
1 Introduction

Rounding

The Mean

Standard Deviation

Five-Point Moving Average

Terms Related to Aggregates

CHAPTER ONE: *INTRODUCTION*

Quality Control/Quality Assurance (QC/QA) is often used synonymously with the term Quality Assurance (QA). AASHTO defines Quality Assurance as "All those planned and systematic actions necessary to provide confidence that a product will perform satisfactorily in service." This definition considers QA to be an all encompassing concept which includes quality control (QC), acceptance, and independent assurance (IA). A better understanding of the QC/QA concept may be made if the characteristics of the specifications are considered. These include:

- 1) QC/QA recognizes the variation in materials and test methods.
- 2) QC/QA uses a statistical basis that is applied and modified with experience and sound engineering judgement.
- 3) QC/QA places primary responsibility on the Producer for production control.

The procedure used by INDOT in the past to accept aggregates required that a stockpile of aggregates be tested to verify compliance with specifications, and the stockpile subsequently approved or disapproved prior to shipment. This pass/fail specification became very confrontational with Producers when failing tests were obtained and shipments delayed or stopped to active contracts. Even when eventually resolved, project delays were inevitable in many cases. A QC/QA procedure whereby Producer's tests could be used for acceptance, and shipments of aggregates made on demand was needed. The Certified Aggregate Producer Program (CAPP) was introduced as the procedure to accomplish both needs.

The CAPP designates specific quantities of material to be tested, material test values, test equipment calibrations, and statistical concepts to be applied to control aggregate products. As such, a standard method for rounding values is required to be established and basic statistical rules be presented. This chapter discusses the procedures for rounding numbers, and the basic statistical calculations.

ROUNDING

When calculations are conducted, rounding is required to be in accordance with 109.01(a) using the standard "5" up procedure. There are two rules for rounding numbers:

1. When the first digit discarded is less than 5, the last digit retained should not be changed.

Examples: 2.4 becomes 2
 2.43 becomes 2.4
 2.434 becomes 2.43
 2.4341 becomes 2.434

2. When the first digit discarded is 5 or greater, the last digit retained should be increased by one unit.

Examples: 2.6 becomes 3
 2.56 becomes 2.6
 2.416 becomes 2.42
 2.4157 becomes 2.416

The Certified Aggregate Producer Program requires that test and statistical values be calculated to the nearest decimal place as indicated in Figure 1-1.

Property	Nearest Whole Unit (0)	First Decimal Place (0.0)	Second Decimal Place (0.00)	Third Decimal Place (0.000)
Crushed Particles	X			
Flat & Elongated	X			
Percent Compliance	X			
Control Limits*	X	X		
Absorption		X		
Decantation		X		
Deleterious		X		
Gradation		X		
Surface Moisture		X		
Target Mean		X		
5-Point Moving Ave.		X		
Fineness Modulus			X	
Standard Deviation			X	
Z Value			X	
Bulk Specific Gravity				X
Proportionate Factor				X

* May be rounded to (0.0) or (0)

Figure 1-1. Decimal Places.

THE MEAN

The simple mathematical average of any group of numbers is the mean. In other words, the mean is the sum of all the measurement values divided by the number of measurements. The symbol for the mean is \bar{x} . As an example, the mean for five numbers would be calculated as follows:

$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_4 + x_5}{5}$$

STANDARD DEVIATION

Whereas the mean is an average of all the data values, the standard deviation is an average value of the dispersion of data from the mean. Standard deviation is usually signified by a small s or the Greek letter Sigma (σ). For the CAP Program σ_{n-1} is used.

The procedure used to compute the standard deviation is to subtract the mean from each value, square this difference, sum, divide by one less than the number of values, and take the square root. These steps may be expressed in terms of a formula as follows:

$$\sigma_{n-1} = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

where \bar{x} is the arithmetic mean, n is the number of sample values and \sum indicates the summation of all values.

Note that squaring the deviations from the mean removes the negative signs. Dividing by n - 1 gives us approximately an average squared deviation. Taking the square root puts the result back into the same units as the original values.

Example:

x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	
14.3	1.7	2.89	$n = 10$ $\bar{x} = \frac{\sum x_i}{n} = 12.6$ $\sigma_{n-1} = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} =$ $\sqrt{\frac{10.09}{9}} = \sqrt{1.121} = 1.06$
11.2	-1.4	1.96	
14.1	1.5	2.25	
12.6	0.0	0.00	
12.9	0.3	0.09	
12.7	0.1	0.01	
13.2	0.6	0.36	
11.4	-1.2	1.44	
12.3	-0.3	0.09	
<u>11.6</u>	<u>-1.0</u>	<u>1.00</u>	
126.3		10.09 (Sum of squared differences)	

FIVE-POINT MOVING AVERAGE

The moving average is a useful tool for tracking trends of the mean. The CAPP requires that the moving average be the average of the most recent five data points.

For a moving average of five test values, the group of the first five measurements is averaged. When an additional test value is obtained, the first value is dropped, the sixth value is added, and the new group averaged. When a seventh value is obtained, the second value is dropped, and the new group averaged, and so on. An example of this procedure is as follows:

Data: 4.8, 5.3, 5.0, 4.7, 5.1, 5.5, 4.6

$$\begin{aligned}\text{First Average} &= \frac{4.8 + 5.3 + 5.0 + 4.7 + 5.1}{5} \\ &= \frac{24.9}{5} = 5.0\end{aligned}$$

The first number, or 4.8, is dropped and the sixth value, or 5.5, is added and the second average is:

$$\begin{aligned}\text{Second Average} &= \frac{5.3 + 5.0 + 4.7 + 5.1 + 5.5}{5} \\ &= \frac{25.6}{5} = 5.1\end{aligned}$$

Next, the 5.3 is dropped and 4.6 is added:

$$\begin{aligned}\text{Third Average} &= \frac{5.0 + 4.7 + 5.1 + 5.5 + 4.6}{5} \\ &= \frac{24.9}{5} = 5.0\end{aligned}$$

TERMS RELATED TO AGGREGATES

AASHTO - American Association of State Highway and Transportation Officials

Abrasion Resistance - The resistance of coarse aggregates to fracturing under impact and breaking down into smaller pieces from abrasive action

Absorption - The increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass

Adherent Fines - Fine particles smaller than the No. 200 (75 μm) sieve created from handling, or silt or clay that adheres to the coarse aggregate particles

Aggregate Base - A layer of aggregate placed on a subgrade or subbase to support a surface course

Air-Cooled Blast Furnace Slag (ACBF) - Material resulting from solidification of molten blast-furnace slag under atmospheric conditions

Apparent Specific Gravity - The ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature

ASTM - American Society for Testing and Materials

Bulk Specific Gravity - The ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight of an equal volume of gas-free distilled water at a stated temperature

Artificial Aggregates - Aggregates that are manufactured or by-products of an industrial process. Blast furnace slag, steel slag and wet bottom boiler slag are examples of by-product artificial aggregates.

B Borrow - Material used for special filling such as for displaced peat deposits, bridge approach embankments, and fillings over structures. B borrow is required to be acceptable quality, free from large or frozen lumps, wood, or other extraneous matter. Materials used for B Borrow are suitable sands, gravel, crushed stone, ACBF, GBF, or other approved materials.

Bulk Specific Gravity (SSD) - The ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours (but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature

Category - Source classification used to determine the production quality sampling frequency

Certified Material - An aggregate product produced in accordance with the Certified Aggregate Producer Program (CAPP) for Department use

Certified Aggregate Producer - A Plant/Redistribution Terminal that meets the requirements of ITM 211, continues to be under the same ownership, and is approved by the Department

Chert – An aggregate of varied color, composed of glassy silica, and very fine grained quartz. Unweathered chert appears hard, dense, and brittle with a greasy texture. Weathered chert appears chalky and dull. Chert is likely to have concave surfaces with sharp outer edges when freshly broken.

Class A - Quality rating assigned to aggregates which meet requirements for all Department uses except for specified slab on grade concrete applications

Class AP - Quality rating assigned to coarse aggregates cast into concrete beams and subjected to freeze and thaw cycling procedures in accordance with ITM 210. Class AP aggregates are required for concrete pavement and other concrete applications

Classes B, C, D, E, and F - Quality ratings assigned to aggregates with restricted uses

Class G - Quality rating assigned to materials which do not meet requirements for any Department use

Clay Lumps – Materials that are easily crumbled or mashed with the fingers as determined by AASHTO T 112

Coarse Aggregate - Aggregate that has a minimum of 20 percent retained on the No. 4 (4.75 mm) sieve

Coatings – A layer of substance covering a part or all the surface of an aggregate particle. The coating may be of natural origin, such as mineral deposits formed in sand and gravel by ground water, or may be artificial such as dust formed by crushing and handling. (see Adherent Fines)

Composite Stockpiling – Stockpiling of natural fine aggregate from multiple sources into one stockpile

Core Drilling Log - A written field description of a rock core sample and the operations

Core Sample - A rock sample obtained with a bit affixed to a barrel with drill rods that are advanced by a rotary drilling machine

Decantation - A test utilizing water to determine the amount of material that is passing the No. 200 sieve. The decantation test is conducted on both fine and coarse aggregate and is usually done in conjunction with the sieve analysis test.

Deleterious - Undesirable aggregate material

Density - The weight per unit volume of a substance

Dolomite - Carbonate rock containing at least 10.3% elemental magnesium when tested in accordance with ITM 205

DTE – District Testing Engineer

Fine Aggregate - Aggregate that is 100 percent passing the 3/8 in. (9.5 mm) sieve and a minimum of 80 percent passing the No. 4 (4.75 mm) sieve

Fineness Modulus - A factor commonly associated with aggregates used for portland cement concrete that is used to determine the relative coarseness or fineness of the aggregate grading

Gradation - The range and relative distribution of particle sizes in the aggregate material

Granulated Blast Furnace Slag (GBF) - Glassy, granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water

Gravel - Unconsolidated deposits of all rock types transported and deposited by glaciers

Hardness - A measure of the cementing and interlocking quality of an aggregate that controls the resistance of the aggregate to abrasion and degradation. The Mohs Hardness Scale is frequently used for determination of mineral hardness.

Igneous Rocks - Rocks formed from hot volcanic magma-molten mineral material

Independent Assurance – Independent Assurance testing is conducted by District Testing personnel to verify the reliability of the results obtained in acceptance sampling and testing. Certified Aggregate Technicians are checked annually by Independent Assurance Technicians for the sampling and testing procedures that are conducted at the aggregate source.

Lightweight Chert - Chert that has a bulk specific gravity of less than 2.45 as determined using the saturated surface dry condition

Recycled Foundry Sand - A mixture of residual materials used for the production of ferrous or non-ferrous metal castings and natural sands. Recycled foundry sand is required to comply with the Indiana Department of Environmental Management (IDEM) Class III or Class IV residual sands classification.

Ledge - Any stratigraphic unit which may be separated from adjacent units by lithologic differences

Ledge Sample - Core or face sample taken to represent ledges

Limestone - Sedimentary rock primarily consisting of carbonates of calcium and dolomite

Maximum Particle Size - The sieve on which 100 percent of the material will pass

Metamorphic Rock - Rocks that were originally igneous or sedimentary rocks, but were changed by pressure and/or heat

Mineral Filler - Dust produced by crushing stone, portland cement, or other inert mineral matter having similar characteristics. Mineral filler shall be in accordance with the gradation requirements for size No.16.

Natural Aggregates - Rock fragments which are used in their natural state such as crushed stone, sand, and gravel

Nominal Maximum Particle Size - The smallest sieve opening through which the entire amount of the aggregate is permitted to pass

Non-durable particles - Soft particles as determined by ITM 206 and other particles which are structurally weak, such as soft sandstone, shale, limonite concretions, coal, weathered schist, cemented gravel, ocher, shells, wood, or other objectionable material

Point-Of-Use Sample - Production quality sample obtained at the last opportunity prior to incorporation into the end use

Polish Resistant Aggregates - Dolomite containing less than 10.3% elemental magnesium, crushed limestone, or gravel meeting the requirements of ITM 214. Aggregates meeting these requirements are maintained on the INDOT Approved List of Polish Resistant Aggregates.

Production Quality Sample - An aggregate sample representing finished materials obtained at the aggregate source or the point-of-use

Quality Assurance Materials - Certified Materials controlled by aggregate gradations by the Producer

Quality Control Plan (QCP) - A document written by the Producer that is site-specific and includes the production, policies, and procedures used by the Producer

Qualified Technician - An individual who has successfully completed the written and proficiency testing requirements of the Department Qualified Laboratory and Technician Program

Rating L - A rating for information only

Riprap - Typically large aggregate materials used as a protective coating. Riprap may consist of steel furnace slag for dumped riprap only, sound stone, stone masonry, or other approved materials, free from structural defects and of approved quality.

Sandstone - Sedimentary rock composed of siliceous sand grains containing quartz, chert, and quartzose rock fragments in a carbonate matrix or cemented with silica, calcite, or dolomite

Sedimentary - Rocks formed from the disintegration of other rocks and organic materials. Limestone, dolomite, sandstone, shale, and siltstone are examples of sedimentary rock types.

Sieving - A test procedure that is used to determine the gradation of a material. A sample of the aggregate material being tested is weighed and then passed through a series of sieves to determine the gradation.

Soundness - The durability of fine and coarse aggregate and their resistance to the forces of weathering, in particular to alternate freezing and thawing conditions

Source - Facility that processes or handles aggregates. A Redistribution Terminal is classified as a source.

Source Map - A map of the quarry showing critical features and operating areas

Source Sample - Production quality sample representing finished materials that are stored at an aggregate source or redistribution terminal

Subbase - A layer of aggregate placed on a subgrade to support an aggregate base

Subgrade - The layer below the subbase that may be comprised of various aggregate types

Specific Gravity - The ratio of the mass of a unit volume of a material to the mass of the same volume of gas-free distilled water at a stated temperature

Standard Specification Materials - Certified Materials controlled by aggregate gradations as defined in the Department Standard Specifications and the construction contract documents

Steel Furnace Slag (SF) - A material derived from the further refinement of iron to steel

Subcategory - Source classification based on results of tests conducted on source samples and used to determine the production quality sampling frequency

Structural Backfill - Suitable sand, gravel, crushed stone, air-cooled blast furnace slag, or granulated blast furnace slag used to fill designated areas excavated for structures that are not occupied by permanent work

Wet Bottom Boiler Slag - A material which is a by-product from coal combustion at electrical generating plants