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An Explanation and Demonstration of the Sand Equivalent Test

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16. ABSTRACT

Well, I was told to make this snappy and get through here, so I'll move along as rapidly as I can. I brought some equipment which at first I considered demonstrating, but, in the interest of saving time, I'll not do that. And, we'll start in with the slides rather quickly. Preliminary to this I'll say that the purpose of this discussion is to describe this so-called sand equivalent test, and it might be well to attempt to explain why we use this term.

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"AN EXPLANATION AND DEMONSTRATION

of the

SAND EQUIVALENT TEST"

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Materials & Research Dept.

presented at the

Sixth Annual Convention
National Bituminous Concrete Assn.
Jan. 28 – Feb. 1, 1961
Houston, Texas

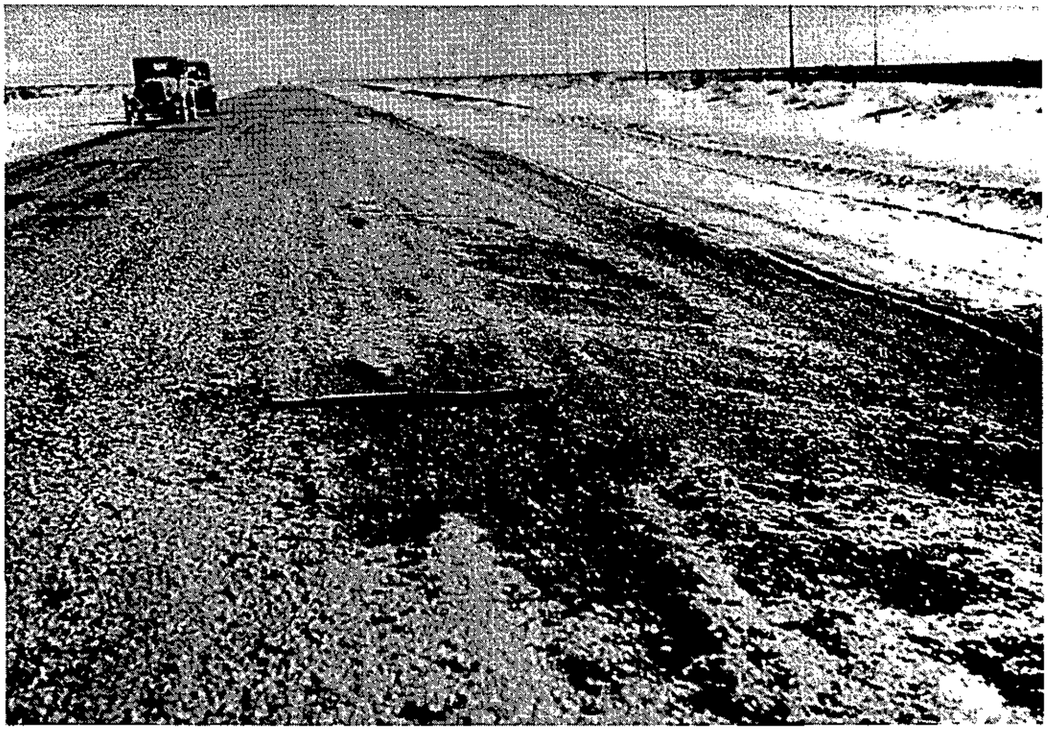
Thank you, Mr. Chairman, Gentlemen of the Convention.

I feel a little bit diffident -- it's incumbent on me to get up here and say something worthy of this laudatory introduction that your Chairman has just given. I can't quite think of anything appropriate except I recall an old saying attributed to Bill Nye many years ago about the need for knowledge, and he said, "It ain't ignorance that keeps the world behind; it's knowing so damned many things that ain't so." Of course some of us haven't found out all the facts and can console ourselves with some such excuse from time to time.

Well, I was told to make this snappy and get through here, so I'll move along as rapidly as I can. I brought some equipment which at first I considered demonstrating, but, in the interest of saving time, I'll not do that. And, we'll start in with the slides rather quickly. Preliminary to this I'll say that the purpose of this discussion is to describe this so-called sand equivalent test, and it might be well to attempt to explain why we use this term.

This particular development, this test, is the outcome of some 20 or 30 different devices which we worked with over a period of some two or three years before we settled on this one, and we had it variously called the plastic index, the plastic ratio and one thing and another. I've always had a dislike for the Bureau of Public Roads plasticity index determination, the so-called p. i. determination, because it is not a measure of plasticity. It's simply an arbitrary moisture content between two arbitrary limits one of which is determined by rolling out soils by hand. In other words, if it were a measure of plasticity, you could measure the plasticity of anything; but just try a wad of putty with a p. i. test and see what you come out with. Putty is definitely a plastic material. We decided we wouldn't call this a plasticity test either; but groping around for something, we concluded that all soils, natural materials, can generally be reduced to a range of sizes. If you separate them and wash them out, you will find that they contain a fraction of coarser particles generally called sand. Other fractions of finer particles are called something else. In other words, if you break big rocks down into smaller ones, you call the larger particles coarse rock; and when you get down to a certain size, you call it sand; and when you break them down further, you call them filler dust. By calling these fractions different names, there is a tendency to imagine that they obligingly take on different properties because you call them something different. But, actually, all we're talking about is fragmentary matter -- particles of stone, sand grains or earthy materials of various sizes. And this subject today deals with a test for identifying some of the characteristics of some of the smaller sizes.

May we have the first slide, please?



This is one of California's outstanding highways and I might say I had to hunt around to find this one here; but I thought it was only proper -- (in view of the gentlemen from Florida and Texas here) -- to show them what we can do out in the Far West.

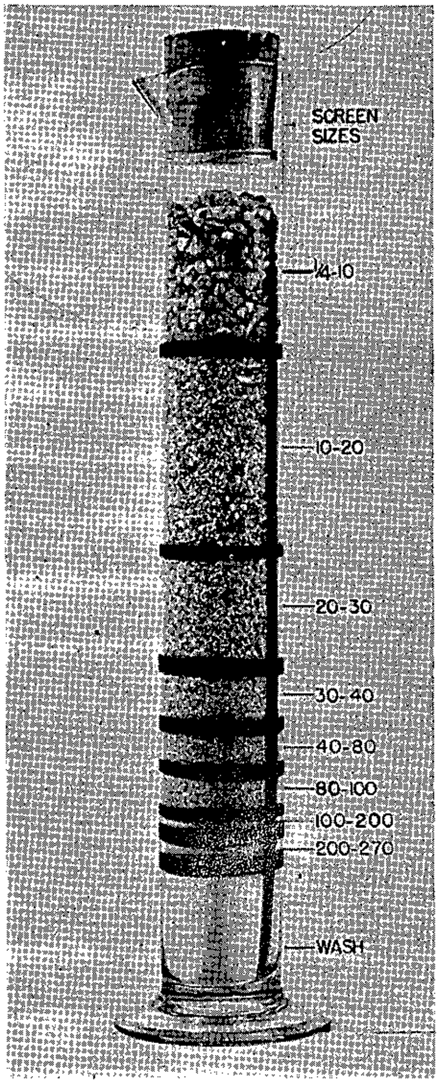
This project was the cause of my getting shaken out of a fairly comfortable job as resident engineer. Not that I was resident engineer on this job, but my move into the laboratory came about because of the great controversy that developed between the construction people and the laboratory as to the reason for this trouble. And, without going into all the ramifications, there were many reasons. Essentially, we found out after much investigation that every single particle of sand and coarse aggregate in this mixture was coated with a layer of clay, clinging very tenaciously to it, with the result that a dry sieve analysis (which was common at the time this work was done) gave about 4% minus 200 and the wash analysis gave 15. This clay content had the effect of drying up the mix. We had 22 miles of this sort of pavement which was a little disturbing, even to us careless people out in the Far West.

(QUESTION FROM AUDIENCE): May I ask a question?

MR. HVEEM: Yes.

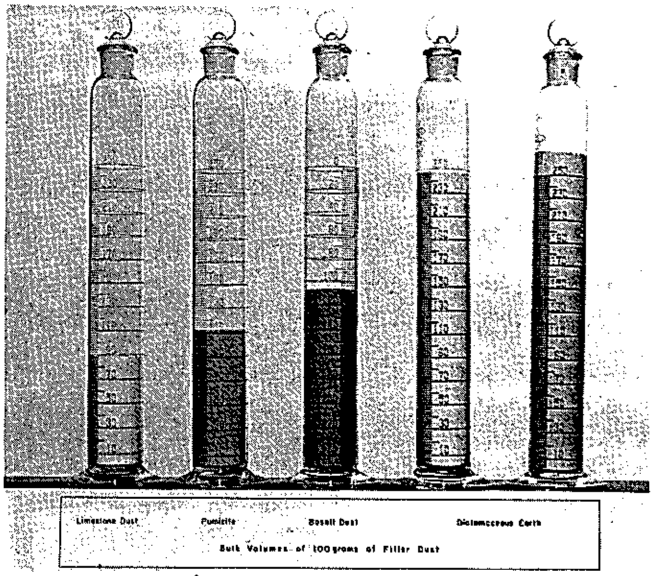
(QUESTION FROM AUDIENCE): How much per cent would that be 200 of?

MR. HVEEM: Well, dry sieve analysis 3 and by wash 15. Next slide, please.

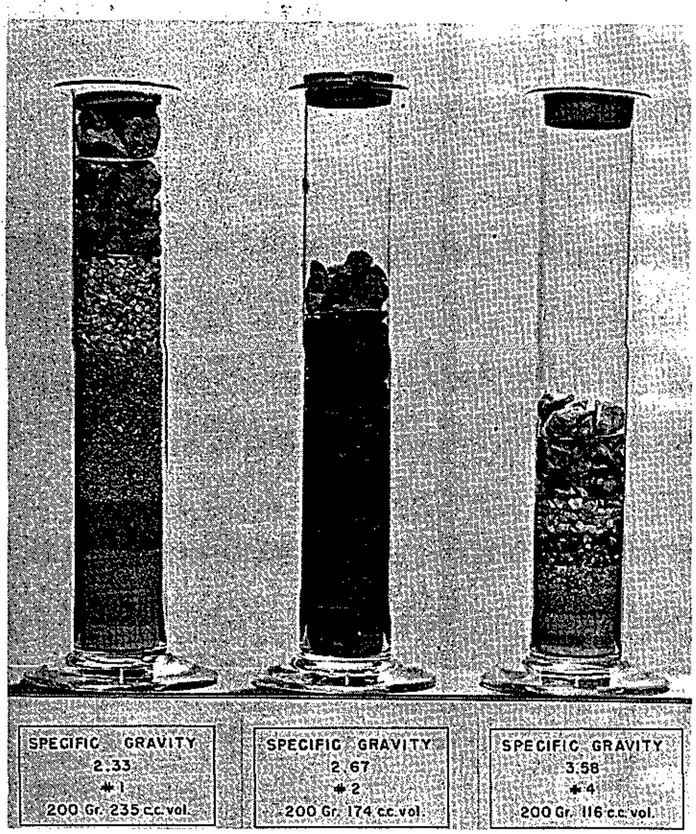


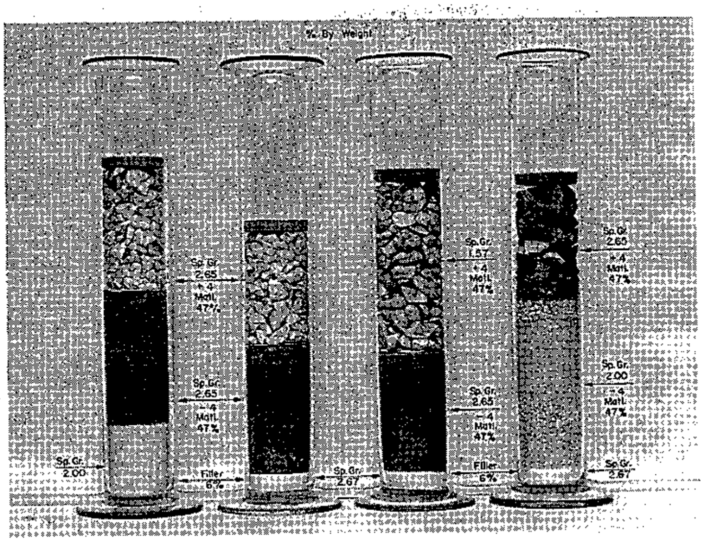
This is a sample of the material separated into the sieve sizes. These are the old style sieves used at the time but should serve to give you visually a picture of the relative volumes of the various sizes including the so-called wash fraction, the #200 to #270 and the other sizes up the line characteristic of this material. Next, please.

Then the question came to our mind as we worked in the laboratory, "Was this dust like any other dust or was it somehow peculiar, or what?" We didn't know what the other dusts were. We scrounged around and gathered up all the loose samples of dust we had and weighed out 100 grams of each thoroughly dried and put them in these glass cylinders; then shook them down to a constant state. There are 100 grams of dust in each one of these. I don't think it's necessary to belabor the point, but when you say 5% of dust, or 6% or 2%, it makes a heck of a lot of difference what dust you're talking about as to how much dust you are going to have. Next, please.

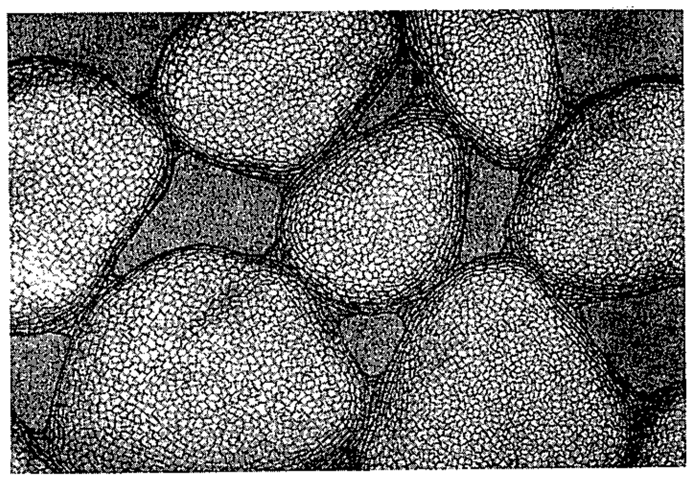


Then we wondered, of course, if the same thing is true of coarse aggregate. So we gathered up some materials of different specific gravity -- on the left you have 2.33 and in the center, normal material of 2.67, and on the right a rather heavy one at 3.58. Each one of these has the identical gradation. If you were to look at the grading on a chart, they would be exactly the same, and the weight would be the same. So, on paper, there would be nothing to tell you that you are dealing with a vastly different quantity of material on the left sample than you are on the right. Next, please.



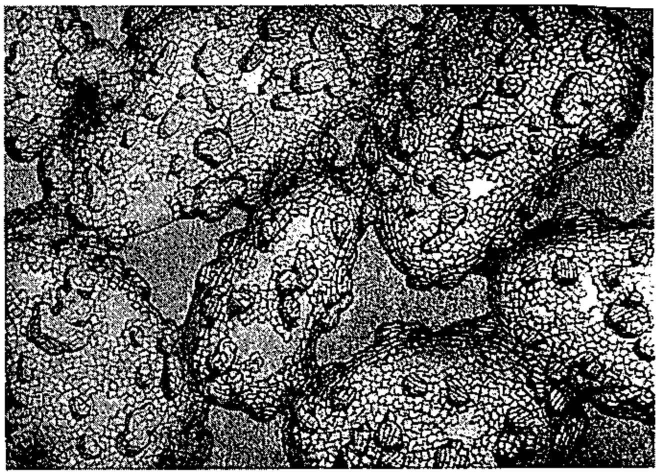


So, just to make the thing complicated, we made up some more samples. Four samples still with the identical gradation, exactly the same percentages in each. This is what happens when you combine materials of both light and heavy specific gravity. I am not here discussing the problems of absolute volumes and aggregate gradation today, so will skip lightly over it, but note that at the bottom of the graduates, the varying volumes of dust which exist, all of which would be expressed as the same percentage say four or five per cent of minus 200 dust. Next, please.



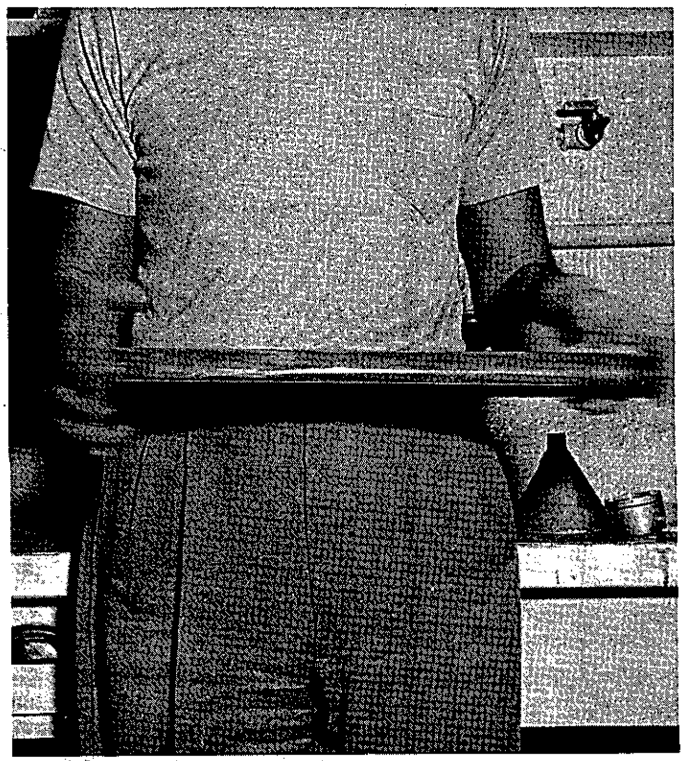
So, pursuing this thing scientifically, we took to reading books about clays and things like that and ran across the work of Dr. Grim and his cohorts, who were investigating the phenomena of molding sands mixed with different types of clay. They examined these through a microscope and made these drawings. This is the appearance of sand grains coated with montmorillionite clay, or bentonite. Notice the extremely uniform, tightly placed coating of these platelettes. They said they could not get a photograph of this so it was necessary to make a drawing, and this is what they could see through the microscope.

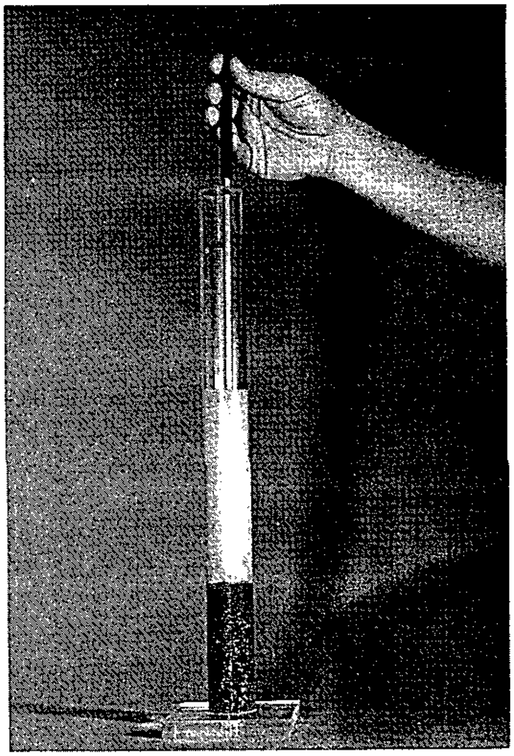
Next, please.



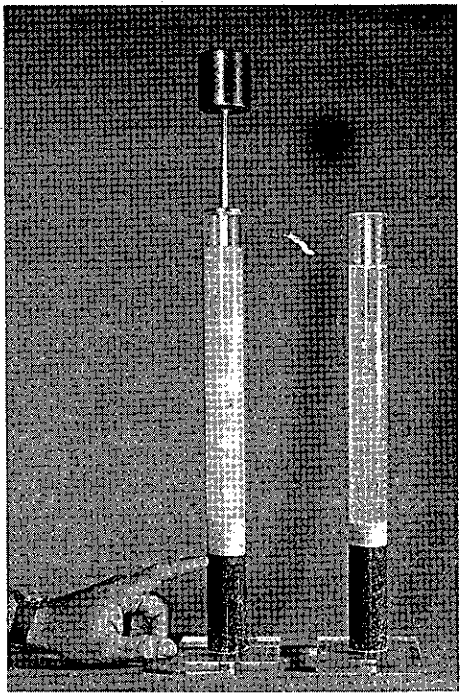
And kaolinite, on the other hand, produced a pattern like this -- the sand grains very poorly covered, irregular and lumpy clay particles. Some of the marked differences in lubricating properties produced by these clays in a mass of sand might seem to be explained by this markedly different appearance of the intimate films of clay on the sand grains.

Anyhow, we are getting pretty long-haired about this so we had better stop and remind ourselves that we must deal with engineers and practical problems; so we decided to get down to earth. Next, please.

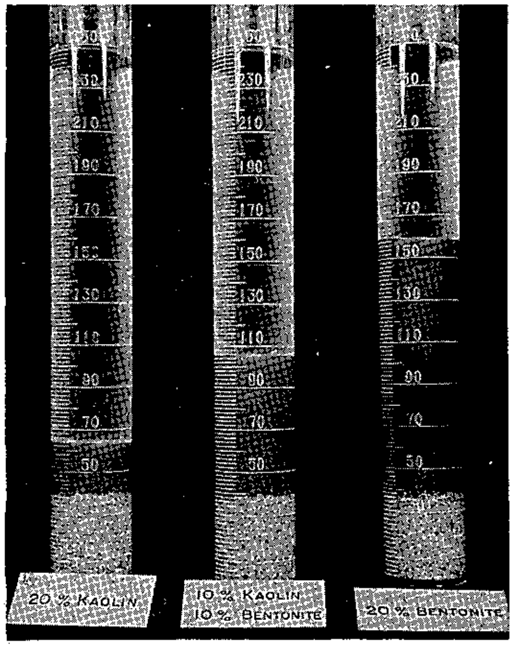




So we concluded that it might be illuminating if we were to put some sand and soil mixtures in a cylinder filled with water and shake it up. A few field men have long been accustomed to putting a handful of sand in a milk bottle, shaking it up and looking at it. So all we added to this technique was a little irrigating tube that we could push down into the graduate with a stream of liquid flowing out of it to flush all of the mud and clay out of sand in the bottom of the graduate and into the superimposed liquid so we could get a clean separation from the sand of anything that would float or stay suspended in the water. Next, please.



Here, you can clearly see a sharp color distinction -- the line of demarcation between the sand layer and the clay, but unfortunately most of the materials we deal with do not have this visible demarcation and by appearance they shade from one gradually into the other. So we decided that "sand" would be anything that would support this weight. We dropped a "depth gauge" with a 1000 gram weight down in through the clay suspension and wherever that weight rested, everything below that was sand, by definition. Next, please.



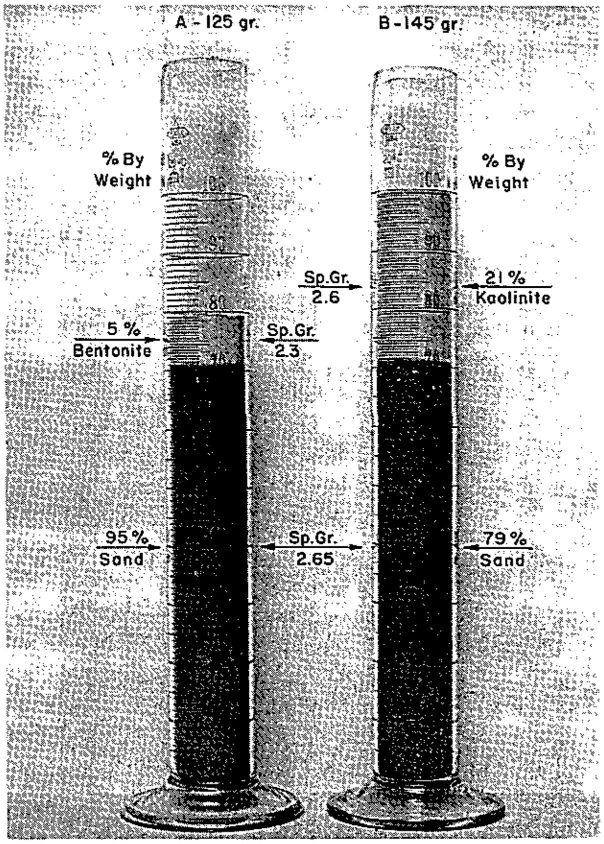
So, remembering about Kaolinite and Bentonite, we took some sand and put 20% of Kaolinite in the graduate on the left, and in the center one we mixed half Kaolinite and half Bentonite, and on the right, 20% Bentonite. Each of these cylinders has the same amount of sand and the same amount of clay in it by weight.

Next please.

This slide shows the relative volumes a little more clearly because of the color contrast. So, these three samples in a solution of calcium chloride in water were shaken up and allowed to settle for the same length of time. Here, it is obvious that with the same weight percentage of clay you get a vastly different apparent volume after a certain period of sedimentation, depending upon the nature of the material as well as the quantity of it.

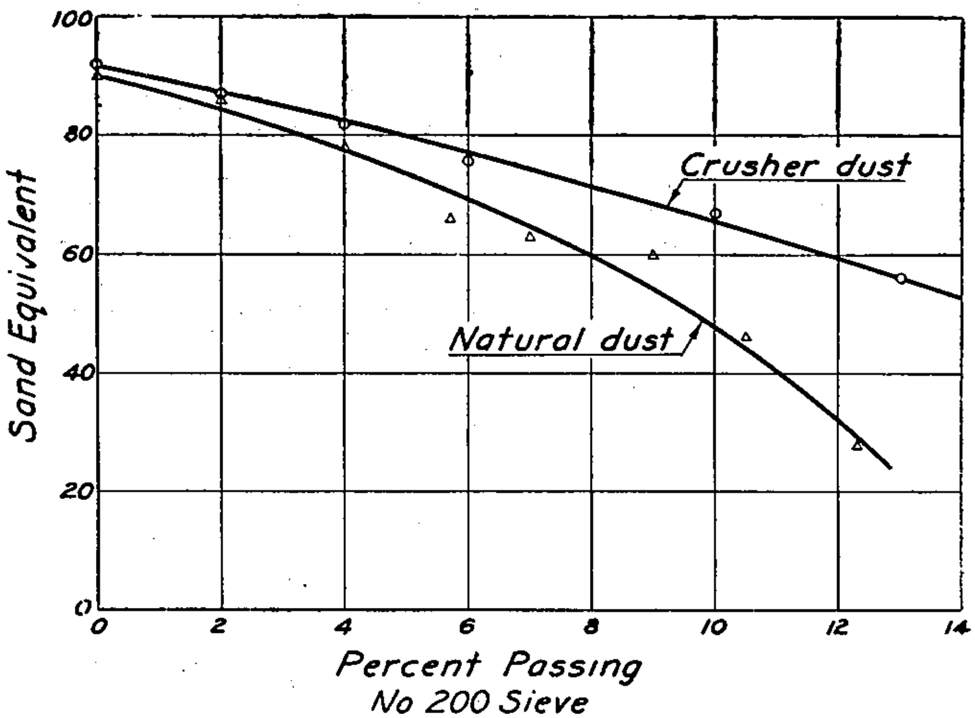
So, at this point you begin to wonder what are the effects of these clays on the sands. We decided we had better run a lot of stability tests to find out. Next please.

Then we discovered that 5% of wet Bentonitic clay mixed with sand would produce the same reduction in stability as would be caused by 21% of Kaolinite. In other words, the lubricating potential of Bentonite or Montmorillionite clay is vastly more serious than is Kaolinite, so it wasn't enough to say that you just had so much clay in there. You would have to have an idea of what kind of clay you're talking about. Next slide please.



Anyway, after we had developed this thing to this point, (we had a test of sorts and had carried our technology on to the high level for which California is famous) we were confronted with a road like this on the main line between the State Capitol and San Francisco. The news about this novel pavement seemed to spread widely over the State - just how it was carried is not clear -- some thought the Portland Cement Association mentioned it here and there, but this of course is just pure suspicion. Nevertheless, there were unreasonable people who came to us and demanded to know why these things should exist. Fortunately, we now had the sand equivalent test so we rushed down and got some samples of the material and showed that none of it would meet the sand equivalent test because the materials from this quarry were coated with a film of clay. We immediately put a sand equivalent requirement in our specifications and the contractor put in a washing plant and washed his material clean so we never had this type of failure again. This job was the occasion for the introduction of the Sand Equivalent test into our specifications.

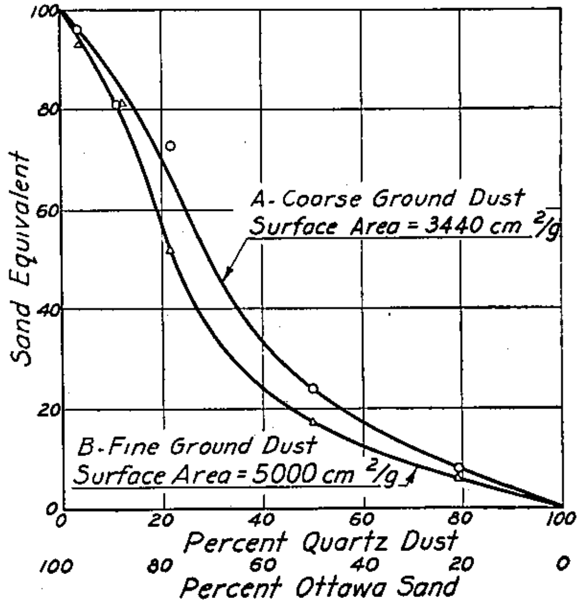
The first slide you saw showed an ordinary Sc2-road oil mixture. This slide shows a job in which 50 penetration asphalt was used, and of course, like most failures, it was not due to one simple cause. This road was put down, rolled and left for two months before it was opened to traffic. The day they turned the traffic on there was a tremendous downpour of rain, and the road had never been sealed up by pneumatic-tired traffic. We now require all of these jobs to have a pneumatic roller on them; but at that time, we did not make it mandatory. Nevertheless, one primary factor was this clay coating on all of the sand grains even though this aggregate met all of the grading analysis requirements in passing #200 and all that sort of thing. Next please.



Effect of dust on the sand equivalent of plant-mixed-surfacing fine aggregate, Sample 52-2745.

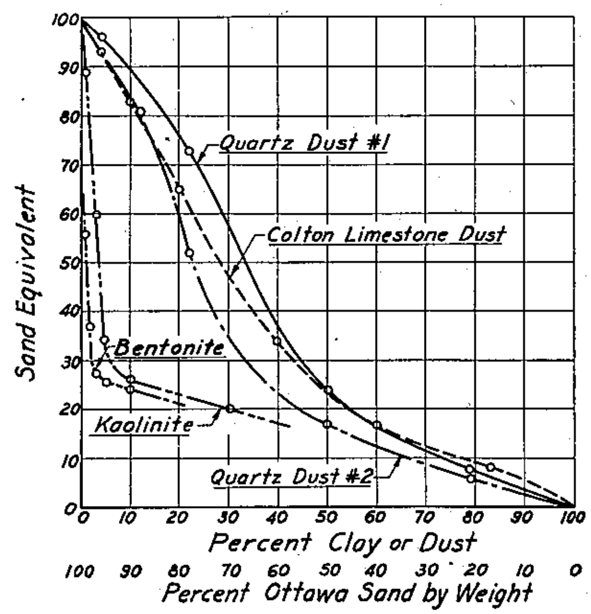
Getting back now to the sand equivalent test -- this slide shows a chart where the vertical scale represents various sand equivalent values and the horizontal scale the percentage of fines passing #200 sieve. You can see that for a given amount, say 10% passing 200, we get a sand equivalent value of about 45 for natural dust, whereas crusher dust in the same quantity passing #200 gives a much higher test value. Here is evidence showing the ability of the test to discriminate between ground rock particles and material that probably contains some clay, organic material, or what have you. Next please.

This slide shows the effects of fineness alone. This dust was made in a laboratory ball mill and ground to different degrees of fineness. The upper curve is dust ground to produce a surface area of 3400 square centimeters per gram, and the lower one is ground finer to produce about 5,000 square centimeters per gram. Referring to the left hand scale, if there is no dust in the sand, you get 100 sand equivalent. Where the entire sample is dust, you get the same value for both, but intermediately you get a distinction in the sand equivalent test depending on the fineness of the dust. Next please.



Quartz dust and Ottawa sand: Effect of particle size on the sand equivalent. (Tests made with ground quartz dust.)

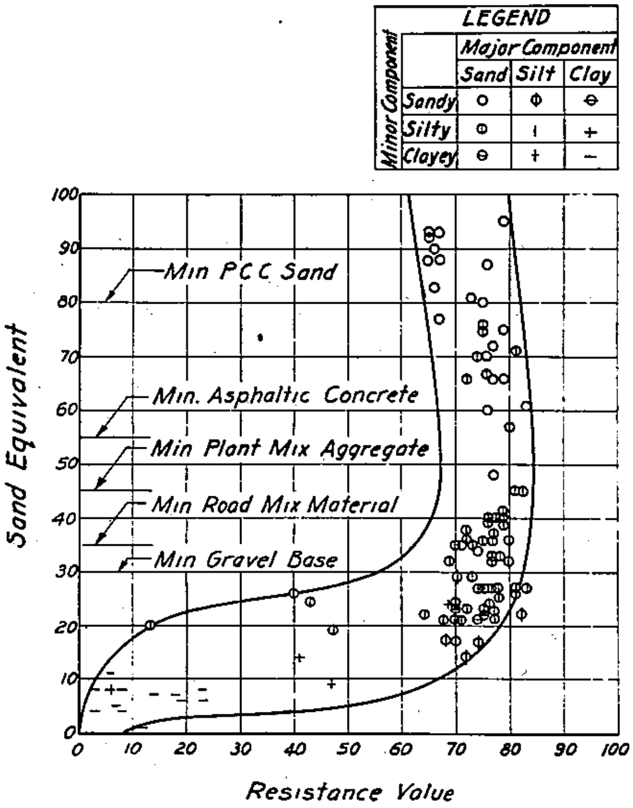
This slide shows much more profound differences. Here we have a variety of materials, including quartz dust and limestone dust. Near the left boundary are the curves for two types of clay, and you can see that as little as 5% of Bentonite will produce a sand equivalent value that is as low as would be registered by 50% of ground rock dust. So here we see the great virtue of the sand equivalent test because the ordinary



Effect of various fine materials on the sand equivalent.

specification limiting the amount of passing #200 makes no distinction whatsoever as to the nature of this traction. Next please.

Dealing with untreated materials for the moment, this is a vertical scale of the sand equivalent values. Horizontal is the Resistance value (R value) from Stabilometer tests, and you can see that, if the sand equivalent is above 25 or 30, the Resistance value is nearly always good. When it is below 10, it is always poor. But in the region from 20 to 25, R values are liable to be anything from good to poor. The very low ones, indicated by the little horizontal dashes to the lower left, are all fine clay-like materials - low in sand equivalent and when met, are invariably low in stability or R value.



Sand equivalent versus resistance value.

The sand equivalent test for crusher run bases and untreated rock bases, loses its definition in the realm of 20 to 25 S.E. value. We set the value of 30 as the minimum for gravel bases. On the left hand scale are typical values that we now specify for different purposes. For concrete sand our present specification is 75 minimum. For asphaltic mixtures we require sand to be in the range of 45 - 55 and for untreated rock 30. Therefore, the test is applied for three different purposes.

This then is an illustration of the manner of performing the test. I have here a typical kit showing the tubes and the apparatus required and we have here a shaking device developed by Leif Ericson of the Idaho State Highway

Department, which is an extremely ingenious device and has the virtue of simplicity and relatively low cost to construct.

We'll now have a break and show the motion picture which will illustrate the techniques of performing the test and I'll follow up with a few slides to show the comparisons between the results in the hand operation and the mechanical shaking. I haven't tried to describe the tests because I thought this film would do it more expeditiously than I can do by talking.

SHOWING OF FILM WITH COMMENTARY BY MR. HVEEM

You are supposed to visualize people loading a sample in a sample bag, hauling it in, throwing it out of a pick-up truck onto the laboratory platform, dropping it on the floor and doing all of these things up to this point. Now, I want to show you what happens in this bag.

Of course, if the Auditor General finds us cutting sample bags like this, we'll probably have to answer to somebody.

You are supposed to note on his right hand -- your left -- the collection of fines in the bottom of the bag compared to the coarse material itself, showing that it is a very inadequate method to dip a scoop down into a bag of material and come out with a small portion of it and run a test on it. This process is absolutely essential to be sure that they are getting samples that are representative. In this case, we sieve the entire quantity. We since decided to furnish him some laboratory equipment, so he wouldn't have to use his pocket knife for this sort of thing. He doesn't show you what he's going to do; he takes it off and puts it in a special tumbler drum, which we use to shake the fines and dust from the sand. This is a subject which I would not want to go into with the laboratory -- as to how do you get all the dust and clay off an aggregate without altering the material. This is quite a subject in itself. At any rate you are supposed to do this. All laboratory men know how, but they all do it differently.

Actually, the only way to do this properly is to take the whole shooting works and wash it, collect all the wash water, dry all the water out, and collect the mud a day or two later. But this is very time consuming. What he has here is an ordinary, small size sample splitter -- riffle splitter. We have more efficient splitters than this, but this is the type that is readily available.

If we are going to check results, we cannot over-emphasize to any one who wishes to undertake to operate this test that you must use care to be sure that the sample you are going to test is representative; if you are going to try to get check results, both of the samples must be taken out as carefully as possible. You have a very small sample for the test, and if it is not representative, you have something that is worse than useless.

We generally attempt to come out with a quantity that will fill four of these little tins. There is no waste in this test. It is based on volumes and an attempt is made to fill these small ointment tins up to the same loose volume of material. This is the kit such as you see here on the table in front. This is the package for shipping to our resident engineers and field men. It contains everything necessary except a large gallon jug for dispensing solutions, a bottle of concentrate with the kit, that is what you dilute with to produce a working solution.

These cylinders are made of plastic. We are not able to obtain glass cylinders that are true in diameter; also these are much more rugged and less subject to damage.

This is supposedly around 36 inches above the table height. He now introduces enough of the solution which is a calcium chloride with a little bit of formaldehyde. The purpose here was to aid in dispersing the sample rather than trying to pour the liquid in on the dry sample. We thought it was more expeditious to pour the dry material down into the liquid where the resulting disturbance would speed up the dispersion and the wetting of the sample.

You are supposed to allow this to stand now for a period of time, according to the test procedure, but these are telescoped in time to represent a 10-minute soaking period. The results will vary with the length of soaking time. If you start out with a damp sample, the sand equivalent results will usually be a little higher than if you start with a dry one. This other man has been doing the same thing. He shows up here suddenly now to show you the difference between the two operators. You see some slow motion pictures of the shaking. They have 90 strokes. You are looking at a timer up there. If you watch the wrist, you will see that the one fellow is much more rapid in the one direction than he is in the other. It is all rather mysterious. We wondered for a while how they could effect the differences - the same number of shakes, done as carefully as possible and yet come up with different answers.

At this point now, the sample is allowed to stand for 20 minutes for sedimentation -- no, I am ahead of myself. He first has to irrigate it, and this brass tube has #60 drill holes bored in at right angles. He washes the material from the sides and churns it around. About the only thing that requires anything approaching skill is this operation of being able to stab down through the sand, twisting the irrigator tube as you have to wash the sand clean of all clay and get it out before the graduate is filled up beyond the 15-inch mark. It is certainly by no means difficult, but the washing must be accomplished with this amount of liquid. It is brought to a precise level and then set aside and allowed to stand for 20 minutes... so if you will compose yourselves now for 20 minutes.

This time is purely arbitrary; it might have been anything. These are actual photographs of this sedimentation, but speeded up. The strength of the solution is quite important. It must be maintained to standard because the ultimate height of the sedimented column will vary depending on the strength of the solution also, the water used should be free from any other salts or alkalis. Distilled water is, of course, preferable. First, note the top of the column of clay suspension. The operator makes a note of the height, and then drops in the depth gauge which has a circular foot of one square inch area -- 1,000 grams of weight on it, lowered until the sand supports it. This is a very definite point. It is not at all a delicate evaluation. When the depth gauge comes to rest, you can't force it down by hand. There is usually a silt layer transition between the clay and the sand. The gauge will sink through that until it rests on sand.

You can readily appreciate that what we're talking about here is the volume relationship; but it is only the volumes under the conditions of this test. The volume of water occupied by the clay after the end of the 20-minute sedimentation, which is a function of the flocculation rate of the clay, i.e. whether it is peptized or not, and the response to the media in which it is settling. The particle size and the quantity -- all of these things are integrated by this one operation. The strength of the solution was adjusted so that about 5% of Bentonite would give about the same sand equivalent reading as would 20% of Kalonite. That was indicated to be about the equality between these two clays in terms of their potential detrimental effects. This scene shows the difference between the two high and low sand equivalents.

This test was picked up by the French Department of Parts at Chavesees. We built this shaker in California. I was attempting to improvise something; so here are two old automobile piston pads turned upside down, mounted on the connecting rods with a motor agitating them.

I thought it was pretty good, but our boys weren't very enthusiastic about it. It was a little bit heavy; so when the French Department, picked up the sand equivalent test, they thought well of it, and put it to use in all districts. In one of the Highway Departments in France, an ingenious individual, came up with a shaker, and Monsieur Peltier sent us pictures of it. So we promptly invented the French shaker and built it in our own Lab. This is our version of the design which was developed in France. So this is a good example of reciprocity and "hands across the sea". We developed a test, they adopted the test, developed the shaker and sent it back to us; so we build it. We have all of our district laboratories equipped with this shaker. It is a very nice running piece of equipment; but due to the cam action, it produces a sort of sine curve. There is no abrupt reversal at the end of the stroke, so this apparatus is much less severe than the hand shaking. You have to make about 120 throws in this machine to give the same results that they get by ordinary hand shaking at 90. These shots give a picture of the action inside the tubes.

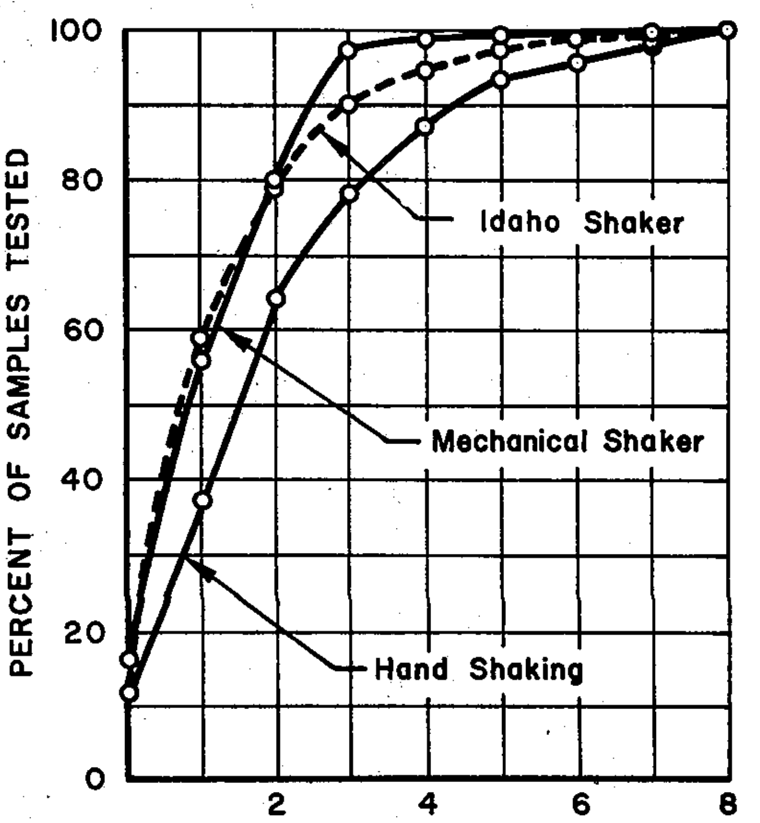
This is quite uniform. The results are reproducible, and our modern young engineers like this sort of thing as there is no particular effort involved.

But Leif Ericson up in Idaho decided that $365.00 for this mechanical shaker is a little too much, so he comes up with this. You just simply have to agitate it; then all you have to do is to watch it and maintain your throw about the same each time. We promptly adopted this one and have built about 50 or 60 of them, and are putting them out for our field men. The cost is low enough so we can afford to put one in the hands of each resident engineer where he has to have one. It irons out, considerably, the variability in the hand method. This is the device he's setting up on the table here if any of you wish to inspect it more closely, later on.

End of Film Commentary

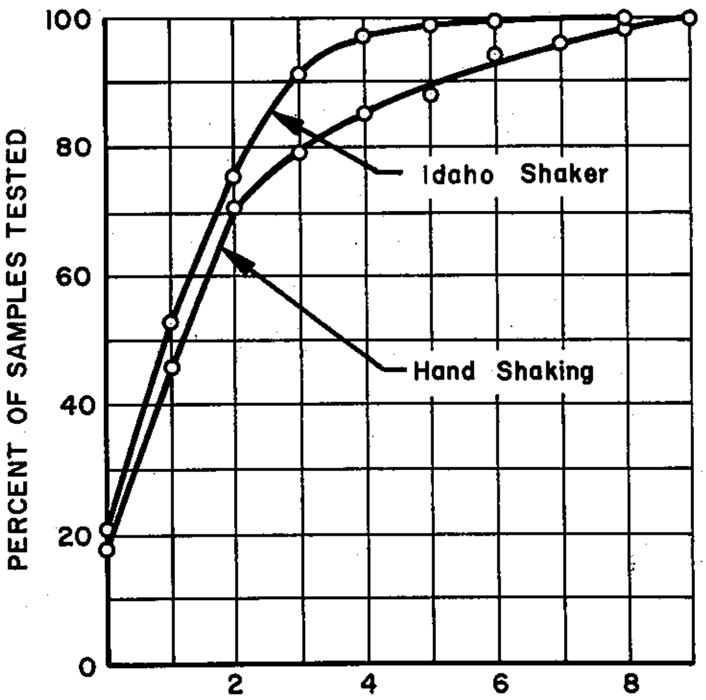
We have a few more slides now to show you some correlations between the hand operation and the mechanical devices, so that you can see what the factors of correlation may be. I hope you will bear with me jumping back and forth from slides to motion pictures and back again. These slides were made up primarily to present at this meeting. Next slide please.

Here you see the curve showing the differences -- the hand shaking series; and then the one to the left -- the mechanical shaker; then comes the Idaho shaker, showing that there is a slight variation in the results of Idaho shaker



MAXIMUM DIFFERENCE BETWEEN HIGH AND LOW S.E. VALUES OBTAINED FROM THREE REPRESENTATIVE PORTIONS OF SAMPLE TESTED

which is somewhat intermediate. Assuming that results in the mechanical device are reproducible, you can see the definite improvement by either of the two mechanical devices as compared to the hand shaking. The differences are not profound, and an individual shaking by hand can produce quite acceptable results. Next please.



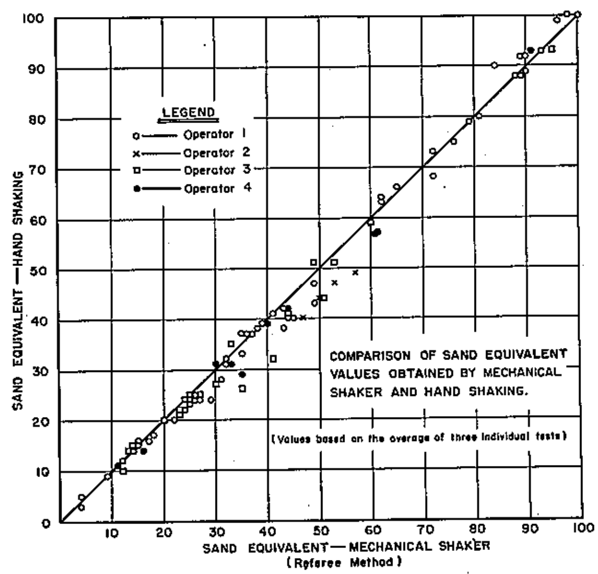
MAXIMUM VARIATION FROM SAND EQUIVALENT VALUES OBTAINED BY REFEREE METHOD.

(Values based on the average of three individual tests)

Here the comparison between hand shaking and the Idaho shaker alone. Note the improvement here in the variations. It is based on an average of three individual tests in each one.

Next please.

This is a correlation between the mechanical shaker shown on the horizontal scale, where the ordinate is the sand equivalent by hand shaking. The points range all the way from sand equivalents represented by the very low values on the left, mostly pure clay, up to practically clean sand on the right. There were different operations, and some operators come closer to a check than do others. What we're now doing in California is that each operator, who must operate this by hand, checks himself against the mechanical shaker and finds out whether for his particular technique he should shake it 85, 90, 95 or 100 times, whatever he has to do to bring himself into better agreement with the mechanical device.

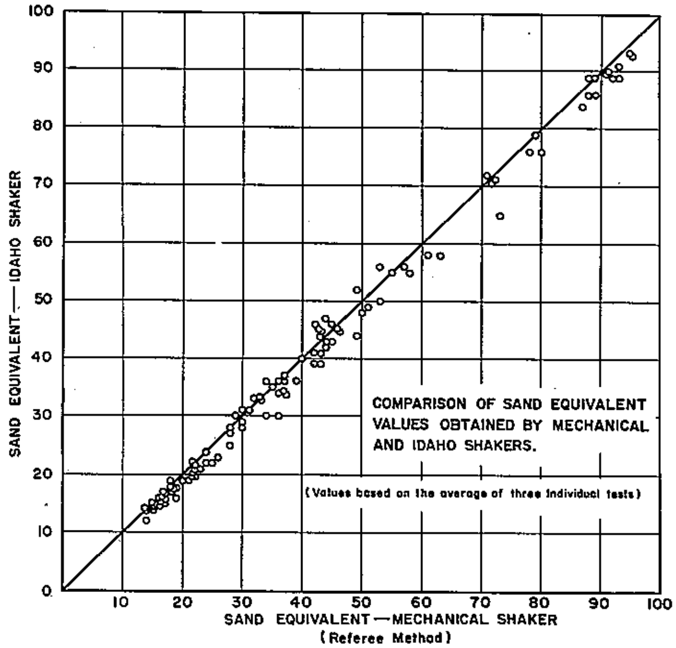


COMPARISON OF SAND EQUIVALENT VALUES OBTAINED BY MECHANICAL SHAKER AND HAND SHAKING.

(Values based on the average of three individual tests)

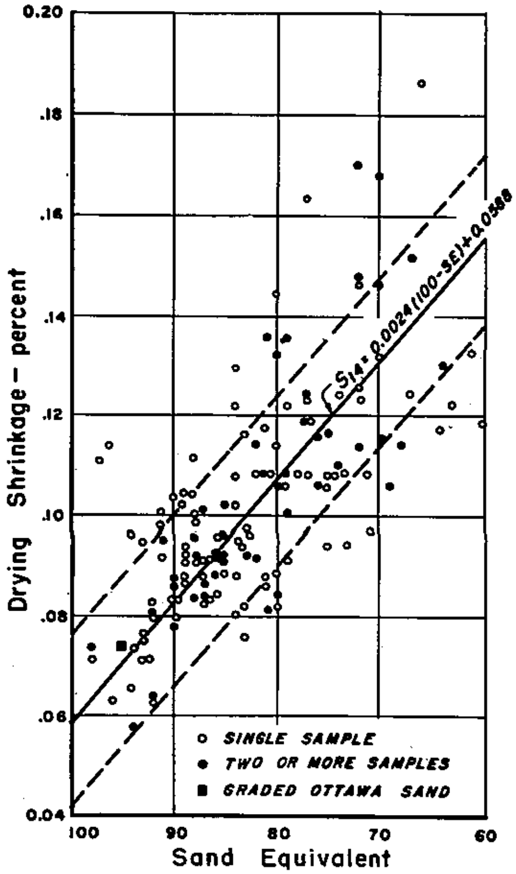
Next please.

This is a comparison of the mechanical shaker against the Idaho device. It gives a little closer comparison all the way down the scale. For all practical purposes, this agreement is excellent.



Next please.

While this is out of the realm of the hot-mix industry, just to show you the correlation that exists between the sand equivalent and the drying- shrinkage of concrete sands. This is a very good correlation showing the sand equivalent horizontally and the increase in drying-shrinkage vertically. There are other factors that increase shrinkage but this relationship is so marked, that we are now requiring that all concrete sands meet this test in order to keep our volume change and shrinkage under control.



Sand Equivalent versus drying shrinkage.

I think that is probably all the slides now, and I imagine I have about used up my time.

QUESTION AND ANSWER PERIOD

(QUESTION FROM AUDIENCE): How does this method compare with hand washing?

(MR. HVEEM): I don't know. We got into the question of cleaning up coarse aggregate for concrete a year or two ago in which the specifications say it shall be "agitated vigorously". So we got some of these rocks into the pan and agitated it vigorously, washed it, and got 3% of dust. We put the same rock back in again, agitated vigorously, and again got 3%. We kept this up until the boys were worn out... ending up with 18% of wash material, getting 3% every time they did it. Then we decided that we had better standardize the test, so that now we do all the washing in a metal pot on a Tyler sieve shaker to get away from this personal equation of shaking. I don't know how this agitation would compare with any other method. We were rather greatly surprised to find out how much difference this shaking can make even within the frame of reference of 90 strokes in the Sand Equivalent Test with the distance carefully regulated; and still certain individual operators would make consistent differences.

We first started out with the idea that we wanted to break down all the little clay balls and get everything off the stone or sand grains. It is just the idea of getting all clay and soft particles out of there. The first operation was a hand rammer -- a little piece of steel, 1/4-inch wide on a rod. We churned down through the sand with a great deal of vigor and energy using the tamper or "pestle" with a most strenuous action. I was quite sure we had ground everything up, and I had to be convinced by quite a bit of evidence that just simply shaking this cylinder back and forth would break the materials down more than we were able to do with this steel rammer rammed down in by hand. So I have acquired a hearty respect for the degrading effect of this shaking action. We have to face the fact that, whether we can explain it or not, this is a most potent way of cleaning up and breaking down the materials. I still don't know how this compares to any of the more orthodox methods.

(QUESTION FROM AUDIENCE): Maybe I should clarify -- I'm talking about preparing the methods used here for cleaning up the aggregate, and how we contractors are going to meet that?

(MR. HVEEM): Oh, well, you just put in a washing plant, and if one washing doesn't do it, then you run it through and wash it again.

This generally does it. Down at Oceanside, where we have this sort of thing, the producer had a regular washing plant; but the product didn't meet specifications, so then he put in another one. Now he's getting by fine. There is no problem.

(QUESTION FROM AUDIENCE): Instead of being scientific all the time, how can this stuff help the contractor make more money in his business?

(MR. HVEEM): You know, Charlie Foster wrote this question back to me, something like this, and I've been studying ever since how I could come up with an answer. I think the only thing I can say is that I don't know. I don't think there is much doubt that the people who are buying the hot-mix can save some money, and what this will actually mean to the producer is difficult to say.

I think actually that this is almost entirely a question of the quality of the final product, and all of you dealing with asphalt are aware of the fact that there is nothing to equal dust as a means of inhibiting the adhesion of asphalt.

One analogy that occurs to me is the practice of the Asphalt Industry in shipping air blown asphalt where they take a paper bag, coat the inside with clay and pour this hot asphalt in at high temperature. They are able to strip the paper off cleanly without any adhesion at all simply by coating with Bentonite, or some other clay-like material. As an inhibitor against adhesion, I think that a film of dust is the most effective means known, and this is what we are trying to eliminate.

The sand equivalent test has been applied in our State for three distinct purposes: (1) for untreated rock bases in order to avoid the presence of lubricating fines creating an unstable base; (2) for the asphalt mixes, it is used to detect the presence of fines that are likely to exist as a coating on the coarser grains, and (3) to prevent adhesion and cause stripping. We have had in California three serious failures. You saw pictures of two of them here. We had a third one near San Diego where a whole section went out, traceable simply to the fact that all aggregate particles were coated with a tenacious coating of clay-like material. We probably have had others we did not identify.

And finally, for Portland Cement concrete materials, we showed you a definite correlation between the expansion volume change of the concrete as against the sand equivalent values for the sand and against the cleanness values for the stone.

So, there are three purposes for which we use these tests.

(QUESTION FROM AUDIENCE): I wonder if this putting-in of water-washing equipment hasn't been exaggerated. It is my impression that practically any crushed stone will meet this without washing. Many of your local sources make it without washing. I just kind of think that this particular point has been exaggerated beyond truth, and I would like to get some comments from you or from some of the other people here who know about it?

(MR. HVEEM): Well, I think that it is definitely true that crushed stone from any quarry on massive ledge rock should present few problems at all. We did run into trouble in one case where a commercial plant was producing sand through a tube mill and were breaking up half-inch stone. The sand they produced by this would not pass the tests, and I can still remember the feeling that went over me when I saw the results. I feared that maybe we had really pulled a boner at last, but when I examined the stone carefully we found out that they were dealing with the clay cemented sandstone. When we ground up this sandstone, the clay that had served as cementing agent since was apparently just as active as it ever was. There was no doubt about the material being adverse even though it was produced by breaking up rocks. It is possible to grind up stone into sand grains and produce very adverse fine fractions, but this is rather rare. There is only one area in California where this occurs, but the majority of our crushed stone products are clean gravel and are no particular problem. We have large areas of the state in which this is no problem at all. They meet the test without any difficulty whatsoever.

For those of you who are interested, we have -- I believe they are out in the lobby here -- some samples which I brought along representing this fine dust which remains in suspension after this test was accomplished. Many of you might like to see just what we're talking about. Some of these have been wetted up so that they're paste-like, and others are dry.

If anyone here who is interested in good hot-mix work will stick his fingersin that mud and rub it around and then stand up here and say this won't hurt an asphalt pavement, I'd like to see who it is.

(QUESTION FROM AUDIENCE): Mr. Hveem, I would like to ask one question. Up in your sand equivalent of 79 or 19, I believe, would you try to tell us where the good is?

(MR. HVEEM): Well, 79 would be the clean sand -- that is, a very good sand for Portland Cement concrete. It would be better than 75, so 79 would be virtually clean sand with nothing of any sort involved. 19 is definitely low. We think that for a stone base, gravel base, or anything of the sort, it should not go below 30. The State of Arizona tried out this test and made hundreds of tests. I think they ran over 500 of them on which they ran the PI, and the percentage passing 200, and the sand equivalent. I have a copy of this report. Wayne O'Harre presented it a few years ago, if any of you are interested in that correlation. They concluded that the test did put the finger on nearly all of the materials with which they were having trouble.

For road work - for asphalt mixes - we have allowed as low as 45, for our better hot-mix jobs about 55. The specifications, I think are set very close to what are considered acceptable limits.

Arizona, by the way, thought that we should set the sand equivalent value at 35 rather than 30. They thought we were being a little too lenient, but these are moot points. There are no absolutes involved here. It is a matter of opinion or judgment what you would want to require.

(QUESTION FROM AUDIENCE): First, may I help with an answer as to what this means dollar-wise, as a contractor. Two examples: One on the Garden State Parkway - on black base construction we ran into a pit, called Devil's pit. We had just exactly the conditions there he described; and if you don't think that contractor had to spend some extra money because the engineers nor the contractor recognized why he was having difficulty both in the plant and lay-down. Running these tests ahead of time would have saved many headaches for the contractor and for the engineers.

Another example that happened to us out in New Mexico around Gloriette, where a section of the interstate went bad in one winter, caught everybody -- the owner, the contractor, the engineers; so these things, when used, do save everyone money.

(MR. HVEEM): Thank you, Warren. I think this is definitely to the point for any responsible industry in putting down materials of this sort, you can be very much misled by the ordinary methods. One point, I touched on here briefly, and which could well be elaborated on is this question of volumes of material. All engineering specifications today are based upon weight, but the weight which is expressed in a sieve analysis is most misleading; and you may have a mixture which says you've only got 6% minus 200 mesh. Unless you know what this 200 mesh is, this may be a quantity that will upset the mixture seriously; and I'm afraid it's not too well known, at least I'm expressing

California conditions. Our own people are too often unaware that, whenever you have a fraction in the dust area that is abnormal, it affects the sieve analysis of every fraction in the coarser sizes. This is always not recognized. So you can have two materials in which the sieve analysis, as ordinarily reported, may appear to be identical and yet be actually very different. The quantities of asphalt and the stability can be profoundly affected so, as I gather, that one of the prime interests of this group is in turning out a product which they can stand behind and guarantee, I think you can strongly urge that this is a type of information that is easily obtained, quickly run and likely keep you out of some very serious difficulties. If that's a method of saving money, I think that's the way it should be done. I probably should say too that when we developed this test we were thinking about imported materials out of borrowed pits, sub-base materials etc. where there is the practical impossibility of our engineers making the conventional tests fast enough. We were trying to develop something that would permit us to grab a sample out of every truckload that went by and find out whether we were getting too much clay or mud so we could do something about it while the job was going on. This was the motive when we started work on this test.

(QUESTION FROM AUDIENCE): Just one more question. You say that the main thing in developing this test was ravelling, and may I ask how this would eliminate gravity at other points?

(MR. HVEEM): I don't think that -- of course you saw that one slide of this road that was "potted out" and gone to pieces -- could be classed as extreme ravelling. Actually this is a problem we're not having any longer. I can't think of a job for several years where we've had anything of the sort, and the problem of unstable pavements is something we're not faced with any longer either. I tried to find out from the boys in the laboratory the last time when they had seen one of our jobs that were definitely unstable where there was no slip up or something and where something didn't go sour with the plant scales (which can happen) but otherwise I think we've got this problem behind us. On the problem of raveled pavement, I don't think we've had one, recently; so how much of that is due to this test and how much is due to better all around control is a little difficult to state. We have had our problem, like everybody, because every hardheaded construction engineer and resident engineer is quite sure he can look at a mix and tell how much asphalt to put in it. We've run tests and made laboratory recommendations and he decides "that looks too wet to me, let's cut it down", or else "let's put some more in it" if it looks dry. We finally managed to get a letter out over the signature of the Chief Engineer to the effect that it was as much as his job was worth if they fail to follow recommended asphalt contents; so now they're putting in what we say, and I think, by and large, the results are better.

(QUESTION FROM AUDIENCE): Mr. Hveem, is it a practical process if washing is too costly and your sand percentage is -- can you stay within your sand percentage to import a blend of better sand and blend with your sand material and stay within your grading tolerances and get you a good sand equivalent?

(MR. HVEEM): Oh, yes, it would be possible to bring material within specification by importing a clean sand. This has been done. Also, it's been possible to remove excess dust by operating a drier to blow some of this dust out of it; but, unfortunately, this sometimes works two ways. We've had cases where the drier apparently removed the very fine sand and left the clay fractions clinging to the particles. If there's moisture in the aggregate, there's a good chance you may bake the clay on and really aggravate the situation. So, whether or not the process of drying and blowing the dust out will reduce the sand equivalent depends a good deal on the particular material. We've had it work both ways.

- END -

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