IOWA DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

BONDED, THIN-LIFT, NON-REINFORCED PORTLAND CEMENT CONCRETE RESURFACING

MAY 1977

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May 1977

by

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PURPOSE

The purpose of this report is to describe Iowa's first attempt at constructing a bonded, thin-lift, non-reinforced portland cement concrete resurfacing project.

SCOPE

The scope of this report is threefold: 1) to explain the development of the specifications, mix designs, and construction methods, (2) to describe and discuss each of the various phases of the project, and (3) to provide recommendations for changes in specifications and procedures for use on future projects of thin-lift concrete resurfacing.

ABSTRACT

In October, 1976, the Iowa Department of Transportation constructed a 1500 ft. (457 m) long project of thin lift (2 inch - 50 mm) bonded, portland cement concrete resurfacing on a concrete pavement. The project was located on U.S. 20, at the east edge of Waterloo, in Black Hawk County.

The project was conceived because of two developments: (1) the availability of a high production scarifying machine, the Roto-Mill Profiler, and (2) super water reducing admixtures to provide workability in concrete with lower than normal water-cement ratios.

The objectives of the project, with pertinent comments, are listed below.

<u>Objective 1.</u>

To determine the feasibility of proportioning, mixing, placing, and finishing a thin lift (approximately 2 inches - 50 mm) of bonded, dense, non-reinforced portland cement concrete using conventional slip-form plant and paving equipment in resurfacing existing concrete pavements.

Comments:

Objective was achieved. Some problems with uniform mixing, and discharging, from transit mix trucks. Material was readily placed with slip form paver. Refinements of proportioning, mixing, delivery, are still needed. Uniformity of concrete mixture will most likely alleviate the finishing problems experienced. More knowledge and experience is needed with use of super water reducing admixtures.

<u>Objective 2.</u>

To determine the feasibility of partial depth repair of deteriorated transverse joints in concrete pavements using a bonded, dense, non-reinforced, portland cement concrete.

Comments:

Existing partial depth repairs, with and without resurfacing, are performing excellently to date. Recommend additional research to determine (1) if partial depth repair is a viable alternate to traditional full-depth repair in different pavement conditions, and (2) the minimum requirements for concrete mixtures used for partial depth repair.

<u>Objective 3.</u>

To determine if an adequate bond between the existing pavement and an overlay of thin lift, dense, non-reinforced portland cement concrete can be obtained. (Surface scarified with Roto-Mill).

Comments:

Objective achieved to our satisfaction. Delamination testing indicates complete bond attained and still

existing to date. Shear testing at the interface indicates very high bond strengths, 1000 psi (6.9 megapascals) ± average. Additional research recommended to determine if sufficient and lasting bond can be attained when old surface is cleaned rather than scarified. Additional equipment development needed to provide for mechanical application of grout.

Objective 4.

To determine the economics, longevity, and maintenance performance of a bonded, thin lift, non-reinforced portland cement concrete resurfacing course as a viable alternate to bituminous resurfacing of concrete pavements.

Comments:

Concrete paving industry spokesman indicate that competitive initial construction costs are quite possible. Refinements to procedures, equipment, etc., as mentioned above, as well as a larger sized project are needed to verify expectations.

Conclusions:

Iowa's first attempt to apply its bridge deck repair and overlay procedures and techniques to pavement resurfacing was successful as verified by the experience and test results of the short Demonstration Project on U.S. 20.

Additional research is required to refine the procedures, equipment, techniques, etc., in order to provide designers with a viable alternate for concrete pavement restoration and rehabilitation. Objectives of that research should be:

(1) To determine the mixing and proportioning procedures required in using a conventional, central mix proportioning plant to produce a dense portland cement concrete mixture using standard mixes with super water reducing admixtures.

(2) To determine the economics, longevity, and maintenance performance of a bonded, thin-lift, non-reinforced portland cement concrete resurfacing course using conventional procedures, equipment, and concrete paving mixtures both with and without super water reducing admixtures.

(3) To determine if an adequate bond between the existing pavement and an overlay of thin lift, dense, non-reinforced portland cement concrete can be obtained with only special surface cleaning and no surface removal or grinding.

INTRODUCTION

Iowa has many thousands of miles of paved Primary and Interstate highways, Secondary or County roads, and City streets. Many of these streets and highways, constructed of portland cement concrete, have been in service in excess of forty years with little or no surface maintenance and no additional wearing surface. Many, however, and especially those carrying high volumes of traffic, are in need of surface attention at this time. The serviceability (rideability) is approaching, if not having arrived at, the point where surface restoration, or reconstruction, is imminently needed.

The national and local trend has shifted from building new miles to restoring and rehabilitating the existing miles. This has been for the most part, due to financial, environmental, and ecological restrictions.

It is a historical fact that the restoration process on portland cement concrete roads and streets has almost always involved resurfacing with bituminous materials to provide an acceptable riding surface. The bituminous resurfacing process has provided city, county, and state government agencies with a viable method of extending the service life of portland cement concrete pavements for a few years and, at least historically, at a cost of considerably less than of reconstructing or replacing the facility.

Various types of P.C. concrete overlays, including plain, nominally reinforced, and continuously reinforced, have been demonstrated on concrete pavements as well as in few cases on bituminous pavements. Thirteen different states, including Iowa (Greene County) since 1959, have had projects of continuously reinforced concrete overlays.[1]

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[1] L. T. Norling, Principal Paving Engineer, P.C.A. "Concrete Overlays and Resurfacing - A Status Report." January, 1976.

In 1973, a research project was conducted in Greene County, Iowa, with 2 in. and 3 in. (50 mm and 75 mm) thicknesses of fibrous reinforced concrete in various conditions of bonding; unbonded (2 layers of polyethylene), partially bonded (wet interface) and bonded (dry cement broomed over wetted surface). Also, in the fall of 1954, P.C. concrete resurfacing was placed on U.S. 34 in West Burlington. This was reinforced with steel mesh and most of the project was bonded with a nominal 1/2 inch (13 mm) of cement-sand grout (dry).[2]

In recent months, this nation has been made aware that petroleum, and products derived from petroleum, are becoming more and more expensive. Further, and more importantly, is the forecast that this nation's natural supply of crude oil is quite limited and may be exhausted well before the turn of the century. Thus, the strong emphasis in the search for substitute fuels, products, and methods that are not dependent on petroleum for their existence.

Although there are a variety of designs and construction procedures available, the projects mentioned above demonstrate the practicability of concrete for resurfacing in rehabilitating old concrete pavements. In previous attempts at full bonding of overlays, the limited information available is not conclusive relative to bond obtained.

A definite need exists for a high strength, durable, skid resistant, long lasting, and economic resurfacing course for P.C. concrete pavements. Such a resurfacing course, completely bonded

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[2] I.S.H.C. Research Project, HR-34

to the existing pavement, would provide additional support for the ever increasing traffic loads and volumes on our roads and streets.

Iowa has had much success in the use of thin, bonded, dense concrete overlays used in the repair of deteriorated bridge decks.[3] By applying the same principles and methods learned from the last twelve years of experience with bridge deck resurfacing, it is felt that this system could provide a viable alternate to the bituminous product that has been traditionally used in the restoration , rehabilitation, and resurfacing process on P.C. concrete pavements.

From the successful experience with bridge deck repair and surfacing in Iowa, as noted above, it was expected that new, dense, Portland Cement Concrete could be placed and bonded to an existing concrete slab. However, it was recognized that higher production, different equipment, and higher slump concrete would have to be used to provide a viable process for large volume projects.

A typical one-day bridge deck resurfacing placement would be 50-600 feet (15 m-183 m) long and 14 to 22 feet (4 m to 7 m) wide using 0 to 3/4 inch (0 to 19 mm) slump concrete on a prepared (ground or scarified) surface. This concrete would be mixed in a small (1/4 cu. yd. - .19 cu. m.) paddle mixer or a Concretemobile.

Obviously this rate of production would not be economical if a 7 to 10 mile (11 to 16 km) project were to be resurfaced. Also, conventional paving equipment would require a higher slump concrete for production and workability. Usually higher slump means more mixing water and hence lower strength.

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[3] "An Evaluation of Concrete Bridge Deck Resurfacing in Iowa" April, 1975, B.C. Brown and J.V. Bergren

Another concern was the amount of patching that might be necessary before resurfacing. Spalled joints, faulted joints or joint failures should be considered. Whether it would be necessary to full-depth patch these areas or if partial depth patches could be used was another question.

OBJECTIVES

With these questions in mind a project was proposed with the following objectives.

1. To determine the feasibility of proportioning, mixing, placing, and finishing a thin lift (approximately 2 inches - 50 mm) of bonded, dense, non-reinforced portland cement concrete using conventional slip-form plant and paving equipment in resurfacing existing concrete pavements.
2. To determine the feasibility of partial depth repair of deteriorated transverse joints in concrete pavements using a bonded, dense, non-reinforced, portland cement concrete.
3. To determine if an adequate bond between the existing pavement an an overlay of thin lift, dense, non-reinforced portland cement concrete can be obtained.
4. To determine the economics, longevity, and maintenance performance of a bonded, thin lift, non-reinforced portland cement concrete resurfacing course as a viable alternate to bituminous resurfacing of concrete pavements.
5. To determine the economics, longevity, and maintenance performance of a bonded, dense, non-reinforced portland cement concrete in partial depth repair of deteriorated joints in concrete pavements.

PROJECT LOCATION CRITERIA

Choice of project location was based on essentially three criteria. First, there had to be distress in the existing pavement to the extent that maintenance repairs were imminent or presently being made. Second, sufficient traffic volumes must be present to allow proper evaluation of durability of the proposed research resurfacing. Lastly, location that would be condusive to allowing a contractor to employ high projection slab preparation, concrete mixing equipment, and slip form paving equipment.

The project site chosen is located on Primary Road U.S. 20 at the east edge of Waterloo, Iowa. An area, approximately 1500 lineal feet (457 m) long, of the westbound lanes just east of Evans Road was selected for resurfacing. The existing roadway is a four-lane divided, 10 inch (250 mm) thick, plain, jointed, Portland Cement Concrete pavement, originally constructed in 1958.

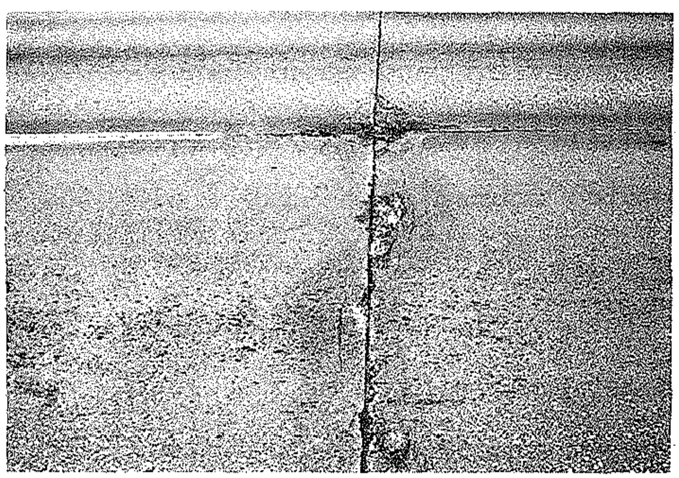

Figure 1
Original Pavement Condition

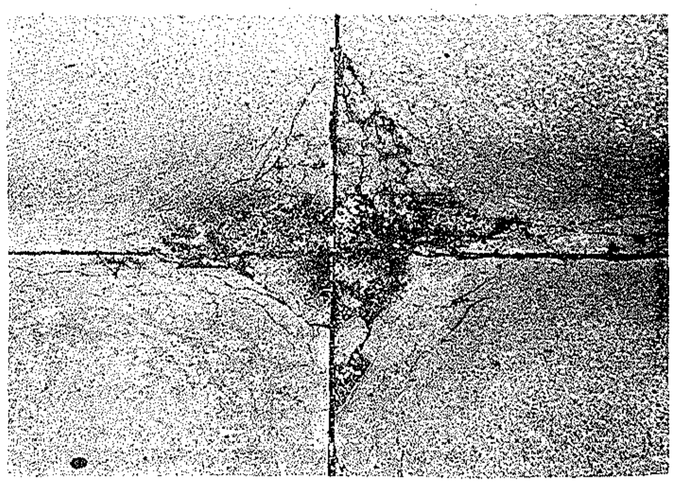

Figure 2
Original Pavement Condition

The existing pavement was originally constructed with a crushed limestone coarse aggregate which is susceptible to d-cracking (Figure 1 and 2). Immediately prior to this research project, most of the transverse joints (20 ft. - 6 m spacing) exhibited typical d-cracking deterioration with secondary cracking and some spalling. A small amount of bituminous surface patching had been done. Conditions indicated that additional patching would be necessary in the near future.

Present traffic on this section of road is as follows:

Average Daily Traffic	9,980
Average Daily Truck Traffic	407

PROJECT DEVELOPMENT

On July 27, 1976, the Iowa Department of Transportation Commission authorized $50,000 from contingency funds for a Demonstration Project, FN-20-6(21)--21-07, at the location mentioned above. The project was to be let in cooperation with the Iowa Concrete Paving Association. On September 21, 1976, a contract was awarded to Cedar Falls Construction Company, Inc., of Cedar Falls, Iowa, in the amount of $36,101.50 with the stipulation that certain labor and equipment cost were being donated through the Iowa Concrete Paving Association.

The contract period allowed 20 working days with a completion date of October 29, 1976. All of the work was paid for directly under or incidental to four contract items. They are as follows:

Item 1. Surface Preparation - 15 stations. This item of work included the removal of the top 1/4 inch (6 mm) of the existing pavement, sandblasting, and air blasting.

Item 2. Patches, Partial Depth - 28.9 cu. yds. (22.1 m^3). This item of work included the additional removal of the existing slab at the joints, sandblasting, grouting, and filling the patch with new concrete.

Item 3. Patches, Full Depth - 32 sq. yds. (26.8 m^2). This item of work included full depth removal of the existing slab, disposal of the removal concrete, and new concrete to fill the patch.

Item 4. P.C. Concrete Resurfacing, 2 Inches (50 mm) thick - 4,000 sq. yds. (3345 m^2). This item of work included grouting, placing, texturing, and curing the new concrete. Also incidental to this item was the sawing required on the plans at transverse joints and end runouts. The respective unit prices for the above items are as follows:

P.C. Concrete Thin Lift Overlay				
1 - Surface Preparation	15	Stas.	520.00	7,800.00
2 - Partial Depth Repair	28,900	cu.yds.	135.00	3,901.50
3 - Patches, Full Depth	32	sq.yds.	50.00	1,600.00
4 - Portland Cement Concrete Resurfacing, as per Plan	4,000	sq.yds.	5.70	22,800.00
			GRAND TOTAL	36,101.50

Additional items considered incidental to the contract were placing the material removed in surface preparation on the shoulders and sawing the 4 inch (100 mm) pressure relief joints at each end of the project.

Data were collected both before construction started and after completion of construction. This is, of course, in addition to the measurements necessary for payment of contract items.

The following tests and observations were made on both Divisions of the proposed project.

1) Skid number determination prior to and after completion of the project. See Appendix A.
2) Coring for bond strength. See Appendix B.
3) The normal slump and air content testing common to conventional concrete paving. See Appendix C.

4) 25 Foot Profilometer Testing before and after project work. See Appendix D.

5) Compressive and flexural strength determinations. See Appendix E.

A complete joint inventory and crack survey (including photographs) was made prior to the start of the project. Any cracks in the resurfacing will be evaluated in a later report as to their size, location, and number relative to the existing cracks and joints.

MIX DESIGN

The concrete mix objective was to design a mix which could be delivered in transit mix trucks, and having comparable characteristics to the Iowa bridge deck overlay concrete with enough workability to be placed with a conventional slip form paving machine. The Iowa bridge overlay mix has a water cement ratio in the area of 0.32, a slump of 3/4 inch (19 mm) or less, and it is extremely stiff, requiring special placing equipment. Because of the dry, stiff consistency of that concrete, ready mix trucks are not used and mixing is done either by concrete mobile continuous mixers or rotating-paddle type mixers.

During the past few years, super water reducing admixtures were introduced in the United States and have since been used in this country to a limited extent. It has been reported that these admixtures have been successfully used in Japan and some European countries since the mid-sixties. Claims had been made that flowing concrete could be made using super water reducers and still have low water cement ratios. It appeared that the use of these products might be a solution to the thin overlay mix design. In 1975, the Iowa D.O.T. decided to do some investigational work with these admixtures.

Laboratory tests using super water reducers in concrete were conducted in the Central Laboratory. The test results indicated it was feasible to obtain the mix objective using these materials and it was decided to proceed further.

Two mixes, A and B, were studied using two different super water reducers with each mix. Mix A was the Iowa bridge overlay mix containing 823 pounds of cement per cubic yard (283 kg/m^3) while B was a conventional concrete paving mix with 626 pounds (215 kg/m^3) of cement. Workable concrete was obtained with slumps in the range of 1 to 2 inches (25 to 50 mm) and water cement ratios of 0.36 and less. Low slump concrete would become very fluid when vibrated. Water requirements were reduced about 18-20 percent as compared to 5-8 percent when using conventional water reducing admixtures. Since the overlay would have a nominal thickness of 2 inches (50 mm) the coarse aggregate used was a crushed stone with 97-100 percent passing the 1/2 inch screen.

A decision was made to overlay the subject project using the two mixes and materials studied in the laboratory. To gain further experience before doing the U.S. 20 project, an opportunity developed wherein three sections of city streets, one in Ida Grove and two in Waterloo, were resurfaced using super water reducing admixtures with mixes A and B. This experience was very beneficial and much was learned regarding mix characteristics.

PROJECT MIX INFORMATION

Batch Quantities - CUBIC YARD:

	Mix A	Mix B
Cement (TYPE I)	823 lbs.	626 lbs.
Water	288 lbs.	225 lbs.
Fine Aggregate	1370 lbs.	1536 lbs.
Coarse Aggregate	1370 lbs.	1536 lbs.

The quantities are based on the following assumptions. Corrections in batch weights were made for values different from those assumed.

Specific Gravity Cement	3.14
Specific Gravity Fine & Coarse Aggregate	2.65
Weight of water	62.4 LB./FT.^{3}

Additional mix design information is shown in Appendix F.

ADMIXTURES:

Melment - Super Water Reducing Admixture American Admixtures Corporation Dosage-42 Fl.OZ. per 100 LB. CEMENT.

SIKAMENT - Super Water Reducing Admixture Sika Chemical Corporation. Dosage-26 Fl. OZ. PER SACK cement.

Protex - Air Entraining Admixture Protex Industries, Inc. Dosage-as required.

PROJECT CONSTRUCTION

Because of the season of the year and the need for special handling of traffic, the contractor was encouraged to establish a fairly short construction schedule. This was particularly true since the contractor was doing a similar project for the City of Waterloo, Iowa, at the same time. Operations would have to be dovetailed for efficiency in equipment utilization.

The first operation consisted of sawing a 4 inch, (100 mm) full-depth, pressure relief joint, just outside of the area to be resurfaced, at each end of the project. This was done with an ES-30 Ditch Witch circular saw.

The contractor elected to remove and replace the full-depth patches prior to surface preparation because he desired to use the roadway for delivery of resurfacing concrete. Super water reducers were used in this patching concrete in an attempt to gain experience on mixing and consistency prior to resurfacing. A total of 32.98 square yards (27.6 m^2) of full depth patching (10" - 250 mm depth) were placed in four separate patches of nearly equal size. Approximately one half of this concrete was Mix A (see Supplemental Specification 796 in Appendix F) with Sikament as the super water reducing admixture and one-half was Mix A with Melment as the super water reducing admixture. Removal and replacement was accomplished in one day.

Scarification of the existing pavement surface was done with a CMI Roto-Mill Pavement Profiler, which has a 9 ft. 2 in. (2.8 m) cutting head. This removed approximately 1/4 inch (6 mm) from the pavement surface to provide a roughened surface, free from road oils, linseed oil, tire rubber, and other contaminants that might impair a uniform bonding of the resurfacing.

The scarification (grinding) was done in three passes (Figure 3). The two outside passes were done first, followed by a third pass for the remaining portion in the center. Since grade control of the Roto-Mill machine was accomplished by sensoring from a ski, occasional low spots were not scarified. An additional pass, on each side of the pavement, was necessary to insure scarification of the entire pavement surface. Some spalling of the joints and pavement edge occurred as a result of the scarification. The third pass down the center tended to remove some of the original pavement crown. Although a cross sectional elevation differential between centerline and edge of pavement was maintained nearly the same as in the pavement before grinding, a high spot resulted at approximately 3 to 4 feet (.9 to 1.2 m) from centerline. This was somewhat undesirable due to a possible reduction of the desired resurfacing thickness, but not serious enough to warrant additional grinding. Effective grinding was obtained with machine forward speed of up to 40 lineal feet (12.2 m) per minute. End runouts to tie into the existing pavement surface were accomplished by additional removal to 1-1/4 inches (31 mm) in depth to provide a flush header.

As per plan 35 transverse joints received partial depth repair. Thirty of these joints were repaired full pavement width and five joints were repaired one-half pavement width. Plans indicated partial depth removal to a depth of 3 to 4 inches (75 to 100 mm). Because of the shielding around the cutting head on the Roto-Mill machine, a depth of approximately 2 inches (50 mm) of removal resulted. All of the full pavement width patches were initially removed to this 2 inch (50 mm) depth.

After inspection of the partial depth removal done by the Roto-Mill machine, some of the repair areas had to be deepened. For this additional removal, a Galion RP-30 Road Planer, having a 30 inch (0.76 mm) cutting head, was used (Figure 4). Because of more extensive deterioration at the intersection of the centerline and transverse joints, additional area of partial depth repair removal was done.

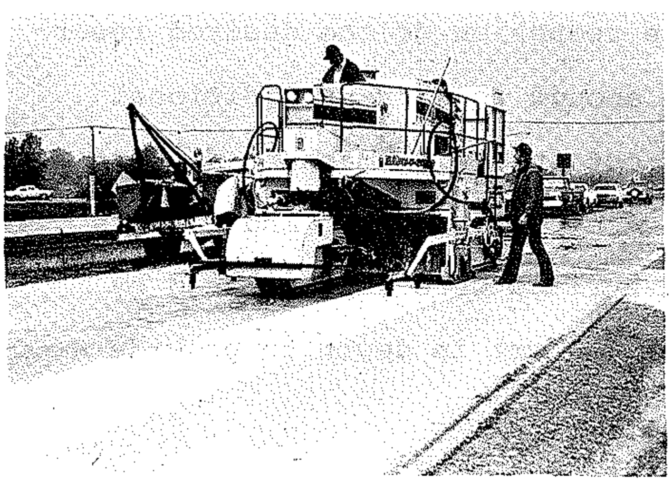

Figure 3
Roto-Mill Profiler

Figure 4
Galion Road Planer at joint

The entire area was sandblasted using a self-propelled, trailer mounted sandblasting machine manufactured by Capitol Engineering Company, a subsidiary of Oster & Pederson, Inc. of Minneapolis, Minnesota. This machine was able to sandblast from 0 to 14 lineal feet (0 to 4.3 m) per minute, at widths from 9 to 16 feet (2.7 to 4.9 m), with four oscillating No. 7 nozzles at 110 pounds per square inch (758,340N/m^2) nozzle pressure (Figure 5).

After sand blasting, and just prior to the grouting-concrete placement operation, the entire surface was cleaned by air blasting (Figure 6).

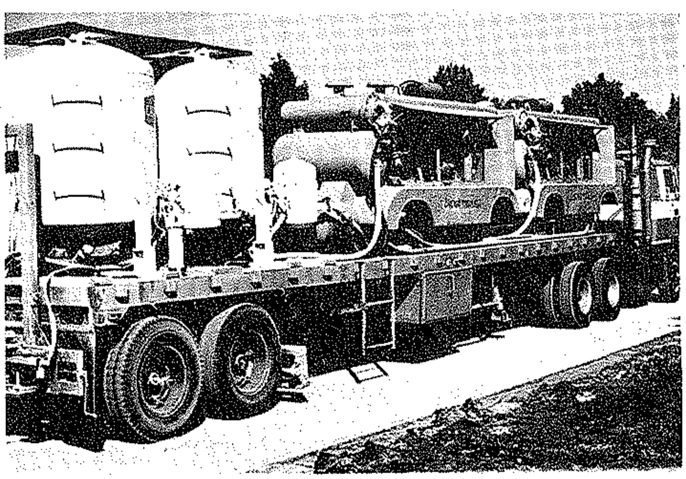

Figure 5
Self-propelled Sandblaster

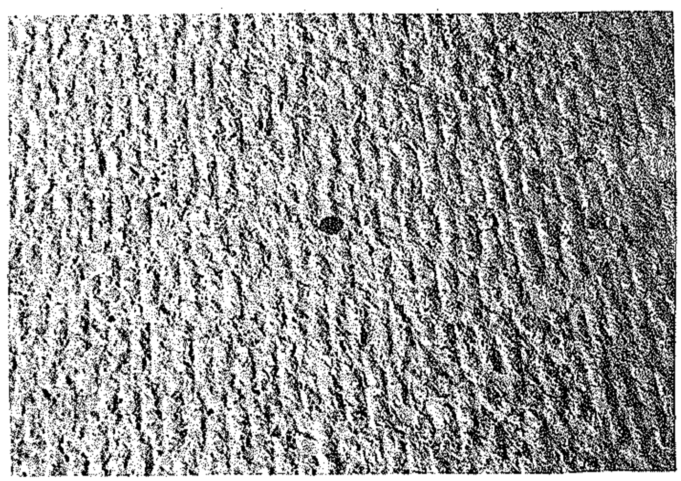

Figure 6
Scarified surface

The bonding grout was mixed and hauled in transit-mix trucks. The grout consisted of 50% cement and 50% sand mixed with enough water to attain a creamy consistency. It was placed on the <u>dry</u> pavement surface immediately ahead of the paving operation and manually spread with stiff bristle brooms (Figure 7). Care was taken to insure grouting in the depressions of the partial depth patch areas which were placed with the resurfacing. When the grout was spread too far ahead of the paving operation, it tended to dry on the surface.

A Rex, Model STR, slipform paver was used for the resurfacing (Figure 8). It was set for 2 inch (50 mm) pavement thickness and operated on a graded pad line constructed on the shoulders. A special 2 inch (50 mm) trailing form on the paver was fabricated for this project. The paver was equipped with internal tube vibrators as well as pan vibrators. There were also tamping bars in front of the extrusion meter.

The concrete was discharged from the transit mix trucks directly in front of the paver and spread with the auger on the paver. When the paver stopped, if the concrete was slightly wet, a ridge tended to form behind the extrusion meter that required trimming with a straight edge. Conversely, a problem of surface tearing tended to develop when the consistency of the concrete was drier then desired. Additional finishing, including hand finishing, was necessary to close the open surface in these instances. The internal tube vibrators were shut off in the early part of the placement because the pan vibrators were sufficient to achieve adequate consolidation.

Figure 7
Workmen Spreading Grout

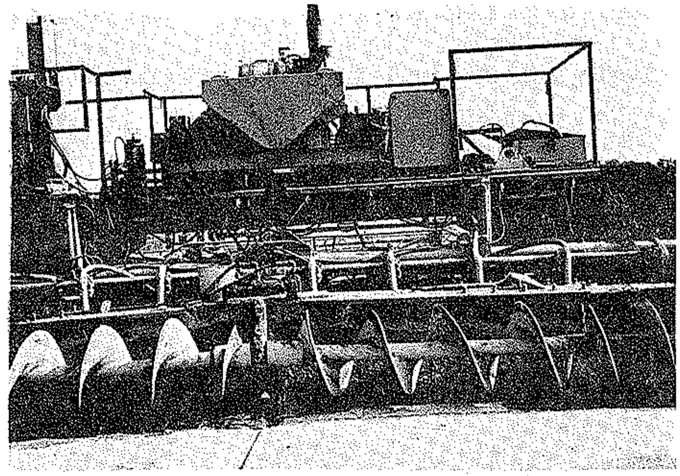

Figure 8
Slip-form Paver

The plastic concrete was textured with a longitudinal Astro-Grass drag and then transversely grooved with a CMI-TC-280 texture and cure machine (Figure 9 and 10). Some difficulty in achieving the specified groove texture was experienced when the concrete was drier then desired.

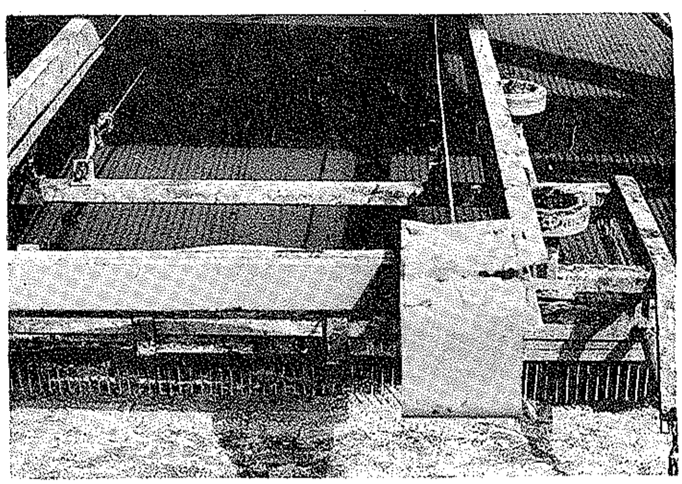

Figure 9
Texturing Machine

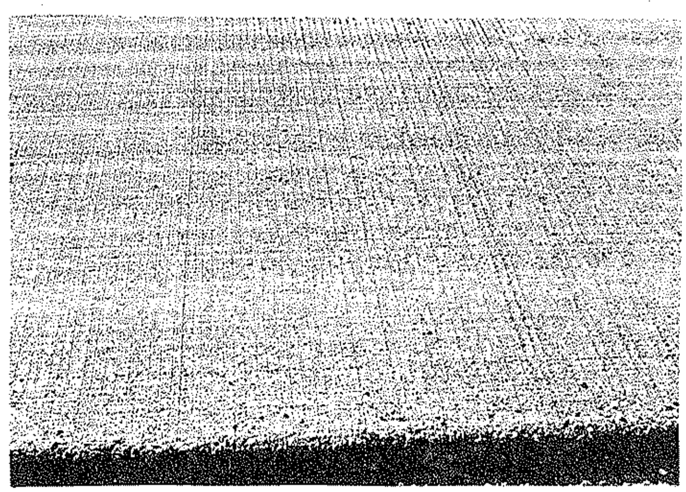

Figure 10
Surface Texture

A white pigmented liquid membrane curing compound was used on all but 400 lineal feet (122 m) of the project (Figure 11). It was applied at 0.13 gal./sq.yd. (0.41/m^2) which is twice the minimum rate specified for concrete pavements in Iowa. Wet burlap was used on the remainder of the project. This was done so that a comparison of curing methods could be evaluated. The wet burlap was so located so that two different cement content concrete mixes were cured by this method. The burlap was kept continuously wet for 24 hours and then covered with 4 mil polyethylene for an additional 48 hours.

Nails were driven into the shoulder along each side of the pavement at each transverse joint prior to resurfacing so that the joints could be relocated for sawing and evaluation. No sawing was done over the centerline joint. The resurfacing was sawn a minimum of 1 inch (25 mm) deep over approximately 20 percent of the existing transverse joints. The joints requiring sawing were noted on the plans. Of the 38 joints where no partial depth patching was done, 7 were sawn after resurfacing.

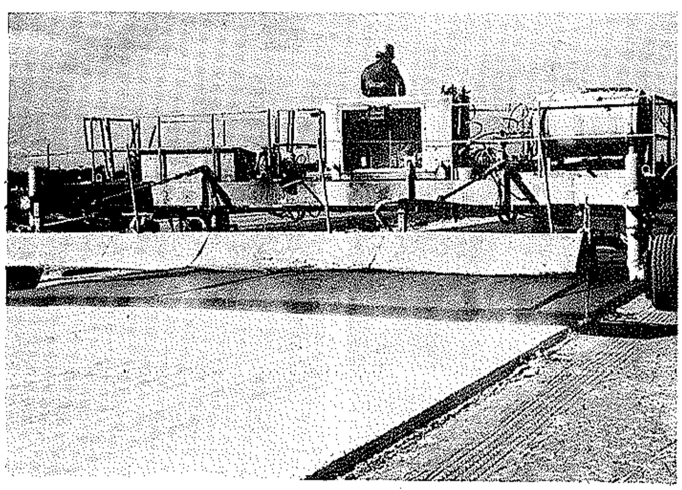

Figure 11
Applying Membrane Curing Compound

OBSERVATIONS AND RECOMMENDATIONS

The following are observations of the various phases of the project and recommendations for changes where appropriate.

Surface Scarification:

It was originally planned to control the scarification with the use of a string line set to grade and the automatic controls on the Roto-Mill. After considerable discussion with the manufacturer's representative, he advised that better results could be obtained using a ski which would ride on the existing pavement with the automatic controls. This was done.

It was recognized that the use of a string line probably would be impractical for a project of several miles in length. In order to use the string line, considerable survey and stake setting is necessary to establish the string line grade. Also, even if string line is set on both sides of the pavement, the use of long sensor arms are necessary particularly if three passes of the machine are required to obtain full grinding coverage of the pavement.

The ski, which was as long as the wheel base of the Roto-Mill Profiler, worked well for normal removal where there were no low areas in the existing pavement. High areas were trimmed without problem and enhanced profile characteristics were achieved. See Appendix D. Where low areas existed, the Roto-Mill tended to ride over or skip areas. This necessitated an additional grinding pass to obtain the normal 1/4 inch (6 mm) removal desired. The additional pass slowed production, even though additional profile enhancement was achieved.

The width which could be ground in one pass (9 feet 2 inches - 2.8 m) presented some problems. Because at least one half of the pavement width could not be ground with one pass, a third pass down the center of pavement was necessary. Since the grinding wheel is a plane surface, some of the original crown was removed with this pass.

If a scarifying machine of this type could be developed which could cover twelve feet in one pass, several of these problems could be eliminated. Additional production could also be attained.

The Roto-Mill is able to effectively grind concrete made from limestone coarse aggregate at speeds up to 40 lineal feet (12.2 m) per minute. There were no apparent disadvantages to grinding at this speed over slower speeds.

In the past, the repair of d-cracked distressed joints has been by full-depth removal and replacement. The timing for this repair has usually been delayed until the spalling has progressed to the point that very offensive riding roughness exists. Since most of the joints on the project indicated this type of deterioration had not started but was certainly imminent, it was decided that partial depth removal and patching with the resurfacing concrete could be done in lieu of full-depth removal and patching. This partial depth removal was done at the time of the surface preparation.

There also was some question about how a slightly distressed joint would react if simply covered with the resurfacing with no partial depth removal. As a result, the following was proposed for preparation of the transverse joints:

1. at approximately 30% of the deteriorated transverse joints, only the top nominal 1/4 in. (6 mm) would be removed.
2. at the remaining joints, approximately 3 to 4 inches (75 to 100 mm) of the deteriorated concrete would be removed.

Partial depth removal for patches was only marginally successful. Shields on the machine limiting its cutting depth to approximately 2 inches (50 mm), plus some impatience on the part of the operator seemed to be a part of the problem. It is felt that the Roto-Mill can be successfully used to accomplish this type of removal. Here again a twelve foot (3.7 m) wide grinding capability would be an advantage. The smaller Road Planer performed well in widening the area of removal at the intersection of the joints (Figure 4).

The removal of approximately 1/4 inch (6 mm) from the surface by the Roto-Mill Profiler was accomplished quite satisfactorily. As previously described, this operation was controlled by a ski rather than by a string line. Measurements of surface smoothness and skid resistance were taken before and after grinding. The results are shown in Appendix A and D.

Some edge and joint spalling occurred as a result of the grinding. This was not considered undesirable since the pavement was resurfaced. However, when grinding to improve skid resistance or reprofiling, this spalling could be a problem. Further research is needed to reduce or eliminate this spalling on pavements that are not to be resurfaced.

Because of the marked improvement in the profile and skid resistance, it is recommended the Roto-Mill Profiler be considered for use on pavements, both portland cement and asphaltic concrete, that are otherwise structurally sound and adequate, to restore rideability (profile) and/or skid resistance.

SAND BLASTING:

The self-propelled sand blasting unit provided a high production rate for this operation. There was a considerable amount of dust that could present a problem, especially in developed urban areas. It is suggested that for future work in built up or residential areas, the nozzles could be hooded to reduce the amount of blowing dust. It is possible that the same end results could be obtained with a high pressure water blast. Water blasting would perhaps be less expensive, as material availability is better, and it would be environmentally more desirable.

GROUTING:

The bonding grout was mixed and delivered to the project in a transit mix truck and spread by hand as previously described.

A mechanical means of spreading the grout will be necessary to provide an adequate production rate for this operation and to be economically feasible. It is necessary that such a machine operate immediately in front of the paving machine in order to prevent drying of the grout before placement of the overlay concrete. A very light fog of water can be used as an emergency measure to keep the grout damp if there are unusual delays in concrete delivery or paving machine progress. However, in instances of major break downs or other stoppages, the dried grout should be removed.

The cement/water contact time in the grout should not exceed ninety (90) minutes. It is felt this can be readily controlled on a project by properly matching the grout mixing and proportioning unit with the grout spreading equipment.

BOND:

One of the most important criteria for the success of this type project is the attainment of adequate bond of the resurfacing to the old pavement. It has been demonstrated on bridge decks that bond can be obtained with a scarified, clean, dry surface of old concrete using a grout of cement and sand. The question is whether adequate or sufficient bond can be obtained if any of these conditions are changed. For that reason, four special sections were designated within the resurfacing project. Each section is approximately 20 ft. (6.1 m) long for the full width of the pavement.

Two of the sections were sandblasted only with no grinding and two other sections were scarified but not sandblasted. All were resurfaced in the normal manner including grouting.

Also of interest was the consideration of doing partial depth patching of joints where no resurfacing was planned. Seven joints outside of the resurfacing area were chosen for partial depth removal and patching. All of these joints showed the same d-cracking distress as those joints within the resurfacing area.

The removal at these joints was by grinding with the Galion machine in two different positions. Four of the joints were ground with the grinding wheel normal to the transverse joint. This produced a removal area 30 inches (0.7 m) wide. Three of the joints were ground with the grinding wheel parallel to the joint. This produced a removal area which was somewhat circular and required the machine to be continually moved to get coverage of the entire slab width. These removal areas were from 2-1/2 inches (63 mm) to 5 inches (125 mm) in depth (Figures 12 and 13).

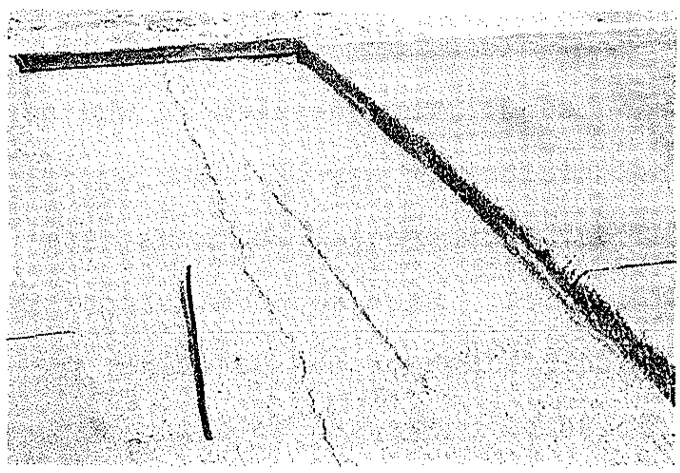

Figure 12
Partial Depth Repair Area

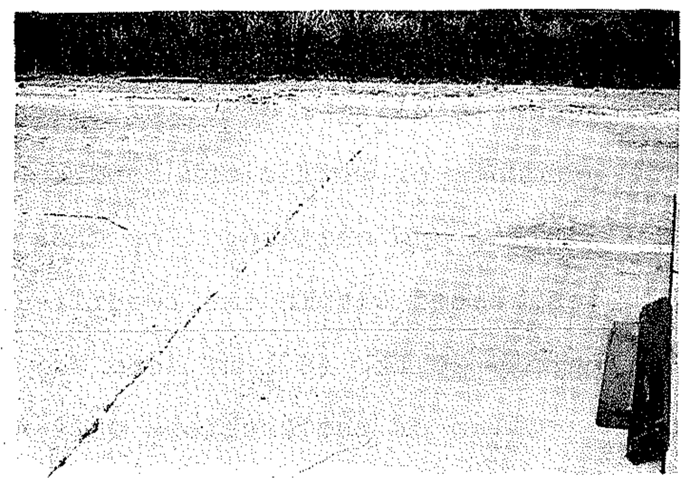

Figure 13
Partial Depth Repair Area

All patches were grouted prior to placement of patch concrete.

The concrete used to fill the patches was the same as that used in the resurfacing i.e., both Mix A and B, with the exception that no super water reducing admixtures were used in the patching concrete. These patches were cured with liquid membrane cure.

One half of the transverse joints in the partial depth patches in the special section outside of the resurfacing were sawn. No longitudinal centerline sawing was done.

The above described partial depth surface patches without resurfacing are performing above our expectations. To date, the transverse joint, as well as the centerline joint, have reflected through. However, there is no evidence of cracking around the edges of these patches.

Due to the excellent performance of these partial depth patches to date, it is recommended that additional research be performed on pavements having different degrees of joint deterioration to determine if partial depth concrete patches are a viable alternate to the traditional full-depth repair.

The amount of bonding achieved has been checked twice with a mechanical delamination detection device (Delamtect). The first check was performed shortly after the project was completed, in the Fall of 1976, by testing each (4) wheel track. The second test was performed in the Spring of 1977, checking the outside edge, both sides of the centerline joint, a wheel track, and both sides of randomly selected transverse joints, both sawn and not sawn. With the exception of a single, small area at a transverse joint, there was no indication of a delamination. Thus complete bond was achieved.

The bond results, measured by the resistance to shear at the interface, between the resurfacing and the old pavement, are considered to be excellent. See Appendix B. These values, as well as the performance of the surface patches without overlay, indicate that adequate bond can apparently be achieved without the removal of the top 1/4 inch (6 mm) of surface.[4]

It is recommended that the surface preparation for a future project be modified to at least include sections being cleaned rather than ground. It is suggested the cleaning procedures include such operations as sandblasting, high pressure water blasting, and high pressure water blasting with sand.

If adequate and sufficient bond can be achieved without the removal operation, as is anticipated, considerable cost savings should result.

MIXING:

At the two stop batch plant, cement, water, and air entrainment were added at the first stop. The second stop picked up the fine and coarse aggregate, together with the water reducer. The admixture manufacturers recommend introducing the water reducer as late as possible. Melment was put into the mix after all other materials were batched. Sikament was folded in with the fine aggregate. Water was available on the mixer for any necessary adjustments at the job site. This was somewhat of a problem because at times the trucks had excessive waiting prior to being able to unload and in those instances, slump loss was experienced.

Super water reducing admixtures have a limit to the life at which their plasticizing characteristic is at maximum effectiveness. After the mix has reached that effective time limit, the

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[4] Roy W. Gillette, P.C.A. "A 10-Year Report on Performance of Bonded Concrete Resurfacings", 1964.

concrete will lose slump. Generally speaking, that time limit is somewhere in the area of 30 to 60 minutes, depending upon the admixture being used and other conditions which affect concrete mixes. This apparently can be overcome by retempering the mix with an additional dosage of the water reducing admixture after the effective time limit has been reached. This was not known at the time this project was constructed. On this project, when slump loss was experienced, water was added to restore workability.

Concrete on the project had slump in the range of one inch, but was not always consistent because of unloading delays and/or the addition of water to the transit mix trucks. It is difficult to effectively add water at the job site when using these admixtures because a very thorough mixing is required to get proper distribution of the water.

Super water reducing admixtures are very sensitive to water and slight changes while batching can cause drastic changes in the consistency of the mix. A slight excess of water can cause a complete collapse in slump.

Water cement ratios on this project were as low as 0.26 when using Sikament and 0.29 with Melment in Mix "A". See Appendix C. Water cement ratios of the "B" mix were somewhat higher and averaged around 0.36 for each material. Any difference between the two admixtures could be attributed to the dosages used.

Another interesting feature of mixes containing super water reducing admixtures is that vibration has a tremendous effect on them. A one inch slump concrete when vibrated will immediately become very fluid and will appear to have a high slump. However, the material does not seem to segregate because the admixture has a characteristic of inhibiting segregation and bleeding.

CONCRETE PLACEMENT:

Even though the project was short (1500 l.f. - 457 m) and four different mix proportions were used, it seems apparent that thin-lift, dense, low water-cement ratio (W/C - 0.4) concrete can be proportioned, mixed, and placed with existing, conventional mixing and slip form placing equipment. The super water reducing admixtures provide the workability, as well as other beneficial qualities, that are required for a high production paving operation. See Appendix C.

The rate of discharge of the transit mix trucks used on the project was a limiting factor to the rate of production. It is recommended that consideration be given to using a central, drum mixing proportioning plant and wet-batch delivery for a future project. All else being equal, the anticipated increase in delivery rate should provide for a high rate of placement, estimated at 2 miles (3.2 km) per day, ±.

It is further anticipated that by using a central drum-mixing plant, a more uniform mixing of the concrete will result. Due in part, to the characteristics of the super water reducing admixtures, and to the low water-cement ratio concrete, the lack of uniform distribution of mixing water was sometimes quite apparent during the discharge from a transit mix truck. This was especially true when water was added at the project site, i.e., wet at the rear and drier at the front of the drum. This problem existed even though new or nearly new trucks in very good condition were used.

Both the delivery rate and consistency are very important in the quality of the finished pavement. Inconsistency of concrete workability causes problems in finishing and consolidation and usually results in a rough pavement surface. If the delivery rate is either slow or sporadic this may cause the paver to repeatedly stop and start. Each time the paver stops some of the concrete may start to dry or begin its initial set depending on the length of time involved. This may, and often does, cause a bump behind the machine. Removal of bumps by straight edging becomes very critical with possible reductions in effective thickness.

The Rex paver performed well in that it was large enough in power and weight, to handle the drier concrete with no vertical or horizontal displacement. This machine could have proceeded at a higher rate had it been possible to increase delivery rates of the concrete.

For this project, a pad line for the slip form paver was constructed of material removed by the grinding operation, compacted, and mechanically cut to grade. On future projects, some sort of grade line will have to be established, whether or not the existing surface is re-profiled prior to resurfacing. It is recommended that a surface-ski-sensoring system on the paving machine being considered for future projects of this type.

Such a system would offer several advantages: (1) it would not be necessary to construct a pad line for grade control for the paver, (2) it would not be necessary to set a grade control stringline or establish the grade or profile to be set in the stringline, and (3) it would provide the self-leveling, smoothing, of the profile, inherent with a properly designed and operating ski-sensoring-system.

TEXTURING:

The quality of the texture, both from the Astro Grass drag and the transverse grooving, is directly related to the consistency of the concrete. When the workability of the concrete was poor (too stiff) the texturing was poor. One noticeable difference was the apparent density of the resurfacing concrete with the super water reducing admixtures as compared to normal paving concrete. The resurfacing concrete seemed to become more dense after vibration than normal paving concrete which made texturing more difficult. It is recommended that a different shape of tine on the texturing machine be considered for use on this type of dense concrete. The tine used was oval shaped and quite flexible. This has worked satisfactorily in conventional concrete paving. Perhaps a round tine and/or a stiffer tine might be better able to provide the desired groove. The texturing operation should be kept close behind the paver for effective texturing.

CURING:

As previously mentioned the liquid membrane curing compound was applied at twice the minimum rate for paving. No discernable difference in strength or performance has been observed between the area with liquid membrane cure and the area cured with wet burlap.

The curing machine was not able to apply the membrane satisfactorily in a single pass. The best results were obtained by making two passes. This method seemed to provide the most uniform and complete coverage.

Because of the thin section involved, and the importance of adequate curing, it is recommended that liquid membrane curing compounds be applied at similar rates on future projects. Also, consideration should be given to using two machines, one for texturing and one for application of curing compound.

SAWING:

None of the centerline joint, and only approximately 20 percent of the transverse joints, were sawn in the resurfacing on this project. After two or three months, most of the transverse joints (20 foot spacing) had reflected through the resurfacing (Figure 14). Some meandering of these reflective cracks exists, however, most are relatively straight, following the old contraction joint. The meandering seems to be most prevalent at transverse joints where partial depth repair was done. Four months after the resurfacing was placed, 10 to 15 foot (3 to 4.6 m) lengths of fine, tight, reflective cracks over the centerline were visible.

An occasional spall, 4 inches to 6 inches (100 mm to 150 mm) long, approximately 1/2 inch (13 mm) wide, and up to approximately 1/2 inch (13 mm) deep, is present on a small number of the transverse cracks (Figure 15). This cause is unknown at the present time. These will be located by a crack survey and their extent and size will be monitored.

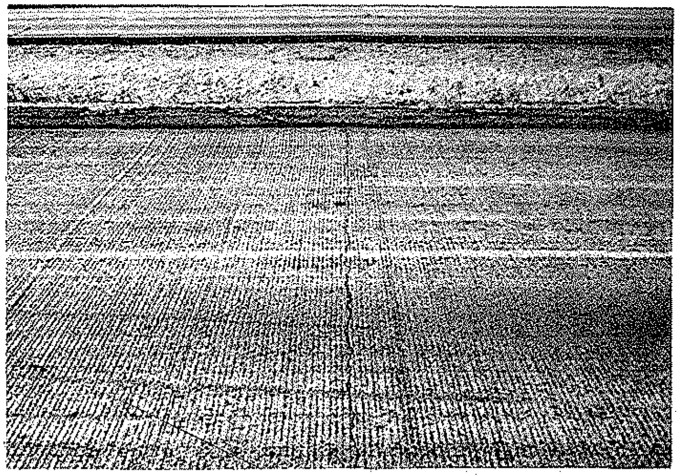

Figure 14
Reflected Transverse Crack in Resurfacing

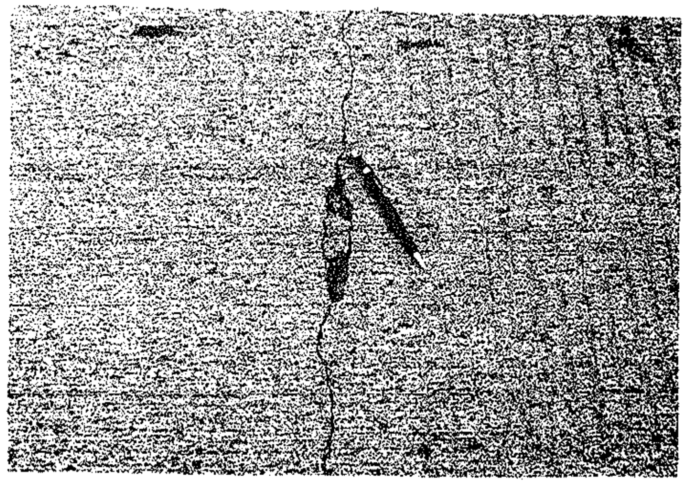

Figure 15
Spall in Transverse Crack

TEST RESULTS:

An average of compressive and flexure strengths from project samples of the various mixes is shown in Appendix E.

To determine bond strength between the overlay and old pavement, cores were taken from the project and tested for shear. Average shear strength was found to be around 1000 p.s.i. (6.9 MPa) when checked after 6 weeks. A further check at 16 weeks brought forth similar results. It is interesting to note that testing showed the shear strength between the new overlay and old concrete was very similar to the shear strength of the new concrete and the old pavement by themselves. Shear Test Results in Appendix B.

In addition to shear testing, the grout was tested under severe conditions in the laboratory. Broken flexure test beam ends with no special preparation, were welded together with the grout, cured for seven days in the moist room, and broken again at the same point. Results were a flexure strength of about 400 p.s.i. (2.8 MPa).

Super water reducer concrete has been tested at the Iowa Department of Transportation laboratory for freeze and thaw durability. Durability factors were found to be in excess of 95 at 300 cycles.

Cost of Super Water Reducing Admixtures:

At the time this project was constructed, the approximate material cost of super water reducing admixtures was as shown below.

	A	B
Melment	\$8.10 Cu.Yd.-6.19/m^3	\$6.16 Cu.Yd.-4.71/m^3
	45¢ Sq.Yd.-38¢/m^2	34¢ Sq.Yd.-28¢/m^2
Sikament	\$8.00 Cu.Yd.-6.12/m^3	\$6.09 Cu.Yd.-4.66/m^3
	44¢ Sq.Yd.-37¢/m^2	34¢ Sq.Yd.-28¢/m^2

Just what these costs would be at a later date are not available at this time. Prices of other super-water reducing admixtures have not been made available.

CONCRETE MIXES:

It appears that the coarse aggregate quality and gradation requirements which were specified for this project are higher than necessary. This is particularly true for the restriction on chert and absorption. A normal class 2 quality aggregate would be acceptable.

Considering the flexural strengths achieved in seven days, it does not appear that the high (823 lbs. - 283 Kg/m^3) cement content in mix A is required. The strength of the lower 626 lbs. - 215 Kg/m^3) cement content (mix B) concrete is more than adequate since it is considerably stronger than the existing pavement concrete. See Appendix E.

Consolidation of the plastic concrete presented no problem. It appeared that vibration tended to change the consistency of the concrete, causing it to flow and creep, more so than normal concrete without super water reducing admixtures. The standard slump test did not give a true indication of workability because of this phenomenon.

The consolidated concrete had a shiny, wet appearance but in fact was very dense. Nuclear densometer checks of the in-place concrete density, while still plastic, indicated between 99 and 103 percent of the rodded unit weight was achieved. Generally there was little problem getting the edge to stand behind the trailing form. It should be noted, however, that some of the concrete which was too wet when placed had a tendency to creep out of the back of the extrusion meter on the paver when it had to stop.

Note: Based on the experience derived from this project, a recommended revision of Supplemental Specification #796 for use on future projects is included. See Appendix G.

APPENDIX

HIGH CEMENT MIXES vs. STANDARD CEMENT MIXES

Because both high cement content (823 lbs./c.y. - 283 Kg/m^3) mixes and standard cement content (626 lbs./c.y. - 215 Kg/m^3) mixes were used on this project, some comparisons and evaluation can be made.

Considering the shearing bond strengths attained at the original pavement-resurfacing interface, it is believed the resulting pavement is functioning as a monolithic composite pavement.

Work done by Robert Packard of the Portland Cement Association[5] on composite pavements indicates that equivalent thickness can be calculated for different strengths of concrete in a composite pavement. This is based theoretically on Pickett's formula for the radius of relative stiffness wherein a ratio of thickness and the cube root of Modulus of Elasticity for a given concrete can be equated to a ratio of the thickness and cube root of Modulus of Elasticity of another concrete. This permits a design theory for composite sections.

It was hoped that the higher strengths of the concrete in this project would indicate an equivalent thickness greater than the original thickness plus resurfacing thickness. However, because the cube root of the Modulus of Elasticity is used, the increase in equivalent thickness is computed as only 0.02 to 0.06 inches per inch (0.5 mm to 1.5 mm per mm). Therefore, for this particular purpose there is no advantage in the higher strength concrete.

All Modulus of Elasticity test results are listed in Appendix H.

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[5]"Preliminary Studies of the Design of Composite Concrete Pavements". Robert G. Packard, Principal Paving Engineer, Portland Cement Association.

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE RESURFACING AND PATCHING ON U.S. 20 FN-20-6(21)--21-07 BLACK HAWK COUNTY, IOWA

	INSIDE LANE	OUTSIDE LANE
ORIGINAL PAVEMENT	36	31
AFTER 1st GRINDING	58	57
NEW CONCRETE	39* 40	35* 40

*MEMBRANE CURE NOT WORN OFF

SKID NUMBERS AT 40 M.P.H.

BONDED, THIN LIFT, NON-REINFORCED PORTLAND CEMENT CONCRETE
RESURFACING AND PATCHING ON U.S. 20
FN-20-6(21)--21-07 BLACK HAWK COUNTY, IOWA

BOND STRENGTH IN SHEAR
BETWEEN ORIGINAL PAVEMENT AND RESURFACING

Core No.	Station	Rt. or Lt. From ℄ (ft.)	Surface Treatment	Mix	Shear p.s.i.	Date Sampled
2	1107+00	7.0 Rt.	Grind & Sandblast	A-Melment	297	11-5-76
3	1106+00	6.0 Rt.	Grind & Sandblast	A-Melment	1238	11-5-76
7	1102+70	4.0 Rt.	Grind Only	B-Melment	1197	11-5-76
8	1102+20	5.5 Lt.	Sandblast Only	A-Sikament	704	11-5-76
9	1101+20	8.5 Rt.	Sandblast Only	A-Sikament	1570	11-5-76
10	1101+00	5.0 Lt.	Grind & Sandblast	A-Sikament	1337	11-5-76
11	1100+80	3.5 Lt.	Grind Only	A-Sikament	1041	11-5-76
13	1099+00	6.0 Rt.	Grind & Sandblast	A-Sikament	1103	11-5-76
14	1098+00	8.5 Lt.	Grind & Sandblast	B-Sikament	1205	11-5-76
16	1095+00	7.0 Rt.	Grind & Sandblast	B-Sikament	1052	11-5-76
1a	1108+99	11.6 Lt.	Grind & Sandblast	A-Melment	930	3-8-77
6a	1103+40	11.6 Lt.	Grind & Sandblast	B-Melment	760	3-8-77
9a	1102+20	6.5 Lt.	Sandblast Only	A-Sikament	940	3-8-77
10a	1102+15	℄	Sandblast Only	A-Sikament	1280	3-8-77
11a	1101+22	12.0 Lt.	Sandblast Only	A-Sikament	311	3-8-77
13a	1100+65	11.6 Lt.	Grind & Sandblast	A-Sikament	670	3-9-77
18a	1102+70	6.0 Rt.	Grind Only	B-Melment	210	3-9-77
19a	1102+19	12.0 Rt.	Sandblast Only	A-Sikament	830	3-9-77
20a	1101+25	11.3 Rt.	Sandblast Only	A-Sikament	1370	3-9-77
21a	1101+20	7.0 Rt.	Sandblast Only	A-Sikament	1090	3-9-77

The test of bond strength is a shear test not a tensile test. The test is run by placing two collars around a 3 inch diameter core spaced approximately 1/8 inch apart and pulled laterally in opposite directions until a shearing failure occurs. In the above tests the bond between the original pavement and new resurfacing was tested.

100 psi = 0.69 MPa

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE
RESURFACING AND PATCHING ON U.S. 20
FN-20-6(21)--21-07 BLACK HAWK COUNTY, IOWA

SHEAR STRENGTH - NEW CONCRETE

Core No.	Station	Mix	Shear p.s.i.
6	1103+20	B - Melment	1184
4	1105+00	B - Melment	1078
12	1099+90	A - Sikament	1498
15	1096+70	A - Sikament	1303

SHEAR STRENGTH - ORIGINAL CONCRETE

Core No.	Station		Shear p.s.i.
4	1105+00		1409
5	1104+00		1380
12	1099+90		997
15	1096+70		959

The shear strength test is run by placing two collars around a 3 inch diameter core spaced about 1/8 inch a part and pulled laterally in opposite directions until a shearing failure occurs.

100 psi = 0.69 MPa

ACTUAL BATCH WEIGHTS

Material	A - Melment	B - Melment	A - Sikament	B - Sikament
Coarse Aggregate (Dry Weight)	1474 lbs.	1570 lbs.	1493 lbs.	1586 lbs.
Fine Aggregate (Dry Weight)	1452 lbs.	1550 lbs.	1473 lbs.	1566 lbs.
Cement	823 lbs.	626 lbs.	823 lbs.	626 lbs.
Water	229 lbs.	236 lbs.	214 lbs.	207 lbs.

Sp. Gr. Fine Aggregate = 2.66   Sp. Gr. Coarse Aggregate = 2.69

1 lb. = 0.45 Kg

% Entrained Air	5.7 - 6.66	6.2 - 7.5	5.6 - 6.1	5.7

Slump in Inches	½ to 4	¼ to ½	3½	1/8 to 2

1 inch = 25 mm

Water/Cement Ratio	0.290-0.300	0.359-0.369	0.260-0.264	0.330-0.362

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE RESURFACING AND PATCHING ON U.S. 20 FN-20-6(21)--21-07 BLACK HAWK COUNTY, IOWA

	INSIDE LANE	OUTSIDE LANE
ORIGINAL PAVEMENT	25.00	25.35
AFTER 1ST GRINDING	7.39	4.58
AFTER 2ND GRINDING	3.07	2.96
NEW CONCRETE	28.2	36.1

25 FOOT PROFILOMETER - INCHES PER MILE

1 in./mile = 15.6 mm/km

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE
RESURFACING AND PATCHING ON U.S. 20
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28 DAY COMPRESSIVE STRENGTH

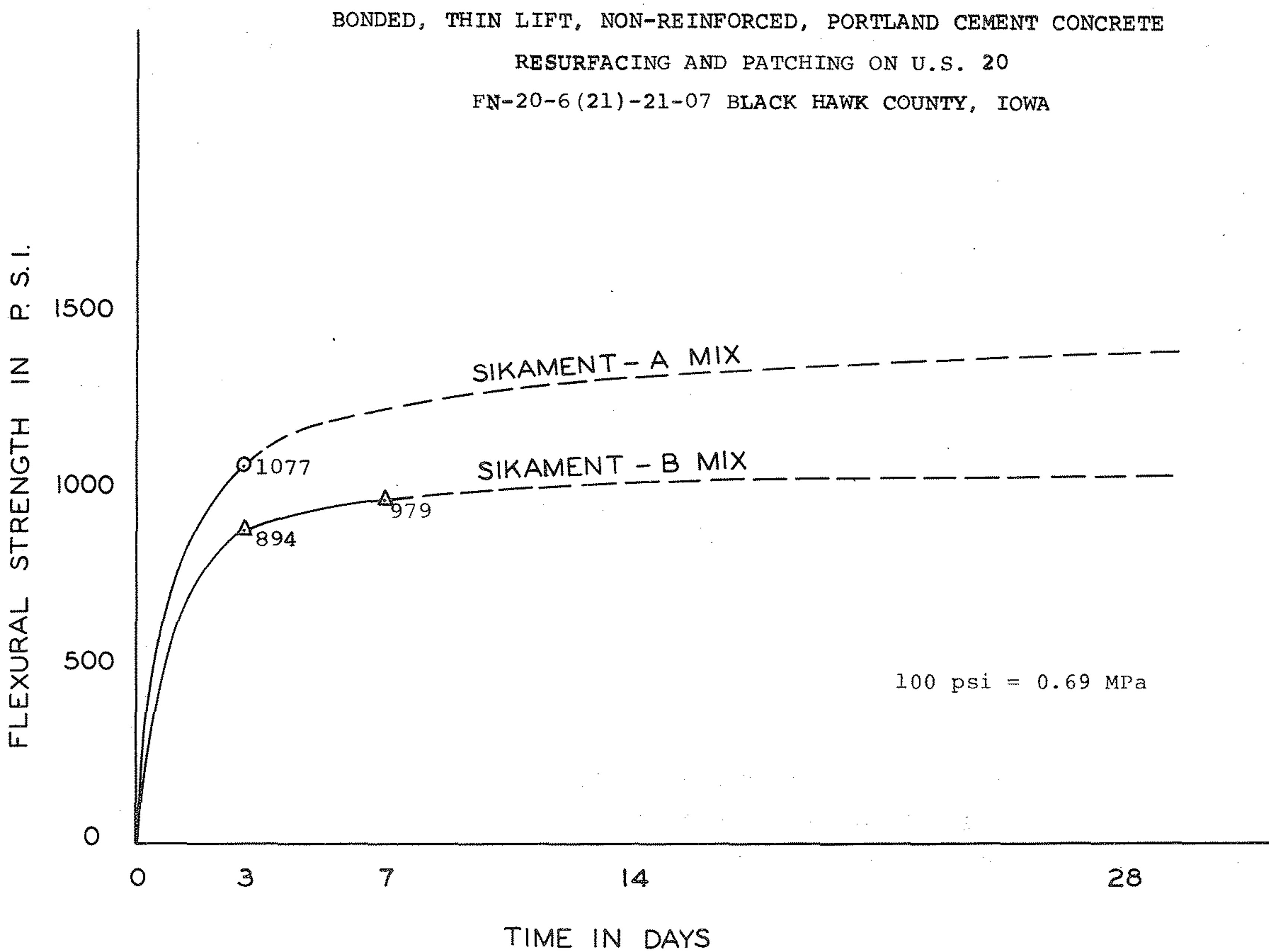
Lab. No.	Mix	Water Reducer	Total Load	Lb./Sq. In.
783	A	Melment	150,000	9,430
784	A	Melment	144,000	9,050
785	A	Melment	150,000	9,400
786	B	Melment	129,000	8,110
787	B	Melment	128,000	8,050
788	B	Melment	131,000	8,240
789	A	Sikament	122,000*	7,670
790	A	Sikament	144,000	9,050
791	A	Sikament	144,000	9,050
792	B	Sikament	112,000	7,040
793	B	Sikament	107,000	6,730
794	B	Sikament	112,000	7,040

*Cylinder Not Consolidated

These cylinders were made from the concrete as it was placed on the project.

1 lb. = 0.45 Kg

100 psi = 0.69 MPa

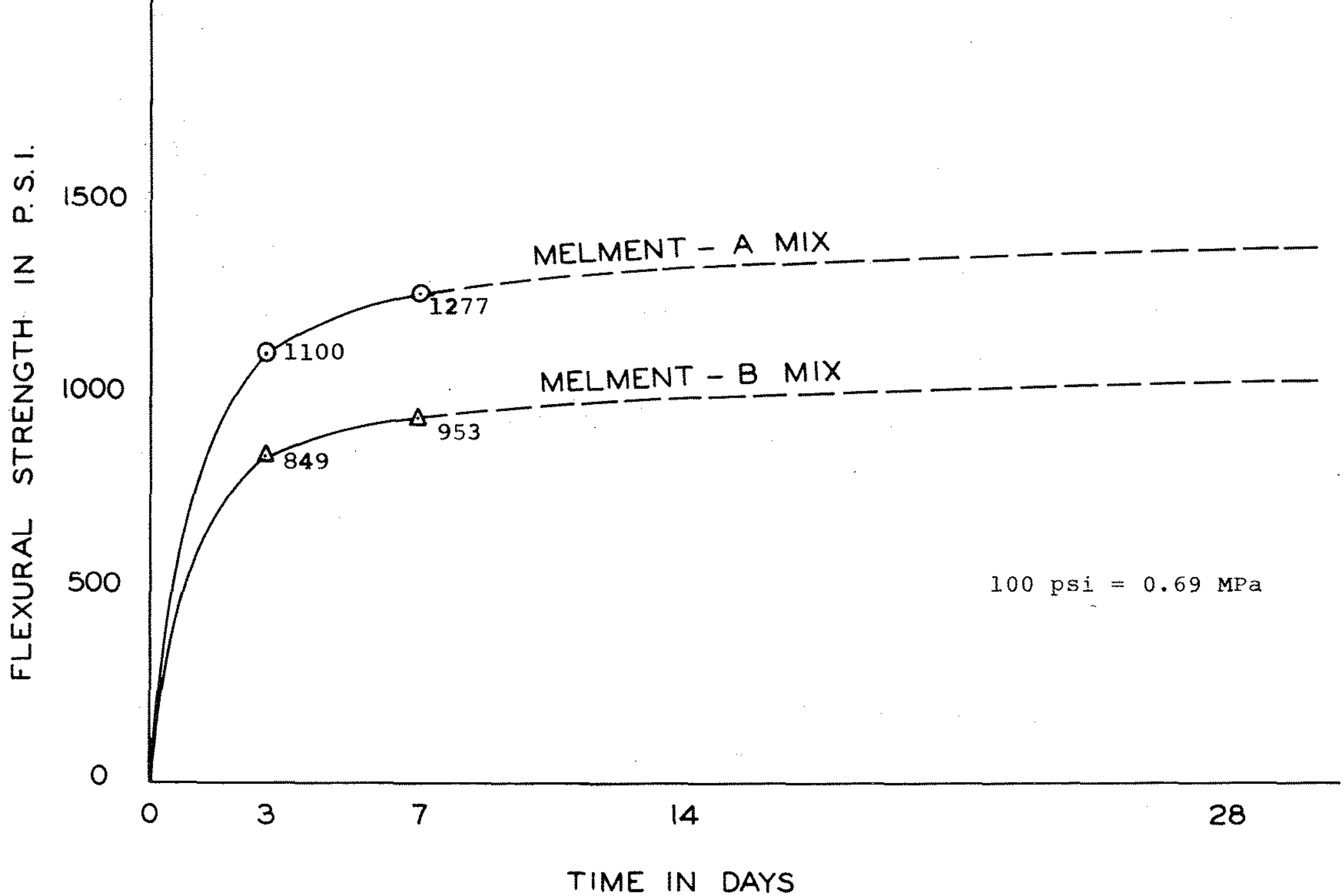


BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE
RESURFACING AND PATCHING ON U.S. 20
FN-20-6(21)-21-07 BLACK HAWK COUNTY, IOWA
FLEXURAL STRENGTH IN P.S.I.
1500
1000
500
0
SIKAMENT - A MIX
SIKAMENT - B MIX
1077
894
979
100 psi = 0.69 MPa
0
3
7
14
28
TIME IN DAYS

Appendix E

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE RESURFACING AND PATCHING ON U.S. 20

FN-20-6(21)-21-07 BLACK HAWK COUNTY, IOWA



IOWA DEPARTMENT OF TRANSPORTATION

Ames, Iowa

Supplemental Specification

for

PORTLAND CEMENT CONCRETE RESURFACING
September 14, 1976

THE STANDARD SPECIFICATIONS, SERIES OF 1972, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SUPPLEMENTAL SPECIFICATIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

796.01 DESCRIPTION. Resurfacing of concrete pavements shall consist of removing concrete from the existing surface, replacing and overlaying with new concrete, and other necessary work as shown on the plans or as specified. The work shall be done according to the Standard Specifications and this specification. Unless otherwise provided on the plans, resurfacing shall accomplish a raise of the existing roadway surface and shall cover the entire pavement surface.

796.02 MATERIALS. All materials shall meet the requirements for the respective items in Part IV of the Standard Specifications, with the following exceptions:

A. Cement. Article 4101 shall apply. The use of Type III (high early strength) cement will not be permitted.

B. Aggregate. Sections 4110 and 4115 shall apply with the exception that the coarse aggregate shall meet the following gradation requirements and shall be a Class 2 crushed stone produced by crushing ledge rock. It shall contain no chert and shall have an absorption not exceeding 3.0 percent.

Sieve Size	Percent Passing Min.	Percent Passing Max.
3/4"	100	
1/2"	97	100
3/8"	40	90
No. 4	5	30
No. 200	0	1.5

C. Concrete shall meet the following requirements.

Basic Absolute Volumes per Unit Volume of Concrete:

	Mix A	Mix B
Coarse Aggregate	0.306731	0.343955
Fine Aggregate	.306731	.343955
Air	.060000	.060000
Water	.170970	.133760
Cement	.155568	.118330

Approximate Quantities of Materials Per Cubic Yard of Concrete:

	Mix A	Mix B
Coarse Aggregate	1,370 lbs.	1,536 lbs.
Fine Aggregate	1,370 lbs.	1,536 lbs.
Cement	823 lbs.	626 lbs.
Water	288 lbs.	225 lbs.

These quantities are based on the following assumptions:

Specific gravity of cement	3.14
Specific gravity of coarse and fine aggregate	2.65
Weight of one cu. ft. of water	62.4 lbs.

Water-cement ratio, 0.35 lb./lb. for Mix A and 0.36 lb./lb. for Mix B.
The maximum water-cement ratio, including free water in the aggregate, shall be 0.39 lb./lb for Mix A and 0.40 lb./lb. for Mix B.
A super water-reducing admixture for improving workability will be required. This admixture shall be approved by the engineer.
The slump, measured in accordance with AASHTO T 119, shall be a maximum of 2 1/2 inches.
The intended air entrainment of the finished concrete is 6 percent, but the air content of fresh, unvibrated concrete at the time of placement, as determined by AASHTO T 152, shall be 6.5 percent, with a maximum variation of plus or minus 1.5 percent.

D. Grout for bonding new concrete to previously placed concrete shall consist by equal parts of weight of portland cement and concrete sand, mixed with sufficient water to form a stiff slurry. The consistency of this slurry shall be such that it can be applied with a stiff brush or broom to the old concrete in a thin, even coating that will not run or puddle in low spots.

796.03 EQUIPMENT. Equipment used shall be subject to approval of the engineer and shall comply with the following:

A. Surface Preparation Equipment shall be of the following types:

1. Sawing Equipment shall be capable of sawing concrete to the specified depth.
2. Sand-Blasting Equipment shall be capable of removing rust, oil, and concrete laitance from the existing surface on the pavement.
3. Scarifying Equipment shall be a power-operated, mechanical scarifier capable of uniformly scarifying or removing the old surface to depths required in a satisfactory manner. Other types of removal devices may be used if their operation is suitable and if they can be demonstrated to the satisfaction of the engineer.

B. Proportioning and Mixing Equipment shall meet requirements of 2001.20 and 2001.21. Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

C. Placing and Finishing Equipment. An approved machine complying with requirements of 2301.07B shall be used. The machine shall be inspected and approved before work is started on each project.

796.04 PREPARATION OF SURFACE. The entire, existing concrete pavement surface shall be uniformly scarified or prepared to a depth of 1/4 inch, except over areas of partial-depth or full-depth repair where the 1/4-inch removal may be coincidental with operations for repair removal.

The thickness of all new concrete above the prepared surface shall be as specified on the plans.

Prior to applying grout in preparation for placement of new concrete, the surface shall be sandblasted followed by an air blast. The sandblast shall be of such an extent to remove all dirt, oil, and other foreign material, as well as any unsound concrete or laitance from the surface and edges against which new concrete is to be placed. It is desired that the surface be roughened by the sandblast to provide satisfactory bond with the surfacing concrete. It is not intended or desired that existing concrete, prepared for resurfacing, be presaturated before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

796.05 PROPORTIONING AND MIXING OF CONCRETE MATERIALS. The applicable provisions of 2301.16 shall apply with the following exceptions and additional provisions:

A. The super water-reducing admixture for improved workability shall be mixed and incorporated in the concrete mixture in accordance with the manufacturer's recommendations and the engineer's instructions.

796.06 PLACING AND FINISHING CONCRETE. The contractor shall take every reasonable precaution to secure a smooth-riding surface. Prior to placement operations, he shall review his equipment, procedures, personnel, and previous results with the engineer, and the inspection procedures will be reviewed to assure coordination. Precautions shall include the following:

Assurance that concrete can be produced and placed within the specified limits, continuously and with uniformity.

After finishing, the contractor shall check the surface with a 10-foot light straightedge; causes for irregularities exceeding 1/8 inch should be eliminated, and corrections should be made, if practical.

At transverse and longitudinal joints, the surface course previously placed shall be sawn to a straight and vertical edge before the adjacent surface course is placed.

After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete.

Placement of the concrete shall be a continuous operation throughout the pour, including patch areas. Internal, hand vibration will be required at full-depth patches and may be required at partial-depth patches. Hand finishing with a wood float may be required for producing a tight, uniform surface.

When a tight, uniform surface has been achieved, the surface shall be given a suitable texture with a wire broom or comb having a single row of tines. The desired texture is transverse grooving which may vary from 1/16-inch width at 1/2-inch centers to 3/16-inch width at 3/4-inch centers, and the groove depth should be 1/8 inch to 3/16 inch. This operation shall be done at such time and in such manner that the desired texture will be achieved while minimizing displacement of the larger aggregate particles. The texture need not extend into the areas within approximately 6 inches of the outside edge.

After the surface has been textured, the surface shall be promptly covered with a single layer of clean, wet burlap or shall be cured in accordance with 2301.22A except that liquid curing compounds shall be applied at twice the minimum specified rate. The locations for wet burlap curing will be shown on the plans.

It is intended that the surface receive a wet burlap or liquid membrane cure for at least 72 hours. For the first 24 hours, the burlap shall be kept continuously wet by means of an automatic sprinkling or wetting system. After 24 hours, the contractor may cover the wet burlap with a layer of 4-mil polyethylene film for a minimum of 48 hours in lieu of using a sprinkling or wetting system.

796.07 LIMITATIONS OF OPERATIONS. If traffic is to be maintained during the construction period of this contract, it will be noted on the plans. The contractor shall provide such traffic contols as required by the plans and specifications.

No traffic shall be permitted on finished resurfacing course until 72 hours after placement. At temperatures below 55 degrees F., the engineer may require a longer waiting time.

No concrete shall be placed when the air or pavement temperature is below 40 degrees F.

796.08 METHOD OF MEASUREMENT. The quantity of the various items of work involved in the construction of portland cement concrete resurfacing will be measured by the engineer in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing. The area of resurfacing constructed of the mix proportions and thickness specified will be computed in square yards from surface measure longitudinally and the nominal plan width.

B. Surface Preparation. The length of pavement prepared in accordance with the specifications will be measured in stations along the centerline of the pavement.

C. Partial-Depth Repair. The volume of concrete for partial depth repair of transverse joints will be computed in cubic yards, to the nearest 0.1, from measurements of the repair locations. Partial-depth repair will be considered to start 1/4 inch below the existing pavement surface, but this shall not preclude removal coincidental with preparation for resurfacing.

D. Full-Depth Patches. Patches involving full-depth removal of old pavement and its replacement with portland cement concrete will be computed in square yards from measurements of the areas of concrete removed, except that each patch which is less than 18 square feet in area will be counted as 2.0 square yards.

796.09 BASIS OF PAYMENT. For the performance of acceptable work, measured as provided above, the contractor will be paid the contract unit price in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing. For the number of square yards of portland cement concrete resurfacing constructed, the contractor will be paid the contract price per square yard. This shall be full compensation for furnishing all material, equipment, and labor necessary to complete this work, including the placement of the grout, in accordance with the plans and these specifications.

B. Surface Preparation. For the stations of pavement prepared as specified herein, the contractor will be paid the contract price per station. This shall be full compensation for removing a nominal 1/4 inch of pavement, stockpiling the material, sandblasting, air blasting, and placing the material removed on the shoulders adjacent to the resurfacing.

C. Partial-Depth Repair. Partial-depth repair will be paid for at the contract price per cubic yard. This price shall be full compensation for the removal and stockpiling of the old pavement.

D. Full-Depth Patches. For the number of square yards of full-depth patches placed, the contractor will be paid the contract price per square yard. This price shall be full compensation for removal and disposal of the old pavement and for all materials and other items involved in construction of such patches.

IOWA DEPARTMENT OF TRANSPORTATION
Ames, Iowa

Supplemental Specification
for
PORTLAND CEMENT CONCRETE RESURFACING

THE STANDARD SPECIFICATIONS, SERIES OF 1972, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SUPPLEMENTAL SPECIFICATIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

.01 DESCRIPTION. Resurfacing of concrete pavements shall consist of cleaning and preparation of the existing surface, overlaying with new concrete, and other necessary work as shown on the plans or as specified. The work shall be done according to the Standard Specifications and this specification. Unless otherwise provided on the plans, resurfacing shall accomplish a raise of the existing roadway surface and shall cover the entire pavement surface.

.02 MATERIALS. All materials shall meet the requirements for the respective items in Part IV of the Standard Specifications, with the following exceptions:

A. Cement. Article 4101 shall apply. The use of Type III (high early strength) cement will not be permitted.
B. Aggregate. Sections 4110 and 4115 shall apply with the exception that the coarse aggregate shall meet the gradation requirements of Classification 67 and shall be a Class 2 aggregate.
C. Concrete. Concrete for resurfacing shall conform to 2301.04C, Mix No. C-4 or Mix No. C-4SWR with a super water reducing admixture, as designated on the plans.

Basic Absolute Volumes per Unit Volume of Concrete

	Mix C-4	Mix C-4 SWR
Coarse Aggregate	.330931	.343955
Fine Aggregate	.330931	.343955
Air	.060000	.060000
Water	.159808	.133760
Cement	.118330	.118330

Approximate Quantities of Materials
Per Cubic Yard of Concrete

Coarse Aggregate	1478 lb.	1536 lb.
Fine Aggregate	1478 lb.	1536 lb.
	626 lb.	626 lb.
	269 lb.	225 lb.
Water-Cement ratio (Design)	0.43 lb./lb.	0.36 lb./lb.
Water-Cement ratio (Maximum)	0.488 lb./lb.	0.40 lb./lb.

These quantities are based on the following assumptions:

Specific gravity of cement	3.14
Specific gravity of coarse and fine aggregate	2.65
Weight of one cu. ft. of water	62.4 lbs.

For Mix No. C-4 SWR, a super water reducing admixture shall be used. This admixture, and the dosage rate, shall be approved by the Office of Materials.
The slump, measured in accordance with AASHTO T 119, shall be a maximum of 2-1/2 inches.
The intended air entrainment of the finished concrete is 6 percent, but the air content of fresh, unvibrated concrete at the time of placement, as determined by AASHTO T 152, shall be 6.5 percent, with a maximum variation of plus or minus 1.5 percent.

D. Grout for bonding new concrete to previously placed concrete shall consist by equal parts of weight of portland cement and concrete sand, mixed with sufficient water to form a stiff slurry. The consistency of this slurry shall be such that it can be applied with a stiff brush or broom to the old concrete in a thin, even coating that will not run or puddle in low spots. The grout shall be agitated prior to and during its use. The cement to water contact time of the grout shall not exceed ninety (90) minutes before it is placed.

.03 EQUIPMENT. Equipment used shall be subject to approval of the engineer and shall comply with the following:

A. Surface Preparation Equipment shall be of the following types:

1. Sawing Equipment shall be capable of sawing concrete to the specified depth.
2. Sand Blasting and Water Blasting Equipment shall be capable of removing rust, oil, and concrete laitance from the existing surface on the pavement.
3. Scarifying Equipment shall be a power-operated, mechanical scarifier capable of uniformly scarifying or removing the old surface to depths required in a satisfactory manner. Other types of removal devices may be used if their operation is suitable and if they can be demonstrated to the satisfaction of the engineer.

B. Proportioning and Mixing Equipment shall meet requirements of 2001.20 and 2001.21. Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

C. Placing and Finishing Equipment. An approved machine complying with requirements of 2301.07B shall be used. The machine shall be inspected and approved before work is started on each project.

.04 PREPARATION OF SURFACE. The entire, existing concrete pavement surface shall be uniformly cleaned with sand blasting or water blasting, or shall be scarified, as designated on the plans. The sand blast or water blast shall be of such an extent to remove all dirt, oil, and other foreign material, as well as any unsound concrete or laitance from the surface and edges against which new concrete is to be placed. Where designated, the existing surface shall be scarified to a depth of 1/4 inch. At transverse joints where the faulting is in excess of 1/4 inch, the high part of the joint will be removed.

Partial depth repair of transverse joints shall be performed at locations shown on the plans, or as directed by the engineer. The deteriorated concrete shall be removed to a nominal width and depth as indicated on the plans, normally to sound concrete. After the partial depth removal, the area shall be cleaned as described above.

Prior to applying grout in preparation for placement of new concrete, the entire surface shall be cleaned with an air blast.

It is not intended or desired that the existing concrete, prepared for resurfacing, be pre-saturated before grout and new concrete are placed. The prepared surface shall be dry to allow some absorption of the grout.

.05 PROPORTIONING AND MIXING OF CONCRETE MATERIALS. The applicable provisions of 2301.16 shall apply with the following exceptions and additional provisions:

A. The super-water-reducing admixture for improved workability shall be mixed and incorporated in the concrete mixture in accordance with the manufacturer's recommendations and the engineer's instructions.

.06 PLACING AND FINISHING CONCRETE. The contractor shall take every reasonable precaution to secure a smooth-riding surface. Prior to placement operations, he shall review his equipment, procedures, personnel, and previous results with the engineer, and the inspection procedures will be reviewed to assure coordination. Precaution shall include the following:

Assurance that concrete can be produced and placed within the specified limits, continuously and with uniformity.

After finishing, the contractor shall check the surface with a 10-foot light straightedge; causes for irregularities exceeding 1/8 inch should be eliminated, and corrections should be made, if practical.

The thickness of all new concrete above the prepared surface shall be as specified on the plans.

The transverse and longitudinal joints of the previously placed surface course shall be sawn to a straight and vertical edge before the adjacent surface course is placed.

After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete.

Placement of the concrete shall be a continuous operation throughout the pour, including patch areas. Internal, hand vibration will be required at full-depth patches and may be required at partial-depth patches. Hand finishing with a wood float may be required for producing a tight, uniform surface.

When a tight, uniform surface has been achieved, the surface shall be textured in accordance with 2301.19 A.

After the surface has been textured, the surface shall be cured in accordance with 2301.22 A, except that liquid curing compounds shall be applied at twice the minimum specified rate.

Unless specified otherwise, joints in the resurfacing will be sawn over the existing transverse joints to a depth of one (1) inch.

.07 LIMITATIONS OF OPERATIONS. If traffic is to be maintained during the construction period of this concract, it will be noted on the plans. The contractor shall provide such traffic controls as required by the plans and specifications.

No traffic shall be permitted on the finished resurfacing course until 72 hours after placement if Mix No. C-4 SWR is used. When Mix No. C-4 is used, no traffic shall be allowed on the resurfacing course for seven (7) days after placement. At temperatures below 55 degrees F., the engineer may require a longer waiting time.

No concrete shall be placed when the air or pavement temperature is below 40 degrees F.

.08 METHOD OF MEASUREMENT. The quantity of the various items of work involved in the construction of portland cement concrete resurfacing will be measured by the engineer in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing. The amount of resurfacing concrete of the mix proportions specified, shall be measured in cubic yards, using a count of batches incorporated. The area of resurfacing constructed of the mix proportions and thickness specified will be computed in square yards from surface measure longitudinally and the nominal plan width.

B. Surface Preparation. The amount of pavement prepared in accordance with the specifications will be measured in square yards from surface measure.

C. Partial Depth Repair. The areas of partial depth repair of transverse joints will be computed in square yards from measurements of the repair locations.

D. Full-Depth Patches. Patches involving full-depth removal of old pavement and its replacement with portland cement concrete will be computed in square yards from measurements of the areas of concrete removed, except that each patch which is less than 18 square feet in area will be counted as 2.0 square yards.

.09 BASIS OF PAYMENT. For the performance of acceptable work, measured as provided above, the contractor will be paid the contract unit price in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing. For the number of cubic yards of portland cement concrete incorporated, payment will be at the contract price per cubic yard. This shall be full compensation for furnishing all raw materials, and the proportioning, mixing, and delivery of concrete to the paving machine. For the number of square yards of portland cement concrete resurfacing constructed, the contractor will be paid the contract price per square yard. This shall be full compensation for furnishing all labor and equipment necessary to place, finish, texture, saw, and cure the concrete, including the placement of the grout, in accordance with the plans and specifications.

B. Surface Preparation. For the square yards of pavement prepared as specified herein, the contractor will be paid the contract price per square yard. This shall be full compensation for scarifying the existing pavement, stockpiling the material, sand blasting, water blasting, air blasting, and placing any material removed on the shoulders adjacent to the resurfacing.

C. Partial-Depth Repair. Partial-depth repair will be paid for at the contract price per square yard. This price shall be full compensation for the removal and stockpiling of the old pavement.

D. Full-Depth Patches. For the number of square yards of full-depth patches placed, the contractor will be paid the contract price per square yard. This price shall be full compensation for removal and disposal of the old pavement and for all materials and other items involved in construction of such patches.

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE
RESURFACING AND PATCHING ON U.S. 20
FN-20-6(21)-21-07 BLACK HAWK COUNTY, IOWA

MODULUS OF ELASTICITY

UNDERLYING CONCRETE PAVEMENT

Core No.		Ultimate Compressive
Core No.	E (P.S.I. x 10^6)	Strength (P.S.I.)
2	5.04	8600
7	4.72	8480
8	4.94	8040
9	4.40	6770
11	4.79	7440
16	4.61	7090
Ave.	4.75	7740

E at 40% of Ultimate

OVERLAY CONCRETE

Cylinder	Mix	Admix	E (P.S.I. x 10^6)	Ultimate Compression Strength (P.S.I.)
1	A	Sikament	5.86	11,260
2	A	"	5.59	10,750
3	A	"	5.73	10,940
4	A	"	5.83	11,290
5	A	"	5.58	11,030
6	A	"	5.79	11,070
7	A	"	None	10,970
Ave.	A	"	5.73	11,040
1	A	Melment	5.31	10,030
2	A	"	5.20	10,000
3	A	"	5.40	10,090
Ave.	A	"	5.30	10,040
8	B	Sikament	5.05	8,200
9	B	"	4.90	8,300
10	B	"	5.00	8,300
Ave.	B	"	4.98	8,270
4	B	Melment	4.43	7,580
5	B	"	5.98	7,450
6	B	"	5.01	7,730
Ave.	B	"	5.14	7,590

Note: All cores were taken from existing pavement. All cylinders were prepared and cured in the laboratory.

100 psi = 0.69 MPa

BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE RESURFACING AND PATCHING ON U.S. 20
FN-20-6(21)-21-07 BLACK HAWK COUNTY, IOWA

MODULUS OF ELASTICITY

UNDERLYING CONCRETE PAVEMENT

Core No.	E (P.S.I. x 10^6)	Ultimate Compressive Strength (P.S.I.)
2	5.04	8600
7	4.72	8480
8	4.94	8040
9	4.40	6770
11	4.79	7440
16	4.61	7090
Ave.	4.75	7740

E at 40% of Ultimate

OVERLAY CONCRETE

Cylinder	Mix	Admix	E (P.S.I. x 10^6)	Ultimate Compression Strength (P.S.I.)
1	A	Sikament	5.86	11,260
2	A	"	5.59	10,750
3	A	"	5.73	10,940
4	A	"	5.83	11,290
5	A	"	5.58	11,030
6	A	"	5.79	11,070
7	A	"	None	10,970
Ave.	A	"	5.73	11,040
1	A	Melment	5.31	10,030
2	A	"	5.20	10,000
3	A	"	5.40	10,090
Ave.	A	"	5.30	10,040
8	B	Sikament	5.05	8,200
9	B	"	4.90	8,300
10	B	"	5.00	8,300
Ave.	B	"	4.98	8,270
4	B	Melment	4.43	7,580
5	B	"	5.98	7,450
6	B	"	5.01	7,730
Ave.	B	"	5.14	7,590

Note: All cores were taken from existing pavement. All cylinders were prepared and cured in the laboratory.

100 psi = 0.69 MPa