In the case of gradation, stiffness and fatigue life of 35% and 50% caused higher result until the fracture than those of 32% and 53% which were out of specification. Through this result, we found that the asphalt mixture becomes fragile since it didn't correspond the limit of specification which has 40% of standard passing percentage #8.

CONCLUSIONS

- Forty U.S. states apply the pay adjustment method, using their own factors which affect performance of pavement such as density and asphalt content. The density, asphalt content, gradation and smoothness are mostly applied factors. Thus we assumed five pay adjustment standard factors, the four factors just mentioned and the thickness of the pavement.
- Many U.S states use pay adjustment and the PWL is calculated using their quality index tables. Thus we assumed that PWL was a reasonable approach to adjust pavement quality.
- We performed an indirect tensile test to analyze the relationship between fatigue cracking and pay adjustment factors. The tendency of fatigue cracking was very clear, according to the density, asphalt content, gradation.

In the case of asphalt content, every specimen reduced its stiffness as asphalt content increases, and the fatigue life was reduced as the asphalt content with its stiffness at the same time. Especially 98% theoretical maximum density showed the highest fatigue life. That seems to be an effect of over compaction. In the case of gradation, stiffness and fatigue life of 35% and 50% caused higher result until the fracture than those of 32% and 53% which were out of specification.

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Temperature Calibration of EICM Model in New Mexico

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Abstract: The Enhanced Integrated Climate Model (EICM) is a program that integrates most of the climate conditions to simulate climate effects on pavements. It was originally designed for all regions in the United States. However, it was proposed on the basis of the nation wide average climate data and not accurate for regional conditions. Therefore, it is necessary to calibrate the EICM using local climate data before its application by state DOTs and other agencies. In the State of New Mexico, because of its special climate condition, the calibration of EICM is very important. In this paper, the EICM was used to predict pavement temperature profile with the input data obtained from the LTPP Datapave. Then the EICM-predicted temperatures were compared with the measured temperatures to validate the feasibility of the current EICM in New Mexico. Finally, the correlation between the EICM-predicted and measured temperatures is provided.

INTRODUCTION

Temperature and moisture are the two main climate factors that influence the pavement design and performance (Ahmed et al., 2005). However, the two factors vary with time and seasons. It is not easy to analyze their effects on pavement design and performance. The Enhanced Integrated Climate Model (EICM) integrates most of the climate conditions modeling climate effects on pavements.

The EICM was originally designed for applications in all regions in the United States. However, it was developed on the basis of the nation-wide average climate data and may not accurate for regional conditions. It is necessary to calibrate the EICM model using local climate data before its application by state DOTs and other agencies. Validations of EICM were carried out in New Jersey (Ahmed et al., 2005) and Idaho (Bayomy and Salem, 2005). However, neither of them shows a very good capability in temperature prediction. In New Mexico, the temperature fluctuates more than many other states. Therefore, the calibration of the EICM model is very important in New Mexico.

In this paper, the latest EICM program – version 3.2 was used to predict pavement surface temperature and temperature profile with depth. To check the consistency, comparisons between the predicted and the field measured temperatures were carried out. Finally, the correlation between the EICM-predicted temperature and field measured temperature is established.

REQUIRED CLIMATE DATA IN THE EICM

To execute the EICM program, certain climatic data are required as inputs, which include air temperature, wind speed, percentage of sunshine, precipitation, humidity, and ground water table depth (Larson and Dempsey, 2003). Air temperature is used to determine the air temperature at each time increment. Wind speed is used to calculate the convection at the pavement surface. Percentage of sunshine is for calculating the amount of solar radiation on pavement surface during day light hours and the amount of cloud cover for radiational cooling at night.

INPUT DATA

In this paper, most input data are from the LTPP Datapave. In the Datapave, only several test sites in New Mexico, i.e., SHRP 1002, SHRP 1003, SHRP 1005, SHRP 1112, SHRP 2118, SHRP 3010 (see Figure 1), have the required humidity and wind speed data. The test site number, e.g. SHRP 1002, is coded with specific site ID by the LTPP for easy understanding (FHWA Website, 2005). Of these sites, SHRP 1002 and SHRP 1003 are close to each other in the same route, the same for test sites SHRP 1112 and SHRP 3010. Sites that are close to each other and in the same route share the same climate and pavement conditions. As a result, four test sites, i.e., SHRP 1002, SHRP 1005, SHRP 1112, SHRP 2118, are selected in the analysis.

The EICM requires either the minimum/maximum or hourly temperature values to be input for each day. In this analysis, the input of air temperature was chosen from the minimum and maximum temperatures of each day, as recorded in LTPP Datapave. However, because of the large amount of data, not all the everyday temperature data is required as input. For each month, only the temperatures of the 1st, 10th, and 20th date were chosen as input. Then temperatures of the rest days in a month will be generated by the EICM program according to the variation trend of the input temperature. The generated temperature has the same seasonal variation trend as the LTPP data. In addition, in the LTPP Datapave, the precipitation data is the total amount of daily precipitation, and humidity is the maximum daily humidity. Both precipitation and humidity are input into the EICM in a similar way as temperature. For the input of wind speed, the daily mean wind speed was used. Other required climate input data are the ground water table depth and the percentage of sunshine (SS). Because these data are not recorded in the LTPP Datapave for New Mexico State, it is necessary to determine acceptable values that will not cause large errors in the analysis.

For the ground water table depth, data from the U.S. Geology Survey (USGS) were used. For each site, the average recorded water table depth was used in the analysis. The determined water table depths for each site are listed in Table 1. Take the test site SHRP 1002 as an example. The ground water table recorded near the SHRP 1002 fluctuates from 6 to 15 ft in 2007 with the average of 10 ft. Therefore, 10 ft is selected as the ground water table depth for the SHRP 1002. In a same way, water table depths for other sites can be determined.

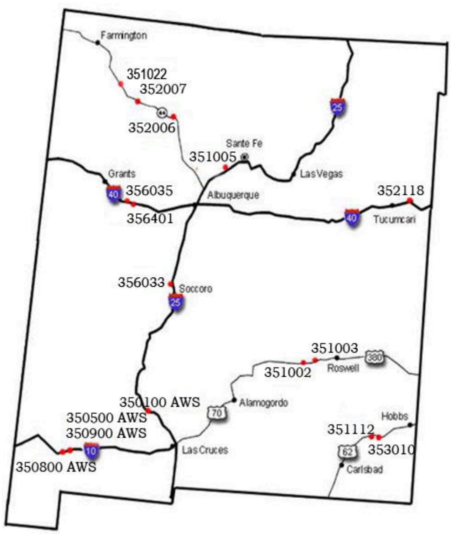

Figure 1. LTPP sites in New Mexico

In this analysis, the SS, which is one of the required climate data in the EICM, is not available for the above mentioned four test sites. Assumptions were made for every site to get the SS value. For example, the test site SHRP 1002 has 106 wet days in 2002, which is about 30% of the whole year. Therefore, a default value of 70% was used for the SS in the SHRP 1002. The same approach was applied to determine the default values of SS for other sites. Table 1 also gives the default values of SS for each test site in the analysis.

Table 1. Selected ground water table depths and default values of SS

Test Site	Water Table Depth (ft)	Percentage of Sunshine (SS, %)
1002	10	70
1005	65	79
1112	45	84
2118	50	80

TEMPERATURE VALIDATION

After inputting all the required data, the EICM program can be run. The output data in the EICM program include predicted pavement temperature profile with depth, water content, pore water pressure, ice content, frost heave and penetration, etc (Larson et al., 2003). In this research, because of the limited data, only comparisons on pavement surface temperature and pavement temperature profile with depth were made to check the feasibility of the EICM.

Comparisons for the test site SHRP 1002 are presented in this paper, as shown in Figure 2 and Figure 3. In Figure 2, comparisons were made among the EICM-predicted pavement surface temperatures and the measured ones. Temperatures used for comparison were selected from the temperatures at 12:00 pm in the first day of each month of year 2002. It can be seen that the measured pavement surface temperature is always higher than the EICM-predicted ones. This may be attributed to the special soil condition in New Mexico. Because the site SHRP 1002 is located in southern New Mexico which is in sand area, for the same density and moisture, sand has higher thermal conductivity than clay and silt (Bu-Hamdeh and Reeder, 2000). Therefore, comparing with clay and silt, sands may cause higher ground temperature at noon. From Figure 2, it can be seen that the measured temperatures in July is much higher than the EICM predicted ones. This can be explained by the specific climate condition during that period. In the area of the test site SHRP 1002, July is the rain season with rains happening in the late afternoon or at night, which leads to limited influence on pavement surface temperature at noon. So the drop of temperature in this period is not large. However, the EICM program takes the total amount of daily precipitation to predict pavement temperature. That daily precipitation will cause a sharp drop on predicted temperature. Therefore, the differences between the predicted and the field measured temperatures in this season are larger than other seasons.

To obtain the influence of percentage of sunshine on pavement temperature, comparisons among the EICM-predicted pavement surface temperatures with different SS values were carried out. As shown in Figure 2, for the site SHRP 1002, the SS values were set as 50%, 70%, and 90%. Figure 2 also shows that, the higher the SS value, the higher the predicted pavement surface temperature.

Figure **3** gives the comparisons between the EICM-predicted and the field measured temperature profiles. For the test site SHRP 1002, there is only one group of temperature profile data recorded in LTPP Datapave. This group of temperature profile data was measured on May 12, 2002. Therefore, comparison was performed based on these data. From

Figure **3**, it can be seen that there are some differences between the EICM-predicted and the measured pavement temperature profiles with depth at the SHRP1002. After comparisons were made for all test sites, it can be concluded that for different test sites, the differences between the EICM-predicted and measured temperature profiles vary. Therefore, the current EICM can not be directly used in New Mexico. It still needs further calibration with local data.

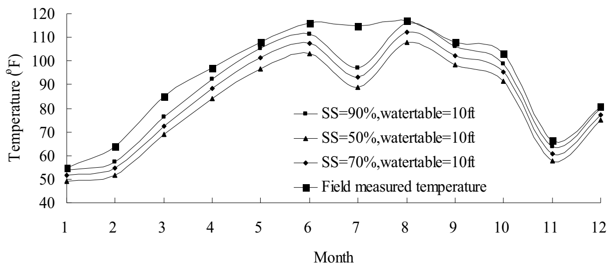

Figure 2. Comparison among the EICM-predicted and measured pavement surface temperatures at SHRP 1002

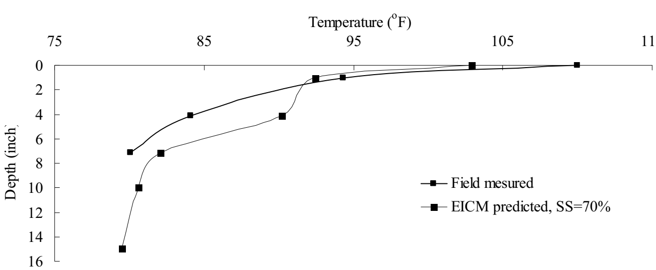

Figure 3. Comparison of EICM predicted and field measured pavement temperature depth profile at SHRP 1002

CORRELATION ANALYSIS

Because of the differences as above mentioned, a correlation should be established between the EICM-predicted and the field measured pavement temperatures. In this research, it is not possible to find the relationship between the EICM predicted and measured temperature profile with depth based on the data available, so only pavement surface temperature correlation was established for all the test sites, based on the predicted pavement surface temperature under the selected SS value (Table 1). Eq. (1) gives the relationship between the field measured pavement surface temperature and the EICM-predicted ones. Because of the page limitation, the deduction process was not described here.

$$y = 0.9193x + 14.085 \quad (1)$$

where y = field measured temperature ($^\circ F$), x = EICM-predicted temperature ($^\circ F$). Through statistical analysis, about 97% of the data which were used to develop the model satisfy this relationship, with the $R^2 = 0.968$. The relationship between the EICM predicted and measured pavement surface temperature is acceptable.

Based on the particular climate in New Mexico, the correlation analysis should be carried out seasonally to show the particular climate condition in July. However, with very limited data, it is not easy to show a good result by seasonal analysis. Future work is necessary to be done on the theoretical part of the EICM based on seasonal analysis.

CONCLUSIONS

In this research, a temperature evaluation on EICM was carried out to validate of the application of EICM program in New Mexico. Through the temperature validation, it is concluded that the current version of EICM can not be directly used in New Mexico due to the differences between the EICM-predicted and the field measured temperature. Finally, because it is not possible to find the relationship between the EICM predicted and measured temperature profile with depth based on the data available, a correlation between the EICM-predicted and the measured pavement surface temperature was established.

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Improvement of Coastal Silty Sand of Saudi Arabia Using Preloading Technique

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ABSTRACT: The subsurface formation at sites along the western Red Sea coast of Saudi Arabia often have loose to medium dense silty sand at several parts. This type of material was encountered at levels immediately below the foundation depth commonly used in practice. These soils undergo excessive settlement when supporting concrete structures, slab on grade systems and pavement structures. This work was aimed at studying the improvement provided by preloading technique to these coastal deposits. Technical College Building Complex site located at Al Qunfoda was selected for this study. The site was preloaded using 4.5 to 6m height of sand over six month period. The settlement was monitored every week throughout the period of preloading. The density and compressibility of the formation was noted to improve in different stages; an initial fast stage occurring within the first four weeks, intermediate stage which continued for 12 weeks and a slow stage which is noted to continue for more than 26 weeks. A final stable stage is considered when no variation in settlement can be reported over a satisfactory period. The process improved the site and established a close to uniform density across the area studied. Plate load tests carried out on improved areas confirmed that the settlement after preloading was reduced to tolerable limits for a particular foundation stress range. This paper provides a guide for monitoring, verification and decision making tool for practicing geotechnical engineers.

INTRODUCTION

This paper is aimed at investigating the performance of preloading technique as used in practice along the Red Sea coast of Saudi Arabia where loose silty sand material is encountered. Damage in the form of excessive settlement was noted in different types of structures and pavements. History of severe damage was reported in the major urban areas along the coast. Jizan city and the nearby towns and settlements were known to be the most affected. A report prepared by the Ministry of Municipality and Rural affairs (Saudi Arabia) in 1985 surveyed the problem and suggested some approaches to improve foundation design. The preloading technique is among these methods. Preloading means placing a temporary load to exert stresses on the ground equal to or higher than stresses to be applied by a proposed structure. This will cause the substrata to densify and form a stiffer support which will help in reducing the compressibility when the actual structure is built. Normally an earth fill of a predetermined height and soil density is placed and the settlement is observed over a period of time until the deformation is stopped or becoming extremely small. Other methods of soil improvement include dynamic compaction, heavy tamping, use of RIC (rapid impact compaction) compacters, stone columns, soil replacement and or soil treatment using a cementing agent. The preloading is found practical, economical and easy to apply. The concept of preloading was known since long time. The documented approach is tracked as early as 1930s. Busiman (1936) presented a study on a long duration settlement test at the First International Conference on Soil Mechanics and Foundation Engineering. Johnson (1970) used the term precompression for improving soil density. He suggested sand drains to reduce the time of consolidation. Although the method is simple and straightforward it was found that several pitfalls can make the process not successful (Ramli Mohamed 1992). These include: designing for compensation of primary settlement only, removing surcharge too early and inadequate instrumentation and monitoring.

The preloading technique can also help in reducing liquefaction risks in areas with seismic hazards.

SITE BACKGROUND AND CHARACTERISTICS OF THE SUBSTRATA

The site for this study is located at the south west of Saudi Arabia along the Red Sea coast at Al Qunfoda town. The project is a Technical College Complex which consists of several buildings, roads and boundary walls. The soil investigation was conducted by AMNK Consulting Engineers. It was found that the site is underlain by medium dense silty sand followed by very loose to medium dense silty sand to sandy silt. Standard penetration test results reported values as low as 4 blows per 300 mm in some sections. The groundwater is encountered at 2.8 to 3.4m below ground level. The recommendations of the consulting firm suggested alternative solutions to be considered including preloading, stone columns or cast in place pile foundation to support the proposed structures. The geotechnical firm suggested to limit the width of foundation to 2.4m and to adopt narrow strips so that the significantly high stresses would be within the top improved soil layers. The client decided to adopt the preloading option as being economical and easy to apply. Figure 1 shows a generalized subsurface profile.

The subsurface material is predominantly classified as SM. ML and SC. The clayey material is very limited and it is encountered as thin films. The measured plasticity index varied from 3 to 7 except for a few samples indicating some values of 8 to 17. The fine material passing sieve number 200 (75 microns) is in the range of 16.9 to 53.8%. This is mostly silt or clay with low plasticity.

The soil profile given in this study does not represent the worst loose condition along the Red Sea coast. Very loose silty sand with SPT blows of 1 and 2 blows/300 mm down to depths of 20m were noted in Gizan region. The ground water table is variable and influenced by the low and high tide sea levels. The seismic ground acceleration of 10% probability of exceedance in 100 years in western Saudi Arabia indicates the highest relative level of ground motion in the site area (Thenhaus et al 1989). Therefore density improvement of the near surface liquefiable layers is of great concern.