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BLENDED AGGREGATES TESTED ON THE MICHIGAN DEPARTMENT OF TRANSPORTATION CIRCULAR WEAR TRACK

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

BLENDED AGGREGATES TESTED ON THE MICHIGAN DEPARTMENT OF TRANSPORTATION CIRCULAR WEAR TRACK

R. W. Muethel

Research Laboratory Section
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Introduction

The Michigan Department of Transportation circular wear track was constructed in 1974 for the primary purpose of evaluating the polishing resistance of quarried carbonate aggregates and high-carbonate content glacial gravels. Since completion, the wear track has tested quarried carbonates, glacial gravels, slags, and individual lithologies. Recent test series have included experimental blends of gravel or carbonate aggregate with various proportions of selected anti-skid materials, primarily sandstone or crushed gravel.

Due to increased interest in the use of blending to upgrade the polishing resistance of quarried carbonates and high-carbonate gravels, the results of the wear track tests completed on blends have been excerpted for presentation in this report.

The complete results of wear track tests conducted since 1974 are included in MDOT Research Reports No. R-1098 (March 1979) and No. R-1132 (April 1980).

Aggregates Tested

The following blends have been tested on the MDOT wear track:

Control Aggregate, percent	Blending Agent, percent
1. Gravel, Green Oak, 80 (Pit No. 47-3)	- Sandstone, Grindstone Quarry, 20 (Pit No. 32-64)
2. Gravel, Green Oak, 60 (Pit No. 47-3)	- Sandstone, Grindstone Quarry, 40 (Pit No. 32-64)
3. Gravel, Green Oak, 80 (Pit No. 47-3)	- Sandstone, Napoleon Stone Quarry, 20 (Pit No. 38-81)
4. Gravel, Green Oak, 60 (Pit No. 47-3)	- Sandstone, Napoleon Stone Quarry, 40 (Pit No. 38-81)
5. Gravel, Green Oak, 80 (Pit No. 47-3)	- Sandstone, Rowe Rd Quarry, 20 (Pit No. 30-65)
6. Gravel, Green Oak, 80 (Pit No. 47-3)	- Sandstone, 11 Mile Rd Quarry, 20 (Pit No. 13-90)

Control Aggregate, percent (Cont.)		Blending Agent, percent (Cont.)
7. Limestone, Inland, 80 (Pit No. 75-5)	-	Sandstone, Grindstone Quarry, 20 (Pit No. 32-64)
8. Limestone, Inland, 50 (Pit No. 75-5)	-	Sandstone, Grindstone Quarry, 50 (Pit No. 32-64)
9. Limestone, Inland, 80 (Pit No. 75-5)	-	Gravel, Green Oak, 20 (Pit No. 47-3)
10. Limestone, Inland, 50 (Pit No. 75-5)	-	Gravel, Green Oak, 50 (Pit No. 47-3)

The standard test aggregates for these blends are the control aggregates which have been incorporated in all wear track test series. The Green Oak gravel contains approximately 40 percent carbonate rock material, and represents typical glacial gravel found in southeastern Michigan. Inland limestone was selected as a control aggregate because of a low insoluble residue content and an in-service history of vulnerability to traffic polishing.

All aggregates were crushed to passing 3/8-in. retained No. 4 for embedding in the test slabs, as described in Research Report No. R-1098, previously noted.

Discussion of Test Results

Table 1 includes the results of wear track polishing tests conducted on test slabs containing the selected blends and control aggregates.

The effect of carbonate rock content upon resistance to wear track polishing has been apparent in all of the test series conducted on the wear track. The carbonate effect is particularly evident in the suite of blends selected for this report. A relationship between carbonate rock content and skid resistance is suggested by the test data. The initial, intermediate, and final friction coefficients indicate that lower friction values tend to correspond with higher carbonate content. Figure 1 includes a least square linear regression line developed for the carbonate rock content of the aggregates vs. the correlated friction coefficients obtained at four million wheel passes of wear track polishing. A linear correlation coefficient of -0.96 indicates a high correlation between the two variables.

TABLE 1
WEAR TRACK POLISHING TEST RESULTS ON
BLENDED AND CONTROL AGGREGATES

Aggregate Blend		Total Carbonate Content, percent	Correlated Skid Coefficients From Wear Track Skid Tests*		
			Initial Value	0.5 Million Wheel Passes	4.0 Million Wheel Passes
Gravel, Green Oak (47-3) Sandstone, Grindstone (32-64)	60% 40%	24	0.76	0.66	0.53
Gravel, Green Oak (47-3) Sandstone, Napoleon (38-81)	60% 40%	24	0.74	0.65	0.53
Gravel, Green Oak (47-3) Sandstone, Napoleon (38-81)	80% 20%	24	0.73	0.55	0.53
Limestone, Inland (75-5) Sandstone, Grindstone (32-64)	50% 50%	50	0.68	0.61	0.49
Gravel, Green Oak (47-3) Sandstone, Grindstone (32-64)	80% 20%	32	0.68	0.55	0.47
Gravel, Green Oak (47-3) Sandstone, Rowe Rd (30-65)	80% 20%	32	0.70	0.52	0.46
Gravel, Green Oak (47-3) Sandstone, 11 Mile Rd (13-90)	80% 20%	32	0.67	0.51	0.46
Gravel, Green Oak (47-3) (Control Gravel)	100%	40	0.59	0.52	0.45
Limestone, Inland (75-5) Sandstone, Grindstone (32-64)	80% 20%	80	0.58	0.46	0.35
Limestone, Inland (75-5) Gravel, Green Oak (47-3)	50% 50%	70	0.59	0.39	0.34
Limestone, Inland (75-5) Gravel, Green Oak (47-3)	80% 20%	88	0.58	0.39	0.31
Limestone, Inland (75-5) (Control Limestone)	100%	100	0.51	0.34	0.24

* These values are approximate 40 mph wet sliding coefficient of friction values converted from the laboratory friction tester values.

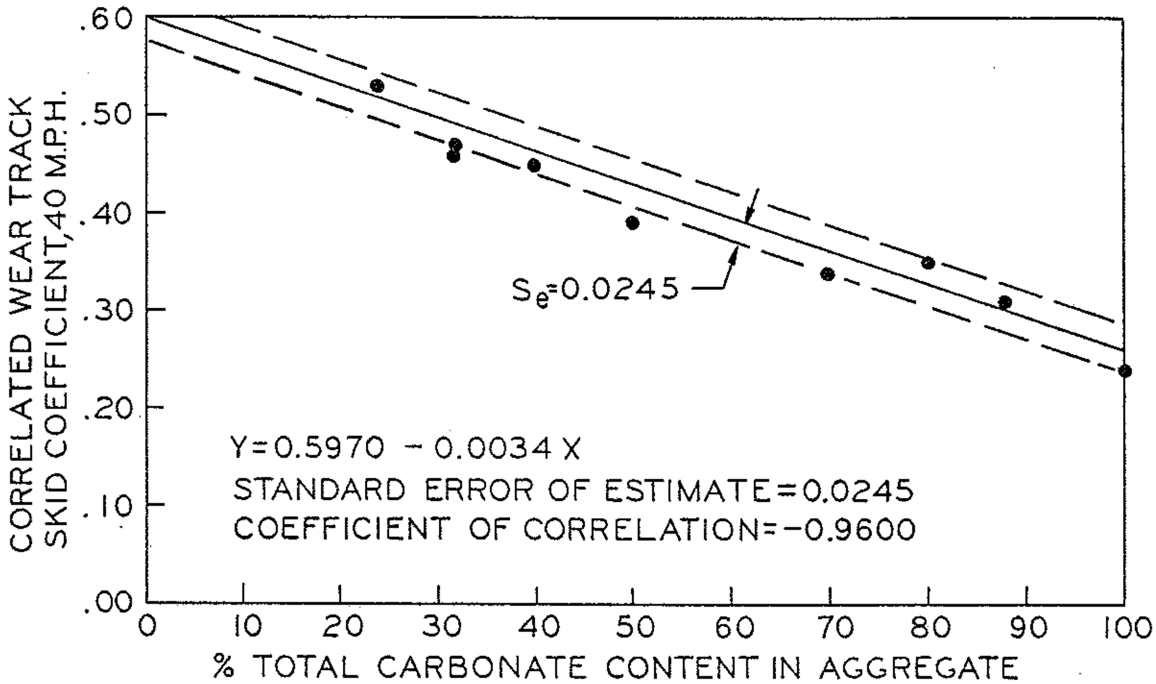

Figure 1. Least square linear regression line for carbonate rock content vs. correlated friction coefficients.

The initial friction test values contained in Table 1 indicate a general decrease in skid resistance with increasing carbonate rock content, suggesting that the carbonate content effect is partially due to the aggregate particle surface microtexture. Most of the carbonates tested were found to be composed of very fine-grained to microcrystalline material. In comparison, most other lithologies generally contained medium to fine-grained material. The effect of wear track polishing upon the relatively smooth, relatively soft carbonate particles is to rapidly reduce the surface microtexture of the particles to a very low level of relief. The carbonate particles were found to develop a glassy, smooth surface appearance after less than 250,000 wheel passes of wear track polishing.

The sandstone blending agents were found to be much more effective than the crushed gravel which contained approximately 40 percent carbonate material. However, two of the selected sandstones—Rowe Rd Quarry, Pit No. 30-65, and 11 Mile Rd Quarry, Pit No. 13-90—became deeply worn, reducing their effectiveness.

Blending of High-Carbonate Gravels

The need for blending of polish-resistant material with most quarried carbonates for use as surfacing aggregate is evident from the wear track test results just described. Also, wear track tests conducted on three crushed high-carbonate gravels indicated that these aggregates exhibit marginal to low polishing resistance. Table 2 presents the results of the tests, completed as part of wear track series Nos. 1 through 5.

TABLE 2
WEAR TRACK POLISHING TEST RESULTS ON HIGH-CARBONATE CRUSHED GRAVELS

Aggregate Type and Composition	No. of Test Slabs	Correlated Friction Coefficients From Wear Track Friction Tests*		
		Initial Value	0.5 Million Wheel Passes	4.0 Million Wheel Passes
Crushed Gravel, High Carbonate				
Rondo Pit No. 16-52 (82% carbonate)	2	0.59	0.39	0.36
Pierce Pit No. 45-19 (90% carbonate)	2	0.62	0.48	0.35
Big Cut Pit No. 71-15 (90% carbonate)	2	0.58	0.46	0.34

* These values are approximate 40 mph wet sliding coefficient of friction values converted from the laboratory friction tester values.

The beneficial effects of blending are also indicated by the results of wear track series No. 12. This series includes a high-carbonate gravel, a polish-resistant gravel, two blends of the high-carbonate gravel with the polish-resistant gravel, two blends of the high-polishing control limestone with the polish-resistant gravel, and the gravel and limestone control aggregates. Due to the use of grooved tires in series No. 12, the test results were not included with the data from previous series. The test values

TABLE 3

TEST RESULTS OF WEAR TRACK SERIES NO. 12

Aggregate Type and Composition	No. of Test Slabs	Correlated Friction Coefficients From Wear Track Friction Tests*		
		Initial Value	0.5 Million Wheel Passes	4.0 Million Wheel Passes
Crushed Gravel, 100% Noncarbonate				
County Rd Comm. #3 Pit No. 17-62	2	0.66	0.62	0.59
Crushed Gravel, Approx. 40% Carbonate				
Green Oak Pit No. 47-3 (control gravel)	2	0.65	0.57	0.52
Crushed Gravel, High-Carbonate				
Pierce Pit No. 45-19 (97% carbonate)	2	0.61	0.41	0.37
Quarried Carbonate, High-Polishing				
Inland Pit No. 75-5 (control limestone)	2	0.47	0.31	0.29
Blended Aggregates				
(Pierce Pit No. 45-19 and County Road Commission #3 Pit No. 17-62)				
Pierce: County Rd Comm., 60:40 (58 percent total carbonate)	2	0.55	0.51	0.45
Pierce: County Rd Comm., 80:20 (78 percent total carbonate)	2	0.55	0.48	0.40
(Inland Pit No. 75-5 and County Road Commission #3 Pit No. 17-62)				
Inland: County Rd Comm., 60:40 (60 percent total carbonate)	2	0.48	0.40	0.36
Inland: County Rd Comm., 80:20 (80 percent total carbonate)	2	0.47	0.37	0.34

* These values are approximate 40 mph wet sliding coefficient of friction values converted from the laboratory friction tester values.

NOTE: Series No. 12 was conducted with ASTM E-501 grooved test tires on the wear track and friction tester, replacing the discontinued E-524 smooth tread test tires used in test series Nos. 1 through 11.

for this series are included in Table 3. The high-carbonate gravel, Pierce Pit No. 45-19, contains a variety of carbonates, some of which contain impurities and slightly coarser grain sizes than the high-polishing control limestone, resulting in somewhat higher friction values. However, the effect of carbonate content upon resistance to polishing is evident from the friction test values.

Conclusions

The blending of polish-resistant aggregate with high-carbonate gravels and quarried carbonates is shown to produce higher frictional values, and is strongly recommended whenever such aggregates are considered for use in bituminous surfacing pavements.

A specific case for the use of blending is the planned resurfacing of the US 2 roadway in the eastern upper peninsula of Michigan. The local aggregates available for the project are quarried carbonates or glacial gravels containing high percentages of carbonate material incorporated from local carbonate bedrock formations. Further north, approximately 40 miles, the bedrock exposures change to sandstones which furnish polish-resistant material to the local gravel deposits. The County Road Commission No. 3 Pit No. 17-62 blending gravel used in wear track series No. 12 is a representative gravel containing sandstone derived from the sandstone surface formations which extend in a wide arc from Chippewa County across the eastern upper peninsula to Menominee County.

The selection and proportioning of blends must be carefully evaluated to achieve satisfactory long-term frictional performance.

Recommendations

Based upon the results of the wear track tests on quarried carbonates and high-carbonate gravels, the following restrictions on the use of such materials are recommended:

1) Prohibit the use of local high-carbonate gravels for the US 2 resurfacing project unless the aggregate is blended with material from Pit No. 17-62 or a source with similar composition.

2) Prohibit the use of high-carbonate gravels on high-traffic trunklines in the lower peninsula in bituminous wearing course mixes, either 4.12 or 4.11, unless blended with a suitable sandstone or other polish-resistant aggregate.

3) Change footnote "r" in Table 8.02-2 of the MDOT Standard Specifications for Construction to eliminate the use of crushed limestone or high-carbonate gravel for type CM and F bituminous concrete surfacing unless blended with a suitable polish-resistant aggregate.

To implement the above three recommendations, it is proposed that a Supplemental Specification be issued to control the usage of the various possible types of coarse aggregates for both 4.11 or 4.12 wearing course mixes according to the ADT limitations given in Table 4.

REFERENCES

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

"The Michigan Department of Transportation Circular Wear Track - Results of Supplemental Aggregate Polishing Tests," MDOT Research Report No. R-1132, April 1980.

TABLE 4
AGGREGATE USE LIMITATIONS BASED ON ADT

Aggregate Type	Maximum Traffic ADT/lane - Rural	Maximum Traffic ADT/lane - Urban	Special Considerations
Quarried carbonate	500	250	
Reverberatory furnace slag or quarried carbonate with more than 10% insoluble residue [1,2]	5,000	2,500	
Natural gravel with more than 70% carbonates	2,500	500	Sources with more than 70% carbonates that have demonstrated satisfactory field performance may be permitted on higher ADT routes.
Quarried noncarbonates, natural gravel with less than 70% carbonates, and blast furnace slag	No restrictions	No restrictions	
Blends [3]	No restrictions	No restrictions	
Steel furnace slag	Special Provisions Only	Special Provisions Only	

[1] Insoluble residue passing the No. 200 sieve must consist of less than 10% by weight of the rock.

[2] The quarried carbonate must have 10% + insoluble residue by weight retained on the No. 200 sieve. The residue retained must consist of discrete quartz grains.

[3] Blends must be proposed by the contractor and approved by the Testing and Research Laboratory regarding proportions to be blended and blending procedure.