GROUP D

LOAD AND ENVIRONMENTAL VARIABLES

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Group D felt that each of the variables being considered is predictive in nature and represents the extreme variability of conditions throughout the design life of a pavement. It is, therefore, necessary to obtain as many data as are economically feasible and to be able to judge how accurate that information is. Other groups that will be using this information should consider how accurately the variables of load, temperature, and moisture content need to be determined.

LOAD EFFECTS

For evaluating load effect, the best system available is the equivalent axle load concept. For highway pavements, this type of representation can be used to predict the load effect on the pavement in terms of fatigue distress or permanent deformation. It does not, generally, make it possible to estimate the ultimate load capacity of a pavement in terms of shear failure.

Use of the Equivalent Load Concept

The method of dividing the traffic into various vehicle types to study the effect of an individual type is considered appropriate. When the effect of each vehicle type has been established, this value is multiplied by the number of vehicles. These effects are summed for all vehicles and then summed for all years during the design period to give the total equivalent number of axle loads. The load equivalency factors from the AASHO Road Test are considered the most appropriate to use at this time because they are based on the only data now available on the effect of axle loads on pavement performance.

Methods have been presented for using the AASHO Road Test equations directly for estimating the load effect of the various axle loads and configurations used at the road test (1, 2, 3). The load effects thus determined are called the load equivalency factors.

To apply the equivalent load concept to actual traffic situations, it is necessary to determine the number and weight distribution of the axles to use a roadway during the design period. The appropriate load equivalency factors are then multiplied by the number in predetermined weight classes and summed to give the total number of equivalent loads. A number of methods that use these concepts have been developed and presented by various authors (4, 5, 6, 7, 8).

The following is an example of a method that can be used to estimate total equivalent loads by using the present state of the art.

1. A determination should be made of the average effect of various types of vehicles based on the AASHO equivalency factors. This can be done on a statewide basis by using standard W-4 tables that are available each year. The W-4 tables present a summary of the distribution of axle weights for each state, as well as the average equivalent load effect for each type of vehicle. The distributions in the W-4 tables represent the statewide data for a given year and state. For a particular location that is not felt to be representative of statewide conditions, the individual factors should be determined (6). Information on related analyses is available from the California and Utah highway departments or in other works (4, 5, 6, 7, 8).

2. The variation of the average vehicle effect (N18 factor) from year to year must be estimated. This can be done by using W-4 tables of previous years and considering the annual change in the factor. This change may then be projected into the future with some limit put on the maximum value that can be attained. Some work of this nature has been done by the Utah and Kentucky highway departments and by the University of Minnesota.
3. The number of each vehicle type used for the analysis must be determined for the design period. This distriubtion of vehicles may vary significantly throughout the period and should be considered. This information can be obtained from the traffic section of most state highway departments. The distribution is usually based on the type and use of the highway being planned.
4. The N18 factors are multiplied by the number of respective vehicle types and summed to give the total number of equivalent axle loads.

Other representations of traffic, such as maximum wheel load, average of 10 heaviest wheels daily, and so forth, are now being used. The method outlined represents what is considered an example of the present usable state of the art with respect to the equivalent load concept. For low-traffic roads the equivalent load procedures should be modified to accommodate a limited number of relatively high axle loads. The mode of failure for this situation would not be fatigue but would be based more on an ultimate load concept.

Needed Short-Term Research

First of all, to establish the error involved in the present system of estimating equivalent wheel loads, we should establish the accuracy of present predictions. This can be done in a manner similar to that done by the Kentucky Department of Highways and by the Franklin Institute Research Laboratories (10).

Load equivalency factors should be established for heavier axle loads and for different axle load configurations. It would be best if this could be done by observing the effects of various axle loads on the distress in a pavement section under controlled conditions, but this is a costly process. It is, therefore, recommended that these other configurations be evaluated by using a calculable stress or strain that can be used to predict a given mode of failure.

A functional road use system should be established to categorize highways in order to determine appropriate load effects and vehicle type distributions. This type of road use classification would make it possible to consider the type of traffic along with the volume of traffic. With this information it would be possible for highway departments to utilize the system more readily. The research should be directed toward determining how accurately the traffic parameter needs to be known for design purposes.

Future Research Needs

Load equivalency factors should be determined for each mode of distress. These will be dependent on the stress or the strain or deflection or both used to evaluate the pavement failure mode. Examples of such modes are the calculation of tensile strain in the bottom of the asphalt layer to minimize cracking and the calculation of vertical strain at the subgrade to minimize permanent deformation.

The effect of vehicle speed on the equivalent axle load factors should be established. This effect would consider the additional effect due to impact loading on the pavement and the decreased effect at higher speeds due to the inertia of the pavement section. The dynamic load effect has been studied at the University of Texas by using weighing equipment developed there (9, 10).

As mentioned earlier, more weight and volume data are needed so that the significant parameters can be estimated more accurately. This can be done by making more weighings and by continuous weighings either by using portable scales at various locations or by using an electronic weighing device such as that developed at the University of Texas.

ENVIRONMENTAL VARIABLES

At the present time the environment is being evaluated in a number of ways. Design procedures generally use one of the following concepts: (a) the most critical condition, (b) a regional factor, or (c) the variation of in situ conditions. Each of these in some respect relates to the temperature and moisture conditions estimated for the pavement section during its design period. The presence or absence of frost and the depth of frost are also implied in the evaluation of environment.

TEMPERATURE VARIABLES

Tables were constructed to aid the group in considering the input of the temperature and moisture variables into the evaluation of performance with respect to environment. The group checked those items that it unanimously agreed could have an effect, although some felt that more intensive study would indicate many of these to be insignificant. An explanation of each check is not given here because the effects of temperature or moisture content or both have been discussed by Group A.

Table 1 gives the temperature factors that affect the respective layers of the pavement section. Where the pavement sections and temperature functions coincide (indicated by "X") there is an effect of that temperature function on that layer; thus, the number of Xs generally indicates how important that variable is. The effect of temperature on the properties of soils has been presented elsewhere (20).

At the present time the level of air temperature at an hourly basis is available at almost any location. In some cases this has been synthesized and is being used to estimate the properties of the asphalt concrete. The air temperature has been correlated to pavement temperatures for various conditions of wind and cloud cover by a number of groups around the world. This information is available in various Highway Research Board publications (11, 12, 13, 14) and in other journals. The gradient of temperature through the pavement section has been determined by The Asphalt Institute, the Kentucky Department of Highways, the AASHO Road Test researchers, and others (12, 15).

The daily and monthly variations of temperature at a number of locations have been used by The Asphalt Institute to predict monthly average temperatures over a design period (16, 19). Daily variations of temperature have also been used at the Ste. Anne Test Road, Hybla Valley, the WASHO and AASHO Road Tests, The Asphalt Institute, West Virginia, and other tests (13, 14, 17, 18, 19, 26).

The use of heat transfer equations to predict the gradient and level of temperature throughout a pavement section has also been done on a limited scale. Solutions to these equations are available at Purdue and other locations.

Short-Term and Long-Term Needs for Temperature Variables

For both the short-term and long-term it is recommended that the present temperature data be expanded, that more be gathered, and that they be synthesized into the

TABLE 1

EFFECT OF TEMPERATURE FUNCTION WITH TIME ON ASPHALT PAVEMENT SECTION LAYERS

Temperature Function	Asphalt Concrete	Base				Subgrade
		Granular	Asphalt-Treated	Cement-Treated	Lime-Treated	
Level throughout layer (mean, max, min)	X	X[a]	X	X	X	X[a]
Gradient through section at given time	X	–	X	?	?	X
Cyclic						
Long-term	X	–	X	X	X	–
Daily	X	–	X	–	–	–
Space variation (longitudinal and lateral)	X	X	X	X	X	

[a] Frozen.

TABLE 2

EFFECT OF MOISTURE CONTENT WITH TIME ON ASPHALT PAVEMENT SECTION LAYERS

Moisture Content	Asphalt Concrete	Base				Subgrade
		Granular	Asphalt-Treated	Cement-Treated	Lime-Treated	
Level throughout layer (mean, max, min)	–[a]	X	X	X	X	X
Cyclic (long-term)	–[a]	X	–	X	X	X
Time and space	–[a]	X	X	X	X	X

[a] Moisture effects are unknown at this time, and the group felt them to be insignificant.

forms found significant for the particular failure mode being considered. For instance, at The Asphalt Institute it was found that the monthly level of temperature could be used to reasonably estimate the level of temperature in the asphalt surface for a fatigue analysis of an airport design (16). Similar analyses should be made on the effects on other failure modes for both airfield and highway pavements.

Moisture Variables

Table 2 gives the moisture functions that affect the layers of an asphalt pavement. Again, the areas with Xs indicate that there is an effect of that moisture function on that layer; thus, the number of Xs generally indicates how important that variable is.

At the present time there are essentially no moisture data available in published form for asphalt-and cement-treated bases. For granular bases and subgrades, there is information published by the Highway Research Board (20). There is, also, information from Australia, South Africa, and other areas. For both the short-term and long-term, this information needs to by synthesized and related to local factors such as rainfall, humidity, topography, drainage conditions, soil properties, and pavement section characteristics (10). For the long-term other similar tests should be run in representative areas throughout the country to improve the correlations. Very little information is published on cyclic variations in moisture contents.

In Oklahoma a study has been made in which the variation in moisture content of embankment soils under pavements with time has been determined (21). It is recommended that more studies be made and that cyclic variations be determined, especially for periods of precipitation and drying. These variations should also be determined for bases and subgrades both for general moisture changes and especially for moisture levels during the spring thaw. The moisture content at the interface between thawed and frozen materials should especially be determined. These conditions should be determined in a few areas where performance and materials properties are being monitored with time to see whether these moisture conditions have a significant effect on pavement performance.

The distribution of moisture longitudinally and laterally has been studied at the British Road Research Laboratory by researchers whose findings are presented in Highway Research Board reports and at the AASHO and WASHO Road Tests (13, 14, 15, 18, 22, 23, 24). This variation should be checked at specific test locations where performance and materials properties are being monitored to see if there is a significant effect of variation in moisture content.

SUMMARY

In this report an attempt has been made to summarize the state of the art in load, temperature, and moisture variables that affect the performance of an asphalt pavement. Some references have been given as examples of this work, but it is realized that much more work has been done in these areas. We apologize for the omissions, but time does not make it possible to review and present all of the work being done. Perhaps in the near future it will be possible to make a more complete study of the current work.

It is suggested that the equivalent load concept is the best method to use for evaluating traffic and that research be directed toward improved procedures for collecting and using traffic volume and weight data for this purpose. The accuracy of the final equivalent loads calculated should be determined. In addition, a determination should be made of how accurate the parameters should be for practical design purposes.

A few methods have been established that use temperature information directly to sum up the fatigue effect on an asphalt pavement. Studies should be made for both airport and highway pavements to define and establish the temperature effects more accurately and to determine the degree of accuracy necessary for a reasonable pavement design.

The effect of moisture level and its function with time on the performance of a pavement have also been considered. Work should be directed toward developing an accurate function to predict moisture content in embankments and granular bases with time so that the variation in materials properties with time can be determined. The required accuracy for a practical design situation should also be determined.

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