Introduction

• More than 25 design methods exist for jointed plain concrete pavements (JPCPs).
• Many are based on the 1950 AASHO Road Test, including AASHTO 93 and CHI922.
• The prominence of these methods created an expectation for JCP thicknesses.
• Modern JCP design methods in North America are:
  1. Rooted in mechanistic (M) principles such as finite element analyses and
  2. Supplemented with empirical (E) calibration to field performance to increase the accuracy of key performance predictions of importance to owners and users, such as:
     • Cracking in slabs,
     • Faulting in joints, and
     • International Roughness Index (IRI).

Performance Predictions Comparison

The traditional mindset is to manage percent slabs cracked after determining the required thickness; if the above is for 10% slabs cracked, slab thickness of 8 in. (200 mm), 9 in. (225 mm), and 10 in. (250 mm) can have maximum joint spacings of 11.75 ft (3.5 m), 16.6 ft (5.0 m), 18.7 ft (5.7 m), respectively, to achieve 10% slabs cracked; shorter panels can become thinner and still achieve the same performance requirements.

Now consider the same inputs modeled in OptiPav in a joint spacing of 8 ft (2.4 m) and less, as shown below and with a single line between 8 ft (2.4 m) and 11.75 ft (3.5 m) to complete the trend in sensitivity to joint spacing for this example.

As shown above, StreetPave provides a reasonably accurate solution, and via a relatively simple design framework. Also shown, Pavement ME's consideration of local conditions and more complex models can reduce thickness by approximately 1 in. (25 mm) versus StreetPave in this case and OptiPave's consideration of shorter joint spacing can produce approximately 2 – 2.5 in. (50 – 64 mm) of thickness reduction versus StreetPave.

Thicknes Requirements Comparison

• Although there are many variables with which a pavement engineer can optimize a JCP with regards to cost, sustainability, etc., the JCP thickness required for the same set of conditions is of particular interest to practicing pavement engineers.

• The table and image at the top of the next column show the required thickness of the “defaults” case example previously presented for varying levels of trucks per day.

Performance Predictions Comparison

As shown above, StreetPave provides a reasonably accurate solution, and via a relatively simple design framework. Also shown, Pavement ME’s consideration of local conditions and more complex models can reduce thickness by approximately 1 in. (25 mm) versus StreetPave in this case and OptiPave’s consideration of shorter joint spacing can produce approximately 2 – 2.5 in. (50 – 64 mm) of thickness reduction versus StreetPave.

Summary and Conclusions

• The modern software are increasingly adopted in NA and abroad because of their more accurate and reliable performance predictions of the key indicators that owners and users observe and feel as they drive across a pavement.

• Comparison of the modern JCP design approaches approaches responses and failure modes of interest to users whereas AASHTO 93 cannot.

Limitations of the Design Framework

- Incomplete consideration of k-value
- Beam-based fatigue model
- Dwell-simplified fatigue model
- No accounting for time of loading

Increasing number of inputs and model complexity

- Modern software are increasingly adopted in North America and abroad because of their more accurate and reliable performance predictions of the key indicators that owners and users observe and feel as they drive across a pavement.

Mechanistic and Empirical

Modern (2000s Era) JCP Design Methods

- AASHTO ‘93
- StreetPave
- Pavement ME
- AASHTOWare
- OptiPave
- TCPavement’s OptiPave

AASHTO ‘93

- AASHTO ‘93 ACPA’s StreetPave
- AASHTOWare Pavement ME
- Not calibrated to modern, local JPCP
- Less than 25% of concrete cells failed
- 8 million ESAL limit in testing
- Based on empirical 1950s field testing

AASHTO ‘93 Modelling began with Pavement ME, where a 6 in. (150 mm) thick non-stabilized stone base was added atop an 8-7.6 in. (200-192 mm) thick concrete slab on a 10 in. (250 mm) thick base. StreetPave in this case and OptiPave’s consideration of shorter joint spacing can produce approximately 2 – 2.5 in. (50 – 64 mm) of thickness reduction versus StreetPave.

• pavement ME and OptiPave both compute and report accumulated percent slabs cracked, magnitude of faulting, and IRI over the design life

AASHTO ‘93

- Increasing number of inputs and model complexity
- Crack model only for bottom-up
- Requires panels < 8 ft (2.4 m)
- Incomplete consideration of k-value
- Underestimating slab capacity

• As with the previous comparison, “default” input values are used as much as possible

AASHTOWare Pavement ME

- Complete consideration of k-value
- Edge support, design reliability, and k-value
- To illustrate the breadth of design variables considered and the sensitivity of required thickness to joint spacing as shown above when considering OptiPave and Pavement ME solutions across varying joint spacing presents a national transition in sensitivity to this key input variable

Pavement ME and OptiPave both compute and report accumulated percent slabs cracked, magnitude of faulting, and IRI over the design life rather than being a performance prediction design tool, thickness is adjusted to manage the maximum joint spacing from 15 ft (4.6 m) to 6 ft (1.8 m) instead of reducing the total thickness of the pavement.

Although there are many variables with which a pavement engineer can optimize a JCP to the left, the sensitivity of required thickness to joint spacing as shown above when considering OptiPave and Pavement ME solutions across varying joint spacing presents a national transition in sensitivity to this key input variable.

Summary and Conclusions

- Project level pavement management and network level asset management are increasingly trusted by owners as a means to maximize the effectiveness of their limited resources

- Key to that is accurate pavement performance predictions and an understanding of how the various modern JCP methods can facilitate optimization by means such as inclusion of sensitivity to joint spacing, or adjustment of any other inputs allowed in the design framework.

- AASHTO ‘93 is historically the most common JCP design method in the world; its limitation prompted development of modern mechanistic-empirical frameworks, such as AASHTO’s StreetPave, AASHOWare Pavement ME, and TCPavement’s OptiPave.

- The modern software are increasingly adopted in NA and abroad because of their more accurate and reliable performance predictions of the key indicators that owners and users observe and feel as they drive across a pavement.

- With adoption of such modern JCP design methods, pavement engineers have an opportunity to optimize JCP design while minimizing their risk and liability.

- Comparison of the modern JCP designs to AASHTO ‘93 illustrates that AASHTO ‘93 is the outlier, with a distinctly different slope of its sensitivity of thickness to traffic

- Among the modern JCP designs, thickness may be reduced through consideration of more complex models and key inputs such as joint spacing

- Continuous sensitivity of required thickness to joint spacing is preserved through modeling comparable inputs in both Pavement ME and OptiPave; the trend illustrates that while the thickness reductions suggested by OptiPave seem optimistic if approached with an incorrect design methodology, the results are consistent with the thickness reduction trendline realized in Pavement ME.

Comparison of Modern Concrete Pavement Performance Predictions, Thickness Requirements, and Sensitivity to Joint Spacing

Robert Rodden (PNA), Eric Ferrebee (ACPA), Sherry Sullivan (CAC), Juan Pablo Covarrubias (TCPavements), Ben Nantasai (PNA)

Tables 1 and 2 above present a rational transition in sensitivity to this key input variable.