ANSWER:
No. That just scares you. It is a visual scare. It is not detrimental to the pavement.

QUESTION: Anonymous
What are they looking for when they are questioning you about your moisture? Are they expecting 6 months from now is it going to ravel, push, shove, or what have you?

ANSWER:
I think the State of North Carolina's main concern is ravelling of the mixture with the moisture in it. They like to keep you down to around 0.2 to 0.3 percent moisture in the aggregate.

QUESTION: L. C. Krchma
Have they confirmed that ravelling occurs when you exceed that 0.2 - 0.5 percent?

ANSWER:
To my knowledge - they haven't.

QUESTION: Herb Schweyer - University of Florida, Gainesville, Florida
Is there any documented proof that a mix with 5 percent moisture in it does cause problems?

ANSWER:
To my knowledge there is no documented proof as to what causes the problems. If they had 1 percent, 1/2 percent, 0.2 percent - you could take a mix of 0.2 percent and be subject to ravel just as much as a mix with 5 percent that was laid under the same conditions.

QUESTION: L. C. Krchma
Do you really mean 5 percent?

ANSWER:
That's what he said. He said 5 percent. At 5 percent it is going to run out of the truck with asphalt; it's not going to be there. But, to my knowledge, there is no documented proof that the moisture causes it to ravel.

## ASPHALT PAVING MIXTURES -- DRUM DRYER

R. L. TERREL

### ABSTRACT

The dryer-drum mixing process can accommodate a wide range of apshalt mixtures, particulary regular hot-mix asphalt concrete. The system includes a cold feed unit for aggregate which goes directly to the drum at which point the asphalt is added. Blending and heating takes place in the drum and mixtures with temperatures ranging from 180° - 300°F are produced. The asphalt is aged less than the conventional plants and well-coated mixtures are readily compacted at low temperatures because of the moisture present. In addition, stack emission of dust is reduced considerably.

### INTRODUCTION

The manufacturing and placing of hot asphalt mixtures has become a standardized and routine process for most producers throughout the world. Consumers such as state and federal highway departments, as well as private developers, have come to trust the product of well-controlled plants operated by conscientious producers and contractors. Unfortunately, this state of affairs was established many years ago and very little has been done to modernize the technology of asphalt paving at a rate consistent with other contemporary industries.

Many years of experience have taught the engineer and contractor that several basic steps are necessary to produce high quality mixtures. Basically, these include the following:

1. production, handling, storage and measurement of materials;
2. heating and drying of aggregate;
3. mixing the materials; and
4. transporting, placing and compacting.

During the past several years, however, through research and experience developed in the Pacific Northwest and elsewhere, it has been shown that the total production system may be simplified considerably without sacrifice of quality or production. In this paper the author attempts to describe briefly a new process for manufacturing asphalt paving mixtures using the dryer-drum or Shearer Process as developed by Pavement Systems, Inc. of Seattle, Washington. This drum mixer type of plant is now being manufactured and marketed under license by the Boeing Construction Equipment Company, Seattle, Washington.

### BACKGROUND AND SCOPE

Blending of asphalt mixtures in a revolving drum is not a novel idea, but its history is not well documented. K. E. McConnaughay Co. of Lafayette, Indiana has produced emulsion mixes under a patent for several years and also holds a patent on a similar process for hot mixes. Prior to this in 1959, however, the Asheville (N.C.) Paving Company [1] attempted to promote the production of paving mixtures using the dryer from a conventional plant.

In West Germany, a "dust free" asphalt is being marketed by the Wibau Company. In this plant the materials are blended first with a pugmill and then heated in the dryer-drum or activator. Both this process and the one of McConnaughay's [2] utilize chemical admixtures to promote coating and adhesion. To the author's knowledge, the success of the processes discussed above has not been reported in technical journals, but rather, this information is of a proprietary nature.

The Shearer Process (patent pending) was developed beginning in late 1969 with modifications of standard plant components, and several concepts which appeared to be vital to the needs of the paving industry. These include at least the following: (1) overall reduced cost through higher production rates with lower equipment and production costs; and (2) improvements in the control of dust and other stack emissions in order to become more compatible with new environmental controls now in vogue; and (3) decrease in move and set-up costs of portable plants due to mobility and less equipment handling.

The first testing by an outside agency of the Shearer Construction Company plant was conducted in July 1970 and sponsored by the National Asphalt Pavement Association. Although results of these tests were not published in total, the basic conclusions were presented by Foster (3) of that organization. Further evaluation of the process was presented in two other reports [4,5], which along with Foster's report, attested to the general suitability of this process for producing acceptable materials provided that appropriate quality control practices were adopted and maintained. The general properties of the asphalt mixture were very similar to that produced by conventional hot plants.

During the Spring of 1971, the Federal Highway Administration Division Office of Olympia, Washington initiated a study of the Shearer Process as a part of an overall evaluation of all such methods being proposed for use on Federal projects. This initial study was conducted at two private construction projects during the 1971 construction season in Western Washington [7,8].

During the 1972 construction season several projects were monitored by FHWA [9] in North Dakota, Iowa and Minnesota. A total of more than 800,000 tons of hot mix was placed on several projects. Most of this tonnage was in North Dakota where the contractor, Northern Improvement Company of Fargo, North Dakota, operated two plants of Shearer Process design. The successful experience on these projects under normal construction conditions has done much to promote the acceptance of dryer-drum mixing by both contractor and highway agencies alike. At the time of this writing, there are plants operating in many states of the U.S. with a total mix production to date approaching three million tons.

## PRODUCTION OF MIXTURE

The production and laydown of hot-mix asphalt materials has been suggested [6] as a total system similar to that shown in Figure 10, which depicts a conventional plant. As indicated earlier, one goal of the Shearer Process is to reduce the amount of equipment required. The simplified Shearer Process essentially eliminated item nos. 4, 5, 6, 7, and 8 (actually no. 4 is included in no. 16).

The Shearer Process incorporates two basic features which tend to simplify the overall production process:

(1) aggregate cold feed control; and
(2) mixing drum with parallel flow of air and materials.

The system is depicted schematically in Figure 11 showing the general arrangement of equipment.

Shearer's first plant as used at Port Ludlow, Washington, produced about 20,000 tons of hot-mix asphalt concrete including asphalt treated base (pit run aggregate up to 2" maximum size). A gate-controlled single-bin cold feed was used with 6-ft diameter by 24-ft long modified dryer-drum. This prototype plant was modified frequently throughout 1970 while it was being used to produce mixtures for numberous paving sites [4].

By the 1971 construction season, Shearer had a completely new plant as shown in Figure 12. Basic changes included the addition of a three-bin feeder system and conversion to parallel flow within the drum (i.e., air and materials move in same direction).

In May of 1972, the first commercially built plant using the Shearer Process was delivered to Northern Improvement Company of Fargo, North Dakota. The large 10-ft by 40-ft drum had an apparent capacity of about 600 tons per hour, but was limited at this site by the slot conveyor system which could handle only 450 tons per hour.

The major components of the Shearer Process plants are noted in Figure 11, and can be further seen in the photographs in Figures 13 and 14.

<u>Three-bin feeder</u>. Aggregate gradation is controlled by a combination of variable speed belts on each bin and variable gate opening. By calibration and control of the stockpile gradation, very uniform gradations can be produced. An alternative system has been individual weigh belts for each bin.

<u>Aggregate conveyor</u>. Combined aggregate moves to the drum on a conveyor belt which is fitted with a load cell type weighing system. This electronic scale is linked directly to the

Figure 10. Scheme of a conventional plant for the production and laydown of hot-mix asphalt materials

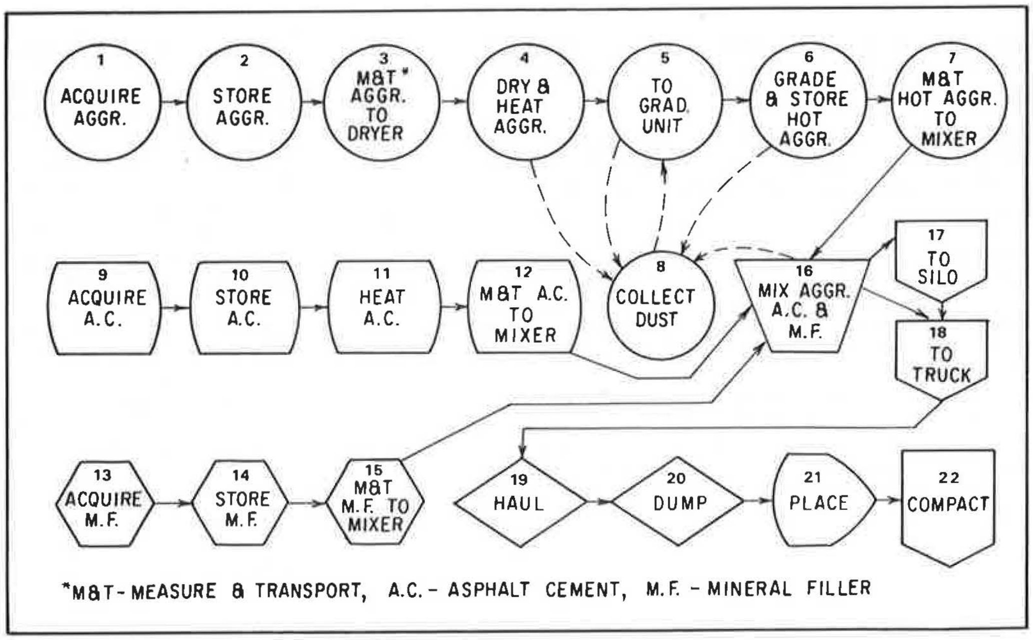

Figure 11. General management of equipment for production of mixes.

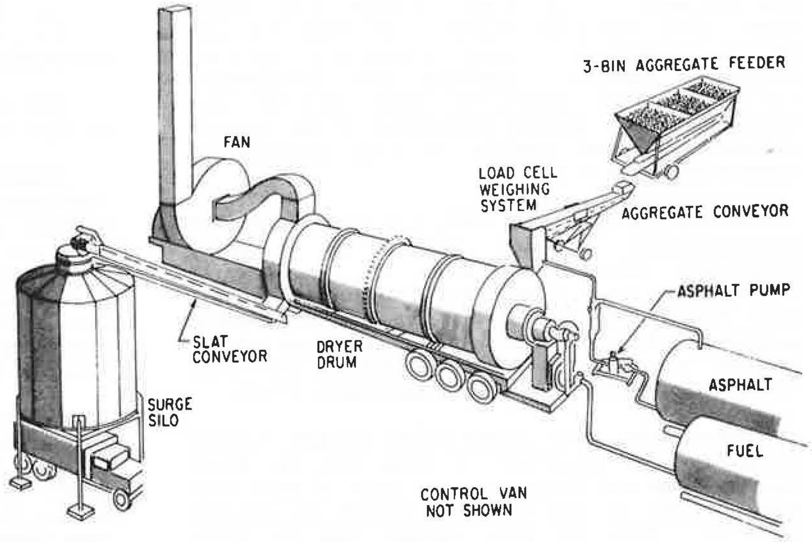


Figure 12. New Shearer plant used in 1971 included dryer-drum

Figure 13. Three-bin feeder system also part of new Shearer plant system

asphalt pump so that a predetermined asphalt-aggregate ratio is constantly maintained.

Asphalt pump. A positive displacement type asphalt pump that sprays hot asphalt directly on to the aggregate as it enters the hopper at the top of the drum.

Dryer-drum. The heart of the system; the drum is fired by a conventional type burner using either diesel or propane-type fuel. Flite design is such that the aggregate-asphalt blend is directed away from the hottest part of the flame. A combination of heating, drying and mixing produces a uniform paving material. The low-oxygen atmosphere reduces hardening and the presence of steam enhances coating. Retention time in the drum is about 3 - 3 1/2 minutes and the discharge temperature is usally maintained at about 210$^{o}$F. The discharge mixture at this lower than normal temperature generally contains about 1 - 2 percent water, which aids the handling and compactablity at lower temperatures.

Slot conveyor and surge silo. This type of temporary storage is convenient for most operators of the plant. Since the plant normally runs continuously, the silo eliminates the usual need to shut down when trucks are delayed. However, even if the plant needs to be temporarily stopped, the fire is simply shut off and the drum stopped. Once the silo can accept more mix, the plant is started and production continues as before, with no loss or damage of materials.

Control van. All switches and other plant controls operate from a central point. Material proportioning and temperatures are controlled and recorded. A single operator usually monitors the plant and loads trucks from his vantage point within the van.

Of some concern to most engineers is the hardening process that takes place in the drum in the presence of the high temperatures. Figure 15 indicates the behavior of asphalt within the mix thoughout the construction process [8]. The dashed lines show that the original asphalt was

Figure 14. Slat conveyor, surge silo, and dryer-drum components of Shearer plants

Figure 15. Behavior of asphalt within the mix during construction

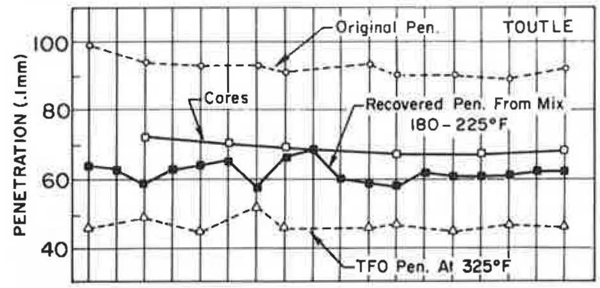


Figure 16. Paving operation in progress in Washington State at 16 F.

reduced in penetration from about 93 to about 47 following the TFO test. The data in this figure represent about 15,000 tons of mix produced on a project in Washington. The solid lines show the penetration of asphalt recovered from mix samples at the plant and from the road several weeks after construction. Since the TFO test generally represents the aging after about one year and from a conventional pugmill type plant, the reduction in penetration is somewhat less for the drum mixer. These data indicate that hardening is not as severe as might be anticipated, and in many instances is less than for a conventional type plant.

Asphalt pavements with a full range of asphalts have been constructed. All paving grade asphalts have been used, from 60-70 pen to 200-300. In addition, both MC-800 and emulsion mixes have been produced successfully.

Paving operations and laydown of mixtures produced by the dryer-drum process are very similar to those for conventional plants. The mass viscosity of the mix is the key factor. The characteristics of the mix at 220°F with 2 percent water is similar to the conventional dry mix at 300°F. Moisture continues to evaporate from the mat during laydown and compaction. Earlier photos taken in North Dakota were during warm weather, while Figure 16 was a scene in Washington with the air temperature at 26°F where evaporation is much more noticeable.

It would appear that the moisture is a key factor in the success of dryer-drum mixing. Production of mix at lower temperatures is possible with moisture present. However, mixes have been made with this type of plant at the usual temperatures of 300-325°F with no serious problems. Operation between these limits may not be advisable because the moisture is insufficient and the temperature too low to provide the low mass viscosity needed for handling.

Most aphalt pavements in service have a residual or equilibrium water content of about 1 percent or even more depending on the nature of the aggregate and void structure. This equilibruim is reached after the first year or so of service following construction. By following the water content changes throughout the mixing-paving process, one can note that the dryer-drum process may permit the mix to approach this equilibrium in a normal manner. Figures 17 and 18 show the water content change for two different material combinations and situations in general. In Figure 17 the aggregate stockpile had about 4 percent water and eventually leveled out to about 1/2 percent. The aggregate material shown in Figure 18 was more porous and the stockpile was wetter (this was November, while Figure 17 was in August). Again, the mixture tended to seek an equilibrium water content, but somewhat higher than for that shown in Figure 17. In summary, the water content in the dryer-drum produced materials tend to approach an equilibrium from the wet side, while in conventionally produced mixtures, it is approached from the dry side.

The compaction process itself is similar to that for other materials. As an illustration of what occurs during compaction, Figure 19 indicates (in the upper curve) that increased density is obtained as the number of roller passess increase. The lower curves show that the temperature drops from the laydown at 190°F to 155°F during this same period. In addition, as shown by the water plus asphalt curve (as measured by the nuclear gauge), water continues to evaporate, and eventually may level out. The final water of 2 percent content is the same as in Figure 18 and the asphalt content was 5.5 percent. The total water and asphalt content of 7.5 percent then checks with the curve shown in Figure 19. In summary, it appears that Figure 19 is a reasonable illustration of what occurs during the compaction process and that increasing densities are possible at these lower temperatures.

In general, most engineering properties of mixtures produced by the dryer-drum process are comparable to those produced by conventional plants. There appears to be some concern with both the short-term and long-term effects of the added moisture. It is possible that in some situations a temporary "tenderness" may be observed, but in projects known to the writer to date, this has been minimal. Longer range durability is still somewhat unknown, but after more than 3 1/2 years since the first project paved in Washington, no adverse effects have appeared.

The particulate emissions from the stack of a dryer-drum plant can be reduced dramatically. All factors relating to stack emissions have not been evaluated to date. However, the writer has observed several dryer-drum plants which would no doubt meet existing requirements without any collection equipment being used. In other situations, because of material and fuel combinations, a cyclone or some other add-on unit would be appropriate. Figure 14 shows the asphalt plant in full production and Figure 20 is a

Figure 17. Water content change: 4 percent water leveled out to about 0.3 percent (August).

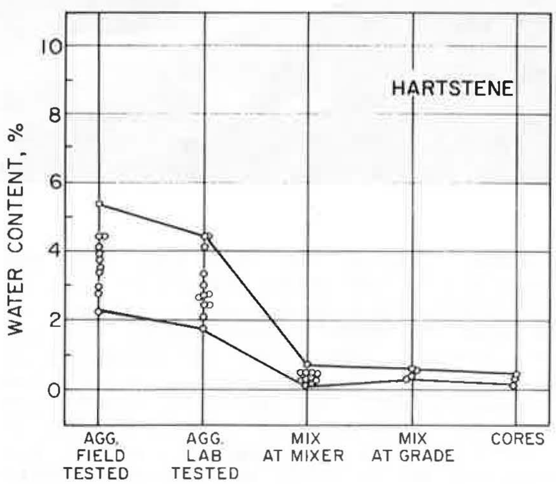


Figure 18. Water content when aggregate is more porous and stockpile is wetter (November).

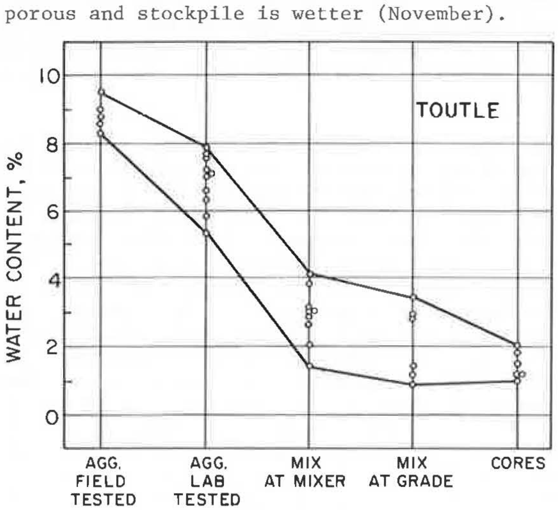


Figure 19. Density and temperature during compaction.

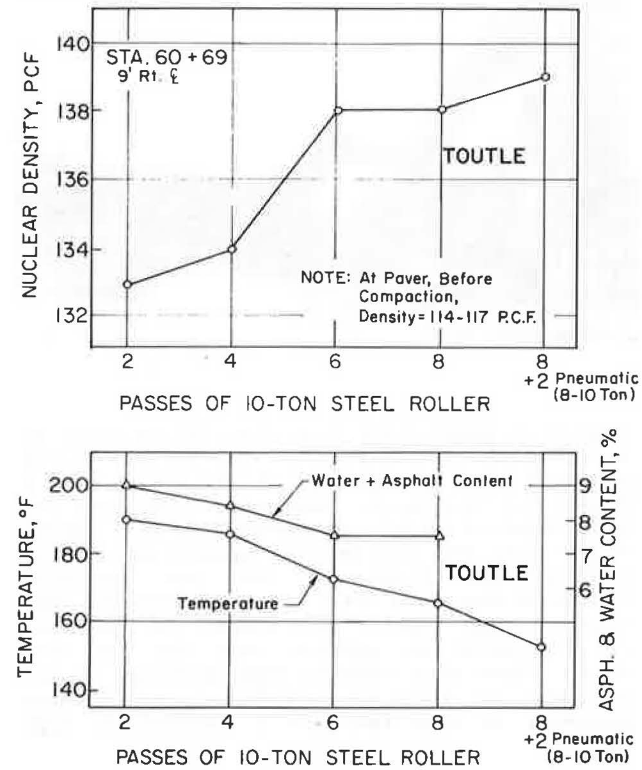


Figure 20. Close-up of plant stock.

close-up of the stack, indicating how clean the plant can operate.

In addition to the large (10-ft. diameter by 40-ft. long) size plants which can probably operate at a consistent 600 tph, there are medium size and small or "mini-plants" available.

CURRENT USE OF DRUM MIXER PLANTS IN THE U.S.

During the 1972 and 1973 construction seasons, drum mixing has blossomed in the United States. From the handful of "pioneer" contractor operations in 1972, at least 34 drum mixer plants were producing in 1973. Several plant manufacturers have configurations or variations of the basic drum mixer and include at least the following:

| Manufacturer | No. of Plants Operating 1973 |
|---|---|
| Boeing Construction Equipment Co. | 21 |
| Barber-Greene | 6 |
| Stan-Steel | 1 |
| CMI | 3 |
| Cedar Rapids | 1 |
| Aztec | 2 |
| TOTAL | 34 |

Acceptance by state agencies, particularly highway departments, has been remarkable, and the trend would indicate that acceptance will soon be nationwide. Although many states have used the process, the bulk of production (2,525,000 tons) has been in the following states:

| State | No. of Plants | Production |
|---|---|---|
| Alaska | 1 | 50,000 |
| Arizona | 2 | 200,000 |
| Michigan | 2 | 100,000 |

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DISCUSSION: "Asphalt Paving Mixtures -- Drum-Dryer -- R. L. Terrel

QUESTION: Claude Marais, South African Council for Scientific and Industrial Research.

Please comment on the effect of performance of a lesser drop in penetration and additionally on the effect of the moisture present on the early performance.

ANSWER: Terrel

I believe that several things happen with regard to these factors, and I don't know if I really have that ability to explain them. First, if we consider the moisture effect on early performance, it is probably best to think in terms of the compaction process, or workability in general. The viscosity of the asphalt binder will be somewhat less because of reduced hardening; however, at this point, it is probably not too significant. Our feeling is that there is a direct relationship between the amount of water in the mix and the temperature. In other words, I like to emphasize that the drum mixer is a lower temperature process, with typical recommended mix temperatures at about the boiling point of water, 210° to 220°F., as compared to conventional mix at, say, 275° to 300°F.

The phenomenon here is that we are trading water for heat. The moisture, usually one to two percent, provides lubrication which restores the mix viscosity lost due to lower temperature.

In answer to your question regarding the early performance of these mixtures, I have often heard questions and comments to the effect that "we don't know what is going to happen when we try these mixtures." The natural tendency is probably to expect a 'tender' mix. On occasion, this may happen, but probably no more often than with conventional mixes. At worst, it is a very temporary situation and is not detrimential as Bob Schmidt has repeatedly pointed out in earlier discussions. It is temporary, if it happens at all, and since the moisture is rapidly evaporating during laydown and compaction, the normal equilibrium water content is eventually reached in either case."

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

I observed on a job they were adding lime to the aggregate. What effect would this have on a job and on stripping?

ANSWER: Terrel

I really don't know, since I haven't seen any reports on this job. With regard to early stripping, we don't have extensive data as yet. However, we do have test results from immersion-compression tests that show more than 100 percent retained strength. This test may not be sophisticated, but it does indicate something with regard to water susceptibility. Some preliminary tests were made by Professor Bob Lottman using the procedure being developed in the NCHRP Project. Results from an Oregon project indicate that mix may be more susceptible to moisture damage than we might expect. However, these tests were very limited and the samples used were considered non-representative.

QUESTION: Anonymous
What was the aggregate absorption on that last slide that had about 2 percent residual water, and were these paved under traffic conditions?

ANSWER: Terrel
From memory, I believe the aggregate absorption averaged about 3 percent. It was glacially deposited volcanic material with a mixture of dense granitic material and pumice, which is quite porous. The project was paved under traffic conditions. It was a private logging road and traffic was permitted on the fresh mat within four hours after laydown. Traffic consisted primarily of 5-axle, 150 kip logging trucks spaced at 2 to 3 minute intervals, 24 hours per day.

QUESTION: Anonymous
Did the water content in the mix exceed the absorption of the aggregate?

ANSWER: Terrel
I don't recall, since I didn't bring that information with me. Furthering my comment on traffic conditions, there have been quite a variety of projects using drum mixers. Extreme environments have been encountered from Arizona to Nome, Alaska. Rural highways and Interstate Projects have been completed, but I can't recall any major urban paving. In total, quite a few million tons have been placed to date.

## HAULING, SPREADING, AND ROLLING - CONVENTIONAL MIX SYSTEM

DUNCAN A. McCRAE, District Manager
Lane Construction Corp.
Cumberland, Foreside, Maine

From my Northern Maine observations, I feel qualified to state that a reasonable amount of moisture in bituminous concrete does not seriously effect the operations of hauling, spreading and rolling this product. After I had written that statement I sat back and discovered that it really wasn't profound; in fact, I suspect that among pavement engineers and contractors that is reasonable accepted knowledge. Based on recent papers and on Charlie Foster's statements to Committee A2F02 of last year, we know that moisture in mixes manufactured in "Drum Mixers" is acceptable and, in fact, perhaps even necessary. However, these considerations posed two additional questions to me.

1. What is a reasonable amount of moisture?
2. Can moisture contents be readily determined in the field and at what point should the control be established?

My experience is that gained from observations made at our Northern most plant location in Caribou, Maine. As a construction engineer, and later as a construction superintendent, I have lived or travelled in the New England States, New York and the Middle Atlantic States and I felt that this range of experience made me qualified to observe and reasonably rate the quality of construction raw materials. The first time I was able to see typical Aroostock County Gravel I knew my experience had just included the lowest quality range of gravels.

Our aggregate processing plant was a multi-wash on both fine and course aggregates with special adaptations designed to remove soft pieces of aggregate not destroyed in the crushing process. The bituminous plant when originally set-up had one dryer, designed I suspect for average drying conditions. It was almost immediately that a second dryer was purchased in order that even a minimum production level could be maintained.

However, after all this aggregate preparation and drying we still produced bituminous concrete, on occasion, with excessive moisture.

Hauling wet bituminous concrete, I use the term loosely, presents no problems. Depending, on the amount of moisture, the load might flatten in the truck. Other times free water would run out of the tailgate. The haul distances would usually affect its physical appearance.

As far as I have observed the spreading of high moisture bituminous concrete required no special adjustments or considerations. The most notable occurrence was numerous blisters that would form most frequently in the middle of the mat. When the material is augured to the side, then most of the moisture was freed. These blisters would quickly subside and leave no trace.

Rolling did not require special tactics. The only consideration would be to hold back until all blistering had ceased. This usually occured within a few minutes after laydown.

The paradox that I now find puzzling concerns the pavement in its final position. Does it in fact contain moisture in excess of 1/2 or 1 percent. I know the aggregate had moisture in it for I have seen steam rising from hot bins. On occasion I have actually seen water dripping from those bins. I have seen loads level out in trucks. I have seen water drip from loaded trucks. I have seen steam escape from laydown mats. From this it appears the moisture content was high though we did not collect the confirming data. Yet after all these adverse situations I now seriously doubt that in our final mat we exceeded 1 percent moisture.

From observations I conclude that as long as bituminous concrete can be spread and rolled in the conventional manner, then the moisture content should not be a restrictive specification.

DISCUSSION: Duncan McCrae's presentation -- "Hauling, Spreading, and Rolling - Conventional Mix System"

QUESTION: Vaughn Marker, Asphalt Institute, College Park, Maryland
I do not usually associate slumping in the truck with the problems of tearing under screed. Did you observe this, and did you use silicone in your asphalt?

ANSWER:
No. We did not use silicone but with Kellam's talk about it this morning, I am going to look into it. We do use silicone in making certain of our cold mixes - at least in the summer time. But the workability was excellent. We never had a tender mix; we never had any experience with tearing, except when you let the temperature get down. It is necessary to work these mixes, in general above 275°; better around 290° to 300°. As the temperature dropped under 275°, the speading was more difficult and it was more obvious there was some tearing. In the normal temperature range it worked very well. I think this might just be true of a gravel aggregate. When we moved out of the gravel and into the quarry stone the mix did not