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OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

December 4, 1973

To: T. A. Coleman
Assistant to Engineer of Soils

From: E. C. Novak, Jr.

Subject: Drainability Analysis of Samples Submitted to the Porous Materials Specification Committee by District Soils Engineers.
Research Project 66 E-38, Research Report No. R-893.

During the second meeting of the Porous Material Specification Committee, held in Ann Arbor on February 6, 1973, it was decided to have each District Soils Engineer submit to the Committee a sample of porous material they thought represented good drainable subbase, and a sample they thought represented the borderline between materials they would and would not accept for subbase. A total of 14 samples from 7 Districts were received by the Testing Laboratory. Each sample was split in half, one half to be tested by the Testing Laboratory the other by the Research Laboratory. The reason for this was to see how well the permeability results obtained by the two Laboratories agreed. This report describes the test results obtained by the Research Laboratory.

The samples as received from the Testing Laboratory were labeled by number and source but there was no indication as to which sample represented good drainable material and which represented borderline material. In addition, there is some question regarding the source of samples 190-195. The labels indicate that only one sample, 190, came from Alpena and that three, 193, 194 and 195, came from Cadillac. This report assumes that the samples were assigned in order so that samples 190-191, 192-193, and 194-195, are pairs respectively submitted from the Alpena, Kalamazoo, and Cadillac Districts. It is also assumed that the fastest draining sample of each pair is the same as that selected by the engineer to represent good drainable subbase material.

Table 1 summarizes the density and gradation characteristics of each sample tested. Permeability tests were run on samples compacted to as near maximum cone density as it was possible to obtain in the permeameter. Some samples were easy to compact to maximum density while others could not be compacted to more than 90 percent of maximum density. This undoubtedly influenced results since permeability is directly related to percent compaction. However, the densities at which permeability was determined are thought to be representative of the density that the material would have in the field.

Figures 1 and 2, respectively, show the grain size distribution of samples representing good subbase material and borderline material. Generally speaking, there is little difference in the gradation characteristics except that borderline samples tended to be better graded and to have a greater percentage of minus 100 material. Poorly graded materials have better drainability than do well graded materials of the same minus 100 material content. Most District Soils Engineers took advantage of this characteristic by submitting samples that are poorly graded. Only three of the samples submitted (188, 191, and 192) are well graded.

Drainability data are summarized in Table 2. The method for determining drainability of pavement base and subbase layers used in this study was first reported by Casagrande (1) in 1951. Since that time, the Corps of Army Engineers (2) have developed the test procedures needed to utilize Casagrande's method and these have been used in this study with the exception that permeability was determined in accordance with ASTM Designation D 2434-68. The time required for proper drainage of Michigan's typical pavement cross-sections was calculated for each sample submitted, using procedures described in Reference (3).

In Reference (1) Casagrande recommended 10 days as the maximum allowable drainage time for base-subbase layers. Since the Corps of Army Engineers still adhere to this drainage time requirement it is apparently a realistic and satisfactory value. Of the samples submitted by the District Soils Engineers, only two of the three well graded samples (191 and 192) as well as sample (143) exceeded the 10 day drainage criterion to any significant extent. For the other samples, drainage times for Standard Michigan cross-sections A, B, and C are, respectively, 4, 5, and 6 days for good drainable samples and 6, 7, and 9 days for borderline samples. These results are all within Casagrande's 10 day criterion, indicating that for standard Michigan pavement cross-sections, and for samples selected on the basis of experience and judgement of the majority of District Soils Engineers, Casagrande's 10 day drainage criterion appears to be a reasonable value for use in Michigan. The extremely poor drainability of three of the seven borderline samples submitted, indicate the difficulty of identifying materials of acceptable borderline drainability, and suggests that some reliably consistent method of identifying such materials should be made available to the engineer.

In comparing gradation and drainability, it is interesting to note that several of the samples tested, although not meeting the minus 200 gradation requirement for subbase materials, were acceptable on the basis of Casagrande's drainability criterion (Fig. 3). This illustrates that the addition of a drainability criterion to porous material specifications could enable utilization of good materials which, on the basis of present specifications, are rejected.

Samples 143 and 218 illustrate the difficulty encountered when gradation alone is used to identify materials which have acceptable drainability characteristics. Although having similar gradations the drainage characteristics of the two were quite different. Sample 218 was among the most porous of those tested while sample 143 was one of the most impermeable. The difference in their suitability for subbase use could not be identified on the basis of gradation alone.

Well graded materials usually require fewer fines (minus 100 material) to clog their pore spaces and make them slow draining than do poorly graded materials. This gradation characteristic is reflected in Casagrande's recommended criteria for identifying frost free material, Reference (4). It states that for well graded materials to be considered frost free they must contain no more than 3 percent material smaller than 0.2 mm in diameter. For poorly graded materials the limit is no more than 10 percent material smaller than 0.2 mm. Casagrande's concept of a different fines content requirement for well graded and poorly graded materials is not, but perhaps should be, included in our porous material specifications which presently require the same fines content for well graded and poorly graded materials. To a limited extent, Figure 3 illustrates that well graded materials are relatively slow draining compared to poorly graded materials of the same fines content. For example, sample 188 has a very low fines content, yet poorly graded samples 142, 218, and 219, which have greater fines content, are more drainable. Considering only the minus 100 material content, well graded samples 191 and 192 would appear to be acceptable porous materials when, in fact, they are very poorly drained. In addition a previous drainability study (5) shows that well graded materials with as little as 9.5 percent passing the 100 sieve and 7.0 percent or less passing the 200 sieve are extremely slow draining and could be considered impermeable for all practical purposes. These data are inadequate to prove that a change in porous material gradation specifications is necessary. However, it is recommended that a study be conducted for the purpose of determining if present porous material specifications would accept a significant quantity of well graded materials which have poor drainability characteristics and if so, to recommend appropriate grading limits to correct this situation.

In summary, the samples submitted indicate that there is good agreement among the District Soils Engineers as to what constitutes good drainable and borderline drainable subbase materials and that test results obtained from their samples agree well with the arbitrary 10 day drainage time limit for base-subbase layers established by Casagrande. The test results also emphasize that many materials which have acceptable drainage characteristics are rejected by present gradation specifications, and they indicate that further consideration be given to the establishment of separate grading requirements for well graded and poorly graded porous materials.

Since the findings of this study verify those of Research Report No. R-805, Reference (3), it is recommended that Casagrande's subbase design method and 10 day drainage criterion be used for the design of subbase layers and to supplement gradation specifications in the selection of subbase materials. It is also recommended that porous material specifications for subbase use be modified by defining well graded and poorly graded materials and establishing appropriate gradation specification limits for each.

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REFERENCES

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2. Nettles, E. H., Calhoun, Jr., C. C., "Drainage Characteristics of Base Course Materials Laboratory Investigation," Technical Report No. 3-786, July 1967.

3. Novak, Jr., E. C., "A Method of Determining Subbase Drainability," Michigan Department of State Highways and Transportation, Research Report No. R-805, April 1972.

4. Casagrande, A., "Discussion on Frost Heaving," Highway Research Board Proceedings, Vol. 11, Part I, 1932.

5. Novak, Jr., E. C., "Permeability Characteristics of Various Subbase Materials," Michigan Department of State Highways and Transportation, Research Report No. R-781, August 1971.

TABLE 1

MAXIMUM DENSITY, COMPACTED DENSITY, AND GRADATION OF POROUS MATERIAL SAMPLES

Sample No.	Maximum Density (Mich. Cone Test)	Average Density of Permeability Sample	Gradation, Cumulative Percent Passing										
			1 in.	3/4 in.	1/2 in.	3/8 in.	4	8	16	30	50	100	200
142	111.69	106.70				99.9	99.8	99.6	99.0	92.6	55.1	5.6	2.2
143	117.75	112.32				99.8	99.3	98.7	98.0	96.5	74.7	34.6	13.7
145	109.81	108.58			99.6		99.5	99.4	99.2	96.7	70.8	15.8	3.9
146	119.42	111.38		99.5	98.2	97.5	95.7	94.1	91.8	84.1	56.0	17.4	6.9
188	127.56	122.92	98.8	96.4	90.8	86.8	78.6	68.6	57.2	42.9	15.3	3.8	2.2
189	119.83	108.27		99.4	97.1	94.8	92.2	89.3	83.9	74.6	51.4	22.1	9.1
190	112.11	106.08			99.7		99.4	99.1	98.9	98.5	83.2	24.1	3.7
191	125.47	125.42	96.2		92.8	90.2	83.0	75.3	66.4	54.5	34.0	18.0	13.9
192	129.02	128.34		98.0	93.6	90.4	80.9	70.1	60.7	49.8	30.8	18.1	14.8
193	113.57	109.82			99.9		99.6	99.2	97.9	87.9	31.5	6.3	4.3
194	108.98	105.14					99.8	99.6	99.1	97.3	89.5	27.6	5.6
195	108.14	102.65						99.9	99.8	99.6	97.4	35.4	5.2
218	116.08	110.76			99.9	99.7	98.7	97.7	96.1	92.0	87.7	36.0	10.2
219	111.27	104.84						99.9	99.7	99.1	82.0	20.2	3.7

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Figure 1. Soil grain size distribution of good drainability materials.

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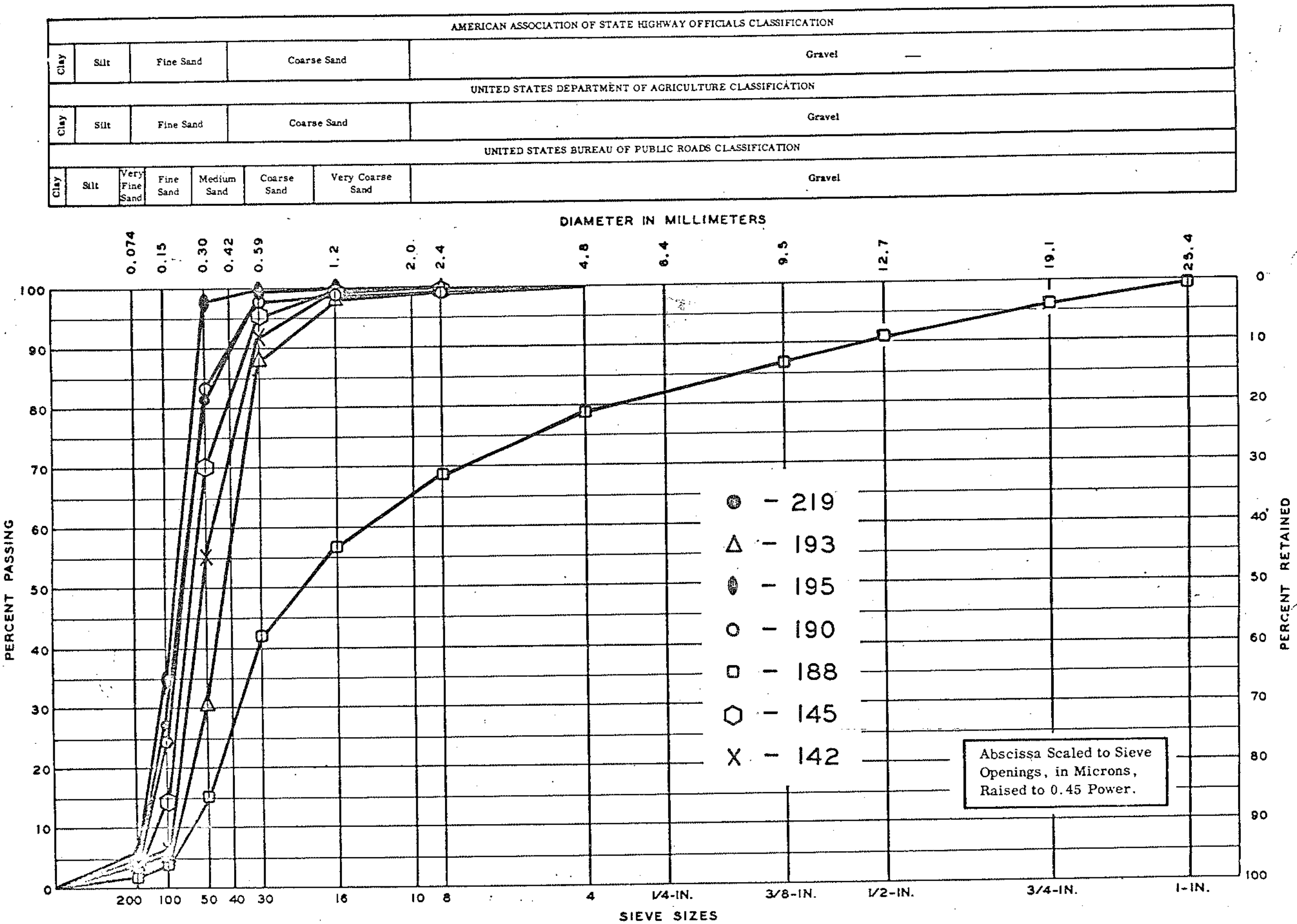

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Figure 2. Soil grain size distribution of borderline drainability materials.

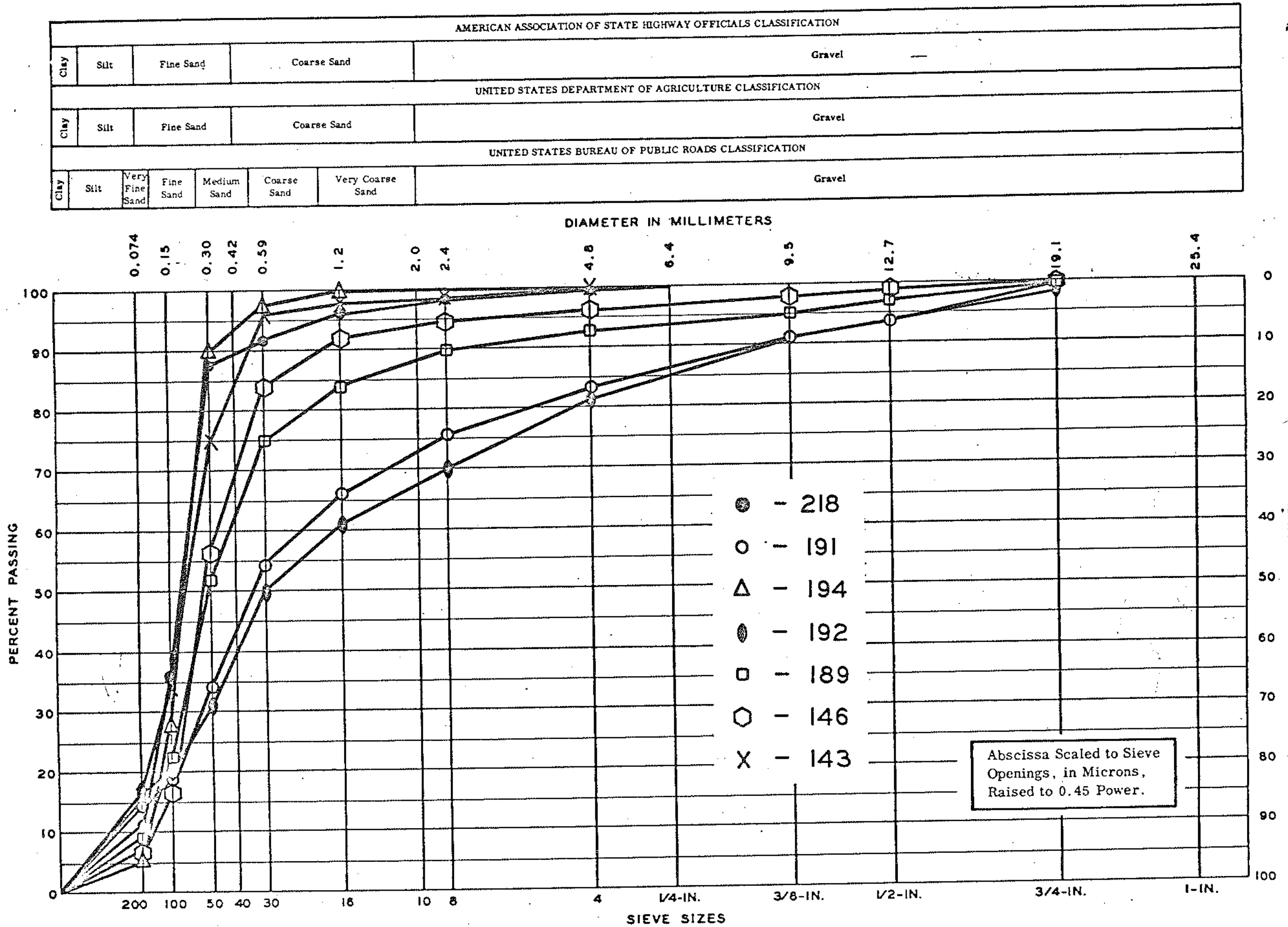

TABLE 2
DRAINABILITY DATA

Sample No.	Coef. of Permeability k, ft/day	Effective Porosity, n_e	k/n_e ft/day	Percent Sat. When Gravity Drained	Drainage Time, In Days For Standard Michigan Cross-Sections			Sample Source (District)
					9A	9B	9C	
142	19.96	0.102	195.7	72.5	1.7	2.2	2.7	Grand Rapids
143	0.56	0.106	5.3	68.8	65.0	82.0	103.0	Grand Rapids
145	6.88	0.088	78.2	75.0	4.4	5.6	6.9	Saginaw
146	4.54	0.088	51.6	74.0	6.6	8.4	10.4	Saginaw
188	14.54	0.096	151.4	66.7	2.3	2.8	3.5	Crystal Falls
189	7.42	0.107	69.4	70.3	4.9	6.3	7.8	Crystal Falls
190	5.36	0.096	55.8	73.0	6.1	7.8	9.6	Alpena [2]
191	0.33	0.044	7.5	79.9	46.0	58.0	72.0	Kalamazoo [2]
192	Impermeable [1]	-----	-----	----	Over 100 Days			Kalamazoo [2]
193	8.56	0.098	87.4	71.8	3.9	5.0	6.2	Cadillac [2]
194	3.41	0.094	36.3	74.9	9.4	12.0	14.7	Cadillac [2]
195	5.16	0.101	51.1	74.3	6.7	8.5	10.5	Cadillac [2]
218	17.71	0.078	227.0	76.7	1.5	1.9	2.4	Metro
219	16.73	0.083	201.6	78.1	1.7	2.2	2.7	Metro

[1] Permeability is less than 0.1 ft/day.

[2] Samples, as received from the Testing Lab, appear to have been mislabeled. Therefore, samples 190 and 191, 192 and 193, and 194 and 195 were considered paired samples. This report assumes that the fastest draining sample of each pair is the same as that selected by the Engineer to represent good drainable subbase material.

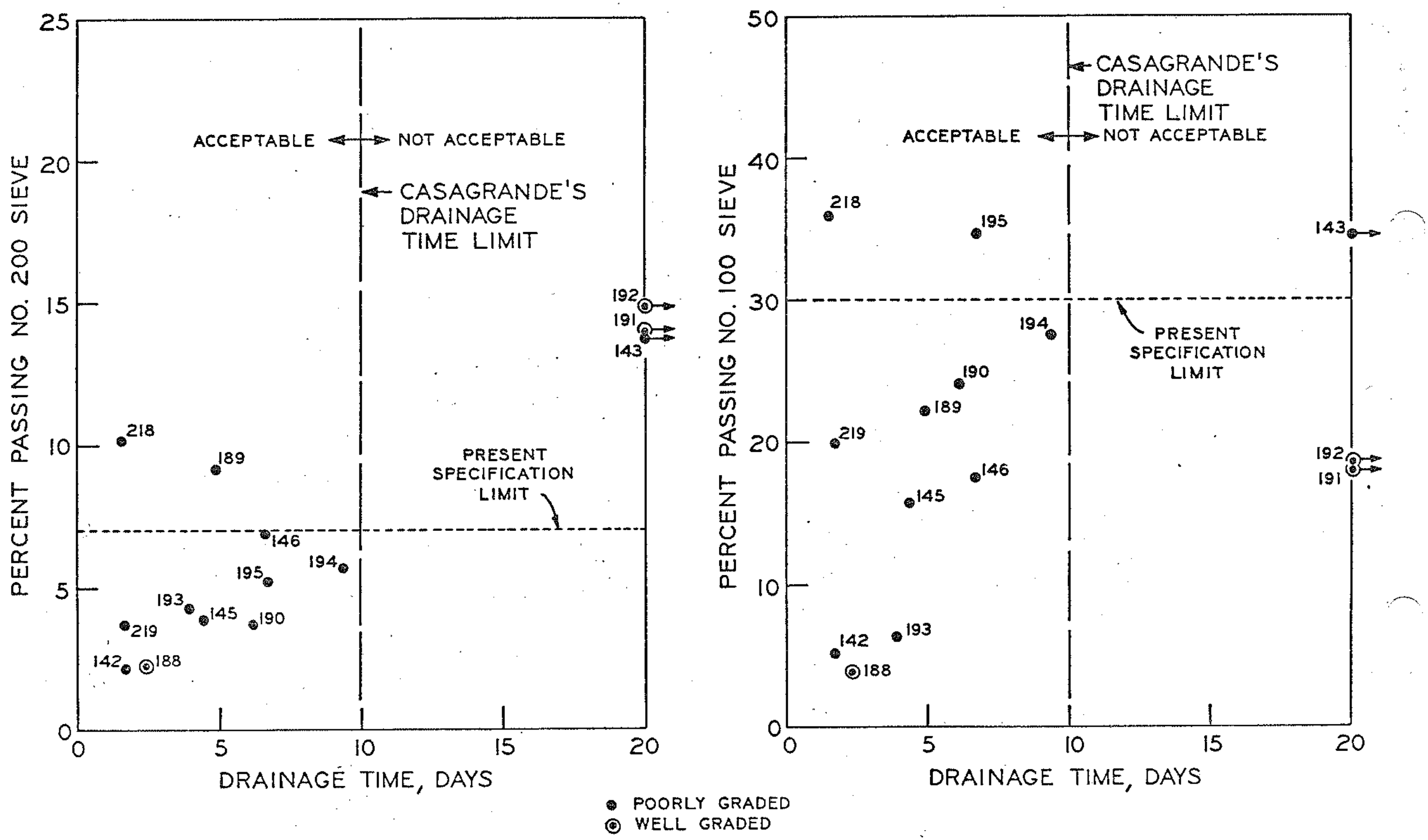

Figure 3. Fines content vs. drainability (based on 9A pavement cross-section).