LOW COST TECHNIQUES OF BASE STABILIZATION

FINAL REPORT
IOWA HIGHWAY RESEARCH BOARD
PROJECT HR-312

JANUARY 1994

Highway Division

Iowa Department of Transportation

Final Report
Iowa Highway Research Board
Project HR-312

LOW COST TECHNIQUES OF BASE STABILIZATION DUBUQUE COUNTY

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American Consolid, Inc.
Soil Stabilization Products Company
Contech Construction Products

8. ABSTRACT

Research project HR-312, "Low Cost Techniques of Base Stabilization", was initiated in 1988 to study the effectiveness of four different construction techniques for establishing a stable base on a granular surfaced roadway. After base stabilization, the roadway was then seal coated, eliminating dust problems associated with granular surfaced roads. When monies become available, the roadway can be surfaced with a more permanent structure. A 2.8 mi. (4.5 km) section of the Horseshoe Road in Dubuque County was divided into four divisions for this study.

This report discusses the procedures used during construction of these different divisions. Problems and possible solutions have been analyzed to better understand the capabilities of the materials and construction techniques used on the project.

The project had the following results:

- High structural ratings and Soil K factors for the BIO CAT and Consolid bases did not translate to good roadway performance.
- The Macadam base had the best overall performance.
- The Tensar fabric had no noticeable effect on the Macadam base.
- The HFE-300 performed acceptably.

9. KEY WORDS Base stabilization Soil stabilization Soil treatment Soil additives	**10. NO. OF PAGES** 37

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DISCLAIMER

INTRODUCTION

There are 68,610 mi (110,420 km) of rural granular surfaced secondary roads in Iowa. This represents 76% of the total rural road system. Granular surfaced roads provide the County Engineer with a continuous maintenance problem. Dust, frequent grading, and loose material in curves and at approaches to paved roads are a constant hazard.

Granular surfaced roads also increase the travel costs of all types of vehicles in comparison to those same vehicles traveling on hard surfaced roadways. A recent study revealed that for automobiles, pickup trucks and commercial vans the operating cost per mile increased 38 to 40 percent when driving on a granular surfaced road. The cost per mile for a school bus increased by 42 to 45 percent.

The high cost of construction has made it a necessity to look for alternative methods of establishing dustless roadways for low volume secondary roads. Before dustless roads can be established the road base must be sufficiently stable to support a low cost surfacing method.

The Dubuque County Board of Supervisors has made a valiant effort to connect the towns in Dubuque County with a hard surfaced roadway. The high cost of construction has minimized these efforts. The present cost for new paved construction is approximately $155,000 per mi ($96,000 per km).

The roadway Dubuque County considered for research was known locally as the Horseshoe Road, a 2.8 mi (4.5 km) road connecting the towns of Balltown and Rickardsville. The 1989 construction year traffic count as well as the preliminary 1993 count has remained about 140 vehicles per day (VPD). The road is a direct connection to US 52 and IA 3 from Balltown and the Great River Road. The nearest paved parallel route from Balltown to US 52 and IA 3 requires traveling an additional 8.3 mi (13.4 km).

There has not been any dust control placed on this roadway by Dubuque County, resulting in numerous dust complaints from citizens living near the cities of Balltown and Rickardsville. The roadway has rolling hills which presented a continuous problem of keeping aggregate from washing into the ditches. The road required regular maintenance to prevent "washboarding".

Therefore, Dubuque County looked for a method of creating a dustless stabilized roadway that would prove economically feasible. The method would require preparing a stabilized base and then placing a surface maintenance mat such as a seal coat.

This road is classified as an Area Service Road and therefore, to prepare the road for any future paving, it was necessary to establish a minimum roadway top width of 28 ft (8.5 m) and design the road for a minimum speed of 40 mph (64 km/h).

Iowa Highway Research Board project HR-312, "Low Cost Techniques of Base Stabilization" was developed by Dubuque County with the assistance of the Iowa Department of Transportation. This project was initiated to compile laboratory data from the field application of four different methods of base stabilization prior to the placement of a permanent pavement structure on the roadway.

OBJECTIVES

The objectives of the research project were:

1. To construct an experimental project consisting of several methods of base stabilization to facilitate surfacing with a low cost sealer which would provide a dustless, stable roadway.
2. To evaluate the field performance of each of these methods.
3. To develop the most cost effective technique of constructing a dustless roadway for low traffic volumes which could be surfaced with a thin lift asphalt mat in the future.

PROJECT DESCRIPTION

The project was a 2.8 mi (4.5 km) section of the Horseshoe Road in Dubuque County between Balltown and Rickardsville (Appendix A). The project was segmented into four divisions. All construction was performed by the Dubuque County Highway Department.

Division I involved the mixing of a high float emulsion with the base stone on the roadway. Three inches (75 mm) of Class A granular surfacing were thoroughly mixed with HFE-300 at a rate of 6.0% HFE-300 by volume. Once this material had been thoroughly mixed, it was bladed into shape and rolled with a steel drum roller.

Division II involved using BIO CAT 300-1, which is a biochemical formulation designed to modify and stabilize soils. This procedure is similar to the Consolid System in that the BIO CAT 300-1 is thoroughly blended with the roadway material. The material was blended into the existing roadway in separate 6 in. (150 mm), 8 in. (200 mm) and 10 in. (250 mm) deep sections. The BIO CAT 300-1 is applied at a rate of 1 gallon per 240 cu ft (0.56 L/m^3) of material. Once the material was thoroughly mixed, a steel drum roller was used to compact the treated material.

Division III used the Consolid System method of base stabilization. Depending on the natural moisture content of the soil, the Consolid System uses one of two types of soil additives. If the soil is generally dry, then a combination of two inverted emulsions is used (Consolid 444 + Conservex). If the soil has a high natural moisture content, then a combination of an inverted emulsion and a lime hydrated base powder is used (Consolid 444 + Solidry). The Consolid 444 + Solidry combination was initially used on this project. This method is basically new to Iowa. The procedure requires the soil to be broken up to a depth of 10 in. (250 mm). The soil is pulverized so as not to contain any particles exceeding 3 in. (75 mm) in diameter. Using a mobile distribution tank with spray bar, the Consolid 444 inverted emulsion is applied at a rate of 6.25 gallons per 100 square yards (0.28 L/m^2) of roadway area and mixed thoroughly into the soil. This material is then compacted. The next step involves loosening the top 4 in. (100 mm) only. Using a distributor truck, the lime hydrated powder (Solidry) is applied at the rate of 4 pounds per square yard (2.2 kg/m^2) and compacted. Later the Conservex inverted emulsion was added to the top 4 in. (100 mm) of all of Division III due to the poor performance of the Solidry.

Division IV involved constructing a macadam base that met current Iowa DOT specifications. Dubuque County placed 5 in. (125 mm) of material meeting Spec. 4122.02, Gradation 13 choked with 2 in. (50 mm) of material meeting Spec. 4122.02, Gradation 14 on the roadway. A 320 ft. (97.5 m) length of Tensar fabric was placed under one section of the macadam to determine the effect this material would have on the performance of the base.

All four divisions were sealed using a double seal coat. This was done to prevent moisture from penetrating into the base.

SOIL CHARACTERISTICS

The soil was classified as AASHTO Class 6 (4), Glacial Clay Loam. The color was dark yellow to brown. It was 30% gravel, 17% sand, 30% silt, and 23% clay by gradation.

The proctor densities for untreated soil and the various treatments are in Table I.

Table I
Proctor Density

Treatment	lbs/cu ft	kg/m^3	Moisture (%)
Untreated	129.1	2071	9.6
BIO CAT	131.1	2103	9.9
Consolid	124.6	1999	10.2
Cement-Fly Ash	128.6	2663	9.2

CONSTRUCTION

Dubuque County was performing grading work to correct two curves on the roadway which affected Division II and Division III; therefore, the divisions were not constructed in numerical order. Table II provides a description of the project division layout.

Table II
Test Division Layout

Division	Base Material	Stationing		Length	
		From	To	Ft.	m
I	HFE-300	0+00	37+00	3700	1128
II	BIO CAT 300-1	37+00	70+00	3300	1006
III	Consolid	70+00	104+00	3400	1036
IV	Macadam	104+00	147+50	4350	1326

Construction of Division I began September 7, 1988. Class A granular surfacing was placed on the roadway to a depth of 3 in.(75 mm) and a width of 28 ft (8.5 m) for the length of the division.

The operation of mixing HFE-300 with the Class A stone followed. A target application rate of 2.26 gallons of HFE-300 per square yard (10.2 L/m^2) was used. The Class A stone was bladed to one edge of the roadway. A motor grader then pulled a small amount of stone to the middle of the road and a distributor having an 8 ft (2.4 m) spray bar sprayed the stone with the HFE-300. Another motor grader following the distributor moved the combined material to the other edge of the roadway. This procedure was repeated until the targeted amount of emulsion had been applied to all the stone. Once this blending was completed, the material was again windrowed to one edge of the roadway.

A similar procedure was used to mix the material. A motor grader pulled a small amount of material from the windrow. A Seaman Travel Mixer was then used to mix the material. A second motor grader moved the mixed material to the opposite edge of the road. The entire windrow was moved from one edge of the road to the other four times before the material was adequately mixed.

The Dubuque County crew was able to mix 1500 ft (457 m) of material the first day. Since it was a first time operation for the crew, the operation took considerably longer than anticipated. Because of the lateness of the day, David Leach of Koch Materials recommended that shaping and compaction of the roadway be postponed to the next morning. The material was left in a windrow overnight.

The following day the stone that had not yet been blended was sprayed with water prior to addition of the HFE-300. This was done because the stone was dry and it was felt the emulsion would start balling up and not mix well. The previous day's blending and mixing procedure was then used to mix the material. Only 900 lineal ft (274 m) of new material was mixed since the crew had to shape and compact this and the previous day's mixture.

The material was shaped with a motor grader and compacted using three passes of a sheepsfoot roller. A rubber drum roller and a pneumatic tired roller were then used for final compaction. It was difficult to obtain a tightly knit surface, but this did not seem to pose a difficult problem since the surface was to be covered with a double seal coat.

On the third day the final 1,300 ft (396 m) of HFE-300 treatment was placed using the same methods. The process went well and a considerably better finish was obtained as the crew gained experience.

On September 12, 1988, Division III was scarified from Station 70+00 to Station 80+00. A volume of material 28 ft (8.5 m) wide and 10 in. (250 mm) deep was loosened using the Seaman Travel Mixer. The application of the Consolid 444 material was initiated. The material came in 55 gallon (208 L) drums and was added to a water tanker. The specifications called for a Consolid 444 concentration of 6.25 gallons per 100 square yards (0.28 L/m^2) of roadway area be mixed with enough water to bring the soil to optimum moisture. Because the soil was so dry, as a result of the dry summer, the mix proportions used were approximately sixty parts of water to one part Consolid 444. The material was spread on the roadway and blended into the soil using the Seaman Travel Mixer. Although the water tanker had an extended spray bar, three passes were still required to spread the material across the entire 28 ft (8.5 m) of the roadway. The material was mixed and compacted in two 5 in. (125 mm) lifts.

In the area which was on a grade, the liquid ran downgrade in the tanker's wheel tracks. This problem was rectified in later applications by following the tanker with a springtooth cultivator pulled by a small, track type tractor.

Once the 10 in. (250 mm) were compacted, the top 4 in. (100 mm) were reloosened and mixed with the Solidry material. The Solidry was applied at a rate of 4 pounds per square yard (2.2 kg/m^2).

It was then mixed with the Seaman Travel Mixer and compacted with the sheepsfoot roller.

The remainder of the division was scarified and windrowed for the next week's placement of the materials. Over the weekend 3 in. (75 mm) of rain fell, reducing the roadway to a quagmire. The next few days were spent trying to dry out the roadway. On September 26, 1988, it was felt the Consolid 444 could be added to the roadway. The Consolid 444 then was applied to the remainder of the division but the crew was unable to apply the Solidry because of high winds. The next day the Solidry was added to the roadway, blended and compacted.

Several areas were noticed that did not appear to be adequately compacted. These were small, confined areas. The roadway was primed and it was decided to watch these unstable areas for any further deterioration. The areas remained unstable. The vendor's representative recommended the section be treated with Conservex, which is a chemical mixed with MC-30 asphalt.

The entire III division was scarified 4 in. (100 mm) deep. Fifty-three gallons (200 L) of Conservex were mixed with 1,100 gallons (4164 L) of MC-30 and blended into the roadway material using the travel mixer. The material was recompacted using sheepsfoot and steel vibratory rollers. This improved the overall stability of the roadway considerably. However, there was a 12 in. (.3 m) wide seam approximately 800 ft (240 m) long in the center of the roadway that did not compact. The problem seemed to be that this material did not get thoroughly blended, as there was not the required percent of MC-30 in this small seam.

Construction of Division IV began on September 28. This division involved the placement of macadam and choke stone to a width of 28 ft (8.5 m). The plans called for 5 in. (125 mm) of macadam and 2 in. (50 mm) of choke stone. The area between Stations 104+00 and 107+50 included the placement of Tensar reinforcement beneath the macadam. The macadam rock was placed using a jersey type spreader and compacted using a drum roller. The choke stone material was then placed. A motor grader was used to spread the material across the roadway.

The quantity of choke stone used ran considerably more than intended because of the crew's inexperience in placing this material. The county was able to take advantage of this, however, by using the extra material to dress up the surface. The extra material also added to the structural capabilities of the roadway.

On October 4, construction began on Division II. This division included stabilizing a 28 ft (8.5 m) wide road base with a blend of water and a chemical called BIO CAT 300-1. The BIO CAT 300-1 was blended such that the application rate would be one gallon (3.8 L) of BIO CAT 300-1 per 240 cubic ft (6.8 m^3) of material.

Enough water was added to the BIO CAT 300-1 to bring the soil to optimum moisture.

Division II was divided into three segments of six in. (150 mm), 8 in. (200 mm), and 10 in. (250 mm) depths of treatment (see Table 3). Construction started with the 6 in. (150 mm) segment. The roadway was scarified and the BIO CAT/water mix was applied full width using the distributor. The distributor was followed by the springtooth cultivator and Seaman Mixer. Compaction was attempted using a flat drum roller. This did not give adequate compaction, so the sheepsfoot roller was used for initial compaction and the drum roller was used for finish rolling. Soil from the 8 (200 mm) and 10 in. (250 mm) segments was placed in a windrow and treated by pulling part of it from the windrow and applying the BIO CAT/water mixture. The springtooth cultivator and Seaman Mixer then blended the material. A motor grader then moved the material across the road. This procedure provided better distribution of the BIO CAT 300-1 through the soil compared to the 6 in. (150 mm) section.

Table 3
BIO CAT 300-1 Subdivisions

Segment Depth		Stationing		Length	
inches	mm	From	To	Ft.	m
10	250	37+00	48+00	1100	335
8	200	48+00	59+00	1100	335
6	150	59+00	70+00	1100	335

Some soft areas developed in the roadway during the process. The vendor's representative believed this was due to cool temperatures not permitting the soil to dry adequately. His opinion was that with time the roadway would improve.

The roadway was then primed and a double seal coat was applied to complete the project.

CORRECTION OF CONSTRUCTION PROBLEMS

Division I - It was determined the material should be bladed, shaped and rolled the same day the emulsion is added. This aids in compaction and enables the material to form a more tightly knit surface.

Division II - The compaction problem encountered in the 6 in. (150 mm) thick section was corrected by adding the sheepsfoot to the operation. The BIO CAT material should also be added in warm weather as the material took longer than anticipated to dry. This seemed to hinder compaction.

Division III - The problem with the Consolid System procedure involved the Solidry. The material is a dry powder and windy conditions caused problems during placement. Upon the vendor's recommendation, Conservex was used to help stabilize the top 4 in. (100 mm). This procedure, with the blending of the Consolid 444, would work better in the summer than early fall. The material took too long to dry and considerable time was lost because of rain. The problem with the seam was merely a blending problem and could be alleviated by ensuring the material is thoroughly mixed.

Division IV - The only problem involved the choke stone being placed in excess of the proposed 2 in. (50 mm) lift. The lift was slightly more than 3 in. (75 mm) thick. The crews now understand how to do periodic yield checks that should correct this problem.

TESTING

Iowa DOT Materials Research personnel performed Road Rater, Roughometer and density testing following the completion of the project in November of 1988. The results of the tests are in Appendix B.

Annual Road Rater tests were performed on the entire project (Table 4). The Road Rater is a dynamic deflection measuring device used to determine the structural adequacy of pavements. The differences in pavement structural ratings for a given test section may be caused by the fact that annual testing is performed on the outside wheel track during the months of April and May when the roadway exhibits the poorest structural support. The structural rating can vary from one year to the next depending upon the moisture content. Figure 1 and Figure 2 show the Structural Rating and Soil K values for the annual testing.

FIELD VISUAL REVIEW

Field visual reviews have been performed on the roadway each year. By 1991 (year 3) significant differences in performance could be noted between the test sections. In 1992, even more dramatic differences occurred along the test sections. appendix C contains pictures taken during the 1992 field visual review.

Section I (HFE-300) had some chuck holes and alligator cracking in the seal coat by 1991. In the 1992 visual survey, the alligator cracking had increased. Some rutting was evident in the test section.

In 1991, Section II (BIO CAT 300-1) was noted as having substantial alligator cracking and showed signs of instability. The severity of the roadway condition led to the placement of subdrains in all areas of Section II. It was hoped the subdrains would help the road base drain and stop the deterioration of the roadway. However, in 1992 the roadway continued to deteriorate to the point that the extensive repairs were no longer acceptable to maintain the section. The deterioration was independent of the depth to which the soil base was treated with BIO CAT. The section was replaced with a Macadam base in 1992.

Section III (Consolid) also had substantial alligator cracking and signs of instability by 1991. The severity of the segment also warranted the placement of subdrains. These subdrains were hoped to help the base drain and, thereby, stop the deterioration of the roadway. However, the Consolid treated section continued to deteriorate. In 1992 the section was replaced with a Macadam base since the extensive necessary repairs were no longer acceptable.

Section IV (Macadam) appeared to be in good condition for all the visual reviews. In 1991, a few places had been patched. By 1992 some minor rutting had occurred.

PROJECT COSTS

The total cost for the project was $147,651 including materials, labor and equipment. Division I (High Float Emulsion) cost $26,163 for the 3,700 ft (1128 m). Division II (BIO CAT) cost $12,909 for the 3,300 ft (1006 m). Division III (Consolid) cost $29,241 for the 3,400 ft (1036 m). Division IV (Macadam) cost $39,225 for the 4,350 ft (1326 m). Table 5 shows the cost per mile and per kilometer for the divisions.

Table 4

	Station to Station	Base Material		1989	1990	1991	1992
Division 1	0+00 to 37+00	HFE-300	Avg. S.R.	2.05	3.63	3.4	2.94
			Avg. Soil K	125	192	180	181
Division 2A	37+00 to 48+00	6" BIO-CAT 300-1	Avg. S.R.	2.41	3.16	2.65	3.33
			Avg. Soil K	162	186	174	220
2B	48+00 to 59+00	8" BIO-CAT 300-1	Avg. S.R.	2.2	3.01	2.88	2.91
			Avg. Soil K	138	203	205	207
2C	59+00 to 70+00	10" BIO-CAT 300-1	Avg. S.R.	3.92	4.16	3.8	3.66
			Avg. Soil K	225	225+	225+	225+
Division 3	70+00 to 104+00	Consolid	Avg. S.R.	2.76	4.6	3.66	3.51
			Avg. Soil K	177	225+	212	225+
Division 4A	104+00 to 107+50	Macadam w/fabric	Avg. S.R.	1.73	1.57	1.91	1.58
			Avg. Soil K	111	72	91	116
4B	107+50 to 147+50	Macadam	Avg. S.R.	2.24	2.33	2.15	1.83
			Avg. Soil K	196	162	168	172

FIGURE 1

Annual Structural Rating Values
Horseshoe Road, Dubuque County

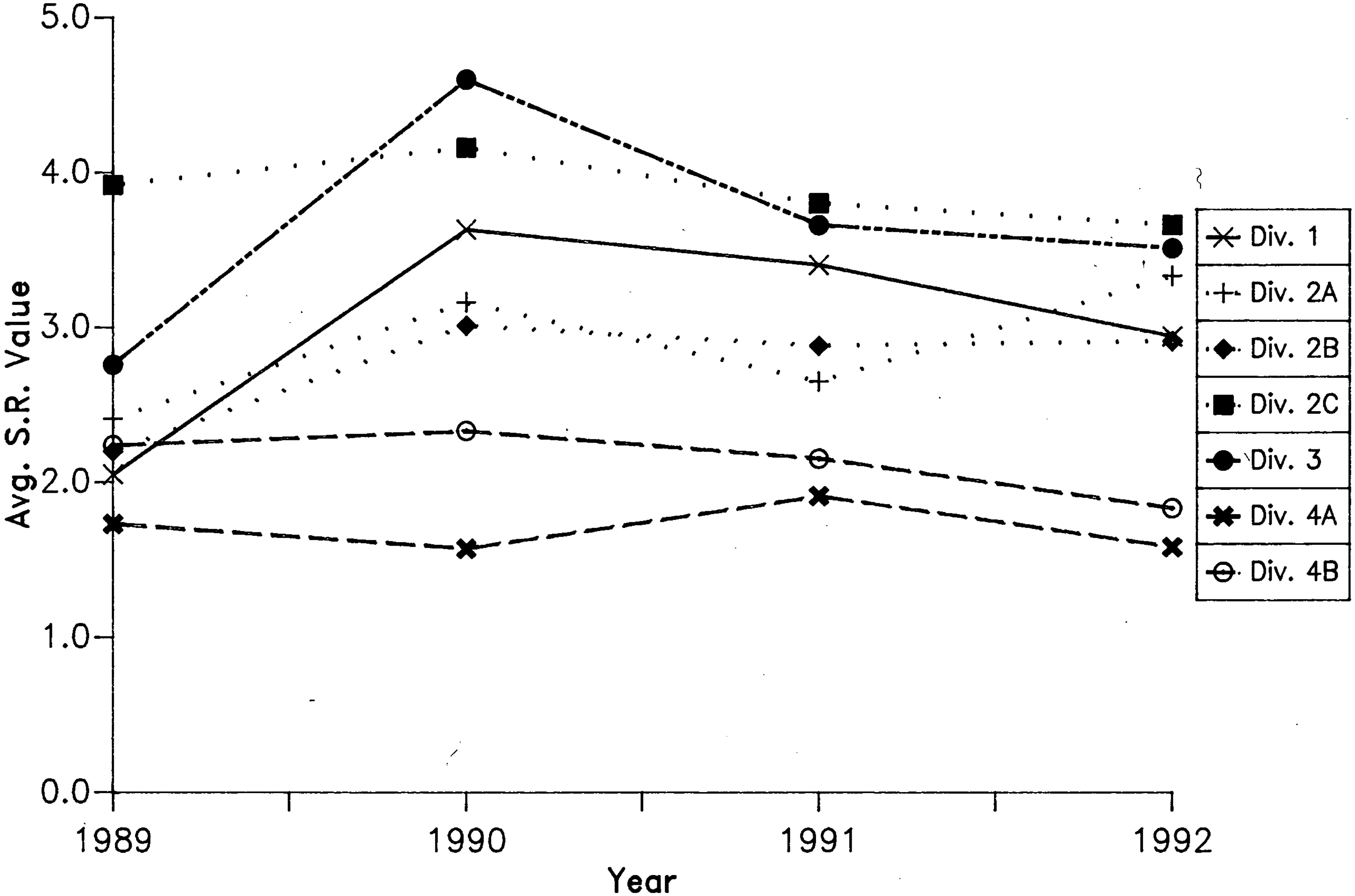
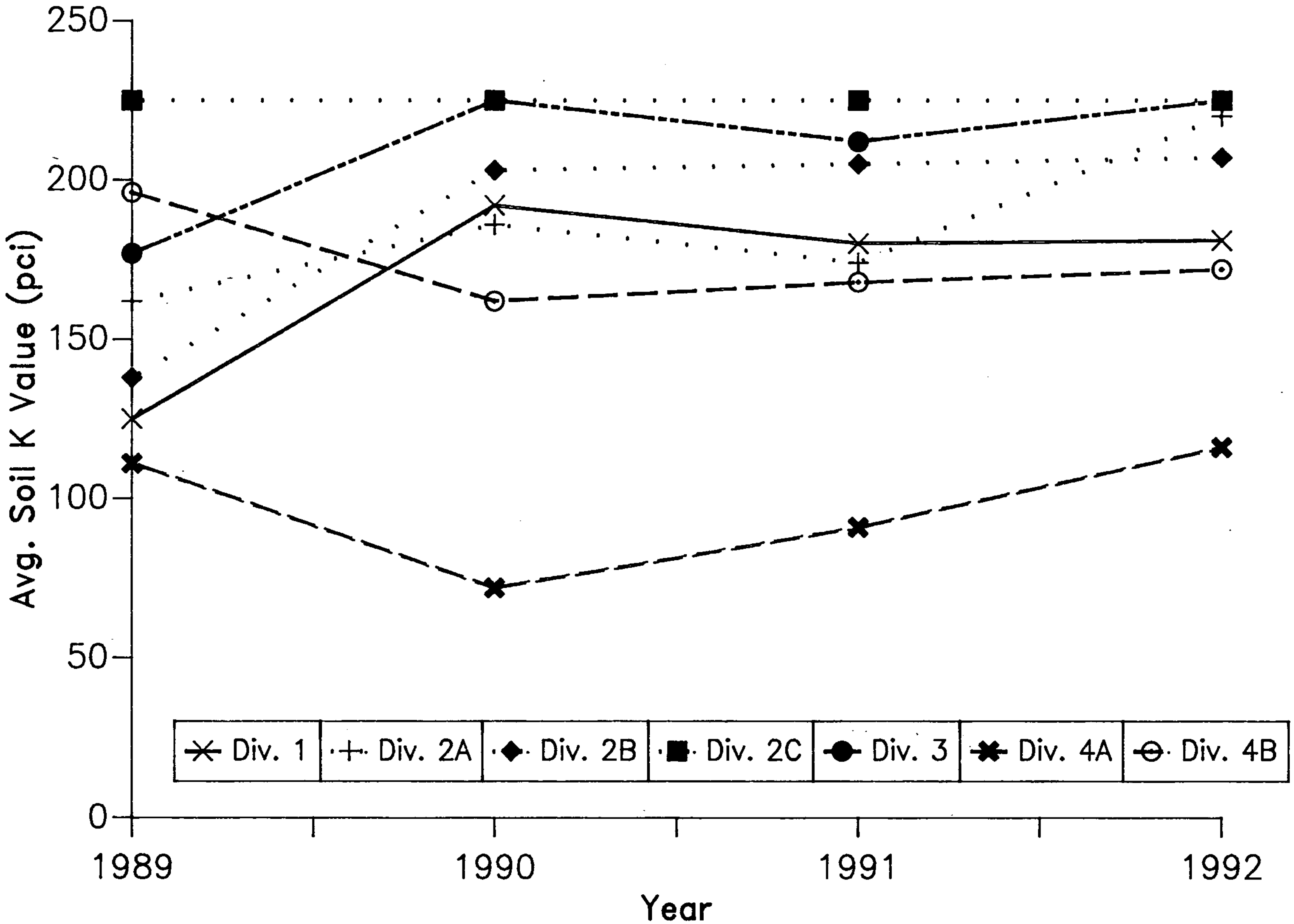


FIGURE 2

Annual Soil K Values
Horseshoe Road, Dubuque County



The seal coat for the 2.8 mi (4.5 km) cost $40,113. The roadway was sealed for a width of 28 ft (8.5 m) for the entire length of the project.

Table 5

DIVISION	$/Mile	$/km
I (Emulsion)	$37,335	$23,199
II (BIO CAT)	20,654	12,833
III (Consolid)	45,410	28,216
IV (Macadam)	47,611	29,584
All (Seal Coat)	14,326	8,902

The costs may be slightly deceiving because of the distinct variations in construction techniques. The costs are also inclusive of the variations that occur in a division. For example, the BIO CAT cost includes the 6 in. (150 mm), 8 in. (200 mm) and 10 in. (250 mm) section.

EVALUATION AND DISCUSSION

The variation in the performance of the bases indicate a problem with the BIO CAT and Consolid soil stabilization techniques. The problem with the BIO CAT and Consolid system was not structural strength or the soil modulus K. The soil stabilization methods had higher values in both measurements than the emulsion or the Macadam base.

The failure of the soil stabilization techniques was primarily alligator cracking followed by rutting as the base completely gave way to the forces of the traffic. This may have been due to freeze/thaw cycles damaging the base. The Iowa DOT evaluation MLR-87-10, "Evaluation of the Consolid System of Soil Stabilization" indicated that the method was susceptible to freeze/thaw cycles. The alligator cracking was another indicator that frost action may have caused the failure.

Additionally, the alligator cracking mode of failure made rut depth surveys impractical. Originally it was believed that a potential mode of failure would be severe rutting. Since the alligator cracks started well before rutting occurred, the rut depth survey was no longer a reasonable measure of effectiveness.

Two of the test sections had subdivisions. The Consolid section had depths of 6 in. (150 mm), 8 in. (200 mm) and 10 in. (250 mm) while the Macadam base had a standard base and a Tensar fabric reinforced base. The Consolid subsections all failed in the field visual reviews. But there was a correlation between thicker treatments and higher structural ratings and Soil K values. The Macadam had higher structural ratings and Soil K values where there was no Tensar fabric. The field reviews also indicated no noticeable difference between the sections that had and did not have the Tensar fabric.

Life cycle costs could not be calculated since two of the divisions, Macadam and high float emulsion, have not yet reached their design life. However, both of these are more cost effective than the soil stabilization techniques.

CONCLUSIONS

1. High structural ratings and soil K factors for the BIO CAT and Consolid bases did not translate to good roadway performance. Both the BIO CAT and Consolid stabilized sections failed early and had to be reconstructed.

2. The Macadam base sections had the best overall performance.

3. The Tensar fabric showed no noticeable effect on the Macadam base during the 5 years of the study.

4. The HFE-300 performed acceptably during the study period. Some minor alligator cracking did occur.

ACKNOWLEDGEMENT

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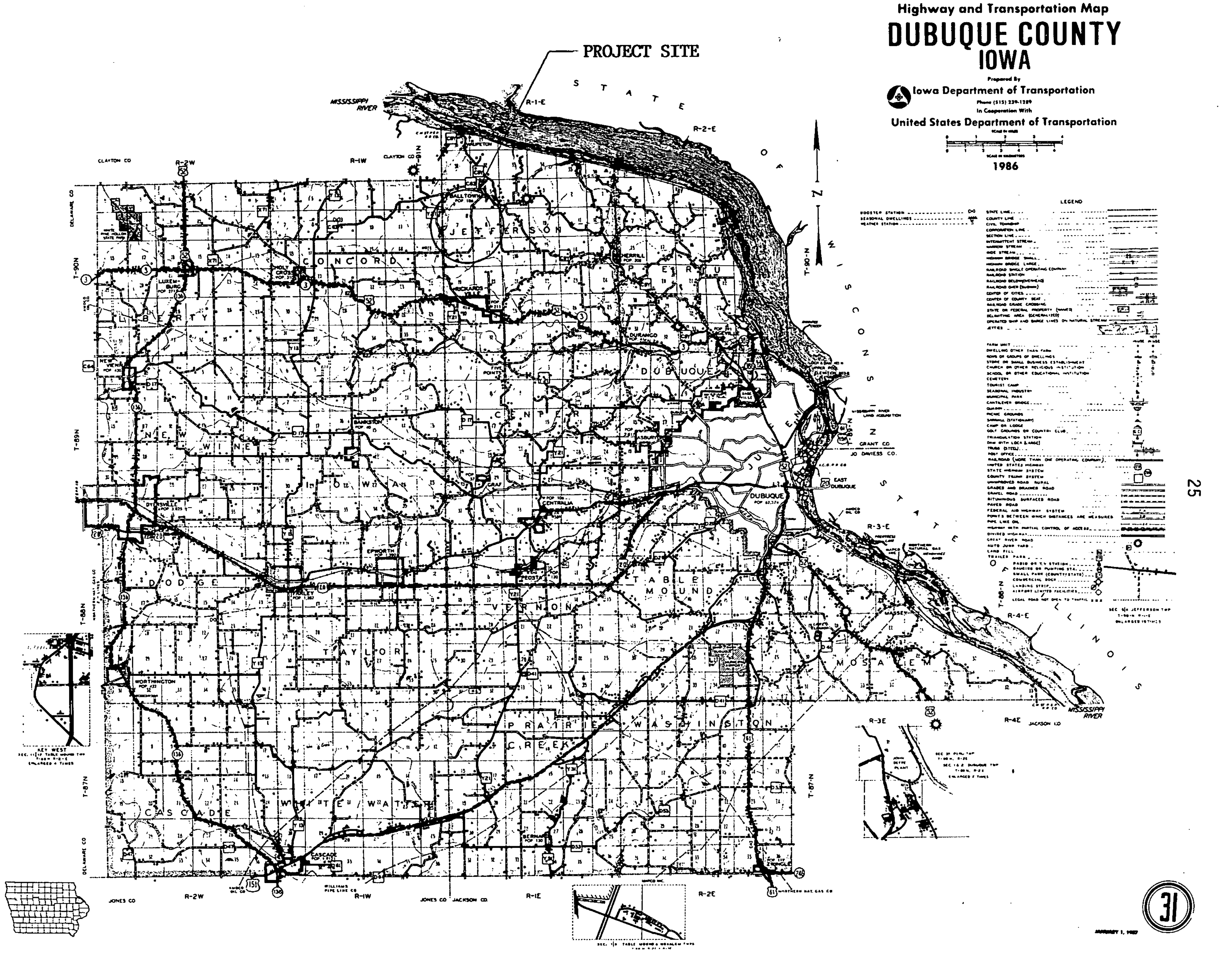
The authors wish to extend appreciation to the Dubuque County Board of Supervisors and the Iowa Department of Transportation for their support in the development and implementation of this project.

We also wish to thank David Leach with Koch Materials Company, Paul Raiford, Jr. with American Consolid, Inc., Bob Randolph with Soil Stabilization Products Company and Steve Spanagel with Contech Construction Products. These gentlemen were invaluable in their assistance with the construction techniques used on this project.

The Dubuque County crewmen who performed the innovative construction techniques also deserve recognition for the extra effort each put forth on the project.

Appendix A
Project Location Map



Highway and Transportation Map
DUBUQUE COUNTY
IOWA
Prepared By
Iowa Department of Transportation
In Cooperation With
United States Department of Transportation
1986
PROJECT SITE
LEGEND
STATE OF WISCONSIN
STATE OF ILLINOIS
MISSISSIPPI RIVER
CLAYTON CO
DELAWARE CO
JONES CO
JACKSON CO
GRANT CO
JO DAVIESS CO.
R-2W
R-1W
R-1-E
R-2-E
R-3-E
R-4-E
T-91N
T-90N
T-89N
T-88N
T-87N
JEFFERSON
CONCORD
PERU
LIBERTY
DUBUQUE
CENTER
NEW WINE
IOWA
JULIEN
DODGE
TABLE MOUND
VERNON
TAYLOR
MOSALEM
PRAIRIE CREEK
WASHINGTON
CASCADE
WHITEWATER
BALLTOWN
SHERRILL
LUXEMBURG
HOLY CROSS
RICKARDS
DURANGO
NEW VIENNA
BANKSTON
ASBURY
DYERSVILLE
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EPWORTH
PEOSTA
FARLEY
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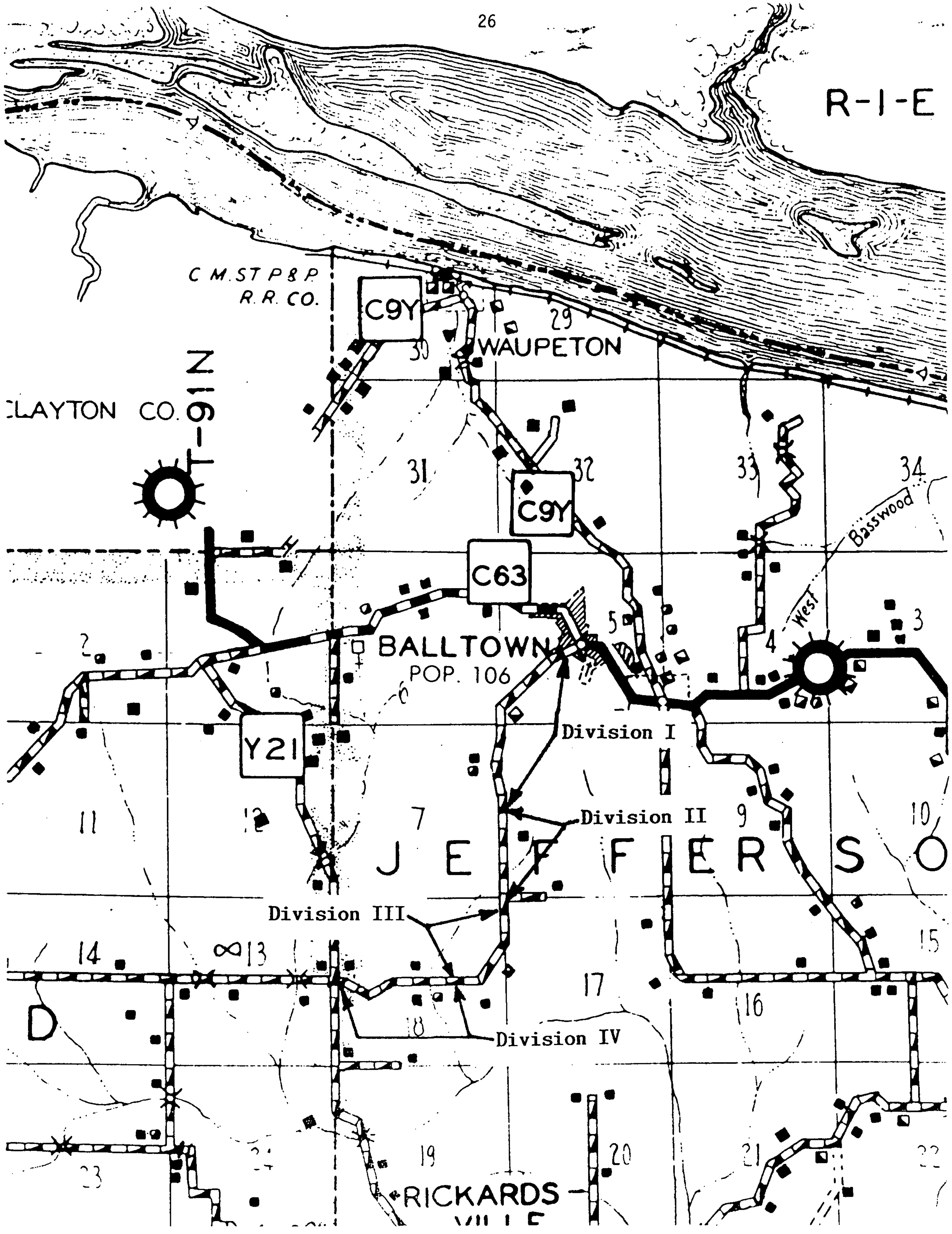
BERNARD
KEY WEST


R-I-E
C M. ST P & P.
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WAUPETON
T-91N
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33
34
Basswood
West
C9Y
C63
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BALLTOWN
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Y21
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Division II
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RICKARDS
VILLE

Appendix B
Field Testing

NUCLEAR DENSITY

DATE	STATION	LOCATION	DEPTH	DENSITY
DIVISION II			(inches)	(lb/ft^3)
9-29-88	72+00	6'R	6	116.95
			4	114.00
		5'L	6	116.05
			4	112.75
	74+00	CL	6	116.30
			4	113.00
		11'R	6	109.80
			4	109.40
		11'L	6	111.75
			4	110.60
	76+00	6'L	6	112.50
			4	105.50
		6'R	6	133.00
			4	114.00
	80+00	6'L	6	119.15
			4	117.40
		11'R	6	116.10
			4	114.35
	84+00	CL	6	121.25
			4	120.20
		6'L	6	120.80
			4	119.35
		4'R	6	123.55
			4	121.10
	86+00	8'R	6	113.05
			4	112.50
		11'L	6	119.95
			4	116.80
	88+00	6'R	6	114.00
			4	113.55
		6'L	6	121.25
			4	118.45
10-03-88	92+00	6'R	6	117.25
			4	118.75
		10'L	6	103.50
			4	106.50
	94+00	6'L	6	112.45
			4	106.45
		6'R	6	122.45
			4	122.40
	96+00	9'L	6	114.20
			4	111.70
		11'R	6	117.20
			4	115.00

NUCLEAR DENSITY

DATE	STATION	LOCATION	DEPTH	DENSITY
DIVISION II			(inches)	(lb/ft^3)
10-07-88	92+00	7'R	6	122.30
			4	117.50
		CL	6	127.50
			4	122.80
		7'L	6	123.80
			4	119.30
	94+00	9'R	6	122.00
			4	120.30
		CL	6	132.40
			4	128.30
		10'L	6	120.20
			4	117.50
	96+00	7'R	6	128.30
			4	122.70
		CL	6	131.70
			4	126.90
		7'L	6	131.70
			4	127.80
	98+00	7'R	6	115.50
			4	112.00
		LL	6	115.30
			4	107.80
		7'L	6	116.40
			4	116.10
	100+00	7'R	6	118.80
			4	118.70
		CL	6	120.10
			4	116.70
		7'L	6	119.20
			4	115.50
	102+00	9'R	6	125.20
			4	122.90
		CL	6	119.70
			4	112.60
		9'L	6	126.10
			4	122.00

NUCLEAR DENSITY

DATE	STATION	LOCATION	DEPTH (inches)	DENSITY (lb/ft^3)
DIVISION III				
10-05-88	50+00	7'R	6	122.50
			4	122.75
		CL	6	119.00
			4	117.50
		7'L	6	114.75
			4	114.50
	52+00	8'R	6	115.75
			4	116.50
		CL	6	115.50
			4	115.50
		8'L	6	116.00
			4	118.75
	54+00	7'R	6	119.25
			4	121.00
		CL	6	116.50
			4	117.75
		7'L	6	114.25
			4	112.25
	56+00	10'R	6	118.50
			4	118.25
		CL	6	115.75
			4	113.75
			6	118.50
			4	118.25
	58+00	7'R	6	116.75
			4	118.00
		CL	6	121.25
			4	121.75
		7'L	6	121.25
			4	123.50
	60+00	5'R	6	131.50
			4	130.50
		CL	6	128.50
			4	129.50
		6'L	6	129.25
			4	130.50
	62+00	10'R	6	120.75
			4	118.75
		CL	6	132.25
			4	130.75
		10'L	6	122.25
			4	122.75

NUCLEAR DENSITY

DATE	STATION	LOCATION	DEPTH	DENSITY
DIVISION III			(inches)	(lb/ft^3)
10-05-88	64+00	7'R	6	117.00
			4	116.50
		CL	6	122.00
			4	123.00
		7'L	6	125.25
			4	124.50
	66+00	10'R	6	117.50
			4	119.00
		CL	6	123.50
			4	122.00
		10'L	6	125.00
			4	125.00
		7'R	6	119.00
			4	121.50
		CL	6	125.50
			4	124.00
		7'L	6	121.75
			4	121.50

NUCLEAR DENSITY

DATE	STATION	LOCATION	DEPTH	DENSITY
DIVISION IV			(inches)	(lb/ft^3)
9-09-88	2+00	7'R	BS	132.50
	2+40	L-edge	BS	114.90
	6+00	L-edge	BS	122.60
	8+00	CL	BS	128.20
	12+00	R-edge	BS	112.80
	14+00	7'L	BS	139.70
	15+00	CL	BS	136.50
	18+00	R-edge	BS	120.90
	18+00	L-edge	BS	117.40
	20+00	CL	BS	142.50
	22+00	7'L	BS	131.30
	22+00	7'R	BS	136.70
9-14-88	2+00	7'R	2	127.10
			2	124.70
	6+00	L-edge	2	129.00
		7'L	2	135.30
	10+00	R-edge	2	127.70
		7'R	2	141.70
	14+00	7'L	2	142.00
		CL	2	136.30
	18+00	7'R	2	142.50
		CL	2	138.10
	22+00	L-edge	2	143.80
		7'L	2	145.50
	26+00	R-edge	2	130.50
		7'R	2	149.00
	30+00	L-edge	2	139.50
		7'L	2	147.00
	34+00	7'R	2	149.30
		CL	2	145.20

*1 lb/ft^3 = 16.02 kg/m^3
*1 in. = 25 mm
1 ft = 0.3 m

ROAD RATER STRUCTURAL RATING
TEST RESULTS

DATE	DIVISION	DESCRIPTION	80% SR	SOIL K
11-08-88	I	3 inch High Float Emulsion	1.55	172
	II A	10 inch BIO-CAT	1.15	170
	II B	8 inch BIO-CAT	1.22	127
	II C	6 inch BIO-CAT	1.23	172
	III	Conservex	1.39	170
	IV A	Macadam w/Fabric	1.5	161
	IV B	Macadam	2.01	222

BPR ROUGHOMETER

DATE	DIVISION	REVOLUTIONS	ROUGHNESS	ROUGHNESS* IN/MI
11-08-88				
EASTBOUND LANE	I	511	90	132
	II	465	104	168
	III	483	111	172
	IV	627	131	157
11-08-88				
WESTBOUND LANE	I	508	94	139
	II	463	101	164
	III	497	112	169
	IV	617	123	150

$$\text{*Roughness. (IN/MI)} = \frac{\text{Section Roughness} \times 750}{\text{No. Revolutions}}$$

*1in/mi = 1.577 cm/km

Appendix C
Field Visual Review Photographs
(1992)

Photo 1 - Macadam Base Section

Photo 2 - Typical Alligator Cracking and Rutting
of Soil Stabilized Base

Photo 3 - Failure of Soil Stabilized Base

Photo 4 - Typical Rutting After Seal Coat
Has Eroded Away