locations the rutting shall be less then 1/8 inch [3 mm].

324-7.5 Other Tests: The Department reserves the right to run any tests at any time for informational purposes and for determining the effectiveness of the Contractor's Quality Control. The Department will determine the Marshall properties, a minimum of one set per four days of recycling, to determine whether or not the Contractor is meeting the specification requirements. In the event that the Marshall properties fail to meet specification requirements, the reworking and remixing operation shall be halted until the problem is adequately resolved. The approval of the Engineer will be required prior to resuming operations.

Appendix C

Mix Design for SR-19 Project

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
STATEMENT OF SOURCE OF MATERIALS AND JOB MIX FORMULA FOR BITUMINOUS CONCRETE

SUBMIT TO THE STATE MATERIALS ENGINEER, CENTRAL BITUMINOUS LABORATORY, 2006 NORTHEAST WALDO ROAD., GAINESVILLE, FLA. 32609

Contractor: Angelo Benedetti, Inc. Address: 84 1st Avenue, Bedford, Ohio 44146

Phone No. (440) 439-3420 Fax No. (440) 439-3418 E-mail

Submitted By: Construction Materials Services, Inc. Type Mix: S-I Recycle Intended Use of Mix: Structural

TYPE MATERIAL	F.D.O.T. CODE	PRODUCER	PIT NO.	DATE SAMPLED
1. Milled Material		404126-1-52-01 Top 1.5" MP 0.569 to MP 9.725	SR-19 Roadway	06 / 03 / 2001
2. S-1-B Stone	51	Rinker Materials Corp.	87-089	06 / 03 / 2001
3. Reclamite		Golden Bear Oil Specialties	Oildale California	
4.				
5.				
6.				

PERCENTAGE BY WEIGHT TOTAL AGGREGATE PASSING SIEVES

	Blend	92%	8%					JOB MIX	GRADATION
	Number	1	2	3	4	5	6	FORMULA	DESIGN RANGE
S I E V E	1" 25.0mm								
	3/4" 19.0mm	100	100					100	100
	1/2" 12.5mm	98	100					98	88 - 98
	3/8" 9.5mm	92	100					93	75 - 93
	No. 4 4.75mm	61	46					60	47 - 75
S I E V E	No. 10 2.0mm	45	4					42	31 - 53
	No. 40 425µm	29	1					27	19 - 35
	No. 80 180µm	11	1					10	7 - 21
	No. 200 75µm	6.0	1.0					5.6	2 - 6
	Sp. Gr.	2.585	2.305					2.560	

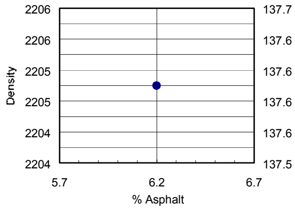
The mix properties of the Job Mix Formula have been conditionally verified, pending successful final verification during production at the assigned plant, the mix design is approved subject to F.D.O.T. specifications

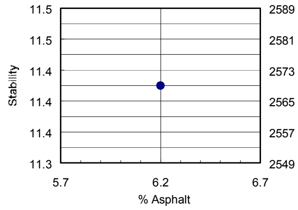
LD 01-2505A (TS-I)

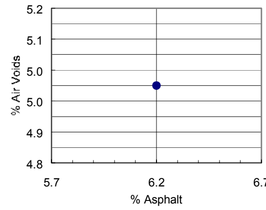
HOT MIX DESIGN DATA SHEET

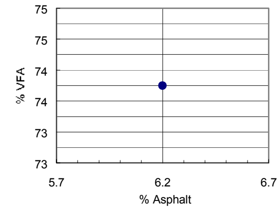
LD 01-2505A (TS-I)

Percent A.C. Total Wt. of Mix	Bulk Specific Gravity (Gmb)	Max. Measured Spec. Grav. (Gmm)	Air Voids Percent	%VMA	%VFA	Effective Asphalt Content	Dust to Effective AC Ratio	Stability (English)	Stability (Metric)	Flow Average (English)	Flow Average (Metric)
6.2	2.205	2.322	5.0	19.2	74	6.6	0.8	2569	11.4	12.0	3.0









Optimum Asphalt 6.2 %

V.M.A. 19.2 %

Mixing Temperature 230 °F 110 °C

Lab. Density 137.6 Lbs/Ft³ 2205 Kg/m³

Air Voids 5.0 %

Additives Reclamite 1.5 % ______ %

Stability 2569 Lbs 11.4 kN

NCAT Oven Calibration Factor ______ %
(+To Be Added)/(-To Be Subtracted)

Appendix D

Technical Special Provisions For Hot-In-Place Asphalt Recycling SR-19 Project

TECHNICAL SPECIAL PROVISIONS

FOR

HOT IN-PLACE ASPHALT RECYCLING

SR-19 PROJECT

FINANCIAL PROJECT NUMBER: 404126-1-52-01

Prepared By: ______________________
James A. Musselman, P.E.

Date: ______________________

Pages: ______________________

SECTION 324
HOT IN-PLACE ASPHALT RECYCLING

324-1 Description.

The work specified in this section consists of furnishing all labor, equipment, materials, and performing all operations in connection with heating, scarifying, applying recycling agent, adding new raw materials or hot mix asphalt, mixing, redistributing and compacting the recycled asphalt material.

324-2 Equipment.

324-2.1 General Requirements: The equipment used to recycle the existing asphalt surface shall be designed and built for this specific purpose. The equipment shall be capable of a continuous single pass, multi-step operation that includes; multi-step heating, scarifying, introducing recycling agent and virgin materials or hot mix asphalt, mixing the new material with the reclaimed material in a separate on-board chamber (pugmill/drum mix plant), redistributing the recycled material, leveling, and compacting.

The equipment will be on site in good operating condition sufficiently in advance of the reworking operation to allow full evaluation. As required by the Engineer, the Contractor shall demonstrate that the machine proposed for this purpose meets all the requirements specified herein.

324-2.2 Pavement Preheaters: Preheaters shall be capable of heating the existing pavement to a temperature high enough to allow dislodging of the material to the desired depth without fracturing aggregate particles, without charring the existing asphalt, and without producing undesirable pollutants. The heaters shall be adjustable in width. The heating mechanism shall be so equipped that heat shall be under an enclosed or shielded hood as to prevent damage to adjacent property.

324-2.3 Pavement Scarifiers: The pavement scarifiers shall be capable of uniformly loosening the pavement to the depth specified in the plans. Scarification shall be accomplished by using spring-loaded tines. The entire system shall be continuously operating and in contact with the preheated asphalt surface at all times. The system shall be flexible in order to process the entire area with minimum monitoring of the system. Tooth spacing of the scarifiers shall be such as to allow material to pass without excessive retention. The equipment shall be capable of raising and lowering sections of the scarifiers in order to scarify the material around manholes and other obstacles. As an exception to this requirement, all manhole and utility covers may be lowered prior to construction, in order to minimize interruptions to the recycling operation.

324-2.4 Rejuvenator Application System: A metering system will be used for adding and uniformly applying a recycling agent with the hot, loosened material. The application of the recycling agent and new raw materials shall be synchronized with the machine speed to provide a proportional application at the predetermined application rate. The rejuvenator shall be added after scarification has taken place to provide a uniform application and absorption of recycling agent during the mixing of the recycled material.

324-2.5 Auger: The equipment shall be equipped with an auger that is capable of gathering the heated and loosened asphalt concrete pavement. The auger(s) shall be operated in such a manner as to minimize aggregate degradation. The auger shall be capable of windrowing the material ahead of the mixing chamber. Use of milling heads in lieu of an auger shall not be permitted.

324-2.6 Mixing Chamber: The equipment shall be equipped with an on-board mixing chamber (either a pugmill or drum mix plant) that is capable of thoroughly mixing the heated, reworked material with new materials. This unit shall be completely enclosed and configured such that the materials are lifted from the roadway surface to allow for complete blending without segregation or coking of the materials.

324-2.7 Screed: The equipment shall be equipped with a heated, vibratory screed system, which is capable of distributing the blended mixture, without segregation, evenly over the area being processed. The screed shall be equipped with a longitudinal grade control system (either the skid or traveling stringline type) with a minimum length of 25 feet [7.5 m].

324-3 Materials

324-3.1 General Specifications: The materials used shall conform with the requirements specified in Division III of the Standard Specifications. Specific references are as follows:

(1) Asphalt Cement/Recycling Agent . . . . .916-1 and 916-2
(2) Coarse Aggregate 901
(4) Fine Aggregate 902

324-3.2 Mix Design: Prior to the commencement of any recycling operations, the Contractor shall submit a proposed mix design and corresponding materials to the State Materials Office. The proposed mix design shall include the information required in 331-4.3. The Contractor shall determine the amount of new material to be added to the existing material such that the gradation meets the requirements for a Type S-I structural mix as specified in Table 331-1. In addition, the mix shall meet the Marshall Design properties for a Type S-I mix as shown in Table 331-2. Modifications to the Marshall Design Method, such as mixing time and compaction temperature shall be shown on the proposed mix design. The Department will have two weeks from the date of receiving the design and materials to either verify or reject the mix as designed.

324-4 Environmental Regulations.

Special attention is directed to the fact that local environmental and other regulations governing the operation of this type of equipment may vary considerably from place to place. It shall be the Contractor's responsibility to become familiar with and comply with all such local regulations, as well as State and Federal rules, and to obtain all necessary permits.

324-5 Construction.

324-5.1 General Requirements: Prior to commencing construction operations, all major defective portions of the existing pavement are to be repaired as indicated in the plans or as directed by the Engineer.

The minimum ambient temperature required to begin recycling shall be 50^{o}F [10^{o}C] and rising.

The pavement shall be cleaned so as to be reasonably free from sand, dirt, and other deleterious substances that would affect the quality of the reworked mix. Specialized equipment, such as vacuum or street sweepers, may be necessary in urban areas with curb and gutters so as to prevent excessive amounts of material from entering storm drains. Cleaning shall also include removing existing raised reflective pavement markers (RPM) and thermoplastic paint markings prior to recycling.

324-5.2 Heating and Scarifying: The pavement surface shall be evenly heated and scarified to the widths and depths as shown in the plans. Heating shall be controlled to assure uniform heat penetration without causing differential softening of the pavement. The Contractor shall make all efforts to protect all adjacent landscape from heat damage, and will be responsible for such damage.

324-5.3 Rejuvenating, Mixing, and Placing: The reclaimed materials shall be blended with the recycling agent and new raw materials, then automatically fed into the mixing chamber. The type and quantity of new material and reclaimed material shall be as specified on the mix design. All materials shall then be thoroughly mixed while maintaining the minimum temperature as shown on the mix design.

Virgin materials (asphalt concrete or aggregate) shall be added prior to the mixing operation in order to allow for complete blending. All virgin asphalt concrete shall be added after heating as to prevent damage.

Following the remixing process, the recycled material shall be distributed and leveled in such a manner as to produce a uniform cross-section in conformance with the plan thickness and as specified below. The recycled asphalt pavement shall have a minimum temperature of 225°F [105 °C] measured directly behind the screed.

324-5.4 Compaction: The Contractor will select the compaction equipment and rolling sequences necessary to meet the density specifications as set forth below. All equipment shall meet the criteria established in 320-6.3. All compaction operations shall be completed before the pavement surface temperature reaches 150°F [65 °C].

324-6 Contractor's Quality Control.

324-6.1 General: The Contractor shall furnish and maintain a Quality Control System that will provide reasonable assurance that all materials and products submitted to the Department for acceptance conform to the contract requirements, whether manufactured or processed by the Contractor or procured from suppliers or subcontractors. The Contractors Quality Control procedures, inspection, and tests shall be documented and that information made available for review by the Department throughout the life of the contract. These documents shall become the property of the Department at the end of the project.

The Contractor shall furnish a fully equipped asphalt laboratory (permanent or portable) within 25 miles [40 km] of the project site, meeting the requirements defined in 330-2.2.

The Contractor shall submit a proposed Quality Control (QC) Plan outlining all necessary Quality Control activities, prior to the commencement of construction. As a minimum the proposed QC Plan should contain the following:

8. Determination of asphalt content and gradation – 1/500 tons [1/450 metric tons]
9. Determination of gradation of incoming virgin aggregate - 1/500 tons [1/450 metric tons]
10. Determination of asphalt content and gradation of incoming hot mix asphalt – 1/500 tons [450 metric tons]
11. Determination of pavement temperature – 1/100 feet [1/30 m]
12. Determination of maximum specific gravity – 1/day

13. Depth determination – 1/50 feet [1/15 m]
14. Visual inspection – continual

324-6.2 Corrective Actions: The Contractor shall take prompt action to correct any errors, equipment malfunctions, process changes, or other assignable causes which have resulted or could result in the submission of materials, products, and completed construction which do not conform to the requirements of the specifications.

324-6.3 Quality Control of Binder Viscosity: The Engineer will monitor the viscosity and penetration of the asphalt binder during production. The viscosity of the asphalt material in the bituminous mixture, determined by the Engineer in accordance with FM 1-T 202, shall be in the range of from 4,000 – 12,000 poises [400 – 1200 Pa-s] or as approved by the Engineer. The Engineer reserves the right to request reasonable changes throughout the construction duration. This determination will be made on samples obtained by the Department on a random basis at a frequency of approximately one per 2000 tons [1800 metric tons] of mix.

324-7 Acceptance Requirements.

324-7.1 Extraction/Gradation Analysis of the Mix: The recycled asphalt mixture will be accepted with respect to asphalt content and gradation as specified in 331-5. Samples shall be obtained randomly from behind the paver prior to compaction.

324-7.2 Density Requirement: The pavement will be accepted with respect to density in accordance with 334-5.4, meeting the requirements for a fine mix.

324-7.3 Straightedge and Thickness: The bituminous mixture will be accepted with respect to surface tolerance and thickness in accordance with 330-13 and 330-16 respectively.

324-7.4 Finished Pavement: The finished pavement at time of completion shall meet the following requirements. Areas failing to meet these criteria shall be corrected as approved by the Engineer.

324-7.4.1 The finished pavement shall be free of all types of disintegration, (including, but not limited to, mix delamination, potholes, and raveling) and excessive asphalt cement (flushing).

324-7.4.2 At all locations the rutting shall be less then 1/8 inch [3 mm].

324-7.5 Other Tests: The Department reserves the right to run any tests at any time for informational purposes and for determining the effectiveness of the Contractor's Quality Control. The Department will determine the Marshall properties, a minimum of one set per four days of recycling, to determine whether or not the Contractor is meeting the specification requirements. In the event that the Marshall properties fail to meet specification requirements, the reworking and remixing operation shall be halted until the problem is adequately resolved. The approval of the Engineer will be required prior to resuming operations.

324-8 Compensation.

324-8.1 Heating and Remixing: The quantity of hot in-place asphalt recycling shall be paid for at the contract unit price per square yard [per square meter], completed and accepted. Such price and payment shall be full compensation for performing all work, and shall include the cost of all materials, including the cost of the liquid asphalt, asphalt recycling agent, virgin aggregate or asphalt concrete admixture.

324-8.2 Payment Items: Payment shall be made under:

Item No. 324-1 Asphalt Recycling Hot In-Place – per square yard.