DESIGN AND CONTROL OF SOIL-AGGREGATE ROAD MIXTURES BY MEANS OF THE METAL HYDROMETER

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The Pennsylvania Department of Highways has developed a time-saving method of testing soils in connection with soil-aggregate roadway construction.

The method is suitable for use in the field to determine the grading and proportions of the soil mix. It reduces the work to be done at the laboratory and at the same time partially moves the design and control of soil-aggregate mixes into the field.

from the standard soil mortar curve of the United States Bureau of Public Roads (Fig. 1). It soon became apparent that, with very few exceptions, the trend of the soil mortar grading curve was controlled by the No. 270 mesh content of the material, the remainder of the points of the curve rising or falling as the No. 270 point increased or decreased. Once this No. 270 point was known, the remainder of the curve could be accepted as being

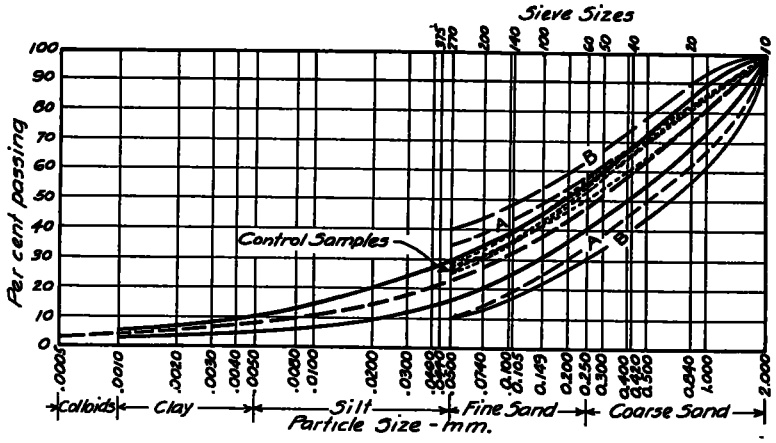

Figure 1. Soil Mortar Gradation Chart

The wash-out test previously used consisted of dispersing the sample, washing over a No. 270 sieve, drying and grading dry over various sized sieves between the No. 10 and the No. 270. No attempt was made to determine the grading of that portion of the sample finer than the No. 270 sieve, the characteristics of this fraction being determined by the plasticity index test.

In using the wash-out method of testing grain size, the points representing the quantity of material passing the various sieves were plotted on a curve developed

uniform for all practical purposes. This meant, with certain exceptions, that in order to establish the soil mortar grading of any material to be used for soil-aggregate construction purposes, only the quantity of material passing the No. 10 and the No. 270 sieves need be known. These facts being established, the Laboratory was able to develop a simple field method of design and control.

EQUIPMENT

The equipment consists of a metal hydrometer (Fig. 2), calibrated in the

laboratory by the use of solutions of known specific gravity, and a metal settling cylinder marked by lugs to indicate a predetermined level. Both these pieces of equipment are readily made by a good tinsmith. An ordinary egg beater

PROCEDURE

The metal hydrometer is used on the soil mortar fraction of the soil (that portion of the sample passing the No. 10 sieve). All reference in this paper to the quantity of material passing the No. 270

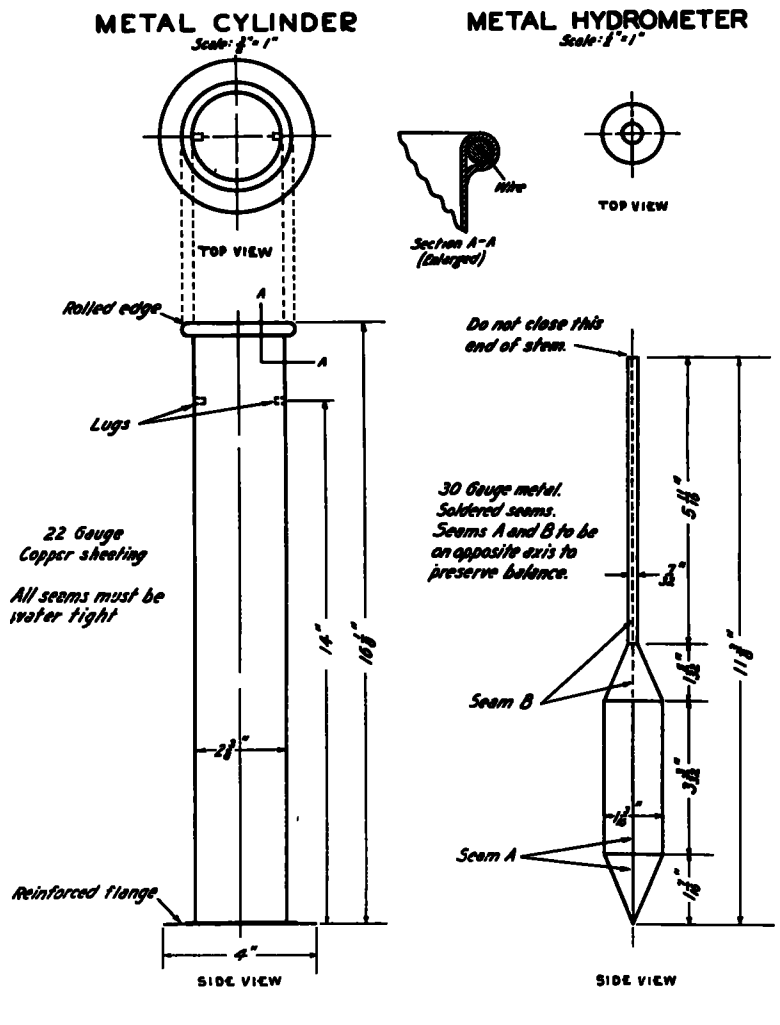

Figure 2. The Metal Hydrometer

with bowl, a small postal scale and a pan for weighing are obtainable at local stores. The postal scale can easily be calibrated to weigh the pan and one hundred grams of material. In addition, a No. 10 sieve and a dairy thermometer are required.

sieve refers only to this soil mortar fraction.

In using the hydrometer a sample of the material to be tested is dried, thoroughly screened over the No. 10 sieve and quartered. One hundred grams of this

material is weighed with the small scale, soaked in water for 15 min., then agitated in water, using the egg beater for at least two minutes. The solution is transferred to the metal settling cylinder, sufficient water is added to bring the mixture up to the predetermined level indicated by the lugs, and agitated further by placing a hand over the open top and turning the cylinder end for end for approximately one minute. The settling cylinder is then placed on a firm level surface, allowed to stand for one and one-half minutes, at which time the metal hydrometer is placed carefully in the mixture, and read at the expiration of another one-half minute (Fig. 3). A temperature reading

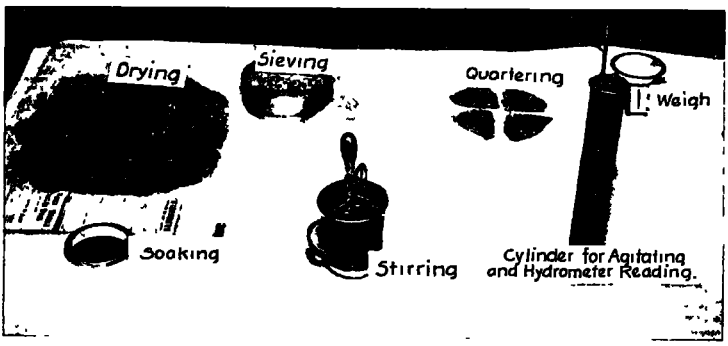

Figure 3. The Hydrometer Method of Determining the Material Finer than the No. 270 Sieve.

of the mixture is then taken. The hydrometer reading is corrected for temperature by means of a temperature correction table. This corrected reading represents the amount of material passing a No. 270 sieve, the hydrometer being calibrated at 67 degrees Fahrenheit.

APPLICATION

To date the metal hydrometer has been used chiefly in Pennsylvania by the field forces as a means of control in checking the percentage passing the No. 270 sieve in soil-aggregate mixes prior to their being placed. A laboratory wash-out analysis of the respective materials to be used in the construction is made and reported to the field. From this report the proportion of binder and granular materials required is established. Now knowing the mix proportions and the percentages passing the No. 270 sieve of the materials the field forces calculate the fraction of the finished mix passing the No. 270 sieve. They are now able, with the use of the hydrometer, to check the percentage passing the No. 270 sieve of the finished mix, or of the materials being used in the mix at any time. Any great variation between this hydrometer reading and the percentage passing the No. 270 sieve calculated or as established by the laboratory washout test, indicates either a change in the grading of the materials or an error in proportioning.

The value of this instrument in design now becomes apparent. With the hydrometer the usual necessary calculations of the percentage passing the No. 270 sieve of the finished mix can be eliminated entirely. This is accomplished by making up several trial mixes, using various proportions of granular and binder materials, (see Table 1) and testing with the metal hydrometer until a mix is obtained that meets the specification requirements on the No. 270 sieve. In using this method on one project, an apparent discrepancy of some 20 points between the hydrometer reading and the wash-out test, brought to light a break in the No. 270 sieve, too minute to be seen by

eye, but sufficient to cause a sizable error in the wash-out test.

ACCURACY

The metal hydrometer has proved to be very accurate within the range of the allowable limits of Pennsylvania's specifications. These specifications allow from 10 to 40 per cent of the soil mortar fraction of the finished mix to pass the No. 270 sieve, depending on the design being used (see Fig. 1). Use of the hydrometer on numerous projects has shown an error of not more than ±5 points, with the hydrometer usually giving a lower reading than the laboratory wash-out test. This is probably due to the less vigorous stirring obtained with the egg beater, as compared to electric dispersion in the laboratory.

The metal hydrometer has not proved accurate in all cases in the higher ranges, particularly when used on soils having high clay content. (The use of a deflocculating agent might remedy this error.) However, despite this apparent weakness, the metal hydrometer has been used to test both binders and granular materials in the field. The error in testing a material falling within the higher range of the metal hydrometer is eliminated, when the final mix is checked, since the material falls within the lower range of the hydrometer after the addition of granular admixture.

ILLUSTRATION

The field hydrometers may be used on mixes using stone or slag screenings, run of bank gravel, red dog or cinders. Table 1 shows the mixes, using these various granular materials, in several proportions with a soil. Comparative values for the percentage passing the No. 270 sieve, by both metal hydrometer and screen wash-out tests are given. The table shows the error between the two methods when used on the soil, the reduction in error as the granular content is increased, and the lower reading of the metal hydrometer as compared with the corresponding wash-out tests (note the single exception). The tabulation also shows how a mix can be set up by using trial mixes. This is illustrated best in the case of soil plus slag screenings. The results obtained on the trial mix using 70 per cent of granular admixture (slag screenings) and 30 per cent of soil, produces a material meeting Pennsylvania's specification requirements on the soil mortar fraction passing the No. 270 sieve.

TABLE 1

COMPARISON OF METAL HYDROMETER AND SCREEN WASH-OUT TESTS

	Soil*	Cinders + soil			Red dog + soil			Slag Screenings + soil			Stone Screenings + soil			Run of bank grave + soil		
Mix Soil	100%	70%	50%	30%	70%	50%	30%	70%	50%	30%	70%	50%	30%	70%	50%	30%
Mix Granular admix	0%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
% passing No. 270 washout	68.6	58.4	57.0	46.0	56.4	51.2	40.8	54.0	45.4	31.0	55.4	47.6	36.6	57.0	50.4	41.6
% passing No. 270 hydrometer	58.5	55.5	54.0	45.0	52.0	49.0	39.5	49.5	44.0	31.0	49.5	44.0	37.5	51.0	46.0	40.0
Variation	−10.1	−2.9	−3.0	−1.0	−4.4	−2.2	−1.3	−4.5	−1.4	0.0	−5.9	−3.6	+0.9	−6.0	−4.4	−1.6

* Plasticity index 5.1.

CONCLUSION

We do not present this method of testing as applicable to all conditions. As stated before the equipment was primarily developed to reduce laboratory work and partially move design and control into the field. Its full value in this

line of work only became apparent as it was used

In using the metal hydrometer method, the field is still dependent upon the laboratory for the plasticity index values of all binder soils used The general downward trend in plasticity indexes for stabilized mixes may make this determination less important than at present Pennsylvania's specifications now allow a zero plasticity index on wearing course, but require that the binder soil originally used must have a plasticity index of not less than five In Pennsylvania it is believed that, in the simplification of soil mortar control, a quick method for the determination of plasticity index in the field is needed This would complete the transfer of design to the field, with the further reduction of the time factor, the laboratory only being required to perform periodic check tests as a matter of supervision