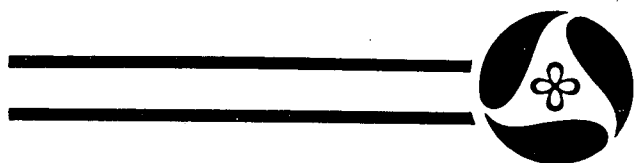


Pavement Profiling By Milling

**Addendum to
Iowa Highway Research Board
Project HR-283**

September 1988

Highway Division



**Iowa Department
of Transportation**

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Iowa Highway Research Board
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PAVEMENT PROFILING
BY MILLING

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DISCLAIMER

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ABSTRACT

Iowa DOT research in 1986, demonstrated that carbide tooth milling can produce an acceptable surface texture. Based upon that research, specifications were developed for "Pavement Surface Repair (Milling)". This specification was applied to reprofile a nine-mile section of badly faulted portland cement concrete (pcc) pavement on route 163 just east of Des Moines. The Profile Index (measured with a 25-foot California Profilograph) was improved from an average of 55.2 inches per mile prior to milling to 10.6 inches per mile after milling. The bid price was \$0.75 per square yard for pcc containing limestone coarse aggregate and \$1.21 for pcc containing gravel coarse aggregate. Carbide tooth milling should be considered as an acceptable alternate method of reprofiling even though there is some spalling of joints.

INTRODUCTION

Iowa has over 13,000 miles of pcc pavements. Due to the abandonment of rail lines, there has been increased freight shipment by truck. This, in conjunction with undoweled joints and inadequate underslab drainage, has resulted in substantial mileage of faulted pavement. Iowa has initiated a program to reprofile these faulted pavements. This is currently accomplished by diamond grinding which costs approximately \$2.20/sq. yd.

The use of carbide tooth milling to remove or smooth pcc pavement began over ten years ago. Initially, milling was used to quickly remove a thin surface layer as preparation for an overlay. This resulted in a very coarsely textured surface. Research in 1986 using a greater number of teeth demonstrated that milling can produce a smoother, more acceptable surface texture (1).

PROJECT LOCATION AND DESCRIPTION

The project selected for the first milling profiling of faulted pcc pavement was Polk FN-163-1(42)--21-77 on Iowa route 163 just east of Des Moines. The road is a four-lane, divided pavement beginning at Pleasant Hill and extending easterly 9.1 miles. The profile index of the pcc pavement ranged from 21.0 to 111.8 inches per mile (0.1 mile segments) with a weighted average of 55.2 inches per mile measured with a 25-Foot California Profilograph.

The major item on the rehabilitation project was installation of longitudinal subdrain. The successful bidder was Feldman Bros.

Landscaping, Inc. of Letts, Iowa. The "Pavement Surface Grinding Milling Limestone-65,518 sq.yds" was bid at \$0.75/sq. yd and the "Pavement Surface Repair Milling Gravel-54,691 sq. yds" was bid at \$1.21/sq. yd. Some of the pcc pavement was made with gravel coarse aggregate while other was made with crushed limestone coarse aggregate. The gravel is harder to cut than the limestone.

The milling was sublet to All Purpose Utility of LaVista, Nebraska (phone 402-331-2550).

MILLING EQUIPMENT

The mill was a 12-foot wide Barber Greene equipped with a mandrel manufactured by Keystone Engineering & Manufacturing Corporation of Indianapolis, Indiana (phone 317-271-6192). The teeth were arranged in two spiral wraps around the drum. Depth of cut was controlled by a sliding ski.

A narrow Gallion mill was used to blend significantly different levels between the driving and passing lanes.

MILLING PROFILING

Profiling began on November 6, 1987 in the eastbound lane at the east end of the project. All milling proceeded against the normal traffic flow. The cutting depth by individual teeth was very irregular. Iowa DOT Supplemental Specification 1044 (Appendix A) required 60 cutting teeth per foot at a transverse spacing of approximately 5mm. The distance between teeth cutting marks meas-

ured approximately 10mm. The relatively blunt nosed teeth were causing substantial joint spalling (Fig. 1). Efforts were made to adjust the position of the teeth to produce a satisfactory cut. Subsequent milling was reviewed on November 12, 1987. There was still substantial irregularity. The subcontractor elected to suspend the milling operation until 1988.

Milling profiling resumed July 6, 1988. The subcontractor had obtained a new mandrel from Keystone Engineering & Manufacturing Corp. The teeth cutting marks on the pavement were spaced at approximately 5 mm and the cutting plane was very uniform producing an acceptable texture.

The conveyor for removing the material cut from the surface was not attached to the Barber Greene. The material was windrowed behind the machine on the milled surface. The cuttings were bladed onto the shoulder. The surface was then swept clean. An immediate inspection of the milled surface was not possible due to the deposited material. Ridges resulting from broken teeth were not apparent until after the brooming which sometimes amounted to 1000 feet.

There was much less damage to transverse joints than that of the November 1987 milling (Fig. 2). The subcontractor had changed to sharper teeth than those used in November 1987. Another factor in the reduced damage may have been the 90°F+ temperatures with subsequent thermal expansion of the pcc pavement.

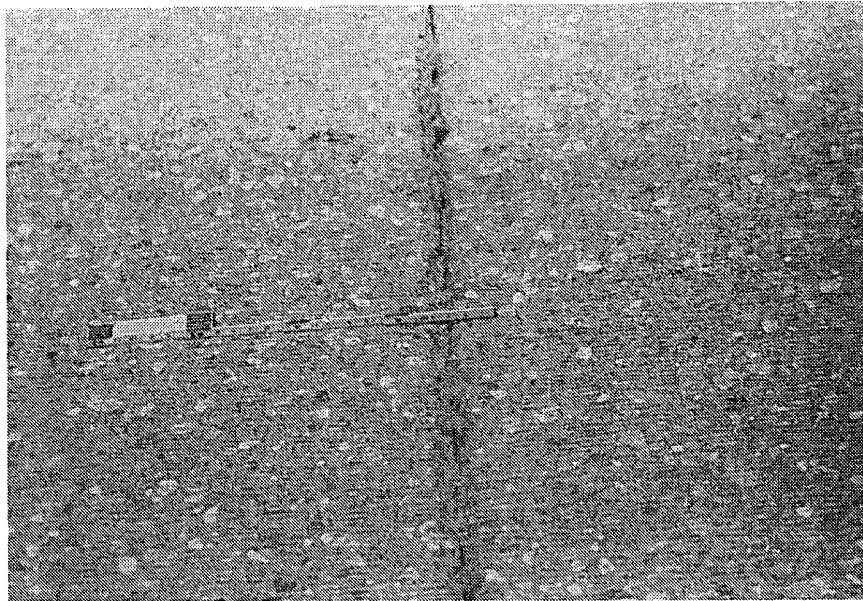


Figure 1
Substantial Joint Spalling

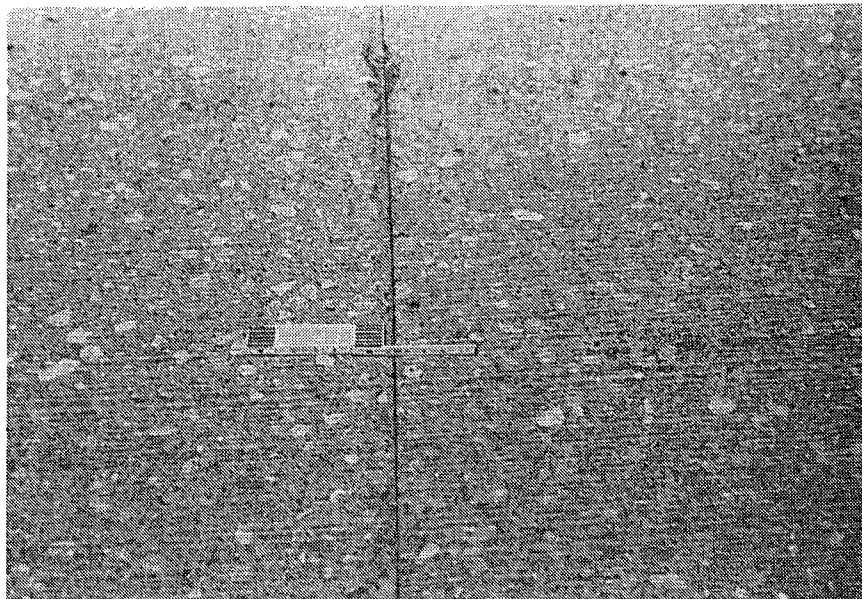


Figure 2
Very Little Joint Spalling

Milling profiling was completed on July 25, 1988. In general, the texture of the milled surface was very good. There were some areas where the forward speed of the mill was too fast resulting in visible corrugations (Fig. 3). These are considered objectionable.

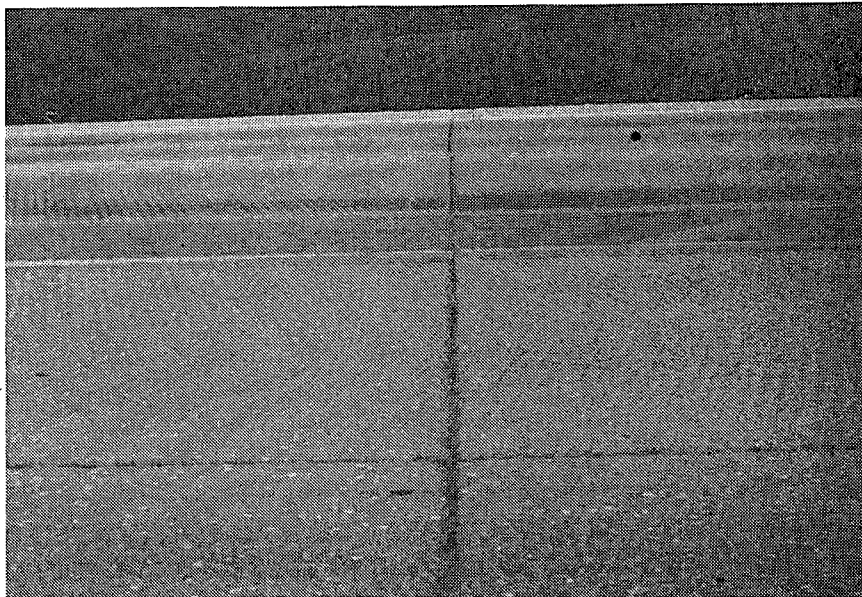


Figure 3
Objectionable Corrugations

TESTING AND EVALUATION

The Profile Index (July 13-20, 1988) of the once milled surface ranged from 2.0 to 34.5 inches per mile with a weighted average of 10.6 inches per mile. Regrinding was required on some pavement that exceeded the 15 inch per mile specification. The reground sections ranged from 0.0 to 5.6 inches per mile with an average of 2.4 inches per mile.

Friction testing of the milled surface on August 12, 1988 yielded an average friction number (FN) of 44 with a treaded tire and an FN of 35 with a nontreaded tire. The unmilled passing lane yielded a FN of 45 with a treaded tire and a FN of 18 with the nontreaded tire.

CONCLUSIONS

The evaluation of milling profiling supports the following conclusions:

1. Profiling with a mill equipped with carbide teeth spaced at 5 millimeters will produce an acceptable surface texture and should be considered as an acceptable method of reprofiling.
2. Milling with sharper teeth during warmer summer temperatures results in much less damage to transverse joints.
3. The milled surface yields FN's equivalent to those of unmilled surface with a treaded tire and a substantial improvement over

the unmilled surface with a smooth tire. This indicates a substantial improvement in wet-weather friction qualities.

RECOMMENDATIONS

The following changes to the specification are recommended for future Pavement Surface Repair (Milling) projects:

1. Require sharp pointed cutting teeth with a point not greater than 75°.
2. Milling shall progress against the direction of traffic.
3. The material milled from the surface shall not be deposited on the newly milled surface.
4. The drum shall produce a uniformly cut surface, free of ridges or valleys. Broken teeth shall be replaced immediately.
5. Milling profiling shall be allowed between June 15 and September 30.
6. There shall be no transverse troughs due to lowering the drum below the cutting plane (caused by continued down pressure when forward motion of the machine has stopped).

REFERENCE

1. Marks, V. J., "Pavement Texturing by Milling", Iowa DOT, January 1987

Appendix A



Iowa Department of Transportation

 SUPPLEMENTAL SPECIFICATION
 for
 PAVEMENT SURFACE REPAIR (MILLING)

September 1, 1987

THE STANDARD SPECIFICATIONS, SERIES OF 1984, ARE AMENDED BY THE FOLLOWING MODIFICATIONS. THESE ARE SUPPLEMENTAL SPECIFICATIONS, ANY THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

1044.01 DESCRIPTION. This work shall consist of milling the surface of asphalt or portland cement concrete pavement to improve the surface profile and cross section, for use as a traffic surface without resurfacing. The intention is also to improve surface texture.

For the purpose of this specification, milling is a general term meaning removal of a pavement surface, in accord with the plans, by milling with cold-planing equipment.

The work shall be done according to the plans and this specification. The plans will identify the type of coarse aggregate used in the concrete. A copy of the profilograph trace for the project or a typical part of the project is to be available in the Office of Contracts for inspection by prospective bidders. After the letting, the trace will be available from the Engineer.

Milling shall extend across bridges only when specifically designated.

1044.02 EQUIPMENT. Milling equipment shall be capable of removing the pavement surface to the necessary depth. Cold-planing equipment shall be used. The width shall be such that not more than two cuts will be necessary in each normal-width traffic lane. The milling drum shall have a minimum of 60 cutting teeth per foot of width with a transverse spacing of approximately 5 mm. The milling equipment shall be automatically controlled on one side and also with cross-slope control or shall be automatically controlled on both sides.

A rotary broom described in 2001.14 shall be used to clean the milled surface.

Water shall be used as necessary to avoid a traffic hazard and a dust nuisance.

1044.03 CONSTRUCTION. The plans will show the intended pavement surface repair and/or the intended new cross section, and the surface shall be milled as required.

Pavement surface repair shall consist of milling the entire surface of the pavement in a longitudinal direction. Substantially the entire surface area of the pavement shall be milled until the pavement surface on both sides of the transverse joints and all cracks are in the same plane and have the same surface texture and the pavement meets the smoothness requirement. In each lane, at least 95 percent of the area in each 100-foot section shall have a newly textured surface. Except at or near joints and cracks, milling shall not exceed 1/2 inch in depth. At joints and cracks, milling shall not exceed 1 inch in depth.

Milling shall be done in a longitudinal direction. Milling shall begin and end at lines normal to the pavement centerline within any one milled area and at the project limits. However, this will not be required at the end of each shift. The depth of adjacent cuts shall be controlled so as to result in a smooth, uniform cross section, free from irregularities between adjacent cuts of the milling equipment. Each traffic lane shall be milled with not more than two cuts, but additional passes in the cutting path may be necessary to secure a smooth profile. A single cut shall not extend to both sides of the centerline or a laneline between traffic lanes; however, the first cut at the centerline or laneline shall overlap the jointline approximately 2 inches, to minimize spalling. The jointmatch, if any, between two cuts in a traffic lane shall be within 1 foot of the center of the lane, to avoid joints directly in the wheel path, and shall be reasonably straight or parallel to the centerline or laneline. Each cut shall be designed to maintain the existing crown and a taper from centerline to pavement edge.

The transverse slope of the milled pavement shall be uniform to a degree that there is no depression or misalignment greater than 1/4 inch in 12 feet when tested by stringline or straightedge placed perpendicular to the centerline. The jointmatch between two adjacent cuts shall match with 1/8 inch.

The finished surface shall have a uniform, coarse texture, subject to approval of the Engineer. The forward speed of the milling machine shall be controlled so as to prevent the formation of visible corrugations on the pavement surface.

1044.04 SMOOTHNESS. The finished, milled surface shall have a final profile index not exceeding 15.0 inches per mile, using a standard 0.2-inch blanking band, with no individual bump exceeding 0.5 inch in 25 feet, unless otherwise specified.

The pavement may have been profiled or partly profiled by the Engineer using a procedure similar to that described in Section 2316. The bidder is advised that this profilograph information is available for inspection at the DOT office in Ames, by a request to the Contracts Engineer. After the contract is awarded, the profilograph information will be available from the Engineer. This information represents a summary of conditions found to exist at the time the survey was made. The bidder may use this information as he sees fit. The appearance of this information will not constitute a guarantee that a profile other than that indicated will not be encountered at the time of milling.

The milled surface shall be tested and evaluated in accord with Section 2316, with the following modifications.

1. The test is to be run and the profilograph is to be evaluated using the same procedure as for the original trace.
2. Each segment, as evaluated, shall meet the smoothness and bump requirements specified above. Short sections are to be combined, as provided in 2316.03A. (See General Supplemental Specification for Construction Projects.)
3. The evaluation will consider skipped areas and areas where excess in milling would have been necessary to meet smoothness requirements, as described in 1044.03. In these areas, smoothness requirements will be modified or may be waived by the Engineer.

4. The Contractor shall certify smoothness of the finished surface in accord with 2316.02C. (See General Supplemental Specification for Construction Projects.)
5. The Engineer may test for smoothness and bumps near the centerline and at other spot locations where compliance is questioned. Additional milling may be required.

1044.05 LIMITATIONS. The Contractor shall use every reasonable means to protect persons and vehicles from injury or damage that might occur because of his operations. During the construction, the Contractor shall provide such traffic control as required by the plans. Articles 1107.08 and 1107.09 shall also apply.

This work shall be done with only one lane closed, and traffic control shall be as shown on the plans.

Requests for nighttime work will be favorably reviewed for approval by the Engineer. For such work, appropriate lighting will be required. Except for nighttime work, the work schedule shall be adjusted so that all barricades and equipment are removed from the roadbed from 30 minutes before sunset to 30 minutes after sunrise, and overnight lane closures will not be permitted. No work will be permitted on Sundays or holidays described in 1108.03.

Milling may progress in the direction or against the direction of traffic in the adjacent lane. However, all construction traffic entering or leaving the work area shall move in the direction of traffic.

Removal of all slurry or residue resulting from the milling operations shall be continuous. Pavement and paved shoulders must be left in a clean condition. Residue from milling operations should not be permitted to flow across lanes occupied by public traffic or to flow into gutters or other drainage facilities. This residue may be disposed of on the shoulder foreslope and in accord with 1104.08.

When other work is included in the contract, the operations shall be sequenced so that undersealing, longitudinal subdrains, patching, milling, installation of load transfer, and crack and joint sealing are done in an area in that order. Also, all of these operations required by the contract should be completed in an area in the same construction season, or not started until the following construction season.

1044.06 METHOD OF MEASUREMENT. The Engineer will calculate the area of Pavement Surface Repair (Milling), satisfactorily completed, for pavement of each type of coarse aggregate from the length of each milled area and the nominal pavement width, as shown on the plans.

1044.07 BASIS OF PAYMENT. For the number of square yards of Pavement Surface Repair, (Milling Limestone) or (Milling Gravel), completed and measured as provided above, the Contractor will be paid the contract price per square yard. This payment is full compensation for furnishing all equipment, materials, and labor to mill the pavement and test for smoothness according to the plans and this specification, including removal and/or disposal of slurry and residue from this operation.