A Guide to Architecturally Exposed Structural Concrete (AESC)

# A New Concrete Glossary

# Authors

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## ABSTRACT

Assertion: The current method of concrete construction is both environmentally and economically outdated. Present methods of concrete construction have not fundamentally changed since the early 1960's. With the rise in popularity of polished concrete and other architectural concrete finishes the construction industry was forced to behold what quality of concrete had actually been created after the carpet, tile and epoxy had been removed.

When designer and constructer attempted to make sense and solve these problems it became apparent that they were speaking differently about concrete and even perhaps viewing the material's end function in non-similar ways.

Ancient methods seem to have produced better results without the plethora of modern industrial additives currently in use. These results came not only by understanding available materials, but also clearly communicating how to design and build for resiliency, perhaps in some ways better than we do today. In order for us to properly describe the differences between cement, concrete and finishes, the necessary vocabulary must be identified, developed and defined.

This glossary is an attempt to frame the debate and produce common understanding, both of concepts and proposed solutions to overcome language obstacles between designer and constructor and build with *structural, aesthetic, and resiliency* benchmarks in mind to meet Owner needs.

It is the intent that this document should be dynamic to our changing understanding of concrete. We look forward to the constructive criticism, review, and knowledge of those that would make this guide better than the current imperfect document you now hold.

# Preface

This glossary is the culmination of nearly five years of directed study from across varied disciplines in professional construction, design, specifications and academia as well as many lifetimes of experience from the authors and distinguished contributing editors.

We wish to thank Carlos Cruz-Noguez and the team at University of Alberta Donadeo Innovation Centre for Engineering (DICE) for their efforts on and off the slab as well as Fatimeh Hashemi, University of Manitoba/Imam Khomeini International University, Robert Dye, Johnson County Community College, our amazing editors from around the globe that graciously donated their time to this effort, and the countless contractor and designer attendees at symposiums and hands-on training events.

North America 2018

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**Architecturally Exposed Structural Concrete (AESC**) is the methodology for creating concrete that not only contributes to the durability and structural integrity of concrete, but also its visual character. Further, it may be argued that perhaps by requiring a higher standard of finish, color and texture one ends up creating a more resilient concrete structure. AESC is not limited to shapes, forms, colors or even levels of reflective finish. Whether interior or exterior, vertical or horizontal AESC should be specifically designated as such in the contract documents.

- Critical factors affecting AESC include, but are not limited to the following considerations:
  - Engage those who have greatest impact in the quality of concrete as a part of the design process (design assist), including prequalifying those participants to limit uncertainty of outcomes resulting from competitive bid process.
  - Temperature and humidity during installation, high or low of either factor is not as much of a factor as consistency.
  - Contact with form liners; generally, the longer the better with time span adjusted to account for temperature and humidity.
  - Quality of aggregates that may require coordination with concrete supplier.
  - Complete mix of ingredients at the concrete supplier, do not allow mixing as a part of transit delivery to contribute to correct mixing of ingredients.
  - **Mixing Water (efflorescence, etc.)**
  - **Alkalinity of Water Source (acidic water, impermeability, strength of concrete)**
  - Specify progressive submission of Samples, Sample Panels, Small and Large Mock-Ups, with demonstration of repair methods and confirmation of work methods to achieve specified finish.
  - A picture is worth a thousand words – include representative photographs as a part of the specification to illustrate final appearance, or fully describe textures of form liners or finishing methods.
- Concrete standards and tolerances are written to address structural performance of concrete associated with shrinkage, temperature reinforcing, and typical deflection limitations and are likely not conservative enough for the demands of AESC.
  - Crack control is vital and it is advisable to exceed the typical minimum requirements for shrinkage and temperature rebar. Joints, joint locations, and even joint width are all extremely important considerations.
  - Forms, form tightness, form liners, ties, tie locations, mix designs, and admixtures all have a significant effect on the visual impact of the finished product.
  - Typical repair details and repair methodologies must be described in the specifications.
  - Prepare specifications for architecturally exposed structural concrete using an approach similar to the guidance offered by the American Institute of Steel Construction (AISC) for architecturally exposed structural steel (AESS), and limit architectural concrete only to those areas that have maximum impact on project aesthetics.
- Communication to all contributors from the outset of the project, which can include involving concrete suppliers, formwork trades and concrete finishers in addition to full coordination between disciplines on the project (it is often better to show locations of architectural finishes on structural drawings); continue communications through the bid period (special bid meeting) and into construction (preinstallation meetings) to verify that all parties buyin to the process and that requirements of the specification are fully and completely understood.
- Modify expectations, concrete is a natural material that can result in unexpected outcomes despite intensive involvement to control concrete at all stages of the work… sometimes concrete has a mind of its own and simply does not cooperate despite the efforts of all involved with the project. Methods described and listed in this glossary reduce the probability of unexpected outcomes, but do not eliminate all factors that can affect placement of architectural concrete.

**Concrete** is a building material made by combining water, sand, aggregate, and cement.

**Cement** is a fine powder made from calcined mixtures of clay and limestone. Cement becomes a binder of other ingredients for concrete upon hydration.

**Aggregate** comes from crushed stone, sand or gravel. However, it is also common to use iron blast- furnace slag and other waste products to compliment traditional aggregate compositions. Recycling broken brick, stone rubble and even concrete for use as aggregate is also common.

**Mortar** is made by mixing water with cement and sand (no aggregate).

**Calcium Silicate Hydrate (C-S-H). Mixing** water, cement creates an incredibly complex reaction; it produces a variety of compounds (depending on its original composition). Of these, the most important is calcium silicate hydrate (C-S-H). Without C-S-H - the 'glue' holding the concrete together, one would simply have a loose collection of sand and stone.

**Admixtures** are material added immediately before or during mixing process of concrete, to modify the properties of the mix in the fresh and/or hardened state. It is important to remember admixtures can affect the chemical composition of the calcium silicate hydrate (C-S-H) and the other hydration products formed in the reaction, so correct use is vital. See BSEN 934-2: 2001 on importance of limiting the admixtures in a quantity not more than 5% by mass of the cement content of the concrete.

**Air entraining** admixtures are ideal for use in freeze-thaw zones as they introduce microscopic evenly distributed pores into the concrete increased durability and reduce effects of surface scaling resulting from chemical deicers.

**Calcium Chloride ($CaCl_2$)** is ideally not to be used with reinforcement and only used when adhering to the bounds set by ASTM D98 as tested by ASTM D345. Working as an accelerating agent Calcium Chloride provides accelerated strength gain with all the possible negative effects such as drying shrinkage, potential reinforcement corrosion and increased possibility of scaling.

**Granulated Slag** (GGBS) is a non-metallic by-product, resultant from the production of iron in a blast furnace. It comes from the addition of a flux to the charge of iron ore, which at 1400-1550ºC produces a liquid containing all the impurities from the iron ore and coke; liquid slag. As a result of this, the principal oxide components are lime (added as flux), silica and alumina. If this liquid is cooled rapidly, by means of converting the liquid into small droplets (granulation), crystallization is prevented. This forms a glassy structure which, after grinding resembles sand, with latent hydraulicity. As the GGBS hydraulicity is latent, hydration reactions are very slow, so an activator is required. There are a range of activators that could be used, such as alkali, lime and gypsum. However, the most common and the one used in this study is Portland cement. After activation GGBS also produced C-S-H like that of Portland cement. There can be several benefits derived from using these including, a greater resistance to sulphate attack, a high stability with alkali reactive aggregates, lower heat of hydration, and lower chloride diffusion rates at 25ºC. This also makes it possible to have no reduction in protection against corrosion of reinforced steel and in general enjoy greater mechanical strength at longer ages. However, being a by-product GGBS has varied composition and as such should only be used when complying to ASTM and AASHTO standards.

**Pozzolans**, the resultant of a chemical reaction of a pozzolan is dependent on its original chemical composition of pozzolan a reaction which is highly complex and not needed to be discussed here. The important thing to remember about pozzolans is the necessity to follow ASTM C 618, ASTM C 311 and ASTM C 595. The use of fly-ash as a cement replacement has become increasingly common, due to its well reported benefits, such as resistance to: sulphate attack; chloride-ion penetration; and de-icing salt-scaling. There is also a reported increases in density and strength (as a results of an alternative chemical reaction to that which OPC undergoes) Other benefits include increased workability and less water demand, lower heat of hydration and reduced drying shrinkage.

**Reactive Co-Polymerizing Solids** (RCS): An internal curing process where nano-silica particles react at the atomic level with water molecules resulting in a concrete matrix that permanently retains placement water. Water is bonded to cement grain as a gel allowing for continued production of calcium silicate hydrate (C-S-H) with minimal water loss. The result is a higher strength concrete at an accelerated hardening schedule significantly less susceptible to the transmission of deleterious materials and negative effects of moisture. Some RCS processes are suitable for topical applications like concrete polishing.

**Water Reducing** agents are admixture, which, without affecting the consistency, permits a high reduction in the water content of a given concrete mix. Governed by ASTM 1017, water reduces the need for vibration, reduced bleeding or segregation. Depending on the dose, type of water reducer, concrete mix design and how the reducer was added the setting time can be accelerated or retarded.

**Floor Smoothness and Evenness** describes the architectural design intent for planar finishing of concrete slabs. Historically these measurements have relied on descriptions of tolerances required for structural concrete describing floor flatness and levelness, but degrees of interpretation affect the quality outcomes that the architect requires.

- Achieving an average floor flatness of $F_F$25 to $F_F$35 is within the skills sets of most concrete finishers, but most resilient flooring and tile flooring manufacturers recommend flatness in the range of $F_F$50 that is achieved through enhanced concrete finishing methods.
    - This requirement stems from straightedge flatness measurements of ⅛" in 10'-0" and requires a maximum 2 modulations under the bar edge, increasing the number of modulations to 3 reduces the $F_F$50 to $F_F$25 and results in an unacceptable architectural tolerance while maintaining acceptable structural tolerance.
    - Structural tolerances for floor flatness often allows for local deviations of up to 50% of the overall flatness at locations like boundaries between columns lines or pour joints meaning that an $F_F$50 concrete finish could have a local deviation of $F_F$35, meaning that the specifier needs to specify a much higher level of flatness such as $F_F$100 with local deviation of $F_F$65 if a truly flat floor is required with resulting cost differential to account for additional work and skills necessary to complete this type of work.

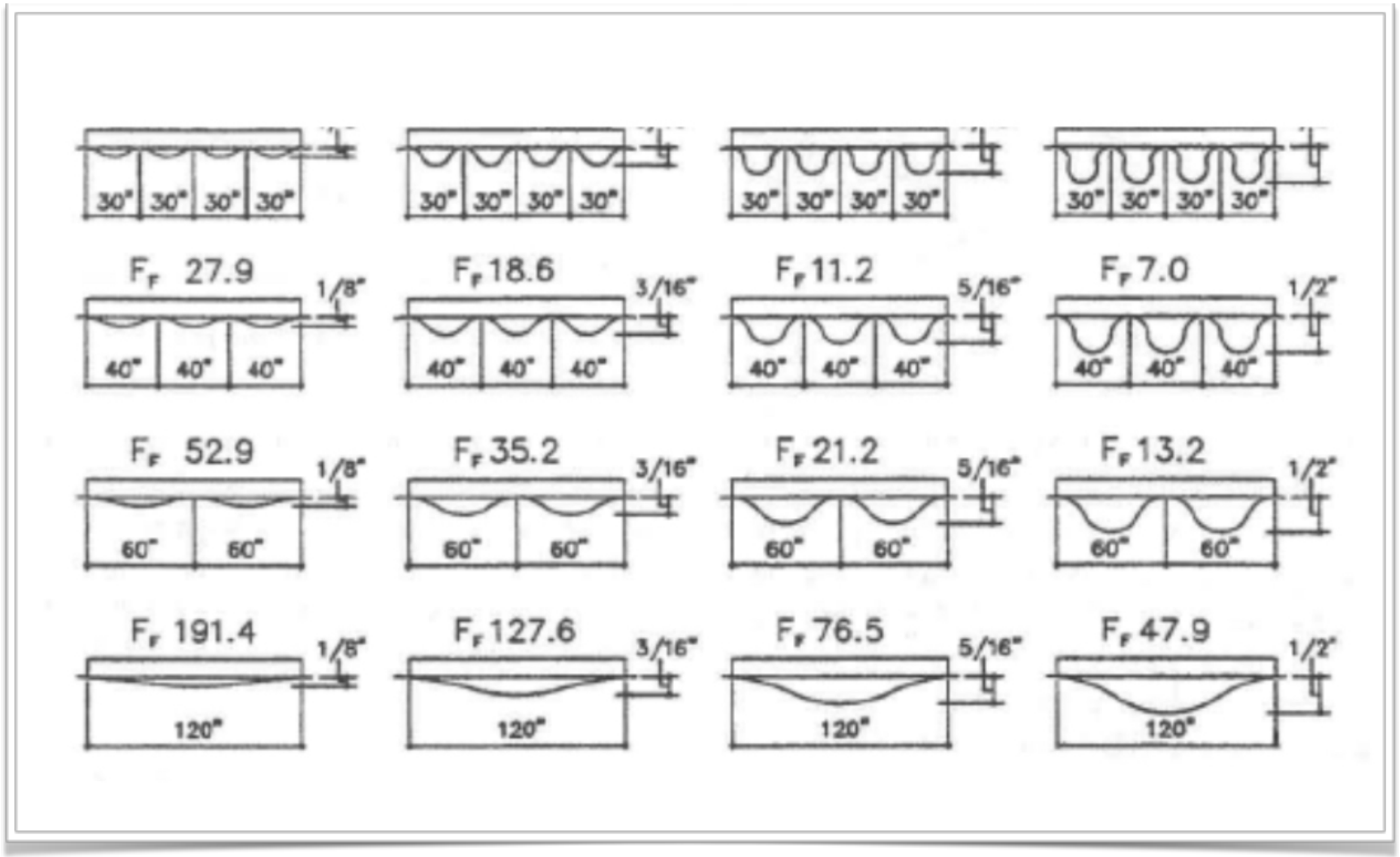


*Figure 1: FF Illustration Extracted from ASTM E1155*

- Floor levelness is seldom a factor for architectural finishing; leveling is performed by a different trade and toolset than concrete finishing, and levelness should not be used as an assessment factor for suspended floors.

- Floor flatness requirements should be reasonable for the type of building construction and anticipated usage, with modified specifications allowing for application of selflevelling toppings, mediumset to thickset tile setting beds when surface planarity is the dominant design criteria.
- Moisture loss during curing can cause undulation which affects not only Ff and Fl levels but also aggregate exposure.


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**Hardened Concrete** uses a variety of post-cast aggregates troweled into concrete paste during concrete finishing operations to improve the abrasion resistance of the concrete surface, the rate of application (weight of aggregates per square foot) increases based on the expected wear of the end use.

- Greater weight of aggregate hardeners requires increasingly more work effort to 'push' the material into the surface paste and increases the wear on concrete finishing tools, and results in generally higher costs to the project – that are justified when increased surface wear properties form the design intent of the work.
- Aggregates, internal curing admixtures and other materials can change the hardness of the concrete surface based on the MOH scale of hardness, which can provide a comparative increase in abrasion resistance based on the starting hardness of standard concrete mix.
- Liquid Hardeners (Densifiers) improve abrasion resistance to a small degree. They are not a substitute for aggregates or internal cure admixtures to achieve a hardened concrete surface. However, they do enhance concrete by reducing surface dusting and carbonation, and can be applied to aggregate hardened concrete floors.

**Sealed Concrete** is an overused and generic term that describes a variety of liquid applied concrete finishes that can reduce water evaporation during concrete placement, seal the surface to trap mix water within the concrete and enhancing the hydration process (curing) by allowing more cement powder to combine with water resulting in better setting (hardening).

- Sealers can be called curing agents, curing/sealing agents, sealing/hardening agents (or any combination or reversal of the stated effect) based on the formulation and end results that the manufacturer has designed to product for, and control conditions on site.
- Sealers can be film forming or absorptive, and are typically intended as a temporary application for the stated purpose of sealing the surface, aiding curing and enhancing the formation of cement paste:
    - Film forming sealers can adversely affect adhesion of subsequent applied floor finishes, although many sealers are advertised as compatible it is always advisable to confirm adhesion before application of glues and be aware that additional floor preparation may be required.
    - Sealers can also adversely affect application of other liquid applied finishes such as stains and densifiers, meaning that the specifier should specify other wet curing methods not dependent on application of manufactured products such as misting or water retaining membranes.
- The usage of sealers must be thoroughly researched before applying this label to architectural concrete finishes, with correct specifications applicable to the actual usage and purpose on site. As stated in the opening definition, the term 'sealed concrete' is applied generically to a wide variety of materials and varied performance, with frequent unexpected outcomes of performance requirements not being met.

| Material | MOH Scale | Comparative Improved Abrasion Resistance | Usage |
|---|---|---|---|
| Plain Concrete | ±5.5 | 1 | Foot Traffic |
| Liquid Densifiers | ±6.0 | 1.3 to 1.5 | Foot Traffic, Rubber Wheeled Traffic |
| Basalt (Trap Rock) | ±6.5 | 2 | Light to Medium Traffic |
| Silica (Quartz/ Feldspar) | ±7.5 | 3 | Light to Medium Traffic, Light Manufacturing or Warehousing |
| Carborundum (Emery) | ±8.0 | 4 | Medium to Heavy Traffic, Heavy Manufacturing or Mining |
| Reactive Copolymerizing Solids (RCS) | ±8.25 - 8.75 | 4-5 | Heavy Manufacturing, Hard Wheeled, Heavy Compression Loading |
| Metallic (Steel Shot) | ±8.5 | 5 | Normally Dry, Hard Wheeled, Heavy Compression Loading |

**Polished Concrete** is the act of mechanically processing a floor to achieve a concrete surface with high durability, physical resistance to chemical and stain attacks within an aesthetic framework. Benchmarks for polished concrete are quantified by readings taken from the concrete microsurface texture. Microsurface benchmarks are measured in **microinches** (μin) or in **micrometres** (μm).

- A microinch is unit of measurement, the length of one one-millionth of an inch, equivalent to 25.4 nanometers.
- Polished concrete does not rely on application of a resinous coating or topical sealers to achieve performance benchmarks.
- The term *grit* (i.e. 400 grit, 800 grit) should not be used to specify polished concrete due to this term having subjective considerations from individual manufacturer, contractor and industry.
- Gloss/Distinctness of Image (DOI) benchmarks should not be used for specifying polished concrete as they only measure for aesthetic considerations (see coated concrete).
- Polishing process can be enhanced by using densifiers to enhance abrasion resistance, achieve a low dusting and stain resistant finish.
- Polished concrete can achieve a dynamic coefficient of slip resistance that requires minimal maintenance because of the microsurface texture or “surface roughness” achieved through the mechanical abrasion process.


*Profilometers measure surface micro texture to provide arithmetic average roughness (Ra) readings.*

- Aggregates are not only a structural element of concrete but can also be used as an aesthetic. The color and type of your sand or rock will impact the visual elements of your concrete surface. Aggregate size can be quantified in the construction documents from exposing only fines and sand to progressively larger pieces. Other materials such as seashells, marble chips, and decorative glass can be broadcast into concrete.

**Coated Concrete** is an underused generic term that describes a variety of resinous or waxlike coatings that can be applied to fully cured concrete to enhance sheen and reflectivity of surfaces, and that requires a maintenance regime to preserve long-term appearance and performance of the coating materials. Coated concrete is not polished concrete, which is achieved using an abrasive grinding and polishing process.

- Resinous coatings are typically a highbuild materials that can be transparent, translucent or opaque and can provide flexibility in patterning or other artistic effects required to meet design intent.
- Resinous coatings are comprised of a widerange of chemical families such as epoxy, polyurethane, methylmethacrylate, polysiloxane, polyurea and other materials having different performance properties that should be selectively specified based on project requirements.
- Wax-like coatings are typically acrylic based and form a thinbuild wear layer that must be routinely removed and replenished to preserve underlaying concrete surfaces.
- Coatings can enhance or diminish dynamic coefficient of slip resistance for concrete surfaces depending on type, all must be regularly checked and replenished to confirm slip resistance is maintained.
- Some products marketed as “grouts” may perform like a coating if they are of a non-cementitious nature (i.e. acrylic, epoxy, latex).
- Epoxy resin matrix diamond tooling can also form a coating on a surface when superheated under the pressure of commercial grinding equipment. While this method of coating a floor may enhance the reflective quality of a concrete surface COF can be diminished.
- Distinctness Of Image (DOI) Gloss DOI an aspect of gloss characterized by the sharpness of images of objects produced by reflection at a surface (ASTM E 284 Standard Terminology of Appearance). Gloss meters measure light reflected off of surfaces but do not provide information on performance qualities such as durability, stain resistance, and coefficient of friction (COF). DOI and gloss benchmarks may be suitable for coated floors, but should not be used when calling for polished concrete.

**Integrally Colored Concrete** uses pigment admixture that is intentionally added and forms a part of specified concrete mix; added in either liquid or powder form, to provide a durable and consistent color quality between batches that minimizes variances and discoloration inherent when using standard aggregate and cement color factors, and provides coloration that is resistant to fading and degradation when exposed to sun, rain and freezethaw cycles for the lifespan of the inplace concrete.

- Integrally colored concrete is colorthrough the entire thickness of placed materials, meaning that chips and other surface imperfections will not be as visible as with other coloring procedures.
- Integrally colored concrete additives are typically limited to a maximum of 10% of the cement within the concrete mix design (dosages are as recommended by the manufacturers for the color density required) and will not reduce the 28day compressive strength to less than 90% of specified values and watercement ratio to a maximum of 10% of that of the control mix without color additive.
- The maximum prescribed dosage rate of pigment is directed by the pigment additive manufacturer; but in any case, must be equal to or less than 10% of the mass of cement when used singly or if a combination of pigments is used to produce the specified color and color intensity (dosage rates are higher for more intense color rendition).

**Acid Stained Concrete** uses a process of physical staining (microsolids) or reaction with free-lime to alter the surface appearance of concrete, that is not an applied coating, and is often sealed with a wax-like or clear resinous coating to preserve the appearance.

- Stained concrete can be transparent or semitransparent and is used to achieve highly artistic outcomes through blending of edges and colors, or highly detailed graphics that preserve the natural appearance of concrete.
- Stained concrete can mimic other materials (stone, brick, slate) in combination with stamped surface textures where use of other materials is not practical from a cost or durability aspect.
- Water Based Stains

**Dye** colored concrete are colored pigments that penetrate the concrete. They are usually applied in liquid form.

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