FOREWORD

This conference was held during the Highway Research Board Annual meeting in January 1974. There were seven presentations, each followed by discussion, and a general discussion at the end of the conference. At that time there were no plans to publish any part of the conference; however, the entire proceedings were recorded on tape, and eventually it was decided to publish the presentations and all discussion. Of the presentors, only R. W. Beaty declined the opportunity for publication. It was concluded that the proceedings could be published by omitting this presentation and the discussion pertaining directly to it without detracting from the remainder of the document. Some editing has been done in order to clarify the meaning, but the text is essentially still in the verbal presentation form. There are some statements in the proceedings that are definitely "dated", that is, statements which were correct in 1974 but which are not necessarily correct in 1983. Nevertheless, the vast majority of the material is correct. The committee decided that despite its age the report contains much information which has not appeared elswhere in the technical literature and would otherwise be lost. This information has added significance in light of the present questioning of maximum limits of moisture content and minimum temperatures for mixing, laydown and compaction of hot mixes.

Gerald S. Triplett, Chairman
Committee A2F02

CONFERENCE SESSION -- SECOND LOOK AT MOISTURE RESTRICTIONS IN HOT-MIX PLANT OPERATIONS AND CONSTRUCTION

HRB Committees -- A2F02 and A2D02

L. C. KRCHMA - (Opening Remarks)

Two HRB Committees, A2F02 (Flexible Pavement Construction), and A2D02 (Effects of Natural Elements on Bituminous Aggregate Mixes), have been converging on the moisture problem. A2F02 is chaired by Frank M. Drake; Herb Schweyer chairs A2D02. About this time last year, these committees arrived at the same point, asking, "Are past moisture limits and controls still best in today's situation?", "What are the new priorities with need for more emission controls, more fuel conservation, wider use of local, even marginal aggregates, etc?"

A2D02 proceeded to prepare a "Research Needs Statement" on 'Reducing Dependence on Low Moisture for Good Hot-Mix Plant Operations, Good Construction and Good Pavement Performance'. A2F02 meanwhile was concerned that the optimum use of existing equipment and new developments might suffer if we continue with moisture controls that were found appropriate for conditions that no longer apply.

In all of this there is agreement that (1) to make more progress or do research, the moisture problem needed restructuring, and (2) time was of the essence.

Events were moving too fast to obtain this restructuring by the customary processes -- a speeded-up, give and take was needed.

In this situation, a conference was indicated to thrash out the concerns and at least start developing the right questions. So, Mr. Drake and I were asked to organize such a conference. Through the good offices of Jack Dillard, Morland Herrin, Herb Schweyer, Bill Gunderman, Ian Kingham and others, this conference was scheduled for this date, an unprecedented few months ago.

The subcommittee that carried out this assignment was made up of members from both committees:

For A2F02 -- R. W. Beaty
Duncan McCrae
For A2D02 -- R. P. Lottman
Gene Morris
C. Potts

The subcommittee recommended the discussion topics and speakers indicated in the program.

Strange things come to light as one examines the questions that might be asked and debated. Among these - "Are the moisture controls set at too low a level?", "Are we measuring moisture correctly?". Then as we go further, we might ask, "Is percent moisture a good measure of moisture's effects?" "Is the basic problem moisture or workability?" "Should workability be measured directly or do we accept an indirect measure like percent moisture?" "Are there other factors like equipment design, equipment operation, mix design and character, as well as moisture to reconsider?" If so, how do we examine and control them? In the present situation, can we continue to say the drier the better? If not, how high can we go and what should we control?

The SECOND LOOK AT MOISTURE program included the following:

R. P. Lottman -- Moisture Monitoring;

R. J. Schmidt -- Laboratory Measurement of Workability and Performance;

Bill Kellam -- Plant Operations: Conventional;

R. L. Terrel -- Plant Operations: Drum-Mixer;

Duncan McCrae -- Hauling, Spreading, and Rolling - Conventional;

R. W. Beatty -- Hauling, Spreading, and Rolling - Drum-Mixer (The text of this presentation was not submitted for publication.) and;

Synopsis of Paul Serafin's paper Effect of Moisture in Bituminous Mixtures as Experienced in Field Pavement Operations in Michigan by Frank Drake.

MOISTURE MONITORING

R. P. Lottman, University of Idaho

I would like to speak about two areas of moisture control in hot-mix plant-field operations which I think are of prime importance. These areas are workability and durability.

Workability is needed to achieve initial mixture properties during the paving operations that will affect the eventual outcome of the mix -

such things as achieving adequate mixing, finishing, compaction. The initial voids and other physical properties become established at this level.

Present moisture monitoring is essentially but not exclusively related to achieving workability. Foaming or unstable mixtures at paving are examples of problems that have required a limit of moisture in aggregate or in the mix.

To begin with, the conventional asphalt plant dryer is really a heater in terms of objective. Aggregates need to be hot enough to maintain mix workability after asphalt mixing. This has required average aggregate temperatures about 75-80°F over the atmospheric boiling point of water. Aggregates having moisture on their surfaces require enough heating in the dryer to boil off the surface water before their surface temperatures will rise above water boiling point. If the aggregates are porous then also some pore water needs to be driven off to achieve average aggregate temperature above water boiling point. Thus is the connection to the common term: "dryer."

Larger aggregates, the coarse aggregates, take longer to heat than the sand or fine aggregate because of the greater distance that heat must penetrate under constant thermal diffusivity. Also, sand surface area (area exposed to heat) is greater. In many dryers, especially 10-15 years ago, the sand was always hotter than the coarse aggregate. It was common to find coarse aggregate temperatures about 230-240°F and sand temperatures about 375-400°F. A mixture of these two sizes when combined in the pugmill produced an average temperature that was desirable.

Although some hot bin residence time would reduce sand temperature and allow some additional vaporization of moisture from coarse aggregate pores, differentials of temperature persisted in the pugmill during mixing. The additional heating of the coarse aggregate by the hotter sand would drive out more moisture from the coarse aggregate and, when mixed with hot asphalt, uncontrolled foaming and other instability would occur.

Several contractors and manufacturers made changes in dryers so that coarse aggregates would have greater heating and drying and that sand would have lower heating relative to the previous situations. This was accomplished by changes in drum flights, veil patterns and residence times. These changes produced lower temperature differentials and helped to reduce further moisture loss in the coarse aggregate after mixing.

However, there was enough variability that uniform results were not achieved for all dryers in operation. Consequently many agencies set moisture content maximums in the aggregate. Sampling and control was usually at hot bin discharge into the mixer (pugmill). Some of these maximums were small, especially when one considers the moisture amounts to be weighed versus the total weight of the aggregate sample and the problems of rate loss of vapor at sampling and after sampling. However, these restrictions did bring about some improvement in controlling mix workability.

It is difficult, however, to set limits since each aggregate type contains different kinds of pores and volumes, and gradation and the fines-asphalt mastic also affect moisture sensitivity to some extent.

The inherent problem of uniform moisture restrictions is due to the different volumes of pore moisture (moisture supply) and the ease of moisture removal from the pores (rate of loss) due to different aggregate types. Conventional moisture content monitoring is related to moisture supply - being measurements of moisture sensible by weighing. The rate at which this moisture is leaving under a driving force of heat differential is not measured. Perhaps it is the rate of moisture loss, and its uncontrolled nature, that is really the problem here. This, however, is difficult to measure and control.

Durability of the compacted mix is a very much needed consideration. There really isn't much in the way of moisture monitoring of the hot mix or compacted mix from conventional plants. However, this monitoring has been or is being considered by agencies when dryer-drum mixer plants are involved.

The durability question is, What effect does residual moisture have in the mix after it has reached its "final" compacted state? In addition, What equilibrium moisture content will be achieved, finally? Is it dependent upon climate, time of year of paving, the type of drying and mixing operation? Does this residual moisture have any effect on the eventual (long-range) moisture susceptibility of the pavement mix? In this regard, is a better, worse or the same condition of durability being produced by the different drying and mixing operations?

Perhaps specifications that restrict the retained moisture in aggregate in order to eliminate stripping are necessary for durability. Two types of specifications known are (1) limiting moisture content in aggregate and (2) eliminating the use of highly absorptive aggregates. These types of specifications refer to conventional plants. The success or non-success of these specifications can best be evaluated by the experience of the agencies involved.

In summary, existing moisture monitoring is related to the amount of moisture available. At best, this monitoring is only indirectly associated with the rate of moisture loss. The rate of moisture loss, could be the significant variable but, unfortunately, it is difficult to measure. Also, existing moisture controls in most specifications are mainly associated with workability. Some specifications, however, have dealt with durability. From a viewpoint of pavement performance, durability is an important consideration. It appears possible that latitude should be given regarding moisture specifications for achieving a desired workability, but the trade-off on durability, if the trade-off exists, needs to be known. In this regard the application of moisture damage tests now found in the current literature may be useful.

DISCUSSION: "MOISTURE MONITORING" - R. P. Lottman, University of Idaho, Moscow, Idaho

QUESTION: L. C. Krchma.

Concerning the moisture rate feature you have brought to our attention, how is this measured?

ANSWER:

If you have moisture inside the pores of the aggregate and it is not coming out, then the rate is about zero and it may be "inert"; as far as affecting the mix is concerned, I don't know. But, what is coming out as diffusion into the asphalt during mixing and maybe afterwards seems to be the problem. This requires a rate in addition to supply, so it can't be measured very easily unless you measure the change of moisture supply over a period of time; in other words, the moisture content changes over a period and, from that, one can get an idea of the rate to see if it is satisfactory. But the problem has been that this is maybe an uncontrollable thing; you sort of get it and if the rate is too high, then you drop the moisture content down by additional drying, and you try to write the kind of moisture specification needed for a region or a state. But this changes with aggregates and also changes with the actual value of the moisture content in a given aggregate source. Some days when aggregates are wetter, you will have a different rate than when they are a lot drier, so the rate is quite a variable thing, which cannot be controlled easily in a practical sense. I mentioned this has only been indirectly related to the present monitoring test which was simply a measure of the supply of water or the amount of water available, but it doesn't really have anything to do directly with the rate of moisture loss. That is the problem I think.

QUESTION: Anonymous

We recall a break-down of pavement in the last few years. Due to the heavy rains, the aggregates were more wet when going into the drum. Unless we lengthen the drum time, can we control the moisture?

ANSWER:

The residence time in the drier can be changed; some people do it by changing the cold feed, by dropping that down. You can change the drum slopes a little bit, flatten them out, and increase the burners -- usually for efficiency you run the burners at the highest settings. But it's residency time no doubt that helps through slope and flight changes. If aggregate is wetter, you just leave it in there longer to dry it out. Many times you cannot rely on hot-bin storage for the more complete drying so if you have been having problems in making the mixture, one just has to go back to heating aggregate longer. Now you might not get much of an increase in temperature by leaving aggregate in the dryer for a longer time if they are wetter. A lot of your heat is going into vaporization of the water on the aggregate and so it is costing you more money, but in order to get aggregate up to the temperature, you unfortunately have to dry them out. And this has been the problem, a dryer is really a heater, but one has to dry in order to heat.

QUESTION: Anonymous

What about pavement performance, wet vs. dry years?

ANSWER:

I don't know; maybe this is the part that I touched on in durability versus residual moisture in the mix. Now and then residual moisture is in the mix. It may be between the aggregate and the asphalt; it might be diffused in the asphalt eventually. This might make the mix more moisture sensitive; it may go to an equilibrium moisture content relative to the air, after it is on the road for awhile perhaps increasing to a fairly high humidity, if it is at that time of year, and this might make the mix more moisture sensitive. I think Bob Schmidt will be showing a few slides about how much the modulus does go down even with a 1/4 of one percent moisture left in the mixture. This modulus drop and also a strength drop could be enough to start causing stability problems under traffic. This is a tie-in to durability. We really don't know that much about it except what we monitor in the laboratory right now. I don't know that there are field data on this durability problem insofar as residual moisture is concerned. Maybe some of the people here have some data on the effect of residual moisture on stripping or other properties connected with durability. We can see it in the lab; we can see the long-range effects of water coming into the voids, but we haven't seen much field data on just the long-range effect of residual moisture going into equilibrium after paving. Maybe someone could shed some light on that. Does that touch on your problem? I didn't give you an answer but maybe we just sort of extented it a little bit.

QUESTION: Bob Gallaway - Texas A&M, College Station, Texas

What field experience do you have with wheel track distress in plant mixed seals in areas where ice forms in the voids?

ANSWER:

No direct experience with plant mix seals. However, when water intrudes into the voids for the dense graded mixes, the damage is almost proportional to the voids content. When you get up to the plant-mix seals, especially open-graded ones where water is just sitting there with lots of room that is a little different kind of a problem. If the mix starts to close up in the wheel tracks bringing the void content down to 12-10 percent for example, then the water may build up some internal pressures under freeze-thaw. Also, traffic might build up pressures. If you have residual moisture in the mix it might make it even worse. The best approach for an answer is to core and run some tests on your plant-mix seals under freeze-thaw in saturated conditions.

QUESTION: B. Gallaway

Have you observed stripping at the interface between layers of hot-mix? How does this type distress first appear--that is, how is it detected when it first starts? Is this an emulsification process?

ANSWER:

Yes to your first question. Most of the time we find the stripping damage starting from the bottom of the pavement going up - sort of like a rotting log concept in the woods -- a lot of rot on the bottom and the top is sometimes pretty good. Usually when it occurs only at the top it is mainly ravelling. Interfaces may have higher void contents giving more water and more stripping pressures. This seems to be a faster kind of a damage rather than a longer range damage. Long range damage seems to start from the bottom of the pavement and works upward toward the surface.

QUESTION: Vaughn Marker -- The Asphalt Institute, College Park, Maryland

I had a little difficulty following your presentation with regard to the monitoring of moisture. It seemed to me you were talking about intrusion of moisture into the asphalt and yet you were talking about monitoring the moisture content of the aggregate coming out of the drier. The temperature equilibrium between the coarse and fine particles--the temperature derived evidently--I understand. With relationship to monitoring moisture in the mix, this is difficult to understand. Did I understand you to say you were trying to figure rate of loss in the mix after the asphalt had been added to the mix?

ANSWER:

This caused some of the foaming problems that happened years ago in Michigan and Ohio. This was essentially due to rate but it couldn't be measured and controlled easily at that time so you had to go to moisture content determinations and control that.

QUESTION: Vaughn Marker

My question -- have you been working on developing a measure for these systems? That is what I don't understand.

ANSWER:

We did this at Ohio State awhile ago in the early sixty's. This involved aggregate types, how they dried, what their temperatures were at times of mixing and the approximate rates of moisture loss at that time. Also, there probably have been some data on rates of moisture loss after hot mixing with asphalt. But further development would be necessary to arrive at a control test for moisture "specifications."

LABORATORY MEASUREMENT OF THE EFFECT OF MOISTURE ON WORKABILITY AND PERFORMANCE OF ASPHALT TREATED MIXES

SPEAKER: R. J. Schmidt, Chevron Research Company, Richmond, California (deceased)

(An account by L. C. Krchma based on a presentation given without benefit of a prepared manuscript)

Schmidt has been associated with studies of rolling and the physical properties of laboratory specimens and drew on these in considering the laboratory measurement of the effect of moisture on workability and pavement performance (1-5).

To measure the hot-mix workability involved in rolling required full scale rolling under laboratory conditions. Part of this study was concerned with the way differences in the "voids filled" with asphalt influenced roller compaction. This provided an insight to the effect of residual moisture on compaction to the extent that moisture, either as a liquid or steam, would also occupy void space. This, like the asphalt, would be expected to lubricate the mix, which in turn would affect the stability of the mix under the roller, and hence the compaction. Figure 1 from "Behavior of Hot-Mix Asphaltic Concete under Steel Wheel Rollers (1)" was shown to illustrate the compaction mechanism and how the stability of the mix contributes to the uncertainty, what with decompaction in front of the roller, offsetting the compaction under the roller.

Schmidt showed Figure 2 from the same reference giving normal rolling behavior where decompaction was not a problem with a normal mix having adequate voids to accommodate the fluids present (asphalt) provided it was not overloaded by too heavy a roller or too small a roller diameter (1). He showed good compaction could be

Figure 1. Behavior of Hot-Mix During Rolling