Determinants of Material Intensities and Environmental Impacts of Roadway Designs

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Roadway Issues to Discuss

Like all life-cycle and supply chain problems, we need to understand the technologies involved, the project-level data, and the expected trends:

- Roadways versus pavements
- Life cycle
- Design
- Material selection
- Material sourcing and supply chains
- Pavement management systems
- Pavement–vehicle interactions
Understanding Life-cycle Effects

Energy, GWP

Manuf. → Constr. → Use/Maint → EOL

Recycling

Recycling
>90% of US pavements are asphalt

https://www.britannica.com/technology/road/The-modern-road; 3/02/18
http://www.cts.umn.edu/Publications/catalyst/2013/march/pavements
Concrete Pavement Design Differences

https://engineering.purdue.edu/JTRP/Highlights/reducing-joint-spacing-for-high-performance-concrete-pavement; 3/02/18

http://onlinemanuals.txdot.gov/txdotmanuals/pdm/rigid_pave_design.htm; 3/02/18
Evolving Pavement Technologies

- Use of supplementary cementitious materials (chiefly fly ash) in place of cement
- Warm-mix asphalt
- Asphalt recycling technologies
  - Hot in-place recycling
  - Hot-mix plant recycling
  - Cold in-place recycling
- Concrete recycling technologies
  - Crushing old pavements into aggregates
  - Carbonation
- Maintenance
- Transportation
Typical Design for Roadways in the U.S. and Europe

Great Variability in Design

Concrete Production Globally

Water withdrawal for the production of concrete to total water withdrawal (a) and industrial water withdrawal (b)

Revealed: Qatar in new quagmire as an unlikely natural resource runs out

Qatar has built up significant stockpiles of sand and other construction materials but, it is unclear how much sand Qatar has. (Shutterstock)
Comparison Indices: Strength vs. Global Warming Potential

Eco-efficient cements:
Potential, economically viable solutions for a low-CO₂, cement-based materials industry
Pavement Management Systems

- Pavement management systems are maturing in terms of:
  - Measuring service
  - Planning over long periods of time, over multiple cycles
  - Allocating money
  - Seeing pavements as a component of societal environmental strategies
  - Decision-support tools (e.g., for environmental assessment
    *PaLATE* – Pavement Life-cycle Assessment Tool for Environmental and Economic Effects; contact A. Horvath)
  - Available case studies for validation
Designing “Perpetual” Asphalt Pavements

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**Conventional Deep Strength Design**
- 40 mm Wearing Course
- 120 mm Asphalt Binder Course
- 150 mm Granular Base
- 450 mm Granular Subbase

**Perpetual Pavement Design**
- 40 mm Wearing Course
- 120 mm Asphalt Binder Course
- 90 mm Rich Bottom Layer
- 150 mm Granular Base
- 370 mm Granular Subbase

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https://www.canadianconsultingengineer.com/features/perpetual-pavement/; 3/03/18
How Often Should We Replace Pavements?

Increase in Trucking and Load Consolidation

• Worldwide increase in trucking
• Increased maximum weight limits
• Increase in load for a given axle causes exponential pavement damage
• 4th Power Law: The damage caused by a particular load is related to the load by a power of four.


• Freight consolidation centers
• Consequences need to be better understood. See, e.g.,:
Other Drivers

- Permeable asphalt pavements
- Carbonation
- Albedo