FORTA®
Corporation

Fiber-Reinforced Decorative Concrete

Technical Report

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TECHNICAL REPORT

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Overview

Concrete has been considered as a very strong, durable, formable – and gray – building material for thousands of years. Conventional natural-gray concrete was accepted as the basic building block for a wide variety of flatwork applications, such as pavements and highways, commercial and industrial floors, and all types of slabs-on-ground and slabs-on-deck. The advent of improved and consistent concrete coloring products and practices many years ago began to change the appearance of concrete, and to expand the applications and perceptions of this age-old building material. As concrete coloring became more widespread, so did a variety of surface treatments, allowing concrete to be stamped, textured, and decorated. More recently in the 1990's, grinding and polishing of both new and old concrete surfaces became commonplace, further expanding the range of concrete applications and adding a tremendous variety of aesthetic properties. Throughout this concrete decorating process, cracks were an obvious detriment to the otherwise eye-pleasing enhancements, causing owners, specifiers, and contractors to search for better ways to reinforce concrete projects and control this cosmetic cracking. The development of the fiber-reinforced concrete industry offered improvements to the crack-controlling process, but questions remained about the fibers' compatibility to the wide variety of decorative concrete methods and practices. A study of available fiber types and technologies along with a review of the many facets of decorative concrete offers the project owner a more educated platform to consider the best reinforcing practice to optimize their project results.

Fiber History and Background

Micro-Synthetic Fiber

FORTA Corporation introduced micro-synthetic fibers to the U.S. market in 1978, which were designed to reduce plastic shrinkage cracking and add an element of shrinkage/temperature crack control. These products generally took the form of very fine single-filament polypropylene or nylon fibers (micro-monofilaments) used at a low dosage of 1.0 lb/cu yd (.6 kg/cu m), and deformed net-shaped polypropylene fibers (micro-fibrillated) typically used at 1.5 lb to 3.0 lbs/cu yd (.9 to 1.8 kg/cu m). These micro-fibers were generally limited to relatively low dosage additions due to their high surface area characteristic which caused mixing and placing challenges at elevated dosages.

Macro-Synthetic Fiber

After years of research and trials, FORTA® introduced the first of its kind **macro-**synthetic fiber in 1999 to solve the user-friendly issues at higher dosages. The solution keys became a twisted-bundle shape to eliminate balling, a polypropylene/copolymer chemistry and long lengths to enhance strength, and a special fibril shape to accommodate finishability. For over a decade, the result has made FORTA-FERRO® the most user-friendly macro-synthetic fiber in the industry, with scores of successful projects all over the world. And with these higher fiber dosages came considerable evidence of other important benefits – the dramatic reduction in shrinkage cracking and the notable improvement to post-crack capacity.

Micro-monofilament

Micro-fibrillated

Macro-synthetic

Important Fiber Characteristics

Concrete reinforcing fibers are available in many shapes, chemistries, and lengths, each offering different benefits and results. The following fiber characteristics focus on these fiber types, and allow the designer and user a basic fiber formula to help them anticipate what to expect from their use in a particular application such as decorative concrete. This characteristic formula generally places these fibers into one of three performance categories or levels: Level 1 – monofilament micro fibers to reduce plastic shrinkage cracking prior to initial set; Level 2 – fibrillated or net-shaped micro fibers to reduce plastic and hardened shrinkage and control temperature-related cracking; and Level 3 – macro fibers to control temperature-related cracking and offer an additional measure of post-crack performance. Determining the proper fiber characteristics will help define and ensure the expected fiber performance results in decorative concrete.

1. Shape

As in conventional concrete, the shape of the fiber affects not only several important ease-of-use aspects in decorative concrete, but also impacts the fibers' ultimate performance in the plastic and hardened concrete. To achieve a goal of reducing plastic shrinkage cracking during the early life of the concrete, i.e. the first 24-hours, a very fine, mono- or single-filament fiber shape is sufficient. To enhance the fibers' ability to reduce additional temperature-related cracking, a deformed or net-shaped fiber should be considered. To accomplish a goal of temperature crack-control and added post-crack capacity, a heavy-duty macro-fiber filament shape should be used. Each of these shapes will have different degrees of effect on the fibers' visibility and surface finish in decorative concrete. For instance, if the goal is to essentially allow the fibers to disappear in the concrete, then very fine hair-like fibers might be selected, however any additional toughness and post-crack benefits typically diminish with the smaller filament sizes. When additional long-term durability and crack-control of the decorative concrete is desired, then a macro-fiber that exhibits excellent surface-finish characteristics should be selected so as not to mar the aesthetics of the concrete.

2. Chemistry

Most micro fibers used in decorative concrete are made of polypropylene, which is non-absorptive and does not break down over time in an alkaline environment. In some cases, very small cellulose (paper) fibers are used in colored or decorative concrete, however the expected benefits are very short-term in nature due to their small size. Where macro-fiber shapes are selected, the chemistry is polypropylene or co-polymers which provide a strong, durable make-up that is inert to alkali or chemical attack.

3. Dosage

Fiber dosage is dictated, again, by the desired performance results, but may also be limited by the fiber shape. If Level 1 early-age crack control is the sole requirement, dosages of 1.0 to 1.5 pounds per cubic yard are typical. For enhanced

Level 2 temperature-crack control performance, dosages of 1.5 to 3.0 pounds per cubic yard have become the norm. For Level 3 post-crack benefits, macro-fiber dosages have ranged from 3.0 to 7.5 pounds per cubic yard, depending on the level of toughness desired. The fiber shape, chemistry, and length may all affect the optimum dosage level for a specific fiber type. For decorative applications where a reduction or elimination of control joints is desired, then macro-fiber dosages of 7.5 pounds per cubic yard and higher are utilized.

4. Length

In conventional concrete applications, longer fiber lengths have proven to have improved hardened and post-crack values than shorter fibers, however fiber length may also affect mixability and uniform distribution. Fine micro-fibers are typically limited to relatively short lengths of ¼" to ¾", while deformed-net fibers range from ¾" to 1 ½" lengths. Though macro fibers are available in short lengths, the longer 1 ½" and 2 ¼" lengths offer improved toughness characteristics. Long fiber lengths should not necessarily be of major concern regarding surface finishability, as long lengths often lay down and into the surface much better than shorter, stiffer lengths.

Once the performance requirements are determined for a particular project application, each of the important fiber characteristics selected can be trialed with the project specifics, in order to optimize those characteristics. Naturally, it is important to balance the performance elements with the user-friendly aspects as well regarding surface appearance and finish, and pre-project trials will allow time for adjustment of the fiber shape, dosage, and length to accommodate the decorative concrete. For the most part, FORTA® has focused on the use of macro-synthetic fibers in decorative concrete in order to improve crack-resistance properties as well as toughness and durability. Reducing cracks and joints where possible are desirable goals on projects where extra time and expense have been used to create a decoratively pleasing concrete treatment. Selection of the proper fiber characteristics may depend on the type, finish, and color of the many variations of decorative concrete available in today's market.

Types of Decorative Concrete

There is a wide variety of products, materials, and techniques available in the decorative concrete market, most of which are compatible with at least some level of fiber reinforcement. In some applications, fibers might be relegated to short lengths and low dosages, however many applications benefit from much higher dosages of long-length fibers for improved crack control and long-term durability. In each application case, certain fiber nuances may affect the results, and should be considered carefully before use.

Colored or Stained Concrete

Synthetic fibers made of polypropylene or propylene co-polymers are hydrophobic, and will not absorb water. As such, they are also not capable of absorbing integral liquid colors often used in decorative concrete. As a result, the goal becomes using a fiber that will finish **within** the surface paste and therefore not stand out against the colored concrete background. The same would apply to surface-applied stains, placing importance on the specific fiber characteristics that will allow for a reasonable surface finish. Though most synthetic fibers do not accept integral or surface-applied color, they are surrounded by and coated with the colored mortar/paste, and therefore do not impact the overall color of the concrete. If the fibers whisker up out of the slab surface, then the aesthetics will obviously be affected.

Finishable fibers are compatible with this integral brown color

Stamped Concrete

Surface finishability of a particular fiber is also important when the concrete surface is imprinted with temporary forms or imprint stencils. In addition to fiber characteristics, the key becomes using finishing practices that will create sufficient surface cream to cover and hide fibers that are at or near the concrete surface. One common method of creating surface paste for stamped concrete is the use of a roller-bug or jitter-bug on the fresh surface. The use of these methods not only creates paste for the imprint, but often also helps embed and hide fibers that may be within the paste surface.

A pass or two with a roller-bug may help create surface paste and embed fibers

Generally, it there is sufficient surface cream to allow for a decorative detail or imprint, then there is enough paste to also hide surface fibers. Most 'soft' or rounded-edge imprint textures are very compatible with most synthetic fiber shapes, though fiber evidence may be more apparent with sharp-edged stamps. In any case, a pre-project trial is highly recommended with the specific type of stamped practice for a particular fiber shape, length, and dosage to allow the owner to approve or alter the final surface look.

Jitterbugging helps minimize fiber appearance on stamped concrete.

Ground and Polished Concrete

Many forms of decorative concrete are applied before the fresh concrete ever sets, however treating the surface post-set has become an ever-increasing popular method of creating a unique and beautiful surface appearance. While some slabs are simply polished with very fine-grit diamond wheels to create a shiny or glossy surface, many floors are actually ground down to reveal more of the 'inside-the-concrete' look. In either case, the selection of the particular fiber type may be critical to the resulting appearance and should be considered and trialed carefully prior to placement of the entire slab. Due to the variety of methods available to produce polished concrete and the many fiber nuances that may affect them, a closer and more involved study of the art is required to assure owner satisfaction (see section: Ground and Polished FRC).

LEED Impact

The U.S. Green Building Council (USGBC) was founded almost 20 years ago, creating a platform for the LEED – Leadership in Energy and Environmental Design – program. Projects may earn various levels of LEED certification by following a wide variety of related energy-saving and green-friendly protocols. Decorative concrete applications often contribute to LEED project points by eliminating the need for additional toppings or surface treatments, such as tile, carpet, or other flooring systems. The use of the concrete floor as the final wearing surface also leads to improvements in life cycle values, by promoting additional benefits directed towards durability and practicality. Decorative concrete may earn credits towards LEED certification in a growing list of areas:

- IEQ c4.1: Low Emitting Materials, Adhesives and Sealants
- IEQ c4.2: Low Emitting Materials, Paints and Coatings
- IEQ c4.3: Low Emitting Materials, Flooring Systems
- IEQ c5: Indoor Chemical and Pollution Control
- IEQ c8.1: Daylight and Views, Daylight 75% Spaces (reflectance value)
- IEQ c10: Mold Prevention, Schools
- ID c1: Innovation in Design

The fact that concrete is composed of natural materials is valuable to LEED-type construction, and maintains a history of being an extremely sustainable flooring method. The use of decorative concrete as the final floor surface helps reduce potential adverse environmental effects of coatings and toppings, and likely uses considerably less energy in the making than alternate floor topping systems. In addition to the many green elements of decorative concrete are the savings offered by lower maintenance cost of cleaning along with longer lifespan.

Ground and Polished FRC

One of the unique and beneficial aspects of three-dimensional fiber reinforcement is the fibers' ability to act as a suspension element, keeping both fine and coarse aggregates suspended and discouraging fall-out through the mix. This feature becomes extremely valuable for the grinding and polishing process, adding an element of uniformity and homogenization on the slab surface, as well as throughout the mix. In addition to providing benefits regarding shrinkage from a more uniform moisture and temperature gradient throughout the slab, the fiber-suspension dynamic aids in the sand and aggregate distribution and improves the uniformity of the ground or polished reveal. While a homogenous fiber-reinforced mix is not a replacement for the critical flatness and levelness requirements for polished slabs, it adds a distinct advantage to both placement and polishing contractors.

To understand the variances created when grinding fiber-reinforced concrete requires a basic understanding of the actual grinding process. Because fibers are uniformly distributed throughout the concrete mix, they are similarly distributed throughout the entire slab cross-section - from top to bottom. As a result, varying levels and degrees of grinding and/or polishing will allow for varying degrees of fiber visibility in the final surface. Knowledge of the nuances of fibers with respect to the grinding process will help predict the resulting surface appearance, and help achieve the project owner's ultimate goals.

Grinding of a concrete surface is much like sanding a piece of wood – start with a coarse grit sandpaper and move through a series of finer-grit papers until the final desired appearance and smoothness are achieved. With concrete, the 'sandpaper' consists of grinding-wheel attachments that use various sizes of diamond crystals to abrade the surface, and the crystals are bonded to the wheel in several ways. The key to adequate grinding success is for the diamond crystals to wear about as much as the concrete being affected, so that sharp new diamonds appear as the old ones become dull during the grinding process. The bonding of the diamond crystals is important to that crystal-replacement process, generally comprised of one of three types: 1. Metal bond, which is an extremely strong anchorage of the crystals and therefore typically used for aggressive, deep grinds; 2. Resin bond, comprised of a polymer or resin bonding material creating a much softer bond and less aggressive grind; and 3. Hybrid bond, made with a resin bonding material with metal-coated diamond crystals allowing for a middle-aggressive grinding option.

Once the basic grinding process has taken place, various levels of polishing can also be applied to affect the client's desired level of shine or sheen for the floor. These polish degrees are generally described in four levels:

Level 1 - A hazy, non-reflective surface; typically achieved by stopping at a 100-grit resin bond attachment.

Level 2 - Low-luster matte finish with minor overhead reflection; typically achieved at a 400-grit resin bond.

Level 3 – Higher sheen level with clear light reflectivity; achieved at an 800-grit polishing attachment.

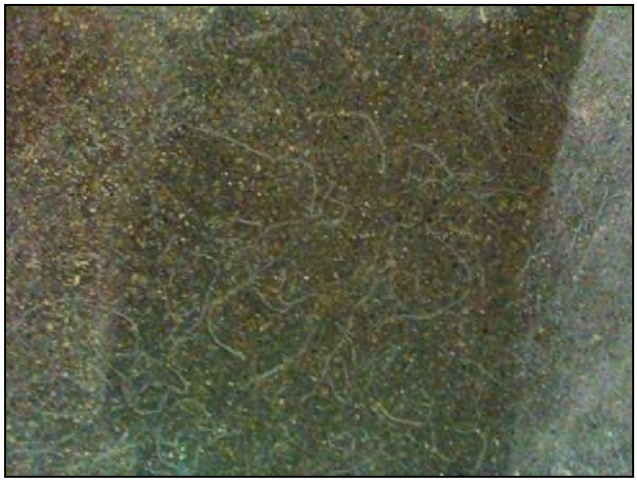
Level 4 – Very high shine and reflectivity level; achieved with 3,000-grit resin bonds or high-speed burnishing.

The importance of the grinding and polishing process to FRC – Fiber Reinforced Concrete – is primarily the depth of the actual grind or polish. Depending on the grind depth, the appearance of the fibers will vary. With regards to FRC, primarily macro-synthetic FRC, there are three approximate grind depths, each with different amounts of resulting fiber appearance. In general, only one of the depths will risk fiber evidence, and owners should be alerted to the possibility in advance during pre-project trials. The following levels and photographs may assist the floor designer, specifier, and owner in determining how to most effectively use fiber reinforcement in their particular decorative floor project.

1. High-polish only: This level would represent a polishing or burnishing of just the very top skin layer of the concrete with non-aggressive resin-bond attachments, to add sheen and light-reflectivity to the floor. This process would involve removal of only a very thin amount of the floor skin, i.e. < $1/64^{th}$ in or .4 mm. With the proper cream-inducing finishing practice, fibers that may have been at or near the surface would have been covered with paste and therefore not revealed by the minimum grind. There would be very little evidence, if any, of fiber appearance on the surface.

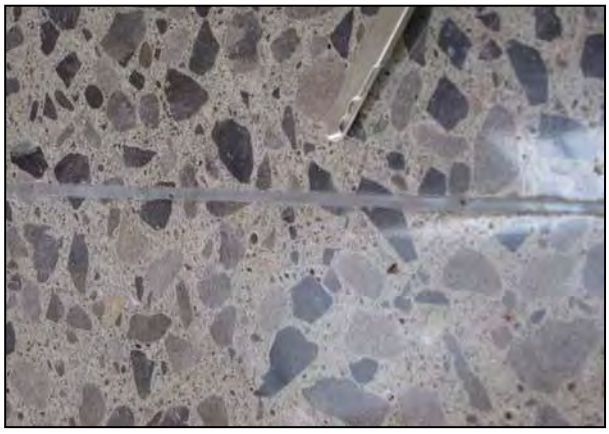
Surface polish reveals minimal fiber appearance

2. Salt-and-pepper grind: This level would be a grind into a deeper paste depth, to expose some of the fine aggregates (sand) used in the mix for a salt-and-pepper reveal. This depth is approximately 1/32nd to 1/16th in. or .8 to 1.5 mm for most applications, and digs into the surface paste area where the fibers are hiding. Because of the finishing screed process that lays surface fibers over primarily into a horizontal plane, the fibers revealed appear as irregular 'worms' in the surface, similar to a textured stucco look. Though surface fibers are visible, the pattern is quite uniform and appealing to many floor owners.



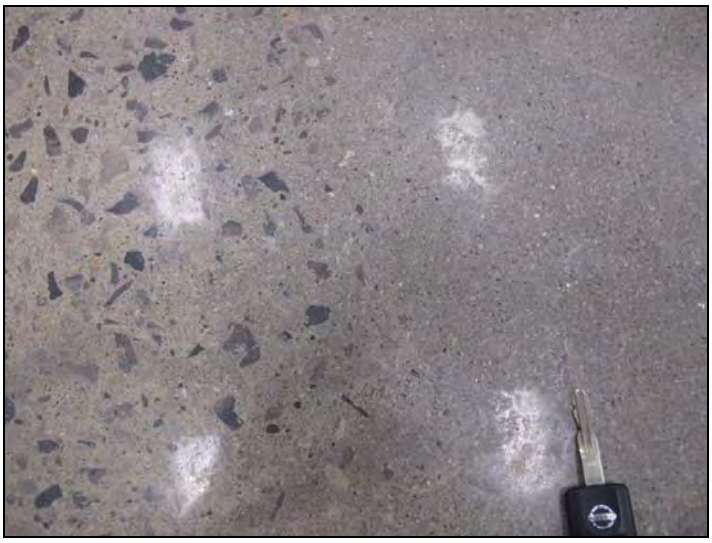
Sand reveal shows horizontal macro-fibers

3. Coarse-aggregate grind: This level requires grinding through the skin and paste layers and into a portion of the coarse aggregates near the surface. This level is one of the most aesthetically stunning and pleasing of all polished concrete, and one of the most popular decorative concrete looks as a result. In this grind depth for an aggregate reveal, typically in the range of 1/8th in. or 3 mm, evidence of horizontal or otherwise-situated fibers disappear, though a microscopic inspection might show a few fiber ends that are not visible to the naked eye.



Deep aggregate grind eliminates fiber appearance

The actual grind or polish depths mentioned are somewhat arbitrary, and subject to each project's mix design, paste content, and finishing methods. The correct depths will be those that result in the appearance that the client prefers: surface polish only, sand exposure, or aggregate reveal. In any case, the value of pre-project finishing and grinding trials is immeasurable.



Fiber evidence disappears once grind depth goes through the surface paste

Important Fiber Aspects for Decorative Concrete

While micro-synthetic fibers at their typical low dosages have little noticeable impact on the concrete or different aspects of placement, higher dosages of macro-synthetic fibers offer various nuances that are best addressed prior to the project start. As macro fibers have become the fiber of choice for a majority of decorative concrete project applications, the areas of fiber addition and mixing, slump, and finishing are worthy pre-construction topics to help maintain a trouble-free jobsite.

Fiber Addition Point

The correct time and place to add macro fibers to the concrete mixing system varies for different fibers, and therefore it becomes very important to determine the optimum process for the particular fiber being used on the project. Recommendations for one fiber may not apply to another, and therefore the correct addition point and practice should not be assumed as normal, especially with the higher dosages that may be involved in decorative concrete applications. To affect the capacity to hold potential cracks tightly together, it is especially critical to have uniform fiber distribution without clumping or balling. A reasonable litmus test to pre-determine a particular fiber's ability to mix without clumping is to inspect the fiber in its original package – it's safe to assume that if the fiber is tangled in the bag it comes in, it's not likely to un-tangle in 4,000 pounds of wet concrete! If the fibers do not gravity-feed well when dry, then special addition tactics will be required, such as feathering them slowly into the mixing system which would require extra time and patience on the part of the ready-mix supplier. Efforts to eliminate or minimize fiber clumping are especially critical to decorative concrete applications.

FORTA-FERRO® patented bundles

One of the keys to the mixing success of the FORTA-FERRO® macro fiber is a patented twisted-bundle form, which allows the bundles to remain untangled when dry, and then spring open and separate into individual macro fiber filaments during the wet mixing action. This feature is especially critical in high-volume applications, where 3.0, 5.0, or higher pounds per cubic yard are required. Many fibers will mix and distribute fairly well at low dosages, but will be compromised by balling at dosages over 3.0 pounds per cubic yard. Because of the twisted-bundle form, the correct addition point for FORTA-FERRO® is **during** the mixing process as other ingredients are being added, or **after** the mixing cycle has been completed. For instance, the fibers could be added with the coarse aggregates to a central-batch system,

or to the back of the ready-mix truck after the truck has been loaded. In either case, essentially the only **wrong** time and place to add FORTA-FERRO® is as a first ingredient to the mixing system or alone with a portion of the initial mix water, which would encourage the opportunity for fibers to cling to the sides of the mixing chamber or drum and not get into the actual concrete until the discharge process begins. In general, adding fibers as a first ingredient also raises the likelihood that they may become nose-packed by the cement and other fines, and therefore not become involved in the vigorous mixing action process. For less-than-full loads in a ready-mix truck, i.e. less than 5 cubic yards in a 10 cubic yard capacity drum, it is recommended that the concrete be brought up to the point of discharge and the fibers added directly on top before mixing commences.

Mixing Time and Speed

Fibers also differ in their sensitivity to mixing time and mixer speed for proper and uniform distribution. All fibers can be under-mixed, and some fibers can be over-mixed as well. In the case of the FORTA-FERRO® bundles, normal central-batch mixing cycle time is sufficient for proper distribution. In ready-mix truck mixing, the fiber typically requires a minimum of 4 to 5 minutes mixing time at normal mixing revolution speed, at an RPM rate recommended by the mixer manufacturer. If insufficient mixing time is allowed, it will be evidenced during discharge by bundles that have not opened and separated properly. It is important to note that the slow agitation speed used for road travel is not sufficient to properly mix the fibers, and should not be added into the minimum fiber mixing time allotted. This same mixing time and speed recommendation would also apply if fibers are added to the truck on-site rather than at the batch plant, and mixing time should not be shortened even under rushed project conditions. Further, excessive agitation-speed revolution time will not negate or ruin the uniform fiber distribution, in the event of project placement delays. Excessive mixer speed can be just as problematic as slow mixing speed, causing the concrete to hang onto the drum wall rather than be subject to the normal blending and folding action required for uniform mixing of all the ingredients – including fibers. Using an RPM speed that is too high in an attempt to shorten the required mixing time will also result in unopened fiber bundles during discharge. When concrete including FORTA-FERRO® is mixed at the proper time and speed, the extremely uniform fiber distribution is readily evident even to the untrained eye during discharge.

Fiber Absorption and Slump

A common perception is that most man-made fibers will absorb mix water, and therefore reduce the concrete slump. The FORTA-FERRO® macro fiber chemistry is a blend of polypropylene and copolymer materials, and as such, is hydrophobic and therefore cannot absorb liquids, including integral liquid color. However, macro fibers **do** act as a cohesive agent in the plastic concrete, binding the ingredients together to some degree, which provides a valuable benefit by reducing mix segregation. This binding characteristic is especially apparent when using high fiber dosages and long fiber lengths. Though high-fiber dosages do reduce the visual slump as measured by the slump-cone test, the actual flowability and workability are only effected to a lesser degree.

Fiber Slump

As an example, a typical concrete mix with 4.0 pounds of fiber per cubic yard (2.4 kg/cu m) may reduce the visual slump by 1 to 2 inches (25.4 to 50.8 mm), however the actual workability will be impacted to a much lesser degree. It is also important that the ready-mix supplier add the total water content when high-fiber dosages are used, and not hold out allowable water at the batch plant. When allowable water is held out, insufficient cement paste is created to properly coat the high surface area of the fibers, and slump is dramatically reduced as a result. Holding out mix water may also reduce the effectiveness of plasticizing admixtures. To regain any loss of workability, the use of superplasticizing admixtures is highly recommended rather than adding additional water. If necessary, pre-project laboratory mixes can be worked up by the ready-mix supplier to help predict the necessary admixture dosage per cubic yard for a given concrete mix and fiber dosage, which can then be adjusted on the job based on ambient temperatures, aggregate absorption, delivery and standing time, etc. It is generally recommended that the fibers be added and mixed prior to the addition of the superplasticizer to insure that sufficient mixing friction is available to properly distribute and mix the fibers, though mixes will differ in that regard. Though the fibers cannot absorb color, they will be surrounded by colored paste and therefore not be a visible issue when finished properly. Pre-project trials are highly recommended for colored-concrete projects where the ultimate liquid content could affect color consistency.

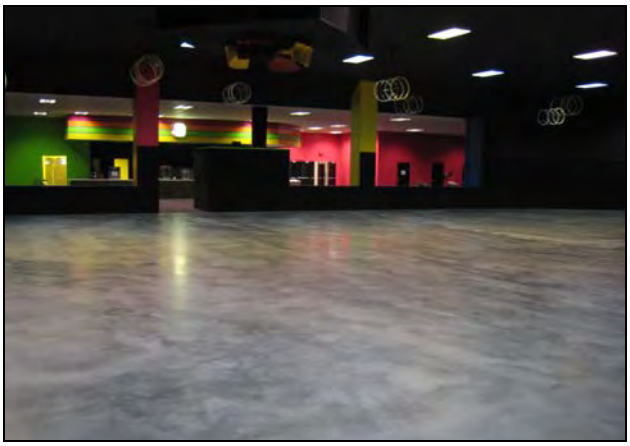
Bleeding

If the decorative concrete is placed on a vapor-barrier membrane, bleeding can only occur in one direction – upwards – a fact that must be recognized by the finishing team. High dosages of macro fibers can also impact the bleeding dynamics in decorative applications, which must also be a finishing consideration. As mentioned previously, the FORTA-FERRO® fiber is hydrophobic, and therefore will not affect the free water content within the plastic concrete. Further, unlike fiberglass, nylon or some other fiber chemistries, the polypropylene/copolymer fibers will not wick water to the surface. However, because of their random, three-dimensional location throughout the slab cross-section, these fibers will mechanically block or divert the normal water bleed channels. Common perception suggests that excess mix water, known as bleed water, rises to the top of a concrete slab, however a more accurate dynamic reveals that the heavier materials in the mix – those heavier than water – are actually settling towards the slab bottom. One of the unsung major benefits of a well-distributed fiber reinforcement is the capacity to dramatically reduce settling and allow for a much more uniform moisture and thermal gradient, and create a much more homogeneous concrete. As a result, concrete reinforced with high volumes of macrosynthetic fiber will bleed slightly slower and slightly less than non-fibered concrete. This phenomenon should be acknowledged by the concrete finisher to help them properly time the finishing operations. As with plain concrete, the historic finish-timing indicators remain the same for high-volume synthetic fiber reinforced concrete. For example, when a footprint leaves only a slight indentation in the screeded slab surface, timely finishing procedures may commence. Naturally, if the concrete has not finished bleeding of excess or unused mix water, then finishing should be delayed to avoid prematurely sealing the surface which would add to the risk of future delamination and scaling. And obviously at the other extreme, if surface indicators are misread and the slab has gotten away from the finisher, then it will naturally represent a challenge to reopen the surface to allow for a suitable finish. In either case, 'blessing' the young concrete slab with water as a regular practice is just as harmful to fiber-reinforced slabs and colored or decorative slabs as it is for unreinforced or plain slabs. Like all slabs, fiber-reinforced slabs must be monitored closely to allow for the correct time – not too early and not too late – for a suitable surface finish.

Finishing

Finishing of decorative concrete containing high volumes of macrosynthetic fibers is likely the most feared aspect by contractors not experienced with this high-fiber technology. Because all macrosynthetic fibers are different, this fear is not completely unfounded in some cases. However, great efforts were made in the development of the FORTA-FERRO® brand fiber to facilitate easy and nearly invisible surface finishing, such as softening agents and a good filament shape. However, high dosages such as 4.0 or 5.0 pounds per cubic yard (2.4 or 3.0 kg/cu m) or higher do represent millions of individual fiber pieces and thousands of linear feet of fiber reinforcement throughout the concrete cross-section, some of which will naturally be at or near the slab surface. The key to an acceptable surface finish will be to use techniques

that will allow the surface cream to hide and cover those fibers. As mentioned previously, changes in high-fiber concrete bleeding dynamics should be acknowledged and observed by the finishing contractor to avoid premature or late sequencing of the various levels of finishing. And certainly, the type of desired finish will help dictate recommended practices to minimize fiber appearance on the surface.



Superior high-gloss finish with high-volume fibers

As mentioned previously, the characteristics of the FORTA-FERRO® fiber allow it to be a premium finishing fiber for machine hard-trowelled surface finishes. The fibers are easily laid into the surface without creating the 'fuzzies' or rigid needles of other fiber types. Even at the higher fiber dosages used in many decorative concrete projects, FORTA-FERRO® allows for a smooth and glossy finish, without negatively impacting flatness and levelness efforts. In some cases, the use of a roller bug or jitterbug may also assist in depressing surface fibers deeper to accommodate a particular finish.

Owner Expectations

As would be expected, the primary focus of decorative concrete is the aesthetics and the appearance is subject to the likes and dislikes of the owner. Regardless of the concrete color, stain, texture, or polish, the results must meet owner expectations in every way. Those expectations can only be realized by allowing the owner to preview the appearance by offering a pre-project trial that accurately simulates all real-world conditions – the exact mix, color, reinforcement, surface finishing method, ambient conditions, polish or grind level, curing approach, etc. Often times, several different variations might be placed during the trial for the owner to choose from to help offer perspective. Depending on the level of decoration, these trial sections may need to be placed well before the project placement dates, to allow for sufficient curing time for grinding or polishing. Consistent concrete color can be extremely challenging in conventional concrete, and even more challenging when owners expect a specific shade or tint. Similar inconsistencies are common to levels of polish and grind as well, and care must be taken to educate owners to the many variables involved in a concrete mix and placement techniques that could alter the final appearance. Regardless, the effect of integral fiber reinforcement would be minimal, depending on the specified and desired surface treatment. It is important to note that cracks in decorative concrete are also unwanted and unsightly, and the use of sufficient dosages of macro fibers can go a long ways to minimize their occurrence when used properly. Macro fibers may be used in two ways – to act as a simple alternate to conventional temperature steel reinforcement at a calculated dosage, or to allow for the consideration of extended-jointing practice at an elevated fiber dosage, which is often desirable for decorative concrete projects. If normal joint-spacing is to be extended, many ancillary concrete practices and aspects must also be carefully considered in addition to high-volume fibers to increase the opportunity for success. (See FORTA® Technical Report: "High-Fiber Slabs: Extending Joint Spacing" for additional details.)

Specifying Fiber-Reinforced Decorative Concrete

The results for a successful fiber reinforced decorative concrete project depend largely on a complete and accurate specification for the decorative aspects themselves. Sufficient dosages of macrosynthetic fibers have a proven track record for reduction of cracking and curling, however they cannot be viewed as a miracle cure for all other concrete deficiencies. Architects and engineers have become students in the art of decorative concrete, and therefore pay close attention to the aspects of the concrete and practice that are critical to the outcome.

Concrete Strength

Naturally, the concrete must possess sufficient strength to withstand the design loads for the application, and contain sufficient reinforcement to control cracking caused by temperature and shrinkage considerations. For ground and polished concrete surfaces, the question of concrete strength becomes even more important, as there are risks for overly low and overly high strengths for this treatment. In the early days of polished concrete, the perception was often that stronger concrete was better to create a tougher, harder surface, and ultimate strengths in excess of 6,000 psi were not uncommon. The result, however, was most often a surface that was so dense that even the most aggressive grinding tools and wheels were unable to effectively treat the floor skin. Most experts in the industry now recommend more reasonable concrete strengths in the range of 3,500 to 4,000 psi (24 to 28 MPa) to facilitate proper grinding and polishing functions, knowing that the surfaces are generally at least 28 days old prior to grinding. The use of macrosynthetic fibers is focused towards the reduction of cracking caused by temperature and shrinkage concerns, and while they can certainly improve the post-crack performance of concrete, there would be no expected increase nor decrease in compressive strength from their use.

Fiber-Related Specification Concerns

There are various fiber-related considerations that are critical for specifications of both conventional and decorative concrete projects. By addressing these fiber topics in the specification, nothing will be left to chance and will allow project bidders equal footing for their quotation submittals.

- Fiber characteristics: the fiber shape, chemistry, length, and dosage must all be addressed in the materials specification
- Mix design: the mix design should be reviewed to evaluate aggregate sizes, cement content, and allowable water content, all with an eye towards encouraging a low-shrinkage mix
- Slump: the required fiber-reinforced slump should be noted to allow the contractor/ready-mix team a target to address admixture requirements
- Admixtures: a specification note recommending superplasticizers vs. mid-range water reducers for high-fiber mixes will save time, money, and trials on the project
- Finish or grind/polish levels: surface finish or texture, and grinding depths and polish levels should be clearly identified with regards to acceptable fiber visibility
- Trials: pre-project trial mixes and placements are highly recommended to verify acceptable practice and results for owner approval; trial placements should be of sufficient size to allow for real-world batch sizes and real-world finishing equipment and techniques

Project References

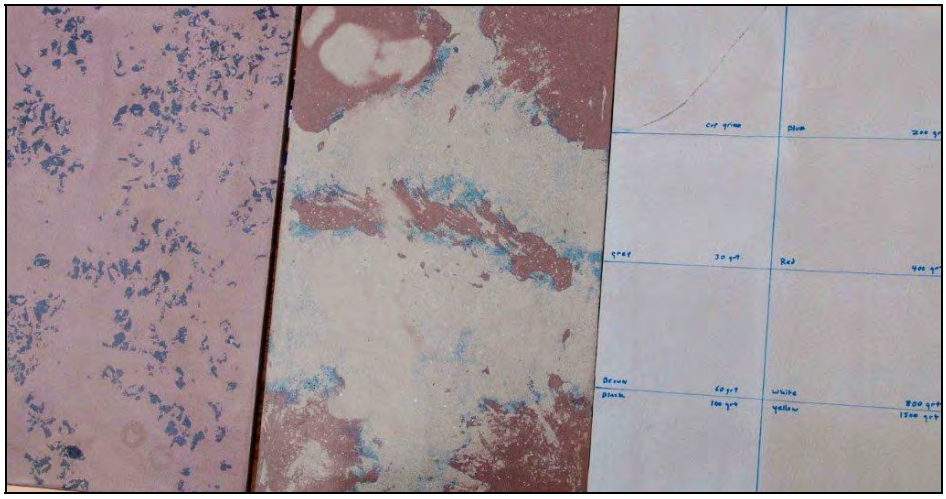
Synthetic fibers produced by FORTA Corporation have been used successfully in decorative concrete projects and applications for many years. The FORTA® technical and engineering staff is available to assist designers by providing the necessary fiber characteristic information and dosage recommendations to meet specific project requirements. Following are representative project examples where the FORTA-FERRO® macrosynthetic fiber was utilized.

World of Concrete
January 2012

For the past several years, the World of Concrete tradeshow has sponsored a variety of special events and demonstrations to highlight new concrete technologies and applications. At the 2012 event January 24 – 27 in Las Vegas, program leader Joe Nasvik organized the Concrete Artistry and Tools demonstrations to reveal the opportunities involved with colored and polished concrete. Nasvik's demonstration crew cast and finished a collection of 12 very thin (.75 in, 19 mm) concrete table-tops and counter-tops 2 ft. x 4 ft. (.61 m x 1.2 m) a week before the show, to allow for grinding and polishing treatments for the demonstrations. The thin panels were cast using a small-aggregate bag mix called "TRU" supplied by Rapid Set Cement, a self-leveling material that achieves 4,000 psi within 24 hours. Each of the demonstration panels was reinforced only with FORTA-FERRO® macrosynthetic ¾" long fiber supplied by FORTA Corporation, and dosed at 7.5 pounds per cubic yard (4.5 kg/cu m). The fibers opened and distributed very uniformly in the small trial-batch mixer, and did not affect the flowability of the mix during casting. During the show demonstrations, the panels were treated by either a surface-only polish or a deep-aggregate grind and polish to highlight the beauty and variety of the gray and colored concretes. In all cases, the macro fibers did not show on the surface, though they were evident on the bottom form edges. The decorative and beautiful polished table and countertops were then donated after the show to the Habitat for Humanity Re-Sale Shop in Las Vegas, to assist fund-raising efforts towards their local home construction program.

Panels were polished with portable grinders

Fibers appeared only on the form edges in this gray deep-aggregate reveal



Various color combinations and polish levels

Brown color deep-aggregate grind with fibers

Application: Colored and polished site-cast table-tops
Owner: World of Concrete 2012, Las Vegas, NV
Fiber: FORTA-FERRO® macrosynthetic, ¾" @ 7.5 lbs/cu yd

Seabrook Residential
April 2009

When Hurricane Ike slammed the Texas coastline in the fall of 2009, considerable damage occurred in the small town of Seabrook, a southeastern suburb of Houston that sits directly on Galveston Bay off the Gulf of Mexico. As part of the repair program at a residence in Seabrook, macro-fiber reinforced concrete was selected for a variety of patio and walkway areas. In this case, the homeowner chose to up-grade the previous gray concrete work with colored, stamped pavements and thin 1 ½ in. (38 mm) toppings, and selected the FORTA-FERRO® macrosynthetic fiber as the optimal reinforcement method. The concrete was mixed on-site in a small 5 cubic foot mixer, sufficient to uniformly distribute the fiber reinforcement and integral color. The freshly placed concrete was jitterbugged to help depress coarse aggregates and fibers below the surface, which allowed for a premium surface finish and stamping with the colored flagstone imprint. In all, approximately 30 cubic yards of FORTA-FERRO® reinforced decorative concrete were placed for this residential repair project.

Hand floating after jitterbug raised cream for stamping

Fibers did not show in the broadcast-color and stamped field-stone surface

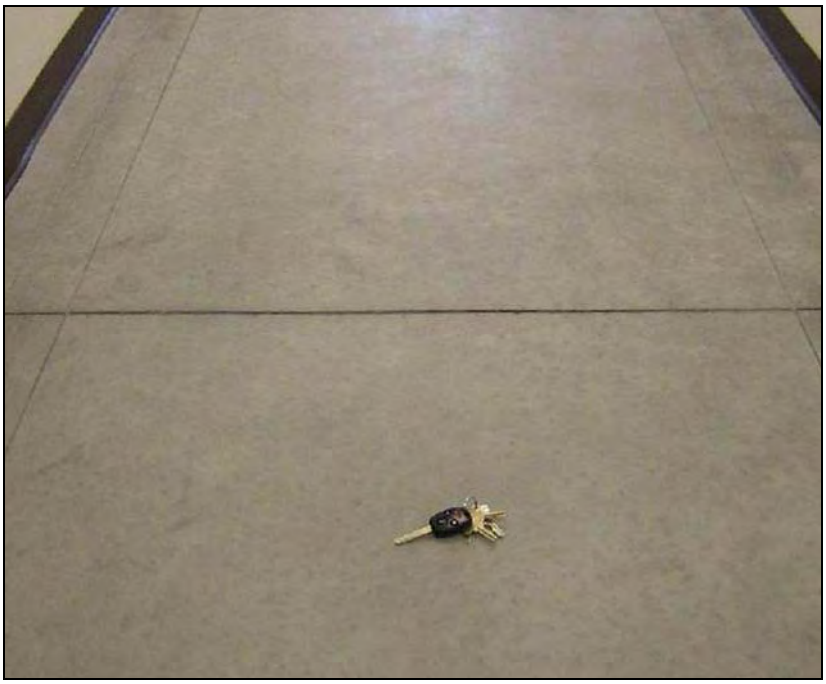
Decorative concrete pedestrian bridge

Application: Thin stamped and colored overlays for residential repairs
Owner: Residential, Seabrook, TX
Contractor: L & L Concrete Contractors, Seabrook, TX
Fiber: FORTA-FERRO® macrosynthetic, 2 ¼ in (54 mm) @ 7.5 lbs/cu yd (4.5 kg/cu m)

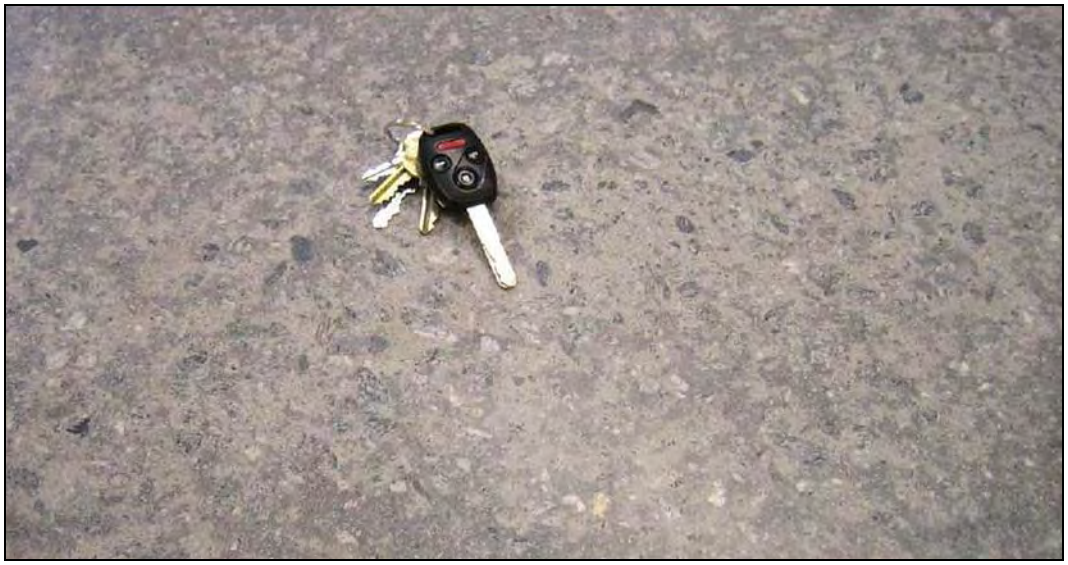
Thomas Concrete Floors
April 2010

In the spring of 2010, Thomas Concrete of Atlanta, GA, took advantage of their own concrete product to create sustainable flooring for a new quality-control and laboratory facility. To show off their own concrete, Thomas used two different reveal methods to accentuate various slab on ground areas within the building. In both areas, the reinforcement of choice was 7.5 lbs/cu yd (4.5 kg/cu m) of the 2 ¼ in. (54 mm) FORTA-FERRO® macrosynthetic fiber. For the office hallways, a light polish was applied to the 6,000 psi concrete to a dull reflective sheen, whereas the conference room used a much heavier grind to reveal the coarse aggregates. Even at the relatively high fiber dosages, neither treatment showed fiber evidence at the surface.

Light polished hallway



Polished hallway close-up



Close-up heavier grind conference room floor

Application: Polished office and conference room floors
Owner: Thomas Concrete, Atlanta, GA
Ready-Mix Supplier: Thomas Concrete, Atlanta, GA
Fiber: FORTA-FERRO® macrosynthetic, 2 ¼ in. (54 mm) @ 7.5 lbs/cu yd (4.5 kg/cu m)

Atlantic Aviation PDK Hangar M
July 2011

National aviation design and consulting firm, Dye Aviation Facilities, Inc., of Atlanta, GA, began using high-volume macrosynthetic fiber reinforcement in 2008 to reduce cracking and improve durability in their aircraft hangar floor slabs. Previous projects included Atlantic Aviation Hangar B at Nashville International Airport, Nashville, TN, in 2008, and Missouri River Aviation Hangar 10 at the Charles B. Wheeler MKC Airport, Kansas City, KS, in 2010. The most recent installation took the FRC – Fiber Reinforced Concrete – to an new level with regards to surface finish, at the July 2011 DeKalb Peachtree Airport, Atlanta, GA, for Atlantic Aviation. In addition to serving as an alternate to a large percentage of the conventional steel reinforcement, the FORTA-FERRO® allowed designers to create a tough, durable, and sustainable floor surface while realizing a cost savings over other methods. The concrete placement followed conventional screed, bull-float, pan and steel-trowel finishing practices, along with a conventional joint-space panel design of 15 feet (4.5 meters) for the 8 in (20.3 cm) floor slab. The project polishing contractor used a 6-step grinding process that included 100, 200, 400, 800, 1000, and 1500 grit diamond polishing wheels, along with a liquid combination densifier and hardener/sealer. The three-dimensional FORTA-FERRO® fiber reinforcement was very compatible with the finishing and polishing processes on this 16,000 square foot project.

Pumping 7.5 lb/cu yd macro-fiber

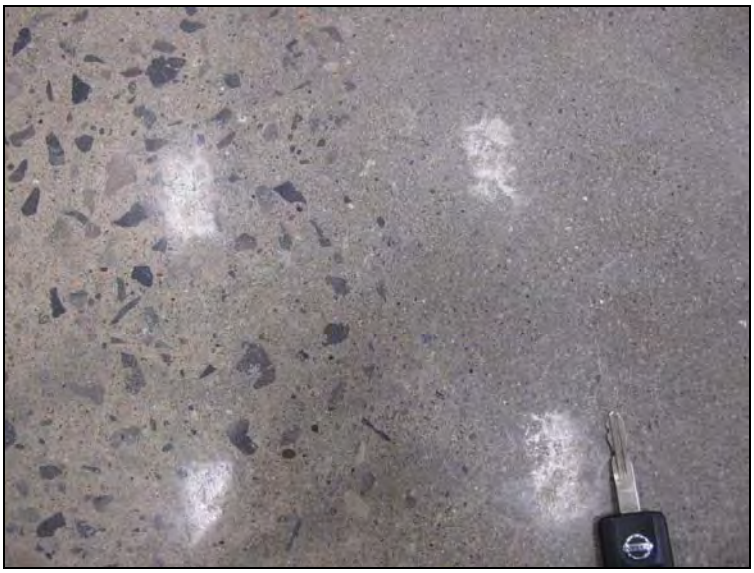
High reflectivity polished fiber floors

Application: Regional jet hangar floor slab
Owner: Atlantic Aviation, Atlanta, GA
Location: PDK – Peachtree Dekalb Airport, Atlanta, GA
Aviation Design Consultant: Dye Aviation Facilities, Atlanta, GA
Architect: Mastin Associates Architects, Atlanta, GA
Engineer: Robinson Associates Consulting Engineers, Norcross, GA
General Contractor: Pro Building Systems, Atlanta, GA
Concrete Contractor: Otis Contracting, Atlanta, GA
Ready-Mix Supplier: Lafarge, Atlanta, GA
Fiber: FORTA-FERRO® 2 1/4 in (54 mm) macrosynthetic @ 7.5 lbs/cu yd (4.5 kg/cu m)

C & J Industries
February 2011

As part of the largest expansion in company history, C & J Industries added over 30,000 sq. ft. of manufacturing space to its facility in Meadville, PA. A premier U.S. plastic injection molding and manufacturing company, C & J constructed a new white molding room, additional warehouse space, an up-graded QA laboratory, and a new assembly room. In lieu of conventional matt-steel reinforcement, design/build firm Struxures LLC opted for the FORTA-FERRO® high-volume macrosynthetic fiber reinforcement, calculated to handle the considerable 55 ton to 720 ton loading for the plastic injection molding machines in the new manufacturing areas. And to allow for a sustainable floor surface without additional covering, C & J selected a variety of grind and polish treatments for serviceability and aesthetics. For instance, in the general manufacturing slab area, a minimal grind process involving 2 passes with a 60 grit metal-bond wheel was selected to produce a salt and pepper appearance where horizontal fiber appearance added to the unique surface look. In several laboratory and showroom areas, ownership chose a deeper aggregate-reveal grind and polish with no fiber visibility. The 8 in (20.3 cm) thick floors had been struck with a laser-guided screed and then trowel-finished prior to surface treatment, and jointed in 31 ft x 36 ft (9.5 m x 11 m) panels reinforced with a fiber dosage of 6 lbs/cu yd (3.6 kg/cu m).

Salt and pepper grind for manufacturing area with horizontal-fiber reveal



Deep and shallow grind areas meet between areas

Highly-reflective deep aggregate grind floor

Application: Ground and polished slabs for manufacturing, laboratory, and showroom floors
Owner: C & J Industries, Meadville, PA
Design/Build General Contractor: Struxures, LLC, Seneca, PA
Concrete Contractor: Maya Brothers Construction, Erie, PA
Polishing Contractor: Diamond Designer Concrete, Inc., Erie, PA
Ready-Mix Supplier: Baycrete Inc., Erie, PA
Fiber: FORTA-FERRO® 2 ¼ in (54 mm) macrosynthetic @ 6.0 lbs/cu yd (3.6 kg.cu m)

FORTA Office Floor
September 2010

Part of the FORTA Corporation office expansion in the summer of 2010 afforded the opportunity to trial fiber reinforcement in various application areas. In addition to a macro-fiber reinforced pervious walkway and a 1,750 square foot slab on metal deck level, the FORTA-FERRO® fiber was included in an office space scheduled for a grind and polish process rather than conventional carpet covering. The 210 square foot office floor used a 4,000 psi design mix that included a blend of #57 limestone and # 8 river gravel for contrast, as well as 7.5 lbs/cu yd (4.5 kg/cu m) of macrosynthetic fiber. Polishing contractor Diamond Designer Concrete performed a deep-aggregate grind that resulted in no evidence of the fiber reinforcement, and added a mocha-colored penetrating translucent stain to complement office trim and décor. The final finish was a semi-gloss reveal to minimize glare and possible slippage, ending with a 3000 grit resin bond polish.

Floor grind prior to wall enclosure.

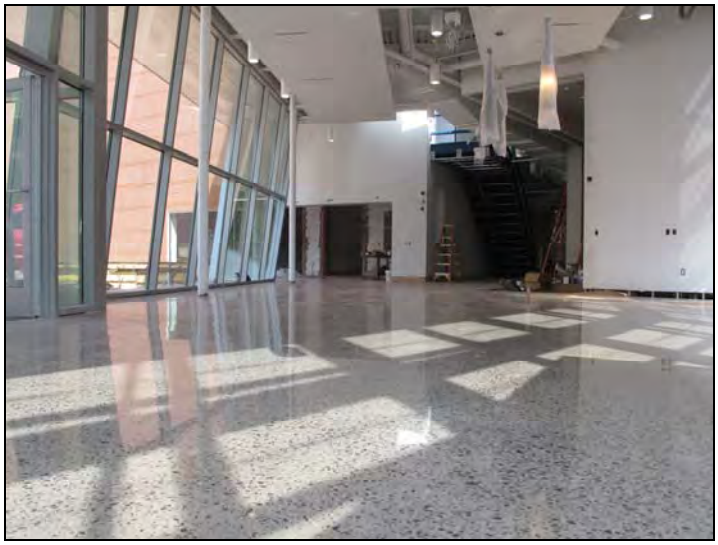
Mocha stain to complement office décor

#57/#8 aggregate blend used for contrast

Application: Ground and polished office floor
Owner: FORTA Corporation, Grove City, PA
Design/Build General Contractor: Struxures, LLC, Seneca, PA
Ready-Mix Supplier: Castle Builders Supply Co., New Castle, PA
Fiber: FORTA-FERRO® 2 ¼ in. (54 mm) macrosynthetic @ 7.5 lbs/cu yd (4.5 kg/cu m)

Erie Art Museum
July 2010

Macrosynthetic fibers played a critical reinforcing role in the 2010 $9 million expansion project at the Erie Art Museum in Erie, PA. The museum owner's desire for an eye-catching and joint-free floor surface for their 10,000 sq. ft. addition prompted concrete contractor Tom Maya to submit high-volume macrosynthetic fibers as an alternate to the specified matt-steel reinforcement. Based on previous macro-fiber experience, Maya felt fibers offered the best opportunity to minimize joints and cracking on the high-profile gallery floor. Critical to the success would be the fibers' ability to mix and distribute uniformly and finish well at the high dosages required (7.5 lb/cu yd, 4.5 kg/cu m), while not negatively affecting the aesthetics of the grind-and-polish surface treatment. The positive results showed that the FORTA-FERRO® macrosynthetic fiber succeeded in controlling shrinkage, cracking, and curling in the large and irregularly-shaped floor sections, and the final floor finish was impressive enough to cause concern by museum curators that the floor might actually divert attention from the gallery exhibitions! The floor system included a 1 ½ in (38 mm) fiber-reinforced mud matt required due to poor sub-grade conditions, and topped with a 5 in (12.7 cm) thick concrete floor separated by a double slip-sheet to allow for possible movement. The floor was comprised of a 3,000 psi high-performance aggregate-reveal concrete that involved a 5-step grind-and-polish process. Grinding contractor Diamond Designer Concrete of Erie has used the project as a showcase reference for their fiber-reinforced, polished-floor system since the official museum opening in October of 2010. The green-friendly Erie Art Museum project was subsequently assigned gold-level LEED project status, and was the 2010 Greensite Award –Institutional Category winner by CONCRETE PRODUCER and CONCRETE CONSTRUCTION magazines.

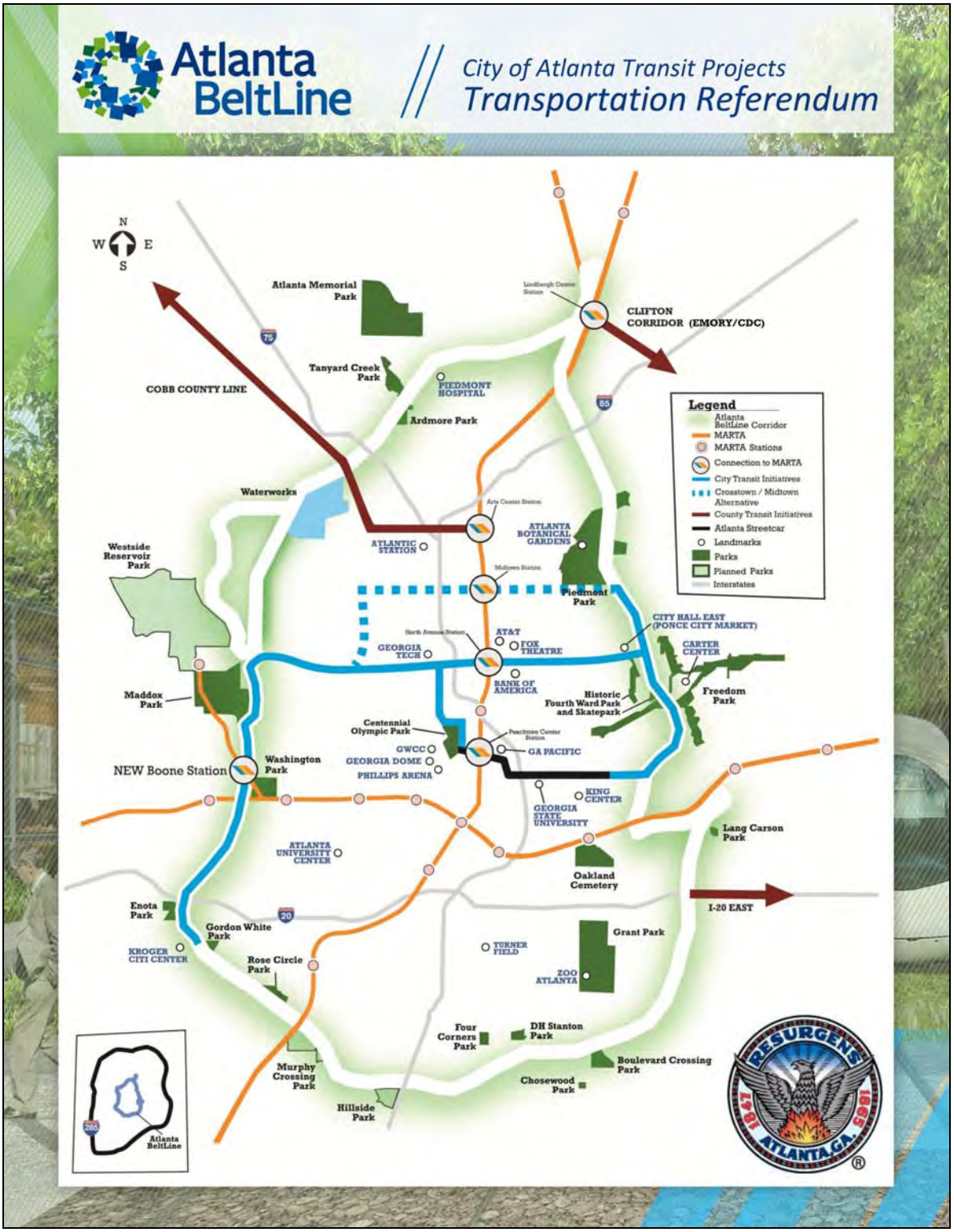


Deep aggregate-reveal grind and polish created a museum-like floor surface

High- gloss, high-reflectivity entry area polished floor

Application: Ground and polished museum gallery floor
Owner: Erie Art Museum, 411 State Street, Erie, PA
Architect: Edge Studio, Pittsburgh, PA
Structural Engineer: Desimone Consulting Engineers, San Francisco, CA
Civil Engineer: Civil and Environmental Consultants, Pittsburgh, PA
LEED Consultant: Evolve, Pittsburgh, PA
Construction Manager: Spaulding Banks Project Management, Erie, PA
Concrete Contractor: Maya Brothers Inc., Erie, PA
Grind/Polish Contractor: Diamond Designer Concrete, Erie, PA
Ready-Mix Supplier: Baycrete Ready-Mix, Erie, PA
Fiber: FORTA-FERRO® 2 ¼ in (54 mm) macrosynthetic @ 7.5 lbs/cu yd (4.5 kg/cu m)

Concrete Sculpture
September 2012



Conceived in 1999 from a master's thesis by a student at George Tech University, the Atlanta Beltline has become a massive long-range coordinated plan and project to connect 45 in-town communities via regional transportation, land use, greenspace, and sustainable growth. Based on a 22-mile historic rail corridor circling the city, the project will ultimately evolve into a pedestrian-friendly rail system and over 33 miles of multi-use trails. Beginning in 2010, a high-profile part of the endeavor called "Art on the

Beltline" offered a variety of visual and performance arts to enhance the aesthetics and user-friendly aspects along the completed Beltline segments. One such contribution was a concrete sculpture designed and created by artists Aaron Albrecht and Frank Fralick that was placed in late 2012 in Washington Park near the MARTA Ashby Station in west Atlanta. Exploring concepts of contrast and irony, the piece – named "Premeditated Spontaneity" – transforms a massive and heavy material like concrete into a lightweight and airy form, creating an arch and gateway into a Beltline segment. The cast sculpture is a 20-foot long concrete ribbon that is 3 inches thick and 3 feet wide, formed to represent the curl, swoop, and flow of a ribbon in the breeze, which presented considerable reinforcement challenges. Requiring approximately ½ cubic yard of concrete consisting of Portland cement, fly ash, lightweight aggregates, and various superplasticizers, designers opted to use integral macrosynthetic fiber reinforcement rather than attempt the struggle to place conventional rigid steel reinforcement. At a high dosage equivalent of 20 pounds/cubic yard of multi-length fibers, the FORTA-FERRO® macro fiber mixed and moved well into the challenging 4-segment forms, and allowed the artists a freedom of artistic form with an unconventional concrete material. Using epoxy-bonded dowels to connect the cast pieces, the sculpture was assembled to capture the fluidity and liquid form of concrete in a solid state, and offered a unique and aesthetically pleasing piece to contrast lightness and mass and contribute to the overall appeal of the Art on the Atlanta Beltline experience.

Flexible reinforced-fabric forming material

Concrete formed in panel segments and assembled

Fiber offered reinforcing flexibility

Assembled sculpture depicts concrete 'ribbon'

Application: Decorative cast concrete sculpture
Owner: Atlanta BeltLine Partnership/Atlanta BeltLine Inc., Atlanta, GA
Artists: Aaron Albrecht,AIA, NCARB and Frank Fralick, Atlanta, GA
Location: Washington Park Gateway, West Atlanta, GA
Fiber: FORTA-FERRO® macrosynthetic, ¾" (19 mm) and 1 ½" (38 mm) @ 20 lbs/cu yd (12 kg/cu m)

Industry Resources

Though decorative concrete might be considered by some as an industry in its infancy, there is a tremendous amount of available information, guidelines, project references, and technical advice available to the contractor, specifier, supplier, and owner. The following list of industry resources represent just a small portion of the available knowledge bank regarding decorative concrete.

American Concrete Institute
www.concrete.org

The American Concrete Institute – ACI - is home to two committee groups that focus on decorative and architectural concrete. Committee 303 Architectural Cast-in-Place Concrete was formed to develop and report information on the production of architectural finishes for cast-in-place concrete. One of the valuable goals of ACI 303 is to document and collect case studies of previous architectural concrete projects to enhance industry comfort level for such treatments. Active committee documents include a 303R-12 Guide to Cast-in-Place Architectural Concrete Practice and a 303.1-97 Standard Specification for Cast-in-Place Architectural Concrete.

Committee 310 Decorative Concrete is a 5-year old group formed to develop and report information on the application of artistic finishes of cast-in-place concrete. Due to the wide variety of industry advancements concerning ingredients like color, stain, aggregates, and fibers, and the quickly changing range of practices such as finishing, grinding and polishing, Committee 310 is challenged to maintain currency within this relatively young industry.

Decorative Concrete Council
www.ascconline.org

ASCC – American Society of Concrete Contractors – is a 50+ year old association formed by and for concrete contractors, and has been the unified voice and presence in the construction industry representing these contractors. The DCC – Decorative Concrete Council – is a specialty group within ASCC that focuses on the issues, trends, and practice of decorative concrete. Especially in a down construction market, the DCC has been instrumental in helping member contractors gain experience in bidding and placing decorative concrete projects to help increase their business targets, and provides an invaluable source of information and assistance regarding new products, materials, and methods to increase the odds for a successful project. The annual DCC Decorative Concrete Project Awards have become a very desirable and well-regarded program, as well as a valuable collection of creative, unique, and high-profile project references across the country.

Concrete Polishing Association
www.concretepolishingassociation.com

The Concrete Polishing Association of America – CPAA – was formed to help define industry standards with regards to polishing, and has developed a variety of written specifications to help the project owner achieve the desired results.

Those important specification topics include the concrete mix design, placement, finishing, and joint practice, and the polished finish and protection. Based in Stevensville, MD, the association membership includes a wide cross-section of industry-affiliated functions, such as architects, engineers, contractors, designers, and manufactures of related materials used in the polishing industry. The CPAA has defined polished concrete as "the processing of a concrete surface with bonded abrasives to achieve a desired class of aggregate exposure and level of reflective clarity and reflective sheen." One of the most industry-valuable contributions by the CPAA has been the development of classification charts and descriptions for both the level of aggregate exposure as well as the reflective clarity and sheen for polished concrete surfaces. These descriptions can be very helpful to designers who are considering integral fiber reinforcement, to help identify those levels that may or may not contribute to fiber exposure.

Aggregate Exposure Levels

Class	Name	Surface Cut Depth	Appearance
A	Cream	Very little	Little aggregate exposure
B	Fine aggregate (salt & pepper)	1/16"	Fine aggregate exposure with little or no medium aggregate exposure at random locations
C	Medium aggregate	1/8"	Medium aggregate exposure with little or no large aggregate exposure at random locations
D	Large aggregate	¼"	Large aggregate exposure with little or no fine aggregate exposure at random locations

In general, previous polished-fiber projects have shown that the only fiber evidenced in the various exposure levels is # B for a salt & pepper sand look, where random fibers may be revealed as a horizontal 'worm' effect. Though this appearance is often desirable by project owners, pre-job trials are always recommended for final acceptance. In the other lesser or deeper cut depths and grind levels, fibers are typically not visible to the human eye.

Clarity and Sheen

Level	Name	Reflective Clarity	Reflective Sheen	Grit Range	Minimum Number of Abrasives
1	Ground	Flat appearance with no to very slight diffused reflection	None to very low	Below 100	4
2	Honed	Matte appearance with or without slight diffused reflection	Low to medium	100 to 400	5
3	Semi polished	Objects being reflected are not quite sharp and crisp but can be easily identified	Medium to high	800 and higher	6
4	Highly polished	Objects being reflected are sharp and crisp as would be seen in a mirror-like reflection	High to highest	800 and higher	7

Mr. Bob Harris is a worldwide author and presenter of all things decorative for concrete applications. As President of his Decorative Concrete Institute, Temple, GA, Mr. Harris a wealth of decorative concrete information, publications, training, and workshops. A long-time decorative concrete speaker and presenter at World of Concrete and a host of other national and international venues, Mr. Harris has become a valuable resource to owners, specifiers, contractors, and suppliers as they continue to learn more about this relatively young industry. Four of his most valuable publications for this industry include:

- Bob Harris' Guide to Concrete Overlays & Toppings
- Bob Harris' Guide to Stamped Concrete
- Bob Harris' Guide to Stained Interior Concrete Floors
- Bob Harris' Guide to Polished Concrete Floors

Myths, Lessons, and Conclusions

An often-heard perception is that macrosynthetic fiber reinforcement cannot be used in decorative nor ground and polished concrete, however the FORTA® macro-fiber history and collection of successful decorative concrete projects would suggest this as myth rather than reality. Decorative and polished fiber concrete can indeed be performed successfully, when proper techniques and reasonable expectations are part of the process. Throughout the FORTA® history of decorative concrete projects, several key lessons and recommendations have become apparent:

- Contractor: Choose a decorative concrete contractor who has ample experience with color, texture, and polishing. A week-end warrior that dabbles in decorative concrete will likely produce results that are less than satisfactory. If high-volumes of macrosynthetic fibers are to be used, both contractor and fiber supplier should also be experienced in the nuances that can accompany this practice.

- Mix and Placement: The concrete mix must be carefully selected and properly placed, knowing that it will be colored, textured, ground, or polished. The placement contractor must be included in all pre-construction meetings and discussions when the final surface will be polished. Slab flatness and levelness will be an important consideration to help minimize variances in surface color or aggregate appearance.

- Strength: The design mix strength should be carefully considered for ground and polished treatments. Ultra-high strength concrete can provide challenges to the contractor who is required to grind it down.

- Fiber: Choose a fiber that will mix, distribute, and finish well. A fiber that is not user-friendly will result in fiber clumps and uneven spacing, as well as surface fuzzies that present challenges to the finisher and polisher.

- Dosage: The fiber dosage does not appear to affect the grind and polish process. Because higher fiber dosages are common to decorative concrete applications, it is important to select a fiber type and brand that can accommodate these dosage levels.

- Color: Integral color or surface stain does not impact synthetic (polypropylene or copolymer) fibers, and the fiber does not impact the color or stain. Because of their non-absorptive nature, the finishing process is critical to avoid fiber/color conflict.

- Grind Depth: The depth of the surface grind can have impact on possible fiber surface appearance. A well-distributed and well-finished fiber will typically not be visible in a shallow polish or deep aggregate grind finish, but may be visible as surface worms in salt and pepper depths.

- Trials: The very nature of decorative and polished concrete demands ownership approval and blessing. Because aesthetics are very subjective and owner expectations are paramount, pre-project trials are highly recommended for all aspects of a decorative concrete project.

Due to wide variety of aesthetic and sustainability concerns, decorative concrete is becoming more common and more popular by the minute. The growth of the polished concrete market is increasing at exponential rates, and shows no signs of slowing down in the near future. And because the results must be aesthetically pleasing, concrete cracks and even conventional joints can negatively affect the appearance of the entire project. The right macrosynthetic fiber at the right dosage provides the owner and project participants with a viable reinforcement system to help capitalize on the popularity of decorative concrete. Because surprises are generally not welcomed on decorative concrete projects, pre-job trials along with realistic expectations become an important part of the process. One of the most compelling and unique characteristics of concrete is that it is not a perfectly uniform material nor perfectly regimented both inside and out, which affords it the luxury of providing an unusual and random appearance. Per Ms. Cori Sutton, an award-winning concrete polisher, "The beauty of polished concrete lies in its irregularities." The combination of concrete's unique characteristics with a non-corrosive and user-friendly macrosynthetic fiber such as FORTA-FERRO® offers decorative concrete contractors, suppliers, and buyers a valuable and attractive building material to capitalize on this growing market and application.

FORTA® personnel are available to assist with fiber selection and use, as well as the explanation of reasonable expectations of the fiber. FORTA® representatives do not engage in the practice of engineering or architecture as licensed by government agencies, nor are they licensed to act in a role of overall project supervision where FORTA® products are used. FORTA® personnel are available solely for the support of our customers – those that purchase and specify our products.

FORTA®

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