Technical Paper T-133

Heating, Mixing and Storing Modified Asphalt

By Jim May
and
Tom Wilkey

NOTICE

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The authors of this paper are affiliates of Heatec. The information they present is based on the knowledge and experience they have gained from contact with technical representatives of asphalt cement suppliers and by working closely with asphalt paving contractors.

The authors have endeavored to present factual information in an unbiased way. However, their statements and recommendations are strictly their opinions and are not in any way intended as a warranty of the products or materials described.

Contents

Abstract

The use of road paving materials made with polymer-modified asphalt cement (PMAC) will likely be required for many state and federally-funded roads in the near future. Testing has conclusively shown that PMAC significantly extends the life of roads in parts of the U.S. where there is heavy traffic and wide variations in climatic temperatures.

Hot mix asphalt contractors will either have to add new equipment or modify existing equipment to most effectively use PMAC. A number of modifications and equipment choices are presently available at low-to-moderate costs. Moreover, contractors will need to learn some new techniques and follow prescribed procedures when using PMACs.

Some problems have been encountered using polymer-modified asphalt. Some were due to the chemical makeup of the mixtures while others were caused by the equipment and handling procedures. But most problems can be avoided by selecting suitable equipment and following recommendations of knowledgeable suppliers.

Introduction

If you are an owner, manager or operator of an asphalt terminal or hot mix asphalt (HMA) plant, the information in this paper should be of interest to you. It can help you to understand how using polymer-modified asphalt cements (PMACs) differs from using conventional liquid asphalts. It can help you avoid problems often related to PMACs. And it can help you select equipment most suitable for PMACs.

Some of the information in this paper is from an article in Hot Mix Magazine and is used with permission from Astec Industries, the magazine's publisher. The article reported an interview with Ronald Collins, president of Pavement Technology, Inc. Collins spent 37 years with the Georgia DOT and retired as state Materials and Research Engineer. He has received a number of awards for his contributions to the advancement of the paving industry.

The use of modified asphalt has begun to increase significantly in the United States. The increase is due mainly to recent testing under the Strategic Highway Research Program (SHRP). This is a $50 million program presently led by the Federal Highway Administration to specify, test and design asphalt paving materials for highways in the United States. Testing indicates that roads last remarkably longer when made with asphalt binders that incorporate modifiers **(Figure 1).** The SHRP also gave birth to a new system of grading asphalt cement or binders known as *performance-grading*.

This paper discusses asphalt cement (AC) that incorporates modifiers known as polymers. The polymers commonly used to modify asphalt are listed in **Figure 2.** These asphalts are known as *modified asphalt*, and *polymer-modified asphalt cement* (PMAC). They are modified by adding polymers to virgin asphalt *before* it is used to make HMA. Thus, the modified asphalt or PMAC is premixed. This paper does not discuss other types of modifiers, such as fillers, antistrip, oxidants, extenders, etc.

Please note that rubber is one type of polymer. So, it is not technically correct to speak of polymers as if they exclude rubber.

Making HMA using premixed PMAC is commonly known as the *wet* method. There is another method of making HMA with modifiers. It is known as the *dry* method. In the dry method, powdered rubber or other modifiers are introduced directly into the hot mix while it is in the mixing drum or pugmill.

But the wet method is far more popular than the dry method. And it has some significant advantages over the dry method. The dry method of making HMA is not covered in this paper.

Performance-Graded asphalt binders

Designations for performance-graded asphalt binders are prefixed with *PG*. Each grade designation also includes two sets of numbers that denote a temperature range. This is a range of climate temperatures to which the road may be exposed and still be expected to give superior performance. The PG numbers do not indicate viscosity as in conventional liquid asphalt designations.

Consider, for example, the binder designated PG 58-46 **(Figure 3)**. The first set of numbers 58 refers to the high temperatures in degrees C. The second set –46 (minus 46) refers to the low temperature in degrees C. Thus, this binder should perform well in climates where temperatures range from plus 58 to minus 46 degrees C (plus 136 to minus 51 degrees F).

The points where the temperatures are measured and the average durations of time that the temperatures are sustained are detailed in PG specifications.

Conventional, unmodified virgin asphalts (commonly known as *neat* asphalts) are also assigned PG designations. Their PG designations reveal that they perform well in a more limited range of climatic temperatures than modified asphalts.

A rule of thumb is sometimes used to indicate whether an asphalt incorporates modifiers. Just add the two sets of numbers of any PG designation. (Disregard the minus sign.) If the sum is 92 or greater, that asphalt probably includes modifiers.

Background

Permanent deformation or rutting has always been one of the primary concerns of engineers that design asphalt pavements. In recent years, rutting has become the major reason that asphalt pavements lose their smoothness and serviceability, leading to premature replacement. Increased axle loadings, higher tire pressures, and greater traffic densities are major causes of rutting. To combat the rutting problem, highway engineers have tried using leaner, stiffer mixes, but this has generally resulted in failures of other kinds: fatigue cracking and moisture damage.

Figure 1

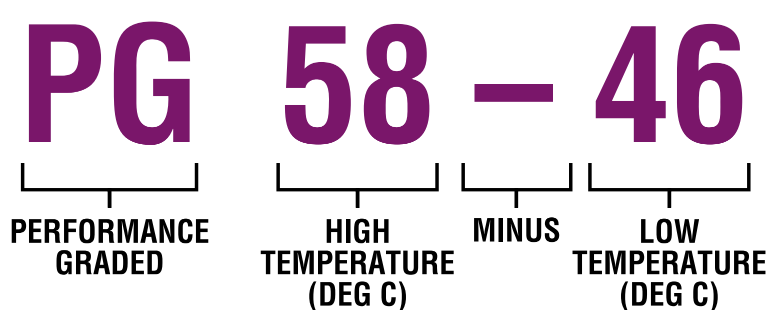
Modified Asphalt Can Make Our Highways Last Longer

Figure 2

TYPE OF POLYMER	EXAMPLES
RUBBER (elastomer)	
natural latex	natural rubber
synthetic latex	styrene-butadiene-rubber or SBR
block copolymer	styrene-butadiene-styrene or SBS
reclaimed rubber	recycled tires
PLASTIC	polyethylene polypropylene ethyl-vinyl-acetate or EVA polyvinyl chloride or PVC
COMBINATION	blend of rubber and plastic

Polymers Commonly Used To Modify Asphalt

Figure 3



What A PG Asphalt Designation Means

These are not new problems, nor are they limited to the highways of North America. Countries in Europe started experiencing the same sort of problems at about the same time we did.

In Europe, the highway builders were quicker to respond to the problem than we have been here in the U.S. They have been adding polymers to asphalt cement for 20 or 30 years with a history of good success. So our industry's move toward the use of polymer-modified asphalt cement has a lot of precedent and good research behind it.

The Georgia DOT started getting interested in polymers about 15 years ago according to Ronald Collins, former research engineer from the Georgia DOT. He was involved in PMACs at different stages of research, from putting down test sections to full implementation of the technology. Georgia was one of the first states to make a major commitment to polymer-modified mixes. Georgia is now using polymers on all of their interstate work.

Perhaps the biggest reservoir of knowledge about polymers in this country is in the engineering departments of the major suppliers of liquid AC. They have people on staff who understand polymers better than almost anyone else in the industry. Some of these engineers came from Europe, where countries like France, Germany, Sweden, and Italy have been using polymers for years. These polymer suppliers are beginning to gear up to meet the future demand for polymers that will be generated by the hot mix industry in this country.

WHAT ARE POLYMERS?

In 1846, a Swiss chemistry professor accidentally altered the chemical composition of the cellulose molecule in the cotton of his wife's apron—and the history of the world was also altered.

It took another 60 years, but scientists eventually discovered how to alter molecules more or less at will to create materials that are not found in nature. In 1907, bakelite was invented—a product of the process known as "polymerization". Before long, a parade of polymers followed: rubber, lucite, rayon, polyethylene, nylon, vinyl, Styrofoam, polystyrene. . .

A simple, small molecule made up of a group of atoms is called a "monomer" (from the Greek "monos" meaning "one"). When a large molecule is formed from many monomers of the same kind, the result is a "polymer" (from the Greek "polu-" meaning "many"). The term "polymerization" is used to describe the process of linking the small molecules or monomers together.

Polymers are found all around us in nature. Wool is a polymer. So is the starch produced by plants. Lignin is a type of glue produced by trees to hold cellulose fibers together, forming what we call "wood". The DNA in our bodies' tissues and fluids are polymers.

If you use more than one type of monomer to build a large molecule, you have a "co-polymer"—and this is the situation with the additives used in liquid asphalt cement (liquid AC). To get one of the additives—typically referred to as "SBS"—the engineers link the monomer of styrene with the monomer of butadiene to form the new, giant molecule: styrene-butadiene-styrene. SBS is a common synthetic rubber that is capable of withstanding high temperatures and extreme tearing forces.

Both of these are ideal characteristics for a polymer that is to be added to liquid AC in order to reduce the rutting and cracking of hot-mix asphalt roads and highways.

How polymers affect performance of hot-mix

Research and testing has proved the potential value of PMACs. It is a fact that polymers can significantly improve the performance of asphalt mixes and substantially increase the service life of highway surfaces. Many industry observers are convinced that there will be a big increase in the use of polymers as the industry implements the Superpave program and the performance-grade binder specifications in this country.

Specifically, there will be a significant improvement in the quality of asphalt pavement with the widespread use of polymers. The asphalt mixes will be more stable at warmer temperatures and more flexible at colder temperatures. This is an important engineering characteristic of pavements made with PMAC.

There are some potential concerns, too. The use of polymers will mean stiffer asphalt mixes. The mixes are going to be more difficult to work with during the manufacturing, transporting, placement, and compaction processes. It will not be as easy to achieve the desired degree of smoothness. Success will undoubtedly require use of all the technology and innovations available. Many potential construction problems can be overcome with continuous paving operations utilizing a material transfer device such as the Roadtec Shuttle Buggy®.

General characteristics

The term polymer can be applied to almost any giant molecule. (See sidebar) But not all polymers can be used with liquid AC for road-building purposes. All polymers do not perform the same. Some polymers have adequate high-temperature properties, others have low-temperature properties. But premium polymers exhibit both high and low-temperature performance characteristics.

In addition to rutting resistance, a premium polymer can provide a degree of flexibility or elasticity to an asphalt mix, improving the fatigue characteristics of the mix. A layman's definition of fatigue is how many times you can bend something before it breaks. This fatigue-resisting characteristic of polymers is very important because today's typical asphalt pavement is flexed an enormous amount every day. Just imagine how many micro-strains a road surface must experience if more than 300,000 vehicles travel over it every day.

Figure 4

Vertical Mixing Tank For PMAC

There are certain techniques involved with the handling of polymers. And contractors who intend to pave with PMACs will have to learn those techniques. They do not have to know much about the chemical composition of PMACs but they do need to know how to handle the PMAC and the mixture.

Experience teaches that it is the handling of PMAC mixtures that usually has the greatest impact on contractors. There are some very sharply delineated needs that must be met. For example:

• There is a need to store the PMAC as a homogeneous fluid prior to mixing it with aggregate.

• There is a need to maintain higher mixing temperatures, both for the polymer-modified elements and the mixture.

• There is a need for special measures when transporting the hot-mix in trucks.

• And there is a need for special procedures during spreading and compaction on the roadway.

In other words, both producers and contractors must know the handling characteristics of the PMACs used in their mixes. As far as chemical compositions and molecular makeup are concerned, there are not a lot of contractors who understand the specifics. For that matter, neither do most of the state-agency people. But there are a lot of things in our society that we use regularly without a full understanding of how they work—everyday things such as airplanes and computers, for example. But we see the end results of those technological marvels and how they can simplify, improve, or impact our lives. We don't avoid things simply because we don't understand them.

Handling PMACs

The day-to-day handling of the PMAC material will be a totally new experience for most people. The polymers and the liquid AC have a tendency to separate. So the real challenge is to keep them stored in a homogenous mixture until they can be used. You can blend the polymers with liquid AC and keep it in special storage tanks for a number of days. Some polymers do have a tendency to settle out or separate. Not all polymers are the same in this regard. When they do separate, the polymers will generally come to the top of the tank and the liquid AC will settle to the bottom. Consequently, the industry is beginning to see a new concept in liquid-AC storage tanks: they are vertical storage tanks that are equipped with mixing impellers.

PMAC Mixing System At Asphalt Terminal

Figure 5

- COMPATIBILITY
- PUMPING
- TIME
- TEMPERATURE
- SEPARATION
- STICKINESS
- EQUIPMENT PERFORMANCE

Common Concerns With PMACs

Figure 6

Heatec has sold a number of tanks that were especially designed to maintain the integrity of polymer binders prior to mixing with aggregate. Some of their tanks have gone to producers and contractors **(Figure 4)**, while others have gone directly to the suppliers of the basic PMAC product **(Figure 5).**

Of course, there are some other issues that are certain to arise in connection with the handling of PMACs at asphalt plants **(Figure 6).** During storage, for example, the ability to pump the material can become a problem because it is a much more viscous material than the liquid AC most users are accustomed to handling. Consequently, it may be necessary to increase the size of the pumps, strainers, and pipes handling PMACs.

Another potential problem occurs later. Once the PMAC has been mixed with the virgin aggregate, the critical factors become time and temperature. The contractor must be able to keep the mix hot, get it to the roadway quickly, get it spread, and get it compacted—all before it has time to cool down too much.

A polymer-modified mix is stiffer than a conventional asphalt mix because you make a significant increase in the softening point of the binder when you add polymers. In other words, in PMAC mixes, you significantly increase the temperature at which the mix tends to become pliable. Therefore, if you let the mix get very cool after you spread it, it will be very difficult—if not impossible—to obtain adequate compaction and smoothness.

Most contractors and state-agency personnel who have had experience with PMACs report that it is very important to maintain a continuous paving operation and not have a lot of stop-and-go paving. With some agencies, continuous paving is a mandatory procedure to follow. You should also roll the mix immediately after it is spread, while it is still hot.

Another potential problem with PMACs is the stickiness of the material. It will adhere to almost any surface it touches: silos, haul trucks, material-transfer vehicles, pavers—whatever. That is the bad news. The good news is that it is just as sticky when it comes to holding together the aggregate in the hot mix.

After all, the very stickiness and elasticity of the polymers is the main reason we're going to all the trouble. Most people will probably agree that it is worth all of the trouble to get a good, long-lasting pavement.

Uniting polymers with asphalt

Most polymers dissolve in asphalt when the two are mixed at certain high temperatures. The temperatures required are higher than those customarily used for heating virgin asphalt when adding it to HMA. Temperatures up to 171 degrees C (340 degrees F) are commonly used. The actual temperature used should be the one specified by the supplier for the specific product used. The dissolved polymers disperse throughout the asphalt and increase its elasticity to improve its performance.

Some polymer molecules swell significantly when added to hot asphalt. When polymers are added in sufficient concentrations they will dominate the mixture. And their molecules create a network that absorbs an amount of asphalt many times its own weight. Such mixtures behave like rubber extended with asphalt.

As already noted, the use of polymers in asphalt cement makes the binder stiffer or more viscous. Polymers absorb the light ends or volatile fractions in the asphalt cement and that contributes to the increased stiffness or higher viscosity.

Compatibility of ingredients

Lack of compatibility is a problem sometimes encountered with PMACs. Compatibility in PMAC refers to the ability of the polymer to fully disperse and blend with the virgin asphalt cement. Incompatibility exists when the polymer will not remain dispersed and blended in the asphalt cement even though prescribed procedures have been followed. As a result the polymer separates from the asphalt cement and collects on the surface of the liquid asphalt. The type of polymer used and the composition of virgin asphalt are the main factors that govern compatibility of the two components.

Incompatible mixtures not only result in unsatisfactory HMA, but can cause major malfunctions in heating, mixing and pumping the material. So, if problems are encountered with operation of the equipment there is a possibility they are caused by incompatibility.

Contractors must rely on their suppliers to provide them with PMACs whose ingredients are fully compatible with each other. There is very little a contractor can do to solve compatibility problems at his facility. However, both contractors and suppliers should be alert to recognize when the problem is caused by lack of compatibility and not by failure to follow proper mixing procedures. Contractors who encounter problems that could be caused by incompatibility should try to resolve the problem with the help of their AC supplier.

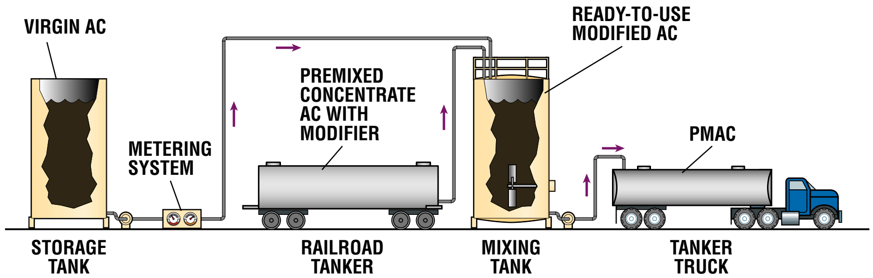
If you can see the polymer in a PMAC it is not suitably dispersed. Thus, if incompatibility is suspected, looking into the top of the tank may confirm whether compatibility is the cause. Gelled masses of polymer found floating on top of the mixture indicate that the polymer is not properly dispersed. Even if floating masses of polymer are not observed, it might be well to dip out a sample of the mixture and to check it further. Put the sample in a beaker and place it in an oven heated to 171 degrees C (340 degrees F). Leave it at that temperature for at least 20 hours. Then note whether the sample has an accumulation of film on its surface. The presence of film indicates incompatibility.

PMAC mixing systems

Asphalt terminals do not need the same types of mixing systems as HMA plants. Terminals normally do the initial blending of PMACs. They endeavor to mix only enough material to keep up with demand so as to minimize the amount of mixed material that must be stored in the mixed state. However, when they do store mixed material they maintain it at a lower temperature to prevent degradation. HMA plants usually purchase premixed PMACs from asphalt terminals.

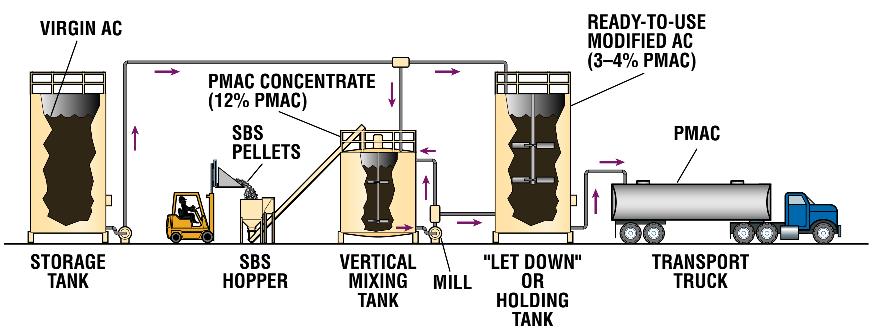
The type of PMAC mixing system used at asphalt terminals and at HMA plants depends mainly on the type of polymer being mixed. The most popular PMACs at the present time contain SB, SBR or SBS polymers.

Terminals that are set up to mix PMACs using SBS polymers usually have systems that incorporate a grinding mill. The mill shears the polymer solids as the mixture is recirculated during the mixing process, until the material is thoroughly blended. The grinding process is completed before the material is delivered to the HMA plant. However, the HMA plant does need to keep the material in constant agitation and at elevated temperatures until it is used to make HMA. However, its temperature can be reduced for extended storage.



SB Blending System For Asphalt Terminals

Figure 7



SBS Blending System For Asphalt Terminals

Figure 8

PMAC systems for asphalt terminals

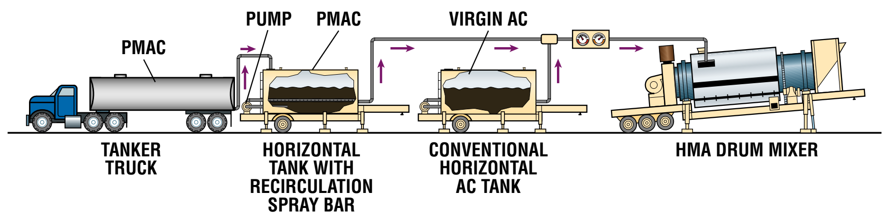
A typical asphalt terminal with a system for blending SB is illustrated in **Figure 7.** This system blends a hot, premixed liquid concentrate of asphalt and SB with hot virgin AC. The virgin AC is metered out of a heated storage tank into a heated mixing tank. The hot premixed concentrate is pumped out of a rail tanker or other storage tank into the same mixing tank. About 24 to 36 hours are required to heat the rail tanker before the concentrate can be pumped.

The two liquids are blended with each other by a mixer mounted in the side of the mixing tank. The mixer runs continuously to constantly agitate the mixture and prevent separation. The temperature of the mixture is elevated to about 170 degrees C (340 degrees F) to ensure proper blending. If the mixture is to be stored over a period of time, the temperature is reduced to prevent degradation. This is a batch system. So each batch is limited to the size of the mixing tank. A new batch is made only after the tank is emptied.

A typical asphalt terminal with a system for blending SBS is illustrated in **Figure 8.** This system blends SBS pellets with hot virgin AC. An important difference between this system and the one described in **Figure 7** is that this one requires an extra tank because it makes the concentrate on site.

The virgin AC is metered or weighed out of a heated storage tank into a

Figure 9



HMA Plant With Horizontal Tank Using Spray Bar

heated mixing tank. The SBS pellets are augured from a hopper into the same mixing tank. In the mixing tank the virgin AC and pellets are blended with each other to make a concentrate of about 12 percent polymer. Impellers of a mixer mounted through the top of the tank pull the pellets down into the liquid AC. This wets and disburses them before they are circulated through a grinding mill near the bottom of the tank. The pellets are sheared into smaller and smaller pieces as they make multiple passes through the mill. This speeds up the blending process and ensures that all of the pellets are dissolved. The temperature of the mixture is elevated to about 170 degrees C (340 degrees F) to ensure proper blending. Some of the heating is due to extra heat generated by the grinding process.

The amount of mixture made in this tank is usually limited to small batches of concentrate. This is because the mill grinds more effectively when higher concentrations of polymers pass through it. Moreover, making small batches affords better quality control. And there is less waste in case there is a problem with a batch and it can't be used. Each batch of concentrate requires about 3 to 4 hours of blending time.

After the initial blending, the concentrate is pumped into a heated *let down* or holding tank where it is blended with additional virgin AC. The virgin AC is metered to produce a mixture containing about 3 to 4 percent polymer. This tank also has a mixer mounted in its top. Its mixer runs continuously to constantly agitate the mixture and prevent separation. The mixture is maintained at a temperature of about 170 degrees C (340 degrees F). The mixture only requires about 45 to 60 minutes for blending before it is ready for load out. If the mixture is to be stored over a period of time, the temperature is reduced to prevent degradation.

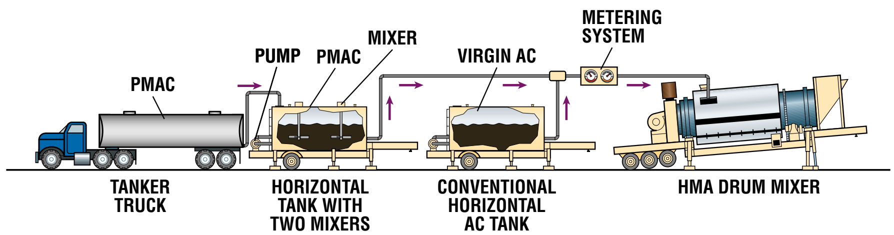
While this system is actually a batch system it has a great deal of flexibility. The holding tank is usually larger than the mixing tank and provides surge capacity. If the mixing tank cannot keep up with demand because of its smaller size and the blending times required, another mixing tank can be added.

PMAC systems for HMA plants

A number of older HMA plants have been adapted to use premixed PMAC. There are several ways it can be done, depending on the existing type of AC system in use. Some have tried to use PMACs with conventional, unmodified equipment used for unmodified AC. But the results are usually unsatisfactory.

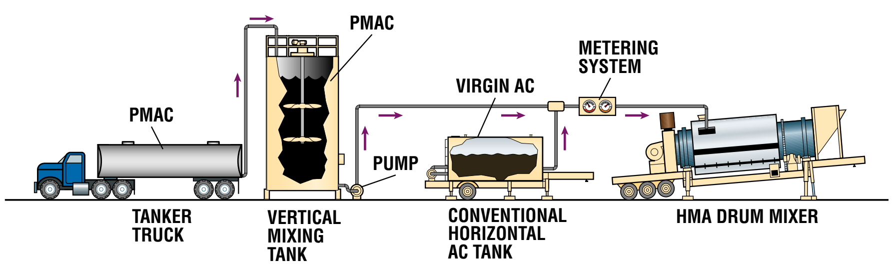
Adding a spray bar inside a horizontal AC tank that incorporates coils heated by hot oil can enable it to satisfactorily maintain PMAC **(Figure 9).** Its pumping system must be modified to constantly recirculate the material. This can be done by adding a new pumping system or by modifying the existing unloading system. Also, its heating system must be adjusted to maintain its temperature at approximately 170 degrees C (340 degrees F) or as specified by the PMAC supplier. This adaptation is very economical to make. It performs fairly well with most premixed PMACs on high volume jobs when the PMAC is stored for relatively short times. This is the type of work typically done using portable HMA plants.

This modification may take a couple of days to complete. It requires taking the tank out of service while the work is being done. The tank must be completely drained and allowed to cool before it can be modified.



HMA Plant With Horizontal Tank Using Mixers In Manholes

Figure 10



HMA Plant With Vertical Tank Using Mixer And Baffles

Figure 11

Another method has also been used to adapt a horizontal AC tank that incorporates coils heated by hot oil for use of PMAC. The adaptation is made by mounting either one or two mixers in the manholes in the top of the tank **(Figure 10).** Again, the heating system must be adjusted to maintain its temperature at approximately 170 degrees C (340 degrees F) as specified by the PMAC supplier.

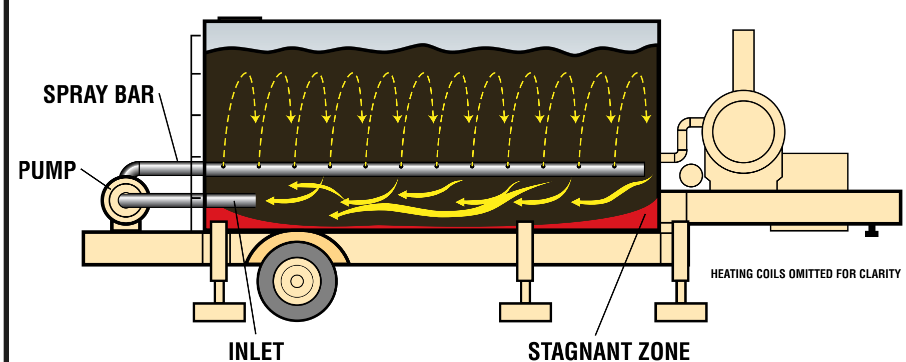
The major cost for this adaptation is for the mixers and depends on whether one or two are used. Additional costs may also be involved if new manholes or openings are added to get better positions for mixing than provided by existing manholes. In all cases this adaptation is somewhat more expensive than adding a spray bar. This adaptation performs quite well with some premixed PMACs, depending on the number of mixers and their positions.

This modification may take only a relatively short time if existing manholes are used. But if new openings have to be added the modification may take as long as adding a spray bar. The tank would have to be taken out of service while it is being modified.

Another method of adapting a HMA plant to use premixed PMACs is to add one or more heated vertical tanks designed specifically for PMACs **(Figure 11).** They work just as well with older plants as with new plants. Adding vertical tanks cost somewhat more than adapting existing tanks. But they can be expected to perform more reliably and more efficiently with virtually all PMACs. Consequently, contractors are now choosing vertical tanks over other methods.

Nearly all of the work involved in installing a new vertical tank at a HMA plant can be done without interrupting plant operation. It is usually necessary to shut down the plant only while making final connections to the existing system.

Figure 12



Flow Patterns In Horizontal Tank With Spray Bar

In some states contractors have the option of using a PMAC made with an SBR that is a water-based latex polymer. The latex polymer is usually blended with the virgin AC as both materials are pumped into the HMA mixer. The blending is accomplished by a *static in-line blender* installed in the asphalt line leading to the HMA mixer. Only minor modification is required to install the blender. Moreover, this method of blending works very well when blending this type of polymer.

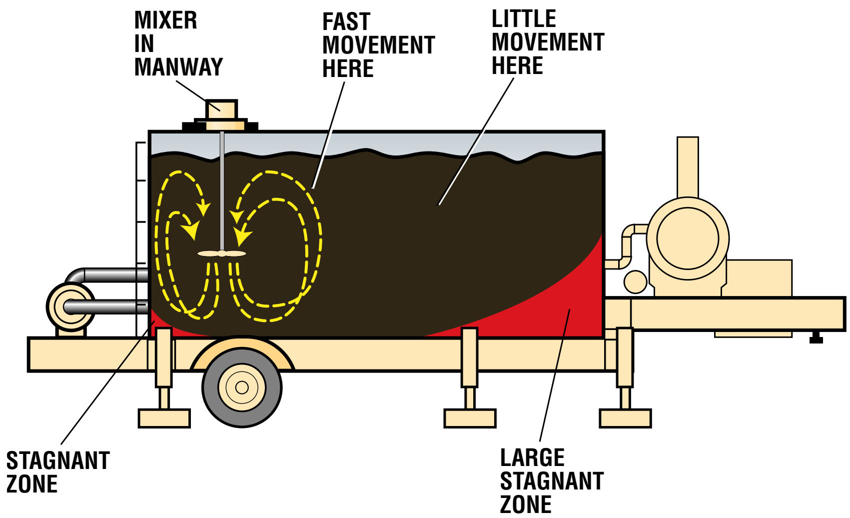
When the same mixing tank is used for more than one type of binder the contractor needs to avoid unintentionally mixing the different binders. This requires emptying the tank of the old material before filling it with the new material.

In the past, tanks were not normally emptied. So they were not designed with that in mind. Drain lines and AC pump outlets were purposely not at the very bottom of the tank. Instead, they were at a level that would maintain enough material to keep the heating coils immersed. That protected the coils from coking. Those tanks can be emptied only by inserting a drain line into the tank through the manhole and pumping all of the material out. Heatec now puts a drain valve in the very bottom of their tanks to allow them to be completely drained.

Mixing efficiency

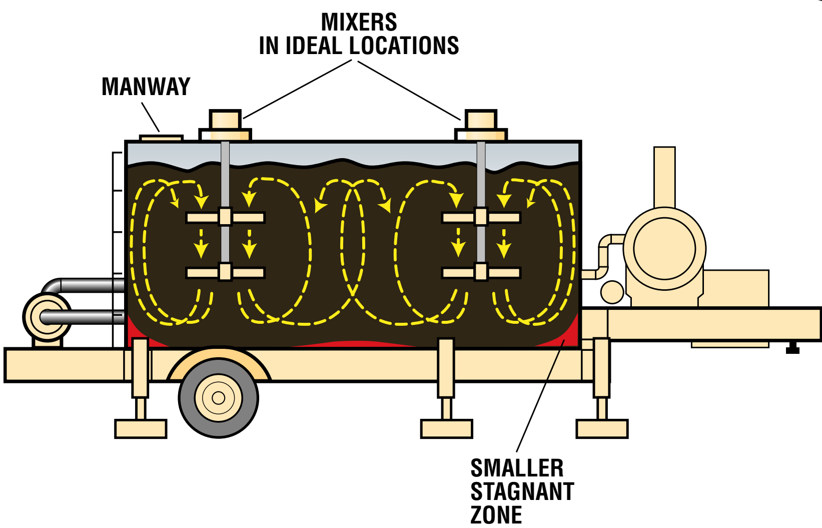
A major concern of all tanks used for PMACs is mixing efficiency. All PMAC must be thoroughly and uniformly blended before it is introduced into the hot mix. It is also important that there is no significant build-up of residue inside the PMAC tank. If residues are allowed to build up they can eventually affect the uniformity of the PMAC. Moreover, residues may also affect the heating ability of the tank and the ability to pump the PMAC. To maintain PMAC uniformity and to avoid residue build-ups the mixing system must have flow patterns that minimize stagnation zones.

Flow patterns of a horizontal tank with a spray bar are illustrated in **Figure 12.** With this arrangement some stagnant zones are unavoidable. The long range effects are not presently known. But it seems likely that there will eventually be a build up of residue in some areas. And if allowed to progress the build up may produce undesirable effects.



Flow Patterns In Horizontal Tank With One Mixer

Figure 13



Flow Patterns In Horizontal Tank With Two Mixers

Figure 14

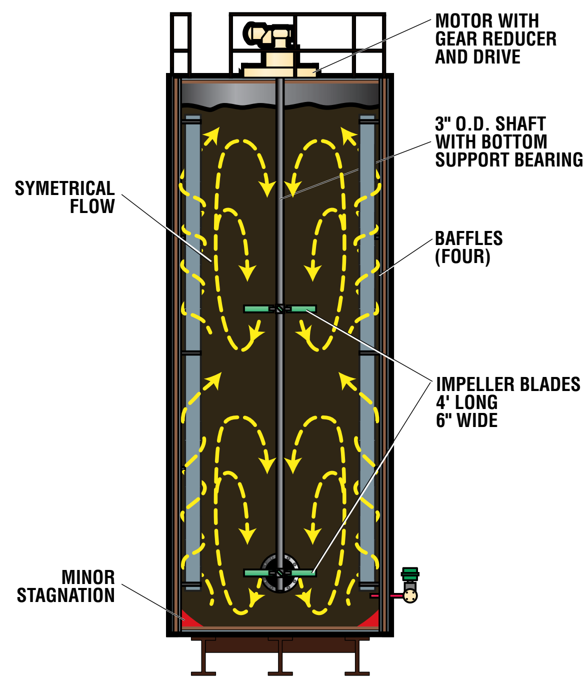
The flow patterns of a horizontal tank with one mixer in a manhole is illustrated in **Figure 13.** One drawback of inserting mixers through manholes is that the mixing blades have to be short enough to go through the opening. Thus, they cannot provide as much agitation as longer blades. Another drawback is the location of the manholes. They are usually located near the tank ends. These are not locations that will enable the mixers to produce uniform flow throughout the entire length of the tank. Some stagnant zones are unavoidable.

The flow patterns of a horizontal tank with two factory-installed mixers is illustrated in **Figure 14.** In this case the mixers are not in manholes, but are located to provide better flow patterns. They also have longer mixing blades. As might be expected, two mixers leave smaller stagnant zones than one, especially when the mixers are installed at optimum locations. It appears that two mixers at optimum locations give slightly better results than a spray bar. The long range effects of mixers in horizontal tanks are not known at the present time.

Vertical tanks have proved to make better mixing vessels than horizontal tanks mainly because of flow patterns. The flow patterns for a well-designed vertical mixing tank is illustrated in **Figure 15.** Its flow patterns appear to have very minimal stagnation zones. It has impellers that drive the liquid to the bottom of the tank and allow it to circulate upwards and around baffles on its sidewalls. Heatec and CEI have produced a number of tanks using this design. They have proved to work very well.

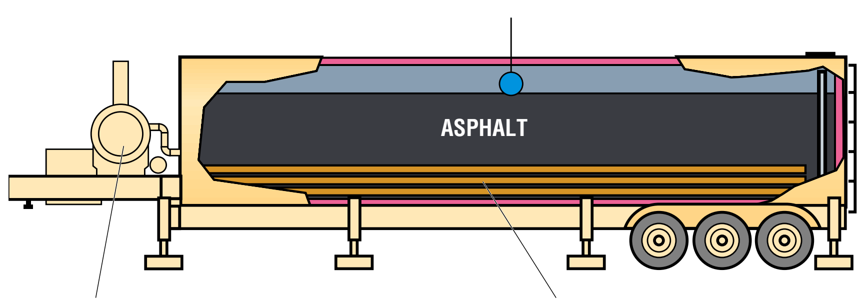
Vertical tanks also have other advantages. The area of the liquid that is exposed to air within the tank is far smaller than in a horizontal tank. Thus, the potential for oxidation is far less. It is a well known fact that oxidation occurs at a much higher rate as temperatures are

Figure 15



Flow Patterns In Vertical Tank With Impellers And Baffles

Figure16



177°C (350°F) APPROX SURFACE TEMPERATURE OF COILS

Temperatures Of Heating Surfaces In Tank Heated By Hot Oil Heater

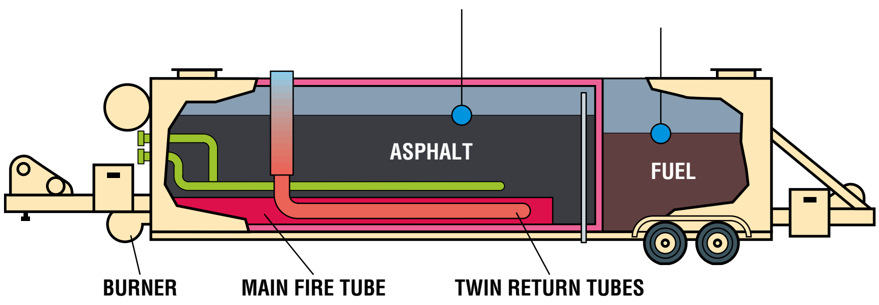
increased. Yet, PMACs must be maintained at higher temperatures to keep its components from separating. Thus, controlling oxidation is more important with PMACs than with virgin ACs used at lower temperatures.

Another advantage of the vertical tank is the land area it occupies. Vertical tanks require far fewer square feet of land than horizontal tanks.

Temperatures of heating surfaces

Most PMACs have a maximum film temperature of about 204 degrees C (400 degrees F). Thus, the material should not contact surfaces hotter than that. That does not present a problem for tanks heated with hot oil, but it does for direct-fired storage tanks.

Tanks heated with hot oil have serpentine heating coils in their bottoms (**Figure 16).** Hot oil circulates through the coils.



Temperatures Of Heating Surfaces In Direct-Fired Tank

Figure 17

The outer surfaces of these coils heat the PMAC, which is in direct contact with the coils. The temperature of these surfaces never exceed the temperature of the hot oil circulating in them.

In a direct-fired tank one end has a burner that fires directly into a fire tube that extends well into the tank and doubles back **(Figure 17).** The outer surfaces of the fire tube heat the PMAC, which is in direct contact with these surfaces. The temperature of these surfaces range from 316 to 482 degrees C (600 to 900 degrees F). Thus, some of the PMAC comes into contact with these superheated surfaces even though its overall or average temperature is maintained much lower. So direct-fired tanks will expose PMACs to temperatures that exceed the maximum allowable film temperature and will rapidly degrade the material. Consequently, direct-fired asphalt tanks are not recommended for use with PMACs. However, if one must be used despite recommendations, it is essential to equip it with a high-circulation system, such as a spray bar or mixers.

Delivery of PMACs to drum mixer or pugmill

The mixing and storage system is not the only consideration. It will probably be necessary to modify the pump and piping that delivers the liquid AC to the asphalt drum mixer or pugmill. Because PMACs are more viscous than virgin ACs they need larger pump motors and piping to maintain the same rate of flow as virgin ACs. Moreover, the pump should be located as close as possible to the PMAC storage tank to help maintain adequate pressure at the inlet port of the pump.

Choosing the equipment

Contractors who want to begin using PMACs with existing HMA facilities have to choose between adding new tanks or modifying old ones. Modifying old tanks might be more economical. But if it is done during a busy season, any plant downtime could easily lose that advantage.

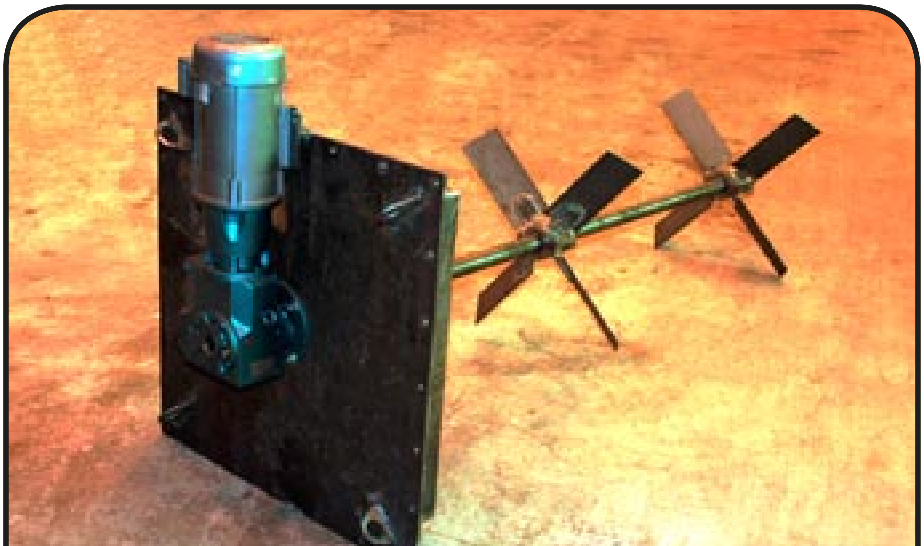
Adding new vertical mixing tanks is probably the best solution for contractors doing high volumes of PMAC. One may cost more than modifying an old tank, but it is apt to be more troublefree. Vertical tanks are preferred over horizontal ones because they work better for mixing and have other advantages.

Contractors with a portable asphalt plant that is frequently moved face a somewhat more difficult decision, especially if their plant uses a direct-fired asphalt

Figure 18

Heatec Heli-Tank With Two Factory-Installed Mixers

Figure 19



Mixer Used In Heli-Tank

tank. As already noted, direct-fired tanks are not recommended for PMACs. But if one is used anyhow, it should be modified as previously noted.

One choice for a portable plant is a new vertical mixing tank along with a new hot oil heater. The other choice is a new portable tank that incorporates heating coils and includes a hot oil heater. Heatec's Heli-tank is an example of such a tank (**Figure 18**).

The disadvantage of a vertical tank is that it is not available in a portable configuration. It is not cost-effective to equip a vertical tank with wheels and suspension or to build it with a self-erect system. However, the vertical tank can be handled with a crane and can be moved on a flat-bed trailer. A second trailer is needed for parts that will have to be detached for shipping.

Another consideration for a vertical tank is what it rests on. It normally needs a concrete pad. However, a vertical tank can rest directly on earth when extensions are bolted to its base.

Some may prefer a Heli-tank because of its portability. It can be factory-modified for PMACs either by adding a spray bar or by installing mixers (**Figure 19**). A modified Heli-tank will likely cost more than a vertical tank and heater because the Heli-tank has a chassis with wheels and suspension for highway travel.

Contractors planning to buy new non-portable HMA plants and want to use PMACs have some additional choices. A vertical mixing tank is still the best choice for PMACs. Either vertical or horizontal tanks are fine for virgin asphalt, fuel and other liquid additives. A new plant using a vertical mixing tank

HMA Plant Using Horizontal Tank And Vertical Tank

Figure 20

HMA Plant Using Tanks With Provisions For Adding Mixers Later

Figure 21

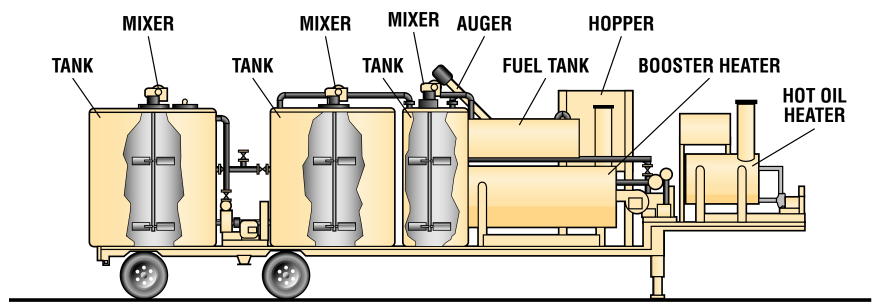
for PMAC and a horizontal tank for virgin asphalt is shown in **Figure 20.**

However, using all vertical tanks is also a logical choice and has some advantages. And some interesting options. A new plant using all vertical tanks is shown in **Figure 21.** This is a new plant recently installed in Florida and had the benefit of extraordinary planning by its owner. A close look at this plant's AC system is worthwhile.

The plant uses three 20,000 gallon vertical tanks with provisions for adding the mixers to each tank later. The tanks already have mounting flanges for the mixers and four mixing baffles. The vertical tanks are also very efficient for storing and heating unmodified asphalt and occupy smaller land areas than horizontal tanks.

The system is configured to provide a high degree of flexibility. At the present time two of the tanks store and heat different grades of unmodified liquid

Figure 22



Components Of A Batch System For Blending GTR

Figure 23

A Batch System For Blending GTR

asphalt cement. The third tank stores and heats No. 5 fuel oil, but will be used for asphalt in the future. A single condenser serves all three tanks to prevent vapors from escaping the vent system. The heater skid and tanks have two feet of clearance under them in case the containment area becomes flooded with rain water.

Two metering systems allow asphalt from the two tanks to be blended with each other on the fly. Or, asphalt from either tank can be used alone. An external supply of pre-blended asphalt-rubber can also be connected to the metering system. The system uses anti-strip agent from another tank located alongside the third tank.

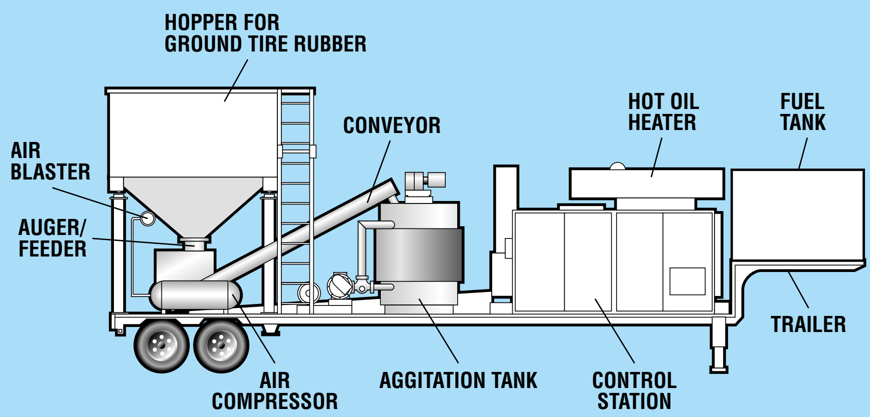
Ground tire rubber

Ground tire rubber (GTR) is not as widely used to make PMAC as other polymers. Although it is a polymer it is not processed the same way as other polymers when making PMAC. It has a greater tendency to separate than most other polymers. Premixed asphalt modified with GTR is not usually available from asphalt terminals. It is nearly always mixed with virgin AC at the HMA plant before being used to make HMA.

Systems are available designed specially for blending the GTR at HMA plants. One system uses a *batch* process. Another uses a *continuous* process. Both portable and stationary models are available.

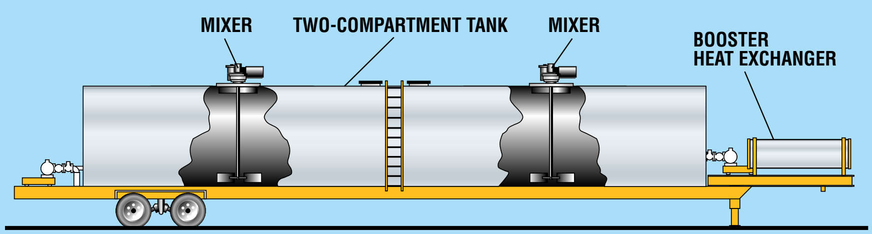
Major components of a typical *batch* process rubber system are shown in **Figure 22.** This system is designed for GTR with fine particles of 40 to 80 mesh. The system has three tanks, one hopper, an asphalt booster heater, a hot oil heater and a pumping system**.** All three tanks are used for blending and are heated by hot oil. Each has a mixing impeller powered by an electric motor. One tank holds 800 gallons. The other two each hold 3,000 gallons.

The booster heater increases the temperature of the liquid AC before it is introduced into the mix. The increased



Components Of The Primary Trailer
Used In A Continuous System For GTR

Figure 24



Components Of The Secondary Trailer
Used In A Continuous System For GTR

Figure 25

temperature makes up for heat loss resulting from the addition of unheated GTR. Moreover, the asphalt and GTR are blended at temperatures higher than those used for conventional HMA mixes. The hot oil heater maintains the tanks at the temperature prescribed for the mixture of asphalt and rubber.

A batch system built for an asphalt contractor in Florida is shown in **Figure 23.** This type of system is commonly used in Florida. Their DOT has worked closely with the University of Florida in developing procedures for using GTR. The equipment was developed by Heatec working closely with Florida contractors.

A typical *continuous* process GTR system requires two trailers, a primary and a secondary. Such systems are usually designed for GTR with coarse particles (10 to 14 mesh).

The primary trailer has a hopper for GTR, a conveyor, a heated primary mixing tank, a hot oil heater, a control station, and a fuel tank (**Figure 24**). The primary mixing tank has a mixer that rapidly wets the rubber. The system includes a mass flow asphalt meter and load cells mounted on the hopper. Mixing is controlled by a computer that can be programmed to ensure precise mixing ratios. The computer constantly monitors the system, records mix data, and safeguards against out-of-tolerance conditions.

The secondary trailer has a two-compartment tank and a booster heat exchanger (**Figure 25**). The two-compartment tank receives the rubberized asphalt after it has been mixed in the primary mixing tank and serves as a holding tank. Each compartment has a turbine mixer to keep the crumb rubber in suspension. Each compartment also has a set of coils heated by hot oil and controlled independently.

Figure 26

A Continuous System For Blending GTR

Figure 27

Typical Secondary Trailer Of A Continuous System For GTR

The booster heat exchanger increases the temperature of the virgin AC as it is pumped into the primary mixing tank on the primary trailer. The increased temperature compensates for heat loss that results from introducing GTR that is unheated.

The primary trailer of a continuous system built for a contractor in Arizona is shown in **Figure 26**. The secondary trailer used with that system is shown in **Figure 27**. This type of system is commonly used in western states of the U.S. It was developed by CEI working closely with asphalt contractors in those areas.

Choosing a system for ground tire rubber

Contractors who want to use GTR will do well to consider blending systems like those described above. The choice is mainly between a batch system and a continuous system.

The cost of the batch system is notably lower than the cost of the continuous system. The batch system, used mainly in Florida, is capable of making HMA acceptable to Florida DOT. The continuous system, used mainly in California, is capable of making HMA that meets their specifications.

Historically, the batch system has been used for GTR with fine particles, whereas the continuous system has been used for GTR with coarse particles. However, both systems can use GTR with either fine or coarse particles.

It might be noted that GTR with fine particles costs more than GTR with coarse particles. But use of GTR with coarse particles usually requires the addition of extender oils. Extender oils are typically heavy fuel oils. When added to the asphalt-rubber mixture they speed up the wetting action of the rubber particles and help reduce the stiffness of the mixture.

NOTES

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5200 WILSON RD., CHATTANOOGA, TN 37410 • PHONES 423-821-5200 • 1-800-235-5200