

Life Cycle Assessment (LCA) of Highway Pavements
Concrete Sustainability Hub
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Because of the enormous environmental and economic impact of infrastructure in the United States, there is a growing need to better understand the life cycle performance of highway pavements and to investigate methods of reducing their global warming potential (GWP). It is essential to consider the full life-cycle environmental performance of pavements, including the energy and resources required to construct, maintain, and dispose of pavements over time.

In the last year, we have created a new model to quantify the life cycle carbon emissions of pavements from manufacturing to disposal. Unlike the majority of previous life cycle assessment (LCA) studies on pavements, our work includes a detailed analysis of the operating, or use, phase of the life cycle. This provides an essential starting point for both policy discussions as well as design discussions, and the results are of interest to a range of audiences.

LCA of Highway Pavements

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Focus: This study makes a comparative analysis of the carbon emissions of asphalt concrete (AC) and portland cement concrete (PCC) pavements through life cycle assessment. The goal is to quantify the carbon emissions associated with pavement material selection over a 50-year lifetime, including maintenance and differences in fuel consumption. The scope of the study is limited to high-volume pavements for highway applications, in an effort to quantify the impact of traffic volume on life cycle emissions.

Approach: The PCC and AC pavement designs include sub-base, base, and overlay layers, designed according to the American Association of State Highway and Transportation Officials (AASHTO) standards. The functional unit for the LCA consists of four lanes in each direction with a length of one kilometer. The traffic properties are based on national averages and cover fuel savings for the two main categories of passenger cars and trucks. Maintenance schedules and changing International Roughness Index (IRI) values over time are used to account for variations within the lifetime of the two pavement systems. As part of the analysis of the impact of maintenance, the associated increase in fuel consumption due to traffic disruption is also considered. The traffic level on the pavements is based on data from the Federal Highway Administration (FHWA) statistics and is divided into two main categories of cars and trucks.

Results Highlights: In the first year, we have concluded the following:

- For a high traffic volume highway, the potentially greater fuel efficiency of vehicles driving on concrete pavements could lead to significantly lower life cycle carbon emissions compared to an asphalt pavement. Improved understanding of the mechanisms involving fuel consumption and pavement structure will lead to more reliable and quantifiable results.
- Greenhouse gas emissions due to initial construction of PCC and AC pavements are on the same order of magnitude, but varying maintenance schedules and lane closures can cause lower emissions for concrete pavements over time. Depending on the initial design and maintenance schedule employed, concrete pavements can also provide a lower average IRI, leading to fuel and emission savings.
- The use phase of the life cycle accounts for 3% – 85% of greenhouse gas emissions. The large range is primarily due to varying traffic demand and uncertain data. The use phase is most significant for high-volume roads, where the effects of traffic-related emissions are magnified.

Potential Impact: Our research on life cycle pavement emissions will provide better understanding of the current performance of pavements as well as areas for improved design and operation. Numerous LCA tools are under development around the world for pavements, and our work will help to improve the ways in which they are applied, and in particular, will help to identify areas where cost savings can also deliver energy savings.

Work Plan: In the coming year, we will extend the current work on pavement emissions to:

- Create fuel consumption models to further account for pavement-vehicle interactions and to instill greater confidence in potential fuel savings according to pavement design.
- Combine life cycle carbon emissions with life cycle economic costing to help balance economic and environmental concerns, and to identify practices which both save money and lower greenhouse gas emissions.
- Further investigate the impacts of maintenance schedules and lane closures on a range of pavement designs, including those for low- and high-volume pavements, different climate locations, and different pavement service lives.

Project Conclusion: August 31, 2011

Summary

In year one, the life cycle assessment project of the Concrete Sustainability Hub has made significant contributions to our understanding of the environmental performance of pavements. We are delivering a new level of clarity for the industry, for policy makers, and for designers, and we have created a foundation to build upon for future studies. Life cycle assessment provides a rigorous means of testing the relative environmental merits of various design alternatives, and can provide quantifiable means of reducing both economic and environmental costs of pavement design alternatives. Combining the pavement LCA model with Life Cycle Cost Analysis (LCCA) will allow policymakers, Departments of Transportation (DOTs), and designers to accurately measure both cost and the environment impact in the design of pavements in order to have a better maintained and more sustainable US highway system.