EXPERIMENTAL PROJECT

THIN BONDED CONCRETE RESURFACING

US 34 WEST BURLINGTON, IOWA

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The Experimental Project was designated as Research Project No. HR-34, sponsored by the Iowa Highway Research Board and constructed by the Iowa Highway Commission. Construction was supervised cooperatively by Engineers of the Iowa Highway Commission and the Portland Cement Association.

The objective of the experiment is to study the behavior of relatively thin portland cement concrete resurfacing courses placed with bond on old concrete pavements. The phase of the problem being studied now, involves only pavements in which the old concrete is structurally sound.

Location and General Description

The pavement selected for this study is the west bound lanes of Highway U.S. 34 just west of West Burlington. The old pavement was built in 1921 under Project No. P-53 Des Moines County. It is 18 ft. wide, 7 in. thick at the edges and 8 in. thick at the center. The concrete is sound, but presents a rough riding surface. It was built without longitudinal center joint or transverse joints except at construction stops. Consequently the pavement has a considerable amount of irregular transverse and longitudinal cracks. It was recognized that most of these cracks will be reflected up through the resurfacing but because of the random nature of the cracking no plan of jointing for crack control was feasible.

The resurfacing experiment extends from station 251 + 98 to station 267 + 53, a distance of 1555 ft. including two 32-ft. replacements, one at each end of the project to form a ramp to meet the grade of the adjoining pavement. The pavement at each end had been replaced with a 22-ft. pavement of 10-8-8-10-in. cross-section. The site was selected because the detour problem could be solved by operating on the existing east bound lanes of the highway as a two lane pavement for the short distance involved in the experiment. A diagramatic sketch of the experiment is shown in Figure 1.

The project includes the widening of the old pavement from 18 to 22 ft. with a 2-ft. strip at each edge and the resurfacing of the old pavement with nominal thickness

of 1, 2 and 3 in., and the necessary transition thickness between sections. The widening strips were in part built integral with resurfacing (both edges, station 255 + 69 to station 255 + 99 and station 259 + 90 to station 260 + 68) but for most of the length they were built to the elevation of the old slab edge ahead of resurfacing the entire 22-ft. plan and construction details.

Mesh reinforcement, style 66-66, weighing 42 lb. per 100 sq.ft., was placed full width in the resurfacing except from station 252 + 30 to 254 + 25 where 6x10-ft. sheet was placed only over each edge of the old pavement. This change was made because of difficulty in placing the mesh in resurfacings less than 2 in. in thickness.

A bonding course about $\frac{1}{4}$ in. thick was placed between the resurfacing and the old pavement, except for 50 ft. at the beginning and end of resurfacing (station 252 + 30 to 252 + 80 and station 267 + 21 to 267 + 71). The bonding course was placed just ahead of paving using Jet-Crete equipment furnished on the project by Concrete Machinery Co., Waterloo, Iowa. The bonding course was proportioned 1:2$\frac{1}{2}$ by weight.

Two concrete mixes were used in the resurfacing concrete; one made with $\frac{1}{2}$-in. maximum size aggregate and 8 sacks of cement for resurfacing less than 2 in. thick and one made with 1-in. aggregate and 7 sacks of cement per cubic yard for the widening strip and resurfacing 2-in. thick or greater. The concrete was supplied to the paving contractor by the W. G. Block Ready Mix Co. of Burlington, Iowa.

In accordance with Iowa Highway Commission policies a contract was negotiated with the Quad City Construction Co., Rock Island, Ill. for the following items:

A - The excavation for widening strips.
B - The furnishing, placing, finishing and curing the concrete for the widening and resurfacing.
C - The furnishing and placing of the steel reinforcement.

The cost for these items was included in a single unit price of $27.18 per cubic yard of concrete placed.

The following items of work in the project were done by the Highway Commission on a day labor basis:

A - A detailed and accurate crack survey of the existing pavement.
B - A detailed survey to establish the contour

of the existing pavement surface and establish grades for the resurfacing.

C - The removal of all foreign material such as asphalt from the surface of the old pavement, particularly from edges, joints and cracks.

D - The thorough cleaning of the old pavement surface with a detergent to remove oil and the etching of the cleaned surface with a commercial muriatic acid.

E - The application of a bonding course composed of a pneumatically placed concrete.

The bonding course was placed by John E. Waggoner by agreement made with the Iowa Commission at a cost of $4\frac{1}{4}$ cents per sq.ft.

Items of work as performed chronologically on the project will be described in detail under main headings; Preparation of Old Pavement Surface; Placing and Finishing the Resurfacing; Observations of the Experiment and Service.

PREPARATION OF OLD PAVEMENT SURFACE

Removal of Bituminous Material

The surface of the old concrete was sound and free from scaling or surface ravel. The only step necessary in preparing the surface was to remove bituminous material by scarification. Most of the bituminous material was sealer along joints and cracks, the painted center stripe and asphalt along the north edge shot on the pavement when the narrow stone shoulder was stabilized. Random areas of bituminous material spilled or tracked on the surface during maintenance were also removed.

The bituminous areas were removed with model G-25 concrete cutting machine obtained on a rental basis from the G. H. Tennant Co., Minneapolis, Minn.

The machine is equipped with a 4-in. cutting head driven at 1600 rpm with a 25 horse power gas engine through V-belts. The head was packed with 2-in. cutters to remove bituminous material on the pavement surface and with $4\frac{1}{2}$-in. cutters for deeper cuts and to route the asphalt from joint and crack crevices.

For heavy surface cutting the $4\frac{1}{2}$-in. cutters were packed 14 to the head, on 6 pins with the necessary spacer washers. For the joint and crack routing the $4\frac{1}{2}$-in. cutters were packed in line, on each of the 6 pins in a head. For light surface cutting 2-in. or number 3 cutters were used.

They were packed 288 to the head on 12 pins and 144 to the head on 6 pins.

Pictures 1 and 2 show the Tennant machine in operation. One and two men are used to operate the machine depending on the depth of cut made during a pass. In order to maintain good output for each machine it is necessary to clearly define the edge of each pass by brooming or blowing with an air jet.

Surface scarification and crack routing was done by maintenance forces on October 14, 15, 16, 18 and 19 working a total of 41 hours. A recapitulation of costs for all surface preparation will be shown later.

A sand blast was used on a trial basis to remove bituminous material from the interstices along routed joints and cracks. This avoided cutting out deep and wide areas which is objectionable as well as being costly and time consuming. Sand blasting was not effective in removing blobs of asphalt but was effective when the asphalt was scored or partly removed with the Tennant machine. As an adjunct to the Tennant machine sand blasting was effective and economical. The sand blast operation is shown in Picture 3.

County Engineer Frank Ingraham loaned us the sand blast equipment for the trial run. In a day's time, including time to pick up and set up the equipment, the cracks and miscellaneous areas were given a final cleaning on the entire project. Not more than 1000 lb. of dry sand were used in the operation.

Further cleaning of the surface was interrupted at this point to excavate for the widening strips and to set side forms. In this way any soil, oil, or other debris that is tracked onto the old pavement surface during the trenching and form setting can be cleaned off in one operation.

The trenching for side forms was done with a blade grader. A pass along each edge was made with only the blade, the grader operating on the shoulder. This pass cut the full width of the shoulder some 2 or 3 in. below the edge of the old pavement. Subsequent passes of the blade grader, operating on the slab, and with a trenching attachment on the blade excavated the widening trench to proper depth and about 3-ft. wide. Picture 4 illustrates this operation.

Crusher run limestone, with an excess of fines, was used in the bottom of the trench as a bedding for the side forms and a thin subbase. This facilitated form setting to line and grade and also prevented scouring of the bottom of the trench from flush water used in subsequent clearing operations. Picture 5 shows the side forms being set in the

trench. Grade points for each side form painted on the old pavement surface about 9 in. in from the edge.

After the forms were set final cleaning operations were undertaken. The first step was to thoroughly dry sweep the surface. A powered revolving rattan broom, towed behind a light tractor, was used in this operation. See Picture 6. An air compressor towed by a 1½-ton truck was used to blow out dirt and debris from the routed out joints and cracks. See Picture 7. A total of 5 hours was required for each two men to dry clean the surface preparatory to the scrubbing and acid etching operations.

The dry cleaned pavement surface was then scrubbed with a detergent. Metzo 66, a sodium metacilicate with 7 per cent resin soap was used as a detergent. It was applied by hand to the wetted pavement surface. The surface was wetted with a tank truck equipped with a spray bar as shown in Picture 8. Two men spread the detergent at the rate of 2 lb. per 100 sq.ft. by hand from 16-qt. buckets as shown in Picture 9. After the detergent became moist it was thoroughly scrubbed into the surface with the towed power broom as shown in Picture 10. The quarter point area of the 18-ft. pavement generally had more oil on the surface; also had abraded rubber from the blade grader tires left there during excavation for the widening trenches. Operation of the power broom was therefore scheduled to give maximum detergent and scrubbing action along this area as follows:

1. Two passes in a central position, with broom revolving at an angle to throw out in the direction of travel.
2. One pass along each edge with broom set to throw inwards in the direction of travel.
3. Two passes in each traffic lane brooming the accumulation of Metzo 66 on the quarter point outward and inward.
4. Four passes over the entire width of the pavement with the broom set at right angles to center line. These four passes covered the full width, 18 ft., of the slab.

The Metzo 66 and these scrubbing operations, with few exceptions, removed all traces of oil and tire marks from the pavement surface. The detergent slurry was then thoroughly washed from the surface with street flusher loaned to us by the City of Burlington. The flusher was equipped with side mounted nozzles, one nozzle flushing one-half of the roadway in traveling forward on the opposite half. Two passes were made over the width of the pavement, the first pass being made at 6 mi. per hour and the second at 3 to 4 mi. per hour. This flushing reduced the surface to neutral reaction with

pH paper which is necessary because the detergent is highly alkaline and would reduce the effect of the acid in the etching operation.

A total of 7500 gallons of water was required in this flushing operation. Some 500 lb. of Metzo 66 was applied and the entire detergent operation was accomplished in 4 hours. In addition to the street flusher with driver and helper aboard, the power broom with two operators and a tank truck and driver were used in the operation. The detergent was spread by hand by two laborers in three hours.

The neutralized and scrubbed surface of the pavement was then etched with acid. A commercial muriatic acid, 20°Baume was shipped to the project in hard rubber drums by the C. P. Hall Co., Chicago. This materially expedited the handling and spreading of the acid as compared to glass carboys, and without any additional net cost for the acid. The net weight of the acid was 120 lb. per drum. Costs quoted were $3.60 for the acid and $1.45 cartage per hundred weight delivered to the maintenance shed at West Burlington.

The apparatus used to dispense the acid from the drums to the pavement surface was developed by W. W. Wegner and A. A. Anderson in the maintenance headquarters shop. The rubber drums are fitted with only one screw cap bung for filling and dispensing. Three self venting spigots (one spare) were purchased for dispensing from the drums, through a 25-ft. length of Koroseal hose. Each end of the hose was attached to a spigot with hose clamps. A central length of the hose (about 9 ft.) was drilled with 5/64-in. holes at 1-in. centers. Experience indicates that better distribution of acid could have been obtained with holes drilled at $\frac{1}{2}$-in. centers. The perforated length of hose was taped to a horizontal spacer bar made from a 1x3-in. board. Wire loops were taped to the hose near each end for hooking the spray bar assembly on the truck end gate bolts. These wire loops supported the spray bar assembly some 4-6 in. above the pavement surface.

The rubber drums were placed in a horizontal position in a wooden rack on the end-gate of a $1\frac{1}{2}$-ton truck, one drum at each end of the end-gate. Picture 12 shows the dispensing apparatus assembled. All 16 drums needed for the operation were loaded on the truck and made it possible to quickly change drums when empty.

When the drums were in position, spigots in place and spray bar suspended in position, the spigots were opened and the truck traveled forward at speeds which would give the specified rate of application of muriatic acid on the previously wetted pavement. The pavement was wetted with a tank

truck equipped with a spray bar (see picture 8). This gave some dilution and permitted a uniform distribution of the acid. During the etching period the acid was further distributed over the surface by four men using rattan stable brooms as shown in picture 13. The acid was allowed to stand on the surface until foaming or visible indication of etching had stopped.

After etching had stopped the pavement was washed with the street flusher loaned from the City of Burlington. (See picture 11.) Two passes over the surface, as used for the detergent, were required to rid the surface of all acid and acid residue. A total of 6000 gal. were used for this flushing. The test employed to determine when the surface was adequately flushed was by means of pH paper. After the first flushing test showed an acid to weak acid reaction and after the second flushing showed a neutral or slightly alkaline reaction. The pH paper used was manufactured by the Hychex Products Co. and was obtained at a local medical supply house.

The acidizing operation on the 1500 ft. of 18-ft. pavement was done between 1:00 p.m. and 3:30 p.m. A total of 14½ drums each containing 120 lb. of acid were required. It was originally estimated that 15 drums would be required but 16 were ordered to be on the safe side. One and one-half drums were returned to the supplier for credit as were the empty drums on which a deposit of $35.00 was required.

The following equipment and hours are chargeable to the etching operation:

1 - 1½ ton truck - 4 hours
1 - street flusher - 4 hours
1 - tank truck with spray bar - 2½ hours
4 - rattan push brooms
1 - tank truck operator - 2½ hours
1 - operator and helper on street flusher - 4 hours each
1 - truck driver - 4 hours
3 - hand sweepers - 2½ hours each
1 - hand sweeper - 2 hours
1 - acid tender on truck - 4 hours

The pavement surface after the detergent cleaning, acid etching and flushing operations had a sand paper texture clean of all dirt and debris. Delaying these operations until the trenching and form setting operations were completed avoided the need for any recleaning. It also provided adequate drainage for the flush water, along the road. Drains under the forms were provided at sags. The pavement after all surface preparation was completed and with forms set for

the widening is shown in Picture 14. This picture also shows transverse and longitudinal random cracking in the old pavement. Mesh reinforcement was stored on the pavement for use in the resurfacing. A roadway was provided on each shoulder for construction equipment. No construction equipment was permitted to operate on the cleaned pavement surface.

Recapitulation of Costs for Surface Preparation

The following items of cost cover actual equipment rental, supplies and labor for each operation:

Surface Scarification and Routing Joint and Cracks

G. H. Tennant Machine - rental 4 days at $30.00	$120.00
Small cutters (2-in.) 960 at 0.15	140.00
Large cutters (4½-in.) 90 at $1.35	121.50
Freight and Cartage	113.05
Gas and Oil	7.54
Sub Total	$506.09
Labor - Oct. 14, 15, 16, 18 and 19 -	
82 hours at $1.47 per hour	$120.54
65 hours at $1.44 per hour	93.60
Sub Total	$214.14

Sand Blasting

County Machine (no charge)	-
Labor - October 20, 1954	
18 hours at $1.47 per hour	$ 26.46
9 hours at $1.44 per hour	12.96
Sub Total	$ 39.42

State Maintenance Equipment

2-ton truck - 50 hours	$ 8.74
Air compressor - 15 hours at $2.18	32.70
Sub Total	$ 41.44

Total Scarifying and Routing Cost . . $801.09

Dry Cleaning

Powered Broom and Tractor	$ 2.50
2-ton Truck	1.58
Compressor - 6 hours at $2.18	13.08
Labor - Oct. 21, 1954	
18 hours at $1.47	26.46
8 hours at $1.79	14.32
Total Dry Cleaning Cost	$ 57.94

Scrubbing with Detergent

Metzo 66 - 512.5 lb. at $0.08	$ 41.00
Water tank truck - 4 hours at $2.75 . .	11.00
Powered Broom and Tractor	2.50
Street Flusher - 2 men - 7500 gal.	
H_2O (No Charge.	-
Labor - Oct. 22, 1954	
12 hours at $2.505	30.06
8 hours at $1.47	11.76
4 hours at $1.79	7.16
Total for Detergent Cleaning.	$103.48

Acid Treatment

20° Baume Muriatic Acid - 14½ drums . .	$133.61
2-ton truck	1.58
Water tank truck - 3 hours at $2.75 . .	8.25
Rattan Brooms - (No Charge)	-
Acid Dispensing Equipment-(No Charge) .	-
Street Flusher - 2 men - 6000 gal.	
H_2O (No Charge)	-
Labor - October 22, 1954	
3½ hours at $2.70	9.45
10 hours at $2.505	25.05
10 hours at $1.47	14.70
4 hours at $1.79	7.16
Total Acid Etching Cost	$199.80
GRAND TOTAL-SURFACE PREPARATION . .	$1,162.31

The above total surface preparation costs reduced to unit area costs are as follows. The pavement surface prepared is $\frac{(1555 - 64) \times 18}{9}$ = 2982 sq.yd.

Scarifying and Routing	$801.09 ÷ 2982 =	$0.272	per sq.yd.
Dry Cleaning	57.94 ÷ 2982 =	0.019	per sq.yd.
Detergent Scrubbing	103.48 ÷ 2982 =	0.035	per sq.yd.
Acid Treatment	199.80 ÷ 2982 =	0.067	per sq.yd.
Total Surface Preparation . . .		$0.393	per sq.yd.

PLACEMENT OF CONCRETE

Placement of all concrete for the widening, resurfacing, ramps at each end of project and transverse patching was awarded to contract on a cubic yard basis. A contract for this work was negotiated by the Commission with the Quad City Construction Company, Rock Island, Illinois at a blanket price of $27.18 per cu.yd. This included all work incidental to placing, finishing and curing the concrete but did not include placement of the bonding course or removal of the old

concrete for the end ramps or transverse patches. These latter items will be described before covering placement of the concrete.

Removal of Concrete for Ramp and Patches

The removal of the concrete for the two end ramps and two transverse areas at badly spalled transverse cracks was performed by the State Maintenance force using their own and rented equipment. A concrete saw, cutting a 2-in. surface slot was used to define the areas. The old concrete was then broken up with a pavement breaker and jack hammer, loaded in trucks with an end loader and a portable dragline (truck mounted) and hauled away from the job. Picture 15 shows operations during the removal of the old concrete for the easterly ramp. Costs compiled for these operations are as follows:

Pavement Breaker and Operator			$ 78.00
Concrete Saw	12½ hours	at $7.00	87.50
Water Truck	12½ hours	at $2.75	34.38
Jack Hammer	4 hours	at 0.625	2.50
Truck Rental			1.60
Dragline	.2 hours	at $2.125	4.25
End Loader	.6 hours	at $1.25	7.50
Sub Total Equipment			$215.73
Labor			
	12½ hours	at $2.70	33.78
	4 hours	at 2.505	10.02
	8 hours	at 1.79	14.31
	4 hours	at 1.64	6.56
	20 hours	at 1.47	29.40
	8 hours	at 1.44	11.52
Sub Total Labor			$105.59
Grand Total - Concrete Removal			$321.32

Jet-Crete Bonding Course

Placement of the bonding course just ahead of paving was carried out by John E. Waggoner under an agreement made with the Iowa Highway Commissioner. A jet-crete machine was furnished for trial by the Construction Machinery Co., Waterloo, Iowa. Mr. Sharp supervised and actually handled the gun. The mixer and truck mounted compressor operated from the north shoulder. The 1:2½ dry mix, delivered to Waggoner by the Keeley Sand Company by transit mixer, was dumped on a tarpaulin from which it was shoveled into the Jet-Crete machine by hand. The transit mixer was dried before receiving the dry mix batch of 20 sacks of cement and 4700 lb. of sand. The transit mixer produced a uniform dry mix and although requiring more time for discharge than for wet concrete was considered both practical and satisfactory. Water added to mix during the shooting operation was supplied from a tank truck.

The jet-crete was shot on the pavement about 40-ft. ahead of placing the concrete for the resurfacing. On the thinner resurfacing, where it was necessary to place the mesh and secure it to the pavement the jet-crete was shot through and around the mesh. During placement of the 3-in. resurfacing and the transitions to 2-in. thickness, the grout was shot on the old pavement ahead of placing the reinforcement.

The gun assembly was held in a near vertical position. Water was added and became intermixed with dry sand-cement as it entered the gun. Valves for controlling the water and sand-cement are provided at the nozzle. Picture 16 shows the jet-crete bonding course being applied after the mesh reinforcement had been placed.

Considerable difficulty was encountered in maintaining proper water content which would avoid a sandy surface and in avoiding the accumulation of pratical clean sand as it rebounded from the surface during the shooting operations. It is believed that the dryer applied jet-crete and the accumulation of rebounded material had a considerable effect on the degree of bond secured between the resurfacing and the old concrete. This will be discussed in detail under "Performance Observations" later in the report.

No bonding course was placed for 50-ft. on each end of the project (Station 252 + 30 to 252 + 80 and Station 266 + 71 to Station 267 + 21).

The bonding course was placed at a total cost of $1,111.12. This is at the agreed price $0.0425 per sq.ft. covering a total of 26,144 sq.ft.

Placement of Widening Concrete

Placement of the widening strips at each edge of the old pavement was started on October 25, 1954 and completed on October 26, 1954. Previously the old slab had been scarified, washed, treated with acid and the forms checked for elevation and alignment. The concrete used was made from one inch maximum size aggregate and requiring 7 sacks of cement per cubic yard. Widening at both edges from station 255 + 69 to 256 + 99 and station 259 + 90 to 260 + 68 was placed integral with the widening.

Concrete for the widening was delivered to contractor by the W. G. Block Ready Mix Company in transit mixers. The concrete, having a slump of 3 to 4-in., was spouted into the trench from the mixers traveling on the shoulder. It was then vibrated into place by an internal pug type portable vibratory unit. The surface of the widening was then struck off with a notched board traveling on the side forms and surface of the old pavement. All other surface finishing was

purposely omitted in order to maintain a rough surface which would give the best possible mechanical bond with the resurfacing. Picture 17 shows how the concrete for the widening was placed and struck to grade.

Placing the Resurfacing Concrete

Placement of the concrete for the ramp and resurfacing began 8:30 A.M. on October 27, 1954 at the easterly end of the project and progressing in a westerly direction. The noon stop was made at 265 + 12 without a temporary header and the first day's run was headed out at station 262 + 31. The second day's run on October 28 extended from station 262 + 31 back to a header at station 256 + 06. The third and final day's run was on October 29, 1954 and extended back to station 251 + 98.

Weather conditions during placement of the concrete were variable cloudy to clear and cool to cold. The following was recorded on weather conditions.

October 27 ÷ cloudy but clearing at 10:00 A.M.; Temperatures 44°F at 8:00 A.M., 52°F at 12:30 P.M., 45°F at 6:30 P.M. and 44°F at 9:00 P.M.

October 28 ÷ Heavy frost during night; Temperatures 36°F at 6:30 A.M., 43°F at 8:30 A.M. (started paving), 50°F at 10:30 A.M., 48°F at 5:30 P.M. and 48°F at 10:00 P.M.

October 29 ÷ clear and 36°F at 6:30 A.M., 38°F at 7:30, Snow, 7:30 to 8:30 A.M., 38°F at 8:45 (started paving), 39°F at 11:00 A.M., 38°F at 12:30 P.M. and 36°F at 3:45 P.M.

The contractor was given permission to pave on October 29 by Resident Engineer Pearson, provided he would protect the pavement. An 8-in. layer of straw was placed on pavement as soon as surface was finished.

The concrete for the resurfacing was delivered to the contractor by W. G. Block Ready Mix Company in transit mixers which traveled on both shoulders, each of two mixers spouting concrete for the resurfacing simultaneously from both edges of the pavement. This is illustrated in Picture 18. After partially spreading by hand the concrete was further spread, consolidated, struck to grade and cross-section and finished by means of machine developed by the contractor. As can be seen in Picture 19, the machine consists of a trussed boiler plate, about ½x30 in. which spans the pavement width and slides forward on the side forms. The machine is propelled forward by wenches and cable anchored in a forward

position on the side forms. A vertical screed plate is mounted on the front edge of the base plate and a tamping bar, actuated by rocker arms mounted on the frame puddles the concrete in front of screed and under the base plate. The concrete is consolidated, struck and finished in one forward pass of the machine. A belt which is mounted on the rear of the machine and driven in a transverse direction with a power take-off further finishes the pavement surface. The finished product behind the machine can be seen in Picture 19.

To comply with surface tolerances and for a good riding surface, the pavement was checked with scraping straight edges and smoothed with long handled floats. Final surface finishing was done with a hand operated transverse belt as shown in Picture 20. Curing of the resurfacing was accomplished with wet burlap strips followed with paper mats. See Pictures 21 and 22.

Two concrete mixtures made from each of 1-in. maximum nominal size gravel aggregate and $\frac{1}{2}$-in. maximum nominal size gravel aggregate were used in the resurfacing, widening strips, and ramps. The two concrete mixers were designed by Iowa Highway Commission Laboratory at Ames. Concrete made with $\frac{1}{2}$-in. aggregate was designed to use 8 sacks of cement per cubic yard and the concrete with 1-in. aggregate, 7 sacks per cubic yard. Details on these mixes and tests of the gravel and sand are included in the appendix. The exact location of each mix, day's runs and other pertinent data are shown on sheets 1 and 2 of Figure included in the appendix.

Field tests and the making of specimens for strength tests were done by Representatives of the Department of Materials. Field tests included slump and air content. Beams 6x6x33 in. were cast for flexural strength tests and $4\frac{1}{2}$x9 in. cylinders were cast for compressive tests. Testing equipment used is shown in Picture 23. Test results (non-assembled) are included in the appendix. (Note: it is possible Bert Meyers would like to make a summary of all these test data with locations, etc. and include such a summary in the appendix, rather than the apparent incomplete material herewith appended.)

Tests on six $4\frac{1}{2}$x9-in. cylinders were made by the Research and Development Department of the Portland Cement Association. These included sonic and static modulus of elasticity. A letter on these tests in also in the appendix.

The resurfacing concrete was completed on October 29, 1954. The pavement was opened to traffic on November 12, 1954. Some delay was made in opening due to low strength because of the prevailing low hardening temperatures.

Concrete placed by the Quad City Construction Company is as follows:

	Cu.Yd.	Unit Cost	Total Cost
End Replacements	36.0	$27.18	$ 978.48
Patches	1.7	"	46.21
Replacements Sidewalks and Driveway	5.0	"	135.90
Resurfacing	255.1	"	6,933.62
Widening	148.7	"	4,041.66
Totals	446.5		$12,135.87

A recapitulation of costs for all items of work is as follows:

Total Surface Preparation Costs	$ 1,162.31
Concrete Removal (Ramp and patches)	321.32
Bonding Course	1,111.12
Concrete and placement	12,135.87
TOTAL COST OF PROJECT	$14,731.62

The cost of resurfacing alone for the three thicknesses including unit surface preparation cost, bonding course costs and the placement of concrete may be computed as follows: Unit surface preparation cost was $0.393 and unit bonding course costs were $0.373. This gives a total of $0.77 per sq.yd. Then unit costs for the resurfacing would be:

3-in. Resurfacing = (0.083 cu.yd. x $27.18) + $0.77 = $3.02 per sq.yd.

2-in. Resurfacing = (0.056 cu.yd. x $27.18) + $0.77 = $2.29 per sq.yd.

1-in. Resurfacing = (0.028 cu.yd. x $27.18) + $0.77 = $1.53 per sq.yd.

OBSERVATION OF EXPERIMENT UNDER SERVICE

Periodic surveys and observations have been made of the experiment since it was opened to traffic. The first such survey was made on November 16, 1954. The second on May 17 and 18, 1955 and the third survey on November 7 and 8, 1956. The results of these surveys have been plotted on Sheets 1 and 2 of Figure 2 included in the appendix. On Figure 2 there has also been shown pertinent construction data such as day's runs; concrete mix; bonding course; widening integral and built as separate strips; resurfacing thicknesses and other pertinent construction data.

The first survey just after opening to traffic showed that only about half of the transverse cracks had reflected through the resurfacing. They were very fine cracks and were difficult to see. None of the longitudinal cracks in the old pavement had come through the resurfacing. The resurfacing was also sounded with a hammer to determine bond between the resurfacing and old pavement. Only 10 very small areas totaling less than 1 sq.yd. sounded hollow and are possibly lacking in bond.

The second survey in May, 1955 shows the pavement to be excellent in appearance and to have excellent riding qualities but that more of both, the transverse and longitudinal cracks in the old pavement have reflected up through the surfacing. The longitudinal cracking has developed to a lesser degree than the transverse cracks although cracks have not developed over all the transverse cracks in the old pavement. Soundings of the surface with $\frac{1}{2}$x36-in. steel rods indicate some loss of bond between the resurfacing and the old pavement. Where soundings indicated poor bond these areas were mapped on Figure 2 by random dotted areas. They are generally 3 to 6 in. wide and bound transverse cracks and joints. Exception is the area along the north edge of the old pavement. When soundings indicated this prevailing pattern, care was taken to specifically locate and determine the extent of these areas. It may be said with surety that the area is 3 to 6 in. wide and entirely within (inward from the edge) old pavement. The almost complete absence of a similar area along the southerly edge of the old pavement seems pertinent. No clearcut answer is known but the following speculation is worthy of mention:

1. The northerly widening strip may be subject to deeper frost penetration and result in more vertical rise of the widening strip. A differential rise of the widening strip could cause loosening of the resurfacing in this rather narrow band.
2. A possible effect of traffic, assuming more of the heavier loads travel along this position on the finished pavement.
3. The accumulation of more rebounded clean sand particles along this edge of the old pavement. The manner of shooting the jet-crete would create this tendency -- the jet-crete machine was operated on the north shoulder and the hose would cause the inclination of the nozzle in northwesterly direction.

The indicated lack of bond adjacent to transverse joints and cracks and very little such indication along longitudinal cracks on this survey (May, 1955) also may have some significance. Again the manner of shooting the jet-crete would tend to cause an accumulation of sandy dry shot-crete and rebound materials in and adjacent to the routed out transverse crevices. There is another possibility, prevailing temperatures at the time of placing the resurfacing, which also may have some significance. As previously reported, the highest daytime temperature recorded during paving was 52°F and most of the time temperature ranged between 38 and 48°F. Also nighttime temperatures probably ranged between 34 and 36°F.

Under these conditions the old pavement at the time of resurfacing, would be in a contracted condition and have residual openings at the cracks and joints. These openings would vary in amount depending on the distance between cracks and/or joints. The resurfacing, which probably hardened at a temperature ranging between 45 and 50°F spanned these openings as an integral mass. Subsequent higher temperatures would cause the resurfacing and the old pavement to expand but some space was available in the old pavement at the cracks and joints. Therefore, subsequent expansion of the pavement would be largely resisted only by the resurfacing layer. A shearing force would thus be created at transverse cracks which would tend to cause a loosening of the bond between the resurfacing and the old pavement. This same action is known to cause surface spalls on concrete pavements at joints where the space above expansion material is not equal to or greater than the thickness of the filler.

The next observation relative to performance of the resurfacing developed during the summer of 1955. On July 4 Art Swander, Maintenance Foreman at the West Burlington maintenance depot reported to W. W. Wegner that a small area of the resurfacing was dislodged and was crumbling under traffic. The area involved was between station 266 + 43 and station 266 + 45.5 and was about 3 ft. long transversely. ~~It is of interest to point out that this is at the exact location of a half width replacement in the old pavement~~ (See Photographic Survey previously submitted.)

Mr. Wegner worked with four men from the maintenance department in repairing the area. An irregular area of the resurfacing totaling 100 sq.ft. was removed in the south half of the pavement. (Station 266 + 43 to 266 + 52 along center joint) The edges along the perimeter were cut reasonably straight and vertical; mesh cut along the edges; and surface was blown clean. The surface of the old pavement was then washed with water and dusted with dry neat cement and new concrete placed, tamped, struck off and finished. A standard Iowa Commission patching mix but with $\frac{1}{2}$-in. aggregate was

used for the replacement. The replacement area was cured with paper covering for 72 hr. and opened to traffic. The location of the patch is recorded on Sheet 2 of Figure 2.

Observations made by Wegner during the replacement, indicated poor bond in the area and that the jet-crete bonding course had been too dry for good bond. Further loosening the resurfacing was noted beyond the area replaced.

The next observation on service performance occurred on June 5 of 1956. Warner Harwood and Bill Bester made the inspection following a report from Art Swander that an additional area of the resurfacing was breaking up under traffic. The area (5 x 2½-ft.) involved was at station 265 + 82 in the central portion of the pavement. Soundings for bond at the time indicated looseness of the resurfacing beyond the area involved. After consultation and full consideration of the existing conditions it was decided to use a temporary black cold mix for repair of the area. The area repaired in this manner is shown on Sheet 2 of Figure 2. It should be mentioned that both of these areas described above are all in the 1-in. resurfacing placed with full width mesh reinforcement during the first day's run and before it was found necessary to add more water and use a blow-pipe in placing the jet-crete bonding course.

A third detailed survey was made of the experimental project on November 7 and 8, 1956. The survey was made by L. M. Arms, Earl Felt, Bill Bester, Steve Roberts from the Materials Department, Iowa Highway Commission and the writer. All cracks were accurately located, the resurfacing sounded for bond and all observations mapped. The results of this survey is shown in detail on Sheets 1 and 2 of Figure 2.

This survey showed that cracks have developed in the resurfacing over most cracks in the old pavement. It also shows that some additional fine cracks have developed and most of these are in areas where soundings indicated no bond or poor bond between the resurfacing and the old pavement. For the first time a crack was noted over the edges of the old pavement on the short experimental lengths where the widening strip was placed integral with the resurfacing. This cracking is confined to north edge of the old pavement, being for full length on the 3-in. resurfacing and about one-half the length on the 2-in. resurfacing. This phenomenon seems to confirm previous indications that the northerly edge is subject to ~~deeper frost penetration.~~

Soundings of the pavement surface for indication of bond shows a considerable increase in the area where the resurfacing has loosened from the old pavement. Calculations

show that for the full length of the project about 29 per cent of the resurfacing area is loose. These areas have been mapped on Sheets 1 and 2 of Figure 2. Relatively better bond is indicated for the areas where no jet-crete bonding course was used and the portion placed after more water was used in the jet-crete mix and where shooting procedure was changed to employ a blow-pipe which in some measure avoided accumulation of rebonded relatively clean sand particles.

The loose area along and inward from the north edge of the old pavement has increased in width and length and a similar pattern has developed but only for a length of about 200-ft. along the south edge. This difference in performance was noted on the second survey and was previously discussed.

There is no marked difference in the performance of the resurfacing, in regard to bond for the 1, 2 or 3-in. resurfacings. The 1-in. resurfacing on the easterly end (first day's run) has developed areas which needed repair, but as previously discussed this is a function of the placement of the bonding course rather than thickness. Like difficulties have not developed on the 1-in. resurfacing on the westerly end. Relatively the 3-in. resurfacing has developed as much looseness as the 1 and 2-in. resurfacing.

The project as a whole has good appearance and excellent riding qualities. The easterly end and particularly part of the first day's run has developed conditions requiring special maintenance and replacements. Judging from performance to date replacements in this area would place the whole experiment in condition to give satisfactory performance for several years. These replacements are worthy of consideration as well from the standpoint of extending the experiment. A comparison of methods of placing bonding courses would be developed. Since the Iowa Experiment was placed, bonding courses used have been a 1:1 grout, mixed to a heavy paint consistency and thoroughly scrubbed into the old pavement surface. Good bond has been developed by this means. Also they have been found more practical to apply with good uniformity than the jet-crete as used on the Iowa Experiment.

Picture 1 - Close up of G. H. Tennant surface scarifying machine removing bituminous material.

Picture 2 - Removing center line paint stripe from old pavement surface.

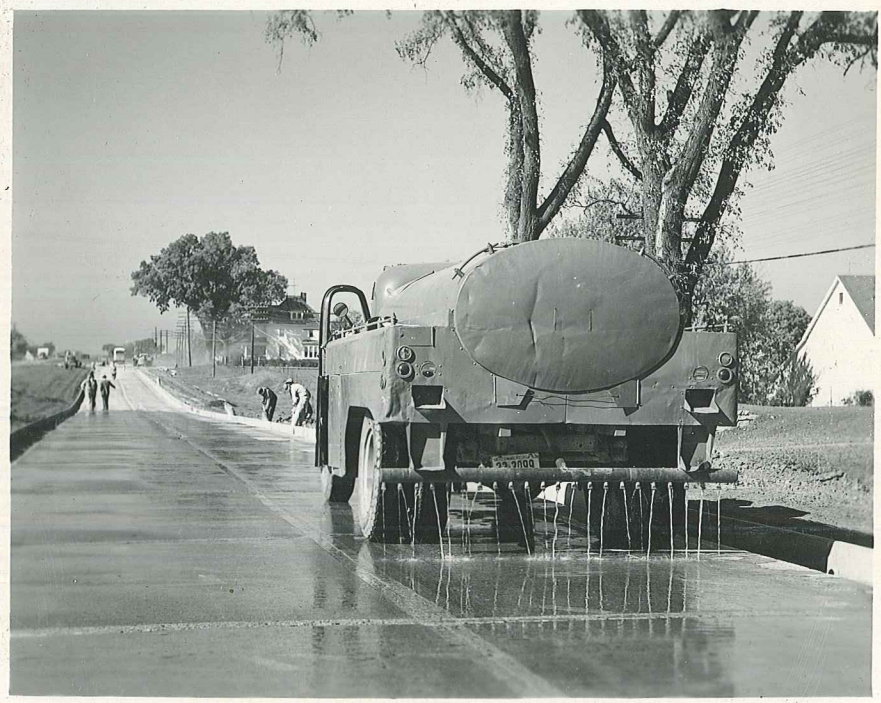
Picture 3 - Sand blasting bituminous material from routed out joints and cracks.

Picture 4 - Excavating trench, for widening using blade grader with trenching attachment.

Picture 5 - Forms being set for 10x24 inch widening strip and the resurfacing.

Picture 6 - Old pavement surface being dry swept with powered broom towed by light tractor.

Picture 7 - Loose material being blown from crack crevices with air jet.



Picture 8 - Old pavement surface being wetted by tank truck equipped with spray bar. Surface was sprinkled ahead of applying detergent and acid.

Picture 9 - Metzo 66 detergent was spread by hand at rate of 2 lb. per 100 sq. ft.

Picture 10 - When detergent became moist, it was thoroughly scrubbed into surface with powered rotary broom.

Picture 11 - Detergent residue was flushed from pavement until it showed neutral with pH paper. Same equipment used to flush surface after etching with acid.

Picture 12 - Muratic acid was applied to wetted surface from rubber drums through home made Koroseal spray bar.

Picture 13 - Acid was further distributed by hand with rattan brooms.

Picture 14 - Forms set and old pavement surface ready for widening and resurfacing. Note randon cracking in old pavement.

Picture 15 - Concrete being removed for 32 foot ramps placed at both ends of project.

Picture 16 - Jete-crete bonding course being shot on surface.

Picture 17 - Concrete for widening was placed from transit mixers, vibrated into place and struck to grade by hand.

Picture 18 - Concrete for the resurfacing was placed from transit mixers, traveling on both shoulders, each of the two depositing concrete at the same time.

Picture 19 - Concrete for the resurfacing was puddled, struck to grade and finished by this machine developed by contractor.

Picture 20 - Final surface finish was by hand operated transverse belt.

Picture 21 - Initial curing was accomplished with wetted burlap strips.

Picture 22 - After 24 hours, final curing was with paper blankets.

Picture 23 - Equipment used by Iowa Highway Commission Engineers in making concrete field tests and specimens for laboratory tests.