CONCRETE INTERNATIONAL V. 44 NO. 12 CONCRETE PRODUCT & SERVICE GUIDE DECEMBER 2022

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## 2023 CONCRETE PRODUCT & SERVICE GUIDE



## ALSO FEATURING

# Tech in Concrete

**Charles K. Nmai**
**ACI President**

The holiday season is upon us, and it's the time of year when we exchange gifts or treat ourselves to new things. High on the list for many people each year are new gadgets, in particular, the latest mobile phones and electronic appliances, smart home devices such as home voice controllers, doorbell cams, smart locks, and smart light switches. While it might not be obvious to most consumers, most of these gadgets are Internet of Things (IoT) devices.

IoT refers to a network of devices that are connected to the internet and the technology that enables communication between them and also with the cloud. As noted by Statista, IoT devices use sensors and processors to collect and analyze data acquired from their environments. The data collected from the sensors are then sent to a gateway or to other IoT devices and analyzed in the cloud or locally. Statista forecasts that there will be more than 75 billion IoT-connected devices in use by 2025, a fivefold increase from 2015 and a threefold increase from 2019. The data volume created by IoT connections is projected to reach a staggering total of 79.4 zettabytes! To put it in perspective, one zettabyte is equal to a trillion gigabytes. Statista also forecasts that global spending on IoT will reach $1.1 trillion by 2023.

What a perfect segue to what's going on in the concrete industry today—specifically, with the use of technology in concrete! This year-end President's Memo will highlight various technologies that are redefining and transforming concrete construction, with a focus on artificial intelligence (AI) and machine learning, concrete sensors, and additive manufacturing.

A concrete producer will typically have core mixture designs for different concrete classes. As these designs get tweaked as needed to meet the needs of specific projects within the producer's service area, a producer may develop hundreds, if not thousands, of concrete mixture designs. This practice may not be optimal from a sustainable perspective, and it has created a space for the use of AI and machine learning to automate data collection and optimize local materials for sustainable and more cost-efficient concrete. These AI systems have the ability to optimize and validate a concrete mixture in days rather than months. This approach is helping concrete producers to develop more advanced, cost-effective, durable, and sustainable concrete mixtures with a lower $CO_2$ footprint.

While optimizing and producing a sustainable concrete mixture is the first step, maintaining the integrity of the fresh concrete—specifically, slump and air content—during transport to a jobsite can be a challenge for quality control personnel. Technology in the form of in-transit monitoring systems is available to help concrete producers improve efficiency, eliminate rejected loads, and reduce concrete waste. Sensors in these systems are mounted on concrete trucks and collect real-time data that are uploaded to the cloud and allow producers to monitor, measure, and manage fresh concrete properties during transit to the jobsite.

After the concrete is delivered and placed, concrete maturity sensors measure and log concrete temperature history, calculate maturity, and evaluate in-place strength. They include fully autonomous data collection options to collect and access concrete data remote from the jobsite. With the current focus on low-carbon concrete, early-age strength development has come into sharper focus, resulting in increased interest in these in-place maturity systems. Although maturity systems have been available for decades, IoT has recently accelerated growth in their availability, functionality, and use!

Nearly 40 years ago, I got exposed to computer numeric control (CNC) milling machines and was amazed by how quickly and precisely the notched metal steel coupons that I needed for my PhD research work could be manufactured using a CNC machine. Fast forward to today, and it's amazing to see how three-dimensional concrete printing (3-DCP) is transforming the concrete industry. It's a marvel to see the various types of printers that are being developed and their use in the construction, layer by layer, of new shapes previously not possible using conventional construction techniques. Many of these machines are capable of printing one-story walls for houses, and one has been sized and used to construct the walls for the world's first 3-D-printed three-story building in Germany!

I believe this is an exciting time to be in the concrete industry as we witness the infusion of technology from concrete batching through construction. I wish you all a happy, relaxing, and safe holiday season!

Charles K. Nmai

وزارت علوم، تحقیقات و فناوری

# مرکز تحقیقات بتن (متب)

دارای مجوز کارشناسی ارشد MSc و دکتری PhD رشته عمران

با مجوز ۵۱۱۶-۲۲

ConREC aci Iran Chapter

Concrete Research & Education Center

Affiliated with ACI International Concrete Institute

Advancing Concrete Knowledge

**برگزارکننده:**

## دوره های آموزش عالی آزاد بتن و ساخت سازه بتنی

### آموزش ترکیبی دانش تئوری و یاددهی- یادگیری فعال مهارت های تکنیکی بتن

### انجمن علمی بین المللی بتن آمریکا (ACI) - شاخه ایران

(پیوند تئوری و عمل)

دوره های آموزش عالی آزاد با ارائه گواهینامه مورد تایید وزارت علوم، تحقیقات و فناوری و

سازمان ملی استاندارد ایران

# ACI CHAPTER LEADER NETWORKING EVENT

**WEDNESDAY, JANUARY 18, 2023 AT 5:30 PM**

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مرکز تحقیقات بتن (متب)

تحصیلات تکمیلی مهندسی عمران

با مجوز ۵۱۱۶-۲۲

Concrete Research & Education Center

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# گروه های آزمایشگاهی
# مرکز تحقیقات بتن (متب)

مرکز رشد فناوری های نوآورانه در ایران با مجوز وزارت علوم، تحقیقات و فناوری

**دارای گواهینامه تایید صلاحیت بازرسی و آزمایشگاه همکار سازمان ملی استاندارد ایران**

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بهترین در آزمایش، برترین در کیفیت

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Each year, approximately
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Building the Future

# Thank You to the 2022 Overall Excellence Award Judges

The American Concrete Institute is pleased to acknowledge the judges of the Overall Excellence category for the Eighth ACI Excellence in Concrete Construction Awards. These three globally renowned concrete professionals reviewed the first-place winners from each project category to choose the project that received ACI's prestigious Overall Excellence Award for exceptional use of concrete in its design and construction.

The Overall Excellence Award project was the University of Sydney's Chau Chak Wing Museum, which was also the first-place winner in the Mid-Rise Structures category. The winning projects were recognized at the ACI Excellence in Concrete Construction Awards Gala on October 24, 2022, during the ACI Concrete Convention in Dallas, TX, USA.

Judges for the Overall Excellence Award included:

**Stephen T. Ayers**, the 11th Architect of the Capitol and President of The Ayers Group, LLC, is the Interim CEO of the National Institute of Building Sciences (NIBS). He previously served as Chair of the NIBS Board from 2017 to 2018. He also served as Chair of the Construction Management Association of America and the Construction Users Roundtable.

On February 24, 2010, President Barack Obama nominated Ayers to serve as the 11th Architect of the Capitol. By May of that year, the U.S. Senate confirmed Ayers, and the President officially appointed him to a 10-year term as Architect of the Capitol.

The Architect of the Capitol is responsible for facilities maintenance and operation of the U.S. Capitol building and the operation and maintenance of 18.6 million $ft^2$ (1.7 million $m^2$) of buildings, including the House and Senate Congressional office buildings, Capitol Visitor Center, Library of Congress, U.S. Supreme Court Building, and Thurgood Marshall Federal Judiciary Building.

**Emily Guglielmo** has nearly two decades of structural engineering experience, all with Martin/Martin, Inc. She began her career in its Denver, CO, USA, area office and is currently a Principal with the firm, managing its San Francisco Bay Area office. She has lectured on building code provisions nationally and internationally. Guglielmo is the Vice Chair of the ASCE 7 Seismic Subcommittee and is the Chair of the National Council of Structural Engineers Associations (NCSEA) Wind Engineering Committee.


Ayers


Guglielmo


Paul

She has received several awards, including Structural Engineering Institute Fellow and the Susan M. Frey NCSEA Educator Award for effective instruction for practicing structural engineers. She received her bachelor's degree in civil engineering from the University of California, Los Angeles, CA, USA, and her Master's degree in structural engineering from the University of California, Berkeley, CA. Guglielmo is a licensed PE, SE, and CE.

**Michael J. Paul** is an ACI Vice President and a Trustee of the ACI Foundation. He chaired the ACI Board task group that mapped out what would become the Excellence in Concrete Construction Awards, and was the initial chair of the International Project Awards Committee. In his day job, Paul is Principal Structural Engineer for Larsen & Landis, Inc., based in Philadelphia, PA, USA. In this role, he oversees the engineering, documentation, and management of structural engineering for commercial, institutional, industrial, recreational, and residential projects. Paul's experience includes troubleshooting, repair, restoration, and rehabilitation of existing concrete structures in addition to new structure design.

Sponsorship opportunities are available for the 2023 ACI Excellence in Concrete Construction Awards Gala. Contact Esther Beery, ACI Chapter Activities Coordinator, at esther.beery@concrete.org with questions.

# Carbon-Neutral Concrete

## What does it really mean?

*by Andrea Schokker*

We're hit with a plethora of terms: green, resilient, low-carbon footprint, sustainable, low emissions, carbon offset, eco-conscious, net-zero, renewable, global warming potential, carbon neutral, and the list goes on. The first thing to note is that the word carbon is being used to represent $CO_2$, or in some cases, $CO_2$ equivalents (combined impact of all greenhouse gases). Given our name, NEU: An ACI Center of Excellence for Carbon Neutral Concrete, I will focus on the term **carbon neutral**. Note that NEU in the name is not an acronym but is from the word **NEU**tral, as that is our goal.

In the context of the concrete industry, there are focused efforts around lowering the $CO_2$ emissions during the production of portland cement, specifically the combustion of fossil fuels when converting limestone to clinker (calcination), which is ground and mixed with gypsum to create cement. Knowing that calcination produces the majority of the carbon emissions in this process and that cement is a component in concrete, it can be hard to envision how we expect to get to carbon-neutral concrete. Let's start by defining two terms:

- **Carbon neutral** means a neutral effect of $CO_2$ on the atmosphere. Any $CO_2$ emissions released must be balanced by an equal amount of $CO_2$ being removed from the atmosphere through carbon sinks, carbon sequestration (CS), or offsets. Sinks include forests, oceans, and soil, which all absorb $CO_2$. Concrete itself also acts as a sink but does not absorb $CO_2$ fast enough or in great enough amounts to balance the emissions from its production.
- **Net-zero** carbon emissions refers to an activity that releases a net of zero $CO_2$ into the atmosphere.

These two terms are very similar, and the result for both is to balance carbon emissions. The difference is that in the net-zero case, no carbon was emitted from the activity in the first place. To get to net-zero, we must start by implementing carbon-neutral practices. Figure 1 shows a simplified example of this concept. The first two cases are carbon neutral if the left side (emissions) is balanced with the right side (CS and offsets). The third case is net-zero and doesn't need CS or offsets to be carbon neutral. The more we can reduce from the emissions side, the less we need in CS and offsets. A net-zero contribution to carbon emissions is not likely to be feasible worldwide for concrete in the near term. However, the science behind net-zero concrete and associated pilot projects is on the horizon.

It's important to understand that carbon-neutral concrete and carbon-neutral cement are different levels of scope. In the case of carbon-neutral cement, carbon reductions would need to offset the emissions from cement production. The cement industry has reduced its carbon footprint through the reduction of the use of fossil fuels, modernizing plants, and many other changes. These reductions have been critical in reducing the embodied carbon of the end product—concrete. In the future, we will have a scalable solution

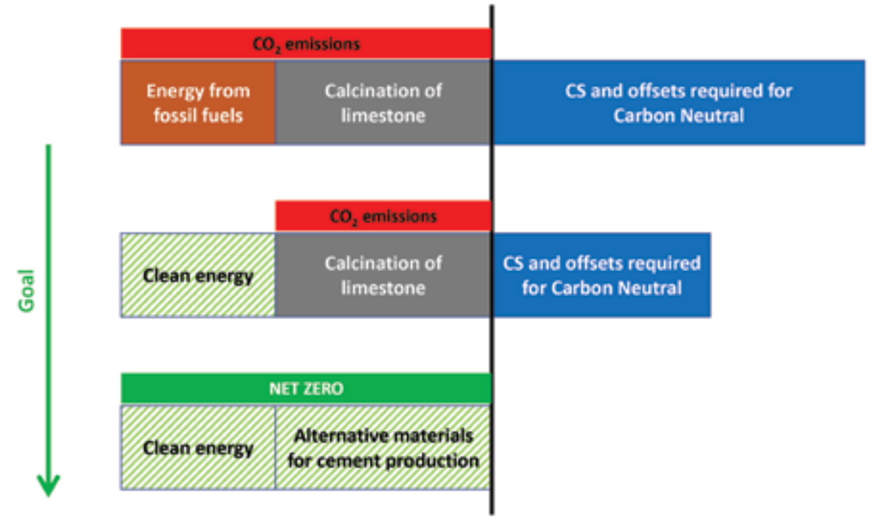


**Fig. 1: Balance for carbon neutrality of cement**

**The Leopoldo 1201 residential building in the city of São Paulo, Brazil, was a first-place award winner in the High-Rise Buildings Category in ACI's 2021 Excellence in Concrete Construction Awards Program. The use of high-performance concrete in this project made it possible to build columns with a reduced cross section, reducing the overall consumption of materials**

for producing cement from a different base material that is net-zero. In the interim, we need to continue to act on all possible fronts while considering the larger scope of concrete and the products in which concrete is used. Any carbon reduction in cement will directly apply to concrete.

NEU's focus is on the bigger picture of carbon-neutral concrete. Cement is obviously an important part of this. However, if we don't consider all the components of concrete, we lose sight of the whole picture. Much of the current and proposed language around reducing the carbon footprint of concrete focuses on embodied carbon rather than the end product and its performance (for example, a building, pavement, or a bridge). As the most used construction material, we know that concrete cannot simply be replaced with another material at a large scale. More importantly, concrete provides a durable and resilient solution at a reasonable cost that other materials cannot match. The life cycle of carbon emissions of an end product, as evaluated through whole building (or other structure) modeling, must be at the forefront of our goals of carbon neutrality for the planet. To stop at embodied carbon emissions is to focus only on the short-term rather than the more important longer-term future. A building that has a long service life that can withstand extreme storms, flooding, fire damage, and reduce energy for heating and cooling is the path we must take for a carbon-neutral future while reducing carbon footprints.

Carbon capture, use, and storage (CCUS) will play an important part in a carbon-neutral future. NEU's goal is to support a reduction of carbon emissions from concrete as much as possible so that the amount of CCUS needed is minimized. The focus of NEU is to support efforts to reach carbon neutrality in concrete by considering all of the points in the process, from the raw materials through the life cycle of the concrete product and beyond to a potential new life. This includes all stages, including materials, construction, repair, and end-use. The result of these efforts will not only be the necessary evolutionary change needed for concrete, but also a revolutionary change in the concrete industry.

For more information about NEU, visit **www.neuconcrete.org**.

neu
An ACI Center of Excellence for Carbon Neutral Concrete

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# Africa's Tallest Building Rises in the Land of the Great Pyramids

## Egypt's Iconic Tower sets new records in North Africa

*by Deborah R. Huso*

The Great Pyramids of Giza have a new competitor in a land known for its ancient megaprojects. While the recently topped-out Iconic Tower in Egypt does not reach the heights of the world's tallest building in Dubai (the Burj Khalifa at nearly 830 m [2723 ft]), the new project is the tallest structure on the African continent and is almost 385 m (1263 ft) tall. The tower's base alone contains 8200 tonnes (9040 tons) of concrete, and it has superlatives of its own, being the largest concrete raft foundation in Africa.

Designed as part of Egypt's New Administrative Capital, the landmark tower is a centerpiece in a $58 billion project proposed to fully relocate the North African nation's capital (and some five million people) to a desert location 35 km (516 miles) east of Cairo. Designed to pay homage to the Luxor Obelisk, Egypt's first high-rise tower is scheduled for full completion in 2023.

### Placing a Foundation of Massive Proportions

While work on the tower began in the spring of 2018, the construction of its foundation, which had to support the building's reinforced concrete core and surrounding composite steel framing system, didn't begin until February 2019.

Laid directly on a layer of basalt rock, the 3710 $m^2$ (12,170 $ft^2$) roughly oval raft is composed of an innovative and sustainable cement solution, new to the Egyptian market, with a high slag cement content designed to increase the concrete's durability and strength. Manufactured by Cairo-based Lafarge Egypt (part of the Holcim Group), ECOPlanet Prime CEM II cement allowed a reduction in $CO_2$ emissions of 60% and saved over 6800 tonnes (7495 tons) of $CO_2$ (compared to concrete made using ordinary portland cement [OPC]). Because no slag cement is locally produced in Egypt, Lafarge imported the slag cement constituent from France. According to Mostafa Ali Taalab, Contractors Segment Sales Manager for Lafarge Egypt, the company first used the sustainable cement to build tunnels in Switzerland.

Lafarge Egypt was also the exclusive supplier of concrete for the tower's raft foundation. To ensure the timely provision of concrete to the project, Lafarge established concrete batching plants nearby and at the jobsite.

With a thickness of 5 m (16 ft) and over 18,000 $m^3$ (59,055 $ft^3$) of placed concrete, the project's raft foundation contains 21,000 shear studs and over 4 million kg (4410 tons) of steel reinforcement, resulting in a reinforcement density of 250 $kg/m^3$ (420 $lb/yd^3$). The vast raft foundation will ensure uniform distribution of weight and stress on the soil and minimize the impacts of differential settlement on the tower's superstructure. The tower's core places the center of lateral stiffness close to the center of mass to minimize torsional stress from wind and seismic activity. It took workers more than 2 months to set the formwork and complete the steel reinforcement placement prior to concrete placement.

Beirut, Lebanon-based Dar Group, the architectural and structural engineering firm that led the work, also evaluated the heat of hydration of the concrete and established a means of cooling the concrete. To ensure the concrete remained cool while casting the raft foundation as a single unit, Dar Group and Lafarge tested their design solution using a 5 x 5 x 5 m (16 x 16 x 16 ft) mockup of the tower base. The test verified that the CEM II cement would minimize the heat of hydration. Other types of cement would not have been suitable for the raft foundation construction given the need for low heat of hydration, according to Tang Lin with Beijing-based China State Construction Engineering Corporation (CSCEC), the builder of the Iconic Tower.

Silica fume and special admixtures were used to create a flowable concrete with a setting time of 11 hours and a cube strength of 45 MPa (6530 psi). According to Taalab, Lafarge

**View of the Iconic Tower construction** *(photo courtesy of Alamy)*

delivered some 8000 tonnes (8820 tons) of cement to the jobsite in under 36 hours in preparation for placing the raft. The raft was cast without any construction joints, which required uninterrupted concrete placement using mobile pumps and transit mixers over the course of 36 hours, at a rate of 485 $m^3$/hour (634 $yd^3$/hour), making it the longest continuous concrete placement in North African history. Batch plants used crushed ice to help keep the concrete below an allowable temperature limit of 25°C (77°F) for the delivered concrete.

Curing and casting took place simultaneously. Once concrete reached the surface, workers began curing with polyethylene sheets immediately followed by the application of a fiber quilt for temperature insulation. Throughout the process, strategically placed temperature sensors monitored the temperature of the concrete to ensure it would not exceed the maximum allowable temperature of 70°C (158°F). Remarkably, the highest temperature recorded during the placing and curing operations was 68°C (154°F).

According to Dar Group, the 28-day compressive strength of the concrete was 45 MPa.

## Building the Structure

The structure of the tower is made up of a reinforced concrete core surrounded by a structural steel frame with composite steel tube perimeter columns, according to Lin. Two outriggers couple the building's central core to the perimeter columns. According to a recent paper, "Structural Design of Iconic Tower, Egypt: Culmination of a Concrete Optimization Process,"[1] whose lead author was Tarek Hassan, Principal at Dar Group, the maximum height-to-width (aspect) ratio for towers included in a study he conducted of 76 high-rise concrete towers was 10:1. In the case of the Iconic Tower, the average aspect ratio is 7.7:1. However, the aspect ratio of the tower height to core width at its base is 12:1. Given that this ratio exceeds an aspect ratio of 6:1, engineers had to include outriggers to resist lateral loads and control drift.

The Iconic Tower's width tapers as the building rises. This helps reduce wind tributary area on the higher floors and provides a stiffer outrigger system due to decreased arm lengths at the upper floors. "The central concrete core and composite peripheral columns are configured to respond to the architectural form of the building, while addressing the stringent design requirements," Hassan writes.

According to Hassan and co-authors Yehia El-Ezaby, Head of the Structural Engineering Department at Dar Group, and Charles Malek, Director of Structural Engineering, Bridges, and Special Structures, the maximum thickness of the walls in the core is 800 mm (30 in.).

**The Iconic Tower's massive foundation under construction** *(photo courtesy of Alamy)*

**Rendering of the completed Iconic Tower in Egypt's New Administrative Capital** *(rendering courtesy of Lafarge Egypt)*

The concrete cube compressive strength of the tower's vertical elements ranges from 80 to 60 MPa (11,600 to 8700 psi). The Iconic Tower's construction was the first use of 80 MPa concrete in Egypt.

According to Hassan, composite slabs outside the tower's central core and cast-in-place concrete slabs within the core carry the structure's gravity loads, while the floor system serves to integrate exterior composite columns with the central core, thus establishing the building's structural system.

The tower resists lateral loads, like wind and seismic shifts, through the frame action of the composite columns and structural steel beams, central reinforced concrete core, and outriggers placed at two different levels in the building. The outriggers, placed at floors 49 and 73, reduce dependence on the central core for structural stability while also maximizing living and working space between the core and exterior columns.

The first step after completion of the raft foundation was assembling the steel structure of the tower, then placing concrete for the composite columns from the bottom up. The biggest challenge in placing concrete for the tower was, unsurprisingly, height—getting the tubes for placing up to the level needed. According to Lin, the concrete composition for the tower itself included OPC.

CSCEC required construction of the tower's central core and concrete slabs first. This was accomplished through a self-climbing wall form system.

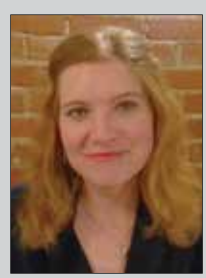
The tower was constructed in seven-floor intervals. Lin said it was possible to place three floors of the building at a time. Construction of the exterior composite columns, floor beams, and steel on metal deck slabs followed construction of the central core at a maximum height of 30 levels at a time. While the exterior components were under construction, the central concrete core was allowed to creep and deflect freely.

The concrete portion of the Iconic Tower's construction was completed in the summer of 2021. The tower is projected to be fully complete and ready for occupancy in 2023.

## References


1. Hassan, T.; El-Ezaby, Y.; and Malek, C., "Structural Design of Iconic Tower, Egypt: Culmination of a Concrete Optimization Process," *CTBUH Journal*, No. II, 2022, pp. 20-27, https://global.ctbuh.org/resources/papers/download/4583-structural-design-of-iconic-tower-egypt-culmination-of-a-concrete-optimization-process.pdf.


Selected for reader interest by the editors.



**Deborah R. Huso** is Creative Director and Founding Partner of WWM, Charlottesville, VA, USA. She has written for a variety of trade and consumer publications, such as *Precast Solutions*, *U.S. News & World Report*, *Concrete Construction*, and *Construction Business Owner*. She has provided website development and content strategy for several Fortune 500 companies, including Norfolk Southern and GE.

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# UNIVERSITY

## دوره های آموزش ترکیبی دانش تئوری و یاددهی-یادگیری فعال مهارت های تکنیکی بتن انجمن علمی بین المللی بتن آمریکا (ACI) – شاخه ایران

دوره های آموزش ترکیبی دانش تئوری و یاددهی-یادگیری فعال مهارت های تکنیکی انجمنACI، در نوزده سطح، و بر اساس استانداردهای بین المللی موسسه آزمایشات استاندارد مواد و مصالح آمریکا (ASTM)، انجمن حمل و نقل و بزرگراه های ایالتی آمریکا (AASHTO) و انجمن بتن آماده آمریکا (NRMCA) تعریف و طراحی شده است که با توجه به کارایی و اثر بخشی آن در جهت کمک به ارتقای سطح دانش نظری و مهارت های تکنیکی و اشاعه فرهنگ رفتاری و کاربردی مهندسان، مشاوران، پیمانکاران، دانشجویان و فن ورزان کشور با اعطای **گواهینامه آموزش عالی آزاد مورد تایید وزارت علوم، تحقیقات و فناوری و گواهینامه مورد تایید سازمان ملی استاندارد ایران** توسط مرکز تحقیقات بتن (متب) به عنوان تنها مجری برنامه های فنی مهندسی، آموزشی و پژوهشی انجمن بتن آمریکا (ACI) - شاخه ایران و انجمن تولید کنندگان بتن آماده آمریکا (NRMCA) برگزار می شود.


**ارائه گواهینامه معتبر بین المللی ۵ ساله پس از قبولی در آزمون**

**ارائه گواهینامه مرکز تحقیقات بتن (متب) گواهینامه آموزش عالی آزاد وزارت علوم**

**ارائه گواهینامه معتبر مورد تایید سازمان ملی استاندارد ایران**

## CONCRETE FIELD TESTING

### Concrete Field Testing Technician - Grade I

دوره تکنیکی مهارت های بتن کارگاهی - پایه ۱


**Definition:**

A Concrete Field Testing Technician—Grade I is an individual who has demonstrated the knowledge and ability to properly perform and record the results of seven basic field tests on freshly mixed concrete.

**Scope and Knowledge:**

The program requires a working knowledge of the following ASTM test methods and practices:

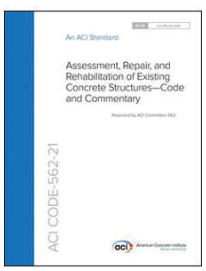
- **C1064/C1064M** —Temperature of Freshly Mixed Hydraulic-Cement Concrete
- **C172/C172M** —Sampling Freshly Mixed Concrete
- **C143/C143M** —Slump of Hydraulic-Cement Concrete
- **C138/C138M** —Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- **C231/C231M** —Air Content of Freshly Mixed Concrete by the Pressure Method
- **C173/C173M** —Air Content of Freshly Mixed Concrete by the Volumetric Method
- **C31/C31M** —Making and Curing Concrete Test Specimens in the Field

Prerequisite Course

## CONCRETE REPAIR

### Concrete Surface Repair Technician

دوره فن ورز (Technician) تعمیرات و ترمیم سطح بتن




**Definition**

The Certification course, Concrete Surface Repair Technician-Grade 1, is for individuals who want to become a qualified inspector of concrete repair as outlined in ACI 562-19. This program qualifies the individual to perform pre- and post-placement inspections and testing, and includes the in person Education course training modules and graded exams, an online knowl-. exam, and a performance exam.This education course provides fundamental knowledge and best practices in concrete. surface repair

**Scope and Knowledge**

- Deterioration of Reinforced Concrete
- Quality Requirements
- Repair Methods and Materials
- Pre-placement Inspection
- Post-placement Inspection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