CHAPTER 11. CONCLUDING REMARKS

Sustainability is a journey, not a destination. This document provides guidance to the pavement community on how to begin this journey by incorporating sustainability considerations throughout the pavement life cycle. Even today there are a number of technologies and innovations that can be exploited to help facilitate that journey, and several of those key items are summarized in this chapter, along with the current and expected trends in each area. This is followed by a number of recommended implementation activities for helping to advance the adoption of more sustainable practices within the pavement community.

Review of Technologies, Innovations, and Trends

Throughout this reference document, a number of technologies and innovations that hold the potential for improving some aspect of pavement sustainability are described; summarized below are just a few of the more prominent ones that are making significant contributions.

- **Recycled material use at higher rates of replacement**. While the standard use of recycled materials (e.g., RAP, RAS, RCA) has been a long-standing practice, the rates of use have often been limited by design procedures, technology, performance risk (perceived or real), and availability. Recent and likely continuing budget cuts associated with the general cost of construction have driven owners, designers, and contractors to explore ways of incorporating locally available recycled material at greater replacement levels. Rethinking mixture design processes, manufacturing requirements, specification limits, and construction practices from the ground up has already led to higher rates of use and better acceptance of recycled materials. As an added benefit, the reduced virgin material use and associated reductions in processing and transport can and has led to significant reductions in energy consumption and GHG emissions, which are now also becoming drivers for the greater use of recycled materials.
- **Adoption of WMA technologies as standard practice**. For asphalt pavements, WMA has received much attention in both technology improvement and implementation. Documented benefits of reduced energy consumption, reduced emissions (GHG and others), and improved construction quality have been primary drivers in the expanded use of WMA.
- **Use of SCMs to reduce cement GHG emissions**. The cement industry has put forth a substantial effort in reducing GHG emissions by reducing the cement content per unit volume while providing equal or better performance. Cement producers are producing a greater variety and amount of blended cements using SCMs or interground limestone to further reduce GHG emissions. Mixtures containing less than 50 percent cement of the total cementitious content are available and have shown good performance. As SCMs, limestone cements, and mixtures containing less cement per unit volume gain more acceptance by highway agencies, significant reductions in GHG emissions associated with concrete pavement construction will be realized.
- **Mechanistic based pavement design procedures**. Improved pavement designs are being implemented as state transportation agencies adopt mechanistic-empirical pavement design methodologies, which are based on a better understanding of pavement responses to traffic and environmental loadings and how those responses are linked to pavement performance.

- **Optimization of use of materials**. Two-lift concrete pavements and perpetual asphalt pavements are examples of design approaches that optimize the use of paving materials to meet specific needs. For example, two-lift pavements use higher recycled or marginal aggregate content in a thicker bottom lift while reserving more durable material for the thinner surface lift, thereby reducing the environmental impact of the overall structure without compromising performance.
- **Porous pavements for stormwater management**. As concerns continue regarding the volume and quality of stormwater runoff from paved surfaces, permeable asphalt (porous asphalt) and concrete (pervious concrete) pavements are becoming more widely used. These materials can not only be used to reduce stormwater runoff, but they can also be effective in reducing contaminants in waterways and renewing groundwater supplies. Other permeable pavement surfaces also exist, including those made with permeable interlocking concrete pavers.
- **Precast pavements and interlocking pavers**. Precast pavement systems, either intermittent or continuous, offer a unique solution to certain pavement challenges, particularly where short work windows are demanded or when maintaining overall traffic flow is critical. Interlocking concrete pavers provide an aesthetically pleasing appearance while providing utility access without compromising the pavement structure, thereby making them an attractive alternative in urban settings.
- **Construction technologies**. A number of emerging construction technologies are resulting in the production of higher quality, longer lasting pavements that can have significant environmental, economic, and social benefits. Intelligent compaction, stringless paving, and real-time smoothness measurements are providing real-time data to contractors. These data allow them to better control their processes to achieve improved in-place material properties and higher levels of initial pavement smoothness.
- **Expanded use of preservation treatments**. Preservation treatments that use little material yet maintain pavements in a smooth condition for longer periods of time have great environmental benefit, especially on higher traffic volume roadways. This realization is making the use of ultra-thin asphalt surfaces and diamond grinding of concrete pavements particularly attractive.

In addition to these technologies, several trends are emerging within the sustainability arena that are expected to play a significant role in future activities and developments, including:

- **Recognition of the importance of the use phase.** The use phase is beginning to be recognized as having one of the most important impacts on pavement sustainability over the life cycle. Vehicle fuel consumption, noise, safety, stormwater runoff, and urban temperature can be impacted by pavement characteristics such as structural response, macrotexture, roughness, permeability, and surface reflectivity. Studies are ongoing to define the effects of these variables for possible inclusion in future pavement LCA tools, potentially shifting the perspective to focus on pavement attributes that are most critical to minimize environmental and social impacts over the pavement life cycle.
- **Recognition that pavement systems are a small part of larger systems.** Pavements do not stand alone, but are part of larger systems that include both communities and ecosystems possessing their own sustainability goals. Advances are occurring in the development of pavement specific tools that integrate economic, environmental, and

societal impacts within the pavement system and in the broader context of these larger systems.

- **Development/enhancement of sustainability tools**. Advances are occurring in the development of tools that integrate pavement LCCA, LCA, and elements of pavement sustainability rating systems. Considerable work remains on building a consensus LCA framework, populating the LCI database with accurate and regionalized data, and developing improved models that accurately reflect the contribution of the use phase. It is envisioned that the emergence of these tools will positively impact the paving community in the next decade.

It is again emphasized that sustainability is context sensitive, and the development of sustainable strategies will depend on the characteristics of the specific project, the materials and technologies that are readily available, and the specific economic, environmental, and societal goals of the agency. Closely linked to this is that the selection of sustainable solutions often requires the consideration of trade-offs between several competing sustainability goals or objectives. The development of an LCA framework is one key area required to be able to assess relative environmental impacts and to monitor overall progress that is being made in the sustainability area.

Implementation: The Next Step

The information presented in this document forms the foundation for moving ahead in adopting sustainability principles in pavement systems. Key factors and activities that are essential to implement pavement sustainability best practices include:

- **Leadership at the national level**. FHWA should work to make sustainability a strategic priority in all areas of pavement design, materials, and construction and in communicating the principles, strategies, and techniques outlined in this document. As part of this, the development of a sustainable pavements framework can help provide a measured, detailed approach on how to advance the concepts, provide the implementation, and promote the research of sustainable pavement systems.
- **Leadership at the state level**. This is necessary to incorporate elements of pavement sustainability in the design and construction of state highway systems. This includes having strategic directions for sustainability established within an agency that include pavement systems. In addition, highway agencies can also contribute to the adoption of more sustainable practices by revisiting their design standards and material and construction specifications to ensure that they are not barriers to implementing more sustainable solutions. This can also have a positive "trickle down" effect to local governments that often rely on state design standards and material and construction specifications. Finally, agencies should identify a short list of items related to sustainability that make sense to adopt or implement within their organization.
- **Partnership between stakeholders**. Collaborative relationships are needed in which industry, academia, and highway agencies work together to implement sustainability principles and address issues and problems that emerge during the ongoing sustainability journey.
- **Education and outreach**. Educational materials and outreach programs must be developed to provide information on basic sustainability principles as well as on specific examples of "low-hanging fruit" in which the implementation of innovative materials and

technologies can have immediate economic, environmental, and societal benefits. Given that the available information is overwhelming, it must be simplified and properly directed as part of the implementation effort. The development of useful resources—such as guide documents, technical briefs, case study examples, a user-friendly web page, simple computer-based tools, and mobile applications—are considered essential to this effort. Furthermore, sharing case studies, findings, and recommendations through workshops, webinars, and targeted conferences is also a fundamental part of that outreach effort.

- **Identify knowledge gaps and develop a focused research map**. The research should be fundamental and basic as well as practical. Broad stakeholder support is needed if research results are to be accepted and implemented. Potential topics requiring additional research include rolling resistance, urban heat island effects, maintenance and preservation impacts, and energy consumption and GHG emissions associated with a pavement over its entire life cycle.
- **Educate, encourage, and implement LCA tools**. Sustainable practices can only be implemented if the environmental impact of decisions over the pavement life cycle can be quantified to a high degree of certainty. The only tool capable of accomplishing this is LCA, and therefore the application of LCA principles are critical for evaluating many of the trade-offs encountered through the pavement life cycle. Efforts should be made to educate the pavement community on LCA concepts and tools, encourage the community to adopt changes in policy based on knowledge garnered from LCA studies, and ultimately implement pavement-based LCA tools developed and vetted through a peer-reviewed process representing all stakeholders.