EXECUTIVE SUMMARY

The Federal Highway Administration (FHWA), its customers, communities, environmental organizations, and individual landowners are increasingly interested in the road surfacing types used for new road projects. Arising from this increased interest in the appearance of roadway surfacings, the Federal Lands Highway (FLH) Division of the FHWA has developed a Context Sensitive Roadway Surfacing Selection Guide (Guide). The purpose of this Guide is to provide consistent, objective, and comprehensive information regarding all roadway surfacing types and to present a rational, transparent, systematic process for selecting surfacing types for a particular project or site application. The selection process itself is intended to facilitate discussion and understanding of critical project issues and their relative importance to the overall project. A review of the existing literature indicates that this Guide is the first to explicitly include aesthetics and context sensitivity in the roadway surfacing selection process.

This Guide is intended to be used by all stakeholders with an interest in the roadway surfacing selection process for a FLH project. Therefore, an effort has been made to present this information in a manner that is understandable to those without a technical background in road or pavement design. The Guide contains a brief explanation of technical terms that relate to road construction materials and performance, an introduction to pavement design concepts, and a description of the FLH project delivery process. Within the context of the roadway project delivery process, the Guide presents a rational selection process to facilitate the identification of the optimum roadway surfacing for a particular project. The selection process allows consideration of the required engineering design factors, such as structural capacity, ride comfort, performance, durability, and safety, but also allows consideration of other important factors, such as aesthetics, context compatibility, and environmental impacts, in an integrated manner. While the step by step approach to surfacing selection is intended to be rigorous, it is also flexible and still allows for engineering judgment in the final decision-making process. The Guide may be used for any roadway project, but it is particularly useful for roads in culturally, environmentally, or historically sensitive areas where aesthetics and context compatibility have elevated considerations.

A unique feature of this Guide is the inclusion of a comprehensive, yet concise, catalog of over 50 roadway surfacing products. This catalog is provided as background to the selection process and is an easy-to-use source of independent product technical data. The product descriptions contain information on where the surfacings can be used, design parameters, contractor availability, serviceability expectations, safety, potential environmental impacts, appearance, and cost. A bibliography and reference sources are also provided when additional, more detailed, product information is needed. The catalog also includes some products that are often used as part of the roadway pavement structure, but are not suitable for use as a permanent roadway surfacing, such as some recycling products. These have been included in the Guide since they are frequently used as temporary surfacings and their behavior is integral to the performance of the permanent surfacing placed immediately above them, especially on road rehabilitation

projects. The Guide is intended for use on both new road construction or reconstruction projects (i.e. 4R projects) as well as on road resurfacing and rehabilitation projects (i.e. 3R projects).

One of the main focuses of the Guide is to present the widest possible range of surfacing alternatives, including those which are not commonly used, to maximize the effectiveness of the selection process as a tool for identifying the optimum surfacing for a particular project, based on the specific project's conditions and needs. Since stakeholders may be unfamiliar with many of the surfacings included in the Guide and since appearance and aesthetics can be key discriminators in the selection process, the Guide also includes a CD-ROM photo album that shows examples of the various products in service. While many of the applications depicted are from FLH projects, the photo album includes some applications from around the world.

Ultimately, the Guide is intended to facilitate the public consultation process and to assist in the selection of an appropriate roadway surfacing for a particular project or application, especially in culturally, environmentally, or historically sensitive areas. The selection process permits a balance between functionality, strength, and cost while ensuring that the completed roadway enhances or is at least compatible with the surrounding landscape. In addition, one of the hoped for benefits of this Guide is to bring a greater awareness to the diversity of road surfacing products currently available, to encourage their appropriate use, and to achieve greater recognition for the importance of context compatibility in the selection of roadway surfacings.

CHAPTER 1 — INTRODUCTION

BACKGROUND

The Federal Lands Highway (FLH) Division of the Federal Highway Administration (FHWA) works in cooperation with Federal land management agencies, state highway agencies, and local highway agencies to plan, design, construct, and rehabilitate highways and bridges on federally owned lands or roads that access federally owned lands. The program includes forest highways, public lands highways, park roads, parkways, refuge roads, and Indian reservation roads. These roads serve recreational travel and tourism, provide sustained economic development in rural areas, and provide needed transportation access. Overall, the FLH program provides funding for more than 145,000 kilometers (90,000 miles) of federally owned and public authority owned roads that serve Federal lands. The roads constructed or rehabilitated by FLH are generally low to medium volume roads.

The FLH has found that customers, communities, environmental organizations, and individual landowners are increasingly concerned about the road surface types used for proposed road projects. The FLH is finding it more difficult to reach consensus on surface type selection due to the lack of consistent and comprehensive information regarding alternative surface types and a defined process for selecting surface types. As a result, FLH has funded development of a Context Sensitive Roadway Surfacing Selection Guide (Guide). This Guide documents the available options for roadway surfacing and provides a decision-making process to allow consideration of engineering design factors, such as structural capacity, performance, durability, and safety, as well as other factors, including aesthetics, context compatibility, and environmental impacts. A CD-ROM photo album of roadway surfacings accompanies this Guide.

One recent project, the Guanella Pass Road Improvement Project located in the state of Colorado, illustrates the challenges the FLH currently faces when attempting to reconstruct a road. The maintaining agency desired a surface that was easy and inexpensive to maintain. The U.S. Forest Service (USFS) requested a surface that resulted in little to no sediment transport into nearby creeks. Many of the public and environmental groups wanted a surface that appeared rustic and discouraged excessive speed. As a result, three surface types were selected for use on different segments of the road in an attempt to address, at least partially, all of the concerns expressed by these parties. The surface types were 1) asphalt concrete with a chip seal, 2) multiple surface treatments, and 3) gravel with a dust suppressant. Reaching agreement on the use of these three surface types was a long and protracted process, creating substantial project delays. Given this experience, the engineering and environmental staff from the FLH agreed that there was a need for some additional “tools” that would expedite road surface selection for future road projects. These tools include:

- A comprehensive catalog of available roadway surfacing types that would facilitate the identification of viable roadway surfacings and allow them to be understood and evaluated by both technical and non-technical persons;
- A rational and transparent evaluation and selection process that allowed competing needs and objectives, such as performance, aesthetics, and cost, to be considered in a roadway surfacing selection process; and
- Presentation and brochure material that would explain the process to users and attendees at public information meetings.

This Guide was developed by an independent consultant to provide the above "tools" to FLH to assist in selecting a context sensitive roadway surfacing for FLH projects. Oversight of the preparation of the Guide came from the Central Federal Lands Highway Division (CFLHD)-based Contracting Officer's Technical Representative (COTR), and an Advisory Committee comprised of cross-functional representatives from the CFLHD, the Eastern Federal Lands Highway Division (EFLHD), the Western Federal Lands Highway Division (WFLHD), and the FHWA Resource Center.

The traditional approach to transportation infrastructure design has been to provide the highest level of functionality and safety at the least possible cost. Environmental impacts, cultural sensitivity, and aesthetics have not always been included in these design considerations. However, in 1997, FHWA published its groundbreaking document, *Flexibility in Highway Design*,(1) and more recently in May 2004, AASHTO published *A Guide for Achieving Flexibility in Highway Design*.(2) These documents provide ideas, processes, and options for designing more environmentally friendly highways, without compromising safety and mobility. Such an approach is referred to as Context Sensitive Solutions or CSS. A vital component of the CSS approach is to seek public input early in the design process so that community interests can be identified and creative thinking fostered in arriving at solutions. Such solutions will not be universally applicable but will be influenced by the specific characteristics of the site and the context of its use.

Though the CSS approach has been mainly applied to geometric design, it also sets the framework for the development of this FLH Guide. In its role as the primary road-builder for Federal Lands, the FLH interacts with numerous stakeholder groups. These include land owners, permitting agencies, community groups, and environmental organizations. When considering preliminary design alternatives, it is critical that roadway surfacing treatment options, especially those that may be innovative, be effectively communicated to the stakeholder groups. Effective communication of these alternatives should include:

- Photographs of the treatments in service.
- Costs of the treatments.
- Information on the functionality, durability, life expectancy, maintenance requirements, constructability, etc.
- Assessment of any environmental impacts.
- Any other relevant information, such as limitations on use, availability, etc.

This Guide provides the necessary information and resources needed to educate stakeholders about the different roadway surfacing options available and the process used to select the preferred surfacing type for a particular project.

STRUCTURAL PAVEMENT DESIGN CONCEPTS

It is important that a project team understands the fundamental principles of roadway pavement structural design prior to beginning the surfacing selection process. A basic introduction to some structural pavement design concepts is presented here. For the purposes of this introduction, the term "pavement" includes the roadway surfacing and any native or imported materials under the surfacing that are counted on to work in combination to provide a structure capable of supporting vehicular traffic and protecting the subgrade.

Roadway pavements are generally classified as either flexible or rigid. Flexible pavements are allowed to deflect somewhat under load, and the applied traffic loading is distributed down through the pavement structure. Examples of flexible pavements include Hot Asphalt Concrete Pavement (HACP) or granular surfacing. Rigid pavements are designed as rigid slabs that transfer very low pressures to the underlying support layer. Therefore, rigid pavement structures tend to have a lower overall pavement thickness than flexible pavements designed for the same traffic. The most common type of rigid pavement is Portland Cement Concrete Pavement (PCCP). Unit surfaces (e.g. brick, concrete pavers) function based on a combination of flexible and rigid pavement principles, but may be generally classified as flexible unless they are supported on a rigid base.

Roadway surfacings are also often classified as unbound or bound surfacings. Unbound surfacings are composed of particulate material that is not held together by a binding agent. Untreated aggregate, sand, or dirt roads are examples of unbound surfacings. Bound surfacings are composed of particulate material that is held together by a binding agent, such as asphalt or portland cement. Generally speaking, unbound surfaces have higher maintenance requirements than bound surfaces due to surface material loss and defects, leading to a more rapid decrease in ride quality and structural support.

Flexible Roadway Pavements

Flexible roadway pavements have four basic components, subgrade, base, surfacing, and a drainage system. The convention in flexible structural pavement design is to use successively stiffer layers from the subgrade up to the surfacing.

The subgrade is the roadway foundation and consists of the natural soil, or a placed and compacted earth or rock fill where the grade of the road needs to be raised. A properly designed pavement must ensure that sufficient layers of higher quality material are placed above the subgrade to protect it from excessive stress (caused by vehicle wheel loads) that would lead to deformation and, ultimately, failure. The strength of either natural or constructed subgrades can be improved by the addition of stabilizing products, such as cement, lime, fly ash, or a range of proprietary products. By increasing the subgrade strength, the use of stabilizers may allow for a reduction in the overlying base layer thickness.

The base layer is typically a high quality processed aggregate material. Frequently, the base layer is made up of two components, a lower subbase layer typically comprised of a sandy material with some gravel and placed directly on the subgrade, and a higher quality aggregate base layer comprised of a high quality crushed and graded material above it. Treated bases, using binding agents such as cement or asphalt, are sometimes used to increase structural capacity of the base layer.

The surfacing layer can range in thickness from relatively thin (e.g. chip seal) to relatively thick (e.g. HACP). Thin surfacing layers typically do not provide any strength to the pavement structure, but they can enhance ride quality and safety while preventing water infiltration into the pavement structure that can weaken the underlying layers. Thicker surface layers, such as HACP, provide some strength to the overall pavement structure, with the amount of structural support increasing with surfacing layer thickness. For thick surfacing designs, HACP is placed in lifts. Where more than one lift is needed, the top lift is referred to as the wearing course and the underlying lifts are referred to as binder courses. The wearing course is designed to provide a durable surface that can withstand the abrasion from tire impact, retain frictional characteristics, and contribute to the structural capacity of the pavement. The binder courses are designed to be sufficiently stiff to effectively distribute load and avoid permanent deformation.

On low volume aggregate surfaced roads, the aggregate is often used for the surfacing layer as well as the base course. In some cases, a different gradation of aggregate is used for the surfacing layer to improve ride quality and durability. In addition, the surfacing layer is sometimes treated to stabilize the material or to suppress dust generation.

Natural soils and aggregates lose strength when saturated, so providing adequate subsurface drainage of the aggregate layers is essential to the performance of a flexible pavement. In regions with prolonged sub-freezing temperatures, drainage is even more critical, since in the presence of a ready supply of water, fine grained soils may heave as they freeze and then become extremely weak as they thaw. Water infiltration is minimized by designing and constructing roadway surfacings with adequate cross slope to shed water off the surface. The subgrade should also be crowned to avoid ponding of water in the aggregate subbase. Some degree of water infiltration will occur in all pavements through cracks, unsealed shoulders, and the surfacing itself. The aggregate base and subbase layers in a pavement should be free draining to minimize the time and degree to which the pavement is saturated.

For rural roads, road drainage is best achieved by the use of open ditches with inverts extending below the top of the subgrade. The drainage system should have positive fall and regular outlets to avoid ponding of water in the ditches. Aggregate base and subbase layers should extend the full width of the road platform to allow drainage into the ditch. For urban roads where a concrete curb is used, road runoff is collected and removed through a system of catch basins and storm sewers.

Rigid Roadway Pavements

Rigid pavements also have four basic components, subgrade, subbase, concrete slab, and a drainage system. The subgrade and drainage components are essentially similar to those for flexible pavements.

The subbase layer (also referred to as a base layer) is a relatively thin aggregate layer placed directly on the subgrade. While it does contribute a little to the pavement strength, its main function is to provide a uniform working surface for constructing the slab and to enhance uniformity of subgrade support. For high traffic applications, the slab is sometimes supported on an open graded drainage layer that provides sub-slab drainage and prevents the subgrade from pumping under repeated load applications.

The most commonly used rigid pavement is portland cement concrete pavement (PCCP). A pattern of control joints is required to avoid random shrinkage cracking. Good load transfer between adjacent slabs is required for good concrete pavement performance. For low traffic applications, aggregate interlock across the joint is usually adequate. For higher volume roads, dowel bars may be required across the transverse joints.

STRUCTURAL PAVEMENT DESIGN

The structural design of a road pavement involves the selection of a combination of road construction materials and their thicknesses to provide a serviceable road pavement for a predetermined length of time, typically 15 to 30 years, and anticipated traffic loading. This design period is called the design life and is defined as the period over which the road provides an acceptable level of performance with only preventative maintenance activities required. A wide range of considerations affect the choice of materials and layer thicknesses. The typical information that a pavement designer needs to establish a design is as follows:

- Subgrade: Since this is the foundation of the pavement structure it must be characterized from the perspective of soil type, strength, drainage characteristics, seasonal variability, etc.
- Traffic: To complete a pavement design, at least three traffic parameters are needed, namely, the Average Annual Daily Traffic (AADT), which is the average number of vehicles per day using the road section; the percentage of the AADT that consists of heavy vehicles such as trucks and buses; and the projected traffic growth rate over the life of the roadway.
- Climate: The climate has a large influence on the representative strength to be selected for the subgrade. It is necessary to know whether the road will be subject to prolonged sub-freezing temperatures, the extent of precipitation, range of in service temperatures for asphalt mix selection, etc.

A wide range of other considerations, such as desired level of service, drainage, life-cycle costing, construction materials, degree of reliability, environmental considerations, and context sensitivity are also relevant. Successful structural pavement design always requires an integration of adequate structural design and appropriate materials selection, taking into account local experience, cost effectiveness, and level of service required for the specific roadway project.

Pavement Distress and Maintenance

Over time, roadway surfacings begin to exhibit signs of distress due to traffic loading and wear, water infiltration, material loss, and environmental conditions. Common types of distress include cracking, rutting, raveling, washboarding, potholing, spalling, and faulting. If not treated, surface distresses can lead to accelerated pavement degradation and, ultimately, total pavement failure. However, if the surfacing is treated with timely pavement maintenance, pavement serviceability can be maintained and the effective pavement life can be extended. In most cases, the design life given for a particular surfacing is based on the assumption that the road will receive regularly scheduled maintenance; if the regularly scheduled maintenance is not performed, the actual life of a pavement can be significantly reduced. Common pavement maintenance techniques include crack and/or joint sealing, patching, additional surface treatments, overlays, grading, and ditch and culvert cleaning. The types and frequency of maintenance required varies for different surfacing types. Generally speaking, surfacings that have lower initial costs require more frequent maintenance and, thus, have higher maintenance costs. Surfacings with high maintenance requirements may be acceptable for a low volume road if the funds available for road construction are limited and maintenance crews are readily available to perform periodic maintenance. On the other hand, frequent maintenance requirements may be unacceptable for a high volume road where user delays would be significant.

Pavement Life-Cycle Costs

Most roadway surfacings require some maintenance intervention during their design life. Thus, when comparing the costs of alternative roadway surfacings, one must consider the anticipated future maintenance costs in addition to the initial construction cost.

In addition to future maintenance costs, differences in the expected service lives of different surfacings must also be considered. By taking into consideration initial construction costs, expected maintenance costs, expected service life, and the time value of money, a life-cycle cost can be calculated for a specified analysis period. The overall objective of a life-cycle cost approach to surfacing selection strategy is to provide the best long-term value to the owner or agency for their investment in road infrastructure.

The selection process used in this Guide assumes that appropriate life-cycle cost analysis data will be available when comparing alternative surfacing strategies. The extent of life-cycle cost analysis required for a particular project will depend on its size and complexity. The FHWA recommended practice, *Life-Cycle Cost Analysis in Pavement Design*,[3] should be consulted for more details on how to undertake an appropriate life-cycle cost analysis.

ROADWAY SURFACING TYPES

To help facilitate the roadway surfacing selection process, a list of available roadway surfacing products was assembled and pertinent information was compiled for each roadway surfacing product. A list of the available roadway surfacing options identified for this Guide is provided in Table 1. Given the wide range of road surfacing types available, a rational system for classification is helpful. For the purposes of this Guide, the roadway surfacing options were classified into four major categories: Paved and Sealed Surfaces, Aggregate and Soil Surfaces, Unit Surfaces, and Recycling and Reclamation Alternatives. Paved and Sealed Surfaces include flexible and rigid bound surfacings, non-structural asphalt surface treatments, structural asphalt surfacings, and Portland cement concrete surfacings. Aggregate and Soil Surfaces include untreated aggregate/soil surfacings and aggregate/soil surfacings that have been treated or stabilized with dust palliatives, soil stabilizers, or geosynthetic products. Unit Surfaces include different unit paver types and natural stone cobbles. Recycling and Reclamation Alternatives include products that are produced in situ on the road and/or contain some recycled road materials and include recycled HACP, hot and cold In-Place Recycling, and Full Depth Reclamation. A few of the roadway products included are rarely, if ever used as roadway surfacings, but were included in the list because they are commonly used as subgrade or base course layers and are sometimes used as temporary surfacing during construction or as direct support for the surfacings.

Information pertinent to the selection process was collected for each roadway surfacing product; this information is presented in a series of road surfacing product summary tables, located in Appendix A. The information in the product summary tables is organized based on the various criteria that will be used in the roadway surfacing selection process. Product information is presented related to the following criteria: application, design, construction, serviceability, safety, environmental concerns, aesthetics, and cost. In addition, sections have been included for general information, example projects, and select print and internet references. The intent of the summary tables is to provide unbiased product information, in quantitative measures when possible, that can be used by planners and designers at various stages of the roadway project.

The summary tables include information on certain impacts, mainly related to the environment and safety, that are associated with a particular road surfacing product. The impacts presented are limited mainly to direct impacts; indirect impacts are not discussed in detail. Direct impacts differ from indirect impacts in that direct impacts are those that result from the interaction of a component of the surfacing material with the local environment while indirect impacts occur as a potential consequence of the use or misuse of the road with the surfacing in place. Two possible indirect impacts not discussed for the surfacing types include vegetative and water quality impacts due to the use of deicing agents and roadkill due to increased speeds. While surface type is a factor for both of these indirect environmental impacts, a number of other factors contribute to such impacts (e.g. climate and maintenance practices for use of deicing agents and geometrics for increased speeds). As a result, it was determined to be too speculative to indicate potential indirect impacts as a consequence of the use of a specific roadway surface. Nevertheless, these indirect impacts may need to be considered, especially when evaluating bound versus unbound surfaces.

Although every effort has been made to be objective in the assessment of the various roadway surfacing products, a limited amount of information is available for many of the "non-traditional" products, especially proprietary products. Since most of this information is provided by the manufacturer/supplier, there is potential for the product information to be biased. Also, many proprietary products are "reformulated" regularly such that past performance is not necessarily an indication of future performance. As much as possible, the information provided in the tables is based on recent independent performance evaluations, case studies, field investigations, and owner/user testimony. The product summary tables should be continuously updated as new information becomes available in the future.

Roadway surfacing product use, performance, and cost can vary significantly, depending on the project location. Project-specific factors that vary by location include climate, environmental setting and conditions, availability of materials, equipment, and experienced contractors, local construction practices, maintenance practices, labor and material costs, and traffic characteristics. The information presented in the product summary tables represents, to the extent possible, general conditions and ranges found across the United States; however, local practices, experiences, and costs should be used to supplement the product summary sheets, whenever possible.

This Guide deals primarily with roadway surfacings, but also addresses related aspects of pavement design and the type of support needed for the exposed surface layer. It concentrates mainly on surface options for road reconstruction (i.e. 4R projects), but also includes resurfacing and rehabilitation treatments (i.e. 3R projects). The majority of road construction projects are for all-weather surfaced roads; however, there are also applications where seasonal roads are used and will continue to be used.

Table 1. Roadway Surfacing Product Listing.

CLASSIFICATION	SUB-CATEGORIES	ROAD SURFACING PRODUCTS
PAVED AND SEALED SURFACES	Asphalt Surfacing - Surface Treatments or Layers (non-structural)	Cape Seal Chip Seal Chip Seal over Geotextile Fog Seal Microsurfacing Multiple Surface Treatments (Seals) Open Graded Friction Course Otta Seal Sand Seal Scrub Seal Slurry Seal Ultrathin Friction Course
	Asphalt Surfacing - Surface Layers (structural)	Cold Mix Asphalt Concrete Pavement Hot Mix Asphalt Concrete Pavement (HACP) Exposed Aggregate HACP Imprinted/Embossed HACP Pigmented HACP Porous HACP Resin Modified Pavement Synthetic Binder Concrete Pavement
	Portland Cement Concrete (PCC) Surfacings	Cellular PCC Portland Cement Concrete Pavement (PCCP) Exposed Aggregate PCCP Pigmented PCCP Porous PCCP Stamped PCCP Roller Compacted Concrete Whitetopping
AGGREGATE AND SOIL SURFACES	Unbound and Mechanically Stabilized Surfacings	Cellular Confinement Fiber Reinforcement Geotextile/Geogrid Reinforcement Gravel (crushed or uncrushed) Sand
	Other Stabilized Surfacings (including dust palliative applications)	Chlorides Clay Additives Electrolyte Emulsions Enzymatic Emulsions Lignosulfonates Organic Petroleum Emulsions Synthetic Polymer Emulsions Tree Resin Emulsions

Table 1. Roadway Surfacing Product Listing (continued).

CLASSIFICATION	SUB-CATEGORIES	ROAD SURFACING PRODUCTS
	Stabilized Aggregate and Soil (other than surfacing)	Fly Ash (temporary surface) Lime (temporary surface) Portland Cement (temporary surface)
UNIT SURFACES		Brick Pavers Natural Stone Cobbles Unit Pavers Porous Unit Pavers
RECYCLING AND RECLAMATION ALTERNATIVES	Recycling Alternatives	Cold In-Place Recycling (temporary surface) Hot In-Place Recycling PCCP Recycling and Rehabilitation (temporary surface) Recycled HACP
	Full Depth Reclamation (FDR)	FDR-Cementitious (temporary surface) FDR-Emulsified Asphalt (temporary surface) Foamed Asphalt (temporary surface) Pulverization (temporary surface)