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INVESTIGATION OF STEEL FURNACE SLAG OPEN GRADED DRAINAGE COURSE BASE ON I 69-AIRPORT ROAD RAMPS

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

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INVESTIGATION OF STEEL FURNACE SLAG OPEN GRADED DRAINAGE COURSE BASE ON I 69-AIRPORT ROAD RAMPS

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Introduction

One of the recommendations made in Research Report R-1188 was that if steel furnace slag were used for open graded base construction, the installation should be considered experimental and its performance monitored (1). An opportunity to do this was offered by the construction of ramps at the I 69 and Airport Rd interchange near Lansing, where part of the open graded drainage course (OGDC) base was to be constructed using a steel furnace slag, conforming to a modified 17A grading specification as depicted in Figure 1.

Inspection of the OGDC base construction, however, indicated that this project would not be suitable for the intended performance evaluation. Not only were the bases not open graded after the fine grading operations, but the contractor had received permission to change the location of the OGDC drains and elected to place the drain after placement of the OGDC bases (Figs. 2 and 3). This report has been written for the purpose of reviewing the construction of the I 69-Airport Rd ramps so that steps may be taken to ensure that future OGDC bases are installed to function as desired and to simplify construction procedures so that costs are minimized.

OGDC Gradation

Figure 4 shows the general appearance of the modified 17A base after fine grading. Two samples were collected to represent the denser appearing areas and two other samples were collected from the coarser appearing areas. A fifth sample was collected from the coarse side of a small slag stockpile located near Airport Rd. The gradation for each of the samples collected is shown in Figure 5. Density, permeability, and gradation data for these samples are summarized in Table 1.

The gradation data show that all of the samples collected were too fine to meet grading requirements. Figure 4, as well as the gradation data (Fig. 5 and Table 1), show a wide range in passing the No. 4 sieve which indicates the modified 17A has segregated, a condition that could severely restrict drainage of the OGDC base. This experience shows that even moderate quantities of fine aggregates, if permitted in open graded materials, can result in detrimental segregation. For this reason, the percent of aggregates passing the No. 4 sieve should be more restrictive than prescribed in the modified 17A specifications which permitted 0 to 30 percent passing the No. 4 sieve. Suggested limits are 0 to 8 percent passing the No. 4 sieve. These limits are the same as for 6A and 17A which would allow aggregate producers to produce OGDC without plant or production modifications.

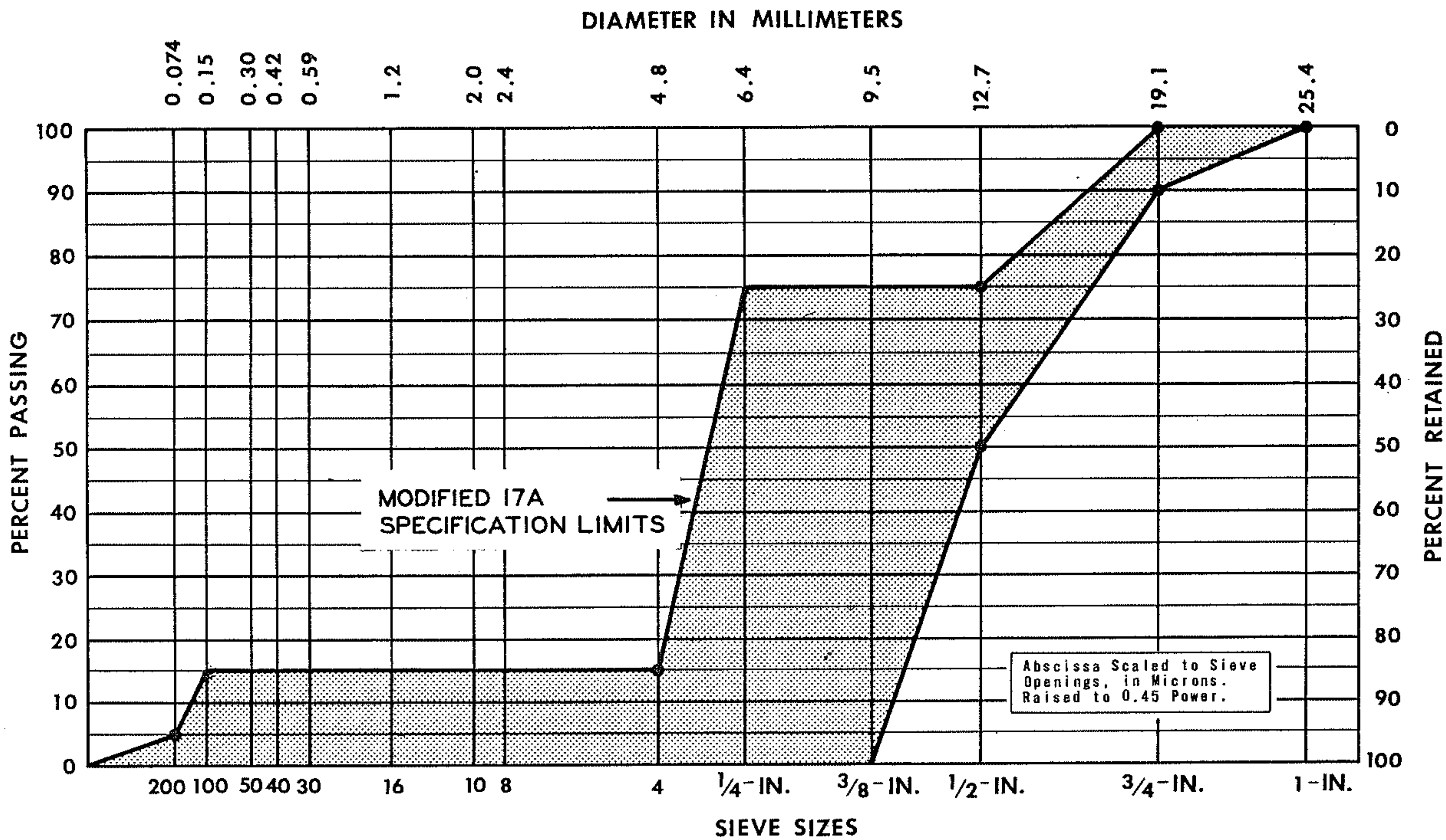

Figure 1. Gradation limits for modified 17A base material.

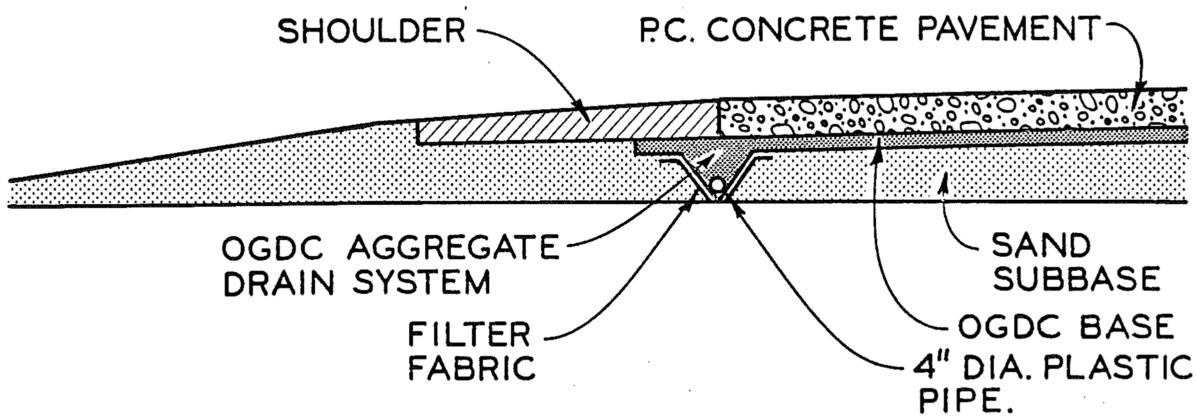

Figure 2. OGDC drain as proposed.

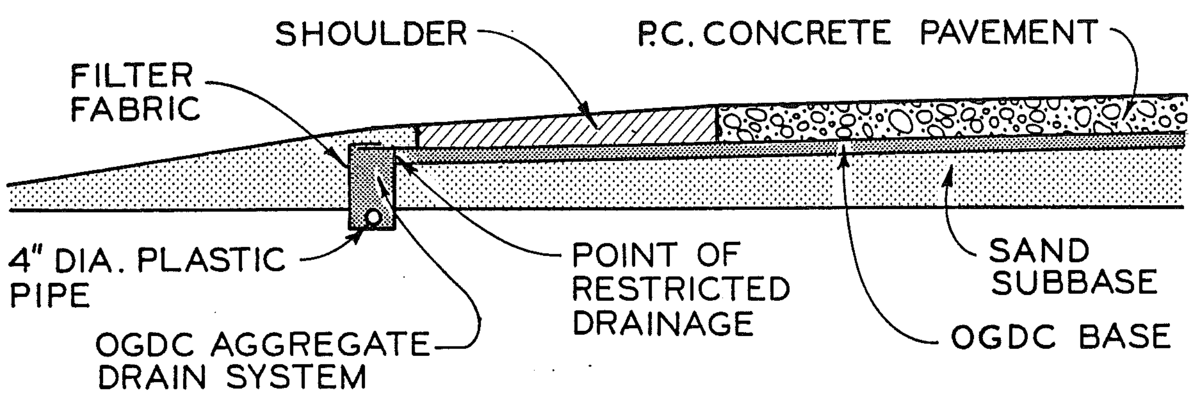

Figure 3. OGDC drain as installed for I 69-Airport Rd ramps.

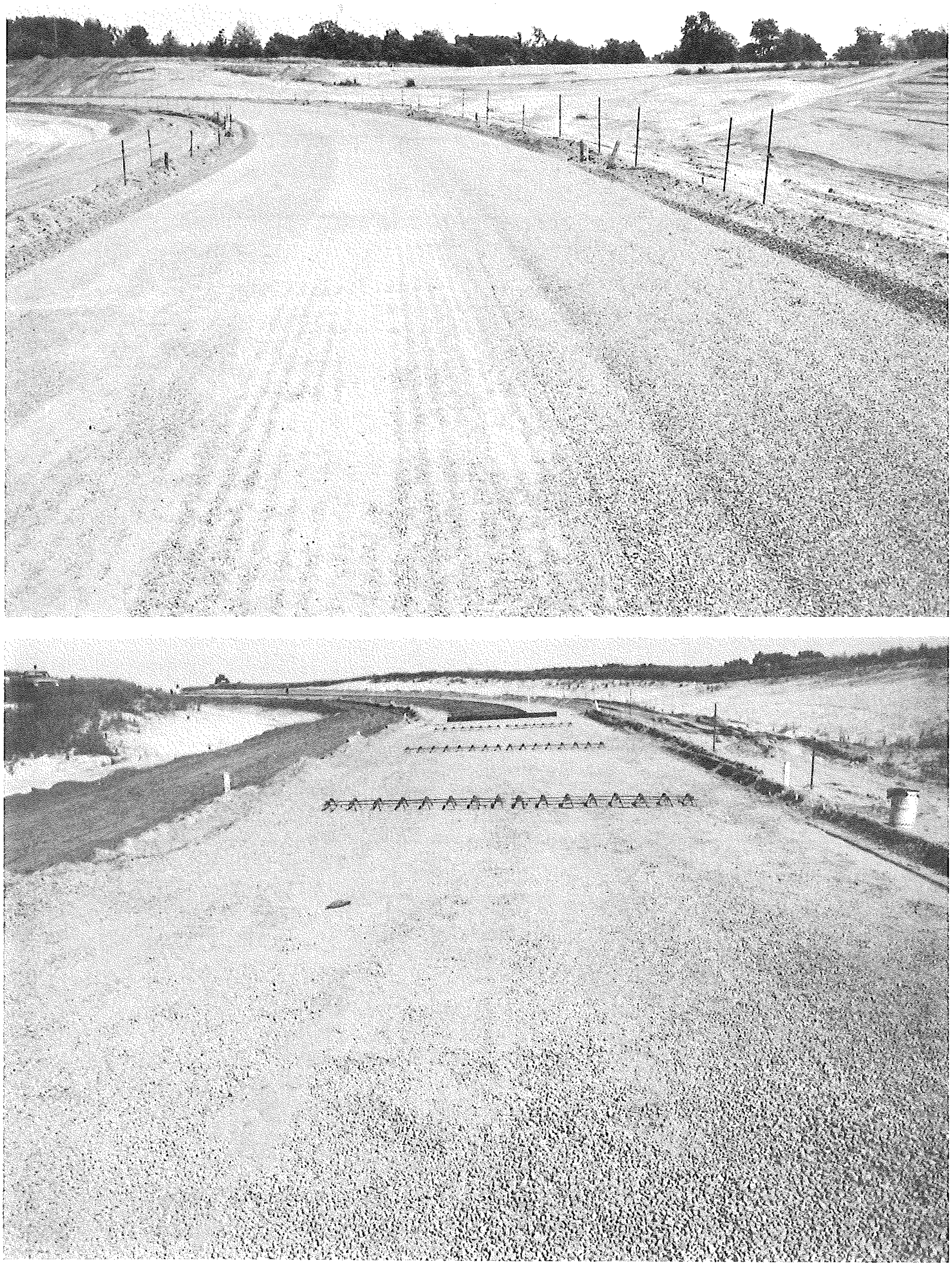

Figure 4. Appearance of slag base after fine grading operations—showing segregation that could restrict lateral drainage to OGDC drains.

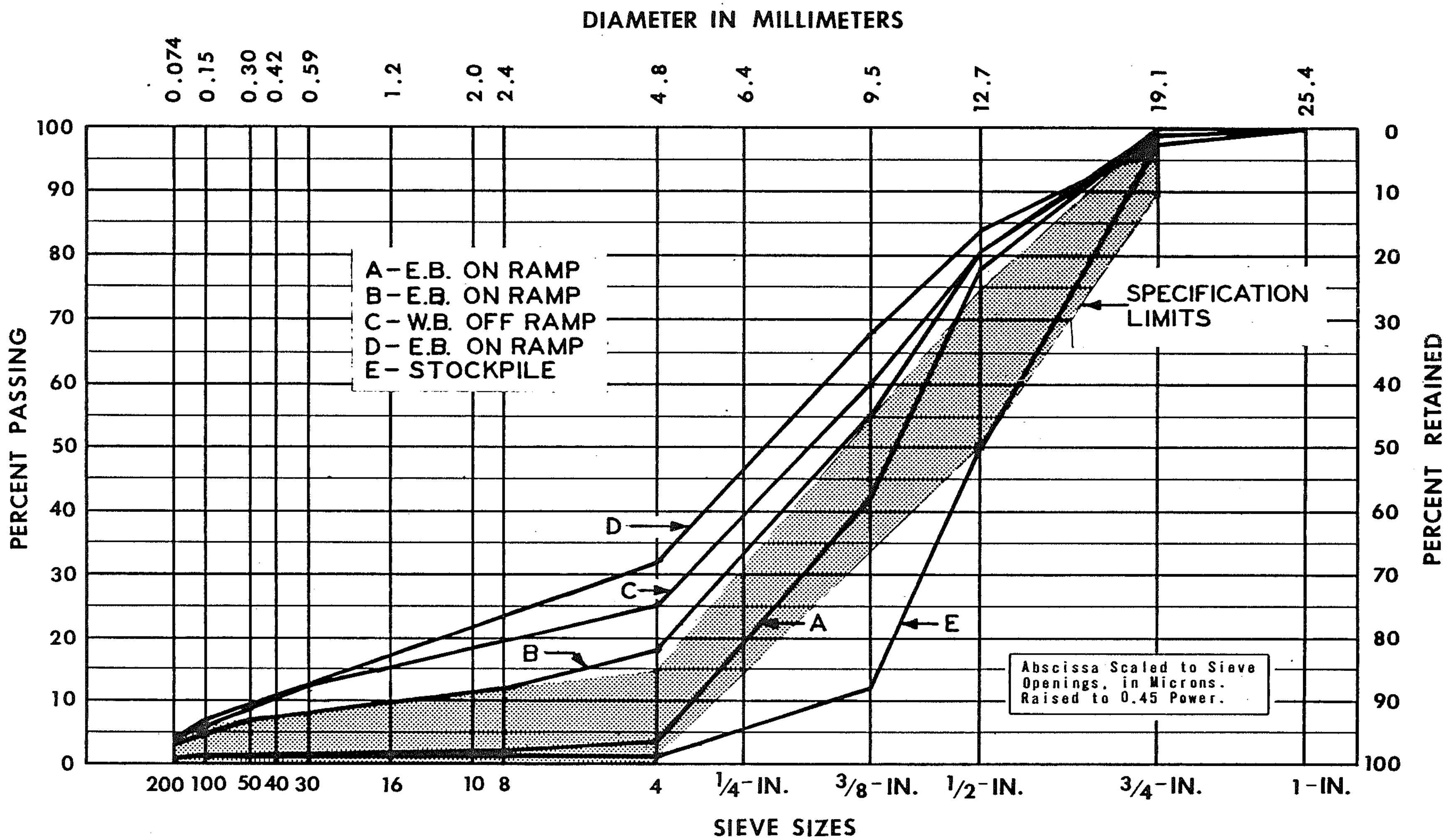

Figure 5. Gradation of slag materials used on the I 69-Airport Rd ramps.

Figure 6. Appearance of OGDC slag base before and after fine grading operations.

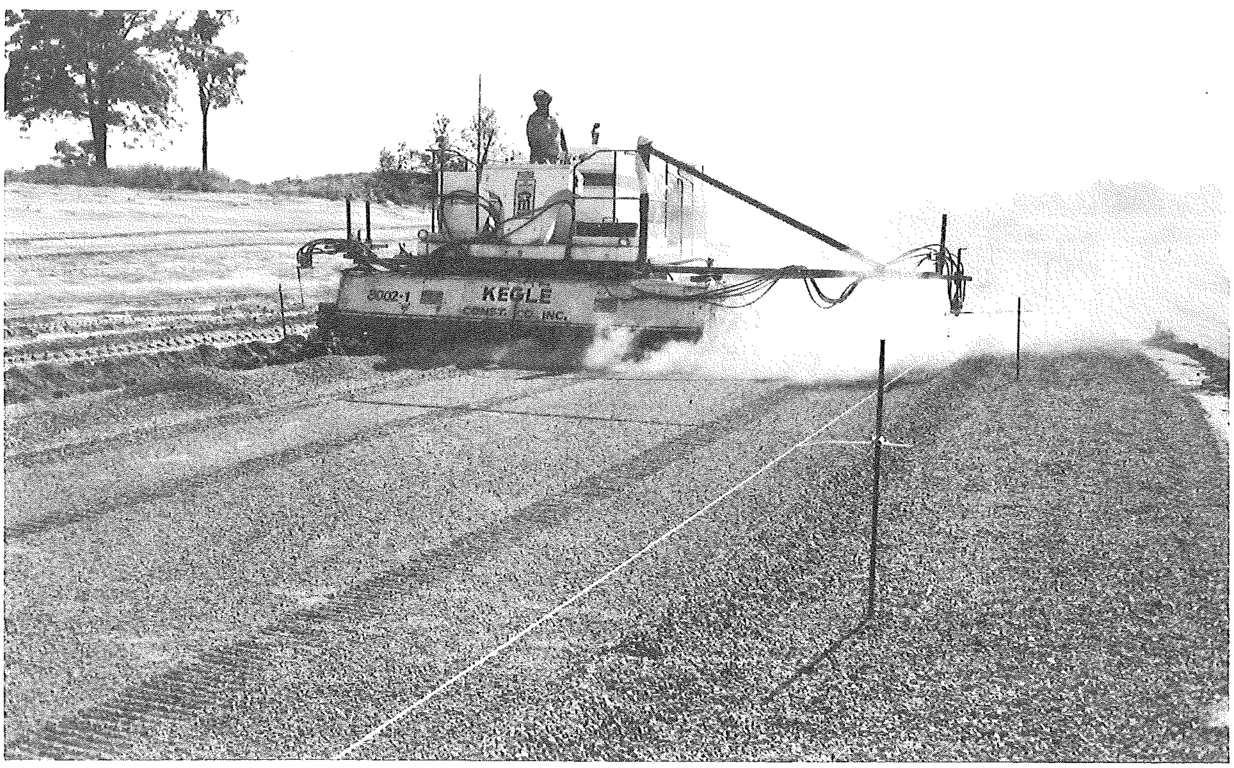

Figure 7. Breakdown of OGDC slag aggregate during fine grading operations as indicated by heavy dust cloud.

TABLE 1
SUMMARY OF LABORATORY DATA FOR OGDC SAMPLES COLLECTED ON I 69-AIRPORT RD RAMPS

Sample	Density, lb/cu ft	Permeability, ft/day		Percent Passing					
		Through Porous Filter	Through No. 10 Sieve	1 in.	3/4 in.	1/2 in.	No. 4	No. 8	No. 200
(A) Eastbound on-ramp	120.4	42	7,300	100	100	78	3	2	1
(B) Eastbound on-ramp	130.9	40	2,300	100	99	80	18	12	3
(C) Westbound off-ramp	133.8	19	150	100	100	80	24	17	3
(D) Eastbound on-ramp	138.0	10	8	100	98	84	32	20	4
(E) Stockpile, Airport Rd	118.1	55	9,900	100	98	49	1	1	0

The fact that none of the on-grade samples tested met grading requirements indicates that either the slag was supplied out of specifications or it degraded as a result of normal construction handling. Figure 6 indicates the appearance of the modified 17A base before and after fine grading. The much finer appearance of the finished grade indicates that degradation due to handling took place prior to fine grading and vertical segregation moved the fines downward or that degradation of the aggregates occurred during fine grading, or both. Figure 7 shows the large cloud of fines generated by the fine grading operation, indicating that fine grading is responsible for at least a portion of the high fines content of the modified 17A aggregate. On the basis of these observations and test results, the modified 17A steel furnace slag used for the I 69-Airport Rd ramps appears to have broken down to an undesirable degree as a result of normal construction handling. Because Los Angeles abrasion test results indicate steel furnace slag to have a high resistance to mechanical breakdown, Ref. (1), there may be justification in investigating the relevance of the Los Angeles abrasion test as an indicator of the resistance steel furnace slag has to mechanical breakdown in the field.

OGDC Permeability

OGDC base sample laboratory permeability tests were conducted in two ways. The first test procedure utilized a permeameter fitted with a porous stone filter at the bottom. The second test method used a permeameter fitted at the bottom with a No. 10 sieve. In most cases, the difference in permeability obtained by these two methods was dramatic. When the samples were drained while resting on, and through the porous filter, the fine aggregates (- No. 10 + No. 200 sieves) collected on the filter and resulted in the slow permeabilities listed in Table 1. When the samples were drained while resting on the No. 10 sieve, the fine aggregate was, in most cases, washed out which resulted in much higher permeabilities. Note that Table 1 indicates that little increase in permeability occurred when samples C and D were drained through the No. 10 sieve rather than the porous stone. The reason is that the gradation of these two samples was fine enough to prevent significant movement of fine material (- No. 8 sieve). This indicates the importance of open grading OGDC to enable flushing of contaminating fines.

These permeability test results indicate what can happen to the effective permeability of an OGDC base if it is not open graded and if a filter fabric layer is placed between the drainpipe and the OGDC material, as shown in Figure 2. Figure 8 illustrates the effective permeability of an OGDC base for various depths of accumulation of segregated fine (+ No. 200 - No. 10 sieves) aggregate. This information shows that unless fine aggregates are essentially removed from OGDC materials, the fine material will control permeability.

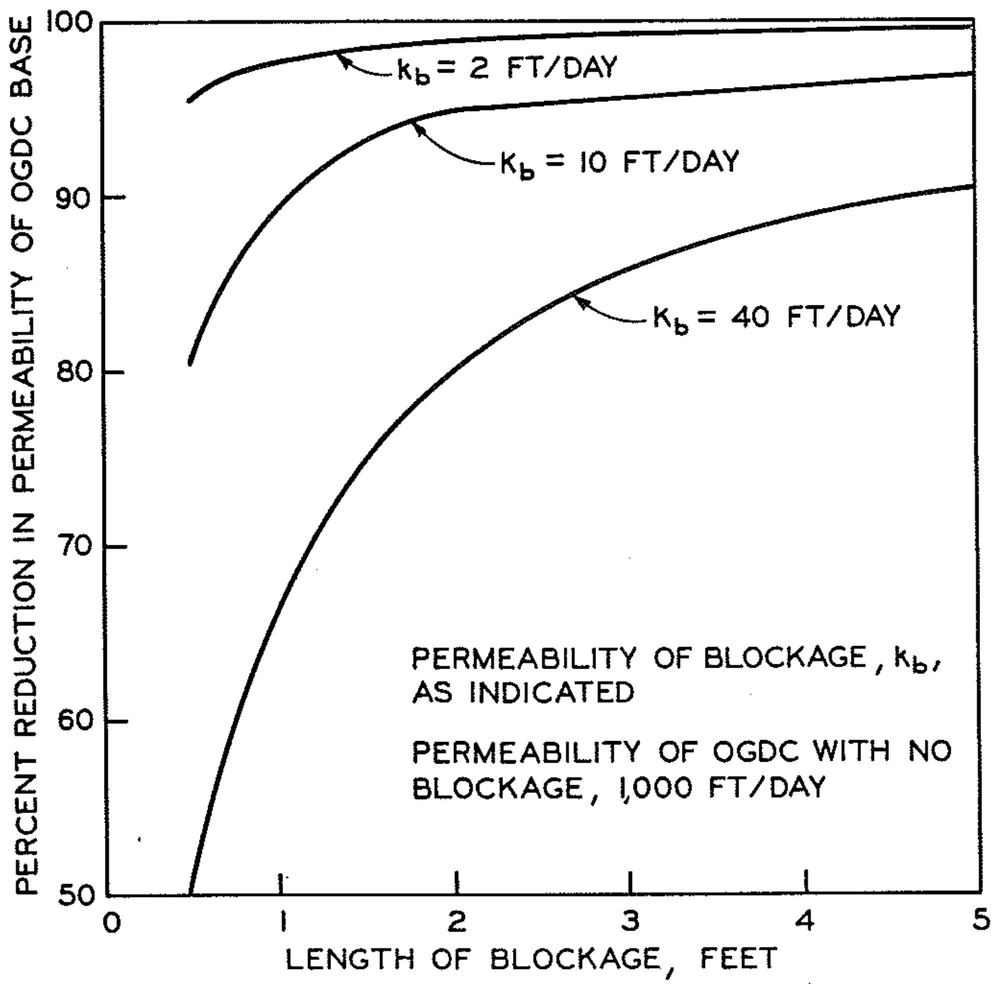

Figure 8. Reduction in OGDC permeability due to blockage by accumulation of sand and fine material at the OGDC base-filter cloth interface.

OGDC Base Drainage Requirements

Considering that the permeability of dense graded 22A bases normally ranges between 0.5 and 0.001 ft per day, the modified 17A bases should drain from 20 to 4,000 times faster. The question then is, even if the modified 17A segregated and has lower permeability than it would have by reducing the fine aggregate content, would it be considered adequately drainable for a base layer? The answer to this question depends on the desired objectives. By placing open graded drainage courses directly below portland cement concrete pavements the intended objectives are:

1) To keep the underside of the portland cement concrete slab relatively dry thus minimizing pavement curl caused by moisture differential.

2) To minimize D-cracking by keeping the portland cement concrete slab drier and reducing concrete deterioration due to its exposure to saltwater.

3) To prevent joint faulting by removing the cause, i.e., fines and free water in the base.

4) To prevent the base from frost heaving by providing base drainage that is so rapid as to preclude freezing of infiltrating surface water.

It is suggested that if an open graded base could remove half the water it contained in approximately one hour, it should be possible to achieve the above listed objectives. If the arbitrary one-hour drainage time is acceptable, it then fixes the minimum allowable permeability for open graded base layers. Figure 9 shows the relationship between the effective permeability of an open graded base and drainage time for the properties of the base listed on the figure. From this figure, the effective permeability of the base layer should be 1,000 ft per day in order to drain one-half the gravity drainable water in approximately one hour. To evaluate open graded bases for their ability to achieve intended objectives, a minimum drainage time of 1,000 ft per day is arbitrarily required.

OGDC Base Construction

It was intended that OGDC drains be installed prior to placement of the OGDC base because this is the least expensive time for the drains to be installed. Further, when installed in a 'daylighted' subbase, filter fabrics, used to prevent sand infiltration of OGDC material, will not have to be placed so as to hinder drainage of the OGDC base layer. Location of OGDC drains should be in the immediate area of the longitudinal pavement shoulder joint in order to limit drainage time to approximately one hour and to provide direct removal of surface water entering the base through the longitudinal joint.

The contractor elected to delay installation of the drain and to place it beyond the outside edge of the shoulder. In doing this, he was forced to use a trencher and employ considerable hand work, all of which was expensive. At the same time, he restricted drainage to the OGDC drain, as shown in Figure 3, and doubled the length of the drainage path thereby further reducing the drainage capacity of the OGDC base. For example, at sample site B, drainage time should have been approximately one-half hour if the drains were installed according to plans, whereas the as-constructed drainage time should be in excess of two days.

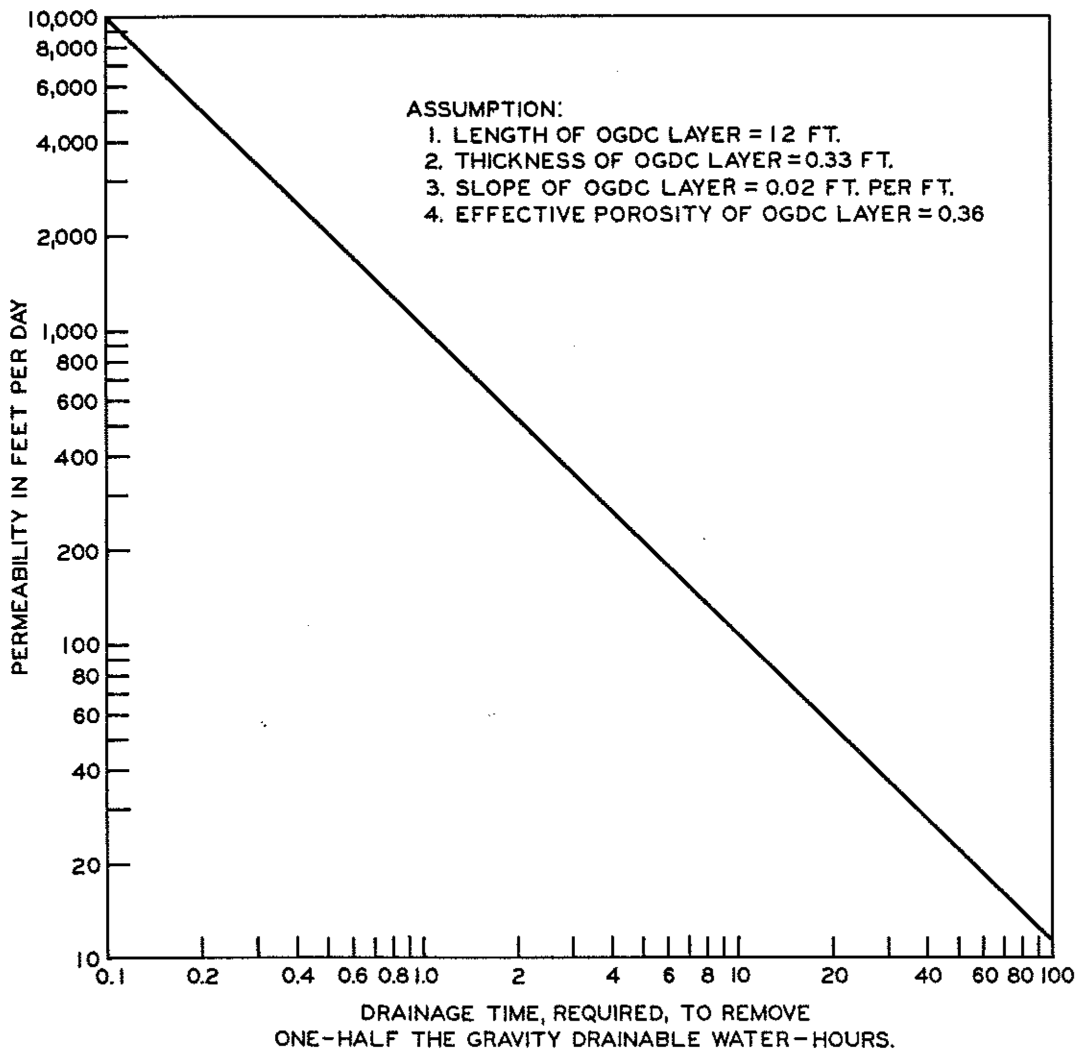

Figure 9. Relationship between effective permeability of OGDC layers and time required to drain one-half the water contained.

Figure 2 shows how OGDC drains were intended to be constructed. In such cases, the construction sequence would be to cut a vee-trench in the subbase with a grader blade, place a small quantity of OGDC in the trench using a dump truck with a side chute, lay the drainpipe in the trench and completely backfill with OGDC using another dump truck equipped with a side chute. A grader would blade the excess OGDC and the windrow of subbase sand formed by cutting the trench to a location beyond the paving area. Outlets would then be installed and the OGDC drain compacted with a single pass of a vibratory steel wheel roller. The subbase is then ready for fine grading followed by placement of the OGDC base. This procedure is fast, economical, and allows placing OGDC drains where they belong.

OGDC Stability

Any material meeting physical property requirements for OGDC and which has a permeability of 1,000 ft per day will have more than enough stability to support a portland cement concrete pavement. The problem is whether OGDC bases will be able to satisfy the contractor's needs for stability during construction. Current proposed specifications attempt to specify the minimum allowable crushed content or stabilization with small quantities of asphalt or portland cement. Because the capability of contractors varies, the Department could end up paying extra for stabilizing OGDC base material that already meets stability specifications but which might not satisfy the contractor's ability to utilize it as a construction platform. Since the contractor on the I 69-Airport Rd project indicated that OGDC has inadequate construction stability, it is suggested that, in the future, construction stability be the responsibility of the contractor. He would then be free to make the OGDC base as stable as he needed. Specifications then would control only permeability of OGDC. Construction problems created by use of OGDC bases could be minimized if gravel haul roads were included in project proposals as a separate bid item.

Conclusions

This study revealed problems with the attempt to construct open graded bases on the I 69-Airport Rd ramps. These problems reduced the drainage properties of the bases to such a degree that the aggregate should not be considered as open graded or OGDC base material. These bases, however, should drain better than would conventional 22A bases. Specific conclusions and recommendations are as follows:

1) In order to minimize segregation and to ensure a minimum permeability of at least 1,000 ft per day, OGDC materials should have no more

than 0 to 8 percent passing the No. 4 sieve. The exception is peastone which could contain as much as 0 to 8 percent passing the No. 8 sieve.

2) The contractor should not be allowed to modify the location or design of OGDC drains unless these modifications will ensure equal or greater drainage capacity.

3) Drains for the OGDC must be installed before placing OGDC bases.

4) Someone from MDOT who has an understanding of OGDC bases and experience with their construction should be present at each preconstruction meeting in which they are to be installed where the contractor has no prior experience with their installation.

5) No layer of filter fabric should lay in the path of water as it drains through OGDC bases and into the drain tile.

6) The high degree of resistance of steel furnace slag to mechanical breakdown, as indicated by its 20 or lower Los Angeles abrasion test values, is contrary to the high degree of degradation found on the I 69 ramps. These findings make the relevance of the Los Angeles abrasion test questionable and further investigation in this area appears warranted.

7) It is recommended that specifications for OGDC aggregate base indicate that stability for construction is the responsibility of the contractor and that crushing or the addition of specified quantities of portland cement or asphalt may be added for stability. This should encourage contractors to use the most economical OGDC base material and avoid extra claims by contractors who are unsatisfied with its lack of stability. Further, to assist contractors with construction problems created by open graded bases, a separate bid item for gravel haul roads is suggested.

REFERENCE

1. Novak, E. C., Jr., "Degradation of Steel Furnace Slag as an Open Graded Base Course for Concrete Pavement," MDOT Research Report R-1188, February 1982.