MATES

MICHIGAN DEPARTMENT OF TRANSPORTATION

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GRADATION AND SEGREGATION OF BITUMINOUS AGGREGATES

Aggregate gradation is defined as a systematic or engineered sequence of particle sizes ranging from a chosen maximum size down through clay size. It is usually expressed as cumulative percent by weight of each size particle that passes a given sieve. Special sieves having carefully controlled opening sizes are used for aggregate testing. The typical bituminous pavement will contain rock particle sizes ranging from a maximum of just under 3/4 in., grading down through all sizes including tiny particles of dust. The gradation of particle sizes in bituminous aggregates is selected to form a stable mass requiring a minimum quantity of liquid asphalt as a binder to create asphalt concrete.

There are several ways a bituminous aggregate can be manufactured to meet specifications. One way is to separate the aggregate into a series of different sizes and then blend the required amount of each just before entering the asphalt mixer. Another way is to produce the aggregate so that it contains a mixture of all the different coarse and fine sizes in the proportions required. This aggregate can be fed directly into the mixer without further proportioning.

It is assumed that each measure or portion of the aggregate is within gradation specification, thoroughly mixed, and exactly like any other measure or portion of the aggregate. However, this is rarely—if ever—the case in actual practice for several reasons. The 'bank run' sand and gravel excavated from a pit, fed into and processed through the gravel plant, is variable. Some portions may be very sandy, other portions may be on the gravelly side, while still other portions may be an equal mixture of both. This often yields a finished product of variable gradation.

Aggregate specifications are usually written to allow for some non-uniformity by permitting the proportion of selected sizes to vary within a range. Particle sizes are checked by shaking them through sieves with precise, known size openings. For example, a mix requirement could allow the total aggregate, by weight, retained on the 3/8-in. sieve to vary within a range of 10 to 35 percent. When the percentage ranges specified are plotted on graph paper, a specification band is formed (Fig. 1). Plots of gradation test results from samples of the aggregate produced must fall within the specification band in order that the aggregate be acceptable.

Although Michigan Department of Transportation specifications no longer require that aggregates for use in asphalt mixtures be tested as the stockpiles are being produced, the producers should perform quality control testing. It is in their own best interests to do this diligently, as after the aggregates are incorporated into the mix, the Department runs acceptance tests on it. Therefore, we recommend that aggregates be tested at a minimum rate of one test per 1,000 tons as they are produced. Depending upon the particular project situation, these tests can be performed by technicians employed by consultants or aggregate producers. Aggregate test results are only dependable if the samples from which the tests were made accurately reflect the make-up of the produced stockpile. Therefore, aggregate samples taken for specification testing must be representative of the material in the stockpile, and this requires knowledge and skill on the part of the technician taking the samples.

A good technician must know the characteristics of different kinds of aggregate stockpiles, how they were constructed, and the effect of the particular stockpiling method on the distribution of the various sizes of particles. The technician also must be skilled in taking samples so they are representative of the materials in the stockpile regardless of how it was made.

It has been noted that a particular bituminous aggregate is made up of many different sizes of coarse and fine particles. This property, by its very nature, causes the particles to separate somewhat into different sizes when the aggregate is handled. Such separation is called segregation, and the different methods of stockpiling all result in some degree of this.

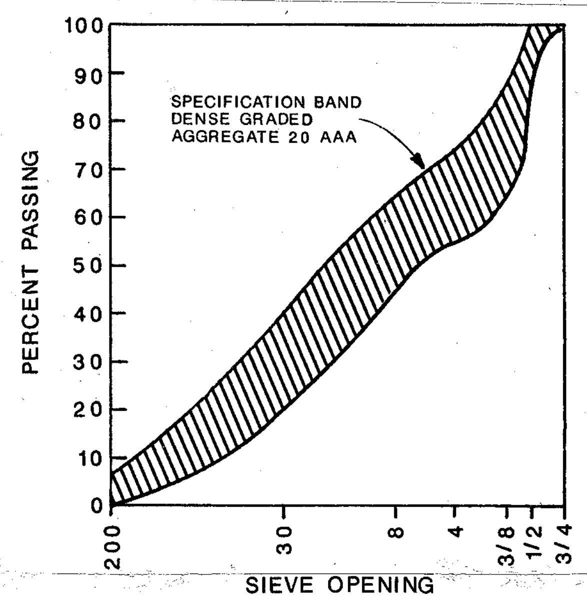

Figure 1

When an aggregate is picked up and dropped, whether by a belt stacker, front-end loader, or by a truck dumping off the end of a pile, the force of the fall segregates the material. The larger rock particles tend to roll toward the bottom of the pile while the finer fraction remains on the top.

A high degree of segregation may be found when belt stackers are used. Belt stackers discharge the aggregate in a continuous stream onto a pile from an elevated conveyor belt. Thus, a conical pile is built with the coarser aggregate particles tending to end up at the bottom and the finer particles toward the top.

A belt stacker with the loading end fixed and the discharge end capable of being rotated to form an arc-shaped pile is called a radial stacker. Unless great care is taken, significant segregation can occur with radial stackers. Depending on how the material is cast onto the pile, the coarse material may end up on one side of the pile (away from the belt) and the fines on the other (toward the belt); or the coarse fraction may be all around the outside of the pile and the fines in the middle of the pile. Segregation can be reduced, however, by placing a baffle at the discharge end of the stacker. The gravel stream strikes this baffle and drops vertically onto the pile rather than flowing off the end of the belt in an arc-shaped stream.

Segregation is also related to the distance the aggregate is dropped, and can be further alleviated in belt stacking operations by repeatedly adjusting the height of the belt, starting with the discharge end of the belt stacker close to the ground. The stacker is subsequently raised as the height of the pile increases, keeping the distance the material falls from the belt to the stockpile to a minimum.

Obtaining test samples that truly represent what is in a radial stacker stockpile is difficult. If an operator blades or flattens the pile with a bulldozer, however, rather than building a tall pile, it is possible to obtain representative samples during production. After the stockpile has been constructed, representative samples from the shipping face—that end of the stockpile that is being loaded for use—can be obtained by proper techniques and with the aid of the loader operator. This sample will tell the technician if the material at the end of the stockpile, when properly mixed, will meet gradation specifications. Continued sampling must be done during the entire shipping operation to ensure that the aggregate in the pile is within specifications.

Successful loading and shipping of aggregates that meet specifications from a radial stacker stockpile is largely in the hands of the loader operator. A competent operator knows the segregation pattern and works back and forth across the face taking representative scoops. The aggregate is mixed when placed in the truck, further mixes when dumped, and mixes again when picked up and put into an asphalt plant. All these actions, when done properly, will help to minimize segregation and provide material of specification gradation. When improperly done, the result can be the delivery of aggregates whose gradation is outside the specification limits.

One persistent problem occurs when the aggregate plant operator produces an aggregate within the gradation band but close to the limits, particularly on the fine side. In this situation, the least bit of change or segregation will result in the material being out of specification. This can be extremely troublesome when a test at one location, the pit, may be within specification while a later test, at the asphalt plant, is outside specification limits. This may cause arguments, delays, extra testing, and production problems. If the aggregate gradation is produced to fall within the center of the specification band, rather than at the edge, these problems generally do not occur.

A bituminous mix prepared in accordance with a laboratory mix design is a carefully engineered material designed to satisfy a number of requirements such as proper air voids, stability, durability, asphalt content, and control of creep, cracking, or rutting. Deviation from this mix design produces an inferior material because one or more of the requirements will be out of balance. The result is a pavement with reduced service performance, premature maintenance problems, and shortened life.

One of the more recurrent problems is segregation of the aggregate in bituminous mixes. It can be seen by the presence of varying patterns on the surface of newly laid pavement. If an area on the surface shows too much coarse material, it means that another part of the surface will contain too much fine material. Too much coarse aggregate will yield an open surface that is weakly bonded and subject to infiltration of water and loss of stones from the surface. Too much fine material will generally result in too few air voids, instability (as evidenced by shoving and rutting) and flushing of bitumen to the surface. All of these conditions can usually be prevented by properly graded and adequately mixed aggregates.

Over 90 percent of the Interstate and other major trunkline pavements in Michigan are paved with asphalt, all based upon carefully engineered laboratory mix designs. Long service lives for these pavements depend upon their components being produced within specification limits, and being properly placed and compacted at the jobsite. Aggregates are the major constituent of an asphalt mix and a critical element in achieving a quality pavement, while the asphalt cement content usually is less than 6 percent by weight. The selection, production, and control of aggregates is vital to obtaining quality bituminous pavements for Michigan's motorists.

-Don Malott

TECHADVISORIES

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

PERSONNEL CHANGES

March 31 brought to a close the careers of three valued Materials & Technology staff members. **Elton K. Casler,** our senior scale inspector, began his career with the Department by working in the summer and fall of 1961 as a seasonal aggregate inspector in the old Field Testing Section of M&T. Although still classified as an agg inspector, Elton began working with the scale inspection crew, again as a seasonal, in 1963. In 1966, he began his year-round employment, working from the central office on scale inspections. The job of checking and approving scales at aggregate, concrete, and bituminous production facilities is a very important part of the highway materials picture, and we're proud of the care and diligence with which Elton carried out these duties through the years. . .**Donald E. Caudell** came to the Division from industry in 1970 to head up our machine shop. Don and his three assisting machinists serve in the Research Laboratory's Structural Research Unit, but their expertise is relied upon throughout our Division, our Department and beyond. It's been Don's job to sit down with technical personnel and help conceive, then build, special devices of all kinds to perform the tasks set forth. If something was needed that didn't exist, nor had ever been tried, Don helped design it, and supervised its fabrication. It's a job that's as much—if not more—art than science, and takes a special sort of person to do it, and do it well. Don's been that person for nearly 20 years, and has been one of the Division's greatest assets. . .**George H. Gallup** has retired after 29 years with the Department and the Division. George graduated from Michigan State University in 1951 with a degree in geology, and from that time until 1960 he was employed by two consulting engineering firms. He came to the Department in September 1960, working as a geologist in the Testing Laboratory Soils Section at Ann Arbor. In 1967 he transferred to Lansing to work in the old Field Testing Section. At his retirement, George was in charge of aggregate quality control in the District Support Section. Over the years, George has served as our liaison with the aggregate producing industry and has helped to develop procedures and specifications for the producers to follow. George was a key figure in organizing and teaching classes for aggregate inspectors pursuing their certification, first within the Department and then at Ferris State. Aggregates are the backbone of concrete and asphalt mixes, and losing a man with George's expertise is always cause for regret. . .**Elton, Don, George,** you've all contributed in very significant ways to the Division and the Department and you'll all be sorely missed; we appreciate your fine work, and wish you all the very best of times in your retirements.

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