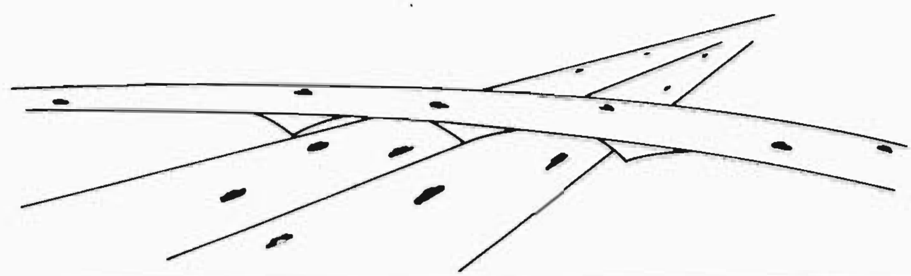

DEPARTMENTAL RESEARCH

Report Number SS 26.0

ASPHALT PAVEMENT RUTTING IN THE WESTERN STATES

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

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16. Abstract

This is a compendium of works that contains two lectures and the WASHTO report on pavement rutting in the western states. The first lecture by Paul E. Krugler, Supervising Bituminous Engineer of SDHPT, deals with specifics for Texas in the areas of materials and mixture design considerations. The second lecture by John B. Mounce, Jr., Engineer of Field Construction of SDHPT, deals with Texas specifics for traffic loading, compaction, construction controls, and correction of rutted pavements. Both lectures were presented as part of the Texas A&M Short Course on Highways.

The WASHTO document reports on a series of workshops which were conducted to assist the WASHTO states in preventing or reducing rutting in asphalt pavements. The asphalt pavement design and construction practices used by western states were collected and analyzed. A series of recommendations for immediate implementation and a list of recommended areas for future research are provided.

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Paul E. Krugler
Supervising Bituminous Engineer
State Department of Highways and Public Transportation

ASPHALTIC CONCRETE PAVEMENT RUTTING - MATERIALS AND MIXTURE DESIGN CONSIDERATIONS

It is the general feeling among Texas highway engineers that the frequency and magnitude of pavement rutting has been increasing steadily over the last decade. In several cases, pavements which had served rather satisfactorily for a number of years were noticed to have developed wheelpath ruts. More commonly, though, rutting has become evident during the first full summer after construction.

Rutting of pavements is a very serious concern of the Department for a number of reasons. Foremost, it creates a safety hazard for the traveling public. Vehicular control is adversely affected, particularly in wet and freezing conditions, because the pavement will not drain properly. Hydroplaning becomes more frequent, and ice patches which otherwise may not have occurred can result when temperatures drop. The uneven pavement is also a perplexing problem to correct. The reconstruction or corrective processes necessary to successfully restore a proper profile can be very time consuming and expensive. Simple level-up and overlay of deeply rutted pavements may result in the reappearance of the ruts because of poor compaction in the depressions or further lateral material movement within the problem layer below.

Other state highway agencies have also become concerned with the apparent increased frequency of rutting. Representatives of twelve western states met last October and December to address this problem. Mr. John Mounce of the Construction Division and I represented Texas at these meetings. Each of the individuals attending these meetings gave a brief presentation concerning the extent of the rutting problem in their state, what factors they believe to most often trigger this problem, and what their state was doing or plans to try to do to prevent frequent pavement rutting in the future. In addition, each of the represented states provided information concerning their asphalt pavement design and construction practices. All of this information was gathered, evaluated, and thoroughly discussed as a group.

It was found that the rutting problem identified in the western states, for the most part, falls into three categories:

1. Excessive traffic consolidation in the upper portion of the pavement.

2. Plastic deformation due to insufficient mixture stability.

3. Instability caused by the stripping of asphalt below the riding surface.

The first category, excessive traffic consolidation, usually occurs when poor compaction is attained during construction on high truck traffic routes. The second category, insufficient mixture stability, may result from either a poor mixture design or improper plant production. The third case, instability caused by asphalt stripping, results when the asphalt bond to the aggregate is lost. This usually occurs in underlying layers and the freed asphalt migrates toward the surface. Instability can occur in the stripped layer from lack of binder, from the upper layer which now may have become "over-asphalted", or both.

In my presentation today I would like to summarize for you the material quality and mixture design recommendations which resulted from these meetings. Following each I will explain what Texas has done and still hopes to accomplish in the future to prevent frequent occurrence of pavement rutting. The recommendations of the twelve state committee might be broken down into the eight areas listed below.

Aggregate Acceptance
Paving Asphalts
Mixture Design
Compaction
Construction Controls
Corrections of Rutting Pavements
Traffic Loading
Information Exchange

I will be discussing the first three. The remaining areas will be covered by Mr. John Mounce a little later this afternoon.

AGGREGATE ACCEPTANCE

Beginning with aggregate quality considerations, the committee recommended that each state require the aggregates to be non-plastic. In the same vein, it was recommended that a sand equivalent minimum of 45 should be required. It was the consensus that the presence of clay fines must be limited to control problems with volume swell and adhesion of asphalt to the rock, which in turn creates a stripping problem. In this regard, Texas currently requires a plasticity index of 6 or less for the minus No. 40 sieve fraction of each fine aggregate. We also require our combined aggregates to meet a 45 sand equivalent minimum.

Two recommendations were made addressing aggregate durability. One is that each aggregate meet a Los Angeles Abrasion test maximum loss of 40 percent. Also, the aggregate should be required to meet a Sodium Sulfate or Magnesium Sulfate Soundness test maximum loss of 12 percent. These requirements should insure that the aggregates can resist crushing, degradation, and disintegration under traffic and should not deteriorate under the action of weather. Texas has had the Los Angeles Abrasion requirement of 40 percent maximum for a long time.

However, we do not have a Standard Specifications requirement for soundness on our hot mix aggregates. As most of you know, though, about five or six different Districts have occasionally required a four cycle magnesium sulphate soundness maximum loss of 30 percent in their plan notes. We have not to my knowledge ever required a loss as low as 12 percent as recommended by a consensus of western states. The effect of adding a requirement such as this would require careful study prior to adoption in Texas.

A final aggregate quality recommendation is that at least 60 percent of the aggregate retained on the No. 4 sieve should have more than one fractured face. As friction between aggregate particles depends on the aggregate surface roughness and the area of contact, stability should be increased if both of these conditions are positively affected by crushing. Also, the amount of natural, rounded fines used should be controlled by also using an appropriate amount of crushed fines. Texas requires a maximum of 85 percent of the gravel particles retained on the No. 4 sieve to have more than one crushed face. So we are a little stronger in this area than the group recommended.

PAVING ASPHALTS

Next let's look at requirements on our asphalt cements. There was a feeling among many at these meetings that the approach of our asphalt specifications should be improved. It was felt that asphalts meeting specifications may actually perform poorly on the road. This is particulary true when the specifications are based on AASHTO M-226, Table #1. The group recommended that a specification based more on performance be developed. Problems such as rutting, stripping, cracking and raveling should all be considered in the development of a performance specification. Although we do not believe that we have some of the specification problems that several other states have, we always are interested in making our specifications more performance oriented. One void in our current specification is a test and requirement for adhesion. Until a performance specification can be developed, it was felt that the states should adopt AASHTO M-226, Table #2 material requirements for their paving asphalt. The need to address temperature susceptibility of the asphalt was also stressed. This characteristic of an asphalt can be described using a viscosity-temperature chart as shown in Figure 1. The steeper the plot, the more temperature susceptible the asphalt is. Current requirements for asphalt cement in Texas are already very near those of the proposed AASHTO M-226, Table #2. We also agree that temperature susceptibility is a characteristic which is of primary importance to overall material quality. The problem is not so much how to specify what we want, but how to obtain adequate quantities from producers should we tighten our specification. We would be interested in evaluating practical methods of specifying and obtaining improved temperature susceptibility characteristics in our asphalts.

A recommendation was made that a cooperative study be made to compare asphalts from rutted and nonrutted pavements. All representatives expressed a willingness to participate in this effort, but it has not gotten underway at this time. Having recognized a need for this work several years ago, Texas authorized the Texas Transportation Institute to gather samples and determine asphalt characteristics, gradations, and mixture properties for rutted and nonrutted pavements. A report on this work is forthcoming and we should be in a good position to participate in the cooperative state study should it occur.

MIXTURE DESIGN

A number of factors should be considered during mixture designing. Aggregate gradation is a primary consideration for a stable mixture. The distribution of particle sizes determines the volume of voids that will be available for asphalt cement between the aggregates after compaction. This volume is often described as the voids in the mineral aggregate, or VMA, of the mixture. The following sieves are considered the primary control sieves by the committee. They suggest that the gradations shown are near maximum density and that potential for pavement rutting increases if greater values are adopted.

Sieve	Percent Passing
No. 4	55
No. 10	37
No. 40	16
No. 200	3 to 7

These values are toward the midpoints of our Types C and D master grading limits. Figure 2 depicts both the current Department Type D master grading limits, transposed to percent passing, and the above values on a 0.45 power gradation chart. The use of this type of chart for analyzing asphalt mix gradations, particularly when troubleshooting, is recommended.

The use of VMA analysis was recommended in conjunction with gradation limits in the specifications. The group did not recommend any specific values, however. We do not currently have a direct control of VMA in our specifications in Texas. We indirectly speak to this need when we specify a minimum allowable asphalt content in our mixtures. The need for incorporating a VMA requirement in our specification is being studied.

The group recommended that a minimum Hveem stability of 35, or a minimum Marshall stability of 1500 lbs, be required. Texas recently increased the Hveem stability requirement to 35 in our standard specifications. In addition, the Marshall stability test is being evaluated for possible future use in Texas in conjunction with our Hveem stability. Over twenty mixtures produced across the state this summer were evaluated using the Marshall procedure, as well as the indirect tensile test and resilient modulus determination. The results are still being compiled and evaluated.

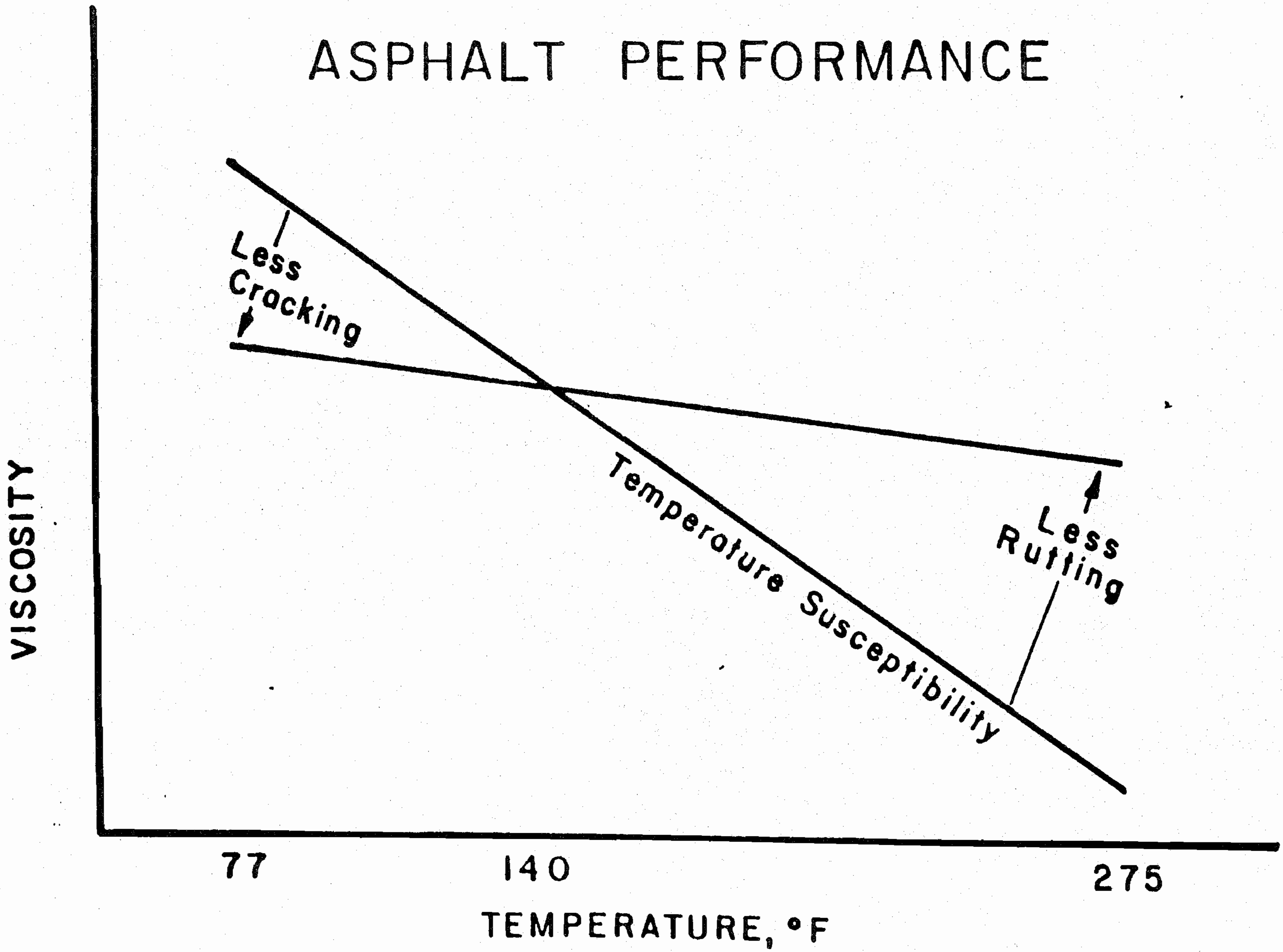
ASPHALT PERFORMANCE
Less Cracking
Temperature Susceptibility
Less Rutting
VISCOSITY
77
140
275
TEMPERATURE, °F

Figure 1

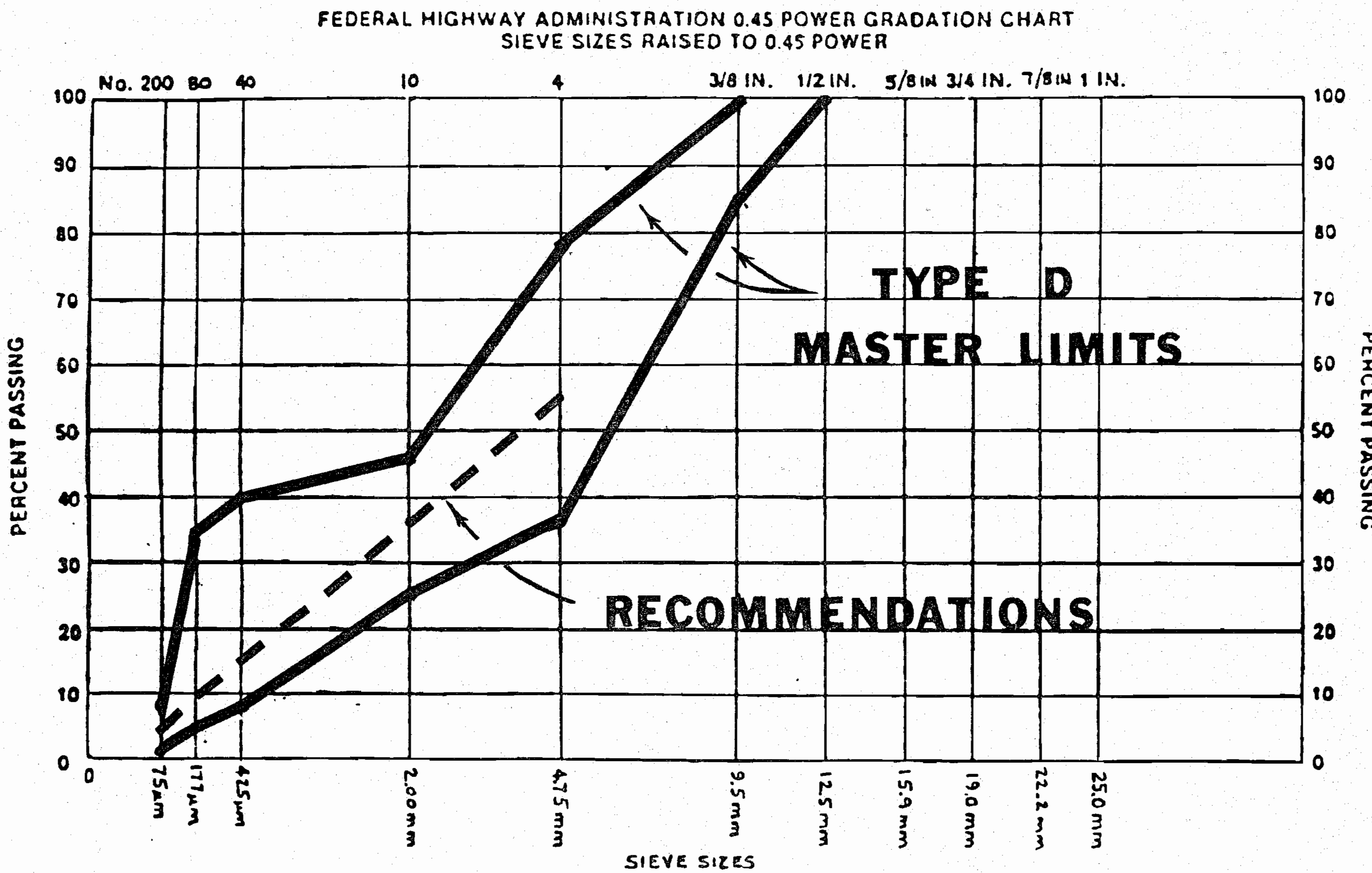
FEDERAL HIGHWAY ADMINISTRATION 0.45 POWER GRADATION CHART
SIEVE SIZES RAISED TO 0.45 POWER
No. 200 80 40 10 4 3/8 IN. 1/2 IN. 5/8 IN 3/4 IN. 7/8 IN 1 IN.
PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
TYPE D
MASTER LIMITS
RECOMMENDATIONS
75µm
177µm
425µm
2.00mm
4.75mm
9.5mm
12.5mm
15.9mm
19.0mm
22.2mm
25.0mm
SIEVE SIZES

Figure 2

Another mixture design recommendation was that mixtures be designed to contain from 2 to 5 percent voids as determined by the Rice method. Texas, of course, requires that mixtures be designed to have 3 percent air voids. Our design method utilizes individual aggregate and asphalt specific gravity values to derive a theoretical combined value for determining density, or air void level. The Rice method has recently been included in Texas' Manual of Testing Procedures as Test Method Tex-227-F. At this time, though, the test is primarily for use in determining the effectiveness of pavement compaction.

It was further recommended that laboratory mixes be made and compacted at temperatures corresponding to the following asphalt viscosities.

Laboratory mixing: 150 - 300 centistokes
Marshall compaction: 250 - 300 centistokes

We do not vary our mixing and molding temperatures in Texas. Instead, we have set our mixing temperature at 275 F, our molding temperature at 250 F, and hold them constant. Although asphalt viscosities are then allowed to vary, these temperatures should be adequate to insure a proper coating of the aggregate and consistant compaction of our specimens. I do not foresee us changing our laboratory temperatures except when special experimental materials are involved.

It was finally recommended that design asphalt content be determined by the use of an accepted design procedure, that the design procedure should include a moisture susceptibility test, and that any changes of the asphalt content be made by District or Central Materials staff. Texas designs all of its mixtures according to our own mix design method. A number of moisture susceptibility tests are available, but it is not required that one be performed every time a lab mix design is made. I would recommend, though, that a moisture susceptibility evaluation be made whenever an apshalt-aggregate combination is used for which we have not established a good performance record. The recommendation that changes in design asphalt content should only be made by those responsible for the initial mixture design is probably not practical in Texas. The point that thorough consideration should be given before approving asphalt content change is valid. The asphalt content is extremely critical to the performance of the paving mixture.

Although not included in the recommendations of the committee, I believe that the ratio of maximum aggregate size to overlay thicknesses is an important factor also. I believe this particularly true on overlays of existing pavements. If the maximum aggregate size is too small for the thickness to placed, the probability of lateral material movement is increased. Relatively larger aggregate should more effectively carry heavy loads without movement because there are fewer planes for movement to occur in these mixtures. Lateral movement of material should also be better resisted, in my opinion, by a coarser mixture surrounding the stressed area. I do not know what the optimum ratio of maximum aggregate size to overlay thickness is. I would think, though, that from a rutting resistance standpoint the largest maximum aggregate size should be used which will still allow adequate workability for in-place density to be achieved.

Another consideration when discussing overlay thickness is the applicability of our Hveem stability test. The specimens which we test are a standared two inches in height. I support our policy of using a constant specimen height. As we discussed earlier, an overlay height of three inches will not exhibit the same load carrying characteristics that the same mixture would have when placed one inch thick. The mixture design and job control Hveem stability value would be the same, however. It may be adequate for one placement and not for the other. And so, our structural design thickness and type of mixture selected must be considered as the project is in the design stage.

Although touched on lightly by the committee recommendations, I would like to emphasize that using crushed stone screenings promotes a toughness to the mixture that should help resist pavement rutting. Field sands tend to be round in shape and promote workability, which is good up to a point as you are placing the material but can be detrimental thereafter. I believe that an optimum mixture in that regard is one that contains only the minimum amount of field sand necessary for placement and satisfactory compaction.

In summary, then, we do believe that rutting is becoming more frequent and is a serious concern. This is a consensus feeling of most all of the western states. As with most pavement problems, there can be a variety of causes. And usually there are several contributary factors when a certain pavement begins to deteriorate. We will hear more about other contributary causes in Mr. Mounce's presentation in a few minutes. Texas' specifications already include most of the recommendations of the twelve state committee that I have covered. However, we are continuing to work with various research organizations and in our Materials and Tests Laboratory to learn more about the rutting phenomenon. It is hoped that these efforts may result in reduced pavement rutting of Texas highways in the future.

ASPHALTIC CONCRETE PAVEMENT RUTTING -
TRAFFIC LOADING, COMPACTION, CONSTRUCTION CONTROLS,
AND CORRECTION OF RUTTED PAVEMENTS

John B. Mounce, Jr.
Engineer of Field Construction
State Department of Highways and Public Transportation

As Paul pointed out earlier, the twelve state committee made recommendations in eight general areas that might help reduce the rutting of our asphaltic concrete pavements. Paul has discussed the first three. I will briefly enumerate and discuss the last five. These recommendations were published in a report that was recently distributed to the members of the committee from the twelve states. Even though these recommendations were published by FHWA, it must be stressed that they are just that: recommendations and they may or may not have an official sanction by the states from which these representative engineers come. It was hoped that by adopting one or more of these recommendations, a step would be taken toward eliminating or reducing the rutting problem being experienced by all the western states in their asphaltic concrete pavements.

TRAFFIC LOADING

I don't believe that any of you here today would argue with me that the traffic using today's pavements is the same as the traffic of just five years ago - there's more of it, the truck tire pressures are greater, and the gross loads being moved by the trucks are almost unbelievable. This same report was given almost unanimously by the representatives of all 12 states attending the pavement rutting workshops. Based on this information, the concensus of the participants of the workshop was that the traffic load data used for our pavement design is probably outdated or does not accurately reflect the loads being applied to the pavement. Reasonably accurate load prediction is basic and essential to designing pavements if these pavements are to provide the service life intended. It follows that the design life of a pavement is considerably reduced when calculations are based on erroneous load data. Several states indicated that studies made on pavements experiencing premature distress found that the 20 year load predictions were actually applied in 8 to 10 years.

As a result of the limited data available to the committee, the following recommendations on traffic loading were made:

1. That the states pavement design personnel should become involved in the development of load prediction information.

2. That the states should improve the quality of loading data for design, and stress the importance of enforcing load regulations.

   A. Load regulations and enforcement are a matter of high level policy making and are beyond the scope of the asphaltic pavement rutting workshops.

   B. The W-4 tables are the basic source for the 18 KIP Equivalent Axle Loads used for pavement design. The information in the W-4 tables is obtained from truck weight and traffic classification data. This data is collected by sampling traffic at a limited number of locations for short periods of time. Considerable evidence indicates that the procedures typically used to collect this data do not accurately sample the actual traffic.

3. That the states should install weigh-in-motion equipment to gather design data.

   A. Weight and axle data is commonly collected manually at fixed or portable weigh stations. The amount of data collected is severely limited by costs, manpower, and traffic disruptions. The widespread use of CB radios by truckers makes it relatively easy for overloads to avoid these sites when they are being used to collect weight data. Weigh-in-motion data collection can minimize most of these limitations.

   Substantial improvements in collecting traffic data for design purposes can be realized through the use of currently available equipment. (Five different companies demonstrated weigh-in-motion scales at the Pavement Rehabilitation Conference in Oklahoma City in May).

COMPACTION

The WASHTO workshop committee felt that if we are to prevent rutting in our asphaltic concrete pavements that we are going to have to improve our compaction controls at the roadway. To do this the committee made five recommendations:

1. That the states should control compaction by specifying a percent of measured voidless mix as determined by the Rice Method. The following density requirements were also recommended: 94% of voidless mix based on the mean of five tests with no test below 91%.

   A. These limits were based on the recommended design voids of 2 - 5%. (Texas Requirements are 3 - 8%).

Some states control field densities using a per cent of Marshall, either a design Marshall or briquets pounded out in the field. Other states use the Hveem's method. In most mix analysis the void content is the most important factor. Since the Rice method is directly concerned with the relationship of the voids in the mix and it directly represents the mix being laid, it was considered the most reliable method to use for field control of compaction.

Some states had reservations and concerns about using the Rice Method, but the majority of the states at this meeting decided that the benefits to be derived from adopting this recommendation far outweighs the problems that might be encountered by requiring the use of this method.

2. That the states should require the paving contractor to demonstrate a rolling pattern that would achieve the required compaction at the start of the paving operations.

The initial recommendation discussed by the committee required the states to develop a procedure for achieving compaction and establish a rolling pattern. However, some states representatives questioned the state's roll in establishing rolling patterns. The final concensus on this recommendation was that the states should not accept or imply responsibility for the contractor's rolling patterns. It was suggested that the states might assist the contractor by preparing time - temperature curves and temperature - compaction curves but the responsibility for providing the necessary rolling equipment and establishing the rolling pattern must remain with the contractor. (See sample time - temperature and temperature - compaction curves in the appendix). Although these curves contain a very limited amount of information it demonstrates that aggressive rolling combined with a systematic rolling procedure will yield the highest and best compaction.

3. The states should specify that the required density be achieved before the mix temperature drops below 200°F.

This recommended temperature is several degrees higher than the 175°F required by Texas Hot Mix Specifications. However, to repeat what has been previously stated: both the Texas Specifications and the committees recommendation recognizes that aggressive rolling and better compaction is a positive step toward reducing rutting in asphaltic pavements.

4. The states should specify the pneumatic roller as one of the rollers in the compaction process.

Not only does the pneumatic roller provide a kneading action that is needed to tighten and seal the mix, it is especially important on level up and overlay courses of hot mix. When an overlay is placed on an old, uneven pavement, the steel wheel rollers tend to ride on and compact only the high points while the pneumatic roller will compact the valleys or depressions as well.

5. The states should control late season paving by adopting a minimum roadbed surface temperature of 50°F and/or a cutoff date.

Some districts in Texas presently have a cutoff date for placing surface courses of asphaltic pavement. However, most Texas engineers feel that the surface temperature and/or wind chill factors are more important criteria than seasons.

CONSTRUCTION CONTROL

Another area of concern expressed by most of the participants at the WASHTO workshop centered on construction control. Several charges have been suggested to the specifications that would improve our paving asphalts and our mix designs. Improvements have been suggested for our design data collection and compaction considerations have been discussed. But there was concern by many states that ineffective construction control and conscious deviations from specifications could effectively cancel most of the other benefits that might be derived from implementing the materials and compaction recommendations. With this in mind the committee made three recommendations:

1. The states should make a special effort to ensure that agency construction personnel and contractor personnel are familiar with the importance of quality control and the impacts of deviating from prescribed specifications.

Several states indicated severe rutting problems in dryer drum mixes produced at lower temperature. This was attributed to higher mix moisture content and less age hardening of asphalt during the mixing process. Rather than specifying temperature ranges for different grades of asphalt, it was decided to recommend a viscosity range based on centistokes. The states could then establish temperature ranges that would give the desired viscosity for the asphalts they use.

2. The states should adopt a discharge temperature at the mixing plant based on a viscosity of 150 to 300 centistokes.

Oregon did a research study that checked asphalt from the refinery to the finished pavement. In many instances they found an increase in penetration during the mixing process.

As a result of this research, the "C" test procedure was developed. Mixes that contain asphalts with "C" values of less than +30 have a high rutting potential, while mixes having "C" values of greater than +50 have little potential for rutting. Oregon's experience indicates little or no problems with rutting of pavements with gas type fuels such as propane or natural gas. Most of the problems have been with the heavier burner fuels and reclaimed motor oils. Several states indicated that they suspected mix contamination by unburned fuel as one of the causes of pavement rutting. Therefore, it was recommended that:

3. The states should evaluate the "C" value test as developed by Oregon for determining mix contamination by burner fuels. Until this evaluation is completed, burner fuels should be restricted to propane, natural gas, #1 and #2 fuel oils.

CORRECTION OF RUTTED PAVEMENTS

When a pavement is found to be rutting, each section should be thoroughly investigated and the longitudinal, lateral, and vertical plane of failure determined. Once the cause of failure has been determined, the following recommendations were made to correct the rutted pavement:

1. The states should remove pavement ruts to a determined plane, usually to the full depth of failure. The material removed may be recycled.

2. When the material removed from the rutted sections is to be recycled, the states should do a complete mix design for the recycled material, and the structural adequacy of the final pavement section should be checked.

INFORMATION EXCHANGE

At present, materials personnel from WASHTO only meet at the annual AASHTO materials meeting. There is little time to discuss specific problems peculiar to the western states. A Western States Material Association would allow these materials people an opportunity to address unique Western States problems. Therefore,

1. The states should form a Western States Materials Association.

2. The states should join in a cooperative effort to evaluate the Creep Test Procedure. The Creep Test specifically addresses rutting pavements. The states of Utah and North Dakota presently run this test and can supply additional information to other states interested in performing the test.

3. The states should establish a means to check design and test procedures used to arrive at a final mix design.

The AASHTO states presently, through AMRL, have a means of addressing procedures, repeatability, and reproducibility of testing. It is not the intent of this recommendation to duplicate or interfere with this process, but to address a particular mix and the resultant mix design.

4. The states should compile a directory of testing capabilities and cooperate to the extent possible in providing testing assistance to the Western states.

This has been a brief overview of the recommendations made by the representatives from the 12 western states attending these meetings. The full text of these recommendations concerning rutting of asphaltic concrete pavements was published in a report dated May, 1984. These reports will be distributed to the states on a limited basis very soon.

Thank you!

APPENDIX

TEST NO. 1

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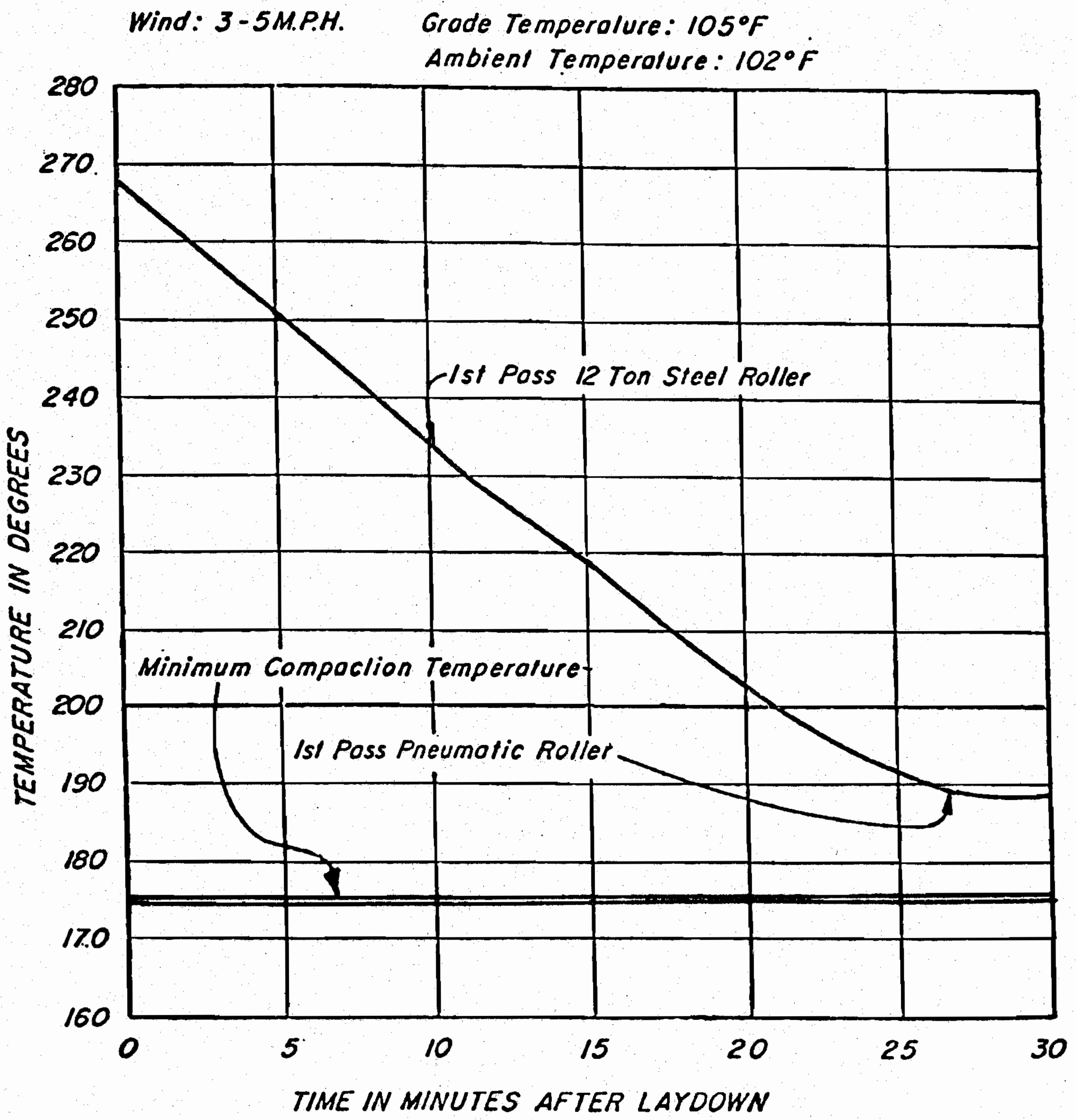

91.4% Compaction

TEST NO. 2

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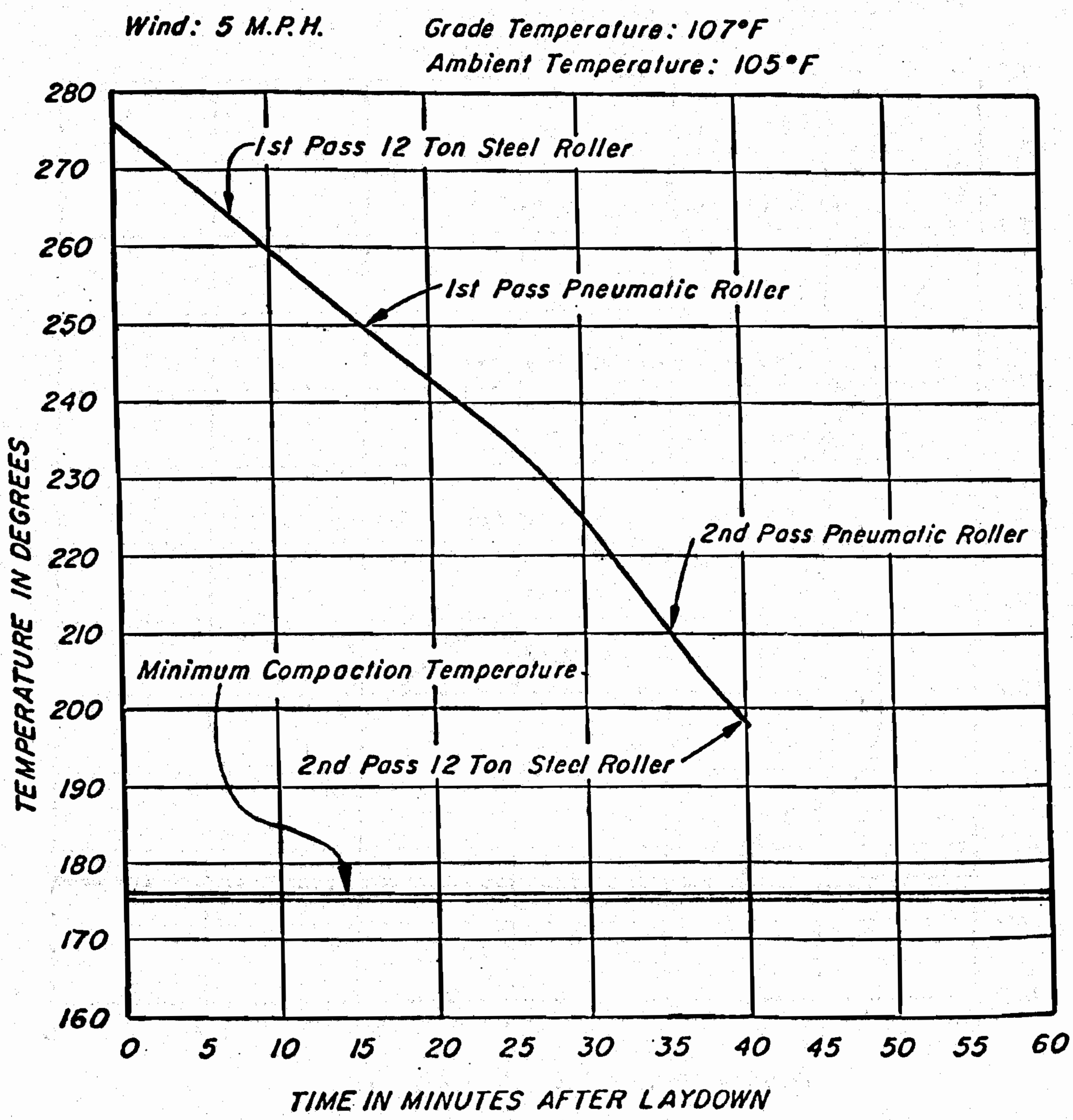

90.0% Compaction

TEST NO. 3

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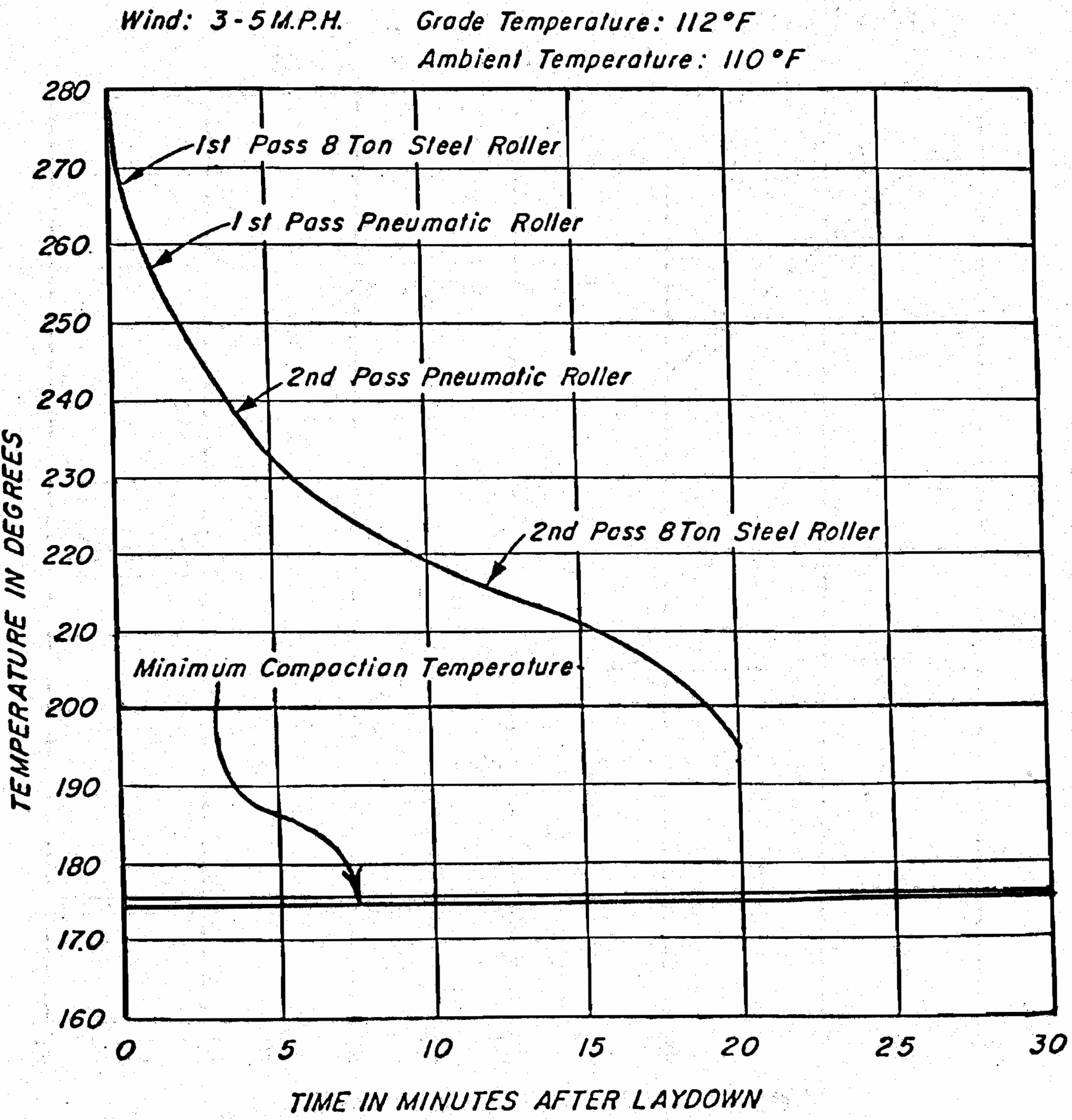
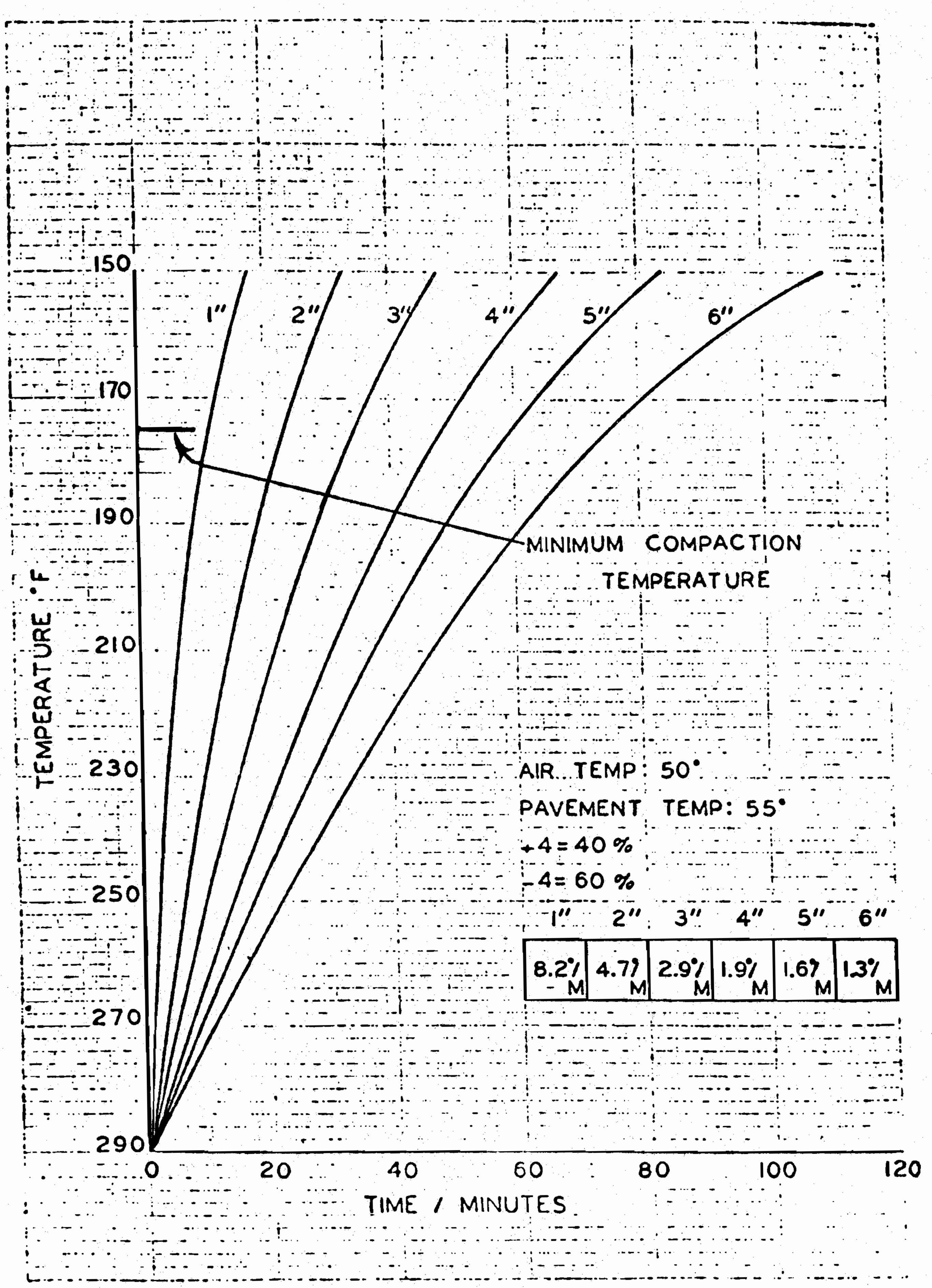
3/4" MAX.

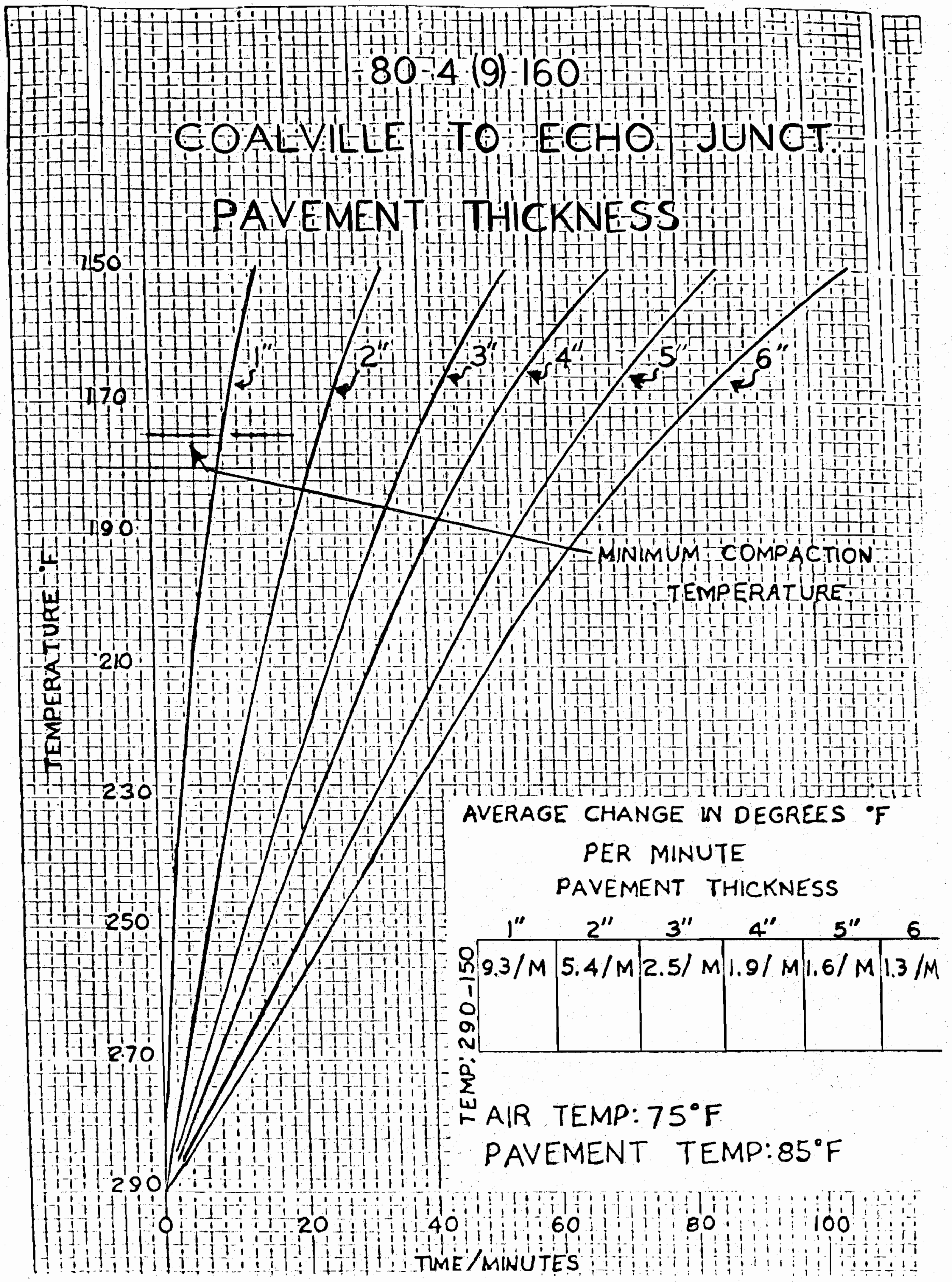


96.4% Compaction

5

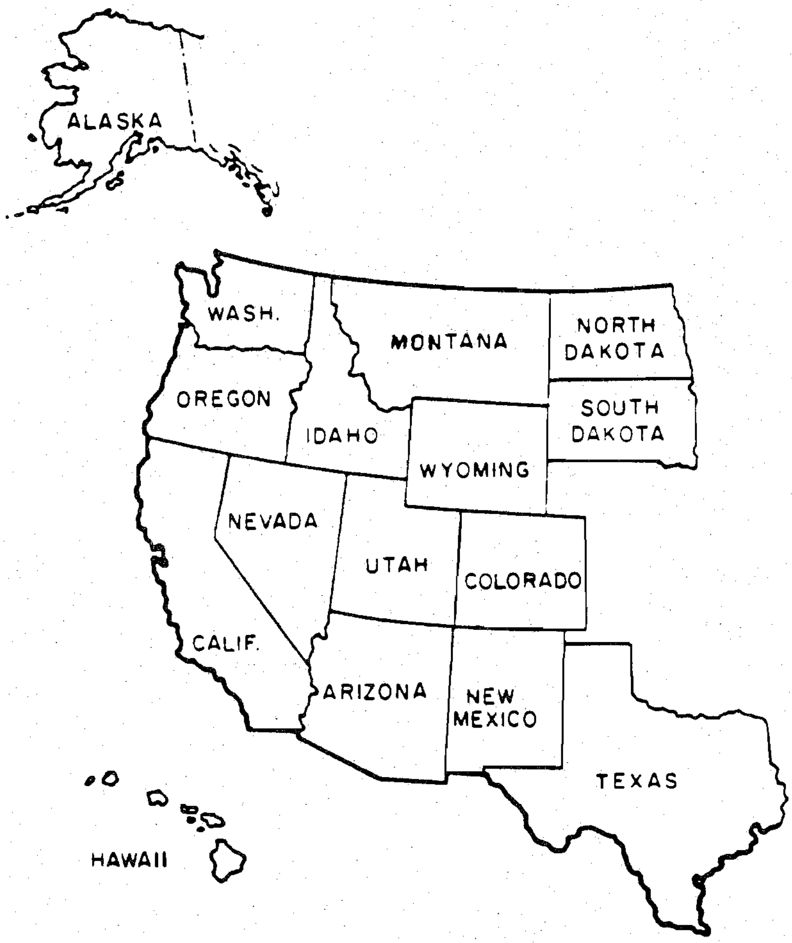

TEMPERATURE °F
150
170
190
210
230
250
270
290
1"
2"
3"
4"
5"
6"
MINIMUM COMPACTION TEMPERATURE
AIR TEMP: 50°
PAVEMENT TEMP: 55°
+4=40%
-4=60%
1" 2" 3" 4" 5" 6"
8.2%/M 4.7%/M 2.9%/M 1.9%/M 1.6%/M 1.3%/M
0
20
40
60
80
100
120
TIME / MINUTES

6


80-4 (9) 160
COALVILLE TO ECHO JUNCT.
PAVEMENT THICKNESS
150
170
190
210
230
250
270
290
TEMPERATURE °F
1"
2"
3"
4"
5"
6"
MINIMUM COMPACTION TEMPERATURE
AVERAGE CHANGE IN DEGREES °F
PER MINUTE
PAVEMENT THICKNESS
1" 2" 3" 4" 5" 6
TEMP. 290–150
9.3/M 5.4/M 2.5/M 1.9/M 1.6/M 1.3/M
AIR TEMP: 75°F
PAVEMENT TEMP: 85°F
0
20
40
60
80
100
TIME/MINUTES

Western Association of State Highway and Transportation Officials

ASPHALT PAVEMENT RUTTING WESTERN STATES



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16. ABSTRACT

A series of workshops were conducted to develope guidelines to assist the WASHTO States in preventing or reducing rutting in asphalt pavements. The asphalt pavement design and construction practices used by the Western States were collected and analyzed.

A series of recommendations for immediate implementation and a list of recommended areas for future research are provided.

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ASPHALT PAVEMENT RUTTING

WESTERN STATES

MAY 1984

A WORKSHOP REPORT

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This report is respectfully submitted by the

Asphalt Pavement Rutting Subcommittee.

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Gratitude is expressed to the New Mexico State Highway Department and Utah Department of Transportation for the typing and printing of the report.

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INTRODUCTION

BACKGROUND

During the mid and late 1970's, many Western States started to detect asphalt pavement rutting in proportions that were considered a problem. In some of the States, the problem has grown to the point that it is considered the most pressing issue presently facing the highway agencies.

Several States have reported recent evidence of rutting in pavements over 10 years old. In addition, pavements only a few months old have also exhibited severe rutting. The severity of the problem ranges from ruts which are less than 1/2 inch in depth to ruts which are 1 1/2 inches or more in depth.

The rutting problem identified in the western states, for the most part, falls into two categories:

1. Excessive traffic consolidation in the upper portion of the pavement.
2. Plastic deformation due to insufficient mix stability or instability caused by the stripping of asphalt below the riding surface.

In general the problem is not associated with subgrade deformation or failure.

In both of the cases above, traffic loading must also be considered as a major contributor to the problem. This may account for the rutting in the older pavements.

Possibly the design and construction practices used during the initial construction of the pavement were adequate for the loads applied at that time. The increase in tire pressure, tire configuration, gross loading and load repetitions may have exceeded the load carrying capability of the pavement.

A contributing factor may also be the results of efforts to reduce previous cracking problems through the use of softer asphalts and richer asphalt content design mixes.

The severity of the rutting problem has reached such magnitude that most of the western states have expressed a willingness to accept some cracking, and deal with it through normal maintenance practices, in order to reduce rutting which cannot effectively be handled by maintenance.

In early October 1983, when the AASHTO states' representatives met in Denver, Colorado, a group of executives from various western states and the Federal Highway Administration (FHWA) met and decided to assemble the WASHTO states to addressing the rutting of asphalt pavements.

All the WASHTO states and the FHWA were contacted by the Wyoming Highway Department regarding a kickoff meeting, and all representatives agreed to attend with the exception of California and Washington. The initial meeting was held in Cheyenne, Wyoming on October 20, 1983.

At that time, the state and FHWA participants gave a brief presentation regarding problems and proposed solutions for their particular rutting pavement problems. At the conclusion of the meeting, representatives from New Mexico, Montana, Utah, Wyoming and the FHWA were requested to form a subcommittee to pursue the problem of rutting asphalt pavements; each of the represented states were requested to provide information concerning their asphalt pavement design and construction practices. The subcommittee meeting in Salt Lake City in November 1983 summarized information provided by the states, and prepared a list of proposed recommendations for the prevention or reduction of the rutting problem. All the representatives of western states and the FHWA, with the exception of California, Washington and South Dakota, met in Denver on December 15, 1983. All information gathered at the Salt Lake City meeting was presented and thoroughly discussed. The subcommittee was assigned the task of preparing a final report reflecting the discussions at the three meetings and summarizing the recommendations which were the consensus of the western states.

It should be noted that while a consensus was achieved, there was by no means total agreement among the workshop participants on each recommendation.

OBJECTIVES

The objective of this workshop was to receive input from the western states and the FHWA and to prepare a report that would reflect as nearly as possible the group's opinions on the following items regarding rutting asphalt pavements:

1. Aggregate Acceptance
2. Paving Asphalts
3. Mix Design
4. Compaction
5. Construction Controls
6. Correction of Rutting Pavements
7. Traffic Loading
8. Information Exchange

The first goal was to arrive at some short term recommendations, which could be implemented by the 1984 construction season, regarding design, specifications, testing, job control and other issues. The intent of the workshop was not to require that the proposed changes be adopted by any particular state, but to develop some guidelines that could be of assistance in correcting problems with rutting asphalt pavements. The second goal was to meet with researchers outside of the highway agencies and develop a plan for long and short term research regarding rutting pavements.

PART I
SHORT TERM ACTIONS

PART I - SHORT TERM ACTIONS

DATA GATHERING

During the WASHTO states' meeting in Cheyenne, all of the states' representatives were asked to discuss their experiences with asphalt pavement rutting. In addition they were asked to supply information concerning their asphalt pavement design and construction practices. This information was summarized and used in developing the recommendations contained in this report.

A summary of the western states' design and construction practices are contained in Appendix A.

DISCUSSION

AGGREGATE ACCEPTANCE

1. The states should require the aggregates to be non-plastic.

   The presence of clay fines in an asphalt mix can result in problems with volume swell and adhesion of asphalt to the rock, thus, creating a stripping problem.

2. The states should adopt the Sodium Sulfate or Magnesium Sulfate Soundness Test with a requirement for a maximum loss of 12%.

   Aggregates must be durable; they must not deteriorate under the action of weather. Shale seams are a very common contaminate in aggregate sources through the West. The Sodium Sulfate or Magnesium Sulfate Tests are very useful in screening aggregates that have low resistance to weathering.

3. The states should adopt the Los Angeles Abrasion test with a requirement for a maximum 40% loss.

   Aggregates used for asphalt concrete must be durable. For successful performance in roadway mixtures, they must be able to resist crushing, degradation and disintegration under traffic. The Los Angeles Abrasion Test is a useful tool to measure the durability of an aggregate.

4. <u>The states should adopt a minimum sand equivalent requirement of 45.</u>

The Sand-Equivalent Test is an excellent tool for evaluating the quality of an aggregate with respect to excessive clay fines. These clay fines are detrimental to a mix in that they inhibit the adhesion of an asphalt to an aggregate and thus contribute to a moisture susceptibility problem. It has certain advantages that make it a useful test: the equipment is inexpensive and easily transportable, thus making it useful as a quality control test as well as a design test; also the test can be run in less than 30 minutes. Research by Arizona, New Mexico and California in the late 50's and early 60's indicated that an aggregate with a sand equivalent of 45 or more would be a satisfactory material for the production of asphaltic concrete.

5. <u>The states should adopt a fractured faces specification. At least 60% of the material retained on the No. 4 sieve have two fractured faces.</u>

Friction between aggregate particles depends on the aggregate surface roughness and the area of contact. As surface friction increases, so does resistance of the mix to deformation. A rounded, polished aggregate is more likely to have a lower stability than a crushed angular aggregate. Therefore, it was recommended that the aggregate be primarily a crushed material. The requirement of a crushed coarse aggregate will generally result in a quantity of crushed fines. Efforts should be made to control the amount of natural fines used, by stockpiling the natural and crushed fines separately.

PAVING ASPHALTS

1. <u>The western states should enter into a cooperative effort to establish a performance specification for asphalts</u>.

   In general, it was recognized that many of the current specifications, such as those of AASHTO, fail to measure the relative quality of asphalt. Materials meeting these specifications may actually show poor performance in service. The participants expressed a willingness to pay an increase for asphalt if they could be assured of a quality product. It was expressed that there is a considerable amount of information already available that may be of assistance in developing performance specifications. These performance specifications should consider all of the problems associated with plant mix pavements such as rutting, stripping, cracking, raveling and others.

2. <u>Until a performance specification can be developed and accepted, the states should adopt AASHTO M-226, Table #2 for high volume, heavy highway traffic pavements, with modification on the ductility test from 77°F to 39.2°F (see appendix D).</u>

   A review of the currently used specifications indicates they do not actually evaluate the performance of asphalts, but only the consistency of the product.

   If a specification is so broad all asphalts fit within it, it is not a meaningful specification. The consensus of the participants was that the use of Table #2 was desirable but may lead to the elimination of acceptable asphalt sources in several states. The Table #2 specifications address the temperature susceptibility characteristics of the asphalt to some degree, with more control on the viscosity at 275°F and higher penetration asphalt. The recommendation was accepted in principle by several participants, but they stated they would probably not adopt Table #2 immediately.

3. <u>A cooperative study should be established to compare asphalts from rutted and nonrutted pavements</u>.

   Asphalt comparisons will be made from core samples. The physical test will also be determined from the core samples. All the representatives expressed a willingness to participate in this effort. The objective of this testing will be to determine what properties have changed and what properties may have contributed to the distress problem.

4. <u>Representatives of the western states should meet with local materials groups and technologists to relate the type and need for future asphalt research</u>.

   The subcommittee met with some technologists on December 16, and recommendations for future research needs are included in Part II of this report.

5. <u>Representatives of the states should meet as a group with local asphalt producers to discuss present concerns about the quality of asphalts and the future of the highway rehabilitation program in the western states</u>.

At the present time, paving asphalts are made from several sources of crude oils, as compared with the pre-1973 OPEC oil crisis, when crude oil from a single source often provided the states with the same paving asphalt year after year. Today petroleum refineries must often operate with any crude oil that is available.

The consensus was that asphalts have changed, yet the present physical tests do not indicate this change. An open line of communications must be established with the local asphalt producers so they are made aware of our concerns about the quality of asphalt. With the present emphasis on overlay type construction, it is important to stress to the local producers the need for quality asphalt.

The logistics of meeting with such a group would have to be discussed at the next Western States Materials Engineers meeting in fall of 1984.

"A Literature Summary of Highway Asphalts of Yesterday and Today," regarding concern for the quality of asphalts and the highway rehabilitation program, can be reviewed in Appendix C.

6. A system should be established between the western states to exchange information on the success and failures encountered when an anti-strip additive is used.

There was little or no discussion from the floor of the Denver meeting. Some states have discontinued the use of any chemical bituminous additives, to reduce moisture damage or stripping of asphalt mixtures.

Because of the large number of anti-stripping additives that are used by the western states, there should be a system for providing the additives, performance data to the other states. It was suggested that each state tabulate the anti-stripping additives that are successful and report the results to Wyoming. This information will be distributed to the group of states.

The states should also be exchanging information about the test procedures used to evaluate the need for anti-stripping additives and any test procedures to determine the long term effects. Most participants thought that lime was a better anti-strip agent, and they were using lime both in the slurry and dry form.

MIX DESIGN

1. The #4, #10, #40 and #200 sieves should be considered the primary control sieves. The following gradations are near maximum density, and the potential for pavement deformation increases if greater values are adopted.

Sieve	Percent Passing
#4	55
#10	37
#40	16
#200	3 to 7

The voids in the mineral aggregate (VMA) should also be considered in conjunction with the recommended gradations.

The particle size distribution (gradation) of an aggregate is a primary consideration for a stable mix. The use of the above sieves as a control will result in the reduction of tenderness problems with asphaltic concrete mixes. In recent years a tool for analyzing asphalt mix gradations has received increased use. This tool is the .45 power gradation chart and is extremely useful in reducing tender mixes. The use of .45 power gradation chart is recommended, but prior to its adoption, a report published by J. G. Goode and L. A. Lufsey in 1962 at the annual meeting of AAPT entitled, "A New Graphical Chart for Evaluating Aggregate Gradation," should be studied.

2. The design asphalt content should be determined by the use of an accepted design procedure, and changes of the design asphalt content should only be made by District or Central Materials staff.

   The asphalt content is so critical to the performance of a mix that any changes should be made by those responsible for the initial development of the mix design. However, controls should be flexible enough to allow a quick response when a change is needed.

3. The states using the Marshall design procedure should use the 75 blow method when designing for high volume, heavy traffic, and adopt a requirement for a minimum stability of 1500 lbs. Those states using the Hveem procedure should design for a Hveem stability of 35.

   Increased stability requirements or increased resistance to deformation will reduce the rutting problem. It must be recognized that stability alone does not indicate pavement quality. To increase stability, other factors involved in achieving a quality pavement such as aggregate gradation, crushed aggregate, asphalt grade, and other consideration should be studied.

4. The states should adopt a 2% - 5% design void criteria as determined by the Rice method.

   Nearly all studies done on the life of asphalt pavements have indicated that the amount of air voids in a mix is directly related to the life of the pavement. (See Appendix D.) Increased air voids result in increased water availability to the asphalt-aggregate interface, thus resulting in increased moisture-susceptibility problems. Air voids in excess of those proposed would result in a brittle mix, and those less than proposed would result in an unstable or plastic mix.

5. The states should adopt a moisture susceptibility test as a part of their design procedure.

The moisture susceptibility problem with asphalt pavements has intensified in recent years. It has been described and solutions have been proposed since asphalt paving was first used. Due to the many reported incidences of stripping problems in the western states, testing must be done to identify a potential stripping problem during the mix design process. There is no universally accepted procedure for identifying a water susceptible asphalt mix. Reference should be made to two reports for a discussion of the testing procedures available:

HRB Special Report 98, State of the Art: Effect of Water Bitumen-Aggregate Mixtures, (1968), and Stripping of Asphalt Pavements: State of the Art, by Taylor and Khasla presented at the 62nd Annual Meeting of TRB in January 1983.

Either the Lottman Tensile-Splitting Ratio procedure or the Immersion-Compression (AASHTO T-165) should be used. Nevada has a test procedure that the states may want to investigate.

6. The states should adopt the following design temperature controls:

   Mixing of asphalt-cement based on 150-300 centistokes

   Marshall Compaction based on 250-300 centistokes

These design temperatures are required to insure a proper coating of the aggregate and proper compaction of the briquet.

COMPACTION

1. <u>The states should control compaction by specifying a percent of measured voidless mix as determined by the Rice method. The following density requirements are recommended: 94% of measured voidless mix based on the mean of five tests with no test below 91%.</u>

   The recommendations for the control of compaction are based upon the percent of voidless mix as determined by the Rice Test Procedure T-209. The limits were 94% of measured voidless density based on the means of five tests with no test below 91%. These limits were based on the recommended design voids of 2%-5%.

   After the presentation of the recommendation, considerable discussion followed, particularly concerning the method of determining density requirements using the Rice method. Some states control field densities as a percent of Marshall, either a laboratory design Marshall or briquet(s) pounded out in the field. It was pointed out that should the Marshall control be used, each construction site would have to be equipped to do a complete Marshall design. In most mix analyses the void content is one of the most important factors.

   There was considerable concern expressed about using the Rice method for determining density on high void mix designs. Under these conditions the recommended specification levels could result in specifying a density that was impossible to achieve. If a high void mix is required, consideration of a change in density specification will be necessary.

The consensus was that density and percent voids were important factors in the rutting problem and that high compaction effort was needed to help correct the problem.

After reviewing the concerns, it was determined that the benefits of the recommendations were considered to far outweigh the problems.

2. The states should require the paving contractor to demonstrate a rolling pattern for achieving compaction at the start of paving operations.

   The initial recommendation required the states to develop a procedure for assisting the paving contractors in establishing a rolling pattern.

   Concern was expressed about the states' roles. It was felt that the states should not accept or imply any responsibility for the rolling pattern.

   State agencies may assist the contractor in establishing a rolling pattern. It was generally agreed a rolling pattern should be established and demonstrated to the state agency at the beginning of the project. It is the contractor's responsibility to provide the necessary equipment to obtain the required densities. If the densities are not obtained, it is the contractor's responsibility to bring in proper equipment, adjust mix temperatures, and other factors, to achieve the required densities.

   If it becomes evident that the specified density cannot be achieved, the state agency independently or at the contractor's written request should review the design and specification for changes that may be required.

Appendix E contains temperature compaction curves derived by the use of a potentiometer (temperature measuring device). The procedure assists the paving contractor with his rolling patterns. These graphs verify the fact that the rolling must begin as soon as possible after laydown. This limited amount of data indicates that aggressive rolling combined with a systematic procedure for rolling will yield the highest or best compaction. It is suggested the states review and analyze this information to assist in the development of curves that fit each state's conditions.

3. The states should specify that the required density be achieved before the mix temperature drops below 200°F.

A denser mix is achieved when a higher minimum mix compaction temperature is used. There was concern expressed, however, that under some conditions the required density at the specified temperature may be impossible to achieve.

The agressive rolling and better compaction were accepted as a positive step toward reducing rutting. Consequently, the consensus was to try to achieve the required density at the recommended temperature.

4. The states should specify the pneumatic roller as one of the rollers in the compaction process.

The original recommendation specified the use of a pneumatic roller for the compaction of the final lift. The kneading action of the pneumatic roller is needed to tighten the mix, especially where surfacing or leveling course is placed over uneven surfaces or ruts. Steel wheel rollers ride on and compact the ridges while the pneumatic tire roller will compact the valleys. The benefits of the pneumatic roller are considered to be significant enough to require its use on all lifts.

5. The states should control late season paving by adopting a minimum roadbed surface temperature of 50 degrees F and/or a cutoff date.

   In order to alleviate poorly compacted mixes which result from late season paving, it was the consensus that either a roadbed surface temperature or a paving cutoff date be adopted. It was decided that because of the wide variety of temperatures found throughout and within the twelve western states, a cutoff date might be impractical. A solution was to establish a minimum roadbed surface temperature which would control the placement of bituminous mixes during cold weather.

CONSTRUCTION CONTROL

1. The states should make a special effort to ensure that agency construction personnel and contractor personnel are familiar with the importance of quality control and the impacts of deviating from prescribed specifications.

   Quality control during construction as a significant factor in minimizing rutting problems was included in the presentations of most of the states during the workshop. During the subcommittee meeting in Salt Lake, considerable time was spent in developing recommendations for materials controls and specifications. There was a concern that ineffective construction quality control and conscious deviations from specifications could effectively cancel most of the benefits to be derived from implementing the materials recommendations.

   As an example, early deformation has been observed when traffic has been allowed on freshly paved sections. Therefore, appropriate construction controls should be considered to ensure the temperature of the pavement has cooled sufficiently before opening to heavy traffic.

   It was evident that developing specific recommendations in the area of construction control would require as much, if not more, time than developing the recommendations for the materials control. Several approaches to construction quality control can be taken such as method specifications, end result specifications, contractor quality control and combinations of these.

Some basic elements apply no matter what the approach. The specification must clearly define what is expected, how, when and where it is to be measured and what happens if it is not obtained. Specifications must be written to be as enforceable as possible, and must take into account physical, environmental and legal constraints.

Sampling and testing must be uniform and accurate. Results must be evaluated promptly and uniformly.

Inspectors must have a thorough understanding of specification requirements and the basic process involved. Their authority and responsibility must be clearly defined and they must have the supervision and support necessary to accomplish their task.

Specification writers, material and construction personnel should all be involved in developing specifications and procedures for construction control.

It was determined that rather than trying to write specific construction quality control recommendations, it would be better to recommend making the construction staff aware of the importance of adhering to the materials requirements and the impacts of deviating from them; procedures should be developed to assure adequate construction control.

Concern was also expressed that a lack of trained and experienced construction personnel could seriously hamper effective construction quality control. Many states indicated that due to reductions in force and a hiring freeze, they are forced to operate with the same number of project personnel while their construction programs have doubled.

2. <u>The states should adopt a discharge temperature at the mixing plant based on a viscosity of 150 to 300 centistokes</u>.

Several states indicated severe rutting problems in drum dryer mixes produced at lower temperatures. They attributed this to higher mix moisture content and to less age hardening of asphalt during the mixing process.

The states that have reduced their rutting problems indicated they have raised mixing temperatures.

Rather than specifying temperature ranges for different grades of asphalt from many sources, it was decided to recommend a viscosity range based on centistokes. The states can then establish temperature ranges for the asphalts they use.

3. <u>The states should evaluate the C value test as developed by Oregon for determining mix contamination by burner fuels. Until this evaluation is completed, burner fuels should be restricted to propane, natural gas, #1 and #2 fuel oils.</u>

Oregon has determined that the cause of some of its rutted pavements was due to the contamination of the mix by unburned fuels. They instituted a research program to check the asphalt properties from the refinery to the finished pavement. They found in some cases the penetration increased during the mixing process. This was attributed to the effect of unburned burner fuels.

A test procedure was developed as a result of this research. Using this procedure, a C-value is calculated. Mixes that contain asphalts with C values of less than +30 have considerable rutting potential while values greater than +50 have little potential.

A draft Oregon Research Report describes the research and the test procedure. Oregon's experience indicates little or no problem with gas type fuels such as propane or natural gas or the lighter No. 1 and No. 2 fuel oils meeting ASTM D396. Most of the problems have been with heavier burner fuels and reclaimed motor oil.

The test also has value for determining that mix temperatures are high enough to produce a desired amount of asphalt age hardening during mixing.

Several other states indicated they suspected mix contamination by unburned fuel as the cause of pavement rutting.

The Oregon C Test procedure has considerable potential for eliminating unburned fuel contamination in mixes as a source of rutting. This procedure should be evaluated by other states under different conditions and materials.

The potential for rutting posed by mixes contaminated with unburned fuels justifies limiting fuels used to those that Oregon recommended.

Results of the states' independent evaluations should be sent to Bob Rask, Montana Department of Highways, 2701 Prospect Avenue, Helena, Montana 59620 where they will be compiled and distributed to participants.

CORRECTION OF RUTTED PAVEMENT

1. <u>The states should remove pavement ruts to a determined plane of failure, and the material removed may be recycled.</u>

   Each section of road must be investigated, and the longitudinal, lateral and vertical planes of failure must be determined. There is a serious shortage of asphalt pavement aggregates in the western states; asphalt is very costly and in some areas there is a limited supply. Therefore, the logistics of recycling to conserve materials and reduce costs should be considered.

   There was a consensus that recycled pavement did not appear to be as susceptible to rutting as virgin mixes.

   The plane of failure was also discussed. The plane of failure in each direction must be determined by the condition of the particular section of road investigated. For this reason, a specific depth or width of removal was not suggested.

   A technique for determining the vertical plane of failure is to analyze the void content at different levels in the wheel paths.

2. <u>The states should do a complete mix design for the recycled material, and the structural adequacy of the final pavement section should be checked.</u>

   The use of recycled material does not eliminate the need for a complete and detailed mix design process. The following must be taken into advisement when designing a recycled mix:

a. Proportions of recycled to virgin aggregates.

b. The final gradation of the mix.

c. The resulting stability of the mix.

d. The properties of the resultant asphalt after the addition of new asphalt or other chemical additives.

e. The ability of the final mix to resist moisture damage.

All of these factors are highly dependent on the particular material obtained from the road. Each state will have to design to its particular needs and for the situation. All designs must result in a structural section that is capable of carrying the imposed loading.

TRAFFIC LOADING

1. <u>The state's pavement design personnel should become involved in the development of load prediction information.</u>

   A majority of the workshop participants indicated that increased truck axle loads are a major factor contributing to the rutting problem. Many indicated that loading data used for pavement design did not accurately reflect loads actually applied to the highways.

   Load prediction is basic and essential to designing pavements for a given service life. The actual service life may be considerably less than designed if load predictions are not reasonably accurate. Several participants indicated that review of some prematurely distressed pavements showed that loads anticipated over 20 years were actually applied in 8 or 10 years.

   Pavement designers, in some cases, are furnished only the end result of the load prediction process. Improvements in pavement design can be made if designers become more involved in the load prediction process. Then the pavement designer will better understand load prediction information and give those involved in gathering and analyzing the load prediction data a better understanding of what is needed for pavement design.

2. <u>The states should improve the quality of the loading data for design, and stress the importance of enforcing load regulations.</u>

   The states concern with the quality of load data for pavement design was discussed under the previous item; however, another concern was the lack of enforcement of load regulations which is critical to reducing premature rutting.

Load regulations and enforcement are a matter of high level policy beyond the scope of the workshops. The relationship of load regulation enforcement to pavement performance is an engineering concern and should be communicated to policy makers. Adequate enforcement can be an effective measure for reducing premature pavement rutting.

The W-4 tables are the basic source for the 18 Kip Equivalent Axle Loads used in pavement design. The data in the W-4 table is obtained from truck weight and classification and other traffic studies. The data in most cases is obtained by sampling traffic at a limited number of locations for relatively short periods of time. Considerable evidence indicates that the procedures typically used do not accurately sample the actual traffic. Improvement of the quality of the W-4 data is essential to improving pavement design.

It was suggested that the effects of higher tire pressures on pavement rutting may be greater than higher axle loads. This question is addressed in the research recommendations.

3. <u>The states should install weigh-in-motion equipment to gather design data.</u>

Several workshop participants recommended weigh-in-motion equipment to improve the quality of load data for design. Effectiveness of the weigh-in-motion data collection is greatly reduced if it is used for both data gathering and enforcement at the same time.

Data is commonly collected manually at fixed or portable weigh stations. The amount of data collected is limited due to costs, manpower requirements and traffic disruption. The widespread use of CB radios also makes it relatively easy for overloaded trucks to avoid these sites.

Weigh-in-motion data collection can minimize or remove most of these limitations. States with experience in weigh-in-motion data collection report marked improvement in the quality of load data.

Weigh-in-motion equipment has not been developed to its full potential. Research and development to increase its capabilities is still underway by the FHWA.

Substantial improvements to load data for design can be realized through currently available equipment. The potential for improved pavement performance justifies installation of weigh-in-motion equipment.

INFORMATION EXCHANGE

1. <u>The states should form a Western States Materials Association</u>.

   At present the materials personnel from WASHTO only meet at the annual AASHTO materials meeting. Therefore, at their annual meeting they have very limited time to discuss specific problems. An organization is definitely needed where they can meet as a group to address specifics. Many problems in the western states are common to all states, and an association structured for this geographic area is needed. It is recommended that the first WASHTO State Materials meeting be held in Nevada in October 1984. The time and place will be determined.

   The state of Oregon expressed a concern about severe pavement problems such as ravelling, surface erosion or deterioration from the effects of inadequate asphalt aggregate adhesion or stripping. These subjects were beyond the scope of this workshop and should be included for discussion at the first WASHTO state materials meeting.

2. <u>The states should join in a cooperative effort to evaluate the Creep Test procedure</u>.

   The Creep Test specifically addresses rutting pavements. For this reason it was felt the Creep Test should be brought to the western states attention for evaluation. The states of Utah and North Dakota run this test and can supply additional information.

3. <u>The states should establish a means to check design and test procedures used to arrive at a final design mix</u>.

The AASHTO states presently through AMRL have a means of addressing procedures, repeatability, and reproducibility of testing. It is not the intent of this recommendation to duplicate or interfere with this process but to address a particular mix and the resultant design of that mix.

It is desirable to have a group of states review and evaluate problem mixes. The states do not need to use the same design procedures in making the evaluation. The final result, not the test method, is the most important factor for a particular design.

4. The states should compile a directory of testing capabilities and cooperate to the extent possible in providing testing assistance to the western states.

These lists should be sent to Bob Warburton, Wyoming State Highway Department, P.O. Box 1708, Cheyenne, Wyoming 82002-9019. The information will be distributed to this western states group. (DO NOT SEND A COMPLETE TESTING MANUAL). Compile a two or three page list of tests used; do not include the entire procedure. The printing and tabulating of complete testing manuals would be prohibitive.

CONCLUSIONS

The causes and possible solutions to the rutting problems in the western states are varied and complex. Based on the information provided by the western states and the discussions at the workshop meetings in Cheyenne, Salt Lake City and Denver, it is the consensus that the highest short term pay offs can be achieved by improving and strengthening state procedures in mix design, materials, and construction practices. There are so many variables involved that it is unlikely that a single cause or single solution can be identified that will independently resolve the rutting problem.

The recommendations developed as a result of the activities of the western states are a compilation of practices presently used by many of the states. There are presently no states that have adopted all of the practices.

It is the consensus of the states participating in this effort that the best chances of reducing or preventing rutting of asphalt pavements will be achieved if most or all of the recommendations are adopted.

RECOMMENDATIONS

AGGREGATE ACCEPTANCE

1. The states should require that aggregates be non-plastic.
2. The states should adopt the Sodium Sulfate or Magnesium Sulfate Soundness Test with a requirement for a maximum loss of 12%.
3. The states should adopt the Los Angeles Abrasion test with a requirement for a maximum 40% loss.
4. The states should adopt a minimum sand equivalent requirement of 45.
5. The states should adopt a fractured faces specification. At least 60% of the material retained on the No. 4 sieve have two fractured faces.

PAVING ASPHALTS

1. The western states should enter into a cooperative effort to establish a performance specification for asphalts.
2. Until the performance specification can be developed and accepted, the states should adopt AASHTO M-226, Table #2 for high volume, heavy highway traffic pavements, with modification on the ductility test from $77^{o}F$ to $39.2^{o}F$.
3. A cooperative study should be established to compare asphalts from rutted and nonrutted pavements.
4. Representatives of the western states should meet with local materials groups and technologists to relate the type of and need for future asphalt research.
5. Representatives of the western states should meet as a group with local asphalt producers to discuss present concerns about the quality of asphalts and the future of the highway rehabilitation program in the west.
6. A system should be established to exchange information between the western states about the success and failures encountered when an anti-strip additive is used.

MIX DESIGN

1. The #4, #10, #40 and #200 sieves should be considered the primary control sieves. The following gradations are near maximum density, and the potential for pavement deformation increases if greater values are adopted.

Sieve	Percent Passing
#4	55
#10	37
#40	16
#200	3 to 7

   The voids in the mineral aggregate (VMA) should also be considered in conjunction with the recommended gradations.

2. The design asphalt content should be determined by an accepted design procedure, and changes of the design asphalt content should only be made by District or Central Materials staff.
3. The states using the Marshall design procedure should use the 75 blow method when designing for high volume, heavy traffic, and adopt a requirement for a minimum stability of 1500 lbs. Those states using the Hveem procedure should design for a Hveem stability of 35.
4. The states should adopt a 2%-5% design air void criteria as determined by the Rice method.
5. The states should adopt a moisture susceptibility test as part of their design procedure.
6. The states should adopt the following design temperature controls:

   Mixing of asphalt-cement based on 150-300 centistokes

   Marshall Compaction based on 250-300 centistokes

COMPACTION

1. The states should control compaction by specifiying a percent of measured voidless density as determined by the Rice method. The following density requirements are recommended: 94% of measured voidless mix, based on the mean of five tests with no test below 91%.
2. The states should require the paving contractor to demonstrate a rolling pattern for achieving compaction at the start of paving operations.
3. The states should specify that the required density be achieved before the mix temperature drops below 200°F.
4. The states should specify the pneumatic roller as one of the rollers in the compaction process.
5. The states should control late season paving by adopting a minimum roadbed surface temperature of 50°F and/or a cutoff date.

CONSTRUCTION CONTROL

1. The states should make a special effort to ensure that agency construction personnel and contractor personnel are familiar with the importance of quality control and the impacts of deviating from prescribed specifications.
2. The states should adopt a discharge temperature at the mixing plant based on 150 to 300 centistokes.
3. The states should evaluate the C value test as developed by Oregon for determining contamination of burner fuels. Until this evaluation is completed, burner fuels should be restricted to propane, natural gas, #1 and #2 fuel oils.

CORRECTION OF RUTTED PAVEMENTS

1. The states should remove pavement ruts to a determined plane of failure, and the material removed may be recycled.
2. The states should do a complete mix design for the recycled material, and the structural adequacy of the final pavement section should be checked.

TRAFFIC LOADING

1. The state pavement design personnel should become involved in the development of load prediction information.
2. The states should improve the quality of the loading data for design, and stress the importance of enforcing load regulations.
3. The states should install weigh-in-motion equipment to gather design data.

INFORMATION EXCHANGE

1. The states should form a Western States Materials Association
2. The states should join in a cooperative effort to evaluate the Creep Test procedure.
3. The states should establish a means to check design and test procedures used to arrive at a final design mix.
4. The states should compile a directory of testing capabilities and cooperate to the extent possible in providing testing assistance to the western states.

PART II
RESEARCH NEEDS

PART II - RESEARCH NEEDS

INTRODUCTION

More long term solutions are needed, and will require appropriate research.

In developing the research needs, the discussions at the workshop meetings were considered. In addition, Dr. J. W. Jennings, University of Montana, Dr. Ray Pavlovich, New Mexico Engineering Research Institute, and Dr. Claine Petersen, Western Research Institute, were asked to attend the Denver workshop to gain an understanding of the concerns of the Western States. Later they were asked to give their opinions about research that would produce information pertinent to the rutting problems.

DISCUSSION

During the Cheyenne, Salt Lake City and Denver sessions, a number of problem areas emerged that showed potential for research that could produce long term benefits in the reduction or prevention of asphalt pavement rutting.

In an effort to explore these areas in more depth, Dr. Jennings, Dr. Petersen, and Dr. Pavlovich were asked to discuss beneficial areas for research. These researchers were asked to participate because they represented the research capabilities in the western states, and were somewhat familiar with the needs of the States represented at the workshop. In addition, Mr. Richard Hay, FHWA, was asked to participate to add a national perspective to research activities related to the asphalt pavement rutting problem.

In general, all of the researchers agreed significant research already done has been in the areas of interest, and the results of all this work may not have received distribution to all the states participating in the workshop. They all felt a literature search of available information should precede any other research activities.

Much of the discussion centered around the quality of asphalt presently being used, the relationship between design techniques and the loads being applied, and the interrelationship of the materials making up the asphalt pavement. A synopsis of these discussions follows.

Research efforts should develop and adopt new procedures, tests and standards and not research old techniques. In this regard, the consensus is there is a need for an asphalt specification that addresses performance and the development of the related tests and appropriate acceptance values.

Concern was expressed that the practice of fluxing asphalts may be a contribute to poor performance of asphalts, and there is a need to specify or control this practice.

High pressure liquid chromotography appears to have potential for analyzing the properties of asphalts that may be related to performance.

It should be recognized that improvements in the asphalt's performance characteristics will probably be costly, and the States should be prepared to pay for an increase in quality.

In addition to the concerns regarding traffic loading discussed elsewhere in this report, the states should investigate the relationship between applied loads and the mode of rutting failure.

Changes in tire configuration and pressures, as well as total load should be investigated when considering mix design procedures. It may be possible to develop a stress-strain relationship to be considered in mix design, which will more accurately reflect the conditions the pavement is designed to endure.

When investigating pavement mix designs, the component parts should not be considered separately. It is important to understand the interrelationship of the materials making up the mix and how this relationship benefits or harms the performance of the pavement. Some of the relationship that may be critical to the asphalt aggregate interaction are nitrogen composition of the asphalt, moisture entrapped within the aggregate, chemical composition of the aggregate, absorption of polar compounds by fine materials and additives used to reduce moisture susceptibility.

Asphalt pavement rutting and the mixing operations may also be related. There has been a shift from batch plant mixing to drier drum mixing. The differences between these two operations may be a factor contributing to rutting.

Much of the needed research could be achieved by comparing good and poor performing pavements from several states. The results of the research could then be tested by the use of experimental test sections in a number of states or by the construction of a full scale test track.

RESEARCH CONCLUSION AND RECOMMENDATIONS

The Western States Materials Engineers do not feel that the present procedures and specifications fully address the rutting problem. The general feeling is that the present state-of-the-art in materials testing relating to rutting needs to be upgraded through basic research.

There are definite research needs in the area of asphalt, aggregate, asphalt aggregate mixes, anti-stripping additives, density-void relations, tire pressure, tire configuration, and developing models of rutted and non-rutted pavements.

These research topics are presented in the following recommendations. The Western States Materials Engineers will prioritize the research recommendations and organize the development of research through western states research agencies.

1. Conduct a literature search on available information regarding rutted asphalt pavements.
2. Develop a stress strain procedure to address design mix, tire configuration, tire pressure and loading.
3. Develop a specification to control the fluxing of asphalts.
4. Develop test procedures and specifications that address the performance of asphalts with emphasis on the chemical composition of asphalt.
5. Evaluate the asphalt aggregate interaction by investigating as a minimum:

APPENDIXES

a. The effects of aggregate asphalt bond with wet aggregates.

b. The effect of the interaction of nitrogen in the asphalt with aggregates.

c. The effect of the chemical composition of aggregates.

d. The effect of the absorption of polar compounds by fine materials.

e. The effect of anti-strip agents on the setting of the asphalt mix.

6. Obtain samples of representative rutted and non-rutted pavements from the western states and conduct testing of those samples to develop a model for pavements that do not rut (considering the various modes of failure).

7. Study density-void relationships immediately after laydown and over various time periods.

8. Establish a full scale outdoor test track to determine the performance of asphalt pavements.

9. Appoint (through the western states in conjunction with the FHWA) a committee that will pursue the selection of groups to perform the recommended research.

10. Fund the proposed research through cooperation of the western states and FHWA.

11. Coordinate research in a cooperative effort through several research groups or individuals in the western area.

12. Hire research coordinator from the private sector to oversee the proposed research.

APPENDIX A

STATE PRACTICES

AGGREGATES

	REMARKS
Arizona	Fractured Faces - 30% Min., Sand Equivalent - 45 Min., Percent of loss - 40 Min Combination of +#4 and -#4 stockpiles
Colorado	Percent of wear - 45 or less
Idaho	Idaho has their own degradation test, Minimum fractured faces required L.A. Percent of loss - 30 Min No design sand equivalent, no discussion of crushing.
Montana	Fractured Faces - 50% Min on +#4, Sand equivalent - 45. Percent of loss - 30 or less, degradation - 40 Min Aggregate must be stockpiled seperately in two or more sizes
Nevada	Fractured faces - 50% Min - Type 2 35% Min - Type 1 & 3 Percent of wear - 45 or less; durability -25 or less No discussion of sand equivalent or crushing specs.
N.Dakota	Aggregate - percent of loss -40 or less soundness - 9 or less No discussion on sand equivalent Aggregate is used as curshed from gravel sources, no material is wasted.
N.Mexico	Type I - percent of wear - 40 or less; soundness - 15 or less Type II- percent of wear - 50 or less; soundness - 25 All aggregate 75% crushed faces on +#4 sand equivalent - 45 Min. 100% crushed aggregate on both Type I and Type II unless pit run -#4 or filler required.
Oregon	One fracture face on each designated sieve size, Retained on 1/4" in-60% Min; Retained on #10-50% min Abrasion - 30% max; Soundness - 18% max; Degradation Sediment height - 3" MAX, pass #20 screen - 30% max. No sand equivalent required; plasticity Index AASHTO T90-Max 6 Require separate stockpiles of course (3/4-1/4) and fine (1/4-0).
S.Dakota	Fractured faces - 50% Min., soundness - 12 or less, percent of loss - 40 or less. No discussion of sand equivalent Aggregate normally stockpiled in seperate course and fine piles
Texas	Fractured Face 85% of Material retained on the No. 4 Sieve
Utah	Fractured Face 50% Min Soundness (SO^4) - 16 Max Wear - 40% Aggregate N.P.
Wyoming	Fractured Faces - 50% Min., Type II and Type III percent of wear - 40 or less Type I - 100% crushed, reject on 1/4" over max size Type II - Combine +#4 and -#4 Type III - Combine +#4, -#4 and natural -#4

	SIEVE SIZE Percent Passing	ARIZONA	COLORADO	IDAHO	MONTANA	NEVADA	NO.DAKOTA TYPICAL GRAD.
I	1"	100			100	100	
	3/4"	90-100	100	100	90-98	90-100	100
	5/8"						
	1/2"		70-95	90-100	75-90		
	3/8"	70-85 (±8%)	60-88	75-95	60-80		
	#4		44-72	60-75	40-55	40-65(±7%)	70(±7%)
	#8	41-49(±6%)	30-58(±8%)	40-55		(±4%)	55(±4%)
	#10				30-40		
	#16		(±6%)			15-40	45
	#30			14-25			38
	#40	12-20			15-28		
	#50		7-27				20
	#200	2.0-5.0(2%)	3-12(3%)	3-9	3-8	3-9 (±2%)	10(±2%)
II	1"			100		100	
	3/4"	100		90-100	100	90-100	
	5/8"						
	1/2"	90-100	100		80-100		
	3/8"	70-85		60-85	70-90	63-85	
	#4		50-78	40-65	45-65	45-65	
	#8	43-51	34-60	25-50			
	#10				32-45		
	#16					20-40	
	#30			14-30			
	#40	12-22			15-25		
	#50						
	#200	2.0-6.0	3-12	0-9	4-10	3-9	
III	1"						
	3/4"						
	5/8"						
	1/2"					100	
	3/8"					85-100	
	#4					85-100	
	#8						
	#10						
	#16					20-45	
	#30						
	#40						
	#50						
	#200					3-10	

	SIEVE SIZE	N.MEXICO		OREGON	S.DAKOTA	TEXAS			UTAH	WYOMING	
	Percent Passing	A		B	G	Percent Passing	TYPE B		1"	3/4" GRADING A	GRADING B
	1"	100		100		1"		100	100	100	100
	7/8"					7/8"		95-100			
	3/4"	80-100		95-100		3/4"				97-100	97-100
	5/8"				100	5/8"					
	1/2"	65-85		81-93		1/2"	7/8" RET.3/8"	21-53	75-91(±5.2%)	60-85	
	3/8"	55-75			(±7%)	3/8"	RET.#4	11-42			60-85
	#4	40-55	(Pass. 1/4")	52-72(±6%)	52-70(±5%)	#4	RET.#10	5-26	47-61(±4.8%)	40-60(±7%)	40-65
I	#8	(±7%)				#8	Total RET. #10	58-74		25-45(±5%)	25-55
	#10	30-40(±4%)		21-41(±4%)	32-52	#10	RET.#40	6-32			
	#16					#16			23-33(±3.9%)		
	#30					#30				10-30	10-35
	#40	10-20		8-24	15-32	#40	RET. #80	4-21			
	#50					#50			12-22(±3.2%)		
	#80					#80	RET. #200	3-21			
	#200	3-7(±2%)		2-7(±2%)	3-10(±2%)	#200		1-8	5-9(±1.7%)	2-10(±3%)	2-10
		B	C(1983)	C(1984)	HR		TYPE C		3/4"	1/2" GRADING C	GRADING D
	1"					1"				100	100
	7/8"					7/8"		100			
	3/4"	100	100	100		3/4"			100	97-100	97-100
	5/8"				100	5/8"		95-100			
	1/2"	80-100	95-100	95-100		1/2"	5/8",RET.3/8"	16-42			
	3/8"	70-90				3/8"	RET. #4	11-37	75-91(±4.9%)	60-85	
	#4	50-65(Pass.1/4")	52-72	60-80	50-65	#4	RET. #10	11-32	46-62(±4.8%)	40-60	45-70
II	#8					#8	Total RET. #10	54-74		25-45	25-55
	#10	32-45	21-41	26-46	30-50	#10	RET. #40	6-32			
	#16					#16			22-34(±3.9%)		
	#30					#30				10-30	15-40
	#40	10-22	8-24	9-25	20-30	#40	RET. #80	4-27			
	#50					#50			11-23(±3.2%)		
	#80					#80	RET. #200	3-27			
	#200	3-8	2-7	3-8	3-7	#200		1-8	5-9(±1.7%)	2-11	2-11
		C					TYPE D		1/2"		
	1/2"	100				1/2"		100			
	3/8"	70-100				3/8"		85-100			
	3/8"					3/8"	RET. #4	31-53			
	#4	45-70				#4	RET. #10	11-32	60-80(±4.8%)		
III	#8					#8	Total RET. #10	54-74			
	#10	30-50				#10	RET. #40	6-32			
	#16					#16			28-42(±3.9%)		
	#30					#30					
	#40	15-25				#40	RET. #80	4-27			
	#50					#50			11-23(±3.2%)		
	#80					#80	RET. #200	3-27			
	#200	4-8				#200		1-8	5-9(±1.7%)		

ASPHALT	ARIZONA	COLORADO	IDAHO	MONTANA	NEVADA	NORTH.DAKOTA
GRADING SYSTEM	Viscosity	Viscosity (W)Max.Pen	Viscosity	Penetration	Viscosity of Residue	Penetration
GRADES TYPICALLY USED	A.C.5 Thru A.C.40	AC-10	AC-6 AC-11	120-150	AR 4000	120-150
ADDITIVES						
Liquid Anti-Strip	NO	YES	YES, If Needed		NO	NO
Hydrated Lime	YES	YES-SLURRY	YES, DRY & SLURRY	YES 1-2%	YES 1-3%	NO
Portland Cement	YES		YES		YES 1-3%	NO

MIX DESIGN	ARIZONA	COLORADO	IDAHO	MONTANA	NEVADA	NORTH.DAKOTA
METHOD	Marshall 75 Blow	Hveem	Hveem	Marshall 50 Blow	Hveem	Marshall 50 Blow
CRITERIA						
Stability (Min.)	2000		30	1500	35	500
Flow/ Cohesion	8-16			8-16		8-18
Void Content	5-7,1/2"Mix 4-6,3/4"Mix	3-7,Quarry	2-5,Gravel	3-5	3-7	3-5
TYPICAL AC CONTENT			5.5-6.5		6.0	5.0-9.0
MIX TEMPS	325 Max			225-265	225-325 (for AR-4000	
IMMERSION/ COMPRESSION	YES	YES-75%	YES-85%	YES	NO	NO
OTHER MOISTURE TESTS		Tensil Strength	Tensil Strength		Dynamic Strip Test	

ASPHALT	NEW MEXICO	OREGON	SOUTH DAKOTA	TEXAS	UTAH	WYOMING
GRADING SYSTEM	Penetration and Viscosity	Viscosity of Residue, Viscosity, Penetration	Either Penentration or Viscosity Allowed	Viscosity	Viscosity Table II	Viscosity
GRADES TYPICALLY USED		AR4000W AR2000 AC20 85-100		AC-10 AC-20	AC 5-10 AC 20	AC-20 *AC 10
ADDITIVES						
Liquid Anti-Strip	YES	YES		If Needed YES	YES	YES
Hydrated Lime	YES-SLURRY	YES	YES	YES	YES	YES-SLURRY
Portland Cement	YES				YES	NO

MIX DESIGN	NEW MEXICO	OREGON	SOUTH DAKOTA	TEXAS	UTAH	WYOMING
METHOD	Marshall 75 Blow	Hveem	Marshall 50 Blow	Special	Marshall 50 Blow	Marshall 50 Blow
CRITERIA						
Stability (Min.)	1640	30	1200	35 (HVEEM)	1200 Min	1800
Flow/ Cohesion		--	8-16		10-18	8-16
Void Content	3-5	3-5	3 (min.)	1-5 3 Optimum	2-4	2-6
TYPICAL AC CONTENT		5.5 Wearing 6.0 Base			4-7	5.5-6.5
MIX TEMPS.	250-280	325°F Max 240-300@ Laydown	300 Max.	225-350	270-300	280-310 (AC 20)
IMMERSION/ COMPRESSION	YES-75%	YES-70%	YES-70%	NO	YES-65%	YES-70%
OTHER MOISTURE TESTS		Lottman Resilient Modulus Ration - 70%		Boiling Water Test Lottman Test	Dynamic State Test Method	Visual Inspect I/C Samples

REMARKS

1. Wyoming used AC 10 primarily until the rutting got bad (1981). Then changed to AC 20 as primary asphalt.
2. Montana noted they have stabilities in the western half of the state of 1700 lb and in the eastern half of 900 to 1200 lbs. They also noted rutting in area of 900 to 1200 stability was worse.
3. Mixing temp. varies with grade of asphalt used.
4. Colorado add max. pen. limit on A.C. 10 of 100 Pen. Points.
5. Wyoming going to lime slurry only for water susecptable materials.
6. Texas selects optimum asphalt content based on lab mold density determinations over a range of asphalt contents.

COMPACTION	ARIZONA	COLORADO	IDAHO	MONTANA	NEVADA	NO.DAKOTA	NEW MEXICO	OREGON	SO.DAKOTA	TEXAS	UTAH	WYOMING
SPECIFICATION DENSITY	97% Marshall	95% Hveem		95% Field Marshall	Rolling Pattern "Target" for 2" Greater Mats	97% Field Marshall	96% Marshall	91% Voidless (Rice Method)	Class D G I 94° 95° 96° Marshall	92%Voidless or 95% of Lab Molded Density	93% Voidless (Rice Method)	93% (New) 92% Voidless (Rice Method)
ROLLERS Number Type	3 Steel-Rubber-Steel	3 Steel-Rubber-Steel		As Needed As Needed	Old 3 STL-RUB-STL New 2 STL-RUB	2 Steel & Rubber As Needed	3 One Must be Rubber	Less Than 1 1/2" 2 Rubber-Steel	2 One Must be Rubber	As Needed	As Needed	As Needed One Must be Rubber
CONTROL	Test Strip	Contractor Respon-sibility		Control Strip if 95% Not Obtainable	Rolling Pattern Test Strip	Contractor Control Strip or Special Pattern if Density Not Obtainable	Control Strip	Contractor Respon-sibility	Contractor Respon-sibility		Contractor Respon-sibility	Contractors Respon-sibility
TEMPERATURE Air	Surface Air 1 1/2" (less) 65° 1 1/2" (More) 45° 50°			35° Surface	1" 2" 3" 55° 45° 35°	32°	40°	1 1/2" 60° 2 1/2" 50° 2 1/2+" 40°	1" (less) 45° 1" (more) 40°	Surface 1 1/2" or less 50°F Air 40° and rising		1" 50° 2" 40°
Laydown	250° Min 300° Max					210°-225°	220°	240°-300°	180°			210°
Compaction	220°	185°		175°	old 140° new 185°	170° Initial 140° Final	190°	180°		175°	220°	180°
TESTING	1/500 Tons Statistical Spec.	Changed to 1/2100 yd2 (random)	Nuclear	Nuclear Gaye 1/1000 FT.	Nuclear Gage 2" mat or grater	Cut Sample Random	Nuclear & Nuclear Gage 1/500yd2	Nuclear Random 1/500 Tons	Statistical Spec.	Cut Sample or Nuclear	Statistical Spec.	Nuclear Gauge
CUT OFF DATES		OCT 1		NONE	NONE			Job by Job Basis	OCT 15	Optional By Districts	OCT 15	Job by Job Basis Gen.OCT 15

MISCELLANEOUS	ARIZONA	COLORADO	IDAHO	MONTANA	NEVADA	NO.DAKOTA	NEW MEXICO	OREGON	SO.DAKOTA	TEXAS	UTAH	WYOMING
LOADING												
Bridge Formula		YES		YES	YES							
Single Axle	20,000	20,000		20,000	20,000	20,000		20,000			20,000	20,000
Tandem Axle	34,000	36,000		34,000	34,000	34,000		34,000			34,000	36,000
Max Gross	80,000	80,000			80,000	80,000		80,000		80.000	80,000	80,000
Max Overload	172,000			Pre 1983 105,500 Present NO MAX		200,000 Overloads Restricted on Flex.Pav. When Temp 85°+		105,500			105,000	
CONTROL BURNER FUEL	NO	NO		NO	NO (Considering approach similar to Oregon)	NO	NO (Considering Oregon Procedure)	YES	YES (Prohibits the use of reclaimed motor oil)	NO	NO	NO
SPECIAL TESTS					Nevada Stripping	Shell Creep		"C" Test				Considering Creep Test
LAB. CONTROL		District		District & Central	Strong Central			Mix Production is by Proj. Control Design by Central Lab			District	Central
RUT CORRECTION	Maint. Patch & Milling 1 1/2"±				Leveling Course Cold Milling in Urban Areas	Milling & Overlay Fill Ruts & Seal		Leveling & Overlay Milling & Replace		Milling & Overlay or Leveling Course & Overlay	Milling Leveling Overlay	Leveling Course Mill and Repalce Mill,Replace & Overlay

APPENDIX B

AASHTO M-226

Table 2

Requirements for Specifications for Asphalt Cement Viscosity Graded at 60 °C (140°F)

Grading Based on Original Asphalt

	VISCOSITY GRADE				
TEST	AC 2.5	AC - 5	AC - 10	AC - 20	AC - 30
Viscosity, 60°C (140°F), Poises	250 ± 50	500 ± 100	1000 ± 200	2000 ± 400	3000 ± 600
Viscosity, 135°C (275°F), C_s-Minimum	125	175	250	300	350
Penetration, 25°C (77°F) 100 gr. 5 sec. Minimum	220	140	80	60	50
Flash Point, C.O.C., C(F), Minimum	163(325)	177(350)	219(425)	232(450)	232(450)
Ductility, (39.2°F), 1 Cm-Min., Cm - Minimum	50+	25+	20+	20+	20
Solubility In Trichloroethylene, % Minimum	99.0	99.0	99.0	99.0	99.0
Tests on residue from Rolling Thin Film Oven Test:					
Viscosity at 60°C (140°F), Poise, Maximum	1000	2000	4000	8000	12000

Spot Test (When and if specified), Negative for all Grades

APPENDIX C

A LITERATURE SUMMARY OF HIGHWAY ASPHALTS OF YESTERDAY AND TODAY

In the mid 1930's, three studies were completed by the Bureau of Public Roads and the Asphalt Institute consisting of approximately 119 asphalt samples. The study completed in 1935 and reported at the AAPT in 1940 and 1941 by Lewis & Welborn was followed by another report in 1946 by the same authors was entitled "The Physical and Chemical Properties of Petroleum Asphalts AAPT Vol. 11, 12, & 24 (1).

Penetration GRADES Part I and II

In 1955, a total of 323 samples of asphalt from 105 refineries were collected and tested. The results of 146 samples representing 85-100 penetration grades were reported in Part I of the 1959 AAPT Vol. 28 Properties of Highway Asphalt Grades by Welborn and Halstead.

One year later, Part II was reported in the AAPT Vol. 29 on the remaining 179 samples representing the following penetration grades, 60-70, 70-85, 120-150 and 150-200. The study dealt with the comparison of 1955 asphalt grades with the 1935 asphalt grades. The comparison of the asphalt consisted of the following tests: penetration, flash point, specific gravity, softening point, ductility @ 77^{O}F & 39.2^{O}F, loss on heating, ratio of penetration, furol viscosity @ 275^{O}F, and etc. (2).

The refining of asphalt consisted of the following: (1) refined by vacuum and/or steam distillation, (2) vacuum and/or steam distillation with some air blowing, (3) vacuum and/or steam with fluxing, and (4) propane distillation solvent extraction together with various combinations of distillation, blowing, blending and/or steam distillation (1).

The general conclusion of data from references (1) and (2) follows:

(1) Many of the current specifications, such as those of AASHO, fail to measure the relative quality of asphalt. Materials meeting these specifications may actually show poor performance in service.

(2) In order to raise the overall quality of asphalt, several of the Western States have adopted specification requirements based on the Pensky-Martens flash test, the penetration ratio, the furol viscosity @ 275°F, and the thin-film oven test and ductility @ 39.2°F.

(3) Asphalts from the eastern sources have the highest penetration ratios, and those from western sources the lowest.

(4) Asphalt technology is still based primarily on experimental tests and relations developed by trial and error methods. These methods will undoubtedly be in use for a long time.

(5) Over the years, attempts have been made to define the properties of asphalt in terms of their chemical composition or analysis, however, they have often resulted in uncertain complexity of the organic molecules given by the producers.

Chemical Composition of Asphalts

In 1966, Vol. 35 of the AAPT, Halstead, Rostler and White reported in Part III the influence of chemical composition of the 323 samples from 105 refineries taken in 1955 (3).

The constituents determined in the chemical analysis and the abbreviations used in this report, as well as in other reports are; (3)

A = Asphaltenes The bodying agent

N = Nitrogen basis or unsaturated polar compounds peptizer (solubilizer for A)

A_1 = First Acidaffins or unsaturated hydrocarbons, group 1- solvent for peptized A

A_2 = Second Acidaffins or unsaturated hydrocarbons, group II- solvent for peptized A

P = Paraffins or unsaturated hydrocarbons - jelling agent (flocculent) for A.

It was believed by the authors that groupings by chemical compositon provided a more precise classification and had a more direct approach to testing the influence of composition on performance (3).

Summary of Floor Discussion

(1) Rostler and White reported that asphalts abrasion resistance increases rapidly as the ratio falls below 0.4 $(N+A_1)/(P+A_2)$ because the excess of saturated or nearly saturated components tends to destroy the cohesive forces within the asphalt. They went on to say very poor abrasion resistance is the result of an excess of highly reactive components that degrade rapidly.

(2) However, floor discussion brought out the following: Mr. Corbett asked, "You say if the content of "N" was high, you would have a large abrasion loss; or if it was low, you would have a low abrasion loss?" Mr. Halstead: "That is correct". Mr. Corbett: "Now do you have any indication as to what effect this "N" component has on other properties of the asphalt? I

am going back to the one that you like so well, namely, ductility. I trust you realize, that this N component is the one that is going to give you ductility or take it away. When you ask for an asphalt with a low number for composition parameter, you are approaching a zero ductility asphalt, or an asphalt with very little ductility. Would you explain that?"

Mr. Halstead: "You put your finger right on a very tough point to explain."

(3) Mr. R.J. Schmidt: "First I want to agree with Mr. Corbett. The point I actually wanted to ask about was the validity of the abrasion test. You can certainly vary the ductility or shear susceptibility all over the map by changing the nitrogen bases content. We made an asphalt which was included in the Zaco-Wigmore Test Road. The asphalt was unusually good from the standpoint of the abrasion test. Yet is was among the first to fail in the pavement. I have strong reservations on the significance of the abrasion test."

Viscosity Graded Asphalts

In 1965 the Bureau of Public Roads promulgated a National Program of Research and Development to provide the knowledge of methods and materials to increase highway engineering productivity. Such a program was outlined and discussed at a conference in Washington, D.C. on April 7, 1965, as part of the 3-day conference on Quality Control and Acceptance Specifications. At the conference on asphalt technology, representatives from the asphalt industry, the paving contractors and the consumer interests expressed the need for: (a) better tests to measure and control consistency, (b) tests that will predict durability in service, (c) specification requirements that recognized variability due to manufacturing, sampling and testing and (d) requirements that provide the proper balance of engineering properties to assure optimum specifications (4).

A study of viscosity, graded asphalt cements was reported in 1966, Vol. 35 of the AAPT by Welborn, Oglio, and Zenewitz. The authors felt that consistency was believed to be of primary importance. The research effort was concentrated on the development of tests to measure viscosity in fundamental units and to determine the relation of these fundamental properties to mixture design and pavement performance. The authors reported the primary advantage of such a specification is that the consistency of all asphaltic road binders would be graded at the temperature associated with maximum pavement temperature and the temperature used in mixture design methods. The authors supported the idea of grading asphalts on the basis of viscosity of 140^{O}F., the approximate temperature at which paving mixtures are most critical in the pavement from the standpoint of mixture instability. In addition to the control of grades by viscosity at 140^{O}F, the study specifications also provide for minimum viscosity requirement at 275^{O}F and a provision to control hardening, using a ratio of viscosity at 140^{O}F, before and after the thin-film oven test. Other proposed requirements cover ductility, flash point and solubilities in CCl_4 on the original asphalt.

The above study was based on 50 asphalt samples obtained directly from asphalt producers and was believed to be a fair sample of total production in the United States. The study reported when the thin-film test was first proposed (late 1950's), a ductility requirement for the residue was recommended because some asphalts showed an abnormally high loss in ductility during heating. As indicated previously by the authors there is evidence that low ductility, resulting from hardening occuring in hot mixing or in service, is associated with poor performance. As a result some states have included a requirement for minimum ductility on the thin-film residue.

Floor Discussion

Mr. L.C. Krchma: "Once the road is down, the temperature of 140°F only applies to the top 1/4 or 1/2 inch of pavement, might we include a temperature below that from a standpoint of performance?"

Asphalts of Today

As a result of the 1973 oil embargo, allegations are that currently produced asphalts are inferior or at least different from those produced in the past. Thus, the comparison of the properties of currently produced asphalt cements with the properties of materials produced in the past was one of the purposes of the forthcoming study. In 1979, V.P. Puzinauskas reported on his study, "Properties of Asphalt Cements". The Asphalt Institute request provided a total of 211 asphalt cements. This material was supplied by 40 different manufacturers and came from 78 refineries.

However, limitations of manpower prevented the testing of all 211 asphalt cements. On this basis, 68 asphalt cements were selected for testing by the laboratory or 68 percent of the asphalt samples were eliminated from the study. The report outlined the various types of refineries, vacuum and steam distillation. However, the study reported the most common practice involves processing materials to different consistencies by one or two main methods and then blending these materials to obtain asphalts of the deserved characteristics. From this report there appears to be more fluxing of asphalts than in the past (5).

The primary emphasis of this report was on the evaluation of the consistency properties of the asphalt, such as viscosity, penetration and ductility at 77^{O}F which does not rate performance. Overall, the author reported on the average, the consistency of the asphalt cements are the same, but remember only 32 percent of the asphalt samples were evaluated. The problem with all these studies from the thirties to the present, there were no field studies.

Asphalt Specifications

The present Asphalt Specifications M-226 are listed as Tables I, II, and III.

Table I is the specification for viscosity graded asphalt and meets the requirements for all asphalts produced nationwide. The Table II specification is mainly a western specification requiring tighter control on viscosity @ 275^{O}F and higher penetration. This in turn controls the temperature susceptibility of the asphalt. Table III is the AR grading system based on aged asphalt. The system probably worked well when mixes were made in a batch plant. However, with the advent of the drum mix plant, mix oxidation caused from heating (depending on the discharge temperature), has almost been eliminated. Mixes produced in batch plants normally had approximately a 35 percent reduction in penetration and increased viscosity. This has caused some states to stop using this system.

Conclusions

A review of the current specifications does not really evaluate the performance of asphalts, but only the consistency of the product. If you have a specification that is so broad that all asphalts fit into the specification, you do not have a specification! To have meaningful specifications you must eliminate sources. If states are really committed to improving asphalt performance, two things must happen, (1) a specification on temperature susceptibility has to be implemented to eliminate rutting and cracking, and (2) requirement of a maximum wax content. The flater the slope of the line, the better the performance of the asphalt.

Most asphalt specifications that are on the books test the physical properties, but not the chemical properties. It is believed that most states can testify of a good asphalt(s) that came from a particular source or a particular refinery method that gave very good service. However, this is no longer available because of the shut down of the refinery or the change on crude sources. It has been found in the state of Utah that those asphalt sources that are pulled off the refinery run to meet a particular grade, perform much better than those that are taken down to approximately zero penetration then fluxed back to meet a specification asphalt (6).

Highway Funding

Most states have increased their gas taxes and the 4R funding has increased three-fold. Over the next several years, we will see a tremendous amount of surfacing materials placed on the highways. Most of the interstate and primary systems were built in the early 1960's with little or no rehabilitation taking place in the last 20 years.

Tonage Figure Nationwide

Year	Tons
1979	411×10^6
1981	275×10^6
1983	303×10^6 approx.
1985	450×10^6 est.

This means there is going to be a tremendous need for quality asphalt cements. There have been shortages the last few years and some may feel this is a poor time to upgrade asphalt specifications. However, two things are needed; (1) The asphalt companies need to be more than just aware of the funding increase, the asphalt specifications are going to be specifying performance, and (2) the states need to have an available product, and a product that will give quality performance.

The "Federal-Aid Interstate Highway Funds appropriated for Fiscal year 1983-84" (13 states) are listed for information:

States	Interstate Resurfacing (83)	Interstate 4R (84)
Arizona	17,062,340	50,208,204
Colorado	15,384,004	45,712,467
Idaho	7,713,037	22,383,373
Montana	12,311,322	37,382,327
Nevada	6,549,897	21,507,801
New Mexico	13,364,210	39,210,087
North Dakota	6,829,219	20,118,733
Oregon	12,167,911	36,385,856
South Dakota	7,976,466	24,007,119
Texas	63,722,490	180,789,272
Utah	11,338,665	35,504,786
Washington	16,685,202	53,528,178
Wyoming	10,646,583	32,604,872

References

1. Welborn, J.Y., Halstead W. J., "Properties of Highway Asphalts Part I, 85-100 Penetration" Grade, AAPT Vol. 28, 1959.
2. Welborn, J.Y., Halstead, W.J., and Boone, J.G., "Properties of Highway Asphalts Part II Various Grades", AAPT Vol. 29, 1960.
3. Halstead, W.J. Rostler, F.S., and White, R.M., "Properties of Highway Asphalts Part III," Influence of Chemical Composition AAPT Vol. 35, 1966.

4. Welborn, J.Y., Oglio, E.R., and Zenewitz, J.A., "A Study of Viscosity-Graded Asphalt Cements," AAPT Vol. 35, 1966.

5. Puzinauskas, V.P., "Properties of Asphalt Cements" AAPT Vol. 48, 1979.

6. Evaluation of the Performance of Asphalt Pavements in Utah, December, 1975.

Recommendations

1. The physical (consistency) properties of asphalt may not have changed significantly during the past few years, however, it is believed the performance of the asphalts have declined. It is recommended the states enter into a cooperative effort to establish a performance specification for rating asphalts that meets the needs of the participating states, as outlined in the conclusions.

2. Recommend representatives of the western states should meet with local materials groups and technologists to relate the type and need for future asphalt research.

3. It is recommended a comparison be made between samples of asphalts that have been used by the states experiencing rutting problems and states not experiencing rutting problems. Determine temperature susceptibility slope and PVN index of the asphalt cements.

4. There are numerous bituminous additives that may enhance the quality of asphalt mixes. The states should become aware of the performance of these materials, and a system should be established to exchange information about the successes and failures encountered when the materials have been used.

5. Recommend the states use AASHTO M-226, Table #2 for high volume, heavy highway traffic pavements, with a modification on the ductility test from 77^{o}F to 39.2^{o}F, and an increase in the viscosity @ 275^{o}F.

6. States should consider both stability and durability when selecting the grade of asphalt to be used (temperature susceptibility slope and the maximum wax content).

7. Recommend states adopt the following temperature controls:

   Mixing of asphalt cement - based on centstokes of 150-300

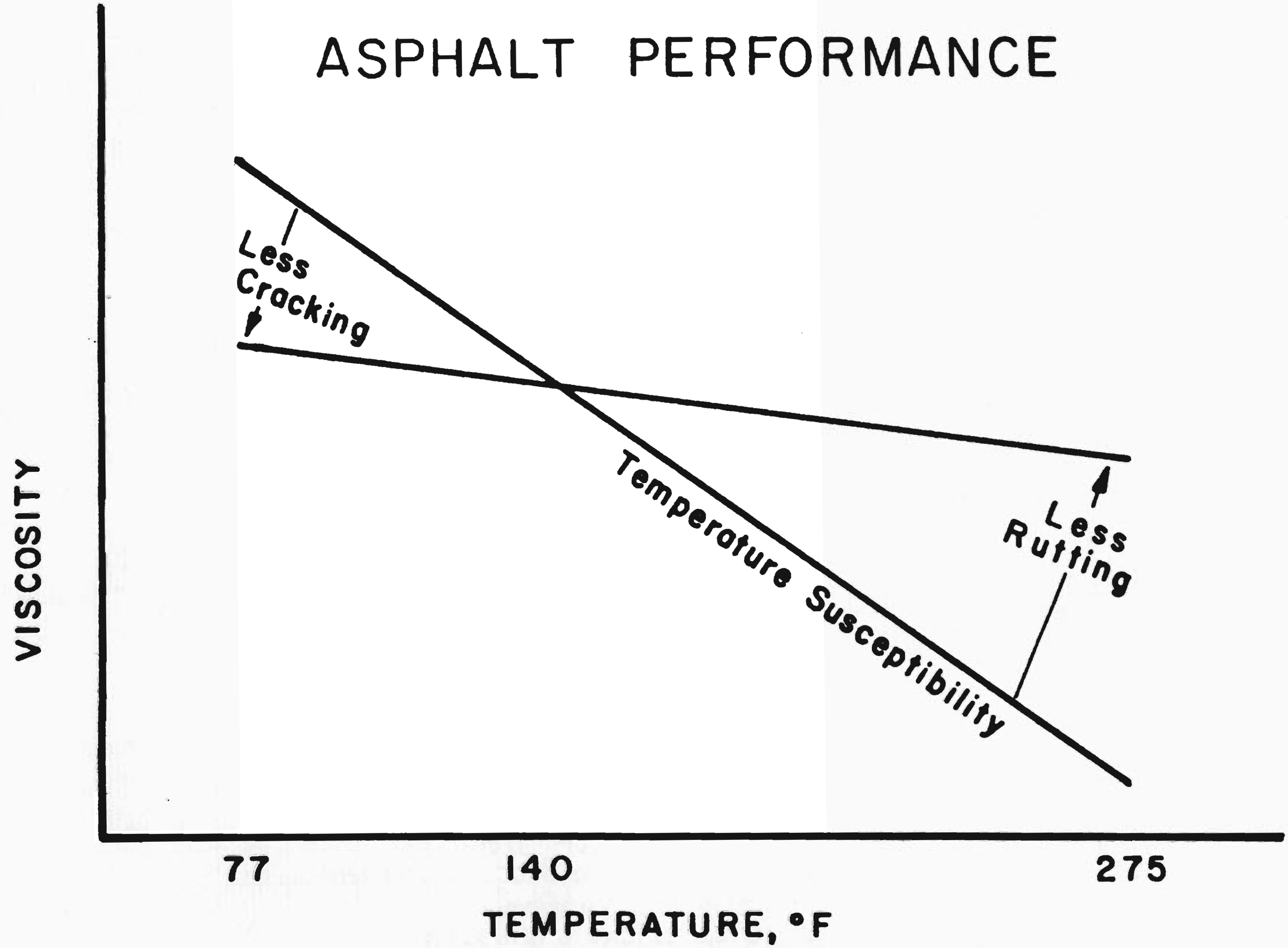
   Marshall Compaction - centstokes of 250-300

   Pavement compaction - the rolling of the mat should be completed before the pavement temperature reaches 5000 centstokes.

8. Recommended changes to the asphalt mix design (asphalt content) may only be made by District or Central Materials staff.

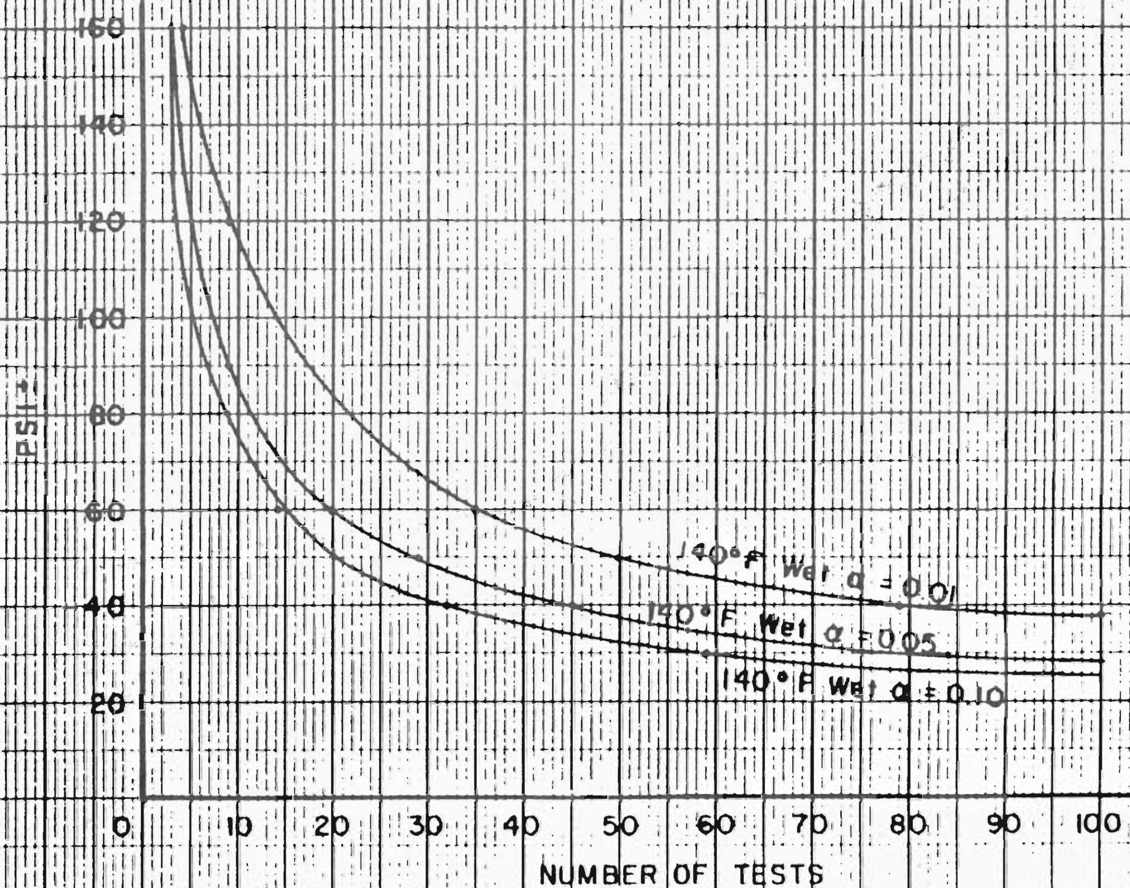
# # #

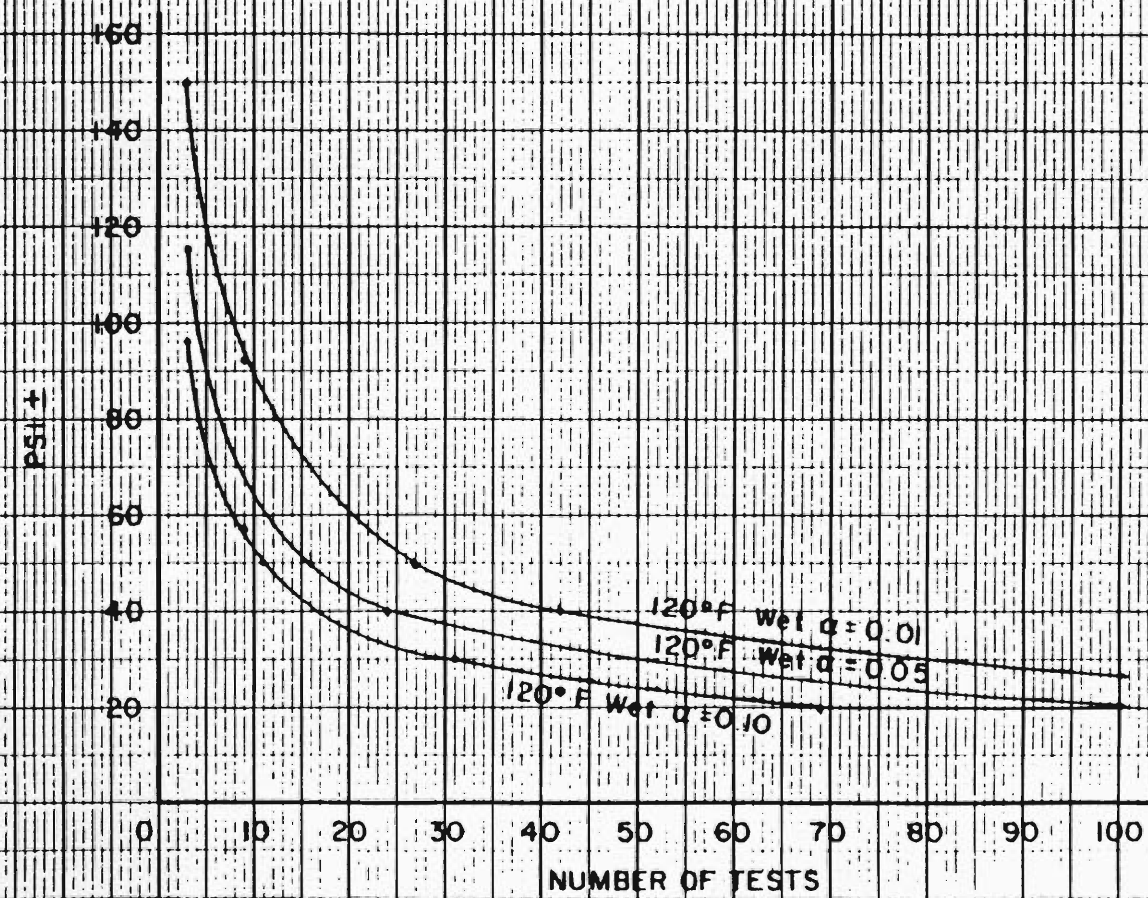
ASPHALT PERFORMANCE



K+E 10 X 10 TO ½ INCH 46 1472
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

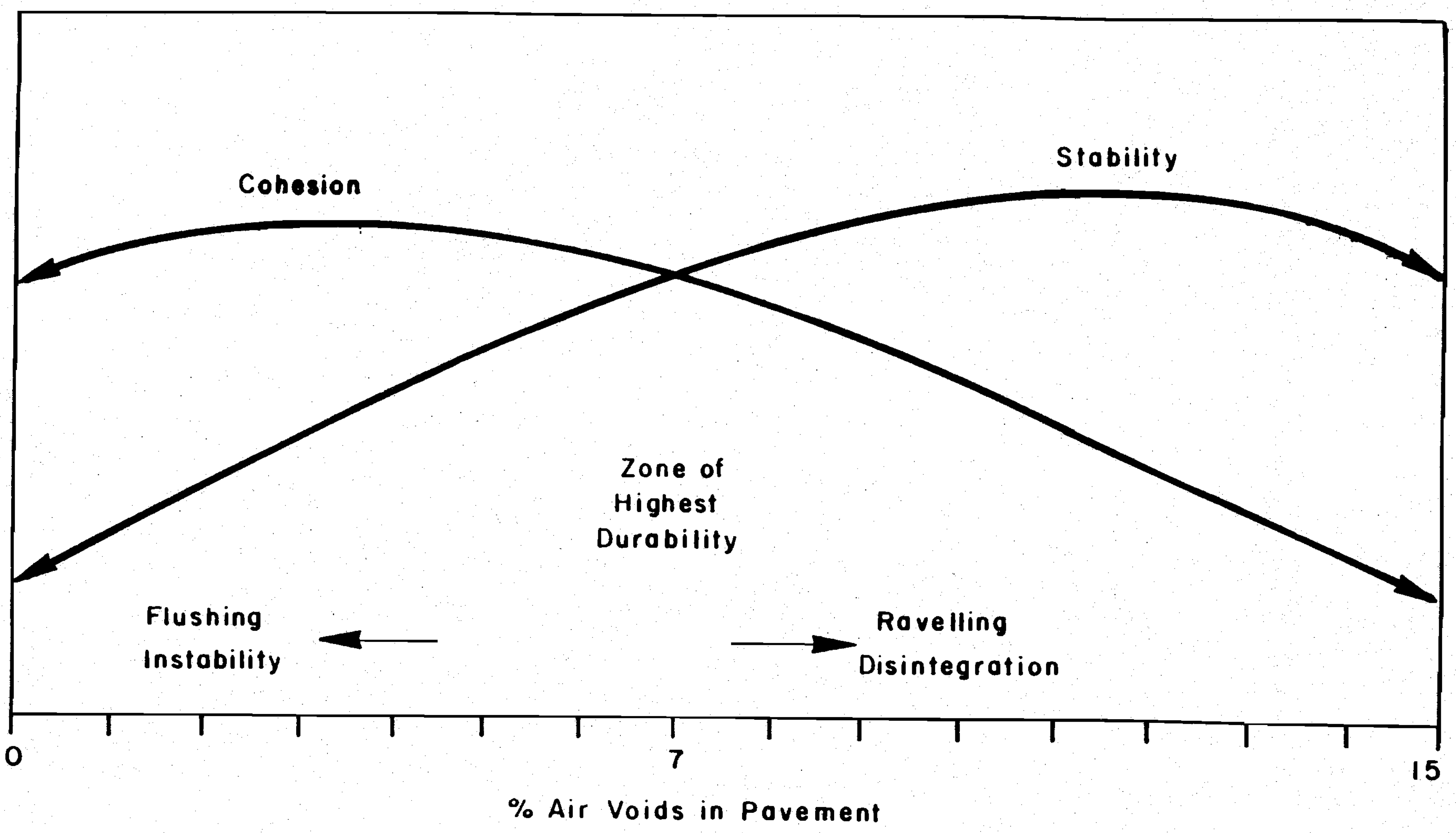
MATERIALS AND TESTS DIVISION
PAVEMENT DESIGN UNIT
IMMERSION COMPRESSION CONFIDENCE LEVEL
DATE: JANUARY 22, 1975




160
140
120
100
80
60
40
20
PSI +
0
10
20
30
40
50
60
70
80
90
100
NUMBER OF TESTS
120°F Wet α = 0.01
120°F Wet α = 0.05
120° F Wet α = 0.10

APPENDIX D

Page

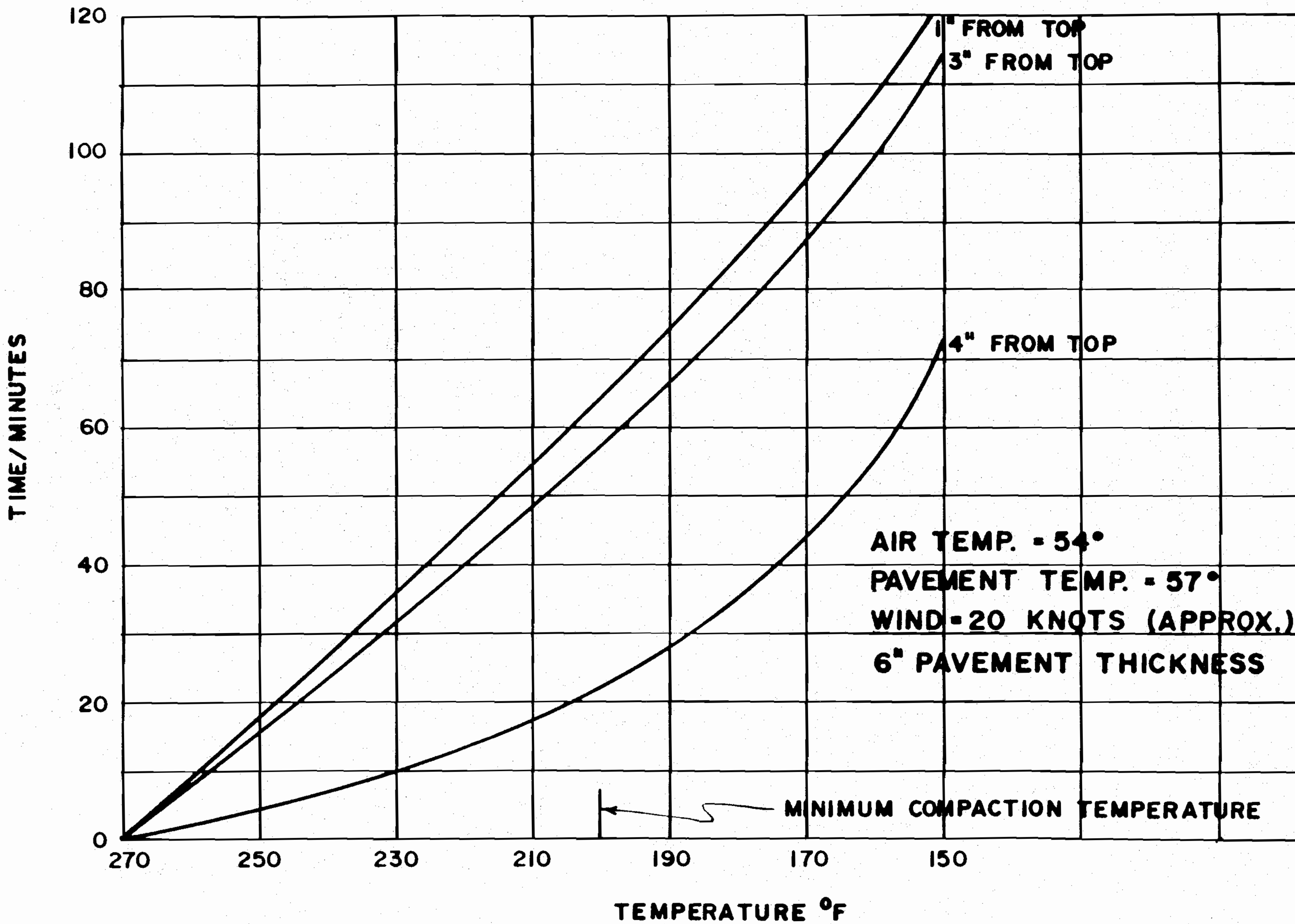


PAVEMENT DURABILITY VS AIR VOIDS

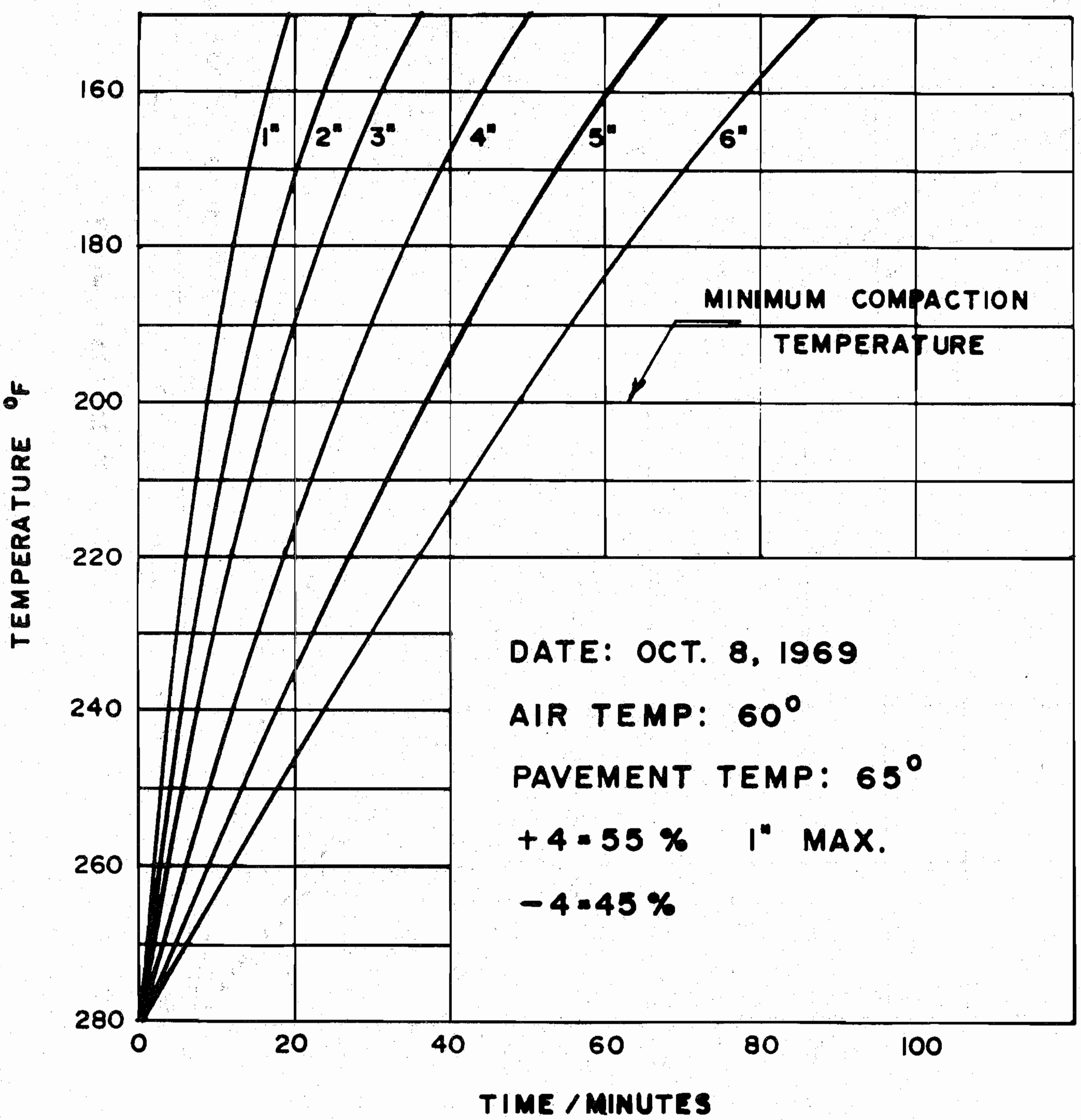
APPENDIX E

COMPACTION TEMPERATURE/ TIME CURVES

TEMPERATURE LOSS ON 6" PAVEMENT



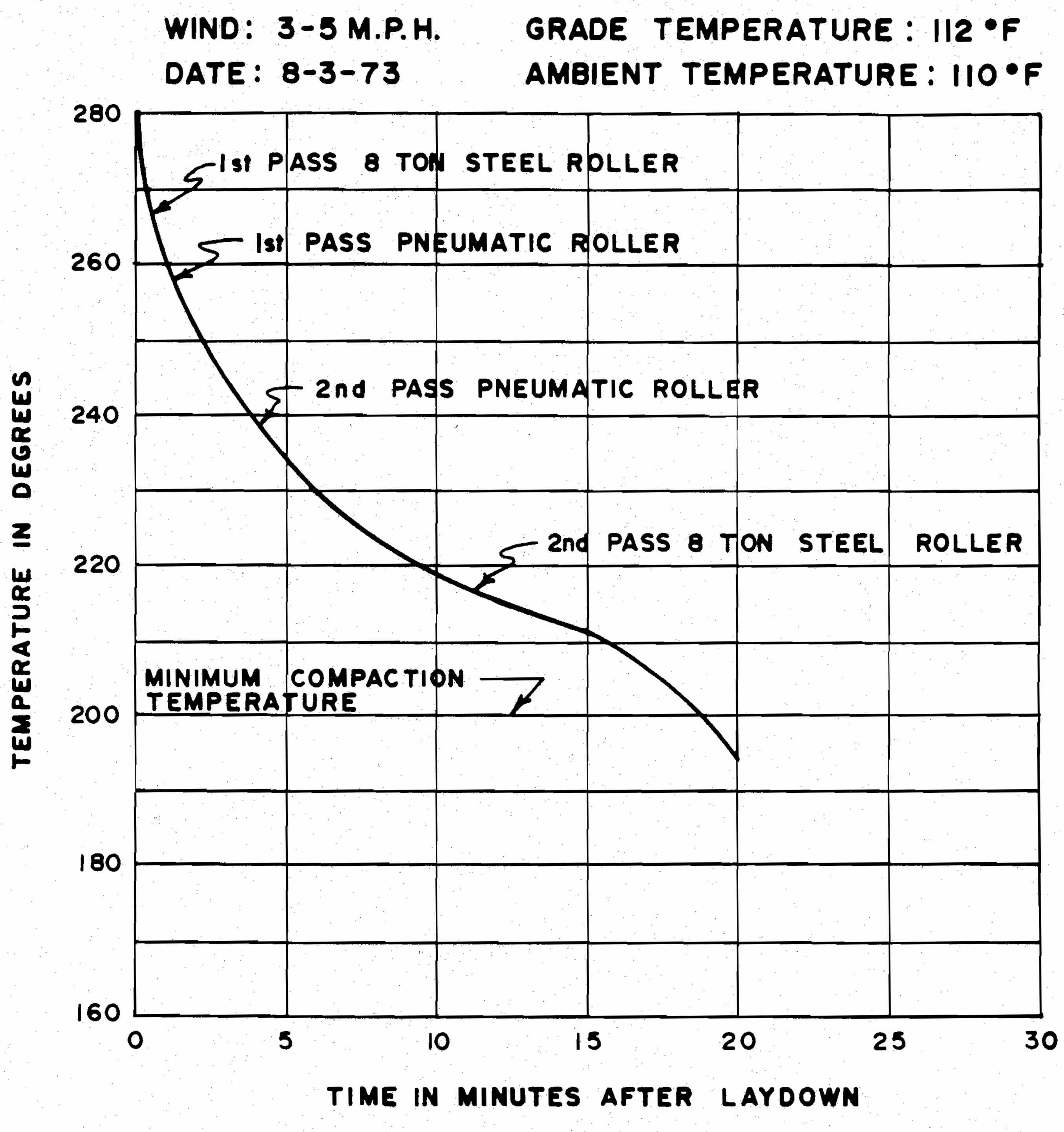
I-80N-6(6)77



TEMPERATURE °F
160
180
200
220
240
260
280
1"
2"
3"
4"
5"
6"
MINIMUM COMPACTION TEMPERATURE
DATE: OCT. 8, 1969
AIR TEMP: 60°
PAVEMENT TEMP: 65°
+4 = 55 % 1" MAX.
-4 = 45 %
0
20
40
60
80
100
TIME / MINUTES

I-215-9(28)303

3/4" MAX.



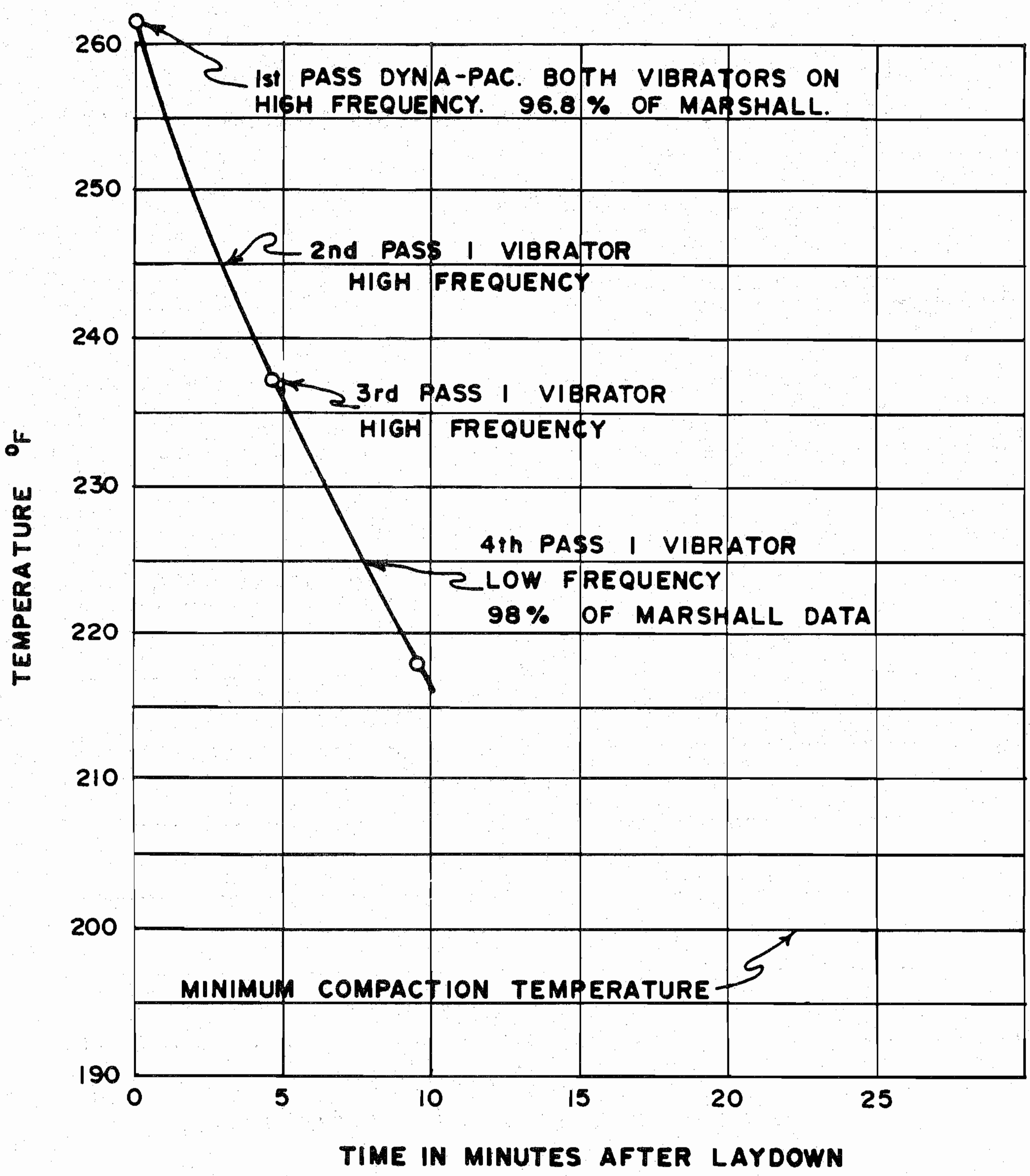
96.4 % COMPACTION

I-15-5(3)228

AMBIENT TEMP. 87°

GUSTS OF WIND TO 4 M.P.H.

9-26-74 TEST NO. 4



APPENDIX F

SUMMARY OF RUTTING RELATED REPORTS

During the workshops a number of reports relating to the subject of asphalt pavements and rutting in general were shared by the participating states. Many of these were used in considering the recommendations reached during the workshop. Most of these reports are available by contacting the materials sections of the State Highway Agency. The following is a listing of these reports:

1. "Evaluation of Asphalt Aging in Hot Mix Plants Preliminary Draft Report," Oregon State Highway Division, Materials Section, August 1983.

2. "Impact of Variation of Material Properties on Asphalt Pavement Life - Final Report," Oregon State Highway Division, Materials Section, May 1982.

3. "Identification and Quantification of the Extent of Asphalt Stripping in Flexible Pavements in Oregon - Phase I," Oregon State Highway Division, Materials Section, March 1983.

4. "Prevention of Early Pavement Deterioration," Utah Department of Transportation, Materials and Research Section, September 1978.

5. "Field Verification and Implementation of the VESYS I IM Structural Subsystem in Utah", Utah Department of Transportation, Research and Development Unit, February 1978.

6. "Predictive Design Procedures, VESYS User Manual - An Interim Design Method for Flexible Pavements Using the VESYS Structural Subsystem" FHWA-RD-77-154, Federal Highway Administration, Office of Research, January 1978.

7. "Evaluation of the Performance of Asphalt Pavements in Utah," J. York Welborn Consulting Engineers, January 1976.

8. "Construction Practice for Seal Coat Treatments" Utah Department of Transportation, Pavement Design and Testing Unit, April 1983.

9. "Rutting Investigation" Wyoming State Highway Department, Materials Laboratory, April 1982.