Preservation Ranks High in GAO Cost: Benefit Ratio

Although highways are highly durable and can last for decades, they deteriorate from traffic wear and tear, inadequate drainage, construction deficiencies, and weather.

Keeping them in good condition requires substantial resources: public entities spent more than $180 billion in 2008 on highways, with about $40 billion coming from the federal government.

Despite these outlays, the Federal Highway Administration (FHWA) estimates that these funding levels are insufficient to maintain or improve the condition of the nation's highways through 2028. Further, the major source of federal surface transportation funding—federal motor fuel tax revenues deposited into the Highway Trust Fund—is eroding.

State highway agencies, the entities that are ultimately responsible for keeping most major highways in good repair, will need to develop strategies for doing so at reduced costs.

Edited by Pavement Preservation Journal *from the Governmental Accountability Office's report,* GAO-13-32R Materials and Practices for Improving Pavement Performance, *November 2012. This report continues with a discussion of pavement construction practices and a literature search. To download the full report, Google "GAO-13-32R." Emphasis and subheads are ours. All images from GAO.*

One potential strategy is using more cost-effective materials and practices. [In this report the Governmental Accountability Office identifies] selected materials and practices that states can use or are using to improve the performance of pavements, including what is known about their costs and benefits, if any, and challenges, if any, to using these materials and practices.

[O]ur literature review and discussions with stakeholders having relevant expertise resulted in the identification of 40 materials and practices that may contribute to improving the performance of pavements, extending service life, and reducing life-cycle costs. These materials and practices cover a range of uses and applications across the stages of a pavement's life cycle, from initial design and construction through maintenance and preservation cycles, and at the time of reconstruction.

U.S. PAVEMENT INVENTORY

In the United States, state and local governments own about 96 percent of the more than 4 million miles of roads. State DOTs are responsible for constructing, repairing, and maintaining most major highways, including the Interstate Highway

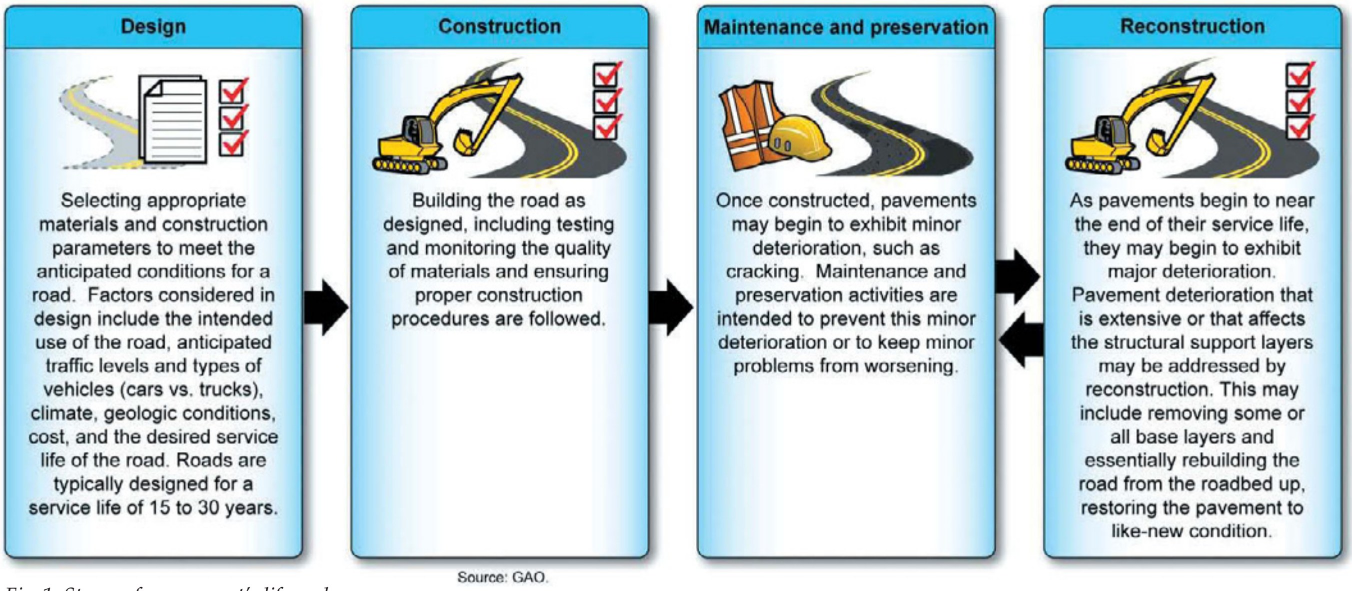

Fig. 1: Stages of a pavement's life cycle

Table 1: Ownership of U.S. Roads by Length in Miles and Vehicle Miles Traveled, 2008

Owner	Miles supported with federal aid	Miles not supported with federal aid	Total miles
Federal	6,596	124,962	**131,559 (3%)**
State	562,170	222,141	**784,311 (19%)**
Local	418,564	2,667,888	**3,086,452 (76%)**
Other	7,188	49,832	**57,020 (1%)**
Total	**994,518 (24%)**	**3,064,823 (76%)**	**4,059,341 (100%)**
Vehicle miles traveled (millions)	**2,534,647 (85%)**	**458,058 (15%)**	**2,992,705 (100%)**

Source: GAO analysis of FHWA data.

System. These agencies generally contract with private sector companies to perform these activities.

The federal government provides funding to states through a series of programs collectively known as the federal-aid highway program. Each program that provides funding specifies how it can be used—such as for construction, reconstruction, and preventive maintenance activities—and specifies eligible project types. Highways supported by federal aid represent about one-fourth of all roads, but about 85 percent of all miles traveled annually occur on them (Table 1).

Highway pavement consists of several layers of durable material. Lower layers of a pavement typically consist of crushed, compacted rock (base or subbase) built on a compacted earthen roadbed (subgrade). The surface layer, upon which vehicles travel, is typically constructed of asphalt or concrete. According to FHWA, of all of the miles of roads supported with federal aid, about 91 percent have asphalt surfaces, about 5 percent have concrete surfaces, and 4 percent are unpaved.

All pavements deteriorate over time but numerous factors—including increased traffic, water intrusion into the pavement layers, freeze/thaw cycles or other weather events, and instability of the roadbed or base layers—can accelerate this aging process. Truck traffic, in particular, contributes to pavement deterioration, because heavier loads are many times more damaging than lighter loads. Evidence of deterioration may be apparent on the surface layer.

The activities performed by state and local governments, or their contractors, to build and keep pavements in good condition can be organized into four stages, corresponding to different points of a pavement's life: (1) design, (2) construction, (3) maintenance and preservation, and (4) reconstruction (see Fig. 1).

Designs that appropriately consider factors specific to the highway, such as anticipated traffic

Table 2: Pavement Materials

Material	Description
Modified asphalt binders	Synthetic or natural material added to asphalt to enhance pavement properties. Includes polymers, chemical modifiers, rubber, fibers, fillers, and biobinders/bioasphalt.
Reclaimed or recycled material	Re-use of materials into new pavements. Includes asphalt and concrete pavement, asphalt shingles, and ground tire/crumb rubber.
Blended or performance cements	Material added to the more typical portland cement to enhance concrete pavement properties or reduce costs. Includes pozzolans, slag cement, fly ash, and limestone.
Concrete curing compounds	Material applied to newly poured concrete to inhibit water evaporation and ensure proper concrete curing.
Geosynthetics	Synthetic polymeric materials used for a variety of purposes in pavement structures, such as reinforcement, separation, and drainage. Includes geotextiles, geomembranes, geogrids, geocells, and erosion control products.
Corrosion-resistant reinforcement for concrete pavement	Materials that resist corrosion and deter corrosion-related damage to concrete. Includes fiber-reinforced polymer bars, discrete fibers, stainless steel, and epoxy-coated steel.

Source: GAO.

Table 3: Pavement Design and Material Testing Practices

Practice	Description
Performance testing of asphalt binder	Testing to predict how the binder in asphalt will perform, using procedures such as the Multiple Stress Creep Recovery test and the Asphalt Binder Cracking Device.
Performance testing for asphalt design mix	Testing to predict how asphalt design mixes will perform using equipment such as the Asphalt Mixture Performance Tester.
Using Mechanistic-Empirical Pavement Design Guide	A tool that predicts the performance of a pavement being designed based on mechanistic-empirical principles.
Optimizing aggregate used in pavements	Consideration of aggregate (granular material, such as sand, gravel, crushed stone, or recycled concrete) characteristics—such as shape, angularity, and texture—in the mix design of asphalt and concrete pavements to improve performance.
Warm-mix asphalt (WMA)	Asphalt mix produced and placed at lower temperatures—ranging from 30 to 120 degrees Fahrenheit lower—than traditional hot-mix asphalt.
Stone matrix asphalt	Asphalt mix consisting of coarse aggregate, high asphalt cement content, filler, and fibers.
Continuously reinforced concrete pavement (CRCP)	Concrete pavement without contraction joints that is reinforced using continuous steel bars throughout its length.
Two-lift concrete pavement	Concrete pavement made of two layers: a thick lower layer that can include materials that are less resistant to wear and a thinner surface layer made of more wear-resistant materials.
Precast concrete panels	Sections of concrete pavement that are made off-site and assembled on-site for construction and repairs.

Source: GAO.

levels, and construction that meets the design specifications are essential to ensuring long-lasting roads.

PRESERVATION PROLONGS LIFE

Likewise, maintenance and preservation activities can improve the performance of deteriorated pavements and prolong their life by preventing minor problems from getting worse and correcting major problems that accelerate deterioration. Over time, a pavement may undergo multiple cycles of maintenance and preservation before reconstruction is necessary.

Our review of existing literature and discussions with stakeholders having relevant expertise resulted in the identification of 40 materials and practices—six materials and 34 practices—that may contribute to improving the performance of pavements, extending service life, and reducing life-cycle costs.

Of the 40, six are materials that could be used in the construction, maintenance and preservation, or reconstruction stages of a pavement's life.

Table 3 describes nine design and material testing practices affecting pavement performance that correspond to the design stage of the pavement life cycle. These include using different pavement types, such as the use of warm-mix asphalt (WMA) or two-lift concrete pavements, and tools that designers could use to predict pavement performance.

In reference to the practice of using WMA, FHWA included it as part of its *Every Day Counts* initiative to promote innovation; FHWA reported that, as of 2009, more than 40 states had constructed WMA projects.

In addition, according to FHWA, the use of precast concrete panels in highway projects may provide pavements in less time and at lower total cost—considering both construction and user costs—than using traditional cast-in-place concrete construction methods.

EVALUATING PRESERVATION PRACTICES

Table 4 describes 13 maintenance and preservation practices affecting pavement performance that could be used during the maintenance and preservation stage of the pavement life cycle. These practices include approaches to monitoring the condition of pavements and examples of specific maintenance and preservation treatments that can be used to cost-effectively sustain road networks.

In reference to maintenance and preservation practices, according to FHWA, applying treatments to roads in good condition is more economical than reconstructing them after they deteriorate: each dollar spent now on pavement preservation could save up to six dollars in the future.

However, FHWA reports that state DOTs have historically allowed pavements to deteriorate to fair or poor condition before taking steps to reconstruct them, a costly, time-consuming activity.

Pavement management/preservation systems can help states monitor the condition of their roads and make decisions to optimize the use of resources by applying appropriate preservation treatments

Table 4: Pavement Maintenance and Preservation Practices

Practice	Description
Evaluating pavement condition using non-destructive technology	Using tools such as deflection testing devices (e.g., falling weight deflectometer), ground penetrating radar, ultra-sonic and impact echo devices, and other nondestructive testing devices that can be used to noninvasively evaluate the condition of pavements.
Pavement management/preservation system	A network-level, long-term strategy that uses an integrated, cost-effective set of pavement maintenance and preservation practices.
Thin or ultra-thin asphalt overlay on asphalt pavement	Applying a thin (generally 1.5 inches or less) layer of asphalt over an existing asphalt pavement.
Mill asphalt pavement and resurface with asphalt overlay	Removing the surface layer of an existing asphalt pavement and replacing it with a new layer of asphalt.
Cold in-place recycling of asphalt pavement	Removing existing asphalt pavement, mixing it with new asphalt, and placing the re-mixed material as a base layer for a subsequent asphalt overlay.
Surface preservation treatments for asphalt pavement	Various thin surface treatments applied to asphalt pavement, involving the application of liquid asphalt and, in most cases, aggregate.
Microsurfacing for asphalt pavement	Spreading a thin mixture of polymer-modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives on an asphalt pavement.
Diamond grinding for concrete pavement	Removing surface imperfections of a concrete pavement using diamond saw blades.
Dowel bar retrofit for concrete pavement	Installing metal reinforcing bars across joints or cracks that exhibit poor load transfer.
Partial-depth repair for concrete pavement	Removing and replacing small, shallow areas of a concrete pavement to restore localized areas of deterioration.
Full-depth repair for concrete pavement	Removing and replacing a segment of concrete pavement through the depth of the concrete slab to restore areas of deterioration.
Joint sealing for concrete pavement	Applying sealant material to the spaces between jointed concrete pavement sections.
Crack sealing for asphalt and concrete pavements	Applying sealant material to cracks in asphalt or concrete pavements.

at the proper time. Several states we spoke with (Georgia, Utah and Washington State) are expanding their use of lower-cost surface preservation treatments.

Georgia, for example, began using a preservation practice involving thin asphalt overlays in 2007. Georgia DOT officials refer to their practice as "micromilling"—that is, removing a thin layer of asphalt from a road and replacing it with a new, thin layer of asphalt. According to Georgia officials, the cost of this practice is significantly less than the cost of a thicker asphalt overlay that they would otherwise place.

In addition, Washington has begun using an asphalt pavement surface preservation treatment typically used on low volume highways to maintain higher volume asphalt highways. The treatment—known as a "chip seal," in which liquid asphalt sprayed on a pavement is covered with aggregate and rolled to embed it—generally provides less additional service life to a pavement than milling and replacing the asphalt surface.

However, the life-cycle cost of a chip seal treatment is about one-third that of milling and replacing the asphalt surface, according to state officials, and the treatment's use should result in lower maintenance and preservation costs over the life of the pavement.

Some of the materials and practices described in the preceding tables offer additional benefits, beyond improving pavement performance, for example:

- Incorporating reclaimed or recycled materials (see Table 2) into highway pavements provides an environmental benefit by making use of a material that might otherwise be disposed of and reducing the amount of new material needed.
- Using precast concrete panels (see Table 3) can provide a benefit to users of the road under repair. Concrete that is placed on-site may take several days to cure, and during that time, affected lanes must remain closed to traffic. Conversely, precast panels may be driven on immediately, thereby reducing the inconvenience to drivers.
- Following the principles of a pavement management/preservation system (see Table 4) can provide sustainability benefits because these tools seek to minimize the amount of natural resources used over a pavement's life cycle.