PMA Facts

Benefits of PMAs

Increasing traffic volumes, vehicle loads and tire pressures are causing accelerated degradation of our road pavements. Improved materials, such as polymer-modified asphalts (PMAs), are being used as a means of better combating these effects.

PMAs have been used in North America for many years to reduce the amount and severity of distress and extend the service life of hot mix asphalt (HMA) pavements and overlays. Particular types of PMA can be selected to increase the mixture's resistance to rutting as well as for increased durability and resistance to thermal and fatigue cracking. Most transportation agencies use PMA only in the wearing surface or the top 2 to 4 inches of pavement when the PG binder specification dictates the need. However, some use PMA in all the HMA mixtures of the pavement including the binder layers. Additionally there are also proprietary PMAs that can be designed for specific HMA pavement performance requirements.

In sprayed seal and interlayer (membrane) applications, polymers can greatly prolong pavement life by inhibiting reflective cracking. In dense-graded asphalt applications, PMAs are effective in reducing rutting and improving fatigue and thermal crack resistance. The higher shear resistance provided by PMAs can provide beneficial effects at intersections, tight corners and other high stress areas. Polymers, particularly elastomeric polymers, have also demonstrated the ability to prolong the life of open-graded surfacings by improving HMA binder drainage properties and thus allowing thicker binder films, which are less prone to oxidation. Greater adhesive and cohesive properties imparted by elastomeric PMAs vastly improve the surfacing's resistance to aggregate loss.and tougher films that resist collection of foreign matter and dust, thus maintaining the desirable water drainage capacity of these mixes.

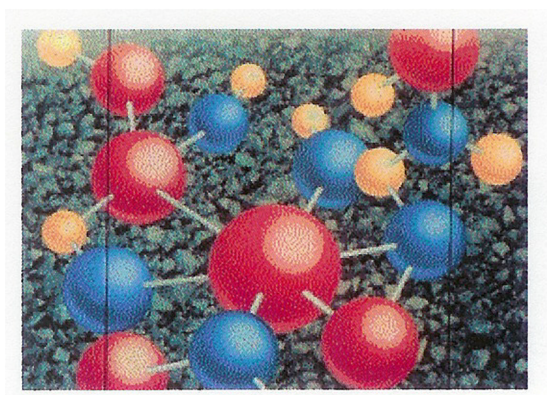
A recent study sponsored by the Asphalt Institute, “Quantification of the Effects of Polymer-Modified Asphalt”, quantifies the enhanced performance characteristics of PMA mixtures. A comparison of PMA test sections and their companion sections showed that the use of an appropriate PMA will definitely extend the service life of flexible pavements and HMA overlays. The PMA mixtures that were studied were found to have lower amounts of fatigue cracking, transverse cracking and rutting. On average, the amount of fatigue cracking exhibited on flexible pavements that include the use of PMA wearing and binder mixtures was about half of the cracking exhibited on companion projects.

The amount of rutting with PMA mixtures was about 40% of that on companion projects. Average service life increased by 25% using PMA mixtures or by 2 to 10 years compared to conventional unmodified HMA mixtures. Use of PMA mixtures can also decrease the cost of maintenance along with the associated traffic delays and safety concerns.

What is a polymer?

'Polymer' is a derived word meaning "of many parts". Polymers can be thought of as long chemical strands that are made up of many smaller chemicals (monomers) that are joined together. Natural polymers, such as cotton, starch, proteins, wool and natural rubber, have been known for centuries. Early in the 20th Century, the first synthetic polymers, such as bakelite, nylon and synthetic rubber, were discovered. Since then, then the use of polymers has grown tremendously.

Polymers are made by chemically connecting small molecules. The same or different small molecules or monomers can be joined together to form polymers. Names of polymers are usually based on the names of the monomers used to make the specific polymer. Thus, the polymer that comes from polymerizing ethylene monomers is polyethylene.



Most often when monomers are polymerized, they form long chains. This type of polymer, called a thermoplastic, can be melted and reformed. Nylon, polyethylene, and polyethylene terephthalate (PET) used in clear bottles are examples of thermoplastics. If, on the other hand, the small molecules are connected to form a three-dimensional network, the polymer is called a thermoset. After polymerization, the shape of a thermoset polymer is permanent. Epoxy resins and vulcanized rubber are examples of thermosets.

Polymers can be made up of different numbers of the monomers and therefore they can have different 'chain lengths'. Only certain chain lengths may be suitable for a particular polymer type when used in asphalt. For example, the polymer 'polystyrene' is made up of many styrene molecules linked together one after the other. A copolymer has two different sorts of repeating molecular units. The most common co-monomer used with styrene is butadiene. Block copolymers, such as styrene-butadiene-styrene (SBS), have these repeating molecular units in a regularly occurring block pattern. When styrene and butadiene are polymerized in a random arrangement, the polymer is called styrene-butadiene rubber or SBR. The physical and chemical properties of a polymer will depend on the nature of the individual molecular units, the number of units in each polymer chain and their combination with other molecular types. Polymers can also have either a linear structure or a radial structure. Consequently, the different polymers behave in different ways and generally the different PMAs have to be tried out in asphalt applications before they can be considered suitable.

Polymers Commonly Used in Asphalt

The two basic types of polymer used in modifying asphalt for road applications in North America are elastomers and plastomers.

Elastomers

An **elastomer** is a polymer that has a flexible 'rubber' backbone and large side-chains in its structure. Styrene butadiene styrene (SBS) is an example of this type. Thermoplastic elastomers derive their strength and elasticity from a physical cross-linking of the molecules into a three dimensional network. For SBS, it is the polystyrene end-blocks that impart strength to the polymer and the mid-block butadiene that gives the material its exceptional elasticity. This combination of strength and elasticity gives SBS modified asphalts the ability to resist permanent deformation and to minimize fatigue and low temperature cracking. Upon heating, the polystyrene softens and will even dissociate under stress, thus allowing easy processing. Upon cooling, the cross linked polymer network is restored, i.e. the material is thermoplastic. SBS-based PMAs are reasonably easy to manufacture by blending powdered SBS polymer into an asphalt using low to medium shear mixing. Cross-linking additives such as elemental sulfur or other proprietary chemicals, or even high temperatures, can enhance the linking of the asphalt with the polymer structure and can minimize the amount of polymer needed for a given level of performance.

SBS is the most common asphalt polymer used in the US. SBS is a triblock copolymer incorporating styrene sections attached to a central butadiene section. As with most polymers, SBS is available in many different forms. The polymer molecules can be different lengths and can have different arrangements of the molecules. These differences can affect the degree of modification provided by the polymer, as well as the ease of blending and the storage stability.

Other common elastomers include, **SB**, which is a diblock copolymer of styrene-butadiene, and **PBD**, which is Polybutadiene a polymer formed from the polymerization of the monomer 1, 3-butadiene.

Styrene-butadiene rubber latex (**SBR**) is a random copolymer of styrene and butadiene in a water based system. SBR is often used in asphalt emulsions for chip sealing or slurry seals.

Ground tire rubber (**GTR**) or crumb rubber (**CR**) is produced from recycled tires. The method of processing the recycled tires can have significant effects on the consistency of performance of the PMA mixture.

Ethylene terpolymer, commonly known through its brand name Elvaloy®, consists of an ethylene backbone with copolymers of n-butyl acrylate and glycidyl methacrylate. (The word terpolymer refers to a polymer made from three subunits.)

Plastomers

A **plastomer** is a polymer that will deform in a plastic or viscous manner at melt temperatures and becomes hard and stiff at low temperatures, i.e. the structure is reversibly broken down with the application of heat. Whereas elastomers can improve the resistance to rutting as well as low temperature and fatigue cracking, plastomers will generally only improve the resistance to rutting.

Ethylene vinyl acetate (**EVA**) is the most common plastomer used in asphalt and acts by making the PMA stiffer than conventional asphalt. EVA polymers are easily blended into asphalt by simple low shear mixing. As with most PMA systems, there must be compatibility between the base asphalt and the EVA polymer to ensure optimum properties are achieved. Phase separation of the EVA polymer from the PMA can be a problem in storage.

Blending Polymers and Asphalt

The art of good asphalt modification is in trying to make the overall binder behave more like the polymer while maintaining good workability in the end-use application. When the polymer is blended into the asphalt it is dispersed either as discrete particles or as a three-dimensional network in the asphalt. The challenge is to form and maintain the desirable network consistently in different asphalt types and for prolonged periods in hot storage. Some polymers form networks under correct conditions due to their structure while other polymers need chemical cross-linking to form a network.

It is important to note that, an incorrectly blended PMA may result in unsatisfactory performance in certain cases. To produce a good PMA a number of factors need to be considered. Due to its complex chemical nature and the interactions between different chemical species in asphalt, there is almost invariably a delicate balance in terms of compatibility between any polymer modifier and asphalt. Achieving this balance depends not only on the accurate selection of grade and chemical composition of base asphalt and polymer modifier (microstructure, molecular weight, total amount) but also on the processing conditions (temperature, time, plant design) used for the production of the PMA. If the correct chemical balance is not accurately achieved, the performance of the PMA could be impaired.

Asphalt can be processed from a variety of different crude oils and its broad chemical composition can be determined by analytical techniques such as thin layer chromatography (Iatroscan). The four main components are referred to as saturates, aromatics, resins and asphaltenes. The relative ratios of these components have a major influence on the way a polymer is solubilized or can swell in the base asphalt and therefore greatly influence the end-performance of the PMA.

Polymer – asphalt compatibility with a specific base asphalt does not necessarily mean that this base asphalt will be compatible with other types of polymers. Chemical cross-linking can be used to avoid some of the difficulties encountered when blending a PMA and may provide further increases in performance by locking networks in place; however, if not used correctly PMA blends may become extremely viscous and form gels.