Evaluation of Iowa Climate Data for the Mechanistic-Empirical Pavement Design Guide

Michael Heitzman
Office of Materials
Iowa Department of Transportation
800 Lincoln Way
Ames, Iowa 50010
Michael.Heitzman@dot.iowa.gov

ABSTRACT

The new Mechanistic-Empirical Pavement Design Guide requires detailed climate data as part of the analysis input files. The national effort to develop the new pavement design guide applied historic climate data records as the future predicted climate. However, early findings by an Iowa State University climate study regarding the implementation of the new pavement design guide for the Iowa Department of Transportation show that the use of historic climate data is not adequate for predicting future pavement performance. A virtual climate database is needed to properly project future climates and predict future pavement performance.

Key words: climate—mechanistic-empirical pavement design guide

INTRODUCTION

In the late 1990s, the highway community embarked on a journey to elevate the national methodology used to design the structure of highway pavements. Most states' current practice uses the empirical results of a single research effort from the late 1950s known as the AASHO Road Test. It is commonly accepted that the pavement design process developed from the AASHO Road Test is no longer applicable to today's increases in traffic and advances in paving materials and testing. The new process, known as the Mechanistic-Empirical Pavement Design Guide (MEPDG), takes a vast array of knowledge and research on traffic, climate, materials, and pavement mechanics to predict the performance of pavements.

Each input component of the MEPDG is formatted to account for variations that naturally occur. The traffic pattern changes through the course of the day. The climate changes hourly and seasonally. The pavement materials respond differently as the traffic and climate change. In an attempt to capture these changes, the MEPDG requires large databases to reflect the project traffic, predict climate, and encompass the range of material responses. The ability to make these estimates over a typical pavement life of 20 to 30 years seems somewhat impractical; however, through a careful and conscience effort, this pavement design process will improve the ability to predict future pavement performance. This paper focuses on the requirements of the climate database.

CLIMATE MODEL

The NCHRP project to develop the national MEPDG model elected to compile climate data using the historic records of weather stations across the country. The required climate data includes hourly air temperature, hourly wind speed, hourly percent sunshine, hourly precipitation, daily maximum solar radiation, and monthly humidity. Only a limited number of weather stations could provide the level of climate data required for the MEPDG. For Iowa, only 15 weather sites are included in the MEPDG national database. While the early versions of the MEPDG software only contained about 5 years of data, the current version has more than 10 years (starting with the 1990s). The software uses the available climate data and repeats the climate data up to the number of pavement performance years desired. For example, a 30-year pavement design would apply a 10-year climate database three times.

This process raises some important questions. How much historic climate data do you need to properly represent the future climate? Should we simply repeat the data to accomplish the pavement analysis period? Are the critical climate features appropriately applied in the MEPDG model? The discussion of these questions leads to the decision to build a "virtual" climate database using the broader historic understanding of weather patterns.

ANALYSIS

The MEPDG research team concluded that 15 to 20 years of climate data was sufficient to represent the future climate in a target location. However, a simple analysis by Iowa State University climatologists demonstrated that temperature trends in Iowa over 10-year periods were dramatically different. See Table 1. Which 10-year period best represents the next 30 years of Iowa's climate? The 1970s may best represent the average temperature. The 1980s represent an above-normal temperature period, and the 1990s represent below-normal high temperatures and above-normal low temperatures. If we have to select a single 10-year period of climate data (and repeat it three times for a 30-year analysis), what 10-year period should we choose?

Table 1. Iowa climate averages and extremes

Decade	Average Daily High Temperature (°F)	Average Daily Low Temperature (°F)	100°F + Events
1970s	58.9	37.4	593
1980s	59.6	38.1	2073
1990s	58.4	38.3	235

Even if we could acquire all 30 years of data, what is the proper order of the 10-year periods? For asphalt pavements, a true test of rutting resistance occurs in the first 5 years during the heat of the summer. The test of resistance to low-temperature transverse cracking occurs after 10 years of binder aging. A conservative approach to the pavement performance analysis would deliberately use harsh climate patterns to measure critical pavement performance criteria. While this approach seems overly aggressive, the opposite approach (mild climate input) tells the pavement designer very little about the capability of the proposed pavement.

Long-term climate prediction is understandably a soft science. An approach that builds a "virtual" climate database using all of the available historical statistics should be better than selecting any 10-year period of climate history. See Figure 1. The broader knowledge of climate patterns and norms includes not only the daily averages, highs, and lows, but also the distribution of these parameters. With standard statistical tools, the climatologist can build a virtual 20-, 30-, or 40-year MEPDG climate input database. This database could represent the normal distribution of climate and the cycles of extremes. See Figure 2. Further, the virtual database could be manipulated to force some extreme climate events into specific pavement performance time windows to test the limits of the pavement design.

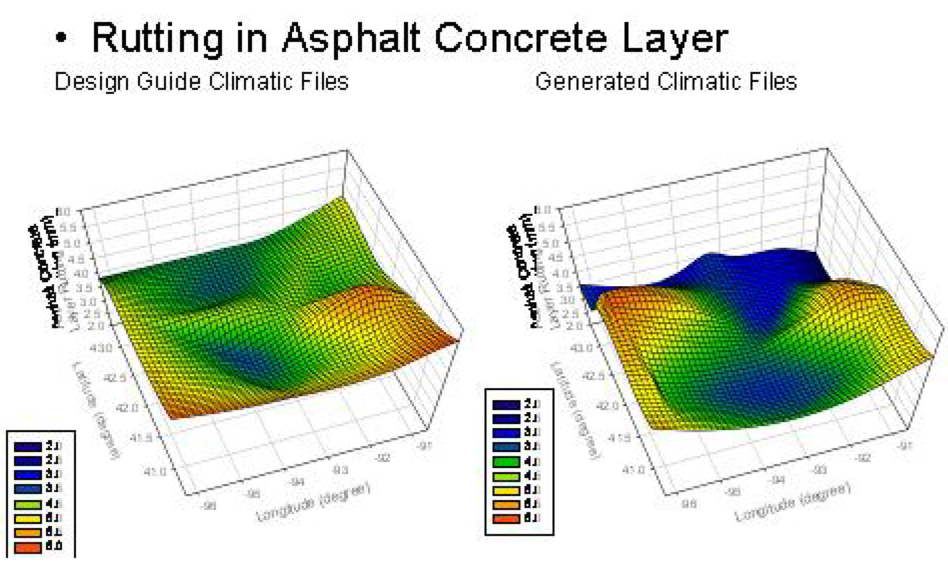

Figure 1. Comparison of repeated 10-yr data and 20-year data, medium-volume traffic

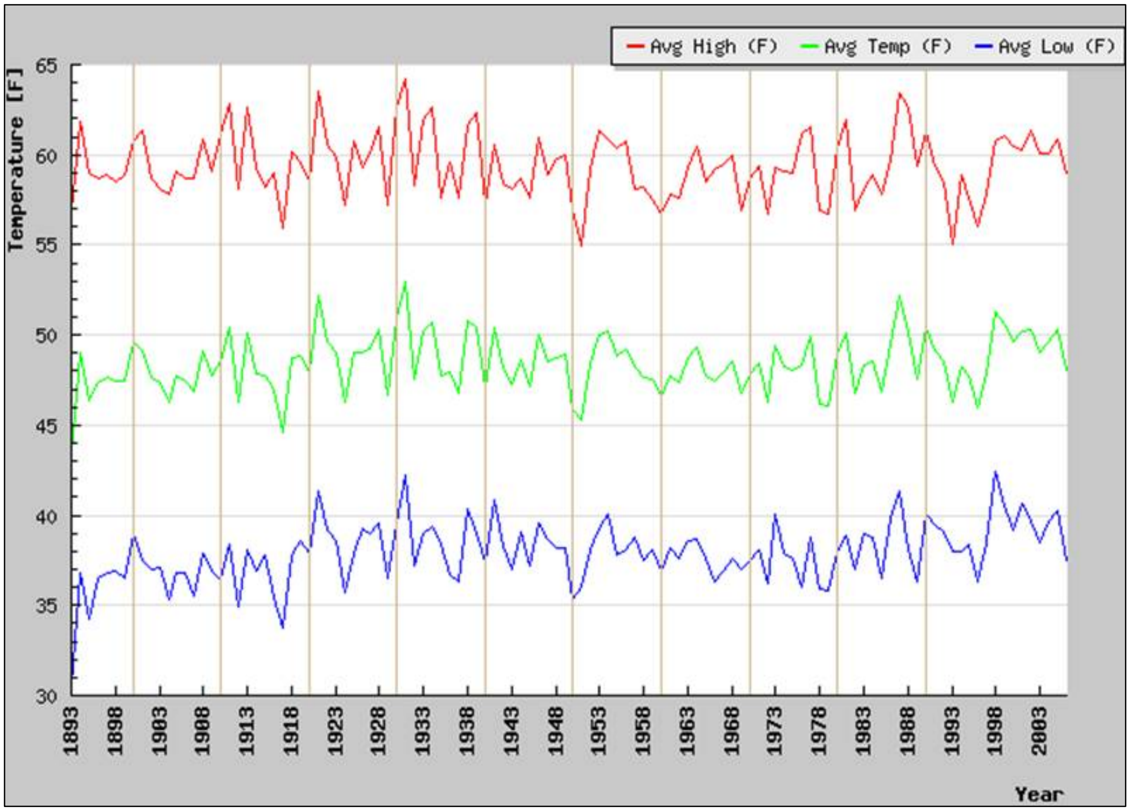

Figure 2. Historic record of climate cycles, Ames, IA

CONCLUSION

What is the future of climate databases for the MEPDG? In reality, the pavement designer needs both the historic climate and a virtual climate. The historic climate is critical for the validation and calibration of the pavement performance curves. Our ability to predict pavement performance is founded on our ability to quantify past pavement performance. The historic climate data should be matched (as close as possible) to the measured historic pavement performance to accurately model pavement performance. Historic climate database files are also needed to perform forensic studies on existing pavements with premature distress or failures.

A virtual climate database, using broad historical trends, will best predict the pavement performance into the future. The virtual model can better project historical cycles and trends in climate than any fixed 10- to 20-year historical climate record. With a careful adjustment of the virtual database, a pavement design performance prediction can reflect the ability of the pavement to perform under extreme climate limits.

ACKNOWLEDGEMENTS

The author recognizes the efforts of Iowa State University's Department of Civil Engineering MEPDG Implementation Team and the Department of Geological and Atmospheric Sciences. Particular recognition goes to Tamer Breakah and Daryl Herzmann for their efforts to analyze data and prepare the graphs used in this paper.