Standard

Title: Measuring Concrete Micro Surface Texture
Specification No.: CSDA-ST-115
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Foreword

This is the first CSDA standard for measuring concrete surfaces for their surface texture value. This specification is the culmination of a major effort and input by members of various committees related to the industries of concrete and surface metrology from ASME, ASTM, ACI and CSDA. A considerable amount of information regarding surface measurement techniques and surface parameters in practical use has been considered and taken into account. Surface metrology is the study of surface geometry, also called surface texture or surface roughness. It examines the real value of the measurement of small-scale features on surfaces.

The approach is to measure and analyze the surface texture in order to understand how the texture is influenced by the finishing process, and how the surface texture influences its behavior with regards to gloss, friction and sustainability. The vision for this standard is to obtain a quantitative measure of concrete surface profile by contact instruments. It is also important to keep abreast of the latest developments in contact profiling techniques, where the degree of measurement control becomes more highly advanced, and encompass a filtered range of other techniques that present valid and useful descriptions of surface texture.

The measurement parameter for the basis of this standard is Ra (roughness average) by contact stylus instruments. Many surface finish height parameters are currently in use and measure various surfaces materials. They distinguish certain characteristics about the working part, the ways in which the surface was processed and finally how it was finished. These characteristics include waviness, lay and process direction.

This standard is concerned with numerically quantifying geometric irregularities of the machined and processed finish that is produced as a result of a particular specified level of surface refinement of concrete finishes. Particular means and methods of producing polished concrete surfaces are not suggested nor are they recommended for any specified level of finish in this document.

The terms in this Standard relate directly to concrete surfaces produced by such means as abrading, cutting, grinding, milling, honing and polishing.

This Standard is not concerned with error of form and flaws of concrete substrates, but discusses these two factors to distinguish them from surface texture metering. This standard is not concerned with luster, appearance, color, corrosion resistance, wear resistance, hardness, subsurface microstructure, surface integrity and other characteristics which may govern functional considerations in specific applications. However, historical data with similar specifications and standards has proven reflective value, performance characteristics and sustainability due to its processed level of specified finish. This section does not recommend specific surface texture suitable for specific purposes, nor does it specify the means by which these irregularities may be produced.

Criteria for the selection of surface qualities and information on techniques and methods for producing, controlling and inspecting surfaces are included in Specification CSDA-PC-113 *Polishing Concrete* and Best Practice CSDA-BP-008 *Polished Concrete Floors*. Surface texture designations, as delineated in this standard, may not provide a sufficient set of indexes for describing performance of a concrete surface. A range of variable components can severely compromise the integrity of mass concrete, such as water to cement ratios, density, geometrical characteristics, design mix materials and structural stability.

References

ASME B46.1-2009 (R2002), Surface Texture (Surface Roughness, Waviness, and Lay)

ASME B89.6.2-1973 (R2003), Temperature and Humidity Environment for Dimensional Measurement

ASME Y14.5M-1994 (R2004), Dimensioning and Tolerancing, Engineering Drawings and Related Documentation Practices

ISO 1302:2002, Geometrical Product Specifications (GPS) – Indication of surface texture in technical product documentation

Table of Contents

1. Executive Summary

This document is a guide to measure various levels of surface texture for the concrete finishing and concrete polishing industry. It establishes a uniform system for the identification and specification of the geometric irregularities of concrete surfaces. It also provides, through the use of numerical classifications, a means for accurately expressing surface roughness and surface texture on drawings, specifications and verbal expressions.

Scope: This standard covers surface irregularities with respect to their height and width. It shall replace all former documentation for specifying concrete finishes and shall apply to any concrete surface of sufficient hardness to be evaluated in terms of micro inches under the provisions herein specified.

Materials and Processes: This document is not concerned with the concrete materials integrity or analysis, microstructure, corrosion resistance, appearance, luster, color or like characteristics except when specified for a particular application.

Surface Refinement and Processing Methods: Surface roughness and surface texture designation is not intended to be directly associated with any method of producing a surface texture. Therefore, unless otherwise specified, the surface refinement activity may use any available manufacturing or proprietary method that will produce the specified finish grade.

Cleanliness: Surfaces to be measured should be free of any foreign material that would interfere with the measurement.

Units of Measure: Values of quantities stated in this document are indicated in units of SI (metric) or US measurement standards and noted as such.

Ra is the average roughness and is the parameter used as the basis of this document.

Filtering: Modern surface texture measuring instruments record the stylus movement over the evaluation length electronically and can produce output readings to a significant level of detail. The instruments measure the roughness variations and the waviness variations. There are three characteristics of filtering that should be acknowledged to understand the parameter values that an instrument may calculate. Filtering is necessary to separate roughness from waviness or waviness from form error. Separating the roughness and waviness is achieved by using filter cut-offs.

λc = the roughness long wavelength cut-off. This filter specifies the long spatial wavelength cut-off and is defined as the wavelength where the filter will attenuate the true profile by 50%. In the roughness requirement, this value is the sampling length. Spatial wavelengths substantially greater than λc are severely attenuated and minimally contribute to the roughness measurement.

λs = the roughness short wavelength cut-off. This filter specifies the short spatial wavelength cut-off and is defined as the wavelength where the filter will attenuate the true profile by 50%. This filter defines the wavelength where the filter will attenuate the true profile by 50%. Spatial wavelengths substantially less than λs are severely attenuated and minimally contribute to the roughness measurement.

Stylus Tip Radius: The stylus tip radius may be chosen by the designer or metrologist based on the value of λs (i.e., the short wave cut-off). For λs equal to 2.5 µm, the tip radius should typically be 2 µm or less. For λs equal to 8 µm, the tip radius should typically be 5 µm or less. For λs equal to 25 µm, the tip radius should typically be 10 µm or less.

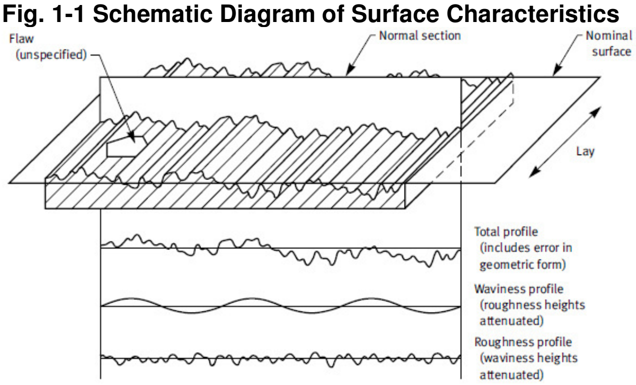
Stylus Force: The maximum static measuring force is determined by the radius of the stylus. It is chosen to assure minimal damage to the surface and that constant contact is maintained with the surface. Specific recommendations for stylus force are the responsibility of the manufacturer and the processor. The established stylus force must fall within the parameters of ASME B46.1-2009 (R2002), Surface Texture (Surface Roughness, Waviness, and Lay).

Measurement Parameters: Many surface finish height parameters are currently in use. From the simplest specification of a single roughness parameter to multiple roughness and waviness parameter specifications of a given surface, product designers have many options for specifying surface texture to control surface function. R_a (Average Roughness) is the base parameter of the surface texture standard. Average roughness is the arithmetic average of the absolute profile deviations from the mean line within the evaluation length. Graphically, this is the area between the roughness profile and the mean line divided by the evaluation length.

2. Terms and Definitions

***surface**:* the boundary that separates an object from another object, substance or space.
***nominal surface**:* the intended surface boundary (exclusive of any intended surface roughness), the shape and extent of which is usually shown and dimensioned on a drawing or descriptive specification (see Fig. 1-1).
***real surface**:* the actual boundary of an object. Its deviations from the nominal surface stem from the processes that produce the surface.
***measured surface**:* a representation of the real surface obtained by the use of a measuring instrument.

Fig. 1-1 Schematic Diagram of Surface Characteristics



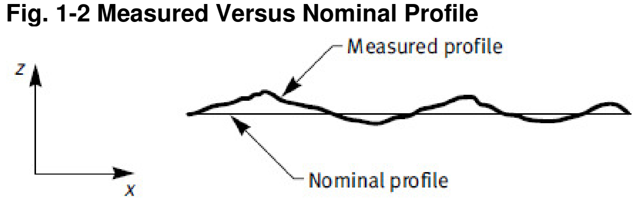
Components of the Real Surface – The real surface differs from the nominal surface to the extent that it exhibits surface texture, flaws, and errors of form. It is considered as the linear superposition of roughness, waviness and form with the addition of flaws.

***surface texture**:* the composite of certain deviations that are typical of the real surface. It includes roughness and waviness.
***roughness**:* the finer spaced irregularities of the surface texture that usually result from the inherent action of the production process or material condition.
***waviness**:* the more widely spaced component of the surface texture. Waviness may be caused by such factors as machine or workpiece deflections, vibration and chatter. Roughness may be considered as superimposed on a wavy surface.
***lay**:* the predominant direction of the surface pattern, ordinarily determined by the production method used.
***error of form**:* widely spaced deviations of the real surface from the nominal surface, which are not included in surface texture. The term is applied to deviations caused by such factors as errors in machine tool ways, guides or spindles, insecure clamping or incorrect alignment of the working surface, or uneven wear. Out-of-flatness is a typical example.
***flaws**:* unintentional, unexpected and unwanted interruptions in the topography typical of a surface. These topographical interruptions are considered to be flaws only when agreed upon in advance by buyer and seller.

If flaws are specified, the surface should be inspected by a mutually-agreed method to determine whether flaws are present and are to be rejected or accepted prior to performing final surface finishing measurements. If specified flaws are not present, or if flaws are not specified, then interruptions in the surface topography of an engineering component may be included in roughness measurements.

Definitions Related to the Measurement of Surface Texture by Profiling Methods – The features defined above are inherent to surfaces and are independent of the method of measurement. Methods of measurement of surface texture can be classified generally as contact or noncontact methods and as three-dimensional (area) or two-dimensional (profile) methods.

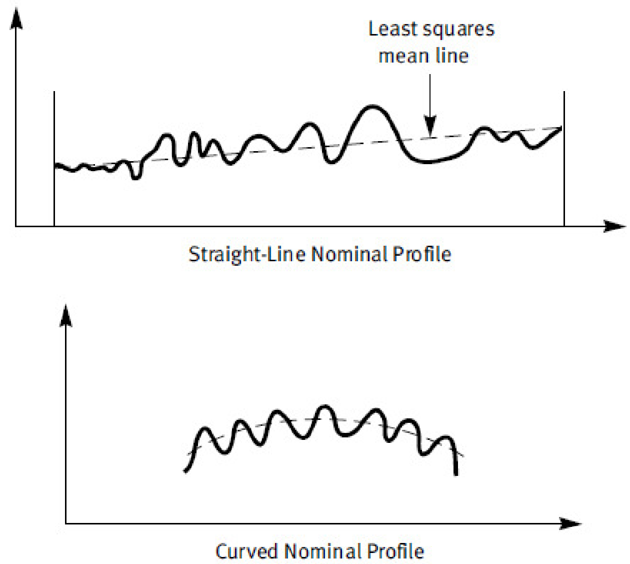
Fig. 1-2 Measured Versus Nominal Profile



***profile**:* the curve of intersection of a normal sectioning plane with the surface (see Fig. 1-2).
***profiling method**:* a surface scanning measurement technique that produces a two-dimensional graph or profile of the surface irregularities as measurement data.
***nominal profile**:* a profile of the nominal surface; a straight line or smooth curve (see Fig. 1-2).

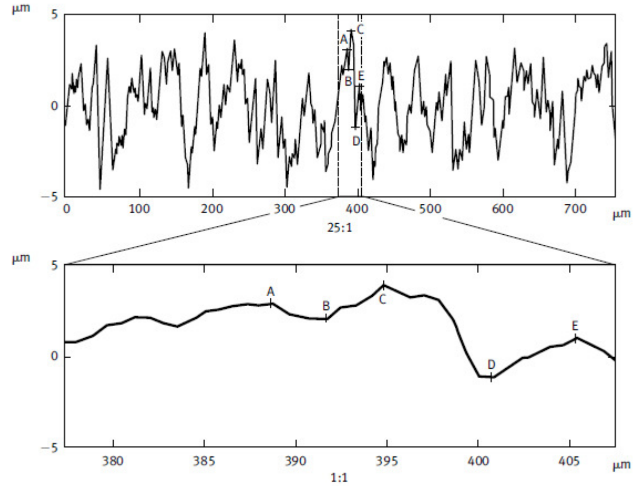
real profile*:* a profile of the real surface.
measured profile*:* a representation of the real profile obtained by a measuring instrument (see Fig. 1-2). The profile is usually drawn in a *x-z* coordinate system.
primary profile*:* primary profile; a modified profile after the application of the short wavelength filter, λ*s*.
NOTE: This corresponds to the primary profile as per ISO 3274:1996.
roughness profile*:* the modified profile obtained by filtering to attenuate the longer spatial wavelengths associated with waviness.
waviness profile*:* the modified profile obtained by filtering to attenuate the shorter spatial wavelengths associated with roughness and the longer spatial wavelengths.

Fig. 1-4 Examples of Nominal Profiles



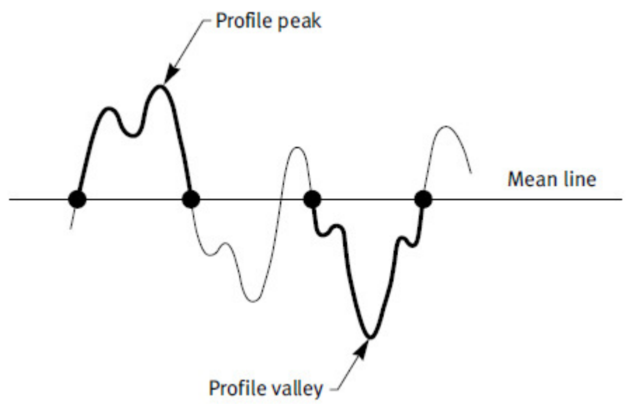
Aspect Ratio – In displays of surface profiles generated by instruments, heights are usually magnified many times more than distances along the profile. The sharp peaks and valleys and the steep slopes seen on such profile representations of surfaces are thus greatly distorted images of the relatively gentle slopes characteristic of actual measured profiles.

Fig. 1-3 Stylus Profile Displayed With Two Different Aspect Ratios



profile peak*:* the point of maximum height on a portion of a profile that lies above the mean line and between two intersections of the profile with the mean line (see Fig. 1-6).
profile valley*:* the point of maximum depth on a portion of a profile that lies below the mean line and between two intersections of the profile with the mean line (see Fig. 1-6).

Fig. 1-6 Profile Peak and Valley



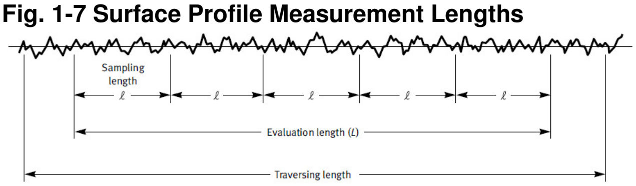
spacing*:* the distance between specified points on the profile measured along the nominal profile.
roughness spacing*:* the average spacing between adjacent peaks of the measured roughness profile within the roughness sampling length.
waviness spacing*:* the average spacing between adjacent peaks of the measured waviness profile within the waviness long-wavelength cut-off.
spatial wavelength*,* λ*:* the lateral spacing between adjacent peaks of a purely sinusoidal profile.

***spatial (x) resolution**:* for an instrument, the smallest surface spatial wavelength that can be resolved to 50% of its actual amplitude. This is determined by such characteristics of the measuring instrument as the sampling interval (defined below), radius of the stylus tip or optical probe size. This is a key specification for a measuring instrument.

NOTE: *Concerning resolution, the sensitivity of an instrument to measure the heights of small surface features may depend on the combination of the spatial resolution and the feature spacing, as well as the system height resolution.*

***sampling interval**:* the lateral point-to-point spacing of a digitized profile (see Fig. 1-8). The minimum spatial wavelength to be included in the profile analysis should be at least five times the sampling interval.
***traversing length**:* the length of profile, which is traversed by a profiling instrument to establish a representative evaluation length. Because of end effects in profile measurements, the traversing length must be longer than the evaluation length (see Fig. 1-7).

Fig. 1-7 Surface Profile Measurement Lengths



evaluation length (L): length in the direction of the *X*-axis used for assessing the profile under evaluation. The evaluation length for roughness is termed L*r* and the evaluation length for waviness is termed L*w*.
sampling length (l): length in the direction of the *X*-axis used for identifying the widest irregularities that are of interest for the profile under evaluation. The sampling length is always less than or equal to the evaluation length. The sampling length for roughness is termed *lr* and the sampling length for waviness is termed *lw*.
***roughness sampling length, lr**:* the sampling length specified to separate the profile irregularities designated as roughness from those irregularities designated as waviness. The roughness sampling length may be determined by electrical analog filtering, digital filtering or geometrical truncation of the profile into the appropriate lengths.
roughness long-wavelength cut-off, λc: the nominal rating in millimeters (mm) of the electrical or digital filter that attenuates the long wavelengths of the surface profile to yield the roughness profile. When an electrical or digital filter is used, the roughness long-wavelength cut-off value determines and is equal to the roughness sampling length (i.e., *lr* p λ*c*). The range of selectable roughness long-wavelength cut-offs is a key specification for a surface measuring instrument.
***roughness short-wavelength cut-off, λs**:* the spatial wavelength shorter than which the fine asperities for the surface roughness profile are attenuated. The nominal values of this parameter are expressed in micrometers (λm). This attenuation may be realized in three ways: mechanically because of the finite tip radius, electrically by an antialiasing filter or digitally by smoothing the data points.
***waviness sampling length, lw**:* the sampling length specified to separate the profile irregularities designated as waviness from those irregularities designated as form. The waviness sampling length may be determined by electrical analog filtering, digital filtering or geometrical truncation of the profile into the appropriate lengths.
***waviness long-wavelength cut-off, λcw**:* the spatial wavelength longer than which the widely spaced undulations of the surface profile are attenuated to separate form from waviness. When an electrical or digital filter is used, the waviness long-wavelength cut-off value determines and is equal to the waviness sampling length (i.e., *lw*=λ*cw*). The range of selectable waviness long wavelength cut-offs is a key specification for a surface measuring instrument.
***waviness short-wavelength cut-off, λsw**:* the spatial wavelength shorter than which the roughness profile fluctuations of the surface profile are attenuated by electrical or digital filters. This rating is generally set equal in value to the corresponding roughness long-wavelength cut-off (λ*sw* p λ*c*).

Misc Definitions
abrasive grain: a small, hard particle or crystal of abrasive material used to machine, grind or finish a work piece.
amplified: to make something larger, to exaggerate detail. A profilometer amplifies surface roughness.
average roughness: The arithmetic mean of the absolute deviations from the mean profile over the evaluation length.
calibration: the comparison of a device with unknown accuracy to a device with a known, accurate standard to eliminate any variation in the device being checked.
comparison measurement: a measurement that compares the surface of a machined part with a standard surface. Inspectors often use their sense of sight and touch to perform comparison measurements.

cut-off: the sample length on the surface of a part that a stylus-type instrument measures. The cut-off length is often specified on a part drawing.
diamond stylus: a cone-shaped spherical point made of diamond that contacts and measures surface roughness. Diamond is the hardest available material and is wear resistant.
dimensional properties: the characteristics of a surface that affect the way it performs. Rough surface texture can cause a surface to prematurely wear and does not have reflective value.
direct measurement: a measurement that calculates the average roughness value by tracing the surface with a stylus-type instrument.
lay: the overall direction of the pattern created by the production process.
machining: the process of removing necessary damage and stock from the cementicous surface to form a specified finish, by means of methods such as: cutting, grinding, milling, honing or polishing.
measured surface: the surface that represents the real surface after it has been measured. The measured surface determines how much the real surface deviates from the nominal surface.
microinches: one-millionth (.000001) of the U.S. standard inch. Microinch is abbreviated µ.
nominal surface: the surface that represents the desired specifications on a part drawing. The nominal surface does not have surface irregularities and is geometrically perfect.
peak: the point of maximum height on the surface of a part that lies above the average line.
physical properties: the characteristics of a surface that affect the way it performs a task. Physical properties affect the way a surface bonds, coats or resists corrosion.
precision reference specimen: a small, square plate that has standard surface characteristics. Precision reference specimens are used to calibrate profilometers.
probe: a device attached to a measuring instrument that uses a stylus tip to contact the surface of a part.
process stability: The consistency of a process over a period of time.
profilometer: a device that uses a stylus to trace the profile of the part to determine average roughness.
real surface: The actual surface produced by a machining process. The real surface contains imperfections.
roughness: the inherent, fine, closely-spaced irregularities created by the production process.
skid: a metal rest that is attached to the probe on a profilometer. The skid moves with the stylus to measure the average roughness of the surface.
skidded gage: a type of profilometer that has a metal rest pad, or skid, that rests on the part. The stylus and skid move together to measure the average roughness.
skidless gage: a type of profilometer that moves relative to an internal reference surface. Skidless gages measure the entire profile of the part.
stylus-type device: a measuring instrument with a cone-shaped spherical tip connected to a probe. The stylus contacts the part and traces its surface irregularities.
surface finish: the smoothness of a machined surface after it has been measured. Surface finish is the complete, desired surface.
surface texture: the combination of the imperfections on the surface of a part. Roughness, waviness, lay, and flaws make up surface texture.
tolerance: an unwanted but acceptable deviation from a given dimension. Tolerances indicate the allowable difference between a physical feature and its intended design.
valley: the point of maximum depth on the surface of a part that lies below the average line. Inspectors often measure the height from the valley to the peak.
variation: a difference between two or more similar things.

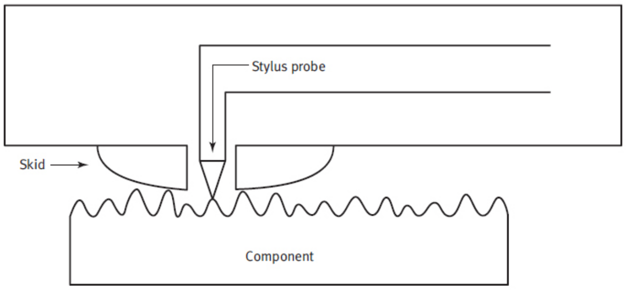
3. Approved Instruments for Surface Texture Measurement

Scope

Contact, skidded instruments (T meter) and procedures used to determine roughness values of a given surface are the basis of this document. They shall comply with the specifications in this section with consideration upon the effective size of the skid relative to the surface spatial wavelengths and amplitudes to be measured. Waviness is not accurately measured with a skidded instrument but is not the basis parameter of this document. Therefore, it is generally recommended that waviness be measured with a skidless instrument. The importance of specifying a portable device (T meter) with accurate results, remote operation and economic considerations have been taken into account with this standard document.

Types IV and V Instruments – Many instruments for measuring surface roughness depend on electrical processing of the signal produced by the vertical motion of a contacting probe traversed along the surface, in general, perpendicular to the lay direction. A convenient means of providing a reference surface for measuring probe movement is to support the tracer containing the probe on *skids* whose radii are large compared to the height and spacing of the irregularities being measured. This document is concerned only with such tracer type instruments using skidded, contact probes (see Fig. 4-1).

Fig. 4-1 Schematic Diagrams of a Typical Stylus Probe and Fringe-Field Capacitance Probe



Purpose

The purpose of this section is to foster the uniformity of surface roughness evaluation among contact, skidded instruments and to allow the specification of desired surface texture values with assurance of securing repeatable results. Special configurations of instruments for special purposes such as small radius skids, long styli, non-contact, fast response and special cut-off characteristics do not meet the requirements of this section but are useful for comparative purposes. The instrument manufacturer shall supply information where deviations exist.

4. Instrumentation

Roughness Average Value *Ra* From Averaging and Digital Readout Instruments – *(a)* The readout device shall display the average deviation from the filtered mean line in λin (λm.). This quantity is the roughness average *Ra*, formerly known as arithmetic average (AA) and centerline average (CLA). The filtered mean line is also described in an earlier Section.

(b) For uniform interpretation of readings from contact type instruments of the averaging type, it should be understood that the reading which is considered significant is the mean reading around which the value tends to dwell or fluctuate with a small amplitude. Analog meters are damped to minimize acute deflections; nevertheless, extremely high and low momentary readings often occur. These anomalous readings are not representative of the average surface condition, and such readings should not be used in determining roughness average. An instrument with a digital readout integrates these high and low momentary readings and displays the surface roughness averaged over a significant length of surface profile.

Cut-off Selection. – In all cases, the cut-off (λ*c*) Values and reference table must comply with ASME B46 Standard.

Recommendation to Settle Interpretation Disputes – In cases of disagreement regarding the interpretation of surface texture measurements, it is recommended that measurements with a Type I (skidless) instrument with Gaussian (50%) filtering to be used as the basis for interpretation.

Profile Filter – The profile filter is the filter which separates the roughness (*R*) from the waviness (*W*) and form error (*F*) components of the primary profile (*P*). This filter consists of either an analog or a digital implementation of a 2RC or a Gaussian filter.

Profile Filter Evaluation Length – Typically the evaluation length is chosen to include at least five roughness long-wavelength cut-off lengths (λ*c*). However, depending on the size of the measurement area, it may be necessary to limit the evaluation length to include less than five roughness cut-off lengths (λ*c*). In this case, the evaluation length used should be noted on the appropriate documentation. Some instruments may automatically change the roughness long-wavelength cut-off to maintain five cut-off lengths within the evaluation length. Therefore, care must be taken to ensure that the proper roughness cutoff length (λ*c*) is used.

Profile Recording and Display – After filtering, the measured profile is typically plotted on a graph, documentation or drawings for visual interpretation. Digital instruments can also store the discrete data points for further numerical analysis and graphical display. Refer to specific performance based specifications for detailed instruction of proper recording requirements.

5. Measurement Procedure

The following section provides guidelines for the use of Skidded instruments in the measurement of concrete surfaces.

Stylus Visual Inspection – Prior to its use, the stylus should be visually inspected for cleanliness and mechanical integrity. If the stylus tip is loose, if the shaft is bent or if the mounting surfaces (for a detachable stylus) appear to have excessive wear, the stylus should be repaired or replaced. The stylus must also be clean and free from any lint or residual film left from the cleaning process.

Magnified Inspection – The stylus tip should also be inspected with the aid of a magnification device (for example, a microscope, optical comparator, jewelers loop). Once again, a broken or worn stylus should be repaired or replaced.

Instrument Calibration – The instrument should be calibrated according to the instrument manufacturer's specifications using a precision reference specimen traceable to the SI unit of length. This specimen should also be clean and free from signs of wear, which may affect the calibration of the instrument. Measurements of the precision reference specimen must be within the stated uncertainty of the precision reference specimen.

Testing Surface Cleanliness – The concrete surface to be assessed should be cleaned with a non-damaging solvent and is to be free from any residual film or other debris prior to measurement. If measuring a surface for Surface Texture Grade Compliance, metering results must be recorded prior to application of topically applied sealers and/or performance enhancement coatings.

Surface Integrity – A visual assessment of the concrete surface should be made to determine a representative portion of the surface on which the trace is to be made. Concrete by nature and design is a product inherent of flaws and irregularity. The quantity of paste removed will ultimately determine the amount of damage such as air voids, craze cracks and roll out that is exposed and potentially metered.

It is quite possible that the specified finish was achieved after the surface was processed, but the damage at the new surface and the concrete matrix will impede a complying finish. It is important to heed this detail and plan accordingly. Designated sampling areas that need to be filled with grouting systems or epoxy fillers should be installed before the last grinding step with a metal bond abrasive disc. Grouting agents and epoxy fillers are not products intended to be above the mean line of the profile. Any readings taken where these filling agents are above the mean profile line are automatically disqualified.

Surface Hardness Consistency Testing (Reading the Real Profile) – It may be determined that a grouting system needs to be applied to the sampling area to comply with the specified texture finish because excessive form and flaw has been identified in the sub-surface of the concrete. In this case, it will be necessary to test the designated sampling areas for hardness to ensure the sample area is a true reading of the profile produced by the refinement process. It should not be a reading of a grouting agent or topical coating. Grouting systems and filling agents are understood to be necessary to conform with texture assignments, though they are also intended to be used only as fillers that reside below the mean line of the profile and adhere to the matrix of the concrete. The surface hardness consistency is calibrated by performing two tests with a penetrometer located within 1 square foot and adjacent to the testing area. Testing results inside the test zone are deemed acceptable if the variance is no less than 10% of the adjacent hardness average of the two results. If tests within the designated testing zone fall outside of the allowable 10% variance, additional grinding will be required to remove excessive grouting agents or fillers that reside above the mean line.

Instrument/Surface Leveling and Alignment – The instrument and surface should be aligned so that the underlying geometry of the surface under test, and its relationship to the traverse, minimize total stylus displacement during measurement over the evaluation length. For flat surfaces, this requires the surface under test to be leveled relative to the instrument traverse unit.

Assessment of the Finished Surface – Upon fulfilling the above requirements, the stylus may be positioned and the measurement made. If a parameter measurement is required, for example the roughness parameter *Ra*, the value can be obtained after proper filtering.

Quantity of Meter Readings – One texture reading shall be taken for every 500 square feet of the specified finish. If the project is less than 500 total square feet then, one texture reading shall be taken for every 100 square feet. Ready mixed concrete is produced off site in batches of approx 10 cubic yards and delivered to the site with a mixer truck. Slabs placed at 6 inches will yield 525 total square feet. This measurement process will provide more complete data to the relative surface texture produced in particular areas if adjustments have been made to the concrete design mix.

Instrument Accuracy – The *Ra* indication of an instrument to a sinusoidal mechanical input of known amplitude and frequency within the amplitude and the cut-off range of the instrument shall not deviate by more than ±5% from the true *Ra* value of the input.

Operational Accuracy – Instrument calibration for *Ra* measurement should be checked using precision roughness specimens at one or two points in the measurement range, depending on the manufacturer's instructions. If two precision reference specimens are used, one should be characterized by a large *Ra* for checking calibration and the second by a small *Ra* for checking linearity. *Stylus check* specimens should not be used for this purpose.

If the *Ra* measurement on either specimen differs by more than 10% of the calibrated value, instrument recalibration is required.

6. Production and Process of Surface Texture

This document is intended to organize the language and narrow the perception of finishes produced on newly-placed and post-cure finishing systems of cast-in-place concrete using a numerical designation code and representative symbol for the specified level of finish. Surface texture should not be controlled on a drawing or specification unless such control is essential to the functional performance or appearance of the concrete surface. Unnecessary specifications may increase processing costs and reduce the emphasis on other more critical surface specifications.

Concrete surfaces such as those in high impact/high traffic conditions are typical of surfaces that require control of the surface characteristics to perform optimally. Non-performance surfaces such as tilt wall panels and vertical structural concrete seldom require any surface texture control. Experimentation or experience with surfaces performing similar functions is the best criterion on which to base selection of optimum surface characteristics.

Determination of required characteristics for finished surfaces may involve consideration of such conditions as the area of contact, the load, speed, direction of motion and material and physical characteristics of concrete design mixes. Variations in any one of the conditions may require changes in the specified surface characteristics.

7. Production

Surface texture is a result of the processing method. Surfaces obtained from polishing or burnishing have undergone some plastic deformation. For surfaces that are milled, ground or honed, the texture is the result of the action of cutting tools, abrasives or other forces. It is important to understand that surfaces with similar roughness average ratings may not have the same performance due to tool transfer, subsurface effects or different profile characteristics. The ability of a processing operation to produce a specific surface texture depends on many factors. For example, in surface grinding the final surface depends on the peripheral speed of the abrasive disc, the speed of the traverse, the rate of feed, the grit size, bonding material and condition of the abrasive tool, the amount and type of lubrication at the point of cutting and the mechanical properties of the concrete surface being ground. A small change in any of the above factors may have a marked effect on the surface produced.

8. Inspection and Test Pilots

Although this document permits considerable latitude in the method of producing and inspecting a surface, it specifies limits on the characteristics of measuring instruments, roughness comparison specimens and precision reference specimens. These specifications are essential for the reliable measurement of surface parameters and are thus necessary for establishing and maintaining control of surface texture. The instruments permit the accurate measurement of characterization parameters for surfaces generated in production.

The precision reference specimens provide an accurate means of calibrating the measuring instruments. The texture comparison specimens allow engineers or designers to obtain an approximate idea of the surface textures produced by various finishing processes. One of the methods of control and inspection is the use of pilot specimens. These are actual finished surfaces from the production setup that conform to the surface requirements specified on the drawings and related specifications.

To assure reasonable accuracy, the surface texture of pilot specimens should be measured by calibrated instruments. Pilot specimens are can be used as a tool to manage the expectation of the specified finish as a calibrated and approved finish. This is done before normal finishing production begins on the project, insuring the same machine setup is used. This way, it may be possible to determine through physical characteristics, like sight or touch, if a finish deviates significantly from the established norm indicated by the pilot specimen. If control is required in more than one zone of the project, multiple pilot specimens may be placed as long as the same measuring device is used and all pilot specimens possess the same texture finish. Fabricated replicas of the pilot specimen are only approved for the submittal process of the project and are not acceptable to be used for on-site comparisons.

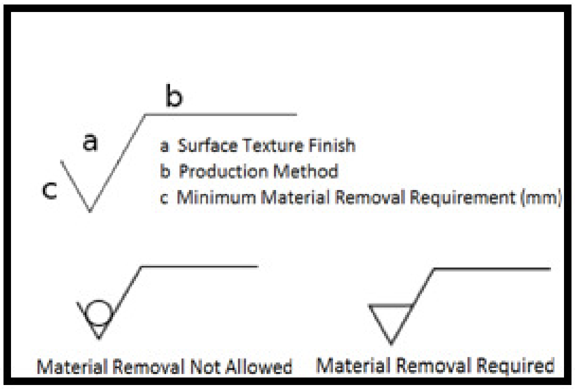
Optical reflectivity is not necessarily a reliable index of surface texture. This is because reflectivity is dependent on such factors as the specular properties of the material, the lighting conditions, viewing angle, roughness, irregularity spacing and color, as well as roughness height.

There is no reliable numerical value between surface texture and gloss metrology that can provide a consistent parallel of results between gloss readings and surface texture readings on the same calibrated finish. In addition, a gloss meter cannot differentiate between a finish produced at high quality standards of refinement and a finish produced by applying a coat of wax.

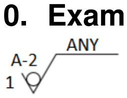
9. Codes, Symbols and Chart

Surface Texture Symbols – Once the various key measurement parameters are established, CSDA Surface Texture Chart and symbols may be used to establish the proper indication on the relevant engineering drawings and specifications.

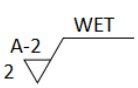
Surface Texture Indication



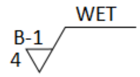
10. Example Specifications



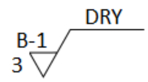
The number 1 located in the lower left indicates that the finishing is to take place in the upper region of the concrete and the specification does not allow exposure of aggregate. The symbol A-2 is the specified surface texture. The word “ANY” indicates that the production method to achieve this specification is at the discretion of the operator. The proper numerical sequence for this specified finish would be: 1A-2.



The number 2 located in the lower left indicates that the finishing process requires adequate removal of paste to expose sand in the finish layer. The symbol A-2 is the specified surface texture. The word “WET” indicates the designer has specified a wet method of processing. The proper numerical sequence for this specified finish would be: 2A-2.



The number 4 located in the lower left indicates that the finishing process requires adequate removal to expose coarse aggregates in the final finish. The symbol B-1 is the specified surface texture. The word “WET” indicates the designer has specified a wet method of processing. The proper numerical sequence for this specified finish would be: 4B-1.



The number 3 located in the lower left indicates that the finishing process requires adequate removal to expose pea size aggregates in the final finish. The symbol B-1 is the specified surface texture. The word “DRY” indicates the designer has specified a dry method of processing. The proper numerical sequence for this specified finish would be: 3B-1.

Stock Removal Formulas – Formula for determining minimum stock removal required to achieve desired surface finish.

$$\frac{\text{Existing Finish} - \text{Desired Finish}}{100{,}000} = \text{Required Stock Removal}$$

Example

Existing Finish = 500 µin ; Desired Finish = 8 µin

$$\frac{500\ (\text{C-3}) - 8\ (\text{A-3})}{100{,}000} = \begin{array}{l} 0.00492 \text{ in.} \\ 0.12496 \text{ mm} \end{array}$$

11. Aggregate Exposure

Processing and/or grinding concrete surfaces with abrasives will achieve various levels of exposed materials within the matrix of the concrete. These materials will vary from light sand to large aggregate depending on the level and depth of the cut. Below is a reference table and classification for exposing aggregate materials within the matrix of concrete.

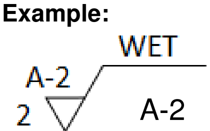
Exposure Specification Table

Level	Type of Exposure	Code #	Description
1	**Paste Region**	1	Surface finishing to reside in the upper region of the concrete. Removal of latency and machine/finishing trowel marks only.
2	**Sand Finish**	2	Aggregate fines and sands located in the upper region of the concrete. This finish has a good ratio of paste/sand typically 50/50 mix.
3	**Moderate Aggregate**	3	Exposure of all the fine aggregates including medium pea size aggregate. Limit depth of cut not to expose aggregate larger than a dime.
4	**Coarse Aggregate**	4	Majority of exposed aggregates located at the surface exceeding the size of a dime.

12. Documenting & Recording Surface Texture Readings

It is required that all corresponding grade symbols located on floor plans or legend charts be properly documented. In addition, the resulting reading by the authorized field recorder and last known calibration by identification of date, time and initials of the authorized recorder shall be documented.

Example:



A-2
Cal: 3-31-13 BAB
8:05 PM

Surface Texture Finishes Chart

(STG) Surface Texture Grade	Unit of Measure = Ra		Surface Grade
	µin	µm	
A-1	**2**	**0.0508**	**Finish by Design Spec.**
A-2	**4**	**0.1016**	**Finish by Design Spec.**
A-3	**8**	**0.2032**	**High Polish**
B-1	**16**	**0.4064**	**Medium Polish**
B-2	**32**	**0.8128**	**Low Polish**
B-3	**64**	**1.6256**	**Honed Smooth**
C-1	**125**	**3.175**	**Honed**
C-2	**250**	**6.35**	**Ground**
C-3	**500**	**12.7**	**Heavy Texture**

Comparative Analysis Reference Chart

Surface Texture Grade	Comparative Industry Averages: Gloss Reading	Comparative Industry Averages: DOI	Produced Finish
A-1	Finish by Design Spec		Ultimate Finish
A-2	Finish by Design Spec		Super Finish
A-3	75-80	80 & up	3000 Grit
B-1	65-75	70 & up	1500 Grit
B-2	40-65	50 & up	800 Grit
B-3	30-40	20 & up	400 Grit
C-1	25 and less	N/A	200 Grit
C-2	15 and less	N/A	100 Grit
C-3	5 and less	N/A	50 Grit

**This reference chart is for comparative analysis only and is not a suggested parameter to be used as a basis for a polished concrete specification.*

13. Control of Surface Texture

It is typical for specifiers of concrete surfaces to require control of surface characteristics to achieve optimum performance, but should be in accordance with the procedure outlined in this document. In general, concrete surfaces and those requiring a high degree of smoothness for appearance and duty, should be controlled in accordance with this document.

In the mechanical field of surface texture, it is a result of the processing method; a machined concrete surface may be relatively smooth or relatively rough for the purpose intended. The surface obtained from high speed polishing and burnishing is the result of plastic deformation. If the surface is ground or honed, it is the result of the tearing action from the cutting tools or abrasive grains.

Regardless of how the surface characteristics evolve, magnified profiles in all instances consist of a series of peaks and valleys which deviate in a more-or-less irregular fashion above and below a mean surface. Superimposed on these major peaks and valleys are irregularities of lesser magnitude. Experience has shown that the ideal surface characteristics for concrete surfaces may involve such operating conditions as the area in contact, the load, speed, direction of cut, type and amount of lubrication, temperature, material and physical characteristics of concrete design mixes. Variations of any one of these conditions may require a change in the specified surface characteristics.

Experimentation or experience with surfaces is, therefore, the only criteria on which selection and specification for a given surface characteristic can be based. Once the required surface characteristics have been established, the requirement should be documented on the engineering drawings and specifications. Detail should be limited only to the characteristics that have definitive processes and are essential to the specific application. The responsibility for achieving the desired surface is thereby transferred to the producer. Interpretation of surface requirements specified on drawings is explained in this document. However, this document also permits considerable latitude in the method or procedure for controlling production of the surfaces and establishing their conformity with the specified drawing requirements.