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Hveem, F.N. and Bailey Tremper

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One of the oldest requirements in engineering specifications describing aggregates for Portland cement concrete is the stipulation that they shall be clean and free from deleterious materials. It is readily apparent that such a statement leaves a good deal of ground for argument between the producer and the engineer. What do we mean by deleterious substances and how does one recognize them? Fortunately, mineral aggregates are not often coated with any exotic material and it is fairly well recognized on both sides of the fence that deleterious materials generally mean some form of clay or mud.

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By

F. N. Hveem
Materials and Research Engineer

and

Bailey Tremper
Supervising Materials and
Research Engineer

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CLEAN AGGREGATES FOR CONCRETE

By
F. N. Hveem and Bailey Tremper*

One of the oldest requirements in engineering specifications describing aggregates for portland cement concrete is the stipulation that they shall be clean and free from deleterious materials. It is readily apparent that such a statement leaves a good deal of ground for argument between the producer and the engineer. What do we mean by deleterious substances and how does one recognize them? Fortunately, mineral aggregates are not often coated with any exotic material and it is fairly well recognized on both sides of the fence that deleterious materials generally mean some form of clay or mud.

For many years, most engineers have assumed that by controlling the sieve analysis and limiting the amount of material that would pass a No. 200 sieve by wet sieving, objectionable fine materials could be controlled within tolerable limits. However, there is quite a range and variety of materials that will pass a No. 200 sieve. This

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*Materials and Research Engineer and Supervising Materials and Research Engineer, California Division of Highways

sieve has openings of 75 microns, or .0029". In other words, anything smaller than 75 microns will go through the sieve and there is a vast difference between clay particles that range from 1 to 5 microns in size compared to rock dust or fine sand in the range of 50 to 75 microns. Practical experience has shown that under ordinary methods of producing and transporting crushed aggregates, clean stone or gravel may develop 2 percent of fine dust passing a No. 200 sieve and even the most fussy engineer should not object to 2 percent of clean rock dust in a mineral aggregate. However, 2 percent of fine clay is something else and is definitely objectionable for most construction purposes. Therefore, it becomes necessary for the engineer to use something beside a sieve analysis to determine whether or not the aggregates meet the stipulation of being "clean and free from deleterious materials." I doubt the necessity of reminding you of the large discrepancies in test results that are sometimes obtained by different laboratory operators in the wet sieve analysis.

The foregoing explains then, why we have developed the sand equivalent test in order to take into account both the quantity of fine material, its degree of fineness, and its character. The test is based on the fact that fine particles settle more slowly than do coarse ones. In fact, particles in the colloidal size may stay in suspension indefinitely in ordinary water, and it is necessary to introduce some flocculating agent in order to produce any appreciable settlement. These two effects have been combined in the sand equivalent test. A sample of sand is placed in a transparent cylinder and shaken up in a solution of water and calcium chloride. The calcium chloride solution causes fine particles to flocculate and settle more rapidly than would otherwise be the case, but the solution is carefully adjusted so that settlement is accelerated only to a moderate degree. As a result, after vigorous shaking, the coarse sand particles settle immediately to the bottom of the graduate and the fine dust and clay remain in suspension for some time. These smaller particles also settle at different rates, the coarse dust or fine sand particles settle first, followed by the silt and clay. By taking a reading within a fairly short time (20 minutes) the results reflect the fineness, the total amount and the nature of the suspended material. The test results are reported so that a large amount of clay or suspended fines gives a low "sand equivalent reading" and a small amount of clay is indicated by a high sand equivalent.

While it is true that engineers have long objected to so-called dirty aggregate, it may be well to offer some evidence to indicate the reasons for this feeling. The sand equivalent test was first devised to control the amount of plastic clay that tends to lubricate crusher run bases and make them unstable. It was concluded that in order to be safe, the sand equivalent value should be above 30 for this purpose. Next, it was realized that fine dust and clay coatings are objectionable for bituminous mixtures as they prevent adhesion between the asphalt and the aggregate, and in order to make sure that there was not enough clay to cause trouble, a cleaner material having a sand equivalent of about 45 has been specified.

The third application was in the field or portland cement concrete. The purpose here is somewhat different as one of the principal effects of clay is its adverse effect on volume change of the hardened concrete and after a long series of tests conducted on aggregates throughout the State, it was concluded that sand equivalent values in the order of 75 or 80 would be necessary in order to make sure that concrete sands were free from objectionable amounts of the fine particles that produce high volume change.

Thus, the sand equivalent test is employed to serve three different purposes and the clay-like fractions which it detects are objectionable for three different reasons:

1. They lubricate granular bases.
2. They prevent asphalt from sticking to sand grains.

3. They cause concrete to expand and contract to a greater degree, thus leading to cracking and other undesirable effects of volume change.

A similar test has been developed for coarse aggregate in which a portion of the wash water produced after a controlled amount of agitation, is shaken with the calcium chloride solution used in the sand equivalent test. After settling for 20 minutes, the height of the flocculated column is used to derive an expression of clay content.

In essence, the tests provide a method of measuring the volume of fine particles of clay sizes in aggregates, but they do more than this because they rate different kinds of clay in accordance with their deleterious effect in concrete. Our laboratory has accumulated voluminous data that demonstrate that the test results are highly significant with respect to the concrete strength developed by aggregates, also and more importantly, the volume change that concrete undergoes during wetting and drying.

The complete equipment for making the sand equivalent test can be purchased for about $100 including a supply of stock solution sufficient for 400 tests. The test for coarse aggregate utilizes part of the sand equivalent equipment. A 2-gallon stainless steel pot fitted with cover, gasket and clamps which can be purchased for about $30,00, is the principal new item provided such things as a scale, No. 8 and No. 200 sieves and a portable sieve shaker are on hand.

Less skill is required in making the tests for cleanness than is required in determining the percentage passing No. 200 sieve by wet sieving. The tests require care, rather than manual dexterity. The matter of securing a representative sample for test is no more or no less exacting than for other tests.

If careful operators follow the rather simple steps as they are prescribed, duplicate results of the same sample should check closely. In borderline cases, we consider it advisable to make three tests which can be run concurrently.

Assuming a dried and cooled sample has been prepared, a single test for sand equivalent can be completed in 30 minutes. Three tests run concurrently can be completed in 40 minutes. Tests can be made on damp samples taken directly from the supply, but the results tend to be a little low. If the material exceeds the test requirements by a reasonable amount, tests made directly on damp samples will show passing results.

A single test for coarse aggregate can be made in 30 minutes. During the settling period, time is available for additional tests or other work.

The material that must be removed from aggregates in order to bring them within test requirements is essentially clay-like in nature. Samples of such clay that has been removed from aggregates of varying sand equivalent are available for inspection.

These tests for cleanness are intended to supplant the wet sieve analysis and the count for clay lumps. The tests are <u>not</u> intended to replace those for soundness, abrasion, reactivity, or organic matter. They are supplemental to such tests. The tests for cleanness make it possible to assure that the aggregates will develop their fullest measure of potential strength producing properties when they are mixed into concrete. Probably the outstanding virtue of the tests is their ability to afford a measure of volume change of concrete due to wetting and drying. They do this to the extent that they provide a scale for comparing aggregates from different sources provided the particles do not differ too much in porosity, or, more properly, rigidity.

As far as we know, the bugs have been pretty well worked out of the tests. For example, we found that in shaking the tube in the sand equivalent test, different individuals tend to give different snaps to the wrists and some would consistently get higher or lower test results than others. We have developed a mechanical shaking device against which individual operators can be "calibrated." When an operator has thus been calibrated, he needs only to make more or fewer throws of the tube in order to obtain standard results. He does not then need the mechanical shaker to perform his tests.

After about a year of use in the field, we found it necessary to modify the so-called sedimentation test for coarse aggregate because anomalous results were being obtained with certain aggregates. Actually the test has been simplified. Materials that do not meet our present requirements can be made to comply by a practical amount of additional washing.

In simple words, so far as these tests are concerned, production to meet our standards for cleanness means thorough washing at the plant. We do not believe we are requiring an unreasonable amount of washing because the majority of aggregates produced under previous specifications would meet our present requirements. No sample that has failed initially to meet our requirements has failed to do so after a reasonable amount of rewashing.

Our requirements could reasonably be tightened without working an undue hardship on the producer were it not for the fact that certain of his customers demand the added plasticity that clay gives to the concrete. In urban areas particularly, aggregates for highway use must come from the same stocks as those used by the building trade. We hope through a process of education to persuade users that the clay is not necessary in their operations of placing and finishing concrete and that they can secure the desired plasticity by other means with less impairment of the concrete.

In washing sand to remove surplus clay, the producer must, of course, take whatever steps are necessary to retain sufficient clean fine sand to meet specification requirements. The producer may also find that original high and satisfactory test results have been lowered if the aggregates during handling have been subjected to excessive abrasion such as might be produced by a bulldozer. The degree of degradation depends on the nature of the parent rock. Sandstones containing a clay cementing agent are particularly vulnerable.

The final thought I would like to leave with you is that the sand equivalent test and its counterpart for gravel have a number of distinct advantages to the producer. Among these are:

1. The long delay, frequently amounting to 24 hours in learning whether current production is up to standard is avoided. Tests for sand equivalent require no weighings and can be made in an unsheltered location if need be. Because the tests can be completed with little

delay, inspectors are less prone to base acceptance or rejection purely on visual inspection rather than on test data. In cases of dispute, new samples can be taken and the results checked by both parties promptly. The harrowing business of waiting for phone calls from a central laboratory is avoided.

2. Competition between producers is more certain to be on the impartial basis of furnishing materials of comparable quality.

3. The inevitable complaints of shrinkage cracks in finished work, some of which trickle back to the aggregate producer, will be reduced substantially.

In conclusion, it may be stated that the sand equivalent test, and its counterpart for coarse aggregate, make it possible to specify cleanness in a way that has more meaning with respect to quality of the resulting concrete than do tests depending on weight relationships, that the tests are simple and quick to perform and that they work toward better contractual relationships between producer and consumer.