FRAMING DOCUMENT
CP ROAD MAP CONCRETE PAVEMENT SUSTAINABILITY TRACK

Background

At its core, sustainability is the capacity to maintain a process or state of being into perpetuity. In the context of human activity, it has been expressed as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (1) Although not universally accepted, sustainability is often characterized as a three-legged stool supported by economic, environmental, and social considerations or pillars.(2) Although there is often synergistic cooperation between the three pillars, it is also true in practice that a balance must be struck between competing interests. This relationship, referred to as the “triple bottom line” is often expressed graphically as shown in figure 1, where sustainability is increased when all three “pillars” or “legs” are considered through cooperation. The system is in danger of toppling if only one or two of the pillars are considered, as it will be unbalanced.

In 2003, when the CP Road Map was under development, the authors debated whether or not environmental issues were suitable for Track status or whether these considerations should be included within each track as appropriate. It was decided at that time that environmental considerations were so broad that they should be considered under each of the 12 Tracks. With the world-wide increase in emphasis on sustainability and the environment, the CP Road Map Executive Committee designated the advancements in concrete pavement sustainability and the environment as a full track on September 11, 2007, believing track status was necessary to examine in a holistic fashion how the design, materials, construction, operation, preservation[3], rehabilitation[3], and recycling of concrete pavements can be made to be more economically, environmentally, and socially sound. This Executive Committee decision requires a planned structured and collective approach to accelerate and consolidate sustainability and environmental efforts through the CP Road Map process. It has been decided to call this new track the *CP Road Map Concrete Pavement Sustainability Track.*

The key to successfully increasing sustainability of concrete pavements is to consider all three pillars of sustainability by having the tools and data needed to quantify each and understanding the relationship one to one another. Sustainability, in the context of this Track, is the use of materials and practices in concrete pavement design, construction, operation, preservation, rehabilitation, and recycling (things we do now) that reduce life cycle costs, improve the environmental footprint, and increase the benefits to society (things we need to learn to do). Each of these will be described in detail within this framework document.

[1] World Commission on Environment and Development (WCED). *Our Common Future: The Report of the World Commission on Environment and Development.* New York: Oxford University Press, 1987.
[2] 2005 World Summit on sustainable development in New York.
[3] Preservation practices include preventive maintenance, minor rehabilitation (non-structural), and some routine maintenance activities. Rehabilitation restores structural capacity by increasing pavement thickness. (K. Smith, T. Hoerner, and D. Peshkin, *Concrete Pavement Preservation Workshop Reference Manual*, FHWA, USDOT, Washington, D.C. 2008.)

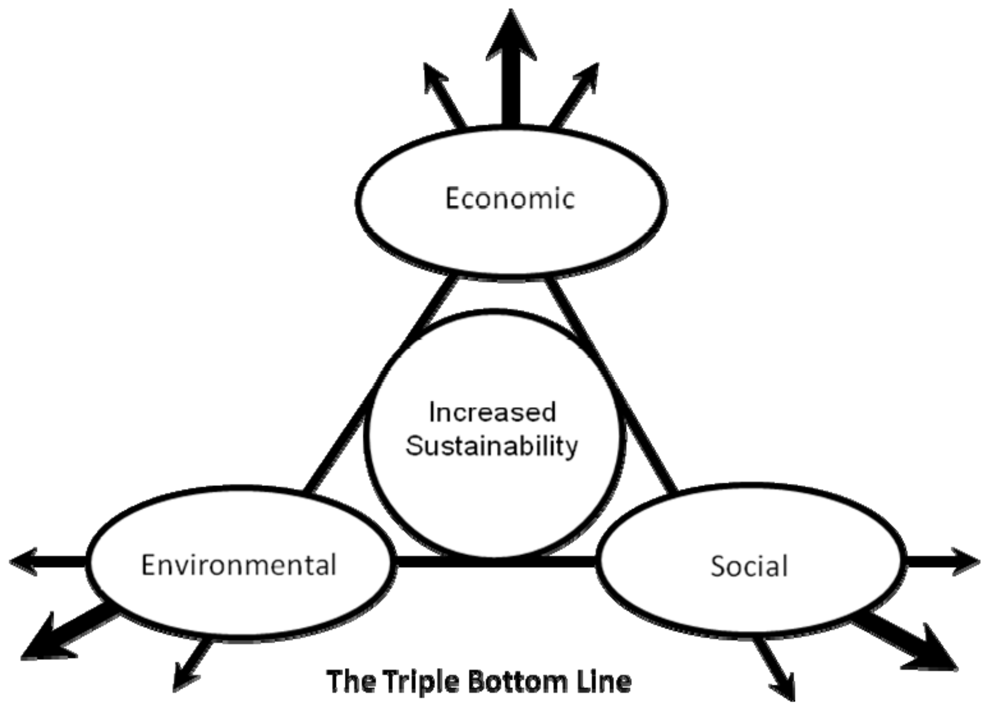

Figure 1. Graphical representation of sustainability and the "triple-bottom line" of economic, environmental, and social pillars.

Research into sustainable practices must not only consider new construction, but must also include the concrete pavement network which already exists. For example, a significant portion of the nation's highway system is more than 40 years old, with some portions over 50 years old. The Interstate and state primary road construction era of the 1950s, 1960s, and 1970's, much of which featured the use of concrete pavements, was followed by a period of rehabilitation featuring repeated asphalt resurfacings of these pavements. It must be recognized that through the appropriate application of sustainable preservation techniques, the service lives of concrete pavements can be extended for decades without the need for rehabilitation. It is also recognized that as traffic loadings increase, it might be necessary to add structural capacity to the existing pavement. This can be accomplished by selecting improvement techniques such as of concrete overlays. The approach of extending the service life of the original pavement, and therefore maintaining equity, is fundamental to increasing sustainability of an existing system. By choosing an appropriate preservation strategy, the low maintenance attribute of a concrete pavement can be preserved, as opposed to using strategies that can eventually lead to the complete reconstruction of the pavement.

This document presents the Track Vision and Objective, identifies gaps in research and technology, provides an integrated approach for quantifying concrete pavement sustainability, and describes eight subtracks to address the gaps. It is emphasized that this document reflects the current thoughts of the Leadership Group and it will continue to be developed and refined to reflect the challenges and opportunities facing the industry in the coming decade.

Track Vision

To identify and quantify characteristics of concrete pavement systems that contribute to enhanced sustainability of roadways in terms of economic, environmental, and societal considerations.

Track Objective

To identify and conduct research and transfer technology that enhances concrete pavement sustainability through the pavement's life cycle (design, materials selection, construction, operation, preservation, rehabilitation and recycling). Work will include:

- Development of advanced materials and processes that optimize reuse and conservation, and measurably reduce waste, energy consumption, water usage, and pollutants generated during all phases of the pavement's life cycle.
- Creation of innovative designs that make full use of the versatility of concrete as a paving material to improve pavement sustainability.
- Adoption of construction practices that directly enhance the overall sustainability of concrete pavements through increased efficiency, reduced emissions and waste, and decreased social disruption.
- Application of preservation, rehabilitation, and recycling strategies that enhance the sustainability of the existing network of concrete pavements.
- Refinement of life cycle cost analysis (LCCA) to fully account for the economic attributes of sustainable concrete pavements.
- Acquisition, preservation, and distribution of data as part of an environmental life cycle inventory (LCI) that accounts for all the individual environmental flows to and from a concrete pavement throughout its entire life cycle, and the adoption of an internationally recognized environmental life cycle assessment (LCA) approach that examines environmental aspects of concrete pavements through their life cycles.
- Further identification and quantification of social considerations that are affected by concrete pavement for inclusion in the integrated design process.
- Development of strategy selection criteria to assist in the decision making process, allowing various alternatives to be compared based on economic, environmental, and social considerations.
- Application of technology transfer for existing concrete pavement technologies that support the "triple bottom line".
- Coordination and collaboration with work being performed under other CP Road Map Tracks.

Identifying the Gaps in Research, Technology, and Implementation

In developing this Framework Document for the CP Road Map Concrete Pavement Sustainability Track, a review of the state of the practice was conducted. There is copious literature on sustainability and sustainability science, but little information is directly available on concrete pavement sustainability, particularly on North American practice. Some notable exceptions are the work conducted by the Cement Association of Canada (CAC)(4)(5)(6), the American Concrete Pavement Association (ACPA)(7)(8), and the Portland Cement Association (PCA)(9). Based on the review of available literature, it is observed that the concrete pavement industry has moved positively to embrace sustainable practices, yet numerous gaps in research, technology, and implementation currently exist, slowing future progress. These gaps can be grouped into the following categories:

- Materials.
- Design.
- Construction practices.
- Preservation, rehabilitation, and recycling.
- Economic life cycle cost analysis.
- Environmental life cycle analysis.
- Other environmental and social considerations.

Most of these categories are being or will be addressed, at least in part, by other Tracks in the CP Road Map. With this in mind, each gap is discussed below.

Materials and Mix Design

The acquisition and processing of the materials from which pavements are constructed is the major contributor to their energy and environmental footprint(10) regardless of the materials used. Pavements have not been made from renewable resources since wood block pavers fell out of favor in the early 1900's (and even these were soaked in coal tar creosote as a preservative). There are currently no immediate alternatives to extraction-based resources for pavement materials. In time, emerging technologies may offer some viable alternatives but these are likely a decade or more into the future. As a result, regardless of the pavement type, the materials used are predominantly responsible for the energy consumed, greenhouse gases generated, and waste/pollution produced to construct and maintain a pavement.

For concrete pavements, it is well known and accepted that the production of portland cement (annually the production of portland cement accounts for roughly 1.5% of the total US CO_2 emissions and 5% of the total global CO_2 emissions) is overwhelmingly the largest contributor to

[4] Smith, T. and P. Maillard, *The Sustainable Benefits of Concrete Pavement*, presented at the 42e Congrès annuel de l'AQTR, Defi: Transport Durable, 2 Au 4 Avril 2007, Montréal, Canada.
[5] Smith, T., *Concrete Pavement: A Truly Sustainable Choice*, presented at the 12th International Conference on the Chemistry of Cement, July 8-13, 2007, Québec, Canada.
[6] The Athena Institute, *A Life Cycle Perspective on Concrete and Asphalt Pavement Roadways: Embodied Energy and Global Warming Potential*, Submitted to the Cement Association of Canada, Ottawa, September 2006.
[7] ACPA, *Green Highways: Environmentally and Economically Sustainable Concrete Pavements*, Publication No. SR385P, October 2007.
[8] Wathne, L. and T. Smith, *Green Highways: North American Concrete Paving Industry's Perspective*, presented at the 10th International Symposium on Concrete Roads, Brussels, Belgium, September 18-22, 2008.
[9] Gajda, J. and M. VanGeem, *A Comparison of Six Environmental Impacts of Portland Cement Concrete and Asphalt Cement Concrete Pavements*, PCA R&D Series No. 2068, Portland Cement Association, Skokie, IL, 2001.
[10] Environmental footprint may be considered to be any change to the environment whether adverse or beneficial, wholly or partially resulting from human activity, industry or natural disasters.

the environmental footprint of concrete , accounting for roughly 80% of the total energy consumed and 90% of the CO_2 emissions associated with concrete production[(11)]. As such, the environmental footprint of concrete pavement can be significantly reduced by reducing the amount of portland cement used, which typically occupies between 9% to 15% of the paving concrete's volume. This can be accomplished through improved aggregate grading (which reduces the amount of cementitious material required), the use of blended (ASTM C595) and performance specified (ASTM C1157) cements, and the increased use of supplementary cementitious materials (fly ash, slag cement, natural pozzolans, and so on). Future strategies to reduce portland cement in concrete are under development, including no or low carbon geopolymer cements[12] and/or the use of carbon-sequestering cements[(13)(14)(15)], that may in time have a positive impact on the concrete pavement industry.

The largest single component in concrete is aggregate, which occupies 70% to 85% of the concrete volume. Aggregate is typically low energy, obtained locally, and is readily available being mined from relatively small quarries or pits which are almost always reclaimed for beneficial use. Aggregate can also be obtained from recycled concrete or hot-mix asphalt, or be derived from an industrial byproduct such as air-cooled blast furnace slag. Increasing the volume of aggregate in concrete is thus a good strategy to increase the sustainability of the concrete mixture as long as engineering properties of the concrete are not compromised. Further, using recycled and/or locally available aggregate can significantly enhance sustainability.

There are many other material considerations that can be used to positively impact the sustainability of concrete pavements. These would often be integrated with design considerations to be discussed next including the use of wear resistant aggregates, waterproofing admixtures, internal curing, high strength, fiber-reinforcement, colors, and possibly even titanium dioxide to treat air pollution. Many knowledge gaps exist in the development and implementation of materials that can have a marked effect on concrete pavement sustainability and this area of research will continue to be a focal point for research well into the future.

Design

Sustainable design starts at the earliest planning stages, where opportunities to enhance sustainability are sought at project inception. A number of design elements can have a marked impact on the sustainability of concrete pavements. Thus it is critical that the design of concrete pavements be approached from the design of the system, not just the selection of slab thickness. Reducing the amount of material used through better design, and emphasizing the use of recycled and locally available materials, is an obvious way to improve sustainability as it will lead to overall economic and environmental improvement. This can be accomplished by better

[11] VanGeem, M., *Sustainability Designer's Notebook*, Reprinted for PCI's Ascent magazine, Precast/Prestressed Concrete Institute, Summer 2006, Winter and Spring 2007.
[12] Davidovits, J., *Geopolymer Chemistry and Applications*. Geopolymer Institute. ISBN-10: 2951482019. March 2008.
[13]Biello, D., *Cement from CO_2: A Concrete Cure for Global Warming?*, Scientific American, August 7, 2008.
[14] Constantz, B. and T. Holland, *Sequestering Carbon Dioxide in the Built Environment*. Seminar presented at the 2009 World of Concrete. Las Vegas Convention Center, Las Vegas, NV. February 2-6, 2009.
[15] Jha, A., "Revealed: The Cement that Eats Carbon Dioxide," *The Guardian*. The Guardian News and Media Limited, London, UK. December 31, 2008.

materials selection and characterization, an improved understanding of the support conditions and the environment, and improved understanding of pavement performance, all resulting in less wasteful over-design. At this stage, cooperative arrangements should be sought between the owners/agencies, planners, designers, materials suppliers, and contractors to ensure that the most sustainable design is conceived, designed, specified and constructed.

Innovative concrete pavement designs also offer a way to dramatically improve sustainability. A good example of this is a two-lift concrete pavement, where the concrete in the lower lift is optimized to make the best use of locally available and/or recycled materials, whereas the top lift is optimized for long-life and functionality under traffic loading. It is easy to imagine using two very different concrete mixture designs to achieve increased economic and environmental benefit while also achieving maximum social value. Concrete in the lower lift could use a high volume of non-wear resistant aggregate since it will never be subjected to traffic, and include a higher volume of SCMs. The upper lift could have a higher cement content with little environmental penalty since it is relatively thin, and also include relatively expensive components that enhance functionality at little additional overall costs. These could include waterproofing admixtures, fibers, internal curing, aggregate grading for wear resistance and noise reduction, colors or lighter cement, or even titanium dioxide for treating pollution. The use of a two-lift design integrated with the versatility of concrete could be used to significantly improve the sustainability of concrete pavements.

Another innovative design that can enhance sustainability is the use of precast pavements. Precasting has numerous attributes that accentuate sustainable construction since the structural elements are made under controlled conditions.[16] Further, the opportunities for application of precast pavements in urban environments may make this design attractive from a sustainability perspective, including the use of patterns and colors (or increased reflectivity) that improve aesthetics and/or reflectivity, rapid construction and replacement/recycling, integrated curb and sidewalks, etc. Research gaps that exist include optimization of materials, jointing systems, support, geometry, performance modeling, and construction expediency.

Construction Practices

Enhancements to construction practices that reduce fuel consumption, emissions, particulate, and waste while improving construction quality will improve the economic, environmental, and social attributes of concrete pavements. Much of this development will be driven by equipment manufacturers and contractors, but research conducted under this track could help stimulate advancements. Further, expediting construction through better construction sequencing and material improvements, as well as better traffic management through construction zones, can reduce economic, environmental, and social consequences of congestion and the corresponding user delays. The research gaps to be considered include concrete materials and production, transport, placement and consolidation, finishing, curing, and joint sawing, all of which can be made more sustainable through increased efficiency, reduced waste, and quality improvements. Additional research on construction sequencing and traffic flow through construction zones is also warranted.

[16] VanGeem, M., *Sustainability Designer's Notebook*, Reprinted for PCI's Ascent magazine, Precast/Prestressed Concrete Institute, Summer 2006, Winter and Spring 2007.

Preservation, Rehabilitation and Recycling

Timely and appropriate preservation and rehabilitation will ensure that a concrete pavement will achieve the long-life that is expected. Accurate anticipation and timely execution of the appropriate treatment is paramount to reducing cost and extending pavement life. Designing and constructing concrete pavements anticipating preservation treatments 30 to 50 years in the future, such as adding nominal additional thickness to accommodate diamond grinding, enhances pavement life and functionality at little initial cost or environmental impact. Over the life cycle, preservation and ultimately rehabilitation will reduce economic, environmental, and social costs. And at the end of life, it is critical that the concrete is completely recycled. The research gaps include better modeling to anticipate optimal timing of various preservation treatments and increased efficiency and longevity of the treatments applied.

Rehabilitation through the use of concrete overlays provides an effective way of extending the life of an existing road using a minimum of new materials because the support provided by the existing pavement is efficiently utilized. A relatively thin layer of concrete is placed over the existing pavement using bonded or unbonded systems, depending on the condition of the existing pavement. When an overlay reaches the end of its life it can be removed and recycled into a new layer. This means that a minimum of new materials are being used while providing long life with a minimum of down time or interference to traffic. Research gaps include the need for a design method for overlays that includes sustainability parameters. Research is also needed to investigate interactions with the original pavement, bond longevity, slab geometry effects and continued fatigue damage to the original pavements.

In recent years, dramatic improvements have been made in the recycling of existing concrete pavement. It is now standard practice to recycle existing concrete pavements instead of considering the removed pavement as waste, and even in-situ recycling on grade is becoming commonplace. Yet often recycled concrete aggregate (RCA) is used only for fill or base course applications and issues with the disposal of crusher fines continues. Additional research is needed to continue advancing in-situ recycling as well as making full use of RCA in all layers of the newly constructed pavement including increasing the use of RCA as aggregate in new concrete.

Economic Life Cycle Cost Analysis and Incentives

Economics is one of the three pillars of sustainability and it is crucial that a better understanding of concrete pavement economics over the entire life-cycle be developed. Life cycle cost analysis (LCCA) has been in use for a number of years, but most approaches are simplified and do not necessarily capture the full economic benefit derived from concrete pavements over the life cycle. At a minimum, better estimations of initial cost, the timing and cost of preservation and rehabilitation, and the value at the end of life are needed. A tool to conduct an LCCA, including a sensitivity analysis for key parameters, would help practitioners better understands the importance and robustness of this approach in selecting the preferred design alternative.

Related to the LCCA is the development of approaches that encourage the use of environmentally superior designs, materials, and processes. This is related to transportation agency policy in which entities work together to share risks and benefits inherent in adopting innovative sustainable approaches for pavement design, materials, and processes.

Environmental Life Cycle Assessment

One of the most critical challenges before us is to establish how environmental benefits and impacts will be quantified and used to compare various engineering solutions. There is a need to adopt a quantification process that is robust and unbiased, allowing the identification of desirable solutions and creating the synergy needed to promote these solutions. It must also be flexible, allowing the consideration of a broad number of alternatives including those that contain innovative features. The quantification process must not assume that one strategy is better than another, but allows comparisons to be made over a range of environmental considerations.

The effort conducted under this task is at the heart of advancing sustainability of concrete pavements through adoption of a life cycle assessment (LCA) approach. An LCA requires the creation and maintenance of a concrete pavement-specific life cycle inventory (LCI) with local/regional data. The data would include values assigned to materials and processes for impact categories such as embodied energy[17] (both primary and feedstock) and global warming potential, and will also include water (use, reuse, and treatment), noise, airborne particulate, emissions, human toxicity, etc. The LCI would also assign ranking of the significance of the impact categories for all the materials and processes used in the design, initial construction, preservation, rehabilitation, and recycling of the pavement. The LCA protocol must adhere to international standards as described in the International Organization for Standardization (ISO) 14040 standards, and must be accessible to the concrete pavement community as a tool or toolkit in an easily usable format to help improve the sustainability of concrete pavements.

Other Environmental and Social Considerations

Environmental considerations regarding the construction, preservation, rehabilitation, and recycling of concrete pavements will be thoroughly quantified and analyzed under the previous task. These considerations are largely under the influence of the agency responsible for administering the facility. There are additional environmental and social considerations that could be added to the LCA, but may better be addressed separately as they more directly relate to the operation of the facility and the community which it serves. These factors include, but are not limited to:

- Vehicular fuel efficiency.
- Surface reflectivity as it contributes to nighttime visibility, artificial lighting needs, and the urban heat island effect.
- Friction and wet-weather safety.
- Noise.
- Stormwater runoff.
- Treatment of smog.

[17] Embodied energy may be considered to be the total amount of energy used during the entire life cycle of a product including the energy used for manufacturing, transporting, and disposing of the product

There is currently no consensus on how these multiple factors can or should be considered in the analysis and thus it will be the focus of this task to develop an understanding of these factors through research and adopt an appropriate approach for their inclusion in the LCA.

A Plan to Fill the Gaps

In the previous section, gaps in research, technology, and implementation were identified. In this section, specific subtracks developed to address the gaps are designated, with individual tasks or projects being proposed as problem statements to meet the Track Objective. It is clear that to accomplish this work will require extensive collaboration with the other CP Road Map tracks including:

Track 1: Performance-Based Concrete Pavement Mix Design System
Track 2: Performance-Based Design Guide for New and Rehabilitated Concrete Pavements
Track 3: High-Speed Nondestructive Testing and Intelligent Construction Systems
Track 4: Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements
Track 5: Equipment Automation and Advancements
Track 7: High-Speed Concrete Pavement Rehabilitation and Construction
Track 8: Long-Life Concrete Pavements
Track 10: Concrete Pavement Performance
Track 11: Concrete Pavement Business and Economics
Track 12: Advanced Concrete Pavement Materials

The Sustainability Track currently identifies XX problem statements representing an investment of between $XX and $XX million in research and technology transfer. The proposed research and activities are organized into the following eight subtracks:

- Subtrack S.1: Materials and Mixture Design Procedures for Sustainable Concrete Pavement.
- Subtrack S.2: Design Procedures for Sustainable Concrete Pavements.
- Subtrack S.3: Construction Practices for Sustainable Concrete Pavements.
- Subtrack S.4: Preservation, Rehabilitation and Recycling Strategies for Sustainable Concrete Pavements.
- Subtrack S.5: Improved Economic Life Cycle Cost Analysis for Sustainable Concrete Pavements.
- Subtrack S.6: Adoption and Implementation of Environmental Life Cycle Assessment for Sustainable Concrete Pavements.
- Subtrack S.7: Identification and Quantification of Additional Environmental and Social Considerations for Sustainable Concrete Pavements.
- Subtrack S.8: Sustainable Concrete Pavement Technology Transfer and Implementation.

Problem statements contained under each subtrack may correspond to one or more individual projects. Over the course of the Sustainability Track, each problem statement will be developed into research project statements that will contain detailed descriptions of the research to be accomplished, specific budgets, and definitive timelines.

In order to implement what already is known, a number of early products are recommended under the Concrete Pavement Sustainability Track. These early products should include:

- The development of a Briefing Document for the various stakeholders (decision makers, engineers, material suppliers, and contractors) that defines sustainability and describes the current state-of-the-practice on implementing sustainable solutions today.
- The development of a "Best Practices" training manual and implementation package for concrete pavement sustainability. This will provide detailed technical information to engineers, material suppliers, and contractors, having immediate and measureable impacts on improving the sustainability of concrete pavements.
- Organize and conduct a conference on Sustainability of Concrete Pavements that addresses economics, environmental, and societal impacts, emerging technologies, and legislative/policy initiatives systematically so as to increase awareness of how the various factors interact.
- Work with federal and state agencies to create Demonstration Projects that feature sustainable solutions and effectively communicate the successes of these projects.

Proposed Projects

The following is a summary of the proposed projects for the work to be completed under each subtask. While categorized under the subtrack headings, no attempt is made here to prioritize the importance of projects. Collaboration with the sponsors and researchers of these projects will be crucial to the success of the Concrete Pavement Sustainability Track.

<u>Subtrack S.1: Materials and Mixture Design Procedures for Sustainable Concrete Pavement</u>

- S.1.1: New Generation Concrete Mixtures for Sustainable Pavements.
- S.1.2: Use of Supplementary Cementitious Materials for Sustainable Concrete Pavements.
- S.1.3: Use of Low Impact Local and Recycled Materials in Sustainable Concrete Pavements.
- S.1.4: Reduced Energy and Carbon Footprint for Sustainable Concrete Pavements.
- S.1.5: Carbon Neutral and Carbon Sequestering Cements for Sustainable Concrete Pavements.
- S.1.6: Durability Enhancing Admixtures for Sustainable Concrete Pavements.

<u>Subtrack S.2: Design Procedures for Sustainable Concrete Pavements</u>

- S.2.1: Planning Tools to Enhance Concrete Pavement Sustainability from Project Inception
- S.2.2: Long-Life Design for Sustainable Concrete Pavements.
- S.2.3: Use of Recycled and Industrial Byproducts in Underlying Pavement Layers.
- S.2.4: Two-Lift Sustainable Concrete Pavement Construction.
- S.2.5: Integration of Optimized Surfaces in Sustainable Concrete Pavement Design.
- S.2.6: Precast Sustainable Concrete Pavement Design Systems for the Urban Environment.

Subtrack S.3: Construction Practices for Sustainable Concrete Pavements

- S.3.1: Adoption of Automated and Wireless Control and Quality Monitoring Instrumentation to Improve Construction Quality.
- S.3.2: Increase Energy Efficiency and Reduce Pollution at the Plant and Construction Site.
- S.3.3: Guidelines to Reduce and Eliminate Construction Waste.
- S.3.4: Guidelines to Minimize the Use of Water During Construction.
- S.3.5: Innovative Curing Methodologies for Sustainable Concrete Pavements.

Subtrack S.4: Preservation, Rehabilitation and Recycling Strategies for Sustainable Concrete Pavements

- S.4.1: Use of Advanced Sensors to Monitor the Quality and Health of Concrete Pavements.
- S.4.2: Concrete Pavement Performance Modeling for Improved Timing of Preservation and Rehabilitation.
- S.4.3: Innovative Preservation and Restoration Strategies.
- S.4.4: In-Situ Concrete Pavement Recycling Techniques.
- S.4.5: Concrete Overlay Construction through Innovative Techniques and Equipment.

Subtrack S.5: Improved Economic Life Cycle Cost Analysis for Sustainable Concrete Pavements

- S.5.1: Establish Key Input Parameters to Conduct an Economic Life Cycle Cost Analysis.
- S.5.2: Development of a User Friendly Life Cycle Cost Analysis Tool.
- S.5.3: Guidelines for Conducting an Economic Life Cycle Cost Analysis.

Subtrack S.6: Adoption and Implementation of Environmental Life Cycle Assessment for Sustainable Concrete Pavements

- S.6.1: Create and Maintain a Concrete Pavement Specific Environmental Life Cycle Inventory.
- S.6.2: Identify and Rank Environmental Impact Categories that Affect Concrete Pavement Sustainability.
- S.6.3: User-Friendly Internationally Acceptable Environmental Life Cycle Assessment Toolkit for Sustainable Concrete Pavements.
- S.6.4: Guidelines and Implementation Package for Conducting an Environmental Life Cycle Assessment of Pavement Alternatives.

Subtrack S.7: Identification and Quantification of Additional Environmental and Social Considerations for Sustainable Concrete Pavements

- S.7.1: Innovative Approaches to Remove Pollutants from Air and Water Using Concrete Pavements.

- S.7.2: Quantify and Document the Impact of Pavement Reflectivity on the Urban Heat Island.
- S.7.3: Quantify and Document How Surface Characteristics Impact Vehicle Fuel Consumption.
- S.7.4: Quantify and Document Artificial Lighting Needs for Various Pavement Surface Reflectivities and Optimize for Energy Savings.
- S.7.5: Establish the Relationship Between Pavement Surface Reflectivity and Nighttime Driver Visibility.
- S.7.6: Determine, Quantify, and Optimize Pavement Factors that Contribute to Public Health and Safety.

Subtrack S.8: Sustainable Concrete Pavement Technology Transfer and Implementation

- S.8.1: Briefing Document on Implementing Sustainable Solutions for Concrete Pavement.
- S.8.2: “Best Practices” Training Manual and Implementation Package for Sustainable Concrete Pavement.
- S.8.3: Organize and Conduct a Conference on Sustainable Concrete Pavements.
- S.8.4: Assembled and Maintain an On-Line Toolkit.