PAVEMENT SURFACE ON MACADAM BASE

ADAIR COUNTY

FINAL REPORT
IOWA HIGHWAY RESEARCH BOARD
PROJECT HR-209

Highway Division
Iowa Department of Transportation

Disclaimer

FINAL REPORT
IOWA HIGHWAY RESEARCH BOARD
PROJECT HR-209

PAVEMENT SURFACE ON MACADAM BASE
ADAIR COUNTY

BY

DON LYNAM, P.E.

ADAIR COUNTY ENGINEER

AND

KEVIN JONES, P.E.

OFFICE OF MATERIALS

IOWA DEPARTMENT OF TRANSPORTATION

AMES, IOWA

515-239-1382

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Research Project HR-209 was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation. Partial funding of the project was from the Secondary Road Research Fund in the amount of $100,347.

The authors wish to extend appreciation to the Adair County Board of Supervisors and the Iowa DOT for their support in developing and conducting this project. We also want to thank Central Paving Corp., Schildberg Construction Company, Inc. and Henningsen Construction, Inc. for their cooperation during the project. The Adair County inspection personnel also deserve recognition for the extra effort put forth on the project. The assistance by Pottawattamie County on this project is appreciated.

INTRODUCTION

The quality and availability of aggregate for pc concrete stone varies across Iowa. Southwest Iowa is one area of the state that is short of quality aggregates. The concrete stone generally available in the area is limestone from the Argentine or Winterset ledges with an overburden of up to 150 feet. This concrete stone is classified as Class 1 durability and is susceptible to "D"-cracking. In addition, the general engineering soil classification rates the soils of southwest Iowa as having the poorest subgrade bearing characteristics in the state.[1]

The combination of poor soils and low quality aggregate has contributed to premature deterioration of many miles of portland cement concrete pavement. Research project HR-209 was initiated in 1979 to explore alternative construction methods that may produce better pavements for southwest Iowa.

OBJECTIVES

The objectives of the research project were:

1. To determine the feasibility, economics and performance of a roadway constructed by placing portland cement concrete and asphaltic concrete on an open-graded macadam base while developing design criteria by varying the thickness of the wearing surface.

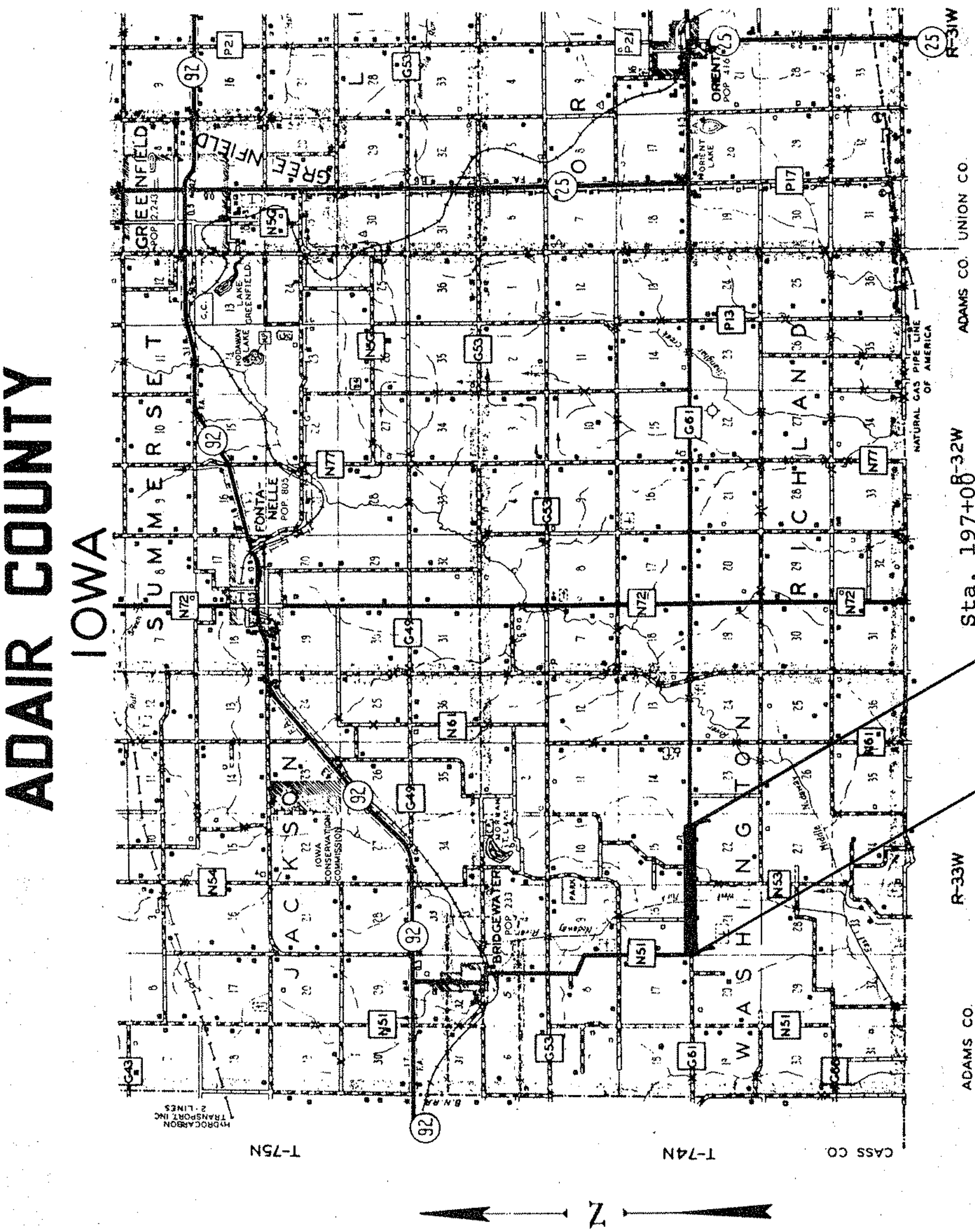
2. To determine if the macadam base is effective in reducing or eliminating the D-cracking deterioration of concrete produced with crushed limestone exhibiting poor durability.

3. To determine the effect of placing asphaltic concrete directly on the macadam base, thus eliminating the chokestone.

PROJECT LOCATION

The project is located on Adair County Road G-61, beginning three miles south of Bridgewater and extending easterly (Figure 1). This highway serves as a shortcut between two primary highways. Trucks, some on regular routes,

Figure 1 -Project Location



frequently use the highway. The average daily traffic is 150 to 200 vehicles per day. The 1999 ADT is estimated at 250 vehicles per day.

TEST SECTIONS

Seven test sections and one control section were planned and constructed. The test sections consisted of a 24-foot wide macadam stone base and a 22-foot wide surface of either pcc or ac pavement. Appendix A contains the typical cross sections. The test section layout and description is as follows:

Section 1 - Sta 100+00 to Sta. 110+00 -
2" Type "B" ac pavement over a 6" macadam stone base

Section 2 - Sta. 110+00 to Sta. 120+00-
3" Type "B" ac pavement over a 5" macadam stone base

Section 3 - Sta. 120+00 to Sta. 138+85-
4" pcc pavement (Early Chapel stone) over a 5" macadam stone base.

Section 4 - Sta. 140+82 to Sta. 160+00 -
4" pcc pavement over a 5" macadam stone base

Section 5 - Sta. 160+00 to Sta. 172+00 -
5" pcc pavement over a 5" macadam stone base

Section 6 - Sta. 172+00 to Sta. 184+00 - (Control)
6" pcc pavement on subgrade

Section 7 - Sta. 184+00 to Sta. 194+00 -
3" pcc pavement over a 6" macadam stone base

Section 8 - Sta. 194+00 to Sta. 197+00 -
2" pcc pavement over a 6" macadam stone base

MATERIALS

Materials of particular interest on this project are the macadam stone and the sources of aggregate for concrete.

Macadam Stone

The specifications for macadam stone base construction on the project were a modification of the 1977 Iowa DOT standard specification for macadam stone base (Appendix B). The requirement for the chokestone base over the macadam was deleted from the standard specification for this project. Stone size requirements for the macadam base were modified by changing from a 4-inch maximum and 1-inch minimum size to a 3-inch maximum and 3/4-inch minimum size.

Schildberg Construction Company, Inc. produced the macadam stone from the Mt. Etna Quarry in Adams County. Haul distance from the quarry to the project was thirteen miles. A typical gradation for the macadam stone was:

Sieve Size	Percentage Passing
3"	100
2"	77
1 1/2"	51
1"	23
3/4"	4.1
#8	0.6

Laboratory Yield Testing

During development of the project plans, Schildberg Construction Company, Inc. of Greenfield, Iowa, crushed a small amount of stone from their Mt. Etna quarry for laboratory testing. Without the use of a chokestone layer between the macadam stone base and the surface course, intrusion of some surface course material into the base was a certainty. To determine the amount of intrusion, macadam stone was placed in a soils ring and consolidated with a vibrator (Figure 2). Fresh concrete was then placed over the macadam stone. From this testing, it was estimated that an additional 4.07 cubic yards of additional 4.07 cubic yards of concrete per station would be required to allow for penetration of concrete into the base and still achieve the desired pavement thickness over the base.

Asphaltic concrete intrusion into the base course was arbitrarily set at one-half that of concrete (4.12 tons of asphaltic concrete per station). The design weight determined for compacted macadam stone base was 135 pounds per cubic foot.

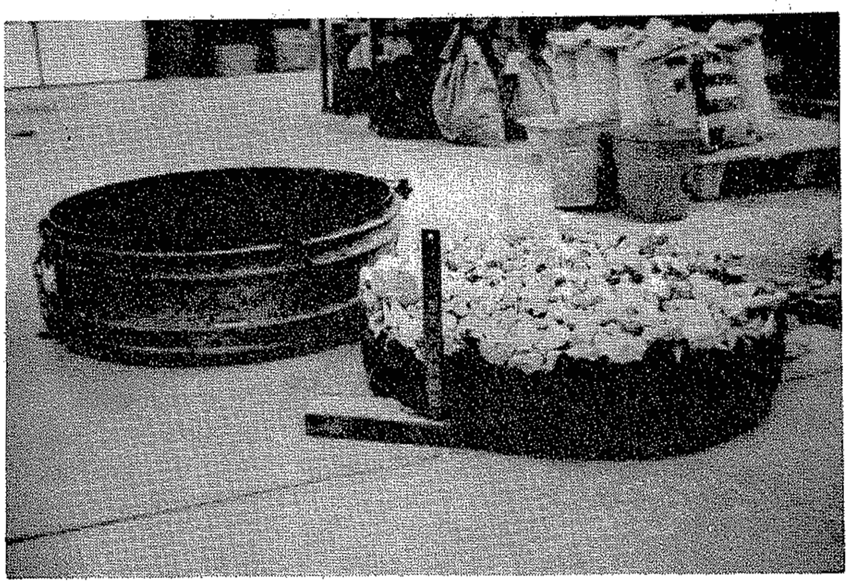


Figure 2 - Laboratory Test Specimen

Concrete Aggregates

Two sources of coarse aggregate were used for the pcc pavement. The project specifications allowed for the use of Class 1 durability concrete stone. Iowa DOT durability classes for concrete stone range from 1 to 3 with Class 3 being the most durable aggregate. Class 1 durability aggregates are those associated with a durability factor of 79 (ASTM C666 Method B) or less when sufficient performance records are not available. Class 1 coarse aggregate cannot be used in portland cement concrete pavement on the primary highway system.

The majority of the pcc pavement on the project was constructed using Class 1 limestone from the Argentine ledge of Schildberg's Menlo quarry in Adair County. Haul distance from the quarry to the project was 30.5 miles.

Test section number 3 was constructed using Class 1 limestone associated with pcc pavements highly susceptible to D-cracking. The aggregate was from the Winterset ledge of Gendler Limestone Company's Early Chapel quarry in Madison County. Portland cement concrete pavement using Early Chapel stone was listed as a bid item. Haul distance was 38 miles from the Early Chapel quarry to the project.

Sand for both concrete mixes was hauled 38 miles from G.A. Finley's plant at Brayton in Cass County. Concrete mix proportions are in Appendix C.

CONSTRUCTION

Central Paving Corporation of Indianola, Iowa, was the successful bidder for the project. The contract is in Appendix D. Normally, the bid item for pcc pavement includes furnishing and placing and is listed as square yards of pavement. On this project, two bid items for pcc pavement were listed for those test sections placed on macadam base, one for furnishing pc concrete measured in cubic yards and another for concrete placement measured in square yards. The effect of the two bid items was to eliminate the need for the contractor to figure concrete overrun due to loss of concrete into the macadam base.

The roadway had been graded in the fall of 1978 under a separate contract. The subgrade crown was built to a 4 percent slope. Bridge construction on the project kept the road closed through the spring of 1979.

Macadam Stone Base Construction

Base construction began on September 18, 1979. A ten-foot wide Jersey spreader powered by a D8 Caterpillar placed the stone 24 feet wide in two passes (Figure 3). Spreading the macadam stone 12 feet in width with a 10-foot spreader caused some minor segregation along the centerline of the base. The base was placed to a 2 percent crown. Consolidation of the base was by a Hyster vibratory roller.

Initial construction efforts demonstrated that the macadam stone base could not be consolidated at the edges without being confined. On subsequent sections, soil was placed next to the base edge and consolidation proceeded satisfactorily (Figure 4).

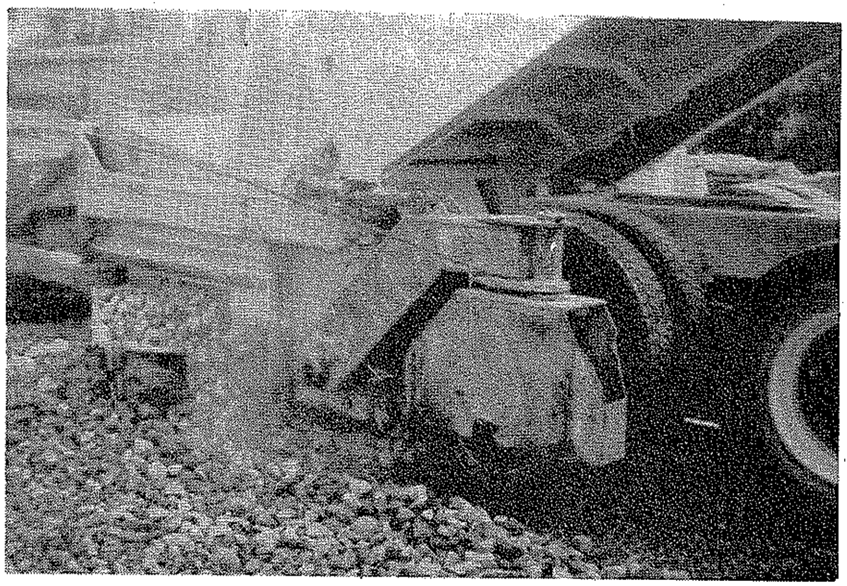


Figure 3 - Placement of Macadam Stone

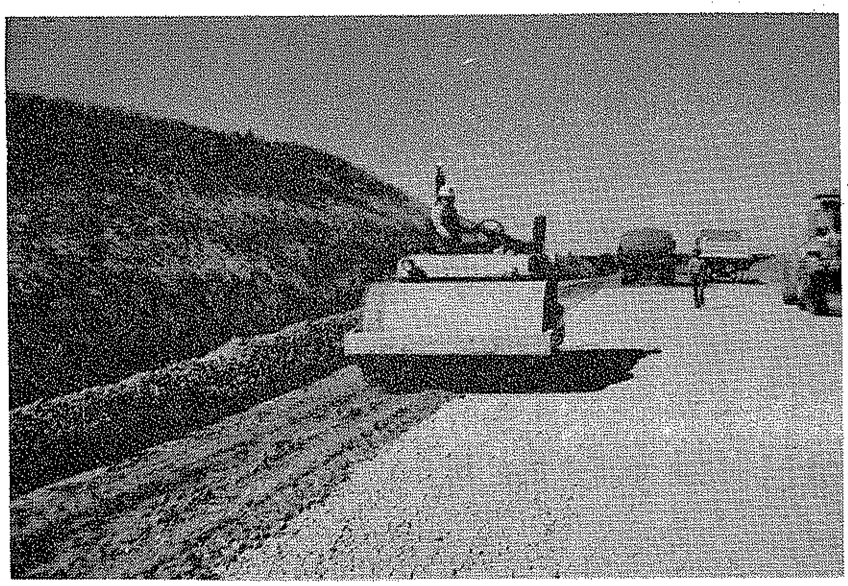


Figure 4 - Consolidation of Macadam Stone

PCC Pavement Construction

On the second day of construction, the pcc paving operation began in conjunction with the base construction. Paving began on the 2-inch and 3-inch thick test sections (sections 7 and 8) and though the macadam stone was damp, the stone drew moisture from the fresh concrete. The loss of moisture from the concrete caused finishing problems for the contractor. To avoid further difficulty, the macadam stone was continually wetted during both base consolidation and paving. This allowed for easier consolidation of the base and prevented the stone from absorbing water, minimizing loss of slump in the fresh concrete.

Only minor problems were encountered during the rest of the paving. One difficulty was the placement of the transition segments between the 6-inch thick pavement sections and the 2- and 3-inch thick pavement sections. The paver could not adequately adjust uniformly from 6 inches to 2 inches and again from 3 inches back to 6 inches. Also, on 2- and 3-inch sections, the trailing forms of the paver had to be raised up from the base to prevent them from gouging into the macadam. This allowed a small amount of concrete to flow beneath the forms.

The pcc paving was completed on September 24, 1979. All joints in the test sections were cut to a depth of 1/4 the pavement thickness. The contraction joints were cut on a 6 to 1 skew right-ahead from the perpendicular direction. The contraction joint interval was 20 feet for the 5- and 6-inch sections and 15 feet for the 2-, 3- and 4-inch sections.

Table 1 lists design quantities and actual quantities used for the pcc pavement test sections. It is interesting that the concrete yields listed in Table 1 show that 6 inches of pcc pavement on grade is only about 0.75 inches greater than the equivalent average depths of the 4-inch sections, and the 5-inch section equivalent depth is equal to the 6 inches on grade.

AC Pavement Construction

The 2000 feet of asphaltic concrete paving was sublet to Henningsen Construction, Inc. of Atlantic, Iowa. Because of the small quantity, material was hauled 30 miles from a plant in Pottawattamie County on a different project. The mix was a 1/2 inch Type B Class 1 asphaltic concrete base mix.

The macadam stone base sections 1 and 2 received a prime coat at the rate of 0.30 gallon per square yard on September 26. Due to difficulties with the asphalt plant, paving was delayed until September 29. A Blaw Knox PR 400 single-lane paver was used to place the surface. Section 1 was placed in a single 2-inch lift. Section 2 was placed in two 1 1/2-inch lifts. No difficulty was experienced during the asphalt construction.

The densities for section 1 averaged 93.6 percent of Marshall density and the densities for section 2 averaged 94.1 percent of Marshall density. Despite the densities below the specified minimum of 94% on section 1, the five densities of the one day production met minimum density requirements based on the quality index formula:

$$\text{Quality Index} = \frac{\text{Ave. Density - (Specified Density - 1.0}}{\text{Highest Density - Lowest Density}}$$

When the quality index is above 0.36 based on five samples, no corrective action is required by the contractor.

Table 2 lists design quantities and actual quantities used for the ac pavement test sections. For the asphaltic concrete yields listed in Table 2, average pavement thickness for pavement on subgrade would be about 2.4 inches for 33.5 tons of base per station and 3.6 inches for 49.6 tons of base per station.

TABLE 1
PC CONCRETE QUANTITIES

Section Number	Design Thickness Nominal (in.)	Allowance for Conc. Pen. (cy/sta.)	Additional Overrun/ (Underrun) (cy/sta.)	Conc. Yield (cy/sta.)	Equiv. Pavement Thickness (in.)
3	4	4.07	4.90	36.1	5.32
4	4	4.07	4.28	35.5	5.23
5	5	4.07	2.81	40.8	6.01
6	6	-	-	40.7*	6*
7	3	4.07	(1.82)	22.8	3.36
8	2	3.40	0.98	18.0	2.65

*Estimated

TABLE 2
ASPHALTIC CONCRETE QUANTITIES

Section Number	Design Thickness Nominal (in.)	Allowance for ACC Pen. (Tons/Sta.)	Additional Overrun (Tons/Sta.)	ACC Yield (Tons/Sta.)	Equiv. Pavement Thickness (in.)
1	2	4.12	1.9	33.5	2.4
2	3	4.12	4.3	49.6	3.6

Shoulder Construction

Shoulder construction began November 2. During the operation, several areas of pavement in section 8 and a few areas in section 7 cracked near the edges. The contractor cut out and replaced the damaged pavement at no charge.

To allow the macadam base to function properly, drainage was provided through the shoulder at the vertical sag areas and at change of test section areas. The shoulder at these locations consisted of full depth open-graded stone. Table 3 lists the locations.

TABLE 3
Shoulder Drain Locations

Station	-	Direction from C/L
100+00 - 102+00		Rt.
100+80 - 102+80		Lt.
132+00 - 138+85		Lt. & Rt.
145+00 - 153+00		Lt. & Rt.
170+00 - 172+00		Lt. & Rt.
184+00 - 186+00		Lt. & Rt.
194+00 - 197+00		Lt. & Rt.

From station 145+00 to 153+00, the vertical sag area of section 4, macadam stone was to be placed as the shoulder. When the temporary earth shoulders were removed, the macadam stone base released a steady stream of water for two days (Figure 5).

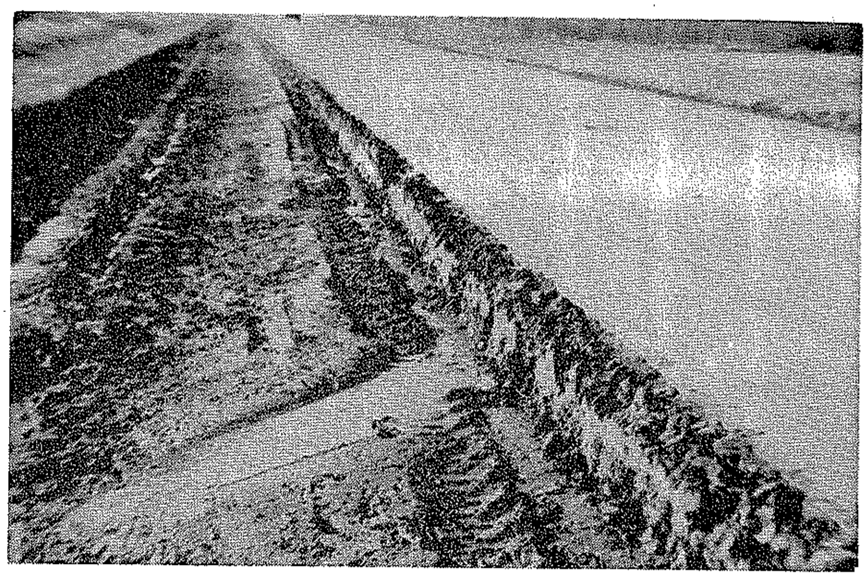


Figure 5 - Drainage from Macadam Base

All other locations for drainage were constructed with Class "D" stone. Gradation limits for the stone were:

Sieve Size	Percent Passing
2"	100
3/4"	20
#8	10

The remainder of the research project was shouldered with 3/4" crushed stone.

EVALUATION

The four-year evaluation of the research project has consisted of:

1. Crack and Rut Depth Survey
2 Joint "D"-Cracking and Faulting Survey
3. Road Rater Testing

Crack and Rut Depth Survey

Results of the annual crack and rut depth survey are in Appendix E. During the development of the project, certain pavement sections were designed with less structure than that suggested by design formulas based on 20-year service life performance. Sections 7 and 8 (3-inch and 2-inch pcc pavement over 6 inches of macadam base) showed signs of distress in the form of longitudinal quarter point cracking and areas of concrete break-up after the first winter. In the fall of 1981, sections 7 and 8 were resurfaced with ac concrete and evaluation was discontinued.

Similarly, section 1 (2 inches of ac concrete over 6 inches of macadam base) began to show distress the first year of service. Distress in the section consisted of ruts in the wheel paths and isolated break-ups of the pavement surface in the wheel paths. Section 1 was also resurfaced in the fall of 1981 and evaluation was discontinued.

The remaining five test sections have experienced only minor distress. Section 2 (3 inches of ac pavement over 5 inches of macadam base) exhibits typical thermal cracking and minor rutting in the wheel paths. The 4-inch pcc pavement sections have experienced both transverse cracking and longitudinal quarter point cracking. Approximately 200 square feet of the 4-inch thick sections need patching after 5 years service.

Joint "D"-Cracking and Faulting Survey

The main objective of the research project was to examine the effect of macadam stone base on "D"-cracking and joint faulting of pcc pavement. As one would expect, no "D"-cracking has appeared on any test section or the control section. No joint faulting has been observed on the project.

Road Rater Testing

Results of the annual Road Rater testing are in Appendix F. Recent experimentation with the Road Rater has led to a method for determination of a structural rating and a modulus of subgrade reaction for a pcc pavement structure. The structural values for the sections are in Table 4.

TABLE 4
Structural Values from Road Rater
(1984)

Section No.	Average Thickness	Subgrade	Subgrade Modulus	Structural Rating
2	3.6"	5" Macadam	85	1.7
3 & 4	5.3"	5" Macadam	50	2.1
5	6.0"	5" Macadam	80	2.5
6 & Control	6.0"	Natural	55	2.2

The modulus of subgrade reaction is similar for all sections indicating that the macadam base is being measured by the Road Rater as structure. Comparing structural ratings from Section 3, 4 and 5 with 6-inch pcc pavement on natural subgrade, the structural rating for 5 inches of macadam is approximately 0.16 to 0.30.

DISCUSSION

The main goals of this research project were:

1. To determine the structural design criteria for pcc pavement and ac pavement over macadam stone base.

2. To determine the economics of macadam stone base under pcc pavements of Class 1 durability stone.

Structural Design Criteria

Road Rater testing on the pcc pavement does show that macadam base adds structural rating to the roadway structure. However, the added structural rating from the 5 inches of macadam base is equivilant to about 1/2 to 3/4 inches of pc concrete. The macadam stone base is serving mostly to keep excess moisture from the pc concrete and to drain excess moisture away from the subgrade. A thickness of 3 1/2 to 4 inches of macadam base would possibly serve the purpose at a lower cost. Asphalt treating the macadam stone could be of additional benefit for stability of the base.

The poor performance of the 2- and 3-inch pcc pavements over macadam and Road Rater testing have shown that no large decrease in pavement thickness can be realized by using a 5-inch macadam base. A 5 1/2-inch pcc pavement over macadam is the minimum section that will provide a 20-year life for this roadway.

Analysis of the ac concrete sections over macadam stone is more difficult. A traffic determination for this road estimates four equivilant 18-kip axle loads per day for the 20-year design life. According to flexible pavement design procedure, the structural number required is about 2.4.[2] The current structural rating determined by the Road Rater is 1.7 for Section 2. Sections 1 and 2 are apparently under designed for a 20-year pavement life.

The early failure of the 2-inch ac pavement section can be attributed to inadequate load distribution to the subgrade. Performance of the 3-inch section is still satisfactory with only moderate wheel path rutting and breakup and normal thermal cracking. It is unlikely, however, that this section will continue to perform many more years without an additional overlay.

of asphaltic concrete.

The lack of significant structural rating for the macadam base is discouraging. A research project constructed in northeast Iowa in 1980[3] has exhibited high structural ratings for an ac concrete over macadam stone. The macadam stone base sections with and without asphalt emulsion treating and a 2- or 3-inch ac concrete wearing course are structurally equal to or superior to 2 inches of ac concrete over 6 inches of asphalt treated base.

Economics

The cost breakdown for the research sections is in Table 5.

TABLE 5
PROJECT COSTS
(Contract Prices - per mile basis)

Section No.	Design Information	Section Cost Per Mile
5	5" PCC Pavement - 5" Macadam Base	$147,920
3 & 4	4" PCC Pavement - 5" Macadam Base	136,040
2	3" AC Pavement - 5" Macadam Base	125,990
6	6" PCC Pavement	122,520
7	3" PCC Pavement - 6" Macadam Base	110,180
2	2" PCC Pavement - 6" Macadam Base	98,780
1	2" AC Pavement - 6" Macadam Base	98,290

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

The major potential economic benefit of macadam stone on this project is to preserve the concrete containing poor, Class 1 durability aggregate from D-cracking. D-cracking is attributed to freeze-thaw action of water absorbed into the limestone aggregate. The macadam stone should drain away water and keep the pavement relatively dry. Five years is too soon to identify the effects of D-cracking either on the test sections or the control sections.

The common alternatives to pcc pavement over macadam stone are pcc pavement with Class 2 durability aggregate or full depth ac pavement. Class 2 durability aggregate for pcc pavement is not readily available in Southwest Iowa and must be hauled from Northwest Iowa or from outside the state. There are sources of aggregate in Southwest Iowa which do meet quality specification for asphaltic concrete construction.

For macadam base construction to be competitive with other alternatives, the project must be close to the quarry. Trucking costs of 10 to 15 cents per ton-mile quickly increase the macadam base cost with increased haul distance. Generally, with today's energy costs, 10 to 20 miles of haul is considered maximum for Iowa.

CONCLUSIONS

From the observations made and data collected to date, the following conclusions can be made:

1. Macadam stone base can be quickly and easily constructed using readily available construction equipment.
2. Significant allowance should be made for material overruns when placing either pcc or ac pavement on macadam without chokestone (215 cy per mile for pcc and 215 tons per mile for ac).
3. The quarry must be in close proximity to the project (within 10 to 20 miles) for macadam stone base to be economically practical.
4. Provisions must be made to drain water from the macadam base to the ditches at low points in the roadway.
5. Five to six inches of macadam stone base did provide some structural support on this project; however, the main function of macadam stone is to allow water to easily drain away from the roadway.

RECOMMENDATION

The major objective of the project was to determine the effect of macadam stone base on D-cracking susceptible pcc pavement. Annual evaluation of the project should continue for an additional 5 years to determine the effects of macadam stone base.

REFERENCES

1. D. A. Anderson, T. L. Welp, An Engineering Report on the Soils, Geology, Terrain and Climate of Iowa, Iowa State Highway Commission, Ames, 1960.

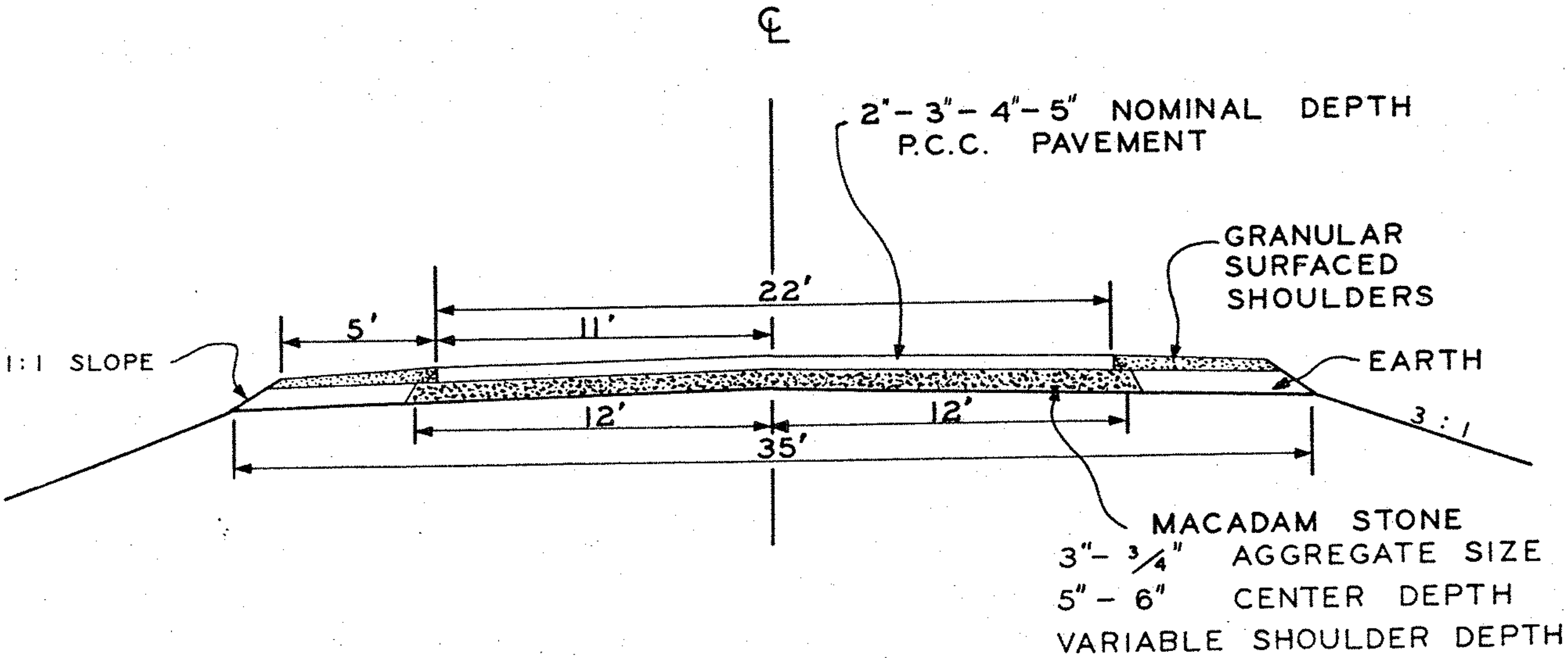
2. H. B. McPhail, Guide for Primary and Interstate Road Pavement Design, Iowa Department of Transportation, Ames, Revised 1976.

3. C. Baule, K. Jones, Unpublished evaluation results of IHRB project HR-216, "Emulsion Treated Macadam Base".

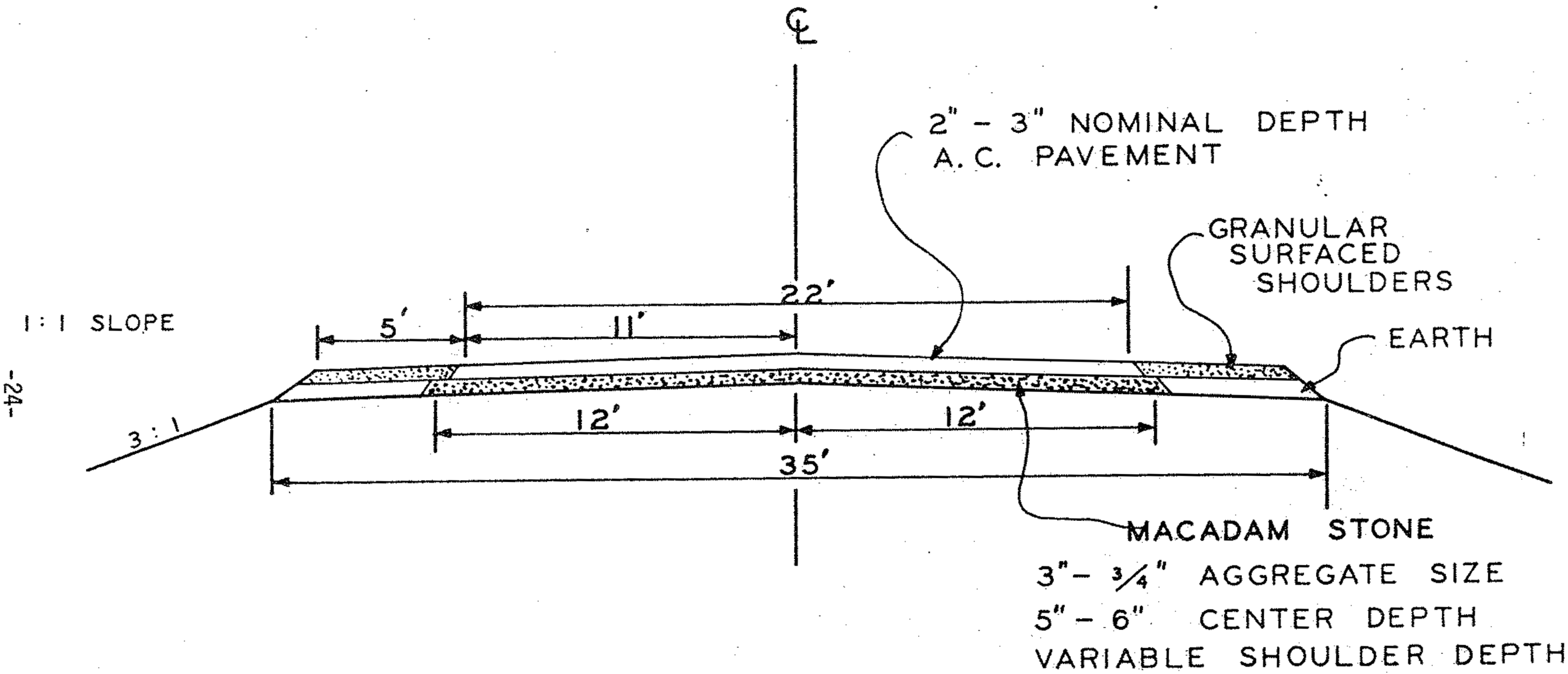
APPENDIX A

TYPICAL CROSS SECTION

ADAIR COUNTY



ADAIR COUNTY



APPENDIX B

MODIFIED SPECIFICATION FOR MACADAM STONE BASE CONSTRUCTION

Section 2210. Macadam Stone Base

2210.01 GENERAL. This work shall involve preparing the subgrade, furnishing, placing, and compacting a Macadam base course and a choke stone base course, and applying a prime to the finished work, all as required by the plans and these specifications.

2210.02 PREPARATION OF THE SUBGRADE. The subgrade shall be corrected and constructed with provision for a filter course as required by the plans. Macadam stone base is not to be constructed on raw soil subgrade.

2210.03 MACADAM STONE BASE. The Macadam stone base shall consist of crushed stone placed on the prepared subgrade and thoroughly compacted, all in accordance with the plans and these specifications.

A. Materials. Aggregate shall meet requirements of 4122.02.

B. Equipment shall meet requirements of 2001.01 and the following:

1. *Weighing Equipment.* Article 2001.07 shall apply.
2. *Compaction Equipment.* Paragraph 2001.05F shall apply.
3. *Spreading Equipment* shall be capable of uniformly spreading base material to the required thickness.
4. *Motor Patrols.* Article 2001.15 shall apply.

C. Construction. Macadam stone base shall be constructed on the corrected subgrade in accordance with the following.

1. *Spreading Base Material.* Base material shall be spread to such width and depth that the base will conform to the desired profile and cross section. The maximum compacted thickness of base material which may be spread for compaction as a single course will be limited to that which will be uniformly and satisfactorily compacted for the full depth of such course by the compaction equipment employed.

   The spreading shall be done in such a way that uniformity of the base material is maintained. When a spreader does not spread to the full design width in one operation, the engineer may require special handling of the center joint to avoid segregation.
2. *Compaction.* Promptly after the material has been spread, it shall be thoroughly and uniformly compacted. Compaction shall continue until the base material is well seated.

D. Fillets for Intersecting Roads, Drives, and Turnouts shall be constructed in accordance with the plans and these specifications.

E. Maintenance of Completed Base. Paragraph 2205.12M shall apply.

2210.04 CHOKE STONE BASE. The choke stone base shall consist of crushed stone placed on the Macadam stone base and thoroughly compacted and primed with a bituminous primer, all in accordance with the plans and these specifications.

A. Materials. Aggregate shall meet requirements of 4122.02.

Primer bitumen shall be MC-70 meeting requirements of Section 4138.

B. Equipment shall meet requirements of 2001.01 and the following:

1. *Weighing Equipment.* Article 2001.07 shall apply.
2. *Compaction Equipment.* Paragraph 2001.05F shall apply; in addition, a smooth-faced, steel-tired roller, meeting requirements of 2001.05B, will be required for the final rolling.
3. *Equipment for Cleaning the Base.* Article 2001.14 shall apply.
4. *Equipment for Heating the Bitumen.* Article 2001.11 shall apply.
5. *Equipment for Distributing Bitumen.* Article 2001.12 shall apply.
6. *Equipment for Applying Water.* Article 2001.09 shall apply.
7. *Prewetting Equipment.* Paragraph 2001.08A shall apply if prewetting is done.
8. *Spreading Equipment* shall be capable of uniformly spreading base material to the required thickness.
9. *Motor Patrols.* Article 2001.15 shall apply.

C. Construction. Choke stone base shall be constructed on the Macadam stone base in accordance with the following requirements:

1. *Delivery of Base Material.* The material may be prewetted before delivery to the Macadam stone base. The engineer may control the rate of delivery of material to reduce the time material will remain on the base in an uncompacted condition to the practical minimum.
2. *Moisture Content.* If the material is prewetted before delivery, or if water is added after delivery to the base, water shall be uniformly distributed throughout the material so that all particles are uniformly wet. The amount of water shall be within 2.0 percentage points of the amount determined as field optimum to produce maximum density together with stability with the field compaction procedure. This moisture content will usually be 85 to 90 percent of the optimum determined according to Laboratory Test Method 103. This moisture content shall be maintained in the material until compaction of the base has been completed.
3. *Spreading Aggregate.* Paragraph 2210.03C1 shall apply.
4. *Compaction.* Promptly after the material has been spread, it shall be thoroughly and uniformly compacted by three passes of a vibratory roller meeting requirements of 2001.05F. During the compaction process, such wetting, shaping, and edge trimming shall be performed as may be necessary to insure proper compaction and to achieve the required profile, crown, cross section, and edge alignment. An additional final rolling with a smooth-faced, steel-tired roller will be required. The finished surface of the base shall be free from irregularities and loose material and shall have a smooth-riding surface.

D. Fillets for Intersecting Roads, Drives, and Turnouts shall be constructed in accordance with the plans and these specifications.

E. Priming Base Course and Subgrade. Article 2205.14 shall apply to priming of the base course and the adjacent subgrade.

F. Maintenance of Completed Base. Paragraph 2205.12M shall apply.

G. Winter Seal. Article 2205.15 shall apply.

DELETE

-27-

4122.02 MACADAM STONE BASE MATERIAL. This aggregate 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.

DELETE

C. Gradation. The aggregate for both base course and choke stone course shall be produced from the same source by an impact breaker primary crusher, both a product of that operation. The grates or breaker bars shall be adjusted to produce a nominal maximum size of 4 inches, and the product of the primary crusher shall be screened over a 1-inch screen. The aggregate retained on the 1-inch screen shall be furnished as the Macadam base course material.

The aggregate passing the 1-inch screen shall be furnished as the choke stone course material; however, additional restrictions may be placed on this material.

Add:

C. Gradation. The aggregate for the base shall be produced by an impact breaker primary crusher. 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.

APPENDIX C

PC CONCRETE MIX DESIGNS

PC CONCRETE MIX DESIGNS

Mix No. B-6

MENLO QUARRY STONE

	lbs./cu yd
Cement	523
Sand	1806
Rock	1204
Water	281

EARLY CHAPEL QUARRY STONE

	lbs./cu yd
Cement	523
Sand	1806
Rock	1186
Water	281

APPENDIX D

PROJECT CONTRACT

FORM 650019 8-77 H-3878

CONTRACT

NO. 16490

TYPE OF WORK PORT. CEMENT CONC. PAV'T. PROJECT NO. SN-6085(4)--51-01

MILES 4.888 COST CENTER 801000 OBJECT 860

COUNTY ADAIR

ON SECONDARY ROAD G61 FROM NW COR. SEC. 21-74-33

EAST APPROX. 5 MILES TO COUNTY ROAD JCT N72

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

PARTY OF THE FIRST PART, AND

CENTRAL PAVING CORPORATION OF INDIANOLA, IOWA 07150

PARTY OF THE SECOND PART

WITNESSETH, THAT THE PARTY OF THE SECOND PART, FOR AND IN CONSIDERATION OF $ ****603,008.92 , 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
1	PAVEMENT, SLIP FORM P. C. CONC. CLASS B, 6 IN.	43,402	SQ. YDS.	7.76	336,799.52
2	SHOULDER CONSTRUCTION, EARTH	516	STAS.	30.00	15,480.00
3	REMOVAL OF PAVEMENT	79	SQ. YDS.	3.00	237.00
4	SHOULDERS, GRANULAR SURFACING OF	4,609	TONS	7.12	32,816.08
5	BASE, TYPE B CLASS 1 ASPHALT CEMENT CONCRETE	813	TONS	28.60	23,251.80
6	PRIMER OR TACK-COAT BITUMEN	1,855	GALS.	.90	1,669.50
7	ASPHALT CEMENT	49	TONS	165.00	8,085.00
8	BASE, MACADAM STONE	6,689	TONS	7.06	47,224.34
9	BACKFILL, SPECIAL	488	TONS	9.56	4,665.28
10	P.C. CONCRETE, CLASS B, EARLY CHAPEL AGGREGATE, FURN. & DELIVER	722	CU. YDS.	45.00	32,490.00
11	P.C. CONCRETE, CLASS B, FURNISH & DELIVER	1,360	CU. YDS.	45.00	61,200.00
12	SLIPFORM, P.C. CONCRETE PAVEMENT PLACEMENT	15,409	SQ. YDS.	2.00	30,818.00
13	EXCAVATION, CLASS 10, ROADWAY & BORROW	150	CU. YDS.	3.00	450.00
14	BRIDGE APPROACH SECTION REINFORCED AS PER PLAN	195.560	SQ. YDS.	40.00	7,822.40
				GRAND TOTAL	$603,008.92

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 12, 1979

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-6085(4)--51-01 , 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
40 WORKING DAYS	NOV. 2, 1979

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 1 DAY OF August 19 79

COUNTY OF ADAIR, IOWA

BY

CENTRAL PAVING CORPORATION OF INDIANOLA, IOWA

BY

C.

Approved:

6 1979
Date

IOWA DEPT. OF TRANSPORTATION

APPENDIX E

CRACK AND RUT DEPTH SURVEY

CRACK SURVEY

(FT./STA.)

Section Number	Aug. 1980		Aug. 1981		Aug. 1982		July 1983	
	Long	Trans	Long	Trans	Long	Trans	Long	Trans
2	0	0	0	0	0	36.8	0	36.8
3	2.1	6.4	3.4	6.9	4.2	8.3	5.4	9.0
4	5.5	0	11.4	1.1	21.4	1.6	26.0	1.9
5	3.3	0	4.5	0	5.3	0	5.7	0
6	0	0	0.7	0	1.6	0	2.4	0

RUT DEPTH SURVEY

(IN.)

	Location	Aug. 1980	Aug. 1981	Aug. 1982	July 1983
Section 1	N. Out W.P.	0.16	0.24	-	-
	N. In W.P.	0.08	0.11	-	-
	S. In W.P.	0.09	0.14	-	-
	S. Out W.P.	0.18	0.28	-	-
Section 2	N. Out W.P.	0.08	0.10	0.18	0.19
	N. In W.P.	0.08	0.09	0.16	0.16
	S. In W.P.	0.03	0.06	0.13	0.12
	S. Out W.P.	0.05	0.09	0.14	0.15

APPENDIX F

ROAD RATER TESTING

ROAD RATER TESTING

			Mils of Deflection					
			On Grade	On Paving				
Section	Station	Description	09/13/79	11/15/79	05/22/80	05/10/82	05/26/83	05/14/84
1	100 - 110	2" Type B AC Over 6" Macadam Base	5.0	3.1	4.8	5.7*	4.5	4.2
2	110 - 120	3" Type B AC Over 5" Macadam Base	5.4	2.25	4.0	6.0	5.1	4.6
3	120 - 138	4" PCC over 5" Macadam Base (Early)	5.7	1.3	1.46	2.1	3.0[a]	3.4[a]
4	140 - 160	4" PCC over 5" Macadam Base	4.1	1.1	1.4	1.6	2.9[a]	2.9[a]
5	160 - 172	5" PCC over 5" Macadam Base	4.8	1.35	1.2	1.5	2.4[a]	2.5[a]
6	173 - 184	Standard Concrete	4.6	1.2	1.4	1.8	2.7[a]	2.8[a]
7	184 - 194	3" PCC over 6" Macadam Base	4.3	1.9	2.9	2.9*	2.9	4.9[a]
8	194 - 197	2" PCC over 6" Macadam Base	5.0	3.7	3.25	3.6*	3.7	6.7[a]
Control	197 - 250	6" Standard PCC	4.6	1.1	1.34	1.7	2.8[a]	3.1[a]

* A.C. overlay in place

a Testing at frequency of 30 hz