PERMEABILITY CHARACTERISTICS OF VARIOUS SUBBASE MATERIALS

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Introduction

At the request of J. C. Brehler (letter of February 10, 1971) the Research Laboratory conducted studies to compare permeability characteristics of flume waste and bank run subbase materials when both fall within the gradation limits imposed by Subbase Supplemental Specification 8.02(4) which requires:

Passing 1-in. sieve, percent - 100
Passing No. 100 sieve, percent - 35 maximum
Loss by washing, percent - 10 maximum

When originally prepared, (as a supplement to the specification for Granular Material Class II) use of this specification was restricted to material owned by the American Aggregates Corporation, or other sources approved by the Engineer. It was understood that this material would consist of screenings or flume waste resulting from crushing operations at an aggregate processing plant.

It is now proposed to use the gradation limits of this specification (8.02.(4)) on a Statewide basis for all sources of subbase materials. Because bank run materials presumably contain less fractured and more clay particles than do flume wastes, it remained to be determined whether increasing the maximum loss by washing content from 7 to 10 percent would adversely affect the permeability of bank run materials. The primary objective of this project, therefore, concerned comparing the coefficients of permeability of bank run gravels with those acceptable flume waste materials, to determine if the suggested gradation change would be generally acceptable for different materials.

Testing Procedure

Representative samples of flume waste, ordinary bank run materials, and laboratory samples prepared to meet certain gradation requirements, were included in the testing program.

Flume waste samples were obtained from the Green Oak plant of the American Aggregates Corporation. Two different materials were available from stockpiles at this source: 1) crushed flume waste, containing both crushed and rounded particles, and 2) clean sand obtained from de-sanding operations, containing all rounded (uncrushed) particles. The uncrushed material is the more readily available of the two. Samples of both, however, were included in the tests and were also used to prepare special rounded and crushed mixtures for comparing the permeability of each type material when blended to the same gradation. Gradations meeting the upper limits of normal Granular Material Class II and those of the proposed supplemental specifications were used for this comparison.

Because it is reasonable to suppose that there would be considerable variation in the coefficient of permeability of materials obtained from different pit locations, samples were obtained from several sources. The minus 200 fraction of these bank run materials varied from 2.3 to 27.4 percent.

Additional materials obtained for testing included: beach sand, 22A dense graded aggregate, and a Granular Material Class II material with 2 percent Ontonagon clay added. With these variations it was felt that representative samples of subbase granular materials could be tested; not only to compare the effect of widening gradation limitations, but to also show the effects that other factors (gradation above the No. 100 Sieve, clay content) would have on permeability values.

Gradation and classification tests of the materials were made according to standard laboratory and ASTM procedures. The coefficients of permeability were determined by the constant head method, in accordance with ASTM Designation D 2434-68. The equipment for this test procedure is shown in Figure 1.

All samples used for the permeability tests were quartered to required size from a mixture of samples representing each source tested. Permeability samples were compacted to as near maximum density (ASTM D698-70) as possible. Each test was run four times (at 5 or 15 minute time intervals, depending upon rate of drainage of the material) and the results averaged. When permeability tests were completed, each sample was allowed to drain for 24 hours (to remove all of the gravity drainable water) after which the effective moisture content was determined. From these values the effective porosities of the materials were computed. This method was developed by the U. S. Corps of Engineers (1). Effective porosity is the ratio of the volume of gravity drainable voids to the total volume of the soil and is used to calculate the total water that can be drained from a material. The percent saturation of the sample, when all gravity drainable water has been removed, indicates that portion of the soil water which is gravity drainable or "free draining".

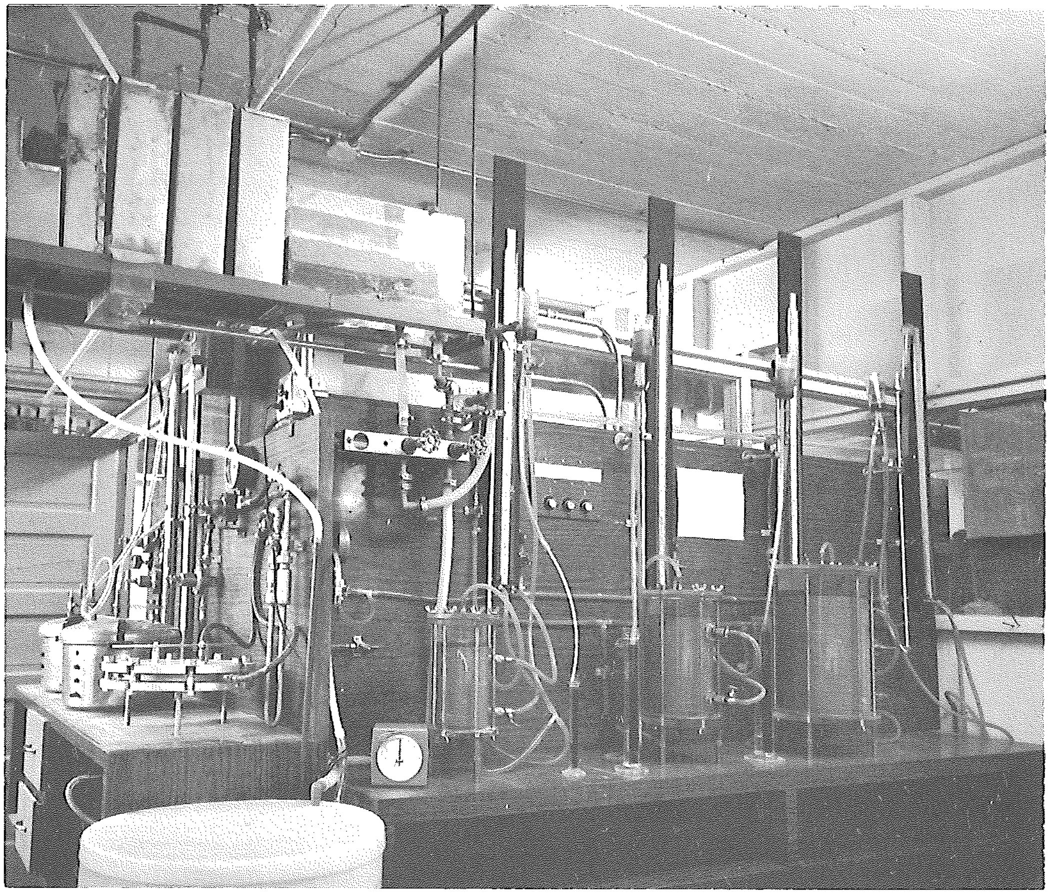

Figure 1. Equipment for permeability tests.

Test Results

Classification and permeability data are summarized in Tables 1 and 2. All samples tested, with the exception of No. 12, fell within gradation limits of the proposed supplemental specification and should be considered representative of materials that might be offered for use under this specification. It should be noted that most of the materials meet Granular Materials Class II grading requirements, with the exception of Nos. 12, 3, and 4, the latter two having been altered deliberately to meet the maximum allowable minus 200 and minus 100 requirements of the proposed specification. A wide variation in the coefficients of permeability is indicated by these test results.

Figure 2 shows the coefficient of permeability of the test samples plotted against the minus 200 material content. No correlation is indicated by these results.

TABLE 1
SAMPLE IDENTIFICATION AND GRADATION

Sample No.	Source	Description	Gradation - Percent Passing Sieve No. Shown							
			200	100	50	30	8	4	3/8-in.	3/4-in.
1	Flume Waste	Green Oak Plant, crushed flume waste	5.9	9.0	19.3	34.0	69.0	87.2	99.7	100
2	Flume Waste	Green Oak Plant, from de-sander (rounded)	1.2	2.3	11.9	40.9	84.7	96.8	99.6	100
3	Lab. Mix	Proposed supplemental spec. crushed aggregate	10.0	35.0	42.0	61.0	90.0	100	---	---
4	Lab. Mix	Proposed supplemental spec. rounded aggregate	10.0	35.0	42.0	61.0	90.0	100	---	---
5	Lab. Mix	Granular Material Class II, crushed aggregate	7.0	30.0	37.0	57.0	89.0	100	---	---
6	Lab. Mix	Granular Material Class II, rounded aggregate	7.0	30.0	37.0	57.0	89.0	100	---	---
7	Lab. Mix	Granular Material Class II, rounded - 2% clay	7.0	30.0	37.0	57.0	89.0	100	---	---
8	Bank Run	North of State Rd, Ingham Co.	8.8	29.4	77.8	97.6	100	---	---	---
9	Bank Run	NE 1/4 of NE 1/4 Sec. 13 Geech Rd Shiawassee Co.	2.9	5.5	25.0	52.2	77.7	86.1	93.9	100
10	Bank Run	SE 1/4 Sec. 9 Vernon Twp. M-78 Sta. 1444 - Shiawassee Co.	4.6	7.8	28.8	71.9	89.6	94.3	97.7	100
11	Bank Run	N 1/2 of NE 1/4 Sec. 12 York Twp. Washtenaw Co., Willis Rd (top layer)	2.3	4.4	32.9	77.2	93.3	95.9	98.6	100
12	Bank Run	Same location as 11 (bottom layer)	27.4	62.8	89.5	98.0	99.5	99.8	100	---
13	Bank Run	Holloway Pit Near Hass Rd Oakland Co. (dense graded)	6.5	9.3	20.5	39.4	70.6	80.3	88.0	100
14	Other	Dense Graded 22A rounded aggregate (100% - 1in.)	7.0	9.5	12.5	24.0	32.5	45.0	61.0	87.0
15	Other	Beach Sand M-57 near Marion Springs Rd	0.7	5.8	69.1	99.5	100	---	---	---

TABLE 2
SUMMARY OF TEST DATA

Sample No.	Specific Gravity	Optimum H_2O Content	Standard (Proctor) Density	Effective Porosity	Saturation at 100% Gravity Drained, percent	Coefficient of Permeability, ft/min.	Coefficient of Permeability, ft/day	Coefficient of Permeability, cm/sec.
1	2.69	9.6	129.1	.05	76.1	1.205×10^{-3}	1.74	0.612×10^{-3}
2	2.67	10.7	119.1	.10	66.1	21.52×10^{-3}	30.99	10.93×10^{-3}
3	2.69	11.9	122.5	.05	82.6	0.207×10^{-3}	0.298	0.105×10^{3}
4	2.67	10.6	125.1	.05	78.0	0.0754×10^{-3}	0.109	0.0383×10^{-3}
5	2.73	10.2	121.3	.06	78.3	0.447×10^{-3}	0.644	0.227×10^{-3}
6	2.69	11.4	123.9	.06	75.8	0.289×10^{-3}	0.416	0.147×10^{-3}
7	2.70	11.4	125.5	.06	76.5	0.0567×10^{-3}	0.0816	0.0288×10^{-3}
8	2.60	12.7	109.5	.06	83.3	1.43×10^{-3}	2.06	0.728×10^{-3}
9	2.71	9.8	122.8	.09	68.6	0.289×10^{-3}	0.416	0.147×10^{-3}
10	2.67	11.9	119.4	.08	74.0	0.0591×10^{-3}	0.085	0.03×10^{-3}
11	2.68	13.6	113.4	.08	75.3	5.18×10^{-3}	7.46	2.63×10^{-3}
12	2.64	14.9	109.3	.07	79.7	0.40×10^{-3}	0.576	0.203×10^{-3}
13	2.66	9.5	132.0	.04	80.5	0.0295×10^{-3}	0.0425	0.015×10^{-3}
14	2.65	5.5	146.0	.04	65.0	0.0591×10^{-3}	0.085	0.03×10^{-3}
15	2.61	12.1	107.9	.001	99.1	7.34×10^{-3}	10.57	3.73×10^{-3}

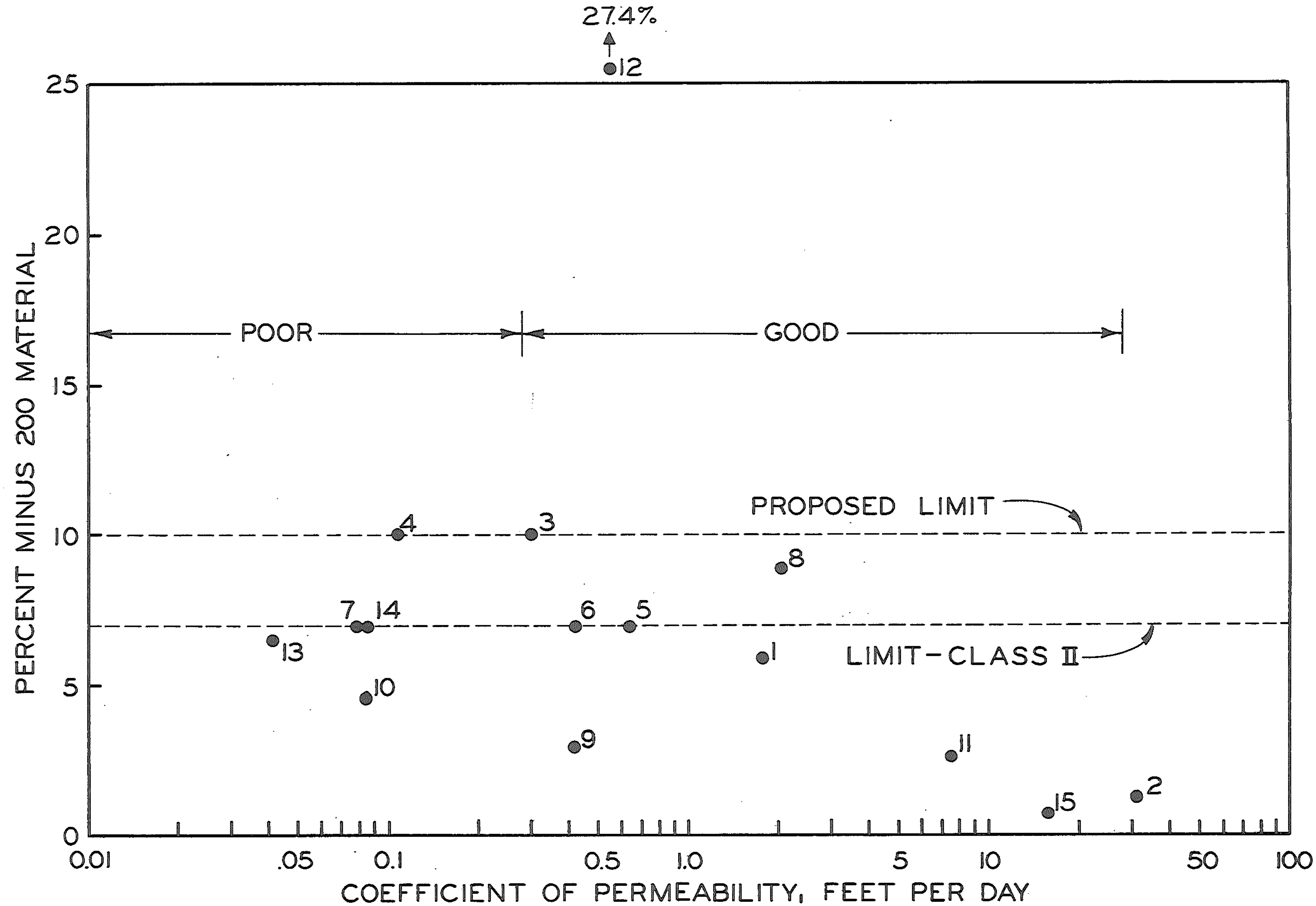

Figure 2. Effect of minus 200 material on permeability coefficient of subbase samples.

There is no specific value of the coefficient of permeability that can be used to determine a dividing line between acceptable and unacceptable permeability. Arbitrary limits have been established by Casagrande (2) which divide coefficient of permeability values into "good" and "poor" categories and these are included in Figure 2. As indicated by this figure, if Granular Material Class II specifications are used (7 percent maximum minus 200 material), four materials of poor permeability would be included (7, 10, 13, 14) but three of good permeability (3, 8, 12) would be excluded. Increasing minus 200 material to the proposed 10 percent limit would allow the use of one additional material of poor permeability (No. 4) but would, also, exclude one good permeability material (No. 12).

Variation in the coefficient of permeability with minus 200 content (loss by washing) is shown further in Figure 3, which presents results obtained from permeability studies at the Testing Laboratory in Ann Arbor. These results show that increasing the allowable minus 200 limit from 7 to 10 percent would result in the acceptance of a larger number of poor permeability materials. These data, with those of Figure 2, show that specifications which control only the minus 200 and minus 100 material content have poor control of the permeability characteristics of a given granular material.

The summary data of Tables 1 and 2 show that both bank run and crushed materials can be of good permeability. It is quite clear, however, that clay content of the minus 200 fraction can be more critical than the quantity of minus 200 material present (Nos. 6, 7, and 12).

The Green Oak material from de-sanding operations (non-crushed) was by far the most permeable material tested, even more so than the crushed flume waste. In other cases, where gradations were made equal and crushed aggregate was compared with non-crushed (Nos. 3, 4, and 5, 6) the crushed material proved to be the more permeable. Granular Material Class II was more permeable than that obtained under the proposed supplemental specification of the same general composition. Sample No. 12 which was far out of specification limits (containing 27.4 and 62.8 percent of minus 200 and minus 100 materials) was more permeable than several materials which fall within Granular Material Class II specification.

Discussion

Although the basic purpose of this project was to determine if non-crushed porous materials could be included in the proposed supplemental specification without detrimental effect on the permeability characteristics of the materials accepted, the test results indicated that factors other than minus 200 and minus 100 material content should also be considered. For example, it was indicated that variations in such material properties as clay

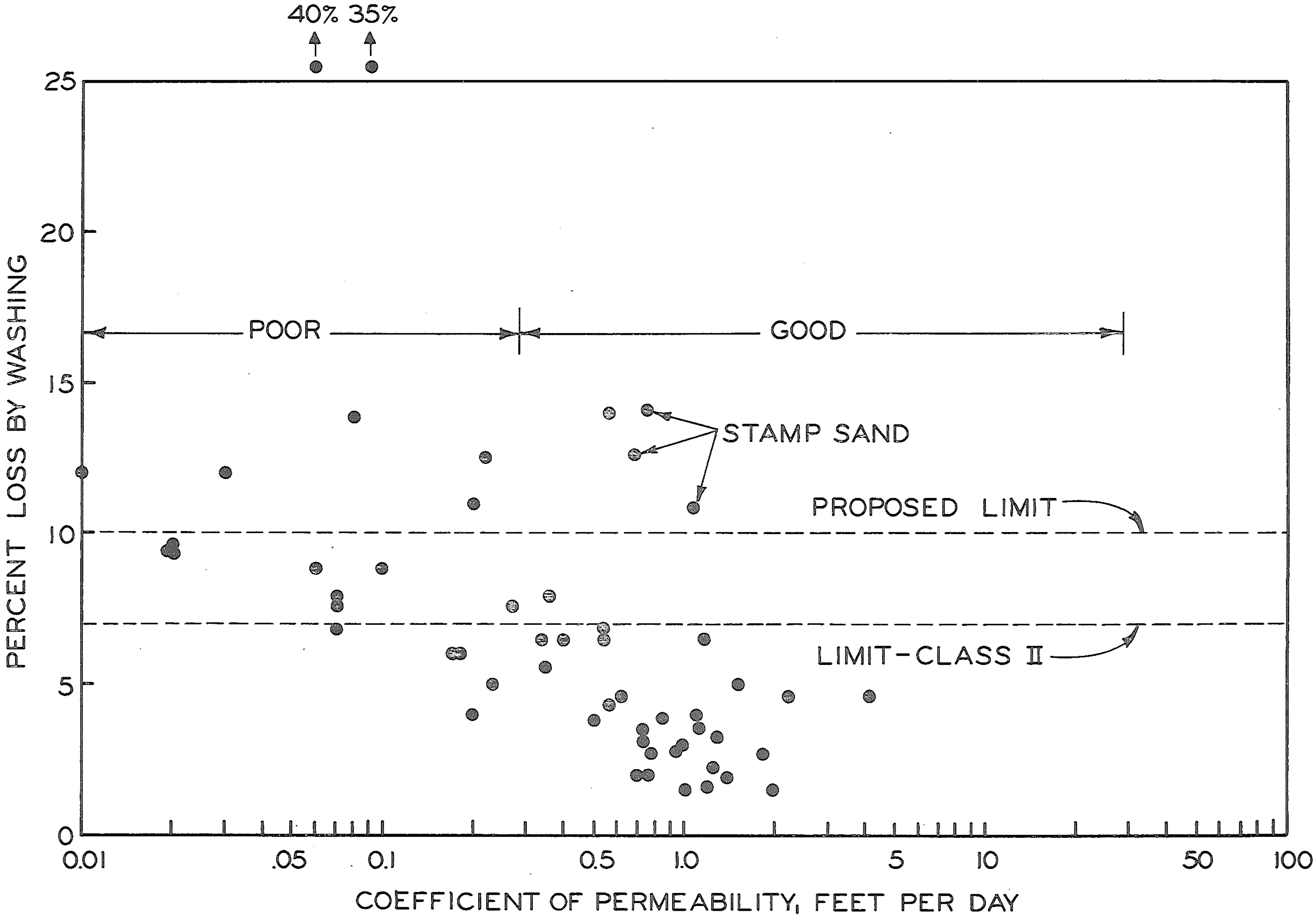

Figure 3. Permeability coefficient vs. loss by washing. (Ann Arbor Testing Laboratory data)

content, gradation of the whole sample, and particle angularity could overshadow relatively small changes in permeability characteristics caused by differences in the content of minus 200 or the minus 100 materials. These results indicate that specifications concerning the permeability of porous materials should control characteristics other than minus 200 and minus 100 material content alone. As an example, samples No. 13 and 14 both grade as Porous Material Class II yet their coefficient of permeability values rate "poor." Materials used in this study, all within specification limits, varied in coefficients of permeability from a high of 31 to a low of 0.043 ft per day. Within such a wide range of values it would be difficult to establish a significant relationship between minus 200 and minus 100 material contents and coefficient of permeability.

Also, of considerable significance to the performance of a pavement subbase are the values which show the percent saturation of gravity drained samples (Table 2). The magnitude of these values indicate that subbase constructed of these materials would not be free draining. In fact, the tests show that less than 25 percent of the water contained in the samples is free or gravity drainable. The relationship between the coefficient of permeability of subbase materials and the drainability of in place subbase layers is complex and this subject is being studied under another project of the Research Laboratory. Results of this work will be reported in the near future.

Conclusions

Based on the testing of 15 different samples of flume waste and bank run aggregates, the following conclusions concerning the coefficient of permeability of subbase materials are presented.

1. The permeability of granular materials cannot be reliably predicted by minus 200 and minus 100 material content values alone. Therefore, the primary purpose of the present study could not be entirely fulfilled.

2. Clay content and gradation above the No. 100 sieve, of compacted subbase materials have a significant effect on permeability. Neither of these characteristics are controlled by present specifications.

3. Specific findings of this study are:

(a) Proposed grading limits (maximum of 10 percent minus 200 and 35 percent minus 100 materials) when applied to crushed screenings and flume waste materials should result, generally, in materials of good permeability.

(b) When applied to bank run materials, the proposed grading limits permit use of some materials of poor permeability. This possibility could be reduced if specifications permitted only the use of non-dense and non-plastic materials.

(c) Widening specifications from those of Granular Material Class II to those of the proposed supplemental specifications, results in the acceptance of materials having both good and poor permeability.

4. Although subbase materials are considered to be free draining, the samples tested indicate that only a relatively small percentage of the voids can be gravity drained.

5. There are several factors, in addition to permeability, that determine the drainability of subbase layers, so that the suitability of a material for subbase use cannot be established by permeability values alone. Studies are being made concerning the overall subbase drainability problem and will be the subject of a future Research Laboratory report.

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