IOWA DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

OFFICE OF MATERIALS

SPECIAL REPORT

AN EVALUATION OF CONCRETE BRIDGE DECK RESURFACING IN IOWA

APRIL, 1975

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AN EVALUATION OF CONCRETE BRIDGE DECK SURFACING IN IOWA

April, 1975

By

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SPECIAL NOTE

This report is essentially a reprint of the original report dated June, 1974.

There were some errors in the original report concerning two bridges in Cherokee County.

Rather than issuing errata sheets with the original report, this report is being re-issued with the erroneous data corrected.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Ed. O'Connor and William Eyer of the Maintenance and Bridge Design Departments of the Iowa State Highway Commission as well as the Chemical Tests and Special Investigations Sections of the Materials Department for their assistance in data acquisition and assistance in the preparation of this report.

A special thanks is extended to Mr. Clark Cattell and his clerical staff for their assistance and patience.

Particular credit should be given to Mr. Ed. O'Connor, Maintenance Special Services Engineer, O.J. Lane, Jr., District Materials Engineer, and John Whiting, Assistant District Engineer, formerly of the Bridge Design Department, for the development of the low slump concrete system.

ABSTRACT

Iowa has been using low slump concrete for repair and resurfacing of deteriorated bridge decks on a routine basis since the mid 1960's. More than 150 bridges have been resurfaced by this method with good results.

A study was initiated in 1973 to evaluate 15 bridges resurfaced with low slump concrete, and one bridge resurfaced with latex modified concrete. The evaluation includes an assessment of concrete physical properties, chloride penetration rates, concrete consolidation, and riding qualities of the finished bridge deck.

Results indicate that the overall properties of these two types of concrete are quite similar and have resulted in a contractor option concerning which system shall be used on bridge deck repair/resurfacing projects.

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INTRODUCTION

Like other states utilizing de-icing materials, we in Iowa are greatly concerned about the unsound concrete found in many of our bridge decks. This concern led to a research project, in 1964, to investigate materials and methods for bridge deck repair.

The results of that project and of the approximately 150 projects in the 10 years hence, have led to Iowa's practice of using the low slump "Iowa Method" concrete for bridge deck repair and resurfacing.

PURPOSE

The purpose of this report is threefold: 1) to explain the development of the "Iowa Method" of utilizing low slump concrete for bridge deck repair and resurfacing, 2) to make an objective evaluation of the characteristics and field performance of this concrete and, 3) to make a comparison of the "Iowa Method" and the latex modified concrete currently in use as a bridge deck resurfacing material.

The evaluation of the "Iowa Method" concrete and the latex modified concrete consisted of determining the chloride penetration, concrete consolidation, physical properties and the rideability or roughness of bridge deck resurfacings.

HISTORY OF LOW SLUMP CONCRETE

The subject of deteriorating concrete bridge decks was discussed at District Engineers' Meetings beginning in the fall of 1962. The outcome was that the districts were to submit a list of bridges in their districts, which in their opinion would require maintenance in the near future.

After this information was submitted, personnel from the Maintenance, Materials and Bridge Design Departments began a complete survey of the bridge deck deterioration throughout the state. They were to determine the extent of the deteriorated decks and to come up with a recommended method of repair. The bituminous materials being used provided only a temporary repair.

During the summer of 1963, some experimental patching was done on a bridge over 4-Mile Creek near the east city limits of Des Moines on Ia. 163. Several different patching products and compounds, including epoxies as well as low slump maintenance concrete, were used on this structure. Different epoxy mortars and different patching treatments were used.

In June of 1964, some partial depth patching was undertaken on a railroad overhead structure in Madrid on Ia. 17 in Boone County. These patches were made using maintenance mix concrete. This is a high cement content mix, containing 823 lbs. of cement per cubic yard. This material was also used for approximately 400 sq. ft. on a railroad overhead structure in Council Bluffs in August of 1964.

In August 1964, a contract was awarded for an experimental research project, HR-95(196), to resurface a 240 ft. bridge on Ia. 196 in Sac Co. Work began in September 1964. This work consisted of removing the unsound concrete and placing a one-inch thick portland cement concrete wearing surface over the entire bridge deck.

The specifications for this project were jointly written by representatives from Materials, Maintenance, Bridge Design and Construction Departments. The experience of others along with the above mentioned patching experience was the basis of the specification. The information from various published articles, PCA bulletins, etc., was utilized. Specifically, the recommendations and procedures from a PCA bulletin, No. D44, entitled "Repair of Concrete Pavement" by Earl J. Felt were closely followed. This bulletin covered in detail the problems and recommendations having to do with cleaning and preparation of the bridge deck surface, the recommendation of having a dry surface to bond to, and the recommendation of using a cement grout as a bonding agent.

Some of the observations and conclusions from the research project are as follows:

(1) The machines used did an adequate job of scarifying the surface to a 1/4 in. depth, although the grinding wheels wore out rapidly.

(2) For the critical phase of removing unsound concrete, any spot having a "hollow" sound under a sharp hammer blow was removed to a depth at least lower than the top mat of reinforcing steel. The heaviest jackhammers, 60 lb. class, should be used first followed by smaller

chipping hammers. If removal started in the center of an area and the hammer held at 45° angle, the bit would "walk-out" on the sound concrete.

(3) The concrete surrounding reinforcing bars that were rusted was removed, and the bars cleaned by sand blasting.

(4) Job mixing was recommended because of problems with mix consistency and delivery from transit mixers.

(5) A continuous operation of placing, spreading and striking off is desirable.

(6) Evidence of poor consolidation at the edge of the pour existed. The vibrators were located at the 1/4 point of the screed. A heavier machine, or more vibratory effort, or both, was recommended.

(7) To insure a good centerline joint, approximately 1-1/2 in. should be sawed and removed before the adjacent pour.

(8) Slumps below 1/2 in. could not be placed satisfactorily. Best results were obtained with slumps between 3/4 in. and 1-1/4 in.

(9) Compressive strengths were best with air-entrained concrete.

(10) A wetting agent was used in two of the four sections repaired, and a water reducer was used on one of the sections.

(11) The cement grout applied on a dry surface was a satisfactory bonding agent.

The success of the highway research project led to the decision of designing bridges for contract repair. In the 1965 design year, plans were prepared for the repair of eight different structures. Seven of these were let in 1965 and one was let the following year. Of the seven, all were for partial depth repair with one exception, and that was the 9th Street Bridge over I-235 in Des Moines. This project called for the resurfacing of the entire bridge floor. This, then was the beginning of our contract bridge deck repair work. With the deterioration of bridge decks becoming progressively more critical, the need for a more permanent type of repair than was afforded by bituminous materials was emphasized. It was felt that by complying with special procedures, the repair of potholes and thin overlays could be accomplished using portland cement concrete.

In August 1965, the Maintenance Engineer requested each of six Districts to submit detailed inspection reports of the spalled bridge floors in their areas. This included sounding the decks and plotting the damaged or hollow sounding areas. The information submitted was then used as a basis for the programming of bridge repairs across the state.

The emphasis on contract work at this time was the patching of spalled and deteriorated areas only. It was several years later that experience showed that spalling developed between the patched areas. This pointed out the continued deterioration caused by corrosion of the reinforcing steel and the need for careful determination of unsound areas around existing spalled areas at the time patching was performed. This continuing deterioration was a factor in the later decisions to resurface the entire bridge deck surface.

On the 9th Street Bridge a great deal of spalling was evident, and it was determined that a primary reason was because of "high" steel. The reinforcing steel was quite close to the surface. At this time our design cover was a minimum of 1-1/2 inches over top steel (2 in. minimum cover is now specified). However, due to apparently inadequate tie-down procedures and perhaps some floating up on the top layer of reinforcing steel, the reinforcing was quite close to the surface. This condition led to the consideration of an overlay to provide additional wearing surface for the structure and additional cover over the reinforcing steel.

In 1966 the Maintenance Department decided to use low slump concrete for the bridge deck repair performed by maintenance forces. The Maintenance Department established a special bridge repair crew in each district. A school was conducted at the central headquarters, explaining the procedures of using low slump concrete. In the field, on the job training schools were conducted covering the mixing and placing of low slump concrete, preparing the deck and the related procedures having to do with this type of operation.

The number of bridges designed in the respective years for bridge floor repair and resurfacing by contract are as follows:

Year Designed	Partial Depth Repair	Bridge Resurfacing
1964	-	1 (Research Proj.)
1965	6[1]	2
1966	6	2
1967	8	4
1968	2	8
1969	6	8
1970	11	20
1971	6	26
1972	2	23
1973	-	22[2]
1974	-	25
Totals	47	141

Notes:

1. Included some work with synthetic asphalt (Wyton).

2. Included five (5) experimental projects on the Freeway and Interstate 35 in Polk County using latex modified concrete. Also included is a membrane project on I-74 in Scott County.

Of the 188 bridge floor repair/resurfacing projects awarded, over a span of nine years, 182 utilized the low slump portland cement concrete. Note: The 25 projects to be awarded in 1974 provide for a contractor's option to use either the "Iowa Method" or latex modified concrete.

The specifications developed and evolved through the years as the patching and resurfacing work continued. The present specifications are quite similar to the original specification written for the research project in 1965. The major changes were to require better cleaning and preparation of the deck, the reducing of the weight of the jackhammers, various requirements having to do with the paving machine, and changes in the placing, finishing and curing methods.

Scope

Chloride Penetration

In 1973, fifteen bridges that were resurfaced with the "Iowa Method" were selected for chloride penetration sampling. To qualify for sampling, the bridges must have been repaired to a depth of greater than 1/2 in. into the old deck so that a meaningful salt penetration profile could be plotted. An effort was made to sample bridge resurfacings of various ages.

Of the fifteen bridges selected one was resurfaced in 1965, one in 1966, three in 1967, two in 1968, one in 1969, three in 1970, two in 1971 and two in 1972. In addition to the bridges resurfaced with the "Iowa Method" the only bridge resurfaced with latex modified concrete with a season's salting was sampled for comparative purposes. This bridge was resurfaced in 1972. None of the bridges sampled exhibited deterioration of the resurfacing concrete.

Two inch diameter cores were obtained at two locations per lane on each bridge. The sampling locations were at the approximate outer edge of the outside wheelpath. In most instances this resulted in cores being taken 3 to 5 feet from the curbline. Cores were taken from the southbound lane only from one bridge (Plymouth Co. Des. No. 169) since there was no resurfacing in the northbound lane. Another bridge (Woodbury Co. Des. No. 1065) was widened in addition to the resurfacing, so the cores were taken a considerable distance from the present curbline.

It is recognized that some of the water soluble chloride may be lost when water is used in the core drilling operation. However, since dry drilling equipment was not available to the department, a minimal amount of water was used to cool the drill bit. When attempting to determine the absolute amount of chlorides the amount of chloride loss due to the use of water may, or may not, be significant. When making a comparison of different resurfacing systems it is reasonable to assume that chloride loss due to drilling water would be approximately equivalent.

It was desired to plot a chloride penetration profile every 1/4 inch at each sampling location. To do this two cores approximately 6 inches apart were drilled at each location on the bridge. Alternate slices were dry sawed with a carborundum blade from each core. Slices from one core would represent depths of 0 - 1/4", 1/2 - 3/4", 1 - 1-1/4", etc. while slices from the second core would represent depths of 1/4 - 1/2", 3/4 - 1", 1-1/4 - 1-1/2", etc. This procedure was utilized until slices representing the top 2 inches of resurfacing had been obtained.

There was considerable interest in the chloride level of the concrete from the original bridge decks. Where it was possible, the top 1/2 inch of the original deck was also sliced for chloride analysis. In some instances the original deck concrete was not analyzed due to fracturing of the concrete at or slightly below the original concrete during the core removal operation.

Each concrete slice was coarse ground in a Chipmunk jaw crusher and fine ground to pass the No. 50 sieve in a Micro-pulverizer. After pulverizing each sample was dried in an oven for at least one hour at 105°C.

The chloride concentration was obtained utilizing the procedure described by H. A. Berman in Report FHWA - RD-72-12. (Ref. 1) A Corning Research Model No. 12 pH meter with an Orion combination chloride electrode Model 96-17 was used for determining the actual titration end point.

No attempt was made to determine the cement content of each sample for two reasons. First, the accuracy of the ASTM method for determining the cement content is questionable (Ref. 2), and second, the relatively small aggregate size used in the "Iowa Method" was such that variable amounts of coarse aggregate in the sample was not considered a problem.

The chloride content of the concrete sample was converted to a cubic yard basis by assuming a dry concrete weight of 140 pounds per cubic yard.

Concrete Density

There is an indication that the rate of chloride penetration into the "Iowa Method" concrete is related to the in-place density of the concrete (Ref. 3). To be effective in preventing chloride penetration it was determined that the concrete must be consolidated to at least 98 per cent of its rodded unit weight.

The most practical way to measure the in-place density appeared to be with a nuclear density gauge in the direct transmission mode.

The only bridge resurfacing project where the concrete density was actually measured by nuclear methods was Polk Co. I-35 northbound over the Raccoon River in 1973. It was felt this project was typical of bridge deck resurfacing in Iowa.

Four inch diameter cores were obtained from the US 20 westbound bridge near Dubuque and I-80 eastbound and westbound bridges over US 65 near Des Moines for the purpose of making a density comparison with the Raccoon River bridge. These bridges were resurfaced by other contractors. If the density of concrete on these bridges were over the theoretical 98 percent of rodded unit weight, we were confident that adequate consolidation of the concrete could be attained with the construction equipment presently in common use.

Because the rodded unit weight of the plastic concrete had not been determined on the US 20 and I-80 bridges, the determination of density had to be made on a theoretical basis. By establishing the relationship between the density of plastic concrete and oven dry concrete from the Raccoon River bridge, the theoretical plastic concrete density of other similar mixes can be determined utilizing oven dry cores by assuming a standard water loss and adjusting for the specific gravity of the aggregates.

Physical Properties

Aggregates used in the construction of the latex modified concrete resurfacing of US 65 in Story Co. were obtained for making a laboratory comparison of latex concrete versus the "Iowa Method" concrete. The latex modified concrete was mixed in accordance with instructions from the Dow Chemical Corp. and with a company representative in attendance.

The following specimen types were prepared for each concrete system:

a. 6" x 12" cylinders for 28 day compressive strength.

b. 6" x 6" x 33" beams for 28 day flexural strength.

c. 4" x 4" x 18" beams for durability per ASTM.

d. Dished specimens for salt scaling tests.

The specific curing and fabrication procedures are detailed in Appendix A.

During 1973, 4" x 4" x 18" freeze-thaw durability beams were fabricated at the jobsite on one "Iowa Method" resurfacing project, and several latex modified concrete projects. The number of specimens, project location and curing conditions were as follows:

Project Location	Concrete System	No. Of Specimens	Curing Conditions
I-35 Northbound over Raccoon River	Iowa	6	3 days moist; 40 days, 50-75% humidity; 90 days, 100% humidity.
I-35 Southbound over Raccoon River	Latex	6	2 days moist; 41 days, 50-75% humidity; 90 days, 100% humidity.
I-235 Westbound over Keoway	Latex	6	2 days moist; 41 days, 50-75% humidity; 90 days, 100% humidity.
I-235 Eastbound over Keoway	Latex	6	2 days moist; 41 days, 50-75% humidity; 90 days, 100% humidity.
I-235 Eastbound over 12th Street	Latex	6	2 days moist; 41 days, 50-75% humidity; 90 days, 100% humidity.
I-235 Westbound over Des Moines River	Latex	6	2 days moist; 41 days, 50-75% humidity; 90 days, 100% humidity.
I-35 Southbound over CGW-RR (Warren Co.)	Latex	4	2 days moist; 41 days, 50-75% humidity, 90 days, 100% humidity.

The latex modified concrete in the above projects contained Modifier "A".

Rideability

A 25 foot profilograph was used to determine the profile index of the six bridges resurfaced with latex modified concrete in 1973, and four bridges resurfaced with the "Iowa Method" in 1973.

The Iowa State Highway Commission Materials Department Instructural Memorandum No. 341 (Appendix B), details the test procedure used in determining the profile index.

Results

Chloride Penetration

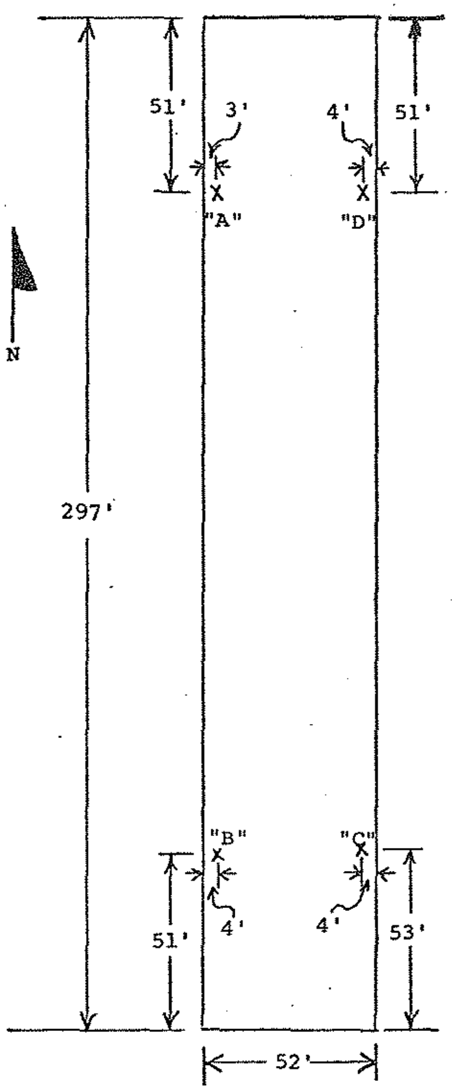
Figs. 1 -15 indicate the chloride level of the concrete versus the concrete depth for the "Iowa Method" of resurfacing.

Fig. 16 shows the same information for the only latex modified concrete bridge deck that had received salt applications. Also, shown is the chloride content of the underlying concrete in the old deck.

Generally the chloride content of the concrete decreased as its depth below the deck surface increased. There are two notable exceptions, namely Woodbury Co. Design No. 1065 (Fig. 2) and Woodbury Co. Design No. 168 (Fig. 7). Fig. 2 indicates a chloride content of 2.96 lbs. per cubic yard at the 0.50 inch - 1.00 inch depth and 4.29 lbs. per cubic yard at the 1.00 inch - 1.50 inch level. Fig. 7 indicates 0.89 lbs. per cubic yard at the 1.0 inch - 1.50 inch level and 1.68 lbs. per cubic yard at a depth of 1.50 inch - 1.75 inch. The chloride content of the underlying concrete in the old deck is relatively high on both bridges, and it is assumed that the higher chloride content of the resurfacing concrete at the lower depth was caused by chlorides migrating upward from the old concrete rather than by chloride penetrating from the surface.

It appears that this same type phenomena occurred on Plymouth Co. Design No. 171 and Cherokee Co. Design No. 172 (Fig. 15), although to a lesser extent than

Polk County
M-1209 Des. No. 3265
Location: 9th St. in Des Moines over I-235
Letting Date: 7-20-65



Chloride Content - Lbs/Cu.Yd.

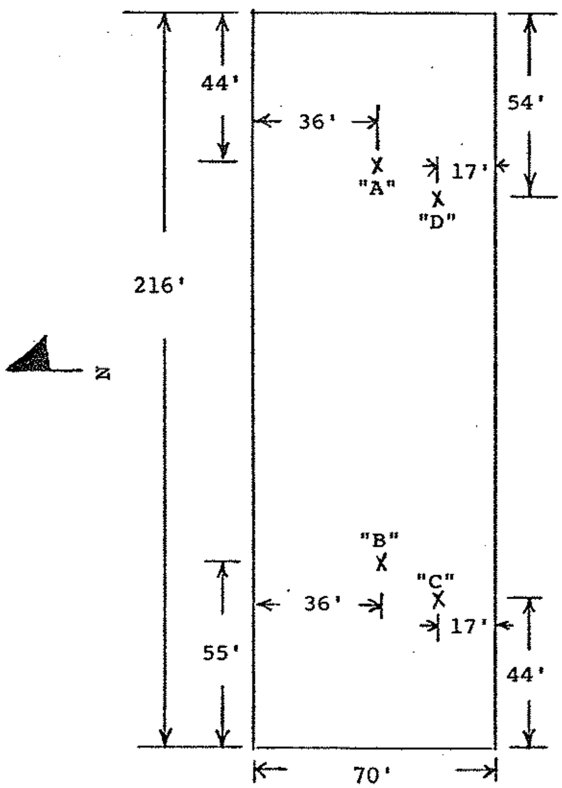
Core No.	Location	0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	Old Deck Top ½"
		Concrete Depth						
773	A	6.43		1.51		0.22		1.74
774	A		1.43		0.66			
775	B	6.24		4.08		3.36		
776	B		3.63		--		1.87	
777	C		5.37		1.78		1.99	
778	C	5.78		2.96		1.71		
779	D	6.54		4.12		2.32		
780	D		4.57		1.80			

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
.25–.50	3.93	4.93	5.57	5.55	5.00
.50–1.00	1.08	4.08	2.37	2.96	2.42
1.00–1.25	0.22	2.61	1.85	2.32	1.91
1.25–1.50					
1.50–1.75	Old Deck 1.74	Old Deck		Old Deck	Old Deck 1.74
1.75–2.00			Old Deck		

Figure 1

Woodbury County
UN-20-1(2)--41-97 Des. No. 1065
Location: US 20 over CM St. P & P in Sioux City
Letting Date: 8-16-66



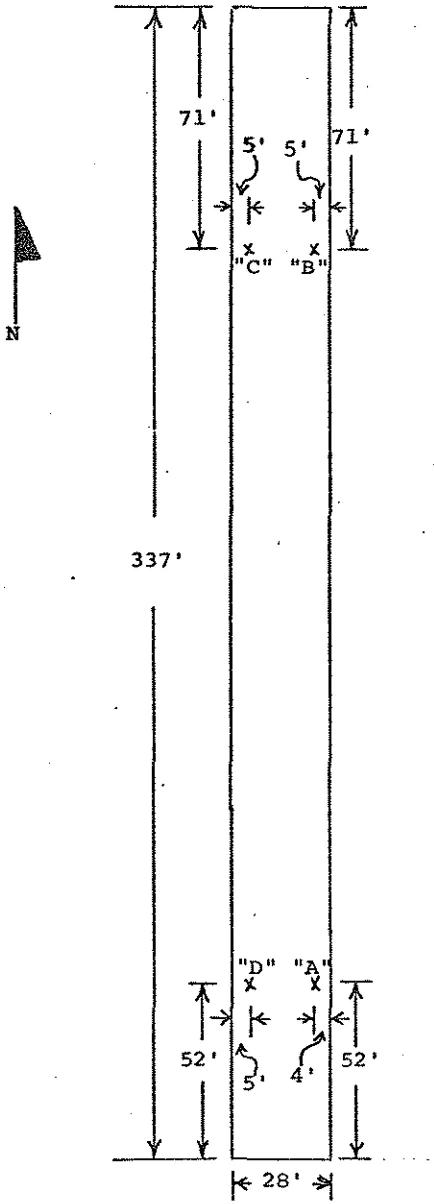
		Chloride Content - Lbs/Cu.Yd.						
		Concrete Depth						
Core No.	Location	0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	Old Deck Top ½"
813	A	16.63		4.54				
814	A		7.86		1.47			
815	B	15.04		4.57		5.63		6.96
816	B		11.94		3.89			
817	C	14.82		1.21		5.29		7.75
818	C		7.60		0.87		7.79	
819	D	15.04		4.73		2.23		
820	D		13.61		2.38		0.53	8.43

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.: .25, .50, .75, 1.00, 1.25, 1.50, 1.75, 2.00

Test Location "A"	"B"	"C"	"D"	Weighted Average
12.25	13.49	11.21	14.32	12.82
3.00	4.23	1.04	3.55	2.96
	5.63	6.54	1.38	4.29
Old Deck	Old Deck 6.96	Old Deck 7.75	Old Deck 8.43	Old Deck 7.71

Figure 2



Polk County
FN-60-4(2)--21-77 Des. No. 866
Location: Ia. 141 Over Little Beaver Creek
Letting Date: 5-23-67

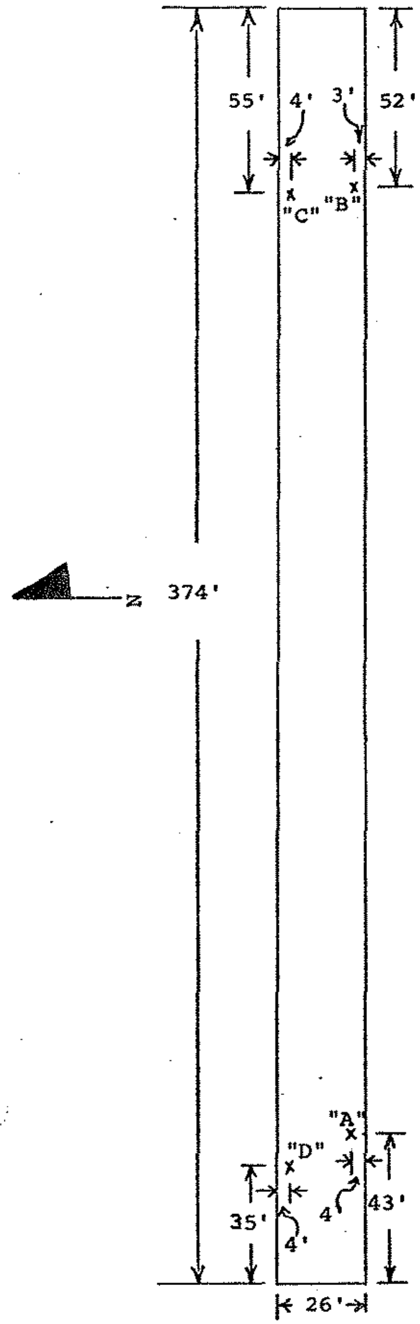
Chloride Content - Lbs/Cu.Yd.

		Concrete Depth								
Core No.	Loca-tion	0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
893	A	14.82		3.70		0.39				
894	A		2.29		0.48		1.82			0.44
895	B	10.21		0.39		0.13		0.88		
896	B		4.80		0.59		2.59			2.50
897	C	13.12		0.52		0.27		0.09		
898	C		3.55		3.59		0.47			0.45
899	D	1.64		0.27		0.44				0.44
900	D		3.08		0.33		0.35			

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
.25–.50	8.55	7.50	8.33	2.36	6.69
.75–1.00	2.09	0.49	2.05	0.30	1.23
1.25–1.50	1.10	1.36	0.37	0.39	0.81
1.75	Old Deck 0.44	0.88	0.09	Old Deck 0.44	
2.00		Old Deck 2.50	Old Deck 0.45		Old Deck 0.96
2.25					
2.50					

Fig. 3



Clay County
FN-374-1(1)--21-21 Des. No. 267
Location: Ia. 374 Over Little Sioux River
Letting Date: 5-23-67

Chloride Content - Lbs/Cu.Yd.

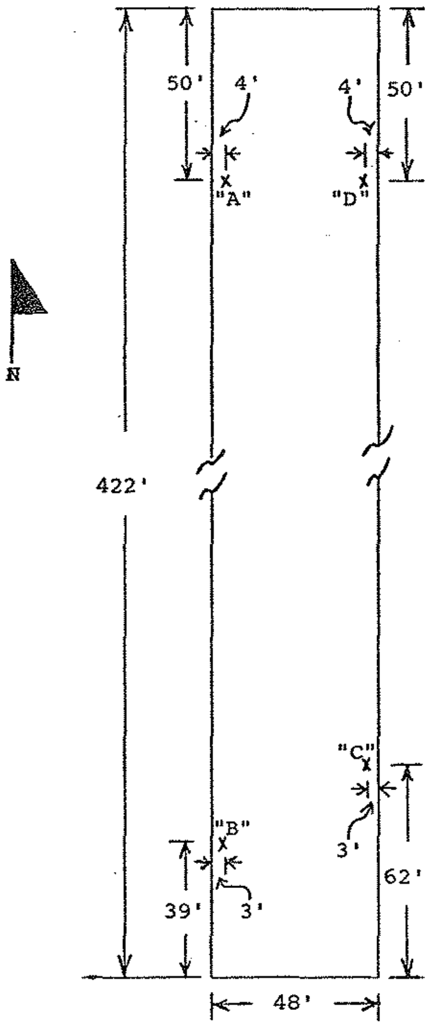
Core No.	Location	Concrete Depth 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
877	A	4.83		0.82		0.39		0.49		
878	A		3.49		2.70		0.50		0.33	0.96
879	B	4.01		0.51		0.48		0.36		0.96
880	B		1.45		0.78		1.00			
881	C	3.48		0.71		0.60		0.56		3.28
882	C		1.92		0.72		0.56		0.78	
883	D	2.55		0.84		0.53		0.72		
884	D		--		0.88		0.64		1.14	

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
.25 – .50	4.16	2.73	2.70	2.55	3.10
.75 – 1.00	1.76	0.65	0.71	0.86	1.00
1.25 – 1.50	0.45	0.74	0.58	0.58	0.59
1.75 – 2.00	0.41	0.36	0.67	0.93	0.63
2.25 – 3.00	Old Deck 0.96	Old Deck 0.96	Old Deck 3.28	Old Deck	Old Deck 1.73

Fig. 4

Clay County
UN-18-2(5)--41-21 Des. No. 167
Location: US 18 Over Little Sioux River
Letting Date: 5-23-67



Chloride Content - Lbs/Cu.Yd.

Core No.	Location	Concrete Depth 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
869	A	14.10		7.45						
870	A		11.75		3.97					3.73
871	B	12.47		2.91		1.32		--		4.65
872	B		6.50		0.45		0.40		0.49	
873	C	14.63		4.27		0.91		0.58		0.75
874	C		8.58		0.91		0.61		0.58	
875	D	10.85		2.56		1.15				
876	D		6.24		0.40					2.93

Chloride Content - Lbs/Cu.Yd.

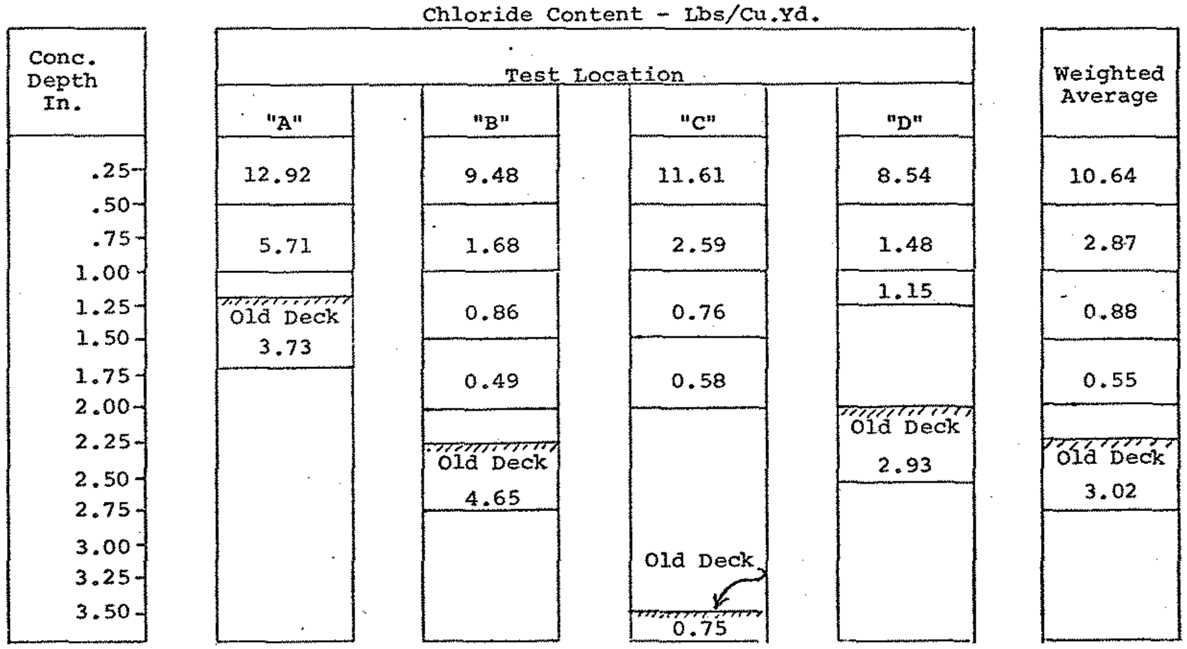
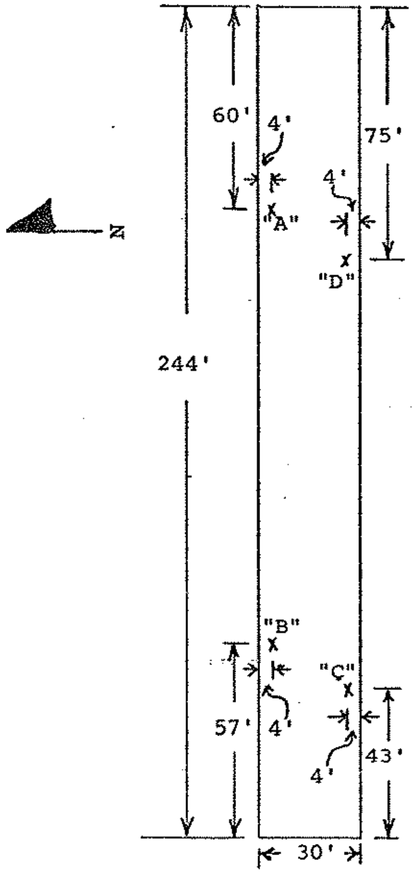


Fig. 5

Monona County
INP-29-6(27)114--15-67 Des. No. 268
Location: Ia. 175 Over I-29
Letting Date: 3-6-68



Chloride Content - Lbs/Cu.Yd.

Core No.	Location	Concrete Depth 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
789	A	2.92		1.23		0.66		0.61		1.10
790	A		1.93		1.49		0.99			
791	B	6.39		4.80		3.86		2.81		
792	B		5.18		2.32		1.10			0.57
793	C	8.51		5.29						0.61
794	C		4.26		0.72					
795	D	4.95		1.10		0.66		0.50		0.72
796	D		1.43		0.61		0.64		0.71	

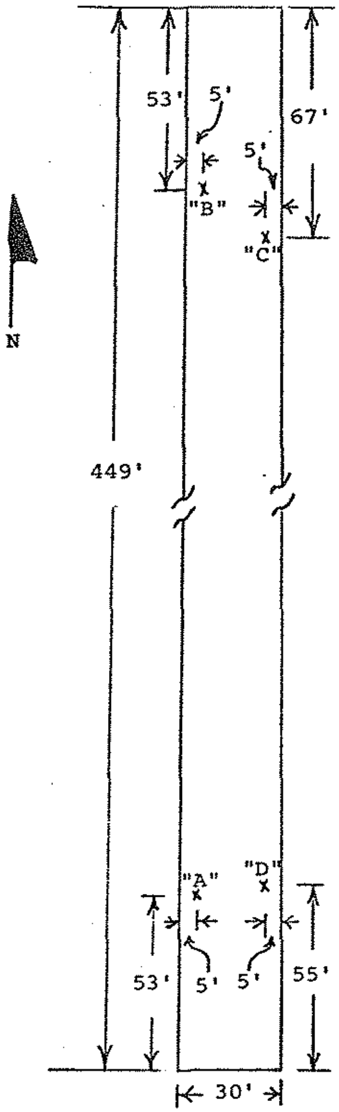
Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.: .25, .50, .75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 2.75, 3.00

Test Location "A"	"B"	"C"	"D"	Weighted Average
2.42	5.73	6.38	3.19	4.45
1.36	3.56	3.00	0.85	2.30
0.82	2.48	Old Deck 0.61	0.65	1.32
0.61	2.81		0.60	1.16
Old Deck 1.10	Old Deck 0.57		Old Deck 0.72	Old Deck 0.75

Fig. 6

Woodbury County
INP-29-6(28)143--15-97 Des. No. 168
Location: I-29 over C&NW Railroad & Wall St.
Letting Date: 4-2-68



Chloride Content - Lbs./Cu.Yd.

		Concrete Depth								
Core No.	Location	0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
797	A	5.78		0.99		2.31				
798	A		5.75		2.43					3.13
799	B	5.86		1.09		0.67		3.01		
800	B		2.99		0.45		0.73			4.69
801	C	9.37		1.08		0.53		1.54		
802	C		4.80		1.85		0.79			5.07
803	D	15.65		1.38		1.27				4.93
804	D		1.21		0.61		0.83		0.48	

Chloride Content - Lbs/Cu.Yd.

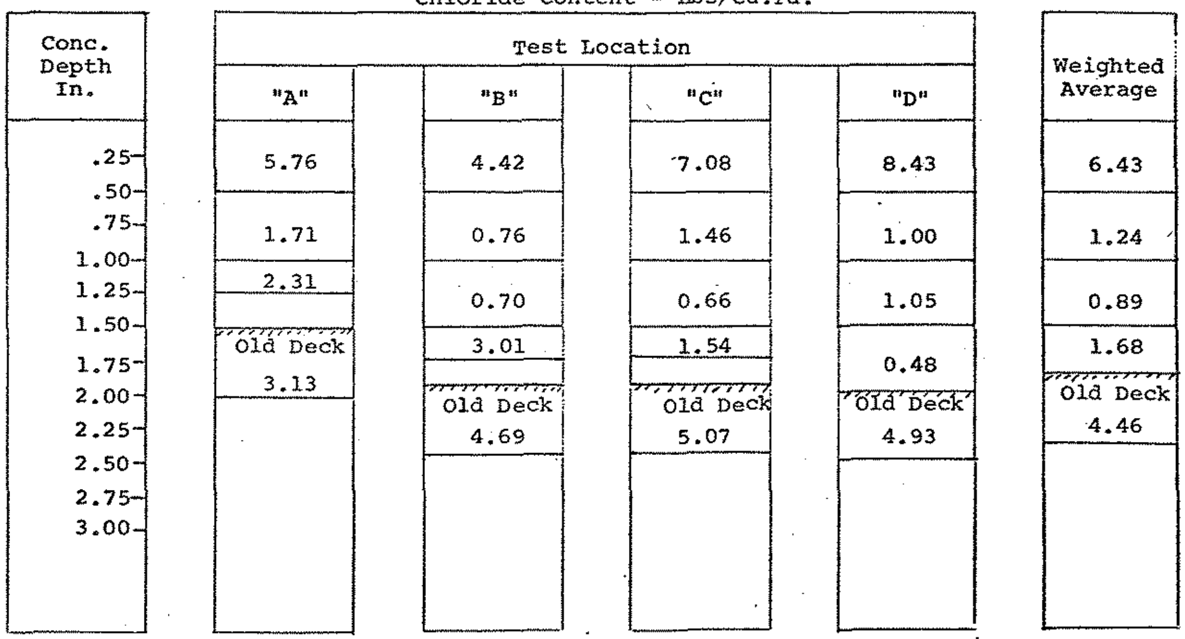
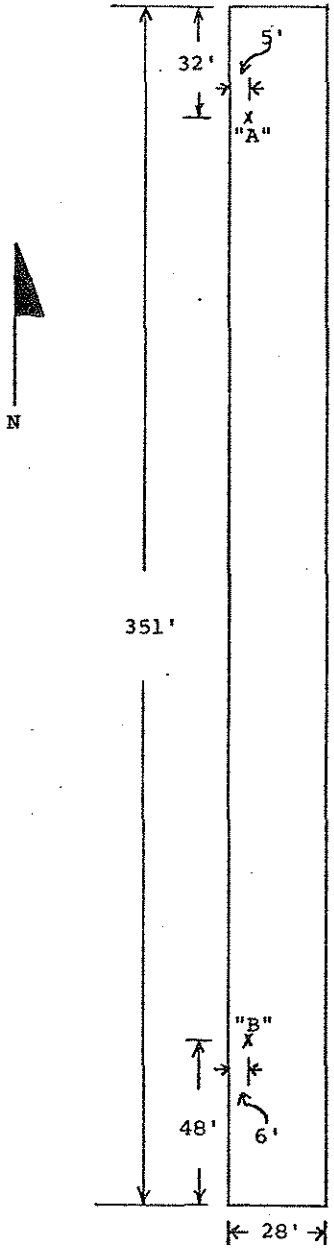


Figure 7

Plymouth County
FN-75-5(4)--21-75, Des. No. 169
Location: US 75 South Bound Over Floyd River in LeMars
Letting Date: 5-27-69



Chloride Content - Lbs/Cu.Yd.

Core No.	Location	Concrete Depth: 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	Old Deck Top ½"
825	A	11.95		2.15		
826	A		5.41			4.54
827	B	9.87				3.57
828	B		7.33			

Chloride Content
Lbs/Cu.Yd.

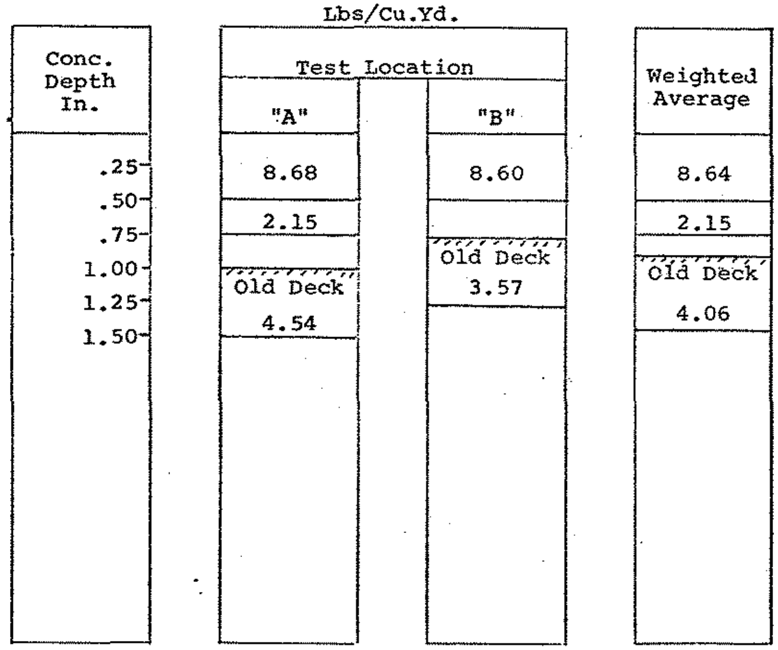
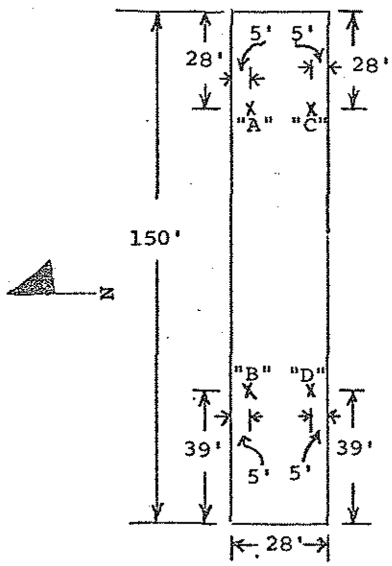


Fig. 8

Woodbury County
FN-20-1(20)--21-97 Des. No. 369
Location: US 20 Over Elliott Creek
Letting Date: 4-30-70



Chloride Content - Lbs/Cu.Yd.

Core No.	Location	Concrete Depth: 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
805	A	5.59		0.44		0.39		0.42		
806	A		1.82		0.42		0.39			2.22
807	B	4.12		0.36		0.83				4.12
808	B		2.18		0.33					
809	C	11.19		4.08		0.46		0.61		
810	C		10.89		2.21		0.44		0.39	0.28
811	D	12.18		2.49		0.28		0.35		0.46
812	D		6.43		0.57		0.37		0.37	

Chloride Content - Lbs/Cu.Yd.

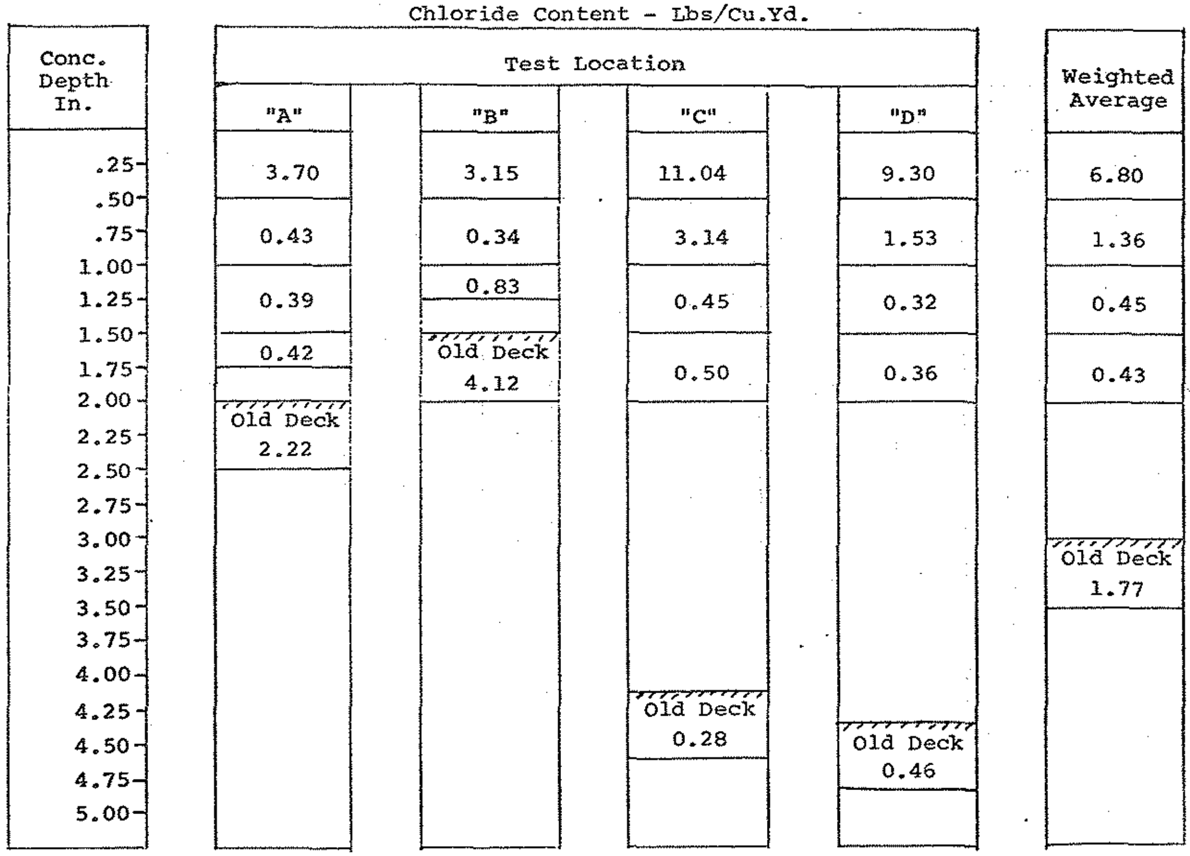
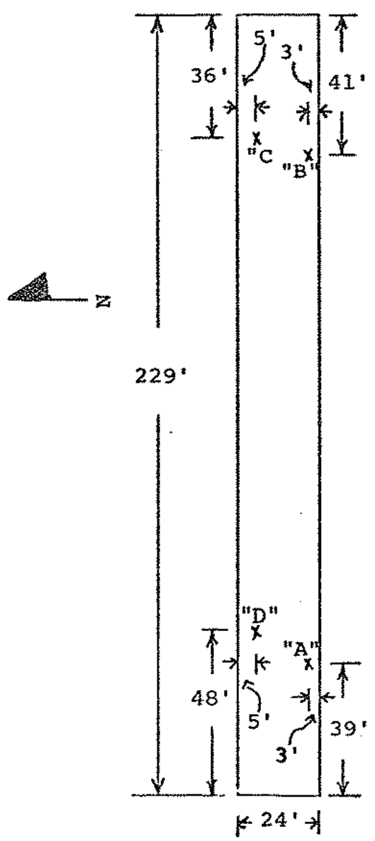


Fig. 9

Calhoun County
FN-175-5(3)--21-13 Des. No. 170
Location: Ia. 175 Over Racoon River
Letting Date: 4-30-70



Chloride Content - Lbs/Cu.Yd.

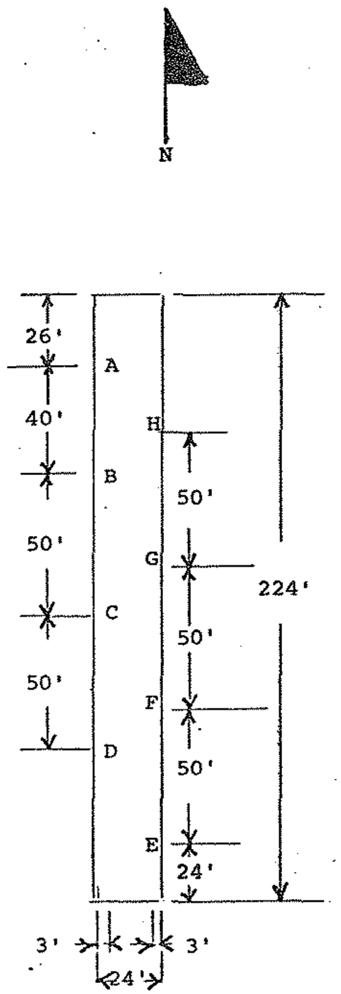
Core No.	Location	0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2"	Old Deck Top ½"
		Concrete Depth								
885	A	8.01		2.73		1.13		--		
886	A		4.84		0.90		0.90		0.63	1.35
887	B	8.66		2.23		0.68		0.73		
888	B		5.44		0.81		1.08		0.65	
889	C	7.26		0.99		0.61				
890	C		3.97		0.55		1.44			2.67
891	D	9.07		1.29		0.55				2.98
892	D		4.65		0.53		2.10			

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	Test Location "B"	Test Location "C"	Test Location "D"	Weighted Average
.25 – .50	6.42	7.05	5.62	6.86	6.49
.75 – 1.00	1.82	1.52	0.77	0.91	1.25
1.25 – 1.50	1.02	0.88	1.02	1.32	1.06
1.75 – 2.00	0.63	0.69			0.67
Old Deck	Old Deck 1.35	Old Deck	Old Deck 2.67	Old Deck 2.98	Old Deck 2.33

Fig. 10

Cherokee County
FN-59-7(11)--21-18 Des. No. 370
Location: US 59 Over Gray Creek--10-92-40
Letting Date: 5-26-70



Chloride Content--Lbs./Cu. Yd.

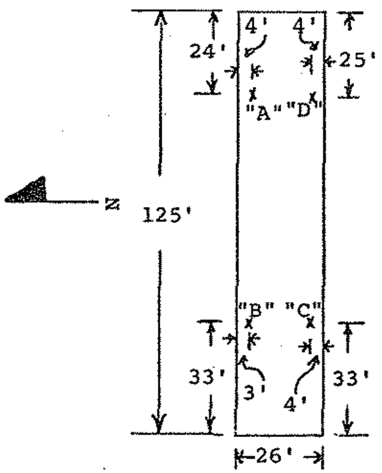
Core Number	Location	Concrete Depth: 0 to 1/2"	1/2" to 1.0"	1.0" to 1-1/2"	1-1/2" to 2.0"	Old Deck Top 1/2"
1634	A	6.43	2.74	0.60	0.67	0.64
1635	B	9.71	4.01	1.47	0.56	0.52
1636	C	7.86	2.46			2.46
1637	D	5.90	4.54			4.84
1638	E	9.68	4.84			1.46
1639	F	7.18	1.73	1.12		1.17
1640	G	6.12	2.34	0.73		1.12
1641	H	10.32	5.14	2.03	0.65	1.51

Chloride Content--Lbs./Cu. Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	Weighted Average
0.5	6.43	9.71	7.86	5.90	9.68	7.18	6.12	10.32	7.90
1.0	2.74	4.01	2.46	4.54	4.84	1.73	2.34	5.14	3.48
1.5	0.60	1.47	Old Deck 2.46	Old Deck 4.84	Old Deck 1.46	1.12	0.73	2.03	1.19
2.0	0.67	0.56				Old Deck 1.17	Old Deck 1.12	0.65	0.63
2.5									Old Deck 1.72
3.0	Old Deck 0.64								
3.5									
4.0		Old Deck 0.52							
4.5									
5.0								Old Deck 1.51	

Fig. 11

Plymouth County
FN-3-1(8)--21-75 Des. No. 271
Location: Ia. 3 Over Mink Creek
Letting Date: 4-29-71



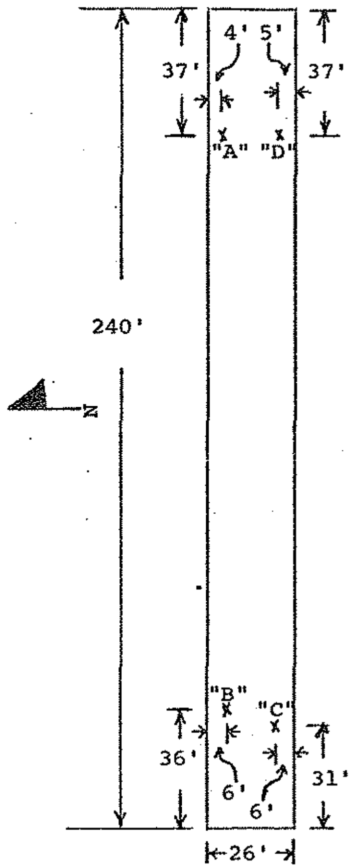
Chloride Content - Lbs/Cu.Yd.

Core No.	Loca-tion	Concrete Depth: 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
837	A	3.82		0.76		0.47		0.64		
838	A		3.50		1.02		0.59		1.47	
839	B	6.12		3.30		1.35		0.41		
840	B		2.30		0.45		0.50		0.57	0.59
841	C	6.69		1.55		0.50		0.62		
842	C		6.43		2.53		1.69		1.22	2.48
843	D	3.82		1.31		0.53		0.53		0.36
844	D		2.85		0.73		0.50		0.51	

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
.25	3.66	4.21	6.56	3.33	4.44
.50					
.75	0.89	1.88	2.04	1.02	1.46
1.00					
1.25	0.53	0.92	1.09	0.51	0.77
1.50					
1.75	1.06	0.49	0.92	0.52	0.75
2.00					
2.25	Old Deck				
2.50					
2.75					
3.00					
3.25			Old Deck		
3.50			2.48	Old Deck	Old Deck
3.75				0.36	1.43
4.00					
4.25					
4.50		Old Deck			
4.75		0.59			
5.00					

Fig. 12



Plymouth County
FN-3-1(8)--21-75 Des. No. 171
Location: Ia. 3 Over W. Branch of Floyd River
Letting Date: 4-29-71

Chloride Content - Lbs/Cu.Yd.

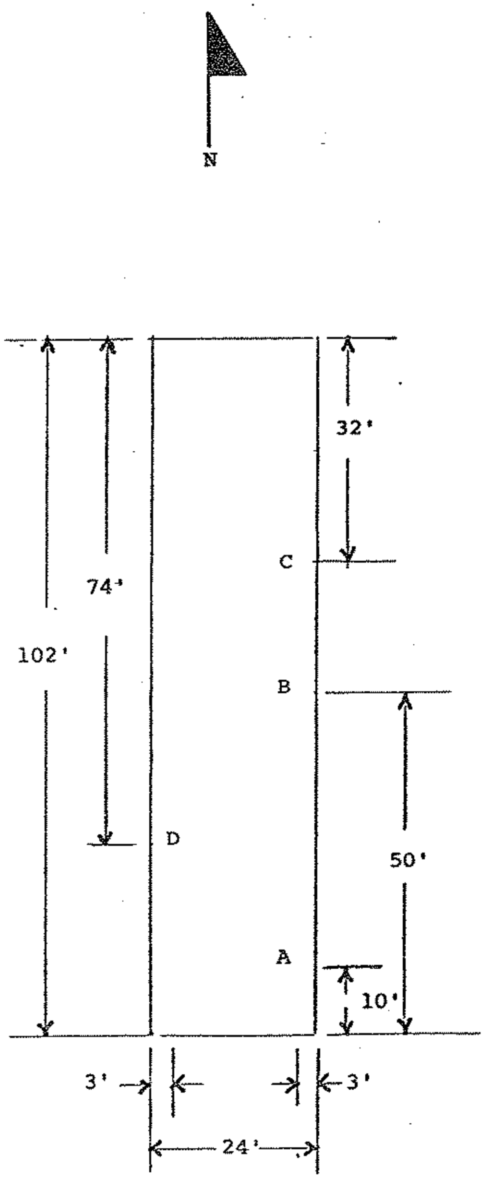
		Concrete Depth								
Core No.	Location	0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
829	A	2.15		0.60		0.51		1.10		
830	A		0.72		0.49		0.43		0.56	0.81
831	B	2.72		0.53		0.46		1.02		
832	B		0.91		0.60		0.68			3.45
833	C	1.84		0.57		.055		0.72		
834	C		1.99		0.44		0.41			1.27
835	D	1.93		0.54		0.42		0.54		
836	D		1.27		0.64		0.57		0.50	0.81

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
0 – .50	1.94	1.82	1.92	1.60	1.69
.50 – 1.00	0.54	0.56	0.50	0.59	0.55
1.00 – 1.50	0.47	0.57	0.48	0.50	0.50
1.50 – 2.00	0.83	1.02	0.72	0.52	0.74
Old Deck	0.81	3.45	1.27	0.81	1.59

Fig. 13

Cherokee County
FN-59-7(14)--21-18 Des. No. 272
Location: US 59 Over Gray Creek 15-93-40
Letting Date: 4-27-72



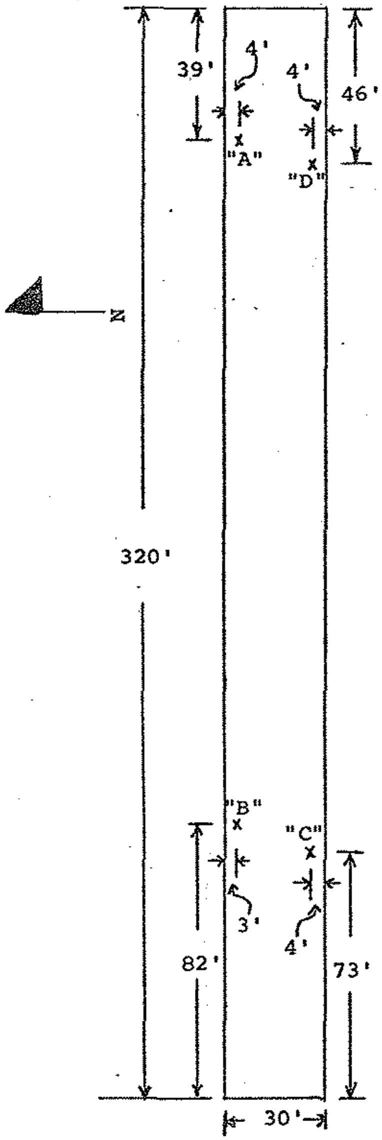
Chloride Content--Lbs./Cu. Yd.

Core Number	Location	0 to 1/2"	1/2" to 1.0"	1.0" to 1-1/2"	1-1/2" to 2"	Old Deck Top 1/2"
		Concrete Depth				
1832	A	3.02	0.68	0.96		3.86
1833	B	4.76	0.84	0.56	0.71	3.89
1834	C	5.25	0.81	0.76		4.57
1835	D	2.62	0.65	0.54	0.82	4.04

Chloride Content--Lbs./Cu. Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
0.5	3.02	4.76	5.25	2.62	3.91
1.0	0.68	0.84	0.81	0.65	0.74
1.5	0.96	0.56	0.76	0.54	0.71
2.0		0.71		0.82	0.76
Old Deck	3.86	3.89	4.57	4.04	4.09
2.5					
3.0					
3.5					
4.0					
4.5					
5.0					

Fig. 14



Cherokee County
FN-3-2(7)--21-18 Des. No. 172
Location: Ia. 3 Over Little Sioux River
Letting Date: 4-27-72

Chloride Content - Lbs/Cu.Yd.

Core No.	Location	Concrete Depth: 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
845	A	3.97		0.78		0.62		0.78		
846	A		2.79		0.63		0.53		0.56	2.48
847	B	4.23		0.76						8.81
848	B		3.62		0.86					
849	C	8.28		1.94		0.60		0.84		
850	C		2.66		0.55		0.56		0.70	
851	D	3.63		1.17						
852	D		2.35		1.23					8.88

Chloride Content - Lbs/Cu.Yd.

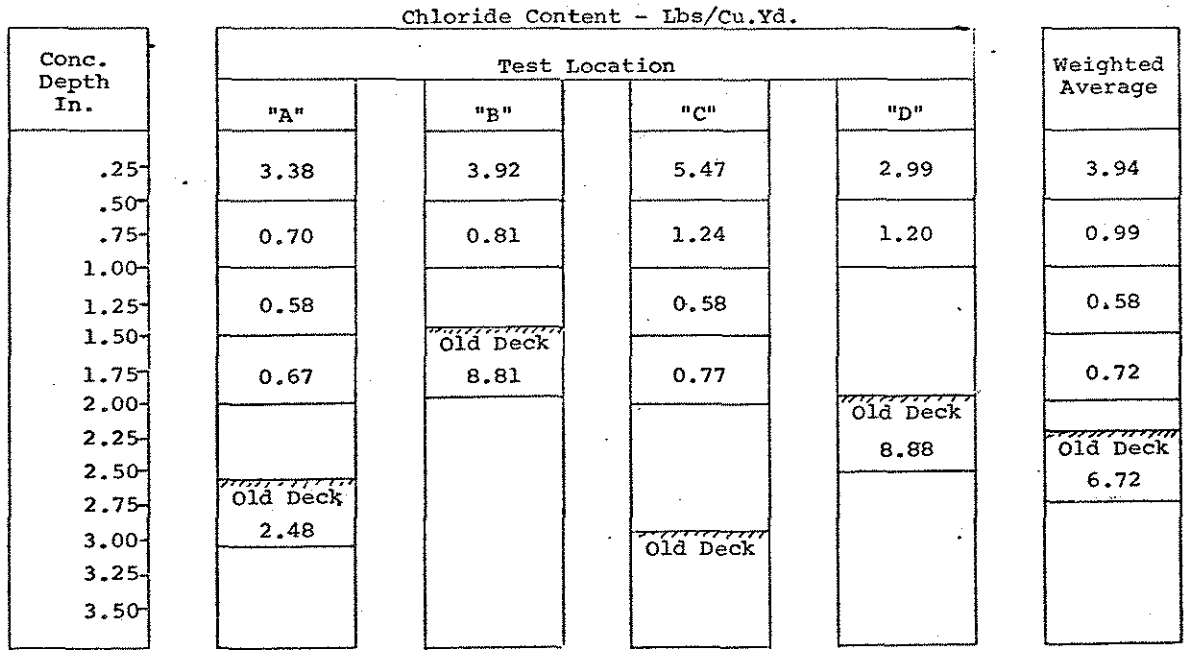
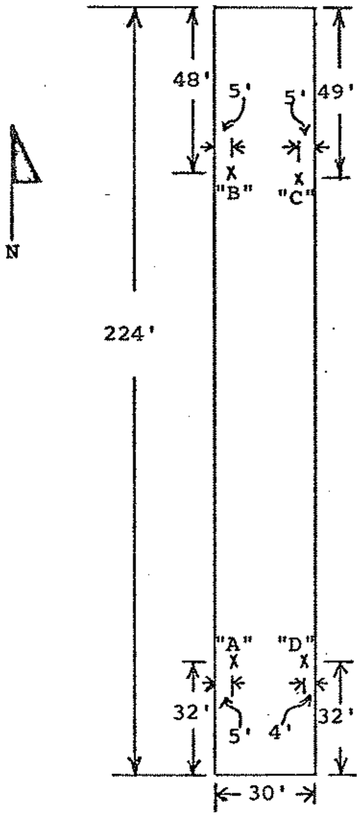


Fig. 15

Story County
FN-65-5(5)--21-85 Des. No. 172
Location: US 65 Over US 30
Letting Date: 5-23-72
Dow Latex Modified Concrete
Modifier "B" Used



Chloride Content - Lbs/Cu.Yd.

Core No.	Location	Concrete Depth 0 to 1/4"	1/4" to 1/2"	1/2" to 3/4"	3/4" to 1.0"	1.0" to 1-1/4"	1-1/4" to 1-1/2"	1-1/2" to 1-3/4"	1-3/4" to 2.0"	Old Deck Top ½"
781	A	12.70		9.75						
782	A	15.08		10.55						
783	B	15.04		9.64		8.32		6.62		3.70
784	B		11.45		7.33		8.92		10.47	
785	C	14.29		9.26		8.77		8.20		7.41
786	C		12.47		7.67		7.33		7.45	
787	D	12.13		10.96		9.49		6.99		
788	D		12.93		9.53		7.86		7.33	1.97

Chloride Content - Lbs/Cu.Yd.

Conc. Depth In.	Test Location "A"	"B"	"C"	"D"	Weighted Average
.25	13.89	13.25	13.38	12.53	13.26
.75	10.15	8.48	8.46	10.24	9.34
1.25		8.62	8.05	8.68	8.45
1.75		8.54	7.82	7.16	7.84
Old Deck	Old Deck	Old Deck 3.70	Old Deck 7.41	Old Deck 1.97	Old Deck 4.36

Fig. 16

on the two bridges previously cited.

The chloride level of the only latex modified concrete resurfacing to receive salt is reflected in Fig. 16. Modifier "B" was used in this concrete and this modifier contains chloride; thereby "building in" a relatively high chloride level. A chloride determination on unsalted concrete specimens from this bridge indicate a "built in" chloride level of approximately 7.0 lbs. per cubic yard.

Figures 17 and 18 indicate the chloride contents versus concrete depth for all of the bridges included in this study.

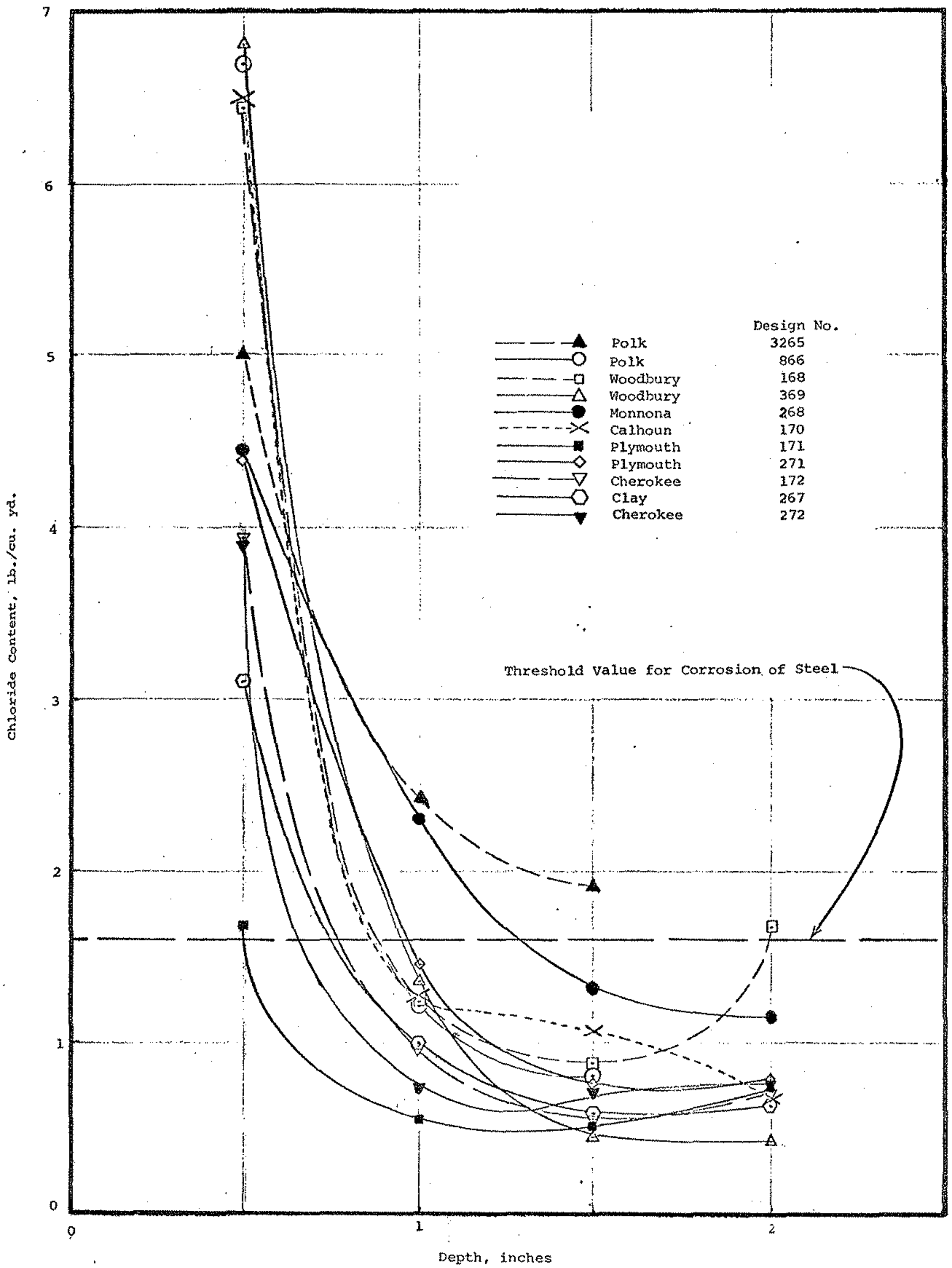
The threshold value for corrosion of steel was plotted utilizing the following formula:

(Lbs. chloride per cubic yard concrete = ((% cl./g cement) x (94 (CF)/100)))

Where CF = cement factor in 94 lb. bags per cubic yard.

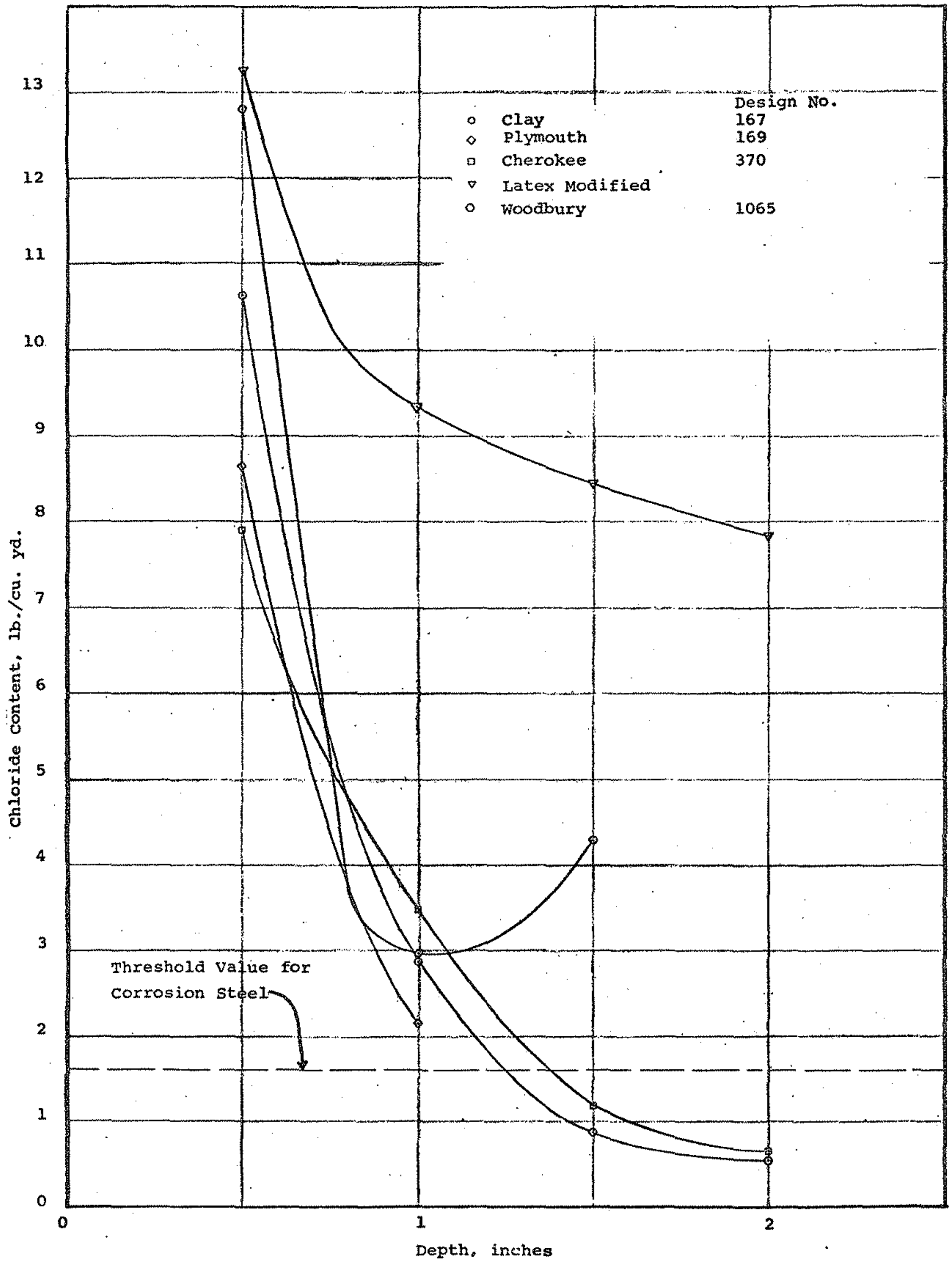
With a cement factor of 8.75 bags per cubic yard, and assuming the 0.20 percent Cl per gram of cement required to initiate rebar corrosion (Ref. 3), the corrosion threshold value is approximately 1.6 lbs. of chloride per cubic yard of concrete.

With exception of the Woodbury Co. Design Nos. 168 and 1065, the general shape of the chloride penetration curves are quite similar. As noted previously it appears that the higher chloride content of the resurfacing concrete at



CHLORIDE CONTENT vs. DEPTH

Fig. 17



CHLORIDE CONTENT vs. DEPTH

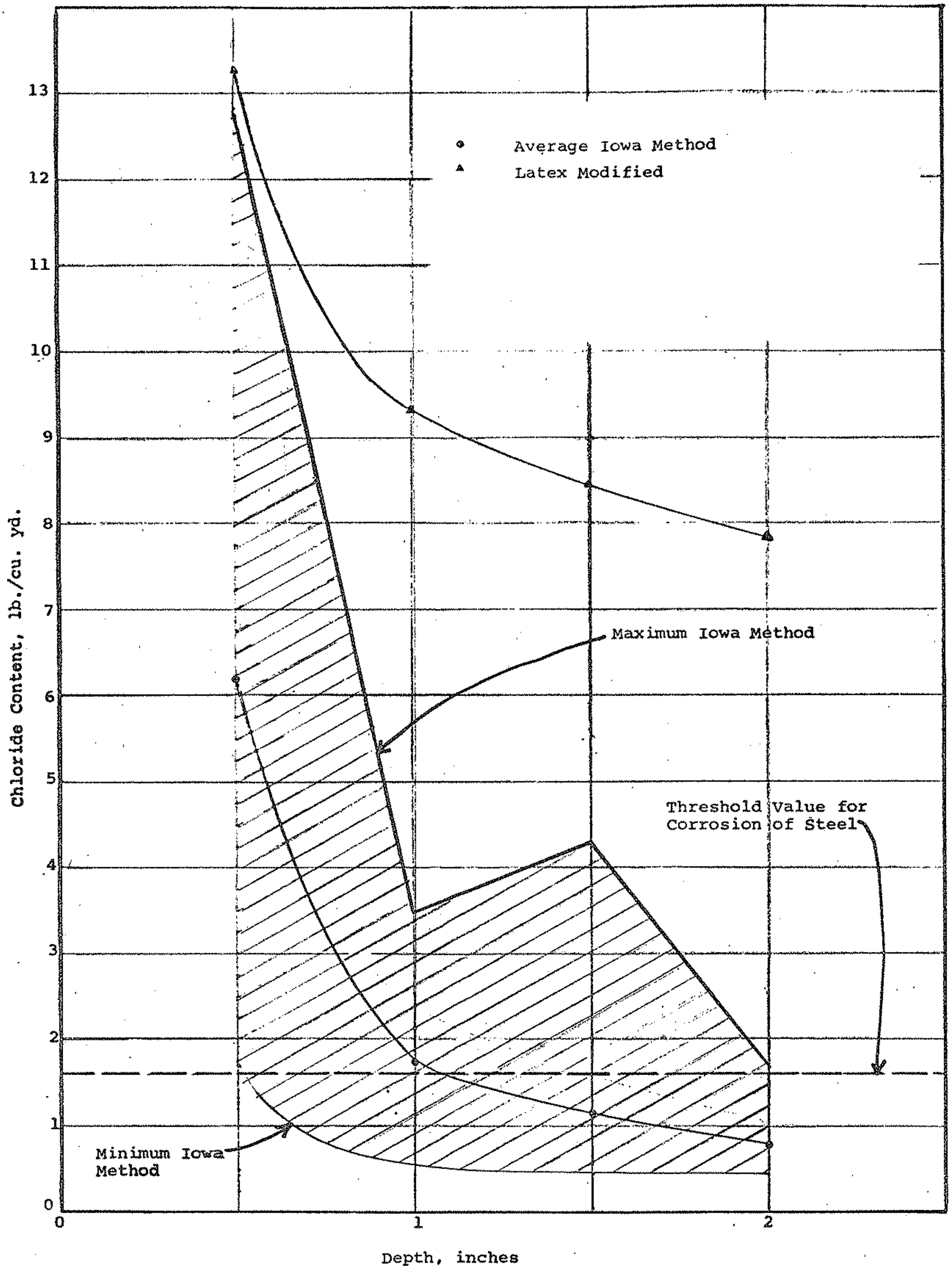
Fig. 18

the lower depths for these two bridges was caused by chlorides migrating upward from the old concrete rather than by chloride penetrating from the surface.

Fig. 19 shows the maximum, minimum, and average chloride levels of all of the bridges included in this study that were resurfaced by the "Iowa Method". Also plotted is chloride level of the one latex modified bridge deck investigated.

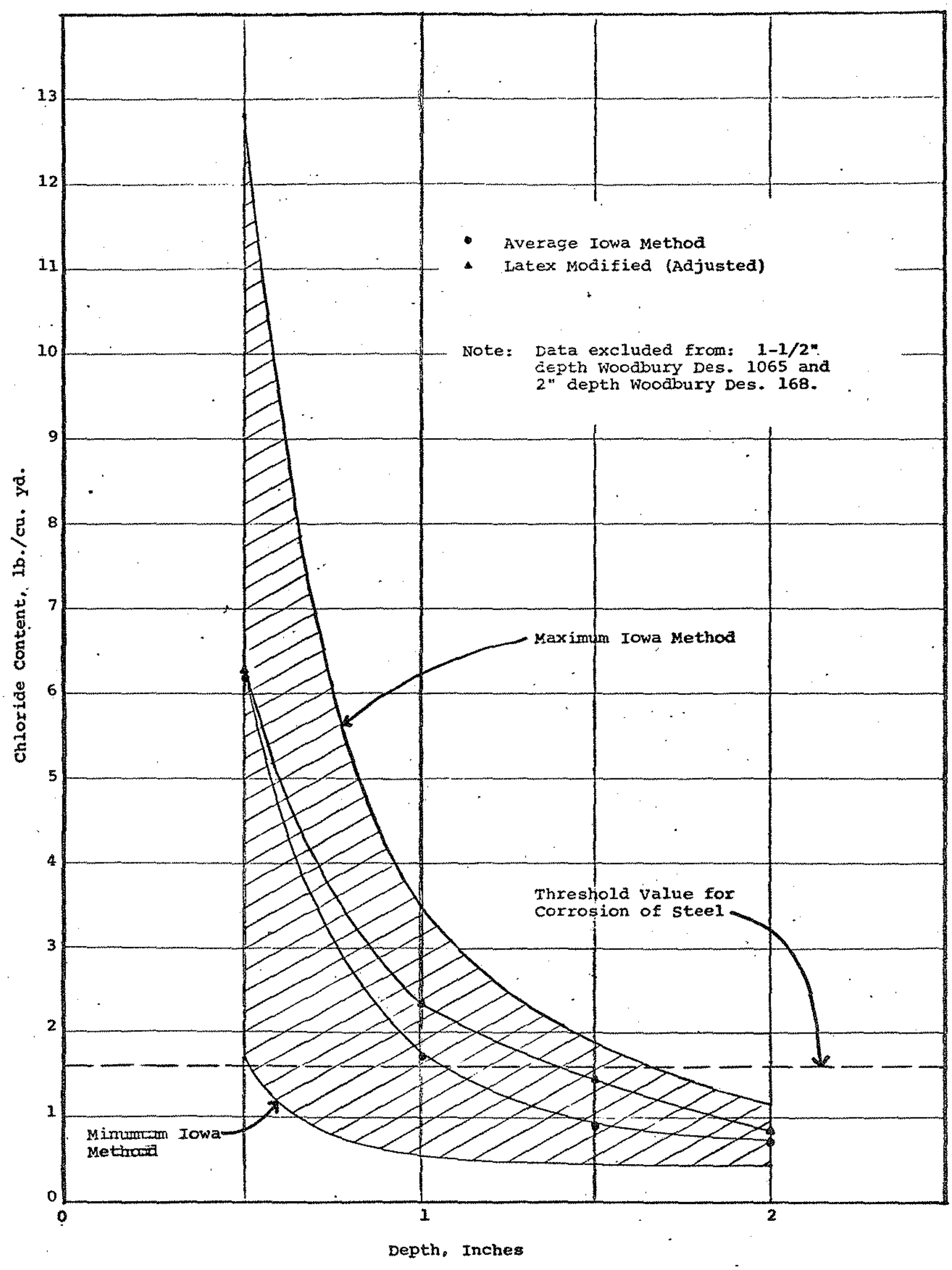
Fig. 20 is a plot showing the same type of information, however the data from the 1-1/2 inch depth of Woodbury Co. Design No. 1065 and the 2 inch depth of Woodbury Co. Design No. 168 are excluded for the reasons previously discussed. The latex modified curve has been adjusted by reducing the chloride content 7.0 lbs. per cubic yard so that a better comparison with the "Iowa Method" curve can be made. There has been no adjustment to the chloride content of the concrete for the "Iowa Method" since a chloride determination was not made on each deck prior to salting. Limited laboratory testing of this concrete with one of the aggregates commonly used indicated a built in chloride level of approximately 0.25 lbs. per cubic yard.

Figures 21 - 24 established the relationship between concrete age of the "Iowa Method" and chloride concen-



SUMMARY OF CHLORIDE CONTENTS

Fig. 19



SUMMARY OF CHLORIDE CONTENTS

Fig. 20

A COMPARISON OF
THE AGE OF BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 1/2" BELOW THE DECK SURFACE

Coefficient of Correlation = 0.451

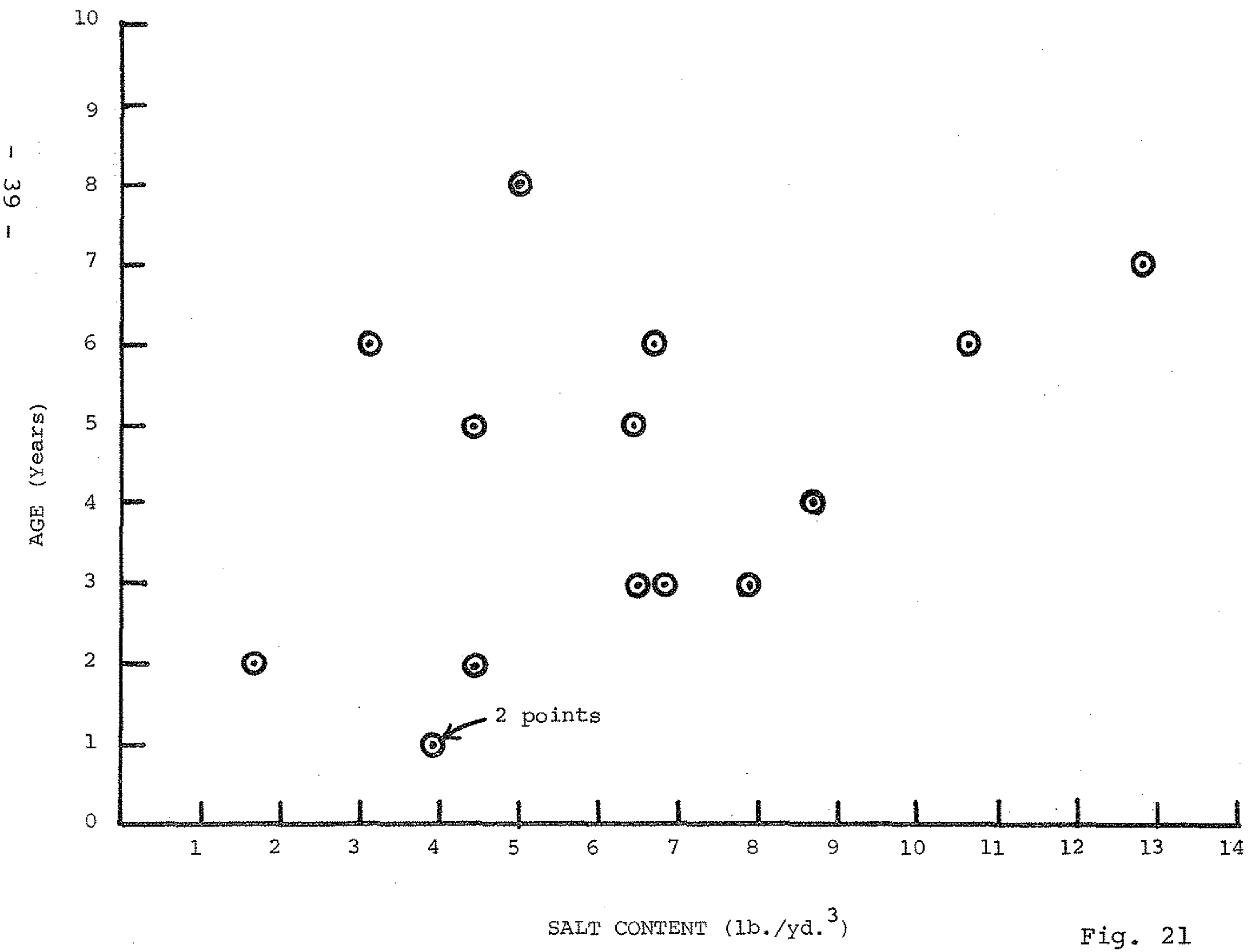


Fig. 21

A COMPARISON OF
AGE OF BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 1" BELOW THE DECK SURFACE

Coefficient of Correlation = 0.491

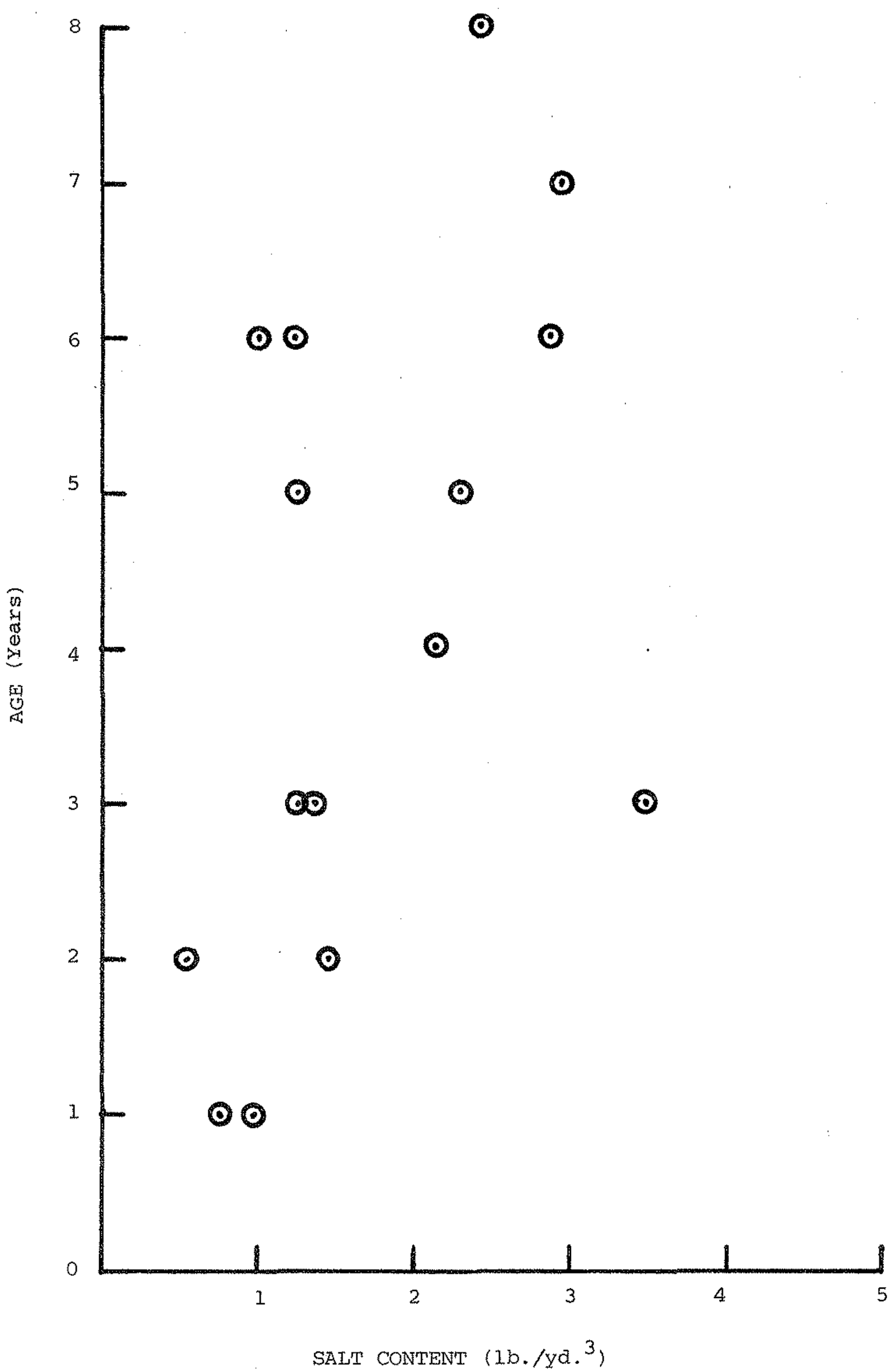


Fig. 22

A COMPARISON OF
AGE OF BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 1-1/2" BELOW THE DECK SURFACE

Note: Data excluded from
Woodbury Des. 1065

Coefficient of Correlation = 0.544

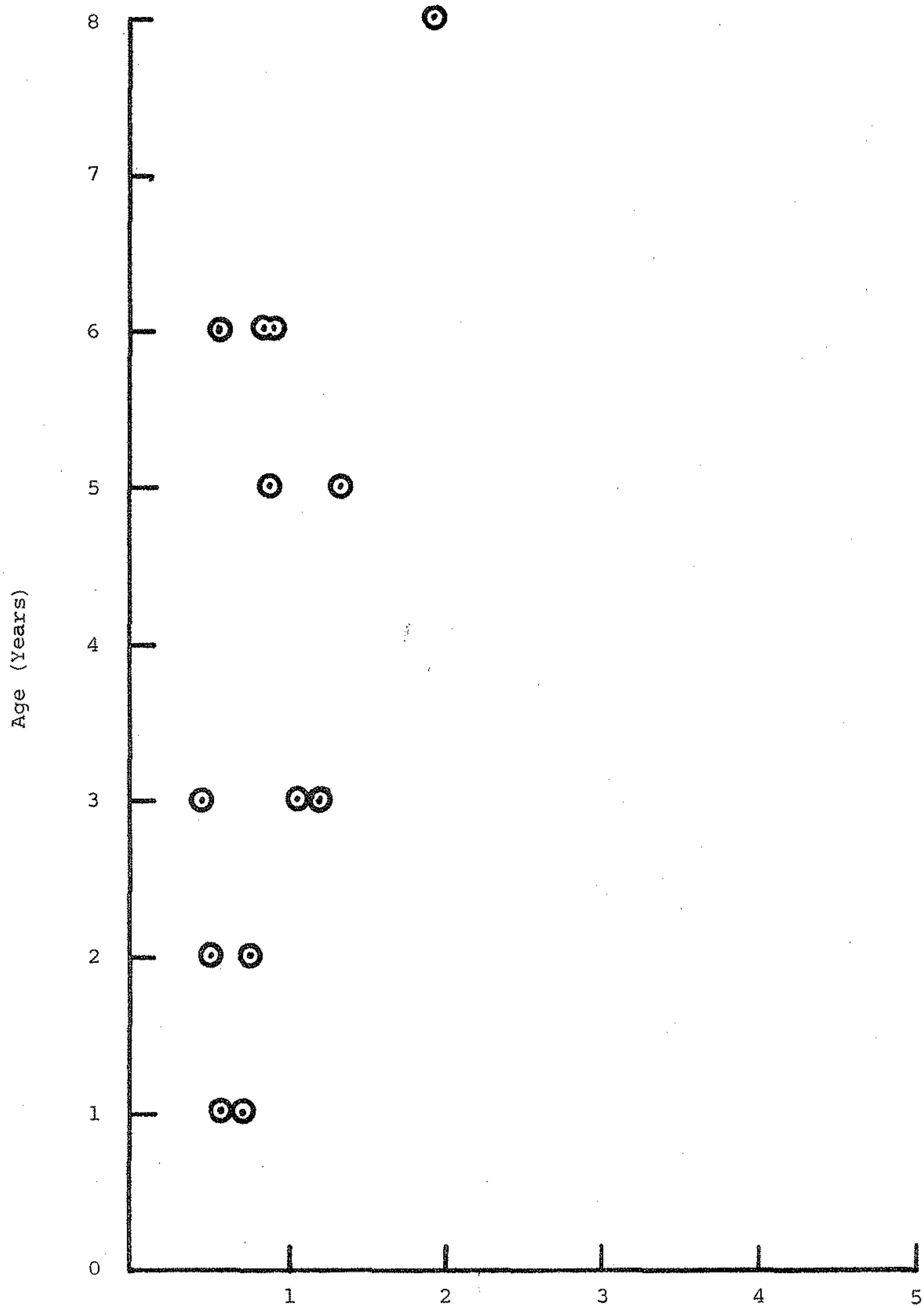


Fig. 23

SALT CONTENT (lb./yd.^{3})

A COMPARISON OF
AGE OF BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 2" BELOW THE DECK SURFACE

Note: Data excluded from
Woodbury Design 168

Coefficient of Correlation = 0.249

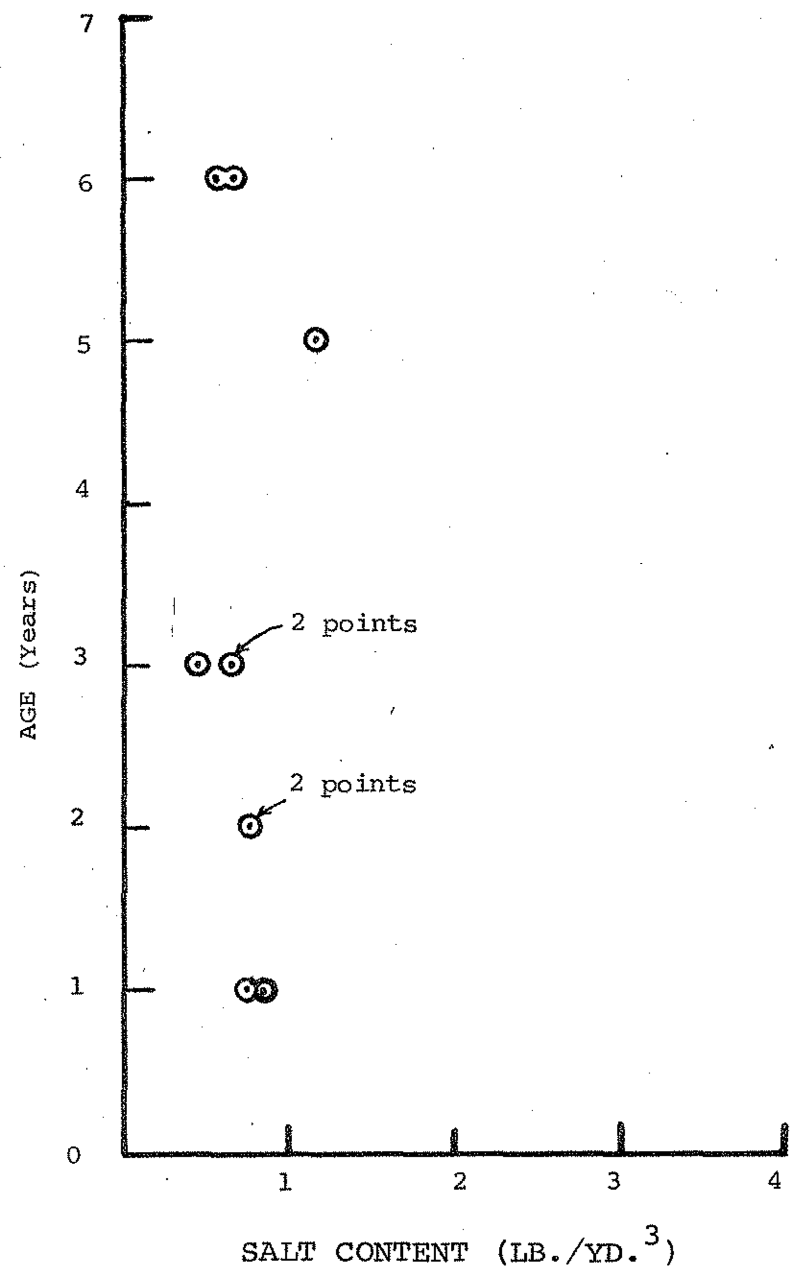


Fig. 24

tration at the 1/2 inch, 1 inch, 1-1/2 inch and 2 inch depths respectively. The questionable data from the previously discussed bridge decks has been deleted. The low correlation coefficient of .451, .491, .544, and .249 indicate no consistent relationship between these variables.

No records have been kept of the amount of salt applied to each bridge since resurfacing. Data is available, however, which establishes the salt usage in maintenance areas responsible for salting these bridges. The average salt usage expressed in tons per 2 lane mile of roadway is known for each year since the bridges have been resurfaced. Figures 25 - 28 show the relationship between total salt usage and chloride concentrations for the bridges resurfaced with Iowa concrete at the 1/2 inch, 1 inch, 1-1/2 inch and 2 inch depths respectively. Again the low correlation coefficients of .458, .183, .107, and -0.209 indicate no definite relationship exists. Data on salt usage on the Polk Co. Design No. 3265 was not available for these figures.

A COMPARISON OF
SALT USAGE ON BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 1/2" BELOW THE DECK SURFACE

Note: Data excluded from
Polk Design 3265

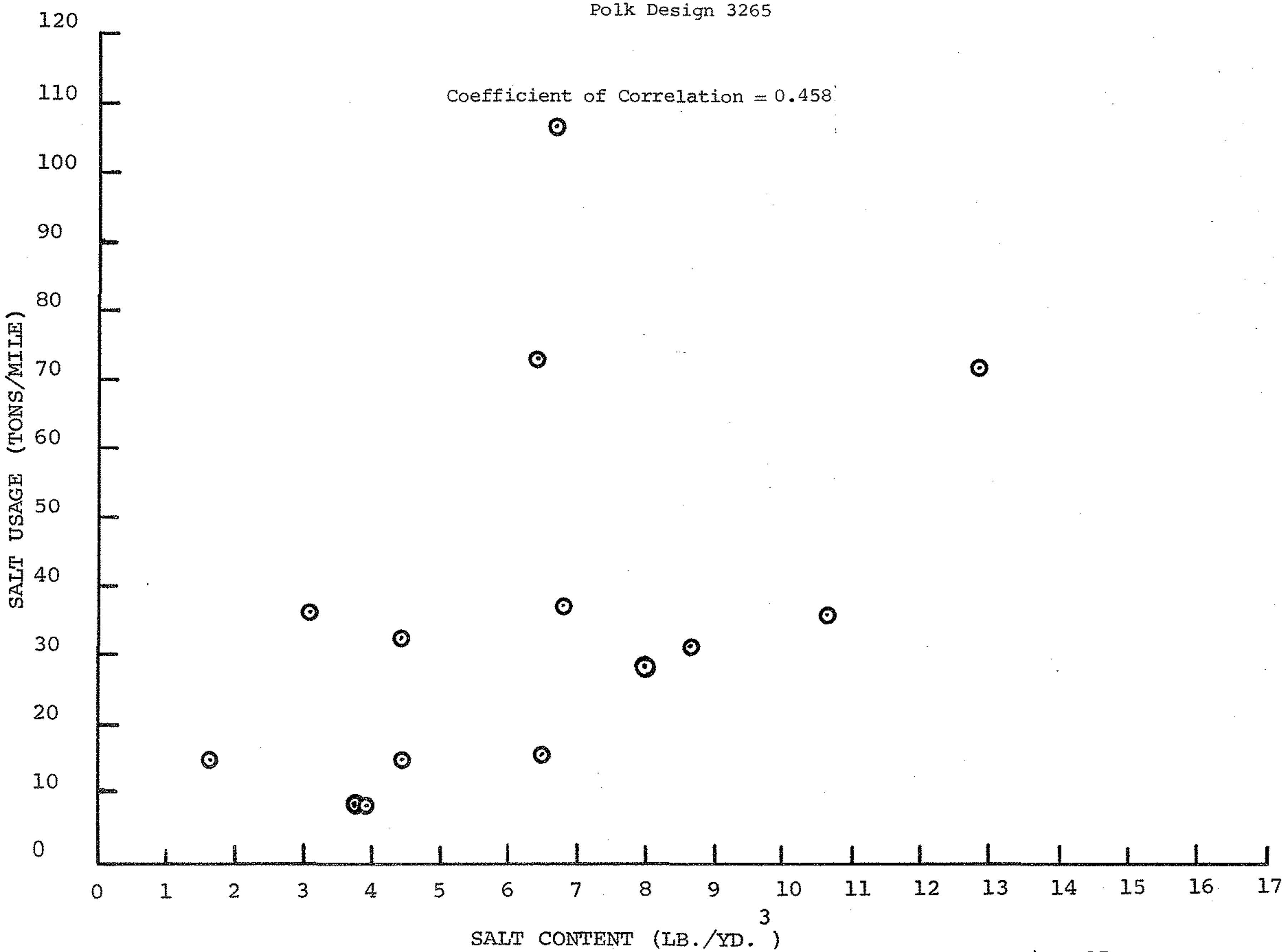


Fig. 25

A COMPARISON OF
SALT USAGE ON BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 1" BELOW THE DECK SURFACE

Note: Data excluded from
Polk Design 3265

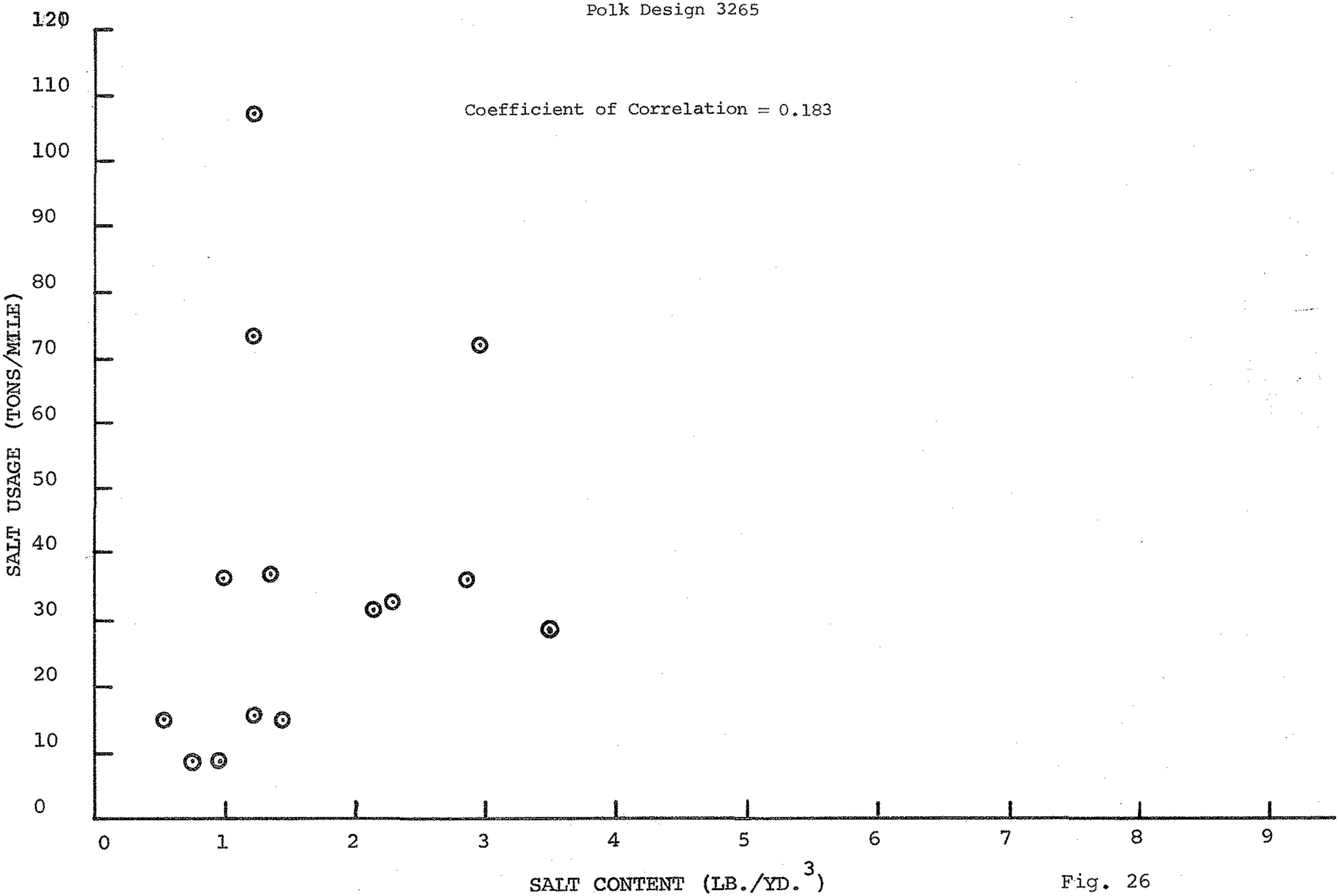


Fig. 26

A COMPARISON OF
SALT USAGE ON BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 1-1/2" BELOW THE DECK SURFACE

Note: Data excluded from
Polk Design 3265 and
Woodbury Design 1065.

Coefficient of Correlation = 0.107

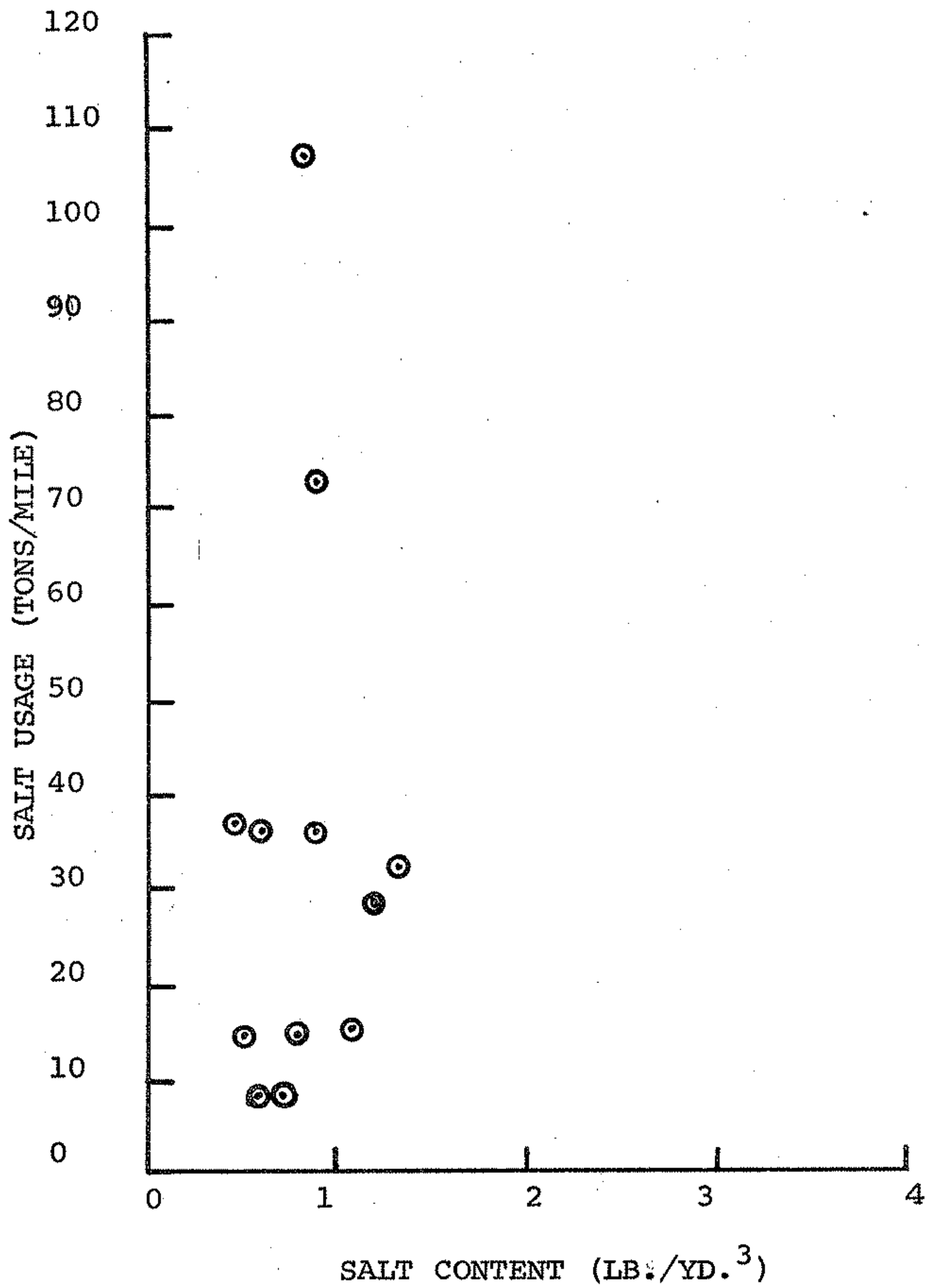


Fig. 27

A COMPARISON OF
SALT USAGE ON BRIDGE DECKS (IOWA METHOD)
VERSUS
SALT CONTENT 2" BELOW THE DECK SURFACE

Note: Data excluded from
Woodbury Design 168.

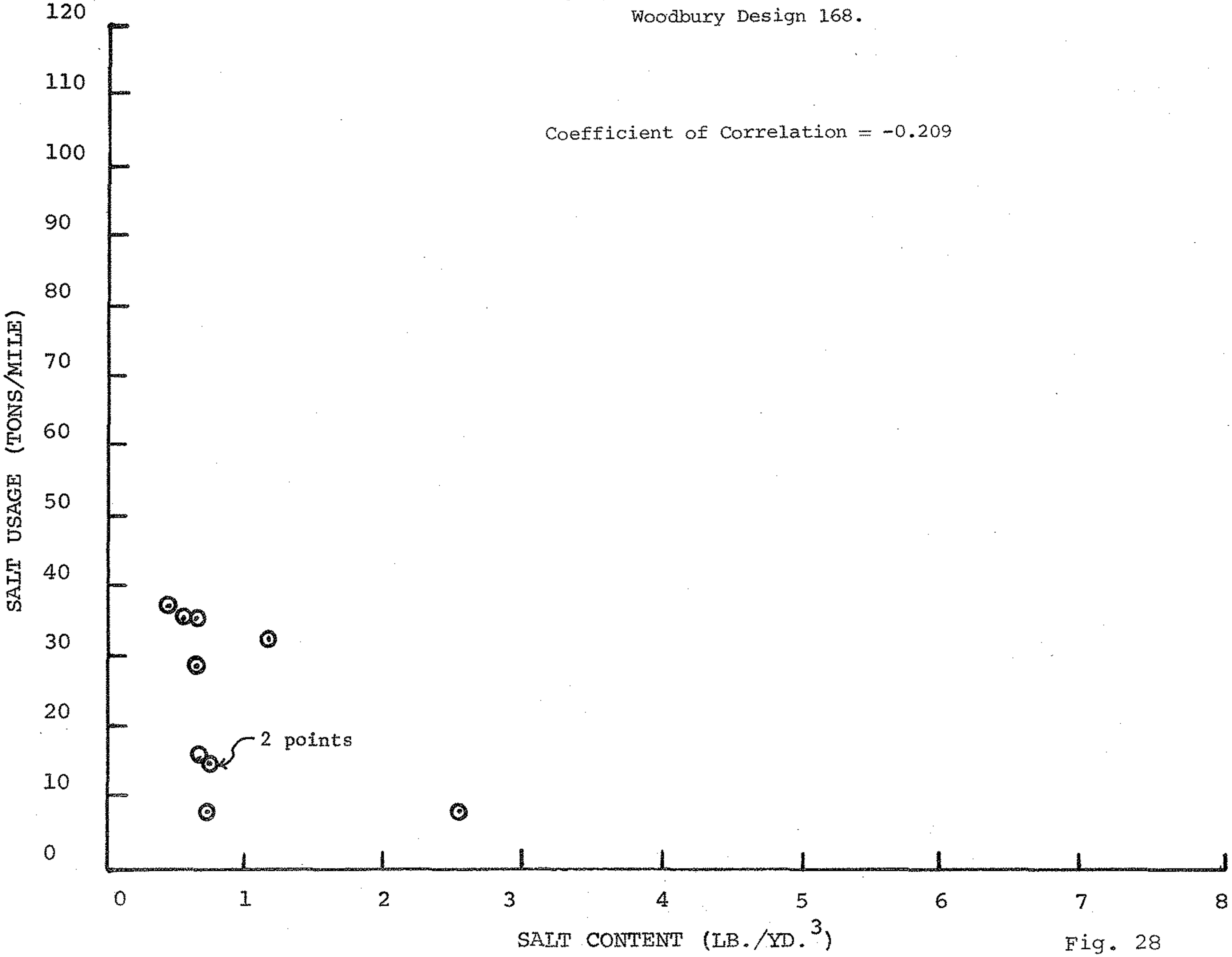


Fig. 28

Concrete Density

The nuclear density of the fresh "Iowa Method" concrete on I-35 northbound over the Raccoon River was measured in the 2 inch direct transmission mode at 6 locations during construction. The same type of testing was performed on the latex modified concrete used in the resurfacing of I-35 southbound over the Raccoon River at three locations.

The average density of the "Iowa Method" concrete at the 6 locations was 99.5% of the rodded density with a range of 99.0% to 99.7%. The average density of the latex modified concrete at the three locations was 100.0% with a range of 99.9% to 100.2%.

The detailed calculations and the test method currently employed for determining the nuclear density of plastic concrete is included in Appendix C.

Concrete cores drilled from the US 20 westbound bridge near Dubuque, and the I-80 eastbound and westbound bridges over US 65 near Des Moines were oven dried and a comparison made with similar oven dried cores of the "Iowa Method" concrete from the Raccoon River bridge. Two cores were taken at the transverse quarter point from two lanes of each bridge (total of 4 cores per bridge) to determine the density of the resurfacing.

The density of the concrete in terms of percentage of rodded unit weight of the plastic concrete is theoretical, since the rodded unit weight was not determined.

By adjusting for specific gravity of the aggregates used, and assuming a constant water content in the mixes, the theoretical percentage of rodded unit weight can be calculated.

Using the above approach, the percentage of rodded unit weight was calculated to be 100.97, 99.58 and 98.88 for US 20, I-80 eastbound and I-80 westbound bridges respectively. Detailed calculations are shown in Appendix D.

Since these bridges were resurfaced by other contractors with other equipment than was used on the Raccoon River bridge, it is felt that consolidation of the concrete is typical of what can be achieved utilizing existing equipment and present construction practices in Iowa.

Physical Properties

The physical properties of laboratory specimens fabricated from latex modified concrete materials used in the US 65 bridge in Story Co. and the "Iowa Method" concrete are as follows:

	Latex Modified	Iowa Method
28 Day Compressive Strength, psi.	7110	7605
28 Day Flexural Strength, psi.	654	733
Durability Factor		
Cure A	39	92
Cure B	30	95
Salt Scaling Resistance (100 cycles)	1	2

Because of the low durability factors obtained in this portion of the investigation, several additional specimens were fabricated in 1973 at the jobsite when the latex modified concrete was used. In addition specimens of the "Iowa Method" concrete were also fabricated in the field. The average durability factors of the specimens were:

Project Location	Concrete System	Average D.F.
I-35 Northbound over Raccoon River	Iowa	94
I-35 Southbound over Raccoon River	Latex	96
I-235 Westbound over Keoway	Latex	97
I-235 Eastbound over Keoway	Latex	97
I-235 Eastbound over 12th Street	Latex	96
I-235 Westbound over Des Moines River	Latex	91
I-35 Southbound over CGW-RR (Warren Co.)	Latex	93

The only significant difference in the latex modified concrete between the laboratory specimens and the field specimens, is that Modifier "B" was used in the laboratory concrete and Modifier"A" in the field concrete.

Whether the differences in durability factor can be attibuted entirely to the type of modifier used is not known at this time. Additional laboratory specimens have been fabricated with Modifier "A" in an effort to establish this relationship. The testing of these specimens has not been completed.

Rideability

The profile index of ten bridges resurfaced in 1973 is summarized below:

Latex Modified Resurfacing	Profile Index In/Mile
Westbound over Des Moines River on I-235	11.61
Eastbound over Keoway on I-235	20.63
Westbound over Keoway on I-235	22.37
Eastbound over 12th St. on I-235	15.33
Southbound over Raccoon River on I-35	19.58
Southbound over R.R. Tracks in Warren Co., approx. 2 miles South of Ia. 92 on I-35	10.83
Average	16.73

Iowa Method Resurfacing	
Northbound over Raccoon River on I-35	40.87
Westbound on US 20 in Dubuque	31.15
Eastbound over US 65 on I-80	42.08
Westbound over US 65 on I-80	41.88
Average	39.00

The westbound bridge over US 20 in Dubuque was selected as being representative of good construction practices with the "Iowa Method" concrete.

Discussion and Conclusions

The penetration rates of chloride into the "Iowa Method" concrete were similar for the bridges included in this study. The data on the latex modified concrete is quite limited and may or may not be representative of this type of concrete. Only one bridge resurfaced with latex modified concrete was investigated and that concrete contained Modifier "B" and had received only one winter's salt application.

Several bridge decks were resurfaced with latex modified concrete containing Modifier "A" in 1973 and will be studied in future years for resistance to salt penetration.

There was no discernable relationship between the age of bridge decks or amount of salt applied, and the chloride content of the concrete. To verify or refute this data, accurate records of salt applications on specific bridge decks would have to be maintained.

The nominal concrete cover over the top reinforcing steel on the bridges, after resurfacing, is 2-1/2 inches. Two bridges (Woodbury Des. 1065 and 168) resurfaced with the "Iowa Method" concrete have chloride contents considerably in excess of the 1.6 lbs. per cu. yd. corrosion threshold value, at the level of the reinforcing steel. There is no apparent distress on these bridges. It may be a distinct possibility that, although contaminated with chloride, there is not sufficient moisture or oxygen at the reinforcing steel level to initiate corrosion or allow it to continue. Electrical half-cell corrosion potentials will be measured on these bridges as an indication of whether or not corrosion is taking place. The measurements will also be made on the bridge resurfaced with the latex modified concrete that has a high "built-in" chloride content.

There does not appear to be a problem in achieving concrete consolidation of 98% of the rodded unit weight with the "Iowa Method" concrete. It is now part of the specification requirements that this level of consolidation be maintained. Limited information available at the time of this report suggests that bridges resurfaced under this specification are meeting this requirement when measured by nuclear methods.

Based upon the information and test data available, the physical properties of the "Iowa Method" concrete and latex modified concrete appear to be similar. Additional information concerning the durability factor of the latex modified concrete when Modifier "A" is used is forthcoming.

Bridges resurfaced with the latex modified concrete result in a smoother ride than bridges resurfaced with the "Iowa Method" concrete. Stricter control of equipment and construction practices should tend to reduce the current difference between these resurfacing methods.

As a result of our preliminary investigations, having to do with chloride concentrations at various levels of bridge decks, and the excellent durability exhibited by the "Iowa

Method" concrete, the two resurfacing methods were considered equivalent and the FHWA gave approval, during early 1974, to let the repair and/or resurfacing contracts with optional or alternate methods, that is, to use either latex modified concrete or the Iowa low slump concrete, at the contractor's option. The specifications for these methods are found in Appendix E. As of this writing, all contractors starting work in 1974 have elected to use the "Iowa Method".

Iowa now has about 10 years of favorable experience in using the high cemented, low slump, portland cement concrete for bridge repair and resurfacing. Several contractors have taken an active interest in this type of work. The resulting competition is a primary reason that the costs for this type of work have risen only a fraction of the increase experienced in conventional bridge construction over the same time period.

REFERENCES

1. Berman, H.A., "Determination of Chloride in Hardened Portland Cement Paste, Mortar, and Concrete". Report No. FHWA-72-12, Federal Highway Administration, September 1972.

2. Sheeler, M. I., "An Investigation of the Chemical Method of Determining the Cement Content of Hardened Concrete". Research Project R-248, Iowa State Highway Commission, March 1971.

3. Clear, K. C., & Hay, R. E., "Time to Corrosion of Reinforcing Steel in Concrete Slabs". Report No. FHWA-RD-72-32, Federal Highway Administration, April 1973.

APPENDIX A

FABRICATION, CURING & TESTING PROCEDURES TO DETERMINE THE PHYSICAL PROPERTIES OF THE IOWA LOW SLUMP CONCRETE & THE LATEX MODIFIED CONCRETE

IOWA LOW SLUMP CONCRETE

Materials

Portland Cement - Blend of seven Type I cements commonly used in Iowa.

Fine Aggregate - Hallett pit north of Ames meeting the requirements of Section 4110 of the Standard Specifications, with the following grading:

Sieve Size	% Passing Min.	% Passing Max.
3/8"	100	
No. 4	95	100
No. 8	75	100
No. 200	0	1.5

Coarse Aggregate - Crushed Limestone from B. L. Anderson's Montour Quarry, complying with Section 4115 of the Standard Specifications and having the following gradation:

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

Water - City of Ames, Iowa.

Air Entraining Agent - Neutralized Vinsol Resin, Pozzolith Type 84 as manufactured by Master Builders, Inc.

Procedure

The mix proportions for 1 cubic yard was:

Cement	823 Lbs.
Fine Aggregate (Sp. Gr. = 2.67)	1404 Lbs.
Coarse Aggregate (Sp. Gr. = 2.67)	1383 Lbs.
Water	302 Lbs.
Air Entraining Agent at 0.35 fl. oz. per sack	3.1 fl. oz.
Water reducing admixture at 8 fl. oz. per sack.	70 fl. oz.

Mixing Procedure

1. Dry the fine aggregate completely.
2. Bring the coarse aggregate to a saturated surface dry condition.
3. Add the fine aggregate and cement.
4. Dry mix for one minute.
5. Add the coarse aggregate.
6. Dry mix for one minute.
7. Add the air entraining agent in approximately 40% of the calculated mix water.
8. Mix for approximately 15 seconds.
9. Add the water-reducing admixture in 40% of the calculated mixing water.
10. Add additional water and adjust to a slump of 3/4 $\pm$ 1/4 inch.
11. Continue mixing until 3 minutes have elapsed since point "7".
12. Determine the slump and air.
13. Return the concrete from the slump and air to the mixer.
14. Remix for a few revolutions.
15. Fabricate specimens.

Specimen Preparation

Compressive Strength

Three 6" x 12" cylinders were made in accordance with ASTM C-192, except that horizontal molds were used. The specimens received 3 days of moist curing and 25 days of curing at 50 - 75% humidity.

Flexural Strength

One 6" x 6" x 33" beam was cast in two well consolidated lifts. Curing was the same as for the compression specimens. The modulus of rupture was determined by center point loading.

Durability

Three 4" x 4" x 18" beams were cast for determining the durability factor. The durability factors were determined per ASTM C-666, Method B, except for dimensions and the beams were not weighed periodically. The beams were cured in the following manner:

Cure A:

A. 3 days moist.
B. 18 days at 50-75% humidity.
C. 89 days at 100% humidity.
D. 1 day in a 40°F. water bath.

Cure B:

A. 3 days moist.
B. 40 days at 50-75% humidity.
C. 89 days at 100% humidity.
D. 1 day in a 40°F. water bath.

Resistance to Salt Scaling.

Two 12" x 12" x 2-1/2" slabs with a 10" wide dished surface formed in the top were used for this test. The cure was 24 hrs. moist followed by 20 days of 50 - 75% humidity. At this time 300, ml. of a 5% solution of calcium chloride was added to the dished depression. The specimens were then subjected to two cycles of freezing and thawing per day. The specimens were kept frozen over the weekends. Testing was continued until they reached 100 cycles of freezing and thawing. The specimens were visually rated at 0, 10, 20, 40, 70 and 100 cycles. This rating system selected as being the best for this test, and was taken from HRR No. 268 (Pages 5 - 7) but in general was originated in a study by R. L. Davis in HRR 173 (Page 2). The rating scale is:

0 - No scale
1 - Slight scale
2 - Slight to moderate scale
3 - Moderate scale
4 - Moderate to heavy scale
5 - Heavy scale

LATEX MODIFIED CONCRETE

Materials

Portland Cement - Same as Iowa concrete.

Fine Aggregate - Same as Iowa concrete.

Coarse Aggregate - Same as Iowa concrete.

Water - Same as Iowa concrete.

Latex - Dow Chemical Co., containing Modifier "B"

Procedure

The mix proportions for 1 cubic yard was:

Cement	658 Lbs.
Fine Aggregate	1645 Lbs.
Coarse Aggregate	1316 Lbs.
Latex	203 Lbs.
*Water (Average)	148 Lbs.

*The water varied slightly for different batches.

Mixing Procedure

1. Dry the fine aggregate completely.
2. Bring the coarse aggregate to a saturated surface dry condition.
3. Add 1/2 of the estimated mixing water.
4. Add the latex.
5. Add the coarse aggregate.
6. Begin mixing.
7. Add the fine aggregate.
8. Add the cement.

9. Add additional mixing water to yield the desired slump and mix until 4 minutes have elapsed since adding the latex.
10. Rest for 4-1/2 minutes.
11. Determine slump and air.
12. Use the slump test concrete without remixing.
13. Fabricate specimens.

<u>Specimen Preparation</u>

Compressive Strength

Same as Iowa concrete, except curing was 1 day moist and 27 days at 50 - 75% humidity.

Flexural Strength

Same as Iowa concrete, except curing was 1 day moist and 27 days at 50 - 75% humidity.

Durability

Same as Iowa concrete, except curing was as follows:

Cure A

A. 24 hours moist.
B. 20 days at 50-75% humidity.
C. 89 days at 100% humidity.
D. 1 day in a 40°F. water bath.

Cure B

A. 24 hours moist.
B. 42 days at 50-75% humidity.
C. 89 days at 100% humidity.
D. 1 day in a 40°F. water bath.

Resistance to Salt Scaling

Same as Iowa concrete.

IOWA STATE HIGHWAY COMMISSION

Materials Department Instructional Memorandum

METHOD OF EVALUATION OF PAVEMENT PROFILES

Scope:

This method describes the procedure used for determining the Profile Index from profilograms of pavements made with the California type Profilograph and also describes the procedure used to locate individual bumps when their reduction is required by specification.

The profilogram is recorded on a scale of one-inch equal to 25 ft. longitudinally and one-inch equal to one-inch, or full scale, vertically. The determination of the Profile Index involves measuring "scallops" that appear outside a "blanking" band. The determination of individual bumps involves the use of a special template.

Determination of the Profile Index

Procedure

A. Equipment

The only special equipment needed to determine the Profile Index is a plastic scale 1.70 inches wide and 21.12 inches long representing a pavement length of 528 feet or one-tenth of a mile at a scale of 1" = 25'. Near the center of the scale is an opaque band 0.2 inch wide extending the entire length of 21.12 inches. On either side of this band are scribed lines 0.1 inch apart, parallel to the opaque band. These lines serve as a convenient scale to measure deviations or excursions of the graph above or below the blanking band. These are called "scallops".

B. Method of Counting

Place the plastic scale over the profile in such a way as to "blank out" as much of the profile as possible. When this is done, scallops above and below the blanking band usually will be approximately balanced. See Figure I.

The profile trace will move from a generally horizontal position when going around superelevated curves making it impossible to blank out the central portion of the trace without shifting the scale. When such conditions occur the profile should be broken into short sections and the blanking band repositioned on each section while counting as shown in the upper part of Figure II.

Starting at the right end of the scale, measure and total the height of all the scallops appearing both above and below the blanking band, measuring each scallop to the nearest 0.05 inch (half a tenth). Write this total on the profile sheet near the left end of the scale together with a small mark to align the scale when moving to the next section. Short portions of the profile line may be visible outside the blanking band, but unless they project 0.03 inch or more and extend longitudinally for two feet (0.08" on the profilogram) or more, they are not included in the count. (See Figure I for illustration of these special conditions).

When scallops occurring in the first 0.1 mile are totaled, slide the scale to the left, aligning the right end of the scale with the small mark previously made, and proceed with the counting in the same manner. The last section counted may or may not be an even 0.1 mile. If not, its length should be scaled to determine its length in miles. An example follows:

Section length Miles	Counts, tenth of an inch
0.10	5.0
0.10	4.0
0.10	3.5
400' = 0.076	2.0
Total 0.376	14.5

The Profile Index is determined as "inches per mile in excess of the 0.2 inch blanking band" but is simply called the Profile Index. The procedure for converting counts of Profile Index is as follows:

Using the figures from the above example:

Length = 0.376 miles, total count = 14.5 tenths of an inch.

$$\text{Profile Index} = \frac{\text{1 mile}}{\text{Length of profiles in miles}} \text{ X total count in inches}$$

$$\text{PrI} = \frac{1}{0.376} \text{ X } 1.45 = 3.9$$

(Note that the formula uses the count in inches rather than tenths of an inch and is obtained by dividing the count by ten.)

The Profile Index is thus determined for the profile of any line called for in the specifications. Profile Indexes may be averaged for two or more profiles of the same section of road if the profiles are the same length.

Example:

	Section length, miles	Counts, tenths of an inch Left wheel track	Right wheel track
	0.10	5.0	4.5
	0.10	4.0	5.0
	0.10	3.5	3.0
400 =	0.076	2.0	1.5
Total	0.376	14.5	14.0
PrI (by formula)		3.9	3.7

$$\text{Average} = \frac{3.9 + 3.7}{2} = 3.8$$

The Profile Index will be computed at the midpoint of each driving lane unless this profile is not representative of the entire lane width.

C. Limitations of Count in 0.1 Mile Sections

When the specification limits the amount of roughness in successive 1/10 mile lots, the scale is moved along the profile in successive 1/10 mile sections and counts are made to determine specification compliance. The limits of the sections are noted on the profile and can be later located on the pavement if corrections are needed.

D. Limits of Counts - Joints

When counting profiles, a day's paving is considered to include the last portion of the previous day's work which includes the daily joint. The last 15 to 30 feet of a day's paving cannot usually be obtained until the following day. In general the paving contractor is responsible for the smoothness of joints if he places the concrete pavement on both sides of the joint. On the other hand, the contractor is responsible only for the pavement placed by him if the work abuts a bridge or a pavement placed under another contract. Profilograph readings when approaching such joints should be taken in conformance with current specifications.

E. Average Profile Index For the Whole Job

When averaging Profile Indexes to obtain an average for the job, the average for each day must be "weighted" according to its length. This is most easily done by totaling the counts for the 0.1 mile sections of a given line or lines and using the total length of the line in computation for the determining the Profile Index.

Determination of Bumps in Excess of the Specification

Procedure

A. Equipment

The only special equipment needed is a plastic template having a line one-inch long scribed on one face with a small hole or scribed mark at either end, and a slot a distance equal to the maximum bump specified, from and parallel to the scribed line. See Figure II. (The one-inch line corresponds to a horizontal distance of 25 feet on the horizontal scale of the profilogram.)

B. Locating Bumps in Excess of the Specification

At each prominent bump or high point on the profile trace, place the template so that the small holes or scribe marks at each end of the scribed line intersect the profile trace to form a chord across the base of the peak or indicated bump. The line on the template need not be horizontal. With a sharp pencil draw a line using the narrow slot in the template as a guide. Any portion of the trace extending above this line will indicate the approximate length and height of the bump in excess of the specification.

There may be instances where the distance between easily recognizable low points is less than one-inch (25 feet). In such cases a shorter chord length shall be used in making the scribed line on the template tangent to the trace at the low points. It is the intent however, of this requirement that the baseline for measuring the height of bumps will be as nearly 25 feet (1-inch) as possible, but in no case to exceed this value. When the distance between prominent low points is greater than 25 feet (1-inch) make the ends of the scribed line intersect the profile trace when the template is in a nearly horizontal position. A few examples of the procedure are shown in the lower portion of Figure II.

EXAMPLE SHOWING METHOD OF DERIVING PROFILE INDEX FROM PROFILOGRAMS

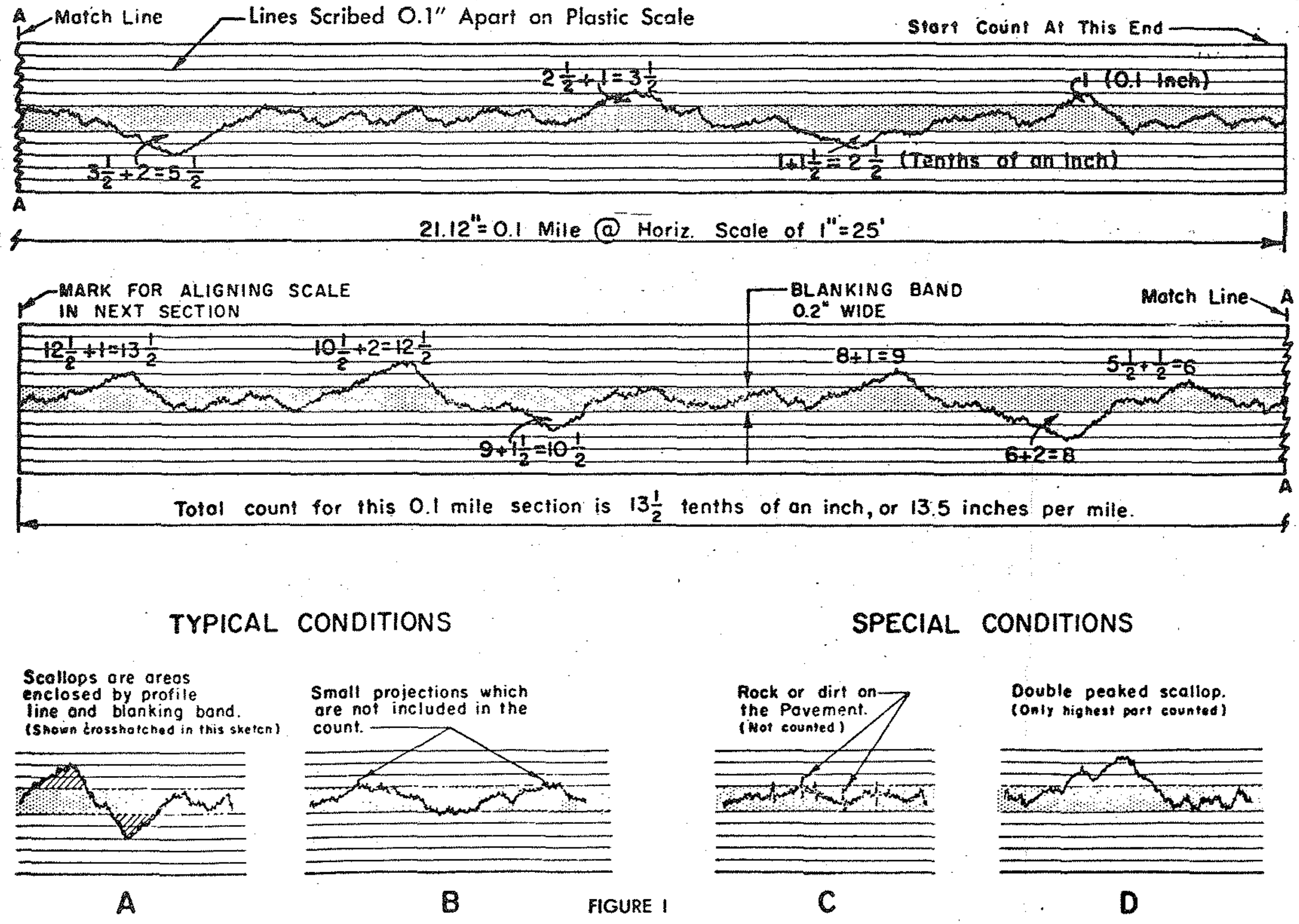
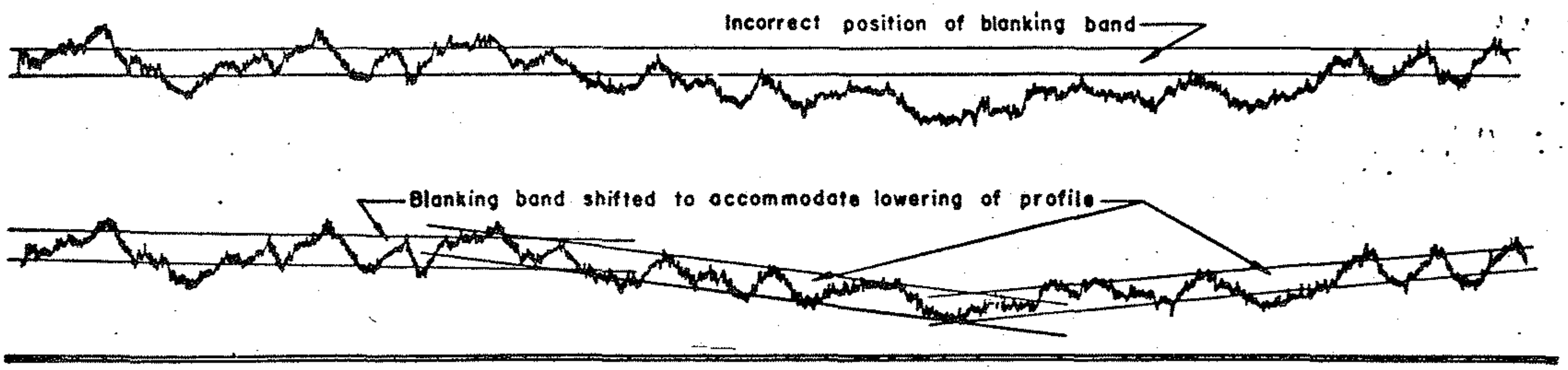
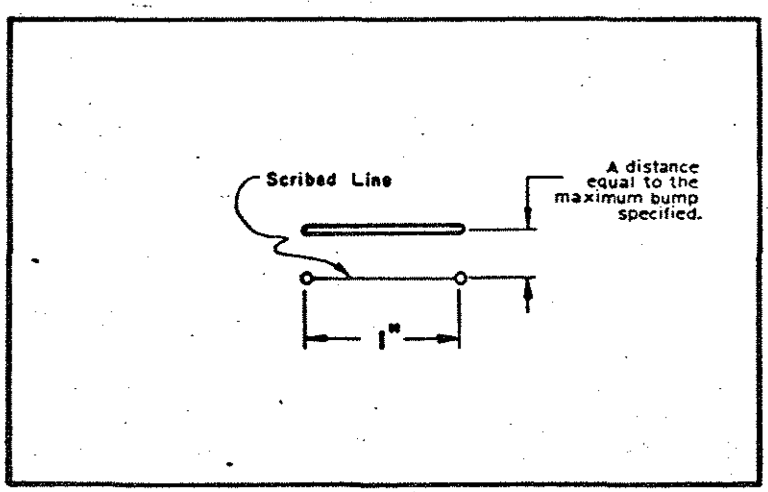


FIGURE I

METHOD OF COUNTING WHEN POSITION OF PROFILE SHIFTS AS IT MAY WHEN ROUNDING SHORT RADIUS CURVES WITH SUPERELEVATION.



METHOD OF PLACING TEMPLATE WHEN LOCATING BUMPS TO BE REDUCED



BUMP TEMPLATE

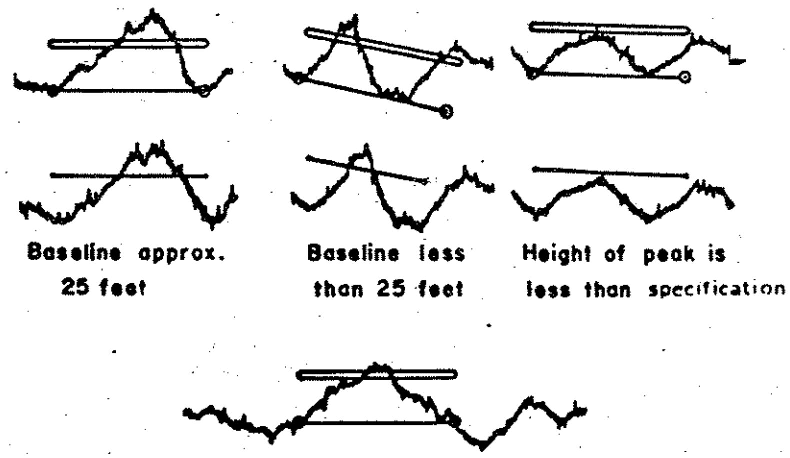


FIGURE II

Iowa State Highway Commission
Materials Department Instructional Memorandum

METHOD OF TEST FOR DETERMINING THE DENSITY OF PLASTIC PORTLAND CEMENT CONCRETE WITH A NUCLEAR GAUGE

Scope:

The density of P.C. Concrete is dependent on the materials, proportions, air content and consolidation. For given materials and proportions, the consolidation of the concrete is an important factor in its durability.

The first part of this test is to determine the standard rodded density. Secondly, even though the nuclear gauge is very accurate and repeatable, sometimes a small correction factor must be applied to the indicated value to yield the true density.

The last part of this test is to verity that the density requirement is met.

Procedure:

Part I Determination of the Standard Rodded Density

A. Apparatus

1. Scale (capacity = 250 lb. accuracy ± .25 lb.
   Sensitivity = .25 lb.)

2. Measure (Base of the Washington Pressure Meter)

3. Tamping rod - 5/8" diameter and approximately 14" long.

4. Strike off - A flat straight bar of steel

5. Rubber Mallet

B. Test Procedure

1. Obtain a representative sample of P. C. Concrete.

2. Fill the measure in three layers of approximately equal volume.

3. Consolidate each layer with 25 strokes of the tamping rod just through the layer being rodded.

4. After rodding each layer, close the voids by striking the measure 10-15 times with the mallet.

5. After consolidation, finish the top surface with the strike-off using a screeding action.

6. Weigh the measure filled with concrete to the nearest .25 lb.

C. Calculations

$$\text{Rodded Density} = \frac{W-M}{V}$$

W - Weight of measure full of concrete
M - Weight of measure
V - Calibrated volume of the measure

D. Test Record Forms

1. Record the following data in a field book:

   (a) Date
   (b) Calibrated volume of the measure (by section 4 ASTM C29 procedure)
   (c) Weight of measure
   (d) Weight of measure full of concrete
   (e) Location where concrete sample was obtained
   (f) Rodded density

2. Report this data on form 1297

Part II Determination of the Correction Factor for the Nuclear Gauge.

A. Apparatus

1. Scale (Same as Part I)

2. Box (27" x 21" x 4")

3. Square point shovel (Approx. 10" wide)

4. Strike-off (1/4" x 1" x 1" steel angle approx. 27" long)

B. Test Procedure

1. When possible, place the box on a flat concrete surface.

2. Obtain a representative sample of P. C. Concrete.

3. Fill the measure in two approximately equal layers.

4. Consolidate each layer by thoroughly spading from end to end and then side to side.

5. After consolidation of each layer, close the spading voids by raising one end of the box approximately 3" and dropping it. Repeat this procedure 4-6 times. Then do the same with the other end.

6. Strike off the consolidated concrete with a screeding motion of the strike-off.

7. Place the nuclear gauge on the concrete approximately the same distance from all sides of the box and obtain a density value (N) by the procedure in 1 and 6-11 of Part III.

8. Carefully remove the gauge and clean any adhering concrete back onto the concrete in the box.

9. Weigh the box full of concrete.

C. Calculations

$$D_1 = \frac{W_1 - B}{V_1}$$

D_1 = Density of Concrete in the Box

W_1 = Weight of Box full of concrete

B = Weight of Box

V_1 = Calibrated Volume of the Box

Correction Factor = $D_1 - N$
(Correction Factor may be positive or negative)

N = Indicated nuclear density

D. Test Record Forms

1. Record this additional information in the same field book as Part I

(g) Location where concrete sample was obtained

(h) Calibrated volume of the box (by section 4 ASTM C29)

(i) Weight of box

(j) Weight of box full of concrete

(k) Density of concrete in the box

(l) Density Standard Count

(m) Gauge reading (Density)

(n) Count Ratio

(o) Indicated Density

(p) Correction factor

2. Report this data on Form 1297

Part III Determination of the "in place" density of the plastic P. C. Concrete

A. Apparatus

1. Nuclear gauge including:

(a) Calibration Standard

(b) Calibration Charts

(c) Manufacturers Instruction Manual

B. Test Procedure

1. Obtain a 4-minute density standard count twice daily per manufacturers instruction.

2. Calculate a correction factor for each half day's use by the procedure in Part II.

3. Determine a rodded density for each two hours of nuclear gauge operation by the Part I procedure.

4. Prior to concrete placement, determine locations to avoid being near steel and select areas where approximately a 4" depth is available. Mark reference points for locations where nuclear densities are to be obtained.

5. Immediately behind the finishing machine, but prior to texturing and curing operations, place the nuclear gauge on the plastic concrete surface at the predetermined location.

6. Lower the source rod to the 2" direct transmission indent.

7. Pull the gauge slightly toward the scaler end.

8. Obtain a 1-minute density county.

9. Without retracting the source rod, pick the gauge up and clean the end of the source rod and the bottom of the gauge. Retract the source rod into the gauge.

10. Using a probe and ruler, determine the depth of resurfacing at the "in place" test location.

11. Obtain the "in place" nuclear density value from the calibration chart (N_2).

C. Calculations

Corrected Nuclear Density = $N_2 + C$

N_2 = "in place" nuclear density

C = Correction Factor

$$\text{\% of Rodded Density} = \frac{\text{Corrected Nuclear Density} \times 100}{\text{Rodded Density}}$$

D. Test Record Forms

1. The following additional data will be recorded in the field book of Part I.

   (q) Location of "in place" nuclear density

(r) Depth at test location

(s) "In Place" Density Count

(t) Count Ratio

(u) "In Place" density

(v) Corrected nuclear density

(w) % of rodded density

2. Report this data on form 1297

E. Precautions

1. Before operating a nuclear gauge, you must have attended a course on operation and safety at the Ames Laboratory.

2. Never touch the end of the source rod with your hand.

3. At the end of each day's operation remove bottom cover plate from the nuclear gauge per manufacturer's instruction to assure that no P. C. Concrete has been carried into the gauge.

4. Keep a light coat of oil and graphite on the probe, lead shield and gauge case to prevent P. C. Concrete from adhering.

TENTATIVE FREQUENCY FOR NUCLEAR DENSITY CHECKS

ON CONCRETE RESURFACING OF BRIDGE DECKS

The following guideline has been tentatively established to determine density compliance as required by Supplemental Specifications 745 and 746. The test procedures will be in accordance with Materials I.M. 358, dated April 1974.

LATEX MODIFIED METHOD

Overall Testing

A minimum of one (1) series of testing per structure will be conducted as per I.M. 358. A series of testing will consist of the following:

1. Rodded Density Determination.
2. Correction Factor Determination for Nuclear Gauge.
3. Initial In-Place Density Checks.

Initial Checking

As soon as each pouring operation begins and immediately behind the finishing machine, a sufficient number of in-place density checks shall be taken across the lane width to assure that the equipment and methods used by the contractor are effective in achieving the density requirements. Basically, for this system, the purpose of this initial testing will be to evaluate the contractor's equipment and methods.

IOWA METHOD

Overall Testing

A minimum of one (1) series of testing per lane of resurfacing will be conducted as per I.M. 358. A series of testing will consist of the following:

1. Rodded Density Determination.
2. Correction Factor Determination for Nuclear Gauge.
3. Initial In-Place Density Checks.
4. A minimum of seven (7) in-place nuclear density checks per lane of resurfacing, including initial checks.

Initial Checking

For this method, initial density checks shall be made immediately behind the finishing machine at the predetermined locations of appropriate depth. These checks shall be made as soon as possible after each pouring operation starts to assure consolidation compliance.

Subsequent Checking

When conducting subsequent checking, every effort should be made to randomly select locations across the width of the lane.

Reporting

Attached are copies of reporting forms to be utilizied in conjunction with I.M. 358.

4-74

Iowa State Highway Commission
NUCLEAR TEST REPORT
DENSITY OF PLASTIC P. C. CONCRETE

County ______________________

Project No. ______________________

Design ______________________

Contract No. ______________________

Date ______________________

(›ntractor ______________________

Resident Engineer ______________________

ıclear Gauge No. ______________________

RODDED DENSITY DETERMINATION					
Sampling Location					
2. Calibrated Volume of Measure (V)					
Weight of Measure (M)					
4. Weight of Measure + Concrete (W)					
Rodded Density (4−3) ÷ 2					
CORRECTION FACTOR DETERMINATION FOR NUCLEAR GAUGE					
Sampling Location					
7. Calibrated Volume of Box (V_1)					
Weight of Box (B)					
9. Weight of Box + Concrete (W_1)					
. Density of Concrete, D, (9−8) ÷ 7					
. Density Standard Count					
12. Gauge Reading (Density)					
. Count Ratio (12 ÷ 11)					
14. Indicated Density (Table)					
. Correction Factor (10−14)					
IN–PLACE DENSITY DETERMINATION					
. Test Location					
17. Depth at Test Location					
. In–Place Gauge Reading (Density)					
19. Count Ratio (18 ÷ 11)					
. In–Place Density (Table)					
21. Corr. In–Place Density (20 + 15)					
. % Rodded Density (21 ÷ 5) X 100					

REMARKS:

DISTRIBUTION:
White Copy - Materials Department - Central Filing
Canary Copy - Construction Department
Pink Copy - District Materials Office
Green Copy - Resident Construction Engineer
Blue Copy - Inspector

Signed ______________________
Inspector

NUCLEAR DENSITY TESTING ON PLASTIC P.C. CONCRETE

Date - 8/7/73 - (Iowa Method)

Location - I-35 Bridge over Raccoon River - Northbound, Outside lane.

Density rodded in .495 cu. ft. bucket.
143.4 lbs. per cubic foot.

Density rodded with shovel in 10-1/2" x 18-1/4" x 3" metal box.
143.6 lbs. per cubic foot.

Density by nuclear on above box.
146.0 lbs. per cubic foot.

Correction Factor = -2.5 lbs. per cu. ft.

Density in place by nuclear.

(1) Sta. 122+18, 13" from E. curb.	145.0 lbs./cu. ft.
(2) Sta. 122+40, 32" from E. curb.	145.5 lbs./cu. ft.
(3) Sta. 122+37, 20" from centerline	145.0 lbs./cu. ft.

Corrected Nuclear Density	% of Rodded Density
142.5 lbs./cu. ft.	99.4
143.0 " "	99.7
142.5 " "	99.4

Date - 8/14/73 - (Latex Method)

Location - I-35 Bridge over Raccoon River - Southbound, Inside lane.

Density rodded in .495 cubic foot bucket.
137.2 lbs. per cubic foot.

Density rodded with shovel in 10-1/2" x 18-1/4" x 3" metal box.
137.4 lbs. per cubic foot.

Density by nuclear on box.
140.0 lbs. per cubic foot.

Correction Factor = -2.5 lbs. per cu. ft.

Density in place by nuclear.

Sta. 122+49, 2' LR	139.5 lbs./cu. ft.
Sta. 122+41, 2' LR	140.0 lbs./cu. ft.
Sta. 122+41, 6' LR	139.5 lbs./cu. ft.

Corrected Nuclear Density	% of Rodded Density
137.0 lbs./cu. ft.	99.9
137.5 " "	100.2
137.0 " "	99.9

Date - 8/22/73 - (Iowa Method)

Location - I-35 Bridge over Raccoon River - Northbound, Inside lane.

Density rodded in .495 cu. ft. bucket.
143.0 lbs. per cu. foot

Density rodded with shovel in metal box.
142.5 lbs. per cubic foot.

Density by nuclear on box.
143.0 lbs. per cubic foot.

Correction Factor = -0.5 lbs. per cu. ft.

Density in place by nuclear.

12 ft. RL	142.0 lbs./cu. ft.
2' RL	143.0 lbs./cu. ft.
12" RL	143.0 lbs./cu. ft.

Corrected Nuclear Density	% of Rodded Density
141.5 lbs./cu. ft.	99.0
142.5 lbs./cu. ft.	99.7
142.5 lbs./cu. ft.	99.7

Iowa Method

Corrected Nuclear Density	% of Rodded Density
142.5 lbs./cu. ft.	99.4
143.0 " "	99.7
142.5 " "	99.4
141.5 " "	99.0
142.5 " "	99.7
142.5 " "	99.7
	Avg. 99.5

Latex Modified

Corrected Nuclear Density	% of Rodded Density
137.0 lbs./cu. ft.	99.9
137.5 " "	100.2
137.0 " "	99.9
	Avg. 100.0

APPENDIX D

THEORETICAL DENSITY CALCULATIONS

1. I-35 Northbound over Raccoon River.

Mix Proportion (Per Supple. Spec. 649)

	Vol. per Cu. Ft.	Density	Wt. per Cu. Ft.	
Coarse Agg.	0.312088	164.112	51.22	
Fine Agg.	0.312088	165.984	51.80	
Air	0.060000	---	---	
Water	0.160255	62.4	10.00	
Cement	0.155569	195.936	30.48	
			143.50	lbs.

136.54 represented 99.45% of rodded density.
136.54/.9945 = 137.30 (100%)

Calculated rodded density of I-35 northbound over Raccoom River	137.30	lbs./cu. ft.
Water Loss	6.20	lbs.

2. U.S. 20 Westbound near Dubuque.

Coarse Agg.	51.80	
Fine Agg.	51.61	
Water	10.00	
Cement	30.48	
	143.89	
Water Loss	6.20	
	137.69	lbs.
Density from cores	139.02	lbs./cu. ft.
Percent of Density	100.97	

3. I-80 over U.S. 65

Coarse Agg.	51.22
Fine Agg.	52.19
Water	10.00
Cement	30.48
	143.89
Water Loss	6.20
	137.69

3A. I-80 Eastbound over U.S. 65

$$\text{Percent of Density} = \frac{(137.11)\quad(100)}{137.69} = 99.58$$

3B. I-80 Westbound over U.S. 65

$$\text{Percent of Density} = \frac{(136.15)\quad(100)}{137.69} = 98.88$$

Specification 746
Supersedes 712

IOWA STATE HIGHWAY COMMISSION
Ames, Iowa

SUPPLEMENTAL SPECIFICATION
for
RESURFACING AND/OR REPAIR OF PORTLAND CEMENT CONCRETE BRIDGE FLOORS
March 5, 1974

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.

746.01 DESCRIPTION. Resurfacing and/or repair of bridge floors shall consist of removing loose or deteriorated concrete; scarifying the remaining existing surface; replacing and/or resurfacing with new concrete; 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.

Bridge floor repair shall be classified as follows:

A. Class 1 Repair shall consist of removing, by a scarifying machine, the surface of the concrete floor, disposing of concrete removed, and resurfacing with portland cement concrete. The depth of the scarification shall be at least 1/4 inch, but may be a greater depth.

B. Class 2 Repair shall consist of removing, by chipping, the loose and unsound floor concrete to a designated depth greater than 1/2 inch but less than full depth, disposing of concrete removed, and replacing or resurfacing with portland cement concrete.

C. Class 3 Repair shall consist of removing concrete full depth by chipping, disposing of the concrete removed, and replacing or resurfacing with portland cement concrete.

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

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

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

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

C. Concrete shall meet the following requirements:

Basic Absolute Volumes per Unit Volume of Concrete

Coarse Aggregate	0.312088
Fine Aggregate	0.312088
Air	0.060000
Water	0.160255
Cement	0.155569
	1.000000

Approximate Quantities of Dry Materials Per Cubic Yard of Concrete.

Coarse Aggregate	1,394 lbs.
Fine Aggregate	1,394 lbs.
Cement	823 lbs. (8.75 bags)

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.

A water-reducing admixture for improving workability will be required. This admixture shall be approved by the engineer.

The slump measured in accordance with AASHO T 119, shall be 3/4 inch with a tolerance of plus or minus 1/4 inch.

The entrained air content of the freshly consolidated concrete, as determined by AASHO T 152, shall be 6.0 percent with a tolerance of plus or minus 1.0 percent.

D. Grout for bonding the new concrete to the old concrete shall consist of equal parts by weight of portland cement and 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. For sealing vertical joints around finished patches or resurfacing, this grout shall be thinned to paint consistency.

746.03 EQUIPMENT. The equipment used shall be subject to the 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. 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.
3. Sand-Blasting Equipment shall be capable of removing rust and old concrete from the exposed reinforcement.
4. Power-Driven Hand Tools for removal of unsound concrete will be permitted with the following restrictions:
   a. "Jack Hammers" heavier than nominal 30-pound class shall not be used.
   b. "Jack Hammers" or mechanical chipping tools shall not be operated at an angle in excess of 45 degress measured from the surface of the slab.
   c. "Chipping Hammers" heavier than a nominal 15-pound class shall not be used to remove concrete from beneath any reinforcing bar for Class 2 repair.
5. Hand Tools such as hammers and chisels shall be provided for removal of final particles of unsound concrete or to achieve the required depth.

B. Proportioning and Mixing Equipment shall meet requirements of 2001.20 and 2001.21B. In addition, the device for proportioning water shall be accurate within one percent. A construction or stationary concrete mixer of the rotating-paddle type, or a continuous mixer used in conjunction with volumetric proportioning, will be required.

C. Placing and Finishing Equipment shall include adequate hand tools for placement of stiff plastic concrete and for working down to approximately the correct level for striking-off with the screed. Manual type screeds or metal plates with approved electric vibrators attached shall be used to consolidate and to finish smaller areas. An approved finishing machine complying with requirements of 2412.06 and the following additional requirements shall be used for finishing all large areas, as designated on the plans. When the plans require resurfacing, a finishing machine will be mandatory. The finishing machine shall be inspected and approved before work is started on each project.

A mechanical strike-off shall be required to provide a uniform thickness of concrete in front of the oscillating screed.

At least one oscillating screed shall be designed to consolidate the concrete to 98 percent of the unit weight determined in accordance with ASTM C138-71T by vibration. A sufficient number of identical vibrators shall be effectively installed such that at least one vibrator is provided for each 5 feet of screed length. The bottom face of this screed shall be at least 5 inches wide with a turned up or rounded leading edge to minimize tearing of the surface of the plastic concrete. Each screed shall have an effective weight of at least seventy-five pounds for each square foot of bottom face area. Each screed shall be provided with positive control of the vertical position, the angle of tilt, and the shape of the crown.

Design of the finishing machine together with appurtenant equipment shall be such that positive machine screeding of the plastic concrete will be obtained within one inch of the face of the existing curbs. The length of the screed shall be sufficient to extend at least 6 inches beyond the line where a sawcut is intended to form the edge of a subsequent placement section, and shall overlap the sawn edge of a previously placed course at least 6 inches.

The finishing machine shall be capable of forward and reverse motion under positive control. Provision shall be made for raising the screeds to clear the screeded surface for traveling in reverse.

Supporting rails upon which the finishing machine travels will be required on all resurfacing projects. The support for these rails shall be fully adjustable (not shimmed) to obtain the correct profile.

When placing concrete in a lane abutting a previously completed lane, that side of the finishing machine adjacent to the completed lane shall be equipped to travel on the completed lane.

D. General. The overall combination of labor and equipment for proportioning, mixing, placing, and finishing new concrete shall be of such minimum capability as to meet the following requirements except when noted otherwise on the plans.

Total Repair Area per Bridge (Sq. Yd.)	Minimum Requirement (C.Y./Hr.)
0 - 328	1.0
329 - 492	1.5
493 - 656	2.0
over 656	2.5

The finishing machine shall be so designed that, when concrete is being mixed and placed at the specified minimum rate, under normal operating conditions, the elapsed time between depositing the concrete on the floor and final screeding shall not exceed 10 minutes.

746.04 PREPARATION OF SURFACE. All loose, disintegrated, or unsound concrete shall be removed from those portions of the bridge floor shown on the plans or designated by the engineer.

A. Class 1 Repair. All areas designated for Class 1 repair shall be uniformly scarified or prepared to the depth specified but in all cases at least 1/4 inch deep and deeper as required. That portion of the curb against which new concrete is to be placed shall be sand blasted. Surfaces of reinforcement, exposed by scarification, shall also be sand blasted.

B. Class 2 Repair. A saw cut approximately 3/4 inch deep shall be made along all boundaries of Class 2 repair areas adjacent to areas of no repair except those boundaries adjacent to the face of a curb. The loose and unsound material shall be removed by chipping and by the use of hand tools. All exposed reinforcing bars and newly exposed concrete shall be thoroughly cleaned by sand blasting. Where the bond between existing concrete and reinforcing steel has been destroyed, the concrete adjacent to the bar shall be removed to a depth that will permit new concrete to bond to the entire periphery of the bar so exposed. A minimum of 3/4" clearance shall be required. Care shall be exercised to prevent cutting, stretching, or damaging any exposed reinforcing steel. The engineer may require enlarging a designated portion should inspection indicate deterioration of concrete beyond the limits previously designated. In this event, a new saw cut with a "dry" blade shall be made around the extended area before additional removal is begun.

C. Class 3 Repair. Within all areas designated for Class 3 repair and any designated areas of Class 2 repair in which the depth of remaining sound concrete is less than 50 percent of the original depth of the bridge floor, all concrete shall be removed. Designated Class 2 repair areas shall be measured as Class 3 Bridge Floor Repair when full-depth removal is required. At the direction of the engineer, limited areas of removal greater than 50 percent of the floor thickness, such as beneath reinforcing, may be allowed; these limited areas of excess depth will be measured as Class 2 Bridge Floor Repair. A saw cut approximately 3/4 inch deep shall be made along all boundaries of Class 3 repair areas adjacent to areas of no repair except those boundaries adjacent to the face of a curb. The material shall be removed by chipping and by the use of hand tools. All exposed reinforcing bars and newly exposed concrete shall be thoroughly cleaned by sand blasting. Care shall be exercised to prevent cutting, stretching, or damaging any exposed reinforcing steel. Final removal at the periphery of Class 3 areas shall be accomplished by 15-pound chipping hammers or hand tools.

Forms shall be provided to enable placement of new concrete in the full-depth opening. These forms shall preferably be suspended from existing reinforcing bars by wire ties. Forms may, in the case of large-area openings, be supported by blocking from the beam flanges. Forms will in all cases be supported by elements of the existing superstructure unless specifically noted or shown otherwise on the plans.

D. General. Resurfacing shall be such as to obtain a new surface profile or elevation for all areas of repair as shown on the plans.

Class 2 and Class 3 repair shall be such as to obtain a finished surface flush with the surface of existing, adjacent concrete if no resurfacing is specified. The thickness of all new concrete above the prepared surface or reinforcing steel shall be at least 3/4 inch and shall be greater if specified on the plans. The clearance shall be checked in the following manner before concrete is placed.

A filler block shall be attached to the bottom of the screed. With screed guides in place, the screed shall be passed over the area to be concreted. All old concrete which does not clear shall be removed. All reinforcing steel which does not clear shall be depressed and fastened down. It may be necessary to remove concrete beneath some reinforcement to permit depressing the reinforcement adequately. The minimum clear distance around these bars for placement of new concrete shall be 3/4 inch.

Areas from which unsound concrete has been removed should be kept free of slurry produced by additional wet sawing of concrete. Work should be planned so that this slurry will drain away from all open areas. All such slurry shall be removed from prepared areas before new concrete is placed.

Hand tools shall be used to remove final particles of unsound concrete or to achieve the required depth.

Immediately before applying grout in preparation for placement of new concrete, the surface shall be cleaned with air blast. If necessary to remove rust, oil, or other foreign material, sand blasting followed by air blast will be required. It is not intended or desired that existing concrete, prepared for repair or resurfacing, be presaturated before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

746.05 PROPORTIONING AND MIXING OF CONCRETE MATERIALS. The applicable provisions of 2403.07 shall apply with the following exceptions and additional provisions:

A. Concrete shall be proportioned and mixed at the project site. Ready-mixed concrete will not be approved.

B. The 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.

746.06 PLACING AND FINISHING CONCRETE. Areas for which a finishing machine is required will be noted on the plans, except that a finishing machine normally will be required for resurfacing. When screed guides are required, they shall be placed and fastened in position to insure finishing the concrete to the required profile.

Supporting rails upon which the finishing machine travels shall be placed outside the area to be concreted. Anchorage for supporting rails shall provide horizontal and vertical stability. A hold-down device shot into concrete will not be permitted unless that concrete is to be subsequently resurfaced. Plans for anchoring supporting rails shall be submitted to the engineer for approval.

At transverse and longitudinal joints, the surface course previously placed shall be sawn to a straight and vertical edge before the adjacent 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 grout does not become dry before it is covered with new concrete.

The new concrete shall be manipulated and mechanically struck off slightly above final grade. It shall then be mechanically consolidated to 98 percent of the unit weight, determined in accordance with ASTM C138-71T, and screeded to final grade. Hand finishing with a wood float may be required for producing a tight, uniform surface.

When two or more classes of repair work are adjacent to each other, the new concrete for the different repair classes shall be placed monolithically. Fresh concrete, 3 inches or more in thickness, shall be vibrated internally in addition to the surface screed vibration.

As soon as finishing has been completed, all vertical joints with adjacent concrete shall be sealed by painting with thinned grout.

After the joint painting is completed, the surface shall be promptly covered with a single layer of clean, wet burlap.

Care shall be exercised to insure that the burlap is well drained, and that it is placed as soon as the surface will support it without deformation.

It is intended that the surface receive a wet burlap 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.

Failure to apply wet burlap within 30 minutes after the concrete has been deposited on the floor shall be cause for rejecting the work so affected; however, if the concrete is revibrated because of failure to meet density requirements with initial vibration, this time limit will be extended 15 minutes. Surface concrete in the rejected area shall be removed and replaced at no additional cost to the contracting authority.

All concrete surfaces shall be sealed as specified for pavement in accordance with 2521, and payment therefor will be incidental to other items in the contract.

746.07 LIMITATION OF OPERATIONS. During the construction period of this project, the contractor shall provide such traffic controls as required on the plans and by the specifications.

Night work will be permitted, in which case supplemental lighting may be required, if necessary to make quality workmanship and adequate inspection possible. The engineer shall be given reasonable notice.

No loads other than construction equipment shall be permitted on any portion of the bridge floor after it has undergone removal of old concrete and before new concrete has been placed. No construction load shall be permitted which exceeds either an 8,000-pound wheel load or a 16,000-pound axle load. Any combination of axles spaced closer than 4 feet center-to-center of axles shall be considered as one axle.

No traffic shall be permitted on Class 1, 2, or 3 repair work until 72 hours after placement. In addition, no preparation work shall be performed in the adjacent lane on areas adjoining new concrete during the specified curing period. At temperatures below 55 degrees F., the engineer may require a longer waiting time.

No concrete shall be placed after October 1.

746.08 FLOODLIGHTING. Floodlights will be required at the approximate locations shown on the "Situation Plan". Section 5D-4 of the Iowa Manual on Uniform Traffic Control Devices shall not apply as it pertains to floodlights. Floodlighting shall be installed and in service before other construction on the contract is started and shall be removed after the completed bridge is placed in service.

Luminaires used for floodlighting shall be standard roadway types with totally enclosed refractors. The IES glare control rating shall be "cutoff". The lamps shall have an initial output rating of 19,000 lumens or greater, for operation in such luminaires. All luminaires shall be approved by the engineer.

The mounting height of luminaires shall be not less than 35 feet above the roadway. The center of the light source shall be directly above the traffic lane edge where practicable, but mastarm lengths shall be not less than shoulder width. Poles shall be placed outside the normal shoulder line at the approximate locations shown.

All luminaires shall be photoelectric controlled for dusk-to-dawn operation.

The contractor shall exercise reasonable care to avoid interruptions during the hours of darkness, shall repair promptly any damage to the system, and shall replace all burned out lamps as soon as possible.

All materials involved in this item shall remain the property of the contractor.

746.09 METHOD OF MEASUREMENT. The quantity of the various items of work involved in bridge floor repair will be measured by the engineer in accordance with the following provisions:

Class 1, Class 2 and Class 3 Repair will be computed in square yards from measurements of the areas so repaired.

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

For the number of square yards of Class 1, Class 2, or Class 3 Repair constructed, the contractor will be paid the respective contract price per square yard which price shall be full payment for removal and disposal of concrete, for furnishing all traffic control in accordance with the specifications and plans and for furnishing all material, equipment, forms, and labor necessary to complete the work in accordance with the plans and these specifications.

When the plans require that the contractor provide floodlighting, the contractor will be paid the lump-sum price bid for this item which price will be full payment for all costs for furnishing, installing, maintaining and servicing the lights, including the electric current.

IOWA STATE HIGHWAY COMMISSION
Ames, Iowa

SUPPLEMENTAL SPECIFICATION
for

RESURFACING AND/OR REPAIR OF PORTLAND CEMENT CONCRETE BRIDGE FLOORS (Latex Modified System)

March 5, 1974

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.

745.01 DESCRIPTION. Resurfacing and/or repair of bridge floors shall consist of removing loose or deteriorated concrete; scarifying the remaining existing surface; replacing and/or resurfacing with new latex modified concrete; 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.

Bridge floor repair shall be classified as follows:

A. Class 1 Repair shall consist of removing, by a scarifying machine, the surface of the concrete floor, disposing of concrete removed, and resurfacing with latex modified Type 2 concrete. The depth of the scarification shall be at least 1/4 inch, but may be a greater depth.

B. Class 2 Repair shall consist of removing, by chipping, the loose and unsound floor concrete to a designated depth greater than 1/2 inch but less than full depth, disposing of concrete removed, and replacing or resurfacing with latex modified Type 2 concrete.

C. Class 3 Repair shall consist of removing concrete full depth by chipping, disposing of the concrete removed, and replacing or resurfacing with Type 2 latex modified concrete.

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

A. Cement. 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.

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

C. Latex Emulsion Admixture. Formulated latex admixture shall be a non-toxic, film forming, polymeric emulsion in water to which all stabilizers have been added at the point of manufacture and shall be homogenous and uniform in composition.

Physical properties. The latex modifier shall conform to the following requirements:

Polymer type	Styrene butadiene
Stabilizers	
(a) Latex	Nonionic surfactants
(b) Portland cement composition	Poly dimethyl siloxane
Percent solids	46.0-49.0
Weight per gallon (lbs. at 25°C)	8.4
Color	White

Latex admixture to be stored shall be kept in suitable enclosures which will protect it from freezing and from prolonged exposure to temperatures in excess of 85 degrees F. Containers of latex admixture may be stored at the bridge site for a period not to exceed 10 days. Such stored containers shall be covered completely with suitable insulating blanket material to avoid excessive temperatures.

D. Latex Modified Concrete. The latex modified concrete for use in Class 1, 2, or 3 Repair shall be a workable mixture having the following properties or limits:

Material or Property	Type 2 Concrete
Cement (parts by weight)	1
Fine Agg. (parts by weight)	2.5
Coarse Agg. (parts by weight)	2.0
Latex Emulsion Admixture - gal./bag cement	3.5
Air Content of Plastic Mix, %	3-6
Slump, inches (Notes 1 and 2)	3-5

Note 1. Following sampling of the discharged, normally mixed material, the commencement of the slump test shall be delayed from 4 to 4½ minutes.

Note 2. Water may be added to obtain slump within the prescribed limits.

745.03 EQUIPMENT. The 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. 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.
3. Sand-Blasting Equipment shall be capable of removing rust and old concrete from the exposed reinforcement.
4. Power-Driven Hand Tools for removal of unsound concrete will be permitted with the following restrictions:
   a. "Jack Hammers" heavier than nominal 30-pound class shall not be used.
   b. "Jack Hammers" or mechanical chipping tools shall not be operated at an angle in excess of 45 degrees measured from the surface of the slab.
   c. "Chipping Hammers" heavier than a nominal 15-pound class shall not be used to remove concrete from beneath any reinforcing bar for Class 2 repair.
5. Hand Tools such as hammers and chisels shall be provided to remove final particles of unsound concrete or to achieve the required depth.

B. Proportioning and Mixing Equipment shall be of a self-contained, mobile, continuous-mixing type subject to the following:

1. The mixer shall be self-propelled and shall be capable of carrying sufficient unmixed, dry, bulk cement, sand, coarse aggregate, latex modifier, and water to produce on the site not less than 6 cubic yards of concrete.
2. The mixer shall be capable of positive measurement of cement being introduced into the mix. A recording meter visible at all times and equipped with a ticket printout shall indicate this quantity.
3. The mixer shall provide positive control of the flow of water and latex emulsion into the mixing chamber. Water flow shall be indicated by flowmeter and shall be readily adjustable to provide for minor variations in aggregate moisture.
4. The mixer shall be capable of being calibrated to automatically proportion and blend all components of indicated composition on a continuous or intermittent basis as required by the finishing operation, and shall discharge mixed material through a conventional chute directly in front of the finishing machine. Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

C. Placing and Finishing Equipment shall include adequate hand tools for placement of stiff plastic concrete and for working down to approximately the correct level for striking-off with the screed. Manual-type screeds or metal plates with approved electric vibrators attached shall be used to consolidate and finish the smaller areas. An approved finishing machine equipped with at least one screed and complying with the following additional requirements shall be used for finishing all large areas, as designated on the plans. When the plans require resurfacing, a finishing machine will be mandatory. The finishing machine shall be inspected and approved before work is started on each project.

1. The finishing machine shall be self-propelled and shall be capable of forward and reverse movement under positive control. Provision shall be made for raising all screeds to clear the screeded surface for traveling in reverse.
2. The machine shall be equipped with not less than two finishing devices, one of which shall be a vibrating screed designed to consolidate the modified composition to 98 percent of the rodded unit weight.
   The second finishing device shall meet one of the following requirements:
   a. It shall be a vibrating or oscillating screed, or
   b. It shall consist of one or more rotating cylindrical drums not to exceed 48 inches in length.
   c. The finishing machine shall be capable of finishing the surface to within one foot of the edges of the area being placed.
   Vibration frequency of screeds shall be variable with positive control between 3,000 and 6,000 vpm. The bottom face of screeds shall not be less than 4 inches wide and shall be metal covered. The screeds shall be provided with positive control of the vertical position.
3. Supporting rails upon which the finishing machine travels will be required and shall be sufficiently rigid that they do not deflect under the weight of the machine. They shall be so attached to the old surface that they may be removed without damage to the edge of the new overlayment.
4. When placing modified material in a lane abutting a previously complete lane, that side of the finishing machine adjacent to the completed lane shall be suitably equipped to travel on the completed lane.

D. General. The overall combination of labor and equipment for proportioning, mixing, placing, and finishing new concrete shall be of such minimum capability as to meet the following requirements except when noted otherwise on the plans.

Total Repair Area per Bridge (Sq. Yd.)	Minimum Requirement (C.Y./Hr.)
0 - 328	1.0
329 - 492	1.5
493 - 656	2.0
over - 656	2.5

The finishing machine shall be so designed that, when concrete is being mixed and placed at the specified minimum rate, the elapsed time between depositing the concrete on the floor and final screeding shall not exceed 10 minutes.

745.04 PREPARATION OF SURFACE. All loose, disintegrated, or unsound concrete shall be removed from those portions of the bridge floor shown on the plans or designated by the engineer.

A. Class 1 Repair. All areas designated for Class 1 Repair shall be uniformly scarified or prepared to the depth specified but in all cases at least 1/4 inch deep and deeper as required.

B. Class 2 Repair. A saw cut approximately 3/4 inch deep shall be made along all boundaries of Class 2 Repair areas adjacent to areas of no repair except those boundaries adjacent to the face of a curb. The loose and unsound material shall be removed by chipping and by the use of hand tools. Where the bond between existing concrete and reinforcing steel has been destroyed, the concrete adjacent to the bar shall be removed to a depth that will permit the new mixture to bond to the entire periphery of the bar so exposed. A minimum of 3/4" clearance shall be required. Care shall be exercised to prevent cutting, stretching, or damaging any exposed reinforcing steel. The engineer may require enlarging a designated portion should inspection indicate deterioration of concrete beyond the limits previously designated. In this event, a new saw cut with a "dry" blade shall be made around the extended area before additional removal is begun.

C. Class 3 Repair. Within all areas designated for Class 3 Repair and any designated areas of the original depth of the bridge floor, all concrete shall be removed. Designated Class 2 Repair areas shall be measured as Class 3 Repair when full-depth removal is required. At the direction of the engineer, limited areas of removal greater than 50 percent of the floor thickness, such as beneath reinforcing, may be allowed; these limited areas of excess depth will be measured as Class 2 Repair. A saw cut approximately 3/4 inch deep shall be made along all boundaries of Class 3 Repair areas adjacent to areas of no repair except those boundaries adjacent to the face of a curb. The material shall be removed by chipping and by the use of hand tools. Care shall be exercised to prevent cutting, stretching, or damaging any exposed reinforcing steel. Final removal at the periphery of Class 3 areas shall be accomplished by 15-pound chipping hammers or hand tools. Forms shall be provided to enable placement of new concrete in the full-depth opening. These forms shall preferably be suspended from existing reinforcing bars by wire ties. Forms may, in the case of large-area openings, be supported by blocking from the beam flanges. Forms will in all cases be supported by elements of the existing superstructure unless specifically noted or shown otherwise on the plans.

D. General. Resurfacing shall be such as to obtain a new surface profile or elevation for all areas of repair as shown on the plans. Class 2 and Class 3 repair shall be such as to obtain a finished surface flush with the surface of existing, adjacent concrete if no resurfacing is specified. The thickness of all new mixture above the prepared surface or reinforcing steel shall be at least 3/4 inch and shall be greater if specified on the plans. The clearance shall be checked in the following manner before concrete is placed. A filler block shall be attached to the bottom of the screed. With screed guides in place, the screed shall be passed over the area to be concreted. All old concrete which does not clear shall be removed. All reinforcing steel which does not clear shall be depressed and fastened down. It may be necessary to remove concrete beneath some reinforcement to permit depressing the reinforcement adequately. The minimum clear distance around these bars for placement of new mixture shall be 3/4 inch.

Areas from which unsound concrete has been removed should be kept free of slurry produced by additional wet sawing of concrete. Work should be planned so that this slurry will drain away from all open areas. All such slurry shall be removed from prepared areas before new concrete is placed.

Hand tools shall be used to remove final particles of unsound concrete or to achieve the required depth.

For any class of repair, the area shall be cleaned by sandblasting. The sandblasting shall clean all reinforcement of visible rust and clinging concrete detached from the deck and all areas of concrete against which new modified concrete is to be placed. Sandblasting may be required on the day new modified concrete is to be placed so that reinforcement is free of visible rust.

Prior to placing new concrete, the surface shall be cleaned by air blast followed by flushing with water. The surface shall be wetted and kept wet for at least one hour prior to placement of new concrete. Puddles of free water shall be removed before covering with concrete.

745.05 PROPORTIONING AND MIXING OF MODIFIED COMPOSITIONS. The operations of proportioning and mixing modified materials shall comply with the following requirements:

A. Measurement of Materials. Mobile continuous mixers shall accurately proportion all materials for the specified mixture. The proportioning equipment for each material shall be calibrated in the presence of the inspector, or the engineer may accept a previous calibration and require satisfactory verification checks only at the settings indicated by the previous calibration. The proportioning equipment shall be operated at the speed recommended by the manufacturer during calibration, checks or normal operation.

The contractor may make yield checks or other checks as he sees fit, and the inspector will cooperate in such checking.

B. Mixing of Materials. Modified composition materials shall be thoroughly mixed in an approved mixer at the site of placement. They shall be mixed in accordance with the specified requirements for the equipment used. The mixture as discharged from the mixer, shall be uniform in composition and consistency. Mixing capability shall be such that finishing operations can proceed at a steady pace with final finishing completed before the formation of the plastic surface film.

745.06 PLACING AND FINISHING MODIFIED COMPOSITIONS. Transverse bulkheads, equal in depth to the thickness of the latex modified concrete, shall be installed to the required grade and profile prior to placing modified material.

When screed rails are required, they shall be placed and fastened in position to insure finishing the new surface to the required profile.

Anchorage for supporting rails shall provide horizontal and vertical stability. Screed rails shall not be treated with parting compound to facilitate their removal.

Placement of the modified concrete shall be a continuous operation throughout the pour.
The modified material shall be manipulated and struck-off to approximately 1/4" above final grade. It shall then be consolidated and finished at final grade with the vibrating screeds. The engineer will evaluate the equipment and methods used to assure that consolidation will be effective in achieving at least 98 percent of the rodded unit weight, determined according to ASTM C 138-71T. Hand finishing with a wood float may be required along the edge of the pour or on smaller areas of Class 2 and Class 3 Repair.

When a tight, uniform surface has been achieved, it shall be texturized by broom or burlap drag to provide a gritty surface for maximum traction. This must be done before the plastic film forms on the surface, approximately 25 minutes in hot, dry weather.

Screed rails and/or construction dams shall be separated from the newly placed material by passing a pointing trowel along their inside face. Care shall be exercised to insure that this trowel cut is made for the entire depth and length of rails or dams after the modified composition has stiffened sufficiently and it does not flow back.

The surface shall be promptly covered with a single layer of clean, wet burlap. Care shall be exercised to insure that the burlap is well drained and that it is placed as soon as the surface will support it without deformation. It is the nature of the latex modifier to form a plastic film at the surface upon drying, usually within 25 minutes in hot, dry weather. It is the intent of this specification that this film be protected from drying and cracking by prompt covering with wet burlap.

Within one hour of covering with wet burlap, a layer of 4-mil polyethylene film shall be placed on the wet layer for the required 48-hour period for curing. The curing material may then be removed for an additional 48-hour air cure.

Burlap-polyethylene sheets may be substituted for the polyethylene film with the approval of the engineer.

745.07 LIMITATION OF OPERATIONS. No traffic shall be permitted on the latex concrete surface until 96 hours after placement. At temperatures below 55 degrees F., the engineer may require a longer curing period.

No modified materials shall be placed at temperatures lower than 45 degrees F. They may be placed at 45 degrees F. when rising temperature is predicted.

When daytime temperatures exceed 85 degrees F., the engineer may require placement to be made at night or in the early morning hours if, in his opinion, a satisfactory surface finish is not being achieved. In such case, adequate lights for nighttime work shall be furnished at the direction of the engineer by the contractor without additional compensation.

A construction dam or bulkhead shall be installed in case of major delay in the placement operation. During minor delays of one hour or less, the end of the placement may be protected from drying with several layers of wet burlap.

Adequate precautions shall be taken to protect freshly placed modified material from sudden or unexpected rain. The engineer may order removal of any material damaged by rainfall.

Screed rails may be removed at any time after the modified material has taken initial set. Adequate precaution shall be taken during screed rail removal to protect the edge of the new surface from damage.

During the construction period of this project, the contractor shall provide such traffic controls as required on the plans and by the specifications. No loads other than construction equipment shall be permitted on any bridge floor portion after removal of old concrete and prior to placement and curing of new concrete. No preparation work shall be performed in an adjacent lane on areas adjoining new concrete during the specified curing period.

Night work will be permitted, in which case supplemental lighting may be required, if necessary to make quality workmanship and adequate inspection possible. The engineer shall be given reasonable notice.

No mixture shall be placed after October 1.

745.08 <u>Cooperation</u>. It is intended that the latex modified concrete be a product of the Dow Chemical Company, who will also furnish certain equipment, supervision, and related service therewith.

The prime contractor shall be responsible for cooperation and coordination with the Dow Chemical Company for satisfactory performance of the work. For further information contact:

The Dow Chemical Company
Suite 203A
4210 Johnson Drive
Shawnee Mission, Kansas 66205

Attention: Ron Chatterton

745.09 FLOODLIGHTING. Floodlights will be required at the approximate locations shown on the "Situation Plan". Section 5D-4 of the Iowa Manual on Uniform Traffic Control Devices shall not apply as it pertains to floodlights. Floodlighting shall be installed and in service before other construction on the contract is started and shall be removed after the completed bridge is placed in service.

Luminaires used for floodlighting shall be standard roadway types with totally enclosed refractors. The IES glare control rating shall be "cutoff". The lamps shall have an initial output rating of 19,000 lumens or greater, for operation in such luminaires. All luminaires shall be approved by the engineer.

The mounting height of luminaires shall be not less than 35 feet above the roadway. The center of the light source shall be directly above the traffic lane edge, where practicable, but mastarm lengths shall be not less than shoulder width. Poles shall be placed outside the normal shoulder line at the approximate locations shown.

All luminaires shall be photoelectric controlled for dusk-to-dawn operation.

The contractor shall exercise reasonable care to avoid interruptions during the hours of darkness, shall repair promptly any damage to the system, and shall replace all burned out lamps as soon as possible.

All materials involved in this item shall remain the property of the contractor.

745.10 METHOD OF MEASUREMENT. The quantity of the various items of work involved in bridge floor repair will be measured by the engineer in accordance with the following provisions:

Class 1, Class 2, and Class 3 Repair will be computed in square yards from measurements of the areas so repaired.

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

For the number of square yards of Class 1, Class 2, or Class 3 Repair constructed, the contractor will be paid the respective contract price per square yard which price shall be full payment for removal and disposal of concrete, for furnishing all traffic control in accordance with the specifications and plans and for furnishing all material, equipment, forms, and labor necessary to complete the work in accordance with the plans and these specifications.

When the plans require that the contractor provide floodlighting, the contractor will be paid the lump-sum price bid for this item which price will be full payment for all costs for furnishing, installing, maintaining, and servicing the lights, including the electric current.