AMERICAN CONCRETE PAVEMENT ASSOCIATION
5420 Old Orchard Road
Suite A100
Skokie, IL 60077
Phone: 847-966-2272

The U.S. House of Representatives
Committee on Science and Technology
Subcommittee on Technology & Innovation

"Surface Transportation Research and Development
for Energy Efficiency"
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Good morning, Chairman Wu, Ranking Member Gingrey, and distinguished Members of the Subcommittee.

My name is Gerald F. Voigt, President and CEO of the American Concrete Pavement Association. The American Concrete Pavement Association represents more than 460 member companies, including paving contractors, cement companies, ready-mixed concrete producers, and suppliers of capital equipment, machines, materials, value-added products, and services that are used in the construction of concrete pavement.

It is both my pleasure and privilege to appear before you today to talk about the concrete pavement industry's research and development activities aimed at reducing life-cycle energy consumption and to address sustainability for surface transportation infrastructure. My testimony today will address questions aligned with three key areas:

1. How concrete pavements contribute to energy efficiency and sustainability;
2. What research is improving or will improve the sustainability of concrete pavements; and
3. What challenges impede the use of innovative and more sustainable materials in the nation's surface transportation infrastructure.

How Concrete Pavements Contribute to Energy Efficiency and Sustainability.

Concrete is the most commonly used building material in the world. It is often taken for granted, but you find it in your homes, buildings, under your feet while walking down a sidewalk, supporting airplanes at airports and, yes, as a major component of many miles of roads and highways in the United States and elsewhere in the world. Concrete is inherently a long-lasting and renewable building material, primarily made from locally available raw materials, including limestone or other natural stones, gravel, sand, and relatively small amounts of water.

To be clear, the other common paving material, asphalt, is also made from locally available aggregate and sand, which is combined with bitumen, a product of distilling petroleum.

One of the unique distinguishing features of concrete pavements is their well-documented longevity compared to asphalt pavements. Most pavements are placed with a targeted design life of 20 years, but in reality concrete pavements generally last much longer, while asphalt pavements last less than 20 years. In fact, there are well-documented cases of heavily trafficked concrete pavements that have performed for longer than 50 years. The State of Minnesota has recently begun specifying a 60-year concrete pavement design and California (CALTRANS) is working toward the goal of 100-year Sustainable Pavements.

Modern technology also continues to extend the service life of old concrete pavements through innovative repair and rehabilitation strategies. Increasingly, highway agencies are turning to a process known as diamond-grinding, which can be used as part of a long-term strategy to restore exemplary surface characteristics to structurally sound concrete pavements. Diamond grinding uses large machines that travel across the surface of the pavement, removing bumps and restoring the surface texture to like-new condition. A study by CALTRANS[1] suggests that the service life of a well-designed concrete pavement can be extended by about 17 years with diamond grinding.

Of the two types of highway pavements—asphalt and concrete—concrete pavements inherently have the lowest overall energy footprint. The reasons for this are many, but the primary factors are the exceptional longevity of concrete pavements, the relatively low amounts of fuel required to place concrete pavements, and, of course, the fact that our product is not a byproduct of petroleum refining and production and thus has a much lower embodied primary (including feedstock) energy.[2] It is the exceptional longevity of

[1] "The Effectiveness of Diamond Grinding Concrete Pavements in California," CALTRANS, May 2005.
[2] "A Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy and Global Warming Potential," Athena Institute, September 2006.

concrete pavement that is primarily responsible for its enhanced sustainability, as the lack of frequent repair and replacement results in reduced congestion; fewer construction cycles (and the associated energy consumption, pollution generation, and use of natural resources); and enhanced safety through surface characteristics.

It is important to distinguish cement from concrete. Concrete is the mixture we form into pavements, bridges and other structures. Cement (technically portland cement) is a powder that when combined with water and aggregates becomes the glue that binds the gravel and sand together and gives concrete its strength and rigidity. Cement requires the most energy to produce of all of the concrete constituents. However, it makes up only about 8 percent of the volume if a typical concrete pavement mixture. The energy and sustainability benefits of hardened concrete used in transportation infrastructure overcome any drawbacks from the energy intensive manufacture of this one component.

The concrete pavement industry has recognized and embraced the concept of sustainability. We are supporters of the Green Highways Partnership,[3] and have taken on self-imposed actions and research focused on improving concrete and concrete pavement sustainability.

In recognition of their corporate obligations, the U.S. cement industry has adopted voluntary reduction targets for key environmental performance measures. Member companies of the American Concrete Pavement Association and Portland Cement Association have adopted four goals:

- *Carbon Dioxide*—Reduce carbon dioxide emissions by 10 percent (from a 1990 baseline) per ton of cementitious product produced or sold by 2020.
- *Cement Kiln Dust*—Reduce the disposal of cement kiln dust by 60 percent (from a 1990 baseline) per ton of clinker produced by 2020.
- *Environmental Management Systems*—At least 75 percent of U.S. cement plants will implement an auditable and verifiable environmental management system by 2010 and 90 percent by 2020.
- *Energy Efficiency*—Improve energy efficiency by 20 percent (from a 1990 baseline) as measured by total Btu per unit of cementitious product by 2020.

Over the past two decades, the trend has been for less portland cement to be used per cubic yard of concrete. This trend stems from improved mixture technology, and the industry's use of industrial by-products, such as fly ash (from coal-fired energy plants) and slag (from iron blast furnaces), to replace cement. Cement manufacturers have developed new products where these supplementary materials are combined during manufacturing as a blended cement product.

Some pavements have been constructed with as much as 25 percent fly ash and 50 percent slag replacing portland cement, and research is just getting underway to further increase the amount of fly ash that can be used. The net effect of this is a positive diversion of a large amount of "waste" away from landfills, while at the same time improving concrete properties and cost effectiveness, ultimately reducing concrete's overall energy footprint. The proper use of these byproduct materials in concrete also improves a pavement's longevity and overall performance, illustrating how the concrete pavement industry is and can be an even more integral part of creating a sustainable transportation infrastructure.

Concrete is also 100 percent recyclable and reusable. Routinely, old concrete is crushed, steel components are removed and recycled, and then, the crushed concrete is used for roadbed materials, for stormwater management, for aggregate in new concrete mixtures, and also for some non-paving applications.

[3] See http://www.greenhighways.org. The Green Highways Partnership (GHP) is a voluntary, public/private initiative. It strives to change the manner in which roadways are developed through concepts such as integrated planning, regulatory flexibility, and market-based rewards. GHP seeks to incorporate environmental streamlining and stewardship into all aspects of the highway life cycle.

With regard to energy consumption, there are a host of energy-related factors that are not considered in the typical pavement type selection process in use presently by state transportation departments. Primary among them is the energy required to build pavements and the energy consumed by vehicles to drive on pavements once they are opened to traffic.

According to the Federal Highway Administration's Technical Advisory on Price Adjustment Contract Provisions, construction of hot-mix asphalt roadways consumes more than five times as much diesel fuel as the construction of comparable concrete roadways. Given the Federal Highway Administration's (FHWA's) estimate of 500 million tons of hot-mix asphalt placed annually, this would equate to a 1.2 billion gallon annual savings of diesel fuel if those pavements were built with a more sustainable concrete pavement. Considering the associated reduction of carbon dioxide by constructing only concrete pavements. this equivalent to taking 2.7 million cars off the road annually.

The National Research Council of Canada[4] recently completed a study on fuel efficiency of commercial trucks on both asphalt and concrete pavements. The study demonstrated a statistically significant fuel savings for semi-tractor trailers (18 wheelers) on concrete versus asphalt pavements. Trucks traveling on concrete pavements use between 0.8 percent to 6.9 percent less fuel. The National Highway System is the primary system for the delivery of goods by truck in the

U.S. Some 80 percent of U.S. communities can be accessed only by truck for deliveries. The system presently consists of approximately 160,000 lineal miles of pavement, 59 percent of which has an asphalt surface. If these asphalt surfaces were converted to concrete surfaces, it would save 2.1 billion gallons of diesel fuel per year at the pump (an $8.2 billion dollar annual savings at $4.00/gallon), reduce our dependence on oil, lower the emissions from vehicles, and decrease the cost of transporting goods.

Concrete pavements are also naturally light-colored, reflect light and do not retain as much heat as darker-colored asphalt pavements. This enhances night-time visibility, which in turn, improves both pedestrian and vehicle safety. These properties also can have a profound effect on energy savings, as it requires fewer lighting fixtures or lower wattage fixtures to illuminate concrete roadways in comparison to the darker asphalt surfaces. When properly accounted for during design, cities and municipalities can save up to one-third on energy costs associated with street-lights. The potential savings are huge, considering that the cost of keeping street lights illuminated is often the third costliest item a typical city might incur, right behind schools and employee salaries.[5]

Concrete pavements have a direct effect on mitigating urban heat island effects. Urban areas can be up to nine degrees Fahrenheit warmer than surrounding areas, related to among other things heat-absorbing dark-colored horizontal surfaces like roofs, roadways and parking areas, which translates to more pollution and more energy required for cooling buildings. Concrete has been used successfully, along with other light colored building materials and strategic planting, to reduce the urban heat island effect. According to work done in 2005 at Lawrence Berkeley Laboratories[6], the potential energy savings in the United States from this type of planned mitigation is estimated at $5 billion per year through reduced cooling costs. At this time urban heat island is not a factor used in the selection of pavements by FHWA or state transportation departments.

Naturally, when we talk about sustainability, it is logical to focus solely on the longevity and environmental aspects of concrete pavements. But there's more. Concrete pavements have indirect societal and economic benefits, too. Downtown areas have been revitalized by the use of decorative concrete pavements, which are colored and stamped with decorative textures to create a higher aesthetic quality. This not only improves civic pride and creates a sense of community; it also tends to improve business along Main Street, U.S.A.

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[4] G.W. Taylor, P.Eng., & J.D. Patten, P. Eng. "Effects of Pavement Structures on Vehicle Fuel Consumption – Phase III," 2006.
[5] Data from City of Milwaukee, Wisconsin.
[6] Akbari, H. "Energy Savings Potentials and Air Quality Benefits of Urban Heat Island Mitigation", First International Conference on Passive and Low Energy Cooling for the Built Environment, Athens Greece, May 17-25, 2005.

What ongoing or future R&D projects will improve the sustainability of concrete pavement? What are the most important current technical challenges, and what types of R&D projects are needed to overcome these challenges?

In September, 2005, the National Center for Concrete Pavement Technology (CP Tech Center[7]), seated at Iowa State University in Ames, Iowa, published the Concrete Pavement (CP) Road Map[8], which is a comprehensive and strategic long–term plan for concrete pavement research, prepared with broad industry participation under the aegis of the Federal Highway Administration. The CP Tech Center is an independent, third-party organization that represents the research and technology transfer needs of the concrete pavement community. It is also unique among technology centers in that it has the established goal of collaboration with universities and other organizations across the country to leverage the best minds and expertise. Today, the CP Tech Center and the Concrete Pavement Roadmap are managed by executive and advisory boards consisting of private, public as well as academic leaders in the field of concrete pavement engineering.

When published, the CP Road Map consisted of 12 research tracks. Although it was decided then that sustainability must be an inextricable component of each of the 12 tracks, the ever sharper focus on sustainability worldwide led the CP Road Map's Executive Committee to create a separate sustainability and environmental track in September 2007.

The track is currently underway, with the first meeting of the Leadership Group[9] scheduled for July 23, 2008. The diverse group will lead the development of a Track Framing Document to guide research and outreach, as well as to select projects for immediate and future funding, all with the goal of advancing the sustainability of concrete pavements, and building on concrete's already outstanding position as a sustainable paving material. This track will closely align with the 12 other CP Road Map Tracks to ensure a coordinated and comprehensive effort to address sustainability.

Inherent to increasing the sustainability of concrete pavements is the need to increase energy efficiency, both in the production and operational phases of the pavement's life. Current and future research that directly or indirectly increases energy efficiency during the production phase includes:

- Development and adoption of new recycling methods for concrete pavements to further advance the means through which existing materials may be reused.
- Development and adoption of advanced construction testing and monitoring to assure the quality of the end-products as more sophisticated and complex material combinations are implemented.
- Development and adoption of advanced, highly efficient equipment, as well as methods for evaluating and improving constructability to ensure that contractors operating under the low-bid procurement process have the technology and capability to achieve specified results.
- Optimized aggregate sizing to reduce cement content to reduce the energy embodied in concrete.

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[7] See http://www.cptechcenter.org
[8] See http://www.cproadmap.org/index.cfm
[9] The Leadership Group, consists of individuals representing government (Federal Highway Administration; U.S. Environmental Protection Agency; the Vermont Agency of Natural Resources; Virginia Department of Transportation; Caltrans; North Dakota Department of Transportation; Kentucky Department of Transportation; Minnesota Department of Transportation; and New York Department of Transportation. Also, the group is represented by industry (in the form of representatives from companies including Holcim (US); Lafarge North America; Duit Construction; The Right Environment, Snyder and Associates; and Applied Pavement Technology), as well as associations (American Coal Ash Association; American Concrete Pavement Association; Wisconsin Concrete Pavement Association; Slag Cement Association; Cement Association of Canada; National Ready-Mix Concrete Association; Portland Cement Association, and the American Association of State Highway and Transportation Officials); and academia (Iowa State University – CP Tech Center and the University of New Hampshire – Recycled Materials Resource Center).

- Increasing fly ash and slag contents in pavement concrete to advance the extent of reuse of these by-products for cement substitution.
- Two-lift slipform paving construction to allow further use of locally available aggregate that may be acceptable in the lower region of the pavement, but not near the surface.
- Development of practices to reduce and eliminate construction waste and increased use of recycled water as further improvements in sustainable construction practice.
- Development and adoption of advanced, highly efficient equipment to minimize fuel consumption and emissions generated during construction.

In addition to improvements during the construction phase, improvements in energy efficiency during the operational phase are being targeted. These include improvements that may be realized through the maintenance, rehabilitation, and recycling operations and those that directly benefit the highway user and surrounding communities. Current and anticipated research that addresses improvements in energy efficiency during the operational phase includes:

- Increased pavement longevity, minimizing future maintenance and reducing user costs and delays resulting in significant energy savings.
- Fast-track (expedited) repairs and rehabilitation of concrete pavements to reduce construction time and congestion and associated wasted energy from vehicles delayed through work zones.
- Precast pavements/slabs for maximum durability, and rapid repair and replacement to minimize disruption to motorists and businesses..
- New and improved in-place recycling techniques that save energy by eliminating any need to transport materials to and from a crushing and processing facility.
- New concrete overlay techniques that extend pavement life with the least amount of materials and energy expended, while also providing the energy-related advantages of concrete pavement surfaces.
- Lower rolling resistance that increases the fuel efficiency of vehicles operating on the pavement surface.
- Highly reflective surfaces that require less illumination, saving lighting energy and lives while lowering energy required for cooling urban areas.
- Optimized textures that reduce tire-road noise, maintain frictional characteristics, and provide pavement demarcation to improve aesthetics and community acceptance.
- Photo-catalytic surfaces to treat air pollution, lowering energy required for alternative treatment strategies.
- Pervious concrete surfaces that eliminate energy consumed to treat point source run-off.

ACPA also is working closely with researchers at Arizona State University’s National Center of Excellence on SMART Innovations for Urban Climate and Energy to better understand how pavement designs and materials contribute to surface temperature changes. Begun in 2005, this research was designed to identify mix design factors that could allow production of cooler pavement surfaces and a modeling tool by which to evaluate the surface temperature changes. This work will provide further awareness of the urban heat island issue, and influence municipal ordinances and building codes to adopt environmentally appropriate materials and solutions.

In pursuing this research, ASU has developed a simplified laboratory test method to evaluate the thermal conductivity of paving materials using conventional construction techniques. ASU also collaborated with ACPA to develop infrared images and place in-pavement sensors for a concrete overlay of an existing asphalt concrete parking lot in Rio Verde, Arizona. This collaboration provided dramatic information and imagery on concrete’s benefit in reducing urban heat island effects in a living community.

What challenges impede the use of innovative materials for transportation infrastructure? What actions can the Federal and state and local governments take to overcome these impediments? What is the role of industry and academia, especially in technology transfer?

Current institutional and technical challenges exist that impede a more widespread use of sustainable and energy efficient pavements. It is our contention that significant improvements could be achieved simply by including consideration of these important factors in the selection process used for pavements. At present, most decisions are based on first cost, and to a limited degree life-cycle cost. However, factors such as user costs, the energy required to build and operate pavements, as well as the energy consumed by vehicles driving on pavement surfaces or used for lighting roadways, is not appropriately considered. New, more comprehensive selection processes could take these real agency and societal impacts into consideration. A stronger federal position on the use of federal-aid funds coupled with an objective and more comprehensive federal pavement selection policy would help insure that states and other agencies effectively apply appropriate considerations for energy use and sustainability.

The culture of considering “lowest first cost” in place by most state Departments of Transportation (DOT’s) must change to impact the use of innovative and current materials that are more sustainable. Traditionally, state departments of transportation have considered the construction and maintenance of a roadway as two separate operations, with separate funding levels assigned to each. Some states have adopted life-cycle cost strategies for some of their pavements, in which both the initial construction costs and long-term maintenance and operation costs are included as a way of comparing alternate pavement designs for a section, but this has not pervaded all of their decisions. An asset management and sustainability strategy can only truly be reached when an agency applies this mindset both simultaneously across their roadway network and continuously throughout time. In doing so, the pavement network is viewed as an asset and a mix of different rehabilitation strategies are employed to sustain its value.

We do not intend to be critical of our partners in the state highway agencies, but the fact remains that a new mindset is needed to achieve more sustainable practices. We also would be remiss if we did not recognize the challenges faced locally with constrained funding that limits an agency’s initiative to adopt new, more sustainable practices.

Application of strategic asset allocation to a pavement network would allow the states to maintain the network in the highest overall condition possible at the lowest constant level of dollar flow into the pavement network. Such a system is inherently dynamic and necessarily would adhere to the principles of sustainability. The FHWA has recognized this need in their publication *A Quick Check of Your Highway Network Health*[10] which states: “By viewing the network in this manner [with each pavement as an asset in a collected network], there is a certain comfort derived from the ability to match pavement actions with their physical/functional needs. However, by only focusing on projects, opportunities for strategically managing entire road networks and asset needs are overlooked.”

A number of specific implementation challenges currently impede the immediate adoption of more sustainable pavements. These include:

- Lack of a clear and universally accepted way to “measure” the sustainability of a roadway. However, research conducted in Canada[11] provides many answers, but has not yet received broad acceptance within the transportation industry. The Canadians have looked at the embodied primary energy of a roadway segment over a 50 year life cycle (including material extraction, processing, mixing, placement, operation, maintenance and salvage). However, more work is required in this area.
- Existing specifications. In most cases, existing specifications unintentionally limit the use of more sustainable practices. Paving specifications are often based on dated information and agencies do not often respond quickly to changes in materials or industry advancements. Current specifications should be replaced as appropriate with specifications that require more sustainable practices. One such change that would have immediate benefit is opening up the use of blended cements. Blended cements (portland cement blended with slag or other supplementary materials

[10] FHWA-IF-07-006 “A Quick Check of Your Highway Network Health”.
[11] “A Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy and Global Warming Potential,” Athena Institute, September 2006.

during manufacturing) are used extensively throughout Canada and Europe, but are not widely used by state DOT's in the US. As noted earlier, these materials have a lower energy footprint than standard cements. Another positive change would be to allow much great amounts of SCM's in concrete paving mixtures. When given the opportunity, industry often will find innovative ways to make use of these by-products, while improving the pavement quality and saving dollars.

- Training the workforce. The design, construction, maintenance, rehabilitation, and recycling of sustainable pavements requires great knowledge and skills. As such, the current and future workforce must be educated with respect to sustainability and the important role each individual plays in increasing sustainable infrastructure. This includes all members of the workforce, from the construction laborers and superintendents through the planners and designers. Immediate and long-term benefits can be derived through focused training programs that bring current and future innovations to light.
- Lack of design and decision tools. There is an acute need for tools designers can use to assess and improve the sustainability of pavements. Although the technology exists to create such tools, none are currently widely available and thus there is no systematic way to determine the sustainability of a given design or to compare design alternatives. Tools need to be developed and implemented that are based on international standards for assessing the life-cycle costs and benefits of design alternatives.
- Demonstration projects and commensurate technology transfer workshops can be used to demonstrate current and emerging technologies that improve the sustainability of concrete pavements.
- Gaps in research, as outlined earlier.

Many of the achievements of the CP Tech Center were accomplished through a cooperative agreement with the Federal Highway Administration and used federal research funds to leverage funding from others, including our industry. We greatly appreciate the efforts of Congress to support of research and development for improved pavements. We are confident that with our public sector partners, we can close gaps in the technology and practice that will break down barriers to use of innovative and more sustainable materials and practices.

Closing Remarks

Mr. Chairman, to summarize these remarks, I submit that the stakeholders in our nation's surface transportation network currently stand at an important fork in the road.

We can let our surface transportation network condition erode through the perpetuation of current practices that ultimately will have dire consequences to the safety and personal mobility of our citizens, as well as the ability of our nation to compete in the global economy. Or, we can re-invest in new practices that contribute to sustainable development of our surface transportation systems.

In many ways, sustainable pavement technology is already available in a familiar building material called concrete. We need to fill some research gaps and develop the mechanisms to put more sustainable practices into common use. If we accept this challenge, we will once again create a system that stands peerless above all others and neither detracts from our environment nor impedes future generations from achieving the standards of living that we have enjoyed as a direct result of our surface transportation network.

The concrete pavement industry stands ready and willing to invest the time and other resources to advance our products and processes in pursuit of even more sustainable practices. We look forward to the support of the public sector to realize the American vision of the best highways and roadways in the world. Thank you for your time, for providing this opportunity to our industry, and for your kind consideration.

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