MAINTENANCE OF PAVEMENT SKID RESISTANCE
(Open Graded Asphalt Friction Courses)
Research Project HR-170

Progress Report To

The Iowa Highway Research Board

BY

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Table of Contents

INTRODUCTION

Dry pavements seldom offer inadequate skid resistance to a rolling or sliding motor vehicle tire. The formation of a film of water between the tire and pavement surface dramatically changes the physical interaction that normally takes place. Even greater changes take place when the vehicle is required to make significant adjustments in direction or speed. Numerous studies have been made in an effort to measure the skid resistance, skid resistance requirements, tire characteristics, and other related parameters. These studies caused the Federal Highway Administration to develop certain design criteria (1) and demonstration procedures (2) for field trials and evaluations by the states. This report documents the Iowa Department of Transportation's activity on such a project designed to evaluate one type of asphalt pavement surface that has, on occasion, shown that it can provide superior skid resistance when wet. When first developed, this surface was called "Plant Mix Seal Coat" because of its resemblance to chip seals commonly in use; through development and usage it has been renamed "Open Graded Asphalt Friction Course".

OBJECTIVES

Previous studies have shown that the characteristics of the aggregate and the design of the mix determine the skid resistance and structural performance of Open Graded Asphalt Friction Course mixes. Generally, aggregate selection for other types of pavement and uses is heavily influenced by availability and cost. Since the quantities of aggregate are significantly reduced through Open Graded Asphalt Friction Course construction, logistical problems associated with long distance shipping and higher unit costs could be justified on at least some high priority safety projects if this type of construction proves to be sufficiently superior. The major objectives of this project involve the evaluation of several aggregates previously rated poor to excellent with respect to skid resistance and certain mix design parameters. Detailed lists of these objectives, divided into three groups, are contained in Table 1.

EVALUATION APPROACH

Project Information. To attain the objectives listed in Table 1, the Iowa Department of Transportation, as the Iowa State Highway Commission, developed Research Project HR-170 on the recommendation of the Iowa Highway Research Board and with approval of the Federal Highway Administration. A construction contract (Story County FN-69-5(15)--21-85) was entered into with the Iowa Road Builders Company to construct ten test sections of Open Graded Asphalt Friction Course on US 69 north of Ames. Construction of the two and one half (2-1/2) miles of test sections began on July 15, 1974 and was completed on July 17, 1974. An as-built listing of the test sections is provided in Table 2 and a layout is provided in Appendix A.

The 2-1/2 miles of test sections are subjected to primary road traffic comparable to many miles of road around the state adjacent to urban areas. The Iowa DOT traffic records indicate the 1974 Average Daily Traffic (ADT) is 4050 VPD. Approximately 5.5 percent of these vehicles are trucks.

The existing pavement consisted of P.C. Concrete eight inches thick constructed in 1957 and asphalt concrete surfaced P.C. concrete pavement. The latter section of pavement had originally been constructed in 1931, widened in 1955, and resurfaced in 1957. Test Section Number 1 and part of Test Section Number 2 were constructed over the bare P.C. concrete pavement; the remaining sections (part of 2, and 3 thru 10) were constructed over the pavement resurfaced with asphalt concrete.

The design, construction, subsequent testing, and evaluations of the test sections generated considerable data. Mix design results are listed in Tables 3 through 7; project control test data are summarized in Tables 8, 9, and 10. Skid test data are listed in Table 11. All measurements and tests were performed per requirements of the Standard Specifications (3) and applicable Instructional Memorandums (4) (5).

Materials. The project was set up to evaluate the Open Graded Asphalt Friction Course using four comparably graded aggregates; quartzite, fine grained limestone, coarse grained limestone, and lightweight expanded shale. Source information and properties are provided in Table 8. These materials were selected because they represent the range of crushed aggregate characteristics normally available to the Iowa DOT.

Quartzite has a good performance history in conventional pavements and has also been extensively and satisfactorily used for filter stone and railroad ballast. Quartzite and traprock have been considered the best materials available. Usage though, has been limited because none of the sources (4 quartzite and 2 traprock) are located in the state.

Calcerous and dolomitic limestones of varying quality and texture-grain size are available locally over much of the state; coarse and fine grained limestone aggregates were therefore included in this project. Performance of the materials in pavements and structures can vary considerably and they therefore must be carefully selected and processed. Generally, limestone aggregates in asphalt surface courses have been found to polish quite rapidly and contribute to low skid resistance values. The polish-rate or SN loss can generally be correlated to traffic volume and aggregate texture or grain size.

Expanded shale-lightweight aggregate, available from three sources (one in Iowa) was selected because it has been used extensively by other states in open and dense graded asphalt mixtures to improve skid resistance. It has the advantage of being significantly lighter and thus less costly to ship. If it can be shown to resist studded tire wear (it may be possible to protect this material through blending) and otherwise exhibit satisfactory performance, it might become a viable alternative on some projects.

Asphalt binder material used throughout on this project was 85-100 penetration asphalt complying with the requirements of AASHTO Specification M-20. The properties of the material are shown in Table 12.

Project Construction. Construction operations were generally uneventful. The contractor arranged to have all of the materials on hand at the plant site and was quite well organized. Except for lowering the mixing temperature, only a few rather insignificant operational adjustments were necessary. The contractor used a conventional Cedar Rapids Batch Plant equipped with a Barber Greene dryer, cold feeder, and pollution control unit. A Cedar Rapids paver equipped with a vibratory screed was used to place the material. The mix was compacted with standard steel tired (static type) rollers. Compactive effort was controlled with a simple procedural specification (3).

Lowering the mixing temperature to prevent drainage of the asphalt cement during hauling and placing operations was found necessary on previous projects. Normally, asphalt mixtures are produced at temperatures ranging from 250°F (121°C) to 325°F (163°C). Because the Open Graded Friction Course mixtures are extremely open graded and contain few fines (minus 200), the viscosity of the binder must be reduced to prevent migration and drainage. The temperature range found satisfactory for producing these mixtures is 200°F (93°C) to 250°F (121°C). The exact temperature for a given mixture must be set on the job, taking into account such parameters as weather, haul distance, aggregate characteristics, and binder properties. For example, it was found that the quartzite mix used on Test Sections 9 and 10 could be produced as low as 200°F (93°C) and yet be handled satisfactorily by the paver. It should be noted this type of mixture cools quite rapidly and therefore can be difficult to place by hand methods. Delays and cool weather can further complicate placement and should therefore be avoided.

PERFORMANCE

The performance f field test sections must always be evaluated in light of the wide variety of variables found in the field, as opposed to laboratory studies which can be performed under more ideal conditions with the variables identified and controlled. The results and conclusions that precipitate from field experiments may be unduly influenced by uncontrolled or unidentified variables and therefore must be more carefully drawn. In some cases, the conclusions must be qualified or postponed because the trials have not run long enough to cause the actions and interactions to set out observations which clearly set trends or give cause to conclusions. Each of the original project objectives (Table 1) has been examined in light of the data collected and in each case, as outlined above, a determination has been made.

The "overall performance" of the ten tests sections of Open Graded Friction Course after 16 months of service can be classified into good and poor categories. Generally, bond, material wear, mixture durability, and skid resistance of all of the mixes must be rated good. Performance of all of the mixes over and adjacent to cracks and joints in the old pavement must be rated poor. Extensive raveling and abrasion of the surfacing over and adjacent to cracks and joints is taking place; this not only is severely detracting from the appearance, but is very quickly resulting in numerous non-uniform areas of driving surface. Field observations during periods of inclement weather also indicate that snow and ice control operations are somewhat more difficult to handle on the test sections as compared to the dense graded asphalt concrete pavement located to the north and the P.C. Concrete Pavement located to the south.

Research Objectives - Group I. Objective A involves, in part, the verification of observed performance demonstrated by the quartzite test sections on the preliminary Woodbury project (6). This objective also requires a determination, if possible, as to whether quartzite is indeed a superior polish resistant material as previously supposed.

Field observations appear to support the claims that quartzite is a sound and durable material, because traffic and weathering action have not depreciated the material on the road. Material loss from the pavement surface can be attributed to raveling of the mix adjacent to the many cracks that have reflected through from the old pavement and widening. The skid resistance test data of the quartzite sections (9 and 10), as shown in Figure 1, compare favorably with the Woodbury results and indicates that quartzite when used alone will provide acceptable SN levels.

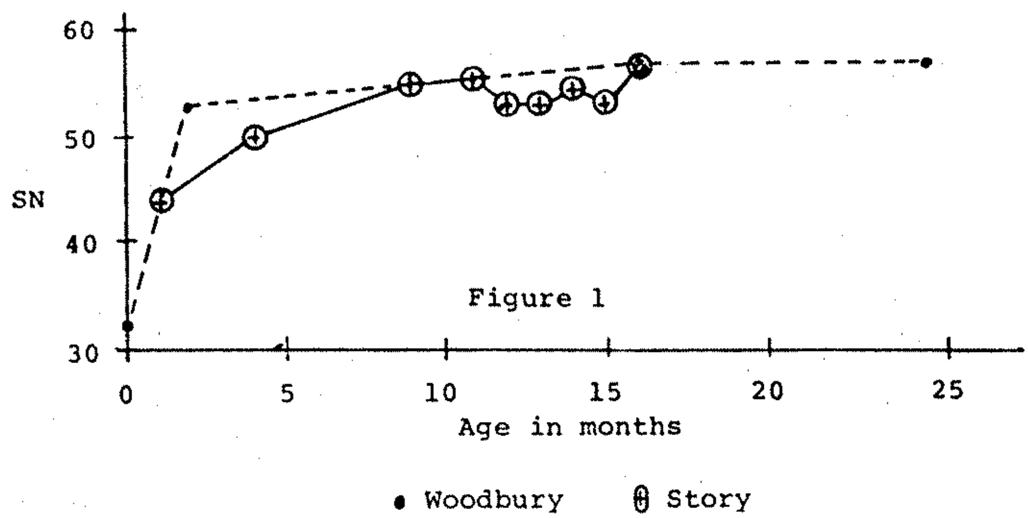


Figure 1

Quartzite

Objective B was designed to evaluate the effect of blending the assumed superior quartzite with a typical coarse grained-textured limestone. Crushed limestones comparable to this one are available over much of the state, but must be quarried selectively and with proper inspection safeguards. This group of crushed limestones has generally performed satisfactorily with respect to soundness and durability, although they have been found to polish when subjected to heavy traffic for long periods. Upgrading by blending may therefore extend usage and longevity. The blend of quartzite and coarse grained limestone was set up on an equal ratio basis, i.e. 50 percent quartzite, 50 percent limestone; each material having comparable gradation. Thus far, this blend (Test Sections 3 and 4) is performing satisfactorily with respect to durability. It is also exhibiting, as shown in Figure 2, an adequate SN history.

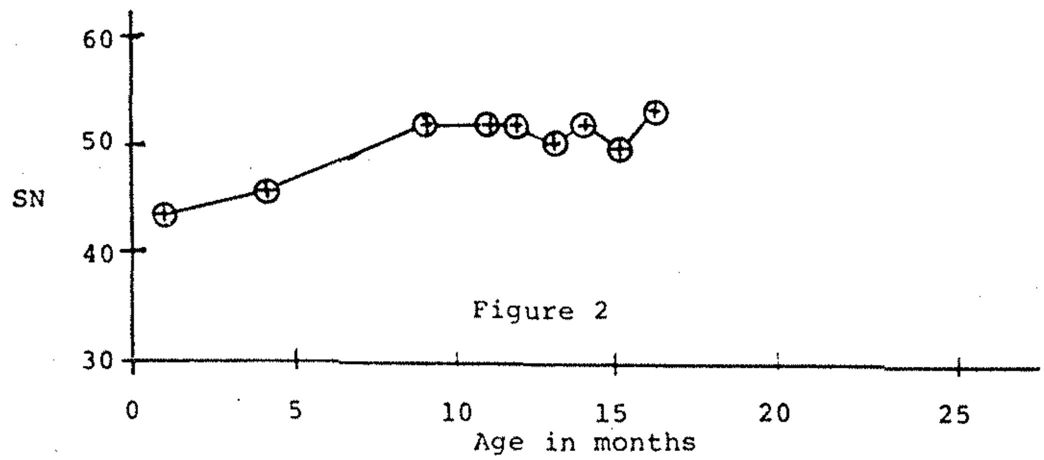


Figure 2

50/50 Blend of Quartzite & coarse grained limestone

Objective C was designed to evaluate an Open Graded Asphalt Friction Course using the previously described coarse grained limestone for aggregate. As mentioned above, this material has been used successfully, in asphalt concrete mixtures and is available locally in many areas. It therefore needed to be evaluated in this type of mixture. Based on the field trial in Test Sections 5 and 6, it would appear that this material will perform satisfactorily with respect to durability and, thus far, there does not appear to be any indication that it will wear excessively. The latter concern must be appreciated in terms of aggregate hardness and mineralogy, traffic volumes, and studded tire usage. All pavement surfaces and materials wear somewhat, but the aggregates in open graded mixes, due to the lack of supporting matrix, are potentially subject to more than average wear. The SN data, shown in Figure 3, appear to be more variable and somewhat lower on the average when compared to the data previously presented. It has maintained a higher SN level than the fine grained limestone test sections constructed in Black Hawk County (7).

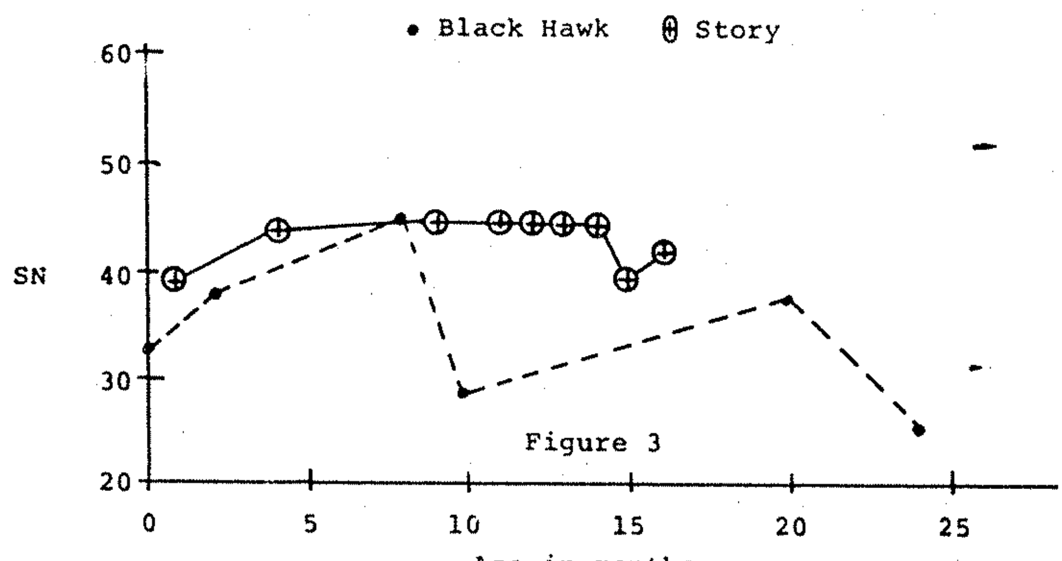
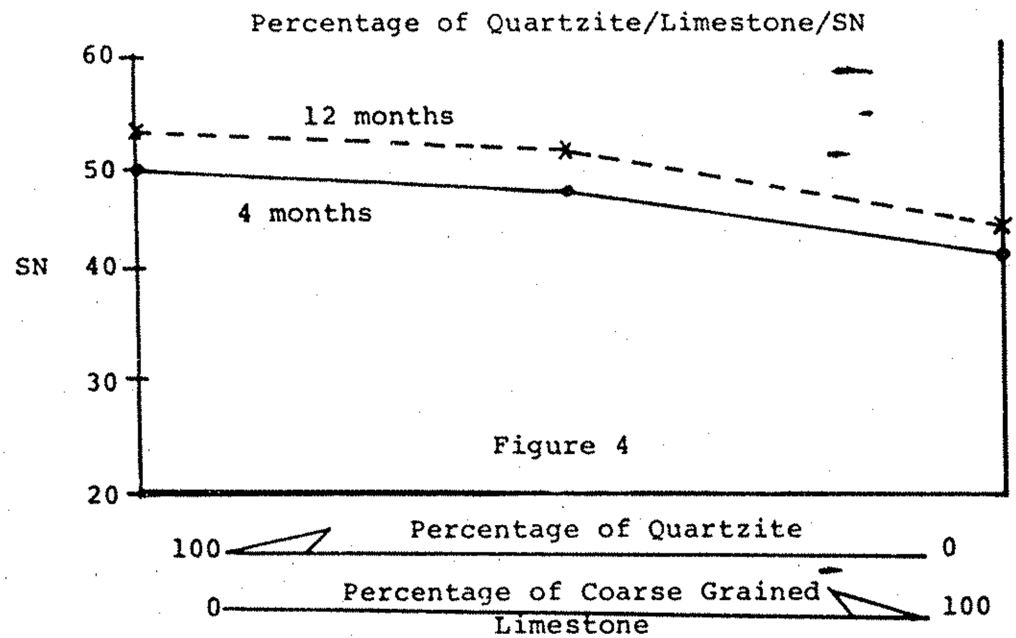


Figure 3

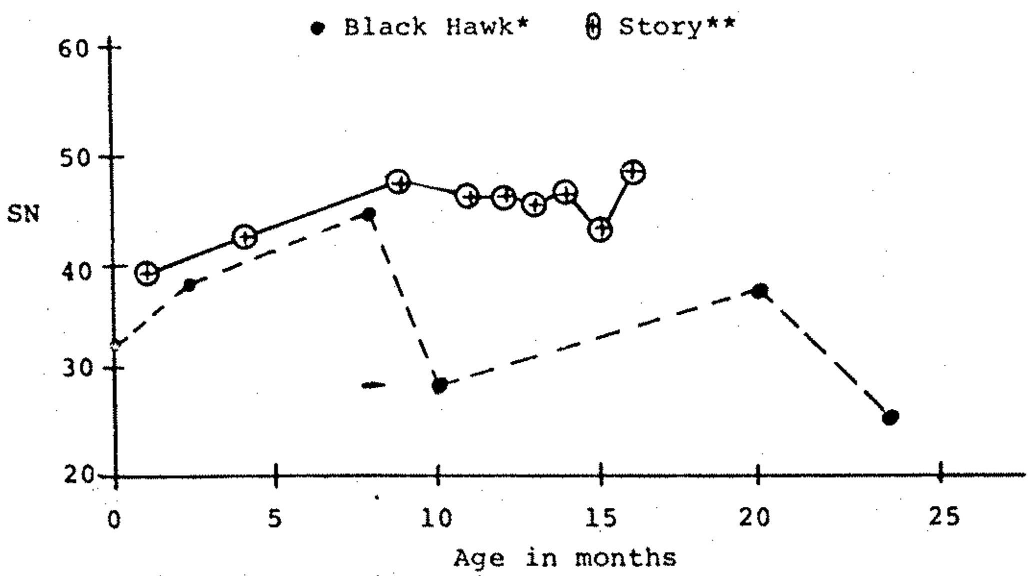
Coarse Grained Limestone

As a side light, the data obtained from the test sections constructed for objectives, A, B and C provide an opportunity to examine the SN performance of two materials separately and in combination. Figure 4 shows how quartzite and coarse grained limestone resist polishing after four months and one year of traffic. It should be noted that the 50/50 blend is composed of comparably graded aggregates.



The one year relationship, as is often the case, shows improvement in SN level over the shorter four month period. This can be attributed to weathering and traffic wear of the asphalt films present on the surface of the new pavement. The longer term trends will be examined in the analysis of the Group II Objectives.

Objective D was designed to evaluate the performance of a blend of quartzite and fine grained limestone. The combined material was comprised of equal parts of comparably graded material. Figure 5 shows that this blend placed on Test Sections 1 and 2, is also performing satisfactorily. The combination generally exhibits lower SN values than the previously described blend of quartzite and coarse grained limestone. This was expected because the Black Hawk (7) Open Graded Friction Course project indicated that fine grained limestone aggregates, when used alone, would not provide high ~~SN~~ values.



*100% Fine Grained Limestone
**50/50 Quartzite/Fine-Grained Limestone

Quartzite/Fine Grained Limestone

Objective E requires that an evaluation be made by extrapolating the data shown in figures 1 and 5 to verify the conclusion drawn on the Black Hawk project that fine grained limestone would exhibit low SN levels. The FHWA (1) et al have recommended that such materials not be used because they tend to polish under traffic.

Figure 6 tends to confirm that this type of material does in fact exhibit lower SN values.

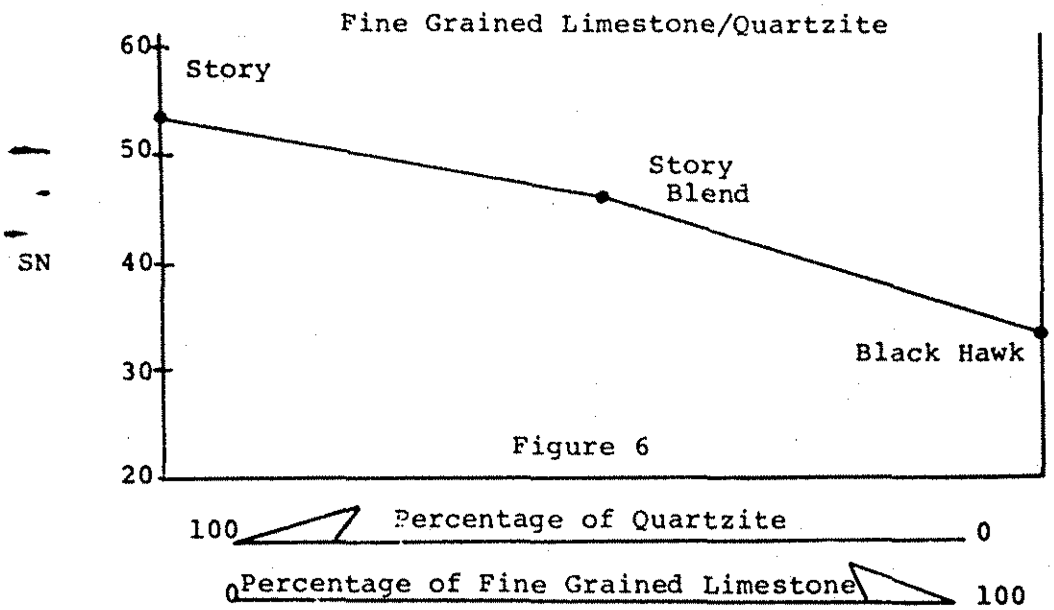


Figure 6

Objective H was designed to determine if an expanded shale (or clay) commonly used to produce lightweight concrete could be blended with a fine grained limestone and thereby obtain improved SN performance. Expanded clays and shales have been used by several southern states in this way quite successfully. Few sources of this material are available to the Iowa DOT; this of course can cause transportation logistics problems and result in higher costs. There is also some concern with regard to whether this aggregate is strong enough to resist studded tire wear. Obviously, test sections using this material were justified on this project.

Figures 7 and 8 indicate that this blend (Test Sections 7 and 8) is exhibiting satisfactory SN levels, Roadway examinations indicate that the combination is performing quite well with respect to wear and durability; surface course material loss thus far appears to be associated with reflection crack raveling.

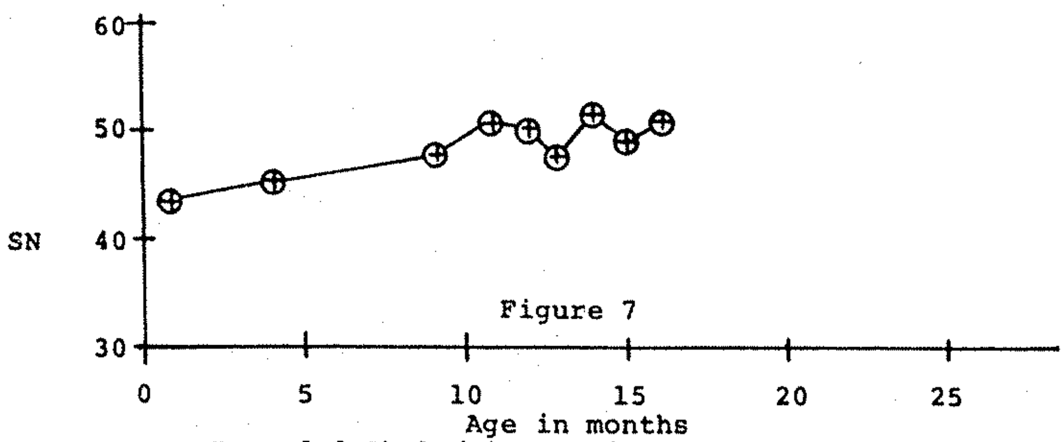


Figure 7

Expanded Shale/Fine Grained-Limestone Blend

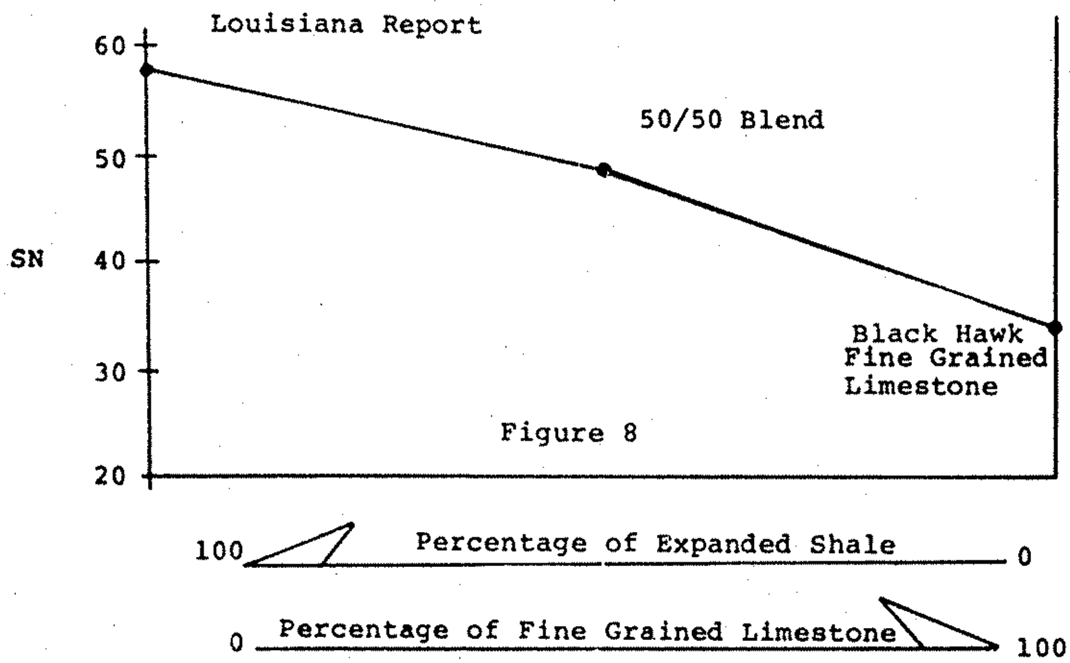


Figure 8

Expanded Shale/Fine Grained Limestone

Research Objectives - Group II

The second set of research objectives, K_1, through K_5, involves the evaluation of the effects of traffic on the aggregates used in the test sections. More specifically, of interest are the polishing rates determined by plotting the observed skid numbers versus the cumulative vehicle passes. The resultant slope K being the polishing rate. It will be noted that such slopes would be valuable design aids when selecting aggregates for projects and for predicting performance.

In evaluating the traffic-SN data for the test sections on the project, it was found that not enough time had passed to accumulate enough data points to establish definite trends. An example is Figure 9 which displays the polish curve data for the most polish susceptible aggregate used, i.e. limestone. The polish curves for the other aggregates indicate similar performance behavior and therefore were not included in this report.

Figure 9

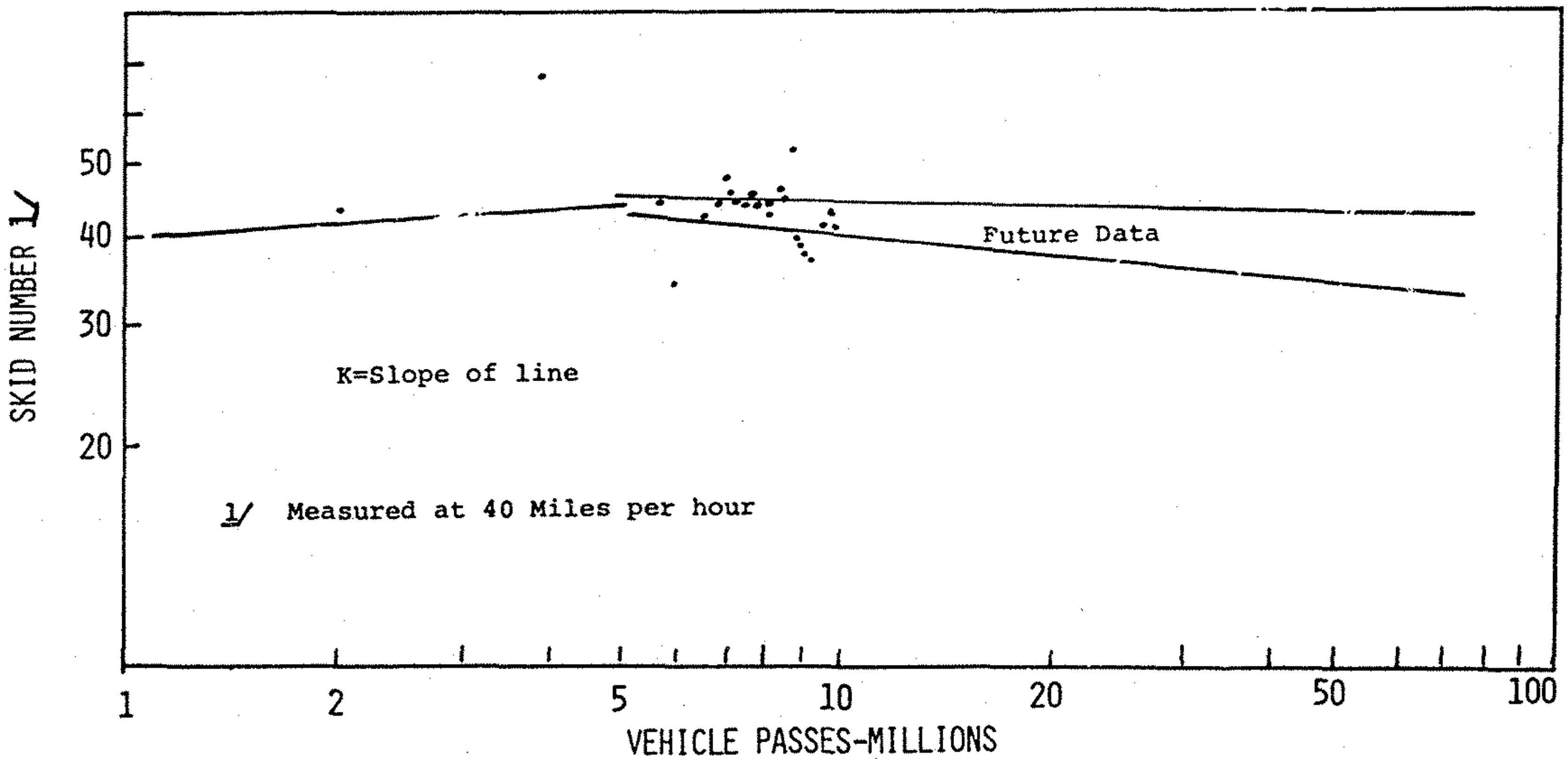


FIGURE 1-PAVEMENT WEAR (POLISH) CURVES

It would appear from the data collected thus far and the traffic volumes that at least several more years of exposure will be required before definite relationships can be established. A follow-up evaluation and report will therefore be needed.

Although the data does not as yet indicate definite long term trends, they do indicate that considerable traffic passages are required to wear the asphalt film off of the aggregate such that the maximum SN values can be realized. On this project, Figures 1 through 9 indicate that up to eight (8) months or about 600,000 vehicle passes respectively are required to maximize the SN potential. It would be reasonable to expect that roads with higher traffic volumes would realize the maximum SN sooner because higher traffic volumes would wear the films more rapidly.

Research Objectives - Group III

The first and second objectives in this group involve evaluating the effects of asphalt content differences with respect to traffic and performance. In order to minimize the effect of aggregate gradation, i.e. surface area, all of the mix designs were set up with comparable aggregate gradation target values. Two levels of asphalt content (5.25 and 6.25 percent) were then set to provide the different asphalt coatings on the aggregate particles and air void levels. Because the expanded shale-limestone aggregate combination had a substantially lower specific gravity than the other aggregate types, the asphalt contents for this special aggregate combination were adjusted upward (one percent) to provide comparable asphalt-aggregate relationships. Specific data for the various mixtures are contained in Tables 3 through 7.

Field examinations of the test sections indicate that after two winters there appears to be no relationship between asphalt content levels and traffic with respect to performance. Raveling type of wear, general wear, and weathering to date does not appear to be influenced by asphalt content. While it is possible to distinguish between aggregate types visually, it is not possible to distinguish between the asphalt content visually, even though there is a 19 percent volumetric difference.

A detailed examination of the substantial reflection cracking also indicates that asphalt content has not influenced raveling of the crack edges. This cracking has developed over virtually all old joints, cracks, and patches and is the primary distress parameter in evidence in all test sections. In addition to being unaffected by asphalt content, the reflection cracking and related raveling does not appear to be influenced by aggregate type.

In view of the performance observed to date, mix design parameters can not be defined exactly; although it can be safely concluded that none of the test sections exhibit evidence of over-asphalting. This finding is supported by the observations that flushing, bleeding, instability or other unsatisfactory behavior caused by over-asphalting are not in evidence on any test section. This would indicate that the asphalt film thickness and air void levels for the higher asphalt content level (6.25%) can be used for future designs. The lower asphalt content level (5.25%) used on this project, although more economical, would, based on past performance on other projects and research, be considered too low for good long term performance. Of course, it will continue to be necessary to exercise good judgment, as is always the case, when designing mixes of this type. The primary characteristics requiring attention and consideration will continue to be material characteristics such as aggregate gradation and absorption, roadway features, and traffic.

The third research objective in the group involved evaluating bond of the open graded friction course mixture in Test Sections 1 and 2 to the portland cement concrete pavement. There had been reports that this type of mix could not be bonded satisfactorily to such pavements without first placing a new asphalt concrete binder course. In examining Test Sections 1 and 2, it was found that all of the mix was satisfactorily bonded except where reflection cracks and joints were showing through. Raveling at cracks and joints was found to be comparable to that observed on the previously overlaid sections, 3 through 10. Again mixture asphalt content (5.25% & 6.25%) did not appear to affect performance with respect to bond or crack raveling. It was also interesting to note that bond on both types of pavement was not affected by the variable and substandard tack coat application which caused some concern while work was in progress.

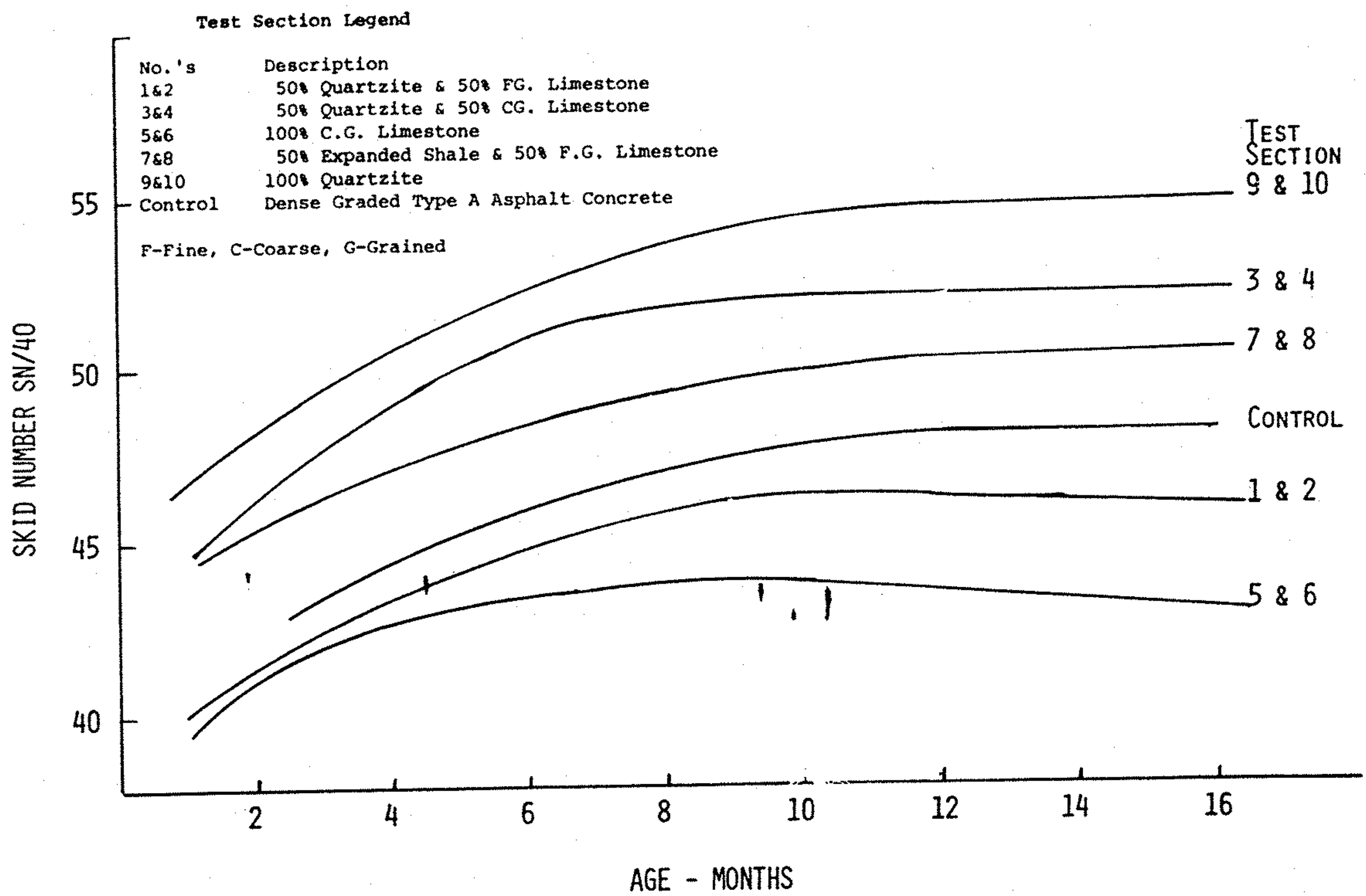
SUMMARY

A research project designed to evaluate Open Graded Asphalt Friction Courses is described. The 2-1/2 mile project located on U.S. 69 north of Ames in Story County involved placement of ten (1) test sections. Mixes were placed using five (5) aggregate combinations, each at two (2) asphalt contents. Performance of the test sections was evaluated by SN testing and field examinations.

The SN performance of all test sections after sixteen (16) months of traffic exposure was fou to be satisfactory in that none of the material combinations had polished to the point where unacceptable SN levels developed. When material combinations were compared, refer to Figure 10, significant differences were noted. Three of the test sections, it is shown, exhibit higher SN levels than the adjacent dense graded 3/8 inch Type A Asphalt Concrete surface placed just before the research project began.

FIGURE 10

SKID NUMBER VS. AGE



Field examinations through the first 20 months of service indicated that, except where reflection crack raveling was taking place, all of the mixes were well bonded, resisting wear and weathering satisfactorily, and did not exhibit obvious sensitivity to asphalt content. Thus far, the primary distress parameter appears to be crack raveling; some maintenance will be needed in the near future because of this. It should be noted that the adjacent surfacing placed in 1974 on comparable base will also soon require crack maintenance, although to a lesser extent.

CONCLUSIONS

The major objectives of this project involve the evaluation of Open Graded Asphalt Friction Courses using the spectrum of aggregates available to the Iowa Department of Transportation, and certain mix design parameters. The following conclusions are based on the performance observed on this project.

1. Open Graded Asphalt Friction Courses can be satisfactorily constructed on and bonded to old portland cement concrete and asphalt concrete bases.
2. The primary distress parameter after 20 months of service is surface raveling over and adjacent to virtually all reflection cracks.
3. Crack raveling will require early maintenance, reduce the effective service life significantly, and detracts from the otherwise satisfactory appearance.
4. Within the range of asphalt contents used on this project, these mixes do not appear to be sensitive to asphalt content. The performance of all of the test sections indicates that future mix designs should exhibit characteristics comparable to the 6.25% Asphalt Content mixes.
5. Crack raveling does not appear to be affected by asphalt content or aggregate type.
6. The quartzite aggregate after 20 months of service appears to develop and maintain higher SN values than the other aggregates and significantly influences and improves the performance of aggregate blends.

Bibliography

1. Report No. FHWA-RD-74-2 Design of Open Graded Asphalt Friction Courses, US Department of Transportation, FHWA Office of Research and Development.

2. Demonstration Projects Program, US Department of Transportation, FHWA Region 15.

3. Standard Specifications, Series 1972, Iowa State Highway Commission as amended by applicable Special Provisions and Supplemental Specifications, (refer to contract documents for specific list).

4. Materials I.M. Manual, Office of Materials, Iowa Department of Transportation, Ames, Iowa.

5. Laboratory Manual, Office of Materials, Iowa Department of Transportation, Ames, Iowa.

6. Bernhard H. Ortgies, Special Report - Plant Mix Seal Coat Test Section, Woodbury County, Materials Department, Iowa State Highway Commission, September, 1973.

7. Bernhard H. Ortgies, Special Report - Plant Mix Seal Coat Test Section, - Black Hawk County, Iowa State Highway Commission, September, 1973.

7. Expanded shale significantly upgrades the performance of the fine grained limestone aggregate. Thus far the expanded shale - fine grained limestone combination (Test Sections 7 & 8) is exhibiting higher SN values than the quartzite - fine grained limestone combination, (Test Sections 1 & 2).

9. The second best SN performance curve is provided by the quartzite - coarse grained limestone combination (Test Sections 3 & 4).

10. It will be necessary to continue to monitor the performance of the test sections for several more years in order to fully assess the effects of environment and traffic.

Table 1
Research Objectives - Group I

A. Compare initial SN* values for quartzite in Test Sections 9 and 10 with Woodbury County project tests. These are the control sections.

B. Determine effect of blending coarse grained limestone and quartzite in Test Sections 3 and 4.

C. Determine performance of coarse grained limestone PMSC in Test Sections 5 and 6.

D. Determine effect of blending fine grained limestone and quartzite in Test Sections 1 and 2.

E. Verify fine grained limestone performance by extrapolating (A-D) and comparing results with Black Hawk County project tests.

H. Determine effect of blending fine grained limestone and expanded shale in Test Sections 7 and 8.

Research Objectives - Group II

K_1. Determine the effect of traffic on SN for quartzite-control sections.

K_2. Determine the effect of traffic on SN for coarse-grained limestone - quartzite blend PMSC mixture.

K_3. Determine the effect of traffic on SN for coarse grained limestone PMSC mixture.

K_4. Determine the effect of traffic on SN for fine grained limestone - quartzite blend PMSC mixture.

K_5. Determine the effect of traffic on SN for fine grained limestone - expanded shale PMSC mixture.

Research Objectives - Group III

1. Determine effect of traffic on asphalt content. LQ_1, LQ_2, MQ_1, MQ_2, M_1, M_2, LH_1, LH_2, Q_1, Q_2.

2. Establish mix design criteria for various PMSC mixes and aggregate combinations.

3. Evaluate bonding of PMSC (Sections 1 and 2) to Portland cement concrete pavement.

*SN - Skid Number - Coefficient of friction as determined by the locked wheel skid test trailer as specified in ASTM E-17.

Table 2
Test Section Layout
Aggregate Evaluation - Story County U.S. 69 No. of Ames

Test Section No.	Actual SB Sta.	Actual SB Sta.	Actual NB Sta.	Actual NB Sta.	Per Cent Aggregates	%A.C.	(EP)	Actual Tonnage SB	Actual Tonnage NB
1	144+85	158+05	144+85	161+34	50% Penn. L.S. - 50% Quartzite	5.25	PC	72.5	72.5
2	158+05	173+08	161+34	174+76	50% Penn. L.S. - 50% Quartzite	6.25	PC	72.5	72.5
3	173+08	186+78	174+76	189+61	50% Maynes Cr. L.S. - 50% Quartzite	5.25	AC	60	72.5
4	186+78	200+17	189+61	202+53	50% Maynes Cr. L.S. - 50% Quartzite	6.25	AC	60	72.5
5	200+17	210+65	202+53	212+80	100% Maynes Cr. L.S.	5.25	AC	72.5	72.5
6	210+65	222+37	217+32	223+18	100% Maynes Cr. L.S.	6.25	AC	72.5	72.5
7	222+37	235+03	223+18	233+12	50% Penn. L.S. - 50% Exp. Shale	6.25	AC	58	58
8	235+03	250+30	233+12	244+47	50% Penn. L.S. - 50% Exp. Shale	7.25	AC	66	58
9	250+30	261+60	244+47	263+65	100% Quartzite	5.25	AC	74.4	135.36
10	261+60	274+60	263+65	276+85	100% Quartzite	6.25	AC	60	71.2

(EP) Existing pavement type
*BOP - Begin project 1/2 mile south of beginning of existing A.C. surfacing.
Section 10 - Part North & part South of Gilbert Cor., Jct. Co. Rd. E-23, and includes Intersection
Section Length approximately 1/4 mile
Penn. - Pennsylvanian System - "Argentine L.S. Member" - Source Menlo, Ia.
Quartzite - Source - New Ulm, Minn.
Mississippian System - "Maynes Cr. L.S. Member" - Source - Ferguson, Ia.
Expanded Shale H - Light Wt. Aggr. - Source - Centerville, Ia.

TABLE 3

Form 860 10/71

H. Ortgies
C. Roberts
Ia. Rd. Bldrs.

Asph Mix Design
FN-69-5(15)--21-85
Story
L. Zearley
R. Henely
P. McGuffin
M. Stump

IOWA STATE HIGHWAY COMMISSION
(MATERIALS DEPARTMENT)

ASPHALT CONCRETE MIX DESIGN
AMES LABORATORY

Mix, Type and Class: Plant Mix Seal Coat Size 1/2" Lab. No. ABD4-94

Intended Use: Spec. No. 743 & proposal Date Reported 8-8-74

County: Story Proj. No. FN-69-5(15)--21-85 Contractor Ia. Road Builders Co.

Proj. Location: On U.S. 69 North of Ames

Agg. Source: Lt. Chips-Menlo Gr.-Adair Co.;3/8" Quartzite chips-New Ulm-Minn.;7/32" Quartzite-New Ulm-Minn.

Job Mix Formula Aggregate Proportions: 50% AAT4-398;31.3% AAT4-393;18.7% AAT4-392

JOB MIX FORMULA - COMBINED GRADATION

1½"	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200
			100	97	44	12	5.2	3.9	3.1	2.6	2.4
Tolerance											

Asphalt Mix, ABC -	Results based on calculations using Sp. Gr. of 1" specimens with 50 blows on one side			
Date Tested	7-9-74	7-9-74	7-9-74	7-9-74
% Dry Agg. in Mix	95.00	94.00	93.00	92.00
% Asph. in Mix	5.00	6.00	7.00	8.00
Marshall Stability - Lbs.	992	1278	1097	1020
Flow - 0.01 In.	10	8	9	12
1" spec. 50 blows one side	2.12	2.14	2.13	2.17
Sp. Gr. By Displacement	2.13	2.13	2.13	2.12
Bulk Sp. Gr. Comb. Dry Agg.	2.646	2.646	2.646	2.646
Sp. Gr. Asph. @ 77 F.	1.025	1.025	1.025	1.025
Calc. Solid Sp. Gr.	2.47	2.44	2.40	2.37
Rice Sp.Gr.	2.48	2.44	2.40	2.38
% Voids	14.2	12.1	11.2	8.3
% Water Absorption - Aggregate	0.67	0.67	0.67	0.67
% Voids in the Mineral Aggregate	23.9	24.0	25.1	24.6
% V.M.A. Filled with Asphalt	40.5	49.5	55.3	66.3
Calculated Asph. Film Thickness (Microns)	22.4	27.6	32.8	38.1

Test Sec.#1- 5.25% 85-100 pen. asp. recommended.
Test Sec.#2- 6.25% 85-100 pen. asp. recommended.

SIGNED: Bernard C. Brown

TABLE 4

Asphalt Mix Design
L. Zearley
FN-69-5(15)--21-85
Story
R.C. Henely
P. McGuffin
M. Stump

Form 956
10/71

IOWA STATE HIGHWAY COMMISSION
(MATERIALS DEPARTMENT)

ASPHALT CONCRETE MIX DESIGN
AMES LABORATORY

B. Ortgies
S. Roberts
Ia. Rd. Bldg.

G. Perrin
C. Jones

Type and Class: Plant Mix Seal Coat Size ½" Lab. No. ABD4-95

Intended Use: Spec. No. 743 & proposal Date Reported 8-8-74

County: Story Proj. No. FN-69-5(15)--21-85 Contractor Iowa Road Builders Co.

Proj. Location: On U.S. 69 North of Ames

Agg. Sources: Lst.Chips-Ferguson Qr.-Marshall Co.; Agg.Lime-Ferguson Qr.- Marshall Co.; 3/8"Quartzite chips-New Ulm-Minn.; 7/32"Quartzite-New Ulm-Minn.

Job Mix Formula Aggregate Proportions: 45% AAT4-394; 5% AAT4-395; 31.3% AAT4-393; 18.7% AAT4-392

JOB MIX FORMULA - COMBINED GRADATION

1½"	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200
			100	93	41	11	6.8	5.2	3.9	2.9	2.4
Tolerance											

Asphalt Mix, ABC -	Results based on calculations using Sp. Gr. of 1" specimens with 50 blows on one side.			
Date Tested	7-9-74	7-9-74	7-9-74	7-9-74
% Dry Agg. In Mix	95.00	94.00	93.00	92.00
% Asph. In Mix	5.00	6.00	7.00	8.00
Marshall Stability - Lbs.	1900	2125	1960	1633
Flow - 0.01 In.	8	9	8	11
Sp. Gr. By Displacement	2.16	2.17	2.17	2.17
1" spec. 50 blows one side	2.14	2.16	2.19	2.16
Bulk Sp. Gr. Comb. Dry Agg.	2.634	2.634	2.634	2.634
Sp. Gr. Asph. @ 77 F.	1.025	1.025	1.025	1.025
Calc. Solid Sp. Gr.	2.47	2.43	2.40	2.36
Rice Sp. Gr.	2.444	2.401	2.407	2.381
% Voids	12.4	10.8	9.5	8.2
% Water Absorption - Aggregate	0.93	0.93	0.93	0.93
% Voids in the Mineral Aggregate	22.1	22.6	23.4	24.1
% V.M.A. Filled with Asphalt	43.5	52.2	59.5	66.2
Calculated Asph. Film Thickness (Microns)	20.6	25.4	30.3	35.4

Test section #3 -- 5.25% 85-100 pen. asphalt recommended
" " #4 -- 6.25% 85-100 pen. asphalt recommended

SIGNED: Bernard C. Brown
(TESTING ENGINEER)

TABLE 5

Form 956 10/71

S.Roberts
Ia. Rd. Bldrs.

IOWA STATE HIGHWAY COMMISSION
(MATERIALS DEPARTMENT)

ASPHALT CONCRETE MIX DESIGN
AMES LABORATORY

Asphalt Mix Design
FN-69-5(15)--21-85
Story
L.Zearley
P.McGuffin
M.Stump
B.Ortgies

Mix, Type and Class: Plant Mix Seal Coat Size 1/2" Lab. No. ABD4-96

Intended Use: Spec. No. 743 & proposal Date Reported 8-8-74

County: Story Proj. No. FN-69-5(15)--21-85 Contractor Iowa Road Builders Co.

Proj. Location: On U.S. 69 North of Ames

Agg. Sources: Lst. Chips-Ferguson Qr.-Marshall Co.; Agg. Lime-Ferguson Qr.-Marshall C

Job Mix Formula Aggregate Proportions: 90% AAT4-394; 10% AAT4-395

JOB MIX FORMULA - COMBINED GRADATION

1½"	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200
			100	86	40	12	10	7.8	6.0	4.7	3.7
Tolerance											

Asphalt Mix, ABC -	Results based on calculations using Sp. Gr. of 1" specimens with 50 blows on one side			
Date Tested	7-12-74	7-12-74	7-12-74	7-12-74
% Dry Agg. in Mix	95.00	94.00	93.00	92.00
% Asph. in Mix	5.00	6.00	7.00	8.00
Marshall Stability - Lbs.	2425	2375	2383	2208
Flow - 0.01 in.	9	9	9	10
1" spec. 50 blows one side	2.18	2.19	2.23	2.25
Sp. Gr. By Displacement	2.18	2.21	2.26	2.25
Bulk Sp. Gr. Comb. Dry Agg.	2.616	2.616	2.616.	2.616
Sp. Gr. Asph. @ 77 F.	1.025	1.025	1.025	1.025
Calc. Solid Sp. Gr.	2.47	2.44	2.40	2.37
% Voids	11.9	10.2	7.2	5.0
% Water Absorption - Aggregate	1.67	1.67	1.67	1.67
% Voids in the Mineral Aggregate	20.8	21.3	20.7	20.9
% V.M.A. Filled with Asphalt	43.0	52.3	65.3	76.1
Calculated Asph. Film Thickness (Microns)	15.9	20.1	24.5	28.9

Test sec.#5- 5.25% 85-100 pen.Asp. recommended.
#6- 6.25% 85-100 pen.Asp. recommended

SIGNED: Bernard C. Brown

TABLE 6

Form 956 10/71

S. Roberts
Ia. Road Bldrs.
C. Jones
G. Perrin

IOWA STATE HIGHWAY COMMISSION
(MATERIALS DEPARTMENT)

ASPHALT CONCRETE MIX DESIGN
AMES LABORATORY

Asphalt Mix Design
FN-69-5(15)--21-85
Story
L. Zearley
R.C. Henely
P. McGuffin
M. Stump
B. Ortgies

Mix, Type and Class: Plant Mix Seal Coat Size ½" Lab. No. ABD4-101

Intended Use: Spec. No. 743 & proposal Date Reported 8-08-74

County Story Proj. No. FN-69-5(15)--21-85 Contractor Iowa Road Builders Co.

Proj. Location: On U.S. 69 North of Ames

Agg. Sources: Lst. Chips--Menlo Qr.--Adair Co.; Light weight aggregate--Centerville-Appanoose County

Job Mix Formula Aggregate Proportions: 63.9% AAT4-398; 36.1% T4-420

JOB MIX FORMULA - COMBINED GRADATION

1½"	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200
% by	volume		100	96	39	11	5.6	4.4	4.1	3.7	3.1
~~*Tolerance*~~ % by wt.			100	96	42	12	6.0	4.6	4.2	3.8	3.4

Results based on calculations using Sp. Gr. of 1" specimens with 50 blows on one side.

Asphalt Mix, ABC -				
Date Tested	7-12-74	7-12-74	7-12-74	7-12-74
% Dry Agg. in Mix	95.00	94.00	93.00	92.00
% Asph. in Mix	5.00	6.00	7.00	8.00
Marshall Stability - Lbs.	1442	1410	1327	1070
Flow - 0.01 in.	11	11	13	12
1" Spec. 50 blows one side	1.70	1.69	1.78	1.74
Sp. Gr. By Displacement	1.72	1.73	1.73	1.73
Bulk Sp. Gr. Comb. Dry Agg.	2.209	2.209	2.209	2.209
Sp. Gr. Asph. @ 77 F.	1.025	1.025	1.025	1.025
Calc. Solid Sp. Gr.	2.10	2.08	2.06	2.04
Rice Sp. Gr.	2.03	1.97	1.96	1.98
% Voids	19.2	18.7	13.5	14.5
% Water Absorption - Aggregate	0.70	0.70	0.70	0.70
% Voids in the Mineral Aggregate	26.9	28.1	25.1	27.5
% V.M.A. Filled with Asphalt	28.8	33.3	46.2	47.3
Calculated Asph. Film Thickness (Microns)				

Test section #7---6.25% 85-100 pen. recommended
Test section #8---7.25% 85-100 pen. recommended

SIGNED: Bernard C. Brown

Form 958 10/71

B. Ortgies
S. Roberts
Ia. Rd. Bldrs.
C. Jones
G. Perrin

TABLE 7

IOWA STATE HIGHWAY COMMISSION
(MATERIALS DEPARTMENT)
ASPHALT CONCRETE MIX DESIGN
AMES LABORATORY

Asph. Mix Design
L. Zearley
FN-69-5(15)--21-85
Story
R.C. Henely
P. McGuffin
M. Stump

Mix, Type and Class: Plant Mix Seal Coat Size ½" Lab. No. ABD4-97

Intended Use: Spec. No. 743 & proposal Date Reported 8/8/74

County Story Proj. No. FN-69-5(15)--21-85 Contractor Iowa Road Builders Co.

Proj. Location: On U.S. 69 N. of Ames

Agg. Sources: 3/8" Quartzite Chips - New Ulm, Minnesota; 7/32" Quartzite - New Ulm, Minn.; Portland Cement Filler

Job Mix Formula Aggregate Proportions: 60.5% AAT4-393; 37.5% AAT4-392; 2.0% Portland Cement

JOB MIX FORMULA - COMBINED GRADATION

1½"	1"	3/4"	½"	3/8"	#4	#8	#16	#30	#50	#100	#200
				100	43	13	5.2	4.4	3.7	3.4	3.2
Tolerance											

Asphalt Mix, ABC -	Results based on Calculations using Sp. Gr. of 1" specimens with 50 blows on one side.			
Date Tested	7/10/74	7/10/74	7/10/74	7/10/74
% Dry Agg. In Mix	95.00	94.00	93.00	92.00
% Asph. In Mix	5.00	6.00	7.00	8.00
Marshall Stability - Lbs.	1033	1108	917	708
Flow - 0.01 in.	9	9	10	12
1" Spec. 50 blows one side	2.14	2.15	2.15	2.15
Sp. Gr. By Displacement	2.15	2.15	2.13	2.11
Bulk Sp. Gr. Comb. Dry Agg.	2.660	2.660	2.660	2.660
Sp. Gr. Asph. @ 77 F.	1.025	1.025	1.025	1.025
Calc. Solid Sp. Gr.	2.47	2.43	2.40	2.36
	2.48	2.45	2.40	2.40
% Voids	13.3	11.6	10.3	9.0
% Water Absorption - Aggregate	0.13	0.13	0.13	0.13
% Voids in the Mineral Aggregate	23.6	24.0	24.8	25.6
% V.M.A. Filled with Asphalt	43.7	51.9	58.6	65.0
Calculated Asph. Film Thickness (Microns)	20.0	24.2	28.6	33.1

Test Sec. No. 9 5.25% 85-100 Pen Asphalt recommended
10 6.25% 85-100 Pen Asphalt recommended

SIGNED: [signature] (TESTING ENGINEER)

Table 8

Aggregate Data

Material	Producer	Source	Average Test Results												
							Gradation								
			F&T-A	Abra.	Abso.	Sp. Gr.	1/2"	3/8"	No.4	No.8	No.16	No.30	No.50	No.100	No.200
1/2" Crushed Limestone	Concrete Materials	Ferguson Quarry NWSWS82N-17N	1.3	32	.70	2.599	100	84	34	2.0	1 6	1.2	1.1	1.0	0.9
Crushed Limestone	Concrete Materials	Ferguson Quarry	---	---	---	-----				100	87	66	50	38	29
Crushed Limestone	Schildberg	Menlo Quarry SWSE-17-77N-31W	5.12	23.6	.70	2.668	100	94	47	24	7.0	5.2	4.5	4.0	3.7
7/32x#8 Quartzite	New Ulm Quarries, Inc.	New Ulm, Minnesota	0.4	24	N.A.*	2.656	100	100	98	24	4.6	3.5	2.5	1.8	1.5
3/8x19/64 Quartzite	New Ulm Quarries, Inc.	New Ulm, Minnesota	0.4	24	N.A.	2.656	100	100	6.3	3.2	2.4	1.8	1.4	1.1	1.0
Expanded Shale	Carter Waters	Centerville NW¼23-69N-18W	1.5	N.A.	6.6	1.651	100	99	32	7.[illegible]	4.1	3.7	3.6	3.3	2.8

*Not Available

Table 9

Comparison of Gradation Tests

Sieve Size	Test Section No. 1			Test Section No. 2			Test Section No. 3			Test Section No. 4			Test Section No.5		
	Percent Passing			Percent Passing			Percent Passing			Percent Passing			Percent Passing		
	JMF	CF	Extr.	JMF	CF	Extr.	JMF	CF	Extr.	JMF	CF	Extr.	JMF	CF	Extr.
1/2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
3/8	97	97	97	97	97	97	93	94	93	93	94	93	86	85	87
No. 4	44	44	47	44	44	48	41	43	44	41	43	43	40	43	48
No. 8	12	15	18	12	15	18	11	18	19	11	18	18	12	19	20
No. 30	3.9	5.2	6.8	3.9	5.2	7.0	7.0	5.2	8.3	9.1	5.2	8.3	7.8	12	12
No. 200	2.4	3.3	3.1	2.4	3.3	3.7	2.4	4.4	5.1	2.4	4.4	4.9	3.7	6.7	7.7
% AC./Batch Wt.		5.25			6.25			5.25			6.25			5.25	

Sieve Size	Test Section No. 6			Test Section No. 7			Test Section No. 8			Test Section No. 9			Test Section No. 10		
1/2	100	100	100	100	100	100	100	100	100	100	100*	100	100	100*	100
3/8	86	85	86	96	98	95	96	98	97	100	100	100	100	100	100
No. 4	40	43	44	42	38	39	42	38	39	43	30	31	43	30	31
No. 8	12	19	19	12	13	15	12	13	9.1	13	12	15	13	12	15
No. 30	7.8	12	11	4.6	6.1	7.0	4.6	6.1	5.4	4.4	3.9	6.3	4.4	3.9	7.0
No. 200	3.7	6.7	7.6	3.4	4.7	5.2	3.4	4.7	4.2	3.2	1.5	3.3	3.2	1.5	3.3
% AC./Batch Wt.		6.25			6.25			7.25			5.25			6.25	

JMF - Job Mix Formula Target Gradation CF - Cold Feed Plant Gradation Extr. - Extracted Gradation *Add 2% Portland Cement Filler

Table 10

Laboratory Test Data

Test Section	Gradation by Extraction										Percent Asphalt By Batch Weight	Lab Density		Marshall Stability	Marshall Flow
	3/4"	1/2"	3/8"	No.4	No.8	No.16	No.30	No.50	No.100	No.200		1"*	24"**		
1	100	100	97	47	19	9.5	6.8	4.8	3.6	3.1	5.25	2.21	2.16	1096	10
2	100	100	97	48	18	9.5	7.1	5.4	4.2	3.7	6.25	2.25	2.16	1065	13
3	100	100	93	44	19	11	9.1	7.3	6.0	5.1	5.25	2.27	2.17	1836	8
4	100	100	93	43	18	11	8.8	7.0	5.8	4.9	6.25	2.30	2.21	1736	9
5	100	100	87	48	20	14	11	10	9.0	7.7	5.25	2.28	2.20	2532	8
6	100	100	86	44	19	13	11	10	8.8	7.6	6.25	2.33	2.24	2393	10
6A	100	100	86	41	16	12	10	8.9	7.9	6.8	6.25	2.32	2.21	2210	9
7	100	100	95	39	15	8.8	7.0	6.1	5.6	5.2	6.25	1.70	1.70	1461	12
8	100	100	97	38	9.1	6.3	5.4	4.9	4.5	4.2	7.25	1.98	1.70	1265	12
9	100	100	100	31	15	8.3	6.3	4.7	3.8	3.3	5.25	2.1[illegible]	2.19	772	10
10	100	100	100	31	15	9.0	7.0	5.2	4.0	3.3	6.25	2.24	2.16	827	12
G.I.	100	100	100	29	14	8.2	7.1	6.5	5.6	4.8	6.25	2.20	2.19	953	12

Table 11
Skid Resistance Results
A.C. Resurfacing Research

(Story Co. FN-69-5(15)--21-85)

Date	1 NB	1 SB	2 NB	2 SB	3 NB	3 SB	4 NB	4 SB	5 NB	5 SB	6 NB	6 SB	7 NB	7 SB	8 NB	8 SB	9 NB	9 SB	10 NB	10 SB	Control NB	Control SB
1974																						
8-19	39	40	40	40	44	45	42	44	39	42	38	36	44	45	45	44	47	45	44	44	--	--
10-28	44	43	41	43	49	48	48	49	43	43	45	41	46	47	47	45	53	48	50	50	43	44
1975																						
4-22	48	48	48	44	52	54	53	52	48	43	45	42	49	49	49	48	56	53	55	57	48	48
6-02	45	46	44	44	49	53	50	50	44	42	43	43	49	50	51	49	56	50	52	56	47	49
6-06	50	45	47	44	53	52	54	49	49	44	43	39	51	50	54	50	57	51	54	57	42	48
6-13	48	45	49	44	52	51	55	50	50	44	45	39	52	49	54	50	57	52	52	56	45	50
6-20	51	48	49	46	54	54	54	53	50	48	47	45	53	53	54	52	59	55	57	58	51	53
6-30	49	45	48	44	54	52	55	53	49	44	46	40	52	52	54	52	58	53	55	57	48	52
7-03	47	46	46	45	54	53	54	52	48	44	45	40	52	52	54	51	58	52	52	56	47	52
7-11	47	44	46	45	50	52	53	52	48	44	44	44	50	51	52	50	58	53	52	57	50	50
7-18	43	50	43	54	50	54	49	48	44	50	42	39	47	42	49	51	55	54	50	42	44	50
7-25	45	47	45	46	52	56	52	53	45	45	42	42	49	50	51	51	59	52	52	60	48	53
8-01	42	48	41	58	48	55	51	49	41	47	38	49	48	37	50	40	54	48	52	51	43	43
8-15		44	45	42	50	52	51	51	46	44	42	38	50	49	51	50	56	51	52	56	48	49
8-26	46	47	48	44	54	54	54	54	49	47	45	42	50	51	53	50	57	53	56	56	48	49
9-05	53	51	52	50	58	57	57	56	55	53	55	48	54	52	55	55	58	54	56	58	52	54
9-12	46	47	47	45	54	53	52	54	51	43	43	43	51	50	51	51	57	52	53	56	49	52
9-22	44	43	44	42	50	52	52	50	44	40	39	38	49	50	52	49	56	52	52	56	45	48
9-26	45	42	46	41	51	51	50	49	41	38	37	39	49	49	50	50	58	51	54	55	44	49
10-03	45	44	42	40	49	49	49	44	42	36	38	35	47	48	49	49	52	50	51	56	45	48
10-07	45	41	42	39	47	51	49	48	39	37	37	36	44	41	51	46	54	48	53	54	44	46
10-27	46	46	45	42	52	54	52	51	44	42	43	36	49	51	54	58	56	51	54	57	47	46
10-31	47	46	48	43	51	53	51	52	43	43	42	39	48	50	54	48	58	51	55	59	49	51
11-07	50	48	52	42	55	52	55	52	46	39	43	37	50	52	53	50	59	55	56	58	47	46

* SUPPLEMENTAL REPORT

Form 258 Special 6-72

NON-PARTICIPATING PROGRESS RECORD SAMPLE

Asphalt
R.C.Henely
FN-69-5(15)--21-85
Story Co.
P.McGuffin

Iowa State Highway Commission

MATERIALS DEPARTMENT

TEST REPORT — MISCELLANEOUS MATERIALS

AMES LABORATORY

TABLE 12

Material Asphalt AC 85/100 Laboratory No. AB4-128

Intended Use Test Section

County Story Proj. No FN-69-5(15)--21-85

Producer American Oil Contractor Iowa Road Builders

Source Sugar Creek

Unit of Material Sampled from valve on plant

Sampled by G.Begg Sender's No. 1-6D4-15

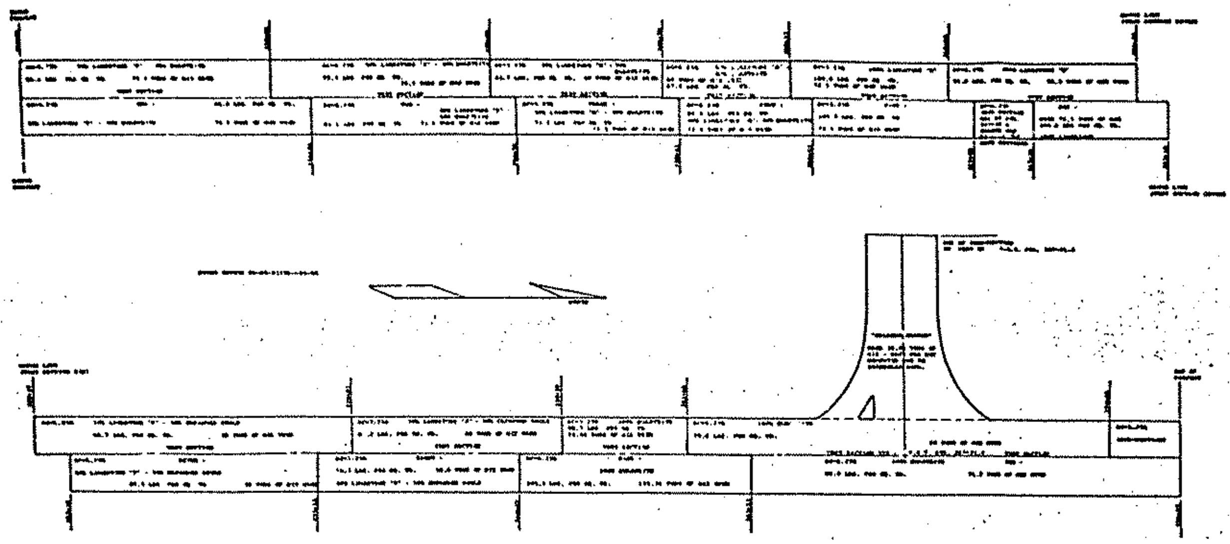
Date Sampled 7/16/74 Date Rec'd 7/17/74 Date Reported 8/6/74

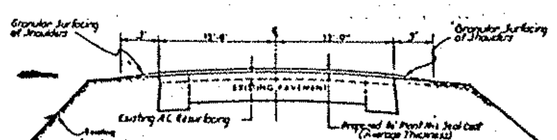
Specific Gravity at 60°F/60°F. ----------------		
Soft. Point: Method (R & B) ------------------		°F.
Pentration at 77°F. 100 Gms. 5 Sec. ------------	98	
Flash Point ------------------------------------		°F.
Soluble in Trichloroethylene ------------------	99.95	%
Ductility at 77°F. ----------------------------	130+	Cms.
Spot Test -------------------------------------		
Thin Film Loss on Heating 5 Hrs. at 325°F. ------	0.02	%
Penetration of Res. at 77°F.100 Gms. 5 Sec. ----	64	
% Original Penetration (Thin Film Res.) --------	65	
Ductility at 77°F. (Thin Film Res.) ------------	130+	Cms.
* Absolute Viscosity , Original------------------------------	848	
Absolute Viscosity, T.F.----------------------------------	1675	

DISPOSITION: Complies

Signed [signature]
Testing Engineer

APPENDIX A





TYPICAL CROSS SECTION

APPENDIX B
SITE PLAN