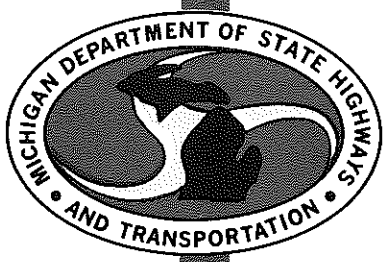
A STUDY TO EVALUATE THE PERFORMANCE OF BITUMINOUS WEARING COURSE CONTAINING SANDY LIMESTONE

A Preliminary Report



TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

A STUDY TO EVALUATE THE PERFORMANCE OF BITUMINOUS WEARING COURSE CONTAINING SANDY LIMESTONE

A Preliminary Report

R. W. Muethel

Research Laboratory Section
Testing and Research Division
Research Project 77 C-18
Research Report No. R-1124

Michigan Transportation Commission
Hannes Meyers, Jr., Chairman; Carl V. Pellonpaa,
Vice-Chairman; Weston E. Vivian, Rodger D. Young,
Lawrence C. Patrick, Jr., William C. Marshall
John P. Woodford, Director
Lansing, July 1979

Introduction

In an effort to more clearly define the traffic polishing characteristics of various aggregates, the Michigan Department of Transportation constructed a circular indoor wear track at the Testing and Research Laboratory. Samples tested for aggregate polishing include carbonates from 16 Michigan and out-of-state sources (1). Most of the carbonates were found to display low to very low resistance to tire polishing which generally substantiates field experience. However, the samples of arenaceous (sandy) carbonates exhibited only slightly lower resistance to polishing than crushed gravel, suggesting that the material might serve as a satisfactory substitute for crushed gravel as bituminous wearing course aggregate. Other studies have reported similar results (2, 3, 4, 5). Preliminary to approval for general use of this material, a test pavement was authorized to evaluate in-service performance.

Test Pavement

Sandy carbonates in Michigan are quarried from the Bayport limestone formation in Arenac and Huron Counties. In April 1977, the MDOT Bituminous Advisory Committee recommended that a paving project in this region be selected to include an experimental wearing course containing sandy limestone from the Bayport formation.

In May 1977, the MDOT accepted bids for the project, described as follows:

Project:	Mb 06071-11004A
Location:	City of Standish; Lincoln Township, in Arenac County
Type of Work:	2.93 miles of bituminous concrete resurfacing
Description:	On US 23 commencing at M 13, thence northerly to the bridge over the Middle Branch of the Pine River in Standish.

The experimental portion of the project was specified as 0.88 miles (Sta. 848+00 to 894+51) to contain bituminous wearing course, Type CM special. This special provision specification required that the coarse aggregate furnished for the wearing course be a 25A crushed limestone from the Bayport limestone formation, and containing 10 percent or more insoluble residue, predominantly discrete, rounded quartz grains, retained on the No. 200 sieve.

The control pavement containing crushed gravel was specified as 1.43 miles (Sta. 772+50 to 848+00) to contain bituminous wearing course Type C with 25A crushed gravel.

Development of bituminous mix designs and the inspection of project asphalt plant operations during paving were assigned to the Testing Laboratory's Bituminous Unit. Paving was completed in July 1977 by the Central Paving Co. of West Branch.

The 1977 MDOT map of average 24-hour traffic flow indicates a total ADT value of 10,900 for the US 23 roadway segment containing the experimental test pavement.

Test Aggregates

As specified, the sandy limestone for the CM special pavement section was obtained from the Bayport limestone formation. The aggregate source for this material was the Glancy Quarry, Pit No. 6-23, located approximately 10 miles south of Tawas City and 1 mile west of US 23, in Arenac County.

The crushed gravel for the Type C pavement section was obtained from the Straits Aggregate and Equipment Corp. No. 1 Pit No. 71-15, located approximately 3 miles east of Millersburg in Presque Isle County.

Petrographic Analysis

Samples of the test aggregates submitted to the Laboratory were analyzed for petrographic composition (6). The sandy limestone sample was found to contain approximately 64 percent arenaceous particles and 36 percent non-arenaceous particles, predominantly limestone.

The crushed gravel sample was found to contain approximately 89 percent carbonate particles (dolomite and limestone) and 11 percent igneous, metamorphic, and non-carbonate sedimentary material. Detailed results of the petrographic analyses are included in the appendix.

Insoluble Residue Analysis

Material from both test aggregates was analyzed for insoluble residue content by dissolution in hydrochloric acid (7). The sandy limestone was found to contain approximately 27 percent insoluble material (22 percent retained on the No. 200 and coarser sieves). The predominant residue was composed of disaggregated quartz grains.

The crushed gravel was found to contain approximately 15 percent insoluble material (14 percent retained on the No. 4 and 3/8-in. sieves). The predominant residue was composed of igneous, metamorphic, and non-carbonate sedimentary aggregate particles. Gradations and detailed descriptions of the insoluble residues are included in the appendix.

Test Pavement Friction Measurements

Annual measurements of pavement friction levels were scheduled by the Research Laboratory's Pavement Performance Group (8). The initial and one-year friction levels were measured August 1977 and August 1978. The sandy limestone and crushed gravel pavements both recorded slight increases in friction levels at the end of one year of service. A tabulation of initial and one-year pavement friction measurements is given in Table 1. The sandy limestone area appears to have slightly higher frictional properties than the crushed gravel after one year.

TABLE 1
PAVEMENT FRICTION MEASUREMENTS
US 23 SOUTH OF STANDISH

Test Section	Direction and Lane	Coefficient of Wsf, 40 mph					
		August 9, 1977			August 10, 1978		
		Low	High	Avg	Low	High	Avg
Sandy Limestone (894+51 to 848+00)	NBOL	0.46	0.51	0.48	0.45	0.49	0.47
	NBIL	0.48	0.49	0.49	0.52	0.55	0.53
	SBOL	0.33	0.39	0.36	0.42	0.43	0.42
	SBIL	0.43	0.49	0.46	0.48	0.52	0.50
Control (848+00 to 772+50)	NBOL	0.41	0.45	0.43	0.40	0.45	0.42
	NBIL	0.45	0.48	0.47	0.42	0.48	0.46
	SBOL	0.34	0.39	0.37	0.42	0.43	0.42
	SBIL	0.46	0.51	0.48	0.46	0.51	0.49

Field Inspection of Test Pavements

In May 1978, the test pavement segments were inspected for visual appearance. The crushed gravel pavement appeared to be normal, with evidence of tire polishing on the exposed aggregate. The sandy limestone pavement was observed to contain numerous shallow pits due to partial loss of material from the more highly arenaceous particles.

Comments

The sandy limestone test pavement appears to be performing satisfactorily. Preliminary evidence indicates that some of the highly arenaceous

particles may contribute to skid resistance through sacrificial wear or weathering.

Due to the high carbonate content of the crushed gravel coarse aggregate contracted for the control pavement (89 percent carbonate rock), traffic polishing resistance may prove to be somewhat lower than that of the sandy limestone test pavement. High carbonate crushed gravels tested on the MDOT wear track had a polish resistance comparable to some of the non-arenaceous carbonates. However, the areas of this project containing both aggregate types should maintain acceptable surface friction properties. For the purpose of this test project it would have been more ideal to use a crushed gravel containing 50 to 60 percent carbonates for the control mix. Annual pavement friction measurements will monitor the performance of the high carbonate gravel control pavement in comparison with the sandy limestone test area.

REFERENCES

1. Muethel, R. W., "The Michigan Department of Transportation Circular Wear Track--Results of Preliminary Aggregate Polishing Tests," Research Report No. R-1098, March 1979.

2. Gray, J. E. and Renninger, F. A., "The Skid Resistant Properties of Carbonate Aggregates," Highway Research Board, Record No. 120, 1965.

3. Gray, J. E. and Renninger, F. A., "Limestone with Excellent Non-Skid Properties," Crushed Stone Journal, December 1960.

4. Sherwood, W. C. and Mahone, D. C., "Predetermining the Polish Resistance of Limestone Aggregates," Highway Research Board, Record No. 341, 1971.

5. Burnett, W. C., Gibson, J. L., and Kearney, E. J., "Skid Resistance of Bituminous Surfaces," Highway Research Board, Record No. 236, 1968.

6. American Society for Testing and Materials, Standard Recommended Practice for Petrographic Examination of Aggregates for Concrete, ASTM Designation C 295-65 (reapproved 1973).

7. Michigan Department of Transportation Test Method for Determination of Insoluble Residue in Carbonate Aggregate Materials, Michigan Test Method 103-78.

8. "Michigan Department of State Highways Equipment for Measuring Pavement Skid Resistance," Research Report No. R-747, February 1971.

APPENDIX

Petrographic Analysis of Test Aggregates

Procedure

Petrographic examination of the sandy limestone and crushed gravel coarse aggregates was conducted in general conformance with ASTM C 295-65 (reapproved 1973), "Petrographic Examination of Aggregates for Concrete." Representative portions--300 particles--of each analyzed sieve fraction of the sample were identified megascopically, along with acid treatment and a scratch test for hardness, and microscopically with a stereomicroscope.

Detailed Petrography

Test Aggregate: Crushed Gravel
Source: Straits Aggregate and Equipment Corp. No. 1 Pit No. 71-15
Gradation: 25A, MDOT 1976 Standard Specifications

Summary

Rock Class	Condition of Particles	Percent of Sample
Igneous	Hard; fresh; non-porous	4
Metamorphic	Hard; fresh; non-porous	5
Carbonate Sedimentary Particles	Moderately hard to hard; fresh; non-porous to finely porous	89
Non-Carbonate Sedimentary Particles	Hard; fresh; finely porous	2

PETROGRAPHIC COMPOSITION

Rock Type	Sieve Fraction Analyzed		Sample Composition, percent
	1/2-in. to 3/8-in.	3/8-in. to No. 4	
Granite	2.7	2.0	2.4
Gabbro	1.0	1.0	1.0
Basalt	---	0.3	0.2
Quartzite	5.3	3.7	4.5
Metasediments	0.7	0.7	0.7
Limestone	44.4	46.3	45.4
Cherty Limestone	0.3	---	0.1
Dolomitic Limestone	3.3	1.7	2.5
Dolomite	40.0	41.3	40.6
Cherty Dolomite	0.3	0.3	0.3
Chert	2.0	2.7	2.3
Total Sample	100.0	100.0	100.0

IGNEOUS ROCKS

Rock Type	Granite	Gabbro	Basalt
Color	mottled pink, buff to white, and dark green to black	mottled buff and dark gray or green to black	black
Texture	medium to fine grained	medium to fine grained	microcrystalline
Luster	dull to subvitreous	dull	dull
Hardness	Mohs 6 to 7	Mohs 5-1/2 to 6	Mohs 6
Porosity	non-porous	non-porous	non-porous
Particle Shape	angular	angular	angular
Particle Surface	fresh, rough, dented to ridged	fresh, rough, dented to ridged	fresh, moderately rough, dented to ridged
Remarks	apparent grain size range = 2 mm to 0.2 mm	apparent grain size range = 1 mm to 0.2 mm	apparent grain size = less than 0.1 mm

METAMORPHIC ROCKS

Rock Type	Quartzite	Metasediments
Color	white, pink, gray, and green	gray
Texture	medium to very fine grained and massive	fine to very fine grained
Luster	dull to vitreous	dull
Hardness	Mohs 7	Mohs 5 to 7
Porosity	non-porous	non-porous
Particle Shape	angular	angular
Particle Surface	fresh, rough, dented to ridged	fresh, rough, dented to ridged
Remarks	apparent grain size range = 2 mm to 0.1 mm	apparent grain size range = 0.5 mm to 0.1 mm

SEDIMENTARY ROCKS

Rock Type	Limestone	Cherty Limestone	Dolomitic Limestone
Color	buff to brown	mottled buff and white	buff, and mottled buff and white
Texture	very fine grained to micro-crystalline	fine grained to microcrystalline	fine grained to microcrystalline
Luster	dull	dull	dull
Hardness	Mohs 3	Mohs 3 to 7	Mohs 3 to 3-1/2
Porosity	non-porous to slightly porous	non-porous	non-porous to slight porous
Particle Shape	angular	angular	angular
Particle Surface	fresh, rough to moderately smooth, dented to ridged	fresh, rough, dented to ridged	fresh, rough, dented to ridged
Remarks	apparent grain size range = 0.4 mm to < 0.1 mm	apparent grain size range = 0.2 mm to < 0.1 mm	apparent grain size range = 0.2 mm to < 0.1 mm

SEDIMENTARY ROCKS (Cont.)

Rock Type	Dolomite	Cherty Dolomite	Chert
Color	buff; brown; and mottled buff and brown	mottled buff and brown	white; buff; and mottled buff and white
Texture	fine grained to microcrystalline	microcrystalline	very fine grained to microcrystalline
Luster	dull	dull	dull
Hardness	Mohs 3-1/2 to 4	Mohs 4 to 7	Mohs 7
Porosity	non-porous to finely porous	slightly porous	finely porous
Particle Shape	angular	angular	angular
Particle Surface	fresh, rough, dented or pitted to ridged	fresh, rough, dented to ridged	fresh, rough to moderately smooth, dented to ridged
Remarks	apparent grain size range = 0.2 mm to < 0.1 mm. Many particles contain small solution cavities.	apparent grain size range = 0.1 mm to < 0.1 mm	apparent grain size range = 0.1 mm to < 0.1 mm. Some particles contain small exposures of calcite.

Test Aggregate: Crushed Stone (Bayport formation)
Source: Glancy Quarry, Pit No. 6-23
Gradation: 25A, MDOT 1976 Standard Specifications

Summary

Rock Class	Condition of Particles	Percent of Sample
Arenaceous Sedimentary Particles	Matrix moderately hard, quartz grains hard; fresh; non-porous to finely porous	64
Non-Arenaceous	Moderately hard to hard; fresh; non-porous to finely porous	36

PETROGRAPHIC COMPOSITION

Rock Type	Sieve Fraction Analyzed		Sample Composition, percent
	1/2-in. to 3/8-in.	3/8-in. to No. 4	
Limestone	28.3	40.0	34.2
Sandy Limestone	24.7	20.7	22.7
Calcareous Sandstone	38.0	33.6	35.8
Shaley Particles	6.3	5.0	5.6
Chert	2.7	0.7	1.7
Total Sample	100.0	100.0	100.0

SEDIMENTARY ROCKS

Rock Type	Limestone	Sandy Limestone	Calcareous Sandstone
Color	buff to brown or gray; and mottled buff and brown or gray	buff; gray; and mottled buff and gray	gray; buff; and mottled gray and buff
Texture	very fine grained to micro-crystalline	fine to very fine grained	medium to fine grained
Luster	dull	dull	dull
Hardness	groundmass, Mohs 3; quartz grains, Mohs 7	groundmass, Mohs 3; quartz grains, Mohs 7	calcareous matrix, Mohs 3; quartz grains, Mohs 7
Porosity	non-porous to slightly porous	non-porous to slightly porous	finely porous to non-porous
Particle Shape	angular	angular	angular
Particle Surface	fresh, rough to moderately smooth, dented to ridged	fresh, rough, dented to ridged	fresh, rough, dented to ridged
Remarks	some particles contain a small number of quartz grains. Apparent grain size range: groundmass, 0.1 mm to < 0.1 mm; quartz grains, 0.2 mm to 0.1 mm.	apparent grain size range: groundmass, 0.1 mm to < 0.1 mm; quartz grains, 0.4 mm to 0.1 mm. Quartz grains are rounded and variably frosted.	apparent grain size range: 0.6 mm to 0.1 mm. Quartz grains are rounded to subangular, and variably frosted.

SEDIMENTARY ROCKS (Cont.)

Rock Type	Shaley Particles	Chert
Color	mottled gray to buff and black	buff; and mottled buff and gray
Texture	fine grained to microcrystalline	very fine grained to microcrystalline
Luster	dull	dull
Hardness	shale, Mohs 2-1/2; limestone, Mohs 3; quartz grains, Mohs 7	Mohs 7
Porosity	slightly porous to finely porous	non-porous to finely porous
Particle Shape	angular	angular
Particle Surface	fresh, rough to moderately smooth, dented to ridged	fresh, moderately smooth to smooth, dented to ridged
Remarks	particles vary from shaley limestone to shaley calcareous sandstone. Apparent grain size range = shaley material $<$ 0.1 mm; limestone, 0.1 mm to $<$ 0.1 mm; quartz grains, 0.6 mm to 0.1 mm.	apparent grain size range = chert, $<$ 0.1 mm; relict quartz grains, 0.4 to 0.1 mm. Quartz grains appear to be rounded.

RESULTS OF INSOLUBLE RESIDUE ANALYSIS

Sieve Size	Gradation of Insoluble Residues, Percent Retained	
	Gravel, Pit No. 71-15	Sandy Limestone, Pit No. 6-23
1/2-in.	0.00	0.00
3/8-in.	5.95	0.00
No. 4	7.81	3.04
No. 8	0.26	0.70
No. 16	0.10	0.33
No. 30	0.08	0.25
No. 50	0.05	1.12
No. 100	0.04	7.65
No. 200	0.04	9.21
P200	0.42	4.75
Total	14.75	27.05

Note: Insoluble residues retained are expressed as percentages of the sample weight before dissolution in hydrochloric acid.

Description of Insoluble Residue

Gravel, Pit No. 71-15: Predominantly igneous and metamorphic particles, with a few chert particles and shaley to siliceous fragments.

Sandy Limestone, Pit No. 6-23: Predominantly disaggregated quartz grains, friable sandstone fragments, and a few chert fragments, siliceous fossils, and pyritic fragments.

RESULTS OF WEAR TRACK AGGREGATE POLISHING TESTS

Millions of Wheel Passes	Polishing Value, Initial Peak Force, lb		
	Control Gravel [1]	Crushed Gravel,[2] Pit No. 71-15	Sandy Limestone,[3] Pit No. 6-23
Initial	440 (0.59)	430 (0.58)	420 (0.57)
0.5	380 (0.52)	330 (0.46)	320 (0.45)
1.0	360 (0.49)	270 (0.37)	310 (0.42)
1.5	350 (0.48)	260 (0.36)	300 (0.41)
2.0	330 (0.46)	250 (0.35)	310 (0.42)
2.5	330 (0.46)	240 (0.34)	310 (0.42)
3.0	320 (0.45)	250 (0.34)	320 (0.45)
3.5	320 (0.45)	250 (0.35)	320 (0.45)
4.0	320 (0.45)	240 (0.34)	300 (0.41)

Note: Numbers in brackets are approximate 40 mph skid coefficients, correlated with the MDOT workhorse skid tester.

[1] Green Oak gravel tested in wear track series No. 1 through 8.
[2] Sample tested in wear track series No. 2.
[3] Sample tested in wear track series No. 6.