EFFECT OF MOISTURE IN BITUMINOUS MIXTURES AS EXPERIENCED IN FIELD PAVEMENT OPERATIONS IN MICHIGAN

given by
PAUL SERAFIN

In 1964 a questionnaire was distributed by the Highway Research Board Committee MC-A2 to the state and provincial highway departments to obtain information concerning the effects of moisture on bituminous mixtures. As in many questionnaires, the questions often do not lend themselves to a "yes" or "no" reply, resulting in some personal interpretations by the reviewers.

A summary of the replies received did, however, indicate that moisture causes a critical condition in hot bituminous mixtures. It is not limited to a few areas but is widespread in the USA and Canada. What was recognized as a problem related to moisture by some people may have been ignored or even gone unnoticed by others. Some engineers, on observing flushing of the bitumen have interpreted it as due to moisture, others examining the same conditions claimed there was to much asphalt in the mix, while still others held that the mixture was too hot.

Prior to 1945, Michigan highway engineers on occasion observed segregation, flushing, loss of stability, blistering, and other conditions during the laying of a hot bituminous mat. Many reasons were given. It was not until people began noticing moisture dripping from the asphalt mix truck box, which was associated with slumping mixes in the truck and other related problems, that it was generally agreed that moisture was the culprit in many instances.

When methods of aggregate drying were improved, the conditions noted seemed to disappear resulting in a conclusion that residual moisture in hot asphaltic concrete, at the time of lay-down, caused these conditions. This resulted in greater effort to require more efficiency in the aggregate drying operation to reduce the residual moisture.

The improved drying operation caused a slow down in production and was an added expense to the contractor, therefore, these efforts were challenged by the contractors with claims made that the drying requirements were unrealistic and unwarranted.

In 1951 the writer made an investigation on the exact amount of moisture that was present in the critical mixtures. This was accomplished by a revision of the equipment for water determination by the trap method described in AASHO Method T55. In place of a circulating water jacket used to condense the vaporized solvent and water in the reflux tube, a tin jacketed reservior filled with cold water was used to condense the solvents releasing the water to the water trap. This method allowed measuring small quantities of water in a bituminous mixture in the field without the need for running water for condensing purposes. A metal container was used in place of a glass flask for the mixture sample, and a gasoline stove was used to supply the heat with a high flash naphtha for the solvent.

Tests were performed and it became apparent that very small amounts of moisture, at contents of 0.05 percent or less, were causing problems with certain bituminous mixtures containing calcareous and dolomitic coarse aggregates. Based on numerous such test results the specifications were written to require the aggregates to be dried to no more than 0.05 percent moisture in the bituminous mixture. After one season of experience with this requirement, it was recognized that other types of aggregates could tolerate higher amounts of moisture with amounts of 0.1 percent and more in some bituminous mixtures without detrimental affects.

Contractors and engineers used various approaches to improve on the drying efficiency. Holding the dried aggregate in the hot aggregate bins for additional short periods to allow for "sweating out" was one procedure. This was accomplished by "keeping the bins full". Increasing the dry mix time was another successful approach which allowed time for moisture to escape before the aggregate was coated with asphalt. Reduction of batch weights resulted in less aggregate going through the drier with better drying efficiency. Fan speeds were increased, slopes of driers were reduced and bigger driers were installed. Orfices in the burners were increased, changes were made in the flight arrangements in the drier, and even double driers were installed. All these changes improved the drying, however, on occasion, residual moisture still continued to plague the engineers and contractors alike in attempting good quality control of bituminous pavements.

Early in 1952 tests were conducted to determine the effects of silicone additives in bituminous mixtures. Additional studies were made in the field to determine the effect of silicone in eliminating mix foaming resulting from the residual moisture escaping through the hot asphalt film, which coated the aggregated particles. The use of this additive appeared to lower the surface tension of the asphalt.

Antifoaming agents of silicone material of the dimethyl polysiloxane type, preferably of about 1000 centistoke viscosity grade, were permitted to be added to the asphalt in amounts not to exceed 5 parts per million. Dow Corning DC-200, General Electric SF-96, and Union Carbide L-45 silicone products were among those additives that met these requirements. Perhaps because of the proximity of the Dow Corning manufacturer, most contractors used the DC-200 additive.

Presently the Department permits the addition to the asphalt of a solution of silicone in kerosene or No. 1 fuel oil. No observations have been noted of stripping or other detrimental conditions where more than 5 parts per million of silicone were added to the asphalt. However, amounts in excess of this quantity of this costly additive do not seem to improve the conditions. There has been some controversy above when the silicone should be added -- at the refinery during asphalt loading for delivery, or at the asphalt plant by the contractor. Because so many procedures were used by the contractors, some adding the silicone with questionable accuracy, it was decided the preferred place for addition was at the refinery. Some refineries now add 3 ppm to their storage tanks and supplement the balance of 2 ppm at the loading dock as requested by the contractor.

Associated with these studies it was further noted that a change in sand gradation from the traditional "belly sand" (high percentage in middle of the gradation) to a uniformly graded sand appeared to offer more tolerance to residual moisture in the resulting mix without causing problems. Further improvements in mix design such as reducing the material finer than the 200 mesh from about 6 to 7 percent to about 4 or 5 percent, also resulted in further tolerance of the mixture to moisture.

It was during this period that contractors began using automatic controls for mixture proportioning. This ultimately became a requirement. Prior to these improvements the inspectors and contractors' personnel were noted to be lenient in permitting partially worn-out equipment to be used. In some cases this resulted in marginal quality bituminous mixtures. With automatic monitoring of the proportioning, this did not permit leniency with the use of worn-out equipment. This probably was the biggest factor in Michigan that helped correct the moisture situation to a point where today this type of problem is almost nonexistent.

These improvements have resulted in permitting greater amounts of moisture in the resulting pavements. What harm has this greater amount of moisture done as an immediate consideration and also as a long term effect? To date no stripping has been attributable to the extra moisture in the pavement.

This brings us to the question of what effect does moisture have in a bituminous pavement in service. Stripping of asphalt from the aggregate, in the presence of water, has been observed by many people. This may be caused by incompatability of certain asphalts with different aggregates in the presence of moisture. Most asphalt technicians recognize that the presence of asphaltic acids in the asphalt gives better adhesion to non-acid or limestone type aggregates, however in contrast this may cause stripping if used with siliceous aggregates. Numerous studies of these conditions have been made and many anti-stripping additives have been developed. However, the writers' observations indicate that the long range benefits of these additives are still to be proved. With the advent of the elevated grades on most modern highways, it is seldom that we find an asphalt pavement submerged in water for long periods of time. This, I believe, has pretty much solved the stripping problem in Michigan and, more than likely, in most other states.

GENERAL DISCUSSION: (Following conclusion of all presentations)

QUESTION: D. Tunnicliff
Both Mr. Kellam and Mr. McCrea do not feel there is much problem in conventional mixes. They can get it down all right, and I agree with them. If they get to where they cannot get it down all right, it is usually affected by temperature, and so the thing to do is raise the temperature. Of course, this then drives off more moisture; so, we don't know whether it is because we lost moisture or because we raised the temperature. That's where the problem has been. But in the discussion of drum mixing, then Wes, Ron and Bob were talking about temperatures that were lower than what Duncan and Bill were talking about, and I can't help thinking that there is something else different here. We are not talking about the same animal.

ANSWER: L. C. Krchma.
No I think they agree with you.

QUESTION: D. Tunnicliff
Then, what is the difference? This is really the question.

ANSWER: L. C. Krchma
If I understand Mr. Beaty's observations, based on his laboratory work, the drum mixer can be and should be compacted at a lower temperature, and it can be compacted at a lower temperature because the moisture adds to the lubrication. The moment the moisture is lost the system reverts back to conventional dryer temperatures.

QUESTION: D. Tunnicliff
O.K., that's fine, but I have to lay this stuff too.

ANSWER: L. C. Krchma
This concerns laying. Mr. Beaty did not see this in the laboratory. He saw it in the field.

QUESTION: D. Tunnicliff
As to what was the problem in laying the conventional pavement to cause tearing, I couldn't agree.........

ANSWER: L. C. Krchma (interrupting)
Due to what? To low temperature or moisture.

QUESTION: D. Tunnicliff
This is what I brought up earlier. We raise the temperature, we get rid of the moisture, but we don't know what causes the effect to be the way it really is.

ANSWER: L. C. Krchma
I understand in some instances tearing has been minimized in the case of conventional mixes by putting in silicones.

QUESTION: D. Tunnicliff
Yes, Bill mentioned this too, and I don't see any reason why we can't put silicone in the drums too. I feel there is a different animal involved here, and one thing I would like to question - is the consistency of the asphalt. Most of what I have read about the drums involves lower consistency asphalt (lower viscoisty asphalt) than most of the work done in this country in the last 50 years. I think this has to be a factor. I don't know how much of a factor, but I would like to find out.

ANSWER: R. Terrel
I'm not sure if I detect any contradiction in what you were saying. I think basically the idea is that you are trading water for temperature in a drum-mixer, but at a lower temperature, and part of what I tried to describe here is something that other people like Mr. Schmidt would perhaps agree on. The asphalt itself actually absorbs some of this water and tends to lower viscosities; in other words, a little bit of water actually is absorbed - would you agree with me, Bob? So, in effect, you have a lower viscosity, while the water is present, and this occurs in the drum-mixer rather uniquely because of the mixing process, the vapor pressures, etc. The same thing does not necessarily occur in a conventional mixer simply because we don't have these conditions in the drum, when the water and asphalt are present together.

I don't know if I am getting to your point or not. I could cite just a quick example in the way of experience. I mentioned a job in Nome, Alaska last summer, and this was built to FAA specifications, and you may recall that they also include the stability as a key factor in that specification. Incidentally, there is a very typical tendency for a first-time user of the drum-mixer to hedge a little bit and say, "well, I don't want to go all the way down to 200°, so I will go to 250° for the first week or two." This is exactly what you don't want to do because you get into this "tough" area that we talked about earlier. So, to alleviate that, we bring the temperature down to 210°F., and also clean up the emissions. The inspectors on the job noticed that the stability was down at the lower temperature because obviously there was a little water in the mix. I am kind of rambling a little bit, but I am trying to answer your original question.

QUESTION: H. Schweyer
I would like to ask any of the past speakers -- does the asphalt harden more, or less; drum-mixer vs. conventional?

ANSWER: R. Terrel
I believe I may have skipped over this earlier. Very definitely the asphalt hardens less in a drum-mixer. This fact has been confirmed through many tests and projects. Quantitatively, the reduction in penetration loss over conventional pugmill mixes is about 30 percent or so.

QUESTION: R. Lottman - to R. Schmidt
The question I have is about Mr. Galloway's question earlier in this session about putting a plant-mix seal over an old pavement that supposedly was all right. However, once it was covered with the plant-mix seal, possibly open and porous, the pavement below began to deteriorate. I could have answered this question by saying much of the trouble could be due to deep stripping action that starts at the bottom and works up. In this case, the old surface now is closer to the bottom and more susceptible to stripping. But, going back to Mr. Schmidt's relative humidity observations -- could he help me answer Mr. Galloway's questions.

What happens in overlays where we have a moderately moisture susceptible paving surface but it has been going through what Bob calls the yo-yo effect, alternately picking up moisture and drying fast enough so that it performs fairly well. However, putting on an overlay, it could possibly increase the humidity of the old surfacing. Would this then increase the tendency of the old pavement to retain a higher moisture over a longer period of time - causing the problems it had a potential to have?

ANSWER: R. Schmidt
I would think that any change in the structure should be suspected as possible cause for a change in the average moisture content in the original asphalt-treated mix. It is hard to speculate on the direction of change. For example, a new tightly sealed surface can reduce the amount of rainfall that penetrates into the structure but at the same time it can reduce the evaporation rate. If there is considerable ground moisture, the seal can increase the moisture in the base because it slows evaporation.

COMMENT: Warren Warden
I cannot agree with Ron and Bob on the asphalt absorbing moisture concept. I visualize the mechanism a bit differently. Namely: that in the hot mass of paving mixture we have a combination of fluids -- air, moisture and liquid asphalt-filler mortar -- encased within the aggregate voids. If the expanding air and moisture cannot escape rapidly enough, the whole fluid portion acts as lubricant, which in some cases may yield improved compaction by assisting particle orientation, but in others results in over-filling of the voids which causes slumping in the truck and tearing behind the screed. I visualize the silicone as having a surface active effect which facilitates release of both air and moisture from the hot mass, thereby reducing the volume of the total fluid enough to permit point-to-point contact within the aggregate portion of the mix.

Conference Session -- Moisture Restrictions

L. C. Krchma -- Meeting Closure:

Our panelists on the subject, "Second Look at Moisture Restrictions in Plant Operations and Construction", have discussed 'Moisture Monitoring', 'Laboratory Measurement' or Workability and Performance', 'Conventional Plant Operations', 'Drum-Mixer Operations', Hauling, Spreading and Rolling Operations', and 'Pavement Performance'.

Lottman, discussing Moisture Monitoring pointed out that the two areas of interest are control of workability, and durability. He briefly reviewed the drying process and the balance sought between heating and drying of coarse and fine aggregates, between surface moisture and absorbed moisture.

In all of this, there was sufficient variability that agencies found it necessary to set a maximum moisture but that there were problems in setting such maximums because of differences in the pore and moisture volumes and the rates of the moisture loss, or rate at which the moisture is driven off. He finds the latter particularly significant though difficult to measure.

He concludes latitude in hot-mix moisture maximums are possible to obtain workability, but in so doing, the durability trade-off needs to be known. Fortunately moisture damage information found in the literature could be useful.

Schmidt, studying laboratory workability, in the area of 'Rolling', found it necessary to resort to rolling under controlled conditions that very closely duplicated actual field conditions. By this process, a good deal was learned about compaction. It is obvious that Mr. Schmidt had to go to a good deal of trouble to measure workability. From this it is evident measurement of workability of mixes is a most important feature that our present mix design and moisture tests measure, indirectly, if at all. We need to give this more attention. This would be workability at all levels--certainly laying and compacting workability -- conceivably at some later time, mixing workability.

Schmidt made the point moisture can be a workability aid or a hinderance but up to now, we have gone only in one direction, towards less moisture. So this looks like a fruitful area of study.

The point was made that we would not have many pavements if moisture and its effects were not reversible.

The cycling in moisture level and moisture effects explored by Mr. Schmidt proved to be reversible. Thus the moisture level in a pavement is not dependent on the initial degree of drying but on an equilibrium set by the pavement and its environment. This state of affairs was used to explain the failure of a pavement once it was overlaid. While it was not brought out in the discussion of this type of failure, it seems there was no basis in believing more complete original drying would have altered the results.

From the above, some amounts of moisture are not automatically harmful. It would appear that with reversible moisture cycling, we are further faced with the rate phenomenon discussed by Mr. Lottman. Obviously, if we are to make the most of hot-mix pavements, this needs further study and better understanding.

Mr. Kellam, in covering the 'Conventional Plant Operations' pointed out the difficulties with restrictive moisture requirements for which there is not an indication such a restriction is associated with better field performance.

Obviously there is room in conventional hot-mix for some more meaningful control, probably workability again rather than percent moisture. In doing so, fuel could be conserved and emissions reduced.

Mr. Terrel, in dealing with 'Drum-Mixer Operations' covered the mixing involved in the 'drum-mixer' and showed in his slides that placing a moisture requirement obviously involved plugging in something about the aggregates. For example, if an aggregate was absorptive, there is no question that the equilibrium moisture is appreciably higher. This is nothing new to you gentlemen but, do the specifications relate the absorptive character of the aggregate and the permissible moisture?

Mr. McCrae, in covering "Hauling, Spreading, and Rolling" reported on his considerable experience with difficult aggregates. He reported again that the moisture levels measured and specified do not correlate with pavement performance. There is a challenge to control in some other way what we tried to do in the past by moisture control.

Mr. Beatty also dealing with "Hauling, Spreading, and Compaction" reaffirmed what can be expected when moisture and workability are examined in terms of the equilibrium moisture condition. He pointed out the distinctions between conventional mixing versus drum-mixing; how moisture can contribute to compaction at lower temperatures; and that the workability-temperature relationship is discontinuous, in that, around and below the boiling point of water, moisture can be an aid, but once the moisture is driven off, workability is more the function of the viscosity of the asphalt, i.e., higher temperature.

As related by Mr. Drake discussing 'Field Performance' Mr. Serafin reported that at one time Michigan had very restrictive moisture requirements. However, adjustments in the aggregate gradations and operations, permitted good construction with appreciably more moisture. What is more important, there was no evidence this additional moisture harmed pavement performance.

In all the above we have evidence some moisture is not detrimental. This suggests further study of what levels of moisture are permitted for workability and pavement performance. This suggests study of adjustments that can be made in other variables that would allow more moisture and the nature of the trade-offs.

Then too, considering the overall variety of situations, aggregates and asphalts, some have not been covered by the experience reported on at this conference. So we need to be alert to exceptions and learn of the reasons for this. Then too, laboratory studies involving moisture tend to be with mixes made with dry aggregates, just because of the nature of the laboratory conditions and operations. It would be of interest to check performance relative to moisture in the laboratory using mixes made with aggregates where the moisture level is maintained comparable to some of the moisture levels reported to us here.

This summary is only one man's view. We, however, have Mr. Drakes, Co-Chairman of this Conference, to broaden or perspective.....Mr. Drake.

Frank Drake

Listening to the remarks that are so pertinent to the subject of the conference, it seems to me workability is a term that should be used more than it is. Presently we have neither the scale nor the measurement of such a term. Yet is it a characteristic of the mixture we can ill afford to ignore when we think of compacting the mixture in the shortest period of time without causing lateral displacement in the mix.

Bob Schmidt has made reference to the term "optimum compactive effort" as the condition where the mixture is exposed to the maximum compactive pressure the mix will support without lateral displacement. This is unquestionably true. However, this condition of optimum very rarely happens because there is very little thought given to bringing into focus the three factors of workability, lift thickness, temperature, and compactive effort.

On the other hand optimum compaction can be achieved by adjusting the compactive effort to accommodate the following: (1) the thickness of lift and (2) the workability of the mixture. The above statement seems to be the most reasonable for efficient construction. However, if adjusting the weight of the roller is not feasible or possible the only alternative is to adjust the lift thickness. This seems to be a vicious circle. Yet, to practice good construction procedures workability is very much a part of the overall consideration.

L. C. Krchma

There is no need to add to Mr. Drake's observations. It is hoped this Conference will add to an improved technology, leading to better engineering, better operations, wider use of more economical aggregates, fewer emissions, and the improved conservation of fuel.

We owe a good deal to the Members of this Panel. We are indebted to the joint A2D02 and F02 Committee Members, who we named and who assisted us in the planning of this Conference, though limited time precluded introduction from the floor.