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ABSTRACT

The properties of aggregates are very important to the performance of hot mix asphalt (HMA) pavements. Often pavement distress such as rutting, stripping, surface disintegration, and lack of adequate surface frictional resistance can be attributed directly to improper aggregate selection and use. Many of the current aggregate tests were developed to empirically characterize aggregate properties based on experience.

This paper gives the 1994 state of practice for aggregate tests and specifications used by state transportation agencies to control quality of aggregate for HMA. The survey of tests and specifications indicates considerable variation. Most of the aggregates tests and/or related specifications have been developed over a period of time and reflect local conditions and properties of available aggregate sources. Therefore, there are no standards which are acceptable on a national basis. There is a need to identify performance related aggregate tests for HMA, which can be adopted by all highway agencies.

KEY WORDS: Aggregates, tests, hot mix asphalt, asphalt concrete, practice

AGGREGATE TESTS FOR HOT MIX ASPHALT: STATE OF THE PRACTICE

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INTRODUCTION

Aggregates constitute 94-95 percent by weight of the hot mix asphalt (HMA) mixtures. Therefore, the properties of coarse and fine aggregate are very important to the performance of the pavement system in which the HMA is used. Often pavement distress, such as rutting, stripping, surface popouts, and lack of adequate surface frictional resistance can be traced directly to improper aggregate selection and use. Clearly, aggregate selection based on the results of proper aggregate tests is necessary for attaining desired performance.

Many of the current aggregate tests were developed to empirically characterize aggregate properties without, necessarily, strong relationships to the performance of final products (such as HMA) incorporating an aggregate. There is a need to identify and recommend tests which are related to HMA performance. This is the primary objective of the NCHRP Project 4-19 “Aggregate Tests Related to Asphalt Concrete Performance in Pavements.” One of the tasks of this project was to develop state of the practice of aggregate tests for HMA used in the United States.

To accomplish this task it was necessary to compile the standard specifications for aggregates (and related test procedures) for HMA pavements used by the various states in the U.S. The National Center for Asphalt Technology (NCAT) library had standard specifications from most of the states in the U.S. A categorical summary of aggregate test properties and specifications was prepared by NCAT and sent to the states for verification and updating in 1994.

This paper gives the state of the practice only, as obtained from a review of specifications from 45 states. Aggregate tests for HMA have been categorized as follows.

1. Particle Shape and Surface Texture (Coarse Aggregate)
2. Particle Shape and Surface Texture (Fine Aggregate)
3. Porosity or Absorption
4. Cleanliness and Deleterious Material
5. Toughness and Abrasion Resistance
6. Durability and Soundness
7. Expansive Characteristics
8. Polishing and Frictional Characteristics

PARTICLE SHAPE AND SURFACE TEXTURE (COARSE AGGREGATE)

The following test procedures (or variations thereof) are currently used in the U.S. to determine the particle shape and/or surface texture of coarse aggregates:

- ASTM D3398 — Index of Aggregate Particle Shape and Texture
- ASTM D4791 — Flat or Elongated Particles in Coarse Aggregate
- ASTM D5821 — Determining the Percentage of Fractured Particles in Coarse Aggregate

Figure 1 summarizes current state practices to control coarse aggregate particle shape and surface texture. All states surveyed have a minimum fractured face/crushed particle requirement for coarse aggregate. Thirty seven percent of the states surveyed also have requirements for

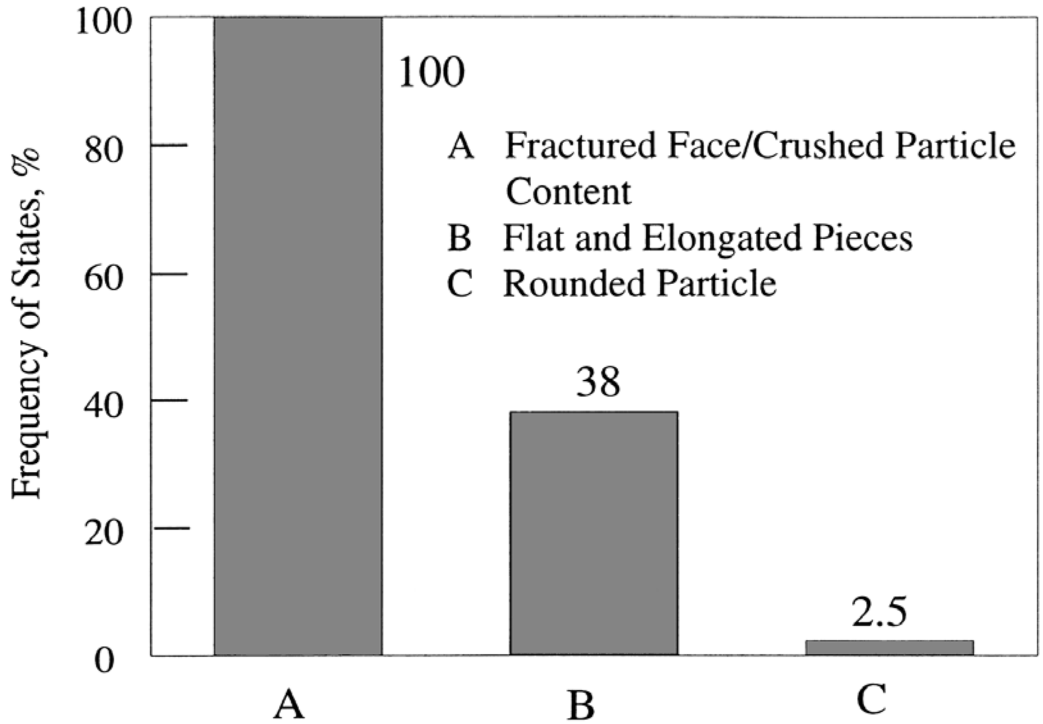

Figure 1. Summary of States' Coarse Aggregate Particle Shape and Surface Texture Requirements

maximum percentage of flat and elongated pieces. One state limits the maximum percentage of rounded particles.

Index of Aggregate Particle Shape and Surface Texture (ASTM D3398)

Huang (1, 2) developed a procedure for evaluating the particle shape and surface texture of coarse aggregates. The test is based upon the concept that the volume of voids between packed, uniform-size coarse aggregate particles indicates the combined effect of shape, angularity, and surface texture of the aggregate. The equipment required for this test consists of cylindrical molds of various diameters (to suit different aggregate size) and corresponding tamping rods. The aggregate is separated into various one-size fractions which are compacted in the molds with the tamping rods. The percentages of voids are determined and are used to calculate an index that reflects the aggregate particle shape, angularity, and surface texture. No state currently uses this test routinely. It has been used primarily for research purposes.

Flat or Elongated Particles in Coarse Aggregate (ASTM D4791)

This method determines the percentages of flat or elongated particles in coarse aggregates, which are defined as those particles of aggregate having a ratio of width to thickness or length to width greater than a specified value. A proportional caliper device is used to identify the flat or elongated particles by testing individual particles of specific sieve sizes. The percentage of flat particles, elongated particles, and total flat and elongated particles is calculated either by number or by mass.

Figure 1 indicates that 37 percent of the states surveyed have some requirement to control flat and elongated particles, but only a very few states measure flat and elongated particles separately as required in ASTM D4791. Most states measure the ratio of the minimum dimension (thickness) to the maximum dimension (length) of the aggregate particle, and usually specify a maximum ratio of 1:3 to 1:5. However, this ratio represents neither flatness nor elongation of the aggregate particles and, therefore, its engineering value is questionable. Figure 2 shows the percentage of states that specify the ratios of 3:1, 4:1 and 5:1 for maximum to minimum dimensions. The 5:1 ratio is specified by 80 percent states. Some states specify more than one ratio based on the HMA course type (base, binder or surface), and this accounts for the greater than 100 percent frequency in Figure 2. Generally, the allowable percentage is more for the particles with 3:1 ratio compared to the percentages of the other two ratios, which is logical. Maximum allowable percentages for 3:1 ratios range from 20 to 30 percent, from 7 to 20 percent for 4:1 ratios and from to 5 to 20 percent for 5:1 ratios.

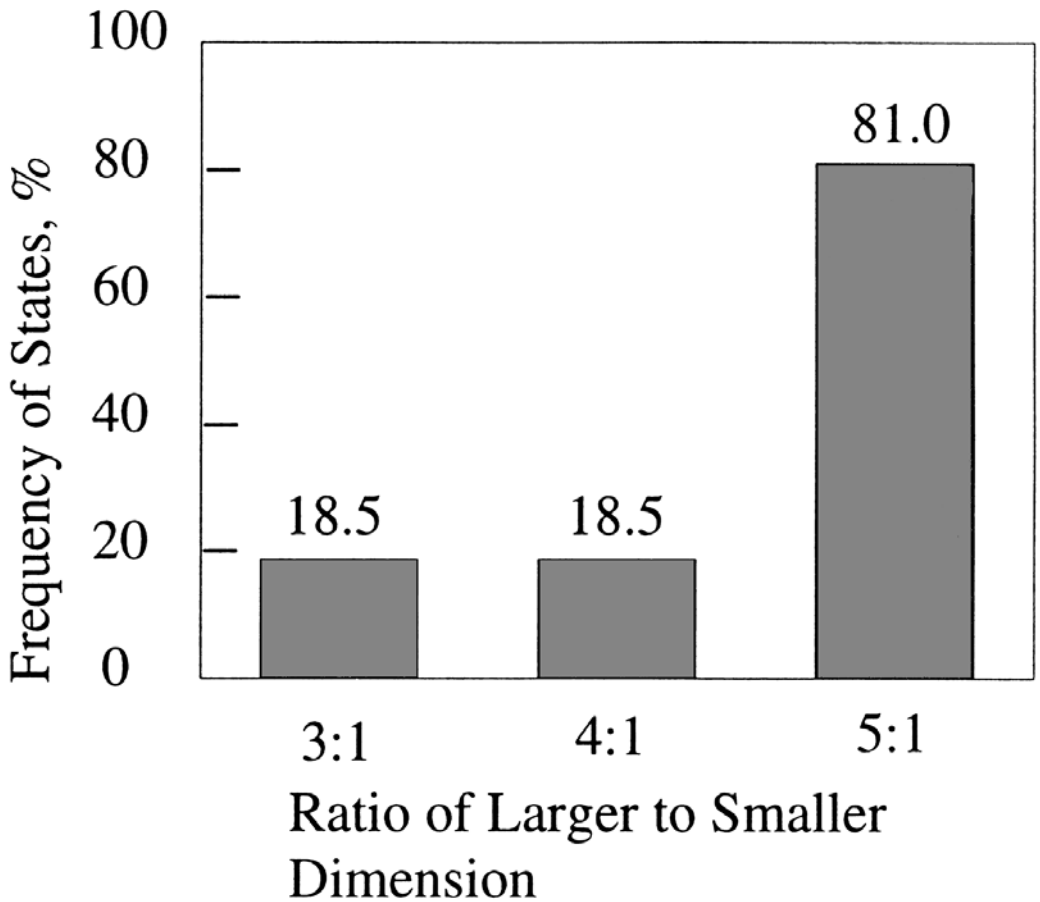

Figure 2. Requirements for Larger to Smaller Dimension Ratio (ASTM D4791 or Equivalent)

Percentage of Fractured Particles (ASTM D5821)

This test is conducted on material retained on the 4.75 mm (No. 4) sieve. A fractured or crushed fragment is defined as one having one or more fractured faces. A fractured face is defined as a face that exposes the interior of a gravel particle. Crushed fragments contained in a sample are weighed after separation and the percentage by weight determined. States have their own criteria of what constitutes a fracture face. The ASTM test specifies a minimum area of 25 percent of the maximum cross-sectional area of the aggregate particle.

All states (100 percent) surveyed have some coarse aggregate fractured face or crushed particle requirements. These requirements may apply to entire aggregate blends or may be specifically directed to crushed gravel components. Some states specify the minimum percentage of particles with one or more fractured or crushed faces. Others specify the minimum percentage of particles with two or more fractured faces, and some have requirements for both one or two fractured faces. Requirements also vary for base, binder course, and surface courses. Figures 3, 4, and 5 illustrate fractured face requirements for base, binder, and surface courses, respectively. Two histograms are included in each figure; one for requirements for one or more fractured faces and one for requirements for two or more fractured faces. All states surveyed have requirements for one or more fractured faces for base, binder, and surface courses. However, only 38, 44 and 58 percent of the states have two or more fractured face requirements for base, binder and surface courses, respectively. Another indication that requirements are generally more stringent for layers nearer the pavement surfaces are the average minimum percent of particles for the three courses shown in Table 1. Average minimum percent particle requirements are largest for surface mixes and smaller for the other mixes.

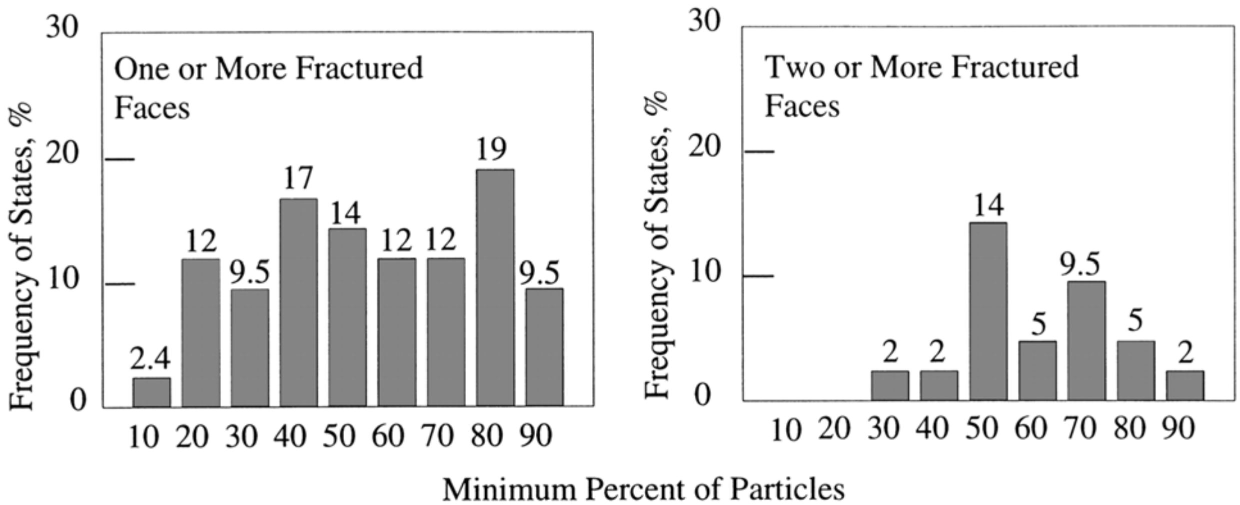

Figure 3. Fractured Face Requirements for Base Courses (ASTM D5821 or Equivalent)

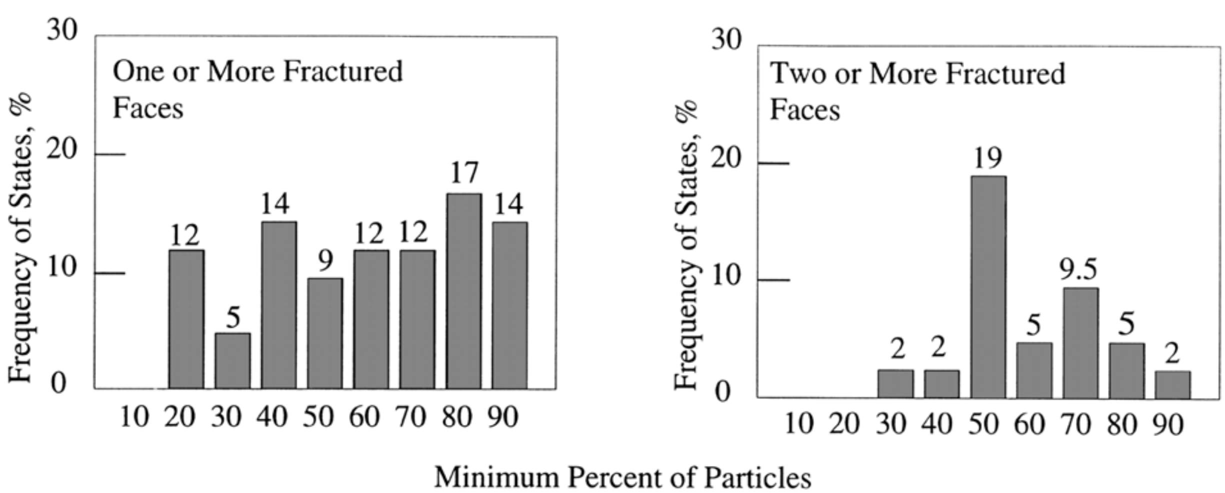

Figure 4. Fractured Face Requirements for Binder Courses (ASTM 5821 or Equivalent)

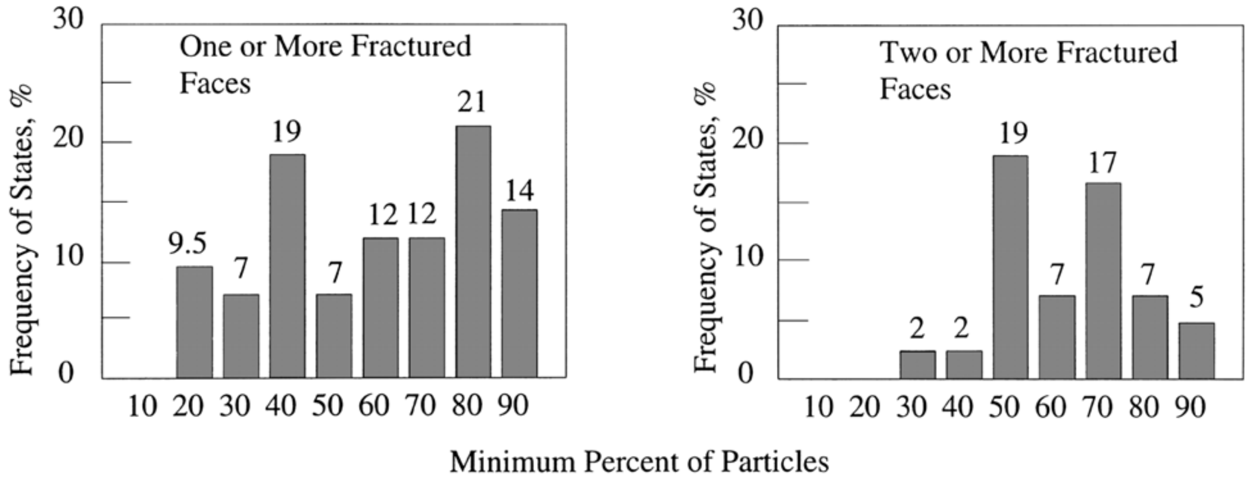

Figure 5. Fractured Face Requirements for Surface Courses (ASTM D5821 or Equivalent)

Table 1. Average Fractured Face Requirements

Mix Type	Average Minimum Percentage Particles with One or More Fractured Faces	Average Minimum Percentage Particles with or Two or More Fractured Faces
Base	57.4	60.0
Binder	56.3	59.5
Surface	61.0	63.1

PARTICLE SHAPE AND SURFACE TEXTURE (FINE AGGREGATE)

The following test procedures (or variations thereof) are currently used in the U.S. to determine the particle shape and surface texture of fine aggregates:

- ASTM D3398 — Index of Aggregate Particle Shape and Texture
- AASHTO TP 33 (ASTM C1252) — Uncompacted Void Content of Fine Aggregate

Most state highway agencies, however, control fine aggregate particle shape and texture in HMA mixtures by limiting the amount of natural sands rather than with criteria based on one of the above tests. Criteria that limits natural sand or requires minimum amounts of manufactured sand is not rational. There are natural sands which are subangular and rough textured rather than rounded and smooth. Similarly, not all manufactured sands are angular and rough textured (*3*, *4*). There is a need to quantify the shape and texture of the fine aggregate in order to write the specifications on a more rational basis.

About 23 percent of the 45 states surveyed specify a maximum allowable percentage of natural sand, and 7 percent specify a minimum percentage of manufactured (crushed) sand. The maximum allowable percentage of natural sand varies from 15 to 50, as shown in Figure 6.

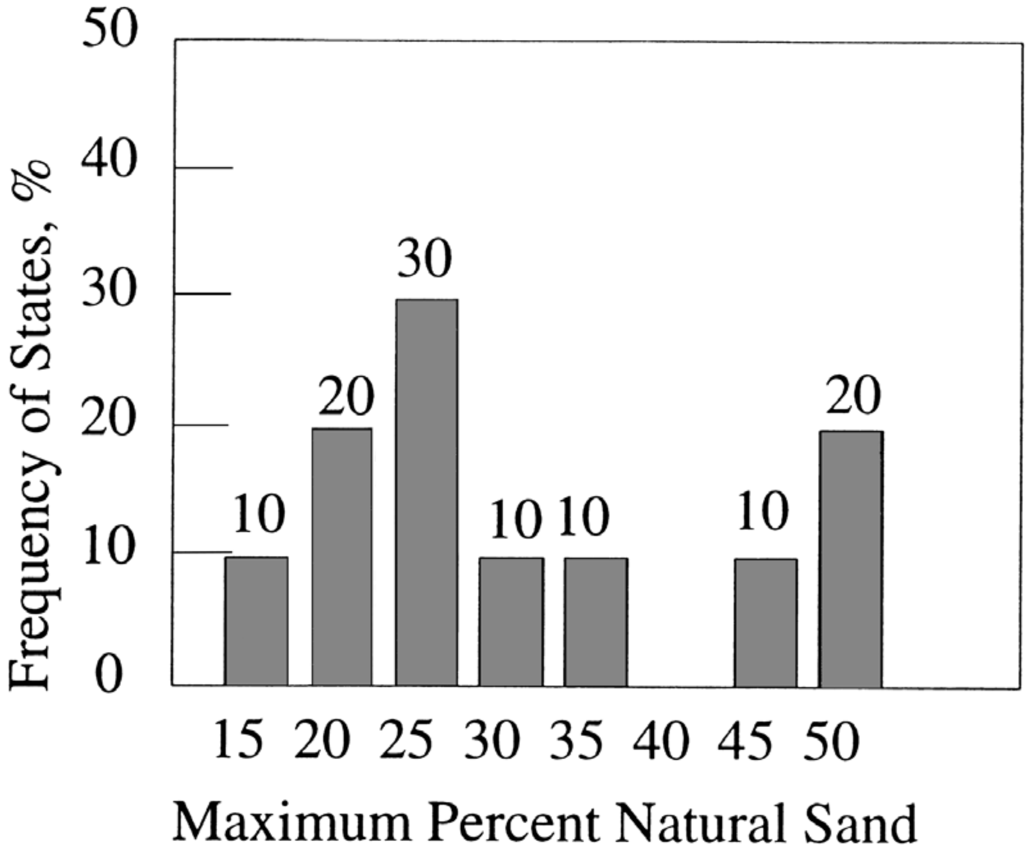

Figure 6. Limiting Criteria for Natural Sand in Binder and Surface Courses

Index of Aggregate Particle Shape and Texture (ASTM D3398)

This test has been described earlier for coarse aggregate. Again, no state uses this test routinely. It has been used for research purpose only.

Uncompacted Void Content of Fine Aggregate (AASHTO TP33 OR ASTM C1252)

This test was adopted by ASTM in 1993. It is recommended by the Strategic Highway Research Program (SHRP) in the SUPERPAVE mix design system. At the time of survey (1994), some state highway agencies were using this test for research purposes, and some were in the process of including it in specifications.

In this method, fine aggregate of prescribed gradation is allowed to flow through the orifice of a funnel and fill a 100-cm^3 calibrated cylinder. Excess material is struck off and the cylinder with aggregate is weighed. Uncompacted void content of the sample is then computed using this weight and the bulk dry specific gravity of the aggregate. Three variations of the method are being proposed. Method A uses a graded sample that is produced by batching individual size fractions on a mass basis. Method B uses three individual size fractions: 2.36 to 1.18 mm (Nos. 8 to 16), 1.18 to 0.600 mm (Nos. 16 to 30), and 0.600 to 0.300 mm (Nos. 30 to 50); and the mean void content is determined. Method C uses the gradation as received.

POROSITY OR ABSORPTION

The following test methods are generally used to determine the amount of water absorbed by the aggregates:

- AASHTO T84 (ASTM C128) — Specific Gravity and Absorption of Fine Aggregate
- AASHTO T85 (ASTM C127) — Specific Gravity and Absorption of Coarse Aggregate

According to the survey of state specifications, 28% of the states specify a maximum percentage of water absorption to avoid highly absorptive aggregates. Some states have used the water absorption specification to prevent the use of the so-called “undesirable” aggregates. However, no significant research data is available to indicate any relationship between the water absorption of the aggregate and the performance of HMA pavement containing that aggregate. This is evident from Figure 7 which shows that the maximum allowable water absorption by the states varies widely from 2 to 6 percent.

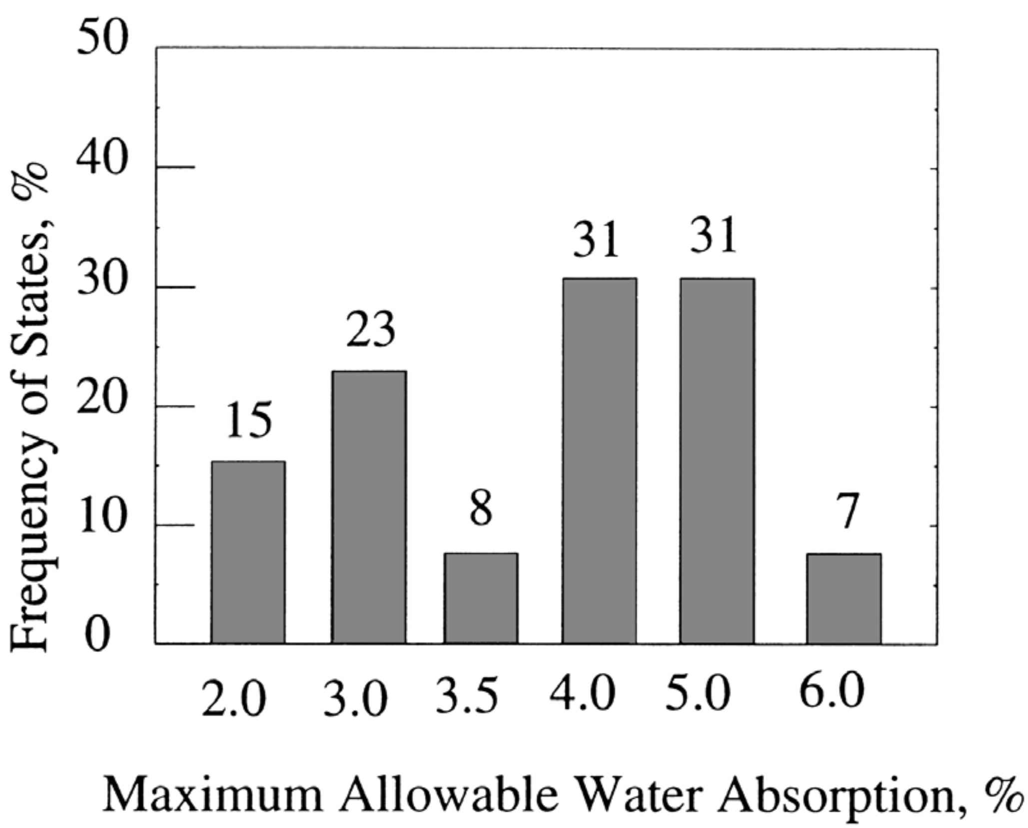

Figure 7. Limiting Criteria for Water Absorption (AASHTO T84 and AASHTO T85 or Equivalent)

CLEANLINESS AND DELETERIOUS MATERIALS

The following test procedures are used to ensure the cleanliness of aggregates and minimize the amounts of deleterious materials.

- AASHTO T176 (ASTM D2419) — Plastic Fines in Graded Aggregates and Soils by use of the Sand Equivalent Test
- AASHTO T90 (ASTM D4318) — Determining the Plastic Limit and Plasticity Index of Soils
- AASHTO T112 — Clay Lumps and Friable Particles in Aggregate (ASTM C142)
- AASHTO T113 — Light Weight Pieces in Aggregate
- AASHTO T11 — Material Finer Than 75:m (No. 200 sieve) in Mineral Aggregate by Washing

“Cleanliness” is concerned with coatings on aggregate particles or excessive finer than 75 :m (P200) material, whereas “deleterious materials” refer to individual particles which are made up of unsatisfactory or unsound materials. Figure 8 shows the percentages of states using specifications for deleterious materials, sand equivalent value, and plasticity of fines. The total percentage exceeds 100 percent because some states specify percentage deleterious materials and sand equivalent value or plasticity of fines.

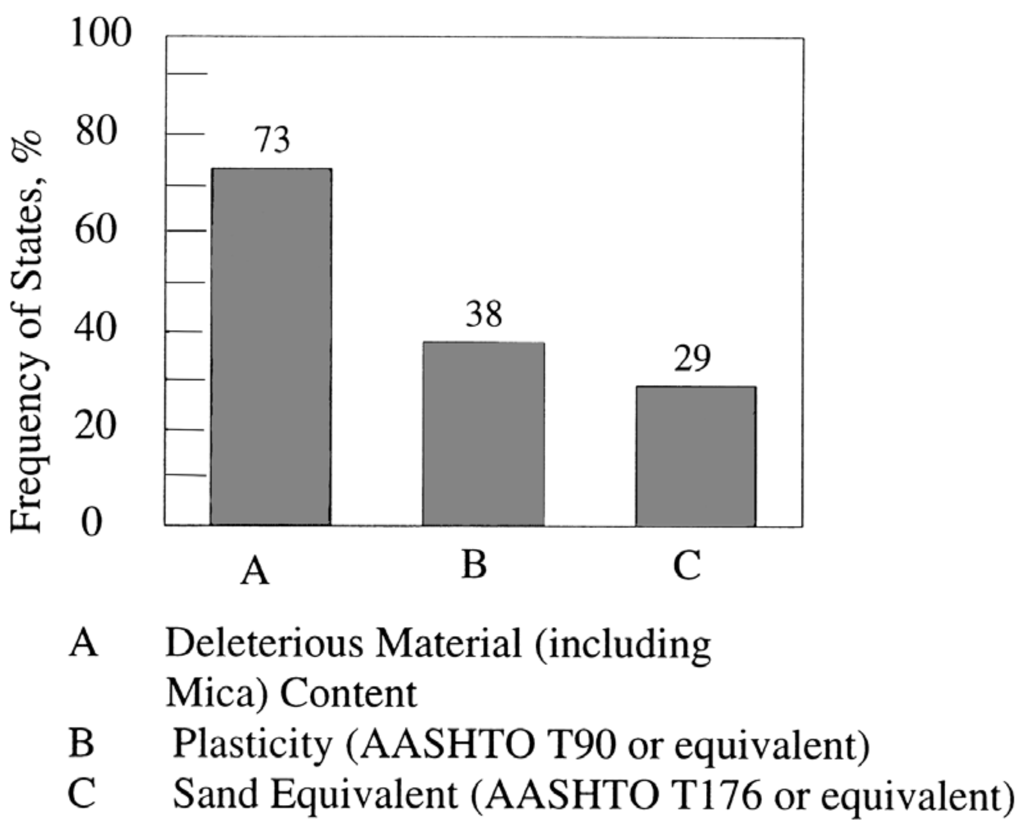

Figure 8. Specifications for Cleanliness and Deleterious Materials in Fine Aggregates

Sand Equivalent Test

The sand equivalent test is used to determine the relative proportions of fines or claylike material in fine aggregates. Aggregate passing the 4.75 mm (No. 4) sieve is placed in a graduated, transparent cylinder which is filled with a mixture of water and a flocculating agent.

After agitation and 20 minutes of settling, the sand separates from the flocculated clay, and the heights of sand and clay in the cylinder are measured. The sand equivalent is the ratio of the height of the sand to the height of clay times 100. Higher sand equivalent value indicates cleaner fine aggregate. Minimum specified sand equivalent values for fine aggregate in HMA range from 25 to 60 as shown in Figure 9. A minimum requirement of 45 is most common. The requirement is also based on the type of HMA course such as base and surface course.

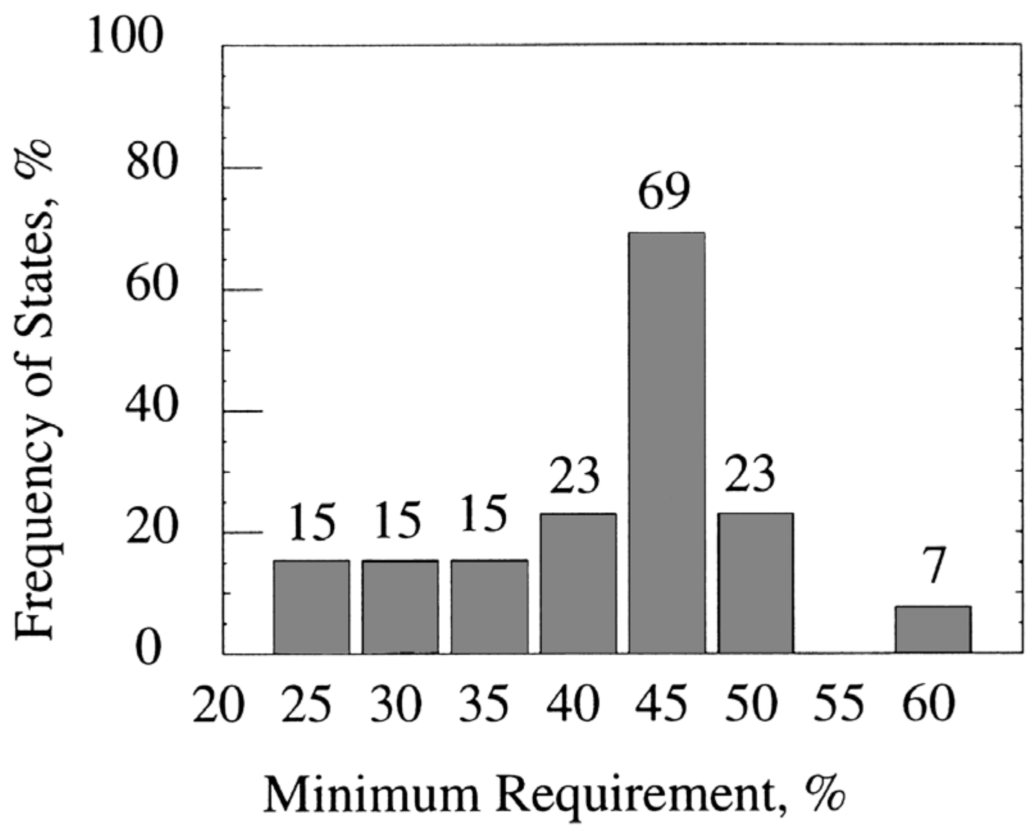

Figure 9. Sand Equivalent Requirements for Fine Aggregate (AASHTO T176 or Equivalent)

Plasticity Index

Plasticity Index is used by several agencies to measure the degree of plasticity of fines. Plasticity Index (PI) is the difference between the liquid limit and the plastic limit of the material passing 0.450 mm (No. 40) sieve. ASTM D1073 (Standard specification for Fine Aggregate in Bituminous Paving Mixtures) and D242 (Standard Specification for Mineral Filler for Bituminous Paving Mixtures) limit the PI of this fraction passing the 0.450 mm (No. 40) sieve (including the mineral filler) to a value of 4 or less. Some states specify a maximum PI for the finer than 75 :m (P200) material.

Clay Lumps and Friable Particles in Aggregate

AASHTO T112 is used as a standard test method for approximate determination of clay lumps and friable particles in aggregates. Aggregate is weighed and soaked in water for 24 hours. Any particle which can be broken with the fingers after soaking and removed by wet sieving are classified as clay lumps or friable particles, and the percentage of this material is calculated by weight of the total test sample. Specifications usually limit the amount of clay lumps and friable particles to a maximum of one percent.

Lightweight Pieces in Aggregate

AASHTO T113 (ASTM C123) covers the determination of the percentage of lightweight pieces in coarse and fine aggregates by means of sink-float separation in a heavy liquid of suitable specific gravity. A heavy liquid with a specific gravity of 2.0 (such as a solution of zinc chloride in water) is used to separate particles which may be classified as coal or lignite. Heavier liquids may be used to check the percentages of other lightweight pieces such as chert having a specific gravity less than 2.40.

Material Finer Than 75 :m (No. 200) sieve by Washing

Material finer than the 75:m (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determination of material finer than 75:m (No. 200) in fine or coarse aggregate is desired, this method is used on the sample prior to dry sieving (which may not be effective for some adherent fines or dust coatings). Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, are removed from the aggregate during the test.

TOUGHNESS AND ABRASION RESISTANCE

The following test procedure (or variations thereof) is used in the U.S. to determine the toughness and resistance to abrasion of coarse and fine aggregates:

AASHTO T96	Resistance to Degradation of Small-Size Coarse
(ASTM C131)	Aggregate by Abrasion and Impact in the Los Angeles Machine

The survey of test procedures indicated that 94 percent of the states surveyed use the Los Angeles (LA) abrasion test or some variation. Only two states have a degradation requirement from some other type tests. Maximum allowable LA abrasion loss criteria for base course, binder course, surface course and open graded friction course are presented for the states surveyed in Figures 10 and 11. The majority of the states have a maximum allowable loss of 40 or 45 percent. Loss criteria becomes more restrictive as exposure and loading conditions increase in severity.

The Los Angeles abrasion test was originally developed in the mid-1920s by the Municipal Testing Laboratory of the city of Los Angeles, California. A 5000-gm sample of aggregate having a specified grading is placed in a steel drum along with 6 to 12 steel balls each weighing about 420-gm. The drum is rotated for 500 revolutions. A shelf within the drum lifts and drops the aggregate sample and steel balls about 69 cm (27 inches) during each revolution. The resulting vigorous tumbling action combines impact, which causes the more brittle particle to shatter, with surface wear and abrasion as the particles rub against one another and against the steel balls. Following the completion of 500 revolutions, the sample is removed from the testing machine and sieved dry over a 1.77 mm (No. 12) sieve. The percent passing the 1.77 mm (No. 12) sieve, termed the percent wear or percent loss, is the Los Angeles degradation value for the sample.

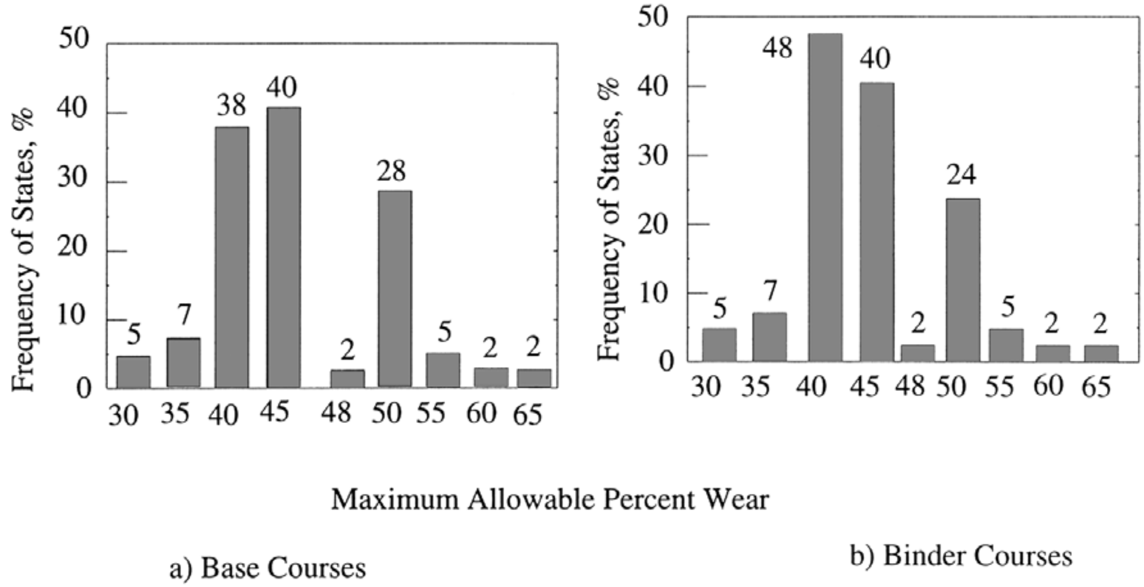

Figure 10. LA Abrasion Loss Criteria (AASHTO T96 or Equivalent)

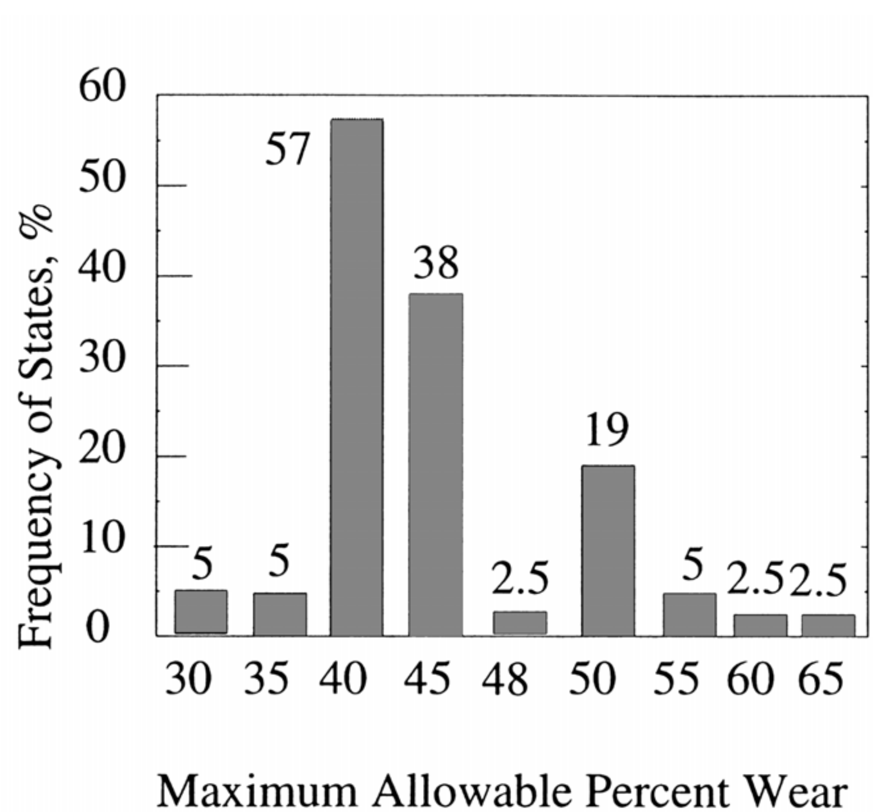

Figure 11. LA Abrasion Loss Criteria for Surface Course Mixes (AASHTO T96 or Equivalent)

DURABILITY AND SOUNDNESS

The following test methods are used to determine the resistance of aggregates in HMA mixtures to degradation when exposed to weathering, i.e., wetting-drying and/or freezing-thawing:

C	AASHTO T104 (ASTM C88)	Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
C	AASHTO T103	Soundness of Aggregate by Freezing and Thawing
C	AASHTO T210 (ASTM D 3744)	Aggregate Durability Index

Results of the survey of state specifications are summarized in Figures 12 through 14. The survey indicated that 54 percent of the states surveyed have a requirement for sodium sulfate soundness, 19 percent magnesium sulfate soundness, 9 percent a freeze-thaw loss requirement, 2 percent (1 state) a durability index requirement, and 16 percent no soundness requirement. Maximum allowable losses for states using sodium sulfate are shown in Figures 13 and 14. Maximum allowable sodium sulfate soundness test loss varies from 5 to 25 percent. Over 50 percent of the states specify maximum losses of 12 or 15 percent for base, binder and surface mixes. Average maximum allowable loss does not vary much with mix type. Average values are 13.8 percent for base and binder mixes, and 14.0 percent for surface mixes.

Similar distributions are noted for maximum allowable magnesium sulfate soundness loss. Maximum allowable values were somewhat higher than sodium sulfate values, ranging from 10 to 30 percent with averages for all three mixes about 16 percent.

Durability and soundness tests are designed to simulate the destructive action of environmental factors, i.e. wetting-drying and freezing-thawing. Freezing-thawing are more detrimental than wetting or wetting-drying, and as a result, most test procedures simulate freezing-thawing. Water in pores or voids expands upon freezing causing a breakdown of aggregate particles. The sulfate

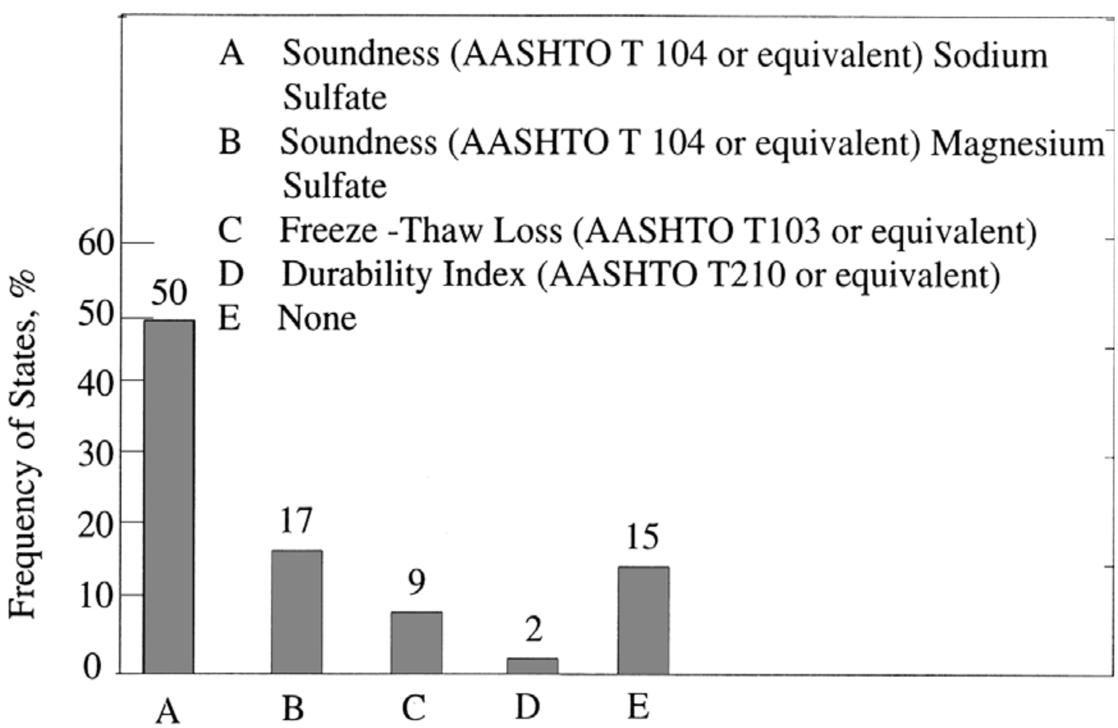

Figure 12. Summary of Aggregate Durability and Soundness Specifications

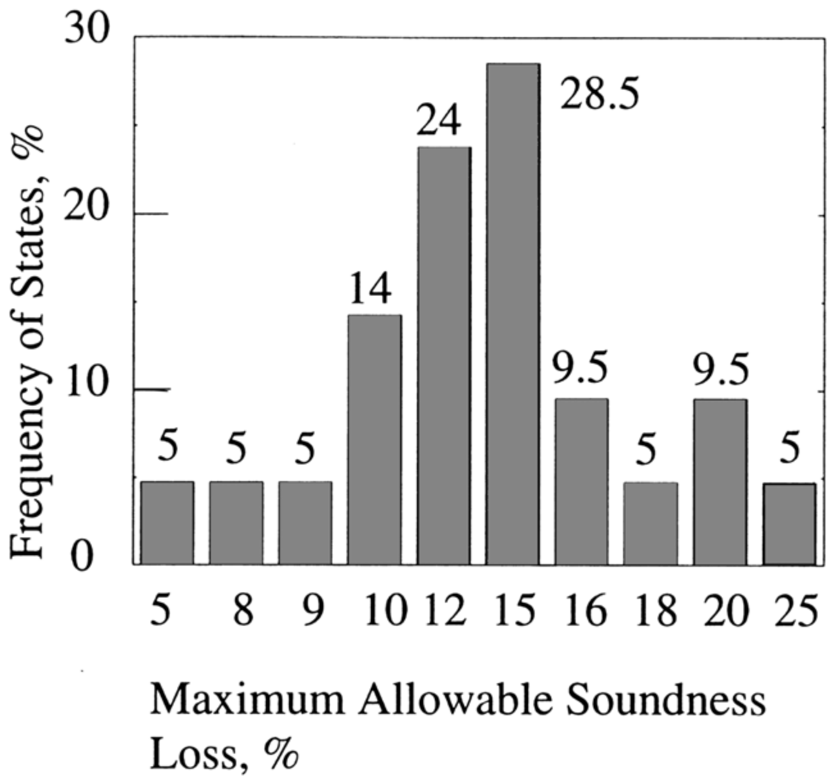

Figure 13. Sodium Sulfate Loss Criteria for Base Course Mixes (AASHTO T104 or Equivalent)

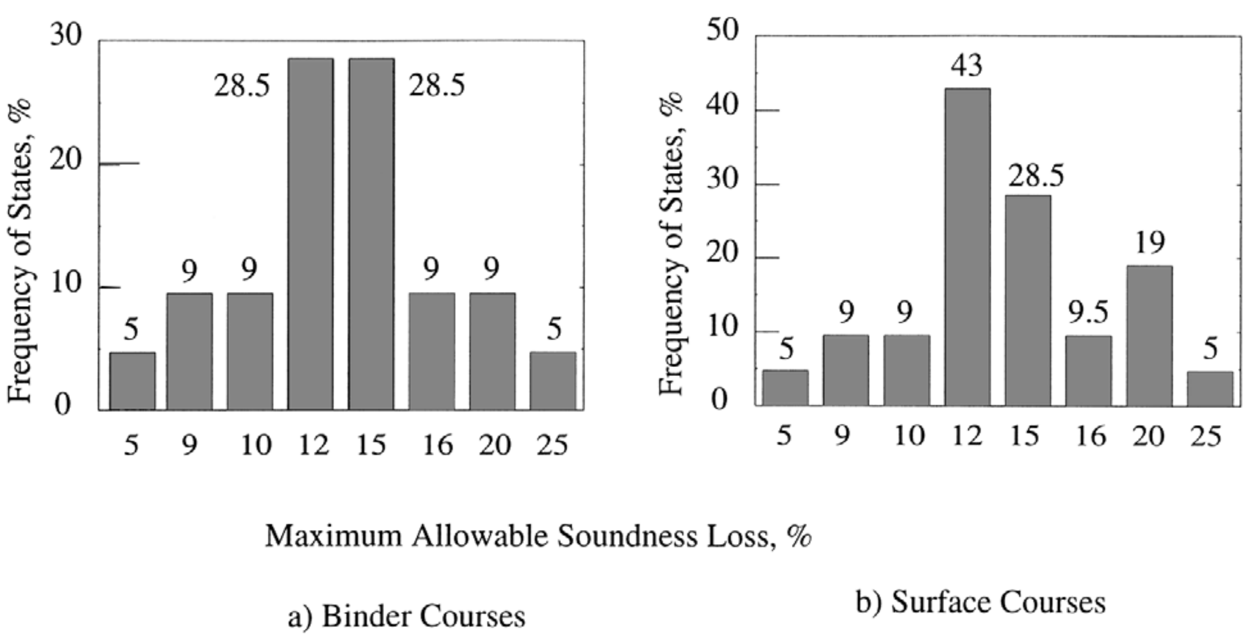

Figure 14. Sodium Sulfate Loss Criteria for Binder and Surface Course Mixes (AASHTO T104 or Equivalent)

soundness tests were developed to simulate this action and were used in lieu of freezing and thawing because of the lack of adequate refrigeration equipment. Reliable, relatively inexpensive refrigeration equipment is now available but the sulfate tests are still used extensively. The Aggregate Durability Index Test (AASHTO T210) and similar tests (5, 6, 7, 8) were developed to detect harmful expansive clay minerals in weathered basalt indigenous to some western states.

Soundness of Aggregate by Sodium Sulfate or Magnesium Sulfate (AASHTO T104 - ASTM C88)

The sodium sulfate or magnesium sulfate test is widely used as an index of general aggregate quality. The soundness is intended to provide an estimate of the resistance of aggregate to weathering action. In the soundness test, the test sample is immersed in a solution of sodium or magnesium sulfate of specified strength for a period between 16 and 18 hours at a temperature of 21±1°C. Next, the sample is removed from the solution and permitted to drain for 15±5 minutes. It is then dried at a temperature of 110±5°C until constant weight is achieved. Usually the sample is subjected to 5 cycles of immersion and drying. During the immersion cycle, the sulfate salt solution penetrates the permeable pore spaces of the aggregate. Partial or complete oven drying dehydrates the sulfate salt precipitated in the pore. The internal expansive force, derived from the rehydration of the sulfate salt upon re-immersion, is intended to simulate the expansion of water upon freezing. After completion of the required number of immersion and drying cycles, the sulfate salt is washed out of the sample. The sample is then sieved through specified sieves somewhat smaller than the original sieves on which a given size fraction was retained. The resulting weighted average loss for each size fraction is used as the indication of durability of the aggregate.

Soundness of Aggregates by Freezing and Thawing (AASHTO T103)

This test is designed to furnish information for judging the soundness of aggregate subjected to weathering. There are three procedures for immersion. In procedure A, samples are immersed in water for 24 hours prior to start of freezing-thawing cycles. During freezing-thawing the sample remains completely immersed. In procedure B, the samples are saturated by subjecting them to a vacuum of not over 25.4-mm (1 inch) of mercury. Penetration into the aggregate pore is increased by using a 0.5 percent (by mass) solution of ethyl alcohol and water rather than water alone. After saturation the sample is frozen and thawed in the alcohol-water solution. Procedure C is the same as procedure B except the water is used instead of the alcohol-water solution. Specifications may require 50, 16 and 25 cycles for procedure A, B and C, respectively. After completion of the final cycle, samples are dried to constant weight and sieved. The resulting weighted average loss for each size fraction is used as the indication of soundness of the aggregate.

Aggregate Durability Index (AASHTO T 210, ASTM D 3744)

The durability index is a value indicating the relative resistance of an aggregate to produce detrimental claylike fines when subjected to prescribed mechanical agitation in the presence of water. Separate and different procedures are used to evaluate coarse and fine portions of aggregate. The test assigns an empirical value to the relative amount, fineness, and character of claylike fines produced during wet degradation. It is especially suitable for basalt type aggregates containing interstitial montmorillonite.

The aggregate durability index test for coarse aggregate can be summarized as follows: A washed and dried sample of coarse aggregate is agitated in water in a mechanical washing vessel for a period of 10 minutes. The resulting wash water and minus 75 :m (No. 200) size fines are collected and mixed with stock calcium chloride solution and placed in a plastic sand equivalent cylinder. After a 20-minute sedimentation time, the level of the sediment column is read. The height of the sediment is then used to calculate the durability index of the coarse aggregate.

EXPANSIVE CHARACTERISTICS

Some aggregates such as steel slag, may contain components susceptible to hydration and consequent volume increase. Significant volume increases can cause noticeable swell in the HMA pavement and lead to its disintegration.

The following two test methods are available to determine the expansive potential of aggregates such as steel slag.

• Pennsylvania Test Method (PTM) No. 130	Evaluation of Potential Expansion of Steel Slag
• ASTM D4792	Potential Expansion of Aggregates from Hydration Reactions

Pennsylvania Test Method (PTM) No. 130 was developed based on the research work done by Emery (9) and the Pennsylvania Department of Transportation (*10*). ASTM D4792 was essentially based on PTM 130.

In this test, the aggregate is compacted to its maximum density in a CBR mold and then submerged in water at 71±3°C for a period of at least 7 days. A perforated plate is placed on the top of the compacted aggregate. Daily readings of the compacted specimen height are taken. The percent expansion is calculated by dividing the expansion by the initial specimen height and multiplying by 100. Maximum permissible expansion specified by the Pennsylvania DOT is 0.5 percent for steel slag to be used in HMA mixtures.

POLISHING AND FRICTIONAL CHARACTERISTICS

The following test procedures (or variations thereof) are currently used in the U.S. to determine the polishing and friction properties of aggregates:

• AASHTO T278 (ASTM E303)	Measuring Surface Frictional Properties Using the British Pendulum Tester
• ASTM D3042	Insoluble Residue in Carbonate Aggregate
• AASHTO T242 (ASTM E274)	Frictional Properties of Paved Surfaces Using a Full-Scale Tire

The summary of the state specification survey, shown in Figure 15, indicates that 12 percent of the states surveyed have a British polish/pendulum requirement, 20 percent a carbonate/limestone content requirement, 16 percent an insoluble residue requirement, and 3 percent (one state) an aggregate wear index requirement. Forty-nine percent of the states surveyed have no aggregate polish or frictional requirement.

Carbonate/limestone content and insoluble residue requirements are included in specifications to restrict the amount of carbonate aggregate used in surface mixes and/or to restrict the mineralogy of limestone aggregates used in surface mixes. The purpose of these restrictions is to ensure that some siliceous polish resistant minerals are exposed at the pavement surface-tire interface.

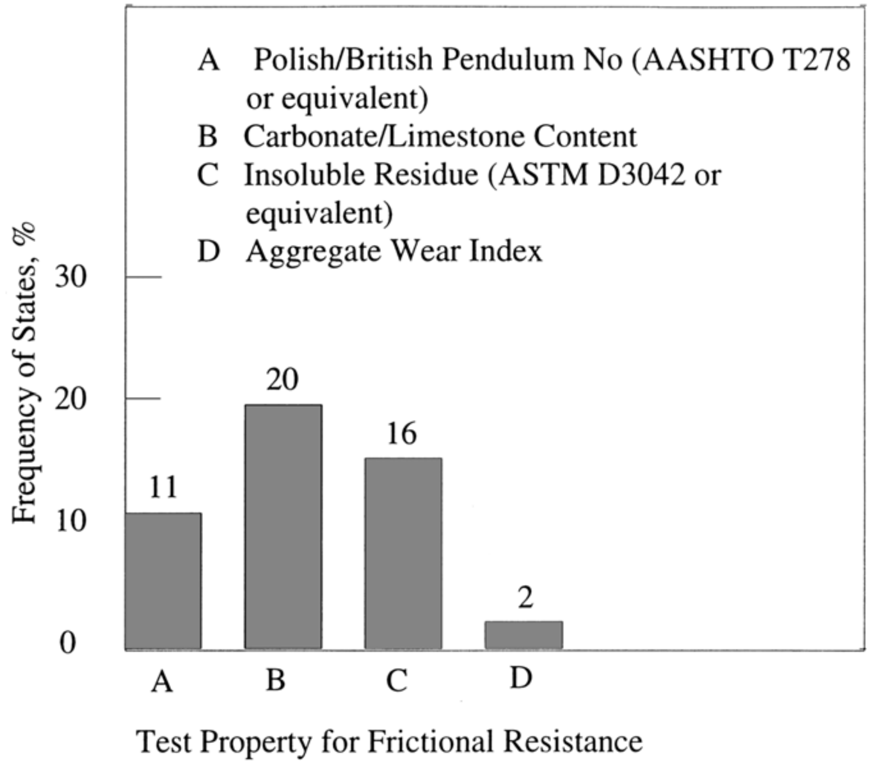

Figure 15. Summary of Polish and Frictional Property Requirements

Measuring Surface Frictional Properties Using the British Pendulum Tester (AASHTO T278) (ASTM E303)

This test method is used to determine the relative effects of polishing on coarse aggregate. Samples are prepared by placing individual aggregate particles in a mold and partially filling the mold with a bonding agent such as epoxy. The resulting specimens have one face with exposed aggregate for polishing and testing. The friction value of the sample before polishing is determined first. The pendulum tester is leveled and zeroed, the height of the pendulum adjusted so as to impact the same area of the test specimen at each test, and a thin film of water applied to the specimen surface. The pendulum is released and a reading of the arc swung through by the pendulum recorded. The arc is inversely related to the frictional resistance of the sample. Four swings are made and average calculated to give the polish value at time zero (PVO). Readings are also taken after polishing with the British polish wheel (AASHTO T279-ASTM D3319) or other polishing device. Values are reported as the polish value PV3, PV6 etc. to indicate frictional resistance after fixed hours of polish. Nine hours of polishing has generally been found to be adequate to obtain reasonably ultimate polished surface (*11*). British polish values are basically a measure of frictional resistance. Higher values indicate higher frictional resistance and imply greater skid resistance. As specimens are polished, maintenance or smaller reductions in frictional resistance indicates greater resistance to polishing.

Insoluble Residue in Carbonate Aggregates (ASTM D3042)

This test gives the percentage of noncarbonate (acid insoluble) material in carbonate aggregates which may indicate the polish susceptibility or friction properties. A sample, 500 gms. of aggregate retained on 4.75 mm (No. 4) sieve, is put in a glass beaker with 1000 milliliter of hydrochloric acid solution. The mixture of sample and acid is agitated until effervescence stops.

An additional 300 milliliters of acid is added and the procedure repeated until effervescence stops. Next, the beaker is heated to 110º C, and new acid added in increments until effervescence stops. The aggregate residue is washed over a 75 :m (No. 200) sieve, dried and sieved again. The weight of the plus 75 :m (No. 200) residue is determined and expressed as a percentage of the original sample weight and reported as the insoluble residue. Larger insoluble residue indicate larger percentages of siliceous minerals which are considered more polish resistant than carbonate materials.

Skid Resistance of Paved Surfaces Using a Full-Scale Tire (AASHTO T242) (ASTM E274)

Skid resistance of paved surfaces is most often determined using the locked-wheel skid trailer. The locked-wheel skid trailer consists of a vehicle towing the skid trailer. The skid trailer is usually two-wheeled. The trailer is towed at various speeds to determine speed gradients but single values are most often reported at 64 km/h. Water is jetted on the surface in front of the test tire when the tire reaches test speed in order to simulate wet conditions. Either one or both wheels are locked to measure the skid resistance of the pavement surface. When the test wheel is locked, the trailer is dragged by the truck. The resistance offered by the pavement surface is measured by a torque applied to the trailer axle. This resistance (torque) is converted into a numerical value called friction number (FN). Higher FN indicates greater frictional resistance.

SUMMARY

This paper gives the 1994 state of practice for tests and specifications used by state transportation agencies to control quality of aggregate for HMA. The survey of tests and specifications indicates considerable variation. Most of the aggregates tests and/or related specifications have been developed over a period of time and reflect local conditions and properties of available aggregate sources. Therefore, there are no standards which are acceptable on a national basis. There is a need to identify performance related aggregate tests for HMA, which can be adopted by all highway agencies.

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