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DEGRADATION OF STEEL FURNACE SLAG AS AN OPEN GRADED BASE COURSE FOR CONCRETE PAVEMENT

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

DEGRADATION OF STEEL FURNACE SLAG AS AN OPEN GRADED BASE COURSE FOR CONCRETE PAVEMENT

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Since 1959, the Testing and Research Division has conducted numerous studies of slag materials, presently referred to as 'steel furnace slag.' These studies have indicated that dense graded steel furnace slag should not be used as a base layer material. In 1979, major pavement failures were linked, in part, to the frost susceptible nature of dense graded slags and, as a result, the Department no longer permits the use of this material. However, open graded steel furnace slags meeting coarse aggregate 6A, 9A, or 17A gradation specifications are still approved by Michigan for use in open graded bases. The FHWA, however, has expressed concern about the possible breakdown of coarse slag under construction and traffic forces and has requested the Department to demonstrate that open graded steel furnace slag aggregates are as durable as typical natural aggregates.

The purpose of this study is to determine whether steel furnace slag, when open graded, is as resistant to deterioration under construction, freeze-thaw, and repeated traffic load conditions as are standard natural aggregates. Because 6A, 9A, and 17A gradations are composed primarily of plus No. 4 sieve material, this study was conducted on aggregates passing the 1 in. sieve and retained on the No. 4 sieve.

TESTING PROGRAM

Steel furnace aggregates from three different sources, a blast furnace slag from one source, and natural aggregates from two different sources were used in this study. Only the plus No. 4 sieve material was considered. The relative durabilities of the different aggregates were compared using the results of five laboratory tests.

Los Angeles Abrasion Test

This test was conducted using Michigan's standard test method, MTM 102-78. The test requires a pre-washing of the sample to remove dust, loose particles, and soluble materials from the aggregate.

Freeze-Thaw Durability Test

The freeze-thaw durability tests were conducted on aggregates washed on the No. 4 sieve to remove weakly cemented and soluble particles of the steel furnace slag, prior to subjecting samples to the immersion portion of the freeze-thaw test. The washed aggregate was placed in 4-1/2 by 5-1/2 by 18-in. wire mesh baskets and the initial weights determined. The wire mesh is equivalent to that of a No. 8 sieve. The test samples were placed in the freeze-thaw chamber used to perform standard freeze-thaw durability tests (ASTM C666) and subjected to 300 cycles of alternate freezing and thawing. At the conclusion of the test the samples were again washed on the No. 4 sieve and the dry weight of the retained aggregate determined. The amount of degradation is expressed as the difference between initial and final dry weights expressed as a percentage of the initial weight.

Impact Resistance Test

In this test the resistance of plus No. 4 aggregate to impact loading was determined by subjecting the sample to the standard AASHTO T-180 compaction effort. Breakdown was based on the sieve analysis of the materials before and after compaction.

Swelling Potential Test

Swelling potential tests were conducted under conditions of 100 percent relative humidity. In this test the plus No. 4 aggregate was tamped into cylindrical plastic containers designed to minimize side restriction during possible volume change. A distilled water level was maintained 1 in. above the bottom of the 6 in. diameter by 11 in. tall samples. Each sample was covered with a porous stone and the change in elevation, measured to the nearest 1/32 in., recorded weekly during the first month and monthly thereafter for a total period of six months.

Cyclic Loading Test

Cyclic loading tests were made to determine possible breakdown of the aggregates when subjected to simulated repeated traffic loading. A small vibratory compactor was used to place six layers of plus No. 4 material in 11 in. tall by 6-in. diameter molds at standard Proctor density. Load cycles were applied using a 22.6 psi haversine load, applied at a rate of 10 cycles per second, for a total of 10^6 load repetitions. After the cyclic load applications the samples were dry sieved to check for any percent passing the No. 4 sieve.

In the above testing program, the Los Angeles abrasion and the compaction tests were performed by personnel of the Testing Laboratory. The other tests were performed in the Research Laboratory.

TEST RESULTS

While washing aggregate samples, as required prior to the Los Angeles abrasion and freeze-thaw tests, it was noticed that the steel furnace slag tended to break down into minus No. 4 material more than did the natural aggregate and blast furnace slag samples. For this reason, the testing method favors the steel furnace slag in that some of the soft and soluble

TABLE 1
DURABILITY AND VOLUME CHANGE TEST RESULTS OF SLAG AND NATURAL AGGREGATES

	Sample	Percent Degradation From Freeze-Thaw Testing* (Average Three Tests)	Percent Wear From Los Angeles Abrasion Testing (Average Three Tests)	Percent Degradation From T-180 Compactive Effort* (One Test)	Percent Degradation From 1 x 10^6 Repetitions of Load* (One Test)	Percent Volume Change, + = Swell, - = Shrinkage (One Test)
Natural Aggregate	Const. Agg. Pit 70-9	3.6	21.8	3.6	0.2	-0.8
	Amer. Agg. Oxford Pit 63-4	2.6	16.9	1.8	0.1	-0.3
Steel Furnace Slag	Slag Westfield Plant 3	11.0	21.2	11.1	1.4	-0.1
	Slag Mellon Plant 6	8.5	18.7	8.8	1.0	-0.1
	Slag Trenton Plant 5	5.9	20.2	6.4	0.7	+0.7
Blast Furnace Slag	- 3/4 in. + No. 4 Slag - Indiana Source	3.0	Not Tested	2.3	0.1	0.0

* Based on percent passing the No. 4 sieve.

particles are removed prior to the actual test. This also indicates that open graded drainage sized slag should be accepted by the Department only after washing.

It was planned that three samples for each material and test condition be used and the results averaged. However, because of the large amounts of material needed to obtain required gradations for the Los Angeles abrasion tests only enough material remained to make single samples for some of the tests.

The test values obtained are summarized in Table 1. Table 2 shows the average value comparison for natural aggregates and steel furnace and blast furnace slags for the different tests.

TABLE 2
AVERAGE DEGRADATION OF NATURAL AND SLAG AGGREGATES

Test	Average Percent Degradation		
	Natural Aggregates	Steel Furnace Slag Aggregates	Blast Furnace Slag Aggregate
L. A. abrasion	19.4	20.0	---
Freeze-thaw	3.1	8.5	3.0
Compaction	2.7	8.8	2.3
Repeated loading	0.2	1.0	0.1

The change in gradation of the samples due to breakdown under the T-180 compaction effort are shown in Figures 1 through 6. Specific results are:

1) The Los Angeles abrasion test, conducted by Michigan's standard procedures, showed no significant difference between natural aggregate and steel furnace slag, and the percent loss (19 to 20) was well within MDOT specification limits. Preparation of the samples for testing, however, favored the slag materials which lost considerably more material from preliminary washing than did the natural aggregate.

2) Loss due to freeze-thaw testing was about 5 percent higher for the steel furnace slag but the losses were low (3 to 8 percent).

3) Under T-180 compaction efforts, steel furnace slag degraded by an amount about 6 percent higher than did the natural aggregate. The values (3 and 9 percent) were close to those obtained in the freeze-thaw test.

4) Under repeated load testing (10^6 repetitions) the degradation for each type material was less than 1 percent but was slightly less for the natural and blast furnace slag aggregates.

5) There was no significant volume change (swell or shrinkage) in either the slags or the natural aggregate samples.

CONCLUSIONS

This study indicates that coarse graded steel furnace slag aggregates are more susceptible to degradation than are natural and blast furnace slag aggregates of comparable gradation. The difference, however, is not great enough to warrant restricting the use of steel furnace slag for open graded base construction, without further study. Although there might be a greater accumulation of fine material in the slag open graded base, the effect that this might have on ability of the base to remove water cannot easily be evaluated.

It is recommended, therefore, if steel furnace slag is to be used for open graded base construction that the installation be considered experimental and its performance be monitored on a long-term basis.

In order to obtain maximum durability for steel furnace slag, the material should be washed prior to testing for acceptance by the Department to meet a loss by washing requirement of 0-3 percent.

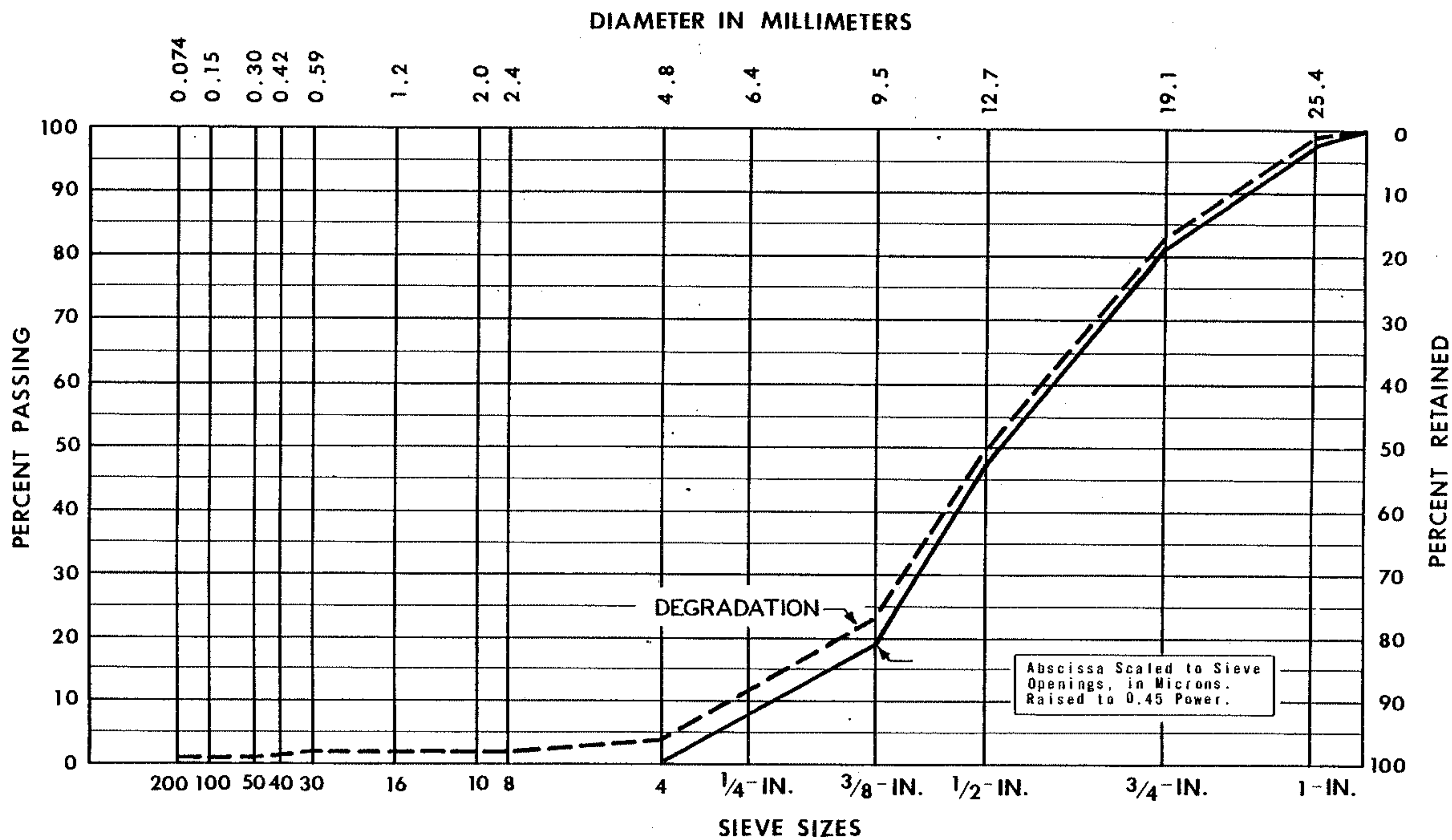

Figure 1. Grain size distribution before and after T-180 compaction of the sample received from Construction Aggregates, Pit No. 70-9.

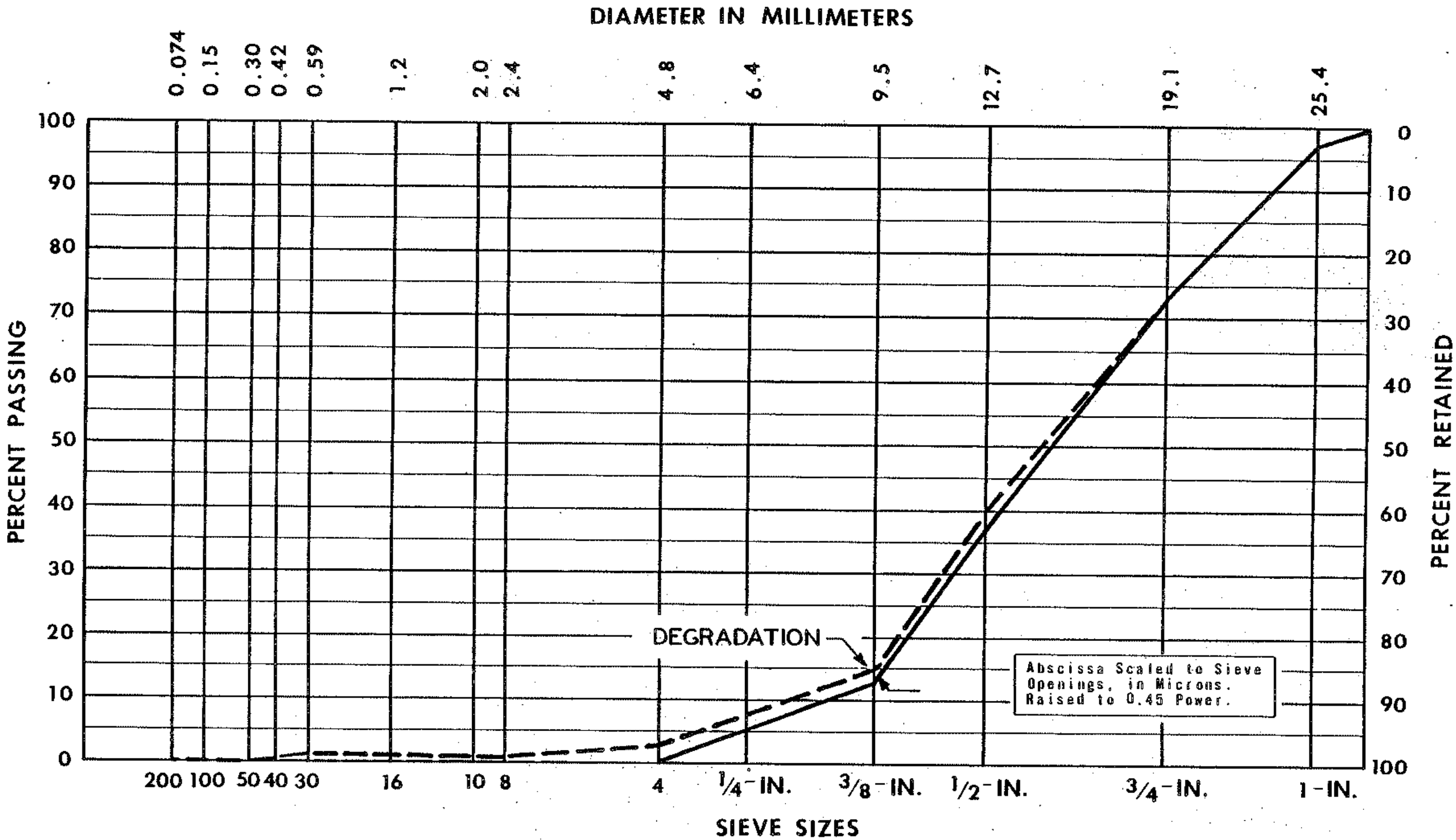

Figure 2. Grain size distribution before and after T-180 compaction of the sample received from American Aggregates, Oxford Pit 63-4.

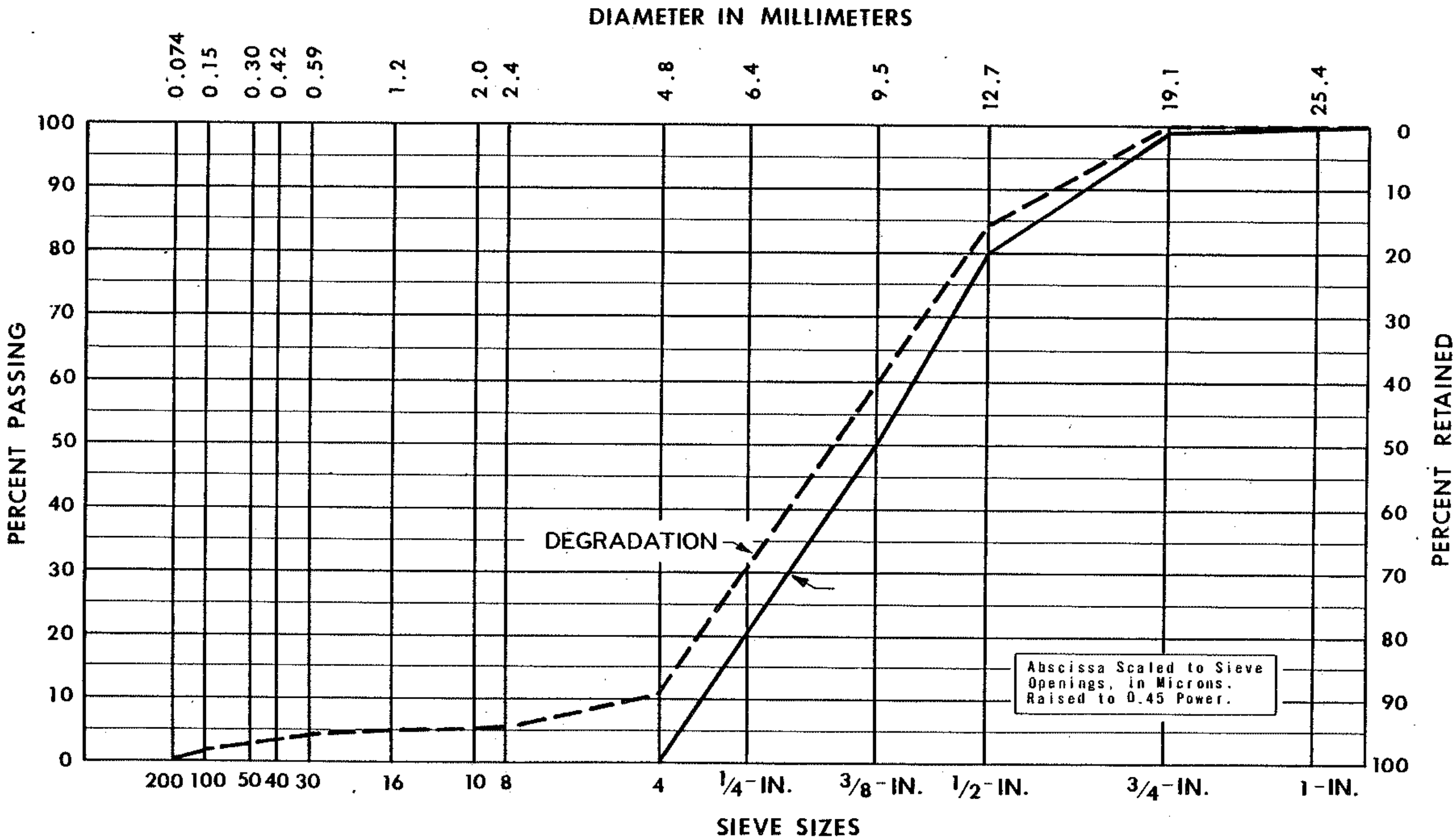

Figure 3. Grain size distribution before and after T-180 compaction of the slag sample received from Westfield Plant 3.

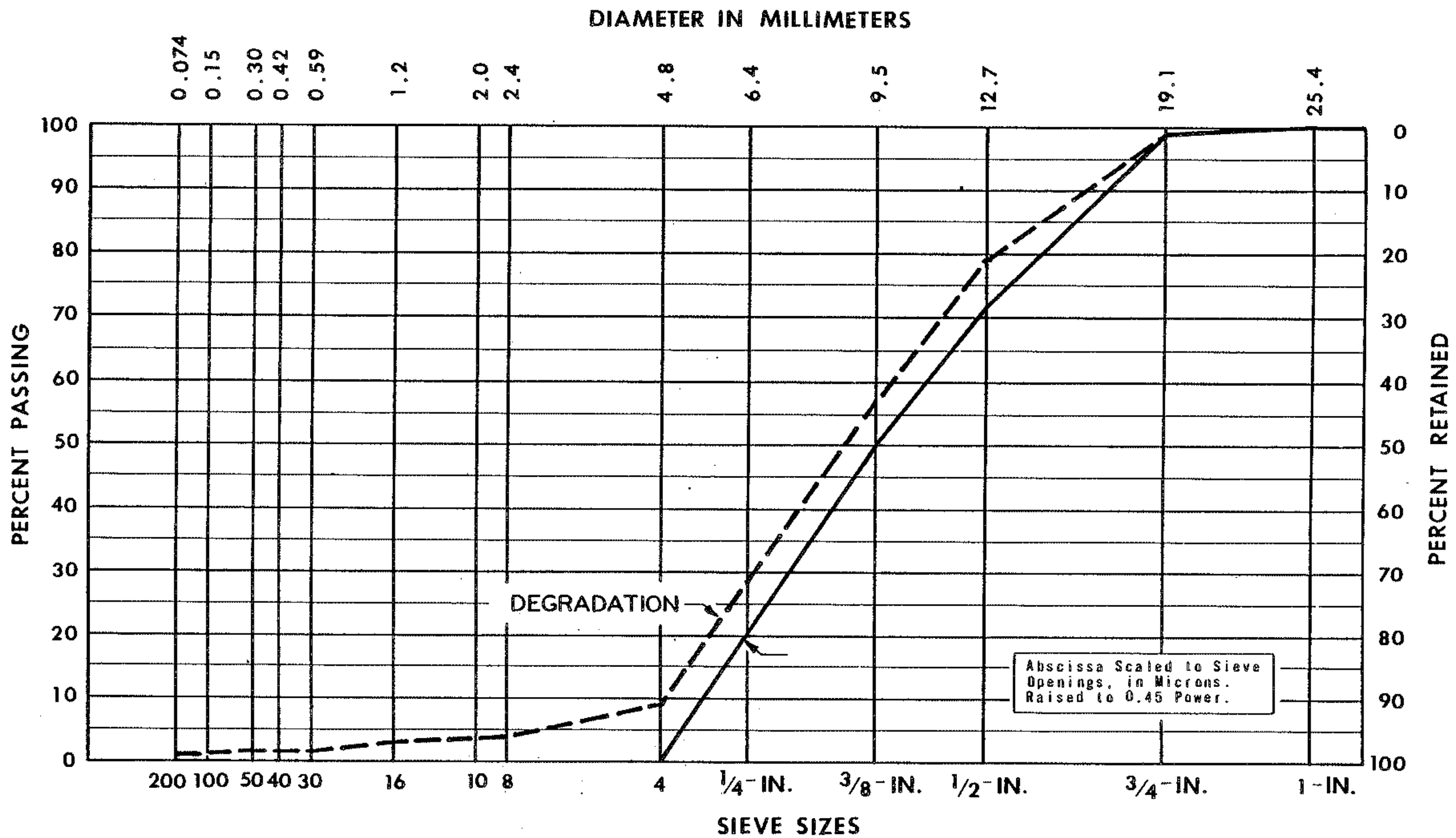

Figure 4. Grain size distribution before and after T-180 compaction of the slag sample received from Mellon Plant 6.

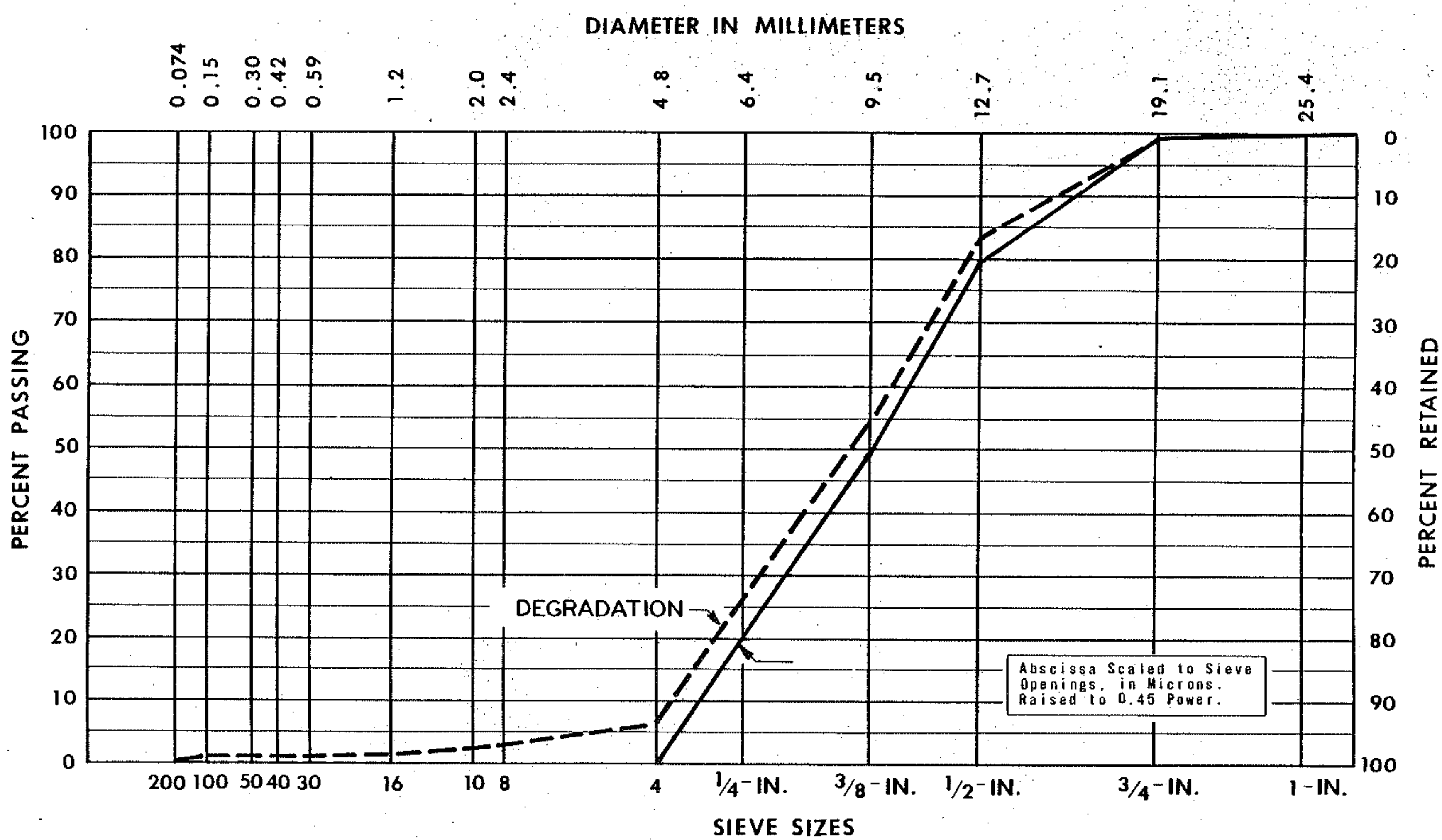

Figure 5. Grain size distribution before and after T-180 compaction of the slag sample received from Trenton Plant 5.

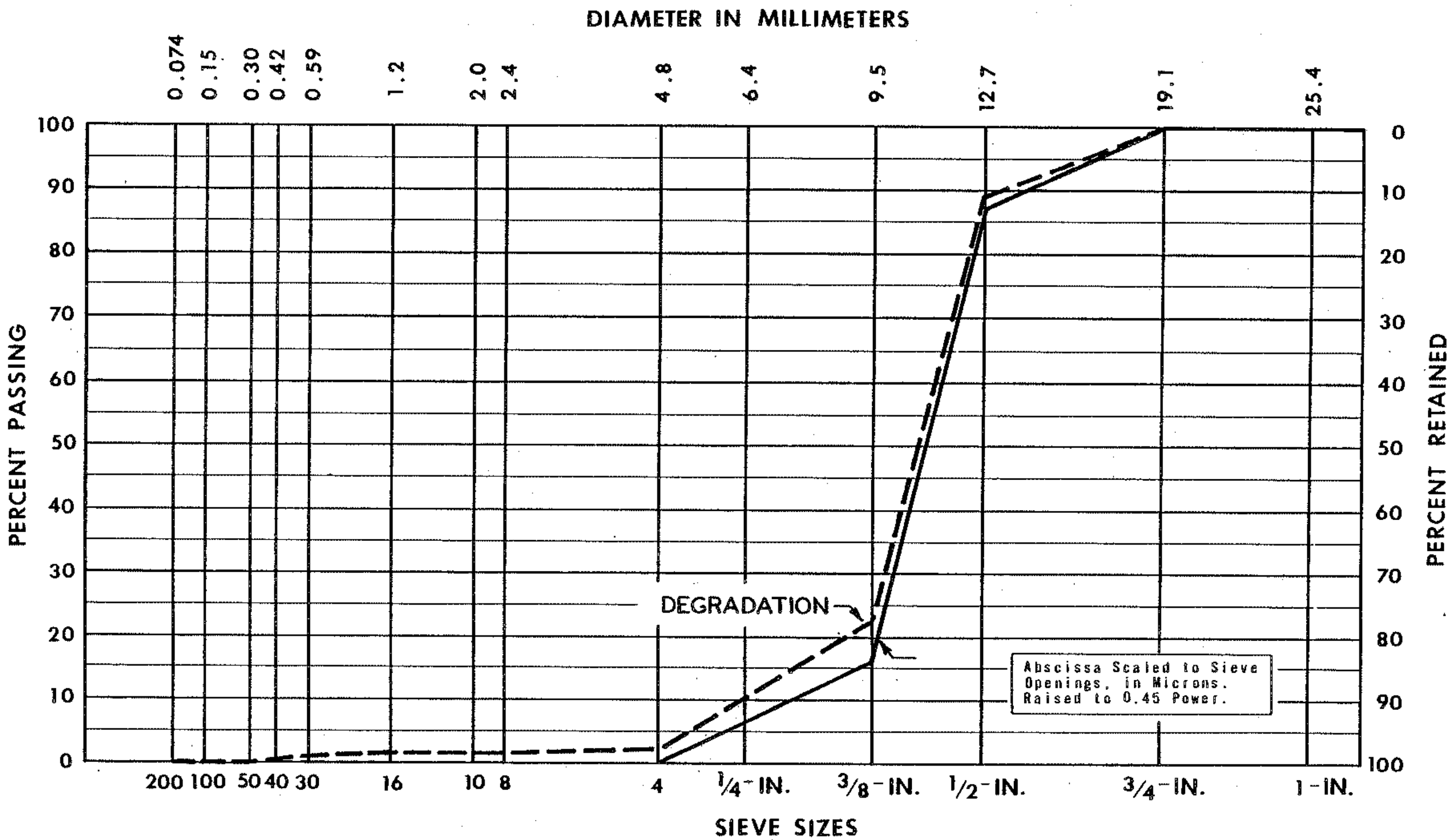

Figure 6. Grain size distribution before and after T-180 compaction of the slag sample received from Indiana (- 3/4 in. + No. 4).