Milling and Planing of Flexible Pavement

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In 1975, a 38-mm (1.5-in) layer of asphalt concrete was removed from 12 km (7.5 miles) of four-lane divided pavement using three different methods: hot milling, cold milling, and hot planing. The site, NY-5 between Albany and Schenectady, is a major thoroughfare with an average annual daily traffic volume of 28 000 to 50 000 vehicles. Its curb and expensive color-contrasted median made removing and replacing the wearing course more economical than raising curbs and manholes and reconstructing the median. Air and noise pollution were monitored, and neither exceeded industrial or construction limits. Tests on the asphalt before and after removal showed virtually no effect on its properties, although the three machines had very different operating characteristics. Their effective removal widths ranged from 1.5 to 3.7 m (5 to 12 ft), the depths from 10 to the full 38 mm (0.4 to 1.5 in) in one pass, and the forward speeds from 3.1 to 12.2 m/min (10 to 40 ft/min). The net result was an effective removal rate—full depth per 10-h day—of 1505 to 5936 m^2 (1800 to 7100 yd^2). All three machines provided efficient means of removing old asphalt, but several factors must be considered before selecting any of the processes for a given location.

For years scarifying was the only method used to remove a specific thickness of flexible pavement in New York State. The result was irregularities in the surface that required a major truing-and-leveling course, which increased costs. In addition, scarification was used only on projects of less than 20 900 m^2 (25 000 yd^2); anything larger required a full-scale reconstruction program.

In the fall of 1974, the New York State Department of Transportation examined the possibility of removing flexible pavement by other means and then overlaying to the same grade. Three general techniques—planing with heat, milling with heat, and milling without heat—were found. Each is unique and has advantages and disadvantages. We decided, therefore, to compare them on a single project.

Early in 1975, personnel of the Engineering Research and Development Bureau and design engineers from Region 1 (the Albany area) agreed that 12 km (7.5 miles) of NY-5 (Central Avenue) between Albany and Schenectady could be used. This highway could no longer be overlaid because its drainage inlets were already well below the proper grade. Another 38 mm (1.5 in) of overlay would have made them deep enough to create a driving hazard. Curb heights would have been reduced to only a couple of inches, and the color-contrasted median would have to have been rebuilt.

Each of the three techniques was evaluated on the basis of (a) precision of cutting depth, (b) production rate, (c) air and noise pollution, and (d) depth of heat penetration. Skid tests were performed on the original pavement, on the planed or milled surfaces, and on the new overlay. The pavement was sampled both before and after each process and the samples physically analyzed for changes in penetration and viscosity. The possibility of reusing material was explored, and cores were extracted to examine the bond between the overlay and the milled or planed surface.

TEST SITE AND EQUIPMENT

The test site is a four-lane divided highway with a 3.7-m (12-ft) median. The average annual daily traffic (AADT) volume is 27 260 vehicles, although for the highway's busiest section, where there are several large shopping centers, AADT is 49 200. The 12-km (7.6-mile) section to be rehabilitated was divided into three areas of about 64 750 m^2 (77 460 yd^2); each process removed 38 mm (1.5 in) of existing pavement thickness (Figure 1).

Heater-Planer

The heater planer (Figure 2A), furnished by Jim Jackson of Little Rock, Arkansas, heats, planes, and cuts the existing surface; blades the cuttings into a windrow; and loads them into a truck. The remaining surface appears smooth but is abrasive in texture. The operating width of the machine is 2.4 m (8 ft) and the wheelbase 5.5 m (18 ft), with tandem rear driving wheels. It can cut 9.5 mm (0.4 in) deep in one pass, flush to all curbs, inlets, manholes, or other obstructions within the paved areas. Open flames fueled by liquid propane provide the heat. Two virtually identical heater-planers were used interchangeably throughout the test section.

Hot Miller

The hot miller (Figure 2B), furnished by the Wirtgen Corporation of Ridgefield, New Jersey, mills the flexible pavement surface after heating it with both open-flame and infrared burners fed by propane gas. It can mill 51 mm (2 in) deep and 3.6 m (12 ft) wide in one pass. The resulting surface has a waffled texture with striations no more than 9.5 mm (0.4 in) deep. This unit is not self-contained and requires a grader, an autoloader, and occasionally a front-end loader to remove the milled material.

Cold Miller

The cold miller (Figure 2C), furnished by the G. J. Payne Company of Carson, California, mills a flexible pavement surface to a depth of 51 mm (2 in) without heat. It has a 1.5-m (5-ft) wide drum for milling and blades for windrowing the milled material. The milled surface has a waffled texture with striations no more than 9.5 mm (0.4 in) deep. It is not self-contained and requires a payloader to remove loose material. Two millers, differing only in their dust control (water spray) systems, were used.

At the end of each work day, a full two-lane width of surfacing had to be removed to prevent drop between lanes in the same direction. Each operation was followed by a vacuum sweeper before the lane was opened to traffic. The planed or milled surface had to be ±6.35 mm (±0.25 in) of the design grade, have a 21-mm/m (0.25-in/ft) cross-slope, and could not be torn, gouged, shoved, broken or excessively grooved.

SAMPLING PROCEDURES

Pollution

Air and noise pollution were monitored before and during

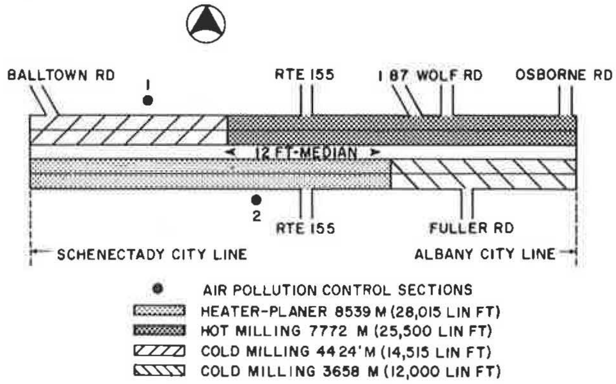


Figure 1. Planing and milling locations (not to scale).

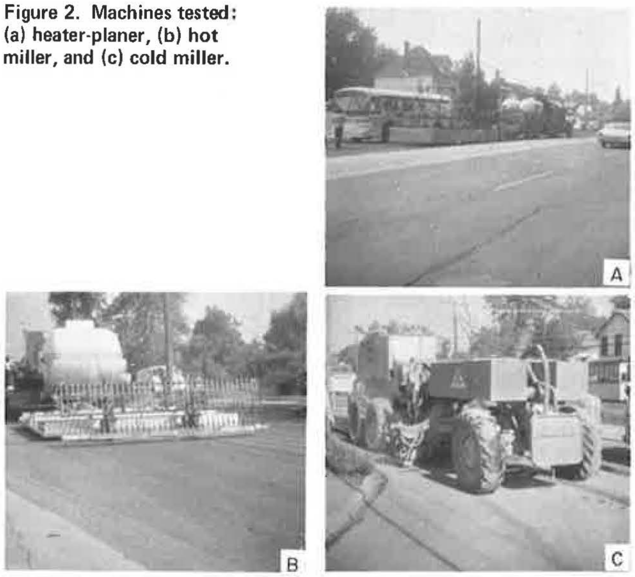


Figure 2. Machines tested: (a) heater-planer, (b) hot miller, and (c) cold miller.

milling and planing. Readings taken before the work began established normal levels for the area.

For air pollution, both particulate and hydrocarbon emissions were monitored. The particulate sampler was mounted on a hand cart and pulled alongside the machines. Filters from the sampler were taken to the laboratory, where particulates were determined in micrograms per cubic meter. Two types of hydrocarbon samples were used, one for readouts at the job site and the other for analysis at the laboratory.

The first was an infrared hydrocarbon analyzer that worked on the nondispensive infrared principle: Energy from an infrared source is absorbed by hydrocarbons. Direct readouts were recorded at the burner units, in front of the machine, and 4.6 m (15 ft) away. The second hydrocarbon collector was a glass cylinder containing activated charcoal, connected in series with a limiting orifice and pump (Figure 3). After collecting the sample, the cylinder was capped and returned to the laboratory, where the filters were analyzed and the results recorded in micrograms per liter.

Each machine's noise level was measured at five points—two approaching the noise meter, one at it, and two past it (Figure 4). The meter was positioned 1.4 m (4.5 ft) above the ground and recorded noise for an accumulated time of only 2 min in any hour in decibels on the A scale [dB(A)], the frequency response closest to that of the human ear (1, p. 2). In addition, a 20-min tape recorded for each machine from 45.7 m (150 ft) before the meter to 15.2 m (50 ft) past it and provided permanent records.

Heat Penetration

Temperatures were measured in the pavement below the machines that used heat. Thermocouples were inserted in the pavement and connected to an automatic recorder that produced a reading every 3 s.

PHYSICAL ANALYSES AND DISCUSSION

The pavement was sampled before and after planing and milling to determine if any oxidation had occurred. The samples were chemically analyzed in the laboratory to check penetration at 25°C (77°F) in accordance with AASHTO T 49 and ASTM D 5 and viscosity at 60 and 132°C (140 and 275°F) in accordance with AASHTO T 202 and AASHTO T 201, respectively.

Skid tests using the state's skid trailer were run before and after each process. In addition, production rate was monitored to establish daily productivity of each machine in square meters.

Air Pollution

Particulates

The normal particulate count along the route was done by New York State Department of Environmental Conservation personnel, who sampled air twice before work was in progress. Each sampling lasted 4 continuous hours on 4 consecutive days and showed particulate concentrations of 85 and 318 $\mu g/m^3$. Several samples, taken beside each device, gave recorded concentrations 5 to 10 times greater near the heating devices and several thousand times greater near the cold miller (Table 1). However, while these concentrations were extremely high within 1.5 m (5 ft) of these devices, they dropped markedly with increasing distance.

Because the particulates are relatively heavy, they do not remain suspended for any significant time. Thus, at 7.6 m (25 ft) from the machines, concentrations were well within any industrial limits. Also, the wide range of measured values for each machine was explained by prevailing winds and gusts, either natural or from passing vehicles.

In sum, large concentrations of solid particulates were found near the devices—particularly the cold miller—but they did not disperse to an objectionable degree.

Hydrocarbons

These were measured by two methods, charcoal sampling tubes and an infrared analyzer. Table 1 summarizes the hydrocarbon emissions, recorded by the first method, which were similar for all three machines. Results for the cold millers, however, are questionable, because asphalt particles may have entered the tubes and increased the readings. Substantiating this was the fact that no hydrocarbons were detected by the infrared analyzer. Table 2 shows that, although high hydrocarbon concentrations were found in the flame areas of the heating devices 4.6 m (15 ft) from the machines, concentrations were significantly lower; no hydrocarbons were detected from the cold miller at any distance. The intense heat is thought to have vaporized hydrocarbons at the road surface directly under the burners, but they would quickly revert to their liquid or solid states as soon as temperatures fell to ambient levels a meter or so away.

All machines were below the maximum allowable industrial limit of 133 000 µg/m³ at any distance. The results show that hot planing creates least hydrocarbons and hot milling the most. The infrared analyzer, on the other hand, showed that neither produced any significant concentration and that cold-milling produced no detectable hydrocarbons.

Noise Pollution

While New York State has not established standard noise level specifications, tentative limits have been developed and are used here (2, p. 15). The highest recorded noise level, 94 dB(A), was produced at the meter by the hot miller's vacuum sweeper, a piece of equipment already in general use; its autoloader was next, at 92 dB(A). All other equipment ranged from 70 to 89 dB(A). In the tentative New York noise pollution specification, the maximum allowable noise level at 7.6 m (25 ft) would be 94 dB(A) for an accumulated time of 6 min during any 1 h. Thus, Table 3 shows that no milling or planing machine or any related equipment exceeded the proposed requirement.

Figure 3. Hydrocarbon collector with charcoal filters.

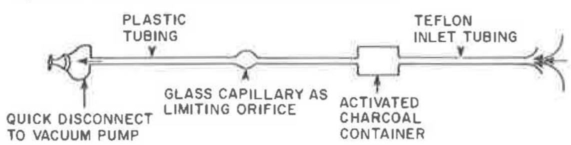
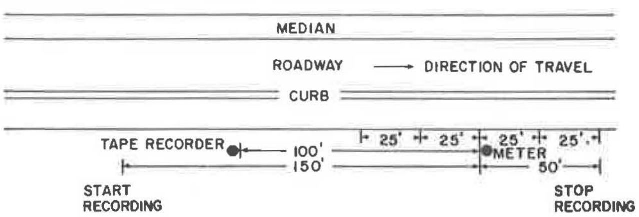


Figure 4. Noise pollution measured incrementally as planer and millers approached and passed meter and continuously by a tape recorder; meter and recorder set up 7.6 m (25 ft) from curb.



Heat Penetration

Little prior information existed on depth of heat penetration or any damage to existing pavement resulting from the use of these machines. This was investigated by using an automatic temperature recorder. Figure 5 shows general heat penetration with depth, and Table 4 gives general temperatures of the existing and removed surfaces. The heater-planer can be seen to have generated tremendous open-flame heat, creating surface temperatures over 176°C (350°F) that penetrated the pavement to a depth of only 6.35 to 9.5 mm (0.25 to 0.40 in).

This is the key to shaving or planing the pavement, because when a depth of 12.7 mm (0.5 in) was tried, the pavement began to shear in large chunks. Since the temperature at this depth was about 66°C (150°F), it would appear that below 76°C (170°F) the pavement is too cool to be planed or shaved. This also implies that the generally used minimum compactive temperature of 76°C is also the beginning temperature for effective removal by planing or shaving.

Figure 5 shows penetration under the hot miller to be similar to that under the planer, but, because of its milling action, the miller removed pavement regardless of temperature. While the hot miller produced surface temperatures of only 132°C (270°F), it penetrated the pavement as well as the planer did. The infrared heater and the miller's slower operating speed obviously led to greater penetration. The hot miller removed the full 38.1 mm (1.5 in) in one pass, so it was actually cold milling (based on 76°C) below the 12.7-mm depth.

Table 4 shows the heat retention of the removed material and indicates a large variation in temperatures of material being loaded into the trucks. Although the hot miller's heat penetrated the pavement more effectively, blending of cooler material from below 9.5 mm yielded cooler material—±32°C (90°F). The heater-planer loaded the heated material without blending, and temperatures were about 76°C (170°F).

Physical Analysis

Pavement samples taken before and after each process were analyzed in the laboratory for penetration and vis-

Table 1. Air pollution measurements.

Process	Particulates (µg/m³[a])	Charcoal Sampler for Hydrocarbons (µg/L[a])	Process	Particulates (µg/m³[a])	Charcoal Sampler for Hydrocarbons (µg/L[a])
Control	85 to 320	0.07	Cold miller 303[b]	23 560 to 152 000	0.20 to 0.48
Heater-planer	1 280 to 2 430	0.04 to 0.48	Cold miller 304[b]	60 780 to 450 000	0.22 to 0.46
Hot miller	1 950 to 2 950	0.10 to 0.90			

[a] Readings were taken within 1.5 m (5 ft) of each machine.
[b] Both millers, differing only in spray-bar capacity, were used in both cold-milling test areas.

Table 2. Hydrocarbon sampling by infrared analyzer.

Process	Probe Location	Approximate Concentrations (µg/m³)[a]		
		Number	Mean	Standard Deviation
Heater-planer	In flame area, unprotected	13	24 672	2 195
	In flame area, wrapped in asbestos	21	19 152	38 770
	About 4.6 m from machine	58	1 796	1 796
Hot miller	Attached to front of machine, open-flame burner on slightly	116	17 822	20 150
	Attached to front of machine, infrared burner on full	23	57 257	39 900
	1.5 m ahead of machine, infrared burner off	24	0	0
	1.5 m ahead of machine, infrared burner on	115	11 172	8 113

[a] Background readings before milling or planing for control purposes showed no detectable concentrations of gaseous hydrocarbons; maximum industrial standard allowable is 200 ppm.

cosity, with a view to recycling and the attendant need to determine material changes. Two test series, each including four samples, were performed for each of the three reconstruction processes. Table 5 gives the means for each test. No significant differences appeared at the 95 percent confidence level, using both the F- and the t-tests. Thus, the material was neither damaged nor oxidized by the burners or millers.

Skid Resistance

All surfaces were tested before and after each operation to determine any changes in skid resistance (Table 6). Only one value is given for the original surface, but it represents the entire length. All processes resulted in skid numbers much greater than 30, a value generally identifying unacceptable pavement.

Unfortunately, the milled and planed surfaces did be-

Table 3. Noise measurements.

Process	Noise Levels [dB(A)[a]] 15 m Before Meter	7.6 m Before Meter	At Meter	7.6 m Beyond Meter	15 m Beyond Meter
Heater-planer	70	76	82	76	80
Hot miller	78	80	81	80	85
Cold miller	78	83	86	87	86

Note: 1 m = 3.3 ft.

[a]Taken at 2-min maximum times, 7.6 m from the curb. The proposed maximum at that distance is 94 dB(A) for an accumulated time of 6 min during any 1 h.

Figure 5. Penetration of heat from pavement surface.

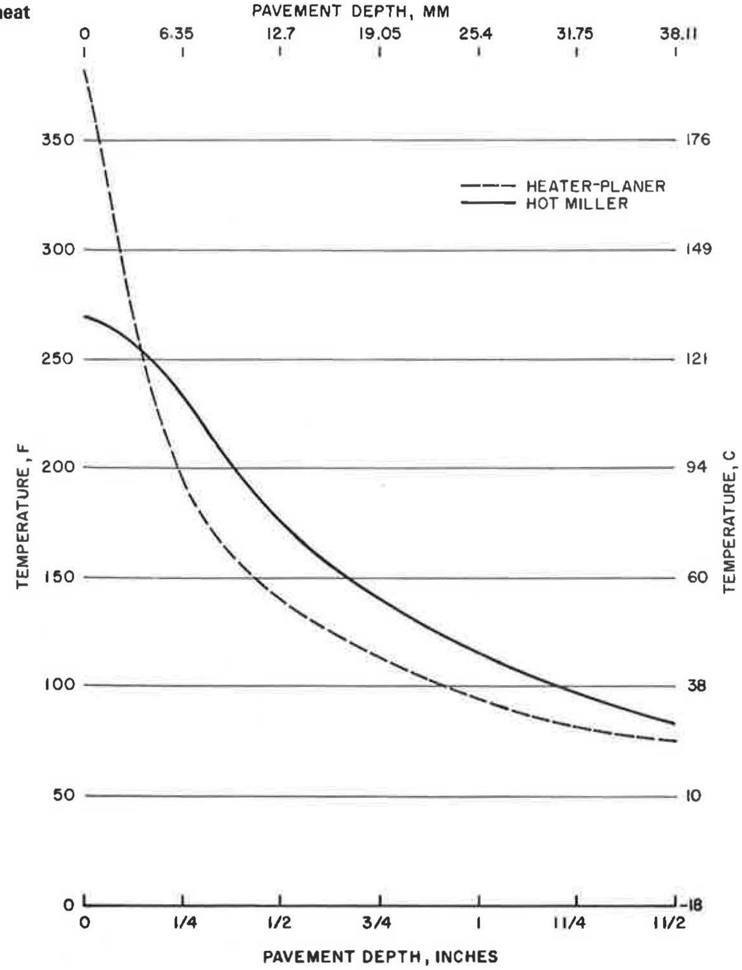


Table 4. Overall average temperatures.

Process	Temperature (°C) Surface After Burners but Before Planing or Milling	In Windrow	After Loading in Truck	Remaining Surface After Planing or Milling
Heater-planer	176[a]	76	76	49
Hot miller	132	54	32	32

Note: 1°C = (1°F - 32)/1.8.

[a]Maximum possible reading on thermometer.

come smoother with time. Although additional skid tests could not be scheduled, a similar condition was observed when transverse grooves were cut for drainage on a rural four-lane, divided flexible pavement having an AADT of 6000 vehicles. These grooves began closing in a few weeks and within 8 weeks were fully closed and smoothed out. Thus, it is doubtful that the milled or planed surfaces would be acceptable for any length of time, and resurfacing should follow milling or planing within 2 weeks.

PRODUCTION RATE AND GENERAL COSTS

After pavement removal, production rates were calculated for each of the three operations, in terms of square meters of pavement removed per 10-h day. It should be noted that hot milling was a one-machine operation, while hot planing and cold milling both involved two machines. Also, not all were always in use, so that working day figures in Table 7 are not necessarily half the machine day figures.

To remove the entire 38.1 mm (1.5 in) of material from the 7.3-m (24-ft) wide roadway in one direction, the hot miller required two passes, the cold miller five passes, and the heater-planer twelve passes. On the other hand, the hot miller progressed at an average speed of 3 m/min (10 ft/min), the cold miller at 4 m/min (13 ft/min), and the heater-planer at 12.2 m/min (40 ft/min), resulting in respective production rates of 5956, 1884, and 1500 m^2/machine day (7124, 2254, and 1794 yd^2/machine day).

Although the hot miller had the highest production rate, it required the most supplementary equipment. Directly behind it was a power grader to windrow the milled material, followed by an autoloader to place the

Table 5. Physical properties.

Process	Time	Penetration at 25°C, 0.1 mm (100 g/5 s) Mean	Standard Deviation	Viscosity at 60°C (Pa·s) Mean	Standard Deviation	Viscosity at 135°C (m^2/s) Mean	Standard Deviation
Heater-planer	Before	41.0	8.9	783.7	2302	7.38	1.496
	After	41.0	10.7	1062.1	3781	8.43	0.616
Hot miller	Before	48.6	10.7	853.1	2209	8.64	0.982
	After	50.0	17.4	848.4	5734	7.70	1.354
Cold miller	Before	33.0	3.8	1331.3	3265	8.73	0.782
	After	32.0	6.3	1533.0	7036	9.06	1.653

Note: 1 g = 0.035 oz., 1 Pa·s = 0.021 lbf·s/ft², 1°C = (1°F - 32)/1.8, and 1 m²/s = 0.039 ft²/h.

Table 6. Skid-resistance measurements.

Process	Original Pavement Number	Mean	Standard Deviation	After Process Number	Mean	Standard Deviation	New Pavement Overlay Number	Mean	Standard Deviation
Heater-planer	26	35.4	3.4	40	51.9	4.5	6	45.3	3.8
Hot miller				15	49.5	4.9	16	46.8	1.5
Cold miller				4	54.8	3.8	21	46.9	2.9

Table 7. Production rates.

Process	Avg. Machine Speed (m/min)	Cutting Width per Pass (m)	Avg. Cutting Depth per Pass (mm)	Total Working Days	Total Machine Days	Avg. Material Removed Daily (m^2)	Material Removed per Machine Day (m^2)	Total Material Removed 38 mm (m^2)
Heater-planer	12.2	2.4	9.5	23.3	43.9	2862	1500	65 831
Hot miller	3.0	3.7	38.1	10.1	10.1	5956	5956	60 153
Cold miller	4.0	1.5	38.1	20.5	33.9	2903	1884	63 883

Note: 1 m = 3.3 ft, and 1 mm = 0.039 in.

Table 8. Typical gradations.

Process	Sieve Size (mm) 25.4	12.7	6.35	3.17	Sieve Size (μm) 841	420	177	74	Pan
Hot miller	100.0	92.7	60.5	11.7	2.6	1.4	0.6	0.3	0.0
Cold miller	97.2	82.9	61.0	33.5	8.4	4.0	1.4	0.3	0.0

Note: 1 mm = 0.039 in, and 1 μm = 0.039 mil.

Table 9. Pavement overlay thickness.

Process	Core Sample of Overlay Thickness (mm) 1	2	3	4	5	6	7	Mean	Standard Deviation
Heater-planer	41.28	47.63	28.58	44.45	38.10	45.45	53.98	42.63	7.96
Hot miller	53.98	38.10	38.10	44.45	53.98	34.93	31.75	42.18	8.93
Cold miller	53.98	44.45	50.80	34.93	38.10	50.80	38.10	44.45	7.56

Note: 1 mm = 0.039 in.

material in trucks. Occasionally, a front-end loader removed material missed by the autoloader. Also, because of its size, this machine had limited maneuverability, which meant more hand removal around utility boxes, drainage inlets, and traffic-counter loops. Cold milling needed only a front-end loader to remove material and could mill in close quarters leaving very little for hand removal. The heater-planer was self-contained and required very little hand removal. These are important considerations in determining which machine to use in a particular situation. The hot miller is by far the most efficient, but its size may not be suitable for narrow city streets, and the equipment train must be considered at intersections where traffic cannot be effectively diverted for a long time.

Material Reuse

Both milling processes removed material in pieces ranging from 25.4-mm to 75-μm (1-in to no. 200) sieve. Table 8 summarizes gradations for both the cold- and the hot-milling processes. Such gradations could not be run on hot-planed material, which, on cooling, fused into large conglomerates. Before cooling, however, material from hot planing looked like well-graded 1A top and hot enough—79°C (175°F) or more—to transport to other locations to be placed, leveled, and somewhat compacted into a solid, firm surface course.

In one location, a parking lot of about 7432 m^2 (8888 yd^2) for sanitary waste trucks, this material was placed 101 mm to 152 mm (4 to 6 in) thick and leveled by a bulldozer. Although the surface was not rolled, it held together firmly and supported large loads of truck traffic.

A second location was a small trailer park, where the material was dumped and leveled by a small farm tractor with a plow. A third location was an automobile junkyard that used material in a muddy area from the heater-planer and from cold and hot milling. The milled material was placed in the same way as crushed stone in a muddy zone, and formed a strong, firm base. Although all the milling and planing material was used immediately, the milled material could have been stockpiled for later use.

Overlay Thickness

Seven cores were drilled at random from each milling or planing location after the new wearing course was placed. We examined these microscopically for thickness because of the difficulty of distinguishing between the new pavement and the older surface. The mean thickness for the hot miller and heater-planer (Table 9) was 42.4 mm (1.67 in) and for the cold miller 44.5 mm (1.75 in). The standard deviation for the processes was about 7.6 mm (0.3 in). Based on these cores, all processes removed more than the required 38.1 mm (1.5 in), but the mean depth stayed within a 6.4-mm (0.25-in) tolerance. In addition, as the need for a microscope shows, the bond between the overlay and the milled or planed surface was extremely tight.

SUMMARY AND CONCLUSIONS

The alternative to these milling and planing operations was full reconstruction—a costly, lengthy choice that would have inconvenienced motorists, nearby residents, and businesses. According to design estimates, completion would have taken about a year and a half and cost \$2 to \$2.5 million. This project, on the other hand, took only 47 d from the first milling and planing operations to completion of the new overlay. It cost less than \$900 000. Thus, from the points of view of both cost and convenience, this operation was successful. Our specific conclusions follow.

1. None of the operations exceeded any tentative or established air or noise pollution standards. All machines would be acceptable in residential areas.
2. The effective pavement softening temperature—76°C (170°F)—did not penetrate beyond the 9.5 mm (0.4 in) by the heater-planer, or beyond 12.7 mm (0.5 in) by the hot miller, which cold milled below that depth.
3. A great deal of heat and propane were lost or expended by the heater-planer's open flame. The hot miller used about half as much propane.
4. None of the operations oxidized or in any other way damaged the removed material; nor did they have any adverse effect on the remaining pavement.
5. The hot miller was the only one of the three machines capable of removing the entire 38.1 mm (1.5 in) of material for an entire lane width in one pass. The heater-planer had a maximum cut 9.5 mm (0.4 in) deep and 2.4 m (8 ft) wide, while the cold miller cut the full depth only 1.5 m (5 ft) wide.
6. The hot miller was less versatile than the other operations in terms of removing material from around obstructions and requiring more hand removal.
7. The heater-planer contained its own material pickup belt that required only haul trucks to follow it and consequently had the shortest lane closure behind it.
8. From randomly drilled cores, hot milling and hot planing were found to achieve a mean depth of 42.4 mm (1.67 in), and cold milling 44.5 mm (1.75 in). The design called for removal of 38.1 mm (1.5 in) by all three operations.
9. Planed or milled material can be reused. Hot-planed material can be transported and replaced within 40 min of removal to form a firm, fairly smooth riding surface. Hot- and cold-milled material served as an excellent base and may lend itself to recycling for resurfacing.
10. These processes have proved excellent where pavement must be removed in busy areas and cause minimum disruption while maintaining proper slope and grade.

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Abridgment

Roadside Management in North Carolina

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North Carolina's climate favors the establishment and rapid growth of vegetation and is complemented by a topography that ranges from flatlands and swamps to rugged mountains and valleys interspersed with streams, rivers, and waterways. Across this terrain, North Carolina maintains the largest state highway system, approximately 120 968 km (75 021 miles), in this country. Maintaining the roadside of this vast highway network at an acceptable level for minimum costs is a formidable challenge. The potential for degrading our natural environment through inadequate, improper, or untimely roadside maintenance is great.

Recognizing this, the North Carolina Division of Highways adheres to a philosophy of roadside maintenance that attempts to maintain a highway facility in as near its original condition as age, normal deterioration, and changing traffic conditions will permit. We also improve those roadside areas where time and nature will assist in the enhancement of the facility.

In recent years, significant design changes have greatly improved the state's ability to maintain our roadsides.

1. Generally, flatter slopes are maintained near the travelway and the cut slopes of drainage channels. This will ultimately facilitate slide removal and maintenance of storm drainage systems.
2. Drainage berms across and down the backs of cut slopes have increased their stability and thus reduced maintenance.
3. Low-growing shrubs and plants at bridge ends reduce the effort required to keep these areas stable and presentable.
4. Detailed erosion control contract specifications and construction standards that include permanent and life-of-contract measures increase the stability of slopes, minimize obstruction of drainage structures caused by erosion, and consequently reduce related maintenance.
5. Ditches inside and outside the typical section are receiving appropriate treatment, such as paved ditches, jute mesh, and fiberglass roving, to minimize erosion. The combination of more stable slopes and ditches will greatly reduce or eliminate the need for back sloping and ditch pulling.
6. By leaving silt detention basins, ditch checks, and silt fences in place after a project is completed, the new project will stabilize itself in time and reduce or eliminate the possibility of damage caused to areas outside the rights-of-way. In the recent past, it was not uncommon for maintenance crews to be required to clean out drainage structures and remove eroded materials from adjacent property almost immediately after acceptance of a new project.

In spite of these and other similar design modifications, anticipated maintenance costs in North Carolina are increasing at an annual rate considerably in excess of anticipated revenue increases. These increases are projected on the basis of no additional maintenance personnel and in spite of a recent 14 percent reduction in our equipment fleet. The professional staff of the Division of Highways is not at this time advocating or anticipating any reduction in the level of services in the foreseeable future. However, it is obvious that the projected increases in the cost of maintenance operations and declining growth rates in revenues cannot continue indefinitely. North Carolina must take every measure possible to offset the spiraling cost of maintenance by better managing maintenance resources and continuing to incorporate into construction projects those features that will result in reduced future maintenance costs.

North Carolina is progressing steadily in the development of a maintenance management system that has reached the stage where planned work quantities and cost of an annual maintenance program by line item activity on both a county and a statewide basis can be reasonably projected. Work is proceeding toward developing the means and methods that will permit objective evaluation of the effectiveness of our efforts and will properly rank line item maintenance activities.

Roadside maintenance is a critical part of the maintenance management process, as indicated by the cost of the following activities in North Carolina.

Activity	Annual Cost ($000 000)
Maintenance of unpaved shoulders	9.7
Routine mowing	5.5
Manual and machine clearing of the roadway	3.5