Performance Specifications

iCrete is a concrete technology company that is transforming the construction industry by shaping the next generation of concrete production and associated technologies. iCrete uses a patented mix design technology that optimizes concrete for efficiency, workability and strength while lowering greenhouse gas emissions. iCrete does not produce concrete, but rather licenses its patented technology to ready mix producers to deliver a better-performing concrete that is more economical and environmentally friendly than conventional concrete—and excels based on performance-based (not just prescriptive) specifications.

Performance vs. Prescriptive

Project specifications that are prescriptive—typical of the concrete construction industry today—can reduce the decision-making power of a concrete producer and stifle innovation by stipulating the types, quantities and proportions of material ingredients. Prescriptive specifications are often overly conservative, which can lead to higher costs and unexpected negative results, ultimately leading to unsatisfied customers.

A performance specification approach empowers the concrete producer to decide how to meet certain specifications in both plastic and hardened states. It is the producer who has control over engineering and combining materials to meet—and even exceed—the required specifications, without having to disclose the mix design.

Under typical prescriptive specifications, some or all of the following may be specified:

- Maximum water-cement or water-cementitious material ratio
- Minimum cement content
- Air content
- Strength
- Slump
- Maximum size of aggregate
- Other requirements relating to such things as strength over-design, admixtures and special types of cement, other cementitious materials and aggregates

Of these, only strength and slump are truly performance requirements. The others are specified in order to achieve objectives that may conflict with good mix design practice.

In comparison, a performance specification defines the functional requirements for both the fresh and hardened concrete according to the application (building type), exposure or intended life. The concrete properties specified should be clear, achievable, measurable and enforceable. For example, a performance specification for the interior columns of a building might dictate compressive strength and creep because durability is a comparatively minor concern. Meanwhile, the specification for a bridge deck (that will be subjected to freeze-thaw action and deicing salts) might include criteria such as strength, permeability and shrinkage.

Criteria	Prescriptive	Performance
Strength	√	√
Slump	√	√
Min Cement Content	√	
Max W/C Ratio	√	
Air Content	√	√
Aggregate Type	√	
Cementitious Types	√	
Admixtures	√	
Shrinkage	√	√
Creep	√	√
Permeability	√	√
Freeze-Thaw	√	√
Modulus of Elasticity	√	√
Durability		√

The differences in prescriptive vs. performance concrete specifications are clear. A chief concern is that prescriptive specifications not only require achievement of engineered criteria but also regulate the use of raw materials that may be at odds with achieving the desired results.

A closer examination of common industry performance criteria shows how iCrete technology can advance achievement of these specifications.

Strength

The ability to design concrete in a strength range of 200 to 18,000 psi is truly performance based. These mixes are expected to be workable, finishable and pumpable. Additionally, they must (in some cases) meet a unit weight requirement, as in lightweight applications. Performance-based specifications enable the industry to cost-effectively design and install all ranges of specified strengths and promote the use of high-strength, high-performance concrete.

Current Industry Thinking

The needs of the industry can be summarized in a variety of strength ranges:

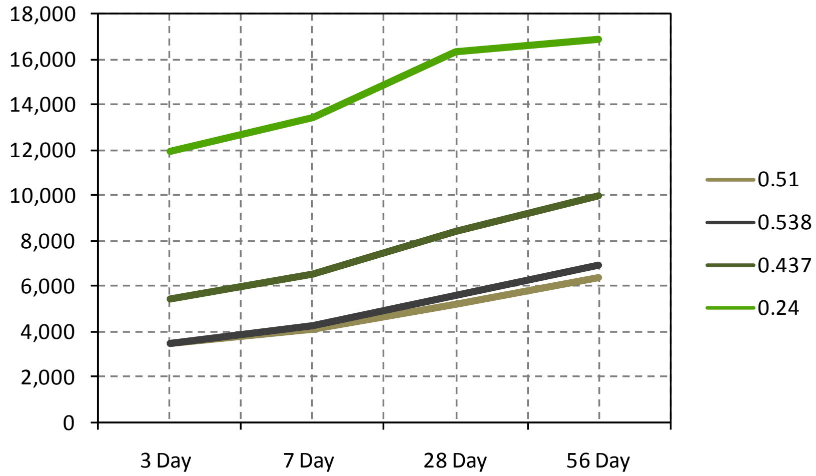
- Low Strength (200 to 3,000 psi) – When working in this lower strength range, a key consideration is satisfaction of the workability requirements of the application. In these formulations, the designer can take advantage of byproducts such as fly ashes and slag cement to meet workability requirements.

- Medium Strength (4,000 to 7,000 psi) – The challenge in this range is to design with the minimum amount of cementitious material in order to be cost-effective. In a performance-based environment, the designer can optimize using synergies realized by combining all of the raw materials efficiently.

- High Strength (7,500 to 18,000 psi) – In this range of specified strengths, the challenge is twofold: create effective combinations of materials, while maintaining workability at a level where these mixtures can be installed with minimum effort. A performance-based system allows for the most efficient combination of materials to achieve the required performance.

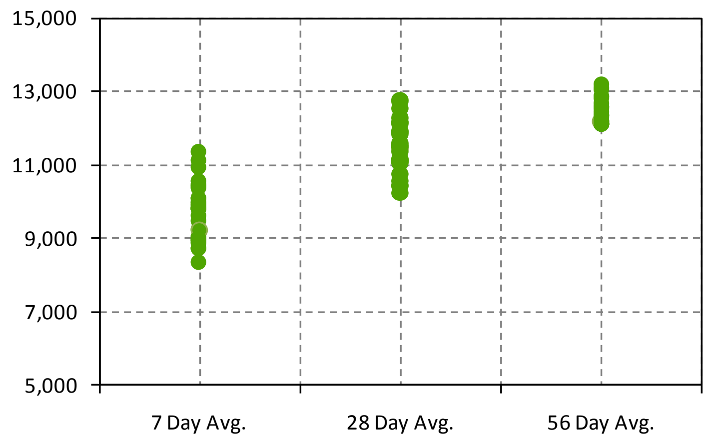
iCrete Advantage

iCrete's technology optimizes all mix components to achieve the required strength, while also providing other characteristics needed in the concrete, such as workability and durability. iCrete can utilize readily available, local raw materials to design concrete mixes that are most cost-efficient for meeting target strength:



Graph: Assuming comparable cement contents, iCrete formulations increase concrete strength by as much as 20% to 30%, depending on materials. Mixes were designed with readily available local materials, including OPC and fly ash. The tests were conducted in Atlanta, Georgia.

iCrete can also achieve higher ultimate strengths for a given set of materials:



Graph: Strength results from a 12,000-psi iCrete mix used in 2008 at the Revel Casino in Atlantic City, New Jersey. Twenty-eight-day and 56-day standard deviations were 674 and 372 respectively, significantly less than expected based on industry averages

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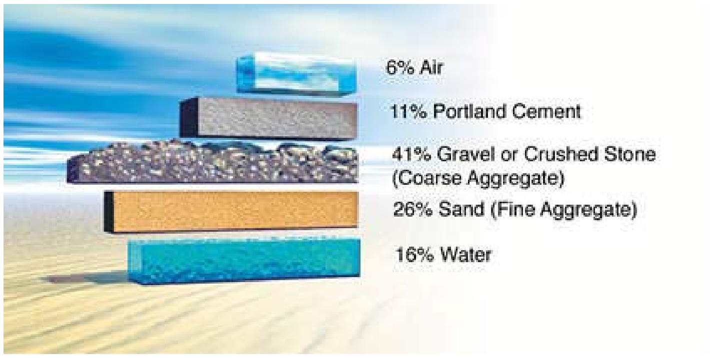
Optimizing Material Usage

Performance-based concrete specifications allow the concrete industry to effectively utilize combinations of aggregates, aggregate long products, cements, slag cement, fly ash, other industry byproducts and admixtures to design concrete. Traditional prescriptive specifications often include unnecessary and even conflicting requirements that make mix proportioning more difficult, stifle innovation, increase cost—and can actually result in lower performance and durability.

On shear walls for the 1,776-foot-high Freedom Tower (which will replace the World Trade Center towers in New York City), the iCrete system was used to produce the highest-strength concrete ever placed in New York City:14,000 psi. Using fly ash and slag cement as supplementary cementitious materials, this concrete was produced with only 527 pounds of cement per cubic yard in order to control temperature rise in the massive walls, reduce costs and minimize the carbon footprint.



Graph: Standard constituents and their respective proportions in a concrete mix. Prescriptive specifications can dictate the proportioning of these constituents, which can have adverse affects on the resulting performance of concrete.

Current Industry Thinking

Material optimization in concrete mix design falls into three main categories:

- Aggregates – The aggregate sources producers have relied on in the past are being rapidly depleted. To minimize the waste of our natural resources, the concrete industry needs the ability to use aggregate sources to their maximum potential. This means having the technology to incorporate long products and quarry byproducts while still achieving the required performance of the concrete. One example is high fines from the manufacture of clear products. There are millions of tons of these materials located in hard rock quarries across North America. Used properly, these materials can actually improve the cohesiveness and overall workability of conventional and self-consolidating concrete (SCC).

- Fly ash, slag cement and silica fume – Performance-based specifications will encourage maximum utilization of these materials by allowing mix designers to combine these products to achieve desired concrete performance both in plastic and hardened states. (Some prescriptive specifiers limit their use based on past experiences where characterization was not conducted.)

- Admixtures – Air, low-range water reducers, high-range water reducers, retarders and viscosity modifiers can be used either individually or in combination to improve the performance of concrete formulations while decreasing the overall raw material costs.

iCrete Advantage

iCrete's technology—when used in a performance-based system—allows the concrete producer to respond directly to the needs of the customer. Using the materials available, an optimal mix is proportioned that meets the concrete's required performance, both in fresh and hardened states. Patented iCrete technology allows producers to be proactive in their optimized materials usage including the following:

- Using a wider variety of cement replacement products such as fly ash, slag cement or silica fume, as available.
- Effective use of a wider variety of aggregate products (even waste products) to design and produce concrete.
- Efficient use of admixtures while balancing performance, material costs and construction costs.

While many mix designers and optimization packages may be able to handle one or two of these changing variables, iCrete's technology can bring it all together to achieve optimal mix designs that perform.

Shrinkage

Shrinkage is classified in two distinct categories: volume changes in concrete caused by moisture loss from the surface that cause plastic shrinkage, autogenous shrinkage or chemical shrinkage; and moisture loss from the hardened concrete that causes drying shrinkage. The changes in concrete volume set up tensile stresses, which result in concrete cracking. The result can cause early deterioration (low durability) depending on the environment to which the structure is exposed.

Current Industry Thinking

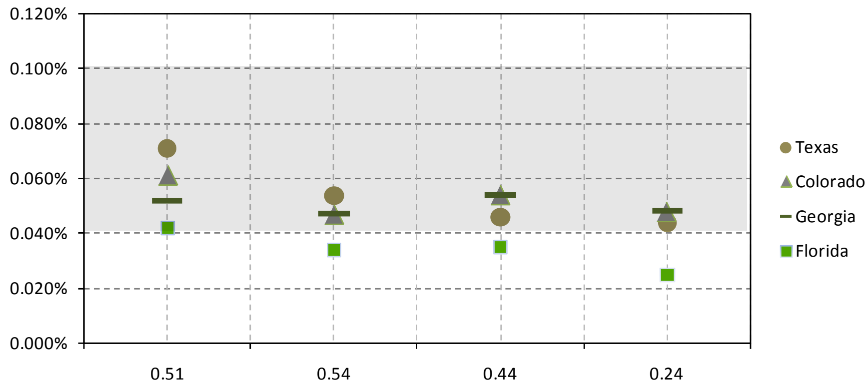
Shrinkage is a critical consideration in the design of structures (such as buildings) and components of infrastructure (such as bridges or tunnels). Designs often have prescribed limits for concrete shrinkage and, in some cases, designs can even be limited by the knowledge that conventional concrete has a minimum shrinkage associated with its use as a building material.

The primary factor that determines how much concrete shrinks is the volume of cement paste in the mix, or, conversely, the quantity of aggregate in the mix. Most quality aggregate does not experience significant shrinkage, so maximizing the size and quantity of aggregate in the mix (thus minimizing the amount of cement paste) will minimize the shrinkage. Aggregate use can be maximized by increasing the maximum size and optimizing the gradation.

Another important factor in shrinkage is the water-cement ratio: the greater the water content (higher w/c ratio) the greater the potential shrinkage. Shrinkage is also affected by different types of cement and admixtures.

iCrete Advantage

While temperature and moisture are the two most prominent conditions affecting concrete shrinkage, iCrete mixes are designed to minimize shrinkage through strict moisture control that yields results which exceed the performance of conventional mix designs.



Graph: Standard iCrete mixes (using only ordinary portland cement and fly ash) are able to achieve low drying shrinkage values across a wide range of water-cement ratios. The shaded area indicates a typical range for the industry.

In addition, iCrete's proprietary particle packing structure and optimized use of supplementary cementitious materials results in a dense, stable particle structure that combats the forces of shrinkage.

<u>Creep</u>

When a concrete structural element is cured under a load, over time, there is a gradual increase in strain that results in creep. The resulting deflection can be considerable, and is of great importance for structural mechanics in the design and construction of buildings.

Predicting the amount of deflection that may occur is difficult and especially complicated in concrete that contains supplementary materials, chemical admixtures and lightweight aggregates.

Current Industry Thinking

Predicting the amount of creep is not easy, and is further complicated by the use of supplementary cementitious components (such as slag cement and fly ash) as well as new admixtures that can affect the amount and rate of creep. Designs may even include prescribed limits for creep that may be in conflict with other prescribed characteristics, such as water-cement ratio.

The primary factors that reduce the amount of creep are the same as for shrinkage: high aggregate content and low water content. In addition, according to *ACI 209.1, Factors Affecting Shrinkage and Creep of Hardened Concrete*, fly ash and slag cement reduce creep, while lightweight aggregate, silica fume and water-reducing admixtures increase creep.

iCrete Advantage

Similar to shrinkage, temperature and moisture are the two of the more predominant conditions affecting creep. iCrete's strict moisture control provides a production environment that results in concrete with less creep, compared to conventional methods and designs. Standard iCrete mixes (using only ordinary portland cement and fly ash) achieve low creep values across a wide range of water-cement ratios.

In addition, iCrete's proprietary particle packing structure and optimized use of supplementary cementitious materials results in a dense, stable particle structure that inherently resists the forces of creep.

Modulus of Elasticity

Modulus of Elasticity (MOE) is the ratio of stress to strain when concrete is subjected to a compressive load. Abbreviated by engineers as "E," it is expressed in force per unit area, such as pounds per square inch (psi), kilograms per square centimeter (kg/cm^2) or megapascals (MPa). The MOE of concrete is a measure of its stiffness and is vital information used in the design of tall buildings.

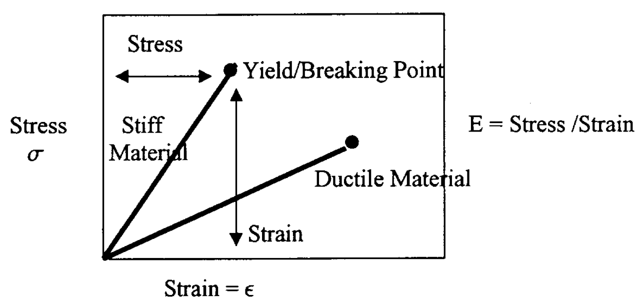


Chart: The stress-strain relationship and the Modulus of Elasticity (E) that is the stress over strain, representing a measure of stiffness of the concrete.

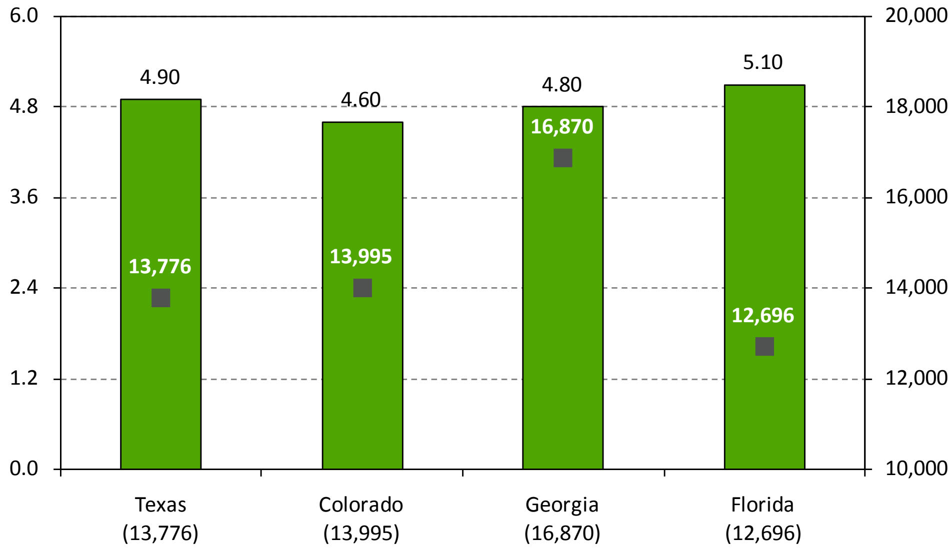
Current Industry Thinking

MOE is used by structural engineers in the design of high rise buildings. Durability, shrinkage and MOE can be designed effectively by using the correct combination of materials. However, prescriptive specifications tend to be very restrictive—and often contradictory. For example, a specifier may prescribe strength and MOE while at the same time requiring a certain water-cement ratio and a minimum cement content. These requirements could easily conflict, making the desired concrete properties very difficult to achieve.

Similarly, heat of hydration frequently restricts the ability to achieve high strength and desirable MOE. When heat of hydration is too high (often as a result of using high cement content in an effort to achieve high MOE), micro-cracking occurs in the concrete matrix, reducing the compressive strength and MOE *and* compromising the structural integrity of the building.

iCrete Advantage

iCrete technology was able to meet and exceed the MOE requirements for one of the most important structures in the U.S., the Freedom Tower on the site of the former World Trade Center in New York City. The measured MOE for this very high-strength concrete (14,000 psi) was 7 million psi, higher even than the MOE specified for the Bruj Dubai—currently the world's tallest building.



Results of regional testing using only using only ordinary portland cement and fly ash to achieve high-strength concrete. Corresponding MOE results are also depicted.

<u>Durability</u>

Durability is the ability of concrete to resist weathering action, chemical attack and abrasion. It is related to the quality of a structure, demonstrated by how well it stands up for a sustained period of time. Durability is also defined as how well properly designed and controlled concrete withstands breakup caused by freeze-thaw, salt scaling and excessive volume change due to shrinkage.

<u>Consistency</u>

Consistency in concrete supply is normally measured by how much the material varies in the plastic state, workability, slump or slump flow, air content, unit weight and set time as received on-site. Consistency in the hardened state is measure by how much the strength, air void system, permeability and other specified features vary.

- <u>Workability</u> is a qualitative measure and is a function of ease of placing, finishing and pumping.

- <u>Slump</u> and <u>slump flow</u> are quantitative and are evaluated by how much the slump or slump flow varies as measured on site. The proper use of admixtures under a performance-based system can control slump loss in transit and decrease the variations.

- Air content and unit weight are quantitative and serve as measures of how much the air contents and unit weights of the concrete vary as measured on delivery to the job site.

- Set time is a function of how long the installers must wait to conduct the final finishing process; it can be measured by the initial set test and how much it varies. The ability to change materials in a timely manner can control these variations.

- The consistency of strength is usually measured by standard deviation, and is also a factor included for calculating the required target strength in production. The lower the standard deviation, the better the consistency of production and control.

- Air void system, permeability and other features are measured by specific test methods and can be evaluated by calculating standard deviation.

Current Industry Thinking

Prescriptive mixes define the types and quantities of materials that can be used in the concrete mix, allowing no potential for innovation to improve performance, economy or consistency. To maintain consistency in concrete supply, producers must have the freedom to operate in a performance-based environment. This offers the flexibility to make mix design adjustments to accommodate changes in raw materials, gradations of aggregates, cementitious variations and ambient conditions.

iCrete Advantage

With the iCrete system in place, producers and contractors can expect a heightened level of consistency that will have a profound impact on all stages of concrete production and usage in both plastic and hardened states. Enhanced quality control and quality assurance in the iCrete system catch problems with raw materials or mixed concrete *before* it reaches the job site, ensuring that each batch of concrete delivered is consistent with job requirements.

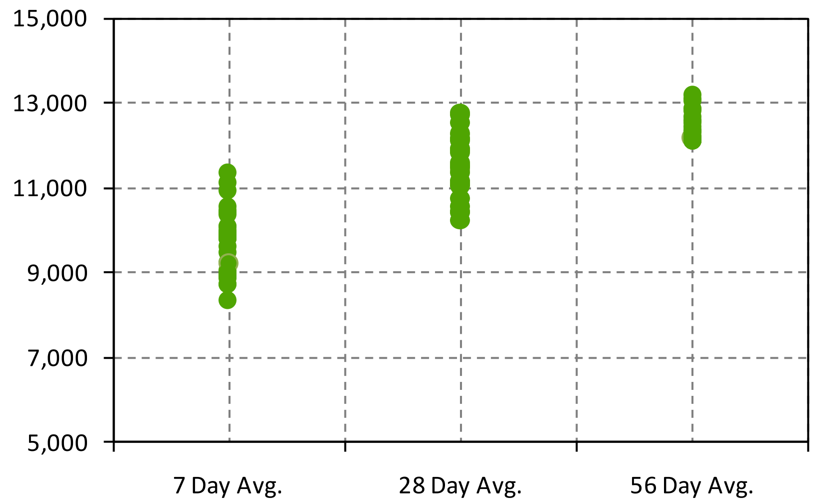


Chart: Strength results from a 12,000-psi iCrete mix used in 2008 at the Revel Casino in Atlantic City, New Jersey. Twenty-eight-day and 56-day standard deviations were 674 and 372 respectively, significantly less than expected based on industry averages.

Sustainability and LEED

"Sustainability," "green building" and "environmentally friendly" are all buzzwords that have taken hold in the construction industry. To be truly sustainable in today's construction environment, builders must reduce their carbon footprint and manage costs in all aspects of their work. Concrete's role as a sustainable building material is not evident on first glance; however, a very long life span—with nearly zero maintenance and the ability to contribute greatly to energy-efficient buildings—means concrete can be a green building material.

In addition, concrete producers can minimize the use of portland cement (the main CO_2 contributor in concrete) and incorporate industrial byproducts such as fly ash and slag cement.

Current Industry Thinking

Recently, assessment tools have been developed to evaluate the sustainable characteristics of a building or other type of structure. The best known is the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System for commercial and residential construction. Aside from the energy-efficient aspects of using concrete as a building material, designing an optimized mix with less reliance on portland cement can also contribute to earning points in each of these assessment methods, and can ultimately help achieve LEED certification.

The ready-mixed concrete industry is beginning to explore a variety of "green" concrete applications:

- Recycled concrete – Suppliers and designers must be aware of the Cradle to Cradle concept, not just the Cradle to Grave ideology of the past. Future utilization of recycled concrete will be an important element of a truly sustainable concrete industry.

- Pervious concrete – Stormwater control is becoming more recognized as an effective sustainable development practice, and builders can use pervious concrete to help accumulate LEED points on some projects. Properly designed, the stormwater conservation applications for pervious concrete will increase over the coming years.

- Use of recycled waste materials such as fly ash, slag cement and silica fume – By properly characterizing the composition of each material chemically and physically, designers are able to maximize their utilization levels based on specific applications, minimizing cement content and reducing the carbon footprint.

- Thermal mass/reduced energy use – A Portland Cement Association report showed that nearly 98% of the energy a building consumes during its lifetime is for operating expenses after occupancy. By fully exploiting the thermal properties of various concrete mixes, energy consumption in the operation of buildings over their design lives can be greatly reduced.

For the concrete industry to become more sustainable, concrete mixes must be proportioned using a performance-based model instead of the less-efficient prescriptive mixes often used in the past. Ready mix producers must be free to optimize their formulations to produce cost-effective designs that meet the requirements for a sustainable material.

iCrete Advantage

Mixes created using iCrete technology use less portland cement than conventional concrete mixes. In fact, reductions of up to 40% have been achieved even with high-performance mixes. iCrete's patented technology allows producers to take advantage of other cementitious products such as fly ash and slag cement, and to incorporate a wide variety of aggregate products (such as crusher fines) to help mange pit balance and reduce waste.

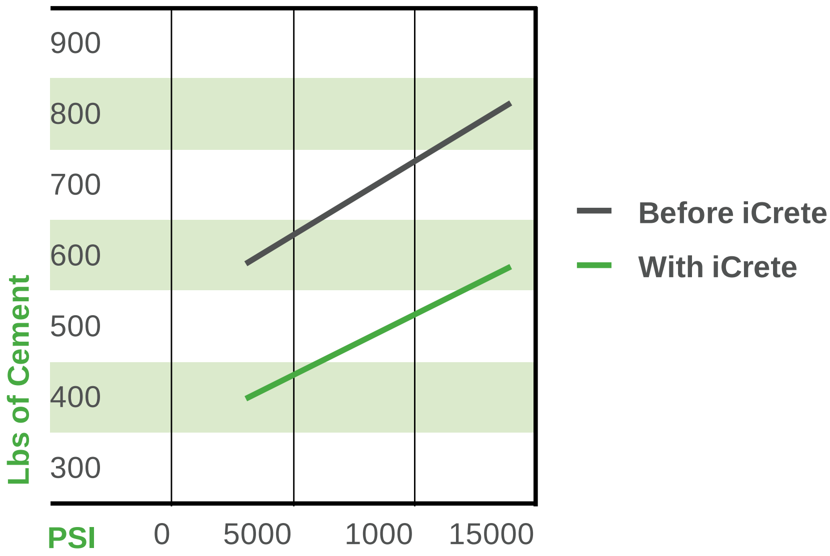


Chart: Regional data showing reduced cement content per cubic yard of iCrete mixes vs. conventional mix designs.

The Solution is Clear: iCrete Means Performance

The ready mix concrete industry recognizes the need to move from prescriptive methods to performance-based mix designs. Now, other decision-makers (such as engineers and contractors) are starting to embrace the shift, which results in better-performing concrete and reduces problems resulting from variability in materials, inconsistent production methods and the inability of some producers to design a reliable concrete mix using older methods.

iCrete has the ability to offer producers distinct advantages in facilitating this shift to performance-based mix design, while alleviating the concerns of the architecture/engineering community. From mix design technology to production and process controls, the results yield a technically superior concrete product that maintains its consistency from batch to batch. iCrete delivers an assurance that producers can meet performance-based criteria, creating concrete that satisfies the engineering community on many levels—including sustainability.

Get started today by contacting iCrete.

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