
Standard Method of Test for

Determining Aggregate Shape Properties by Means of Digital Image Analysis

AASHTO Designation: T 381-22¹

Technically Revised: 2022

Technical Subcommittee: 1c, Aggregates



**American Association of State Highway and Transportation Officials
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1. SCOPE

- 1.1. This standard covers the measurement of aggregate shape properties using the digital image analysis techniques.
- 1.2. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*
- 1.3. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*
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2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 231, Weighing Devices Used in the Testing of Materials
 - M 339M/M 339, Thermometers Used in the Testing of Construction Materials
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - R 76, Reducing Samples of Aggregate to Testing Size
 - R 90, Sampling Aggregate Products
 - T 11, Materials Finer Than 75- μ m (No. 200) Sieve in Mineral Aggregates by Washing
 - T 27, Sieve Analysis of Fine and Coarse Aggregates
 - T 84, Specific Gravity and Absorption of Fine Aggregate
 - T 85, Specific Gravity and Absorption of Coarse Aggregate
- 2.2. *ASTM Standards:*
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

- C802, Standard Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
- E2877, Standard Guide for Digital Contact Thermometers

2.3. *International Electrotechnical Commission Standard:*

- IEC 60584-1:2013, Thermocouples - Part 1: EMF Specifications and Tolerances

2.4. *NCHRP Document:*

- National Cooperative Highway Research Program Report 555, *Test Methods for Characterizing Aggregate Shape, Texture, and Angularity*, 2007.

3. TERMINOLOGY

3.1. *Definitions:*

3.1.1. *aggregate size*—sieve size in which material is retained after passing the next larger sieve.

3.1.1.1. *fine aggregate*—aggregate material passing a 4.75-mm (No. 4) sieve. Sieve sizes are 2.36 mm (No. 8), 1.18 mm (No. 16), 0.60 mm (No. 30), 0.30 mm (No. 50), 0.15 mm (No. 100), and 0.075 mm (No. 200).

3.1.1.2. *coarse aggregate*—aggregate material retained on a 4.75-mm (No. 4) sieve. Sieve sizes are 25.0 mm (1 in.), 19.0 mm (³/₄ in.), 12.5 mm (¹/₂ in.), 9.5 mm (³/₈ in.), and 4.75 mm (No. 4).

3.1.2. *Shape Properties for Each Retained Sieve (x):*

3.1.2.1. *gradient angularity (GA)*—applies to both fine and coarse aggregate sizes and is related to the sharpness of the corners of two-dimensional images of aggregate particles. The gradient angularity quantifies changes along a particle boundary with higher gradient values indicating a more angular shape. Gradient angularity has a relative scale of 0 to 10,000, with a perfect circle having a value of 0.

Gradient Angularity:

$$GA = \frac{1}{\frac{n}{3} - 1} \sum_{i=1}^{n-3} |\theta_i - \theta_{i+3}| \quad (1)$$

where:

θ = angle of orientation of the edge points,

n = the total number of points, and

i = denoting the i th point on the edge of the particle.

3.1.2.2. *texture or microtexture (TX)*—applies to coarse aggregate sizes only and describes relative smoothness or roughness of surface features less than approximately 0.5 mm in size that are too small to affect the overall shape. Texture has a relative scale of 0 to 1000 with a smooth polished surface approaching a value of 0.

$$TX_n = \frac{1}{3N} \sum_{i=1}^3 \sum_{j=1}^N [D_{i,j}(x, y)]^2 \quad (2)$$

where:

D = decomposition function,
 n = decomposition level,
 N = total number of coefficients in an image,
 i = 1, 2, or 3 for detailed images,
 j = wavelet index, and
 x, y = location of the coefficients in transformed domain.

3.1.2.3. *sphericity (SP)*—applies to coarse aggregate sizes only and describes the overall three-dimensional shape of a particle. Sphericity has a relative scale of 0 to 1. A sphericity value of 1 indicates a particle has equal dimensions (cubical).

$$SP = \sqrt[3]{\frac{d_s \times d_l}{d_l^2}} \quad (3)$$

where:

d_s = particle shortest dimension,
 d_l = particle intermediate dimension, and
 d_L = particle longest dimension.

Note 1—The term “sphericity” has been used for many years in research to describe this measurement. In principle, a cube does not have a sphericity of one because the diagonal is considered to be the longest dimension. A digital image acquisition and analysis system would measure a value of one for a cube because it would be sitting in front of the camera on one of its faces and the longest dimension will be measured as the width.

3.1.2.4. *Form 2D*—Applies to fine aggregate sizes only and is used to quantify the relative form from two-dimensional images of aggregate particles. Form 2D has a relative scale of 0 to 20. A perfect circle has a Form 2D value of 0.

$$\text{Form 2D} = \sum_{\theta=0}^{\theta=360-\Delta\theta} \left[\frac{R_{\theta+\Delta\theta} - R_{\theta}}{R_{\theta}} \right] \quad (4)$$

where:

R_{θ} = the radius of the particle at an angle of θ , and
 $\Delta\theta$ = the incremental difference in the angle.

3.1.2.5. *flat and elongated*—those particles having a ratio of longest dimension to shortest dimension greater than a specified value.

Aggregate particle dimensions in an x, y, z coordinate system are:

d_s = particle shortest dimension,
 d_l = particle intermediate dimension, and
 d_L = particle longest dimension.

$$\text{Flatness ratio (S/L): } \textit{Flatness} = \frac{d_s}{d_l} \quad (5)$$

$$\text{Elongation ratio (I/L): } \textit{Elongation} = \frac{d_l}{d_L} \quad (6)$$

$$\text{Flat and elongated value (F\&E): } L / S = \frac{d_L}{d_s} \quad (7)$$

- 3.1.2.6. *flat or elongated*—those particles having a ratio of intermediate dimension to shortest dimension or longest dimension to intermediate dimension greater than a specified value.

$$\text{Flat or elongated value (F or E): } \frac{d_l}{d_s} \text{ or } \frac{d_L}{d_l} > \text{ratio} \quad (\text{i.e., 1, 2, 3...}) \quad (8)$$

4. SIGNIFICANCE AND USE

- 4.1. Shape, angularity, and surface texture of aggregates have been shown to directly affect the engineering properties of highway construction materials such as hot mix asphalt concrete, portland cement concrete, and unbound aggregate layers. This standard provides direct measurement of aggregate shape, angularity, and texture. For coarse aggregates, the shape properties include: gradient angularity, sphericity, texture, and flat and elongated value. For fine aggregates the shape properties include: gradient angularity and Form 2D.
- Note 2**—The National Cooperative Highway Research Program Report 555 provides background information relevant to characterizing aggregate shape, texture, and angularity.
- 4.2. This test method may be used to characterize and monitor the shape properties of aggregate material sizes 0.075 mm (No. 200) through 25.0 mm (1 in.). This method may be used to characterize a single size within a material source or all sizes within the source.

5. APPARATUS

- 5.1. *Digital Image Acquisition and Analysis System*—A computer-controlled electromechanical instrument for capturing digital images at variable magnification and software for image analysis. Instrumentation and analysis software shall include algorithms for gradient angularity, Form 2D, flat and elongated value, sphericity, and texture.
- 5.1.1. A camera and optic system capable of providing the required resolutions over the range of particles being analyzed.
- 5.1.2. A system for positioning the particle for imaging. This can be a movable camera, a movable support tray, or a combination thereof.
- 5.1.3. A system for auto-focusing the image.
- 5.1.4. A system for determining particle three-dimensional measurements x , y , z in millimeters.
- 5.1.5. A system for detecting and removing touching particles from the analysis.
- 5.1.6. A system for presenting the particles for imaging consisting of trays or other support surface for aggregate sizes from 0.075 mm (No. 200) through 25.0 mm (1 in.). The particles shall be presented for imaging on a flat surface. A small recess for aligning particles is acceptable.
- 5.1.7. A variable lighting system for backlighting or top lighting, or both, the material sample.
- Note 3**—The Aggregate Image Measurement System (AIMS) and the associated AIMS Software algorithms for image analysis computations have proven to be an acceptable system for a Digital Image Acquisition and Analysis System.
- Note 4**—The AIMS device was calibrated for uniformly light-colored aggregates. Care should be taken when interpreting texture index results of aggregates with different levels of hue, saturation, and brightness.