Sustainable Concrete Pavements

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Chapter 1
INTRODUCTION

Design Fundamentals

By the end of this section, you will be able to:

- Identify the core challenges currently facing the U.S. pavement infrastructure system.
- Define the three pillars of sustainability and their relevance to pavement projects.
- Explain the shift from a conventional engineering focus to a whole-life, systems-based approach for pavement projects.

Executive Summary: The existing approach to managing, designing, and maintaining the nation's aging pavement infrastructure is unsustainable, facing severe funding shortfalls, poor conditions, and increasing traffic demands. A new paradigm is essential: implement sustainable pavement solutions that simultaneously reduce life-cycle economic costs, lessen environmental impact, and enhance societal benefits.

The Pavement Infrastructure Challenge

The pavement industry faces a critical junction where economic vitality must be maintained while balancing environmental and societal needs.

The current state of the nation's road system presents several key challenges:

- Aging Infrastructure: Pavements are deteriorating.
- Poor Condition: About 1.3 million miles (one-third of the road system) is in poor condition or worse.
- Increasing Demands: Traffic volumes and vehicle loads continue to increase, straining the system and causing serious congestion, particularly in major metropolitan areas.
- Funding Shortfall: There is an estimated $115.7 billion annual shortfall needed to substantially improve pavement conditions.
- Environmental & Social Costs: The environmental and social impacts of these systems are significant and must be addressed.

A new approach is required to solve these problems by implementing truly sustainable pavement solutions. This new approach must aim for reduced economic cost over the life cycle, lessened environmental impact, and enhanced societal benefit. Public agencies are increasingly adopting sustainable practices and starting to rate and award projects based on their ability to enhance sustainability.

1. Defining Sustainability

A basic definition of sustainability is the capacity to maintain a process or state of being into perpetuity, without either exhausting the supporting resources or degrading the operating environment.

In the context of human activity, sustainability means development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

The Triple Bottom Line

Sustainable activity requires finding a workable balance among three often-competing categories, or pillars, known collectively as the "triple bottom line". A sustainable solution must successfully integrate all three pillars.

The three pillars of sustainability are:

- Economic
- Environmental
- Social

Figure 1.1: Graphical representation of sustainability's "triple-bottom line" of economic, environmental, and societal considerations

Assessing Sustainability

To apply this concept to a pavement project, follow these steps for assessment:

1. Identify the applicable factors within the economic, environmental, and societal categories.
2. Collect data for the factors to be evaluated.
3. Apply tools to quantify the impact of each factor.
4. Assess the combined impact of the factors in relationship to one another.

This assessment must be performed across all stages of a pavement's life:

- Design
- Materials selection
- Construction

- Operation
- Preservation/Rehabilitation
- Reconstruction/Recycling

Assessing a project's sustainability requires a robust, sophisticated analysis. While a complete assessment may be currently unattainable, utilizing available tools helps achieve incremental progress toward more sustainable concrete pavements.

2. Concrete Pavements and Sustainability

Concrete pavements are an integral part of a sustainable transportation system when properly designed and constructed, particularly when considering the entire life cycle.

The perception that concrete pavements have a high carbon dioxide CO_2 contribution due to portland cement production is valid, as the manufacturing process is energy intensive and involves CO_2 release from limestone calcination. However, the net environmental impact is decreasing:

- Advances in cement production have greatly decreased these impacts relative to the past.
- Modern pavements use less portland cement per cubic yard.
- Concrete pavements currently have a lower carbon footprint than at any time in history.
- Future innovations are expected to further reduce the carbon footprint and energy use.

Core Sustainable Attributes of Concrete Pavements

Focus on these fundamental attributes that make concrete pavements a sustainable choice:

Attribute	Benefit
Long Life	Reduces future preservation activities, minimizing user delays and associated economic and environmental impacts. Preserves equity long into the future.
Performance	Provides a smooth, comfortable ride (minimizing drag for enhanced vehicle efficiency); maximizes pavement surface visibility and skid resistance.
Resource Efficiency	Enables increased use of industrial residuals (byproducts) and reduced use of non-renewable resources.
Recyclability	The material is fully recyclable.

Environmental Footprint	Has minimal impact on the surrounding natural environment, atmospheric conditions, etc.
Operations	Causes minimal traffic disruption during initial construction and preservation activities.
Community Friendly	Light-colored surfaces reduce ambient noise, surface run-off, urban heat, and artificial lighting needs due to aesthetically pleasing and appropriately textured surfaces.

Implementing strategies (design, material selection, construction, operation, renewal, recycling) that create these attributes is the focus of this manual of practice.

3. Why Sustainability Matters to the Pavement Industry

The focus on sustainability is crucial because it is increasingly demanded by key stakeholders and provides competitive advantages to the industry.

The New Standard for Good Engineering

Sustainability is essentially a new, higher standard for good engineering. The context has changed in two fundamental ways:

- Expanded Factors: In the past, only economic factors were paramount. Now, environmental and social factors must be considered equally.
- Expanded Scope: The period of analysis is now the entire life cycle of a project (from "cradle to grave"), considering all impacts (positive and negative) from mining raw materials to recycling the material.

A systems approach is necessary to fully realize the opportunities for implementing sustainable design over this extended period. Sustainable design is about balancing competing and contradictory interests to achieve incremental change, not perfection.

The Stakeholder Demand

The demand for sustainable infrastructure comes from several key groups:

- The Public: The public is increasingly aware that a more sustainable built environment is achievable. This awareness forces civil engineers to examine new alternative solutions. The profession is "entrusted by society to create a sustainable world".

- Owner Agencies: Local, state, and federal pavement owner agencies are starting to require sustainability metrics to be measured on projects and may use these metrics in the selection process for future transportation work.

Industry Opportunities and Innovation

Focusing on sustainability creates positive opportunities for the concrete pavement industry:

- Positive Communication: Sustainability provides a positive language to communicate the benefits of concrete pavements, rather than just disputing negative perceptions (e.g., concrete is the most used building material globally due to its versatility, economy, local availability, and longevity).
- Workforce Attraction: Embracing these principles makes the industry more attractive to a younger workforce, who often select careers based on an organization's commitment to sustainability.
- Innovation and Competitiveness: Enhancing sustainability naturally leads to innovation and increased competitiveness.

Design Tip: Implement Proven Innovations

You can immediately enhance sustainability by implementing proven innovations:

- In-place recycling of existing concrete.
- Two-lift construction.
- Pervious concrete for drainage.
- Optimized aggregate gradations to reduce cementitious material content.
- Using concrete with higher supplementary cementitious material (SCM) content.

The future will bring even more dramatic changes, such as photocatalytic cements (to treat air pollution), carbon sequestering cements, embedded sensing technologies, and advanced construction processes that minimize energy and emissions.

4. Organization of This Manual

This manual is a practice guide designed to provide decision makers, engineers, material suppliers, and contractors with practical guidance for adopting sustainable concrete pavement solutions. The content addresses relative benefits against the backdrop of limited budgets, increased performance requirements, and congested traffic situations.

Purchase this course to see the remainder of the technical materials.