AN EVALUATION OF

BONDED, THIN-LIFT, NON-REINFORCED

PORTLAND CEMENT CONCRETE RESURFACING AND PATCHING

M. J. KNUTSON, P.E.
EXECUTIVE VICE PRESIDENT
IOWA CONCRETE PAVING ASSOCIATION

PRESENTED AT:

62nd ANNUAL MEETING

AMERICAN ASSOCIATION OF STATE

HIGHWAY AND TRANSPORTATION OFFICIALS

BIRMINGHAM, ALABAMA

November 15, 1976

PROBLEM STATEMENT

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.

Iowa has had much success in the use of thin, bonded, dense concrete overlays used in the repair of deteriorated bridge decks. The degree of success in repairing bridge decks is such that since early 1975 it has been Iowa's bridge design policy for the primary and interstate system to build all new bridges with two-course decks; the top course being a bonded, thin layer of dense, high cement content concrete.

A definite need exists for a high strength, durable, skid resistant, long lasting, and economic resurfacing course for PC concrete pavements. Such a resurfacing course, completely bonded to the existing pavement would provide additional support for the ever increasing traffic loads and volumes on our roads and streets.

By applying the same principles and methods learned from the last twelve years of experience with bridges it is felt that this system could provide a very viable alternate to the bituminous product that has been traditionally used in the restoration, rehabilitation, and resurfacing process on PC concrete pavements.

From the successful experience with bridge deck surfacing as noted above, it was known that new dense PC 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 workable process for large volume projects.

A typical one-day bridge deck resurfacing pour would be 50 - 600 feet long and 12 to 22 feet wide using 0 to 3/4 inch slump concrete on a prepared (ground or scarified) surface. This concrete would be mixed in a small (1/4 cu. yd.) mixer or a Concretemobile.

Obviously this rate of production would not be economical if a 7 to 10 mile 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.

Another concern was with respect to what amount of patching might be necessary before resurfacing. Spalled joints, faulted joints, or joint failure had to be considered. Whether it would be necessary to full depth patch these areas or if partial depth patches could be used was another question.

With these questions in mind a research project was done with the following objectives:

1) To determine the feasibility of proportioning, mixing, placing, and finishing a thin lift (approximately 2 inches) of bonded, dense, non-reinforced portland cement concrete using conventional mixing and slipform 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 and 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.

LOCATIONS

Choice of a 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 eminent or presently being made. Second, sufficient traffic volumes must be present to allow proper evaluation of durability of the proposed research resurfacing. Third, a location condusive to allowing a contractor to employ high production slab preparation, mixing, and slipform paving equipment.

The first project site selected was located on primary road US #20 at the east edge of Waterloo, Iowa. The existing roadway is a four-lane divided 10 inch thick, plain, jointed, portland cement concrete pavement originally constructed in 1958. Approximately 1500 lineal feet of the westbound lanes just east of Evans Road were surfaced.

The existing pavement was originally constructed with a crushed limestone coarse aggregate which is susceptible to d-cracking. Immediately prior to this project most of the transverse joints (20 ft. 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

The second project was a residential city street located on Prospect Boulevard in the City of Waterloo, Iowa. This is a 18 ft. wide section 7 inches thick with integral curb and gutter constructed in 1941. This project begins at the intersection of Prospect Boulevard and Ridgeway Avenue and runs northerly 1478 lineal feet. The surface was badly scaled, and a few joints were deteriorated the full depth of the pavement. This street was originally constructed of limestone aggregates.

The third project was an arterial city street located on Hammond Avenue in the City of Waterloo, Iowa. This is a 25 feet wide section 6 inches thick with integral curb and gutter constructed in 1949. The project begins at the intersection of Patton and goes northernly 666 lineal feet thru the intersection of Glenny Avenue. The surface had minor scaling and had several random settlement cracks due to subgrade failure and utility trenchs. The street was originally constructed of a gravel aggregate.

PROPOSED PROCEDURE

The proposed procedure for all three projects consisted of two contiguous phases. (No transverse joint preparation was necessary on the city projects.)

Phase I. The existing pavement surface was to be prepared for resurfacing by removal of approximately the top 1/4 inch of concrete and complete coverage by sandblasting. This would provide a roughened surface, clean from road oils, linseed oil, tire rubber and other contaminants that might prohibit a uniform bonding of the resurfacing. At deteriorated transverse joints or cracks the existing pavement was to be removed to a depth of 3 to 4 inches and then sandblasted.

In the past the repair of d-cracked distressed joints has been by full depth removal. The timing for this repair has usually been held off until the spalling had progressed to the point where a rough ride existed. Since most of the joints on the proposed project indicated this type of deterioration had not started but was certainly coming, it was decided that partial depth removal and patching with the resurfacing concrete could be done in lieu of full depth removal and patching. It was assumed that this partial depth removal could be done at the time of the surface preparation. There also was some question as 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. would be removed.

2) At the remaining joints approximately 3 to 4 inches of the deteriorated concrete would be removed.

3) In addition, approximately four (4) full-depth patches (nominally 4 ft. in width) were proposed in the project.

The removal or scarifying of both the existing surface and the deteriorated joints was to be accomplished by the 'RP-30 Road Planer", manufactured by Galion or the Roto Mill Pavement Profiler", manufactured by CMI. The former cuts 30 in. wide; the latter cuts 9 ft. 2 in. wide. Both machines are rotary type cutters utilizing teeth with specially hardened tips. The material removed by the cutting operation consisting of approximately 1/2 in. to 5/8 in. maximum size particles which would be stockpiled for use as shouldering material.

Phase 2. Immediately ahead of the placement of the concrete resurfacing, a thick consistency grout consisting of 50% portland cement and 50% concrete sand was to be brushed on the dry prepared pavement surface. It is important to again note here that the pavement should be completely dry before the grout is placed.

This was followed by concrete placement and consolidation, texturing, and curing. The concrete mix proportions would be that used on the bridge deck overlays, 823 lbs.of cement per cubic yard for approximately one half of the project; the remainder of the project would have a cement content common to normal concrete paving of 626 lbs. per cubic yard.

All concrete in the resurfacing would include a super water reducing admixture to provide workability at a low water/cement ratio (approximately 0.35 pounds of water per pound of cement).

The texture desired would be transverse grooving with grooves which may vary from 1/8 inch wide to 1/2 inch centers to 3/16 inch wide at 3/4 inch centers; the groove depth being 1/8 to 3/16 inch. The texturing was to be accomplished by a mechanically operated wire tine or wire comb texturing machine.

The curing was to be as follows: Approximately 400 feet (200 feet in each section of different cement contents) was to be cured with wet burlap. The burlap was to be kept continuously wet for 72

hours or, after 24 hours, could be covered with a layer of 4 mil polyethylene film for an additional 48 hours. The remainder of the project was to be cured by applying a liquid membrane cure in accordance with present Iowa standard specifications except the application rate shall be twice the specified minimum rate.

No longitudinal joint sawing would be required. Transverse sawing (1 inch minimum depth), over the existing joint, would be required at approximately 20% of the existing joint locations. These were to be randomly located over each type of the variously prepared partial depth joints. No joint sawing was required in areas of full-depth joint repair.

CONTRACT PROCEDURE

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 before. 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 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. Cost analysis and unit costs will be discussed later in this report.

The contract 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 of the existing pavement, sandblasting, and airblasting.

Item 2. Patches, partial depth - 28.9 cu. yds. 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. This item of work included full depth removal of the existing slab, disposal of the removed concrete, and new concrete to fill the patch.

Item 4. PC concrete resurfacing, 2 inches thick - 4,000 sq. yds. This item of work included grouting, placing, texturing, and curing the new concrete. Also incidental to this item was the sawing required at specified transverse joints and end runouts.

Other work considered incidental to the contract items were placing the material removed in surface preparation on the shoulders and sawing the pressure relief joints at each end of the project and traffic control.

Data has been and is being 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.

Projects two (Prospect Blvd.) and three (Hammond Ave.) in the City of Waterloo were negotiated between the Iowa Concrete Paving Association, Cedar Falls Construction Company, and the City of Waterloo, Iowa.

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 essential since the contractor elected to construct all three projects within a two-week span. Operations would have to be dove-tailed for efficiency in equipment utilization.

Pressure Relief Joints - The first operation on US #20 consisted of sawing a 4 inch wide 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.

Full-Depth Patching - The contractor elected to remove and replace the full depth patches prior to surface preparation, although the replacement concrete could have been placed with the resurfacing. Because it was planned that the delivery of resurfacing concrete would be over the prepared existing pavement, the open full depth patches could not be tolerated. In addition, super water reducers

were used in this patch concrete in an attempt to gain experience on mixing and consistency prior to resurfacing. A total of 32.98 square yards of full depth patch (10"depth) was placed in four separate patches of nearly equal size. Approximately one half of this concrete was Mix A (see Supplemental Specification 796 in Appendix A) with Sikament as the super water reducer and one half was Mix A with Melment as the super water reducer. Removal and replacement was accomplished in one day without problem.

Surface Grinding - Preparation of the existing pavement surface on all three projects consisted of scarifying with a CMI Roto Mill Profiler. This machine is a converted tri-pod CMI Subgrader which has been fitted with a 9 ft. 2 in. wide grinding wheel. The weight has been increased to 55,000 lbs., and the machine is equipped with a 375 hp engine. The grinding wheel fits under the machine where the subgrade cutting augers usually are. It has 230 high carbon tipped removable teeth which produce the grinding. Production capacity is approximately 1000 - 1500 sq. yds. per day cutting limestone aggregate paving. Our experience in cutting concrete with natural ground aggregates indicated that the above production rate could not be achieved.

Profile elevations were taken on both edges and centerline of the existing pavement prior to grinding. A new profile was established and grade stakes were set on both sides of the pavement. It was intended that the CMI Roto Mill which was equipped with automatic grade control would be operated from a string line on each side of the road so that some profile grade correction of high areas could be accomplished during the grinding operation (normally, only 1/4 inch would be removed for surface preparation). However, after considerable discussion with CMI representatives it was decided to use the automatic grade control from a ski on the existing pavement. This ski was as long as the wheel base of the Roto Mill. This did in fact produce some reprofiling with the grinding as is indicated in the before and after profilometer readings on US #20 (See appendix B). This reprofiling, however, was confined to trimming of high spots. Where the existing pavement had a low spot, the Roto Mill would skip over it without any grinding being accomplished. There

were not a great many of these areas, but enough to require regrinding the outside edges. The grinding was done in three passes. The outside 9 ft. 2 in. was done on each side and a third pass down the center for the remaining width. An additional pass down the outsides was necessary as mentioned previously. 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 at nearly the same as in the pavement before grinding, it created a high spot approximately 3 to 5 feet from centerline. It was decided this was somewhat undesireable due to a possible thinning of the resurfacing depth, but not serious enough to warrant removal by additional grinding.

End runouts to tie into existing slabs were accomplished by grinding from 1/4" to 1 1/4" in 25 feet. This allowed a flush header with the existing slab.

Effective grinding can be obtained with machine speed of up to 40 feet per minute.

Partial Depth Patch Removal - The plans indicated that 35 joints were to receive partial depth patches on US #20. Thirty of these joints were to be repaired full width and five joints to be repaired one half width. As stated earlier in this report, this repair was to include removal to a depth of 3 to 4 inches. It was found that because of the shielding around the cutting wheel on the CMI Roto Mill that only a depth of approximately 2 inches could be attained. All of the full width patches were initially removed to this 2 inch depth. The one half width patches were to be removed with a Galion RP-30 which has a 30 inch long wheel with removable teeth similar to the one on the Roto Mill except that it is mounted on a Galion Motor Grader. The Galion had similar depth limitations as the Roto Mill, but was able to attain more grinding depth by widening the grinding area. The Galion is also considerably more versatile because it is wheel driven and smaller than the Roto Mill.

After inspection of the removal done by the Roto Mill, it was decided that some of the patch areas should be deepened by additional removal. In some cases this was deemed necessary because unsound concrete still existed to a large extent in the bottom of the patch area. In other instances, additional depth was desired to make possible a better evaluation of performance. All of this additional removal was done with the Galion machine.

The material produced by the Roto Mill grinding was placed on the shoulders by conveyor belt from the machine. The material produced by the Galion was swept to the shoulder. This material was used to build a graded pad line for the paver.

Sandblasting - The entire area was sandblasted using a mobile sandblaster manufactured by Capitol Engineering Company, a subsidiary of Oster & Pederson, Inc. of Minneapolis, Minnesota.

The trailer-mounted blasting unit consists of two 600 cfm Chicago pneumatic compressors, two 5-ton canned sand units, a Ford 6-cylinder industrial engine driving a Vickers 29 rpm hydraulic pump and a hydraulic drive system for the rear wheels of the trailer. An International Transtar is used to haul the equipment to the job site.

Sandblasting is a one-man operation. Four switches on the panel control the sand to four #7 nozzles fed by 1 1/4 in. hose and suspended from a metal frame which is mounted on the rear of the trailer. The frame automatically oscillates, and the frequency of the oscillation can be controlled from a dial on the control panel. Blasting with 110 lbs. of nozzle pressure, the four #7 nozzles can cover about 10 sq. yds. per minute. The width of coverage can be varied from 9 ft. to 16 ft. and the forward speed from 0 to 14 ft. per minute.

Concrete Mix - For the resurfacing, each project was divided into four sections of equal lengths. This was done so that two different concrete mixes and two different super water reducers could be placed and evaluated. The two concrete mixes used the same aggregates with different cement contents. Mix proportions were as follows:

	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.

The fresh unvibrated concrete was to have an air content of 6.5 percent with a maximum variation of 1.5 percent. To these mixes, a super water reducing agent was to be added in order to improve workability. Based on economics and some limited previous experience at a trial run on September 12, 1976 at the Gomaco Corp. in Ida Grove, Iowa it was decided that the two water reducing admixtures to be used would be Sikament manufactured in Switzerland and sold by Sika Chemical Corporation and Melment manufactured and sold by American Admixtures Corporation. Both products were furnished in liquid form.

It was expected that water-cement ratios of 0.35 for Mix A and 0.36 for Mix B could be obtained with a maximum water-cement ratio of 0.39 for Mix A and 0.40 for Mix B as was designated in the supplemental specification for this project. Actual water-cement ratios obtained in the field were in the following ranges:

	Mix A	Mix B
Melment	0.290 - 0.300	0.359 - 0.369
Sikament	0.260 - 0.264	0.330 - 0.362

Additional details for aggregate gradation and mix design are shown on Supplemental Specification 796 in Appendix A.

Grout - All concrete and grout was mixed and hauled in ready mix trucks. A cubic yard of grout covered approximately 600 square yards. The grout was dumped immediately ahead of the paving operation and manually spread with hand brooms. Care was taken to insure grouting in the depressions of the partial depth patches which were poured with the resurfacing. Grout could not be spread too far ahead of the paving operation because it tended to dry on the surface.

Slipform Paving Equipment - On the US #20 project a Rex Model STR slipform paver was used for the resurfacing. It was set for 2 inch pavement depth and run on a graded pad line constructed on the shoulders. A special 2 inch trailing form was constructed for this project. The paver was equipped with spud vibrators as well as pan vibrators. There were also tamping bars in the front of the extrusion motor.

On the City of Waterloo projects the Gomaco Corp. of Ida Grove, Iowa manufactured a special mule and frame for 16 ft. and 24 ft. widths. The vertical elevation of the slipform equipment was controlled by a string line with grades set from the existing slab. The crawler tracks of the paver traveled outside the existing slab.

The concrete was dumped directly in front of the paver and spread with the auger on the front of the paver. There was a tendency for slightly too wet concrete to flow out the back when the paver had to be stopped for some reason. This appeared like a wave and had to be trimmed with mops or straight edges to prevent a bump from being created. Although the paver could accommodate and spread drier than normal concrete, a problem of tearing tended to develop in the extrusion meter and additional finishing was necessary to close up the surface.

Delivery rates for the concrete were hampered somewhat by difficulty experienced in getting drier concrete out of the ready mix trucks. There was only enough room to unload two trucks at one time so that the addition of more trucks was of no advantage. The resulting roughness in the finished pavement is probably due to inconsistency of the concrete from one load to the next and the unique characteristics of this high density concrete.

Texturing - The US #20 pavement was textured with Astro-Grass and transversely grooved with a CMI CT-280. The transverse grooving was not as deep in some areas as it should have been. This was primarily due to the use of extremely low slump concrete and surface tearing which had to be corrected as mentioned previously before grooving could be accomplished. This resulted in such a stiff consistency of the surface concrete that the grooving tines did not penetrate to adequate depths.

Some grooving was obtained in these areas however. Essentially the same problem existed with the Astro Grass texturing.

On the city sections a burlap drag was the only texture desired.

Cure - On the US #20 project a white pigmented liquid membrane cure was used on all but 400 l.f. of the project. Wet burlap was used on the remainder of the project. This was done so that a comparison of cure methods could be evaluated. The burlap cure was so located that both concrete mixes were cured by this method. The burlap was kept wet for 24 hours and then removed. The slab was covered with a layer of 4 mil polyethylene film for an additional 48 hours.

On the city section a white pigment liquid membrane cure was used.

Sawing - No longitudinal sawing was required for any of the projects. Transverse sawing (1 inch minimum depth) over the existing joint was required at approximately 20% of the existing joint locations. The joints were marked by pulling a string line directly over the existing joint prior to paving and placing red-head nails to mark the exact location. Three of the partial depth patches outside the resurfacing on the US #20 project were sawed transversely. Four of the partial depth patches were not sawed.

The paving operations were accomplished on the following dates:

1) Prospect Avenue, City of Waterloo	October 5, 1976
2) Hammond Avenue, City of Waterloo	October 7, 1976
3) US #20, State of Iowa	October 12, 1976

SPECIAL SECTIONS (US #20)

One of the most important criteria for the success of this project is the attainment of complete 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 bond can be obtained if any of these conditions are changed. For that reason four special sections were designated with the resurfacing project. Each section is

approximately 20 ft. long for the full width of the pavement.

Two of the sections were sandblasted with no grinding and two sections were ground but not sandblasted. Each pair of sections was so located in the project so that different cement content mixes were used for each pair. All were resurfaced in the normal manner including grouting.

Also of interest was the possibility 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 ways. Four of the joints were ground with the Galion grinding parallel to the joint. This produced a removal area which was all the way across the pavement and 30 inches wide. Three of the joints were ground with the Galion grinding perpendicular 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 to 5 inches in depth.

All patches were sandblasted and grouted prior to placement of patch concrete. The concrete used to fill the patches was the same as that used in the resurfacing with the exception of the super water reducing agent. These patches were cured with liquid membrane cure.

FUTURE CONSTRUCTION AND COSTS

The demonstration project on US #20 was bid by the Cedar Falls Construction Company with members of the Iowa Concrete Paving Association donating manpower and certain special equipment. The quantities, and unit prices bid were as follows:

Units	Quantity	Unit Price
1) Surface preparation	15 sta.	$520.00
2) Partial-depth repair	28.9 cu. yd.	$135.00
3) Patches, full depth	32 sq. yd.	$50.00
4) Portland cement concrete resurfacing	4000 sq. yd.	$5.70

Cedar Falls Construction Company and the Iowa Concrete Paving Association organized the demonstration project so as to utilize equipment with high production capabilities. Super water reducing agents were utilized to allow a higher slump concrete for production and workability, yet maintain dense, high strength concrete as per the Iowa bridge deck resurfacing method.

The experience gained on this short demonstration project proves production capacity of up to a mile of 24 ft. wide paving per day. Production in excess of this would require two CMI Roto Mill profilers and two mobile sandblasters. However, production in these amounts would motivate equipment manufacturers to produce larger equipment to handle higher production rates.

Industry must also produce a mechanical broom applicater or pressure sprayer to apply grout directly in front of the slipform paver. Mixing and transporting grout in a ready mix truck seems to be an economical and practical method.

Mixing and transporting of the mixes using super water reducers appears to produce a mix somewhat more sensitive than normal concrete mixes. The concrete has a low slump appearance until vibration is applied. The concrete is difficult to unload from normal ready mix trucks. However, ready mix trucks equipped with paving mixers or mixing in central mix plants and transporting in dump trucks would solve this problem.

Normal slipform paving equipment with a ski-type sensing device should be used to assure a good yield and good ride characteristics. Finishing behind the paver is more difficult because of the dense concrete. When working with straightedges and floats it has a "rubbery effect". Tines on the texturing machine must be built with a firmer metal. This again is due to the density of the concrete.

Based on the experience of these projects and assuming a project involving 170,000 sq. yds. of nominal 2" thick high density concrete with a type B mix (626 lbs. of cement) with super

water reducing agents, a bid in the range of $5.00 to $6.00 per sq. yd. could be expected. This would include surface preparation. It would not include partial or full depth patch repair nor traffic control.

Future costs will depend on location, price of materials, and surface preparation costs.

TESTING AND OBSERVATIONS

Tests and observations have been and are being made on the following:

1) Skid number determination prior to and after completion of the project. (US #20 only)
2) Roughometer tests, before and after project work. (US #20 only)
3) Roadmeter tests, before and after, project work. (US #20 only)
4) Coring for compressive strength, bond strength, and thickness determination. (All three projects)
5) The normal slump and air content testing common to conventional concrete paving. (All three projects)

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 as to their size, location, and number relative to the existing cracks and joints.

An average of flexure and compressive strengths for various mixes and super water reducing agents is listed in Appendix E.

A progress report will be submitted by May 1, 1977. This will enable observation and evaluation of the resurfacing course and joint condition after one winter's freeze and thaw cycling.

Future reports will be submitted as the need dictates. It is expected that a guide can be developed for the design of bonded, thin-lift, non-reinforced PC concrete resurfacing and will be applicable to all paving systems such as interstate, state, county highways and city streets and airports.

REFERENCES

1) L. T. Norling, Principal Paving Engineer, Portland Cement Association, "Concrete Overlays and Resurfacing - A Status Report", January, 1976.

2) Iowa State Highway Commission Research Report HR-34

3) M. J. Knutson, Executive Vice President, Iowa Concrete Paving Association, "Greene County, Iowa, Concrete Overlay Research Project", ACI SPSI-10, 1974.

We would like to acknowledge the principal investigators for these projects and thank them for their design concepts, specifications, and technical reports.

Jerry Bergren, Office of Materials, Iowa Department of Transportation, Division of Highways

Clare Schroeder, Design Department, Iowa Department of Transportation, Division of Highways

Bruce Radue, City Engineer, Waterloo, Iowa

Gary Heinick, Asst. City Engineer, Waterloo, Iowa

ACKNOWLEDGEMENTS

Equipment, Materials, Manpower, and Donations

Equipment	
Rex STR Slipform Paver	Fred Carlson Company
CMI CT-280 Curing and texturing machine	Central Paving Corp.
CMI Subgrader	Cedar Valley Corp.
Curbmaster Groundhog	Curbmaster Corp.
CMI Rotary Mill Profiler	CMI Corp.
Gomaco Slipform Paver	Northern Paving Corp.
Built Mule and frame for 16' and 24' widths	Gomaco Corp.
Vibration and brooming device for grout	Gomaco Corp.
Galion Grinder RP-30	Cedar Falls Construction Co.
Sullar Air Compressor	Cedar Falls Construction Co.
Elgin Street Sweeper	Cedar Falls Construction Co.
Case 5800 Backhoe	Cedar Falls Construction Co.
Ditch Witch Concrete Cutter	Cedar Falls Construction Co.
International Tractor and Broom	Cedar Falls Construction Co.
Large Sandblaster	Oster, Pederson, Inc.
2 Dump trucks	Cedar Valley Corp.
1 Load King and Tractor	Fred Carlson Company
1 Motor Patrol	Cedar Valley Corp.
Street Vacuum	Cedar Falls Construction Co.
2 Water trucks	Cedar Falls Construction Co.
1 Water truck	Cedar Valley Corp.
Concrete saw	Cedar Falls Construction Co.
Joint sealing machine	Contractors Steel Corp.
Sand trailer and tractor	Cedar Falls Construction Co.

Acknowledgements (cont.)

Equipment

Paint stripe machine and paint	Cedar Falls Construction Co.
3 pickups	Cedar Falls Construction Co.
Pump truck	Cedar Falls Construction Co.

Materials

Ready Mix Concrete	C. W. Shirey & Co.
Melment Super Water Reducer	American Admixtures
Sikament Super Water Reducer	Sika Chemical Corp. and Contractors Steel Corp.

Manpower Furnished

	No.		No.
Fred Carlson Company	5	Contractors Steel Corp.	2
Hallett Construction Co.	3	American Admixtures	1
Cedar Valley Corp.	4	Iowa Concrete Paving Association	2
Gomaco Corp.	3	Northern Paving Corp.	3
Irving F. Jensen Co.	1	Cedar Falls Construction Co.	2
Jackson Construction Co.	1		

Cash Donations

Boswell Contracting Corp.	Allied Construction Company
Koss Construction Company	Western Contracting Corp.
Metro Pavers, Inc., Iowa City	Quad City Construction Company

A Special Thanks to Bernard Larsen and Ron Risting of Cedar Falls Construction Company

For Their Expertise in Construction of These Projects.

Appendix A

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.	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.

Appendix B

US #20 - Black Hawk County

Skid Resistance:

	Inside lane	Outside lane
Before Grinding SN_{40}	36	31
Before Grinding SN_{50}	31	25
After Single Pass of Grinder, * SN_{40}	58	57

Profile Index Using 25 ft. California Profilometer:

Before Grinding	25.0 in/mi.	25.5 in/mi
After Single Pass of Grinder	7.4 in/mi	4.6 in/mi
After Second Pass of Grinder	3.1 in/mi	3.0 in/mi

* No skid resistance measurements were secured after second pass of of the grinding machine.

Appendix E

Strengths ------ Average

Age	Mix	Cement Content	Super Water Reducer	Test	P.S.I.
3 days	A	823 lb/cy	Melment	Flexure	1108
3 "	B	626 "	Melment	Flexure	849
3 "	A	823 "	Sikament	Flexure	1077
3 "	B	626 "	Sikament	Flexure	894
7 "	A	823 "	Melment	Flexure	1277
7 "	B	626 "	Melment	Flexure	953
7 "	A	823 "	Sikament	Flexure	1203
7 "	B	626 "	Sikament	Flexure	979
28 "	A	823 "	Melment	Compression	9300
28 "	B	626 "	Melment	Compression	8130
28 "	A	823 "	Sikament	Compression	9050
28 "	B	626 "	Sikament	Compression	6936

APPENDIX C

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

	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.
	6.5% ENTRAINED AIR	

SUPER WATER REDUCERS

MELMENT	SIKAMENT
42 OZ. PER 100 lbs. CEMENT	26 OZ. PER 94 lbs. CEMENT
20% SOLIDS - 80% WATER	40% SOLIDS - 60% WATER

CONCRETE MIX PROPORTIONS

APPENDIX D

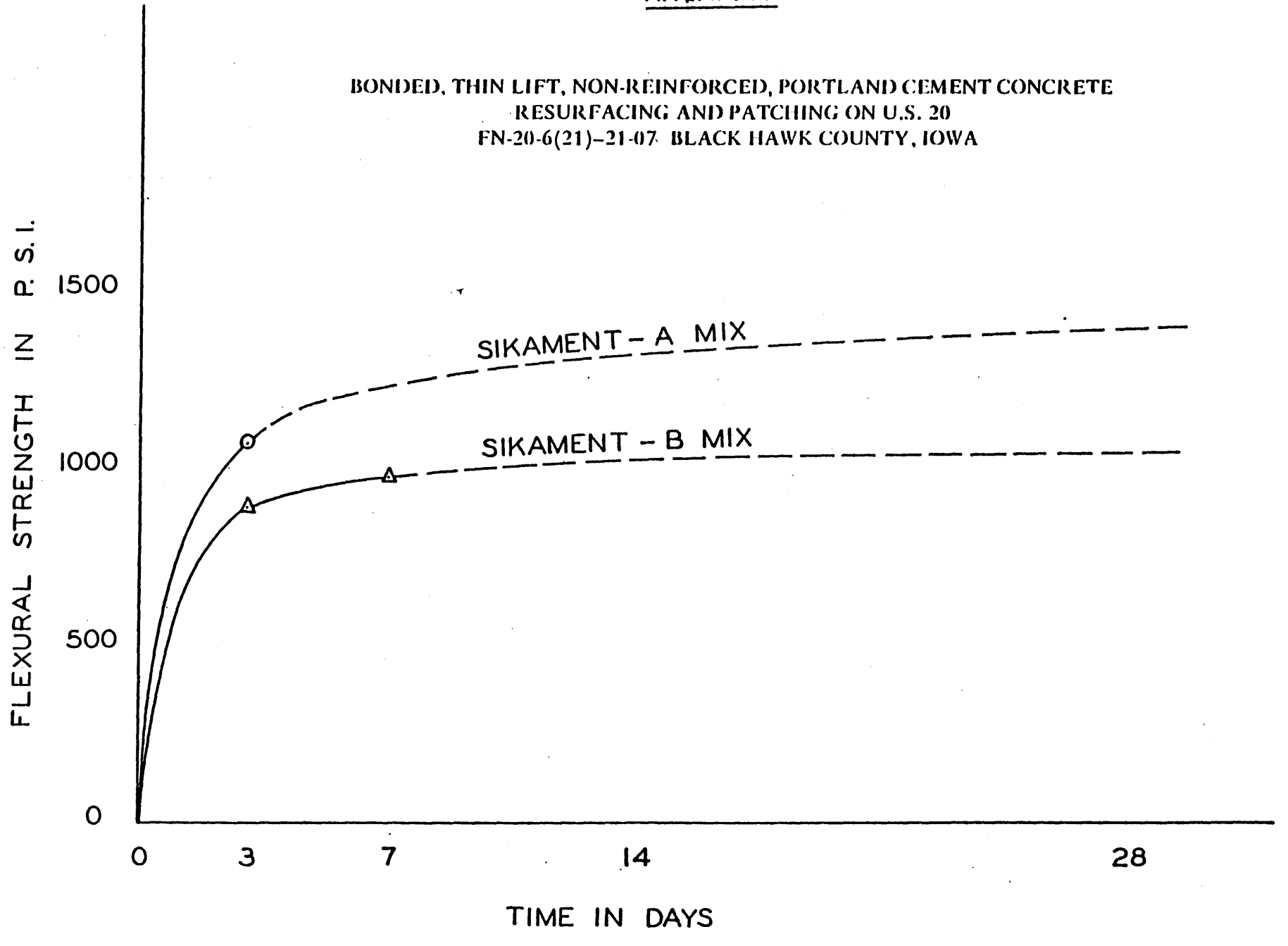
BONDED, THIN LIFT, NON-REINFORCED, PORTLAND CEMENT CONCRETE RESURFACING AND PATCHING ON U.S. 20 FN-20-6(21)--21-07 BLACK HAWK COUNTY, IOWA

	MIX A	MIX B
MELMENT	0.290-0.300	0.359-0.369
SIKAMENT	0.260-0.264	0.330-0.362

WATER/CEMENT RATIO

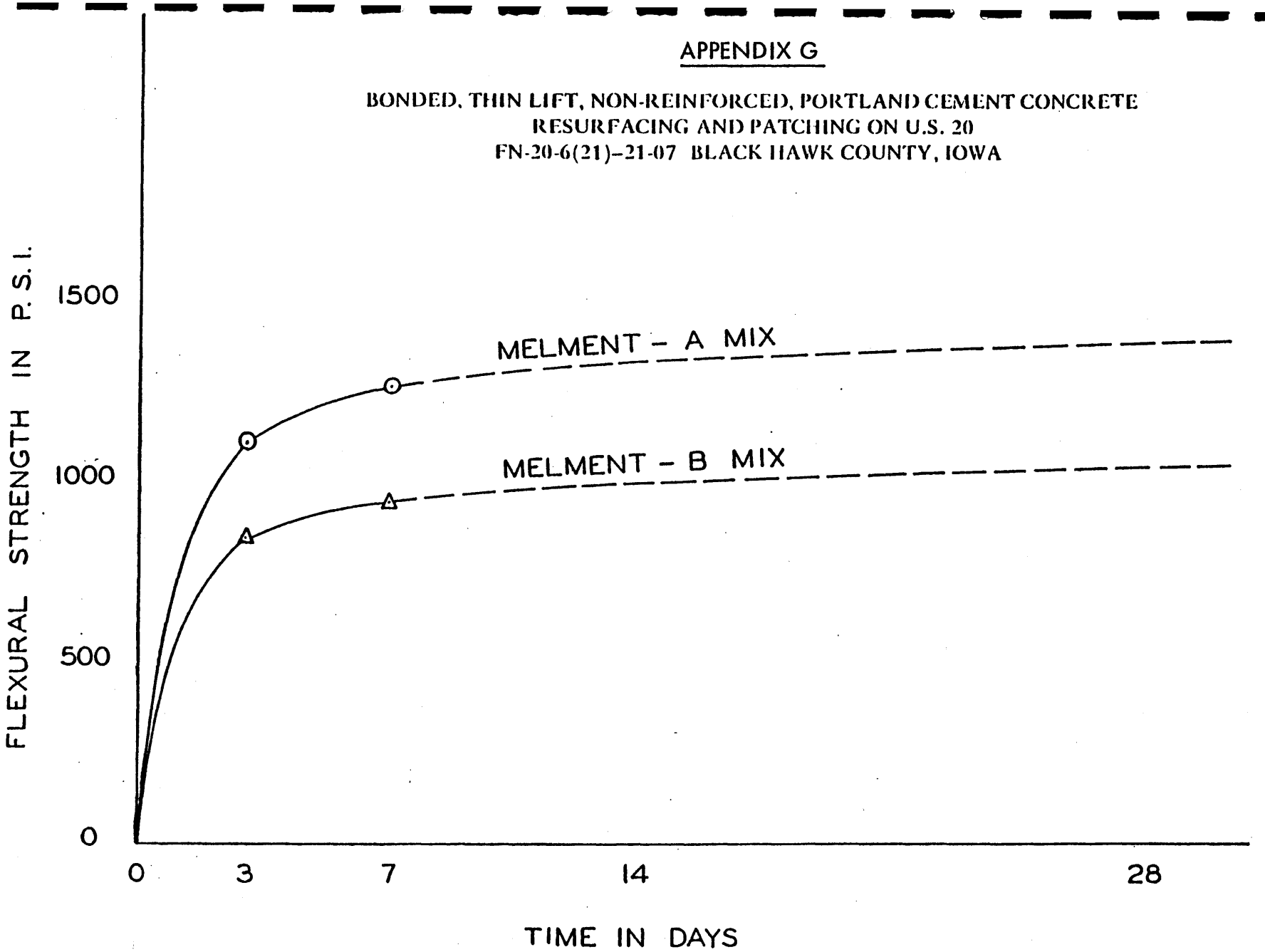
APPENDIX F

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



APPENDIX G

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



APPENDIX 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

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

*MEMBRANE CURE NOT WORN OFF

SKID NUMBERS AT 40 M.P.H.