Functions of Fillers in Bituminous Mixes

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A filler defined as that fraction of an inert mineral dust passing the 200-mesh sieve in a bituminous mixture can perform several functions. One function is that of filling voids in coarser aggregates, which increases the density, stability, and toughness of a conventional bituminous paving mixture. Another, is the creation of a filler-asphalt mastic in which the particles of dust either may be individually coated with asphalt or are incorporated into the asphalt in mechanical and colloidal suspension. These forms of mastic are produced by special processes, such as cooking, atomized asphalt, and foamed asphalt. In paving mixtures the mastic serves as the cementing agent.

The effect of fillers in conventional-type mixes is pronounced. Excess quantity of filler tends to increase stability, brittleness, and proclivity to cracking. Deficiency of filler tends to increase void content, lower stability, and soften the mix.

In mastic mixes the quantity of filler used is not critical. When filler particles are individually coated with thin films of asphalt, strong, stable, tough mixes may be prepared composed of 100 percent filler with 20 to 25 percent of asphalt. In mixes wherein the filler is in suspension in the asphalt (such as the hot liquid asphalt mastic mixes, Gussasphalt, roofing, and waterproofing compounds) the filler-asphalt mastic is the cementing agent. The properties of the filler-asphalt mastic are influenced by the quantity of filler in suspension. An asphalt cement of 200-plus penetration containing 30 to 40 percent of filler will form a cementing agent or binder having a penetration of about 10. However, the asphalt cement itself still retains its original penetration. This phenomenon has been observed in relation with natural asphalts (such as Trinidad), which contain mineral dusts in suspension. The use of such mastics in paving mixtures permits use of higher dust quantities and higher mixing temperatures, yielding tougher denser mixes. Special mixing processes (such as cooking, atomized asphalt, or foamed asphalt) are required to produce such mixes.

•BEFORE any discussion of the functions or behavior of fillers in bituminous mixes can be undertaken, it is essential that the term filler be clearly defined. In the industry the word is used loosely, including almost any mineral flour or dust regardless of basic origin and chemical composition, varying in particle size distribution from passing a No. 10 sieve down to passing a No. 325 sieve. For the purposes of this discussion the term will be restricted to that fraction of a mineral aggregate, flour, or dust present in a bituminous mixture that passes the No. 200 sieve.

Investigations concerning some aspects of the behavior and function of fillers and their effects upon the physical properties of a bituminous mix have been spasmodic, waxing and waning as specific problems arose. Most of these investigations have been directed toward the determination of the ranges of quantity of filler used in conjunction with a specific aggregate blend or mix. Although there has been much theorizing, there has been a lack of study and a dearth of literature pertaining to the actual behavior and specific functions of fillers of various size, shape, source, mineral composition, and their effect on the paving mixture. Unquestionably all of these factors have some effect on the function, behavior, and effects of a filler.

Two fundamental theories, based on the results of studies, observations, and experience, have emerged regarding the functions of fillers in bituminous mixes. One of these theories, referred to herein as the filler theory, postulates that the filler serves to fill voids in the mineral aggregates and thereby create a denser mix. The other theory, referred to as the mastic theory, proposes that the filler and asphalt combine to form a mastic which acts to fill voids and also bind aggregate particles together into a dense mass (1, 2, 3).

The filler theory presumes that each particle of the filler is individually coated with asphalt and that such coated particles, either discrete or attached to an aggregate particle, serve to fill the voids in the aggregate. By virtue of such filling of voids, mixes of higher stability and density can be attained.

Actually in practice the basic assumption of the filler theory is not wholly valid when mixes are prepared by conventional means. Special mixing processes, such as the foamed asphalt process (4) or impact process (5), which can produce extremely thin films of asphalt on the particles, are required to attain full validity of this premise. In conventional mixing operations, observations and tests have shown that only a small portion of the filler particles are individually coated while a larger portion tends to form small agglomeration of particles that are coated, and the remainder adhering to the surfaces of the aggregate particles are coated as integral parts of the aggregates. Regardless of the manner in which filler particles are coated, they do, however, serve to fill void spaces between aggregate particles.

Studies and tests have verified the fact that increasing quantities of filler tend to increase the stability and density of the mix. There is, however, a limit to the beneficial effects of increasing filler content. As filler content increases the brittleness and tendency of the mix to dry out and crack in service also increases. Thus a large portion of the literature pertaining to fillers deals with the optimum quantity of filler for a specific mix. Over the years the quantity of filler used in mixes has fluctuated between high filler content at one period and low filler content at another period. Generally the filler content of a mix seems to depend largely on the specific mix, the gradation of blends of aggregate available, the source and quantity of the filler available, and the preferences of the mix designer. Consequently very little has been done concerning the effects of various types and other properties of fillers.

Experience has indicated that not only the quantity of filler present but also the manner in which the particles are coated has some bearing on the durability of the mix in service. When particles are individually coated with thin films of asphalt, as attained in the special processes mentioned, indications are that good durability can be secured. When agglomerations of filler particles are coated, which frequently occurs in conventional operations, the agglomerations break down under traffic, releasing the individual particles of filler in an agglomeration to adsorb asphalt from the mix and thereby cause a drying of the mix with its attending decrease in durability. In cases where such agglomerations break down at the surface of a pavement pitting or moisture absorption may result, causing other adverse effects. Integral coating of aggregates with filler particles adhering to their surfaces impairs good adhesion between asphalt and aggregate which may enhance stripping.

Other important properties of a filler that undoubtedly have a material effect on its function and behavior are particle-size distribution, particle shape (6), chemical composition (7), and surface reactivity.

Fillers, as described herein, may vary widely with respect to particle-size distribution below the No. 200 mesh sieve. Thus a filler having a larger fraction retained on the No. 325 sieve may conglomerate differently than one with a smaller fraction. Further, the extremely fine particles may tend to adhere more readily to aggregate surfaces than coarser particles. Such variable behavior would have its effects on uniformity and service behavior of mixes.

It is generally recognized that filler particles may be readily suspended in asphalts and that the finer particles will remain in suspension longer than coarser particles. Such suspensions may be either mechanical or colloidal in character. The extremely fine particles may enter in colloidal suspension, while the coarser particles may be held in mechanical suspension. When a filler becomes suspended in an asphalt, a mastic is created that has a lower consistency, as measured by the penetrometer, than the original asphalt cement. When the filler is removed from the mastic the asphalt cement may be recovered with very little change in its original properties. This phenomenon is analogous to that in natural asphalt cements. Trinidad Lake asphalt, which contains in excess of 15 percent of mineral in both mechanical and colloidal suspension, may have a penetration as low as 10, yet the asphalt cement recovered therefrom has a penetration of nearly 200. An important distinction between an asphalt cement without filler and a mastic of the same asphalt cement containing filler in suspension should be recognized. A mastic of this type is harder, stiffer, tougher, and possesses a lower temperature susceptibility than the original asphalt cement. Thus the presence of a mastic in a bituminous mix may have material influence on its properties.

The literature does not contain any work having been done concerning the effect of the shape of filler particles on the properties of a bituminous mix. In most studies pertaining to surface area of fillers the shape has been assumed as spherical, which apparently is not the case. No doubt angular and laminar shapes have some effect on the manner in which the filler tends to agglomerate, the manner in which particles adhere to aggregate surfaces, the manner in which particles are coated with asphalt, and their tendency to suspension in the asphalt. All of these may have some effect on the properties of the mix.

Practically no information appears to be available concerning the direct and specific effects of the chemical composition or surface properties of fillers on the properties of mixes. Considerable work, however, has been done that by inference casts some light on this subject. Very fine silica sands, when used as a filler, have been found to have rather serious detrimental effects on the mix. Such fillers are generally highly hydrophilic, having very low affinity for asphalts. Finely crushed rock flours, such as granites, having particles of various mineral compounds, have been noted to exhibit similar behavior. Fillers containing clayey minerals are also viewed with suspicion. From these observations it becomes apparent that a filler must possess a relatively high degree of affinity for asphalt if adverse effects are to be avoided.

In some instances, where a soft, porous limestone that was considered hydrophobic and possessed high affinity for asphalt was used, adverse results were noted. In these cases the filler appeared to absorb the oily constituent of the asphalt, thereby tending to harden the asphalt materially which in turn was reflected in the behavior of the mix in service.

Very little is known about the chemical composition and surface properties of fillers, and apparently little attention is given to them, as attested by the fact that specifications seldom carry any requirement concerning them.

Observations made during the course of mixing of a bituminous mix disclose that the filler appears to attract and use up its share of the asphalt first, leaving the remainder to coat the coarser aggregate particles. This is quite apparent in low asphalt content mixes wherein during the early stages of mixing the filler and fine aggregate fractions appear well-coated while the coarse fraction is only partially coated. In the later stages of mixing, through the action of the mixer and temperature of the aggregates, the asphalt is more uniformly distributed and coarse particles become coated.

When mixes are produced by special processes such as the foamed asphalt (4), impact (1) and cooking processes (2, 3), virtually all of the filler may be used in the development of a mastic. The foamed asphalt process and the impact process possess the ability to coat individual filler particles with extremely thin films of asphalt and thereby create a strong, tough mastic possessing high stability. In mixes procured by either of these processes the mastic serves to fill the voids between aggregate particles and as a binder to bind aggregate particles together, thereby yielding mixes of higher density, stability, and toughness. Mixes prepared in this manner also permit the use of much higher quantities of filler in a mix without the adverse effects noted when the mix is prepared in the usual manner. Furthermore, because the mastic possesses high stability, and because it fills voids and binds aggregates together effectively the need for uniformly graded aggregates is obviated. Thus local ungraded aggregates having skipgrading or containing one-size particles may be used for preparing mixes for moderately heavy traveled roads (5). The filler therefore serves an entirely different purpose in mixes prepared by these processes than in mixes prepared in the conventional manner. The filler in these special processes must be capable of producing a suitable mastic. Under these circumstances the effects of particle size, distribution, shape, and mineral composition of the filler are more pronounced, and the filler may therefore be more readily classified; and those that do not create a mastic of desired properties may be rejected.

Another form of mastic may also be created by the foamed asphalt, impact, and cooking processes. In this form of mastic all of the filler is incorporated as a suspension in the asphalt. This mastic serves the same purposes in a hot liquid asphalt mastic or "Gussasphalt" high temperature mix as the other does in normal temperature mixes prepared by the special processes. In the cooking process used for over half a century in Germany for the preparation of "Gussasphalt," the mastic is prepared by mixing the filler and the asphalt together for about eight hours at 450 F in a heated single-shaft pugmill mixer. This mixing thoroughly incorporates the filler into the asphalt in a mechanical and colloidal suspension. After the mastic has been prepared, fine and coarse aggregates are added and mixing continued at 450 F for eight additional hours. The resulting mix has a consistency of heavy molasses and is laid at 400 F, making a practically voidless, strong, and tough pavement which does not shove or bleed under traffic.

A hot liquid asphalt mastic mix, very similar to "Gussasphalt," can be prepared at full plant production capacities in regular asphalt plants adapted to either the foamed asphalt process or the impact process. In this case the thin films of binder coating the individual filler particles coalesce under the high temperature of the mix carrying the particles into suspension in the asphalt very rapidly. In this form of mastic that fraction of the filler between the No. 200 and No. 325 sieves appears to be held in mechanical suspension, while that passing the No. 325 sieve appears to be in colloidal suspension. In this mastic, particle size appears to govern the type of suspension, while mineral composition together with size may affect the stability of the colloidal suspension. It is apparent that the filler must not react chemically with the asphalt.

From the foregoing discussion it becomes apparent that fillers may function and behave in many different ways depending on mixing procedure and the properties of the filler used in preparing the mix. In mixes prepared in the conventional manner, fillers serve predominantly to fill voids, with the tendency to form mastics being comparatively low. The tendency to form a mastic depends largely on the temperature of the mix, the quantity of the filler present, and its physical properties. Although the amount of mastic present may be small and its effect on the mix undiscernible, all of the filler should be removed from the extracted asphalt if correct asphalt content and reliable properties of the recovered asphalt are to be secured.

In this discussion an effort has been made to review briefly the functions, behavior, and effects of fillers in bituminous mixes as collected from the literature directly or by inference, and from observations and experience. The discussion clearly shows the paucity of data and stresses the need for extensive basic research in this area of bituminous technology.

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