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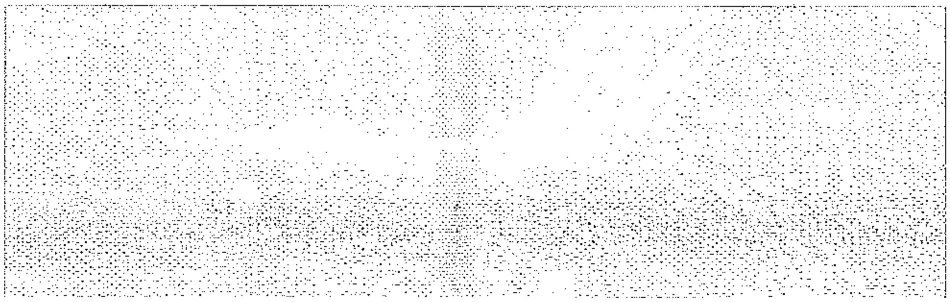
THE MICHIGAN DEPARTMENT OF TRANSPORTATION CIRCULAR WEAR TRACK—RESULTS OF SUPPLEMENTAL AGGREGATE POLISHING TESTS

Interim Progress Report

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION



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The Michigan Department of Transportation circular wear track-results of supplemental aggregate

THE MICHIGAN DEPARTMENT OF TRANSPORTATION CIRCULAR WEAR TRACK—RESULTS OF SUPPLEMENTAL AGGREGATE POLISHING TESTS

Interim Progress Report

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Research Laboratory Section
Testing and Research Division
Research Project 71 C-13
(Phase 2)
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SUMMARY

This report presents the results of seven additional aggregate polishing series completed on the Michigan Department of Transportation circular wear track. The additional series, numbers 13 through 19, included samples of crushed gravel, uncrushed gravel, crushed quarried carbonates, crushed portland cement concrete, and steel furnace slag. Gravels with crushed and uncrushed material, and blends of high-polishing limestone with steel furnace and blast furnace slags were also tested. Each test series included the wear track gravel and limestone control aggregates.

Crushed gravels containing low carbonate rock percentages recorded relatively high resistance to polishing, as did the steel furnace slag, crushed portland cement concrete, and crushed gravel with high sandstone content.

The high-carbonate gravels, crushed carbonates, and uncrushed gravels recorded moderately low to low resistance to polishing. The high-polishing limestone blended with slag displayed improved frictional performance.

Tabulated results and polishing curves are included in Appendix A. A description of the wear track apparatus and test procedure is also included.

INTRODUCTION

In 1971, the Department initiated a study to evaluate restrictions on the use of quarried carbonates and high carbonate gravels for bituminous wearing course aggregates titled, "Study of Aggregate and Mix Requirements for Durable and Skid-Resistant Bituminous Mixtures" (Research Project 71 C-13). The study included the design and construction of a circular wear track for the study of the effect of simulated traffic polishing on various aggregates for use in bituminous pavements.

The development and use of the wear track have been described in detail in an earlier progress report (1).

The report also included the results of test series 1 through 8. Subsequent test series 9 through 11, and test series 12 were included in two additional progress reports (2, 3). A brief description of the wear track testing apparatus and procedure is included in Appendix B of this report. The appendix also includes composite tabulations of the results of the previous 12 test series.

The table below gives an indication of the polishing resistance value ranges.

Typical Aggregate	Polishing Resistance	AWI*	Surface Appearance After Testing
Sandstone, blast furnace slag	Very High	above 400	Rough, unpolished.
Crushed gravel; carbonate content below 40 percent	High	350 - 400	
Crushed gravel; carbonate content 40 to 70 percent; high-residue carbonates	Moderate	300 - 350	Carbonates highly polished; non-carbonates slightly polished. Sandy carbonates polished, with rough surfaces.
Crushed gravel; carbonate content above 70 percent; high-residue carbonates	Moderately Low	250 - 300	
Uncrushed gravel; medium-residue carbonates	Low	200 - 250	Carbonates highly polished; non-carbonates moderately polished.
Low-residue carbonates	Very Low	below 200	Highly polished.

* Aggregate Wear Index.
Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

This report presents the results of test series 13 through 19. Tabulations and polishing curves for the individual series are included in Appendix A. Appendix B includes composite tabulations of the results of test series 13 through 19.

CONCLUSIONS AND COMMENTS

The high-carbonate gravels and low-residue carbonate rock samples recorded moderately low to very low resistance to polishing, supporting previous test results on similar materials.

As in previous tests, sandstone was demonstrated in these test series to provide superior long-term frictional performance.

Steel furnace slag exhibited a high resistance to polishing related to the exposure of many small, pointed inclusions. However, a rapid early polishing effect suggests that this material would be polish-susceptible if the inclusions were not present in sufficient amounts.

The tests comparing crushed versus uncrushed particles indicate that the uncrushed particle content of an aggregate should be taken into account when evaluating the material for possible use in bituminous surfacing pavement. Uncrushed particles, with the exception of such rock types as sandstone and arenaceous limestone, generally exhibit smooth surfaces which rapidly become polished when exposed to traffic.

The blends of slag and limestone recorded considerably higher wear track friction values than the unblended limestone. However, a blend containing 50 percent slag was required to produce wear track performance approaching that of a typical glacial gravel.

WEAR TRACK POLISHING TESTS

Test Aggregates

In addition to the control gravel and limestone, the following aggregates were tested in series 13 through 19:

1) crushed gravels from 10 sources,
2) five samples of uncrushed gravel from three sources,
3) carbonates from nine sources,
4) crushed portland cement from one source,
5) steel furnace slag from one source,
6) eight blends of crushed and uncrushed gravel from three sources,
7) two blends of high-polishing limestone with steel furnace slag, and
8) two blends of high-polishing limestone with blast furnace slag.

Detailed tabulations of the aggregate sources are included in Tables A-1 through A-7 of Appendix A.

Test Slab Preparation

The wear track test slabs were prepared according to the procedures described in the first progress report (1). The use of aggregate passing 3/8-in. and retained on a No. 4 sieve was continued. Two replicate test slabs of each aggregate were cast and tested on the wear track in each series (see Appendix B).

Wear Track Polishing and Friction Tests

Polishing on the wear track was continued to four-million wheel passes in increments of 500,000 wheel passes, as was done in previous test series. Supplemental early friction measurements were conducted at 125,000 and 250,000 wheel passes for reference information not included in this report.

Data Reduction and Test Results

The friction test values representing the average initial peak force (lb) measured on the wear track friction tester at three locations on each test slab were used to compute the polishing values at each polishing increment. The results of the friction test determinations are reported in tabulations containing the initial friction values, at one-half million wheel passes, and at four-million wheel passes, and are included in Appendix A.

The polishing value at four-million wheel passes has been adopted by the Department for use as an Aggregate Wear Index (AWI) to be used in conjunction with traffic volume data to select aggregates which will provide suitable resistance to the anticipated amount of traffic on resurfaced bituminous pavements.

Selected polishing values in the tabulations are converted to approximate pavement friction numbers based on field correlation of the wear track friction tester with a Departmental pavement friction test vehicle (1). The friction numbers correspond to the ARMS (Area Reference Measuring System) scale presently used in the Department's summaries of pavement friction performance. Friction numbers below 30 are considered to be indicative of potentially unsatisfactory surfaces.

RESULTS OF TEST SERIES

Results of Series 13

Four gravels containing between 75 and 95 percent carbonate rock were included in this test series. Three of the gravels recorded low resistance to polishing. One gravel containing 75 percent carbonate, considered to be a high-carbonate gravel, recorded high resistance to polishing due to the presence of 22 percent sandstone in the sample. A sample of dolomite containing siliceous material was included in this series, and recorded a moderately low resistance to polishing, which was considerably higher than previously tested non-siliceous dolomites. The most polish-resistant material tested in this series was steel furnace slag which displayed rapid early polishing followed by continual increase in friction values attributed to the increasing exposure of many small, hard asperities as the softer matrix material was worn away during the polishing process.

Results of Series 14

Four gravels containing between 78 and 95 percent carbonate rock were included in this test series. Three of the gravels recorded low to very low resistance to polishing. One gravel containing 53 percent carbonate rock and 11 percent sandstone recorded a polishing resistance superior to the control gravel containing 40 percent carbonate rock. The higher resistance to polishing is attributed to the sandstone component in the sample. Two samples of low-residue carbonates were tested in this series and recorded very low resistance to polishing.

Results of Series 15

Two low-carbonate gravels were included in this test series. One gravel contained 1 percent carbonate rock and 77 percent sandstone. This material recorded a very high resistance to polishing. The other gravel contained 1 percent carbonate rock and 9 percent sandstone, and recorded a moderate resistance to polishing. Two additional samples of low-residue carbonates were tested in this series and recorded low resistance to polishing.

The effect of rounded particles in test aggregate samples was investigated in this test series. Two samples containing 100 percent naturally rounded (uncrushed) particles were tested in comparison with the normally 100 percent crushed control gravel. One sample was prepared with a petrographic composition equal to the control gravel, and one sample was tested as received. Both samples recorded initial and early friction values which were lower than values usually recorded for the gravel after four-million wheel passes of wear track polishing. Both samples exhibited a small amount of additional polishing during four-million wheel passes of testing. After four-million wheel passes of polishing the rounded control gravel recorded a 26 percent lower friction value than the crushed control gravel.

Results of Series 16

Blends of the control limestone and two types of slag were included in this test series as follows:

1) control limestone + steel furnace slag, 50:50
2) control limestone + steel furnace slag, 70:30
3) control limestone + blast furnace slag, 50:50
4) control limestone + blast furnace slag, 70:30.

The blends of limestone and slag recorded considerably higher friction values than the unblended limestone.

The series also included a sample of limestone containing finely disseminated siliceous material. The sample recorded a low resistance to polishing.

Results of Series 17

The effect of rounded particles in test aggregate samples was further investigated in this test series. In addition to the crushed control gravel, a sample containing 100 percent naturally rounded (uncrushed) particles, and four blends of control gravel containing amounts of uncrushed material were included as follows:

1) crushed content, 80 percent
2) crushed content, 60 percent
3) crushed content, 40 percent
4) crushed content, 20 percent.

The petrographic composition of the blended samples and uncrushed gravel was adjusted to that of the crushed control gravel. After four-million wheel passes of polishing on the wear track, the blends recorded successively decreasing polishing values with decreasing percentages of crushed material. The 100 percent rounded gravel recorded a 40 percent lower polishing value than the 100 percent crushed gravel.

A sample of crushed dolomite from an additional carbonate source was included in this series. The dolomite recorded a moderately low resistance to polishing.

Results of Series 18

Four glacial gravels with various carbonate content and crushed material percentages were included in this test series in addition to the control gravel. After four-million wheel passes of wear track polishing the gravel containing the highest carbonate rock content and the lowest crushed material content recorded the lowest polishing value.

Samples of carbonates from two additional sources were also tested in this series. A dolomite containing 20 percent chert recorded a moderately low resistance to polishing, and a low-residue limestone recorded a low resistance to polishing.

Results of Series 19

The effect of rounded particles was investigated with two additional gravels, one containing approximately 36 percent carbonate material, the other containing approximately 85 percent carbonate material. The samples were tested as follows:

1) crushed content, 100 percent
2) crushed content, 50 percent
3) crushed content, 0 percent.

The petrographic composition of the uncrushed gravel was adjusted to that of the crushed gravel. After four-million wheel passes of polishing on the wear track, the gravel containing 36 percent carbonate material recorded a 36 percent lower polishing value when uncrushed. The gravel containing 85 percent carbonate material recorded a 31 percent lower polishing value when uncrushed.

FUTURE TESTS

The wear track program is scheduled to evaluate a statewide selection of gravels for possible variations in polishing resistance due to compositional differences within the carbonate rock fractions. Samples for Aggregate Wear Index determination will also be tested.

REFERENCES

1. Muethel, R. W., "The Michigan Department of Transportation Circular Wear Track—Results of Preliminary Aggregate Polishing Tests (First Progress Report)," MDOT Research Report R-1098, March 1979.

2. Muethel, R. W., "The Michigan Department of Transportation Circular Wear Track—Results of Supplemental Aggregate Polishing Tests (Interim Progress Report)," MDOT Research Report R-1132, January 1980.

3. Muethel, R. W., "Blended Aggregates Tested on the Michigan Department of Transportation Circular Wear Track," MDOT Research Report R-1146, May 1980.

APPENDIX A

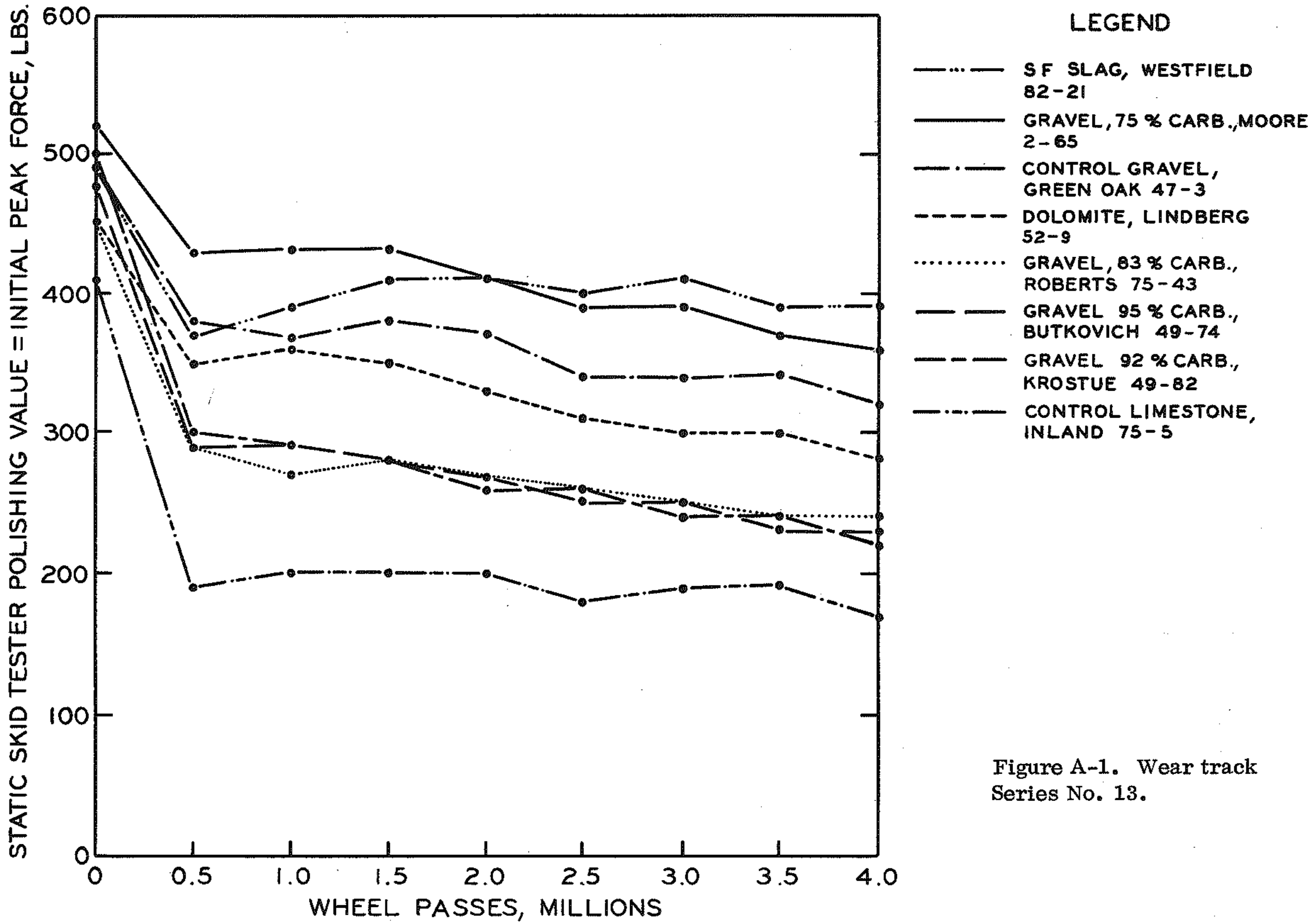

Figure A-1. Wear track Series No. 13.

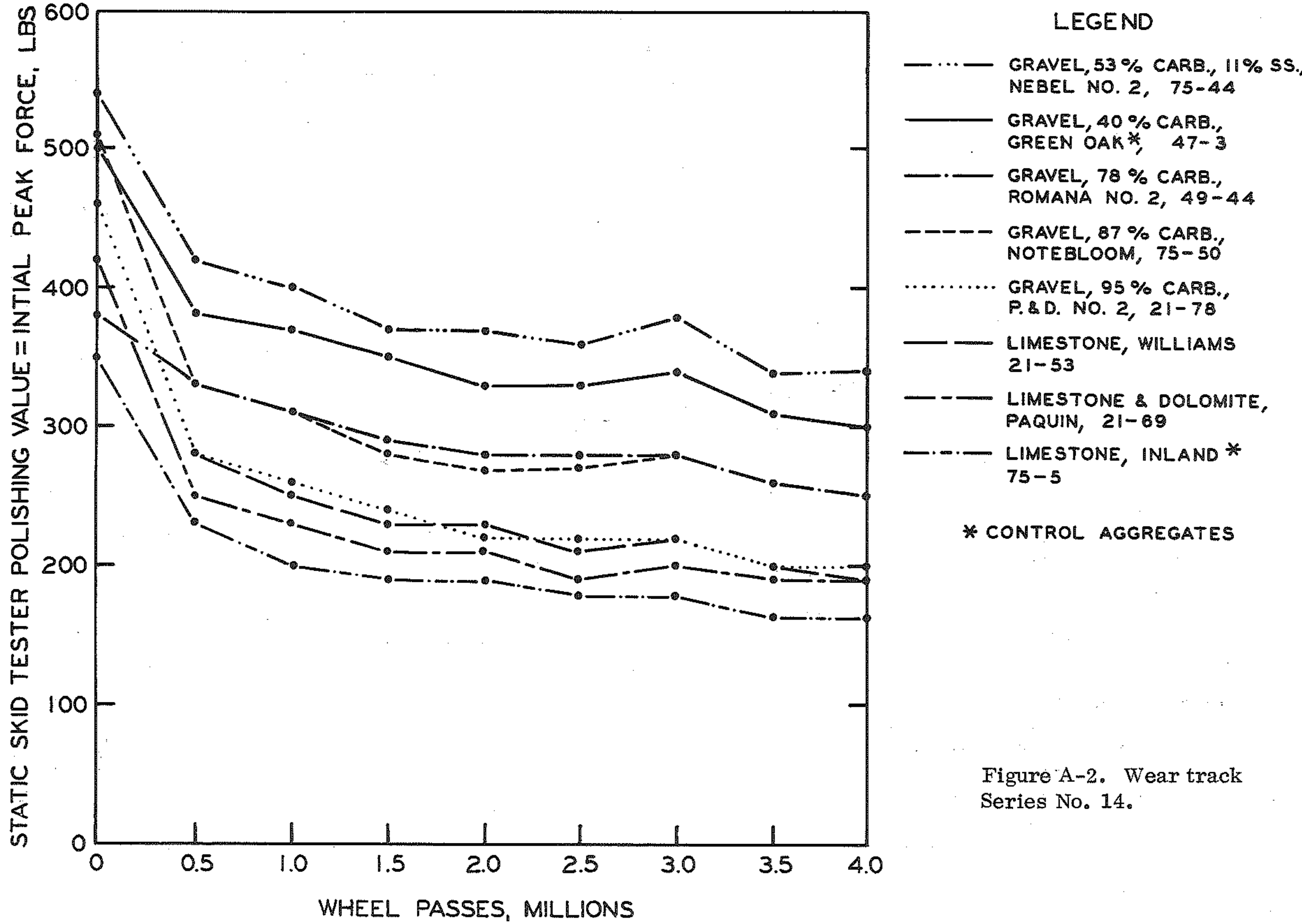

Figure A-2. Wear track Series No. 14.

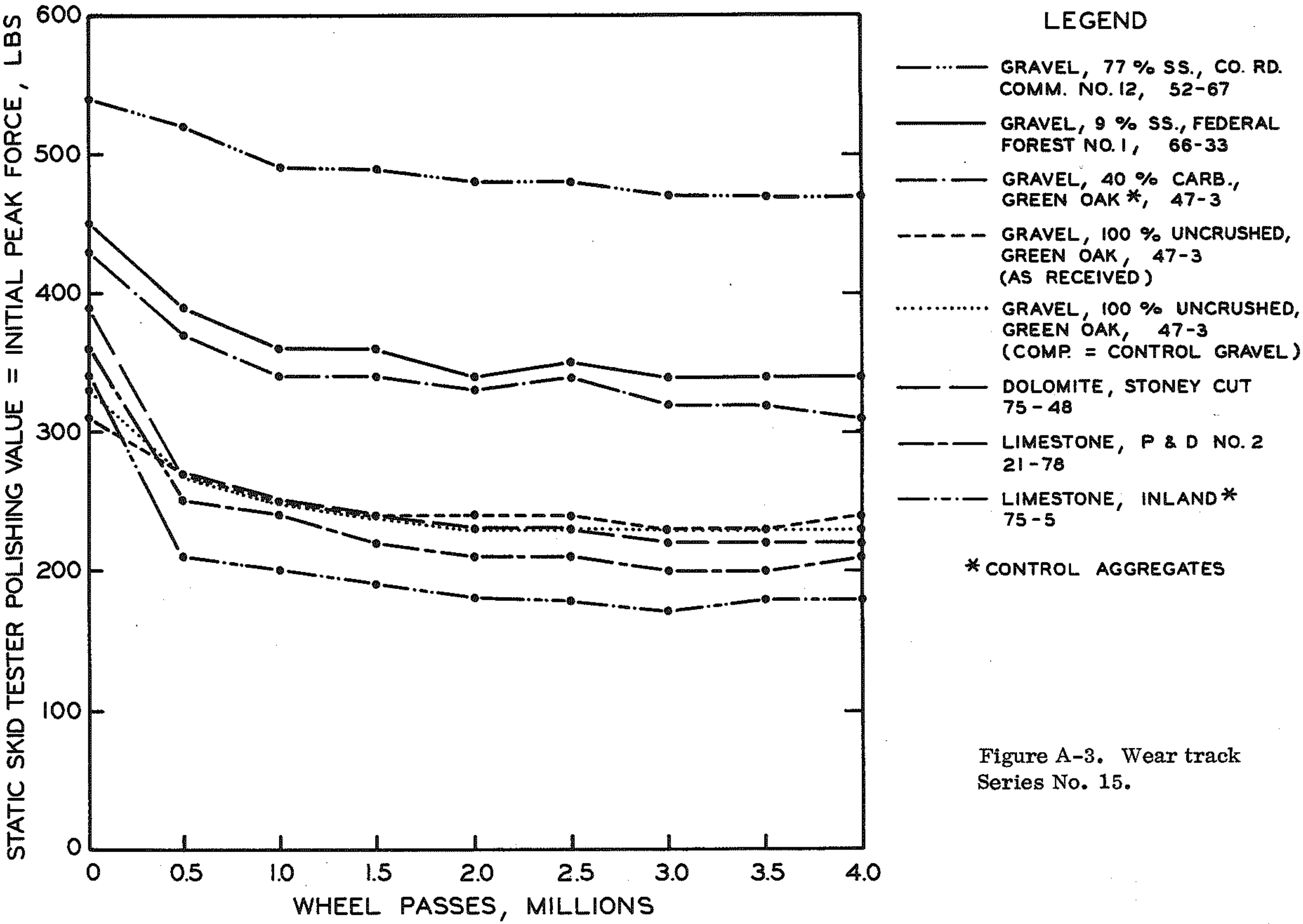

Figure A-3. Wear track Series No. 15.

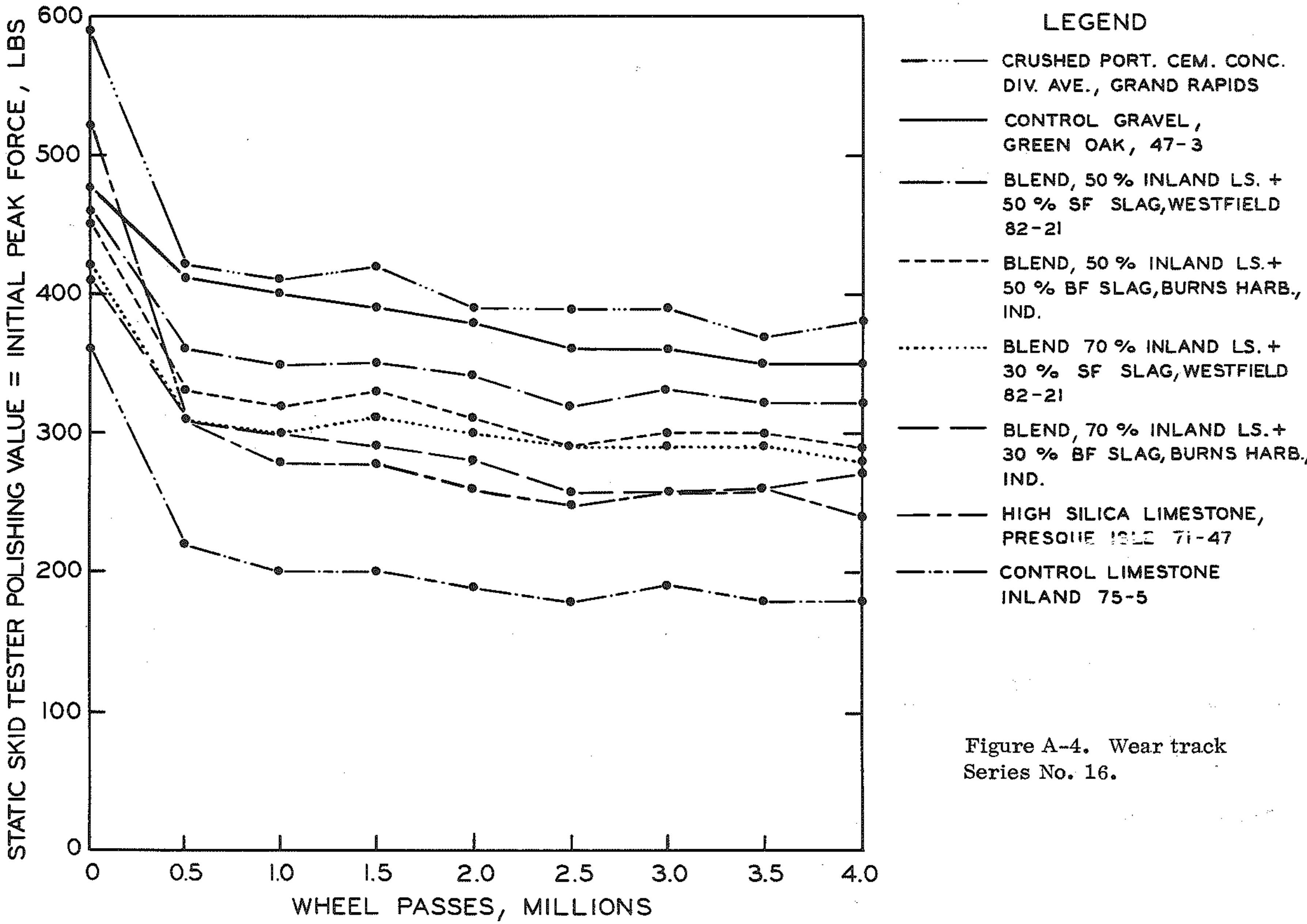

Figure A-4. Wear track Series No. 16.

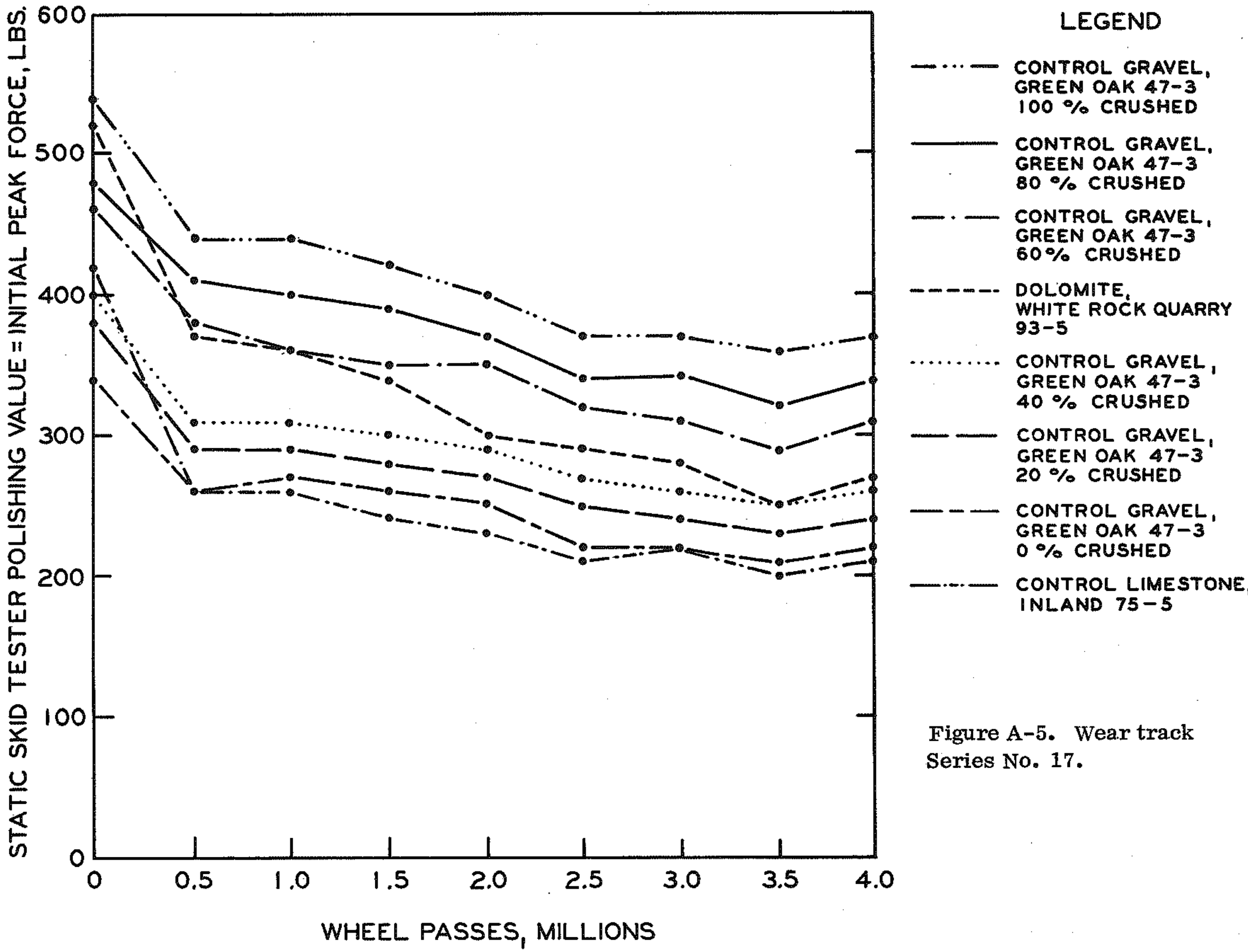

Figure A-5. Wear track Series No. 17.

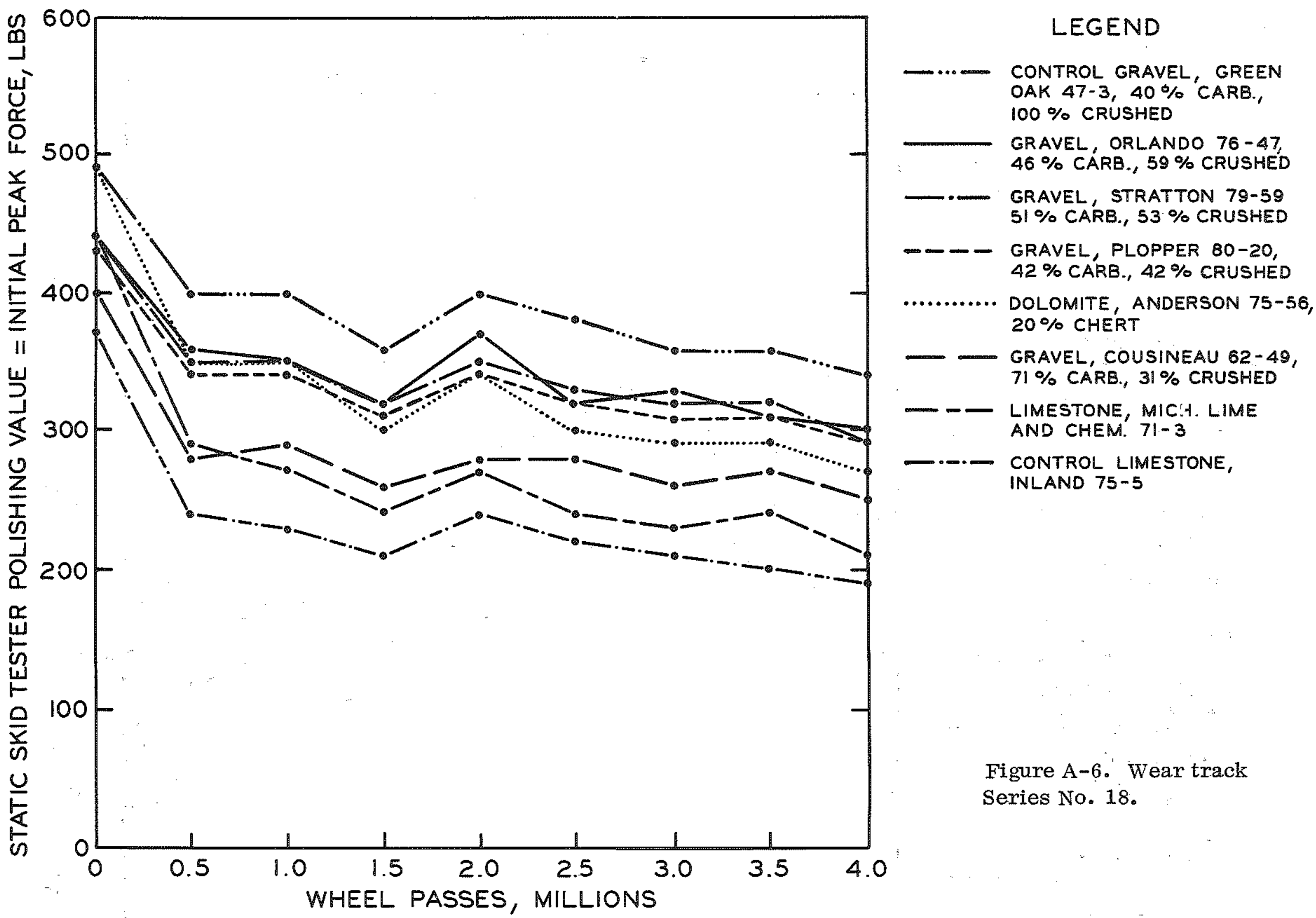

Figure A-6. Wear track Series No. 18.

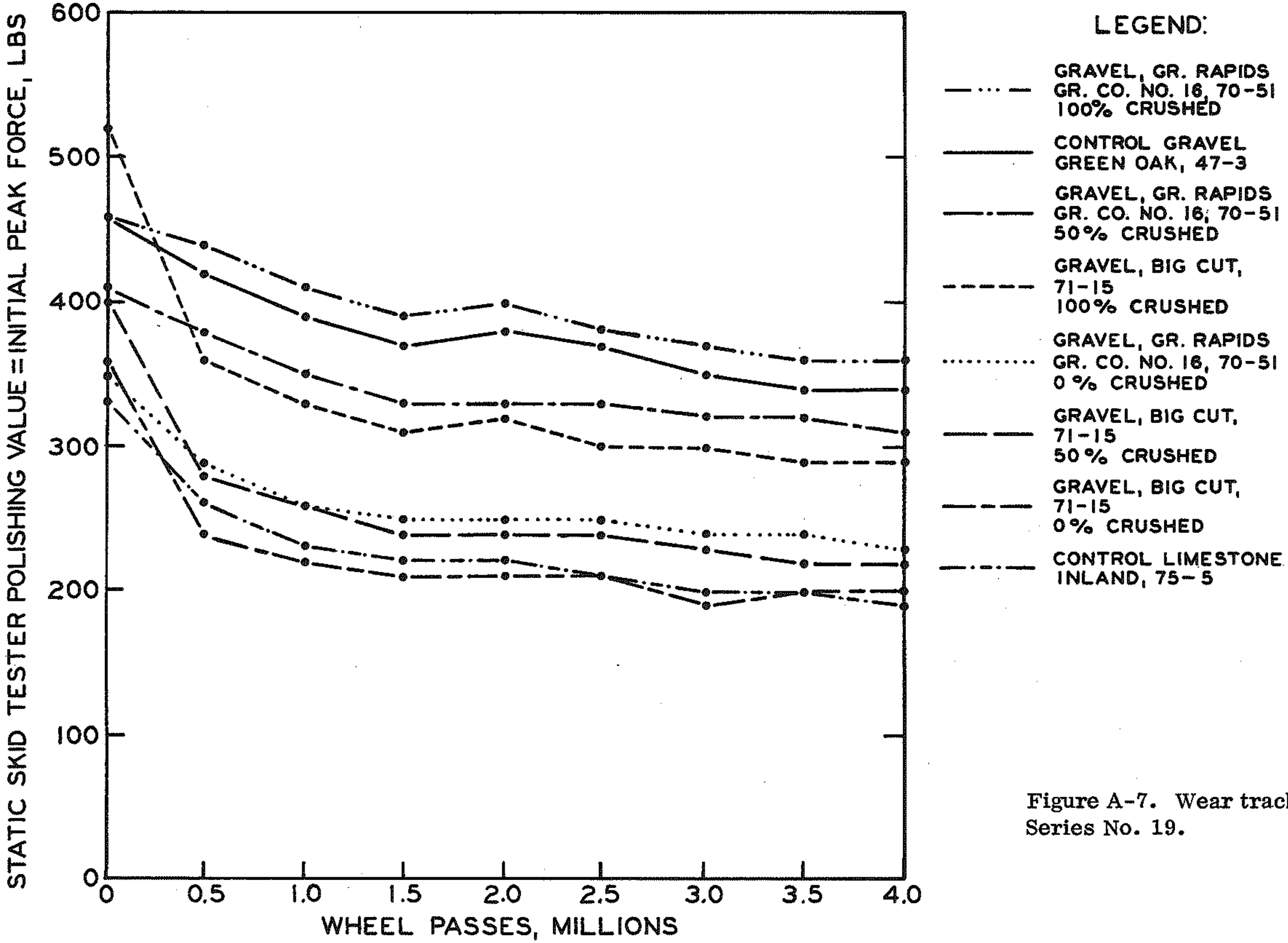

Figure A-7. Wear track Series No. 19.

TABLE A-1
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 13)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Moore Pit No. 2-65	100	75	22	2	520	430	360(40)
Green Oak Pit No. 47-3[2]	100	40	3	2	490	380	320
Roberts Pit No. 75-43	100	83	1	2	450	290	240
Butkovich Pit No. 49-74	100	95	1	2	480	290	230
Krostue Pit No. 49-82	100	92	0	2	500	300	220(27)
Quarried Carbonate							
Lindberg Pit No. 52-9[3] (Dolomite)	100	65	0	2	450	350	280(32)
Inland Pit No. 75-5[4] (Limestone)	100	100	0	2	410	190	170(22)
Slag (Steel Furnace)							
Levy, Westfield No. 82-21	100	0	0	2	490	370	390(42)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Sample contains 35 percent hematitic and siliceous material.
[4] Wear track control limestone.

TABLE A-2
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 14)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Nebel #2 Pit No. 75-44	100	53	11	2	540	420	340(38)
Green Oak Pit No. 47-3[2]	100	40	3	2	500	380	300
Notebloom Pit No. 75-30	100	81	1	2	510	330	250
Romana #2 Pit No. 49-44	100	78	1	2	480	330	250
Payne and Dolan Pit No. 21-78	100	95	3	2	460	280	200(24)
Quarried Carbonates							
Williams Pit No. 21-53 (Limestone)	100	100	0	2	460	280	190(24)
Paquin Pit No. 21-69 (Limestone and dolomite)	100	100	0	2	420	250	180
Inland Pit No. 75-5[3] (Limestone)	100	100	0	2	350	230	160(21)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Wear track control limestone.

TABLE A-3
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 15)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Green Oak Pit No. 47-3[2]	100	40	3	2	430	370	310(35)
Crushed and Uncrushed Gravel							
County Road Comm. #12 Pit No. 52-67	48	1	77	2	540	520	470(50)
Fed. Forest #1 Pit No. 66-33	72	TR	9	2	450	390	340(38)
Uncrushed Gravel							
Green Oak Pit No. 47-3[3]	0	40	3	2	310	270	240(29)
Green Oak Pit No. 47-3[4]	0	34	7	2	330	270	230(28)
Quarried Carbonates							
Stoney Cut Pit No. 75-48 (Dolomite)	100	100	0	2	390	270	220(27)
Payne and Dolan Pit No.[5] 21-78 (Limestone and Dolomite)	100	100	0	2	360	250	210
Inland Pit No. 75-5[6] (Limestone)	100	100	0	2	320	210	180(23)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Sample composition adjusted to composition of control gravel.
[4] Sample tested as received contains 27 percent chert.
[5] Sample is composed of crushed carbonates from high-carbonate gravel.
[6] Wear track control limestone.

TABLE A-4
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 16)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Green Oak Pit No. 47-3[2]	100	40	3	2	480	410	350(39)
Quarried Carbonates							
Presque Isle Pit No. 71-47 (Silica Limestone)	100	100	0	2	520	310	240(29)
Inland Pit No. 75-5[3] (Limestone)	100	100	0	2	360	220	180(23)
Blended Aggregates							
Limestone[3] and SF Slag[4]	100	50	0	2	460	360	320(36)
Limestone[3] and BF Slag[5]	100	50	0	2	450	330	290
Limestone[3] and SF Slag[4]	100	70	0	2	420	310	280
Limestone[3] and BF Slag[5]	100	70	0	2	410	310	270(31)
Crushed Portland Cement Concrete							
K & R, No. 99-1[6]	100	--	-	2	590	420	380(41)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Wear track control limestone.
[4] Steel furnace slag, Levy Westfield Plant No. 82-21.
[5] Blast furnace slag, Levy Burns Harbor, Ind., No. 92-11.
[6] Recycled concrete, Division Avenue, Wyoming, Michigan.

TABLE A-5
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 17)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Green Oak Pit No. 47-3[2]	100	41	3	2	540	440	370(41)
Crushed and Uncrushed Gravel							
Green Oak Pit No. 47-3[3]	80	41	3	2	480	410	340(38)
Green Oak Pit No. 47-3[3]	60	41	3	2	460	380	310
Green Oak Pit No. 47-3[3]	40	41	3	2	400	310	260
Green Oak Pit No. 47-3[3]	20	41	3	2	380	290	240(29)
Uncrushed Gravel							
Green Oak Pit No. 47-3[3]	0	41	3	2	340	260	220(27)
Quarried Carbonates							
White Rock Pit No. 93-5 (Dolomite)	100	100	0	2	520	370	270(31)
Inland Pit No. 75-5[4] (Limestone)	100	100	0	2	420	260	210(25)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Uncrushed gravel composition adjusted to composition of control gravel.
[4] Wear track control limestone.

TABLE A-6
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 18)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Green Oak Pit No. 47-3[2]	100	40	3	2	490	400	340(38)
Crushed and Uncrushed Gravel							
Orlando Pit No. 76-47	59	46	2	2	440	360	300
Stratton Pit No. 79-59	53	51	4	2	440	350	290
Plopper Pit No. 80-20	42	42	3	2	430	340	290
Cousineau Pit No. 62-49	31	71	6	2	400	280	250(30)
Quarried Carbonates							
Anderson Pit No. 75-56[3] (Dolomite)	100	80	0	2	490	350	270(31)
Michigan Lime and Chemical Pit No. 71-3 (Limestone)	100	100	0	2	440	290	210
Inland Pit No. 75-5[4] (Limestone)	100	100	0	2	370	240	190(24)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Sample contains 20 percent chert and cherty dolomite particles.
[4] Wear track control limestone.

TABLE A-7
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 19)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Grand Rapids Gravel Co. No. 16 Pit No. 70-51	100	36	2	2	460	440	360(40)
Green Oak Pit No. 47-3[2]	100	41	3	2	460	420	340
Big Cut Pit No. 71-15	100	85	0	2	520	360	290(33)
Crushed and Uncrushed Gravel							
Grand Rapids Gravel Co. No. 16 Pit No. 70-51	50	36	2	2	410	380	310(35)
Big Cut Pit No. 71-15	50	85	0	2	400	280	220
Uncrushed Gravel							
Grand Rapids Gravel Co. No. 16 Pit No. 70-51	0	36	2	2	350	290	230(28)
Big Cut Pit No. 71-15	0	85	0	2	360	240	200
Quarried Carbonate							
Inland Pit No. 75-5[3] (Limestone)	100	100	0	2	330	260	190(24)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Wear track control limestone.

APPENDIX B

WEAR TRACK APPARATUS AND PROCEDURES

The following description briefly summarizes the wear track test slab preparation and friction testing procedure followed for wear track testing. Also included are descriptions of the wear track and friction tester.

Test Slab Preparation

Preparation of the wear track test slabs is accomplished in the following sequence:

1) gradation of selected aggregate to passing 3/8-in. retained No. 4 size,

2) precoating of dual specimen molds with a medium-etch cement retarding compound,

3) placement of aggregate in the etch-treated molds,

4) placement of portland cement mortar and wire mesh reinforcement in the molds, with brief vibration for consolidation,

5) removal of etched surface cement and fine aggregate by washing and brushing after a 24-hr cure, and

6) curing for 7 days in moist room and 14 days in air.

The test slabs are 1-1/2 in. thick and are trapezoidal with parallel sides of approximately 15-1/2 in. and 19-3/4 in., and non-parallel sides of 11-1/4 in. A set of 16 slabs is required to complete a test bed on the wear track.

The etching process results in the exposure of test aggregates approximately 2 mm above the etched concrete surface.

Figure B-1 shows the specimen molds and vibratory table for consolidating the concrete test slabs.

Wear Track Tests

The wear track polishing apparatus consists of a circular test bed approximately 7 ft in diameter set on a concrete pedestal. The test slabs are securely clamped in place with torquing to equalize hold-down pressure. Polishing is accomplished by two 15-in. smooth tread tires (ASTM E-524)

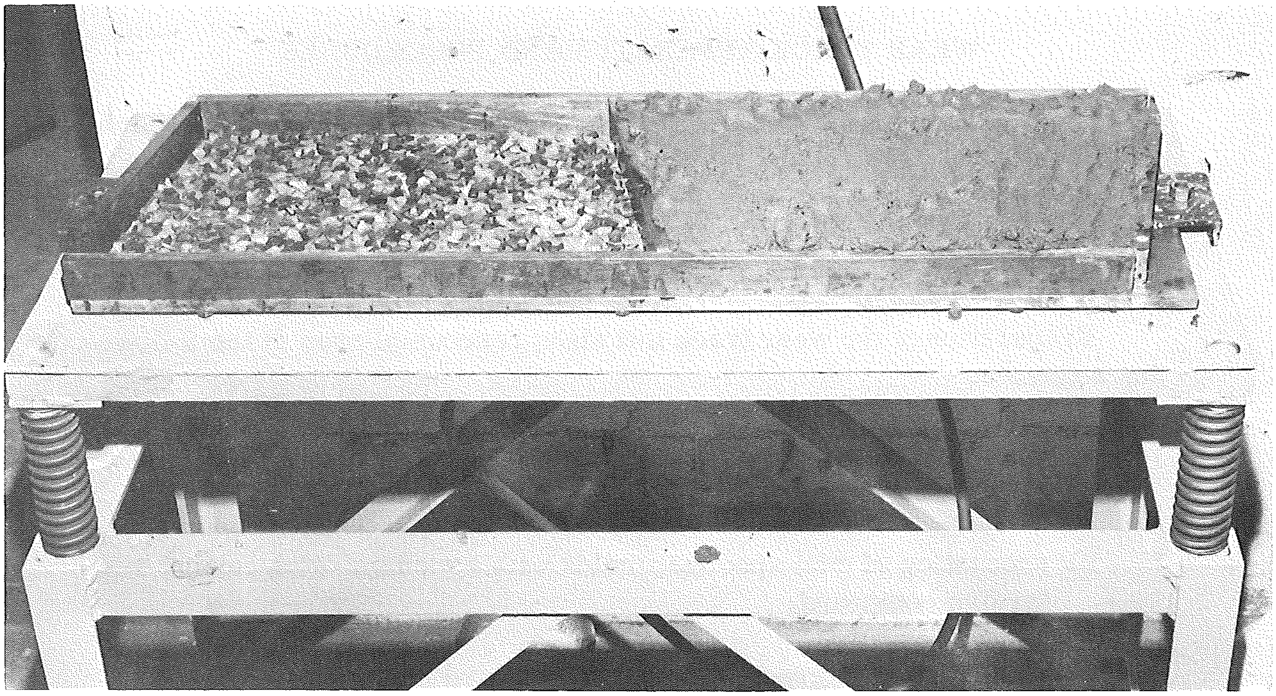

Figure B-1. Vibratory table and test slab molds.

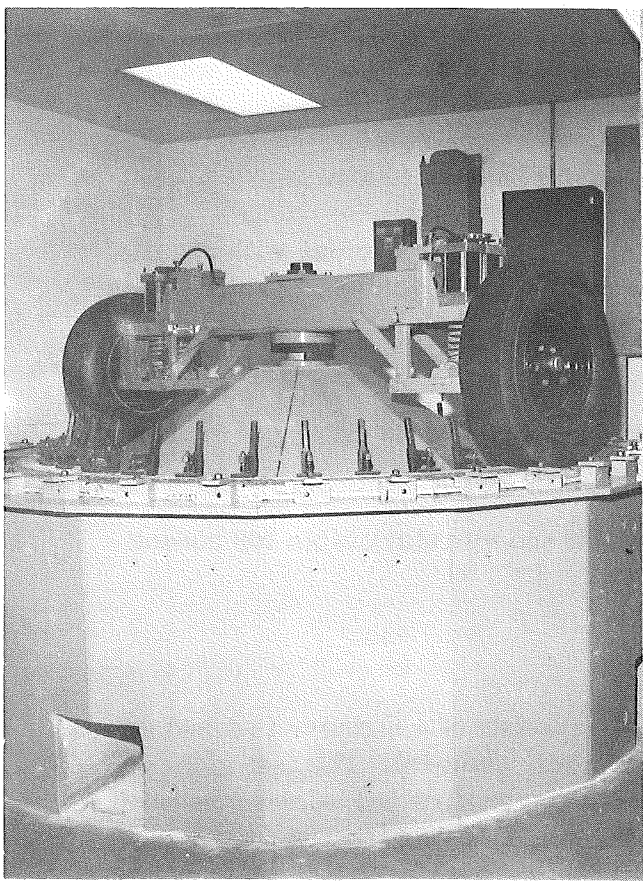

Figure B-2. MDOT wear track.

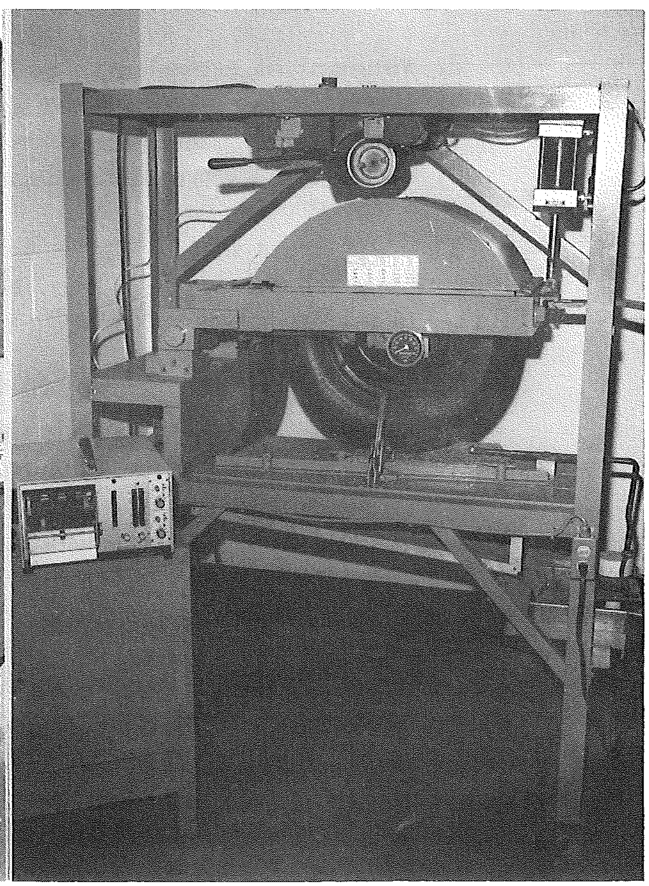

Figure B-3. MDOT static skid tester.

mounted on a horizontal cross-arm powered by a 10 hp a-c motor. Each polishing wheel is spring-loaded to approximately 500 lb of down pressure to achieve accelerated polishing. Polishing is conducted at approximately 40 rpm, with revolutions recorded by an electro-mechanical counter. The normal test interval is 250,000 revolutions. A view of the wear track is shown in Figure B-2.

Friction Tests

At selected intervals (normally 500,000 wheel passes) of wear track polishing, the test slabs are removed from the wear track and tested on the static friction tester containing a 15-in. grooved tread test tire (ASTM E-501) mounted in a framework containing a load cell calibrated to record a maximum of 1,000 lb force. A friction test involves spinning the wheel to 40 mph for a drop-contact with the test slab. The force generated by the tire-slab contact is recorded by a high-speed oscillograph. All friction tests are conducted with the specimens wetted by a recirculating water sprayer. The friction tester is shown in Figure B-3.

A complete set of friction tests for a wear track test series includes the initial friction tests, and retests at successive 500,000 wheel pass intervals, terminating at four-million wheel passes—approximately 10.4-million roadway wheel passes based on a computed distribution of vehicle wheel contact across a typical roadway wheelpath.

Data Reduction

The reported wear track polishing values represent the average initial peak force values read from the oscillograph records. Each value represents the average of a total of 18 test readings—three repeat tests on each of three test locations on two replicate test slabs.

Each 500,000 wheel pass interval provides a data point for development of a polishing curve to monitor the polishing of each test aggregate.

Test Results

The wear track polishing test results are reported in tabulations containing the initial friction values, test values at one-half million wheel passes (to indicate early polishing susceptibility), and test values at four-million wheel passes (to indicate long-term performance).

The wear track polishing value at four-million wheel passes is useful as an estimator of the expected wearing performance of a coarse aggregate to be used in a bituminous pavement top course. The polishing value at four-million wheel passes, referred to as the Aggregate Wear Index, can be used in conjunction with traffic data to estimate long-term polishing performance under the anticipated traffic exposure.

A procedure for computing estimated Aggregate Wear Index values from gravel petrographic composition and wear track polishing values previously determined for the constituent rock types has been developed. The procedure (MTM 112-81) permits the rapid evaluation of a large number of aggregates without the need of long-term testing on the wear track. The procedure is included in this appendix.

METHOD FOR DETERMINING AN AGGREGATE WEAR INDEX (AWI) OF AGGREGATES FOR BITUMINOUS WEARING COURSES BY COMPUTATION FROM PETROGRAPHIC COMPOSITION AND WEAR TRACK DATA
Michigan Test Method 112-84

1. Scope

1.1 This method covers the determination of an Aggregate Wear Index (AWI) for an aggregate or blends of aggregates to be used in bituminous top course mixtures.

1.2 The AWI determined by this method is computed from the petrographic composition of the aggregate sample and the MDOT wear track reference AWI factors established for the rock types contained in the aggregate. These reference AWI factors were determined on 100 percent crushed particles.

1.3 The final computed AWI is based on a grading-weighted summation of the calculated AWI's of the rock types, and a correction for the uncrushed material content in the sample. In the case of blended aggregates, the AWI of the composite material is to be determined from the AWI of each aggregate and the given blend ratio.

1.4 The AWI of the sample is reduced by a factor of 0.26 percent for each percent of uncrushed material in the sample, due to the lower friction values obtained with rounded particles as compared to angular particles.

1.5 The AWI is determined for only the sample fraction coarser than the No. 4 sieve.

2. Applicable Documents

2.1 ASTM Standards

C136 - Test for Sieve Analysis of Fine and Coarse Aggregates

C294 - Description Nomenclature of Constituents of Natural Mineral Aggregates

C295 - Practice for Petrographic Examination of Aggregate for Concrete

C702 - Methods for Reducing Field Samples of Aggregate to Testing Size

2.2 Michigan Test Method Standards

MTM104 - Standard Practice for Petrographic Analysis of Aggregates

MTM111 - Method for Determining an Aggregate Wear Index (AWI) of Aggregate for Bituminous Wearing Courses by Wear Track Polishing.

2.3 MDOT Research Reports

Research Report R-1098, "The Michigan Department of Transportation Circular Wear Track—Results of Preliminary Aggregate Polishing Tests."

Research Report R-1232, "An Aggregate Wear Index Reduction Factor for Uncrushed Material in Gravel.

3. Apparatus and Supplies

3.1 The following items are recommended for the proper analysis of the aggregates. The list is not intended to exclude other items which would serve a similar function, or to require that all items must be available.

3.1.1 Sample splitter

3.1.2 Mechanical sieve shaker

3.1.3 U. S. Standard sieves

Sieve Opening (in.)	(mm)
1	25.0
3/4	19.0
1/2	12.5
3/8	9.5
0.187 (No. 4)	4.75

3.1.4 Balance or scale, minimum 3 kg capacity and readable to 1 g or less.

3.1.5 Stereo-zoom microscope, 10X to 30X, and illumination.

3.1.6 Assorted reagent bottles for acid, water, etc.

3.1.7 Assorted probes, forceps, and holders.

4. Samples and Sample Preparation

4.1 Samples submitted for AWI determination shall be accompanied by proper identification per MDOT procedures.

4.2 A minimum of 50 lb of aggregate obtained from produced material is required for an AWI determination. A separate sample must be submitted for each aggregate to be combined in a blend. The intended blend ratio must be furnished by the contractor.

4.3 A minimum of 2.5 kg of aggregate coarser than the No. 4 sieve is required for an AWI determination on material extracted from bituminous pavements.

4.4 As the AWI determination is conducted on the sample fraction coarser than the No. 4 sieve, material passing the No. 4 sieve may be discarded if not needed for other tests.

4.5 Reduce the sample material coarser than the No. 4 sieve to portions for sieve analysis and petrographic examination, following ASTM C 702.

4.5.1 Prepare a sieve analysis sample of approximately 2.5 kg.

4.5.2 Prepare a petrographic sample of 300 representative particles in each of the following sieve fractions:

Retained 3/4-in.
3/4-in. to 1/2-in.
1/2-in. to 3/8-in.
3/8-in. to No. 4

If the sample contains less than 25 particles in a size fraction, the material shall be included in the next smaller fraction.

5. Sieve Analysis and Petrographic Analysis

5.1 The sieve analysis of the sample portion prepared in 4.5.1 shall be conducted according to ASTM C 136. Determine the grading on the basis of 100 percent retained on the No. 4 sieve, as indicated in Figure B-4.

Figure B-4
WORKSHEET FOR AWI SAMPLE GRADING

Sieve Size	Grading of Coarse Fraction, Sieve Analysis Sample, percent retained	Grading of AWI Sample Fraction, percent retained
1-in.	0.0	0.0
3/4-in.	0.0	0.0
1/2-in.	3.5	5.0
3/8-in.	24.8	35.2
No. 4	42.1	59.8
Total Retained on No. 4	70.4	100.0

5.2 The petrographic analysis of the sample portion prepared in 4.5.2 shall be conducted according to ASTM C 294 and C 295. The rock type categories to be used for the AWI determination are indicated in Figure B-5.

Figure B-5
WORKSHEET FOR GRADING-WEIGHTED PETROGRAPHIC COMPOSITION

Rock Type	Sieve Fraction Analyzed								Grading-Weighted Sample Composition, percent
	1-in. to 3/4-in.		3/4-in. to 1/2-in.		1/2-in. to 3/8-in.		3/8-in. to No. 4		
	Count	Weighted percent	Count	Weighted percent	Count	Weighted percent	Count	Weighted percent	
Igneous/ Metamorphic	0	0.0	6	1.2	57	6.7	67	13.4	21.3
Sedimentary									
Carbonates	0	0.0	18	3.6	225	26.4	217	43.2	73.2
Sandstone	0	0.0	0	0.0	5	0.6	14	2.8	3.4
Siltstone	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Shale	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Clay ironstone	0	0.0	0	0.0	0	0.0	0	0.0	0.0
Chert	0	0.0	1	0.2	13	1.5	2	0.4	2.1
AWI Sample Grading, percent		0.0		5.0		35.2		59.8	100.0
Particle Counts	0		25		300		300		

NOTE: Example includes less than 300 particles in the 3/4-in. to 1/2-in. sieve fraction for illustration.

5.3 Determine the uncrushed particle content in the sample, based on the absence of a fractured face, on the grading sample prepared in 4.5.1, as indicated in Figure B-6. The total uncrushed particle content shall be a gradation-weighted summation. All sandstone particles are to be considered as crushed particles.

Figure B-6
WORKSHEET FOR GRADING-WEIGHTED UNCRUSHED CONTENT

Material in Sample	Sieve Fraction Analyzed								Grading-Weighted Sample Composition, percent
	1-in. to 3/4-in.		3/4-in. to 1/2-in.		1/2-in. to 3/8-in.		3/8-in. to No. 4		
	Percent by Weight	Weighted percent	Percent by Weight	Weighted percent	Percent by Weight	Weighted percent	Percent by Weight	Weighted percent	
Crushed	0	0.0	80	4.0	70	24.6	62	37.1	65.7
Uncrushed	0	0.0	20	1.0	30	10.6	38	22.7	34.3
AWI Sample Grading, percent		0.0		5.0		35.2		59.8	100.0
Material Analyzed, percent	0		100		100		100		

6. Calculations

6.1 Calculate a grading-weighted sample composition from the results of 5.1 and 5.2, as indicated in Figure B-5.

6.2 Calculate a grading-weighted uncrushed particle content as indicated in Figure B-6.

6.3 Calculate a grading-weighted AWI from the results of 6.1 and the rock type AWI factors as indicated in Figure B-5.

6.4 Reduce the gradation-weighted AWI determined in 6.3 by a factor of 0.26 percent for each percent of uncrushed material as determined in 6.2. Report this adjusted value, rounded to the nearest 10 units, as the sample AWI as indicated on the example report of test form, Figure B-7.

6.5 The resultant AWI for a blend shall be calculated from the AWI values determined for each blend aggregate and the given blend ratio, with regard to the quantity of material retained on the No. 4 sieve.

6.5.1 As the AWI is determined on the basis of number of particles exposed in the pavement surface, which is related to volume, blending of aggregates with markedly dissimilar specific gravities may require weighting of the blend ratio.

7. Report

7.1 The results of the grading, petrographic analysis, and AWI determination shall be included in a report for the job mix formula.

7.2 Report AWI results on a general report form as shown in Figure B-7.

FILE 300

1801A (N12/83)

REPORT OF TEST
GENERAL
AGGREGATE WEAR INDEX

Control Section Identification	
Job No.	
Laboratory No.	
Date	

Report on sample of DENSE - GRADED AGGREGATE

Date sampled ____ Date received ____

Source of material ____

Sampled from ____ Quantity represented ____

Submitted by ____

Intended use BITUMINOUS MIXTURES Specification ____

TEST RESULTS

COMPOSITION OF SAMPLE

ROCK TYPE	PERCENT	WEAR TRACK AWI	CALCULATED AWI
IGNEOUS/METAMORPHIC	21.3	370	78.8
SEDIMENTARY			
Carbonates	73.2	250	183.0
Sandstone	3.4	490	16.7
Siltstone	0.0	475	0.0
Shale	0.0	335	0.0
Clay Ironstone	0.0	275	0.0
Chert	2.1	345	7.2

Weighted Sample AWI 285.7

Uncrushed Particles, % 34

AWI Reduction based on uncrushed

Reduction in Percent . . (0.26 X 34) 8.8

Adjusted AWI 260

Signed ____ Geologist

TABLE B-1
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 1 Through 8)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Green Oak Pit No. 47-3[2]	100	40.0	3.0	15	440	380	320(36)
Grand Rapids Gravel Co. #14 Pit No. 41-38	100	47.0	1.0	2	420	380	320
Rondo Pit No. 16-52	100	82.0	2.0	2	440	280	260
Pierce Pit No. 45-19	100	90.0	0.0	2	460	350	250
Big Cut Pit No. 71-15	100	90.0	0.0	2	430	330	240(29)
Uncrushed Gravel							
Hodgkiss and Douma[3] Pit No. 5-74	0	58.0	TR	2	390	330	270(31)
Day Pit No. 40-1[4]	0	60.0	TR	2	400	320	240(29)
Quarried Carbonates							
Weldum Pit No. 21-54 (shaley ls. and siltstone)	100	58.7	30.0[5]	2	460	390	330(37)
Glancy Pit No. 6-23 (aren. ls.) produced	100	78.6	16.6	2	420	340	320
Wallace Pit No. 32-4 (aren. ls.) bottom rock	100	82.5	13.8	2	440	350	310
Glancy Pit No. 6-23 (aren. ls.) top rock	100	80.8	15.4	2	420	320	300
France Pit No. 58-2 (aren. dol.)	100	94.6	4.4	2	470	370	290
Peterson Pit No. 55-95 (aren. dol.)	100	92.0	5.9	2	470	370	290
Wallace Pit No. 32-4 (aren. ls.) full face	100	74.1	23.2	2	450	360	290
Wallace Pit No. 32-4 (aren. ls.) produced	100	79.2	17.2	2	430	380	290
France Pit No. 58-1 (dol. and calc. dol.)	100	87.8	7.2	2	460	360	270
Material Services, Thornton, IL (dol., vuggy)	100	99.6	0.1	2	450	360	260(30)
Bichler Pit No. 21-46 (arg. dol.)	100	90.6	2.1	2	470	350	250
Thornton Pit No. 21-67 (dol. and calc. dol.)	100	93.0	4.2	2	460	340	230
France, Waterville, OH (dol.)	100	94.0	2.9	2	450	310	230
Michigan Stone Pit No. 58-3 (dol. and calc. dol.)	100	97.1	1.0	2	400	290	210
National Lime, Findlay, OH (dol.)	100	96.4	0.3	2	390	300	210
Drummond Pit No. 17-66 (dol.)	100	99.2	0.2	3	410	280	200
Presque Isle Pit No. 71-47 (ls.)	100	98.6	TR	2	400	260	180
Inland Pit No. 75-5 (ls.)[6]	100	98.9	0.1	15	370	240	170(22)
Slag							
E.C. Levy, Detroit, blast furnace	100	0.0	0.0	2	520	450	340(38)
White Pine Copper Co., reverb furnace	100	0.0	0.0	2	420	330	290(33)
Blended Aggregate							
Limestone[5] and gravel[2] 50:50	100	70.0	2.0	1	440	280	240(29)
Limestone[5] and gravel[2] 80:20	100	88.0	1.0	2	430	280	220(27)

Polishing value = average initial peak force lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Sample contains 7 percent shale particles.
[4] Sample contains 3 percent shale particles. Carbonate content is approximate.
[5] HCl acid insoluble residue coarser than No. 200, percent of original sample, reported for quarried carbonates.
[6] Wear track control limestone.

TABLE B-2
RESULTS OF WEAR TRACK POLISHING TESTS
COMPLETED ON ROCK TYPES SORTED FROM
SELECTED MICHIGAN AGGREGATES
(Series 1 Through 8)

Rock Type	No. of Test Slabs	Wear Track Polishing Values		
		Initial Value	one-half million wheel passes	four-million wheel passes[1]
Crushed Gravel Control Aggregate (Green Oak Pit No. 47-3)[2]	15	440	380	320(36)
Igneous				
Diorite	2	480	450	360(40)
Granite	2	460	450	350
Gabbro	2	480	430	350
Felsite[3]	2	440	400	320
Basalt	2	420	380	310(35)
Metamorphic				
Quartzite	2	460	440	370(41)
Schist	2	410	390	350
Metasediments	2	450	410	340
Tillite	2	440	400	320(36)
Sedimentary				
Friable Sandstone	2	530	540	520(54)
Non-Friable Sandstone	2	470	470	460
Siltstone	2	470	460	450
Crag	2	500	420	410
Vitreous and Dark Dull Chert	2	400	360	340
Mottled Chert	2	400	360	330
Shale	2	370	320	320(36)
Light Dull Chert	2	410	320	310
Clay Ironstone, Outer Shells	2	430	320	290
Clay Ironstone, Fossiliferous	2	420	300	270
Clay Ironstone, Hard Centers	2	410	270	250
Clay Ironstone, Massive-Laminated	2	390	300	250
Dolomite (Drummond Island Pit No. 17-66)[4]	3	410	280	200
Dolomitic Limestone (Hendricks Pit No. 49-7)[4]	2	400	260	180(23)
Limestone Control Aggregate (Inland Pit No. 75-5)[5]	15	370	240	170(22)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Sample contains crushed outcrop material.
[4] Quarried low-residue carbonates.
[5] Wear track control limestone.

TABLE B-3
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON AGGREGATES FROM SELECTED SOURCES (Series 9 Through 12)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values: Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
County Road Comm. #3 Pit No. 17-62	100	0.0	29.0	4	520	500	440(47)
Galesburg Pit No. 39-69	100	24.0	6.0	2	520	430	350
Coit Ave Pit No. 41-118	100	34.0	2.0	2	500	430	350
Grand Rapids Gravel Co. #16 Pit No. 70-51	100	41.0	1.0	2	480	420	350
Beisiegel Pit No. 81-57	100	41.0	4.0	2	500	420	340
Green Oak Pit No. 47-3[2]	100	40.0	3.0	8	480	390	330
Pierce Pit No. 45-19	100	97.0	0.0	2	450	300	270(31)
Crushed and Uncrushed Gravel							
Bundy Hill Pit No. 30-35	78	40.0	5.0	2	450	390	330(37)
Quarried Carbonates							
Wallace Pit No. 32-4 (very aren. ls.)	100	52.2	47.2[3]	2	610	540	480(51)
Rockwood Pit No. 82-2 (cherty aren. dol.)	100	62.6	35.6	2	540	430	330
Inland Pit No. 75-5 (ls.)[4]	100	98.9	0.1	8	340	230	190(24)
Slag							
U.S. Steel, Gary, IN, blast furnace	100	0.0	0.0	2	570	530	410(44)
E.C. Levy, Burns Harbor, IN, blast furnace	100	0.0	0.0	2	550	490	390(42)
Blended Aggregates							
Gravel[2] and sandstone, Pit No. 38-81 60:40	100	24.0	42.0	2	550	480	390(42)
Gravel[2] and sandstone, Pit No. 38-81 80:20	100	32.0	22.0	2	550	410	390
Gravel[2] and sandstone, Pit No. 32-64 60:40	100	24.0	42.0	2	520	440	370
Limestone[4] and sandstone, Pit No. 32-64 50:50	100	50.0	50.0	2	510	450	360
Gravel[2] and sandstone, Pit No. 32-64 80:20	100	32.0	22.0	2	500	410	340
Gravel[2] and sandstone, Pit No. 30-65 80:20	100	32.0	22.0	2	520	380	330
Gravel[2] and sandstone, Pit No. 13-90 80:20	100	32.0	22.0	2	500	370	330
Gravel, Pit Nos. 45-19 and 17-62 60:40	100	58.0	10.0	2	410	370	320
Gravel, Pit Nos. 45-19 and 17-62 80:20	100	78.0	5.0	2	410	350	290
Limestone[4] and gravel, Pit No. 17-62 60:40	100	60.0	10.0	2	350	290	260
Limestone[4] and sandstone, Pit No. 32-64 80:20	100	80.0	20.0	2	430	330	250
Limestone[4] and gravel, Pit No. 17-62 80:20	100	80.0	5.0	2	340	270	240(29)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] HCl acid insoluble residue coarser than No. 200, percent of original sample, reported for quarried carbonates.
[4] Wear track control limestone.

TABLE B-4
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON GRAVEL AGGREGATES FROM SELECTED SOURCES (Series 13 Through 19)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Sandstone Content, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Crushed Gravel							
Moore Pit No. 2-65	100	75	22	2	520	430	360(40)
Grand Rapids Gravel Co. #16 Pit No. 70-51	100	36	2	2	460	440	360
Nebel #2 Pit No. 75-44	100	53	11	2	540	420	340
Green Oak Pit No. 47-3[2]	100	40	3	14	470	400	330
Big Cut Pit No. 71-15	100	85	0	2	520	360	290
Notebloom Pit No. 75-50	100	81	1	2	510	330	250
Romana #2 Pit No. 49-44	100	78	1	2	480	330	250
Roberts Pit No. 75-43	100	83	1	2	450	290	240
Butkovich Pit No. 49-74	100	95	1	2	480	290	230
Krostue Pit No. 49-82	100	92	0	2	500	300	220
Payne and Dolan Pit No. 21-78	100	95	3	2	460	280	200(24)
Crushed and Uncrushed Gravel							
County Road Comm. #12 Pit No. 52-67	90	1	77	2	540	520	470(50)
Green Oak Pit No. 47-3[3]	80	41	3	2	480	410	340
Fed. Forest #1 Pit No. 66-33	75	TR	9	2	450	390	340
Grand Rapids Gravel Co. #16 Pit No. 70-51	50	36	2	2	410	380	310
Green Oak Pit No. 47-3[3]	60	41	3	2	460	380	310
Orlando Pit No. 76-47	59	46	2	2	440	360	300
Stratton Pit No. 79-59	53	51	4	2	440	350	290
Plopper Pit No. 80-20	42	42	3	2	430	340	290
Green Oak Pit No. 47-3[3]	40	41	3	2	400	310	260
Cousineau Pit No. 62-49	31	71	6	2	400	280	250
Green Oak Pit No. 47-3[3]	20	41	3	2	380	290	240
Big Cut Pit No. 71-15	50	85	0	2	360	240	200(24)
Uncrushed Gravel							
Grand Rapids Gravel Co. #16 Pit No. 70-51	0	36	2	2	350	290	230(28)
Green Oak Pit No. 47-3[4]	0	34	7	2	330	270	230
Green Oak Pit No. 47-3[3]	0	41	3	4	320	260	230
Big Cut Pit No. 71-15	0	85	0	2	360	240	200(24)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] Wear track control gravel.
[3] Uncrushed gravel composition adjusted to composition of control gravel.
[4] Uncrushed gravel tested as received contains 15 percent chert.

TABLE B-5
RESULTS OF WEAR TRACK POLISHING TESTS COMPLETED ON VARIOUS AGGREGATES FROM SELECTED SOURCES (Series 13 Through 19)

Aggregate Type and Source	Crushed Content, percent	Carbonate Rock Content, percent	Insoluble Residue, percent	No. of Test Slabs	Wear Track Polishing Values		
					Initial Value	half-million wheel passes	four-million wheel passes[1]
Quarried Carbonates[2]							
Lindberg Pit No. 52-9[3] (dol.)	100	64.8	33.5	2	450	350	280(30)
White Rock, Clay Center, OH (dol.)	100	99.8	TR	2	520	370	270
Anderson Pit No. 75-56 (cherty dol.)	100	77.1	21.5	2	490	350	270
Presque Isle Pit No. 71-47 (silic. ls.)	100	92.6	5.0	2	520	310	240
Stoney Cut Pit No. 75-48 (dol.)	100	96.9	0.6	2	390	270	220
Michigan Lime and Chemical Pit No. 71-3 (ls.)	100	99.4	0.2	2	440	290	210
Payne and Dolan Pit No. 21-78[4] (ls. and dol.)	100	--	--	2	360	250	210
Williams Pit No. 21-53 (ls.)	100	91.4	1.9	2	460	280	190
Paquin Pit No. 21-69 (ls. and dol.)	100	93.1	1.7	2	420	250	180
Inland Pit No. 75-5 (ls.)[5]	100	98.9	0.1	14	370	230	180(23)
Slag							
E.C. Levy, Westfield No. 82-21	100	0.0	--	2	490	370	390(42)
Blended Aggregates							
Limestone[5] and SF slag[6] 50:50	100	50.0	--	2	460	360	320(36)
Limestone[5] and BF slag[7] 50:50	100	50.0	--	2	450	330	290
Limestone[5] and SF slag[6] 70:30	100	70.0	--	2	420	310	280
Limestone[5] and BF slag[7] 70:30	100	70.0	--	2	410	310	270(31)
Crushed Portland Cement Concrete							
K & R Pit No. 99-1[8]	100	--	--	2	590	420	380(41)

Polishing value = average initial peak force, lb, measured on wear track friction tester.
Polishing value at four-million wheel passes = Aggregate Wear Index.

[1] Values in parentheses indicate approximate 40 mph ARMS pavement friction numbers based on field correlation tests.
[2] HCl acid insoluble residue coarser than No. 200, percent of original sample, reported for quarried carbonates.
[3] Sample contains hematitic and siliceous material.
[4] Sample is composed of crushed carbonates from high-carbonate gravel.
[5] Wear track control limestone.
[6] Steel furnace slag, E. C. Levy, Westfield Plant, No. 82-21.
[7] Blast furnace slag, E. C. Levy, Burns Harbor, IN, No. 92-11.
[8] Recycled concrete, Division Avenue, Wyoming, MI.