been the result of unfavorable experiences with other methods of paint selection. Performance tests require more time and work than most other methods of paint selection, however, the end results have consistently provided durable, quality paints for use on Nebraska highways at costs no greater than those for inferior paints.

Performance testing has also enabled the following conclusions to be made: (1) At least one-half of the traffic paints offered in the Nebraska area are unsatisfactory from the standpoint of economy and durability. (2) Paints can be selected that are most satisfactory under the traffic and climatic conditions prevalent at the time of use. (3) It is possible to buy large quantities of traffic paint which will give performance equal or superior to the test samples on which selection was based. (4) Manufacturers are encouraged to produce better paint. (5) Experimental considerations can be evaluated under typical traffic conditions.

ACKNOWLEDGMENTS

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Evaluation of the California Sand-Equivalent Test

W. G. O'Harra, *Engineer of Materials*
Arizona State Highway Department

Data from several thousand tests of base materials and mineral aggregates are portrayed in graphical form and the relationships between the California Sand-Equivalent Test results, plasticity index test results and the amount passing the No. 200 sieve are reported. As the plasticity index and the amount passing No. 200 sieve are considered to be two of the most important factors in judging the quality of mineral aggregates and base materials, it is concluded that the sand-equivalent test results reflect the quality of the material and that the test is of definite value as a rapid field test to determine the acceptability of materials. Sand-equivalent values recommended for determining the quality of materials are as follows:

0 to 14, unsatisfactory; 15 to 24, doubtful but usually unsatisfactory; 25 to 34, doubtful but usually satisfactory; 35 to 54, almost always satisfactory; 55 to 100, satisfactory.

● THE California Sand-Equivalent Test is a method proposed for determining the quality of aggregates for bituminous mixes and untreated bases. It was developed by F. N. Hveem, Materials and Research Engineer, California Division of Highways. The development of the test, the detailed procedure and the test limits for different classes of aggregates as specified by the California Highway Department have previously been reported. F. N. Hveem, "Sand-Equivalent test for Control of Materials During Construction", Proceedings, Highway Research Board, Vol. 32, p. 238 (1953).

The sand-equivalent test appears to have certain inherent advantages which make it very desirable. Very little equipment is required. Balances and drying ovens are not used. The equipment is easily transportable and the test may be performed at the pit site. The time required for completion of the test is only slightly over one-half hour. Inexperienced personnel can be trained in a very short time to perform the test.

The usual methods of testing the quality of base materials and mineral aggregates are time consuming and require a laboratory with considerable apparatus. Too frequently the results of these tests are not available until considerable time has elapsed and a large amount of material of unknown quality has been produced and placed. This is not a desirable situation.

The California Highway Department, in the development of the test, correlated the sand-equivalent with the *R* value as determined on the Hveem Stabilometer. The Arizona Highway Department determines the acceptability of base materials and mineral aggregates primarily by means of the screen analysis and plasticity index. It was believed that to determine the suitability of the test for our use, we should evaluate it upon the basis of our own test methods, specifications and experience. This evaluation has been completed and is the basis for this paper.

In the evaluation program the sand-equivalent test was used in our laboratory as an additional test on all mineral aggregate and base material samples received. Included in these were samples from projects under construction and preliminary materials survey samples from pits prospected for possible use. The materials survey samples included overburden, bottom strata and pits found not suitable for use, therefore, the samples tested included both satisfactory and unsatisfactory materials. From the data accumulated on these samples, it is felt that sufficient information has been obtained to evaluate the test for possible use by the Arizona Highway Department.

Test results of 2,427 samples have been obtained. The results were arranged in order of increasing sand-equivalent values and divided into eleven groups. Each group contained all samples whose sand-equivalent was in a range of values such that all samples

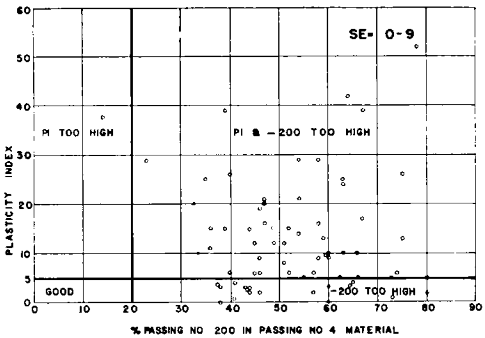
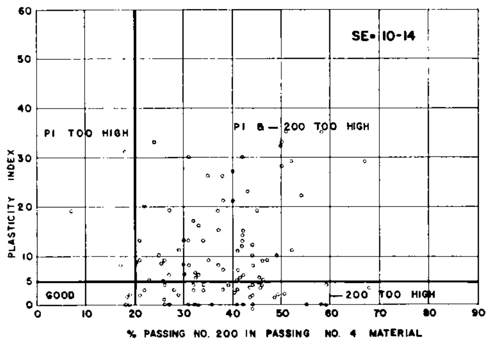


Figure 1



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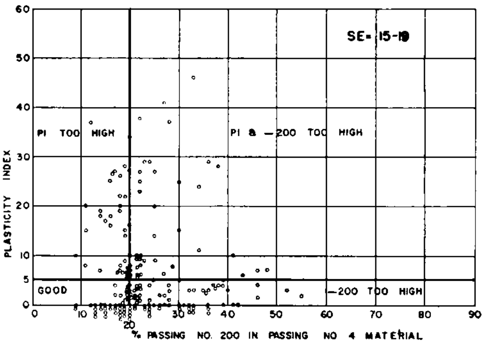

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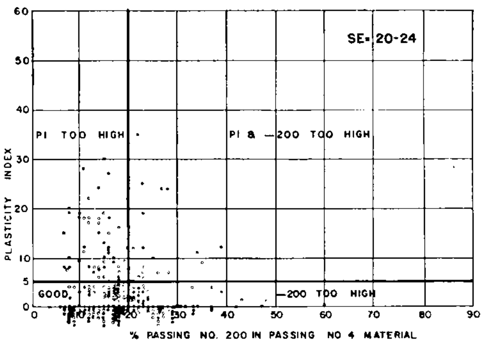

Figure 4

within that group should be of approximately equal quality. These groups have sand-equivalent ranges as follows: 0–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–54, 55–79, and 80–100. Eleven graphs, one for each sand-equivalent range, have been prepared to illustrate the relationship between the sand-equivalent, P. I. and minus 200. These are shown in Figures 1 to 11.

The P. I. of the samples is represented by the ordinate, or vertical axis of the graph. The percentage passing the No. 200 sieve in the portion of the samples passing the No. 4 sieve is represented by the abscissa, or hori-

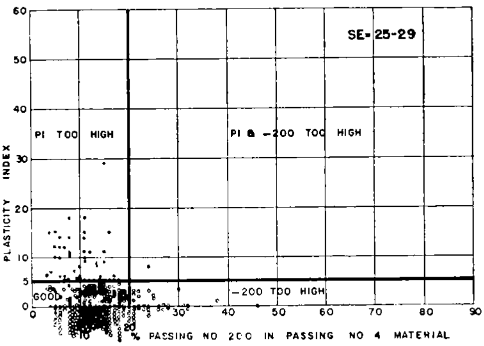

Figure 5

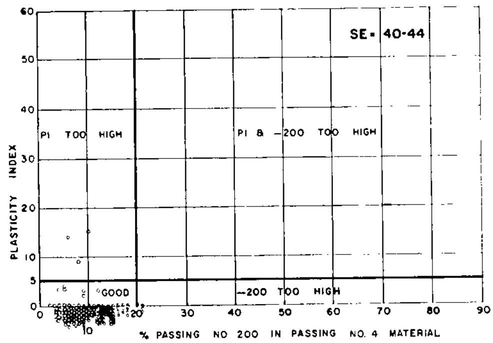

Figure 8.

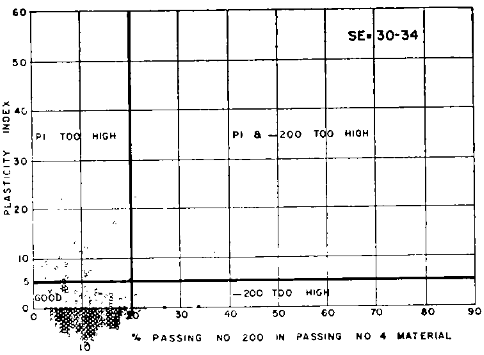

Figure 6

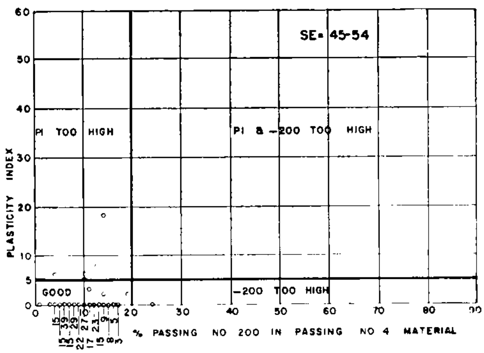

Figure 9

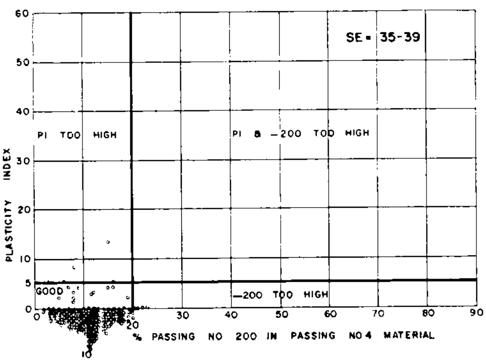

Figure 7

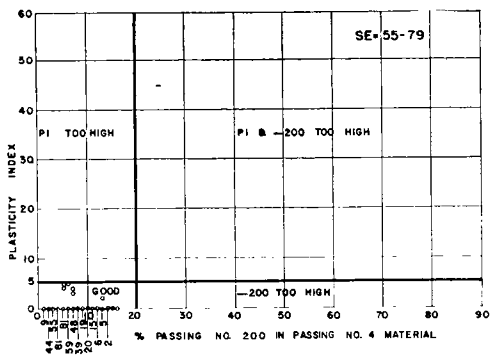

Figure 10

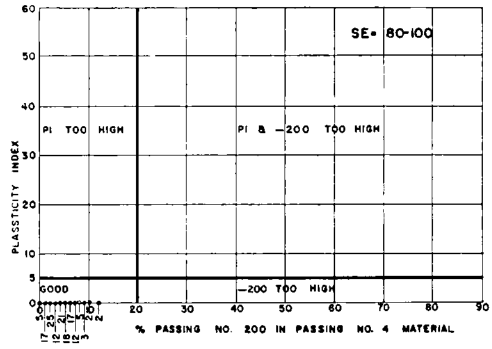

Figure 11

zontal axis of the graph. Each point on the graph represents an individual sample except that on Figures 9, 10, and 11, where many samples fall on the same point, the number of samples which that point represents is indicated.

Our specifications require that acceptable materials for use as base or mineral aggregate have a P. I. of 5 or less, therefore a horizontal line has been drawn across the graph at 5 P. I.

Our specifications usually require that the acceptable materials have 12 percent or less passing the No. 200 sieve in the total sample. As these materials average about 60 percent passing the No. 4 sieve, which is the portion tested in the sand equivalent test, it follows that the usually acceptable limit for the amount passing the No. 200 sieve in the portion passing the No. 4 sieve is 20% or less. Accordingly a vertical line has been drawn upon the graph at the 20% minus 200 sieve material.

It will therefore be seen that all points within the lower left hand corner of each graph represent satisfactory material. All points within the upper left hand corner represent material whose minus 200 content is satisfactory, but whose P. I. is too high. All points in the lower right hand corner represent material whose P. I. is satisfactory, but whose minus 200 content is too high. The points in the upper right hand corner represent material too high in both P. I. and minus 200.

Table 1 summarizes the information which appears on the graphs.

It will be seen from this tabulation that the quality of the material may be foretold by sand-equivalent values as follows:

Sand-Equivalent	Quality of Materials
0–14	Unsatisfactory
15–24	Doubtful but usually unsatisfactory
25–34	Doubtful but usually satisfactory
35–54	Almost always satisfactory
55–99	Satisfactory

TABLE I

Sand Equiv-alent	No. of Samples	Percent of Samples Classified as follows:			
		Satis-factory	Excess P.I.	Excess minus 200	Excess P.I. and minus 200
0–9	67	0.0	1.3	31.4	67.3
10–14	109	3.7	2.7	38.6	53.3
15–19	182	25.7	20.9	34.2	19.2
20–24	267	49.1	18.3	26.6	6.4
25–29	350	79.8	9.4	9.7	1.1
30–34	247	87.8	9.0	2.8	0.4
35–39	182	96.7	1.1	2.2	0.0
40–44	143	95.8	2.1	2.1	0.0
45–54	246	98.0	1.6	0.4	0.0
55–79	494	100.0	0.0	0.0	0.0
80–100	140	100.0	0.0	0.0	0.0

It has been noted from individual test results, although it is not evident from the graphs, that certain types of materials give lower or higher sand-equivalents than would be expected. Volcanic cinders for instance will frequently have high sand-equivalent values even though they may contain some plastic clay. This is probably due to the rough, angular and porous texture of the cinders. Wind-blown sands will have fairly low sand-equivalents even though they are non-plastic and of low minus 200. This is probably due to the rounded, polished surface and uniform size of the particles. The grain size of the material passing the No. 200 sieve will also affect the sand-equivalent value. If this grain size is coarse the sand-equivalent will be higher than if the grain size is small.

It cannot be expected that any one test method will completely classify the quality of all base and mineral aggregate materials and that other pertinent properties must also be considered.

The sand-equivalent test cannot be expected to determine all the properties which affect the quality of base and mineral aggregates, but, from the results of our evaluation study we have concluded that the test is very useful in detecting the presence of excessive amounts of clay or minus 200 material in these aggregates. The rapidity and simplicity of the test should greatly simplify the control of materials during production.