How the Concrete Paving Industry is Incorporating Sustainability into Our Practices

Jim Mack

Over the last five years, I have had the honor to work with the Concrete Sustainability Hub (CSHub) at the Massachusetts Institute of Technology as it has researched processes and developed tools to be used by decision-makers in order to make more informed decisions on pavement designs that are both cost-effective and environmentally responsible. Because of this unique view, I was recently asked to comment on how the cement, concrete and concrete paving industries are implementing sustainability practices into our daily activities to lower the environmental footprint of concrete pavements. In reflecting on this, I concluded that our activities are being driven by these two questions.

1. What are we doing – looking inward – to improve our products
2. What are we doing – looking outward – to ensure that Pavement Life Cycle Assessment Processes are done as best as possible to capture the true environmental impact of pavement decisions.

With respect to “Inward looking”, our industry has made and is continuing to make a number of advancements that improve our products: These include:

- Increasing the use of “Low Carbon Concrete Mixes.” As is well known, cement is the 800 pound gorilla with respect to CO2 emissions for concrete pavements. To have meaningful sustainability reductions, the industry needs to address this issue and we have initiated several activities to do exactly this.

  First, we are improving our mix designs by using optimized mix gradations, recycled concrete and asphalt aggregates, and supplementary cementitious materials (fly-ash, slag and other products) to not only lower our environmental impact, but to also improve the concrete so that our pavements perform better. Nowadays, it is not uncommon to see concrete mixes with supplementary cementitious material replacements rates between 20 and 50 percent.

  Along similar lines, we are trying to increase the use of limestone cements. The use of limestone as a component of portland cement has been common practice in Canada and Europe for about 30 years. In Europe, limestone contents can be as high as 35 percent. In the U.S., the industry and the state Department of Transportations have recently unified the ASTM and AASHTO standards so that limestone cements can be more readily used. If the use of limestone cements can get to the same level of use as other parts of the world, the U.S. will see a 10 to 15 percent reduction of CO2 from the production of cement.

- The cement and concrete industries are also investing in research to lower the environmental impact with the production of cement. In fact, a very recent finding from the CSHub shows that if the ratio of calcium to silicate in the cement nano-structure is altered, it can decrease greenhouse gas emissions in two ways – first by lowering the energy required to produce cement and second by reducing the amount of carbon dioxide released from limestone during the manufacturing process (see http://newsoffice.mit.edu/2014/stronger-greener-cement-0925).

  In the same manner, the cement industry has had a huge focus on energy efficiency. Over the past four decades, we have seen energy reductions of over 40 percent (Figure 1) and currently have several alternative fuel projects under development that will lead to additional decreases as the use of alternative fuels increases.

  While the industry has been working on lowering the impacts of cement and concrete mixes, it has also been working to make sure that concrete pavements are not being “over-designed.” Many concrete pavements in the past were designed too thick. While this can be a benefit for long term performance, the extra thickness is not the most cost-effective or environmentally friendly approach to improve sustainability on a particular project.

  This is why the industry is adamant about using the most up-to-date design tools, such as the AASHTO Pavement-ME Design Procedure for highways and StreetPave for lower volume roads, to optimize pavement designs, and using new products such as Concrete Overlays and Roller Compacted
Concrete to give owners a wider choice of competitive pavement alternatives from which to choose.

Now while we can easily design pavement systems that are structurally 50+ year pavements, we also need ensure our materials last that long. This is why the industry has been investing in and working with the CSHub, the CPTech Center at Iowa State, and others to ensure that our products are more durable by addressing issues such as Alkali Silica Reactivity, freeze-thaw and other material problems. Finally, the industry is developing industry-wide and many individual companies are developing their own Environmental Production Declarations or EPD’s. These EPDs show that the industry is environmentally transparent and ensure that agencies have the best information available when they develop project specific Life Cycle Assessments.

While all this is good, the industry is also looking outward to make sure that what is being measured is done correctly so that designers can determine what really matters on a particular project. We know that each project is unique and that the only way to get meaningful environmental reductions is to look at each project, on a case by case basis, to find where the most meaningful impact reductions can come from for that particular project. This is why we support, and encourage, the use of Comprehensive Life Cycle Assessment (LCA) evaluations on all projects in much the same way that Life Cycle Cost Analysis (LCCA) should be used on all projects.

This is where the investment in the CSHub has really helped. In this partnership, MIT has developed a general, but comprehensive pavement LCA methodology that follows a transparent and well defined framework. MIT and the industry then used this framework and applied it to a variety of scenarios and pavement designs from across the U.S. to quantify emissions; identify opportunities for improvements; and calculate the cost effectiveness of emission reduction strategies to better understand from where the biggest reductions can come. In doing this analysis, we have learned several key points:

First, we have learned that context matters. What is most impactful for a low volume road is not the same as what will be most impactful for a high volume road. Each project is unique and agencies must use a comprehensive LCA to guide them on where the most meaningful impact can be made for that particular project.

Secondly, we have found that the Use Phase and Pavement-Vehicle Interaction (PVI) matter and that under certain conditions the use-phase impacts are the most significant component and are much greater than ALL other phases of the roadway life cycle. For example, on high volume roadways, the materials production, construction and maintenance portions of the pavement may account for somewhere around 5 to 10 percent of the total LCA results, whereas the Use Phase, and specifically the traffic, can account for up to 60 to 65 percent of the total LCA results.

In such cases, a 30 percent improvement in the initial production impacts, while useful, may only mean a 1 to 2 percent savings over the entire life of the pavement. However, if we make as little as a 2-3 percent improvement in the truck/car PVI by building stiffer pavements, pavements that maintain their smoothness longer and have lower rolling resistance, we can offset the entire construction impact.

We have also learned that PVI is not an issue of smoothness or deflection, or surface texture for that matter - it is about understanding when each is important. Yes smoothness can be the most impactful when the road is rough. However, at a given level of smoothness, the contribution of smoothness decreases and the impact of deflection plays a greater role. Understanding when each portion of Pavement Vehicle Interaction plays a meaningful role will lead agencies to overall strategies that provide real reductions in CO2.

We have also found that Albedo matters. While we may not be able to establish the exact magnitude of albedo effects on a given project yet, the fact is that the gross numbers show that albedo has a huge impact, maybe more than PVI, which means the results and measurement issues need to be investigated and developed further.

The third item learned is that risk matters and that there is uncertainty and variability in all LCAs and LCCAs. However, it is an inappropriate response to ignore these issues and assume that they have no bearing because we cannot measure every item to the 3rd decimal point and the exact degree. Ignoring issues because of uncertainty and variability is a decision to say that issue is not important, but it does not make it go away nor does it change the impact.

Instead, practitioners need to apply, and move into practice, the new tools and techniques being developed at the CSHub that quantify uncertainty and variability so that agencies can get a more robust set of results on which it can make informed decisions.

The last item learned is that while LCA and LCCA are good for comparing alternatives, to get the greatest environmental and cost reductions, agencies need to incorporate Life Cycle Thinking into the Design Process. As mentioned earlier, context matters and the only way to drastically lower environmental impacts and costs is to have a structured link between the design tools and the LCA/LCCA tools so that we can optimize pavement designs and quantify the impacts of the different pavement designs.

This requires the pavement community to stop thinking that LCA and LCCA are done after design to determine which pavement type A or B, is better. Instead, pavement designers need to combine LCA and LCCA with design tools such as Pavement – ME to do a trade-off analysis between alternates while the various designs are being evaluated. This is...
done by using Pavement – ME to estimate how the different pavement designs will perform over their life, then using LCA and LCCA to evaluate the tradeoffs in performance, costs and impacts for each of those specific designs. By using this iterative approach to develop designs and measure performance while projects are being developed, designers can prioritize the best designs to minimize the costs and environmental impacts even before the pavement types are compared (Figure 2).

In summary, the cement, concrete and concrete paving industries believe that all the commonly adopted sustainability strategies are important and should be embraced. However, we know that there are still large opportunities to improve. To get the biggest reductions, LCA and LCCA need to be brought into the design process so that agencies do not trade shortterm gains at the expense of longterm benefits. Similarly, we believe that the use phase, although it may be least understood, needs to be included because it can be the most impactful. Just because a concept is new, or cannot be fully characterized yet, does not mean it is inconsequential and should be ignored. It needs to be included so that the full impact of our pavement decisions can be accounted for.

Finally, we think that comparisons among alternates need to be made on every project. The customer is best served when he can compare equivalent systems, on both environmental impacts and costs so that he can create competition in the marketplace. We believe that we have the suite of tools to make these comparisons possible and we strongly urge that they be adopted and used to ensure that we are making the best pavement choices possible.

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Figure 2: Optimizing the pavement designs lowers costs and environmental impact of the pavement system

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