Life-Cycle Analysis: A Powerful Tool for Improving the Sustainability of Concrete Pavements

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Outline of Presentation

• Why should we care about concrete pavement sustainability?
• A tale of three scenarios: how can two-lift construction result in “sustainable” alternatives?
• What is life-cycle analysis (LCA)?
• What does LCA tells us about the scenarios considered for two-lift construction?
What is Sustainability?

“Meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs”

[WCED 1987]
Sustainable Infrastructure

The Triple Bottom Line (TBL)

• Economic
• Environmental
• Societal
Pulling on one of the poles takes the system out of balance

Moving towards the center balances the system

Increased Sustainability

Economic

Environmental

Societal

TBL
Simply Put...

• Sustainability not only considers initial and life-cycle economic factors, but also environmental and societal impacts and benefits
  – It is simply good engineering
  – As with all engineering, it entails working with limited resources to achieve design objectives
  – As such, it is not about perfection, but instead about balancing competing, and often contradictory, interests
What Makes a Concrete Pavement More Sustainable?

• More economic
  – Lower initial cost
  – Lower maintenance and rehabilitation costs
  – Longer life

• More environmental
  – Less energy consumed
  – Less pollution generated

• More societal benefits
  – Safer
  – Quieter
  – Versatile
Some Specifics...

• Economics
  – Maximize use of lower-priced, locally available materials without sacrificing performance
    • e.g. increased aggregate volume/reduced paste, recycled content, marginal aggregates, supplementary cementitious materials (SCMs), etc.
  – Improved design that reduces costs
    • Better understanding of performance, enhanced features
  – Decreased construction costs
  – Improved maintenance and rehabilitation strategies
    • e.g. diamond grinding, in-place recycling, etc.
Some Specifics...(Continued)

• Environmental
  – Reduce the use of portland cement
    • Optimized grading, use of SCMs, etc.
  – Reduce construction impacts
  – Reduced impact during operation
    • e.g. heat island effect, increased vehicle fuel efficiency, reduced urban lighting needs, treat air pollution, etc.
  – Reduced run-off
  – Reduced waste
    • Recycling, waste fuels, waste raw materials
Some Specifics...(Continued)

• Social
  – Reduce noise
  – More livable communities
    • Colored and patterned concrete, integrated urban environment, reduced heat, etc.
  – Increase safety
    • Lighting, skid resistance, etc.
  – Less disruption due to construction
  – Locally made product
The Good News...

• We are currently in the process of becoming “good”
  – Many efforts are afoot to improve the sustainability of concrete pavements including the new CP Roadmap Sustainability Track
  – We need strategies (tools) to assess where we are and to help us get to where we need to be

• The next step is to become even better
  – LCA helps us work toward
How Can Two-Lift Construction Help?

• Two-lift construction can maximize the use of locally available materials coupled with improved performance and longevity
  – The lower lift can be made with materials that might not perform well as a surface
  – The top lift can be designed to withstand the harsh environmental and loading conditions at the pavement surface
The Bottom Lift

• Generally thick, typically being 80 to 90 percent of the total pavement thickness
• Generally optimized to have a lower cement content while making maximum use of locally available materials
  – Recycled concrete and/or recycled asphalt pavement
  – Softer aggregates with poor wearing resistance
  – High SCM content and/or low total cementitious content
    • Scaling is not an issue for this layer
The Top Lift

• Optimized to be durable, wear resistant, and quiet
  – Uses high quality, durable, wear resistant aggregate
    • In some locales, must be imported
  – Aggregate type and sizing can be optimized to reduce noise if used as exposed aggregate surface
  – Often higher cement content is required since smaller maximum aggregate size is used
  – Must be resistant to scaling and deicer damage
The Kansas Two-Lift

• Mainline pavement consists of two, 3.7-m wide travel lanes, with 4.6-m transverse joint spacing
  – Paved in one pass, tied at longitudinal joint, and dowelled transverse joints

• A 150-mm thick cement-treated base on existing subbase

• Total concrete pavement thickness of 340-mm
Three Alternatives

• Alternative 1: Conventional w/ same wearing surface
  – 340-mm thick PCC surface made with imported, wear resistant rhyolite aggregate
  – 150-mm thick CTB made with local carbonate aggregate

• Alternative 2: As-built two-lift
  – 40-mm thick wearing course made with rhyolite aggregate
  – 300-mm thick bottom lift made with local carbonate aggregate
  – 150-mm CTB made with recycled concrete

• Alternative 3: Two-lift with added features
  – Same as above except bottom lift uses recycled concrete coarse aggregate, reduced cementitious content, and 20% Class F fly ash
The Three Alternatives

Alternative 1

340-mm PCC w/ Rhyolite CA

150-mm CTB w/ Carbonate CA

Alternative 2

40-mm PCC w/ Rhyolite CA

300-mm PCC w/ Carbonate CA

150-mm CTB w/ RCA CA

Alternative 3

40-mm PCC w/ Rhyolite CA

300-mm PCC w/ RCA CA, reduced cementitious, and FA

150-mm CTB w/ RCA CA
Assumptions

• The following are constants, so were not considered in the LCA
  – Performance is assumed identical, so anticipated maintenance and rehabilitation was not considered
  – The same shoulders are used throughout so they were not considered
  – The same subbase was used throughout so it was not considered
  – The same joint design is used throughout, so joint details were not considered

• All these things can be considered in an LCA
In Summary

• Sustainability is NOT just an environmental initiative, but instead is an approach to balance economic, environmental, and social benefits and impacts

• Concrete pavements have a lot of advantages when sustainability is considered, and more are emerging every day

• Two-lift construction is one approach to enhance the overall sustainability of concrete pavement
Questions?

Here’s Joep!