H.R. 522
Asphalt Cement Containing AC-13
Iowa D.O.T. Project FR-12-1(8)--2G-97
FINAL REPORT

by
C.E. Leonard
District Materials Engineer

February 1988

Iowa Department of Transportation
Highway Division
District 3 Office
Sioux City, Iowa 51102
712/276-0933

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Introduction

Stopping and turning maneuvers on high traffic volume asphalt cement concrete surfaced roads and streets often cause distortion of the pavement. Distortion may show up as excessive rutting in the wheel path, shoving of the pavement and/or rippling of the surface. Often times repeated corrective work such as cold milling or heater planing is required in these areas to maintain the pavement surface in a reasonable condition.

In recent years polymer additives have been developed for asphalt cement concrete paving mixes that show promise in improving the inplace stability of the pavements. AC-13 (Styrelf 13) available from Bitucote Products Company, St. Louis, Missouri is an asphalt cement that has been modified by an additive to exhibit characteristics of very high stability in asphalt mixes.

Research Objective

Research project HR-522 was developed to evaluate AC-13 (Styrelf 13) in regard to the following characteristics:

1. Stability in the asphalt cement concrete mix.
2. Asphalt cement and asphalt cement concrete mix characteristics.
3. Pavement surface distortion caused from stopping and turning movements when AC-13 is used in mixes.
4. Visual observation of cracking or raveling that might occur when AC-13 is used in an asphalt cement concrete pavement mixture.

Project Location

The urban project selected for the research was located on Iowa Primary Road 12 (Gordon Drive) in Sioux City. The project begins near the east City Limits of Sioux City and continues west 2.6 miles to near US 75. Traffic volumes range from 6,000 A.D.T. with 10% trucks near the east City Limits to 16,700 A.D.T. with 5% trucks near US 75. The route is a limited access four lane facility with turning lanes at service roads and intersections.

PARTOF CITY OF SIOUX CITY

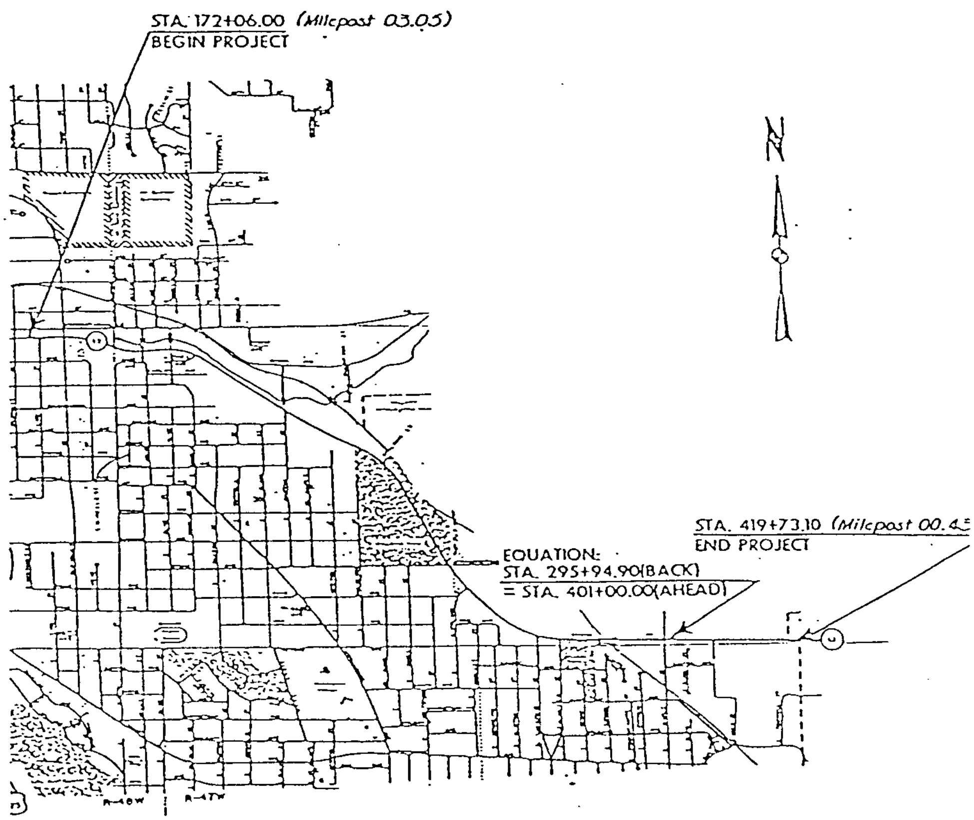


Figure 1

Evaluation Sections

Evaluation sections for AC-13 asphalt cement paving were constructed at four signalized intersections with a fifth section constructed on a four degree circular curve that was not super elevated. The curve is located at a 45 M.P.H. speed zone where traffic speeds approach 50 M.P.H.

Section 1 South Fairmont Street Intersection

A. Posted speed limit 35 M.P.H.

B. Traffic volume 16,700 A.D.T.

C. AC-13 evaluation areas (Figure 2)

1. Eastbound Traffic Lanes
    a. Left turn lane Station 176+62 - Station 178+90
    b. Inside through lane Station 176+22 - Station 178+80
    c. Outside through lane Station 176+22 - Station 178+62
    d. Right turn lane Station 176+62 - Station 178+25±
2. Westbound Traffic Lanes
    a. Left turn lane Station 178+90 - Station 180+42
    b. Inside through lane Station 178+00 - Station 180+42
    c. Outside through lane Station 177+40 - Station 180+42
    d. Right turn lane Station 178+00± - Station 180+42

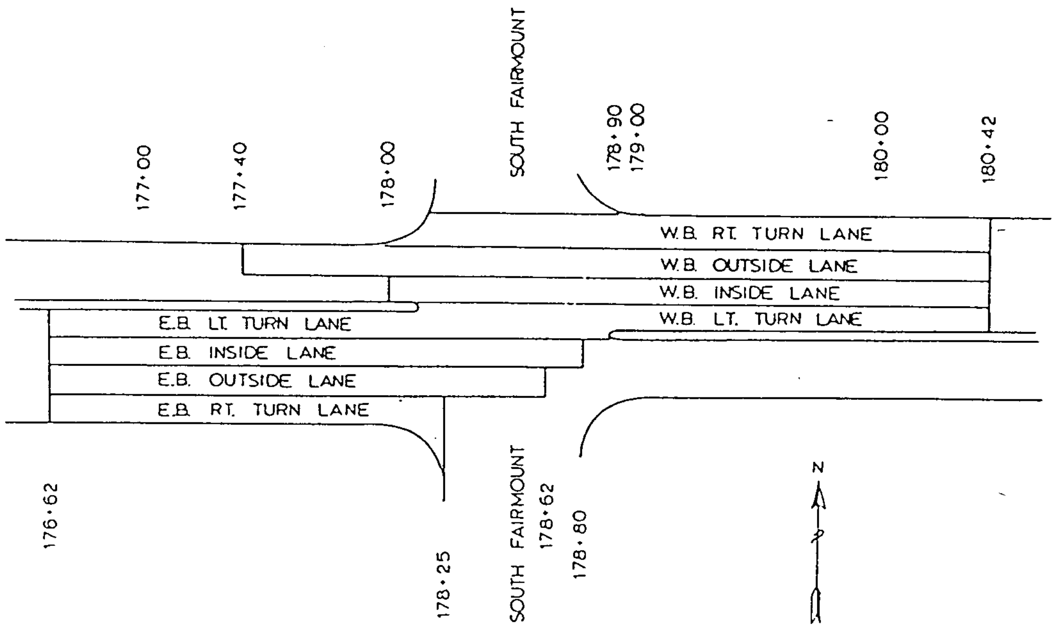


Figure 2

2/3

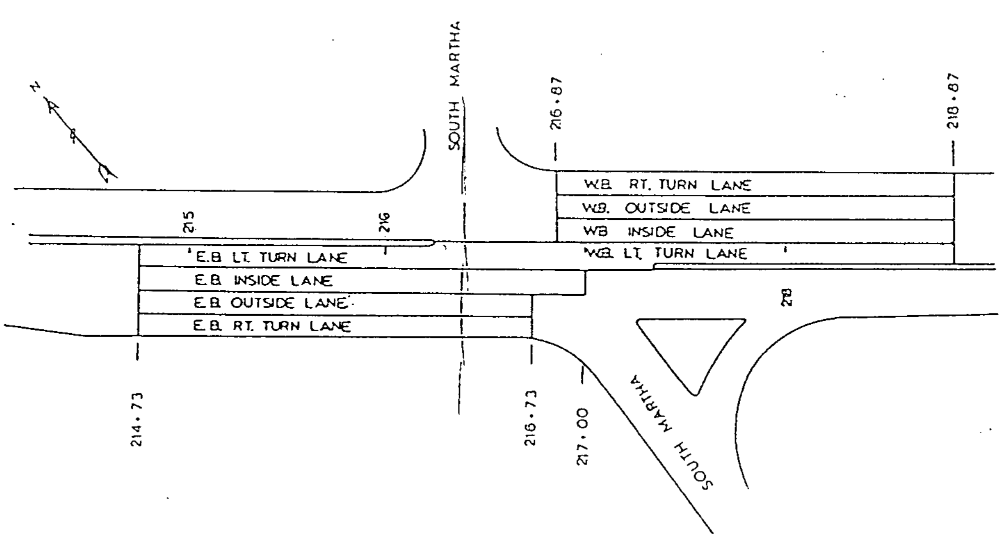


Figure 3

Section 2 South Martha Street Intersection

A. Posted speed limit 35 M.P.H.

B. Traffic volume 15,400 A.D.T.

C. AC-13 evaluation areas (Figure 3)

1. Eastbound Traffic Lanes

   a. Left turn lane Station 214+73 - Station 217+35

   b. Inside through lane Station 214+73 - Station 217+00

   c. Outside through lane Station 214+73 - Station 216+73

   d. Right turn lane Station 214+73 - Station 216+73

2. Westbound traffic Lanes

   a. Left turn lane Station 217+35 - Station 218+87

   b. Inside through lane Station 216+87 - Station 218+87

   c. Outside through lane Station 216+87 - Station 218+87

   d. Right turn lane Station 216+87 - Station 218+87

Section 3 Stone Avenue Intersection

A. Posted speed limit 45 M.P.H.

B. Traffic volume 12,600 A.D.T.

C. AC-13 evaluation areas (Figure 4)

1. Eastbound Traffic Lanes

   a. Left turn lane Station 254+44 - Station 257+00

   b. Inside through lane Station 254+44 - Station 257+00

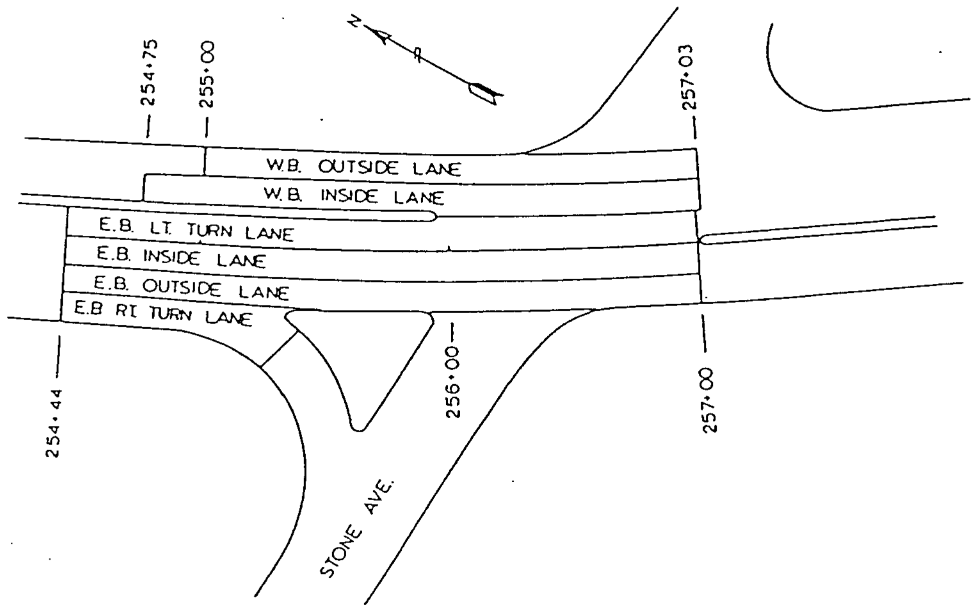


Figure 4

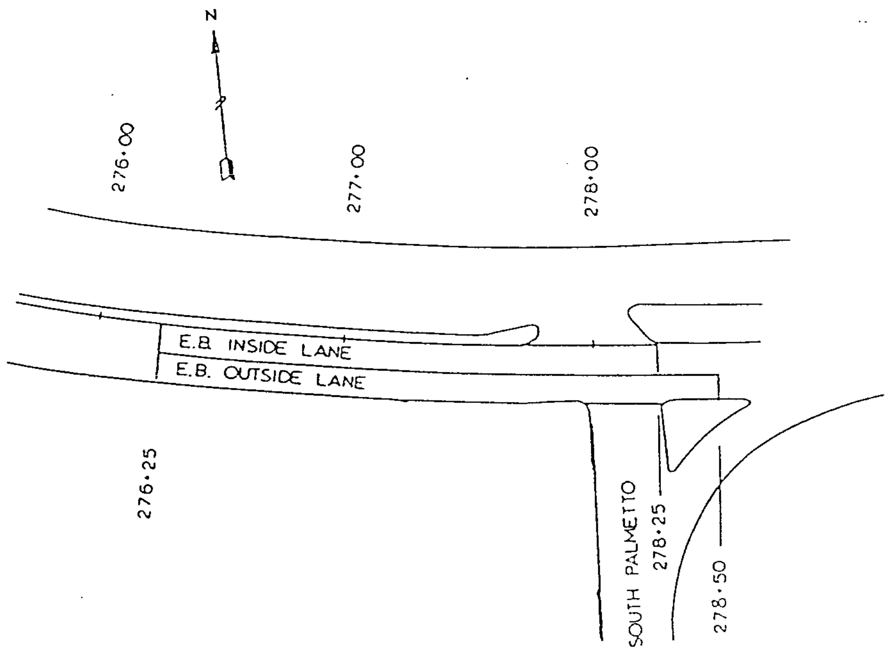


Figure 5

c. Outside through lane Station 254+44 - Station 257+00

d. Right turn lane Station 254+44 - Station 255+44

2. Westbound Traffic Lanes

a. Inside through lane Station 254+75 - Station 257+03

b. Outside through lane Station 255+00 - Station 257+03

Section 4 Palmetto Street Intersection

A. Posted speed limit 45 M.P.H.

B. Traffic volume 9,420 A.D.T.

C. AC-13 evaluation areas (Figure 5)

1. Eastbound

a. Inside through lane Station 276+25 - Station 278+25

b. Outside through lane Station 276+25 - Station 278+50

Section 5 Four Degree Circular Curve With no Super Elevation Station 232+45 - Station 241+60

A. Posted speed limit 45 M.P.H.

B. Traffic volume 12,600 A.D.T.

C. AC-13 evaluation areas (Figure 6)

1. Westbound Only

a. Inside through lane Station 232+25 - Station 242+00

Westbound Lanes - 4° Circular Curve

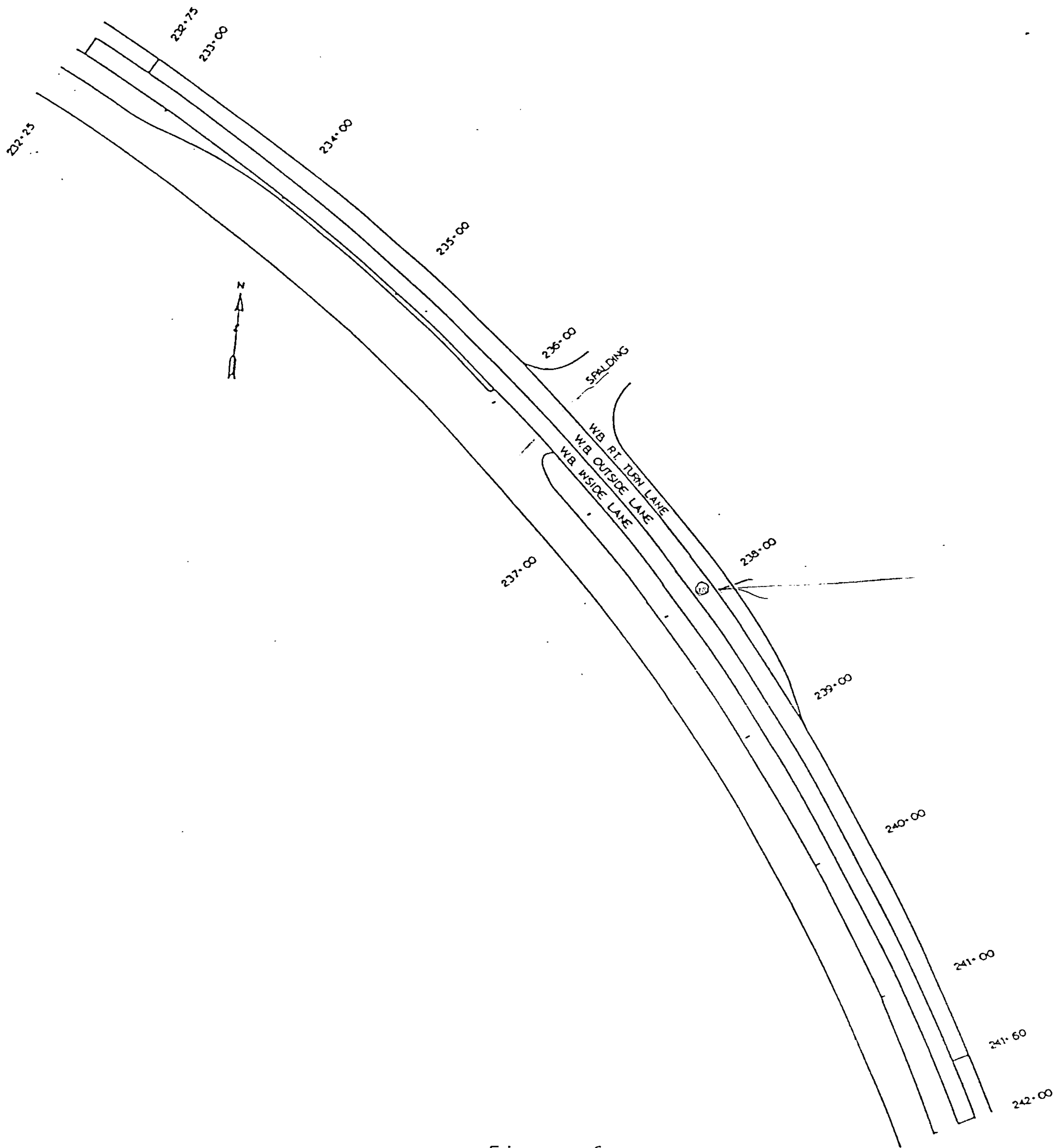


Figure 6

b. Outside through lane Station 232+75 - Station 241+60

c. Right turn lane Station 237+00 - Station 239+00

Project Concept

The first step of the rehabilitation project involved removing the old asphalt cement concrete from the old PC concrete base. This was followed by base repair work. The longitudinal joints were covered with an engineering fabric prior to overlaying the base. The resurfacing of the old PC concrete base was then completed using two (1 1/2" thick) lifts of recycled asphalt cement concrete for all of the project except the special AC-13 research areas.

Virgin aggregate asphalt cement concrete containing AC-13 was placed in both the 1 1/2" thick binder and 1 1/2" thick surface lifts at five locations previously described in this report.

Construction With AC-13

The AC-13 asphalt cement was handled and stored in a conventional manner in a separate storage tank at the asphalt plant. The temperature was maintained at a range of 290°F to 305°F.

A Barber Greene Batch plant was utilized for proportioning and mixing asphaltic concrete materials for the project. When the AC-13 mix was needed for the special areas the normal AC flow was cut off and the AC-13 was allowed to flow to the batching equipment. The virgin aggregates were than batched along with the AC-13 to provide the special mix. This system worked well with minimum inconvenience to the contractor.

The temperature of the AC-13 mix was maintained near 300°F. Normally this would be in the range that conventional asphalt cement concrete mixes are produced. This characteristic of the AC-13 makes it convenient and practical to use in selected areas of a project.

The AC-13 mix was placed and rolled using conventional paving and rolling equipment. No paving gaps were needed for the switch from recycled mix to the AC-13 mix on the project. The average mat temperature at the time of placement was 284°F.

Materials

The material that is being evaluated on this project is the virgin asphalt cement concrete paving mix containing AC-13 asphalt cement. (Styrelf 13 produced and marketed by Bitucote Products Company of Des Moines, Iowa and St. Louis, Missouri.)

AC-13 has the unique characteristics of higher than normal penetration (77°F, 100 gm 5 sec; 60-90 range) with high absolute viscosity (140°F; 2500 poise minimum). A copy of the AC-13 specification is found in Appendix A-2.

The virgin aggregate AC-13 mix used in the special evaluation areas was composed of the following materials:

Job Mix Aggregate

30%	passing 5/8" sieve retained on #4 sieve, crushed quartzite - L.G. Everist, Dell Rapids, South Dakota
10%	passing 3/8" sieve retained on #8 sieve, crushed quartzite - L.G. Everist, Dell Rapids, South Dakota
15%	passing 3/16" sieve, crushed quartzite - L.G. Everist, Dell Rapids, South Dakota
15%	fine limestone - Midwest Limestone, Gilmore City, Iowa
30%	concrete sand - L.G. Everist, Hawarden, Iowa
5.15%	AC-13 (Styrelf) - Bitucote Products Company

The job mix formula is found in Appendix A-4.

Evaluation of Asphalt Cement and Asphalt Mix

The project control tests were very consistant for asphalt cement containing the AC-13. The average penetration, 77°F, 100 gm, 5 sec of the asphalt cement was 81. The average absolute viscosity 140°F, 300 mmHg was 3912 poise (see Appendix B-2).

Tests were run on the AC-13 artifically aged by the thin film oven test method. The penetration 77°F, 100 gm, 5 sec was 48 while the absolute viscosity was 14,990 poise (see Appendix B-2).

Test results from the recovered asphalt AC-13 obtained from the plant mixed asphalt cement concrete samples showed good correlation to those test values obtained from the laboratory aged AC-13. The average penetration of the recovered asphalt cement was 48 and the average absolute viscosity was 13,000 poise (see Appendix B-1).

Pavement Core Evaluation

Daily project control cores taken from the roadway were tested for density and percent air voids. The average field density of all binder and surface cores containing the AC-13 mix was 2.284 (97.8% of 75 blow Marshall density).

The average field voids for all pavement cores containing AC-13 was 6.9% with a range from 5.6% to 7.9%. Daily project control core test results are shown in Appendix B-3.

A set of five cores was cut each year for three years in three sections of the roadway containing AC-13. The pavement cores were tested to determine the change in the absolute viscosity, penetration, and the ductility of the AC-13 recovered from the mix. The cores were separated into binder and surface lifts for testing purposes.

The test results from the surface lift cores show that after one year the average absolute viscosity 140°F, 300 mmHg was 19,557 poise. At the end of the second year the average had increased a nominal amount to 19,735 poise. After three years the average absolute viscosity was 34,994 poise. (Figure 7)

The average penetration 77°F, 100 gm 5 sec of the recovered AC-13 in the one year old surface was 39. The average penetration was 38 after two years of service. At the end of the three years the average penetration had dropped to 33. (Figure 8)

The average ductility 77°F, 5cm/min cm of the recovered AC-13 in the surface cores showed a hardening trend similar to that experienced with the absolute viscosity and the penetration. The average ductility after one year was 29, after two it was 28, and at the end of three years it was 23. (Figure 9)

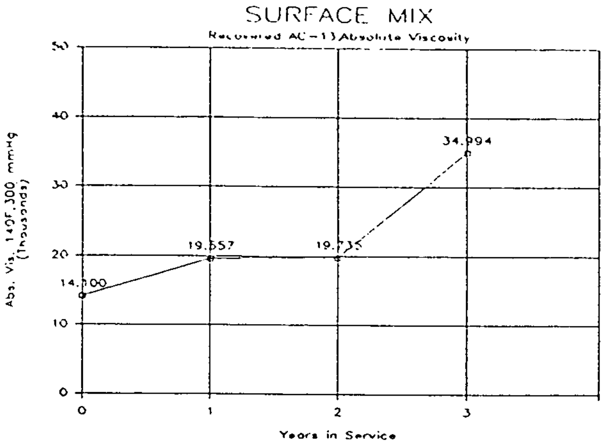


Figure 7

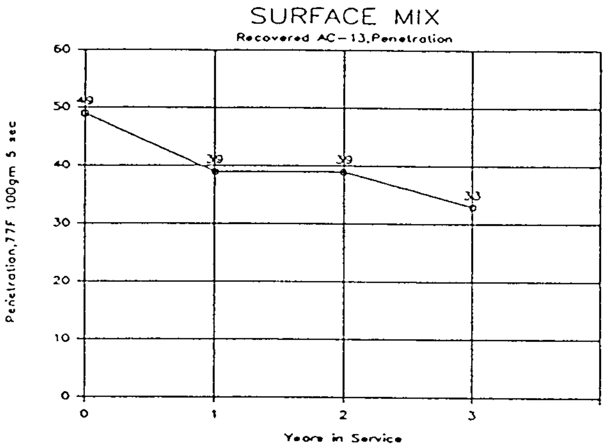


Figure 8

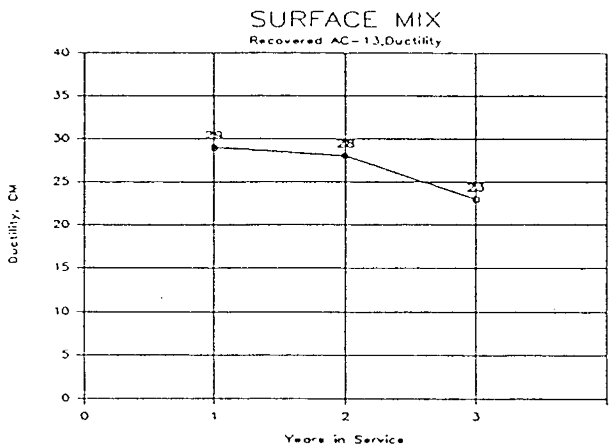


Figure 9

The binder lift cores for all three years were also tested for changes in the AC-13 characteristics. The binder lift test data appears to be suspect for two of the three core locations where cores were taken. The eastbound South Martha Street and eastbound Stone Avenue core test results from the binder lift do not fit well with the trend of the other test results for the binder and surface. All test data is shown in Appendixes C-1 and C-2.

Rutting and Distortion

Rut depth measurements were taken at the end of the first, second, and third year in the locations where the mix containing the AC-13 was placed. The rut depths were measured using a standard four foot rut gage. The measurements were made at 25 foot intervals in each wheel path of the four intersections and at 50 foot intervals on the 4° circular curve containing the AC-13.

There was evidence of some rutting in the pavement the first year after placement, with an average rut depth of 0.08 inches and a maximum rut depth of 0.20 inches. The second year average increased to 0.12 inches and the third year average was 0.14 inch with a maximum reading of 0.38 inch. (Figure 10) A detailed tabulation of the rut depth measurements can be found in Appendixes D-1 through D-3.

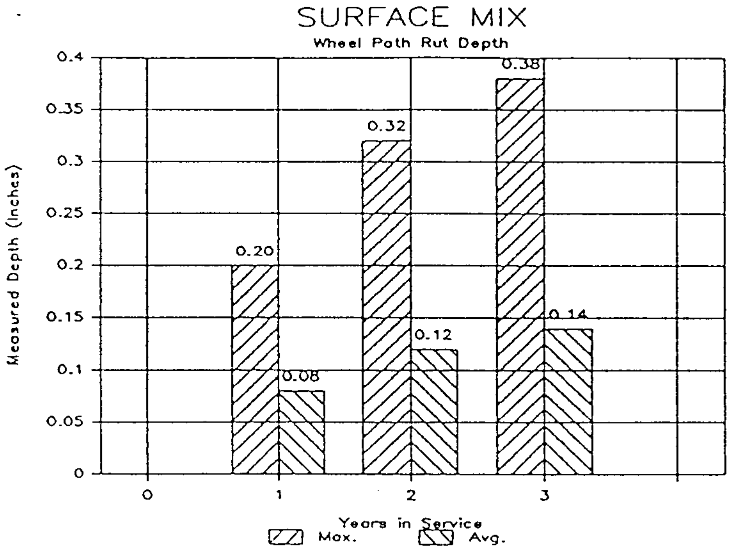


Figure 10

After three years of service there are no visable signs of lateral displacement or rippling of the pavement in advance of the stop lights at the four intersections where maximum stress is developed by stopping traffic. The pavement in the 4° circular curve area is performing well with no evidence of lateral displacement.

<u>Reflection Cracks</u>

The existing four lane portland cement concrete base was modified several years ago to provide raised medians with left turn storage lanes. The construction procedure resulted in longitudinal joints in the concrete base that were not coincident with the normal lane line locations.

As part of the construction on this project, the longitudinal joints in the portland cement concrete base that did not coincide with lane lines were covered with four foot wide engineering fabric strips. The intent of the plan was to retard the reflective cracking at these longitudinal joints. No inventory of the cracks covered with fabric was made prior to placing the overlay.

The pavement surface containing AC-13 mix was surveyed each year after construction, for three years to determine the rate of crack reflection through the asphalt overlay. The cracks were divided into two types. The first type was transverse joints that reflected from the portland cement concrete base. The second type of crack was the fabric treated longitudinal crack that did not match the existing surface lane line locations.

A crack that was evident across the full traffic lane was counted as one transverse joint crack. A crack that extended part way across the traffic lane was counted as 0.5 of a transverse joint crack. A summation of the full and 0.5 transverse crack count was made for each year of the survey. At the end of the first year there were 164.5 transverse joint cracks counted. After two years there were 216 transverse cracks recorded. The third year the count showed 236.5 transverse joint cracks. Nearly all of the normal transverse joints had reflected through the pavement in three years.

The length of longitudinal cracks that occurred in the pavement surface was estimated by the survey team from visual observation at the time of the survey. The first year results show 1060 lineal feet of longitudinal crack in the pavement surface. The cracking increased to 1610 lineal feet the second year and was estimated at 1960 lineal feet after three years of service. (Figures 11 and 12)

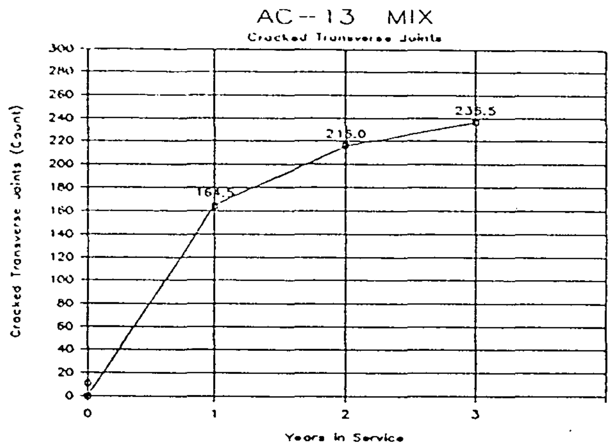


Figure 11

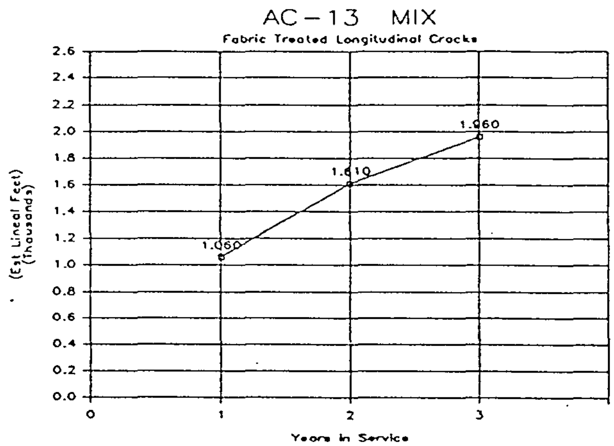


Figure 12

Surface Raveling

Each year the surface containing AC-13 was checked for surface raveling. No evidence of raveling has been found to date. The surface appearence is very good after three years of service.

Conclusion

The conclusions that have been reached from this study of AC-13 performance on this project may not necessarily apply to all types of construction where AC-13 might be used. They are listed as follows:

1. Penetration and absolute viscosity test results obtained for the polymerized AC-13 asphalt cement conformed well with the project specification limits.

2. AC recovered the daily plant mixed project control sample test results show aging characteristics consistant with test results obtained from artificially aged AC-13 using the thin film oven test method.

3. Test results from surface lift cores taken from the roadway surface show a hardening or aging of the recovered AC-13 each year of the study. The hardening appears to have accelerated during the third year of the study in this project. The measured properties of the recovered AC-13 were penetration, absolute viscosity, and ductility.

The higher absolute viscosity (34,994 poise) in the recovered AC-13 after three years of service does not appear to be detrimental in the pavement performance. The test data from the binder lift cores is included in Appendixes C-1 and C-2 of this report, however a portion of the test results appear to be suspect. It appears that the location of the mix containing the AC-13 may have been improperly located on the binder lift.

4. AC-13 did not stop all rutting from occurring. Rutting

has increased each year for three years, however the amount of rutting appears to be stabilizing at an average depth of less than 1/4 inch. The first year of the study the average rut depth of 0.08 inch was likely due in part to consolidation of the pavement under traffic.

5. The paving mix using AC-13 appears to be effective in controlling shoving and lateral movement of the pavement surface on this project.

6. The polymer modified asphalt cement was not effective in controlling transverse joint reflection cracks from occurring on this project. Approximately 70% reflected through the first year. This estimate was based on joint spacing in the portland cement concrete base as no pre-construction joint survey was made.

7. Based on results of this project study there is little evidence to support that AC-13 is effective in reducing the rate of longitudinal joint crack reflection in the pavement. Longitudinal joints in the portland cement concrete base that were not coincidental with the traffic lane lines on the pavement surface were covered with engineering fabric prior to resurfacing.

During the first year after resurfacing cracking occurred over approximately 40% of the total length of the longitudinal joints. This increased to approximately 70% by the end of three years. There were few random cracks in the pavement areas containing AC-13 asphalt cement. No attempt was made to evaluate AC-13 effectiveness in controlling random cracking.

8. Mix containing AC-13 shows no signs of raveling after three years. The pavement appears to be performing well.

Recommendation

The Iowa Department of Transportation aggregate gradation specification and crushed aggregate particle requirement have been modified for heavy service pavements since this study was developed.

The use of the recently developed polymerized asphalt cement specifications (P.A.C. series) should be evaluated using the new mix standards to see if polymerized asphalt cement provide increased resistance to rutting when compared to the standard heavy service mix design currently being specified.

COST CENTER 611000 OBJECT 234

PROJ. NO. FR-12-1(81)--26-97 — COUNTY WOODBURY
RES. ENGR. RICHARD L. BOLTON — RES. CITY SIOUX CITY
LETTING DATE MAY 15, 1984 — LIQUIDATED DAMAGES $210.00
SPECIAL PROV. 9/--/73 #FA-1273, 12/20/83 #941, 11.7.78 #839, 7/15/80 #868,
5/27/83 #920, 2/24/81 #820, 12/20/83 #945, 12/20/83 #935,
3/4/84 SP-367, 5/11/82 #900, 6/3/82 #905, 12/20/83 #940,
12/20/83 #939, 12/20/83 #946, 2/14/84 #952, 12/20/83 #942

DATE STARTED ______ FIELD COMP. ______ OFFICE COMP. ______

CONTRACT NO. 22738

TYPE OF WORK ASPH. CEMENT CONC. RESURF. — PROJECT NO. FR-12-1(81)--26-97
MILES 2.626 — COST CENTER 611000 OBJECT 224
COUNTY WOODBURY

ON IOWA 12 (OLD U S 20) IN SIOUX CITY FROM NEAR SOUTH LINN STREET EAST APPROX. 2.6 MILES TO I.C.L.

IOWA DEPARTMENT OF TRANSPORTATION

THIS AGREEMENT ... ROBERT R RIGLER, DARRELL KENSTAK, DENNIS VOY, DEL VAN HORN, MOLLY SCOTT, AUSTIN TURNER , & C ROGER TAIR ... PARTY OF THE FIRST PART AND 04250
BROWER CONSTRUCTION CO. OF SIOUX CITY, IOWA

PARTY OF THE SECOND PART

... $769,792.15 ... PAYABLE AS SET FORTH IN THE SPECIFICATIONS ...

ITEM NO	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	BASE, CLEANING & PREPARATION OF	2.626	MILES	3,200.00	8,403.20
2A	PAVEMENT SCARIFICATION	12,800	TONS	11.85	151,680.00
3	PATCHES, ASPHALT CEMENT CONCRETE SURFACE	50	TONS	200.00	10,000.00
4	PATCHES, FULL DEPTH	330	SQ. YDS.	97.25	32,092.50
5	PATCHES, PARTIAL DEPTH	100	SQ. YDS.	82.45	8,245.00
6	PATCHES, BY COUNT	50	ONLY	100.00	5,000.00
7	PRIMER OR TACK-COAT BITUMEN	7,635	GALS.	1.25	9,543.75
8B	ASPH. CEM. CONC., TYPE A WEDGE, LEVEL OR STRGTH. COURSE, RECYCLED	364	TONS	30.90	11,247.60
9B	ASPH. CEM. CONC., TYPE A BINDER COURSE, MIXT. SIZE 3/4", RECYCLED	4,958	TONS	18.60	92,218.60
10B	ASPH. CEM. CONC. TYPE A SURFACE COURSE, MIXT. SIZE 1/2", RECYCLED	6,283	TONS	18.25	114,664.75
11	ASPHALT CEMENT CONCRETE POLYMER MODIFIED (AC-13)	1,432	TONS	21.05	30,343.60
12B	ASPHALT CEMENT	496	TONS	205.00	101,680.00
13	ASPHALT CEMENT (AC-13)	83	TONS	325.00	26,975.00
14	CURB REPAIR, AS PER PLAN	2,550	LIN. FT.	15.75	40,162.50
15	FABRIC REINFORCEMENT	19,111	SQ. YDS.	1.15	21,977.65
16	INTAKE, RA-4	1	ONLY	2,000.00	2,000.00
17	PAVEMENT MARKINGS, PREFORMED POLYMER LONGITUDINAL LINES	106,690	STAS.	175.00	18,670.75
18	PAVEMENT MARKINGS, PREFORMED POLYMER TRANSVERSE LINES, 24 IN.	3.250	STAS.	900.00	2,925.00
19	PAVEMENT MARKINGS	443.650	STAS.	17.00	7,542.05
20	SYMBOLS, AS PER PLAN	66	ONLY	40.00	2,640.00
21	TRAFFIC CONTROL		LUMP SUM		40,000.00
22	SAMPLES		LUMP SUM		2,500.00
23	JOINT, PRESSURE RELIEF	87	LIN. FT.	40.00	3,480.00
24	MOBILIZATION	100.00%			26,000.00
			GRAND TOTAL		$769,792.15

MAY 04, 1984

1977

FR-12-1(81)--26-97

70 WORKING DAYS	SEPT. 28, 1984

IOWA DEPARTMENT OF TRANSPORTATION

BY ______

BROWER CONSTRUCTION CO. OF SIOUX CITY, IOWA

BY ______

Iowa Department of Transportation

SUPPLEMENTAL SPECIFICATION
for
ASPHALT CEMENT AC-13

December 20, 1983

942.01 DESCRIPTION. This material is a polymerized asphalt cement intended to be used in asphalt cement concrete mixtures where high stability requirements are necessary.

The contracting authority believes this to be a proprietary product. It is available as Styrelf 13 from Biticote Products Company, St. Louis, Missouri, and Des Moines, Iowa. Bidders should contact this supplier for information concerning this material.

Other sources of a similar material may also be approved. Specific approval will be required. Approval will be based on the manufacturer's proposed method of polymerization, as well as compliance with the test requirements specified.

942.02 MATERIAL. Asphalt cement AC-13 shall meet requirements of AASHTO M 226, Table 1, for grade AC-40, except as follows:

Penetration, 25°C (77°F), 100 g, 5 sec; 60-90.
Viscosity, 60°C (140°F), poises; 2,500 min.
Tensile Stress, ASTM D 412, @ 800%
elongation of the sample, 20°C (68°F),
500 mm/min, kg/cm^2; 0.50 min.

The contractor shall furnish certified test results for each load of this material furnished to the project.

942.03 CONSTRUCTION. Asphalt Cement AC-13 shall be incorporated in the ACC mixture to be placed in the locations designated on the plans, in lieu of the asphalt cement specified for other mixtures specified for the project. The mixture shall be prepared and placed according to requirements of the Standard Specifications.

The contractor shall furnish facilities and use a procedure that keeps this material separate from other asphalt cement used on the project during storage and incorporation into the mixture.

942.04 MEASUREMENT AND PAYMENT. Asphalt cement AC-13 will be separately measured and paid for in accord with 2303.19B and 2303.20B. The quantity shall be for mixture in the areas designated on the plans and such additional mixture as was necessary to cover the designated areas using full truck loads of mixture. This payment shall be full compensation for furnishing and incorporating this material into the mixture and for the special facilities and procedures necessary to accomplish this.

The quantity of ACC mixture with asphalt cement AC-13, furnished and placed as designated, will be included with the other quantities of ACC mixture and will be paid for accordingly.

Iowa Department of Transportation

SPECIAL PROVISION
for
ASPHALT CEMENT CONCRETE

FN-75-1(39)--21-97, Woodbury County
FR-12-1(8)--26-97, Woodbury County

May 9, 1984

This work shall consist of removal by scarification and salvage of the asphaltic pavement surface. Incorporation of the salvaged material into a recycled asphalt cement concrete for the projects is a bidding alternate. Only one group of alternates for each project is to be bid, and the contracts will be awarded on the basis of the alternates bid.

Scarification
Scarification shall be in accord with the plans and Supplemental Specification 940.

Asphalt Cement Concrete, Type A.
When Type A asphalt cement concrete is furnished with virgin aggregates, the mixture shall meet requirements of the Standard Specifications, with the following modifications.

1. The asphalt cement shall meet requirements of Section 4137, grade AC-20.
2. Coarse aggregates for surface course mixtures shall be Type 3 skid-resistant aggregate, as classified in Materials I.M. T-203, dated 1983.

AC-13 Polymer Modified Asphalt Cement Concrete.
This mixture shall be furnished and placed in accord with Supplemental Specification 942. A virgin aggregate mixture is required for all courses, using the aggregate mixture designated herein for the surface course. For lower lifts, the contractor may substitute a virgin aggregate mixture designated for the binder course.
The quantity of this mixture required will be separately identified as an item on the proposal.

Asphalt Cement Concrete, Type A, Recycled.
When the recycled mixture is to be furnished, the following provisions shall apply.
These mixtures shall be furnished, mixed, and placed in accord with Supplemental Specification 939.
Asphalt cement for the recycled mixture shall meet requirements of Section 4137, grade AC-2.5, AC-5 or AC-10. The exact grade will be determined at the time of job-mix approval.
The salvaged material to be used for both projects shall be that which is removed by scarification from the roadway of project FR-12-1(8)--26-97. The existing surface is a 3/8-inch Type A surface mixture on a 3/4-inch Type A binder course mixture. For the purpose of computing crushed particles, it can be assumed that the material salvaged contains 70 percent crushed particles, and the remainder is natural sand.
The aggregate to be used shall be a mixture of 40 or more percent salvaged asphaltic material, combined with new aggregate. It is expected that the material removed from the designated project will be sufficient to provide at least enough salvaged material for the quantity of mixture shown on the plans for both projects. The amount of salvaged asphaltic material in one of the recycled mixtures may be less than the percentage specified, if the percentage in the other mixtures is increased sufficiently to provide for a minimum total usage of salvaged material equivalent to that specified.
New coarse aggregate furnished for recycled surface course mixture shall be Type 3 skid-resistant aggregate, as classified in materials I.M. T-203, dated 1983.
For the 1/2-inch mixture, the required percent passing the 1/2-inch sieve will be modified to 95-100 percent.
For the contractor's information, the average job-mix gradations for the existing surface on the FR-12-1(8)--26-97 project are as follows:

Sieve Size	3/4-inch Binder Course	3/8-inch Surface Course
3/4 inch	100	
1/2 inch	95	
3/8 inch	75	100
No. 4	57	85
No. 8	51	62
No. 30	26	33
No. 200	6	6

There is a significant difference between the binder and surface courses. Separate stockpiles will not be required. However, the method of removal, processing, and handling of the salvaged material shall result in a uniform blending of salvaged material. The method shall be subject to approval of the engineer.
This material shall not be intermingled with material salvaged from the FN-75-1(39)--21-97 project.
The recycling work will be paid for according to Supplemental Specification 939.

Remaining Salvaged Material.
Any salvaged material taken from the roadway of either project and remaining at the completion of the work shall be the property of the contractor, regardless of the alternate basis on which these contracts are awarded.

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
ASPHALT CONCRETE MIX DESIGN
LAB LOCATION AMES

Appendix A-4

MIX. TYPE AND CLASS: TYPE A SURFACE - BINDER LAB NO. ABD4-13

INTENDED USE:

SIZE 1/2" SPEC. NO. 941, 951 942 DATE REPORTED 2/3/84

COUNTY WOODBURY PROJECT FR-12-1(8)--2G-97

CONTRACTOR BROWER

PROJ. LOCATION FROM SOUTH LINN STREET TO E.C.L. IN SIOUX CITY

AGG. SOURCES AGG. LIME - HALLETT, GILMORE CITY - POCAHONTAS CO.: 3/16".
5/8"X4, 3/8"X8 QTZ. - L. G. EVERIST, MINNEHAHA CO., S. DAK.:
SAND - L. G. EVERIST, 15-95-48 - SIOUX CO.

JOB MIX FORMULA AGGREGATE PROPORTIONS: 15% AAT4-408: 15% AAT4-352: 30% AAT4-351: 10% AAT4-372: 30% AAT4-353

JOB MIX FORMULA - COMBINED GRADATION

1-1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
	100	99	90	68	57	46	32	17	9.0	5.4	
TOLERANCE:		98/100	7	7	5		4				2*

ASPHALT SOURCE AND APPROXIMATE VISCOSITY BITUCOTE-3240 POISES (STYRELF 13)

PLASTICITY INDEX			
% ASPH. IN MIX	4.50	5.50	6.50
NUMBER OF MARSHALL BLOWS	75	75	75
MARSHALL STABILITY - LBS.	3443	3227	3130
FLOW - 0.01 IN.	7	8	12
SP.GR. BY DISPLACEMENT(LAB DENS.)	2.32	2.34	2.36
BULK SP. GR. COMB. DRY AGG.	2.651	2.651	2.651
SP. GR. ASPH. @ 77 F.	1.028	1.028	1.028
CALC. SOLID SP.GR.	2.486	2.449	2.414
% VOIDS - CALC.	6.67	4.46	2.24
RICE SP. GR.	2.476	2.441	2.398
% VOIDS - RICE	6.30	4.14	1.58
% WATER ABSORPTION - AGGREGATE	0.37	0.37	0.37
% VOIDS IN THE MINERAL AGGREGATE	16.42	16.59	16.67
% V.M.A. FILLED WITH ASPHALT	59.41	73.08	86.65
CALCULATED ASPH.FILM THICKNESS(MICRONS)	6.68	8.32	9.99
FILLER/BITUMEN RATIO		1.05	

A CONTENT OF 5.15% ASPHALT IS RECOMMENDED TO START THE JOB.
* ALSO CONTROLLED BY FILLER/BITUMEN RATIO.

COPIES:
ASPH. MIX DESIGN
FR-12-1(8)--2G-97, WOODBURY
J. BUMP
R. BOLTON
R. SHELQUIST
D. JORDISON
D. HEINS
BROWER
W. OPPEDAL

SIGNED: BERNARD C. BROWN
TESTING ENGINEER

AC-13 A.C.C. Mix Test Results

I. Sieve Size	Design % Passing	Lab No. ABC4- 156 Binder	178 Binder & Surface	181 Surface	203 Surface	221	AVE
1/2"	98 - 100	100	99	100	100	100	100
3/8"	83 - 97	92	89	89	88	88	89
4	61 - 75	71	66	66	65	66	67
8	52 - 62	59	54	54	53	55	55
16	46	46	43	44	42	44	44
30	28 - 36	33	31	33	31	31	32
50	17	18	17	18	18	17	18
100	9.0	10	9.5	9.7	9.9	9.6	9.7
200	5.4	7.1	6.5	6.0	6.3	6.5	6.5
II. Extracted AC %		5.77	5.38	5.31			5.49
III. Marshall Stability	3345 (interpolated)	3737	4541	3862	3958	4307	4081
IV. Absolute Viscosity Extracted AC (140°F 300 MMHG Poises)		13,750		11,160	14,100		13,000
V. Penn Extracted AC (77°F, 100 gm 5 sec)		45		50	49		48
VI. % AC Batch Wt.	5.15%	5.15	5.15	5.15	5.15	5.15	5.15
VII. Filler/Bit		*1.38	1.26	1.16	1.22	1.26	1.22

* Dist 3 Mtls Lab Extraction 3.8 #200 could not extract the AC-13.

Test Results on AC-13 (Styrelf 13)

I. One Project Assurance Sample Tested in Ames Lab

	Test	Spec	Test Results
A.	Absolute Viscosity 140°F, 300 MMHG Poises	2500 min	4390
B.	Penetration 77°F, 100 gm 5 sec	60-90	74
C.	Ductility 77°F (thin film residue) CMS		40 CMS
D.	Absolute Viscosity (thin film residue) 140°F, 300 MMHG Poises		14,990
E.	Penetration of Residue 77°F, 100 gm 5 sec		48

II. Nine Porject Control Samples Tested in Dist 3 Mtls Lab

	Spec	Sample Sender No. L.G.- 1	1A	4	5	8	11	11A	17	17A	AVE
A. Absolute Viscosity 140°F, 300 MMHG POises	Min 2500	3050		3720	3840	3980	4170		3940		3912
B. Penetration 77°F, 100 gm 5 sec	60-90		86		79					78	81

III. Field Test Results for Construction Testing

A. Field Core Test Results

Lift Placed	Date Placed	75 Blow Marshall Density	% Lab Density Field Core	% Voids in Field Core	Day's Ave % Density Field Cores	Day's Ave % Air Voids Field Cores
Binder	7-5-84	* 2.28	96.5	10.6		
"	"		100.0	7.3		
"	"		100.4	6.9		
"	"		100.0	7.3		
"	"		100.0	7.3	99.4	7.9
Binder	7-6-84	2.35	97.0	7.3		
"	"		97.4	7.0		
"	"		98.3	6.1		
"	"		97.4	7.0		
"	"		95.3	8.9	97.1	7.2
Binder	7-7-84	2.37	98.3	4.5		
"	"		97.5	5.3		
"	"		95.4	7.4		
"	"		97.0	5.7		
"	"		97.9	4.9	97.2	5.6
Binder	7-9-84	2.35	95.7	8.2		
"	"		99.0	4.5		
"	"		97.0	6.9		
"	"		95.3	8.6		
"	"		97.0	6.9	96.7	7.0
Binder	7-10-84	2.32	98.7	6.5		
"	"		97.8	7.3		
"	"		97.0	8.2		
"	"		98.5	6.5		
"	"		97.0	8.2	97.8	7.3
Surface	7-13-84	2.35	97.0	6.9		
"	"		95.7	8.2		
"	"		98.3	5.7	97.0	6.9
Surface	7-16-84	2.33	97.9	7.3		
"	"		100.0	5.3		
"	"		98.3	6.9	98.7	6.5
Surface	7-17-84	2.34	98.7	6.5		
"	"		98.3	6.9		
"	"		98.3	6.9	98.4	6.8

* Lab Density run at 50 blow, traffic volume requires 75 blow.

Characteristics of Asphalt Cement Concrete Mix and Extracted Asphalt Cement

South Martha Street Intersection - Eastbound Lane

	Uncompacted Mix		1985 Core 1 yr of Serv		1986 Core 2 yr of Serv		1987 Core 3 yr of Serv	
	Binder	Surface	Binder	Surface	Binder	Surface	Binder	Surface
Extracted % AC	5.77	5.38	5.50	5.15	5.66	5.37	5.71	5.63
Marshall Stability **	3737 *	4541 *	2024	2008	2099	2693	----	-----
Marshall Flow	10	10	10	15	7	9	----	-----
Abs Vis Extracted AC 300 MMHG Poises	13,750	----	7,860	15,850	5,840	12,280	6,560	15,560
Penn Extracted AC 77°F 100 gm 5 sec	45	----	52	45	51	46	29	42
Ductility, Centimeter	----	----	76	38	95	35	87	33

Stone Avenue Intersection - Eastbound Lane

	Uncompacted Mix		1985 Core 1 yr of Serv		1986 Core 2 yr of Serv		1987 Core 3 yr of Serv	
	Binder	Surface	Binder	Surface	Binder	Surface	Binder	Surface
Extracted % AC		5.12	5.31	5.08	5.52	5.26	5.44	5.14
Marshall Stability **	*	4307 *	2423	2677	----	----	----	----
Marshall Flow		11	10	10	----	----	----	----
Abs Vis Extracted AC 300 MMHG Poises	----	----	9,050	22,110	8,990	22,570	38,340	47,140
Penn Extracted AC 77°F 100 gm 5 sec	----	----	59	33	62	32	33	26
Ductility, Centimeters	----	----	52	29	54	27	22	15

* 75 blow Marshall

** Core values corrected for thickness variation

Appendix C-1

Characteristics of Asphalt Cement Concrete Mix
and Extracted Asphalt Cement

4° Circular Curve Station 232+45 to Station 241+60

	Uncompacted Mix		1985 Cores Cut After 1 yr		1986 Cores Cut After 2 yr		1987 Core Cut After 3 yr	
	Binder	Surface	Binder	Surface	Binder	Surface	Binder	Surface
Extracted % AC	----	5.13	5.26	5.18	5.33	5.22	5.58	5.52
Marshall Stability **	*	3958 *	1167	1404	1421	1612	----	----
Marshall Flow	----	10	15	15	10	11	----	----
Abs Vis Extracted AC 140°F, 300 MMHG Poises	----	14,100	16,930	20,710	21,560	24,354	30,147	42,282
Penn Extracted AC 77°F, 100 gm, 5 sec	----	49	37	40	33	37	31	30
Ductility, Centimeters	----	----	33	21	22	23	17	22

* 75 blow Marshall

** Core values corrected for thickness variation

Pavement Rut Condition

Fairmont Street Intersection

Westbound Lane (inches)

	Left Turn			Inside Lane			Outside Lane			Right Turn		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
Average Rut Depth 12 Readings	0.08	0.13	0.15	0.10	0.13	0.15	0.09	0.17	0.20	0.08	0.12	0.15
High Reading	0.20	0.30	0.30	0.15	0.20	0.20	0.10	0.25	0.32	0.15	0.20	0.25
Low Reading	0.00	0.05	0.05	0.05	0.09	0.09	0.05	0.10	0.10	0.00	0.08	0.09

Eastbound Lane (inches)

	Left Turn			Inside Lane			Outside Lane			Right Lane		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
Average Rut Depth 12 Readings	0.05	0.11	0.12	0.07	0.14	0.16	0.12	0.16	0.20	0.09	0.12	0.12
High Reading	0.15	0.21	0.21	0.15	0.22	0.22	0.20	0.23	0.30	0.15	0.17	0.17
Low Reading	0.00	0.06	0.06	0.00	0.09	0.10	0.00	0.05	0.13	0.05	0.09	0.10

Pavement Rut Condition

South Martha Intersection

Westbound Lane (inches)

	Left Turn			Inside Lane			Outside Lane			Right Turn		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
Average Rut Depth 14 Readings	0.04	0.08	0.10	0.06	0.11	0.12	0.09	0.14	0.16	0.06	0.09	0.09
High Reading	0.10	0.20	0.26	0.10	0.32	0.38	0.15	0.24	0.24	0.10	0.12	0.12
Low Reading	0.00	0.04	0.04	0.00	0.05	0.05	0.05	0.09	0.10	0.00	0.06	0.06

Eastbound Lane (inches)

	Left Turn			Inside Lane			Outside Lane			Right Turn		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
Average Rut Depth 14 Readings	0.05	0.08	0.08	0.07	0.11	0.11	0.10	0.14	0.16	0.09	0.10	0.11
High Reading	0.05	0.12	0.12	0.10	0.15	0.24	0.15	0.23	0.24	0.10	0.12	0.13
Low Reading	0.00	0.02	0.05	0.00	0.05	0.08	0.05	0.05	0.06	0.05	0.08	0.08

Pavement Rut Condition

4° Curve Area Station 235+45 to Station 241+60

West Boundlane (inches)

	Inside Lane 1985	Inside Lane 1986	Inside Lane 1987	Outside Lane 1985	Outside Lane 1986	Outside Lane 1987	Right Turn * 1985	Right Turn * 1986	Right Turn * 1987
Average Rut Depth 18 Readings	0.06	0.09	0.11	0.08	0.13	0.13	0.06	0.09	0.10
High Reading	0.10	0.15	0.16	0.20	0.20	0.20	0.10	0.11	0.13
Low Reading	0.00	0.07	0.07	0.00	0.08	0.08	0.00	0.04	0.09

* 4 Readings

Stone Avenue Intersection

Eastbound Lane (inches)

	Left Turn 1985	Left Turn 1986	Left Turn 1987	Inside Lane 1985	Inside Lane 1986	Inside Lane 1987	Outside Lane 1985	Outside Lane 1986	Outside Lane 1987	Right Turn * 1985	Right Turn * 1986	Right Turn * 1987
Average Rut Depth 12 Readings	0.17	0.20	0.22	0.08	0.11	0.12	0.08	0.14	0.15	0.07	0.11	0.11
High Reading	0.20	0.26	0.29	0.15	0.08	0.09	0.15	0.29	0.32	0.10	0.15	0.15
Low Reading	0.10	0.17	0.18	0.05	0.19	0.19	0.00	0.09	0.09	0.05	0.09	0.09

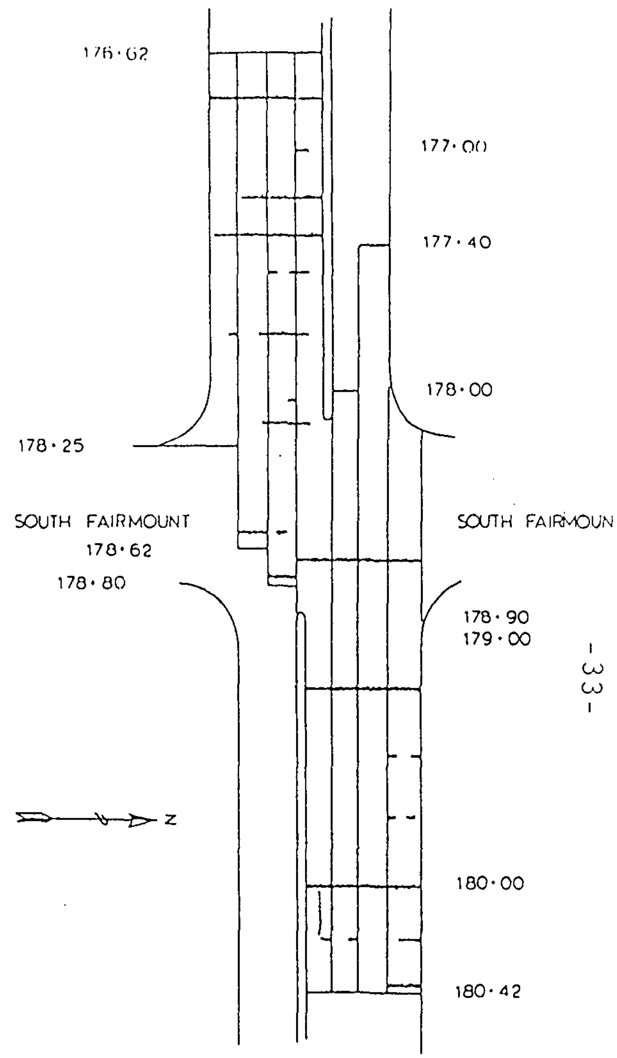
* 6 readings

South Palmeto Intersection

Eastbound Lane (inches)

	Inside Lane 1985	Inside Lane 1986	Inside Lane 1987	Outside Lane 1985	Outside Lane 1986	Outside Lane 1987
Average Rut Depth 12 Readings	0.08	0.12	0.13	0.08	0.11	0.11
High Reading	0.10	0.18	0.18	0.10	0.12	0.18
Low Reading	0.00	0.08	0.08	0.00	0.09	0.05

Appendix E-1



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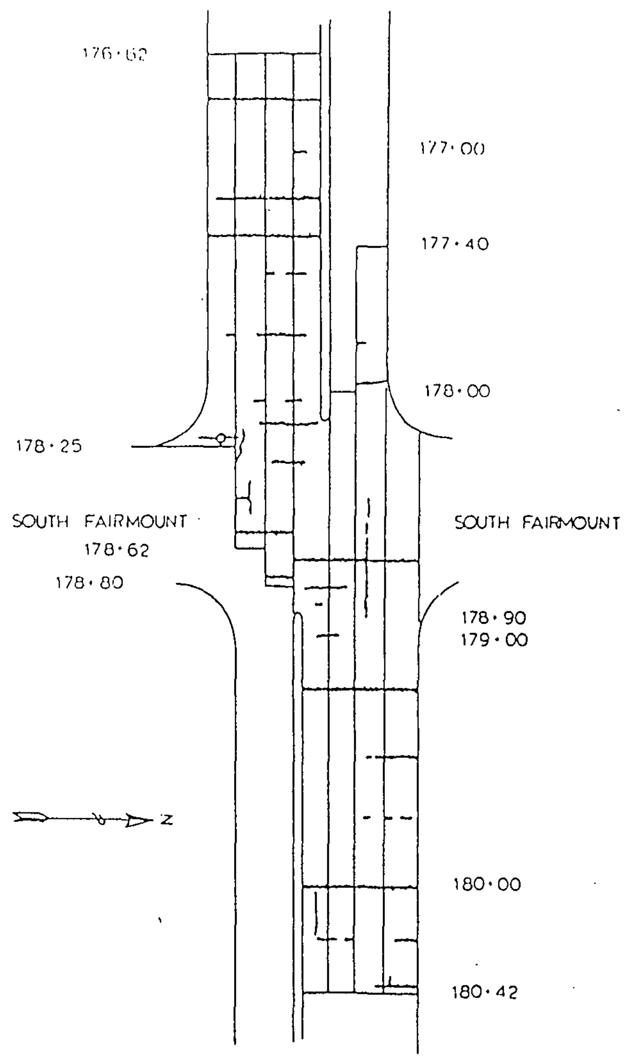
(1985)



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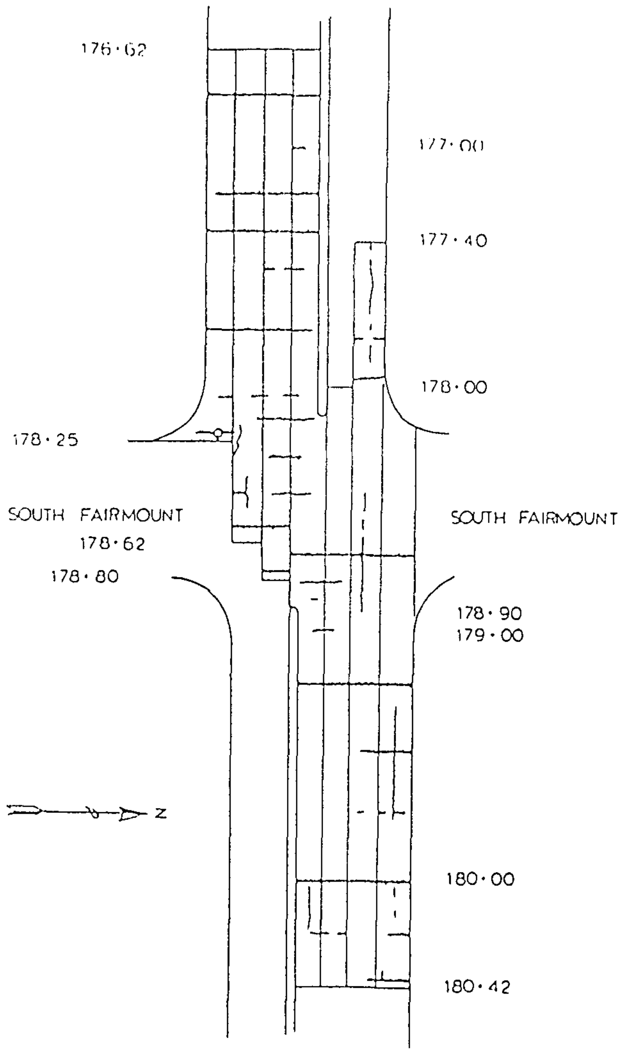

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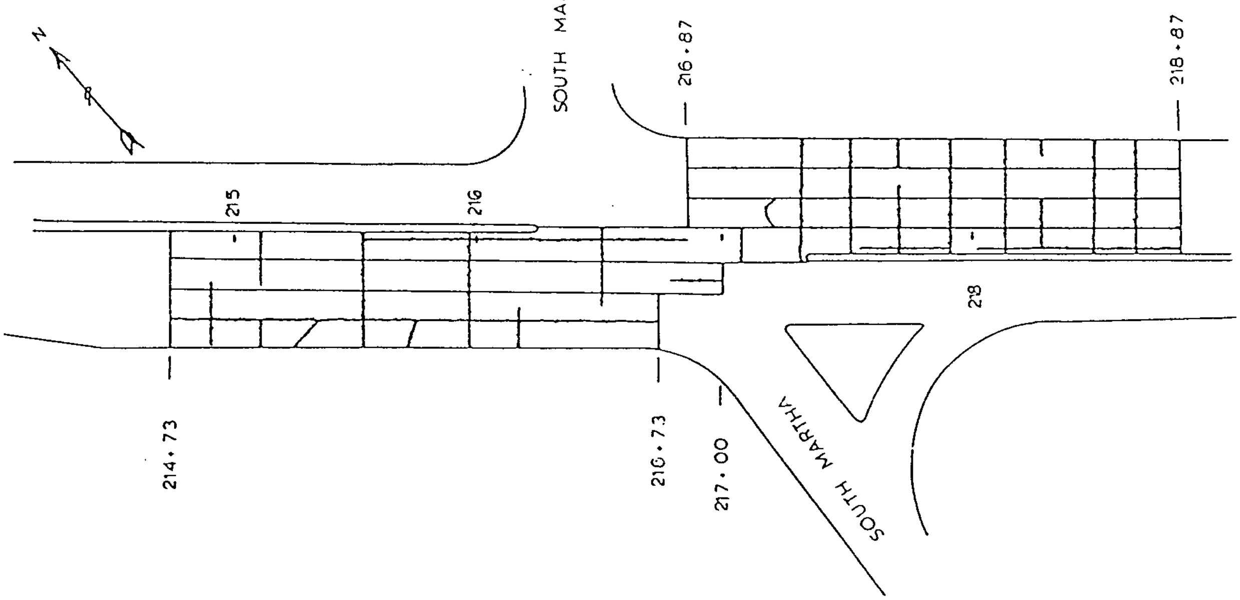

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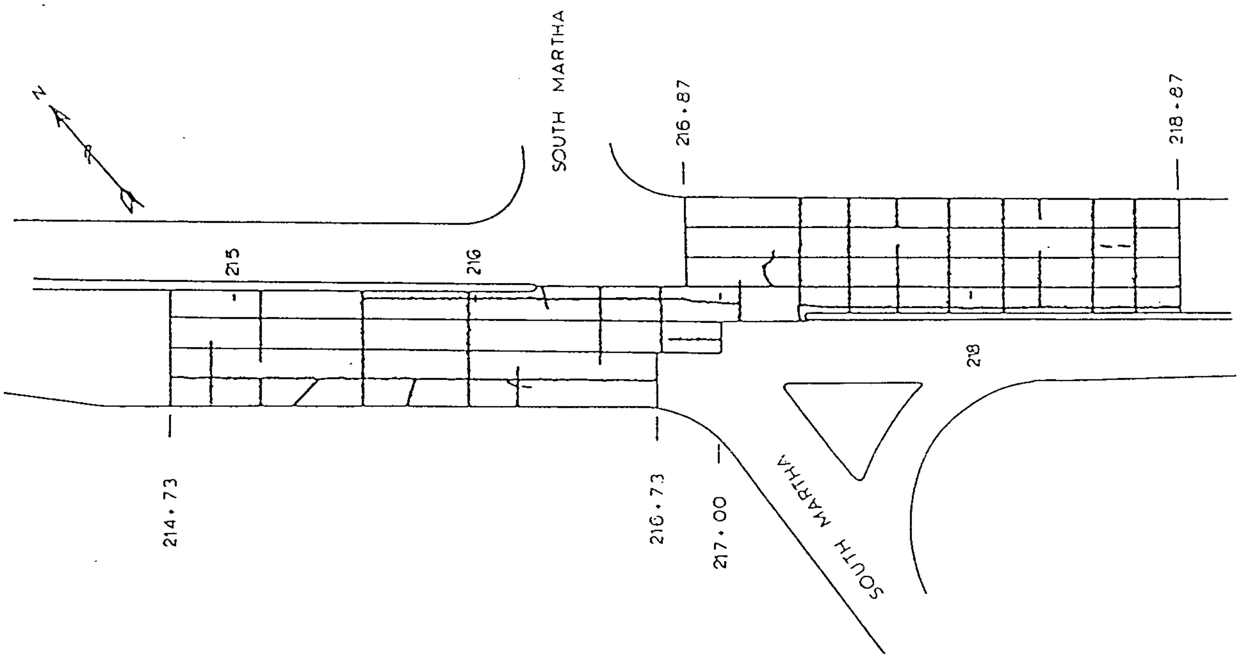

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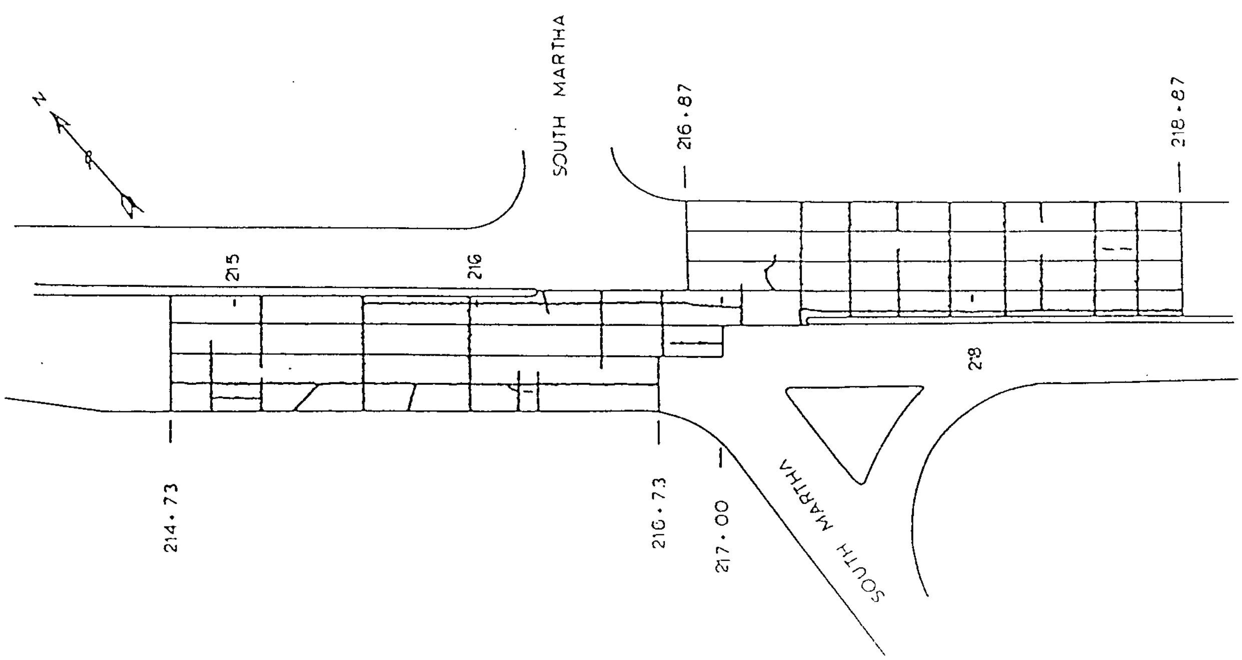

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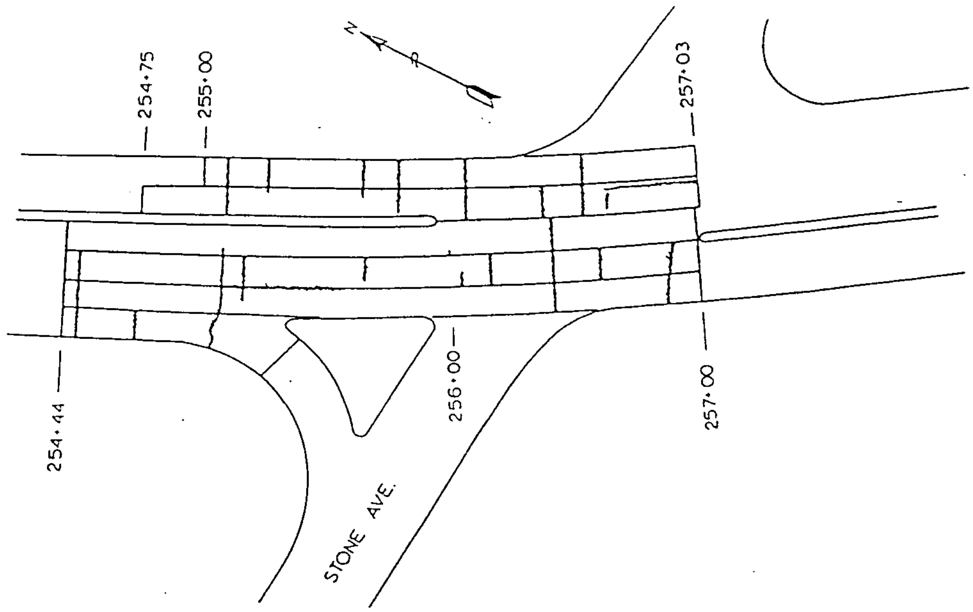

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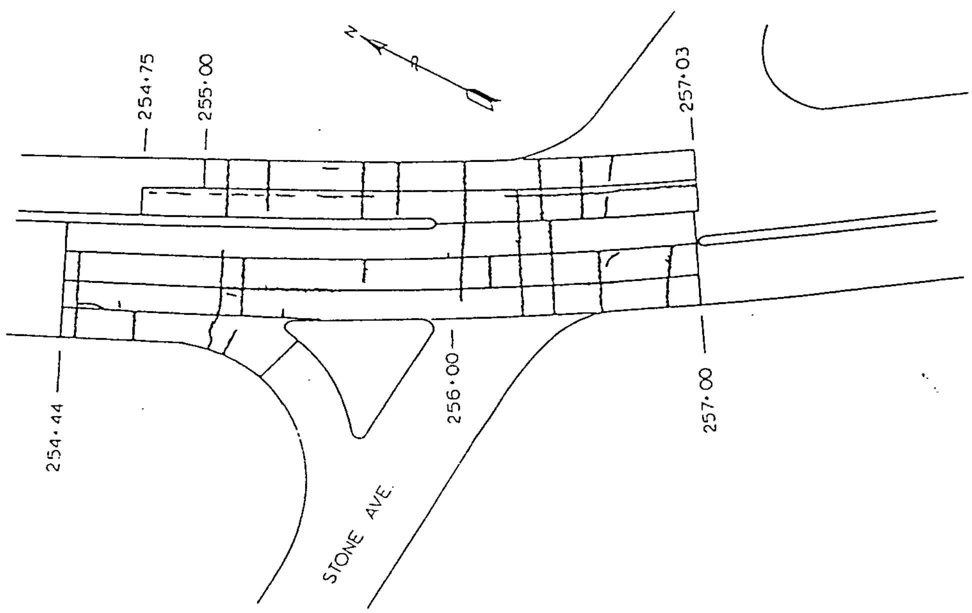

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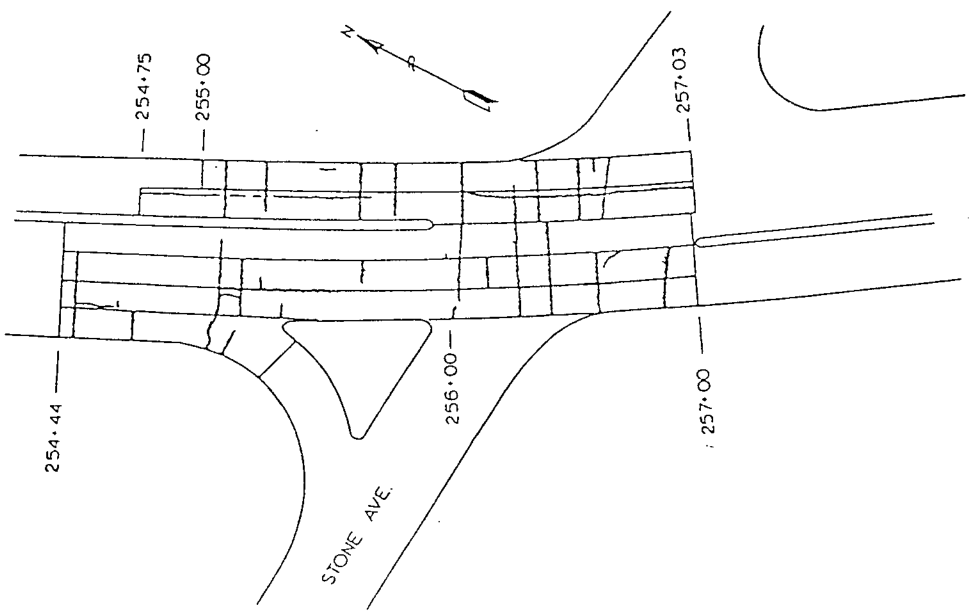

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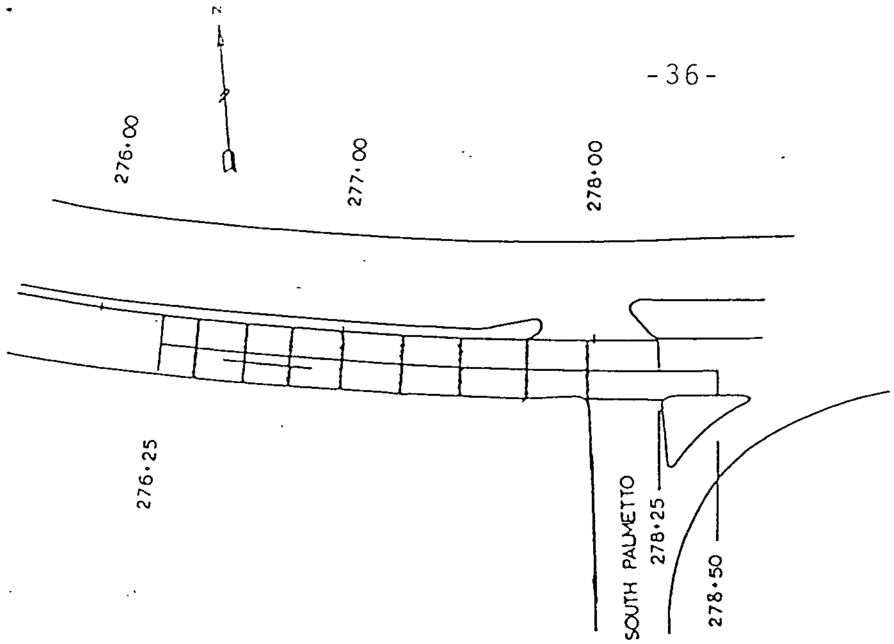

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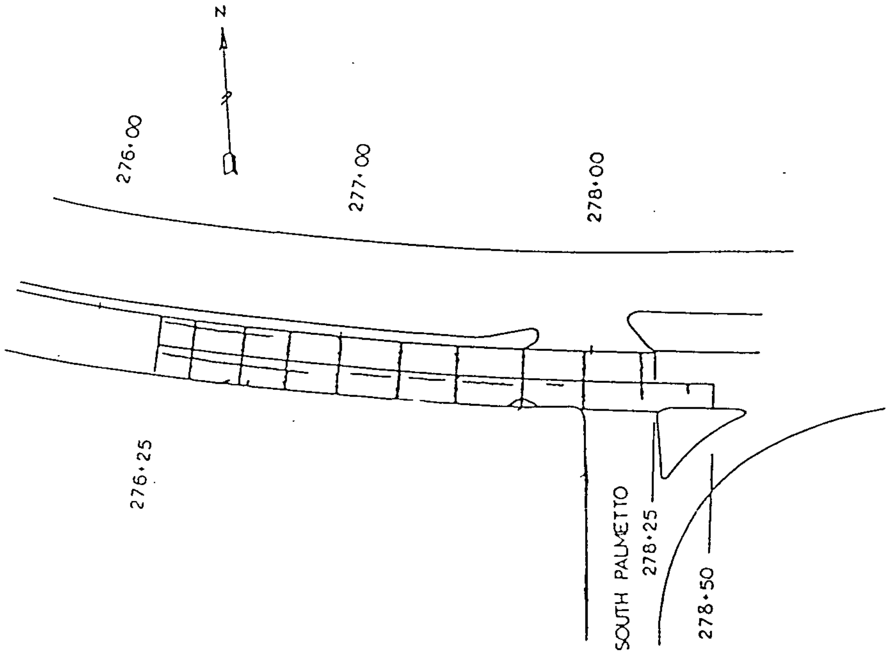

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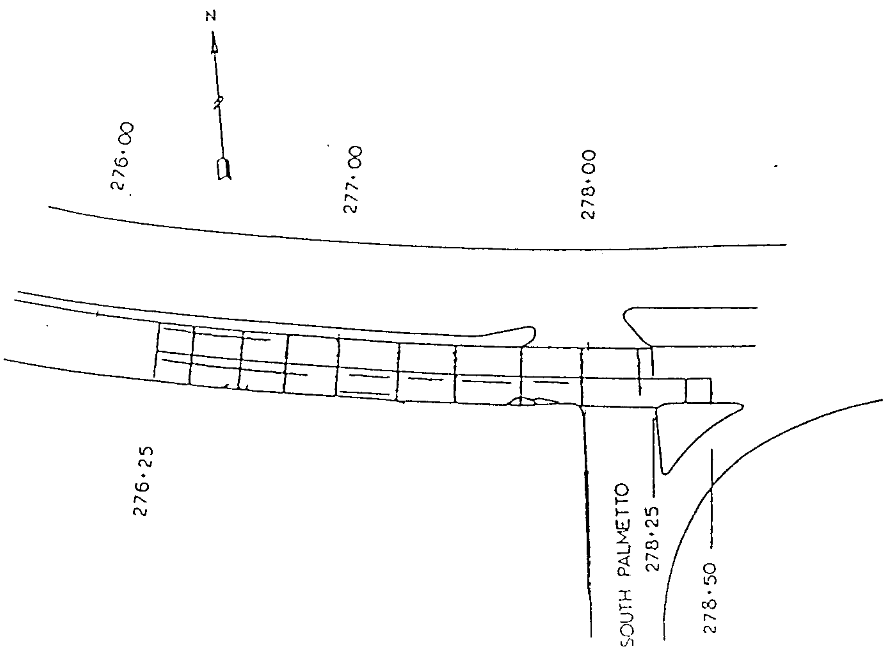

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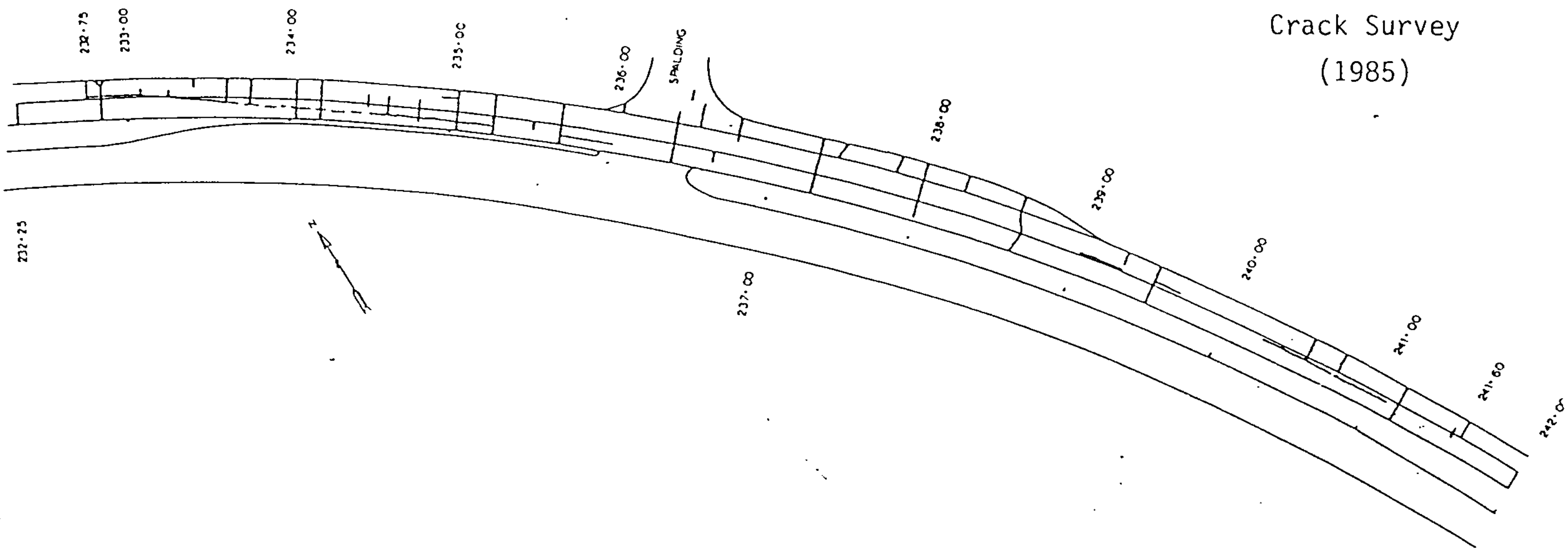

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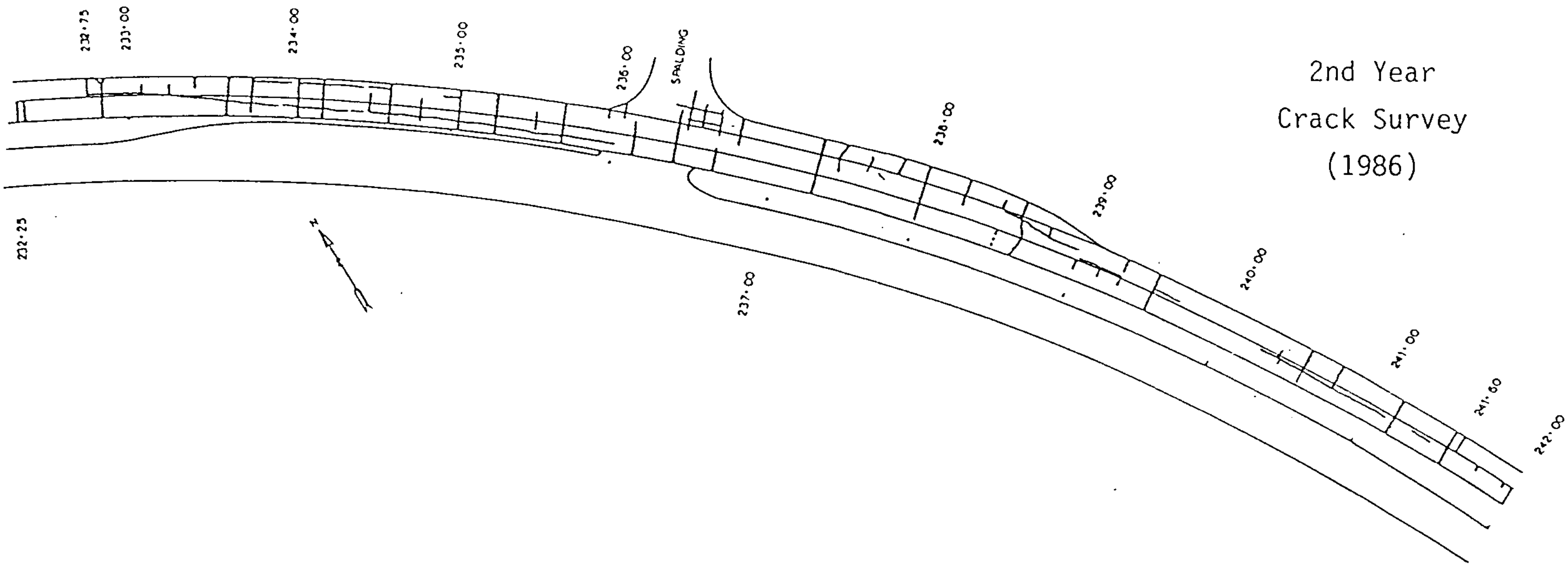

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