By Tom Kuennen, Contributing Editor

Many Paths to Low-Energy Asphalt Mixes

In-plant foamed asphalt processes grow in popularity as producers, contractors and agencies embrace warm mix asphalt

Warm mix asphalt (WMA) is created by mixing a solid chemical compound additive with hot mix asphalt in the plant.

Except when a liquid additive is used to make WMA.

But ask a contractor in different parts of the United States if he produces warm mix asphalt, and he may say, "Yes, we foam our asphalt." That's because in-plant foamed asphalt using plant-mounted equipment also is known as warm mix asphalt. This dedicated equipment foams the liquid asphalt in the drum during mixing.

But foamed asphalt also is created in a cold mix plant, and even *in situ* in the field, using as much as 100-percent reclaimed asphalt pavement (RAP). That technology antedates in-plant foamed processes, but also is called foamed asphalt or foamed bitumen.

And some asphalt producers are creating warm mixes by using liquid additive *combined* with dedicated in-plant foaming equipment.

Welcome to the sometimes confusing new world of what might be better termed *low-energy mixes*; that is, asphalt mixes produced at significantly lower temperatures, with substantial benefits to the producer and consumer in terms of energy costs and environmental impact.

The confusion is exacerbated by the fact that few state DOTs have specifications for warm mix asphalts, leaving their composition up to the contractor, so long as their use is permitted by the contract, and the contractor stands behind his or her work.

The most recent survey, *Synthesis of Warm Mix Asphalt Paving Strategies for Use in Montana Highway Construction*, was published in November 2009 and notes that just 12 states had reported WMA specs. They are Alabama, California, Florida, Idaho, Indiana, Iowa, Maine, Ohio, Pennsylvania, Texas, Virginia, and Washington State.

A review of the specs reprinted in the survey shows tremendous variation in the types of WMA permitted, the circumstances under which they can be used, and in the detail or length of specifications provided by each state. This essential publication may be downloaded at *http://www.mdt.mt.gov/research/docs/research_proj/warmmix/final_report.pdf*.

A template exists for road agencies to start developing a WMA specification. *A Warm Mix Asphalt (WMA) Guide Specification for Highway Construction* was articulated by the Warm Mix Asphalt Technical Working Group in November 2008, but it's just a specification framework into which states may insert their own requirements. This guide spec framework may be downloaded at *http://www.warmmixasphalt.com/submissions/93_20081209_WMA Guide Specification version 1.07 Final_WMATWG.pdf*.

Experts from the National Asphalt Pavement Association (NAPA), state departments of transportation (DOTs), Federal Highway Administration (FHWA), National Center for Asphalt Technology (NCAT), American Association of State Highway and Transportation Officials (AASHTO), the National Institute for Occupational Safety and Health (NIOSH), and many others, comprise the WMA technical working group. Additional information is available at *http://www.warmmixasphalt.com/*.

What is Warm Mix Asphalt?

As is obvious, warm mix asphalt is not a single product, but a variety of technologies that reduce the temperatures at which asphalt mixes are produced and placed. WMA processes generally reduce the viscosity of the liquid asphalt through a variety of means, and enable the complete coating of aggregates at temperatures 35 to 100 degrees Fahrenheit lower than conventional hot mix asphalt (HMA).

In North America, the vast majority of pavements are made in hot mix asphalt plants. The liquid asphalt is a relatively small part of the mix (typically 5 to 7 percent) and performs as a visco-elastic binder between the fine and coarse mineral aggregate.

Because WMA technologies generally reduce viscosity, they reduce compaction challenges associated with cooled mixes or cold weather, possibly lower the number of rollers required at a job site, and reduce the risk of failed compaction with stiff mixtures.

Conventional HMA production takes place from 275 to more than 330 degrees F and compaction temperatures are

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Illustration by Edd Hickingbottom

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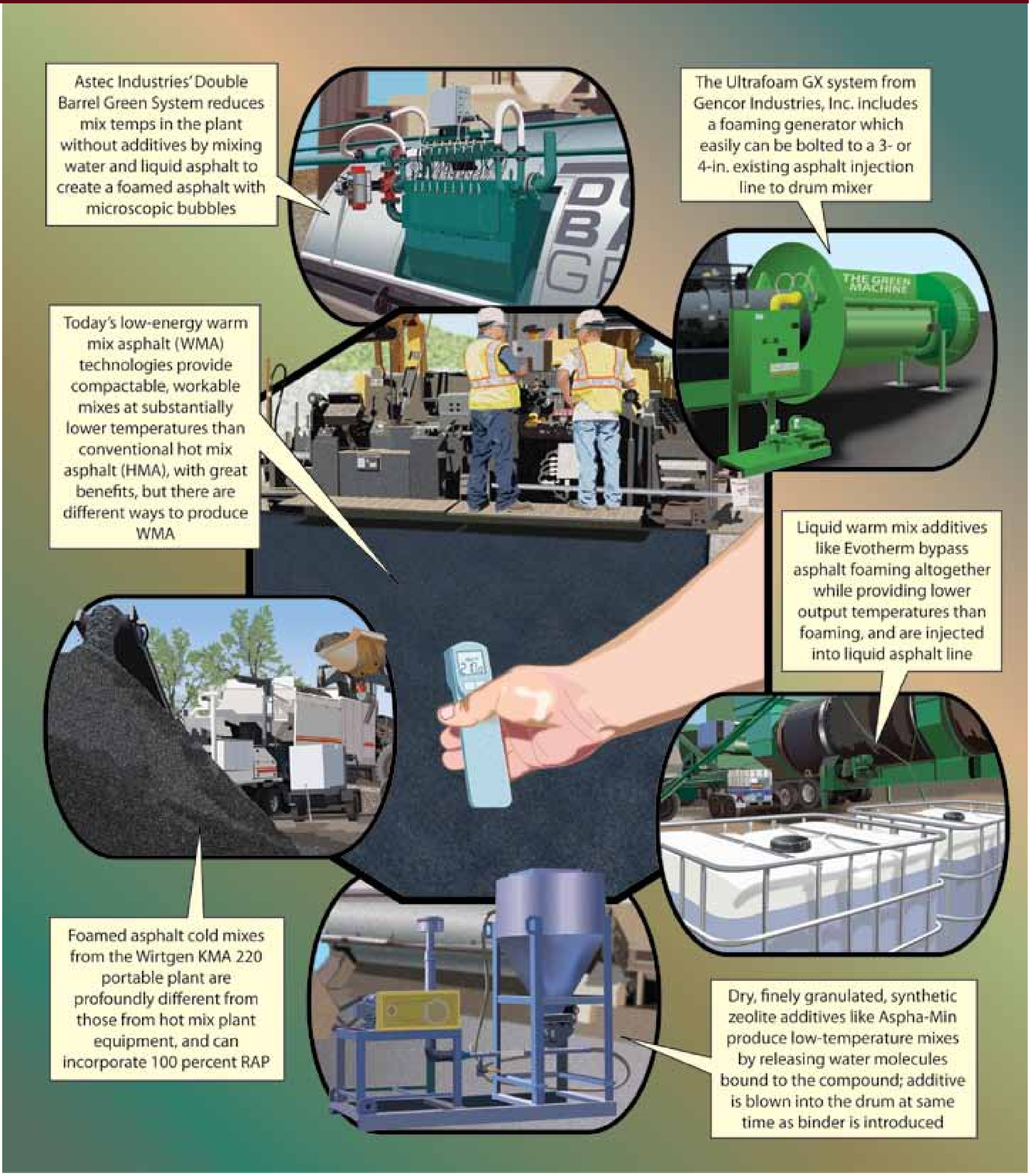
There's more than one way....

...to produce - and define - warm mix asphalt



between 260 and 300 F. Before mixing with hot liquid asphalt, fine and coarse aggregates are heated to high temperatures to drive off moisture, to ease coating of the mineral aggregates with the liquid asphalt, and to keep the complete mix fluid enough to be workable during placement.

In addition to consumption of huge amounts of fuel, heating of liquid asphalt to these temperatures produces volatile organic compound (VOC) fumes which may either be vented to the exterior, or collected with fume enclosures and re-vented back into the process.

Today's warm mixes have the potential to all but eliminate such emissions, giving a plant owner a powerful tool to use in the permitting process. Warm asphalt mixes produce emissions at a greatly reduced level compared to conventional HMA plants, thus potentially enabling the permitting of asphalt plants in air pollution nonattainment areas, or where there is local opposition.

Warm mixes can allow faster construction of pavements made up of deep lifts of asphalt, for example intersections, which need to be opened as soon as possible. Because the mix is not so hot to begin with, less time is required to cool the mix before the next lift is placed.

Warm mixes permit trucking of loads of asphalt over longer distances, without fear of critical loss of temperature, allowing contractors to expand market areas. Similarly, warm mixes may allow construction of pavements in colder weather, because contractors may no longer fear that critical loss of temperature in the cold. The result may be a longer construction season extending into the winter in some regions of the country.

And low-energy WMA may enhance pavement durability, because the lightest hydrocarbon fractions from liquid asphalt in the mix aren't driven off by the heat of the burner. The preclusion of this premature aging of binder via WMA – with a goal of reducing pavement thermal cracking without using costly PG binders – is the subject of a study by Crow Wing County, Minn. (see *At a Crossroads: Secondary Roads in the Balance, Better Roads March 2010, pp 12-21*).

The benefits of WMA are many, and have been articulated by Dave Newcomb, P.E., vice president, research and technology, NAPA. Use of WMA permits, Newcomb says:

- Lower fumes and emissions (by 30 to 90 percent);
- Lower energy consumption (some 30 percent);
- Less plant wear due to reduced mixing times;
- Decreased binder aging due to reduced heat;
- Faster site opening;
- The ability to pave in cooler weather;
- Use as a compaction aid for stiff mixes;
- Cooler working conditions for laborers, and
- Possible reduction of the need for fume evacuation equipment on the plant and paver.

Warm Mix Processes

When warm mix asphalt first gained popular attention in the United States in 2004, the emphasis was on low-energy mixes from chemical additives. These later were expanded to include in-plant, water-based technologies.

In May 2009, at the Southeast Pavement Preservation Partnership Meeting, Danny Gierhart, P.E., regional engineer for The Asphalt Institute, classified WMA types by technology), that is: processes that use some form of **additive**, processes that use **water**, and processes that use both **water and additive**; or conversely processes that **foam** the asphalt and processes that **chemically modify** the asphalt.

In November's *Synthesis of Warm Mix Asphalt Paving Strategies for Use in Montana*, Steven W. Perkins, of the Western Transportation Institute at Montana State University-Bozeman describes four fundamental types of WMA categories, those using **water-based additives**, **water-bearing additives**, **chemical additives**, and **organic additives**. He characterizes the in-plant foamed asphalt processes – such as Astec Industries, Inc.'s *Double Barrel Green System* – as water-based (see *Table 1, Summary of WMA Technologies*).

Three different types of products comprise the chemical WMA technologies. Generically they are solid, synthetic **zeolites**, which release water molecules when mixed with liquid asphalt at the plant, achieving a foamed asphalt binder, an example being *Aspha-Min*; solid **organic** additives, which are synthetic paraffin waxes which reduce the viscosity of the binder at mixing and compaction temperatures, an example being *Sasobit*; and **liquid** additives, which add lubricity to individual microscopic asphalt particles, enhancing workability at various temperatures, an example being *Evotherm*.

Of the mechanical processes, **in-plant foaming** is gaining a lot of attention. "Back about 2004, when interest in warm mix asphalt grew, the early solid chemical additives for warm mix asphalt were found to be a good idea, but the customers didn't like the cost," says Benjamin G. Brock, president, Astec, Inc. "One early product was $600 per ton, which equated to $6 per ton of asphalt mix. When you are having to compete against concrete, that put our customers at a bad advantage."

These chemical additives provided burner savings of about 34 cents per ton, but that was obtained at a cost of $6 per ton, Brock told *Better Roads*. "Then a liquid product was marketed that cost about $3 per ton and prices

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Table 1: **Summary of Warm Mix Asphalt technologies**

Technology	Category	Production Temperature (°F)	Modifications to Plant Required
Aquablack WMA	Water-based	NA*	Yes
Double Barrel Green®	Water-based	255	Yes
Low Energy Asphalt	Water-based	255/220	Yes
Ultrafoam GX™	Water-based	NA*	Yes
WAM Foam	Water-based	145	Yes
Warm Mix Asphalt System	Water-based	NA*	Yes
Advera	Water-bearing	200	Some
Aspha-Min	Water-bearing	215	Some
Evotherm®	Chemical	195	Minor
Low Emission Asphalt	Chemical	275/215	Yes
Rediset™ WMX	Chemical	260	Minor
CECABASE RT®	Organic	215	Not Known
Sasobit®	Organic	235	Minor

*NA: Information not available

IMAGE CREDIT: Steven W. Perkins, Western Transportation Insitutute began to fall, and customers started to pay more attention," he says. "The more they used the WMA additives, the more they liked them, because of the lower temperatures, with no smoke, no odor, and enhanced workability of the mixes."

In-plant Foaming

With interest in WMA growing, Astec began looking for a mechanical means of obtaining the same foaming effects in asphalt that chemical additives were providing. "Adding water to asphalt is the cheapest, easiest way to get that," says Brock. "The challenge was how much to use, and how to get dispersed evenly."

They found it in an in-plant foamed system, basically a manifold mounted on a drum plant, with nozzles that precisely meter water into the drum. Injection of water – along with the liquid asphalt cement – causes the liquid asphalt to foam and expand in volume. The foaming action helps the liquid asphalt coat the aggregate at a temperature that normally is in the range of 230 to 270 degrees F, versus the conventional temperatures of 300 to 340 degrees F.

"We found we were not successful introducing water at high rates through one nozzle, so we went to multiple nozzles," Brock says. "The first unit we came out with had 10 nozzles, but we have adjusted the size and number of the openings, and done machining to get the system to the right point where it will blend asphalt and water properly." Today's units have six nozzles.

Tests in 2007 at Astec's facility, and in the City of Chattanooga, indicated the system would work. "On our test in Chattanooga, the city let us run 50-percent recycle in a surface mix at 265 degrees F, 4,000 tons on a heavily traveled access road," Brock says. "I just drove it last week and it's still perfect."

Now prices of WMA additives have plummeted, Brock says, and all agencies are benefiting from the lower pricing. "In just a few years, we saw a drop from a $6 added cost for a ton of HMA to $1.50 added cost per ton," Brock says.

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Astec's Double Barrel Green System uses a multi-nozzle manifold to make foamed warm mix asphalt, here in Vancouver, B.C.

Photo courtesy of Astec, Inc.

"It's amazing how economics plays into the use of WMA. To us, water is the economical winner in this process."

In the manifold, water is metered through up to six nozzles. The faster the flow rate, the more nozzles that are employed. "The water is atomized, because we are trying to get it evenly dispersed through the mix," Brock says. "We are adding about 1 pound of water for every 2,000 pounds of hot mix. Much of that evaporates as steam and the amount of water that actually gets into the hot mix is very, very minimal as we create microscopic bubbles. We foam the liquid asphalt to coat the aggregate at lower temperatures and stay workable when it gets to the job site. When you hit the mat with that roller, you will get density very quickly because the microscopic bubbles are 'popped' out."

Of course, the process is more complicated than that. "With foamed asphalt warm mix, if you have cold spots in the mix, you will have density problems," Brock says. "Inconsistent temperatures behind the paver will lead to compaction problems."

Other in-plant foamed WMA technologies have appeared since Astec's Green System. World of Asphalt 2010 this spring exhibited nine such systems. Among the WMA systems requiring plant modification are the *Green Machine* from Gencor Industries, the *AQUABlack* system from Maxam, the *WMA System* from Terex, the *Accu-Shear* system from Stansteel, and the *LEA* (Low Emission Asphalt) system from Suit-Kote Corp.

In-Plant WAM-Foam

Yet another in-plant foamed process, *WAM-Foam* from Shell, follows introduction of a "soft" bitumen with a foamed bitumen in the plant. WAM-Foam is a product of a joint venture between Shell International Petroleum Company Ltd., London, U.K., and Kolo-Veidekke, Oslo, Norway.

In WAM-Foam, the binder is formed using two separate binder components in the mixing stage, FHWA reports. By dividing the binder into two separate components, a soft binder and a hard binder in foam form, lower asphalt mixture production temperatures can be achieved.

The soft binder component is mixed with the aggregate in the first stage at approximately 230 degrees F. to achieve full aggregate coverage, FHWA says. The hard binder component is mixed in a second stage into the pre-coated aggregates in the form of foam. As with the other in-plant foamed processes, rapid evaporation of water by injecting cold water into the heated hard binder as it is added to the mix produces a large volume of foam, with plant modification required. The hard binder foam combines with the soft binder to achieve the required final composition and properties of the asphalt product.

"Shell states that WAM-Foam's success depends on careful selection of the soft and hard components," FHWA says in a report on WMA technologies. "In some cases, it is recommended to use an adhesion improver in the first mixing stage. Shell also states that initial coating of the aggregate in the first mixing stage is vital to prevent water from reaching the binder and aggregate interface and entering the aggregate and that water must be removed from the asphalt mix to ensure a high-quality end product."

In general, chemical additives enable even lower mix temperature than do the plant-mounted equipment. One such lower-temperature technology is Evotherm, produced by MeadWestvaco Asphalt Innovations, a chemical compound which adds lubricity to individual microscopic asphalt particles. The particles develop "slip planes" which let the asphalt particles move more easily, requiring lower levels of energy. Because the energy is lowered, Evotherm warm mix has the same viscosity properties at lower temperatures as conventional hot mix asphalt.

"By lowering the temperature of production, we are avoiding some of the potential degradation to binder that can occur at higher production temperatures," says Everett Crews, Ph.D., technical manager for MeadWestvaco.

Evotherm is different from other warm mix technologies in its ability to produce mixes around 200 degrees Fahrenheit, Crews says. "Other warm mix technologies produce material at temperatures up to 260 degrees Fahrenheit," he says. "Evotherm is unique in that we can push the limit lower. We have made mixes at below 200 degrees F that have performed very well.

"In the United States, the bulk of our applications have been dense-graded surface mixes," Crews says. "These typically have 19 mm (3/4- inch) or 12.5 mm (1/2- inch) nominal maximum aggregate size, sometimes down to 9.5 mm (1/3- inch) NMAS. But in the United States we've also done open-graded and gap-graded mixes, and used with neat, polymer-modified and rubber-modified asphalt cements. Evotherm's been used successfully with high-content reclaimed asphalt pavement (RAP) mixes, and even stone matrix asphalt (SMA) mixes. Around the world, and in this country, we've seen a rapid shift in the size, variety and the number of WMA projects containing Evotherm."

In California, temperature of warm mix asphalt is measured as it comes out of plant.

Photo courtesy of MWV Evotherm

Cold Foamed Recycled Mixes

In-plant hot mix asphalt foaming – using mostly screened and processed virgin aggregates in the mix – is totally different from cold recycled base mixes created with foamed asphalt, and employs up to 100-percent recycled materials, says Mike Marshall, director, recycling products, for Wirtgen America, Inc.

If designed correctly, Marshall says, such cold recycle mixes will provide a base course equivalent to one that was manufactured in a hot mix plant, but with as little as 2.5-percent liquid asphalt binder, with 100-percent reclaimed aggregates, either reclaimed asphalt pavement (RAP), or recycled concrete aggregate (RCA) from demolition concrete.

"To make the hot mix product, they will use new, virgin aggregates, with perhaps up to 25-percent recycled aggregates as a blend," Marshall says. "In essence, they are making a manufactured product to a very high standard with very strict tolerances, all bound together with liquid asphalt, typically 5 percent by mass."

The in-plant foamed asphalt in that manufacturing process will reduce the energy required to make that tight-spec manufactured product for base, leveling and driving courses, he says, but doesn't reduce the amount of liquid binder required.

"At the other extreme is foamed asphalt making a base mix with 100 percent reclaimed aggregates," Marshall tells *Better Roads*. "There, we're not manufacturing a mix with the very tight tolerances as seen with hot mix asphalt. Instead we will be making a cold mix base material of up to 100-percent RAP, either done in a plant like Wirtgen's KMA 220, or *insitu*, with a mobile mixer. There the objective is to reuse 100 percent of the aggregates, and bind them back together with foamed asphalt."

Clear differences exist between the two processes, he says. "The former's objective is to create a hot mix asphalt manufactured product with very tight tolerances for driving surfaces, equivalent to what's been done for decades, but with less energy," Marshall says. "The latter process inexpensively creates a base material with the objective being reusing as much recycled material as possible, stabilizing the recycled materials with foamed asphalt."

Aggregates Not Completely Coated

In the cold-mix foamed asphalt process, the recycled aggregate is not completely coated, as is the process with in-plant foamed injection using mostly virgin aggregate.

"In the cold mix recycle process, as we introduce 100-percent reclaimed materials into the pug mill, we inject foamed asphalt into the material stream, and the foam acts as a binding agent to glue the reclaimed aggregates together," Marshall says. "When you are recovering 100-percent of existing aggregates in the cold recycling, you will use 2.2 to 2.5 percent liquid asphalt. Foaming allows us to use less liquid asphalt because we can disperse the binding agent into the mix without the need to completely coat the aggregate. Here we have a clear difference between the two processes, a coated as opposed to a non-coated application."

Typically, Marshall says, because in-plant foamed technologies completely coat the aggregate – as is needed for critical applications like friction courses – they still will use liquid asphalt at 5 percent. "What is needed for that application is a continuously-bound material, face on face, with every element of the aggregate coated, so they are glued together when compacted," Marshall says.

"When we are cold recycling with, for example, the KMA 220," he says, "we are not producing a continuously bound product. Instead, we are producing a stabilized, non-continously bound base material. The aggregates are locked together by finer particles, which carry the foamed binder into place."

Cost differences are based on the fact that the in-plant foamed mixes require larger quantities of new, virgin aggregate, screened to tight specification, plus standard percentages of liquid asphalt for that mix. The cost benefit there comes from the lower energy input. ❖