Innovative Sustainable Pavement Solutions

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Abstract

Because natural resources used in pavement construction and rehabilitation are being rapidly depleted, and due to increased awareness of sustainability issues, decision makers are now looking for alternative paving products and construction methods that provide long service life while conserving materials and energy. Although most of the attention for sustainable development has been focused on materials, construction, and efficient use of buildings, attention is now also focused on paving materials and performance.

It is very important, therefore, to implement strategies that provide sustainable pavement solutions. Pavement strategies should account for long service life, conservation of energy and natural resources, and maintaining the quality of air and natural water supply. In addition to traditional concrete and asphalt pavements, several paving options are gaining recognition rapidly in the United States because they provide options that positively affect the sustainability triple bottom line: Economic Impact, Environmental Impact, and Social Impact.

This paper focuses on sustainability contributions of various paving products including conventional concrete, full-depth reclamation (FDR) with cement, cement-treated base (CTB), and roller-concrete concrete (RCC). A summary of conventional concrete contributions is presented and case studies are presented to highlight the sustainability contributions of RCC, CTB, and FDR. Examples are presented to demonstrate how these products may be leveraged to conserve natural resources; reduce use of energy to mine, process, and transport new materials; provide longer pavement service life; increase recycling; maintain quality of natural water; and reduce cost of construction and maintenance.
**Background**

With the heightened awareness of climate change, potential global warming, and green building over the past decade, it is difficult to imagine someone who has not experienced media exposure to the issues of sustainable development. Sustainable development attempts to change the way we design and build to lessen the impacts of our built environment and throughout the entire life span of a structure. It seeks to find a balance between the economic, environmental and social effects of growing population. Instead of making decisions simply based on economics, factors such as the impact on society at large and the environment are also considered.

Sustainability initiatives are changing the way the project is evaluated and the period of time considered for the evaluation. The analysis includes the entire life cycle of a structure and encompasses all impacts from the point of inception to the end of life, often referred to as “cradle-to-cradle” analysis (McDonough and Braungart 2002).

Green building pioneers have been focusing mostly on construction and operation of buildings. In response to this focus, the United States Green Building Council created an impact measurement system that attempts to quantify the environmental benefits of buildings. Although most of the attention for sustainable development has been focused on buildings, it affects all aspects of our built environment. The spotlight is now expanding to include the paving industry, which is being scrutinized for its contribution as well. Transportation accounts for 26 percent of our nation’s annual energy consumption. It also contributes to the air pollution, time lost for commuting and driver’s stress. Even though the LEED rating system covers site development, it covers very limited aspects of pavements in general. The need for a rating system specifically designed for pavements encouraged several organizations to initiate pilot programs in recent years. Currently, there are no nationally recognized rating systems for highways, county roads, and city streets. However, the following organizations have taken major strides toward that goal:

- **Greenroads**: Developed by the University of Washington and CH2MHILL, Greenroads is a sustainability performance rating system for roadway design and construction (Greenroads 2010). The system is a tool to help designers, owners and contractors design and build sustainable roads. The system considers each project holistically and credits are awarded based on approved sustainable choices.

- **GreenLITES**: The New York State Department of Transportation (NYSDOT) implemented Green Leadership in Transportation and Environmental Sustainability (GreenLITES) in 2008 to recognize transportation project designs, operations and maintenance practices that incorporate a high level of environmental sustainability. GreenLITES is self-certification program that distinguishes transportation projects and operations based on the extent to which they incorporate sustainable choices (GreenLITES 2010).

Much of the published information on the sustainable contributions of cement based paving products focus on conventional concrete and pervious concrete. Outstanding and innovative sustainable contributions of additional cement based paving products, such as full depth reclamation (FDR) with cement; cement-treated bases (CTB); and roller-compacted concrete (RCC), are often overlooked. This paper provides a summary of major sustainable
attributes of conventional concrete and discusses in more detail the attributes of FDR, CTB, and RCC. The paper also provides basis to encourage decision makers to implement an integrated paving solutions concept where all possible sustainable and economically feasible solutions are considered during the design phase of each project.

Although innovative sustainable options that undoubtedly conserve energy and natural resources are discussed, detailed evaluations to quantify energy use and life cycle cost of each sustainable paving option is beyond the scope of this paper.

**Sustainable Contributions of Concrete Pavements**

The following is a brief description of concrete pavements’ major contributions to sustainability. Additional pertinent information is included in a briefing document titled “Building Sustainable Pavements with Concrete,” published by the National Concrete Pavement Technology Center (Van Dam 2009) and a special report titled “Green Highways – Environmentally and Economically Sustainable Concrete Pavements,” published by the American Concrete Pavement Association (ACPA 2007).

**Longevity**

Concrete pavements have long been considered for their longevity. When considering sustainable issues, the one attribute that trumps all is durability. It affects all three aspects of the Triple Bottom Line. First, from an environmental standpoint, long lasting construction reduces the need for additional materials, energy and waste due to replacement; second, long lasting concrete pavements offer a better economic value - a lower annual cost of ownership; and third, the social bottom line – less frequent replacement reduces the downtime and driver’s stress associated with repairs and replacement.

Fifty year old and older pavements are common in U.S. According to the American Concrete Pavement Association, when looking at existing concrete highway pavements over 50 years in age, over half of them have a Pavement Serviceability Rating of 3.1 or greater on a scale of 5. The rating system is based on AASHTO’s 1962 Road Test Scores. Pavement Serviceability Rating between 3 and 4 is good; and between 4 and 5 is very good. The majority of airports built in U.S. were built during WWII using concrete. Airports such as Pittsburgh, Baltimore Washington International, Washington National, Myrtle Beach, Miami International, etc., still have 60 plus year old concrete pavements in use.

Longevity’s most important sustainable contributions are (1) conservation of natural materials by reducing frequency of reconstruction or rehabilitation; (2) reducing energy consumption to mine, process, and transport new materials; (3) less damage to roads from transporting these new materials, and (4) lowering community impact by reducing waste and by reducing traffic congestion at construction zones. Add to those lower emissions from all phases of the construction which impacts air quality and health. Even the physical properties of the surface allow for better ride quality, less chance of hydroplaning and greater visibility.
Embodied Energy

In a paving system, there are energy impacts within each phase of the products life. The initial stage is material acquisition and manufacturing, followed by material transportation and construction. The use phase includes the energy expended for transportation over the pavement, maintenance and repair, and ancillary issues such as lighting. Finally, there is an energy cost for demolition, recycling or renovation.

Cement Manufacturing Carbon Footprint

The effects of greenhouse emissions on the environment, including the effect of CO₂ emission, have been well documented. Concrete as a building material is essential in virtually every market. So, naturally, concrete has a big carbon footprint. The cement manufacturing around the globe accounts for 5 percent of all man-made CO₂ emissions. In the U.S. it is about 1.5 percent. In 1991 the Portland Cement Association (PCA) members created a Voluntary Code of Conduct that maps an action plan for improved sustainable performance throughout all phases of portland cement production. Amongst other sustainable initiatives, member companies committed to reducing or eliminating the release of pollutants to the air, land and water; improving energy efficiency; and conservation of resources (PCA 2008).

Lower Manufacturing Energy Footprint

Asphalt binder is made from petroleum, which is an energy source as well. This is known as feedstock energy, because of petroleum as part of the raw materials also has energy value. Athena Sustainable Materials Institute analyzed total embodied primary energy and feedstock energy for various equivalent concrete and asphalt pavement structures for several different road types in various geographic regions over a period of 50 years. Athena’s analysis
showed significant energy savings when using concrete and considering both primary energy and feedstock energy (Figure 1).

Construction Energy Savings

The 1980 FHWA Price Adjustment Contract Provisions give a fuel use factor for asphalt to be almost 6 times as much as the fuel use factor for concrete (Figure 2). Fuel use factor includes fuel used for production, hauling, and placing. During construction, the difference in fuel consumption to produce asphalt vs. concrete is huge. This is mainly due to the energy required to heat asphalt materials. Additional factors include equipment needed for placement, and multiple lifts vs. single-lift construction.

![Average Diesel Used per Mile](image)

**Figure 2. Diesel Fuel Used During Construction**

Improved Fuel Economy

An in-depth study by the National Research Council Canada concluded in 2006 showed that there is a significant fuel consumption reduction for trucks on concrete pavements as compared to flexible pavements. It is believed that the reduced deflection of rigid pavements produces less rolling resistance and thus improved mileage by an average of 3.85 percent (Taylor and Patten 2006). According to Research and Innovative Technology Administration of the US Department of Transportation, there were approximately 2.6 million heavy trucks operating in US in 2002. Assuming each truck travels 100,000 miles (160,900 km) per year at an average of 5.5 miles per gallon (2.34 miles per liter) and at fuel cost of $2.50 per gallon, ($0.66 per liter) annual savings from improved fuel economy are estimated at $1,750 per truck or $4.6 billion for
all trucks. In terms of overall transportation sustainability, emitted greenhouse gases are reduced by millions of tons annually.

What does this mean in terms of CO₂ emission? To put it in perspective, let’s look at an example using a 62 mile (100 km) long arterial highway with a daily traffic volume of 20,000 vehicles, 15 percent of which are trucks. For a 30 year design life, the savings in CO₂ emissions would be 165,000 tons. Put differently, all of the CO₂ associated with manufacturing the cement used in the concrete pavement is compensated for during the first 9 years by virtue of the reduced deflection and improved fuel efficiency. The remaining 21 years of service life and corresponding CO₂ savings are very important sustainability benefits.

**Solar Reflectance and Urban Heat Island Effect**

The higher temperature in urban areas as a result of absorbing the heat by pavements and other surfaces is known as the Urban Heat Island Effect. Late afternoon temperatures of a typical city downtown in North America can be approximately 8° Fahrenheit (4.4° Centigrade) warmer than the surrounding suburb and rural areas. While this does not have a direct impact to the paving system, it does impact the energy consumption of buildings, requiring as much as 18% more energy to cool our homes and places of work. The energy of sunlight that is not reflected off the pavement is converted into thermal energy that increases the temperature of the pavement and the ambient temperature. This has significant economic and health effects.

The hotter temperatures obviously require more energy to cool occupied buildings. From a health standpoint, it is known that smog formation is very sensitive to temperature and becomes critical at temperatures above 87° Fahrenheit (30° Centigrade). City pavements and building roofs having high solar reflectance may reduce air temperature by a few degrees, help mitigate heat island effect, and can have dramatic impact on smog concentration and related health issues.

Figure 3 shows the solar reflectance (SF) of conventional concrete and asphalt pavements over time. The graph is from a draft report available at the U.S. Environmental Protection Agency website (EPA 2010). Although the X-axis on the website is not identified, it is assumed to be “Time in years.”

The SR test data clearly show that concrete reflects more solar energy that help mitigate the urban heat island effect over the service life of the pavement. Linear extrapolating of the data up to 8 years indicates the SR of conventional concrete pavements decreases with age from about 38 percent when new to about 28 percent at 8 years. Whereas, the SR of asphalt pavements increases with age from about 7 percent when new to about 19 percent at the age of 8 years. Asphalt surface layers on highways and major routes are typically replaced with new materials every 6 to 9 years, which results in an SR of about 20 or less during the entire service life of an asphalt pavement surface.
A CTL Group’s study evaluated the solar reflectance of specimens made using 45 concrete mixtures (Marceau and VanGeem 2008). The mixtures represented exterior concrete flatwork. Solar reflectances of the tested concrete ranged from 34 to 48 percent for mixtures consisting of ordinary portland cement and dark gray fly ash. The lowest solar reflectance for the mixtures tested was 34 percent, which was produced by one mixture containing a dark gray fly ash and one mixture containing one of the darker cements. The average solar reflectance of all mixtures was 47 percent.

Emittance is another surface property measured to determine how well a surface releases heat via radiant energy. Using both, SR and Emittance, the Solar Reflectance Index (SRI) can be calculated in accordance with ASTM E1980, “Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces.” The lowest solar reflectance value of 34 percent results in an SRI of about 37. The LEED rating system requires a minimum SRI value of 29 to qualify for sustainable sites (SS) credit. All of the concrete mixtures studied, regardless of constituents, therefore met the LEED-NC SS Credit 7.1 paving material requirement or the LEED-NC SS Credit 7.2 steep-sloped roofing material requirement.

Concrete Paving Options for Stormwater Management

Impervious pavement surface prevents rainwater from recharging water tables and allows pollutants from vehicles to be flushed into waterways. Detention ponds have been traditionally used to control stormwater runoff, allowing water infiltration into underlying soil and permitting settlement of contaminants and reducing water temperature before discharging excess water into streams, rivers and lakes. Pervious pavement options such as pervious concrete and interlocking concrete pavers are innovative solutions from a sustainability standpoint because they help improve quality of water runoff, permit percolation of water through the soil below the pavement, and recharging groundwater aquifers.
Pervious concrete pavements are typically built on highly porous, single sized stone base. The concrete is a highly permeable product that contains very little or no aggregate fines. Currently, pervious concrete is mostly used in car parking lots and low traffic pavements. However, interest in its use for highway pavements and shoulders is increasing. The base layer underneath the pervious concrete forms a holding basin where rainwater is stored and allowed to percolate into the soil. Pervious pavement systems can treat pollutants found in urban areas (Ashley 2008). The oil-based pollutants captured in the voids of the pervious concrete layer are digested by naturally occurring microorganisms. Properly constructed pervious concrete is recognized as a best management practice by the US EPA for providing first flush pollution control.

Economic benefits include (1) reducing or eliminating the need for on-site detention ponds (2) making more land available for income-generating development, and (3) reducing or eliminating the need for stormwater infrastructure and saving the associated stormwater runoff fees, insurance costs and on-going maintenance.

Innovative Sustainable Pavement Solutions Using FDR, CTB, and RCC

Full-depth reclamation (FDR) with cement, cement-treated base (CTB), and roller-compacted concrete (RCC) have been used in pavement applications for decades because they offer cost effective and durable solutions. What is relatively new is that, with increased awareness of sustainable development issues, engineers and owners are now selecting these products not only because of their durability and cost effectiveness but also because they offer outstanding contributions to sustainable development. Decision makers are now considering innovative solutions using these products, in addition to or in combination with conventional concrete and other paving products, to:

- maximize the use of in-situ soils;
- increase recycling;
- reduce mining, processing, and transporting aggregates;
- reduce cement intensity and associated CO₂ emissions;
- shorten construction time, reduce congestion during construction; and reduce associated stress;
- reduce construction traffic and associated damage to access roads; and of course
- reduce energy consumption for processing, transporting, and placement.

In the subsequent part of this paper, these cement based paving products are introduced and project examples are described to demonstrate how they are being used to construct innovative sustainable pavements.

Introduction to FDR, CTB, and RCC

Full Depth Reclamation (FDR) with Cement

FDR with cement is a pavement reconstruction procedure where the failed pavement surface layer(s) and underlying base, subbase, and/or subgrade materials are pulverized and mixed with measured amount of cement and compacted to provide a new stabilized base. A new
concrete or bituminous surface is then applied, which completes the FDR process, providing a new roadway structure with most of the new pavement materials being recycled materials in place from the failed pavement. Because of the cement stabilization, the new base will be more uniform, stronger, and provide better long-term performance than the original pavement base (Luhr et al. 2008).

**Cement-Treated Base (CTB)**

CTB is a general term that applies to an intimate mixture of native soils and/or manufactured aggregates with measured amounts of portland cement and water that hardens after compaction and curing to form a strong, durable, frost resistant paving material. Other descriptions such as soil-cement base, cement-treated aggregate base, cement-stabilized roadbed, and cement-stabilized base are sometimes used.

CTB can be mixed in place using on-site materials, or mixed in a central plant using selected material (often manufactured aggregates). Mixed-in-place CTB is compacted after blending, and CTB mixed in a central plant is hauled to the placement area in dump trucks and placed on the roadway using a grader, paver, or Jersey-type spreader. A bituminous wearing course or portland cement concrete is placed on top of the CTB to complete the pavement.

**Roller-Compacted Concrete (RCC)**

RCC takes its name from the method used to compact it. RCC refers to a stiff, zero-slump concrete mixture that is spread in lifts (layers) and compacted with rollers. There are two major markets for RCC: (1) RCC for dam applications such as gravity dams, buttressing existing dams, and overtopping protection of earthen dams; and (2) pavement applications.

For pavement applications, RCC is placed in up to 10-inch (250-mm) thick layers with high-density pavers. Typical asphalt pavers may also be used for layers 6-inches (150-mm) thick or less. Like conventional ready mixed concrete, RCC has the same basic ingredients of cement, fine and coarse aggregates, and water. However, unlike conventional concrete, RCC is a drier material that has the consistency and feel of damp dense graded base materials. For similar strength, RCC contains less cementitious materials as compared to conventional concrete. It is the low water content and use of dense graded aggregates that give RCC its high-strength properties, making it an ideal paving material for applications ranging from intermodal facilities and trucking terminals to parking lots, city streets, and intersections (PCA 2006). The main economic benefit of using RCC is the cost savings that result from its method of production and from its ease and speed of construction. RCC pavements do not require joints, dowels, reinforcing steel, formwork, or finishing, and are virtually maintenance-free. However, RCC pavements have had very limited use on high speed roads. Diamond grinding would be required to improve ride quality where speed zones exceed 25 mph (40 km per hour) or so.
FDR Example Projects

FDR at Friedman Memorial Airport Runway, Hailey, Idaho

Friedman Memorial Airport is located in the town of Hailey, Idaho and serves a steady stream of visitors to the state’s central region. The airport operates a single runway having an old asphalt pavement. Airport management projects traffic to grow 44 percent by 2022, the target date of airport long-term master plan. Aircraft operations are projected to increase from 57,888 in 2002 to around 83,800 in 2022 (Halsted et al. 2009).

In 2006, airport managers engaged pavement consultants to perform a detailed evaluation of the airport’s flexible pavement. The evaluation revealed distress in the base and subbase layers due to stripping. Stripping is a common type of asphalt pavement distress, caused when moisture and repeated traffic loads cause the asphalt cement to strip away from the aggregate. Airport management realized that a pavement base problem existed, which required rehabilitation that a surface course repair approach would not address. However, to meet the need of the projected traffic growth, there was strong likelihood that a new airport will have to be developed and opened during the next decade. Thus there was no need for a complete runway reconstruction.

To minimize loss of revenues due to runway shutdown, airport management set a 30-day maximum construction time during which the remedial pavement work must be performed. Based on projected traffic and site geotechnical evaluation, engineers developed four rehabilitation options; three options using Federal Aviation Authority (FAA) approved methods and the fourth using FDR approach. The project team determined that none of the three options using traditionally approved FAA methods could be completed within 30 day construction period. The town petitioned FAA and FAA granted permission for the use of FDR rehabilitation method after determining that FDR would cut 18 days off the construction time. Furthermore, the team estimated the cost of the FDR option at one million dollars less than the other options. The four pavement alternatives considered are shown in Table 1.

Table 1. The Four Pavement Alternatives Considered at Friedman Memorial Airport

<table>
<thead>
<tr>
<th>Standard FAA</th>
<th>Alternate #1</th>
<th>Alternate #2</th>
<th>Alternate #3 (FDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 in (375 mm) #P154 Subbase</td>
<td>0 in (0 mm) #P154 Subbase</td>
<td>0 in (0 mm) #P154 subbase</td>
<td>0 in (0 mm) #P154 Subbase</td>
</tr>
<tr>
<td>6 in (150 mm) #P209 crushed stone base</td>
<td>14 in (350 mm) #P209 crushed stone base</td>
<td>0 in (0 mm) #P209 crushed stone base</td>
<td>12 in (300 mm) FDR with cement Base</td>
</tr>
<tr>
<td>4 in (100 mm) #P401 Asphalt</td>
<td>4 in (100 mm) #P401 Asphalt</td>
<td>14 in (363 mm) #P401 asphalt</td>
<td>6 in (150 mm) #P401 Asphalt</td>
</tr>
<tr>
<td>25 in (625 mm) total section</td>
<td>18 in (450 mm) total section</td>
<td>14.5 in (363 mm) total section</td>
<td>18 in (450 mm) total section</td>
</tr>
</tbody>
</table>
Construction commenced on April 23, 2007 and was completed on time by the May 23 deadline. A total of 73,440 square yards (61405 square meters) of runway were reclaimed, which covered approximately 6,900 feet (2100 meters) of the 7,500-foot (2,286 meter) airport runway. Cement was added at the rate of 2.3 percent by dry weight of pulverized materials.

In addition to the economic benefits from construction cost savings and reducing runway shutdown time (reduced loss of revenue during shutdown), FDR offered significant environmental advantages including:

- conservation of aggregates that must be quarried and transported to the project site;
- conservation of land areas that would be used to dispose of the asphalt and base materials from the failed pavement;
- eliminated an estimated 4,000 truck trips that would have been a huge negative impact on the community; and
- reduced fuel use, air pollution, traffic congestion, and damage of nearby roadways resulting from hauling new materials to the site, and disposal of old materials.

_FDR versus New Base Hypothetical Project_

Due to its cost effectiveness and sustainable contributions, FDR has become the method of rehabilitation many state, county, and city engineers favor to rehabilitate failed asphalt pavements, especially when the existing pavement (1) is seriously damaged and cannot be rehabilitated with simple resurfacing, (2) distress is in the base layer, (3) distress requires full-depth patching of a significant portion of the pavement, or (4) structure is inadequate for the current or future traffic.

Hundreds of FDR projects are being performed each year in U.S. However, decision makers in certain parts of the country are yet to take advantage of this viable rehabilitation method. To once more highlight the energy and materials savings using FDR versus new base construction, a hypothetical project is considered. In this example, two base options are considered: (1) removal of distressed pavement materials and construction of a new dense aggregate base, and (2) FDR with cement. The project is one-mile (1.6-km) long, two-lane road. The base thickness is 6 inches (150 mm).

The comparison results are shown in Figure 4. From a sustainability standpoint, FDR attributes are outstanding and include drastic savings from reduced truck loads, reduced construction materials; zero materials landfilled, and reduced fuel consumption. Cost of FDR with cement over the past few years has been generally in the range of $0.70 to $1.00 per square yard per inch of depth ($0.84 to $1.20 per square meter per 25 mm of depth), which has been found to be very competitive with, and in most cases cost less than, other rehabilitation methods.
Figure 4. Energy and materials use of FDR vs. new base: 1-mile (1.6 km) long, 2-lane road, 6-inches (150-mm) base

RCC and CTB Example Project

BMW Plant in Spartanburg, South Carolina

The project documents for the BMW new automotive plant in Spartanburg, SC were issued for bid in late 2008. Pavements for access road, parking, and loading docks encompassed approximately 20,000 square yards (16,700 square meters). The bid documents showed the pavements to be built using 12 inch (300 mm) crushed stone base over a prepared subgrade and intermediate and surface layers of hot-mixed asphalt totaling 4 inches (100 mm). Figure 5 (a) shows the pavement design section. Subsequent to award of contract, the paving subcontractor proposed a value engineered pavement alternate. The alternate, shown in Figure 5 (b), consisted of 6 inch (150 mm) CTB over a prepared subgrade and an RCC surface layer. The CTB consisted of in-situ soil mixed with 4 to 5 percent cement by dry weight of soil. Most of the paving areas received 6 inches (150 mm) of RCC except at loading docks where 8 inches (200 mm) was used. The owner accepted the proposed alternate and the pavements were built during the first half of 2009.

In addition to the expected longer service life with virtually no maintenance, the as built pavement contributes to sustainable development in many aspects including:

- significant reduction in export and import and corresponding damage to haul and access roads;
- approximately 60 percent less crushed stone aggregate mined and processed;
- reduced excavation and faster construction with fewer construction machines;
- light colored pavements that help mitigate the heat island effect;
- light colored pavements that cost much less to illuminate, which is a significant benefit especially for parking lots illumination; and
- reduced fuel use and associated gas emissions throughout all phases of construction and operations.
Composite Pavement Section Example

Typical Texas Department of Transportation State Highway Section

This example considers Texas Department of Transportation 30-year pavement design section for a typical state highway. The typical design calls for 7 inches (175 mm) of hot mixed asphalt (HMA) over 11 inches (275 mm) of crushed stone base. Using equivalent initial cost, the Cement Council of Texas proposes a value-engineered composite section shown in Figure 6. This alternate consists of 7 inches (175 mm) of concrete, 6 inches (150 mm) of CTB, and a 1 inch (25 mm) of HMA layer sandwiched between the concrete and CTB layers.

The composite section with concrete surface is estimated to take more than 3 times the traffic loads than the asphalt section. In addition, the estimated total cost over the 30-year pavement life discounted to present value is 44% higher for asphalt than concrete. During the 30 year period, it is estimated that the top 2 inches (50 mm) of asphalt would be milled and replaced 4 times. Including the 7 inch (175 mm) initial HMA section, a total of 15 inches (725 mm) of HMA would be needed. However, the concrete pavement would require only grinding at year 25. No additional materials would be needed. Furthermore, at year 30, the asphalt pavement would require reconstruction but the concrete pavement would continue performing for many more years with minor maintenance.
Figure 6. Texas DOT highway section and a value-engineered section of equivalent initial cost

Conclusions

Longevity is the hallmark but not the only sustainable attribute of cement-based paving products. Conservation of natural resources, fuel savings, reduced traffic congestion from frequent reconstruction, maintaining quality of water supply, and help mitigate air and health issues in urban areas are essential sustainable contributions as well.

It is incommant on pavements decision makers to consider all viable paving options and to evaluate not only the economic impacts but also the impact on our health and the environment in which we live. This goal can be achieved through the implementing of an integrated pavement solutions concept, which promotes selecting the most sustainable and cost efficient paving option over the entire service life of the pavement. Conventional concrete and the other cement-based paving products discussed in the paper can certainly help in this regard.

References

