The Asphalt Paving Partnership: How Emission Reduction Initiatives Improved Working Conditions and Provided Sustainability Benefits

by Mike Acott
President
National Asphalt Pavement Association

A presentation for

Making Green Jobs Safe: Integrating Occupational Safety and Health into Green and Sustainability
Hosted By NIOSH
December 14–16, 2009
Washington, DC
# TABLE OF CONTENTS

Keywords ................................................................................................................................. 2  
Abstract ................................................................................................................................ 3  
2. Background ......................................................................................................................... 4  
3. Formation of Partnerships ................................................................................................. 5  
4. Emission Reduction Strategies ............................................................................................. 6  
4.1 Engineering Controls on Asphalt Paving Machines ........................................................... 7  
4.2 Temperature Reduction Strategies ..................................................................................... 9  
4.2.1 Warm-Mix Asphalt ......................................................................................................... 10  
5. Closing the Scientific Gaps ................................................................................................. 13  
6. Summary ............................................................................................................................ 14  
References ............................................................................................................................... 16  

---

**Keywords:** asphalt paving, emissions, engineering controls, warm mix, sustainability

---

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION
5100 Forbes Blvd.
Lanham, Maryland 20706
888-468-6499
www.hotmix.org

Mike Acott
President
Abstract

In the late 1980s and early 1990s, the scientific and regulatory community became concerned about exposure to asphalt fume and potential health effects. The asphalt pavement industry’s response to these concerns led to extensive changes in the way we do business. By making workers’ health and the environment the industry’s top priority, the industry has transformed itself.

This paper describes how an industry/labor/government/academia partnership was formed to deploy techniques that minimize workers’ exposure to fumes from asphalt paving operations and to conduct the necessary science to answer the health effect questions. Details are provided on the initial exposure reduction efforts including the development, bench testing, and field evaluation of ventilation systems on asphalt paving machines. This initiative provided the backdrop for an agreement requiring that these engineering controls be installed on every new paving machine. Since July 1, 1997, all highway-class pavers manufactured in the U.S. have incorporated the control technology. Today, most if not all of the pavers currently being used have the engineering controls in place.

This paper also explains how this “end-of-pipe” exposure reduction approach evolved into a program designed to reduce the generation of fume at its source. The key to reducing fume generation is lowering the temperature at which asphalt pavement mix is produced and placed. The development, evaluation, and deployment of the temperature reduction technologies known as warm-mix asphalt have successfully integrated worker health and safety protection with significant environmental, economic, and social sustainability benefits.

Exhaustive testing has shown that warm-mix asphalt meets or exceeds the pavement performance exhibited by conventional hot-mix asphalt. Because the benefits of warm-mix asphalt are so compelling, it is fast becoming standard practice. Implementation of this technology has become a watershed event for the asphalt paving industry, its workers, and the neighborhoods in which plants and paving operations coexist.

In the meantime, significant gaps in the science have been closed, and results are indicating that fumes from paving operations do not pose a long-term health hazard. The findings from the key health effects studies are summarized in the paper.

The work of the Asphalt Partnership has evolved over a decade and a half from a focus on a very specific program on engineering controls to an ongoing holistic view of worker protection priorities in a rapidly changing and critical segment of the construction industry, namely the construction of asphalt pavements.
1. Introduction to the Asphalt Pavement Industry

The asphalt pavement industry builds the roads, highways, streets, and airfields that connect us all to each other and to our jobs, schools, places of worship, and emergency facilities. Asphalt pavement is widely used for parking areas, driveways, footpaths, cycle paths, and sport and play areas. Some 300,000 workers are involved in the production and placement of asphalt pavements. Because the asphalt industry is America’s number one recycler, almost all these workers can be described as having green jobs.

In 2008, the latest year for which figures are available, about 450 million tons of asphalt pavement material was produced in the U.S. This material had an approximate value of $30 billion. There are roughly 4,000 asphalt pavement mixing plants in the U.S., including at least one in every congressional district.

Asphalt pavement material is a mixture of about 5 percent asphalt cement and 95 percent mineral aggregates (stone, sand, and gravel). Each pavement mixture is designed for a specific application. Because of the importance of the infrastructure and the need to ensure the quality and durability of the paved facilities, the industry must provide materials and apply production methods which result in an end product which meets the high standards set by owner agencies.

Asphalt cement is a petroleum product. It functions as the glue that binds the mineral aggregates into a cohesive mix. The pavement industry uses more than 85 percent of the asphalt cement consumed yearly in the U.S.

The United States has about 2.5 million miles of paved roads and highways, of which about 92 percent are surfaced with asphalt. The extent of this road network is second only to that of Europe, which has about 3.2 million miles of paved roads and highways. In addition, about 85 percent of airport runways and 85 percent of parking areas in the U.S. are surfaced with asphalt (NAPA and EAPA, 2009).

Reuse and recycling are widespread in the asphalt industry. Reclaimed asphalt pavement (RAP) is commonly used in the production of new asphalt pavement material. In the U.S., the industry reclaims about 100 million tons of asphalt pavement each year. An impressive 95 percent of the reclaimed material is reused or recycled. Pavements using reclaimed asphalt perform as well as, or better than, pavements made from all-virgin materials.

2. Background

The asphalt pavement industry initiated a process that has become known as the Asphalt Partnership in 1993. At that time, the National Institute for Occupational Safety and Health (NIOSH) was engaged in a review of the available science relating to potential exposures in asphalt operations such as
paving, roofing, refining, waterproofing, etc. Most notably, research conducted by NIOSH and others during the late 1980s and 1990s indicated that an oxidized roofing asphalt fume condensate generated in the laboratory at 316°C (about 600°F) generated a tumorigenic response in animal skin painting studies (Sivak et al., 1997).

In 1992, the courts had set aside the Occupational Safety and Health Administration’s (OSHA’s) permissible exposure limits (PELs). There was a growing awareness on the part of the paving industry that a significant part of the scientific and regulatory community was concerned about exposure to asphalt fume and potential health effects in workers. During this period, scientists acknowledged that application temperature was likely to influence both the quantity and the chemistry of the fume. At the same time, NIOSH scientists acknowledged that availability of data on paving asphalt fume and its potential impact on workers was limited (Butler et al., 2000).

The asphalt pavement industry took very seriously the need to answer worker health questions. In addition, the industry understood the significant threat to the industry in terms of potential regulation, litigation, and lost jobs. In 1993, the industry’s leadership moved forward on a program to improve working conditions through exposure reduction. The industry took on this mission while working in partnership with key government agencies, labor organizations, and other asphalt industry sectors to fill the gaps in the science.

3. Formation of Partnerships

On health, safety, and environment issues, National Asphalt Pavement Association (NAPA) has consistently deployed a model of working in partnership with key stakeholders worldwide. Over the years, the association has built productive partnerships with national agencies and organizations including NIOSH, OSHA, the U.S. Environmental Protection Agency (EPA), Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), and the American Conference of Governmental and Industrial Hygienists (ACGIH). The industry also partners with the relevant labor organizations, in particular the Laborers' Health and Safety Fund of North America, the International Union of Operating Engineers, and the Building Trades' Center for Construction Research and Training (CPWR). In addition, the industry has developed productive partnerships with academia and researchers, including the Harvard School of Public Health, Auburn University, the German Bitumen Forum, the U.S. EPA's National Center of Excellence on SMART Innovations for Urban Climate and Energy at Arizona State University, and others. U.S. industry partners include the Asphalt Institute, the 39 State Asphalt Pavement Associations, and many other sister associations.

In addition, NAPA has been working with partners in Europe—the European Asphalt Pavement Association, Eurobitume, the European Mastic
Association, and others—to share ideas and develop a unified approach to environmental, health, and safety issues involving international stakeholders. Also, in 2008, a Global Strategic Alliance of Asphalt Pavement Associations was formed to discuss the major issues facing Europe, USA, Japan, Australia, and South Africa.

From the early 1990s it has been evident that a partnership of government, labor unions, university researchers, and industry was needed to conduct credible research and to achieve meaningful reductions in asphalt fume exposure surrounding paving operations and to improve working conditions. One of the keys to a successful partnership is the clear definition of the win-win proposition for all of the key stakeholders. For these stakeholders, there was broad recognition that the health research was incomplete and that further study was needed to determine the health effects associated with exposure to asphalt fumes for each application sector of the industry (paving, roofing, and mastic). The asphalt paving industry embarked on a comprehensive program of research conducted with the involvement of the key stakeholders. Where possible, these studies focused on agreed scientific gaps and included joint funding, joint development and implementation of protocols, and external review by scientific advisory committees with a view to publication in peer-reviewed journals.

In the meantime, while the health studies moved forward, the industry and its stakeholder partners forcefully pursued programs aimed at reducing exposure to asphalt fumes.

This concept of working in partnership with key affected stakeholders has laid the foundation for sustainability in the protection of worker health and the environment.

4. Emission Reduction Strategies

Since 1993, the Asphalt Partnership has been evaluating techniques that have the potential for reducing worker exposure to asphalt fumes. At an asphalt mixing plant, the process is controlled by a small crew—typically three to five employees per plant. At a paving site, larger numbers of workers are involved—usually seven to twelve workers per paving crew. Relatively speaking, asphalt fume exposures are limited and well controlled on a plant site as compared with the paving site, where larger numbers of workers are active and where the process of application lends itself to the occurrence of and potential exposure to asphalt fume.

Initial efforts to reduce worker exposure included the design, evaluation, and deployment of engineering controls for paving equipment. Subsequently, partnership efforts became focused on reducing or eliminating fume at the source. Research indicated that application temperature was a significant driver in relation to the type and amount of fume generation (Lange et al., 2007). With
this knowledge, the mission evolved into one of research and implementation of asphalt mix temperature reduction technologies that reduce fume at the source. These technologies have come to be known as warm-mix asphalt technologies and are fast becoming state of the practice in the US. Warm-mix asphalt will be discussed at 4.2.1, below.

4.1 Engineering Controls on Asphalt Paving Machines

The industry’s initial fume exposure reduction efforts tended to focus on the paving site rather than the plant site. Field testing at the paving site demonstrates that the people incurring the most exposure to fumes are the screed operator and paver operator.

In 1993, industry began testing early prototype engineering control systems on paving machines. Initial results were very promising. By 1994, NAPA, NIOSH, the paver equipment manufacturers, FHWA, and the participating labor unions moved forward with an accelerated plan to evaluate the effectiveness of these systems. Each of the six US manufacturers of highway-class asphalt pavers had moved beyond prototype equipment and developed their own ventilation systems to collect asphalt fumes from the screed area and the paving machine and vent them away from workers. These manufacturers conducted bench tests and field tests of their systems, with NIOSH and NAPA representatives in attendance. This evaluation program was funded by FHWA with considerable sweat equity from all of the partners. Equipment development costs were carried by the paving machine manufacturers.

In December 1995, as a result of its Priority Planning Process, OSHA identified asphalt fume as a possible priority for non-regulatory action. In view of the momentum and favorable results on the engineering controls project, industry was encouraged to reduce exposure to asphalt fumes through a voluntary and cooperative action with the various stakeholders.

Meanwhile, field and bench testing had shown that the engineering controls resulted in significant emission reductions. Given the encouragement by OSHA to pursue a non-regulatory approach, the stakeholders signed a Voluntary Joint Agreement on Engineering Controls for Asphalt Pavers in January 1997. Signatories included NAPA, OSHA, the paver manufacturers, FHWA, and the two principal labor organizations, the Laborers’ International Union of North America and the International Union of Operating Engineers. The agreement required that every new asphalt paver weighing more than 16,000 pounds and manufactured after July 1, 1997 in the US would include an engineering control system. Each such system would conform to NIOSH published guidelines which standardized test procedures for demonstrating a minimum collection efficiency of 80 percent (NIOSH, 1995). Figure 1 shows an asphalt paving machine that incorporates engineering controls.
The second phase of the engineering controls partnership was undertaken in 2004 to determine the effectiveness of the in-place technology and its acceptance in the workplace (Mickelson et al., 2006). The finding was that paving crews are using the controls consistently, and that they are very effective in improving conditions surrounding paving operations. All average fume exposure values were below today’s lowest recommended asphalt fume exposure limit (0.5 mg/m³, benzene-soluble matter, inhalable fraction) established by ACGIH (ACGIH, 2009).

This project has been recognized as a model public-private sector partnership. In 1998, the Asphalt Partnership was a finalist in the Innovations in American Government Awards, which are sponsored by the Ford Foundation and administered by the Kennedy School of Government at Harvard University. In 1999, the partnership received the first-ever National Occupational Research Agenda (NORA) Partnering Award for Worker Health and Safety Protection.

Figure 1
A paving machine with engineering controls that vent fumes away from the vicinity of workers.

Twelve years after the voluntary agreement was put in place, most, if not all, existing highway-class pavers have been replaced with new pavers incorporating the control system. The cost of the equipment is only 2 to 3 percent of the cost of the paving machine. This equates to less than 1 cent per ton of
asphalt pavement material, taking into account the average life of a paving machine and typical throughput. Clearly this has been a very cost-effective and practical approach.

Through the implementation of engineering controls on highway-class pavers, many workers have experienced substantial benefits within a short time frame. More workers have been and will be benefited than if the engineering controls were adopted as an optional add-on to the equipment or through the normal rulemaking and standard-setting process, which can sometimes take ten years or more.

4.2 Temperature Reduction Strategies

By collecting and venting away emissions, the engineering controls could be considered a first-generation “end-of-pipe” technology. They improved the work environment surrounding the paver but did not get at the source of fume. The leaders of the Asphalt Partnership continued to pursue technologies that would reduce the actual generation of the fume at the source.

NAPA and the State Asphalt Pavement Associations had funded research at the National Center for Asphalt Technology (NCAT) at Auburn University on the effect of temperature on emissions, fume, and odor. NCAT’s research demonstrated that temperature is a significant driver affecting the quantity and chemistry of fumes (Lange, 2007). Similar conclusions have been reported elsewhere (Brandt et al. a, b, 1985; Butler et al., 2000; Kitto, 1997; Ruhl et al., 2006; and Ruhl et al., 2007). It was clear that there would be additional worker exposure reductions if emissions could be controlled at the source through reduction of mix temperature. It was also evident that lower temperatures would result in cooler working conditions, reduced overall emissions, a reduction in energy consumption, and other sustainability benefits.

In the late 1990s, mix production temperatures had edged upwards as a result of the implementation of asphalt mixture technologies known as Superpave and stone-matrix asphalt (SMA), and the wider use of high-viscosity polymer-modified asphalt. In 2000, a coalition of NAPA, the Asphalt Institute, and the State Asphalt Pavement Associations worked in partnership to publish a best management practices document to guide the selection and control of plant mixing temperatures to minimize emissions (Asphalt Paving Environmental Council, 2000). The best management practices approach helped educate users that higher mix temperatures were unnecessary and that they contributed to higher levels of fume. While it did offer ways to reduce fume production, it did not offer the potential for eliminating the fume.

Based on the findings from the NCAT research on fume temperature effects, another option was to pursue new technologies that would result in significant decreases in the temperatures at which the pavement material is
produced and placed on the road, below any reductions that could be achieved with the best practices approach of that time.

4.2.1 Warm-Mix Asphalt

Warm-mix asphalt is the generic term for a class of pavement technologies that allow typical asphalt mixture production and placement temperatures to be lowered from the general range of 280 to 320°F to an approximate range of 212 to 275°F. Not only does this temperature reduction result in a significant decrease in fume, it also results in lower fuel consumption, lower overall plant emissions (including greenhouse gas emissions), and a host of operational and product quality advantages. These positive aspects of warm-mix asphalt have led to an exponential increase in its use since its first US applications in 2004. It is anticipated that this will be the standard method for the production of asphalt mixtures by 2013.

In 2000, NAPA leaders first became aware of technologies that were being developed in Europe that had the potential to lower asphalt mix production and placement temperatures by 50 to 100°F (Koenders et al., 2000). In the fall of 2002, NAPA organized a European scanning tour for US contractors that included participation from FHWA, NIOSH, and the labor unions. The tour participants immediately observed the lack of fume and other environmental benefits. Since these technologies had only been used on a limited basis, it was not immediately apparent that they would work under the traffic, temperature and operating conditions in the US.

NAPA organized a major symposium on warm-mix technologies, with presentations by European representatives, for its annual meeting in January 2003. Shortly thereafter, research was begun at the National Center for Asphalt Technology. By 2004, three technologies for warm mix were available in this country. The first US demonstration of warm-mix asphalt was constructed at the World of Asphalt trade show in 2004 in Nashville, Tennessee.

In 2005, NAPA assisted FHWA in organizing a Technical Working Group (TWG) with representatives from NIOSH, the state DOTs, AASHTO, the labor unions, the Asphalt Institute, the State Asphalt Pavement Associations, and others. The TWG’s accomplishments include publishing a permissive specification for purposes of specifying warm-mix and devising a recommended framework for exposure and environmental testing. The First International Conference on Warm-Mix Asphalt, held in Nashville in 2007, brought together over 700 people from all over the globe to exchange information. The TWG maintains a Web site at www.WarmMixAsphalt.com to assist in technology transfer. Many open houses and demonstrations have been conducted to further educate agency officials, contractors, and the public. These activities and others have helped warm mix achieve acceptance rapidly and enter the mainstream. Today at least 18 warm-mix asphalt technologies are available in the US.
Figure 2
A demonstration project at World of Asphalt 2004 introduced more than 600 pavement professionals to the concept of warm-mix asphalt.

The interest in implementation of warm-mix technology by state DOTs is high; about 15 states have permissive specifications as of this writing in 2009 and others are strongly considering implementing the same policy. In the case of warm mix, a permissive specification allows the contractors in the state to use warm mix at their discretion. The contractor is permitted to mix and compact at lower temperatures as long as all the other specifications are met. This removes a significant barrier to implementation.

The technologies for lowering the production and placement temperatures of asphalt mixtures fall into three categories: foaming systems, organic chemical additives, and inorganic chemical additives. Some combine techniques such as foaming and chemical additives. Regardless of the method used to achieve lower-temperature asphalt mixtures, most of the contractors and agencies have not only noticed the lack of fume associated with paving operations, but have also been impressed with significant energy, environmental, operational, and product performance benefits.
One obvious advantage to warm-mix asphalt is that by lowering the construction temperature, the asphalt binder does not age as much as it would normally. This promotes greater flexibility in the product, reducing the potential for premature cracking. To date, recent work in both laboratory and field settings such as that done by Kim et al. (2009), Wielinski et al. (2009), Losa et al. (2009), Akisetty et al. (2009), Buss et al. (2009), and Schmitt et al. (2009) have shown that warm-mix asphalt properties are as good as or better than those for hot-mix asphalt and consequently the resulting pavement performance is expected to be similar, although some concern has been expressed regarding the results of laboratory moisture susceptibility testing (Kvasnak and West, 2009). Warm-mix asphalt also allows a greater amount of reclaimed asphalt pavement (RAP) to be used. In addition to environmental benefits, this helps to stabilize the price of the material (Hodo, 2009).

Operationally, warm-mix asphalt offers contractors the ability to construct pavements in conditions that would normally preclude construction operations. Because the mix cools at a slower rate than it would if it were produced at a
higher temperature, it can be hauled for longer distances or placed and compacted in lower ambient temperatures while maintaining high quality (Manolis et al., 2008; Middleton and Forfylow, 2009). These advantages are significant in that contractors in northern states can work later in the year or bid on projects that would have previously been out of their trucking range. This translates into substantial economic benefits to contractors.

If production and paving temperatures are reduced, it intuitively follows that worker exposure to fume, energy consumption, and overall air emissions would also be lowered. Studies have been conducted on warm-mix asphalt to quantify its positive impact on an environmental level. The overall life-cycle assessment has been conducted by Hassan (2009) and Ventura et al. (2009). In the study by Hassan (2009), it was predicted that the use of warm mix would reduce air pollution by 24 percent and fossil fuel consumption by 18 percent over conventional asphalt mixture production, resulting in an overall reduction in environmental impact of 15 percent. Harder et al. (2008) presented a methodology for calculating the environmental impact of lower production temperatures from warm-mix asphalt. Laboratory (Mallick et al., 2009) and field (Davidson and Pedlow, 2007) evaluations of emissions and fuel consumption have shown that reductions in both of these can be up to 30 percent, depending upon the technology used and practices followed.

As mentioned earlier, a synergistic effect of using warm-mix asphalt is that it allows greater amounts of reuse and recycling of reclaimed asphalt material because the new asphalt binder is not subject to the degree of aging that would normally occur at higher temperatures. Since it is not aged as much, the binder is not as brittle, allowing for more of the stiffer RAP binder to be accommodated in the mix. This allows the use of RAP to be increased, which lowers the amount of new material being consumed. The research for defining the amount of RAP that can be incorporated into warm-mix asphalt is being conducted at a number of institutions such as the US Army Corps of Engineers (Hodo, 2009), the University of Massachusetts at Dartmouth (Mogawer, 2009) and the National Center for Asphalt Technology (TRB, 2009).

5. Closing the Scientific Gaps

While safeguarding worker health, the industry and its partners have simultaneously sought to answer questions about the science of asphalt paving fume through a comprehensive program of research. Where possible, these studies focused on agreed scientific gaps, and included joint funding, joint development and implementation of protocols, and external review by scientific advisory committees with a view to publication in peer-reviewed journals. Some of the more recent key studies include:

- The International Agency for Research on Cancer (IARC), an agency of the World Health Organization, has completed a comprehensive study of
the health of asphalt workers in Europe called the Nested Case Control (NCC) study. This epidemiological study’s primary finding is that there is no evidence of an association between asphalt fume and lung cancer in asphalt workers (Boffetta et al., 2009).

- In a two-year skin painting study sponsored by the Asphalt Institute, researchers painted asphalt paving fume condensate on the skins of mice. Among the preliminary key findings were that the condensate was not carcinogenic; that the animals did exhibit mild skin irritation; that there were no other adverse findings; that the animals tolerated the exposures well; and that survival was consistent with the control group. Final study results will be submitted for publication in the scientific literature during 2010.

- The Fraunhofer Institute in Germany completed another key animal study that showed no traces of lung carcinogenicity in 2005-2006. The Fraunhofer researchers studied the effects on rats of inhaling high concentrations of asphalt paving fumes (Fuhst et al., 2007).

To summarize the recent advances in the science of asphalt fume, major studies in the three key areas of research into lung carcinogenicity – human mortality, animal inhalation, and animal skin painting – have been completed. All three types of studies showed no relation between asphalt paving fume and cancer end points of specific interest.

6. **Summary**

Back in 1993, the asphalt pavement industry faced a need to answer questions about the impact of its operations on worker health and a desire to move quickly to protect workers’ health from any potential threat from asphalt fume. The industry’s leaders had a strong belief, based on the science then available, that the work environment surrounding workers was safe. There were gaps in the science, however. The leadership wanted to close the science gaps and answer the questions about fume; and, while that process was proceeding, they wanted to reduce workers’ exposure to fume.

The Asphalt Partnership was created as a way of reducing exposures while answering the questions through credible research. The partnership has been effective because it brought all the key stakeholders to the table and has operated with transparency, openness, and trust.

The first priority is to protect workers. Accordingly, the Asphalt Partnership very quickly placed engineering controls on all asphalt paving machines manufactured in the US. The controls reduced worker exposure to fume and improved working conditions.

Going beyond end-of-pipe control technology, the industry has found a way to reduce or virtually eliminate fume generation at its source through warm-
mix asphalt. Warm-mix asphalt has environmental, social, and economic sustainability benefits that could not have been anticipated when the partnership began. The rapid development and acceptance of warm-mix asphalt technologies reduces or eliminates workers' exposure to fume. Warm mix also conserves natural resources by increasing recycling and reducing consumption of fuel. Because less fuel is burned, emissions including greenhouse gas emissions are reduced. Construction and performance benefits, which were not anticipated in the beginning, have been documented. Warm mix also offers economic benefits by allowing increased recycling. Thus warm-mix asphalt is not just a win for workers, it is a win for the environment, for the agencies that own the pavements, and for the public. Through engineering controls and now warm mix, workers have been protected and will continue to be protected.

In summary, the asphalt industry’s efforts to take research knowledge into practice have not only improved working conditions, they have created technologies that have many other environmental, economic, and performance benefits.

Moving forward at the same time with research to close the scientific gaps, the partners have achieved important milestones. Major studies in the three key areas of research into lung carcinogenicity – a human mortality study, an animal inhalation study, and an animal skin painting study – have been completed and have shown no relation between asphalt paving fume and cancer.

Some of the key lessons learned from these initiatives include:

- Partnerships between diverse stakeholders are possible if there is an agreed-upon, win-win mission worth pursuing.
- A sound foundation is built upon principles of openness, trust, transparency, and consistency of actions and intent.
- The business and operational case must be factored in, e.g., cost of engineering controls and economics of warm mix, along with a quest for practical, sustainable solutions in which warm mix must perform as well as hot mix.
- Health research and exposure reduction efforts do not have to be mutually exclusive if the objective is worker protection.
- Partnership efforts can logically evolve into an effort that is focused on holistic analysis of worker health and safety with an eye for taking key research into practice.

Finally, it should be noted that these fume-related initiatives are not the only results for the Asphalt Paving Partnership. Building upon the sound foundation that began many years ago, other missions being addressed through partnership now include a very successful effort at developing training programs to reduce work-zone injuries and fatalities, an ongoing study of design and controls to reduce potential silica exposures surrounding asphalt milling operations, and a major long-term study of the effects of dermal exposure in hot-mix asphalt operations.
References


