FHWA-HEP-15-019

U.S. Department of Transportation
Federal Highway Administration

U.S. DOT Gulf Coast Study, Phase 2

Engineering Case Study 9: Pavement Mix Design Exposures to Temperature Changes

This is one of 11 engineering case studies conducted under the Gulf Coast, Phase 2 Project. This case study evaluated the potential impacts to pavement due to projected increases in temperature.

Description of the Site and Facility

Roadway pavement can be sensitive to increased temperatures and heavy loads, which can lead to ruts or cracks. Pavement rutting and cracks can slow traffic and freight movement, damage vehicles, and potentially affect vehicle control in some cases. As such, different types of pavement and paving techniques are used to accommodate different climates. However, design decisions are made based on historical climate conditions, and may not be adequate for future conditions.

This case study looked at the current practices and specifications of the Alabama Department of Transportation (ALDOT) for laying pavement in Mobile, and evaluated whether they would need to be adjusted to avoid rutting and cracking under future temperature conditions. The analysis focused primarily on Asphalt Concrete (AC) pavement, which is the predominant type used in Alabama; however, considerations related to Portland Cement Concrete (PCC) pavement were also noted.

Figure 1: Example pavement cracking

Climate Stressors and Scenarios Evaluated and Impacts on the Facility

The key environmental factor to affect pavement mix design, both in terms of AC rutting and PCC cracking, is temperature. The specific temperature variables relevant to pavement mix design include:

- Maximum seven consecutive day average high air temperature (50% reliability[1])
- Absolute minimum low air temperature on the coldest day (50% reliability)

This analysis considered two temperature scenarios for the 21st century; a "Warmer" narrative and a "Hotter" narrative. The "Warmer" narrative represents the 5th percentile (mean-1.6 SD) of all the climate model outputs under the range of climate scenarios considered, whereas the "Hotter" narrative represents the 95th percentile outputs (mean+1.6 SD). Table 1 summarizes the projected changes to the pavement design-related temperature variables under both the "Warmer"and "Hotter" narrative.[2]

1 Reliability refers to the probability that the given temperature value will be exceeded in any particular year.

2 For more information on the climate information referenced here, please refer to Climate Variability in Change in Mobile, AL (USDOT, 2012) and Screening for Vulnerability (USDOT, 2014).

Maintenance Activity	Observed (Model Baseline) 1980-2009	"Warmer Narrative" 2010-2039	"Warmer Narrative" 2040-2069	"Warmer Narrative" 2070-2099	"Hotter Narrative" 2010-2039	"Hotter Narrative" 2040-2069	"Hotter Narrative" 2070-2099
Maximum Seven Consecutive Day Average High Temperature (°F) (50th Percentile)	94 (34.4°C)	94 (34.4°C)	95 (35°C)	96 (35.6°C)	97 (36.1°C)	99 (37.2°C)	103 (39.4°C)
Coldest day (°F) (50th Percentile)	20 (-6.7°C)	19 (-7.2°C)	20 (-6.7°C)	20 (-6.7°C)	23 (-5°C)	25 (-3.9°C)	28 (-2.2°C)

Table 1: Observed and Projected Pavement Design Related Temperature Variables in Mobile, Alabama[3]

ALDOT uses the Superpave[4] system to help with selection of binders. Pavement binders are often referenced by their Performance Grade (PG). The Performance Grading concept is based on the idea that a hot mix AC binder's properties should be related to the conditions under which it is used. A suitable PG AC binder will minimize thermal cracking under cold temperatures (due to shrinkage of the material) while simultaneously minimizing traffic-induced rutting under hot temperatures. Grades are assigned in 10.8°F (6°C) increments for both minimum and maximum pavement temperatures. The naming of each binder specification corresponds with the metric pavement temperature ranges for which it is rated. For example, a PG 58-22 AC binder meets a seven-day maximum pavement temperature of 58°C (136.4°F) and a minimum pavement temperature requirement of -22°C (-7.6°F). Note that binder specifications are defined in terms of pavement temperature, not ambient temperature, so the ambient temperatures had to be converted to pavement temperatures.

ALDOT currently recommends the use of either PG 67-22 or PG 76-22 in the Mobile region, depending on expected traffic loads.[5] PG 67-22 is the most common application; PG 76-22 is specified for use only as a surface layer on high traffic load roads. To evaluate whether these binder specifications will need to change in the future due to climate change, the temperature projections were converted to pavement temperature values to enable selection of the appropriate PG rating. The analysis found that the current pavement specifications should be sufficient under the projected increases in temperature. However, the PG 67-22 specification comes close to being inadequate late this century if the "Hotter" narrative is realized.

Identification and Evaluation of Adaptation Options

Adaptation measures are not necessary since the current pavement specifications should be adequate for the future climate scenarios analyzed. However, in areas where current pavement specifications are not adequate for projected increases in temperature, the following adaptation options could be employed:

- Use a binder more suitable to higher temperatures
- Use coarser aggregate, which tends to be more resistant to rutting
- Use thicker pavement sections at the time of initial design
- Consider use of PCC pavement in certain applications
- Change the frequency of maintenance to repair damage

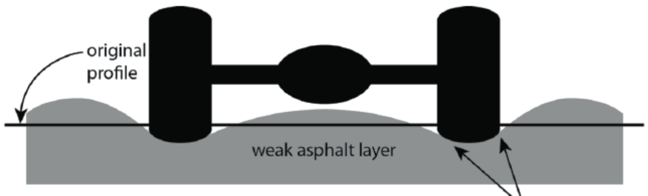

Figure 2: Diagram of Rutting in an AC Layer

3 Source: USDOT, 2014. Note: Figures shown represent an average across the five regional weather stations.
4 The U.S. Strategic Highway Research Program developed the Superpave system to specify optimal hot asphalt pavement mixes for given temperature and traffic conditions based on empirical research.
5 ALDOT, 2012

Potential Course of Action

Since the current pavement specifications appear to be adequate, no adaptation measure is needed.

Lessons Learned

More specific guidance is needed on how to incorporate climate change into pavement design. Moving from exploratory research that raises awareness of climate change to practical guidance aimed at reducing costs and safeguarding infrastructure will require additional efforts and collaboration. Pavement engineers, with assistance from government agencies and climate change experts, should be encouraged to develop a protocol or guide for considering potential climate change in the development and evaluation of future designs. The guide should extend beyond the narrow focus on pavement mix design in this case study to incorporate all elements of climate change impacts on pavement design (e.g., subbase, drainage, pavement texture).

For More Information

Resources:

Gulf Coast Study:
Engineering Assessments of Climate Change Impacts and Adaptation Measures

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