TAMWORTH COLD RECYCLING PROJECT
FR-024-1(8)

Project Description

This project was located on New Hampshire Route 25 in the Town of Tamworth. The project consisted of pavement overlay, partial pavement reconstruction, bridge rehabilitation and safety improvements. This rural primary two-lane highway is subject to heavy seasonal traffic flows. The total length was approximately 3.25 miles.

The project was awarded on May 1, 1981 to Pike Industries of Tilton, New Hampshire for the low bid sum of $923,607.50. Of this total, approximately $55,000 relates to the recycling effort.

Preliminary Investigation

The Materials Division of the State Highway Department provides a comprehensive geotechnical report for the proposed project soon after preliminary engineering is initiated. The following description is a summary of their investigations and recommendations for the Tamworth project.

The travelled way portion of this highway was generally in good condition with the exception of a section approximately 3,500 feet in length. The travelled way and right shoulder in this area were subject to frost heaving. The roadway showed considerable distress and many longitudinal cracks near the centerline. During the frost heave season, this section became very bumpy and many lumps lingered throughout the year. This condition was believed to have been perpetuated by the intrusion of water through the pavement cracks, the moisture then saturated the roadway and shoulder base courses.

The shoulders throughout the remaining length of the project were in fair condition. Most of the existing four-foot shoulders showed major deterioration at the edges. This breakup was due to the thin pavement thickness and unsupported shoulder edges. It was estimated that 80 percent of the existing shoulders were

considerably lower in elevation than the existing through lanes. To bring these low shoulders to binder grade with a hot bituminous leveling course would have been costly. Therefore, on all shoulders where leveling was not feasible, the Soils Division recommended removal of the old shoulder pavement, placement of crushed gravel to shoulder subgrade and overlay with hot bituminous pavement.

To minimize the future infiltration of water into the travelled way base courses and reflective cracking, the placement of reinforcing fabric over the travelled way leveling course was recommended for stations 690 - 725. In this same area, the entire right shoulder should be reconstructed from a cut line established at the edge of the existing travelled way. Due to the variable materials and drainage situation, the Soils Division recommended a 24-inch base course depth, consisting of 18 inches gravel and six inches of crushed gravel.

Subsequent to those investigations and recommendations, a field inspection revealed the section of roadway from stations 690 - 725 had undergone rapid pavement and base deformation. With this new information, the use of a reinforcing fabric to alleviate these conditions was not considered to be a good long-term investment. Rather, it was recommended the travelled way be reconditioned, this being the cold recycling process of pulverizing the existing pavement and constructing a reclaimed stabilized base course. In this area, the placement of subgrade material was required to upgrade the profile and structural section, this in the form of crushed gravel and gravel. The remaining length of the project was to incorporate the placement of a one-half inch bituminous pavement leveling course, a two-inch binder course and one-inch surface wearing course.

Specification Section

In the past few years, New Hampshire has done extensive work with cold recycling of the existing pavement to form a stabilized base course. A hot

bituminous pavement usually consisting of a binder and surface wearing course would then be placed on the stabilized base course.

This section contains the special provision included in this contract which dealt with the implementation of the cold recycling method. For review with this provision, Appendix B contains the appropriate specifications for base courses in their entirety.

SPECIAL PROVISION
SECTION 306 -- RECONDITIONING

DESCRIPTION

1.1 This work shall consist of scarifying and pulverizing existing pavement, removing, stockpiling and constructing a stabilized base course as shown on the plans or as directed.

MATERIALS

2.1 The materials shall consist of the existing bituminous surface and an approximately equal amount of gravel base, consisting of a portion of the underlying base aggregate or added gravel, or both.

CONSTRUCTION REQUIREMENTS

3.1 The existing pavement shall be broken by scarifying with conventional equipment such as a grader-mounted or bulldozer-mounted ripping or scarifying device. After the existing pavement is broken, the specified depth of pavement with approximately equal parts of base gravel shall be windrowed and further processed in the windrow using a traveling hammer mill until all the material will pass a 2½ inch sieve. Gravel shall be added if required and the materials shall be blended together until all materials are uniformly distributed throughout the combined windrow. This processed material shall be removed and stockpiled.

3.2 The base course shall be graded to the lines and grades shown on the plans or as directed and compacted in accordance with 304.3.4.

3.3 The processed material shall be returned to the newly constructed and prepared roadway. The material shall be bladed to lines and grades as shown on the plans or as directed. Spreading and compaction shall be done in accordance with 304.3.4.

3.4 The finished surface shall be inspected for smoothness and accuracy of grade and if any portions are found to lack required smoothness or accuracy, such portion shall be rescarified, reshaped, recompacted, and otherwise manipulated as directed.

METHOD OF MEASUREMENT

4.1 Reclaimed stabilized base will be measured by the square yard of processed material of the required depth, measured in place in its final location. The width will be limited to that shown on the plan.

4.1.1 Gravel ordered to be added and blended to the reclaimed stabilized base material will be measured by the cubic yard as determined by using 80 percent of the loose volume of the material measured on vehicles in accordance with 109.01.

BASIS OF PAYMENT

5.1 The accepted quantity of reclaimed stabilized base will be paid for at the contract unit price per square yard complete in place. Gravel ordered to be added will be paid for under Item 304.2 unless such material is furnished by the State.

Pay item and unit:

306.2	Reclaimed Stabilized Base (6" - Remove and Rehandle)	Square Yard

Equipment and Construction Procedures

Recycling Process

The process from existing bituminous pavement to the reclaimed base was completed in two main parts composed of numerous steps. The initial work consisted of scarifying and pulverizing the existing pavement and, in some cases, stockpiling the material at a site close to the project. Stockpiling of the reclaimed material was necessary where a general upgrading of the profile and section was required. On inspection the existing pavement varied throughout the site:

1/2" surface wearing course	3/4" surface wearing course	1" surface wearing course
1 1/2" previous surface	3/4" surface wearing course	1 1/2" binder course
3" Class C-2 Road mix (large aggregate base)	1/2" shim course	1 1/2" Class C-2 Road mix
	1" binder course	
5"	2-3" Class C-2 Road mix	4"
	5 1/2 - 6 1/2"	

Through the project length where reconstruction was required, the pavement was an average of five inches in depth. It contained very little aggregate with the exception of the two to three inches of Class C-2 Road mix; this was a large aggregate (1 1/2 to 2 1/2 inch) base material. For a photo of this material, refer to the Manchester project Figures M-5 and M-6.

Of the approximate 32-foot overall width of pavement and shoulder, removal began on the southbound section 20 to 22 feet in width with the traffic detoured on the remaining 10 to 12 feet. The detour provided one-way traffic through the construction site with flagmen stationed at each end and in the center to facilitate adequate coordination. For additional information on the step-by-step process, the schematic contained later in the text should be helpful.

Step 1: The pavement was broken up with the use of a grader-mounted ripper tooth into strip widths of 12 to 18 inches. This action also churned up the gravel base because of the two to three-inch penetration of the tooth (See Figure T-8).

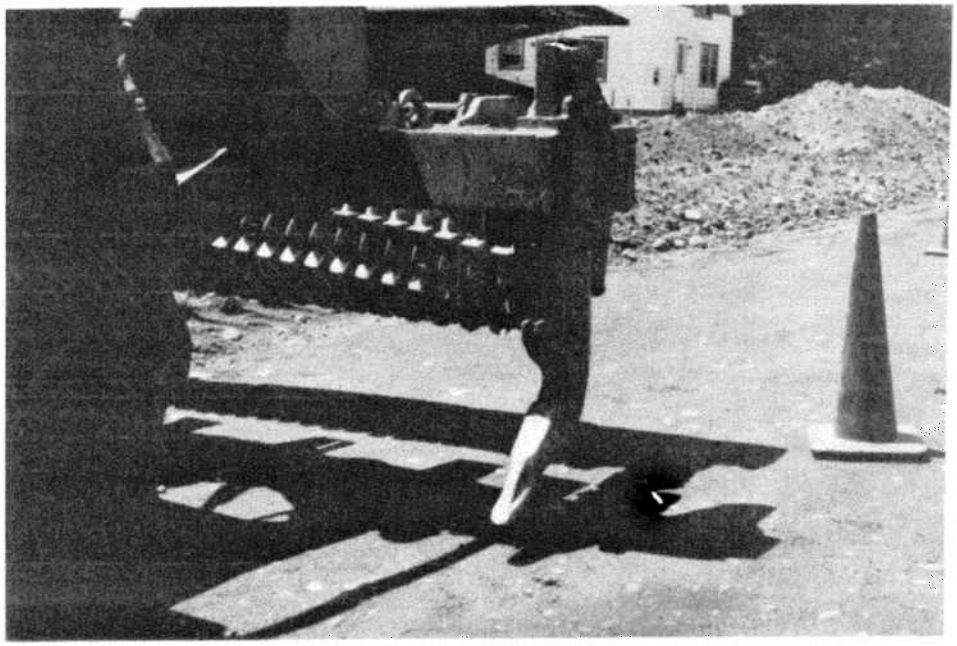


FIGURE T-1: Grader-Mounted Ripper Tooth

Step 2: The material was then crushed in place with the rear-mounted rotating mill. It became quite evident that unless the pavement is ripped and turned over after several passes of the rotating mill, this device will simply ride over the large chunks of pavement, and do little if any crushing. In the forward motion, there is a lack of weight on the mill. In reverse, the weight

of the grader tends to force the mill into the chunks of pavement, which increases the effectiveness of the mill. After 10 to 14 passes, the material still contained several sections of pavement one to three square feet in size (See Figures T-6, T-9 and T-10).

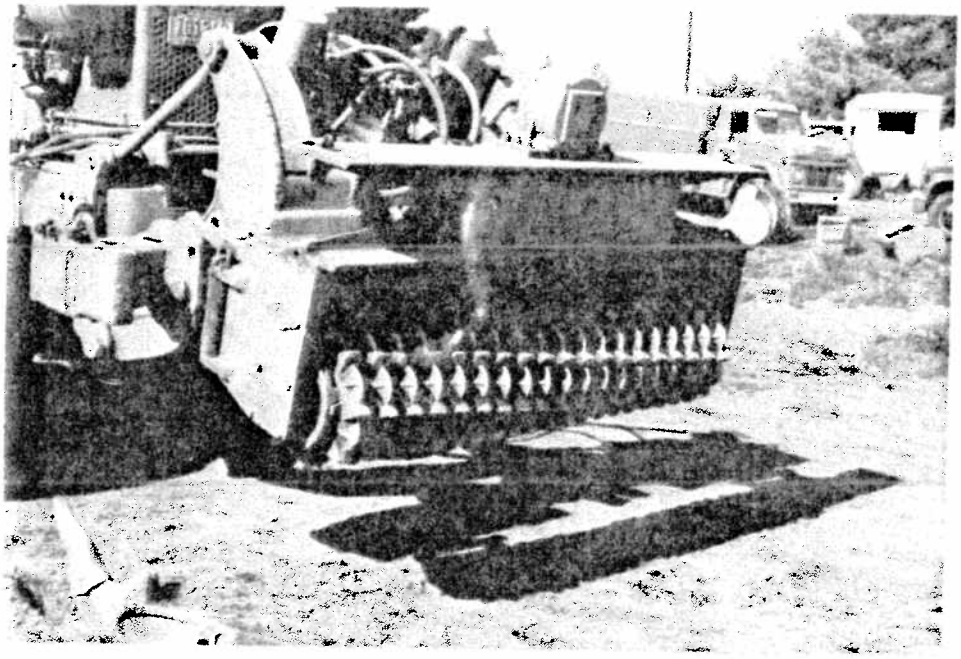


FIGURE T-2: Grader Rear-Mounted Rotating Mill with Optional Vibratory Engine

The use of the travelling hammermill adequately crushed the material in a later step. The inability to crush the material further by the rotating mill could partially be attributed to the inexperience of the operator in this process. The material in the windrow from the previous operator and day appeared to be of a much finer gradation.

Step 3: After the material was crushed to a fair extent by the rotating mill, the crushed pavement was windrowed to the center of the existing roadway (See Figure T-6).

Step 4: The grader operator then bladed a portion of the existing base material onto the windrow. Additional crushed gravel was then dumped in the previously graded portion and bladed onto the

windrow. This windrow was now composed of approximate equal parts of base gravel and reclaimed asphalt (See Figure T-7).

Step 5: The detour was then graded and rolled with a large single drum-vibratory roller. After the water truck passed through, traffic was switched to the new detour.

Step 6: The grader operator then began ripping and crushing the existing northbound pavement (See Figure T-8).

Step 7: After completion of the crushing process, the material from the northbound lane was windrowed to the extreme side. The center windrow which was composed of material from the south-bound section was also bladed to the extreme side. This created a total windrow of approximately 20 square feet in cross section, the entire length. The contractor had removed and processed approximately 32,000 square feet of pavement in an eight-hour day, or a rate of 445 square yards per hour (See Figures T-9, T-10 and T-11).

At this stage, two different methods were incorporated. Stockpiling of the windrowed material for a period of time was required where a general upgrading of the profile and structural section was planned. In areas where this was not required, the process was continued after a field check of the profile and cross section.

Windrowed Material

Step 8A: In the section previously reviewed, the last step in removal was to windrow the material to the extreme right. Thus, because the base course required little additional material to meet the specified elevations, the material was in effect stockpiled. Further processing of the windrowed material by a travelling hammermill was required to meet the passing of a 2½-inch sieve.

To accomplish this task, the hammermill was attached to the rear of the grader. With the grader blade removing a portion of the windrow, the hammermill could effectively crush the material in one pass. Laborers would remove any large aggregate which remained after one pass for further processing in the next windrow. The hammermill also blended the materials together until they were uniformly distributed throughout the base. This process continued until the windrow had effectively been spread and hammermilled the width of the roadway.

Stockpiled Material

Step 8B: After completing the subbase to the specified depth and elevations, the stockpiled material was returned to the site. The reclaimed material was dumped by truck, then hammermilled and graded to the required depth.

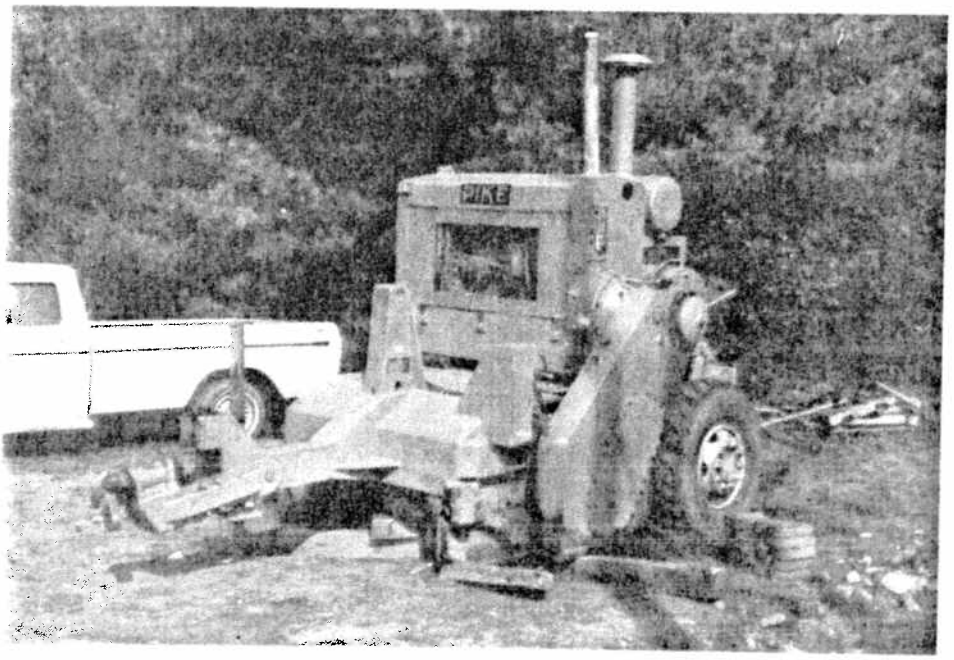


FIGURE T-3: Travelling Hammermill

Step 9: In both cases, the hammermilling operation was programmed to maintain one-way traffic through the site as a minimum. After

grading to the required depth, the reclaimed stabilized base was compacted with a vibratory single drum roller (See Figures T-12, T-13 and T-14).

The process of returning the windrow or stockpiled material to a reclaimed base can be accomplished at the rate of approximately 550 square yards per hour, typically a 1,000-foot by 40-foot wide section per day. Upon inspection after several days, the reclaimed stabilized base appeared to be in excellent condition as a temporary riding surface. Heavy traffic was flowing at a moderate speed (30-40 m.p.h.) through the site and appeared to cause little, if any, damage. The finished product was of very high density, with most aggregate 3/4" to 1½" in size. The reclaimed stabilized base required the use of a water truck every two to three hours to minimize dust and was graded every other day to eliminate any possibility of rutting or potholes. The project engineer had estimated the reclaimed material to contain approximately 50 percent of the existing pavement as was specified.

FIGURE T-4: Existing Pavement After Ripping and Approximately Eight Passes of the Rotating Mill

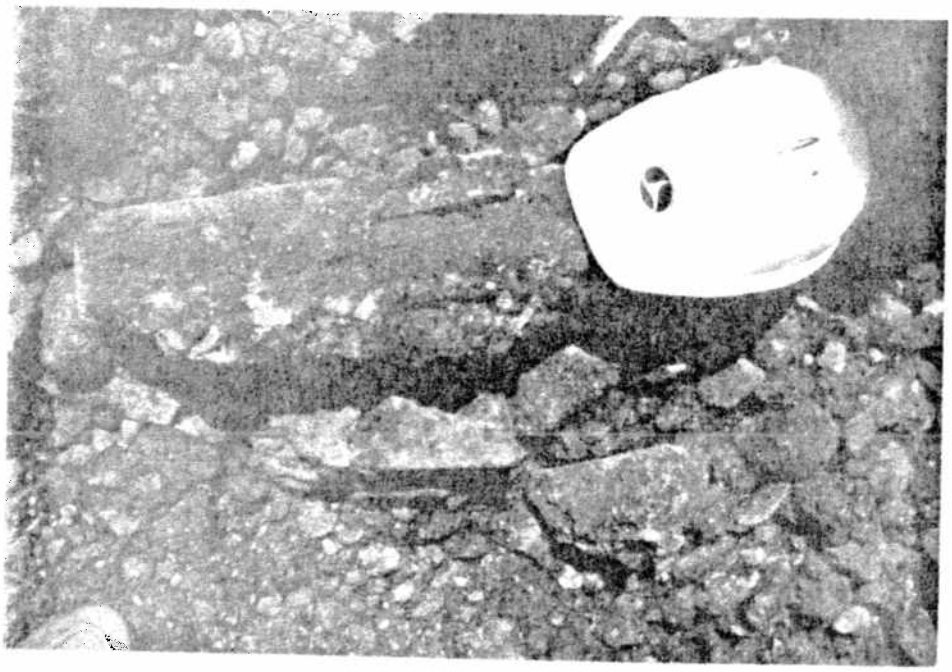


FIGURE T-5: Existing Pavement After Ripping and Some Crushing

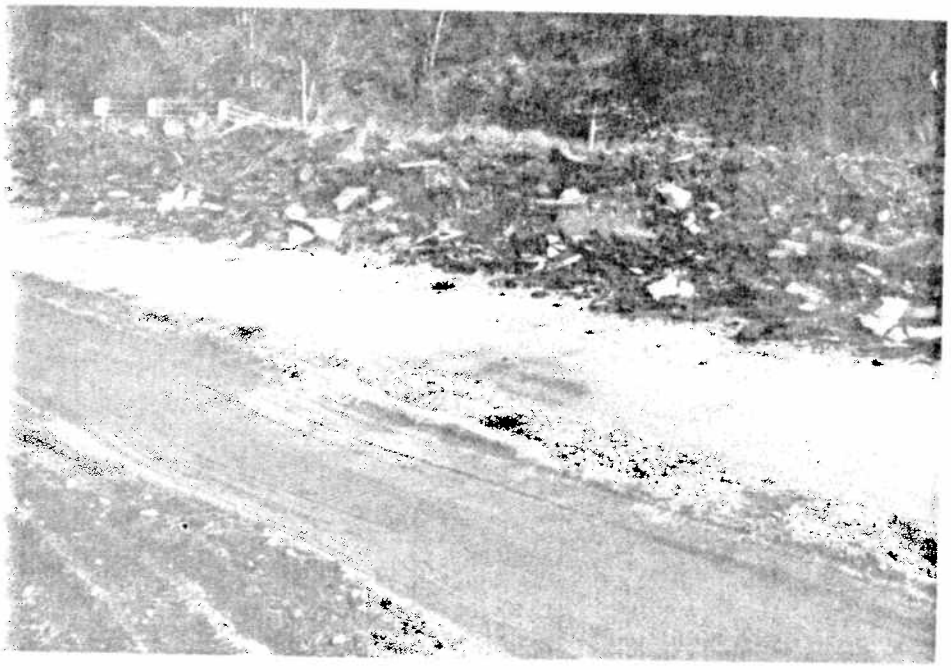


FIGURE T-6: One-Way Detour and Center Windrow of Crushed Pavement

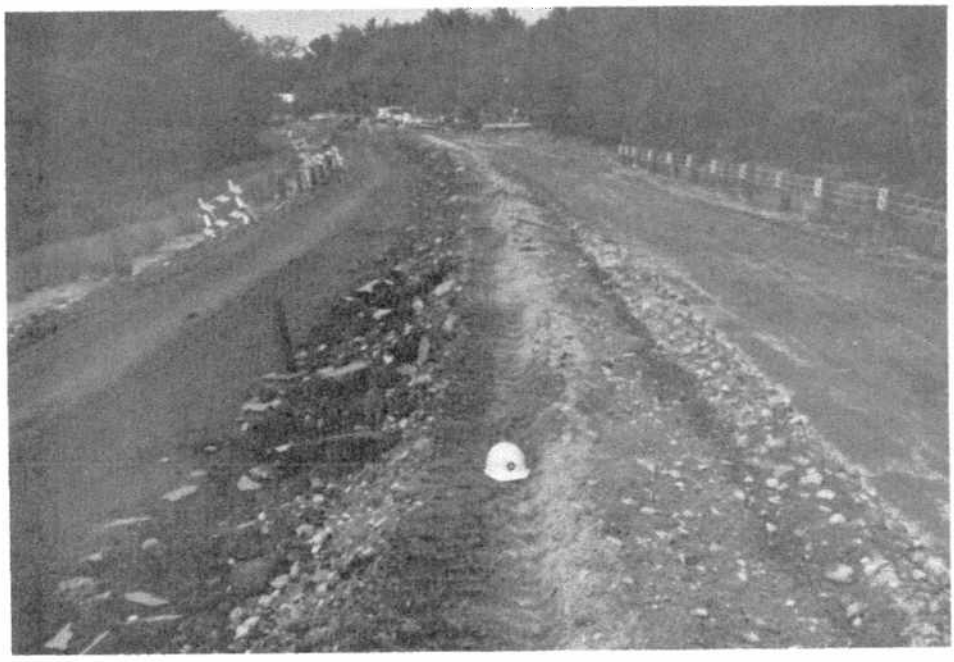


FIGURE T-7: Center Windrow with Partial Placement of Crushed Gravel (Looking South)

FIGURE T-8: Existing Pavement Being Ripped After Traffic Detour Change (Looking North)

FIGURE T-9: Material Being Crushed and Bladed (Looking North)

FIGURE T-10: Material Partially Windrowed (Looking North)

FIGURE T-11: Windrow Completed
(Looking South)

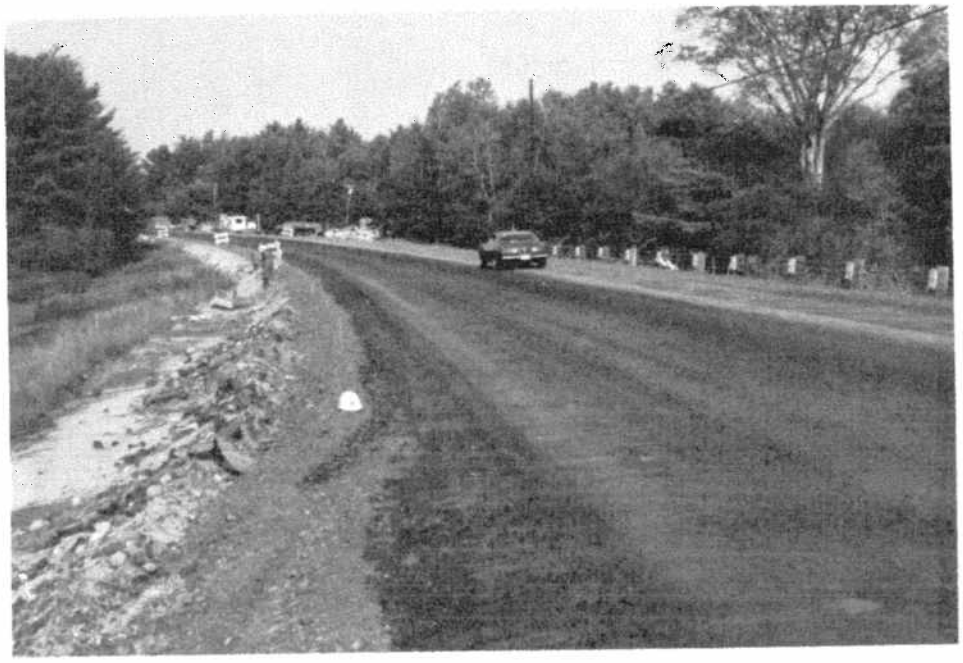


FIGURE T-12: Completed Reclaimed Stabilized Base
Prior to Fine Grading and Placement
of Hot Bituminous Pavement

FIGURE T-13: Completed Reclaimed Stabilized Base

FIGURE T-14: Completed Reclaimed Stabilized Base (Note Consolidation of Material)

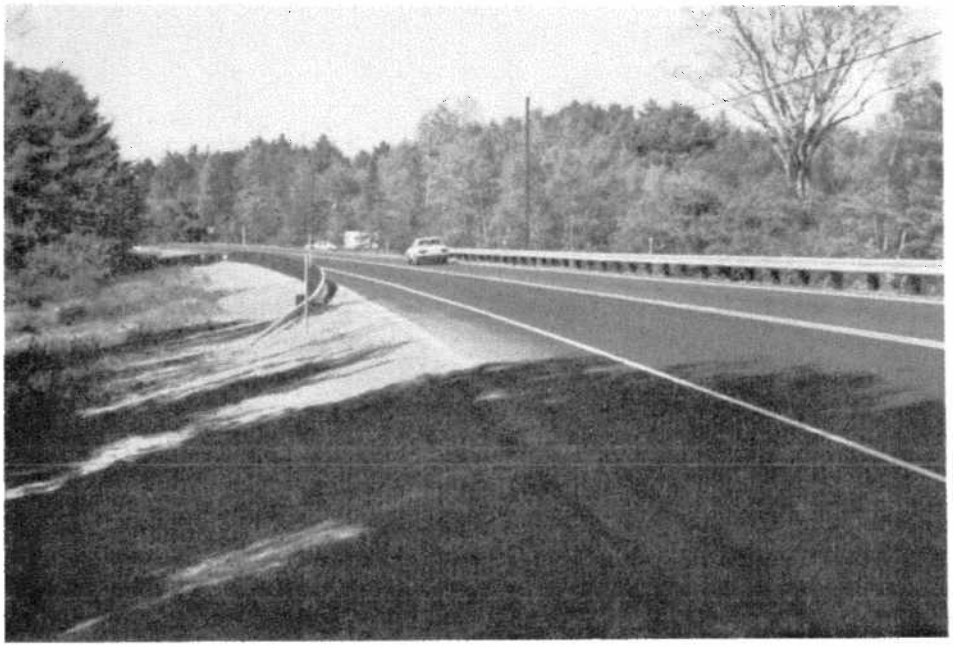


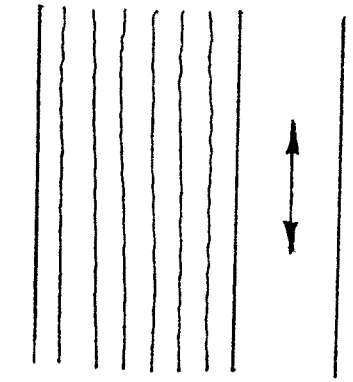
FIGURE T-15: Completed Project
(Same View as T-7
and T-12)

SCHEMATIC OF RECYCLING PROCESS AT TAMWORTH

(1"=20' scale)

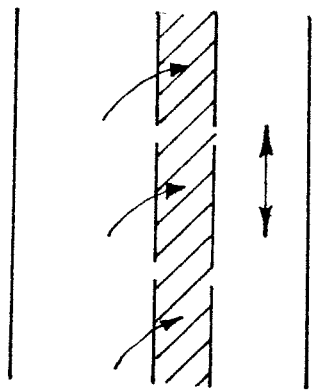
North

South



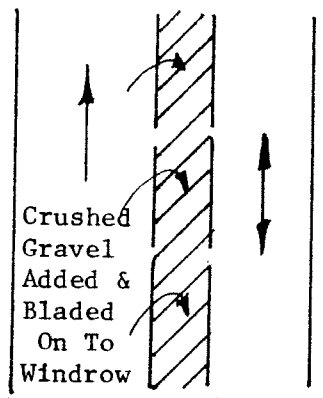
SEE FIGURE T-4
T-5

STEP 1 and 2



SEE FIGURE T-6

STEP 3

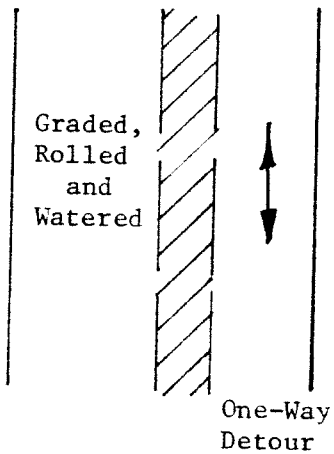


SEE FIGURE T-7

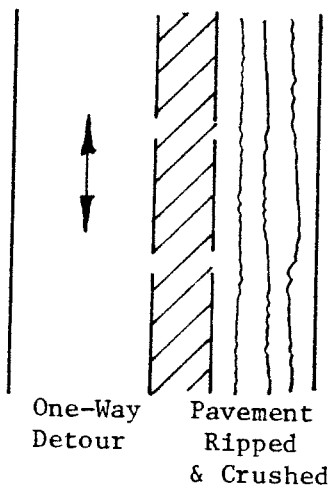
STEP 4

North

South

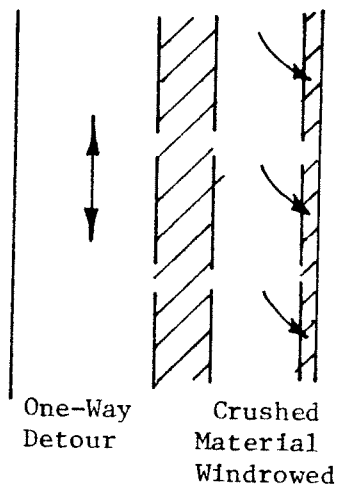


STEP 5



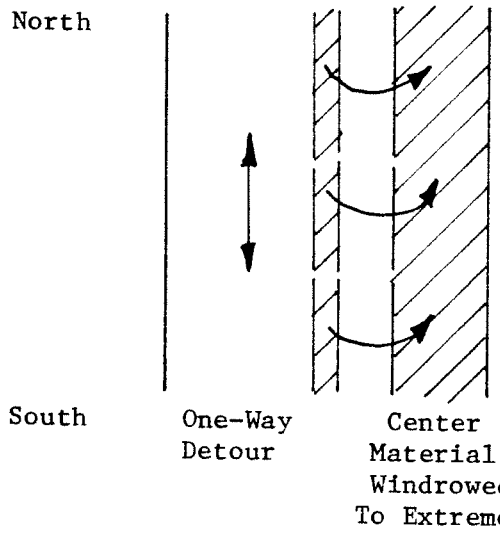
SEE FIGURE T-8

STEP 6



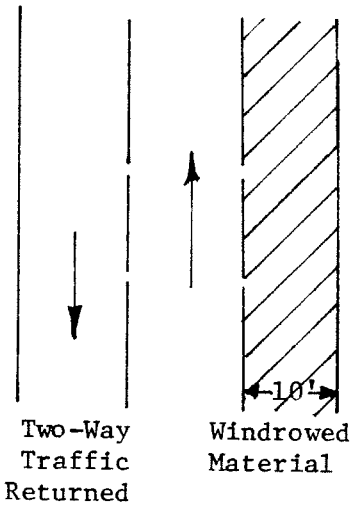
SEE FIGURES T-9, T-10

STEP 7



SEE FIGURES T-9, T-10

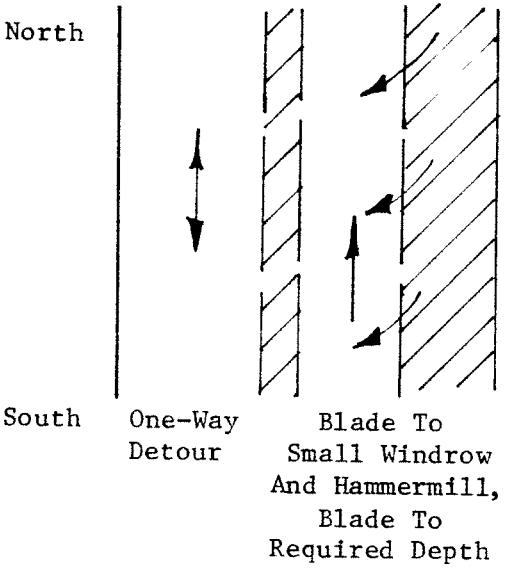
STEP 7



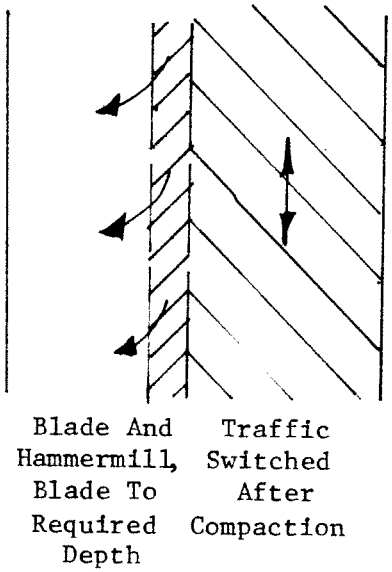
SEE FIGURE T-11

At this stage, two different methods are developed. Stockpiling of the windrowed material for a period of time was necessary where a general upgrading of the profile and section was planned. In areas where this was not required, the process continued after a field check of the specified elevations.

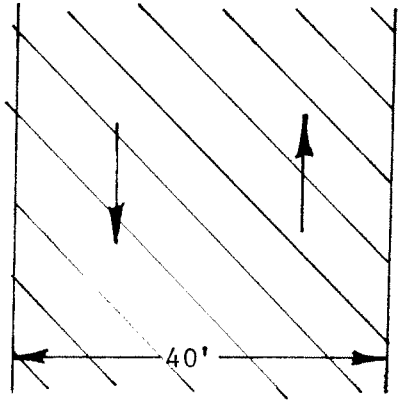
WINDROW COMPLETED



STEP 8a and 9

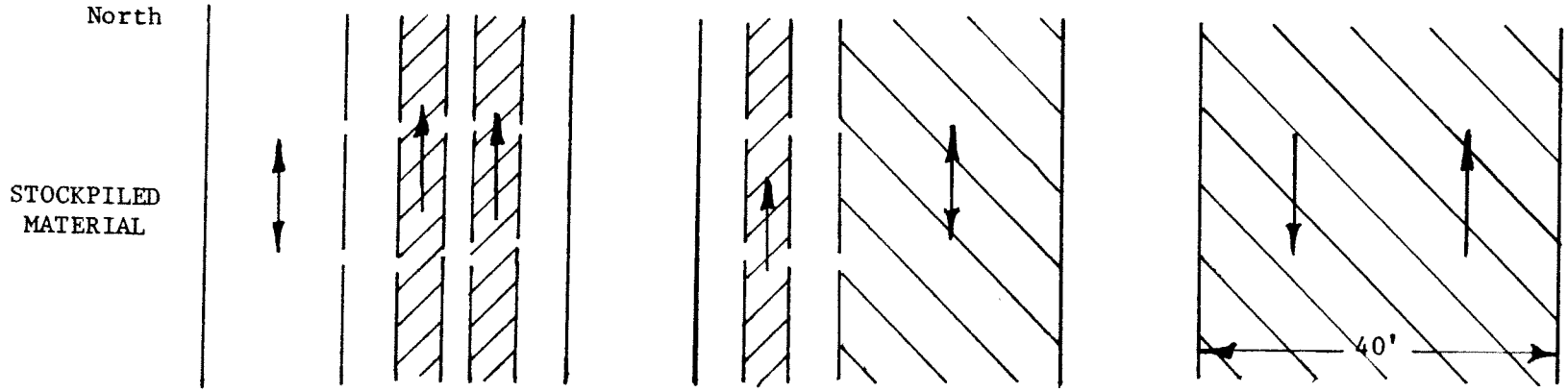


STEP 8a and 9



Reclaimed Stabilized Base Completed, Fine Graded Prior To Placement Of Hot Bituminous Pavement

SEE FIGURES T-12, T-13, T-14



STEP 8b and 9

STEP 8b and 9

SEE FIGURES T-12, T-13, T-14

Cost Analysis

This portion of the paper will analyze the costs involved in the recycled design used, versus an alternate conventional structural section. To fulfill the project objectives, total reconstruction was necessary in several sections, with the remaining sections only requiring an overlay. The cost comparison will only involve a typical section of total reconstruction where the reclaimed stabilized base was incorporated. Whether the material was windrowed or stock-piled will not come into effect in the calculation.

To draw a fair comparison between recycling and conventional strategies, the evaluation should be based upon pavement sections which will offer equivalent performance over the same time period. To develop an equivalent structural section for the cold recycling method, the use of coefficients of relative strength for each material was felt to be the best solution.

Item 403.11 - Hot bituminous surface	0.38
Item 403.11 - Hot bituminous base	0.34
Item 304.3 - Crushed gravel	0.10
Item 304.2 - Gravel	0.07
Item 306.11 - Reclaimed Stabilized Base	0.17

The recycled structural section which was constructed would then have a number of:

1" wearing course:	1" x 0.38 = 0.38
2" binder course:	2" x 0.38 = 0.76
6" reclaimed stabilized base:	6" x 0.17 = 1.02
4½" crushed gravel:	4.5" x 0.10 = 0.45

8" gravel
8" gravel } Note 1: Because of the depth of gravel placed varied throughout the project, due to profile changes, and will remain constant whether a recycled or conventional mode were used, it will not be included in the calculation.

6" gravel: 6" x 0.07 = 0.42

3.03

Using this structural number as a required goal, we can then develop alternate structural sections:

Conventional Section A: This will consist of replacing the reclaimed stabilized base and crushed gravel course, with a bituminous base course and deeper crushed gravel course.

1" bituminous wearing course:	1" x 0.38 = 0.38
2" bituminous binder course:	2" x 0.38 = 0.76
2" bituminous base course:	2" x 0.34 = 0.68
8" crushed gravel:	8" x 0.10 = 0.80
6" gravel:	6" x 0.07 = 0.42
	3.04

Conventional Section B: This will consist of similar structural section as Section A, but will alter the depths of bituminous base course and crushed gravel.

1" bituminous wearing course:	1" x 0.38 = 0.38
2" bituminous binder course:	2" x 0.38 = 0.76
3" bituminous base course:	3" x 0.34 = 1.02
4½" crushed gravel:	4.5" x 0.10 = 0.45
6" gravel:	6" x 0.07 = 0.42
	3.03

Through the developed alternate sections, the cost analysis will demonstrate how even the slightest change in the composition of a section may dramatically increase costs yet maintain an equivalent structural section.

These are the items of possible significance in the structural section for the project estimate:

Item	Description	Quantity	Price Per Unit
304.2	Gravel	7,000 cy	$ 4.20
304.3	Crushed Gravel	2,700 cy	5.00
306.2	Reclaimed Stabilized Base	19,000 sy	2.80
403.11	Hot Bituminous Pavement	8,000 tons	29.80

The above prices are actual bid prices for this project. In the cost analysis, if the item was not included in this project, the cost would be determined by use of the quarterly bid prices.

Recycled Portion of Project Length

Method: Actual Cold Recycled

Remove existing pavement for recycling

Place gravel course to replace pavement depth (placement of gravel varied in depth throughout the project length; see note 1)

Place 4½" crushed gravel course

Place 6" reclaimed stabilized base course

Place 2" binder course and 1" wearing course (bituminous)

Conventional Section A

Remove existing pavement by common excavation

Place gravel course to replace pavement depth (placement of gravel varied in depth throughout the project length; see note 1)

Place 8" crushed gravel course

Place 2" base course, 2" binder course and 1" wearing course (bituminous)

Conventional Section B

Remove existing pavement by common excavation

Place gravel course to replace pavement depth (placement of gravel varied in depth throughout the project length; see note 1)

Place 4½" crushed gravel course

Place 3" base course, 2" binder course, and 1" wearing course (bituminous)

Costs: Actual Cold Recycled

1. Remove and crush existing pavement for recycling; this is included in Item 306.11 = 0.00

2. Place 6" gravel course:

   $4.20/cy x 6" deep x 1 sy = 0.71

3. Place 4½" crushed gravel course:

   $5/cy x 4½" deep x 1 sy = 0.65

4. Place 6" reclaimed stabilized base course:

   $2.80/sy x 1 sy = 2.80

5. Place 2" bituminous binder course:

   $29.80/ton x 0.113 ton/sy = 3.37

6. Place 1" bituminous wearing course:

   $29.80/ton x 0.057 ton/sy = 1.70

$9.23 per square yard

Conventional Section A

1. Remove existing pavement by common excavation:

   $2.60/cy x 6" deep x 1 sy = 0.44

2. Place 6" gravel course:

   $4.20/cy x 6" deep x 1 sy = 0.71

3. Place 8" crushed gravel course:

   $5/cy x 8" deep x 1 sy = 1.10

4. Place 2" bituminous base course:

   $29.80/ton x 0.113 ton/sy = 3.37

5. Place 2" bituminous binder course:

   $29.80/ton x 0.113 ton/sy = 3.37

6. Place 1" bituminous wearing course:

   $29.80/ton x 0.057 ton/sy = 1.70

$10.69 per square yard

Conventional Section B

1. Remove existing pavement by common excavation:

   $2.60/sy x 6" deep x 1 sy = 0.44

2. Place 6" gravel course:

   $4.20/cy x 6" deep x 1 sy = 0.71

3. Place 4½" crushed gravel course:

   $5/cy x 4½" deep x 1 sy = 0.65

4. Place 3" bituminous base course:

   $29.80/ton x 0.169 ton/sy = 5.04

5. Place 2" bituminous binder course:

   $29.80/ton x 0.113 ton/sy = 3.37

6. Place 1" bituminous wearing course:

   $29.80/ton x 0.057 ton/sy = 1.70

$11.91 per square yard

The costs calculated clearly demonstrate that recycling of the existing bituminous pavement into a reclaimed stabilized base can save significant expenditures. The actual savings may vary depending upon the alternate conventional section used.

Conventional Section A:	$10.60/sy	Conventional Section B:	$11.91/sy
Cold Recycling:	- 9.23/sy	Cold Recycling:	- 9.23/sy
	$ 1.46/sy		$ 2.68/sy

For the entire project length, where reclaimed stabilized base was incorporated, a savings was realized of:

Conventional Section A: 19,000 sy x $1.46 = $27,750

Conventional Section B: 19,000 sy x $2.68 = $50,920

Appendix A includes an estimation technique used in determining the energy, aggregate and dollar savings by incorporation of the cold recycling method. On this project, the values were estimated to be:

Tons of Aggregate Saved: 3,050

Equivalent Gallons of Gasoline Saved: 10,970

JACKSON COLD RECYCLING PROJECT
F-FLH-1(7)

Project Description

This project was located on New Hampshire Route 16 in the Town of Jackson and consisted of 1.6 miles of reconstruction. The roadway was a two-lane rural primary highway with an added truck lane. This section is subject to heavy seasonal tourist traffic due to its proximity to Mount Washington in the White Mountain National Forest.

This section was built as part of a Federal-aid project in 1933 and improved by the State as a force account Betterment project in 1967 with a truck lane added. The pavement surface consists of a surface treated gravel pavement with shim courses.

The project was awarded on April 16, 1981 to NCS Enterprises, Inc. of Tilton, New Hampshire for the low bid sum of $862,947.50. Of this total, approximately $60,000 relates to the recycling effort.

Preliminary Investigation

The Materials Division of the State Highway Department provides a comprehensive geotechnical report for the proposed project soon after preliminary engineering is initiated. The following description is a summary of their investigations and recommendations for the Jackson project.

The roadway in this notch generally follows the curvature of the valley floor near the Ellis River. The dominant soils in this area consist of bouldery, dense deposits of glacial till of variable thickness. In some sections, thin sand and gravel deposits overlie the till and bedrock along the valley floor. The bedrock of this area consists of generally a coarse granitic type rock. Basically, this rock is hard and dense, but some of the rock encountered appeared to have undergone extensive weathering.

The constructed roadway is located in the area of the valley which is not subject to rock or landslide. In sections where side hill excavations will be necessary, it was anticipated that the earth cut slopes would be stable.

The ground water is notoriously high throughout this mountain terrain and the project area. Most of the side hill drainage paths are well established in gulleys and small stream beds. In areas where this concentration of water collects near the valley floor, saturated conditions exist. Surface runoff during storm and spring melt causes rapid filling of all streams and flash flooding often takes place. At times, this runoff has resulted in severe ditch erosion and roadway washouts.

An inspection of the proposed project site showed the existing roadway to be in fair to poor condition. The pavement contained considerable cracking, distress and a general uneven cross section. In many areas, this rolling cross section caused vehicles to lurch and dip. The roadway failures and irregularities were primarily due to inadequate control of ground water, heavy vehicular traffic loads, insufficient pavement and base course thickness, and a highly frost susceptible native soil.

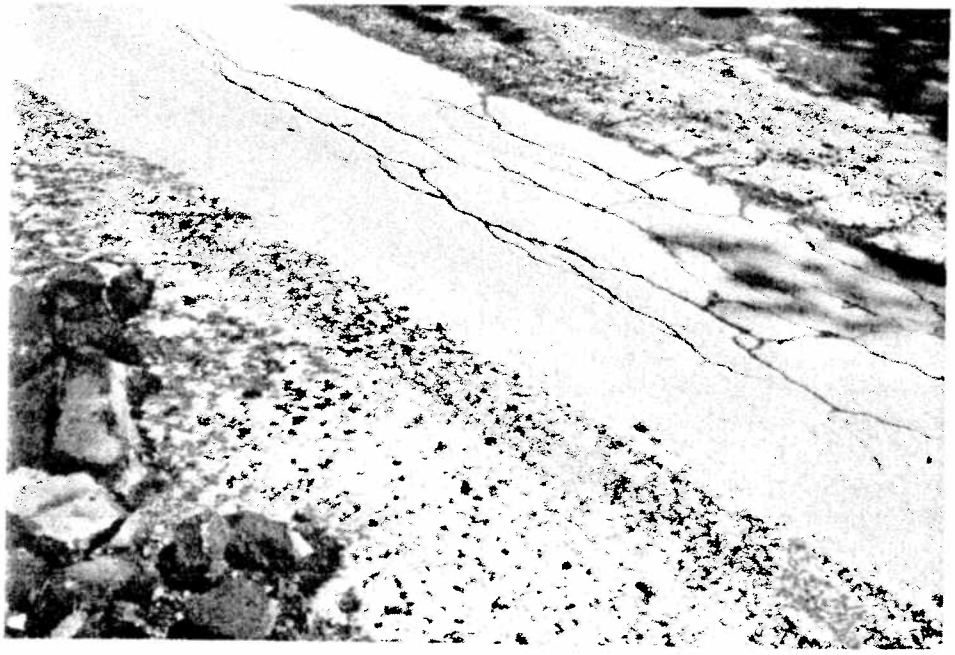


FIGURE J-1: Existing Pavement Condition

With these factors in mind, complete reconstruction with a full granular base was required. The base course would be 36 inches thick and composed of

12-inch layers of crushed gravel, gravel and sand. To provide additional strength to the structural section and recycle the existing pavement, a five-inch Reclaimed Stabilized Base Course was recommended. Within the travel lanes, a three-inch nominal hot bituminous pavement would then be placed, consisting of a two-inch binder and one-inch surface wearing course.

This section of the highway is a continually ascending roadway. In order to accommodate the slower moving vehicles which use this highway, a climbing lane of 12-foot width was analyzed and deemed justifiable. The cross section included two 12-foot travel lanes, an eight-foot shoulder in the southbound direction, and a four-foot shoulder next to the climbing lane in the northbound direction. To provide increased safety and convenience in the recreation area, a 15-space parking lot was also constructed.

The area of the proposed parking lot was designated as a temporary storage site for the stockpiling of the pulverized bituminous pavement to be incorporated in the construction of the Reclaimed Stabilized Base.

Specification Section

In the past few years, New Hampshire has done extensive work with cold recycling of the existing pavement to form a stabilized base course. A hot bituminous pavement usually consisting of a binder and surface wearing course would then be placed on the reclaimed stabilized base course.

This section contains the special provision included in this contract which dealt with the implementation of the cold recycling method. For review with these provisions, Appendix B contains the appropriate specifications for base courses in their entirety.

SPECIAL PROVISION
SECTION 306 -- RECONDITIONING

DESCRIPTION

1.1 This work shall consist of scarifying and pulverizing the existing bituminous pavement, removing and stockpiling material within the proposed parking lot within the project, placing stockpiled materials on a prepared base and mixing with a portion of the base within the typical, and constructing a stabilized base course as shown on the plans or ordered.

1.1.1 Materials left in the stockpile upon completion of the roadway shall be incorporated in the parking lot to the depths specified or ordered.

1.1.2 Any material remaining after construction of the parking lot to the limits specified shall be removed by the Maintenance Division.

MATERIALS

2.1 Materials for the roadway shall consist of equal amounts of the processed bituminous pavement and new crushed gravel.

2.1.1 Materials for the parking lot shall consist of processed bituminous pavement.

CONSTRUCTION REQUIREMENTS

3.1 The existing pavement shall be broken by scarifying with conventional equipment such as a grader-mounted or bulldozer-mounted ripping or scarifying device. After the existing pavement has been broken, it shall be windrowed and further processed using a travelling hammermill until all the material will pass a 2½-inch testing sieve. This crushed material shall be removed and stockpiled at a designated site.

3.2 The crushed material to be returned to the newly constructed roadway, shall be combined with an equal volume of crushed gravel and thoroughly mixed using the approved travelling hammermill until a uniform mixture is produced.

3.3 Spreading and compaction shall be done in accordance with 304.3.4 as amended.

3.4 The finished surface shall be inspected for smoothness and accuracy of grade and if any portions are found to lack required smoothness or accuracy, such portion shall be rescarified, reshaped, recompacted, and otherwise manipulated as directed.

3.5 Processed material remaining in the stockpile shall be incorporated into a stabilized base for the parking area as shown on the plans. Additional processing with the hammermill may be required to ensure a uniform mixture. If additional crushed gravel is required for blending, the crushed gravel will be paid for under Item 304.3.

3.5.1 Spreading and compaction shall conform to 3.3.

METHOD OF MEASUREMENT

4.1 Reclaimed stabilized base will be measured by the square yard of processed material of the required depth, measured in place in its final location. The width will be limited to that shown on the plans.

4.1.1 No additional measurements will be made for the depth of material incorporated within the limits of the parking lot.

BASIS OF PAYMENT

5.1 The accepted quantity of reclaimed stabilized base will be paid for at the contract unit price per square yard complete in place.

5.1.1 Reclaimed stabilized base in the parking area will be paid for as provided in 5.1.

Pay item and unit:

306.11	Reclaimed Stabilized Base	Square Yard

Equipment and Construction Procedures

Recycling Process

The process from existing bituminous pavement to the reclaimed stabilized base course was completed in two main portions which contained numerous steps. For additional information on the step-by-step process, the schematic contained in the text should be helpful. The initial work consisted of scarifying and pulverizing the existing pavement, then stockpiling the material at one of two sites. One being the proposed parking area on the project, the remainder was approximately three-quarters of a mile north of the project.

Step 1: The existing pavement was on the average of five inches in depth. It was composed mainly of shim course built up over the years and contained very little aggregate. The pavement was broken up easily with the use of a grader-mounted ripper tooth and blade. This action also churned up the gravel base below the pavement, which contributed some aggregate to the mix.

FIGURE J-2: Existing Pavement Broken Up
After Use of Ripper Tooth

Step 2: The material was then crushed in place with a rotating mill attached to the rear of the grader. This piece of equipment was used in place of the travelling hammermill as described in the project's special provisions. The lack of aggregate in the existing pavement enhanced the crushing ability of the mill. After five to seven passes, the material was adequately crushed to easily pass a 2½-inch testing sieve. Several laborers removed by hand any large stones which worked their way up from the gravel below.

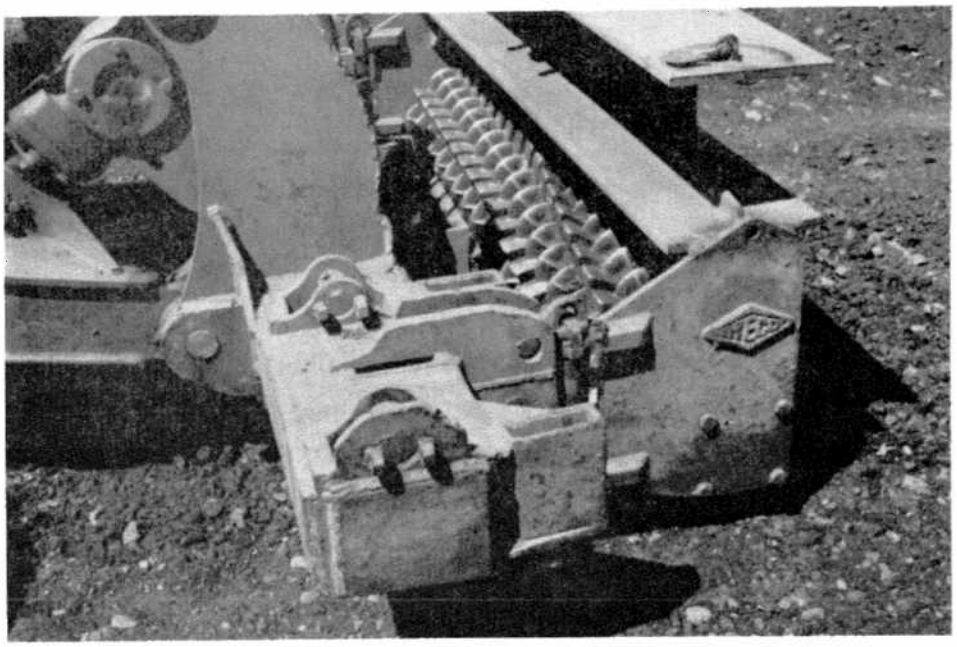


FIGURE J-3: Rotating Mill

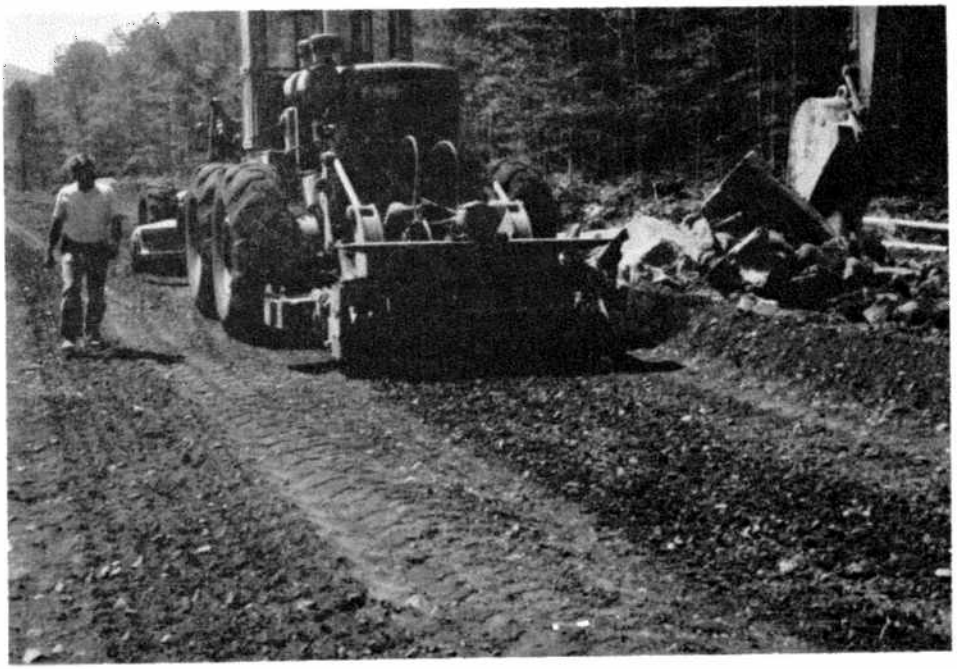


FIGURE J-4: Rotating Mill Crushing the Material In Place With Optional Vibratory Engine

FIGURE J-5: Existing Pavement Crushed; Background, After 5 to 6 Passes of Rotating Mill; Foreground, After 2 to 3 Passes of Rotating Mill

FIGURE J-6: Reclaimed Material Stockpile (After In-Place Crushing, Prior to Hammermill Operation)

Step 3: The reclaimed material was then windrowed for the width crushed. The material was then transported by front-end loader and truck to the designated stockpile site.

The process of ripping and crushing the existing pavement was completed on a 24-foot wide by 500-foot section in an average of five hours. This is an approximate rate of 265 square yards per hour. To maintain one-way traffic through the construction zone, the process was performed on a 15- to 18-foot wide section with traffic on the remaining portion of the asphalt and shoulder. After one section was bladed to form a windrow, the traffic pattern was switched and the operation continued to complete the entire width.

After the material was stockpiled, an upgrading of the general profile and section was undertaken. This included the placement of material to produce a structural section of:

Item 304.3: 12" Crushed Gravel

Item 304.2: 12" Gravel

Item 304.1: 12" Sand

Step 4: The reclaimed material at the stockpile was then blended with the use of a front-end loader. This reduced the effects of reconsolidation which had taken place due to the infiltration of moisture while the section was upgraded. The stockpile had not been covered with any protective material (see Figures J-7 and J-8).

Step 5: The reclaimed material was then returned to the project site and dumped in a four to five-inch course half the width of the roadway. After grading, crushed gravel of equal volume was then applied by truck directly on the reclaimed material (see Figure J-9).

Step 6: The material was then bladed by grader to create a windrow to the extreme outside. This action provided some mixing of the reclaimed pavement and crushed gravel. A windrow of approximately

15 square feet in cross section was bladed the length of the section (see Figure J-10 and J-11).

Step 7: The grader was then used to blade a small portion of the windrowed materials (approximately one to three square feet) to the center of the roadway, in preparation for the next steps (see Figure J-12 and J-13).

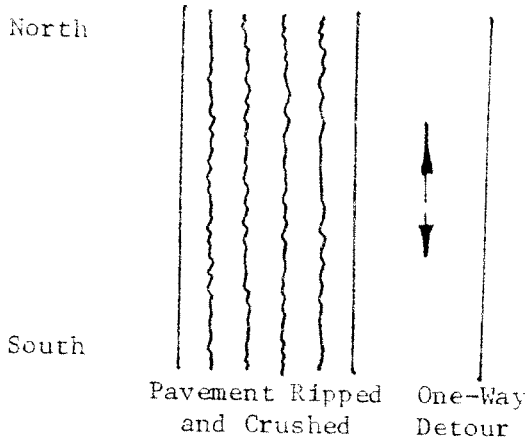
Step 8: Water was then applied to the small windrow to decrease the likelihood of dust during the hammermilling operation. The travelling hammermill, towed by a front-end loader, pulverized and adequately mixed the material with one pass. If any large aggregate still existed, laborers removed the material for additional processing in the next small windrow. The material was then graded and compacted to a depth of five inches and width of four to five feet. Compaction of the material at this time provided a base for the hammermill to ride on when pulverizing the next adjacent windrow. Without this compaction, the hammermill would disrupt the subbase course of crushed gravel. The process from Step 7 was completed several additional times until the large windrow of material had been spread and hammermilled (see Figure J-14, J-15, J-16 and J-17).

This second major portion of the process was accomplished at the rate of approximately 20,000 square feet in a normal working day, this usually being a section of 1,000-foot length by 20-foot width. Progress was inhibited in both steps because of the care taken in maintaining traffic flow through the construction zone.

Step 9: The material was then fine-graded to the specified depth and profile in anticipation of the placement of three inches of hot bituminous material (binder and wearing surface). (See Figure J-18, J-19 and J-20.)

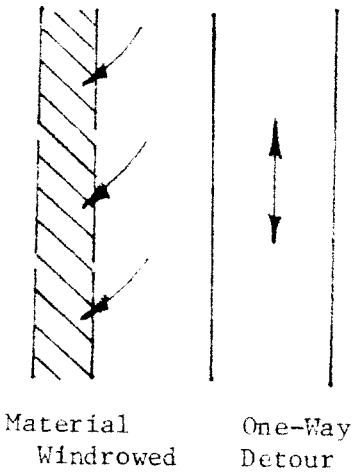
After one section was completed, the traffic pattern was switched and the process from stockpile to finished product repeated. Upon completion of the reclaimed stabilized base to the full width of 37 feet, the material was fine-graded and traffic flowed in both directions with little, if any, rutting of the base. The material became very dense after several days of traffic flow. Prior to the placement of bituminous pavement, the base was graded occasionally and a water truck provided to minimize dust from through traffic.

SCHEMATIC OF RECYCLING PROCESS AT JACKSON (Approx. 1" = 20' scale)



See Figure J-2, J-3, J-4 and J-5

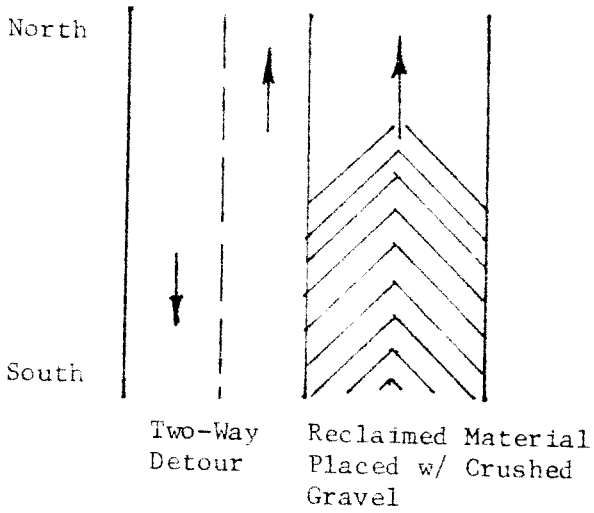
STEP 1-2



STEP 3

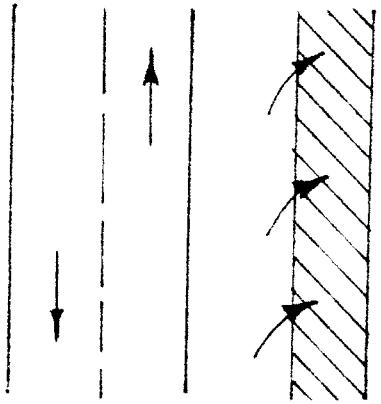
With traffic switched, the remaining width of existing pavement is ripped and crushed. Upon completion of windrowing the material, easy removal was accomplished by front-end loader and truck to the nearby stockpile. The general profile and section were then upgraded to meet final plans.
See Figure J-6, J-7, and J-8

STEP 4



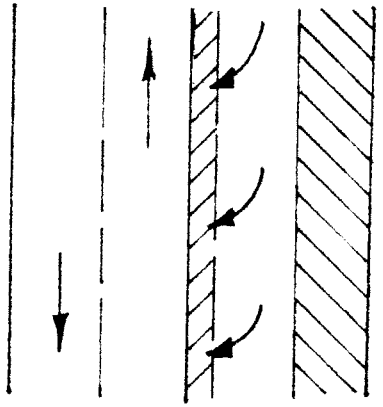
See Figure J-9

STEP 5



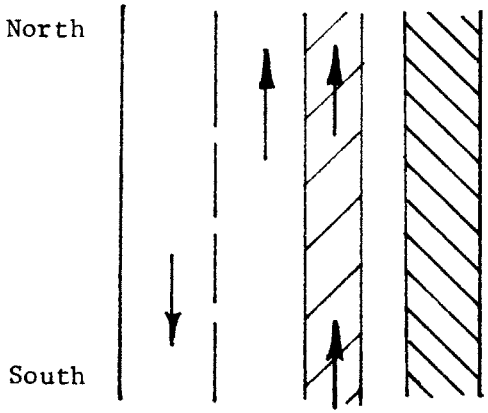
See Figure J-10, J-11

STEP 6



See Figure J-12, J-13

STEP 7



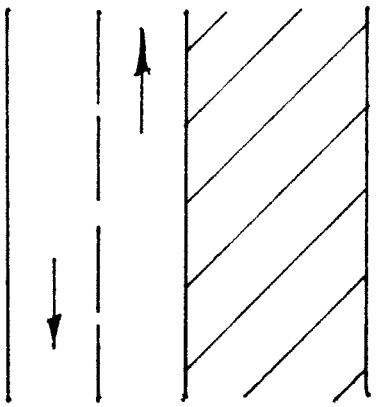
Two-Way Detour

Material Crushed By Hammermill, Bladed & Compacted

This process of removing a portion of the windrow, hammermilling, grading & compacting was repeated several additional times until the width was complete.

See Figure J-14, J-15, J-16 and J-17

STEP 8



Two-Way Detour

Reclaimed Stabilized Base Completed, Fine-Graded Prior to Placement of Hot Bituminous Pavement

See Figure J-18

STEP 9

The traffic pattern was then switched to the reclaimed stabilized base and the entire process from Step 5 repeated. See Figure J-19, J-20.

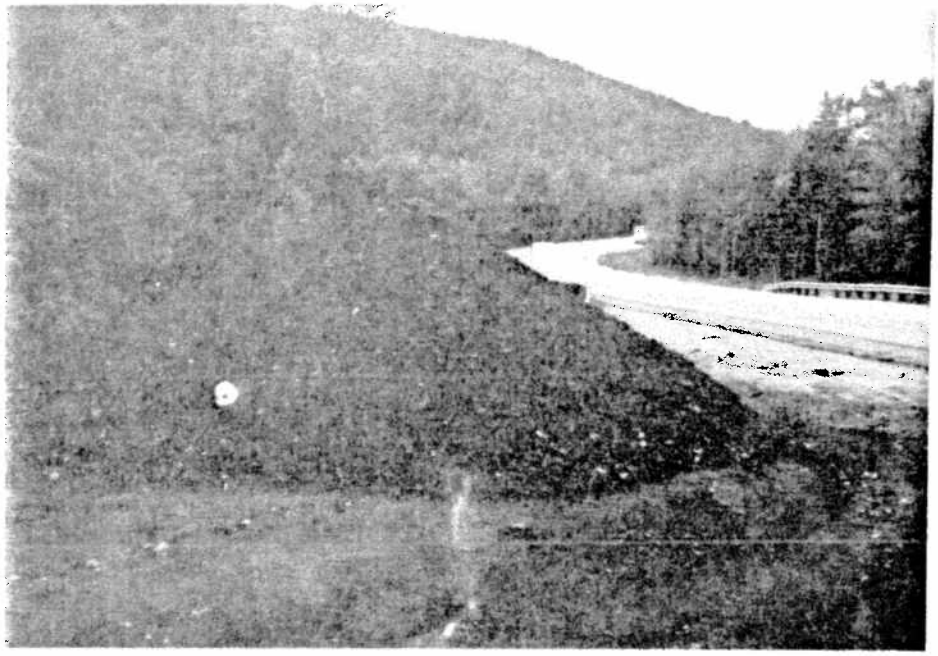


FIGURE J-7: Reclaimed Material Stockpile After Blending Operation by Front-End Loader

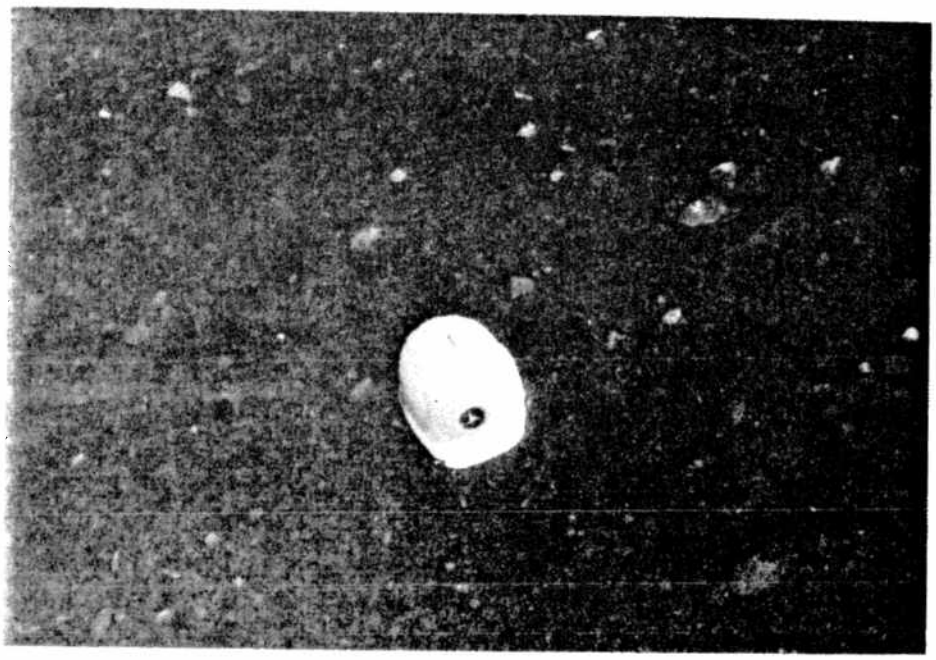


FIGURE J-8: Reclaimed Material Stockpile (Close-Up) After Blending Operation by Front-End Loader

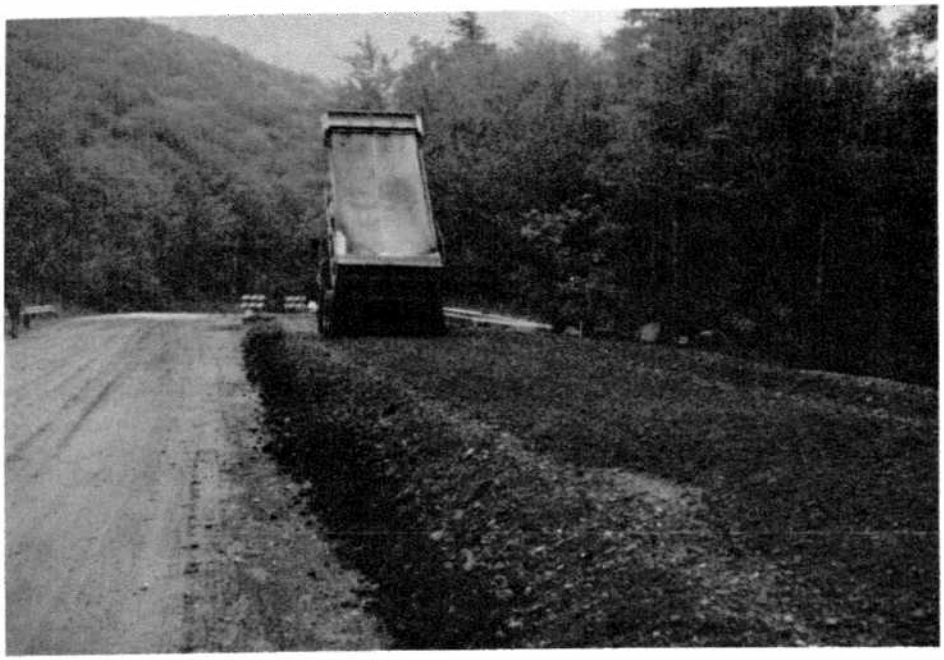


FIGURE J-9: Crushed Gravel Being Applied Directly on Reclaimed Material (Looking North)

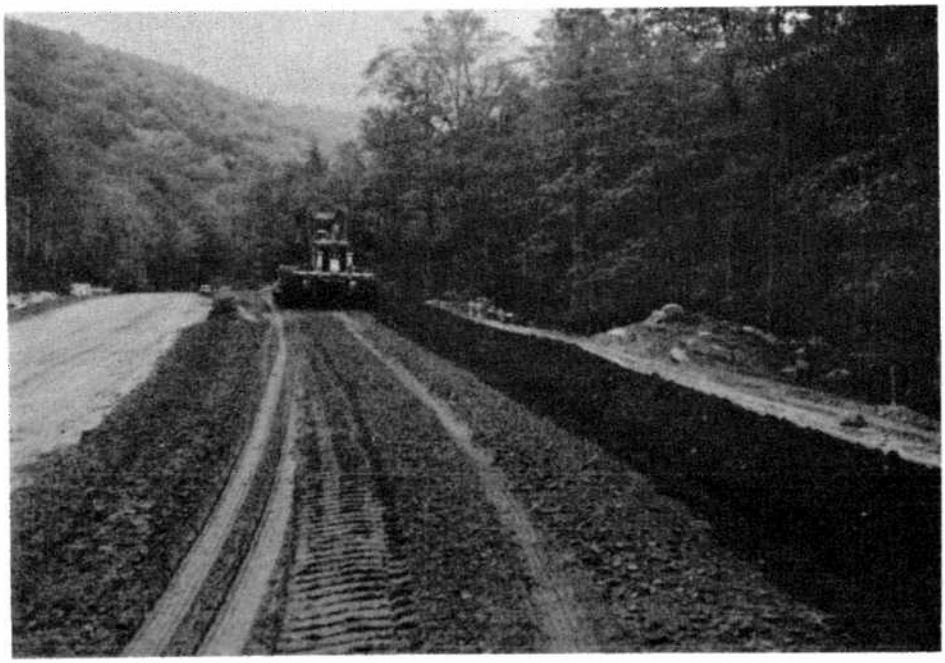


FIGURE J-10: Grader Windrowing Portion of Material to Extreme Outside (Looking North)

FIGURE J-11: Grader Windrowing Remaining Material to Extreme Outside (Looking South)

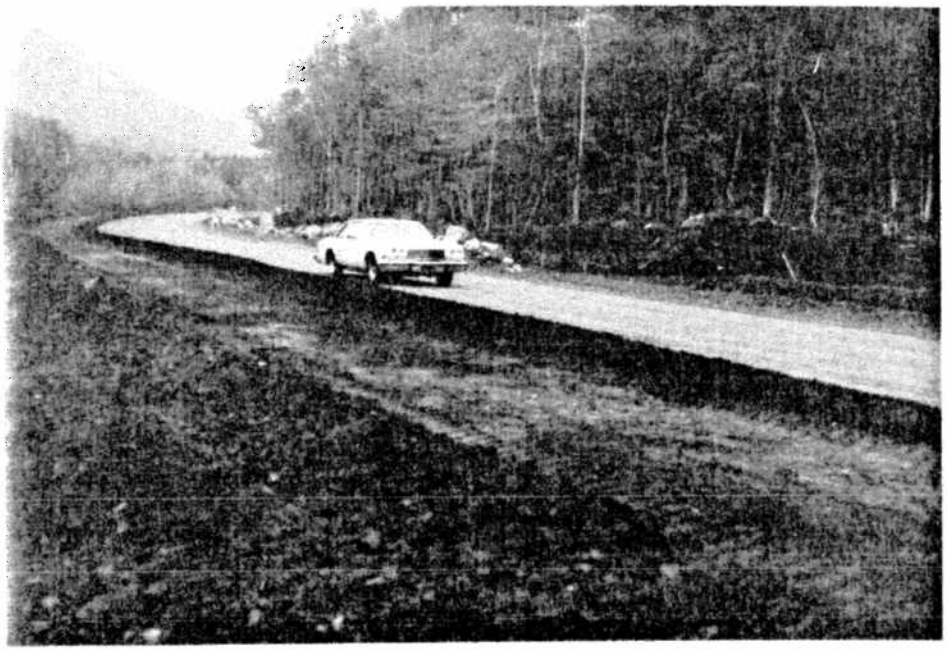


FIGURE J-12: Small Windrow Graded to Center Prior to Hammermilling Operation (Looking South)

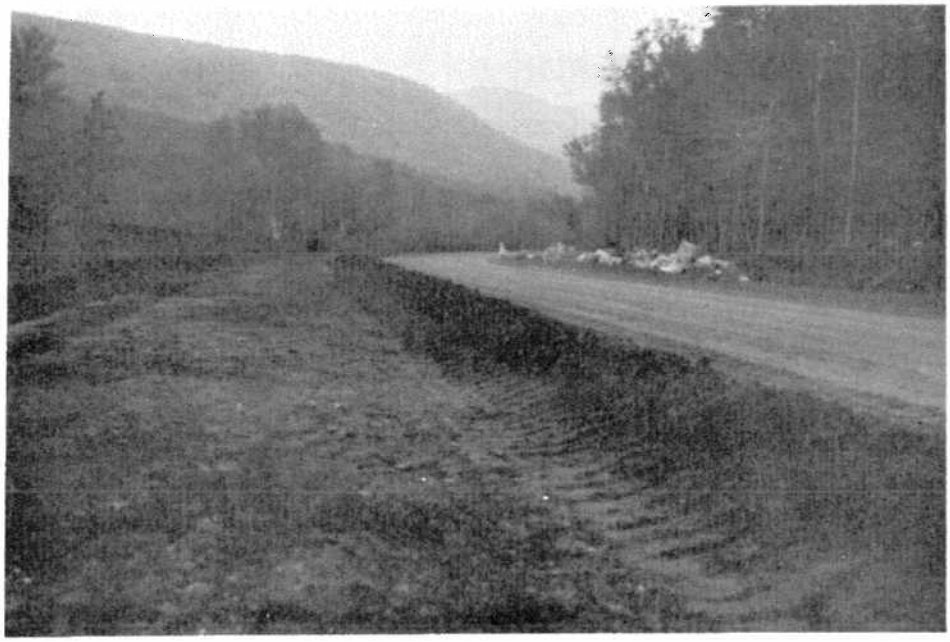


FIGURE J-13: Small Windrow Graded to Center Prior to Hammermilling Operation (Looking South)

FIGURE J-14: Water Applied to Windrow (Looking South)

FIGURE J-15: Hammermilling Operation

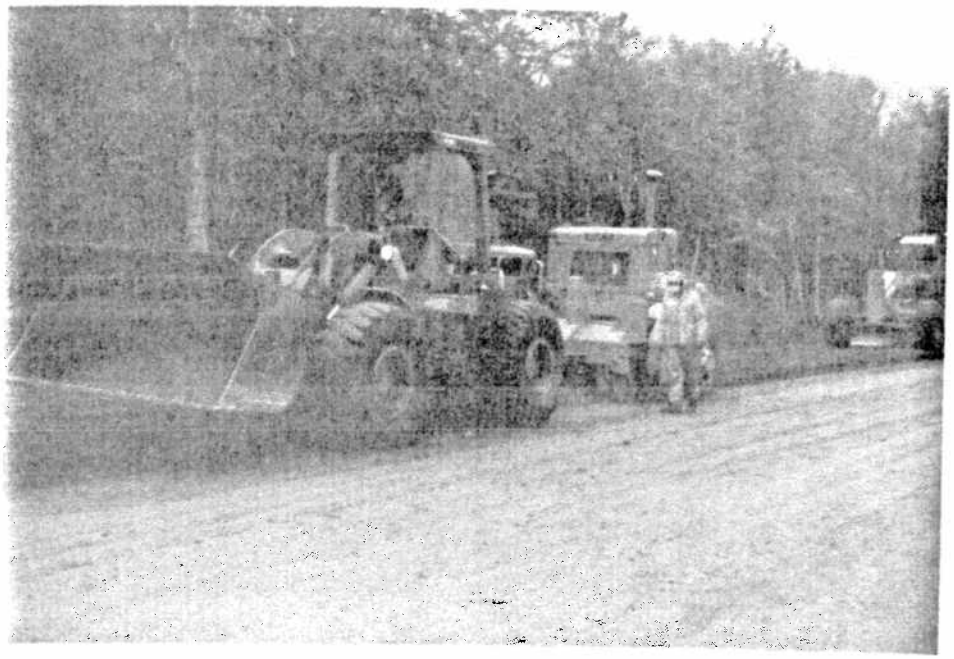


FIGURE J-16: Hammermilling Operation

FIGURE J-17: Pulverized Material Graded to Required Depth, Prior to Compaction (Looking South)

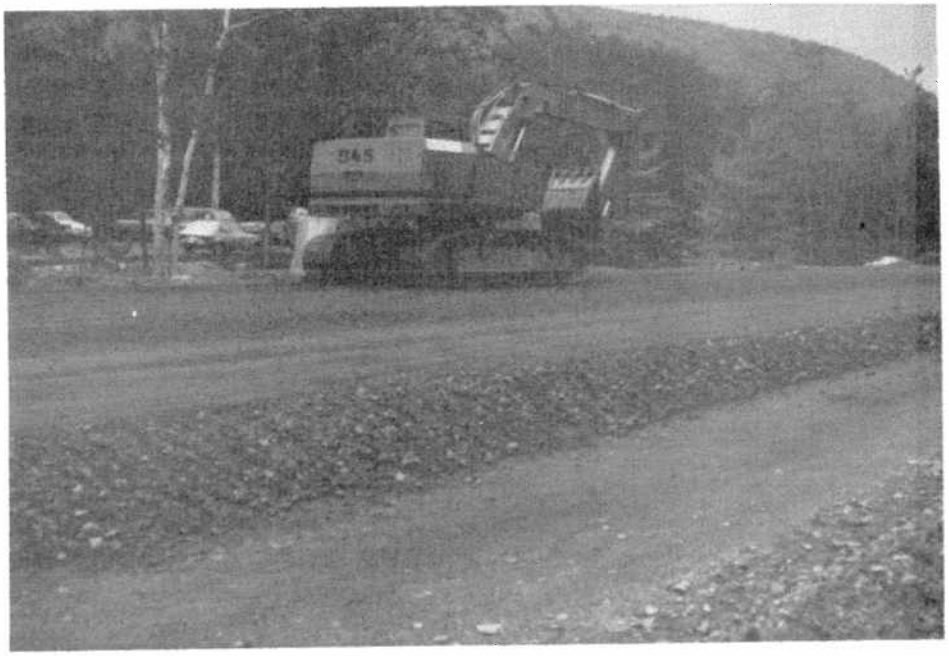


FIGURE: J-18: Completed Reclaimed Stabilized Base Prior to Fine Grading and Placement of Hot Bituminous Pavement

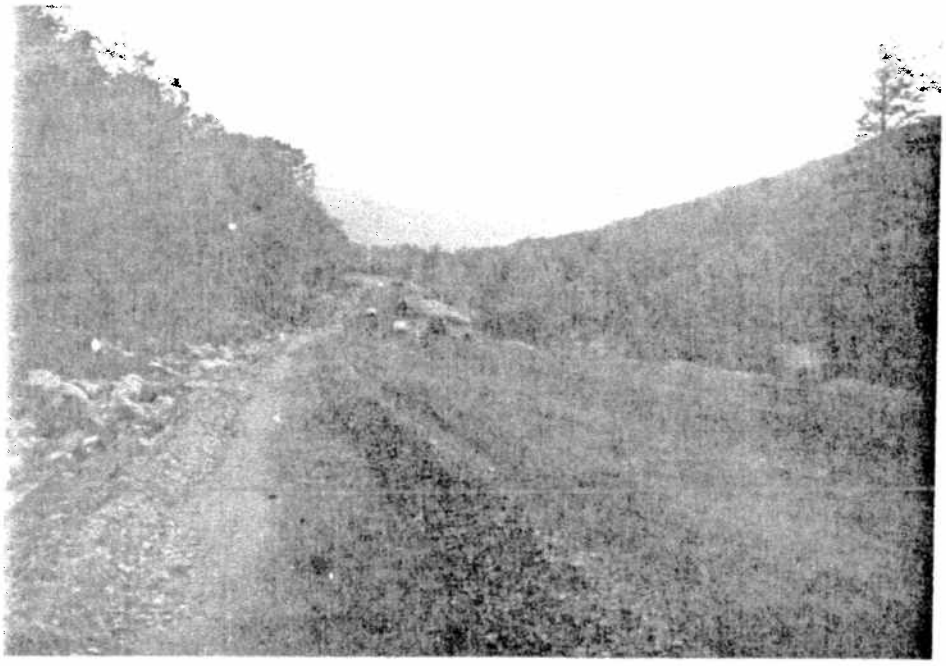


FIGURE J-19: Completed Reclaimed Stabilized Base Prior to Fine Grading and Placement of Hot Bituminous Pavement (Looking North)

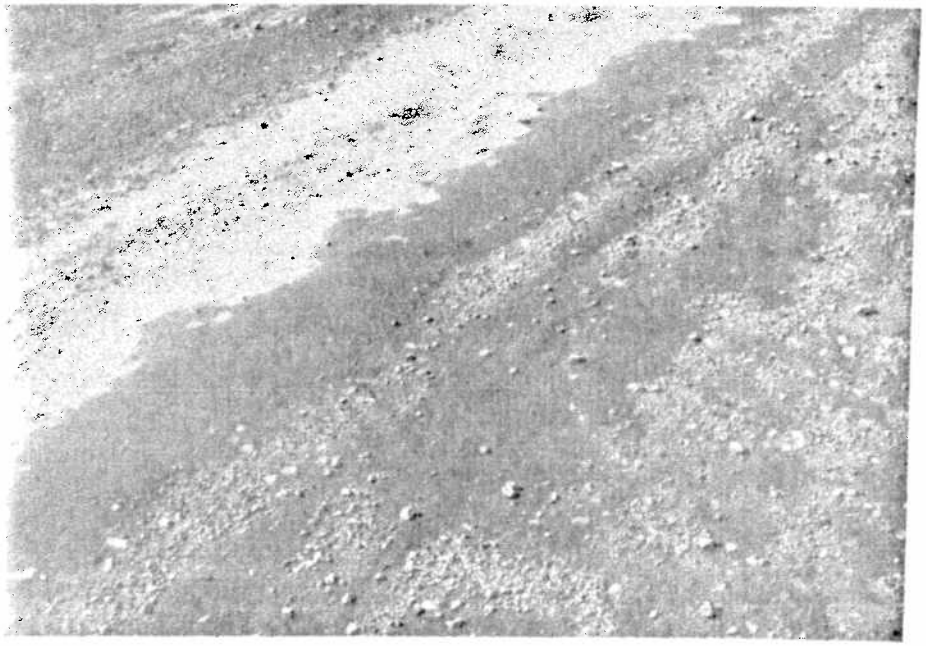


FIGURE J-20: Completed Reclaimed Stabilized Base (Note Consolidation of Material)

Cost Analysis

This portion of the paper will analyze the costs involved in the recycled design used versus an alternate conventional structural section. To fulfill the project objectives, total reconstruction was required the entire project length. Therefore, the placement of a simple overlay was considered inadequate.

To evaluate the costs incurred for each structural section, an equivalent conventional section was estimated using the coefficients of relative strength as listed below:

Item 403.11	Hot Bituminous Surface	0.38
Item 403.11	Hot Bituminous Base	0.34
Item 304.3	Crushed Gravel	0.10
Item 304.2	Gravel	0.07
Item 304.1	Sand	0.05
Item 306.11	Reclaimed Stabilized Base	0.17

The recycled structural section constructed would then have a structural number of:

1" wearing course	1" x 0.38 = 0.38
2" binder course	2" x 0.38 = 0.76
5" reclaimed stabilized base	5" x 0.17 = 0.85
12" crushed gravel	12" x 0.10 = 1.20
12" gravel	12" x 0.07 = 0.84
12" sand	12" x 0.05 = 0.60
	4.63

Using this structural number as a required goal, we can now develop a conventional structural section (x = 2.5"):

1" wearing course	1" x 0.38 = 0.38
2" binder course	2" x 0.38 = 0.76
x" base course	x" x 0.34 = 0.85

12" crushed gravel	12" x 0.10 = 1.20
12" gravel	12" x 0.07 = 0.84
12" sand	12" x 0.05 = 0.60
	4.63

This conventional structural section was used on an adjacent project to the south.

These are the items of possible significance in the structural section from the project estimate.

Item	Description	Quantity	Price Per Unit
304.1	Sand	13,900 cy	$ 3.50
304.2	Gravel	13,600 cy	$ 4.50
304.3	Crushed Gravel	12,500 cy	$ 7.00
306.11	Reclaimed Stabilized Base	23,300 sy	$ 2.50
403.11	Hot Bituminous Pavement Machine Method	4,800 ton	$34.00

The above prices are actual bid prices for this project. In the cost analysis, if the item was not included in this project, the item cost was determined by use of the quarterly bid prices.

Project Length

Actual Cold Recycled:

Remove existing pavement for recycling;

Place sand, gravel and crushed gravel courses;

Place 5" reclaimed stabilized base course;

Place 2" binder and 1" wearing course (bituminous)

Conventional:

Remove existing pavement by common excavation;

Place sand, gravel and crushed gravel course;

Place 2½" base, 2" binder and 1" wearing course (bituminous)

Actual Cold Recycled Cost:

1. Remove existing bituminous pavement for recycling; this is included in Item 306.2: = 0.00

2. Place 12" sand course:
   $3.50/cy x 12" x 1sy = 1.16

3. Place 12" gravel course:
   $4.50/cy x 12" x 1sy = 1.50

4. Place 12" crushed gravel course:
   $7.00/cy x 12" x 1sy = 2.31

5. Place 5" reclaimed stabilized base course:
   $2.50/sy x 1sy = 2.50

6. Place 2" bituminous binder course:
   $34/ton x 0.113 ton/sy = 3.84

7. Place 1" bituminous surface wearing course:
   $34/ton x 0.057 ton/sy = 1.94

$13.25 per square yard

Alternate Conventional:

1. Remove existing bituminous pavement for disposal, common excavation; $2.60/cy x 0.14 yd. deep x 1sy = 0.36

2. Place 12" sand course:
   $3.50/cy x 12" x 1sy = 1.16

3. Place 12" gravel course:
   $4.50/cy x 12" x 1sy = 1.50

4. Place 12" crushed gravel course:
   $7/cy x 12" x 1sy = 2.31

5. Place 2½" bituminous base course:
   $34/ton x 0.141 ton/sy = 4.79

6. Place 2" bituminous binder course:

   $34/ton x 0.113 ton/sy = 3.84

7. Place 1" bituminous surface wearing course:

   $34/ton x 0.057 ton/sy = 1.94

   $15.90 per square yard

The costs calculated clearly demonstrate that recycling of the existing bituminous pavement into a reclaimed stabilized base can save significant expenditures when an equivalent structural section is calculated. Savings by use of recycling:

Conventional Section: $15.90 per square yard

Recycling: 13.25 " " "

$ 2.65 per square yard or 16.7% (approx.)

For the entire project length, where reclaimed stabilized base was incorporated, a savings was realized of:

23,300 sq. yd. x $2.65 per sq. yd. = $61,750

Appendix A includes an estimation technique used in determining the energy, aggregate and dollar savings by incorporation of the cold recycling method. On this project, the values were estimated to be:

Tons of Aggregate Saved: 3,120

Equivalent Gallons of Gasoline Saved: 11,223

CONCLUSION AND RECOMMENDATIONS

Processing of Aggregate for Hot Recycling

1. The method of removal of the existing bituminous pavement should not be specified for full depth reconstruction. This allows the contractor maximum flexibility in determining the most economic method, whether planing, ripping or by other means. The only necessity specified would be the resultant reclaimed material must meet sizing requirements of the hot recycled mix.

   For partial removal of the existing bituminous pavement (i.e., top two inches), a planing operation should be specified as the method.

2. On a project of total reconstruction where the pavement structure has been determined to be of uniform depth through site history or extensive coring, the payment measurement may be satisfactorily completed in tons, cubic yards or square yards per a specified depth. While cubic yards and square yards per depth are the same, tonnage as a measurement would be a departure from present specifications. The use of tons would be advantageous in making mix calculations, but may be difficult to accomplish depending on the project's location relative to scale facilities. Whether planed or ripped, the simplest measurement would be by surface area. It would clearly state to the contractor the depth of removal required and the area which may be involved in the construction zone.

   This technique may also be used if the pavement structure is of irregular depth. Through coring of the pavement, an average specified depth could be calculated. Review in the field could be accomplished through depth checks every 25 to 50 feet. Tonnage may be an ideal measurement in this case, but again scale facilities may not be readily available and this may place an undue burden on the contractor.

   For partial removal by a planing operation, the method of measurement should remain square yards per a specified depth.

   The use of square yards per a specified depth as a measurement unit would introduce a uniform system for removal items, whether the material was recycled immediately or stockpiled.

3. The Concord project demonstrates one excellent technique in the removal of a bituminous pavement for future use in a recycled mix. When the pavement is removed through successive passes by a planer, and some degree of job control is exercised to separate the differing gradations, an opportunity is provided to reclaim a high quality material.

   With this in mind, it appears possible to produce a recycled wearing course through the reclamation of the existing wearing course with little or no detrimental effect in quality.

   When producing a recycled mix, it is helpful to have a predictable source of reclaimed material so that gradation control, asphalt control, aggregate quality and size are considered within each stockpile. For this to become a reality, it is highly desirable to find out as much as possible about the composition and character of the existing pavement.

4. Scarifying and ripping of the existing pavement for recycling followed by only primary crushing, will normally produce a reclaimed material which contains an aggregate distribution of larger aggregates (maximum one and one-half inch). This results in a stockpile combination which without further processing (e.g., secondary crushing, screening) can only be incorporated into a recycled base course material.

5. If the existing pavement structure is relatively sound, removing the surface wearing course by planing may significantly reduce the cost by eliminating the need for the placement of a full leveling course in preparation for additional courses. Due to insufficient and variable thicknesses, leveling courses of asphalt concrete usually add very little to the structural capacity of the pavement. Reclaiming the material for future recycling effectively reduces the cost further. It is less expensive to remove high spots rather than filling in the low areas with a leveling course. One example of this is the Concord project:

   > Cold planing a maximum depth of one and one-quarter inch; bid price $1.00 per square yard. Placement of a leveling course of equal depth would range from $1.70 to $1.90 per square yard.

6. On a multi-lane facility, the use of cold planing and replacement on the more distressed travel lanes is an economic alternative to complete reconstruction of the entire roadway. In most cases, the passing lane(s) would be in good condition. This would also reduce the cost by maintaining traffic flow with minimal conflict.

7. The size of the milled material appears to be primarily determined by the quality of the material being reclaimed and the type of distress in the pavement structure. The aggregate gradation is very similar to that in the original asphalt concrete. Rather than rupturing the particles, the planer tends to break the bond between particles caused by the asphalt cement.

8. For incorporation into the recycled mix, the specification for removal of pavement states a maximum size allowable, usually one and one-half inches. At present, this limits the use of the reclaimed material primarily to base courses. A possible future alternative may involve the removal of this maximum size requirement, and stating the contractor must perform such work as to have the material meet the required gradation for the appropriate mix, whether base, binder or wearing course. This could be accomplished through selective planing or primary, secondary crushing and screening.

Plant Operation

To decrease the quantity of fuel expended to heat the virgin aggregates and in turn the reclaimed material, a future recommendation to the contractor may involve not only covering the reclaimed material, but also the virgin aggregate material. The contractor may then realize a more complete fuel savings.

Cold Recycling

1. On the Tamworth project, it became quite evident during the crushing process that unless the pavement is ripped or turned over after several passes of the rotating mill, the equipment will simply ride over the large chunks of pavement and do little, if any, crushing. Considering the ineffectiveness of this method at times, it greatly increases the number of passes required to crush the material to the specified size. Using the present equipment, one solution which should be considered for possible implementation would be the attachment of several teeth or turning blades to the grader in the blade area. Theoretically, this could turn the material vertically or on an angle prior to the rotating mill passing through. This small addition could significantly decrease the number of passes required to adequately crush the material.

2. Just as the method of removal of pavement for hot recycling is not specified, cold recycling of the existing pavement could benefit economically and provide additional flexibility to the contractor through a similar specification. At present, all work takes place in the construction zone the length of the project. If a suitable site were available, the entire process could be reduced in duration. The existing pavement could be ripped and broken up, hauled to the site, crushed to a specified size, mixed with additional material if necessary, and stockpiled until the roadway was ready for placement. The present coordination necessary for traffic control through the construction zone could be reduced in duration. In some cases, this option may offer the contractor and Department time and money savings.

3. The measurement unit for the construction of a reclaimed stabilized base should remain square yards complete in place. This unit provides the contractor with the depth of removal required and the area involved in the construction zone. The addition of crushed gravel to the mix as a separate payment or nonpayment should be clarified in the specification to avoid any misinterpretation.

4. To further strengthen the reclaimed stabilized base as constructed, one possible change which could be incorporated would involve the addition of an asphalt emulsion to act as a binding agent. Several States have implemented the mixture of asphalt in the range of two percent to the reclaimed material. Upon placement on the windrow, the reclaimed material and asphalt would need to be mixed using one of several pieces of equipment (e.g., Bomag stabilizing unit, Pulva-Mixer). The mix would then be graded and compacted.

Recycling (General)

At present, the material reclaimed from the existing bituminous pavement for the hot recycling process is being under utilized in some cases. Batch plants throughout the State are limited to that portion of the material which can be practically combined with virgin aggregates. Experience has shown this ranges from 25 to 35 percent, depending on moisture content and other factors. On recent projects, the excess material has been placed in stockpiles for future City use, or incorporated as a pavement material at maintenance facilities. Two alternatives exist which may increase the utilization of this material; stockpiling for future use on another project, or turning the material over to

the contractor with no restrictions on its use. Transferring ownership would allow the Department to receive an instant credit in the form of lower bids on the asphalt concrete placed. The credit would theoretically contain the full value of the excess salvaged material.

To eliminate any restrictions in the future, the contractor should be allowed to use salvaged asphalt materials and aggregates in the production of asphalt concrete on any project. The contractor should be permitted to determine the source and amount of the salvaged material to be used as long as the produced mix meets all standard material and mix specifications called for in the contract. Should a change take place, a revised mix design must be submitted to and approved by the Department.

The use of a dryer-drum plant would allow a higher production rate and higher percentage of salvaged material which can be incorporated into a recycled mix. At this time, there are no dryer-drum plants in the State of New Hampshire.

The cold recycling process fully utilizes an asphalt concrete which is normally unsuitable for use in a hot recycled mix.

REFERENCES FOR ADDITIONAL INFORMATION

1. Welke, Robert A.; "Performance Evaluation of Recycled Hot Mix," Testing Laboratory, Michigan DOT, Public Works, September 1981

2. "Alternatives in Pavement Maintenance, Rehabilitation and Reconstruction," The Asphalt Institute, May 1981

3. Welke, Robert A.; "Rural Hot Mix Recycling," Rural and Urban Roads, July and August 1981

4. "Inside and Outside Lanes Paved By Different Techniques," Highway and Heavy Construction, July 1981

5. Dollaire, Gene; "Pavement Recycling," Civil Engineering, November 1980

6. "Proceedings of the National Seminar on Asphalt Pavement Recycling," Transportation Research Record 780, Transportation Research Board, 1980

7. "Guidelines for Recycling Pavement Materials," NCHRP Report 224, Transportation Research Board, September 1980

8. Scherocman, James A.; "Cold Planing and Recycling - An Economical Pavement Maintenance Technology," Barber-Greene Company, July 1981

9. Scherocman, James A.; "Producing Recycled Asphalt Concrete Mixtures in Batch and Drum Mix Plants," Barber-Greene Company, July 1981

10. "Energy Requirements for Roadway Pavements," The Asphalt Institute, IS-173, November 1979

11. Strand, D. L.; "Bituminous Pavement Recycling in Wisconsin," Wisconsin Department of Transportation, October 1981

12. Kennedy, T. W., and F. L. Roberts, "Quality Assurance Considerations in Recycled Asphalt Mixture Design," Center for Transportation Research, The University of Texas at Austin, 1981

13. Brown, Elton R., "Insuring Quality in Hot Mix Recycling," Pavement Systems Division, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, January 1982

14. "Recycling Asphalt Pavements," Demonstration Project 39, Federal Highway Administration, Region 15, Arlington, VA (various publications)

15. "Pavement Profiling," Highway and Heavy Construction, June 1981

APPENDIX A

ANNUAL REPORT ON ENERGY, AGGREGATE AND DOLLAR SAVINGS IN ASPHALT PAVEMENT RECYCLING

In the following pages is a brief description of the energy calculations used in establishing the required data for the subject report.

It should be noted that the calculations involving the cold recycling method assume a structural strength substitution. In order to maintain an equivalent structural number for the pavement depth as constructed, one inch of bituminous base course would be required for two inches of reclaimed stabilized base. In practice, were conventional methods used, the section would include no bituminous base, but a crushed gravel course. The use of the cold recycling process results in an increase in the structural integrity of the pavement depth over a comparable conventional section. As the purpose of this annual report was to compare recycling and conventional strategies on pavement sections of equivalent performance over the same time period, the structural strength substitution is justified.

METHOD USED IN ESTIMATING ENERGY SAVINGS ON RECYCLING PROJECTS

Cold Recycling

The following contains an example and brief discussion of the calculations used in estimating energy savings:

1. Through structural analysis of the pavement, it has been determined that one inch of hot bituminous base pavement is equivalent to two inches of the reclaimed stabilized base. The aggregate and asphalt tons saved through cold recycling will be the materials present in the bituminous base required in place of the reclaimed stabilized base.

   Assuming a sample project of the following characteristics:

24 foot width by 7,500 foot length

2½ inches of existing bituminous pavement mixed with existing and/or additional crushed gravel to form a 50:50 blend of reclaimed stabilized base at a depth of 5 inches

Using the structural analysis substitution, 2½ inches of bituminous base pavement would be required in place of the reclaimed stabilized base course

$2\frac{1}{2}$" @ 0.141 $\frac{\text{ton}}{\text{sy}}$ x 20,000 sy = 2,820 tons

Aggregate tons saved: 0.95 x 2,820 tons = 2,679 tons

Asphalt tons saved: 0.05 x 2,820 tons = 141 tons

2. The energy saved through cold recycling was estimated by using the energy requirements factor for production and placement of one ton of asphalt concrete, as established by the Asphalt Institute's publication, "Energy Requirements for Roadway Pavements." This was felt to be a representative factor for most projects. The energy expended in recycling the existing pavement to form the reclaimed stabilized base was deducted from the asphalt concrete quantity to establish the equivalent gallons of gasoline saved. This energy requirement factor for the cold recycling process was felt to be comparable to that amount of energy expended in cold milling an existing pavement. From the NCHRP Report "Guidelines for Recycling Pavement Materials," this was estimated at 2,500 Btu/sy-in.

$$\frac{1 \text{ gallon of gasoline}}{125{,}000 \text{ Btu}} \times \underset{\text{asphalt concrete saved}}{2{,}820 \text{ tons}} \times \underset{\text{asphalt concrete factor}}{515{,}750 \frac{\text{Btu}}{\text{ton}}} = 11{,}635 \text{ gallons}$$

Deducting: $2{,}500 \frac{\text{Btu}}{\text{sy/in}} \times 20{,}000 \text{ sy} \times 5\text{" depth} \times \frac{1 \text{ gallon}}{125{,}000 \text{ Btu}} = 200 \text{ gallons}$

Equivalent gallons of gasoline saved: 9,635

3. The cost savings attributed to cold recycling was calculated through the use of bid prices for the required quantity of bituminous pavement, cost of common excavation for removal of the existing pavement, and deducting the cost of recycling the material.

2,820 tons x $30/ton = $84,600 cost of bituminous pavement

Adding 20,000 sy x $0.36/sy = 7,200 cost of excavation for non-recycling of existing pavement

Subtotal = $91,800

Deducting 20,000 sy x $2.50/sy = 50,000 cost of cold recycling

Total Savings = $41,800 for this particular sample project

Hot Recycling

1. The aggregate and asphalt tons saved by incorporating hot recycling in a project is the amount of material by ratio which is reclaimed from the existing pavement and incorporated into the recycled mix.

Assuming a sample project of the following characteristics:

5,000 tons asphalt concrete @ 30% recycled material

70% virgin material

Aggregate tons saved: 5,000 tons @ 30% @ 0.95 = 1,425 tons

Asphalt tons saved: 5,000 tons @ 30% @ 0.05 = 75 tons

2. Several factors were established regarding the amount of energy saved.

   a. The existing pavement would be removed whether or not recycling is used. If virgin materials are used entirely, the existing pavement is removed by common excavation. If recycling is incorporated, the pavement will be removed by milling or other satisfactory method for further use. Therefore, no energy savings is calculated for removal.

   b. The asphalt required in the recycled material would theoretically be reduced by the quantity within the reclaimed material. For the

production of asphalt, a factor was established by the Asphalt Institute's publication "Energy Requirements for Roadway Pavements."

Asphalt 5% @ 1,091,500 $\frac{Btu}{ton}$ @ 30% = 16,372.5 $\frac{Btu}{ton}$

5,000 tons x 16,372.5 $\frac{Btu}{ton}$ x $\frac{1 \text{ gallon}}{125,000 \text{ Btu}}$ = 655 gal. of gasoline saved by reduction of required asphalt

c. The virgin aggregate needed for the recycled mix was dried and then heated from approximately 75°F ambient temperature to 475°F. This increase was estimated through the review of several projects in the State and felt to be representative. Again, the appropriate factors were taken from the Asphalt Institute's publication.

5,000 tons @ 70% virgin x 0.95 = 3,325 aggregate tons

Dry aggregate, 5% water @ 28,000 $\frac{Btu}{\%w}$ @ 3,325 tons = 465,500,000 Btu

400°F increase @ 470 $\frac{Btu}{°F/ton}$ @ 3,325 tons = 625,100,000 Btu

Energy Expended = 1,090,600,000 Btu

d. If the conventional method of entire virgin aggregates was incorporated, the energy expended in producing the necessary asphalt concrete can be calculated by use of the plant production factor established in "Energy Requirements for Roadway Pavements."

5,000 tons x 255,490 $\frac{Btu}{ton}$ = 1,277,450,000 Btu

In summary, the energy savings which can be attributed to the use of 30% reclaimed and 70% virgin aggregate, in place of 100% virgin aggregate, is:

(Energy required for 100% virgin aggregate; part d) - (Energy required for 30-70% split; part c) (Gasoline conversion factor) + energy saved by reduction of required asphalt

= Total energy savings

(186,850,000 Btu) ($\frac{1 \text{ gallon}}{125,000 \text{ Btu}}$) + 655 gallons = 2,150 equivalent gallons of gasoline saved

3. The cost savings attributed to hot recycling was calculated through the use of bid prices for the required quantity of virgin asphalt concrete and deducting the difference in removal techniques.

   a. 100% virgin asphalt concrete - $33.50/ton

   b. 30-70% recycled asphalt concrete - $27.50/ton

   c. Removal of existing pavement for recycling - $10.00/cy

   d. Common excavation (nonrecycle) - $2.60/cy

   $$\text{Estimated Savings} = \left(5{,}000 \text{ tons} \times \frac{(\$33.50-27.50)}{\text{ton}}\right) - \left(1{,}000 \text{ cy} \times \frac{(\$10-2.60)}{\text{cy}}\right)$$

   $$= \$22{,}600.00 \text{ for this particular sample project.}$$

RECYCLING REPORT

NH Projects Advertised Between 4/30/80 and 9/30/81

State	Project #	Lane Miles	Depth Recycled	Process	Tons of Aggregate Saved	Equiv. Gas Saved	Savings (Dollars)
NH	Tamworth FR-024-1(8)	1.62	6"	Cold	3,050	10,970	$ 50,695
NH	Jackson F-FLH-1(7)	3.30	5"	Cold	3,120	11,223	$ 61,750
NH	Hinsdale SR-270(10)	4.89	6"	Cold	10,918	39,256	$ 129,580
NH	Milan SR-202(3)	1.82	6"	Cold	10,275	36,947	$ 315,525
NH	Belmont-Gilmanton RS-237(3)	1.47	8"	Cold	6,098	21,966	$ 124,780
NH	Bedford FU-018-1(10)	1.07	8"	Cold	1,610	5,795	$ 36,420
NH	Brookline FR-018-1(12)	1.35	6"	Cold	6,100	21,940	$ 114,075
NH	Epping-Lee FR-019-1(17)	3.56	8"	Cold	6,380	23,550	$ 144,325
NH	Concord IR-I-393-2(90)39	4.06	3"-5½"	Hot	4,675	5,550	$ 120,360
NH	Manchester M-5285(3), #2	2.11	4"	Hot	1,539	1,830	$ 25,740
NH	Hudson S-2234-A	1.29	6"	Cold	2,120	7,621	$ 33,900
						Estimated Total -	$1,157,150

NH Projects Advertised Between 4/30/79 and 4/30/80

State	Project #	Lane Miles	Depth Recycled	Process	Tons of Aggregate Saved	Equiv. Gas Saved	Savings (Dollars)
NH	Manchester M-5285(13)	1.888	6"	Cold	5,728	24,686	$ 153,740
NH	Sunapee SR-326(2)	4.124	4"	Cold	10,425	44,934	$ 285,324
						Estimated Total -	$ 439,064

APPENDIX B

SPECIFICATIONS

Section 203: Excavation and Embankment

Section 304: Sand, Gravel and Crushed Gravel Base Courses

Section 401: Plant Mix Pavements - General

Appropriate Amendments

SECTION 203 — EXCAVATION AND EMBANKMENT

Description

1.1 This work shall consist of excavation of all material not being removed under some other item, placement of all material required for the work, and necessary disposal of all other material. The excavation will be classified as described below. Embankment-in-Place shall mean material placed under such item. Rehandling Surcharge Material shall consist of removing and redepositing the surplus surcharge material which has been loaded to displace soft material in specified sections of fills.

Classification of Materials

2.1 Common Excavation shall consist of all excavation not included as rock excavation or not otherwise classified. Glacial till or boulder clay will be considered as common excavation.

2.2 Rock Excavation shall consist of solid rock and the following when found to measure 2 cubic yards or more: boulders and parts of masonry structures.

2.3 Unclassified Excavation shall consist of all materials of whatever character encountered in the work.

2.4 Muck Excavation shall consist of deposits of saturated or unsaturated mixtures of soils and organic matter not suitable for foundation material regardless of moisture content.

2.5 Borrow shall consist of approved material required for the construction of fills or other portions of the work, and shall be obtained from approved sources, which sources may be designated in the contract.

1

203

Construction Requirements

3.1 General. The excavation and embankments shall be finished to reasonably smooth and uniform surfaces.

3.1.1. Conservation of Growth. Excavation shall be carefully performed in the proximity of trees and shrubs designated to be saved on the plans or ordered. Any roots which have to be removed shall be cleanly cut, and the larger ones shall be painted with approved bituminous paint.

3.1.2 Topsoil and Other Humus Material. Topsoil and desirable humus material shall be removed in excavation areas and also in fill areas to such depths as the Engineer may direct. Such material shall be reserved and shall be stocked in trim piles which can be measured readily and accurately by the Engineer. The Engineer will not order topsoil to be removed in clearing and grubbing areas where stumps have been permitted to remain unless such removal is specifically designated on the plans. Unless otherwise permitted, each stockpile shall contain a minimum of 200 cubic yards, have a height of at least 4 feet, and be trimmed in a workmanlike manner.

3.1.3 Material Found in the Roadway. Sand, gravel, or other materials found in the roadway may be used under the specific item in accordance with 104.05 when permitted.

3.1.4 Removing Abandoned Road Surface. Old road surfaces shown or ordered to be removed shall be stripped neatly to the depth and width ordered.

3.1.5 Drives. Drives shall be retained or constructed as shown on the plans or as ordered.

3.1.6 Degraded Material. When the Contractor's selected method of excavation operations results in saturation of non-porous materials and as a consequence the excavation must be wasted, a deduction from borrow will be made of the amount wasted. The quantity shall be as determined by the Engineer.

2

203

3.2 Rock Excavation.

3.2.1 Preliminary Work. When rock excavation is to be made, to permit cross-sectioning of the rock in its original position, the overburden shall be removed, or trenches shall be excavated through the overburden at the intervals directed: normally 25 feet, but in no case closer than 10 feet apart. Generally, the use of power equipment will be satisfactory. Rock removed prior to sectioning will be considered as common excavation.

3.2.2 Presplitting of rock shall be done in accordance with 3.3.

3.3 Presplitting.

3.3.1 Presplitting will be required in rock slopes where the rock is more than 10 feet in depth above the subgrade, measured along the slope, except when the designed slope is shown as flatter than 1:4.

3.3.2 Presplitting is defined as the establishment of a free surface of a shear plane in rock by the controlled usage of explosives and blasting accessories in appropriately aligned and spaced drill holes so that the resulting split rock will not be affected by subsequent blasting and excavation operations adjacent thereto.

3.3.3 Prior to drilling, all overburden and all loose and disintegrated rock shall be removed down to solid rock in the vicinity of the rock slope line as shown on the plans. Potentially dangerous boulders beyond the excavation limits shall also be removed as ordered.

3.3.4 Presplitting shall extend a minimum of 50 feet ahead of the limits of fragmentation blastings within the section, unless otherwise permitted.

3.3.5 Holes not greater than 3 inches in nominal diameter, spaced not more than 3 feet on centers, shall be drilled along the slope line and at the required slope inclination to the full depth of the cut or to a predetermined stage (lift) elevation. No hole shall deviate more than ½ foot at any

3

place from the plane of the specified slope, nor more than 1 foot at any place from a vertical plane through the top of the hole normal to the plane of the slope. The toe of the completed slope shall coincide, within those limits, with the toe of the slope shown on the plans.

3.3.6 Presplitting holes shall not exceed 35 feet in depth unless permitted. Rock deeper than 35 feet shall usually be presplit in lifts, but no lift shall be less than 10 feet in depth. No payment will be made for additional excavated quantity caused by offsetting presplitting holes beyond the specified face in the top or successive lifts. Presplitting holes in successive lifts shall be offset no more than 2 feet inside of the previously presplit face.

3.3.7 Before placing the charge, each hole shall be inspected and tested for its entire length to ascertain the possible presence of any obstruction. No loading will be permitted until the hole is free of all obstructions for its entire depth. All necessary precautions shall be exercised so that the placing of the charge will not cause caving of material from the walls of the hole.

3.3.8 The spacing of blast holes specified above, and the distribution and type of explosives, methods of detonation, and blasting techniques specified below shall be adjusted as necessary according to the characteristics and structure of the bedrock encountered so as to fracture the rock along the required face.

3.3.9 When the use of cartridge explosives is employed, the charge for each hole shall consist of not less than ⅛ pound nor more than ½ pound of 40 per cent dynamite per foot of hole, spaced not more than 20 inches center to center of charge, except that an extra quantity of dynamite shall be placed in the bottom of the hole, and near the top of the hole the charges shall be reduced sufficiently to eliminate overbreaking and heaving. The top charge shall not be less than approximately 3 feet from the top of the rock.

3.3.10 The spacing of the dynamite charges in each hole shall be accomplished by means of securely taping (or attaching by other approved means) each piece of dynamite to the detonating fuse at the required intervals, or by deck loading. If the latter is used, the dynamite must be in intimate contact with the detonating fuse to assure detonation of all charges.

3.3.11 Either of the following charges may be used as an alternate, provided the results are satisfactory:

(a) Continuous column commercial explosives manufactured especially for presplitting.

(b) Multiple strands of high-strength (175-200 grains of explosive per foot) detonating fuse taped together at 4- to 6-foot intervals.

3.3.12 Except as may be ordered at the top portion of the hole, all space in each hole not occupied by the explosive charges shall be filled with stemming material. Stemming material shall be clean stone chips or other approved angular granular material as shown in Table 1.

Table 1 — Required Grading of Stemming Material

Sieve Size	Percentage by Weight Passing
⅜"	100
No. 4	20-25
No. 8	0-10

3.3.13 Firing shall be by means of detonating fuse extending the full depth of each hole and attached to a trunkline of detonating fuse at the surface, which shall be fired by a dynamite cap or caps. All holes in the slope line shall be detonated simultaneously. The detonation of presplit charges shall precede the detonation of adjacent fragmentation charges within the section by a minimum of 25 milliseconds.

3.3.14 The line of blast holes immediately adjacent to the presplitting slope holes shall be drilled on a plane approximately parallel to the

4

plane of the presplitting slope holes. Except when ordered, no portion of any blast hole larger than 4 inches in diameter will be permitted closer than 12 feet to the presplit face. No portion of any blast hole will be allowed within 4 feet of the presplit face without permission. Other precautions as necessary shall be taken so as not to fracture the rock beyond the presplit face.

3.3.15 The Contractor shall schedule his operations so that all rock excavation within a minimum distance of 100 feet of structures or any portions thereof is completed to the required slope lines and depths before any structure work is started.

3.3.16 All loose and unstable material, even if located beyond the payment lines, and all breakage and slides shall be removed as directed and as the excavation for each vertical lift progresses. It shall be, at all times, the responsibility of the Contractor to perform all phases of this work to produce the required slopes.

3.4 Unclassified Excavation. When the excavation is unclassified, either in the proposal or by the Contractor's bid, the Contractor may make arrangements with the Engineer for the taking of sufficient measurements of the rock in its original position to enable subsequent determination of the quantity of rock involved in any overbreakage. If the Contractor elects not to make such arrangements, he shall have no claim for rock overbreakage.

5

3.5 Muck Excavation.

3.5.1 The excavation of muck shall be handled in a manner that will not permit the entrapment of muck within the backfill. The backfilling of the excavated area shall follow immediately behind the excavation of the muck in order that any soft material which is pushed ahead of the backfill can be removed. With muck removal, the Contractor shall allow the Engineer adequate opportunity to take all the necessary elevations and measurements for determining the volume removed.

6

3.5.2 Any suitable muck removed shall be incorporated in portions of the embankment slopes as directed, or used for other approved purposes.

3.6 Subgrade and Slopes.

3.6.1 Removal of Unsuitable Material. Where excavation to designed elevations results in a subgrade or slopes of unsuitable material, the Engineer will require the removal of the unsuitable material to such limits as he may direct. Muck shall be removed as shown or ordered. The backfilling shall be done with approved materials and compacted to the design subgrade or slope lines unless otherwise ordered. Material placed in wet slopes shall meet the requirements of Item 304.2 or shall be rock as ordered.

3.6.2 Backfill of Over-Excavated Subgrade in Rock. All over-excavated subgrade in rock shall be replaced with approved porous granular materials such as sand, gravel, broken rock, or any combination thereof. Non-porous materials will not be acceptable.

3.7 Embankments.

3.7.1 Backfill of Holes. Holes resulting from the removal of stumps, boulders, and the like, within the zone of anticipated frost action, shall be filled and compacted with material similar to that surrounding the hole.

3.7.2 Placing on Steep Slopes. Benching or terracing of slopes steeper than 3 to 1 shall be performed in conjunction with the placing of embankments abutting such slopes, in the manner directed.

3.7.3 Placing in Unstable Areas. Material used to backfill excavated muck in swamps shall consist of rock or granular material so graded that, of the material passing the No. 4 sieve, not more than 70 per cent will pass the No. 40 sieve and not more than 35 per cent will pass the No. 200 sieve. The material shall be placed in one continuous lift

7

to a maximum elevation of 4 feet above the water level, unless otherwise directed.

3.7.4 Placing Rock On Roadway. Rock fragments in fills shall be placed in layers of such thickness as the Engineer may direct, and in no case in excess of 4 feet. The lifts shall be worked in such a manner as to close the voids with spalls and fines. When sufficient spalls or fines are not available to close the voids, earth shall be used to make a tight surface prior to placing the next lift.

3.7.5 Placing at Pile Locations. Rock fragments, boulders, or other solid material shall not be placed in areas where piling is to be driven.

3.7.6 Placing Earth on Roadway.

3.7.6.1 Earth shall be placed in layers the full width of the roadway, generally parallel to the finished grade. The layers shall not exceed 12 inches of loose depth unless otherwise directed. Each layer shall be spread to a uniform thickness and compacted to the required density prior to placing the next layer. Continuous grading or shaping shall be carried out concurrently with the compactive effort to insure uniform density throughout each layer of material. Embankment material to be placed adjacent to structural fill shall be placed concurrently with the structural fill to provide lateral support.

3.7.6.2 Embankments shall be graded at all times to insure the run-off of water. Any saturation of non-porous material due to the Contractor's selected method of operation will occasion the suspension of additional work on the area until rectification by drying, removing and replacing, or draining has restored the fill to a stable condition, at the Contractor's expense.

3.7.7 Winter Construction Methods. No embankments shall be constructed on frozen earth materials. All frozen material shall be removed from the top of embankments prior to placing additional material. The frozen lumps of earth removed shall

8

be placed outside of the limits of an assumed 1½ to 1 slope from the break in the shoulder and inside the designed or ordered slope line. Each layer of material placed shall be compacted to the required density before it freezes. If the above specified conditions cahnot be met, earthwork operations shall be suspended.

3.7.8 Backfill at Structures. Backfill at structures shall conform to 504.3.4.3.

3.8 Density Requirements and Tests.

3.8.1 General. For earth materials under approach slabs and for earth materials within 10 feet of the back of structures not having approach slabs, at least 100 per cent of maximum density shall be obtained. For all other earth materials, at least 95 per cent of maximum density shall be obtained. Density determinations will be made as specified in AASHO T 99, Method C unless otherwise stated below or in the special provisions. If the required density cannot be achieved with the equipment at hand, the Contractor shall obtain whatever equipment is necessary to achieve the specified density. Manipulation of tills, silts, and clays, or any combination thereof, (including aeration where necessary) will be required to produce a stable fill of the required density. Those materials which cannot be tested in accordance with AASHO T 99, Method C, such as coarse gravelly material, shall be tested in the following manner, when required.

3.8.2 Method of Test. The method of test and the method of determining the per cent compaction shall be as specified in 508.3.4.1 and 508.3.4.2.

3.9 Disposal of Surplus and Waste Material.

3.9.1 Definitions.

(a) Surplus Material. Excess material from excavation beyond the minimum requirements of the project — otherwise suitable for use.

(b) Waste Material. Material unsuitable for use in the work, except in noncritical areas.

9

3.9.2 If the material is surplus, written permission must be obtained before the Contractor may dispose of such material outside of the work.

3.9.3 When practicable and wherever directed, surplus and waste material shall be utilized for flattening slopes or for other grading within the project.

3.9.4 When specified on the plans, surplus material shall be hauled off the project for use elsewhere for highway purposes. Such material shall be placed in accordance with the appropriate specification.

3.9.5 In case it is impossible to dispose of all the surplus and waste material in the manner described above, when the proposal does not contain the item of embankment-in-place, the remainder shall be disposed of as directed or permitted. It shall be the Contractor's responsibility to secure disposal areas for surplus and unsuitable material in case such areas are not shown on the plans.

3.10 Borrow.

3.10.1 Use of Borrow. It shall be the Contractor's responsibility to schedule the excavation so as to incorporate all suitable materials in the work. Premature use of the item of borrow resulting in wasting of suitable excavation will occasion the deduction from borrow of the quantity of suitable material wasted as determined by the Engineer.

3.10.2 Sources. Unless otherwise designated in the contract, the Contractor shall make his own arangements for obtaining borrow and shall pay all costs involved. All sources of borrow, whether within the right-of-way or elsewhere, shall be approved in writing before any borrow is removed. Permission to remove material beyond the template lines within the right-of-way and adjacent thereto will be contingent on many factors and if permission is granted, it will be given by the Engineer only after review by all interested parties concerned. Permission may be contingent, among other considerations, upon consent of the Contractor to leave regular and uniform slopes in the area.

3.10.2.1 The Contractor shall notify the Engineer when an approved pit is stripped if necessary so that it may be cross-sectioned by State forces. No material shall be removed prior to cross-sectioning or beyond the limits established and defined jointly by the Contractor and the Engineer. Pits shall be graded to permit accurate final cross sections to be taken. The Contractor's attention is called to 106.02.

3.11 Embankment-in-Place. When the embankment is constructed under this item, all construction requirements herein shall apply except 3.10.1.

3.11.1 Slopes excavated beyond the template lines without authorization shall be refilled when ordered, at no expense to the State.

3.12 Surcharges. When the item of borrow is included in the proposal and surcharges are required, the materials removed after consolidation shall be properly placed in locations reserved for the excess materials.

Method of Measurement

4.1 Excavation, embankment-in-place, borrow, and rehandling surcharge material will be measured by the cubic yard and in accordance with 109.01. Material removed from outside of template lines without prior approval will not be measured.

4.1.1 When the Contractor is directed to excavate beyond the template lines shown, the material removed will be classified under the appropriate excavation item.

4.2 When the item of embankment-in-place is included in the proposal, no measurements of any borrow pits will be made for the purpose of establishing pay quantities for any item and the item of borrow will not appear in the proposal.

4.3 When borrow is included in the proposal, the amount to be paid will be computed by the common pit method as follows: All borrow, together

with material for base courses when obtained from sectioned pits, will be totaled. All materials which are paid for by in-place measurement, all materials utilized for the Contractor's benefit and not incorporated in the work, all unauthorized fills and waste, and all materials specified to be deducted from borrow will be subtracted from this total to give the net borrow quantity. See 3.1.6 and 3.10.1.

4.4 When the contract does not specifically provide for payment for embankment-in-place, the work of embankment construction will not be measured as such but will be considered incidental to borrow and to the various classifications of excavation.

4.5 Surcharges will be sectioned in place immediately prior to removal, and the designed or revised subgrade template will be used as the final section.

4.6 Where presplitting is not required, actual overbreakage of rock in the slopes will be measured and allowed to a maximum of 24 inches (measured horizontally) beyond the required rock slope lines where adequate cross-sections have been taken of the original rock in accordance with the provisions of 3.2.1 and 3.4. No allowance for overbreakage will be made below the subgrade elevation.

4.7 Where presplitting is required, excavated rock will be measured only to the slope and depth lines shown on the plans or ordered.

4.8 Where the Engineer determines that the removal of additional rock is necessary due to conditions clearly not attributable to the Contractor's methods of operations, the neat lines will be adjusted to the limits ordered.

Basis of Payment

5.1 The accepted quantities of excavation and embankment will be paid for at the contract price per cubic yard for each of the pay items listed below that is included in the proposal, with the following stipulations:

5.1.1 The item of embankment-in-place will be paid only for those materials the payment of which is not specified under a separate item.

5.1.2 When surcharges are required, that portion of the surcharge ordered removed will be paid for as rehandling surcharge material.

5.1.3 Excavation of unsuitable materials in the slopes of roadway cuts will be paid for as common excavation. Backfill of such slopes will be paid for at 2 times the actual quantity under Item 304.2.

5.1.4 Topsoil excavation will be paid for as common excavation except when overlying muck excavation, in which case such topsoil excavation will be paid for as muck excavation. Payment as excavation will be full payment for excavating, transporting, and stockpiling surplus topsoil at approved locations.

5.1.5 Roadside ditches adjoining excavated areas will be paid for as common, rock, or unclassified excavation, as appropriate, unless such ditches are shown on the plans or ordered to be paid for under another item.

5.1.6 When conflicting pay lines for more than one type of excavation exist in an area, payment will be made to the limits of each type of excavation in the following order of priority unless otherwise indicated on the plans:

(1) Common, Rock, Muck, or Unclassified Excavation
(2) Channel Excavation
(3) Structure Excavation
(4) Bridge Excavation

5.2 No payment will be made for materials used to shim unauthorized over-excavated areas back to designed slope lines and subgrade, or for materials placed outside of designed or ordered slope lines.

5.3 No payment will be made under the item of embankment-in-place, nor deduction made under the item of borrow, for materials used to backfill

holes left by the authorized removal of stumps, boulders, and the like.

5.4 No separate payment will be made for aeration, or compaction equipment or methods.

5.5 Except for any extra work which may be ordered, payment for borrow or embankment-in-place will include all work required in connection with pits.

5.6 When common excavation is the only class included in the proposal, any rock encountered will be paid for at 5 times the unit price for common excavation.

5.7 When no item for muck excavation is contained in the proposal, work conforming to that classification will be paid for as common excavation.

5.8 Benching or terracing performed under 3.7.2 will be subsidiary except that rock removed as ordered will be paid for under Item 203.2.

Pay items and units:

203.1 Common Excavation	Cubic Yard
203.2 Rock Excavation	Cubic Yard
203.3 Unclassified Excavation	Cubic Yard
203.4 Muck Excavation	Cubic Yard
203.5 Borrow	Cubic Yard
203.6 Embankment-in-Place	Cubic Yard
203.7 Rehandling Surcharge Material	Cubic Yard

DIVISION 300 – BASE COURSES

SECTION 304 — SAND, GRAVEL, AND CRUSHED GRAVEL BASE COURSES

Description

1.1 This work shall consist of furnishing and placing base courses on previously prepared subgrade or course as shown or ordered.

Materials

2.1 The materials shall consist of stones, rock fragments, and fine, hard, durable particles resulting from the natural disintegration of rock. The materials shall be free from injurious amounts of organic material and shall conform to the following gradations:

2.1.1 Sand — Seventy to 100 per cent shall pass the No. 4 sieve and not more than 12 per cent of the material passing the No. 4 sieve shall pass the No. 200 sieve. The maximum size of any stone or fragment shall be as stated in 2.1.2 unless otherwise directed.

2.1.2 Gravel — Twenty-five to 70 per cent shall pass the No. 4 sieve and not more than 12 per cent of the material passing the No. 4 sieve shall pass the No. 200 sieve. No stones or rock fragments will be permitted which cannot be incorporated in a 6-inch layer.

127

2.1.3 Crushed Gravel.

2.1.3.1 Required Grading

Sieve Size	Percentage by Weight Passing
3″	100
2″	95 - 100
1″	55 - 85
No. 4	27 - 52
No. 200 (Based on the fraction passing the No. 4)	0 - 12

2.1.3.2 At least 50 per cent of the materials retained on the 1-inch sieve shall have a fractured face.

2.1.3.3 When the quantity of Item 304.3 in the proposal is less than 2,000 cubic yards, the grading requirements of the 2-inch and 1-inch sizes of crushed gravel material may be waived, to permit the use of crushed bank-run gravel, all of which shall pass a 1½-inch sieve but not more than 55 per cent shall pass the No. 4 sieve. Also, not more than 15 per cent of the No. 4 sieve shall pass the No. 200 sieve.

2.2 Wear. The per cent of wear of base course material shall not exceed 50 unless otherwise specified.

2.3 Testing.

2.3.1 Samples for provisional approval of materials will be taken after all mixing, hauling, and spreading operations are complete, but prior to the beginning of compaction operations. See 3.3.6.

2.3.2 The amount of material finer than No. 200 sieve shall be determined according to ASTM D 1140 and shall include dry sieving after washing.

Construction Requirements

3.1 General.

3.1.1 Applicable provisions for borrow pits as stated in 203.2.5 and 203.3.10.2 shall apply to base course materials.

128

3.1.2 Base course materials found within the project limits may be used under the specific item in accordance with 104.05 when permitted.

3.1.3 Permission may be given to substitute gravel or a mixture of sand and gravel for all or part of the sand courses when the sand is designed as part of the base of the roadway. That portion of the material passing the No. 4 sieve shall conform to 2.1.1.

3.2 Crushed Gravel Plant.

3.2.1 The equipment for producing crushed gravel shall be of adequate size and with sufficient adjustments to produce the required materials without unnecessary waste. The plant shall be capable of removing excess sand. The Engineer may order final screening of crushed gravel if flat and elongated pieces are present in objectionable amounts.

3.3 Placing.

3.3.1 The subgrade shall be to the specified crown and grade, and maintained in a smooth condition, free from holes and ruts. If the hauling equipment should cause ruts in the subgrade or previously placed base course, the equipment shall be operated only on the course being placed, behind the spreading equipment.

3.3.2 Care shall be taken to avoid segregation when placing gravel and crushed gravel. When base course material is dumped in piles, it shall be dumped on the course being placed, and spread at once onto the previously placed layer. If spreading equipment is not available, dumping will not be permitted. Any segregation which occurs shall be remedied or the materials removed and replaced at no additional cost to the State.

3.3.3 Each entire layer of gravel shall be scarified for the top 2/3 of the layer to bring all oversized stones to the surface for disposal prior to placing the subsequent course. Such scarifying will not be required when the Contractor's method of

129

operation is such that oversized stones are not delivered to the project.

3.3.4 Prior to fine grading, hard spots in the surface of the top layer shall be eliminated by scarifying the top 4 inches.

3.3.5 Stones having any dimension greater than 3 inches shall be removed from the upper 4 inches of the top layer of gravel when the gravel is to be surface-treated and no pavement is to be laid upon it.

3.3.6 Previously tested and accepted materials contaminated by earthen, organic, or other foreign matter, or degraded by hauling equipment, to such an extent that the materials cease to meet the requirements shall be removed and replaced or otherwise made acceptable at the Contractor's expense.

3.4 Compaction.

3.4.1 The compacted depth of any layer of gravel or crushed gravel placed shall not exceed 8 inches.

3.4.2 Rolling shall begin on the lower side and progress to the higher part of the course with lapped rollings parallel to the center line.

3.4.3 Water shall be uniformly applied over the base materials during compaction in the amount necessary for proper consolidation. Rolling and shaping shall continue until each layer conforms to the required grade and cross section, and the surface is smooth and uniform. Sand shall be compacted with vibratory or other approved rollers and shall be rolled sufficiently so that additional passes of the equipment will produce only a negligible impression. As a referee test, 95 per cent density will be considered satisfactory when tested in accordance with AASHO T 99. The required density of each layer of gravel or crushed gravel shall be such that additional trips of rollers weighing a minimum of 10 tons will produce only a negligible impression.

130

3.5 Winter Construction.

3.5.1 Base course materials shall not be placed upon or above frozen material if the depth from the top of the contemplated course to the bottom of the frozen material would exceed 2½ feet.

3.5.2 If the density requirements are not fulfilled for any layer before the material freezes, no further material shall be placed upon that layer.

Method of Measurement

4.1 Base course materials will be measured by the cubic yard of compacted material placed within the lines shown on the plans or ordered.

Basis of Payment

5.1 The accepted quantity of base course materials will be paid for at the contract unit price per cubic yard complete in place. Overhaul to be paid for will be paid for under Item 205.

Pay items and units:

304.1 Sand	Cubic Yard
304.2 Gravel	Cubic Yard
304.3 Crushed Gravel	Cubic Yard

131

401

DIVISION 400 – PAVEMENTS

SECTION 401 — PLANT MIX PAVEMENTS — GENERAL

Description

1.1 These specifications include general requirements that are applicable to all types of bituminous pavements of the plant mix type irrespective of gradation of aggregate, kind and amount of bituminous material, or pavement use. Deviations from these general requirements will be indicated in the specific requirements for each type.

Materials

2.1 Aggregates shall be of uniform quality, crushed to size as necessary, and shall be composed of sound, tough, durable pebbles or fragments of rock, with or without sand or other inert finely divided mineral aggregate. Washing will not be required, except when aggregate plants do not produce clean material by the dry method. In order to obtain uniformity as regards color and appearance of the pavement throughout the project, the aggregate for all the wearing course shall be obtained from the same material deposit. Sufficient material shall be on hand prior to starting daily operations to insure uninterrupted processing for the working day.

2.1.1 Coarse Aggregate is all the material retained on the No. 10 sieve. Coarse aggregate shall be crushed stone or crushed gravel and unless otherwise stipulated, shall conform to the quality requirements of AASHO M 62 except that Sections 4 and 5 shall not apply and unless otherwise specified or permitted in the item designation, the material shall have a wear of not more than 45 per cent. In each stockpile at least 50 per cent of the particles retained on the No. 4 sieve shall have at least one fractured face.

132

2.1.1.1 The use of stockpiles containing both coarse and fine aggregate will not be permitted. Stockpiles of coarse aggregate will not be acceptable if more than 10 per cent of a representative sample passes the No. 10 sieve.

2.1.2 Fine Aggregate is all the material passing the No. 10 sieve. Fine aggregate, unless otherwise stipulated, shall conform to the quality requirements of AASHO M 29 except that fine aggregate shall consist of at least 50 per cent natural sand. Stone screenings shall be produced from stone equal in quality to that specified for the coarse aggregate and shall be free from coatings of fine dust after drying.

2.1.3 Mineral Filler shall conform to AASHO M 17, Section 2.

2.1.4 Gradation. Coarse and fine aggregate shall each be of such gradation that when combined with other required aggregate fractions in proper proportion, the resultant mixture will meet the gradation required under the composition of mixture for the specific type under contract. See Table 1. Not more than 15 per cent of the fine aggregate shall pass the No. 200 sieve. Grading of mineral filler shall conform to the required grading of AASHO M 17 except that 100 per cent shall pass the No. 20 sieve, waiving the requirement for the No. 30 sieve.

2.2 Bituminous Materials shall meet the requirements of AASHO M 226 except for those values shown in 702 Table 2. The grade to be used shall be as ordered.

2.2.1 Approved sampling valves shall be installed in transport tank trucks to permit taking representative samples of the contents. The recommended location of the sampling valve is in the rear bulkhead of the tank, roughly 1/3 of the height above the bottom. The inlet pipe shall project into the contained liquid. At least one quart of material shall be drained off through the sampling valve and discarded before the desired sample is taken. New sample containers will be

133

Table 1 — Composition of Mixtures — Master Ranges[1]

Sieve Size	Base Courses[2]									Wearing Courses[2]					
	Type A: 1½"			Type B: 1"			Type C: ¾"			Type D: ½"			Type E: ⅜"		
	Percentage by Weight Passing — Combined Aggregate														
	Min.	Desired	Max.	Min.	Desired	Max.	Min.	Desired	Max	Min.	Desired	Max.	Min.	Desired	Max.
1¼"	95	100	100	—	—	—	—	—	—	—	—	—	—	—	—
1"	75	85	95	95	100	100	—	—	—	—	—	—	—	—	—
¾"	62	72	84	75	85	95	95	100	100	—	—	—	—	—	—
½"	50	60	70	60	72	80	70	81	92	95	100	100	—	—	—
⅜"	42	50	60	53	60	70	60	71	80	85	90	95	100	100	100
No. 4	28	36	45	38	43	50	42	50	57	60	66	75	64	71	80
No. 10	18	23	27	23	27	31	28	32	38	38	46	50	44	50	55
No. 20	10	15	18	13	17	21	16	20	24	24	27	32	25	30	35
No. 40	5	10	13	7	11	15	9	13	17	14	19	23	15	20	25
No. 80	1	6	9	2	6	10	3	7	11	6	11	14	6	11	16
No. 200	0	2	4	0	2	4	0	3	4	2	3	6	2	4	6
Asphalt Cement: % of Mix[3]	3.8	4.3	4.8	4.3	4.8	5.3	4.8	5.25	6.0	6.0	6.4	7.0	6.25	6.50	7.0

(1) Gradings approaching the maximum amounts permitted to pass the various sieves will result in pavement surfaces having comparatively fine texture, while gradings approaching the minimum amounts passing the various sieves will result in surfaces with comparatively coarse textures.

(2) Alternate aggregate sizes are included to provide that generally the coarse aggregate shall not be larger than one-half the thickness of the layer being placed.

(3) The asphalt content for the above mixtures is based on the use of aggregate with a specific gravity of 2.65 to 2.70. The asphalt content will be adjusted when aggregate with a higher specific gravity is used.

134

furnished by the Engineer. To prevent the loss of solvents, the container shall be sealed with a tight-fitting cover immediately after being filled.

2.3 Approval of Materials. At least 3 working days in advance of the date of starting operations, representative samples of all materials proposed for use shall be submitted to the Engineer for test and for the preparation of trial mixes relating to the job-mix formula. No material shall be used until it has been approved.

2.4 Composition of Mixtures. The bituminous plant mix shall be composed of a mixture of aggregate, filler if required, and bituminous material. The several aggregate fractions shall be sized, uniformly graded, and combined in such proportions that the resulting mixture meets the grading requirements of the job-mix formula.

2.4.1 Job Mix. The general composition limits given in Table 1 indicate the master range of mixtures permissible under this specification. No work shall be started on paving a project until the Engineer approves a job-mix formula appropriate to the raw materials and blends thereof available to the specific project. The job-mix formula shall lie within the master range indicated for the particular type of bituminous concrete. The job-mix formula for each mixture shall establish a single percentage of aggregate passing each required sieve size, a single percentage of bituminous material to be added to the aggregate, and a single temperature at which the mixture is to be delivered at the point of discharge. Gradings which range from the maximum of one sieve to the minimum of the next will not be permitted. The job-mix formula for each mixture shall be in effect until modified in writing by the Engineer.

2.4.1.1 After the job-mix formula is established, all mixtures furnished for the project shall conform thereto within the following ranges of tolerances:

135

Passing No. 4 and larger sieves	±7 per cent
Passing No. 10 to No. 80 sieves (inclusive)	±4 per cent
Passing No. 200 sieve	±2 per cent
Bitumen	±0.4 per cent
Temperature of mixture	±20 degrees F

2.4.1.2 Should a change in sources of material be made, a new job-mix formula shall be established before the new material is used. When unsatisfactory results or other conditions make it necessary, the Engineer may establish a new job-mix formula.

2.4.1.3 The quantity of asphalt cement is given in terms of per cent by weight of the total mixture. The wide difference in the specific gravity of various aggregates, as well as a considerable difference in absorption, results in a comparatively wide range in the limiting amount of asphalt cement specified. The amount of asphalt required for a given mixture should be determined by appropriate laboratory testing or on the basis of past experience with similar mixtures, or by a combination of both.

Construction Requirements

3.1 Mixing Plants. (General).

3.1.1 The site shall have ample storage space for the required separate bins, stalls, or stockpiles, to allow delivery of uncontaminated sized aggregates to the feeder. To prevent spillage from one pile or bin to the next, aggregate assigned to different stockpiles shall be separated by bulkheads or other satisfactory means, and buckets on equipment used to fill bins or stalls shall not be wider than the clear opening of the bin.

136

3.1.1.1 Coarse or fine aggregate material assigned to the different storage areas shall consist of one or more, as ordered, of the sieve sizes shown in Table 1. Coarse aggregate for base course shall be fed to the plant from at least 2 sources, to minimize segregation. In order to meet the grading requirements, it may be necessary to blend 2 or more of the stocks of coarse aggregate and one or more stocks of sand and mineral dust. The blending shall be accomplished through separate bins at the cold elevator feeders and not in the stockpiles.

3.1.1.2 The plant shall be provided with dust collectors to insure that not only shall the heavier dust particles be reintroduced into the flow of aggregate, if and as required by the specifications — or wasted —, but also the plant shall be equipped with adequate systems so that objectionable exhaust will not be dissipated into the atmosphere. The Contractor shall comply with regulations adopted by the New Hampshire Air Pollution Control Commission.

3.1.1.3 Plants shall be of sufficient capacity and so co-ordinated as to handle the paving adequately, keeping the paver operating continuously, except for necessary short stops, while the paver places the depth specified for a 12-foot lane. Approval of the plant and paving equipment shall be obtained before commencing operations.

3.1.2 Safety Requirements.

3.1.2.1 Adequate and safe stairways to the mixer platform shall be provided and guarded ladders to other plant units shall be located where required for accessibility to plant operations.

3.1.2.2 All gears, pulleys, chains, sprockets, and other dangerous moving parts shall be thoroughly guarded and protected.

3.1.2.3 Ample and unobstructed space shall be provided on the mixing platform.

3.1.2.4 A clear and unobstructed passage shall be maintained at all times in and around the truck-loading space. This space shall be kept free of

137

drippings from the mixing platform. A ladder or platform shall be so located at the truck-loading space as to permit easy and safe inspection of the mixture as it is delivered into the trucks. Adequate overhead protection shall be provided where necessary.

3.1.3 Inspection Facilities.

3.1.3.1 At least 3 working days in advance of starting paving operations, the Engineer shall be notified of the fact to allow him to make arrangements for inspection personnel.

3.1.3.2 The Engineer shall have access at any time to all parts of the plant for inspection of the conditions and operations of the plant, for confirmation of the adequacy of the equipment in use, for verification of proportions and character of materials, and for determination of temperatures being maintained in the preparation of the mixtures. The preparation of all bituminous mixtures shall be subject to inspection at the plant. For this purpose, the Contractor shall provide a suitable building, room, or trailer for exclusive use as a field laboratory in which to house and use the testing equipment. Laboratories shall be in an approved location with, unless otherwise permitted, the plant operation visible from one window. Unless otherwise approved, one laboratory shall be provided for each plant.

3.1.3.3. Field laboratories shall meet the following minimum requirements: General specifications shall conform to 698.2.1 with the additional requirement that the following appurtenances shall be provided:

(a) An exhaust fan and hood over hot plates and extractor. The hood shall be large enough to cover both the hot plates and the extractor; the fan shall be a high volume axial flow fan, approximately 12" in diameter.

(b) Free wall-space of at least 12 square feet; or a bulletin board of equal area for posting notices and job-mix formulas.

(c) Suitable shelves and benches. One bench shall be ±24" wide, by ±36" high, at least 10' long. The bench may extend the length of the building.

3.1.3.4 The following office furnishings and testing equipment shall be provided:

(a) Triple beam balance: at least 2000 gram capacity, sensitive to 0.1 gram, with tray.

(b) One desk and chair.

(c) Set of U. S. Standard 8" brass sieves, 2" high consisting of one each: 1½", 1¼", 1", ¾", ½", ⅜", No. 4, No. 10, No. 20, No. 40, No. 80, No. 200, with pan and cover.

(d) Motor driven shaker for 8" sieves.

(e) Double burner hot plate or gas stove.

(f) Motor driven centrifuge extractor: 1500 gram capacity with variable speeds up to 3600 rpm, with filter rings and solvent.

(g) Tachometer to check the speed of the extractor, readily available.

(h) Compaction pedestal meeting the requirements of Section 2.4 of ASTM D 1559, complete with Marshall mold holder, compaction hammer, and 2 molds.

(i) One- or two-pound percentage scale.

(j) Bristle brush for cleaning No. 200 sieves.

(k) Brass brush for cleaning 8" sieves.

(l) Three pans: approximately 2" high, 10" round or square.

(m) Spatula, large spoon, garden trowel, measuring scoop, 1-quart pitcher.

(n) Fire extinguisher: CO_2, minimum 5 pounds.

(o) One round-pointed shovel.

(p) Desk brush and floor broom.

3.1.4 Storage of Bitumen.

3.1.4.1 Tanks for storage of bitumen shall be of minimum 5000-gallon capacity, equipped for heating the material, under effective and positive control at all times, to the temperature requirements set forth in the specifications for the paving mixture. Heating shall be accomplished by steam or oil coils, electricity, or other means such that

138

401

no flame shall come in contact with the heating tank.

3.1.4.2 A complete system providing for continuous circulation of the bitumen between the storage tank and the proportioning units shall be employed. The discharge end of the circulating pipe shall be maintained below the surface of the bitumen in the storage tank to prevent discharging the hot bitumen into the open air.

3.1.4.3 The Contractor shall provide in the bitumen feed lines connecting the plant storage tanks to the bitumen weighing system or spray bar a sampling outlet consisting of a valve installed in such a manner that samples may be withdrawn from the line slowly at any time during plant operation. The sampling outlet shall be installed between the pump and the return line discharge in such a location that it is readily accessible and free from obstruction. A drainage receptacle shall be provided for flushing the outlet prior to sampling.

3.1.5 Control of Bitumen.

3.1.5.1 Satisfactory means, either by weighing or metering, shall be provided to obtain the proper amount of bituminous material in the mix within the tolerance specified. Means shall be provided for checking the quantity or rate of flow of bituminous material into the mixer as follows:

(a) Metering devices for bitumen shall indicate accurately to within 1.0 per cent the amount of bitumen delivered. The section of the bitumen flow line between the charging valve and the spray bar shall be provided with a 3-way valve and outlet whereby the delivery of the meter may be checked by actual weight. The valve controlling the flow of bitumen to the mixer shall close tightly to prevent bitumen from leaking into the pug mill during the mixing cycle. The meter shall be constructed so that it may be locked at any dial setting to 0.1 gallon and will automatically reset to this reading after the addition of bitumen to each batch. The dial shall be in full view of the mixer operator. The

139

140

size and spacing of the spray bar openings shall provide a uniform application of bitumen the full length of the mixer in a thin uniform sheet or in multiple sprays.

(b) If a bucket is used for weighing the bitumen, the bucket shall be of sufficient capacity to hold and weigh the amount required for a batch in a single weighing. The filling system and bucket shall be of such design, size, and shape that bitumen will not overflow, splash, or spill outside the confines of the bucket during filling and weighing, and it shall be so arranged as to deliver the bitumen in a thin uniform sheet or in multiple sprays over the full length of the mixer. The time required to add the bitumen shall be not more than 15 seconds.

(c) Bitumen scales shall conform to the requirements for aggregate scales as specified in 3.1.7.3, except a device to indicate at least the last 20 pounds of the approaching total load shall be provided. Beam-type scales shall be equipped with a tare beam or adequate counterbalance for balancing the bucket and compensating periodically for the accumulation of bitumen on the bucket.

3.1.5.2 Suitable means shall be provided, either by steam or oil-jacketing or other insulation, for maintaining the specified temperatures of the bitumen in the pipelines, meters, weigh buckets, spray bars, and other containers or flow lines.

3.1.6 Control of Aggregate.

3.1.6.1 Feeders shall provide an accurate and positive means for uniform and continuous feeding of the mineral aggregate into the dryer. The feeder or feeders shall be capable of delivering the maximum number of aggregate sizes required in their proper proportion. They shall provide for adjustment of the cold feed and shall be capable of being secured in any position.

3.1.6.2 Dryers shall continuously agitate the aggregate during the heating and drying process without leaving any visible unburned oily residue

141

on the aggregate when it is discharged from the dryer. If unusually wet aggregate is being used, the input to the dryer shall be reduced to that amount which the dryer is capable of drying.

3.1.6.3 Plant screens shall be constructed and operated in such manner that all aggregates will be uniformly separated into the sizes required for proportioning. They shall have sufficient capacity to furnish the necessary quantity of each aggregate size required for continuous operation. Screen cloth which has become broken or has worn sufficiently to affect the gradation shall be replaced.

3.1.6.4 Thermometric equipment shall be provided as follows:

(a) An armored thermometer of suitable range shall be fixed in the bitumen feed line at a suitable location near the discharge at the mixer unit.

(b) The plant shall be further equipped with approved thermometers, pyrometers, or other approved thermometric instruments placed at the discharge chute of the drier and in the hot fines bin to register the temperature of the heated aggregate.

3.1.7 Batching Plants.

3.1.7.1 Hot bins shall be divided into at least 4 separate aggregate compartments. One compartment shall be reserved for aggregate not larger than that passing the No. 6 sieve, and when required, one additional compartment shall be added for dry storage of mineral filler and provision shall be made for accurate proportioning. Bin gradations will be controlled by frequent sampling. When a compartment contains more than 15 per cent undersized material, the compartment shall be drawn, when required, and the cause of the contamination shall be corrected. Each compartment shall contain the following features:

(a) Sufficient volume to supply the mixer at full rated capacity.

(b) An overflow pipe that shall be of such size and at such a location as to prevent any backing

142

up of material into other bins or into contact with the screen.

(c) Adequate telltale devices to indicate the position of the aggregate in the bins at the lower quarter points. In an automatic plant, a shutoff to operate when the upper surface of the aggregate falls below the permissible level.

(d) Gates which cut off quickly and completely, with no leakage.

(e) Adequate and convenient facilities including safe platforms for obtaining representative samples from each bin.

3.1.7.2 Weigh boxes shall be of sufficient size to hold the maximum required weight of aggregate for one batch without hand raking or running over. The weigh box shall be supported on fulcrums and knife edges so constructed that they will not be easily thrown out of alignment or adjustment. All parts of the weigh box shall be free from contact with any supporting rods, columns, or other equipment which will affect the proper functioning of the hopper or scale. Gates on both bins and weigh hopper shall be constructed to prevent leakage when closed.

3.1.7.3 Aggregate scales for any weigh box or hopper may be of either the beam or springless dial type and shall be of a standard make and design, accurate to 0.5 per cent of the indicated load. When of the beam type, there shall be a separate beam for each size of aggregate and a tare beam for balancing the hopper. A telltale dial shall be provided that will start to function when the load being applied is within 100 pounds of the weight desired. Sufficient vertical movement shall be provided in the beams to permit the telitale to function properly. Each beam shall have a locking device designed so that the beam can be suspended or thrown out of action. Dial scales shall be installed in such manner as to be free from vibration. They shall also be of such size that the numerals on the dial can be read at a distance of 25 feet. The dial shall be of the compounding type and

143

have a full complement of index pointers. Dial scales shall be substantially constructed, and those that easily get out of adjustment shall be removed and replaced when so ordered. All dials shall be located so as to be plainly visible to the operator at all times. It shall be the responsibility of the Contractor to arrange that all scales are tested and sealed by the State or by competent commercial scale companies at least on an annual basis. Moreover, scales shall be tested immediately after they have been moved. For checking the scales, the Contractor shall have readily available at least ten clean, standard 50-pound test weights.

3.1.7.4 The batch mixer shall be of an approved pug mill type, hot oil or steam jacketed, or heated by other approved means and capable of producing uniform mixtures within the specified tolerances. The mixer shall have a batch capacity of not less than 2000 pounds and be constructed so as to prevent leakage during the mixing cycle. The amount of material which may be mixed per batch shall not exceed the manufacturer's rated capacity. If the mixer will not operate efficiently at the rated capacity, or if its production does not coordinate with the other plant units, the right is reserved to reduce the size of the batch until the desired efficiency is obtained. The pug mill shall be equipped with a sufficient number of paddles operated at such speed as to produce a properly and uniformly mixed batch. If, in the course of mixing, two adjacent paddle tips become broken, immediate repair will be called for. If the paddle tips become broken at widely separated points, repair may be delayed until the end of the working day. The clearance of the tips from all fixed and moving parts shall not exceed ¾ of an inch. Badly worn or defective tips shall not be used in mixing operations. The mixer shall be covered to prevent loss of fine material. The discharge gate shall be so designed that no uncoated material will be retained at the gate opening during the mixing operation. Leakage from the pug mill gate during operation will not be permitted.

144

401

so as to indicate when the automatic cycling controls are in operation.

(b) The automatic control for each batching scale system shall be equipped with a device for stopping the automatic cycle in the underweight check position and in the overweight check position for each material so that the tolerance setting may be checked.

(c) Each dial scale system shall be equipped with a removable dial puller which can be attached to the dial lever system so that the dial can be moved smoothly and slowly through its range to check the settings of the automatic control system. The plant operator shall perform this automatic control system checkout procedure periodically as requested by the Engineer.

(d) The weight batching controls shall meet the following tolerances for the various components weighed in each batch:

Component Weighed	Percentage of Total Batch Weight
Tare weight of aggregate weigh box	±0.5
Tare weight of bitumen weigh bucket	±0.1
Each aggregate component	±1.5
Mineral filler	±0.5
Asphalt	±0.1

(e) The total weight of the batch shall not vary by more than ±2.0 per cent of the designated batch weight.

(f) Recordation equipment shall be provided in all plants employing automatic proportioning. Each recorder shall include an automatic printer system. The printer shall be so positioned that the scale dial and the printer can be readily observed at one location by the plant inspector. The printer shall print, in digital form, on a delivery ticket the following data:

1. Slip number.
2. Date mixed.
3. Time of batching.
4. Tare weight of aggregate weigh box.

146

401

3.1.7.5 Each plant shall be equipped with an accurate time lock to control the operations of a complete mixing cycle. A mixing cycle shall consist of two periods: the dry mixing period and the wet mixing period. The dry mixing period shall be the interval of time between the opening of the aggregate weigh hopper gate and the start of the application of bitumen. The wet mixing period shall be the interval of time between the start of the application of bitumen and the opening of the mixer gate. The time lock shall be capable of being set at intervals of 5 seconds or less throughout the mixing cycle and shall have a suitable case equipped with an approved lock. The setting of time intervals shall be performed in the presence and under the direction of the Engineer, who may lock the case until such time as a change is to be made in the timing periods. The time lock shall lock the bitumen bucket throughout the dry mixing period and shall lock the mixer gate throughout the dry and wet mixing period. A light or indicator visible from the ground shall show when the time lock is being used.

3.1.7.6 The use of a fully automatic batching plant may be allowed, provided the systems for automatic batching and proportioning of the various components of the bituminous mixtures meet the following requirements:

(a) The automatic proportioning controls shall include equipment for accurately proportioning batches of the various components of the mixture by weight in the specified sequence and for controlling and timing the mixing operations. Interlocks shall be provided which will delay, stop, or lock out the automatic batch cycling whenever the batched quantity of any component weight is not within the specified weight tolerance, the total batch weight exceeds the specified tolerance, or when there is a malfunction in any portion of the control system. The automatic batching or proportioning controls shall be equipped with a light, visible from the ground, which shall be activated

145

5. Tare weight of bitumen weigh bucket.

6. Accumulative weights as batched for each aggregate (total of last aggregate will be aggregate total).

7. Weight of bitumen.

8. Accumulative total batch weight.

(g) Provisions shall be provided in the automatic printer system so that each delivery ticket will show a consecutive slip number.

(h) If at any time the automatic proportioning or recording system becomes inoperative, the plant will be allowed to batch materials manually, but will be required to use the timing and time lock devices, for a period not in excess of 2 working days. Approval will be dependent upon the Contractor's furnishing an alternate satisfactory method of determining the total weight of material delivered to the project. Time extensions greater than 2 working days will require written permission.

3.1.8 Continuous Mixing Plants.

3.1.8.1 Continuous mixing plants shall meet the following minimum requirements:

(a) Capacity, at least 60 tons per hour.

(b) Accurately controlled volume measuring gate with adequate telltale devices at the lower quarter points to indicate the position.

1. The orifice shall be rectangular with one dimension adjustable by positive mechanical means and provided with a lock.

2. Indicators shall show gate opening in inches.

3. A revolution counter shall be provided.

4. Gates shall cut off quickly and completely with no leakage.

(c) A small hopper, mounted directly over the mixer for separate proportioning of mineral filler when specified.

(d) Interlocking feeders mounted under the bin compartments.

147

(e) A means of accurately checking the proportioning of each bin size aggregate by weight, which will establish rate of flow in pounds per revolution.

1. The aggregate fed out of the bins through individual orifices shall be bypassed into suitable test boxes and each compartment material shall be confined in individual test receptacles or compartments.

2. Accessories shall be supplied so that the aggregate in each compartment may be weighed separately.

3. Test containers shall be of convenient size so as to obtain a composite weight at least 600 pounds.

(f) Satisfactory means shall be provided to afford positive interlocking or mechanical control between the flow of aggregate through the gates and the flow of bitumen through the meter or other proportioning source. Means shall be provided to check the rate of flow of the bitumen by scale weight per revolution.

1. Adjustment of these facilities shall be under the control of the Engineer.

(g) A continuous mixer of an approved twin pug mill type which shall be capable of producing a uniform mixture within the permissible job-mix tolerances as specified in 2.4.1.1.

1. The paddles shall be of a type adjustable for angular position on the shafts and reversible to retard the flow of the mix.

2. Mixers shall be equipped with discharge hoppers or other facilities to prevent segregation during discharge.

3. The mixer shall carry a manufacturer's plate giving the net volumetric contents of the mixer at the several heights, inscribed on a permanent gage, and also giving the rate of aggregate feed per revolution and per minute at the plant operating speed.

4. The weight per unit volume relationship of the coated loose mix shall be determined and the pug mill capacity at operating height shall be

148

determined by means of the volume gage on the side of the mixer.

5. The mixing time shall be determined as indicated in AASHO T 195 as follows:

$$\text{Mixing time in seconds} = \frac{\text{pug mill dead capacity in pounds}}{\text{pug mill output in pounds per second}}$$

(h) Continuous mixing plants not complying in all respects with the above requirements but capable of producing a uniform mixture within the job-mix tolerances may be approved.

3.2 Mixing.

3.2.1 The aggregate shall be dried and heated to a temperature between 260 F and 350 F. The bitumen shall be heated to a temperature between 250 F and 325 F. Each size of hot aggregate, the mineral filler if required, and the bituminous cement shall be measured separately and accurately to the proportions in which they are to be mixed. The mixture shall be made by first charging the mixer with the hot aggregate, coarse sizes first unless otherwise directed, which shall be dry mixed for 5 to 15 seconds. The bitumen shall then be added and in batch mixing the mixing shall continue until a uniform coating is obtained and all particles of the aggregate are thoroughly coated. The total dry and wet cycle shall be not less than 35 seconds for base and binder courses and not less than 45 seconds for the wearing course. In no case shall the total mixing period exceed 75 seconds. In continuous mixing, the mixing period shall be not less than 45 seconds as determined by the formula in 3.1.8.1(g)5, but may be longer if necessary to produce a homogeneous mixture.

3.2.2 During hot weather, the temperature of the mixture when discharged shall be as low as is consistent with proper mixing and placing. During cold weather, temperatures approaching the upper limit are desirable. Any mixture which is found to

149

be in excess of 375 F when discharged will be rejected.

3.2.3. If the temperature of the aggregates in the bins is less than 260 F or more than 350 F, or if the aggregates contain sufficient moisture to cause foaming in the mixture, such aggregates shall be removed from the bins. Material having once gone through the mixing plant shall not be returned to the stockpiles without having been reprocessed.

3.3 Hot Storage System.

3.3.1 The hot storage system shall be capable of conveying the hot-mix from the plant to insulated storage bins and storing the hot-mix without a loss in temperature, segregation of the mix, or oxidation of the mix. Storage time duration shall be limited by the ability of the bins to maintain the hot-mix so that, upon delivery to the spreader, the temperature will be minimum 250 F as specified in 3.5.1.2.

3.3.2 The conveyor system may be a continuous type or skip bucket type. If the continuous type is used, it shall be enclosed to prevent a drop in mix temperature. If the skip bucket type is used, the bucket must be of sufficient capacity to transport an entire batch and mass dump into the bins.

3.3.3 The storage bins shall be designed in such a manner as to prevent segregation of the hot-mix during discharge from the conveyor into the bins and shall be equipped with discharge gates that will not cause segregation of the hot-mix while loading the mix into the trucks. The storage bin heating system shall be capable of maintaining the mix temperature without localized heating (hot spots).

3.3.4 Unless otherwise permitted, material placed in a surge or storage bin must be drawn from that bin and used during the same working day. When such permission is given in an emergency, material remaining overnight must be used within 24 hours of the time of mixing.

150

3.3.5 Approval for the use of storage bins may be withdrawn in event there is an excessive amount of heat loss, segregation, and/or oxidation of the hot-mix due to the use of storage bins.

3.4 Weighing and Hauling.

3.4.1 Tested and sealed truck scales shall be provided at each plant; portable scales shall be checked after moving and before being used. Each truck shall be tared twice daily or as often as directed. A weathertight building of sufficient size to house the scaleman while operating the scales shall be provided. It shall be the responsibility of the Contractor to arrange for the above sealing of scales.

3.4.2 The weight of each truckload of paving mixture, as indicated by the truck scales, shall be within plus or minus 3 per cent of the total weight of all batches in the load. Failure to maintain this standard of uniformity shall be sufficient cause for stoppage of plant operations until the cause of such disparity in weight is corrected.

3.4.3 The Contractor may provide an approved printer system which will print the weights of the material delivered. Such weights shall be evidenced by a weigh ticket for each load.

3.4.4 In lieu of plant and truck scales, the Contractor may provide an approved automatic printer system which will print the weights of the material delivered, provided the system is used in conjunction with an approved automatic batching and mixing control system. Such weights shall be evidenced by a weigh ticket for each load.

3.4.5 The mixture shall be transported from the paving plant to the work in trucks having tight, smooth, metal beds previously cleaned of all foreign materials. Each load shall be covered with canvas or other suitable material of sufficient size and thickness to protect it from weather conditions. The inside surface of vehicles may be lightly lubricated with a thin oil or soap solution, but an excess of lubricant will not be permitted to accu-

151

mulate in low spots in the body. When necessary, so that the mixture will be delivered on the project at the specified temperature, truck beds shall be insulated and covers shall be securely fastened. Equipment which leaks oil, diesel fuel, gasoline, or any other substance detrimental to the pavement will not be allowed on the project.

3.5 Placing.

3.5.1 Weather Limitations. Mixtures shall be placed only when the underlying surface is dry, when the atmospheric temperature in the shade is above 40 F, and when the weather is not foggy or rainy, provided, however, that the Engineer may permit, in case of sudden rain, the placing of mixture then in transit from the plant, if laid at proper temperature and if the roadbed be free from pools of water. Such permission shall in no way relax the requirements for quality of the pavement and smoothness of surface. No material shall be laid upon a frozen base course or when wind conditions are such that rapid cooling will prevent satisfactory compaction. No load shall be sent out so late in the day that spreading and compaction cannot be completed during daylight.

3.5.1.1 In special instances, when the Engineer determines that it is in the best interest of the State, he may waive the requirements of 3.5.1.

3.5.1.2 Any material delivered to the spreader having a temperature lower than 250 F shall not be used.

3.5.2 At the beginning and end of the project or project sections, at bridges, and at side road approaches, the existing pavement shall be removed to a sufficient depth to allow the placing of the new pavement to a minimum thickness of 1½ inches unless otherwise ordered. The underlying course shall be clean and free from foreign materials and loose bituminous patches and must present a dry, unyielding surface except that surfaces of any of the base courses which have been exposed for a considerable length of time such as

152

over the winter, when ordered, shall be covered by a tack coat of emulsified asphalt. Contact surfaces of manhole frames and other joints as ordered shall be painted with a thin coating of suitable bituminous material. The bituminous material for any tack coat shall be applied by means of a power sprayer or by other satisfactory methods.

3.5.3 Structures within the limits of the pavement shall be set and raised in accordance with the provision of 604.3.4.

3.5.4 Expansion joints and all other joints or cracks in existing cement concrete pavement containing filler and being wide enough to permit raking shall have any filler removed to a depth of at least 1 inch below the surface of the concrete. The joints and cracks shall then be completely filled with an approved sand-bitumen mixture or other satisfactory non-extruding materials.

3.5.5 When a leveling course is ordered, the material shall be placed on the prepared clean underlying surface at the locations designated, and spread to produce a smooth and uniform patch. Generally, a grader shall be used to spread the mixture; with the approval of the Engineer, however, other means of spreading, such as by a finishing machine or by hand, may be used. The patch material shall be thoroughly compacted and shall match the line and grade of the adjacent existing pavement.

3.5.6 Except as otherwise required or permitted, all courses shall be spread and finished to the required thickness by a mechanical, self-propelled spreading and finishing machine of an approved type. Sufficient material shall be produced and delivered to keep the paver operating continuously except for necessary short stops. When production and delivery of the mixture can be practicably maintained, it is desirable that pavers be used in echelon to place the surface course in adjacent lanes.

3.5.6.1 The paver shall be capable of spreading the mixtures with a finish that is smooth, true to

153

the required cross section, uniform in density and texture, and free from hollows, tears, gouges, corrugations, and other irregularities; and shall be capable of spreading and finishing courses of the required thicknesses and lane widths.

3.5.6.2 The paver hopper gates shall be adjusted to pass the correct amount of mix to the spreading screws so that the screws will operate more or less continuously. The material around the screws shall be maintained at a level which will make the tips of the screws visible but not the shaft.

3.5.6.3 The activated screed or strike-off assembly shall operate by cutting, crowding, vibrating, or other practicable action without tearing, shoving, or gouging the mixture. The paver shall be equipped with a screed heater which shall be used when starting a cold machine and for maintaining a suitable screed temperature when needed. In the traveled way, the activated portion of the screed shall extend the full width of the mixture being placed; extensions to the screed will be allowed only in the following areas: shoulders, tapers, adjacent to curbs, and other locations as permitted. Broadcasting behind the paver shall be held to a minimum.

3.5.7 Automatic screed control devices will be permitted if it can be demonstrated that a satisfactory pavement can be constructed.

3.5.8 When hot bituminous wearing course for bridges is to be placed over membrane waterproofing, the lower thickness of wearing course shall be applied by hand or by machinery as permitted below, in either case leaving a minimum of 1 inch thickness to be placed by a mechanical spreader. The lower thickness may be applied by the use of a mechanical paver instead of by hand, provided the paver is mounted on rubber tires and provided that no damage is done to the membrane waterproofing, either by trucks or by the paver, when using this method. During warm weather, it is suggested that this mechanical paving be done during the cool period of the day.

154

3.5.9 Where pavement is placed adjacent to structural members such as expansion joints, the material in the top course shall be placed so that under no circumstances will the finished grade be lower than the finished grade of the structural member — the grade of the pavement shall preferably be between ⅛ and ¼ of an inch above the grade of the structural member.

3.5.10 When permitted, relatively small areas such as small bridge decks and areas not accessible to the finishing machine may be spread by hand, but extreme care shall be taken to create a surface texture similar to the remainder of the work. Surface material shall be spread by lutes and not by rakes.

3.6 Compaction.

3.6.1 Immediately after the bituminous mixture has been spread, struck off, and surface irregularities adjusted, it shall be thoroughly and uniformly compacted by rolling. The initial rolling of the **base courses** shall be done with a steel-wheeled roller of either the static or vibratory type. If the initial rolling is done with a static roller, this operation shall be followed by the use of a pneumatic-tired roller. The initial rolling of the **surface course** shall be done with a static steel-wheeled roller, after which a pneumatic-tired roller shall be used. Final rolling of each course shall be done with a roller of the 3-axle type, locked. Rollers must be in good mechanical condition, free from excessive backlash, faulty steering mechanism, or worn parts. The empty weight and the ballasted weight shall be properly marked on each roller. The minimum weight of static steel-wheeled rollers shall be 8 tons. The minimum applied force of vibratory steel-wheeled rollers shall be 40,000 pounds. Vibratory rollers shall have separate controls for energy and propulsion and be specially designed to compact bituminous mixtures. When a vibratory roller is being used, the vibration shall be stopped while the roller is stopped or reversing its direction of travel.

155

3.6.2 Pneumatic-tired rollers shall be self-propelled and shall be equipped with smooth tires of equal size and diameter. The wheels shall be so spaced that one pass of a 2-axle roller will accomplish one complete coverage. The wheels shall not wobble and shall be equipped with pads which will keep the tires wet. The rollers shall provide an operating weight of not less than 2,000 pounds per wheel. All tires shall be maintained at a uniform pressure between 55 and 90 psi with a 5 psi tolerance between tires. A suitable tire pressure gage shall be available on each roller.

3.6.3 Unless otherwise directed, rolling shall begin at the sides and proceed longitudinally parallel to the road center line, each trip overlapping one-half the roller width, gradually progressing to the crown of the road. When paving in echelon or abutting a previously placed lane, the longitudinal joint shall be rolled first followed by the regular rolling procedure. On superelevated curves, the rolling shall begin at the low side and progress to the high side by overlapping of longitudinal trips parallel to the center line.

3.6.4 Rollers shall move at a slow but uniform speed with the drive roll or drive wheels nearest the paver except on steep grades. Base courses shall be rolled until all roller marks are eliminated. The wearing course shall be rolled until all roller marks are eliminated and a minimum density of 95 per cent of laboratory specimens made by the Marshall method in the proportions of the job-mix formula has been obtained.

3.6.5 Any displacement occurring as a result of the reversing of the direction of a roller, or from other causes, shall be corrected at once by the use of lutes and addition of fresh mixture when required. Care shall be exercised in rolling not to displace the line and grade of the edges of the bituminous mixture.

3.6.6 To prevent adhesion of the mixture to the rollers, the wheels shall be kept properly moistened with water or water mixed with very small quantities of detergent or other approved material. Excess liquid will not be permitted. All steel rollers shall be equipped with adjustable wheel scrapers.

3.6.7 Along forms, curbs, headers, and smiliar structures, and other places not accessible to a normal full-sized roller, sidewalk rollers weighing at least 2,000 pounds shall be used whenever possible. Where rollers are impracticable, the mixture shall be thoroughly compacted with heated or lightly oiled tampers.

3.6.8 Unless the Engineer determines that for the tonnage and placement conditions a lesser number will be satisfactory to obtain the desired pavement densities, the following is the list of required compaction equipment. The output of each paver placing **base course** materials shall be compacted by the use of one each of the following complement of rollers as a minimum: a static roller and a pneumatic-tired roller — or a vibratory steel-wheeled roller — followed in either case by a 3-axle tandem roller. The output of each paver placing **surface course** materials shall be compacted by the use of one each of the following complement of rollers as a minimum: a static steel-wheeled roller, a pneumatic-tired roller, and a 3-axle tandem roller.

3.7 Joints.

3.7.1 The first lane placed shall be true to line and grade and shall be trimmed by hand to a stringline if necessary to obtain a true longitudinal joint. The longitudinal joints in the base courses shall be made so that the joint in the wearing course will be in the center of the pavement and will not be directly above the joint in the previous course.

3.7.2 The material being placed next to a previously placed lane shall be tightly crowded against the face of the abutting lane. The finishing machine shall be positioned so that in spreading, the material will overlap the edge of the first lane by 1

156

157

401

inch to 2 inches and shall be left sufficiently high to match the first laid lane after compaction.

3.7.3 Placing of the course shall be as nearly continuous as possible, keeping the number of transverse joints at a minimum while still being able to make a hot longitudinal joint.

3.7.4 If it is necessary to make an undesirable number of transverse joints in order to achieve a hot center joint, or if the work is performed between October 1 and May 1, infra-red joint heater devices shall be used on all longitudinal and transverse joints in the surface course unless otherwise permitted.

3.7.4.1 This device, hereinafter referred to as "heater," shall consist of an infra-red generator energized by L.P. propane gas attached to the side of the bituminous spreader and located so as to heat at least 4 inches on each side of the edge of the previously laid bituminous course. The heater shall be constructed so as to permit adjustment of heat intensity in accordance with prevailing conditions. The speed of paving shall be governed by the efficiency of the heater. The infra-red generator shall provide heat energy with the complete absence of direct flame upon the pavement and with a generator orifice pressure of at least 10 psi to assure windproof performance. The units shall be equipped with pilot lights and arranged so that the burners may be controlled from the paver. The previously laid material shall not be heated to more than 300 F.

3.7.5 If a bulkhead is not used to form the transverse joints, the previously laid material shall be cut back to expose the full depth of the course. Unless the joint is to be heated with a heater, the face shall be painted with approved bituminous material before the fresh mixture is placed against it. Extreme care shall be taken to insure that no uneveness occurs at the joint. If unsatisfactory riding qualities are obtained at the transverse joint in the wearing course, the Engineer may order the

158

use of heaters to warm and loosen the surface in order to take away material or add new material.

3.7.6 If it is necessary to leave a longitudinal joint until it becomes cold — such as where the lanes are left not squared off at the end of the day's work or where a third lane is to be paved at a later date — and the joint is not to be heated with the heater, the joint face shall be painted with approved bituminous material before the fresh mixture is placed.

3.8 Test Requirements.

3.8.1 The Contractor shall furnish and have available a 10-foot metal straightedge at the paver at all times during paving operations. All courses shall be tested with the straightedge laid parallel to the center line and any variations from a true profile exceeding 3/16 of an inch shall be satisfactorily eliminated. The finished surface of the pavement shall be uniform in appearance, free from irregularities in contour and shall present a smooth-riding surface.

3.9 Replacement.

3.9.1 If any imperfect places are found in any course, the Contractor shall remove the unsatisfactory material and replace it with satisfactory material after painting the exposed edges with suitable bituminous material.

3.10 Application of Requirements.

3.10.1 Except as specifically noted, these construction requirements shall apply equally to all courses.

3.11 Finished Appearance.

3.11.1 Any bituminous material splashed or sprayed onto exposed surfaces of curbs, sidewalks, or other masonry structures shall be removed by sandblasting or by the use of another approved method, at the Contractor's expense.

Method of Measurement

4.1 Plant mix bituminous pavement will be measured by the ton to the nearest 0.1 of a ton, and in accordance with 109.01. Batch weights will be permitted as a method of measurement only when the alternate provisions of 3.4.3 are met, in which case payment will be based on the cumulative weight of all the batches. The tonnage shall be the weight used in the accepted pavement and no deduction will be made for the weight of bituminous material or additives in the mixture.

4.1.1 Due to possible variations in the specific gravity of the aggregates, and to possible field changes in areas to be paved, the tonnage used may vary from the proposal quantities and no adjustment in contract unit price will be made because of such variation.

4.2 When the surface course of the wearing course for a bridge is placed in combination with the adjacent roadway, thereby precluding the obtaining of separate weight slips for road and for bridge, the weight of bridge wearing course will be computed, using the following constants per inch (nominal) thickness per square yard: 105 pounds for gravel mix and 110 pounds for stone mix. The weight of bridge wearing course will be deducted from the total approved tonnage to obtain the net roadway total.

4.3 Bituminous concrete removed because of faulty workmanship or admixture of foreign materials will not be included in the pay tonnage.

Basis of Payment

5.1 All work performed and measured as prescribed above will be paid for as provided in the respective sections for each type specified.

5.2 Liquid bituminous material ordered under 3.5.2 will be paid for under Item 410.

§304:Page 127 - 9/22/75(2)
Amend the last sentence of 304.2.1.2 to read:

The maximum size stone particles shall not exceed 3/4 of the compacted thickness of the layer being placed.

§304:Page 128 - 9/20/74(1)
Amend the last sentence of 304.2.1.3.3 to read:

Also, not more than 15 percent of the fraction passing the No. 4 sieve shall pass the No. 200 sieve.

§304:Page 128 - 11/1/77(3)
Add to 304.2.1.3:

2.1.3.7 The gravel course of drives which are not designed to be paved under 403 shall consist of crushed bank-run gravel meeting the requirements set forth in 2.1.3.3 as amended.

§304:Page 128 - 9/20/74(1)
Amend 304.2.3.1 to read:

2.3.1 For a preliminary determination of compliance with the specification for grading, samples of sand and gravel may be taken from the pit and samples of crushed gravel may be taken from the stockpile or from the final phase of the crushing operation. Materials obviously not meeting the grading requirements shall not be placed on the roadway. Samples for provisional approval of material in place will be taken as the spreading operations progress on each lift just prior to the beginning of the compaction operations on that lift. Final testing will not be done until the material has been compacted. See 3.3.6.

§301:Page 129 - 9/22/75(2)
Amend 304.3.3.3 to read:

3.3.3 Unless the Contractor's method of operation and his material is such that oversized stones are not delivered to the project, each entire layer of gravel shall be thoroughly scarified for the full depth of the layer to bring all oversized stones to the surface for disposal prior to placing the subsequent course.

§304:Page 130 - 9/22/75(2)
Amend 304.3.4.3 to read:

3.4.3 Water shall be uniformly applied over the base materials during compaction in the amount necessary for proper consolidation. Rolling and shaping shall continue until each layer conforms to the required grade and cross section, and the surface is smooth and uniform. When vibratory equipment is being operated, the amplitude of vibrations may be adjusted as necessary to avoid causing damage to adjacent buildings and property. Sand, gravel, and crushed gravel layers shall each be compacted with vibratory or other approved rollers and shall be rolled sufficiently so that additional passes of the equipment will produce only a negligible impression.

3.4.3.1 As a referee test, the density of sand will be determined by AASHTO T 191 (Sand Cone Method), AASHTO T 204 (Drive Cylinder Method), or by the use of Nuclear Densometer equipment and shall be not less than 95 percent of maximum density determined in accordance with AASHTO T 99.

3.4.3.2 As a referee test, the density of gravel and crushed gravel will be determined by the use of Nuclear Densometer equipment and shall be not less than 95 percent of maximum density determined on a short control test section.

§304:Page 131 - 11/1/77(3)
Add to 304.3:

3.7 GRAVEL DRIVES AND DRIVES TO BE SURFACE-TREATED ONLY.

3.7.1 Drives which are not designed to be paved shall be constructed according to the pertinent provisions of this Section except that 3.4.3.2 will not apply.

Add to Pay items and units:

304.95	Crushed Gravel for Unpaved Drives	Cubic Yard

§401:Page 133 - 11/1/77(3)
Amend 401.2.1.1.1 to read:

2.1.1.1 Stockpiles will not be acceptable if more than 10 percent of a representative sample passes the No. 10 sieve.

§401:Page 133 - 11/1/77(3)
Add to 401.2.1.2:

2.1.2.1 Stockpiles containing aggregate larger than 3/8 inches shall not be used.

§401:Page 135 - 11/1/77(3)
Add to 401.2.2:

2.2.2 Until such time as bituminous material furnished from Canada is graded on the viscosity basis, asphalt cement from Canada will be accepted based on the penetration grading. The grade shall be that approved by the Materials and Research Engineer.

§401:Page 135 - 9/22/75(2)
Add, in 401.2.4.1, after the sentence ending with the words "and a single temperature at which the mixture is to be delivered at the point of discharge," the sentence:

The temperature is subject to change as ordered, depending upon the conditions of the day.

§401:Page 137 - 9/22/75(2)
Amend the heading of 401.3.1.2 to read:

3.1.2 SAFETY REQUIREMENTS FOR INSPECTION.

§401:Page 149 - 9/22/75(2)
Amend 401.3.2.2 and 3.2.3 to read:

3.2.2 The Engineer may adjust the job mix formula temperature within the limits of 260 F and 350 F according to the existing conditions. During hot weather, the temperature of the mixture when discharged shall be as low as is consistent with proper mixing and placing. During cold weather, a temperature approaching the upper limit is desirable. Material with a temperature at discharge outside the job mix formula tolerance may be rejected. In no case will a mixture be accepted with a discharge temperature in excess of 375 F.

3.2.3 If the aggregate in the hot bins contains sufficient moisture to cause foaming in the mixture, such aggregate shall be removed from the bins and the production rate shall be reduced so as not to exceed the capability of the dryer. Material having once gone through the mixing plant shall not be returned to the stockpiles without having been reprocessed.

§401:Page 152 - 9/20/74(1)
Add to 401.3.5.1:

Except when directed, wearing course shall not be placed after October 1 of any year.

§401:Page 153 - 9/22/75(2)
Amend 401.3.5.5, 3.5.6, and 3.5.7 to read:

3.5.5 Except as otherwise required or permitted, all courses shall be spread and finished to the required thickness by approved type, self-contained, power-propelled spreading and finishing machines (pavers). Pavers shall be provided with an adjustable, activated screed or strike-off assembly, and shall be capable of spreading the mixtures with a finish that is smooth, true to the required cross section, uniform in density and texture, and free from hollows, tears, gouges, corrugations, and other irregularities; and shall be capable of spreading and finishing courses of the required thicknesses and lane widths. Horizontally oscillating strike-off assemblies will not be approved.

3.5.5.1 The activated screed or strike-off assembly shall operate by cutting, crowding, vibrating, or other practicable action without tearing, shoving, or gouging the mixture. The activated portion of the screed shall extend the full width of the mixture being placed in the traveled way; outside of the traveled way, such as on shoulders, tapers, and areas adjacent to curbs, and at other locations as permitted, non-activated extensions to the screed will be allowed. Broadcasting behind the paver shall be held to a minimum. The paver shall be equipped with a screed heater which shall be used when starting a cold machine and for maintaining a suitable screed temperature when needed.

3.5.5.2 The paver hopper gates shall be adjusted to pass the correct amount of mix to the spreading screws so that the screws will operate more or less continuously. The height of material shall be maintained at a constant level in front of the screed, to a point where approximately half of the auger shaft shall be visible at all times.

3.5.5.3 Pavers shall be equipped with a control system capable of automatically maintaining the required screed elevation. The control system shall be automat-

... from either a reference line or surface
... of mechanical sensors or sensor-directed
... devices which will maintain the paver screed
... proper transverse slope and at the proper
... to obtain the required surface. When directed,
... slope control system shall be made inoper-
... screed shall be controlled by sensor-directed
... anisms which will independently control the
... each end of the screed from reference lines

... controls shall be capable of working in
... any of the following attachments:

... type device of not less than 30 feet in
... length or as directed.
... wireline set to grade.
... ski or shoe.

... The Contractor shall furnish the long ski
... ski or shoe and furnish and install all
... and wire for a taut line.

... pavers shall not be used until the automatic
... been checked and approved by the Engineer.
... speed of the paver shall be adjusted to the
... supply of material so that the paver will be
... not having to make any but emergency stops.
... determines that the paving operations
... excessive stopping of the paver, he may suspend
... operations until the Contractor makes arrange-
... to synchronize the rate of paving with the rate of
... materials.

... Whenever a breakdown or malfunction of the
... controls occurs, the equipment may be operated
... other methods for the remainder of the
... day on which the breakdown or malfunction
... provided this method of operation will produce
... satisfactory work meeting specifications.

... on projects or parts of projects where the
... that the use of automatic controls are
... he may permit manual operation of the

... production and delivery of the mixture
... fully maintained, it is desirable that pavers
... ready to place the surface course in adjacent

... patching of existing pavement is ordered,
... shall be placed on the prepared clean under-
... the locations designated, and spread to
... and uniform patch. Generally, a grader
... spread the mixture; with the approval of
... Engineer, other means of spreading, such as
... machine or by hand, may be used. The
... shall be thoroughly compacted and shall
... and grade of the adjacent existing pavement.

... - 11/1/77(3)
... to read:

... Hot bituminous bridge pavement is to
... membrane waterproofing, unless other-
... ed, the 1" base course shall be placed
... s after the waterproofing membrane has
... The use of a mechanical paver to
... course will be permitted when the
... ed on rubber tires and provided that
... one to the membrane waterproofing,
... paver or by trucks--otherwise, the
... shall be placed by hand. During warm
... suggested that the above mechanical
... during the cool period of the day. A
... shall be used to place the top
... course.

§401:Page 155 - 9/29/74(1)
Add to 401.3.5:

3.5.11 Unless otherwise authorized, the final wearing course shall not be placed until after guard rail posts have been set and general cleanup has been completed.

In 401.3.6.1, amend the sentence reading "The minimum applied force of vibratory steel-wheeled rollers shall be 40,000 pounds" to read:

The minimum applied dynamic force of vibratory steel-wheeled rollers shall be 27,000 pounds.

§401:Page 157 - 9/20/75(1)
In 401.3.6.8, amend the words "base course" to read:

base and binder courses.

§401:Page 157 - 9/22/75(2)
Add to 401.3.6.8:

If the required density is not being obtained with the rollers supplied, the use of additional rollers of the specified type may be ordered.

Add after the first sentence of 401.3.7.1:

Material not trimmed away shall be packed against the lane by means of lutes, leaving a uniform joint with a vertical or nearly vertical face. Outside joints in subsequent lanes shall be similarly trued, as directed.

§401:Page 158 - 9/20/74(1)
In 401.3.7.4, near the end of the paragraph, delete the words "in the surface course."

§401:Page 158 - 9/22/75(2)
Amend 401.3.7.4.1 to read:

3.7.4.1 This device, hereinafter referred to as "heater," shall consist of an infra-red generator energized by L. P. propane gas attached to the side of the bituminous spreader and located so as to heat at least 4 inches on each side of the edge of the previously laid bituminous course. The heater shall be constructed so as to permit adjustment of heat intensity in accordance with prevailing conditions. The heater furnished shall aggregate at least 8 feet long. The speed of paving shall be governed by the efficiency of the heater. The infra-red generator shall provide heat energy with the complete absence of direct flame upon the pavement and with a generator orifice pressure of at least 10 psi to assure windproof performance. The units shall be equipped with pilot lights and arranged so that the burners may be controlled from the paver. The previously laid material shall not be heated to more than 300 F.

§403:Page 161 - 9/22/75(2)
Amend 403.1.2 to read:

1.2 Blank.

§403:Page 162 - 9/22/75(2)
Add to Pay items and units:

403.71	Hot Bituminous Pavement, Single Course, Machine Method	Ton
403.72	Hot Bituminous Pavement, Single Course, Hand Method	Ton