Effects of Time and Temperature on Hardening of Asphalts

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●EVER SINCE asphalts have been used for any engineering purpose it has been recognized that in order to apply the material as a surface coating or as a cementing agent in paving mixtures the material must be liquefied by some means. One means of accomplishing this is through the dilution with a more or less volatile solvent to form the so-called cutbacks. A more recent technique is through emulsification. By far the oldest method and the one still most widely used is to liquefy the asphalt by elevated temperatures. However, heating of the asphalt alone is ordinarily not sufficient for manufacturing paving mixtures. The asphalt content is usually less than 10 percent of the total and the specific heat of the asphalt is low; therefore, it becomes necessary to heat the aggregates as well as the asphalt, and so far as paving mixtures are concerned it is the temperature of the aggregate that is of most concern to the engineer.

It is not particularly difficult to heat the aggregates sufficiently to permit thorough mixing or coating with the asphalt, but unfortunately all asphalts harden very rapidly when brought into contact with a surface of solid materials heated to high temperatures. Therefore, one of the principal requisites for getting the best results from asphalt pavements is the control of plant temperatures. The aggregates must be hot enough to permit mixing and spreading and compacting on the street after the haul from the plant, but they should never be hotter than necessary to accomplish these purposes. It is also true that paving asphalts vary considerably in their susceptibility to being hardened.

Figure 1 illustrates the drop in penetration that occurred with two different asphalts. The dashed line represents a 50 penetration California asphalt showing the drop in penetration that resulted from different temperatures in the field mixing process. The solid line was taken from a report by J.G. Schaub and W.K. Parr presented at the Montana Bituminous Conference in September, 1939. Here an 85 penetration asphalt shows a relatively linear relationship, the penetration of the recovered asphalt varying inversely with the mixture temperature. The difference in penetration between these two asphalts after mixing at 350 F illustrates the reason why certain states began to use softer grades of paving asphalt some 20 years ago. Although all grades and all types of asphalt appear to harden under these conditions, the softer grades begin their service life at a higher penetration than where an initially harder grade is used.

Figure 2 is a curve taken from the paper by Schaub and Parr showing the effects of mixing time on the penetration of the recovered asphalt. While a smooth curve is drawn between the points, the penetration after 30 seconds is nearly as low as was found after 150 seconds. This same trend is illustrated by Figure 3 which represents two different California asphalts, one having an initial penetration of 170 and the other an 85 pen. In this case, the penetration was little if any different after 5 min of mixing compared to the hardening that occurred in 1 min. These curves and other observations generally support the opinion that the hardening of asphalt occurs very rapidly as soon as the material is brought into contact with the heated surfaces of the stone particles. This may be due to some rapid evaporation of volatiles but it seems more likely that it is also an oxidation phenomenon.

Most studies of asphalt hardening (like the data shown on the first three charts) involve the recovering of the asphalt from the paving mixture and then making penetration tests. However, there is considerable question whether a drop in penetration necessarily implies a corresponding loss in quality; therefore, California has developed an abrasion type of test which is intended to evaluate brittleness. It can be shown that two asphalts of the same penetration may vary considerably in brittleness as represented by the loss under an abrasion type of test. Figure 4 shows abrasion loss in grams of Ottawa sand mixtures prepared in a controlled laboratory mixer at two different temperatures. These curves show clearly a much greater brittlemess and susceptibility

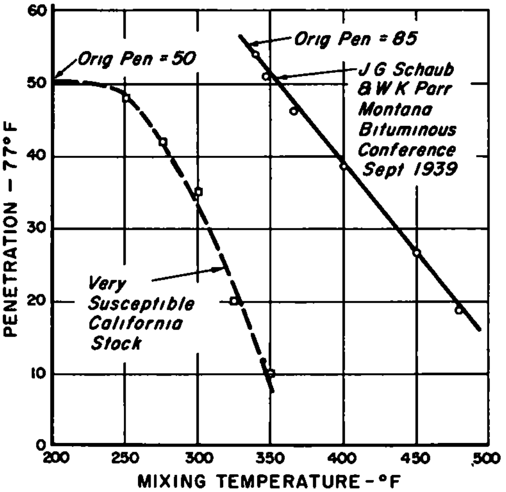

Figure 1. Relation of mixing temperature of bituminous concrete to penetration of recovered asphalt (curves from field mixer studies).

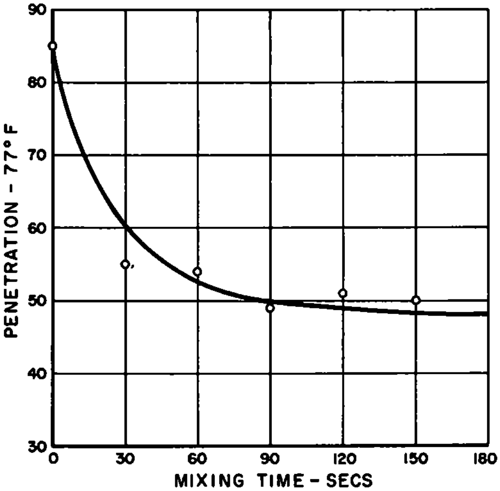

Figure 2. Penetration vs. mixing time, plant-mixed bituminous concrete (from J. G. Schaub and W. K. Parr, Proc. Montana Bituminous Conf., Sept. 1939).

to abrasion in the mixture prepared at 345 F compared to the one mixed at 270 F.

Thus far, the effects on the asphalt during the relatively brief mixing periods at elevated temperatures have been considered. It is also known that asphalts harden after the mixture is placed on the road, but in most regions it is not often that the temperature of the pavement will exceed 140 F. Figure 5 shows four curves where the abrasion loss is plotted against the curing time in hours at 140 F. This curing time is intended to simulate hardening conditions on the road. These curves show

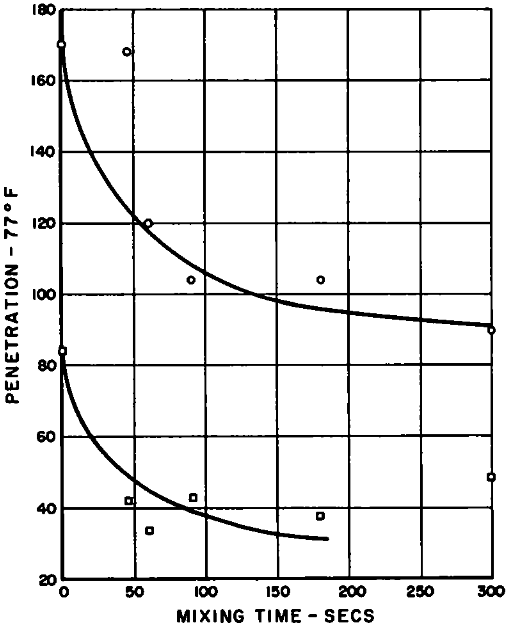

Figure 3. Penetration vs. mixing time VI - kern - 4 - C both asphalts from same production source sampled from field mixer.

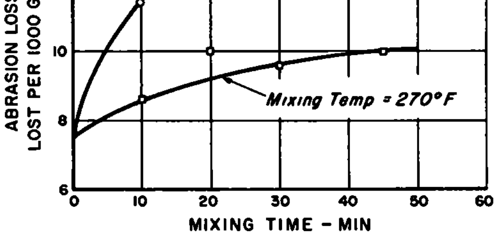

Figure 4. Relation between abrasion loss and mixing temperature laboratory mixer asphalt A, 85-100 grade.

clearly that the rate of hardening under atmospheric temperatures after mixing is virtually unaffected by the amount of hardening developed during the mixing cycle. More extensive studies have confirmed the evidence that there is no fixed relationship between the susceptibility of asphalts in the mixer at high temperatures and the changes that may take place on the road at atmospheric temperatures.

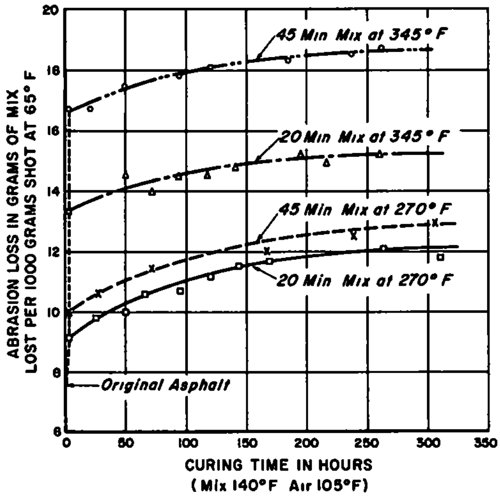

Figure 5. Weathering curves for the same asphalt mixed with Ottawa sand for various times and temperatures in a laboratory mixer asphalt A, 85-100 grade.

Discussion

W. B. Warden, Miller-Warden Associates, Swarthmore, Pa. — I concur with the data and our information supports it.

This matter of just what 75 sec and 150 sec means, and how realistic these limits are, has never really been answered. A research program for that purpose has been suggested to a group in North Carolina, and it is hoped that over this next year some facts will be evidenced to show the relative validity of both the 75 and the 150 limits.

Have you considered when we talk about the viscosity required for mixing that the filler has a great deal of effect? There is the so-called balling effect, or the fact that the asphalt first picks up the fines in a mix, creating a filler mastic or mortar. Coarse aggregate is coated with this mortar, not asphalt.

It takes but little filler to increase the viscosity of asphalt tremendously. A great deal depends on the nature and fineness of the filler, and some observations along those lines are to be presented at the AAPT meeting in Denver. When considering just what viscosity is optimum for mixing, the filler variable must not be overlooked.

In regard to mixing time, the data show that from a quality viewpoint the damage is done very rapidly at any given temperature. Therefore, from a quality viewpoint, it would seem that mixing time is not as important as temperature.

On the other hand, in Figure 5 there was considerable difference under properly controlled conditions, showing that there is a time effect. It is logical from this fundamental concept that this reaction should be a time-temperature reaction. However, mixing time is an important factor from an economic viewpoint in addition to the direct expense of additional power, heat loss, labor, etc., the amount of production time itself can be significant. A difference of 10 seconds mixing time on an ordinary 3-ton mixer can amount to a difference in production of 350 tons per 10-hr day. With a 100-day normal production season, that amounts to 35,000 tons per season or enough to pave 23 mi of 24 ft wide, bituminous concrete, 2 in. thick. Therefore, mixing time can be a very important consideration and should be held to a minimum, commensurate with the proper coating of the aggregate.

Mr. Griffith, The Asphalt Institute. — Mr. Warden introduced one concept that may be a little misleading, and that is in the filler being taken up with the asphalt. There is usually a dry mixing compartment in which the filler and asphalt mix together. It seems inconceivable that the filler immediately lodges on all of the aggregate and coats it from that point on. I think it is not nearly as severe as pictured.

Mr. Warden. — Some very careful work recently conducted by Barber-Green shows that the balling effect is real. Balls of mortar as big as one's thumb or as big as a walnut can be separated from the mix after only 5 to 10 sec mixing, with the larger particles essentially uncoated and the bulk of the asphalt tied up by the fines.

There is additional support for this concept in the laws of probability. The surfaced area of the minus 200 particles in a normal surface mix will amount to about 70 percent of the total surface area of all the aggregate in the mix. The surface area of the minus 10 material will amount to about 90 percent of the total surface area of all the mineral aggregate present.

Therefore, through the laws of statistics, it is probable that the greatest area coated would be the most prevalent area, which would be the fine material, and we have observed it from test.

Mr. Hveem. — One of the things observed in the West is the experience of mixing aggregates with liquid asphalt similar to SC-2 where the asphalt contents were often very low, as little at 3 percent by weight. In all of the cases where there was a deficiency in the amount of liquid asphalt, it was observed that the fines in the pug mill pick up the asphalt and get coated first. Therefore, I support Mr. Warden's statement; and this means that at some stage in the mixing there is actually a heavier coating on the fine particles than on the coarse.

For some years I have been having a controversy with Harry Nevitt, who insists that each particle in the mixture takes on a coat of asphalt proportional to the particle size or diameter. He has mathematical expressions to demonstrate how this must be true but as I do not understand mathematics I do not believe it.

Nevertheless, I think Warden has brought up an important point. His point is that the introduction of filler increases the viscosity of the asphalt. Therefore, as the filler is incorporated in the asphalt you will have a much more viscous liquid to be spread over the coarser particles.

I think that this practice in the East of first dry mixing and then wet mixing is an economic waste. So far as I know, in the West there is no dry mixing. The aggregate and filler is dropped in the mixer, followed immediately by the asphalt, and I question the need for this dry mixing operation.

An extra 10 seconds in the mixer is an important matter so far as mixing costs are concerned and anyone ought to study the results very carefully to see whether dry mixing is necessary before any money is spent for it.

Mr. Warden. — With respect to the discussion on the pros and cons of dry mixing, we feel that the primary purpose of dry mixing is to heat the added mineral filler by giving it some time for contact with the hot aggregate from the bins prior to the asphalt addition. Thus we have long recommended a dry mix time of about ten seconds for surface course or other mixes containing an appreciable amount of added mineral filler but no dry mix time for binder course or other mixes which normally do not involve the incorporation of cold added mineral filler.

We, therefore, find ourselves in an intermediate position between West Coast practice and East Coast practice, basing our recommended operating procedure on the requirements of the mix rather than on location.

Bruce Weetman, The Texas Company. — Mr. Hveem showed the effects of mixing time on asphalt hardening. What is the consideration given to the hardening in the truck, and then transportation to the road? I am talking about a minimum in the mixer, and yet the mixture stays in the truck for 35 or 40 min before it gets to the road and is spread.

Mr. Hveem. — Well, actually, I have no definite data which will answer your question. We have recovered asphalt from mixtures taken from the road but there was no evidence of continued hardening which is assumed to be due to the fact that the bulk of the material is enclosed in a mass and is considerably away from air. This is a conclusion based on observation and is somewhat in the form of a supposition as the mixture has not been followed step-by-step from the plant to the finished road surface.

Mr. Weetman. — We have data that tend to confirm that particular point.

Mr. Hveem. — This is a question of the proper setting or establishment of the mixing temperature. How are you going to fix a standard mixing temperature for asphalt plants where in one case you are mixing in the middle of the summer with the thermometer around 100 F and in another case in the late fall (when you should not be doing the work anyhow)—how can you employ the same temperatures for such widely varying conditions? In our case, all that can be done is to instruct the field men to mix at the lowest possible temperature—and hope that they will do it.

Mr. Weetman. — Mr. Warden was advocating minimum mixing, and I would like to put in a word of caution against it. You have seen roads that used the minimum mixture temperature (that is, 30 seconds total mixing), and looked fairly good, but just went to pieces, primarily on account of the low mixing temperature.

I would rather sacrifice 1 or even 10 points of penetration to get a good road, and a poor mix has not performed satisfactorily in service.

Mr. Warden. — You raised the point on which we do not have sufficient data. On the other hand, it must be recognized that stripping phenomena are subject to many additional factors—the nature of the aggregate, the nature of the asphalt, whether or not an additive is being used, etc.

In a discussion with Mr. Hveem, I offered the concept that when the coarse aggregate is coated, the mix is properly mixed. He said: "Why wait for the coarse aggregate to be coated?" He has laid materials where the aggregate is not coated in the mixer, but was coated by the time the material was down for a day. He said, "We cannot see any difference in performance."

My point is that in this matter of adhesion with respect to stripping resistance, we have to take into consideration a great many other points.

Mr. Campen. — Mr. Hveem in his part of the discussion made the statement that it is not necessary to coat all the aggregate in the mixer, because the lay down operations will finish the mixing. I am in complete disagreement with the statement. The lay down operations do not accomplish any intimate mixing; that is, they do not disperse the asphaltic cement on the surfaces of the aggregates.

The lack of asphalt on the surface of the larger particles (the larger particles coat less easily than the smaller ones) is due to one of two reasons. Either the asphaltic content is too low or the particles are not dry. The former condition can be corrected by adding more asphalt. The only safe way to correct the latter condition is to continue the mixing until the aggregate particles are dry. If complete drying cannot be accomplished in the mixer, either the dryer will have to be made more efficient or the aggregate rejected.

The lack of proper coating in the mixer is an indication of improper conditions. Therefore, rather than expect the lay down operations to do the impossible, it is much better practice to find the source of the trouble and take steps to correct it. It is much more economical to spend a little more in preparing the mixture than to maintain the pavement thereafter.

Ward K. Parr. — We find an insignificant loss in penetration during the hauling period. You have the area of the air penetration, and it is typical from your time of mixing curve that you would assume that, and we find that to be very true.

Gene Abson, Chicago Testing Laboratory. — I think in answer to one of Mr. Hveem's statements that the dry mixing requirement has been the result of experience over a great many years. Normally, 35 or 40 years ago, sheet asphalt mixes were prepared in open pugmill mixes, and frequently the asphalt was added to the sand and then the filler dumped in, in order to avoid the dust incident, and as a result of experience gained by observation, it was found that dry mixing certainly did not augment the quality and the perfection of the mixtures.

I think that is the reason for the dry mixes.

One other thing in reference to what Mr. Warden said—I think the percentage of filler, in addition to the fineness, has a great effect on the temperature required. The temperature required was extremely high, even though it may have caused deterioration of the asphalt, but necessarily on account of the very thin films of asphalt.

The viscosity played a less important part than the requirement of film thickness.

T.K. Miles, Shell Oil Company. — I want to discuss Mr. Hveem's point about the difference in the mechanism of hardening of asphalt at about 165F.

We were concerned with this microfilm durability test for the hardening of asphalt. Initially we ran the test at 120F merely because this simulated the maximum temperatures, and we thought that range was involved on a road on a warm day. This worked out fine except that it took quite a while to harden the specimens in the oven.

We thought that possibly we could speed up the temperature. Therefore, we ran a whole series on a large number of asphalts available to us, varying the temperature from 140F to 150F. With the asphalts thus tested there was no difference in the way one would rate their hardening at temperatures of 140F to as high as 250F.

Perhaps that does not exactly state that there is no difference in the mechanism of hardening. On the other hand, there was no crossover—no asphalt that looked better at one temperature and worse at another.

We felt justified in using a higher temperature (225F) because we could obtain the same amount of hardening in two hours that we could at fourteen.

Mr. Foster. — The inference that the hardening occurs in the truck is not true. We have asphalt plants as far as 50 mi from the job, and there is no particular hardening curve.

I do not think the asphalt plant should be as far away from the contractor as the asphalt plant would like to be.

Mr. Hveem. — We take the view that the Lewis Thin Film Test, if at all significant, can only be expected to correlate with the hardening in the mixer. I do not think that it should be used to predict hardening on the road. We agree thoroughly that testing of asphalts should be performed in the thin film state but films ⅛ in. thick are not very thin.

We are now working with a Thin Film apparatus of our own with which it is hoped to develop the same type of hardening as occurs in an asphalt plant but which should require much less than 5 hr heating.