A Laboratory Method to Determine Polish Susceptibility of Aggregates

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•FROM AN examination of the record of skid tests run in the field, a pattern emerges by which we can associate certain aggregates with slippery pavements and others with pavements that show high skid numbers. At the same time, none of the usual quality tests in our specifications seems to relate directly or even indirectly to these tendencies. Even generalizations based on rock types fail to stand up under close scrutiny.

For obvious reasons, it would be useful to be able to predict in advance that a given aggregate or combination of aggregates can be expected to cause slipperiness. As an extension of this thought, it would also be nice to be able to prescribe corrective treatment for problem aggregates during the mix design stages.

With this in mind, we have attempted to devise a laboratory procedure that will allow us to evaluate the polishing tendencies of aggregates. As a matter of fact, the building of a polishing machine is really no trick at all; however, we are finding that the evaluation of the results is quite another matter.

In the design of our machine, the aim has been to reproduce the action of traffic in the field as faithfully as possible. We, therefore, started by using normal automobile tires as the polishing instrument. Although we have tried several types, we have settled on the use of two 7:50 × 14 ASTM E-17 test trailer tires that have been worn beyond the point of use in the field.

The wheels on which these tires are mounted are at opposite ends of an axle approximately 6 ft long. The system is made to rotate about the midpoint of this axle. It is here that we part company with real-world conditions because this results in continuous turning action with a 3-ft radius. However, it is this tight radius that gives us the polishing action we need. The outer edge of the tire tread actually travels about 14 in. farther than the inner edge on each revolution. This does not sound like much, but it amounts to 6 percent of the total circumference. Our drive speed is such that the wheels go around the 6-ft diameter track at 22½ rpm. This means that in a 24-hour day we produce our 7 miles of drag per tire.

The actual scuff pattern beneath the tire is rather more complex than this because the inner edge is in fact being dragged backward at the same time that the outer edge is being dragged forward. There is also an in-and-out transverse component because any point on the tire is being pulled toward the axis of rotation from the time it comes in contact with the pavement until the hub of the wheel is directly overhead, then that point is pushed outward as rotation continues.

We can, and do, further complicate matters by adjusting the toe-in or toe-out of either tire relative to the axle. We can also alter the speed of rotation and add additional weight to the 300 lb/wheel we normally carry. As you might expect, each of these variables does affect the rate of polish.

In essence, the polishing instrument is a pair of 7:50 × 14 tires chasing each other around a 6-ft diameter circle at about 22½ rpm day and night (Fig. 1).

We have divided the 6-ft diameter track into 16 equal segments, each of which holds one sample. This enables us to conduct replicate tests on a single aggregate and to test more than one material at a time. In comparing data from any given run, we feel

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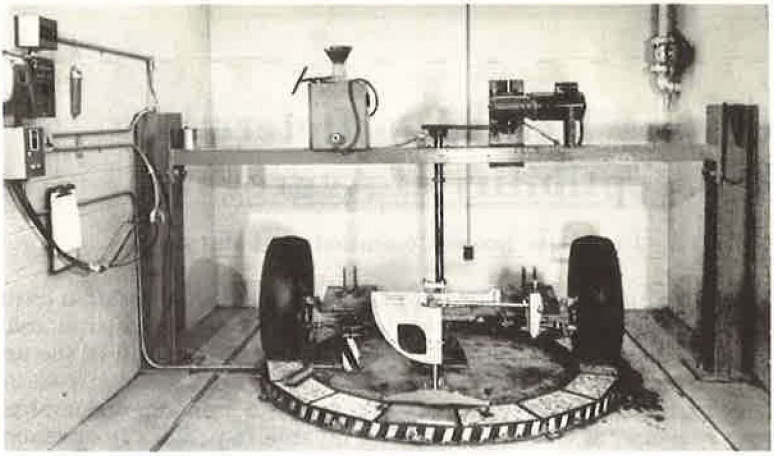

Figure 1.

that we have cancelled out the influence of the several variables in machine adjustment mentioned earlier. We hope to be able to isolate and evaluate these variables at a later date.

Individual samples are trapezoidal in shape, approximately 6 in. wide with a median length of 12 in. (Fig. 1). They are secured in individual metal frames that are bolted into the track. It is convenient to make them 1-in. thick, but provision has been made to increase this up to 3 in.

Although we recognize that sooner or later we will reach a point at which we want to test paving mixtures of various types, we have set this problem aside for the moment, having found by preliminary tests that it can be done.

Currently we are testing the polishing proclivities of aggregates alone. One of the questions we are attempting to resolve is the influence, if any, of the size of the individual particles on the system. For this study, samples of 3 types are being prepared. One type is made up entirely of particles passing a 3/4-in. sieve and retained on a 5/8-in. sieve. The second has only material between 3/8 and 1/4 in., and the third type is a single slab sawed from a large rock.

In the preparation of individual aggregate specimens, we have devised a method through which the bonding agent holding the aggregate particles is kept well below the plane of the sample surface. We have found that our results are more consistent if we take pains to have one relative flat face of each individual particle uppermost, and arrange it so that these faces are in the same plane.

To accomplish this, we carefully select particles of the size we wish to test and hand place them face down on the flat bottom of a watertight mold as close together as possible. Then, enough water to get a depth of about 1/8 in. around the aggregate particles is poured in. The mold is then placed in a freezer at 29 F. Once the water has frozen, an epoxy is poured over the frozen surface, and the whole works is returned to the freezer. The temperature is again held at 29 F.

We have found that the epoxy will set up at this temperature in about 2 days. Lower temperatures would probably work but would extend the curing time; higher temperatures melt the ice because of the heat of reaction of the epoxy.

After the epoxy has cured sufficiently to hold itself and the aggregate together, the specimen is removed from the freezer and the ice is washed away. It is then placed face down on a flat plate and allowed to cure for 1 day in an oven at 110 F. This is necessary to maintain the plane surface because the epoxy is a bit on the limber side as it comes from the freezer. The sample is next mounted into the metal frame in a bed of sand-cement mortar. Once this has cured, the sample is ready to be placed in the track.

Incidentally, we are currently experimenting with the use of portland cement and retarding agents in order to simplify this procedure.

Once the specimens are mounted in the track, we expose them to continuous traffic at the rate of 32,500 revolutions, which produce 65,000 coverages per day. Three days a week, usually Monday, Wednesday, and Friday, are set aside for "pit stops" during which we measure the skid resistance of each individual sample.

As implied earlier, anyone can build a polishing machine, but the evaluation is much more difficult. Our measurements of the degree of polish are being made by the use of the British portable tester (BPT).

A template has been devised that enables the operator to set up over the same 2 spots on each sample every time tests are made. The readings from these 2 spots are averaged to give one value for each specimen. This value is combined with similar ones from replicate samples to give a single number representing the degree of polish of the material at the number of wheel coverages completed at any given pit stop.

On 5 different test series so far, we arranged our testing program so as to allow an analysis of variance of the process. Quite similar results were produced in each case. The components examined were between operators, between samples of the same type, between locations on the same sample, and a residual variance.

Two things of interest show up in these studies. First, we are reassured that our data fall in line nicely with the precision statement for the test method as it is given in ASTM. Second, the variance between samples makes up the greatest part of the total to the extent that it is about 4 times the sum of the rest. This finding dictates the use of a number of replicates in order to produce an average result in which we can place some degree of confidence. It also dictates a continuation of our efforts to refine the sample preparation process and the measuring process. The fact that a full test series in any single pit stop takes 2 men about 5 hours also leads us to seek new methods of evaluation.

In spite of this, we are encouraged by the results of our tests thus far. When we plot the average skid number for a material against the corresponding traffic as measured by machine revolutions, a consistent curve emerges. This curve appears to be hyperbolic. So we have set up a program through which the computer gives us the best fitting hyperbola for each set of data points. Correlation coefficients are usually 0.96 or higher. These calculations also produce an intercept at infinity, and we are interpreting this as being the ultimate skid number that would be produced if the polishing process were continued for an infinite number of revolutions. It is the asymptote that the hyperbolic curve approaches with increased traffic. An additional constant produced is a slope from which we may be able to infer a comparative rate of polish.

If it holds up through the rest of our investigation, this certainly gives a convenient quantitative evaluation of ultimate polish potential of an aggregate.

Although we are not ready at this time to release data condemning or praising any given aggregates, I can give a rough idea of the sort of information we are producing. In a recent test series of a Gabbro aggregate known to give quite satisfactory skid results in the field, we ran concurrent tests of 6 samples each of coarse and fine particles along with 4 slab samples.

After 225,000 coverages, all 3 types had dropped from a skid number near 55 to 49. From this point the slab samples began to diverge from the other 2 types until the series was stopped just short of 3 million. During the run, 19 data points of BPT number versus revolutions were made. At the last pit stop, the coarse and fine particle samples each averaged 37, while the slabs averaged 30. The computer showed correlation coefficients of 0.992, 0.988, and 0.996 for the 3 curves representing this series. Calculated values from these best-fit equations gave standard errors of 0.63 to 0.76 skid numbers. The calculated ultimate skid values were 30.5 for the coarse, 27.0 for the fine, and 11.7 for the slabs.

Figure 2 shows the data from the tests of this set of slab samples on a normal linear plot of BPT versus revolutions. In Figure 3, the same data are shown and the hyperbolic function is used for the revolutions scale. The linearizing effect of the transformation of the data can readily be seen.

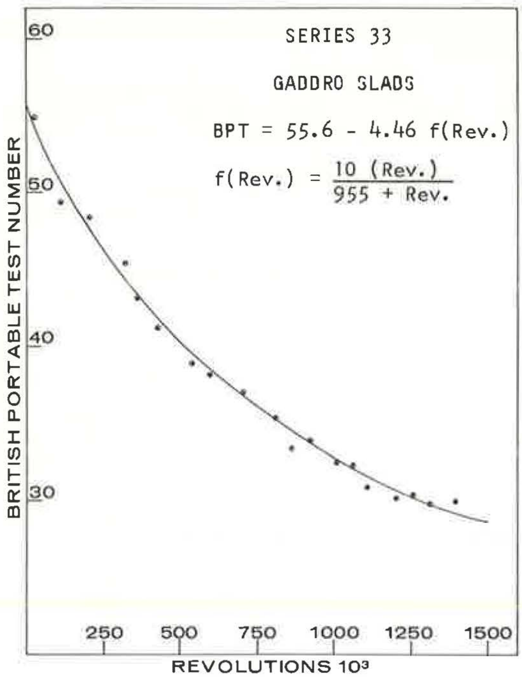

Figure 2.

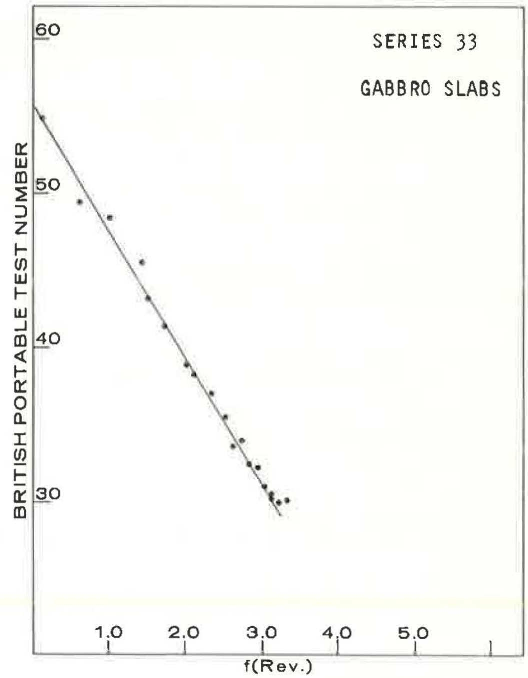

Figure 3.

We are in the process of rebuilding the drive mechanism in order to allow heavier loads to be placed on the tires. At the same time, we have designed and are putting together a device providing a new approach to laboratory skid measurement. By its use we hope to speed up the measuring process and at the same time reproduce the action of skidding in the field more faithfully than we have done with the pendulum type of tester. In the meantime, we intend to continue as we are going and will gladly accept any old, used E-17 test tires anyone wishes to dispose of.