MATES

MICHIGAN DEPARTMENT OF TRANSPORTATION

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WHY ALL THE FUSS OVER AGGREGATES?

The thousands and thousands of miles of local, state, and Interstate roadways that make up our vast transportation system are composed of many different materials. But by far the largest amounts of such components in each of those roadway miles are the sands, gravels, and stones, that we call construction aggregates. They are used in the subbase, base, paving materials, and in many structural uses such as bridge foundations, piers, beams, and decks. The quality of the final product is determined to a large degree by the quality of the aggregates it contains. To help ensure that quality, the Michigan Department of Transportation has specification requirements for the various types and uses of aggregates.

Aggregates exhibit wide varieties of physical, chemical, and geological properties. These properties, along with size, must be evaluated to determine an aggregate's potential for providing optimum, economical service life in the engineering application for which it is intended. Many tests may be involved in order to gain a thorough understanding of the basic properties of aggregates. These tests can generally be classified into two categories: tests to obtain information about a specific aggregate for a specific use, and tests to provide information about engineering properties needed in the design and control of mixtures or for other engineering purposes. The following tests, for which MDOT has applicable specifications, give us a fairly reliable picture of aggregates.

Grading - Grading (or gradation) can be defined as an aggregate's particle size distribution of fine and coarse fractions and those in between. This gradation is usually characterized by a distribution of the percentages passing a series of sieve openings specified for a particular Michigan aggregate series and class. Michigan's series and class percentage requirements vary greatly depending upon the intended use of the material.

There are many reasons why size distribution is specified. For example, the largest size particles used in concrete must be small enough to be placed easily between the steel reinforcement bars, between forms, etc. In asphalt, the largest particle size must be small enough to be accommodated easily within the bituminous layers that make up a pavement. Also, by reducing their size, some aggregates are made less susceptible to breakdown due to repeated freezing and thawing conditions, an important consideration in concrete pavements and bridge decks.

Grading requirements call for uniformity in particle size distribution to help provide uniformity in consistency, workability, placeability, and finishability of the concrete or bituminous material. They provide a mixture that increases the strength of asphalt pavement layers or aggregate bases, and provides economical, effectively strong and stable hardened paving mixtures. Well-graded mixtures will not segregate so easily (segregation refers to like-sized particles migrating to join one another, rather than remaining uniformly mixed).

Loss-by-Washing - This specification test requirement determines the amount of material that will pass through a No. 200 sieve (0.0029-in. openings, the smallest we use) by a washing procedure. Water-soluble materials, clay particles, and other very fine dust-like aggregate particles that are dispersed by the wash water will be removed from the aggregate during this procedure. Certain gradations require this tests.

The loss-by-washing test is used in concrete mixtures to limit the amount of clay-like fines which may impair the bond of mortar to aggregate particles, cause expansive forces in the concrete upon wetting, or require more water in the mix, resulting in reduction of strength. It also helps maintain the correct proportion of clay-like fines needed in bituminous mixtures, where the correct proportion increases stability, lowers the asphalt demand, and increases particle-to-particle bond. Further, in conjunction with the grading requirements, the loss-by-washing test helps to determine particle size distribution and to evaluate production procedures.

Deleterious Particles - Certain aggregates are referred to as 'deleterious,' a term that denotes non-durable rock types unsuitable for construction use. Deleterious particle specifications limit the amount of recognized harmful particles that can be present in an aggregate. The identification of such particles is based upon the collection of experience and research over many years, coupled with the knowledge of locally available materials and specific Departmental design requirements. Since aggregates, climates, and engineering requirements vary from region to region, materials considered deleterious in one part of the country may not be in another. Particles, for example, that deteriorate in wet freezing climates may be suitable in warmer or drier localities. Certain particles, however, are almost universally recognized as deleterious. Most of these are light in weight and can be separated by means of flotation processes; some, however, such as chert and clay-ironstone, are not. It is desirable to limit the latter two, for example, as they readily absorb moisture and when frozen, they expand and contribute to pavement surface problems by 'popping-out' bits of concrete.

Specifications limiting deleterious particles serve to control the quantity of particles that may absorb water and subsequently cause expansive forces during freezing and thawing, resulting in general disruption of the concrete or bituminous pavement. They also limit particles that may break apart in the handling or mixing processes, resulting in changes in particle size, increased surface area, and increased water demand. This ultimately would lower the strength in concrete, or cause raveling and stripping effects in bituminous pavement. The presence of such harmful particles usually becomes very evident during freeze-thaw testing of concrete, described later.

Los Angeles Abrasion - Abrasion testing is a means for measuring the wear degradation potential of a graded aggregate. A rotating steel drum containing steel balls applies a combination of actions to the aggregate, including abrasion, attrition, impact, and grinding. The resistance to abrasion is an indication of two desirable qualities: hardness and toughness. Though closely related, hardness relates more to abrasion resistance while toughness is a resistance to fracture under impact.

Abrasion requirements enable us to evaluate a material's tendency to degrade or break into smaller pieces due to handling and mixing actions, which will provide better predictability of design and performance characteristics

MATERIALS AND TECHNOLOGY ENGINEERING AND SCIENCE

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of the mixtures. By indicating the toughness of an aggregate, the test permits an estimation of the amount of degradation so that gradation guidelines can be provided for maintaining drainability and/or stability. Abrasion test requirements also give a general indication of pavement wear resistance.

Freeze-Thaw Durability - Considering the extremes of Michigan's winter and summer temperatures and abundant moisture, freeze-thaw specifications are important requirements in evaluating aggregates used in exposed concrete. This test, which determines the resistance of concrete specimens to rapidly repeated cycles of freezing in air and thawing in water, is performed in a special chamber which simulates the freezing and thawing actions of many winters in a short period of time. These cycles occur in the out-of-doors, at a slower rate. Aggregates may absorb water which then expands during freezing. Particles near the surface of the concrete that absorb moisture and expand upon freezing can cause the mortar over them to break-out. The ability of an aggregate to resist this freeze-thaw cyclic degradation is related to its porosity, permeability, absorption, and pore structure. Critical particle size is also involved, i.e., the size above which an aggregate will break apart if frozen while saturated.

Freeze-thaw testing is a more realistic method (compared to such tests as sulfate soundness) to evaluate concrete coarse aggregates for their ability to resist natural weathering forces while in service. The test provides information for evaluating particles not included in the definitions of 'deleterious particles,' and it can also help to determine aggregates that may promote 'D-cracking' in concrete pavements (D-cracking is the breakdown of certain limestone aggregates due to freezing while saturated with moisture. See MATES No. 7, May 1987, and No. 24, October 1988).

Crushed Particles - A crushed particle is defined as a particle of aggregate having one or two fractured faces, depending upon the class specified. Crushed particles are identified by visual inspection following Michigan Test Method (MTM) 117. Generally, as particles become more rough and angular, the cement/aggregate bond increases in concrete mixtures. For bituminous mixtures, the stability is greatly increased.

Other reasons for crushed particle requirements include the fact that more angular particles provide greater stability when in direct contact than rounded particles, due to particle interlock. Further, these requirements result in maximizing shear strength in either paving mixtures or unbound aggregate mixtures. Crushed particles increase flexural (bending) or compressive strengths in concrete mixtures, and decrease the potential for rutting and shoving in bituminous mixtures.

Polish Susceptibility - Some types of aggregate particles have a tendency to polish (wear smooth) when used in pavements, causing surfaces that are more slippery when wet. Limestones are softer and tend to polish more rapidly, while granite is hard and resists polishing. Sandstone is polish-resistant because individual grains break off before they will polish leaving a sandpaper-like surface. Other rock types have moderate polishing resistance. The polishing resistance of each type of aggregate particle is determined to provide an Aggregate Wear Index (AWI). The AWI is a direct measure of the frictional resistance to a rubber tire sliding on a wet pavement after that pavement has been polished by 4,000,000 passes of a test-tire in a special wear track. AWI requirements for various roadways are based on the volume of traffic expected (average daily traffic per lane). Weathering will restore roughness to the surface of the particles, restoring greater friction to the pavement, in areas where traffic densities are low. (See MATES, Issue No. 10, August 1987 for further informaterion on AWI.)

Inspection and testing of aggregates continue to be important contributions to our transportation program. As we gain in understanding of the interrelationships of material properties and engineering design, specifications covering aggregates will continue to be refined. Preparing an aggregate specification that specifically and quantitatively defines its desired properties is very difficult; perhaps more so than for any other construction material. But considering their importance, this refinement and development are ongoing parts of MDOT's testing and research programs. Shrinking resources and funds necessitate that the aggregates that go into our roads and bridges meet the requirements of MDOT and the expectations of the driving public at the lowest possible cost.

Doug Branch
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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 NOTES

Fred Copple retired as Engineer of Testing on June 1. Fred's career with the Department began in 1953. He worked in the Construction Division during the summers of 1953, '54, and '55 while attending Michigan State University. After receiving his B.S. and M.S. degrees in Civil Engineering, Fred entered the U. S. Navy as an Ensign, and was sent first to Guam in the South Pacific, and then to Texas, as a supervisor of civilian and Seabee personnel. After his discharge from the Navy in 1959, Fred returned to the Department, joining the M&T's Research Laboratory as a soils and pavement evaluation engineer. In 1966 he became the head of the Pavement Performance Group of the Research Laboratory, where he led such research projects as pavement recycling, apportionment of user taxes between trucks and cars, and improved methods for measuring and improving pavement friction. After serving as Supervising Engineer of the Research Services Unit, Fred left the Research Laboratory to become head of the Bituminous Technical Services Unit of the Division's Testing Laboratory Section in 1985. In 1986, he was promoted to the position of Engineer of Testing, supervising the operation of the Division's Testing Laboratory. He was a busy chap at this point, as he also continued to oversee the Bituminous Laboratories until 1988. Fred has always been a 'doer' and his advice and expertise were much sought after by other Divisions and our transportation Administration. His helpfulness and sense of humor will be greatly missed, both by M&T members, and many others in the Department and in the highway industry. Among other things, Fred is a retired Captain in the Civil Engineer Corps of the Naval Reserve, and was recipient of the Engineer of the Year Award in 1977 by the Michigan Society of State Engineers. A roadside park has been named in his honor on US 27 near Alma. Your departure will leave a void, Fred, and all of us extend our best wishes for the future...We welcome a new addition to the Research Lab's Machine Shop personnel, **Jay Mardigian**, whose presence will bring the shop to full complement. Finally, our congratulations to **LaVerne Lass** who recently was promoted to the position of supervisor of our Machine Shop, a very hard-working, talented crew who contribute to MDOT in so many important ways.

This document is disseminated as an element of MDOT's technical transfer program. It is intended primarily as a means for timely transfer of technical information to those MDOT technologists engaged in transportation design, construction, maintenance, operation, and program development. Suggestions or questions from district or central office technologists concerning MATES subjects are invited and should be directed to M&T's Technology Transfer Unit.

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