Asphalt Pellets: An Alternative Delivery System for Asphalt Products

Contents

Introduction

Asphalt pellets represent an innovative technology designed for convenience, precision, cost-savings and environmental protection in the delivery of bituminous binder and additives for a myriad of paving applications. The patented processes can supply almost any combination of asphalt modifiers in concentrate or ready-to-use form. The pellets form a free-flowing solid that can be transported and stored in Super Sacks or in bulk. They are designed to be mixed with heated aggregate, either for conventional hot or warm mix paving, or for unique applications requiring mix production at the paving job-site. The versatility of this technology has wide-ranging implications for solving such problems as transportation to remote locations, needs for specialized additive equipment, heat stability, binder/additive segregation, high energy consumption, slowed production schedules, waste materials, and worker safety. Pellets offer opportunities to increase profit margins, expand asphalt markets into remote areas, improve efficiency and self-promote a "green image" for recycling, energy savings and environmental stewardship.

Traditional Hot-Mix Asphalt (HMA)

The bitumen binder (modified or not) is transported hot in an insulated transport truck to the hot mix plant, where it is blended with hot aggregate. Manufacturing temperatures are usually between 150 and 190°C. The liquid binder is metered as it is pumped into the mixing chamber with pre-heated, pre-blended, pre-weighed aggregate. The hot bitumen/aggregate mixture (called hot mix, HMA, hot rolled asphalt, macadam, stone mastic asphalt, etc.) is then kept hot during storage (if any), transportation by truck to the construction site, placement of the hot mix on the road with a paver, and compaction with rollers.

Recycling of Reclaimed Asphalt Pavement (RAP)

Few people realize that aged pavement materials milled from asphalt roads represent the most recycled material in the world. In the US, 85-90% of all RAP is reused for paving applications. Historically, unbound RAP has replaced aggregate as a base material under new pavements or shoulders. But only recently has RAP been used in applications that make more economical use of the valuable asphalt contained within. Creating economic value by rejuvenating the aged, brittle asphalt in the RAP is now a high priority for highway agencies and contractors. Increasing the RAP concentration in conventional HMA and WMA is a critical part of this effort.

Warm-Mix Asphalt (WMA)

As attention turns to environmental and energy issues, there is increasing pressure for asphalt contractors to mix and lay asphalt mix at lower temperatures. The paving industry is heavily promoting Warm-Mix Asphalt (WMA) technology, which lowers construction temperatures by 15-40°C. Cited advantages included fuel savings, fewer greenhouse gases, reduced worker exposure to asphalt fumes, improved compaction of the mixture, and favorable plant operating conditions for the recycling of old reclaimed asphalt pavement (RAP). Several very different technologies fall within the definition of WMA, including chemical and organic asphalt additives.

Modification Technologies for Hot-Mix Asphalt

Asphalt is approximately 94% mineral aggregate (stone or rock), sand and filler by weight and 6% bituminous binder (called bitumen or asphalt). Although technically a liquid, bitumen is extremely viscous (thick), approaching a solid at air temperatures. In order to pump and blend the bitumen with aggregate it must be heated to thin it sufficiently. The bitumen binds the rocks together, forming a strong but flexible pavement. The problem with bitumen is that it cracks when cold and ruts (deforms) when hot. Pavement life can be extended significantly by adding elastomeric polymers such as SBS (styrene-butadiene-styrene block copolymers) or SBR (styrene-butadiene rubber latex) the asphalt. It is also possible to replace SBS with cheaper materials previously considered waste streams. In fact the paving industry has been using ground tire rubber and waste polymers for more than 50 years.

Elastomeric Polymers

Using specialized equipment, the polymer can be blended at an asphalt terminal or at the HMA plant. The primary reasons for adding elastomeric modifiers to asphalt are to improve pavement durability and lower life cycle costs. They do this by:

- Increasing serviceable temperature range (stiffen at high temperature and soften at low temperature)
- Improving the bond between bitumen and aggregate, particularly with moisture present
- Increasing the bitumen film thickness on the aggregate (thereby reducing oxidative—air and sunlight—aging)
- Improving durability—the ability to deform and recover under traffic without cracking
- Reducing permanent deformation (rutting), cracking, draindown of bitumen from the hot mix during storage and transportation, flushing and bleeding on the pavement, raveling of aggregate, stripping of bitumen/aggregate bond by moisture, fatigue damage, and life cycle costs.

SBS is one of the additives of choice because it not only fulfills the above requirements, but it is one of the few materials that, when formulated correctly, remains homogeneously suspended in the bitumen, resulting in a modified binder that doesn't separate. Hence, SBS modified bitumen can be manufactured at an asphalt terminal, where economics of scale and plant controls make processing more efficient. But SBS polymers still remain expensive, adding 30-50% to the cost of the binder. In recent years there have also been some serious butadiene shortages, making SBS supply progressively more problematic and expensive. Polymer modified bitumens (PMB), however, have proven themselves in the field and are in increasing demand. Projections for growth suggest that the PMB consumption of

the major road companies in the UK is set to increase by ~95% over the next 5 years. This demand has been driven by a number of requirements including:

- Risk transfer on contracts
- Asset management objectives
- Low noise surfaces
- On- demand supply
- Performance based specifications
- Utilization of warranties for surfaces

The demand for PMB is also expected to grow over the coming years due to:

- Hot Rolled Asphalt requiring PMB to meet new specifications
- Mixes with increased RAP contents requiring PMB binder to meet specification
- SMA mixes requiring PMB to enhance performance

Using Waste Materials for Asphalt Modification

Pavement engineers have long recognized societal needs to reuse waste materials. Asphalt itself was once considered a refining by-product before becoming accepted as the flexible paving binder of choice. And now Reclaimed Asphalt Pavement (RAP) has become the most recycled product in the world, and waste asphalt shingles are also a commonly used component for HMA. Other research has focused on the reuse of waste polymers such as ground tire rubber (GTR) and polyethylene (PE) bottles to create engineered asphalt binders. Given new pressures to derive liquid fuels from bio-based sources, asphalt availability may fall, but new bio-fuel byproducts such as lignin or bottoms from fast pyrolysis processes may be available in large quantities. Now even animal wastes such as chicken and pig manure are being investigated as possible asphalt extenders. And common aggregates are being supplemented by steel slag, crushed glass, porcelain toilets, or mine tailings, while finer materials might be substituted by fly ash, foundry sand or carbon char from pyrolyzed car tires.

Because recycled materials are not specifically designed as asphalt additives, prevailing chemistry is not typically compatible with the highly aromatic character of asphalt cement. Portable blending systems are usually needed to incorporate recycled polymers into the asphalt at the Hot-Mix Asphalt (HMA) plant. Without proper attention to processing details, binder separation occurs quickly. Waste polymers are inexpensive, typically 1/10th the cost of their virgin counterparts. However, the mobilization costs needed to bring specialized processing equipment to each paving job can make the final cost of GTR or PE modified binders more expensive than comparable projects using virgin polymers such as SBS or SBR that are inherently more asphalt compatible and can be delivered in a ready-to-use form.

Ground Tire Rubber

Ground tire rubber can be dispersed in asphalt in many ways. The crumb rubber can be added directly to the heated aggregate before the asphalt as a "dry process", or it can be pre-blended with the asphalt and digested as a "wet process". Pavements built using "dry" process technologies have experienced significant performance problems, so most highway agencies now require a "wet" process.

Asphalt Rubber

Asphalt-Rubber (AR), a blend of 80% asphalt with 20% ground tire rubber, has become an important binder for pavement surfaces on high volume roads, particularly in the southern US. Given their advantages for safety and noise reduction, open-graded AR mixes are receiving priority attention by many agencies worldwide. Most AR binders are manufactured using various versions of the original McDonald process, in which the ground rubber and asphalt are mixed at an elevated temperature for approximately two hours. The rubber particles swell to create a tacky rubber matrix within the bitumen. Accelerated pavement studies at NCAT's Test Track and FHWA's Accelerated Loading Facility (ALF) have shown well-designed AR mixes can perform as well as highly polymer modified mixes.

Unfortunately, there are two key limitations to McDonald's asphalt-rubber process that preclude manufacturing at a centralized terminal:

- The suspended rubber particles separate quickly if agitation is stopped.
- The binder reaches its optimum consistency after a relatively short blending period (e.g. 2 hours at 175°C), but then rapidly degrades with continued heating while in storage.

Hence, Asphalt-Rubber using the McDonald Process must be manufactured at the hot mix plant and blended with aggregate soon after it is produced. Even when the AR is manufactured at the HMA plant, chunks of rubber left in the liquid can block pumps and pipes and damage the hot mix plant when the bitumen is being sprayed onto the heated aggregate.

Crumb Rubber Modified Asphalt (CRM)

Crumb Rubber Modified Asphalt (CRM or CRMA) is a blend of asphalt with less than 15% GTR and other additives as needed to meet local specifications. Processing may be similar to that used for the asphalt-rubber technology described above. However, newer applications of CRM apply heat and shear to further break down the rubber particles so they do not separate from the asphalt during storage. Because extended heat tends to destroy the elasticity of the rubber, CRM formulations often include SBS or SBR polymer modifiers which are added after the crumb rubber is digested. One important application of this technique is Terminal Blend CRM.

Devulcanized Tire Rubber

Although more expensive, GTR can now be purchased as a partially devulcanized product. Breaking down the sulfur bridges in the vulcanized tire enables better dispersion of lower molecular weight molecules, while maintaining the elasticity created by the double bonds in the rubber. Unfortunately, it

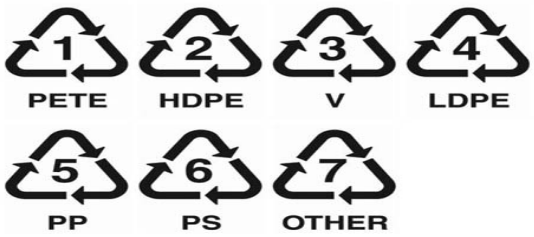
is very difficult and expensive to achieve complete devulcanization, so small chunks of rubber often remain, as does the fine but solid carbon black that was added to the tire formulation. These solid particles settle out of liquid asphalt during storage, making devulcanized rubber less attractive than virgin polymers as an asphalt modifier.

Waste Asphalt Shingles

Approximately 90 million roofing shingle squares are produced per year by 77 plants in the United States. About 1/3 of the shingles are used on new houses and the remaining 2/3 are used for reroofing houses. When a house is reroofed, an equivalent amount of old shingles is removed and discarded. Moreover, each roofing plant generates scrap materials and seconds that can range from 5 to 10 percent of the production capacity. The disposal of old shingles and the scrap material has created a difficult disposal problem. It is estimated that roofing waste contains about 36 percent asphalt content, 22 percent hard rock granules (minus No. 10), 8 percent filler and smaller amounts of miscellaneous materials. Shingles need to be shredded to at least 12.5 mm or smaller prior to introduction in the mix to ensure meltdown and uniform dispersion in the HMA mixture. Asphalt mixes are frequently formulated with 5% shingles, which replaces 30-35% of the asphalt in a typical asphalt mix.

Waste Polymers

Waste polymers exist in many chemical forms, and make up an estimated 8.3% of U.S. consumer and industrial waste. U.S. recycling guidelines classify waste plastics into seven categories. That category symbol is usually stamped on the plastic at time of manufacture. The category symbol is distinguished by the three arrow recycling logo around the category number, as shown by the figure on the right.



All of these polymers are typically comingled in consumer waste, but some recyclers then separate each of the polymer families so they can deliver relatively consistent products to commercial customers.

Waste polymers such as low-density polyethylene (LDPE) are notoriously difficult to disperse in asphalt, and separate quickly in storage even when properly dispersed by high shear mixes. The three common options to overcome separation problems are chemical stabilization, chemical functionalization of the polymer, or binder blending at the HMA plant.

Novophalt

Novophalt is an early commercial PE modified asphalt product. The Novaphalt process uses a portable high-shear mixer system to dissolve waste polyethylene into hot asphalt soon before the PMB is pumped into the mixing drum. The high-shear mixing must take place at the HMA plant due to product instability. Early Novophalt systems used only the plastic polymer polyethylene, and resulting binders were stiff and prone to crack. Later formulations blended polyethylene with SBS elastomers and performance results were promising. Unfortunately, portable high shear mixers had to be transported to

and plumbed into the HMA plants, and plant electrical systems often had to be reworked to handle the high power requirements. Moreover, mill operation required a trained operator, and local sources of clean waste polymer of the desired grade were not always available. Although pavement performance measurements were improving with the dual polymer system, the myriad of production constraints led to unfavorable manufacturing economics, preventing global marketability of the product,

Polyphalt

Polyphalt, a commercial polyethylene-asphalt blend developed by Dr. Hesp used an elegant chemical system to stabilize the PE so that it could be manufactured, stored and delivered as a proprietary blend. Again, commercial constraints on economics and performance led to the financial failure of the business venture.

Chemical Synthesis to Modify Waste Polymers

Daly and Negulescu chlorinated polyethylene to make it more compatible with asphalt. These Louisiana State researches also investigated chemical pathways to replace the chlorine with other functionalities. No significant commercial products have evolved from this research.

Each of these options for using waste plastics has substantial economic barriers that have pushed their use to the periphery of the paving industry. This is unfortunate, because waste polymers are inexpensive and do appear to have considerable value as performance enhancers when used effectively.

Asphalt Pellet Technology

Asphalt pellets are not asphalt additives, but rather represent a new delivery system for almost any combination of the additives and modifiers discussed earlier. Because pellets are manufactured at a single processing facility and then transported to the job-site at ambient temperature, most of the production inefficiencies described for the various modifier systems above are no longer relevant. The only additional production concern at the job-site is to properly proportion the pellets into the mixing chamber of the asphalt plant.

Pellet Formulation

Binder formulation in the laboratory follows standard practice as needed to satisfy performance criteria for the desired application. Many types of polymers, fibres, fillers, anti-strip chemicals and waste materials such as ground tire rubber (GTR) and asphalt shingles can be incorporated, so long as appropriate processing equipment is available. Chemical or organic warm mix additives are recommended to speed pellet dispersion and aid compaction. Unlike conventional bitumen, heated storage is not necessary, so liquid anti-strip amines or other desired additives with marginal heat stability can be considered. Because physical separation is not a problem when delivering modifiers in pellet form, the binder formulator has a greatly expanded choice of materials that could not normally be considered when modified bitumen products are shipped from a bitumen terminal. For example, crumb rubber can be partially digested using the common McDonald Process, waste polymers can be sheared

into the binder, or waste shingles can be premixed with rejuvenating chemicals to restore binder properties before manufacturing the pellet.

Once the binder meets desired specifications, mineral fillers, fibers, or other solid components are added, and the mixture is then pelletized.

The pellets may be formulated with the exact concentrations of binder and additives to produce hot mix, or they may be proportioned as a concentrated additive package to be blended with additional bitumen during the manufacture of the hot mix.

Pellet Manufacturing

Pellets can be made in several ways, including extrusion systems similar to those used by the polymer industry. Most early attempts at bitumen pelletizing had little success because of high costs, as well as problems with pellet agglomeration in storage. A new, proprietary pelleting system developed by Billian International provides high production capacity at lower cost than more traditional pelleting technologies, and addresses previous problems.

Production actually begins by manufacturing the binder to the desired grade at an asphalt terminal, incorporating modifiers as needed. Once the modified binder meets all specification criteria, it is mixed with prescribed solid additives and then pelletized. If the pellet remains tacky, a non-stick coating is applied to prevent agglomeration during storage and handling.

Pellet Concentrates

When hot liquid asphalt is readily available to a hot mix plant, economics may favour delivering modifier packages in concentrated pellet form. For such a system, approximately one-quarter to one-half of the bitumen and all of the modifiers would be delivered to the HMA mix in pellet form. Binder formulation and specification must consider the final formulation after all of the required asphalt cement has been added. Whether full strength or concentrated, the pellets make it very easy to arrive at the correct concentration of binder content to meet mix design requirements.

Using Asphalt Pellets

Because of the unique physical properties of the pellets and the ability to include many different types of

additives and modifiers, there are many more options for using asphalt pellets than for using conventional and modified liquid bitumen.

Transportation and Storage

Bitumen is normally transported in heated tanker trucks, rail cars or barges, and the shipping distances are dependent upon the ability to maintain heat or reheat the material such that it can be pumped. Asphalt Pellets are transported in bulk or in one-ton Super Sacks. They can be stored and transported at ambient, air temperatures. Unlike conventional neat or modified bitumen, pellets do not need to be heated before use. Pellets open opportunities for more modes of transportation, as well as shipping much further distances. The low temperature storage also prevents any degradation of the product by localized overheating, which often occurs when handling bitumen in drums.

Mixing with Aggregates

Conventional Hot Mix Drum or Batch Plants

Asphalt Pellets can be readily mixed with heated aggregate in conventional hot mix paving plants. Most hot mix plants use a small percentage of reclaimed asphalt pavement (RAP) in their manufacturing process. The RAP, which has been milled off of aged, cracked pavements, reduces the raw material costs for hot mix producers and provides a useful way to recycle the waste material. To use the RAP, continuous drum hot mix plants are usually fitted with a collar that adds the RAP to the heated aggregate. Pellets can be added through the RAP collar on a drum plant, weighed into the mixing chamber for a batch plant, or blown into either mixing chamber. If pellets are formulated to deliver modifier concentrates, additional asphalt would be added to the aggregate using the normal liquid spray system.

Whichever method is used, the pellets preclude the need for specialized equipment and processes typically required for the addition of fibres, chemical anti-strip additives, crumb rubber, waste polymers, hydrated lime, latex polymers, warm-mix additives, or other modifiers the mixture may require.

Portable Asphalt Heater/Mixers

Getting high quality asphalt materials for low volume mix applications such as pothole patching, utility cut repairs, driveways, pathways, car parks, golf cart paths, parks and small residential roads has always been a problem. Hot-mix plants operate to support large paving projects, and economics favour high volume output. When pavement repairs are needed, the plant may be running the wrong mix, or it may even be closed for winter. Furthermore, it can be difficult to maintain enough temperature in a small batch to get proper compaction after placement.

To overcome these problems, there are now several types of portable heater-mixers to make asphalt mixes right at the job-site. (A partial list of specialized equipment manufacturers is included as Appendix I of this report.) These heater-mixers are typically designed to support specific applications, and are usually portable enough to move along the roadway with the construction crew. Production capacity for such systems range from small (for patching applications) up to 60 mix tons per hour for car parks and roads. Mixers often resemble Portland cement mixing drums, with heaters typically powered

by natural gas or liquid fuels. More sophisticated heating systems can handle RAP as well as virgin aggregate.

Composite Asphalt Plants Combining Conventional HMA Plants with RAP Heater/Mixers

Newer mixing technologies are emerging to incorporate higher concentrations of RAP at HMA plants. As one example, 100% RAP can be heated to remove moisture, and then mixed with a pelletized modified asphalt concentrate in a pre-treatment heater-mixer. The hot RAP/pellet mixture is then proportioned into the drum or batch mixer for final blending with the hot virgin aggregate and a conventional bitumen. This technique overcomes problems with drying wet RAP by overheating virgin aggregates, making it faster and more economical to produce mixes with 30% RAP or more.

Applications and Advantages of Asphalt Pellets

Asphalt pelleting technology provides a particularly convenient means to deliver almost any combination of asphalt modifiers in concentrate or ready-to-use form for a wide range of road paving applications.

Asphalt Mixtures for Remote Locations

One of the most obvious advantages of asphalt pellets is the ease of transporting the materials at ambient temperatures using all possible modes of transportation. Unlike traditional bitumen products, they do not need heating, and are shipped as a solid rather than a liquid. It is also a cheaper way to store bitumen in areas that are too cold to pave during winter. Further, there is no danger of contamination in liquid transport vehicles (or tanks) that have not been completely emptied of their previous cargo. Bitumen quality varies throughout the world; the chemistry of the crude oil source determines the temperature susceptibility, resistance to oxidation, and the adhesive and cohesive properties. Asphalt pellets allow efficient transportation of high quality modified bitumen to areas where it is needed, whether it is from an oil refinery to a remote island pavement construction site, or from a contractor's storage barn to a small utility cut.

For remote paving applications, pellets are formulated with all of the asphalt in the pellet, so that no hot asphalt would need to be used. This latter option enables:

- contractors and municipalities to produce their own hot mix for paving and patching, including work in remote areas that are far away from the nearest HMA Plant.
- customers located in colder climates can carry on patching and paving throughout the winter when the local plants are typically closed for 4 months of the year due to snow and ice.
- aggregates to be stockpiled near the jobsite at night or when construction traffic is least disruptive to normal traffic flow.
- high quality modified binders to be used for smaller jobs.

Potholes, Utility Cuts, Car Parks, Paths and other Small Paving Applications

Municipalities who do their own work or contractors specializing in applications such as utility cut repairs, pothole patching, golf cart paths, parks, trails, small residential roads etc. can use the pellets on-site, manufacturing the mix as needed for a particular project. This relieves them of their dependence upon hot mix producers whose equipment and economics favour high production rates and large projects. It avoids driving to and from the hot mix plants which are often busy, and it eliminates the surplus asphalt at the end of the day or the mix which is too cold and has to be discarded. And most importantly, the asphalt mix design including binder grade and additives is selected to meet the needs for the application at hand rather than the nearest high-volume paving project.

Most pot-hole gangs in the UK pay~£65-£90 per ton for small quantities of hot mix. By using the Asphalt Pellet system customers can produce higher quality longer lasting modified hot mix at the roadside with no waste and better compaction from heating on site for ~£47 per ton with no waste. Most patching gangs will travel to and from the hot mix plant on average twice per day. By eliminating this wasted time, the gangs are able to repair more potholes, thus increasing efficiency and profitability.

Paving Pellets provide an even greater cost saving for repairing utility trenches. This is because the trenches are often filled in with binder course or cold mix that then has to be milled off and correctly filled with wearing course at a later date. This whole process requires many man-hours and machine time, plus the additional material costs of a temporary repair followed by a more permanent solution. By enabling the contractor to execute a permanent one time repair at the road side with the correct mix design and temperature for compaction, contractors are able to avoid the additional cost of closing the road a second time, digging out the temporary mix, getting rid of the waste and patching it again with the correct mix within days of completing the original utility repairs. It is also difficult to achieve the correct compaction and air voids when only replacing the top two inches of a trench with wearing course. As a result, the utility companies often incur large fines from their local government authorities for trenches that do not meet the required specifications.

Asphalt pellets offer many advantages over conventional bitumen to the paving contractor using small job-site mixing plants, including:

- a binder grade selected for the project.
- a much larger choice of modifiers and additives to improve performance.
- a high quality mineral filler such as hydrated lime which has been formulated into the pellet.
- different pellet formulations which enable the mix to be tailored to the location and need.
- no need to deliver and store small quantities of hot liquid asphalt, which is expensive and problematic.
- pre-weighed sacks of pellets proportioned for single full batches of mix.
- unused pellets may be stored indefinitely until needed.

Recycling of Waste Materials and Other "Green" Paving

Pellets create a particularly convenient mechanism for introducing green paving technologies, such as warm mix, hot recycling of reclaimed asphalt pavement (RAP), and the incorporation of waste materials (crumb rubber, recycled polyethylene, waste shingles) into the asphalt mixture. A typical price for Ground Tire Rubber (GTR) is £130 per ton. This is approximately 30% of the cost of the asphalt being modified, and less than 5% of the cost of virgin elastomers such as SBS. (SBS is currently~£3,000 per ton.) Reducing the percentage of the SBS from 3 to 1.5% and adding as much as 18% GTR (all based on weight of total binder) results in an effective paving material that also eliminates significant numbers of waste tires. By eliminating the mobilization costs needed to process waste polymers into the asphalt at the HMA plant, asphalt pellets change the economic balance to favour recycled rather than virgin polymers. For small producers, the pellets can be used to produce mixes using up to 100% RAP in place of virgin aggregates. Imagine the cost savings if RAP from a utility cut could be crushed and remixed on-site

And hot mix plants trials have demonstrated the ability to use an asphalt recycler to produce a high quality mix with 95% RAP and 5% pellets. This can then be immediately added to the mixing drum of the hot mix plant at the correct temperature as a way to get more RAP into the mix without overheating virgin aggregate, which slows production and reduces the quality of the overall mix. The industry already recycles 85-90% of the RAP milled of pavements each year, but the value of these recycled materials can be significantly enhanced by using pellets. Further, by incorporating thousands of recycled tires, plastic water bottles or other discarded polymers, asphalt pellets can encourage recycling by converting waste into a valuable raw material which extends pavement life at minimal cost.

Hot Mix (Hot Rolled Asphalt, SMA, Open Mixes, Macadam, HMA)

Asphalt pellets can be used in two ways in hot mix plants. Both improve convenience and increase production rates. They can be supplied as concentrates of modifiers, meant to be added with virgin bitumen, or they can be supplied as the total bitumen concentration. Paving Pellets do not need to be reheated, they are simply conveyed into the heated aggregate, either via the RAP feeder or by blowing the free-flowing pellets into the hot aggregate. They then melt to create a finished mix with the desired performance characteristics.

Additive Concentrates

Pellets are particularly useful when producing specialty mixes such as Stone Mastic Asphalt (SMA). The fibres, fillers and polymers needed for such mixtures can easily be incorporated into the pellets. Because pellets are stored and transported at ambient temperature, liquid amine anti-stripping agents don't degrade and polymers don't separate as they would in heated tanks. When formulated into the pellet, hydrated lime dust won't fill the baghouse or cause particulate emissions problems. Fibres can be distributed more uniformly and with better coating. Alternative polymers that separate or agglomerate in bitumen tanks can now be effectively used. And most importantly, pelleting technology is uniquely suited to deliver high quality paving binders when using recycled products such as ground tire rubber, waste shingles and recycled plastic, or when replacing virgin aggregate with high

percentages of Reclaimed Asphalt Pavement (RAP). Because the pellets come pre-blended with these additives, there is less waste.

Logistics

Allowing asphalt contractors to have a ready supply of polymer stored in pellet form at each of their plants frees them from their dependence on having to schedule deliveries of PMB from the bitumen supplier just in time as they need it. No more charges for demurrage or returned freight if bad weather or equipment breakdowns send asphalt tankers home loaded when asphalt tanks are full.

Reducing Transportation, Manufacture and Construction Temperatures – Warm Mix

Organic or chemical Warm Mix Asphalt (WMA) additives can keep manufacture and construction temperatures low. The lower temperatures protect the environment and workers. Asphalt pellets are transported dry; they avoid the potential for burns and spills that sometimes occur while transporting heated bitumen. The incorporation of warm mix additives into the pellet allows the mix to be manufactured and compacted at lower temperatures, with commensurate savings in fuel and reduced fume emissions.

Commercial Pelleting Technologies

NiTech – NiBlock Technology for Pelletized Asphalt

NiTech's website introduction to NiBlock states that its "Patented coating technology allows asphalt to be stored as free flowing asphalts at ambient temperature, thus saving the energy required to maintain asphalt as a molten liquid during storage. The asphalt pellets can then be mixed with stone aggregate heated on site on demand, to create hot mix for HMA or SMA paving. Testing indicates hot mix from pellets provides equivalent quality of conventional hot mix procured from batch or drum plants."[1]

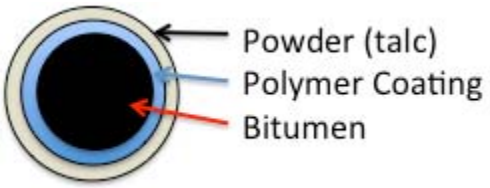


Figure #1

As shown in figure #1, the NiTech pellet encapsulates the liquid binder in a polymer shell, which is then coated with a very fine powder to reduce tackiness. The powder is thought to be a fine clay, but this has not been confirmed. Surface active clays have been documented to contribute to moisture damage in asphalt mixes, so the choice of coating powder is critical to performance.

[1] NiTech Website: http://www.nitechcorp.com/PelletizedAsphalt.html

Billian International – Stabilized "Asphalt Pellets"

Billian International's website[2] describes its corporate vision as follows: "Billian specializes in products and processes that meet needs for minimizing effects on our environment while providing common sense solutions that improve:

- Cost-effectiveness
- Profitability
- Efficiency
- Sustainability
- Transportation options
- Worker health, safety, and the environment
- Recycling and repurposing waste materials

Billian's founder, Bill Bailey, has been developing pelleting technology for asphalt modifiers for twenty years. His consult, inventions & patents include pelleting development with Fox for Trinidad Lake Asphalt, Shell's THIOPAVE pelletized sulfur, and Billian-Lhoist's EZ-Lime pelletized hydrated lime additive. More recently he combined his EZ-Lime system with his many year's of experience with asphalt-rubber to create Asphalt Pellets, a proprietary blend consisting of asphalt, crumb rubber, hydrated lime, and other modifiers. The versatility of this system has led to further research covering the pelletization of asphalt with a broad range of modifiers, some of which were described earlier. As a solutions provider, Billian does not just sell pre-manufactured pellets. As a service provider to its customers and partners, Billian provides a range capabilities needed to develop and maintain attractive business opportunities, including:

- tailor-made pellet formulations for desired applications
- pelleting systems and equipment to support addition of selected modifiers
- heater-mixer equipment designed to mix pellets with aggregate or RAP on-site

Billian Intellectual Property:

Patents issued (Dec. '08 and March '09) for the Paving Pellet products run for 20 years. Issued patent numbers are USPTO/PCT 7,303,623 and 7,517,401 plus a process patent. Two more patents are pending for new products (pelleting neat asphalt w/ polymer coatings & WMX warm mix pellets) and a second 'asphalt rubber patent' is PCT pending as well.[3]

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[2] Billian International Website: www.pavingpellets.com
[3] www.pavingpellets.com

Billian UK Limited:

Billian UK Limited is a specialized waste recycling company focused on the production and supply of "Paving pellets" to the road paving industry in the UK.

Bailey Pelleting Technology

Rather than applying a thick coating to prevent agglomeration, Bailey's pelleting technology suspends high quality mineral fillers in the binder to reduce tack. Hydrated lime is preferred because years of study have shown this additive to be the best option to reduce moisture damage, as well as being the mineral filler with the most pronounced stiffening effect to resist rutting. No clays or other moisture sensitive fillers are used. To date, Billian pelleting technology has been optimized for blends of asphalt, hydrated lime, and crumb rubber. The liquid asphalt-rubber blend is normally digested following guidelines for McDonald's Asphalt-Rubber Process, but other crumb rubber systems can also be pelletized. If necessary to prevent agglomeration, these pellets can be coated with any of several materials which are themselves asphalt modifiers. Warm-mix additives are typically included as compaction aids.

Economic, Strategic and Environmental Advantages for Asphalt Pellets

- All asphalt modifiers and specialized mixture components can be delivered to the hot-mix plant in a single concentrate pellet.
    - No specialized plant equipment is needed to blend asphalt with rubber, polymer, latex, hydrated lime, WMA additives, shingles, liquid amines, fibers or other modifiers.
    - Much higher RAP concentrations can be attained without damaging drum flights from overheating the virgin aggregate fraction
- Hot-mix can be made in portable heater/mixers at the paving site for patching, utility cuts, off-season repairs, driveways, parking lots, or small paving projects.
- Modified binders can be shipped directly to remote paving sites using super sacks packed in standard freight containers.
    - No need for asphalt terminals
    - No heated storage tanks or insulated tanker trucks
    - No dangerous handling of hot asphalt in drums
    - RAP can be preheated and mixed with pellets, enabling much higher RAP concentrations containing up to 100% hot-recycled RAP mixes.
- Waste products can be formulated into binders without worry of phase separation during storage.
    - Crumb rubber can be digested using McDonald Process technology.

  - Partially devulcanized crumb rubber can be used without concern for carbon black or crumbs of rubber that remain vulcanized
  - Polymers from waste plastic recyclers can be melted or sheared into the asphalt without concern for phase separation
  - Waste asphalt shingles can be premixed with rejuvenators, and then added to the pellet without concern for settlement of the solid materials (sand, fibers) that make up the shingle
- WMA savings of energy and emissions can be maintained
- Reduced energy consumption and "greenhouse" emissions
  - No energy needed for transporting and storing hot asphalt
  - Less material transportation (No trips to HMA plant, Use of local RAP, No returned loads)
  - Warm-mix technology with lower construction temperatures
- Less waste (asphalt mix too cold; unused additives)

Appendix I: Portable Asphalt Heater/Mixer Systems

Many companies are now manufacturing low capacity, portable asphalt heater-mixer systems. Some systems are specific to an application (e.g. RAP for patch mixes), some are designed for emergency repairs (remote runways), and others are simply scaled to produce hot-mix asphalt to predesigned capacity on-site. Some examples of companies and equipment are listed below.

RSL Plant Manufacturing and Solutions in Recycling (Leicestershire, England)

VEB-4000 Mobile Asphalt Recycling Vehicle (Capacity: up to 60 tons per hour)

Pot Hole Buster

Whenzhou Engineering Machinery Co., Ltd (Zhejiang, China)

SLJ-10 Asphalt Mixer (Capacity: 10 tons per hour)

Sinosun Group (Zhengzhou, China)

SLB Series Portable Asphalt Mixing Plant

White Birch Co. Ltd. (Shijiazhuang, China)

Portable Asphalt Mixing Plant

HD Equipment Sales and Service (Sioux Ste. Marie, Ont. - Canada)

Astencook Portable Asphalt Recycler Mini Batch Plants

Stepp Manufacturing (North Branch, MN - US)

SRM 10-20 Pothole Patcher – Asphalt Recycler