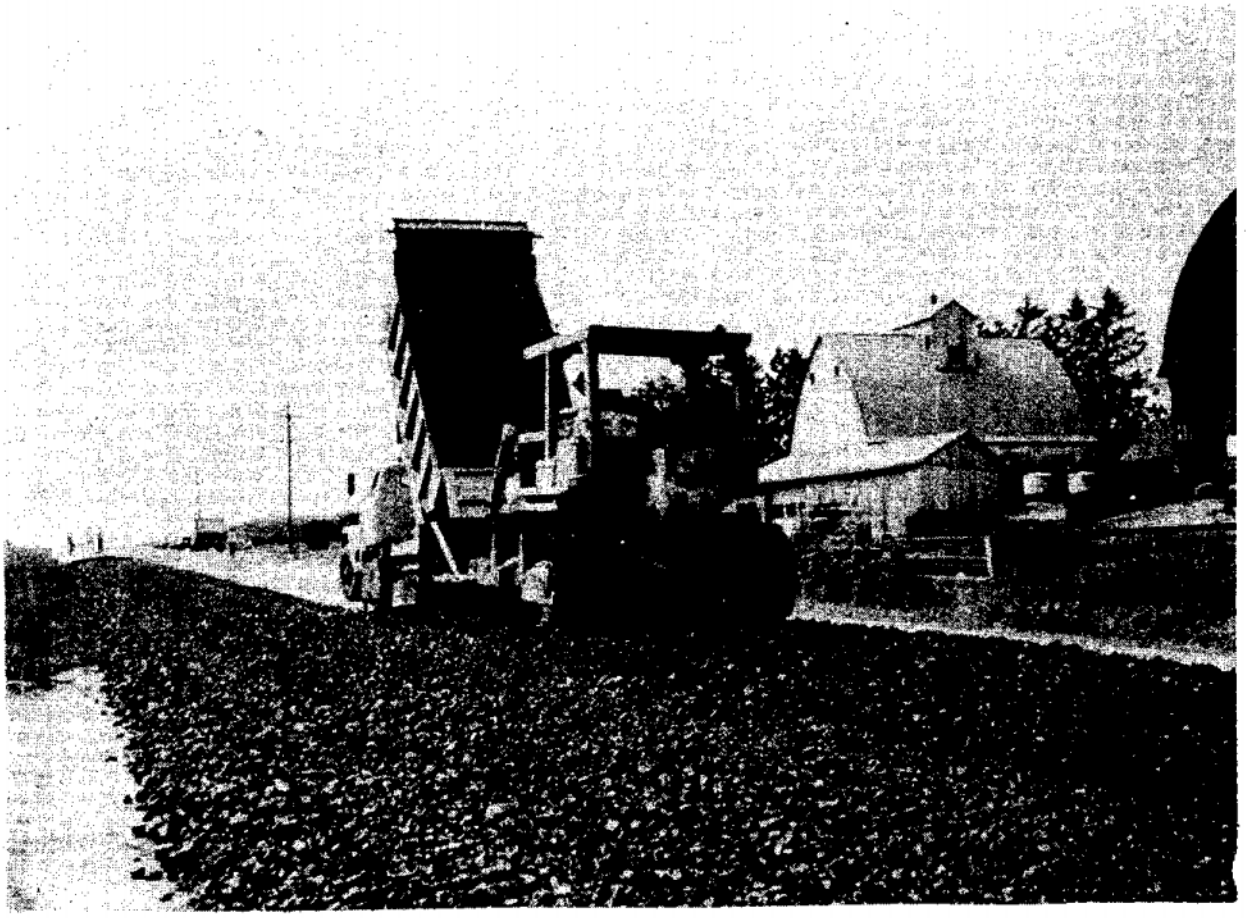
Asphalt Emulsions for Highway Construction in Dubuque County, Iowa



Final Report
Iowa Highway Research Board
Project HR-216

U.S. Department of Transportation
Federal Highway Administration
Region 15
Demonstration Projects Division
Contract No. DTFH71-80-55-IA-02
Demonstration Project No. 55

Highway Division
January 1985

Iowa Department of Transportation

Disclaimer

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FINAL REPORT
IOWA HIGHWAY RESEARCH BOARD
PROJECT HR-216

ASPHALT EMULSIONS FOR HIGHWAY CONSTRUCTION

Contract No. DTFH71-80-55-IQ-02
U.S. Department Of Transportation
Federal Highway Administration
Region 15
Demonstration Projects Division
Demonstration Project No. 55

ASPHALT EMULSION BOUND MACADAM

Dubuque County Project SN-4657 (3)--51-31

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The opinions, findings, and conclusions of this report are those of the authors and not necessarily those of the Highway Division of the Iowa Department of Transportation or the Federal Highway Administration.

INTRODUCTION

Recent years have presented a real financial challenge for highway departments. The energy shortage and rapid inflation have resulted in a severe reduction in proposed programs. The result has been an increased emphasis on investigating alternative roadway sections and construction procedures.

Many secondary roadway departments have utilized macadam stone base construction with varying degrees of success. Macadam base construction does appear to have a potential for providing the structural needs at a lower cost.

The recent macadam stone base projects have provided excellent drainage characteristics but have an apparent lack of stability. Even when the base is properly rolled and keyed together, the large stones are easily displaced. The use of an asphalt emulsion binder may increase stability while still providing a relatively low cost roadway base.

OBJECTIVE

The project objectives are:

1. Identify a cost effective asphalt emulsion bound macadam typical cross section.
2. Determine the effectiveness of engineering fabric placed under macadam roadbeds.
3. Evaluate the use of emulsions in surface seal coats.

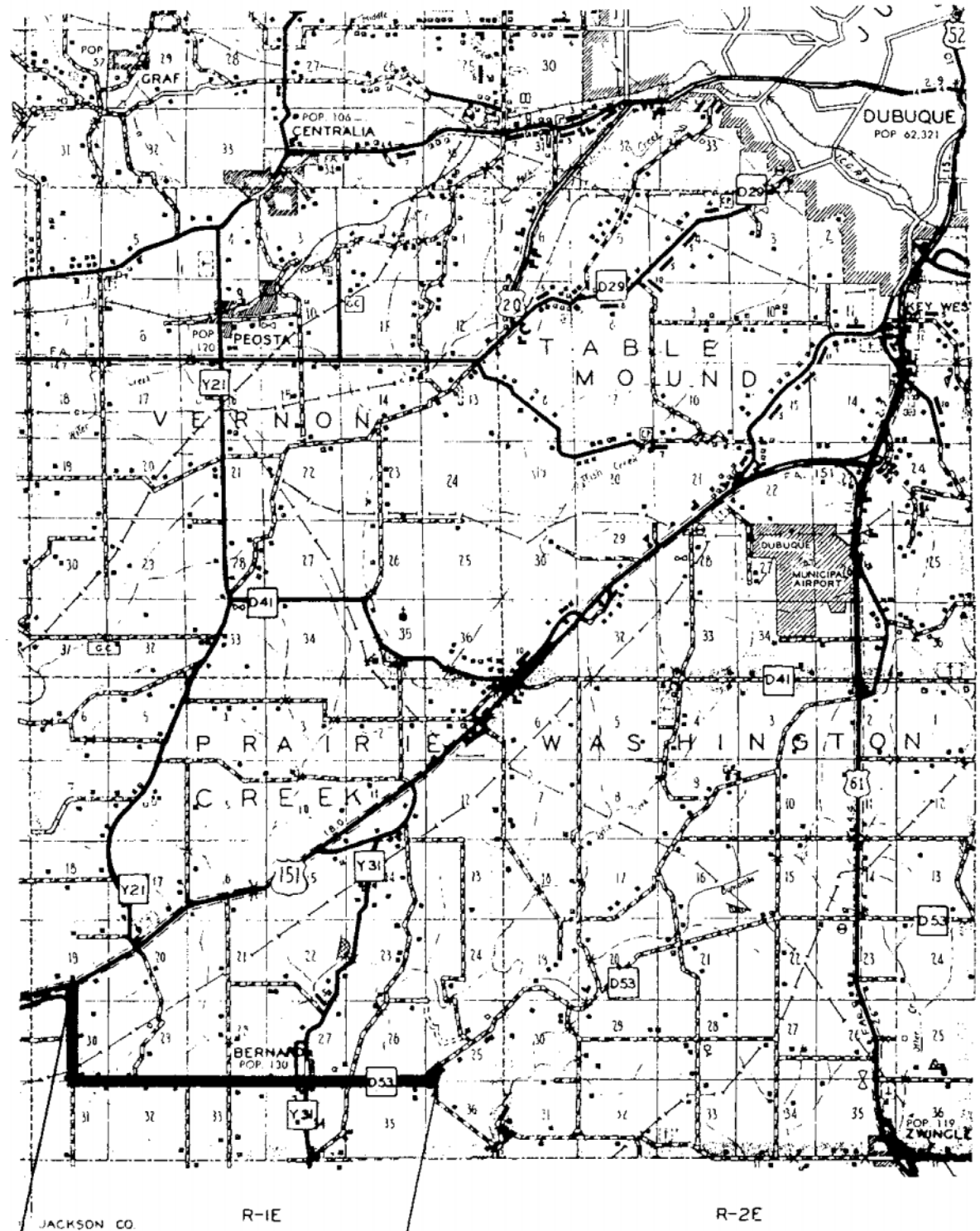
PROJECT DESCRIPTION

The project is a 5.8-mile section of Dubuque County Road D-53 from U.S. Highway 151 south and easterly through Bernard (Figure 1). The roadway serves as a shortcut from U.S. 151 to U.S. 61.

Traffic volume on the roadway from US 151 to east of Benard is 312 vehicles per day of which 13% is truck traffic.

Figure 1 Project Location

DUBUQUE COUNTY
IOWA



TEST SECTIONS

Six test sections and one control section were planned and constructed (Table 1). The control section (sections 1 and 1A) is a typical full depth asphalt cement concrete section used on Iowa secondary roads. Sections 4, 4A, 7 and 7A are typical of waterbound macadam stone base construction, though not extensively used in Iowa. All macadam bases were placed full width of the 36-foot wide subgrade. The completed surface is 24-feet wide with 5-foot double course seal coat shoulders.

Three non-woven engineering fabrics, Monsanto Corporation Bidim C-22 and C-34 and True Temper Corporation True Tex MG-300, were incorporated into the project. The objective of the inclusion of fabric was to evaluate its effect on load carrying capacity and its effectiveness in preventing soil intrusion into the macadam.

Two-hundred feet of C-22 and MG-300 were placed 24-feet wide in each of the first seven test sections. A 200-foot section of C-34 was placed in section 7. The installation locations are in Table 2.

TABLE 2
FABRIC INSTALLATION LOCATIONS

Beginning Station	Fabric
10+00	C-22
14+00	MG-300
37+00	C-22
41+00	MG-300
55+00	C-22
59+00	MG-300
73+00	C-22
77+00	MG-300
100+00	C-22
104+00	MG-300
124+00	C-22
128+00	MG-300
137+00	C-22
141+00	MG-300
145+00	C-34

TABLE 1
TEST SECTION DESCRIPTION

SECTION	STA. TO STA.		SURFACE COURSE	INTERMEDIATE COURSE	BASE COURSE
1	0+00-100'	23+00	2" AC	----	6" ATB
1A	152+00	173+00			
2	23+00	47+05	2" AC[a]	----	6" ETMB
2A	173+00	194+00			
3	47+35	68+00	3" AC[a]	----	6" ETMB
3A	194+00	213+10			
4	68+00	89+00	3" AC	2" CHOKE STONE	6" MACADAM
4A	214+00	238+00			
5	89+00	110+00	DOUBLE COURSE SEAL	3" ETCS	6" ETMB
5A	238+00	262+00			
6	110+00	131+00	DOUBLE COURSE SEAL	3" ETCS/2" CHOKE STONE	6" MACADAM
6A	262+00	286+00			
7	131+00	152+00	DOUBLE COURSE SEAL	3" CHOKE STONE	6" MACADAM
7A	286+00	308+00			

ATB - Asphalt Treated Base
ETMB - Emulsion Treated Macadam Base
ETCS - Emulsion Treated Choke Stone

a. Due to intrusion of mix into the base, approximately 1 additional inch of mix was actually placed.

MATERIALS

Five different bituminous materials and seven different aggregates were used for the project. Appendix A contains the special provisions for materials.

Bitumins

The bitumins were all from the Koch Asphalt Company terminal at Dubuque. The asphalts used are in Table 3.

TABLE 3
ASPHALT TYPES

Bitumin Type	Use	Specifications
Asphalt Cement AC-10	Asphaltic Concrete & ATB	AASHTO M226
Emulsified Asphalt SS-1	Macadam & Choke Stone Binder	AASHTO M140-79I
Emulsified Asphalt HFMS-2, HFE-90	Seal Coat	AASHTO M140-79I
Emulsified Asphalt HFMS-2, HFE-150	Macadam & Choke Stone	AASHTO M140-79I
Liquid Asphalt MC-70	Tack & Prime	AASHTO M82

Aggregates

Limestone aggregate for the macadam, choke stone and shoulder stone was from the Bernard Quarry, less than 2 miles north of the project. The aggregates for 3/4-inch asphalt cement concrete and 3/4-inch asphalt treated base mixes were a sand from the Bellevue Pit in Jackson County and 2 crushed limestones of different gradation from the MarJo Quarry in Dubuque County. Seal coat chips were 1/2-inch limestone aggregate from the Kurt Quarry in Dubuque County. Typical gradations for the aggregates are in Table 4.

TABLE 4
AGGREGATE GRADATIONS
(percent passing)

	3"	2"	1 1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Macadam	100	69	45	22	4.1	1.0	0.8	--	--	--	--	--	--	--
Choke Stone				100	95	66	35	7.9	6.6	6.3	5.4	6.1	5.5	3.8
Shoulder Stone				100	98	86	71	51	38	29	24	20	17	12
3/4" Stone for ACC				100	96	30	3.2	1.6	1.6	1.6	1.5	1.5	1.5	1.5
3/8" Stone for ACC							100	74	57	45	38	30	20	10
Sand							100	98	83	64	38	11	1.0	0.5
1/2" Seal Coat Chips					100	97	68	21	2.4	--	--	--	--	0.7

CONSTRUCTION

The project was started on August 14, 1980, and was completed on October 2, 1980. Tschiggfrie Excavating Company of Dubuque, Iowa, was the contractor. The contract is in Appendix B.

Fabric Placement

Iowa DOT personnel placed the fabrics on grade to a width of 24 feet. A tack coat following placement helped to hold the fabric until the base course could be placed (Figure 2). Despite the tack coat, trucks traveling over the fabrics caused wrinkles to develop in the fabric. The wrinkles could not be removed.

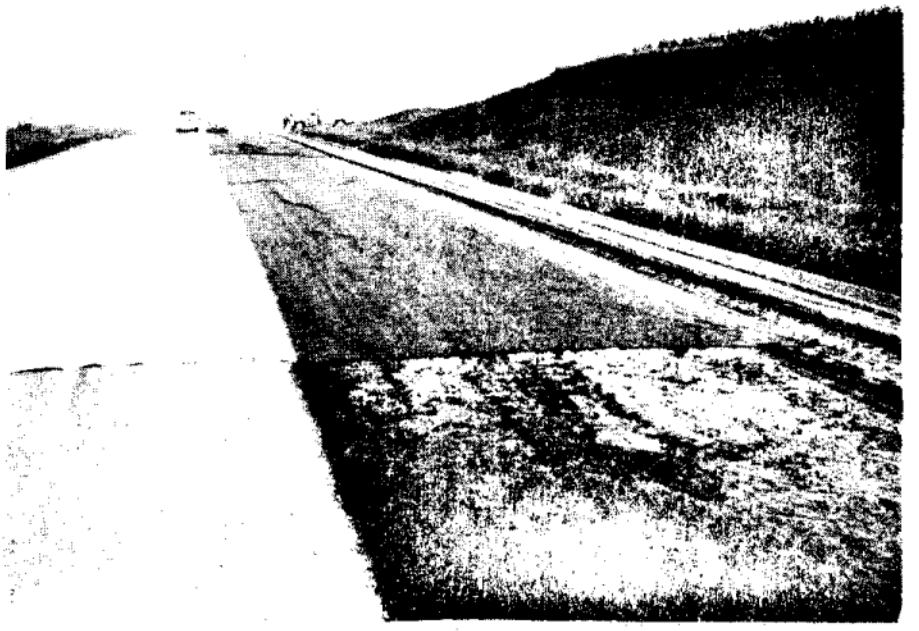


Figure 2 Tack coat application over the fabric

Macadam Placement

Macadam placement began at the east end of the project on section 7A. A Jersey spreader on a D7 Caterpillar tractor placed the untreated macadam stone in 3 passes across the grade. At first, a pass was made on each side of the grade with the final pass down the center (Figure 3). This sequence of placement resulted in excess material at the center of the roadway. Blading the macadam stone to the correct cross section caused segregation. The procedure for placement was changed to three passes beginning the first pass on the left side and proceeding to the right with the second and third passes. The correct cross section was achieved without blading.

Figure 3 Jersey spreader placing plant-mix base

Compaction of the macadam base was with a steel drum vibratory roller. The roller had a tendency to break some of the larger rock at the surface.

A Pioneer pugmill located at the quarry was used to produce the asphalt emulsion treated macadam stone. Poor aggregate coating occurred when more than 4 percent passing the number 200 sieve was present in the macadam. Unsatisfactory coating was also observed when the stockpile moisture content was increased by rain. To reduce the minus #200 material to below 4 percent, the macadam stone stockpile was re-screened. An SS-1 and an HFMS-2 emulsion were both tried with the macadam stone. The HFMS-2 provided better results and was used for the project.

The emulsion treated macadam was placed full width with the Jersey spreader using the same pattern established for the untreated macadam stone (Figure 4). The full width treated macadam base concept was abandoned on section 3A. Emulsion treated macadam was placed in the center 26 feet, and plain macadam was placed at the shoulders. The Jersey spreader placed the treated stone in two passes. A Robins shouldering machine completed the base at each shoulder with the plain macadam.

The emulsion treated macadam stone acted much like the untreated macadam during placement. The material was hauled to the grade and placed before the emulsion broke. The emulsion usually broke within 1 to 2 hours depending on the weather.

Figure 4 Jersey spreader placing emulsion treated macadam stone

Choke Stone Placement

Untreated choke stone was placed full width over the plain macadam base. The Jersey spreader was used to place the material in three passes. Blading the choke stone did not cause significant segregation of the material.

Mixing the emulsion treated choke stone presented the same coating problem. Once the material was re-screened to reduce the minus #200 sieve to less than 4 percent, choke stone coating was satisfactory. The treated choke stone was placed in two 1 1/2-inch lifts to 24 feet wide with an asphalt paving machine (Figure 5).

Consolidation of both untreated and treated choke stone was accomplished with the vibratory steel drum roller.

Figure 5 Placement of emulsion treated choke stone

Asphalt Cement Concrete Pavement Placement

The asphalt treated base course of the control section was placed to a width of 25 feet in two 3-inch lifts. Before asphalt cement concrete placement, the asphalt treated base was tacked at 0.03 gal per sq yd and the macadam base sections were primed at 0.30 gal per sq yd with MC-70.

Asphalt cement concrete placed directly on the macadam base infiltrated into the base. Due to this intrusion, 1/2 to 1 inch of additional mix was required to achieve the desired depth of a.c.c. over the macadam.

Seal Coat Surface Treatment

The seal coat surfaces were constructed as Federal Highway Administration Demonstration Project Number 55, "Asphalt Emulsions for Highway Construction". The seal coating was started on September 24 and was completed October 1, 1980. An Etnyre distributor with 1/8-inch slotted nozzles and a bar height of 13 inches applied the emulsion. A Flaherty Chipper spread the limestone aggregate. The highfloat HFMS-2 (Koch Designation HFE-90) contained 67.5 percent asphalt by weight and had a penetration on the residue of 82.

Emulsion and aggregate were applied from 11 to 14 feet wide on the traveled portion of the road and 7 feet wide on the shoulders. The first and second courses were usually placed the same day. The intended spread rates were 0.35 gal per sq yd of emulsion and 30 lbs per sq yd of aggregate for the first course and 0.30 gal per sq yd of emulsion and 25 lbs per sq yd for the second course Table 5 shows the actual application rates.

TABLE 5
SEAL COAT APPLICATION RATES

SECTION	FIRST COURSE		SECOND COURSE	
	Emulsion (gal/sy)	Aggregate (#/sy)	Emulsion (gal/sy)	Aggregate (#/sy)
7A	0.32	32.2	0.31	34.2
6A	0.40	29.3	0.32	27.0
5A	0.29	28.7	0.36	26.4
4A	0.36	30.9	0.34	31.2
3A	0.34	32.9	0.36	37.6
2A	0.31	32.9	0.33	37.7
1A	0.31	32.9	0.33	37.7
7	0.33	37.3	0.31	30.9
6	0.36	33.1	0.28	33.1
5	0.33	30.6	0.34	30.3
4	0.36	32.8	0.38	37.7
3	0.36	31.1	0.40	31.5
2	0.36	29.6	0.30	31.6
1	0.36	29.6	0.30	31.6

Seating of the chips was by a rubber tired roller followed by a steel drum roller. Before application of the second course, excess chips were broomed off the first course.

Average temperatures during seal coating are in Table 6. Despite the relatively cool weather, the emulsion broke within minutes after application. The total mat thickness was about 3/4 inches.

TABLE 6
AVERAGE TEMPERATURES

DATE	EMULSION (^{O}F)	AIR (^{O}F)	SURFACE (^{O}F)
9-24	170	64	65
9-25	160	61	65
9-29	143	68	69
9-30	150	72	71
10-01	150	65	67

PROJECT MAINTENANCE

The seal coat surfaced sections, section numbers 5 through 7 and 5A through 7A, have required periodic patching. The failures were due mostly to separation of the first and second courses of the seal coat. Some distress was attributed to isolated base failures where subgrade material intruded into the macadam stone base causing loss of support.

Minor patching was performed on section 7A in August 1981 at a cost of $216.00. Additional patching was performed on sections 5, 7, 5A, 6A and 7A in June 1982 at a cost of $5544.60. Spalling and ravelling of the seal coat continued; and in September 1984, all the seal coat surfaced sections were completely covered with a 3/4-inch thick asphaltic concrete skin patch. A single chip seal was applied over the skin patch. The cost of the 1984 repair was $70,815.30, ($28,113.58 per mile). Average total maintenance cost for the seal coat surfaced sections is $30,400.53 per mile over the 4-year period.

POST CONSTRUCTION TESTING AND EVALUATION

Testing and evaluation of the project included Road Rater, IJK Road Meter testing and crack and rut depth surveying.

Road Rater Testing

Results of the annual Road Rater testing are in Appendix C. Recent experimentation with the Road Rater has led to a method for estimating a modulus of subgrade reaction (k) for roadway structures. Structural values and k values for 1981 and 1984 are in Table 7.

TABLE 7
ROAD RATER TESTING SUMMARY 1981 & 1984

Section No.	80th Percentile Structural Rating		Modulus of Subgrade Reaction (k)	
	5-4-81	6-4-84	5-4-81	6-4-84
1	3.2	2.8	75	135
2	3.1	3.0	200	210
3	3.1	3.6	150	185
4	2.5	2.5	215	225
5	1.6	0.9	160	70
6	1.4	1.5	130	115
7	1.6	1.5	200	150

The condition of the pavement structures is a combination of the structural rating and k. Sections 1 through 4 show no loss of structural integrity. Sections 5 through 7, however, show minor to serious loss of integrity. Section 5 with an emulsion treated macadam base, emulsion treated choke stone and a two course seal coat wearing surface has changed considerably from 1981 to 1984. Sections 6 and 7 have isolated areas of high deflection and low modulus of subgrade reaction.

Sections 2 and 4 both have approximately a 3-inch asphaltic concrete wearing surface. The 6-inch emulsion treated macadam base of section 2 has a structural rating 0.5 higher than the 6-inch plain macadam base of section 4. Simularly, the 6-inch emulsion treated macadam base under a 4-inch asphaltic concrete wearing surface of section 3 possessed a structural rating 1.1 higher than the 6-inch plain macadam base of section 4.

The comparison between the seal coated plain macadam base and the emulsion treated macadam base sections in 1981 and 1984 shows no increased structural support for the emulsion treated macadam base of section 5. However, Road Rater testing just after construction revealed a structural rating 0.45 higher for the 6-inch emulsion treated macadam base of section 5 than for the 6-inch plain macadam base of sections 6 and 7.

The Road Rater was unable to detect any consistent structural benefit from the fabric layer placed between the macadam base and the subgrade. The overall average deflection for the 200-foot fabric segments under macadam base was 4.44 mils and the overall average k was 150. The overall average deflection for 200-foot control segments was 4.47 mils and the overall average k was 153.

IJK Road Meter Testing

Results of the 1984 Road Meter testing are in Table 8.

TABLE 8
PRESENT SERVICEABILITY INDEX (PSI)

SECTION	PSI	SECTION	PSI
1	3.8	1A	3.8
2	3.6	2A	3.7
3	3.4	3A	3.6
4	3.8	4A	3.4
5	3.1	5A	3.3
6	3.5	6A	3.4
7	3.6	7A	3.0

The PSI for all the sections is still relatively high. Understandably, sections 1 and 1A, full depth asphaltic concrete pavement, exhibit the highest PSI, indicating a smooth pavement. Sections 2 through 4 and 2A through 4A are slightly rougher, but still good.

Crack and Rut Surveying

Results of the crack survey are in Table 9.

TABLE 9
TRANSVERSE CRACK SUMMARY

SECTION NO.	Transverse Crack Interval (Ft) 3-3-83	1-24-84	10-10-84
1 & 1A	228'	85'	77
2 & 2A	117'	59'	56
3 & 3A	412'	112'	110
4 & 4A	85'	56'	55

Section 4A also has 350 feet of intermittent longitudinal centerline cracking. No transverse or longitudinal cracking was visible on any of the seal coat surfaced sections.

The fabric segments did not exhibit any consistent differences in transverse cracking. Results of crack surveys on the fabric segments and control segments 200 feet long adjacent to the fabric segments are in Table 10.

TABLE 10
TRANSVERSE CRACKING IN FABRIC SEGMENTS

Section No./Segment	Transverse Crack Interval (Feet) 3-1-82	3-3-83	1-24-84	10-10-84
1 - Control	300	200	150	150
C-22 Fabric	---	---	200	100
MG-300 Fabric	---	---	200	200
2 - Control	43	43	35	32
C-22 Fabric	67	67	50	50
MG-300 Fabric	40	40	40	40
3 - Control	200	200	150	150
C-22 Fabric	---	---	100	100
MG-300 Fabric	200	200	200	200
4 - Control	600	600	120	120
C-22 Fabric	---	---	100	100
MG-300 Fabric	---	---	50	50
1-4 AVERAGE Control	120	114	80	75
Fabric	178	178	80	76

The overall average crack spacings for the control segments and the fabric segments are almost equal. Fabric appeared to retard the formation of transverse cracks for about 2 years from the time of construction.

No significant rutting occurred on sections 1 through 4 and 1A through 4A. Final measurements were not obtained on sections 5 through 7 and 5A through 7A due to the extent of the maintenance performed.

PROJECT COSTS

Construction costs for each section type are in Table 11.

TABLE 11
RESEARCH SECTIONS COSTS

SECTION NO.	COST/MILE
1 & 1A	$187,413
2 & 2A	164,520
3 & 3A	184,113
4 & 4A	139,797
5 & 5A	151,411
6 & 6A	127,389
7 & 7A	91,177

Commonly, research projects involving several different sections of short lengths will be bid higher than normal construction by contractors. The frequent changeovers, small quantities, and uncertainty of success result in higher project prices.

Using an HFMS-2 emulsion for the seal coat bitumen instead of an MC-800 cutback asphalt resulted in a cost savings on the project. The contract price for HFMS-2 was $0.75 per gallon and the price for MC-800 in 1980 from Tschiggfrie Excavating Company was $0.98 per gallon. The savings for using 55,946 gallons of emulsion was $12,867.58.

Along with the cost savings by using HFMS-2 instead of MC-800, an energy savings was also realized. Four hundred gallons less of #3 fuel oil were required for each day of production of emulsion than for the cutback asphalt. This is a savings of 57,200,000 BTU's per day. An HFMS-2 contains 5 percent distillate in the #1 fuel oil range and an MC-800 contains 20 percent distillate in the #2 fuel oil range. The resultant energy savings in distillate for each gallon of emulsion would be 20,050 BTU's.

DISCUSSION

The main goal of the research project was to identify a cost effective asphalt emulsion treated macadam stone base pavement section. Sections 2 and 3, 3 to 4 inches of ac pavement respectively over 6 inches of emulsion treated macadam stone base had lower initial costs and also have structural ratings at least as high as section 1, 2 inches of ac surface over 6 inches of ATB. The cost of sections 2 and 3 could have been reduced by $12,000 to $14,000 per mile by using plain macadam for the shoulder base instead of emulsion treated macadam.

Section 4, 3 inches of ac pavement over 6 inches of plain macadam, has a structural rating 0.5 lower than section 2 and 1.1 lower than section 3. Theoretically, for section 4 to be structurally equal to section 2, it would require either about 1 additional inch of asphaltic concrete or about 3 additional inches of plain macadam. This section would have cost about $158,000 per mile to construct compared to a construction cost of $153,000 per mile for a modified section 2 of 3 inches of ac pavement and 6 inches of emulsion treated macadam base and plain macadam stone shoulders.

Sections 5, 5A, 6, 6A, 7A and 7 with a seal coat wearing surface are typical of macadam stone construction as a first stage project. The second stage is normally an asphaltic concrete surface placed over the base 5 to 10 years after initial construction. The Road Rater indicates a loss of subgrade support for these seal coat surfaced sections. A thicker macadam base of 8 to 10 inches may have performed better under the traffic loads. The emulsion treated macadam base and the emulsion treated choke stone did not appear to perform any better than plain stone under the seal coat surface.

The traffic analysis based on current traffic counts, predicts six 18 kip equivalent axle loads per day. The structural number required for a 20-year design life is 2.55. Based on cost, performance, and structural number required, the most cost effective asphalt emulsion treated macadam base section for this project appears to be:

- 2 inches of asphaltic concrete cover with allowance for a 50 to 75 percent overrun of mix due to intrusion of the ac surface into the macadam base during construction. For best smoothness, the mix should be placed in two lifts.

- 6 inches of emulsion treated macadam base placed 2 feet wider than the surface course. A base of 6 inches of plain macadam stone at the shoulder.

The Iowa DOT has in recent years used asphalt cement (grade AC-10) treated macadam stone as base material on widening units for selected primary projects. The macadam base is outletted through the shoulder to the ditch by subdrains placed at about 1000-foot intervals.

The second objective of the project was to determine the effectiveness of engineering fabric placed under macadam roadbeds. The use of fabric is intended to prevent intrusion of the soil subbase into the macadam base. The non-destructive testing and evaluation conducted has not shown any consistent difference between the fabric segments and the control segments. Without actually removing small areas of the pavement surface and examining the base for soil contamination, it is difficult to determine the performance of the fabric.

The third objective of the project was to evaluate the use of emulsions in surface seal coats. The use of an emulsion for the seal coat instead of

cutback asphalt did save money and energy. However, the poor performance of the seal coat certainly negates any actual money or energy savings. The most likely cause of the failure may have been the use of a steel drum roller for final rolling of each seal. The steel drum may have broken down the cover aggregate. The Iowa DOT specifications for bituminous seal coat have since been changed to no longer require the use of a steel drum roller.

CONCLUSIONS

1. The minus #200 sieve material for the macadam stone should be held to a minimum. For the emulsion used on this project, the minus #200 material had to be less than 4 percent to achieve satisfactory coating of the macadam stone.
2. The placement of the emulsion treated macadam required no additional equipment or time than for plain macadam placement.
3. Emulsion treating the macadam stone for the shoulder base appears unnecessary.
4. The emulsion treated macadam base beneath an asphaltic concrete wearing surface yielded a higher structural rating than the plain macadam beneath a comparable asphaltic concrete surface.
5. The performance of the fabric between the subgrade and the macadam base to prevent soil intrusion into the base could not be determined by the non-destructive testing conducted.
6. When no choke stone is used over the macadam base, allowance for ac mix overrun should be made.
7. Use of an emulsion instead of a cutback asphalt saved money and energy. However, the poor performance of the seal coat negated any real savings.

Appendix A

Special Provisions

IOWA DEPARTMENT OF TRANSPORTATION
Ames, Iowa

Special Provisions
for

EMULSION TREATED MACADAM

Dubuque County SN-4657(3)--51-31

July 15, 1980

THE STANDARD SPECIFICATIONS, SERIES OF 1977, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SPECIAL PROVISIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

GENERAL. The work on this project includes several variations of base and wearing course construction, all described on the plans. This specification describes emulsion treated Macadam base and the related emulsion treated choke stone base, neither of which is described elsewhere in the specifications, and modifications to other standard specifications relating to this project.

Certain aspects of this project are of a research nature, and requirements may be changed by the engineer in order to make these aspects more meaningful.

EMULSION TREATED MACADAM BASE AND EMULSION TREATED CHOKE STONE COURSE

MATERIALS. Aggregate for emulsion treated Macadam and emulsion treated choke stone courses shall be the product of crushing limestone, dolomite, or quartzite and shall meet the following requirements:

A. Abrasion Loss. The percentage of wear, determined in accordance with AASHTO T 96, Grading A or B, shall not exceed 45.

B. Soundness. When subjected to the freezing-and-thawing test, Laboratory Test Method 211, Method C, the percentage loss shall not exceed 10.

C. Gradation. The aggregate for both base course and choke stone course shall be produced from the same source by primary crusher, both products of that operation. The gates or breaker bars shall be adjusted to produce a nominal maximum size of 3 inches, and the product of the primary crusher shall be screened over a 3/4-inch screen. The aggregate retained on the 3/4-inch screen shall be furnished as the aggregate for emulsion treated Macadam base course.

The aggregate passing the 3/4-inch screen shall be furnished as the aggregate for emulsion treated choke stone course; however, the percentage of fines passing the No. 200 sieve shall not exceed 5.0 percent for the choke stone course aggregate that is to be treated with emulsion.

Emulsion for emulsion treated Macadam base and emulsion treated choke stone courses shall meet requirements of AASHTO M 140-79I, Grades HFMS-2 or CSS-1. This material or CRS-2 shall also be used for tack coats, if required.

PLANT EQUIPMENT. Article 2205.04 shall apply.

SPREADING EQUIPMENT. Spreading equipment for emulsion treated Macadam base shall be capable of uniformly depositing and spreading the base material to the required thickness. Equipment described in 2001.19 may be used.

Spreading equipment for emulsion treated choke stone course shall meet requirements of 2001.19.

HEATING EQUIPMENT. Article 2001.11 shall apply.

COMPACTION EQUIPMENT. Compaction equipment used shall be of such design that its operation shall not disturb the subgrade or subbase. Initial compaction of the Macadam base shall be by use of a self-propelled vibratory roller, and the engineer may require additional compaction by a steel-tired roller or a pneumatic-tired roller. The same rollers shall be used for the emulsion treated choke stone course, but the engineer may prohibit or restrict use of the self-propelled vibratory roller. Compaction equipment shall meet requirements of 2001.04.

WEIGHING EQUIPMENT. Article 2001.07 shall apply.

DISTRIBUTOR. Article 2001.12 shall apply.

CONSTRUCTION. The subgrade for these bases will be prepared by the county.

At railroad crossings, junctions with existing pavements, bridges, and similar structures, the contractor shall excavate the roadbed to prepare a subgrade to permit the full thickness of courses designated on the plans to be constructed to the proper elevation. In this operation, the granular material existing on the roadbed shall be salvaged and respread over the disturbed area when excavation work is completed.

Placement of filter fabric is also anticipated. This material will be placed in two, 200-foot areas in each test section. Placement will be by others prior to the base-spreading operation. This work will be coordinated by the engineer. The contractor will have no responsibility for either furnishing or placing filter fabric, but his cooperation will be necessary to provide satisfactory construction.

The emulsion treated Macadam base and choke stone course shall be mixed in accord with 2205.12A, C, E, F, and G. The aggregate is not to be heated prior to or during the mixing process, and asphalt cement will not be allowed as an alternate to the emulsion. The bituminous material anticipated necessary for the mixtures for both courses is 4 parts of emulsion per 100 parts of aggregate (on a weight basis). The proportioning shall maintain the amount designated by the engineer within a tolerance of 0.4 part, determined by tank measurements.

Addition of water during the mixing process is anticipated. The amount of both emulsion and water to be used may be adjusted by the engineer.

The emulsion treated Macadam base material and the emulsion treated choke stone material shall be spread in courses as shown on the plans. The material shall be spread to such width and depth that each course will conform to the desired profile and cross section. The intention is that each course will be spread to achieve its full thickness in one operation, though multiple passes may be used to obtain the desired width. A tack coat may be required between these courses, as provided in 2303.14.

The emulsion treated Macadam base material shall be thoroughly and uniformly compacted promptly after it is spread. Compaction shall continue until the material is well seated to the satisfaction of the engineer.

The emulsion treated Macadam choke stone course shall be thoroughly and uniformly compacted promptly after it is spread. Three complete coverages with a vibratory roller are anticipated. An additional final rolling with a smooth-faced, steel-tired or pneumatic-tired roller will be required. The finished surface shall be free from irregularities and loose material and shall have a smooth riding surface.

The emulsion treated choke stone course may be tack coated in accord with 2303.14, as directed by the engineer, prior to placement of the next course.

Each section of completed or partially completed course shall be maintained as provided in 2205.12M.

METHOD OF MEASUREMENT. The quantities of the various classes of work involved in the construction of accepted portions of emulsion treated Macadam stone base and emulsion treated choke stone base will be measured by the engineer as follows:

A. Emulsion Treated Macadam Stone Base will be measured in tons computed by the engineer from weights of individual truck loads, and will include base material for fillets at intersecting roads, drives, and turnouts.

B. Emulsion Treated Choke Stone Base will be measured in tons computed by the engineer from weights of individual truck loads, including base material for fillets at intersecting roads, drives, and turnouts.

C. Primer or Tack-Coat Bitumen. Paragraph 2307.06B shall apply.

D. Emulsion, Treated Base Material. The engineer will measure the gallons of emulsion used in emulsion treated Macadam base and emulsion treated choke stone base. The quantity will also include emulsion used in the mixture for the stabilized shoulders. Measurement will be by stick measurement in the contractor's storage tank before and after transport delivery or by weighing trucks on or near the project before and after delivery to the storage tanks. From this quantity will be deducted the measured or estimated quantity diverted to other uses on or off the project or wasted. The quantity will be converted to U. S. standard gallons as provided in 2307.06B.

BASIS OF PAYMENT. For the performance of the various classes of work involved in construction of emulsion treated Macadam stone base and emulsion treated choke stone base, measured as provided above, the contractor will be compensated as follows:

A. Emulsion Treated Macadam Stone Base. For the number of tons of Emulsion Treated Macadam Stone Base placed, the contractor will be paid the contract price per ton.

B. Emulsion Treated Choke Stone Base. For the number of tons of Emulsion Treated Choke Stone Base placed, the contractor will be paid the contract price per ton.

C. Primer or Tack-Coat Bitumen. For the number of gallons of Primer or Tack-Coat Bitumen placed, the contractor will be paid the contract price per gallon. Article 1109.03 shall not apply to this item.

D. Emulsion Treated Base Material. For the number of gallons of emulsion used in treated base material, the contractor will be paid the contract price per gallon.

This payment shall be considered full compensation for furnishing all materials, including water, and for all operations involved in the construction of the base.

MODIFICATION TO SECTION 2124, STABILIZED SHOULDERS

DELETE 2124.02 and add the following in lieu thereof:
2124.02 MATERIALS. The mixture used for emulsion treated base for shoulder areas and tack-coat material, if required, shall be those specified for emulsion treated choke stone course.

DELETE from 2124.07 the requirement for sealer bitumen and sand cover aggregate.

DELETE 2124.09 and 2124.10 and add the following in lieu thereof:
2124.09 MEASUREMENT AND PAYMENT. The base material used in the shoulders will be measured and paid for in the same manner as emulsion treated choke stone course. The emulsion used therein will be paid for separately, and the quantity will be included with the emulsion for the choke stone course.

MODIFICATIONS TO SECTION 2202, ASPHALT TREATED BASE

DELETE all of 2202.02A and add the following in lieu thereof:
A. Bituminous Material. AC used in asphalt treated base shall meet requirements of Section 4137, Grade AC-5.
Tack-coat bitumen shall be emulsion meeting requirements of AASHTO M 140-79I, Grade HFMS-2, CSS-1, or CRS-2.

MODIFICATIONS TO SECTION 2203, TYPE B ACC BASE

DELETE all of 2203.02A and add the following in lieu thereof:
A. Bituminous Material. AC used in Type B ACC Base shall meet requirements of Sections 4137, Grade AC-5.
Tack-coat bitumen shall be emulsion meeting requirements of AASHTO M 140-79I, Grade HFMS-2, CSS-1, or CRS-2.

MODIFICATIONS TO SECTION 2210, MACADAM STONE BASE

DELETE 4122.02C and add the following in lieu thereof:
C. Gradation. The aggregate for both base course and choke stone course shall be produced from the same source by a primary crusher, both products of that operation. The gates or breaker bars shall be adjusted to produce a nominal maximum size of 3 inches, and the product of the primary crusher shall be screened over a 3/4-inch screen. The aggregate retained on the 3/4-inch screen shall be furnished as the Macadam base course material.
The aggregate passing the 3/4-inch screen shall be furnished as the choke stone course material, but with a maximum of 12 percent passing the No. 200 sieve.

ADD the following to 2210.04B8. Equipment meeting requirements of 2001.19 shall be used for spreading the choke stone course.

DELETE all of 2210.04C2 and add the following in lieu thereof:
2. Moisture Content. Aggregate for the choke stone course shall be delivered, without prewetting, with only the moisture naturally occurring in the material. Water shall be added to the surface before or during compaction, if necessary, at the direction of the engineer.

MODIFICATIONS TO SECTION 2307, BITUMINOUS SURFACE TREATMENT

DELETE all of 2307.02B and add the following in lieu thereof:
B. Bituminous Material for seal coats shall meet requirements of AASHTO M 140-79I, Grade HFMS-2 or CRS-2.

Appendix B

Contract

FORM 650016 6-77 11-3078

CONTRACT NO. 17539

TYPE OF WORK ASPH. CEMENT CONC. PAV'T. PROJECT NO. SN-4657(3)--51-31

MILES 5.855 COST CENTER 801000 OBJECT 860

COUNTY DUBUQUE

ON SECONDARY ROAD FROM U S 151, NEAR THE W 1/4 COR. SE 1/4 SEC. 19-87-1E, SOUTH AND EAST TO JUST EAST OF THE SW COR. SEC. 25-87-1E

THIS AGREEMENT MADE AND ENTERED BY AND BETWEEN THE COUNTY OF DUBUQUE, IOWA

PARTY OF THE FIRST PART, AND

TSCHIGGFRIE EXCAVATING CO. OF DUBUQUE, IOWA 44990

PARTY OF THE SECOND PART.

WITNESSETH, THAT THE PARTY OF THE SECOND PART, FOR AND IN CONSIDERATION OF $ ****897,023.10, PAYABLE AS SET FORTH IN THE SPECIFICATIONS CONSTITUTING A PART OF THIS CONTRACT, HEREBY AGREES TO CONSTRUCT VARIOUS ITEMS OF WORK AND, OR, TO SUPPLY VARIOUS MATERIALS OR SUPPLIES IN ACCORDANCE WITH THE PLANS AND SPECIFICATIONS THEREFOR, AND IN THE LOCATIONS DESIGNATED IN THE NOTICE TO BIDDERS, AS FOLLOWS:

ITEM NO	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	INCLUDES 7 SECTIONS WITH DESIGN VARIATIONS				
1	BASE, TYPE B CLASS 1 ASPHALT CEMENT CONCRETE	6,815	TONS	15.25	103,928.75
2	BASE, ASPHALT TREATED, CLASS 2	4,370	TONS	14.25	62,272.50
3	ASPHALT CEMENT	589	TONS	145.00	85,405.00
4	STABILIZED SHOULDER MATERIAL	6,455	TONS	8.00	51,640.00
5	AGGREGATE, ROADWAY COVER, 1/2 IN.	2,064	TONS	11.00	22,704.00
6	BINDER BITUMEN	48,761	GALS.	.75	36,570.75
7	PRIMER OR TACK-COAT BITUMEN	24,995	GALS.	.80	19,996.00
8	BASE, MACADAM STONE - EMULSION TREATED	15,850	TONS	7.72	122,362.00
9	BASE, MACADAM STONE	16,040	TONS	6.72	107,788.80
10	BASE, CHOKE STONE - EMULSION TREATED	4,067	TONS	7.00	28,469.00
11	BASE, CHOKE STONE	6,628	TONS	7.00	46,396.00
12	EMULSION, TREATED BASE MATERIAL	283,095	GALS.	.74	209,490.30
				GRAND TOTAL	$897,023.10

PARTY OF THE SECOND PART CERTIFIES BY HIS SIGNATURE ON THIS CONTRACT, UNDER PAIN OF PENALTIES FOR FALSE CERTIFICATION, THAT HE HAS COMPLIED WITH 324.17(8) OF THE 1975 CODE OF IOWA AS AMENDED, IF APPLICABLE.

SAID SPECIFICATIONS AND PLANS ARE HEREBY MADE A PART OF AND THE BASIS OF THIS AGREEMENT, AND A TRUE COPY OF SAID PLANS AND SPECIFICATIONS IS NOW ON FILE IN THE OFFICE OF THE PARTY OF THE FIRST PART UNDER DATE OF JULY 10, 1980

THAT IN CONSIDERATION OF THE FOREGOING, THE PARTY OF THE FIRST PART HEREBY AGREES TO PAY THE PARTY OF THE SECOND PART, PROMPTLY AND ACCORDING TO THE REQUIREMENTS OF THE SPECIFICATIONS THE AMOUNTS SET FORTH, SUBJECT TO THE CONDITIONS AS SET FORTH IN THE SPECIFICATIONS.

THE PARTIES HERETO AGREE THAT THE NOTICE AND INSTRUCTIONS TO BIDDERS, THE PROPOSAL FILED HEREIN, THE GENERAL SPECIFICATIONS OF THE IOWA DEPARTMENT OF TRANSPORTATION FOR 1977 TOGETHER WITH SPECIAL PROVISIONS ATTACHED, TOGETHER WITH THE GENERAL AND DETAILED PLANS, IF ANY, FOR SAID PROJECT SN-4657(3)--51-31, TOGETHER WITH SECOND PARTY'S PERFORMANCE BOND, ARE MADE A PART HEREOF, AND TOGETHER WITH THIS INSTRUMENT CONSTITUTE THE CONTRACT BETWEEN THE PARTIES HERETO.

THAT IT IS FURTHER UNDERSTOOD AND AGREED BY THE PARTIES OF THIS CONTRACT THAT THE ABOVE WORK SHALL BE COMMENCED OR COMPLETED IN ACCORDANCE WITH THE FOLLOWING SCHEDULE:

APPROX. OR SPECIFIED STARTING DATE OR NUMBER OF WORKING DAYS	SPECIFIED COMPLETION DATE OR NUMBER OF WORKING DAYS
APPROX JULY 30,1980	40 WORKING DAYS

THAT TIME IS THE ESSENCE OF THIS CONTRACT AND THAT SAID CONTRACT CONTAINS ALL OF THE TERMS AND CONDITIONS AGREED UPON BY THE PARTIES HERETO.

IN WITNESS WHEREOF THE PARTIES HERETO HAVE SET THEIR HANDS FOR THE PURPOSE HEREIN EXPRESSED TO THIS AND THREE OTHER IDENTICAL INSTRUMENTS AS OF THE _____ DAY OF _____, 19____

COUNTY OF DUBUQUE, IOWA

BY _____
PARTY OF THE FIRST PART

TSCHIGGFRIE EXCAVATING CO. OF DUBUQUE, IOWA

BY _____
PARTY OF THE SECOND PART

Approved:

JUL 31 1980

Contracts Engineer Date

IOWA DEPT. OF TRANSPORTATION

Appendix C

Results of Road Rater Testing

STRUCTURAL RATING BASED ON ROAD RATER

Section	80th Percentile Structural Rating					
	Subbase	Pavement in Place				
	8-13-80	10-13-80	5-4-81	5-19-82	4-26-83	6-4-84
1	1.4	3.6	3.2	2.6	2.8	2.8
2	1.9	3.1	3.1	3.0	3.1	3.0
3	1.7	3.2	3.1	3.5	3.7	3.6
4	2.3	2.3	2.5	2.75	2.5	2.5
5	2.0	2.35	1.6	1.3	1.1	0.9
6	2.0	1.9	1.4	1.6	1.5	1.5
7	1.9	1.9	1.6	1.75	1.5	1.5

HR-216 DUBUQUE COUNTY
Modulus of Subgrade Reaction (k)

Section	Date 10/13/80	5/4/81	5/19/82	4/26/83	6/4/84
1	75	75	60	75	135
2	210	200	160	170	210
3	170	150	120	155	185
4	220	215	225+	225+	225
5	220	160	60	55	70
6	225+	130	105	110	115
7	225+	200	150	125	150

AVERAGE DEFLECTION (MILS)

Section	Description	Subbase 8/13/80	Pavement in Place 10/13/80	5/4/81	5/19/82	4/26/83	6/4/84
1	Control	4.7	1.7	2.2	2.8	2.5	2.5
	C-22	5.4	1.7	2.1	2.5	2.4	2.4
	Control	6.1	1.6	2.0	2.3	2.2	2.2
	MG-300	6.2	1.9	2.5	2.8	2.9	2.9
	Control	5.6	1.4	1.8	2.3	2.4	2.5
2	Control	4.1	2.1	2.2	2.2	2.4	2.6
	C-22	3.8	2.0	2.1	2.2	2.5	2.5
	Control	3.6	2.0	2.0	2.2	2.4	2.5
	MG-300	3.4	2.4	2.3	2.2	2.4	2.4
	Control	4.4	2.1	2.3	2.2	2.3	2.6
3	Control	4.5	2.2	2.4	2.1	2.0	2.1
	C-22	4.7	2.0	1.9	1.6	1.7	1.8
	Control	5.4	1.9	2.0	1.6	1.7	1.8
	MG-300	4.7	1.8	2.2	1.8	1.9	1.7
	Control	4.1	1.8	2.0	1.7	1.6	1.6
4	Control	3.8	2.9	2.7	2.5	2.8	2.7
	C-22	3.1	2.9	2.7	2.3	2.6	2.8
	Control	3.2	2.9	3.2	2.5	2.7	3.0
	MG-300	2.8	2.8	2.5	2.3	2.3	2.9
	Control	2.8	2.7	2.7	2.9	3.2	3.5
5	Control	3.2	2.8	5.4	5.9	8.4	9.2
	C-22	3.8	2.8	5.8	7.6	9.7	
	Control	4.1	2.9	5.2	5.9	7.0	7.8
	MG-300	3.0	3.0	4.9	5.7	7.6	7.8
	Control	3.4	2.8	5.0	4.6	5.4	6.2
6	Control	3.7	3.6	6.7	5.4	5.7	6.3
	C-22	2.7	3.5	5.0	3.8	5.0	4.7
	Control	4.1	4.2	6.3	4.6	5.8	5.8
	MG-300	3.8	4.0	6.5	5.5	6.1	6.2
	Control	2.9	3.3	5.6	4.7	5.5	5.0
7	Control	3.7	3.1	5.3	5.0	5.8	6.2
	C-22	4.1	4.5	5.2	5.1	6.1	5.5
	Control	2.9	3.3	4.9	4.2	5.3	4.6
	MG-300	3.4	3.8	5.3	4.2	5.7	5.0
	Control	3.9	4.1	4.7	4.2	5.4	6.4
	C-34	3.3	4.0	5.8	5.4	6.7	6.4
	Control	3.5	3.2	4.9	4.2	4.9	4.9