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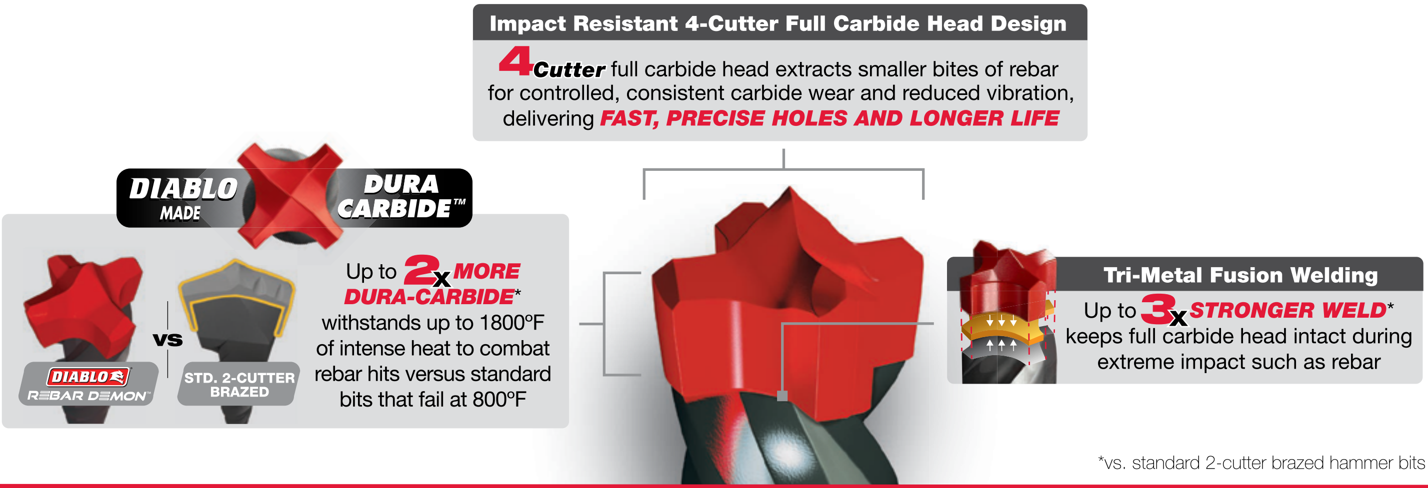

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مرکز تحقیقات بتن (متب)

تحصیلات تکمیلی مهندسی عمران

با مجوز ۵۱۱۶-۲۲

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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

مرجع صلاحیت دار تایید ثبت نوآوری ها و اختراعات از سازمان ثبت اسناد و املاک کشور

بهترین در آزمایش، برترین در کیفیت

Concrete Research & Education Center of Iran

President's

Memo

Expediting Technology Acceptance

Charles K. Nmai
ACI President

I'm truly honored and blessed to be the next ACI President—and for history buffs, the 99th and the first from the continent of Africa and, specifically, Ghana. I sincerely appreciate the trust that has been placed in me by the membership, and I humbly pledge to continue and build upon the excellent leadership provided by my immediate predecessors, Past Presidents Cary Kopczynski and Jeff Coleman, the "COVID-19-era Presidents." With the rapidly diminishing number of new cases, hopefully, I'll be the last in this era.

I studied civil engineering at the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana, and came to the United States in 1981 for my MS and PhD degrees, also in civil engineering, from the University of Kansas, Lawrence, KS, USA, and Purdue University, West Lafayette, IN, USA, respectively. My ACI journey started in September 1983 when I attended the Fall ACI Concrete Convention in Kansas City, MO, USA, my first, courtesy of Past President David Darwin, to whom I owe a debt of gratitude for giving me the opportunity to study in the United States on a National Science Foundation (NSF) grant. I joined Master Builders Solutions, then Master Builders, Inc., as a research engineer in early 1987 after receiving my PhD, and became an ACI member shortly thereafter.

I've been with the Admixtures division of Master Builders Solutions for over 30 years, and one of my current responsibilities is providing technical leadership and strategic guidance in the marketing of admixtures and high-performance concrete technologies. As a result, I'm actively involved in technology transfer activities for innovative products and concrete technologies offered by the company.

As exciting as it is to present new technologies to the industry through various events, including ACI convention technical sessions, local ACI chapter meetings, lunch-and-learns for design professionals, and whole-day seminars and conferences, I've also experienced firsthand the challenges of trying to expedite the acceptance of new technologies in the concrete industry. For example, new chemical admixtures that fall outside the established classifications of water reducers, retarders, accelerators, and air entrainers become a "concept sell." The construction industry is conservative and slow to adopt new technologies, sometimes for good reason. Is the new technology proven, and has it been properly evaluated not only by the manufacturer but by independent accredited third-party laboratories? Anyone who's been in the industry long enough can probably attest to technologies that didn't live up to claims made by their manufacturers! These experiences shouldn't disadvantage innovative technologies that truly provide benefit in concrete construction, however, and it shouldn't take decades before such technologies gain widespread acceptance and use.

ACI is respected globally for its documents because they are developed through a consensus process. Traditionally, apart from ACI 318, which must meet International Code Council (ICC) code development cycle deadlines, and committees with dynamic leadership and enthusiastic volunteers, this process has not lent itself to the timely development of documents. This relatively slow process is not unique to ACI; it also exists within other organizations that develop consensus-based documents. With the growing focus on reducing the carbon footprint of all human activities, however, we have entered an era where owners and design professionals are urgently seeking such solutions for their concrete projects.

Because many potential solutions are either not yet written in the documents or fully proven, expediting the acceptance and use of <u>qualified</u> new technologies for the built environment is one of the primary objectives of my presidency. Note that I've placed a strong emphasis on "qualified," and although I've alluded to new "products" and "technologies," those terms can also refer to things such as analysis techniques, design procedures, or construction methods. This objective dovetails very nicely with recent initiatives undertaken by the Institute—the reorganization of the ACI Foundation Strategic Development Council (SDC) into the new Concrete Innovation Council (CIC); the appointment of Rex Donahey, a fellow Kansas grad, as the Director of Innovative Concrete Technology; and the two ACI Centers of Excellence for Nonmetallic Building Materials (NEx) and Carbon Neutral Concrete (NEU).

Through a collaborative effort, ACI will build upon its leadership as the premier source for concrete knowledge by taking the lead to facilitate the use of qualified technologies, existing or emerging, for the concrete industry. ACI is embarking on a bold new direction, and I'm truly honored to be President of the Institute at this juncture. Stay tuned!

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

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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

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:

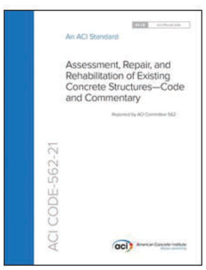
- **C1064/C1064M** —Temperature of Freshly Mixed Hydraulic-Cement Concrete
- **C172/C172M** —Sampling Freshly Mixed Concrete
- **C143/C143M** —Slump of Hydraulic-Cement Concrete
- **C138/C138M** —Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- **C231/C231M** —Air Content of 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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American Concrete Institute
Iran Chapter

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.

ارائـه گواهینامه معتبر بیـن المللی
۵ سـاله پس از قبولی در آزمون

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

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FRP Reinforced Concrete Around the World, Part 1

Initiatives for acceptance and safe implementation: Brazil, Iran, Italy, and New Zealand

This two-part article provides a snapshot of activities taking place around the world intended to make the technology of fiber-reinforced polymer (FRP) reinforcement for concrete structures available to the construction industry. The series is sponsored by NEx: An ACI Center of Excellence for Nonmetallic Building Materials (**www.nonmetallic.org**) and was coordinated by Antonio Nanni, University of Miami, Coral Gables, FL, USA. The authors represent the countries covered in each article. For Part 1, they include:

- **Brazil:** Daniel C.T. Cardoso, Nádia C.S. Forti, Roberto Christ, and Marco A. Carnio;
- **Iran:** Erfan Najaf and Amirhossein Mohammadi;
- **Italy:** Luigi Ascione; and
- **New Zealand:** Pete Renshaw.

Brazil

A single Brazilian producer has supplied FRP reinforcing bars over much of the last two decades, with main applications related to soft-eyes in tunnel construction. More recently, however, interest in FRP reinforcement has grown as the manufacturing costs for FRP products have been reduced, making FRP products competitive relative to conventional steel. Consequently, more producers have started operations in the country and have contributed to identifying and opening new market opportunities. Recent applications have included pavements, slabs-on-ground, bridges, and housing structures. The research volume has also increased significantly in recent years, and many universities and institutes are currently engaged in studies related to the topic, supported mainly by governmental funding agencies.

In 2015, the Brazilian Concrete Institute (IBRACON) and the Structural Engineering Brazilian Association (ABECE) set up Technical Committee 303 (CT-303), intended to promote and to integrate the stakeholders involved with the use of nonconventional reinforcement for concrete. CT-303 was divided into five working groups (WGs) to develop recommended practices with guidelines for characterization, quality assurance, and structural design related to fiber-reinforced concrete (FRC); ultra-high-performance concrete; and the use of FRP for internal and external reinforcement of concrete structures. Other global objectives of the committee were assisting the Brazilian Association of Technical Standards (ABNT) with the development of Brazilian standards. These standards have spread knowledge about different materials and helped to keep structural engineers updated technically. It is also worth mentioning that public works and governmental funding for civil construction in Brazil usually refer to a national database for materials and services, which presently does not include FRP bars. The release of national technical documentation will also facilitate the inclusion of the material in the database and its consequent widespread adoption.

WG-3 was responsible for internal reinforcement of concrete structures with FRP bars and has recently concluded the elaboration of a recommended practice—hereafter called "Practice"—that is about to be released by IBRACON.[1] The document is divided into two parts: Structural Design of FRP Reinforced Concrete; and Specification, Classification, and Characterization of FRP Bars. Both parts accounted for recent advances reported in the literature and results obtained by Brazilian researchers, as well as procedures and guidelines included in codes and technical reports from other countries (CNR-DT 203/2006[2]; CAN/CSA S806-12[3]; ACI 440.1R-15[4]; and ASTM D7957/D7957M-17[5]). For ease of acceptance by the industry, the document structure and many equations and recommendations followed the current national standard for the Design and Construction of Reinforced and Prestressed Concrete Structures (NBR 6118:2014).[6] This strategy will also allow the Practice to be incorporated into NBR 6118 in the future, leading to a single code related to the design of concrete structures.

The Practice considers solid round bars produced with a thermoset polymer matrix and reinforcement made with glass, basalt, carbon, or aramid fibers (GFRP, BFRP, CFRP, and AFRP, respectively), with a minimum of 75 wt%. Different surface configurations are allowed for primary structural applications—except smooth round—and the minimum characteristic properties (5% quantile) to be met by the bars are presented in Table 1. Higher values can be considered for design if correctly verified by standardized tests. These are defined in the document and generally follow international recommendations, with some modifications to allow the tests to be carried out using the equipment usually available

Table 1:
Minimum required properties for the FRP bars

Property	GFRP	BFRP	CFRP	AFRP
Tensile strength, MPa*	800		1400	
Compressive strength, MPa	300			
Shear strength, MPa	150		350	190
Modulus of elasticity, GPa	50		130	70
Bond strength, MPa*	12			
Glass transition temperature, T_g, °C	100			

*Maximum strength loss of 25% and 10%, respectively, for tensile and bond strength after accelerated aging test in alkaline media

Note: 1 MPa = 145 psi; 1 GPa = 145 ksi; °F = 1.8 × °C + 32

countrywide. The document also provides guidance to define the bar nominal diameter (in mm) based on the measured cross-sectional area.

With respect to field acceptance, the Practice specifies that at least 10% of the material volume produced for each batch (less than 10 tonnes [11 tons]) must be visually inspected for imperfections and flaws. Each batch must also have main characteristic properties determined for a minimum of five samples, which shall meet the minimum properties listed in Table 1. Recommendations for identification, transportation, and storage are also provided.

In addition to the type of bars previously mentioned, the scope of the structural design includes:

- Nonprestressed reinforcement ("passive");
- Structural concrete grades with strength ranging from 20 to 90 MPa (2900 to 13,000 psi);
- Use of FRC for crack control or the improvement of ductility through concrete confinement;
- Combination of nonmetallic and steel bars for ductility or other specific loading requirements; and
- Temperatures up to 60°C (140°F).

The Practice describes the mechanisms of degradation of FRP and presents specific requirements for the selection of minimum concrete grade and concrete cover based on the environmental conditions. However, due to the superior corrosion resistance of FRP, lower values for these parameters can also be adopted if verified by accelerated aging tests. WG-3 recognizes that the acceptance of the material by the community depends on the dissemination of the concept that FRP is not meant to be a direct substitute for conventional steel in terms of mechanical properties but when durability and maintenance criteria are dominant.

Another relevant issue discussed in the document is related to the structural analysis of FRP reinforced concrete (RC) structures. Due to the lack of ductility of the material, elastoplastic or elastic models with redistribution structural analyses cannot be used. Moreover, the importance of considering the appropriate distribution of cracked stiffness in the elastic analysis is highlighted for a more accurate distribution of internal forces along member length—load model error increases if gross cross-sectional properties are adopted. Acknowledging that ductility may be a design requirement of major concern, the Practice presents some well-known strategies for ductility, such as the use of metallic bars (noncorrosive or coated) or confinement of concrete in compression zones with dispersed short fibers or stirrups—the latter is valid in the case of beams with compression-dominated failure.

Finally, guidelines are provided for structural verification of both ultimate limit state (ULS) and serviceability limit state (SLS). For ULS, the document includes provisions for bending, combined bending and axial force, and shear and torsion. The use of bars in compression is allowed if appropriate restraint against bar buckling is ensured. To meet the current format of NBR 6118 (which resembles European standards), the partial factors for loading and for the concrete strength remained unchanged, while a single factor associated with the strength of FRP bars was obtained for a target reliability index of 3.5. For beam design in bending, the partial factors are applied directly over the material properties, regardless of the reinforcement ratio adopted with respect to the balanced ratio—this strategy is supported by the work of He and Qiu.[7] Recommendations with respect to construction details, minimum reinforcement ratios, and design of regions with discontinuities are also presented in the document.

The release of the Practice will contribute to disseminating the knowledge, facilitating the acceptance of FRP by civil engineers, and raising relevant discussions on the topic. WG-3 is aware that the work must continue, such as the discussion of behavior under fire.

Iran

In Iran, application of FRP materials for strengthening purposes has drastically increased, and most of the community, including engineers, contractors, and owners, are familiar with the features of these materials. However, nonconventional bars made with FRP obtained their popularity only in recent years. FRP bars are currently being used in limited projects such as tunneling, foundations, and floors built in aggressive environments, offshore structures, and construction projects sensitive to electromagnetic waves such as magnetic resonance imaging (MRI) centers. The declining price of FRP bars on Iran's market has helped accelerate the application of this reinforcement. There are at least three active local manufacturers producing sand-coated and ribbed FRP bars that were tested and qualified using international guidelines such as ACI 440.3R-12[8] and ISO 10406-1.[9]

It should be noted that Iran has 2815 km (1750 miles) of coastline and 21 inhabited coastal islands with highly aggressive environments. Oil industries located in these regions require construction with low maintenance costs and high longevity, which promises increasing demand for FRP bars within the country.

Community awareness for using FRP bars in RC structures is progressing and the real potential of this material in the construction industry has not been mobilized yet. The Iranian national code for RC structures (MMS9:2016[10]) allows restricted use of FRP bars; however, it fails to suggest the minimum required information for the design. To this end, practitioners in Iran are using international codes and guidelines, such as ACI 440.1R and *fib* bulletin 40,[11] technical reports, and other publications as a complement to their national code.

Italy

In Italy, attention to FRP reinforcement has been manifested for some time and the scientific and technical communities in the country helped to draft a technical document on the topic, CNR-DT 203/2006, published in 2007 by the National Research Council (CNR in Italian). However, the Technical Standards for Construction issued by the Ministry of Infrastructure and Transportation (MIT) have so far not allowed unrestricted use. The use is subject to approval by the Superior Council of Public Works on a case-by-case basis. In 2018, MIT set up working groups for the drafting of two guidelines: one on the identification, qualification, and acceptance of FRP bars (QGL) and another on the design of concrete structures reinforced with such bars (DGL).

The working groups have released two draft guidelines, which are currently being reviewed by a rapporteur commission and discussed by the Assembly of the Superior Council of Public Works before approval, with amendments, and subsequent publication. The contents of the two guidelines are summarized in Reference 12.

The purpose of the QGL is to provide the procedures for the identification, qualification, and acceptance of straight bars, bent bars, or bars with terminal anchorage. These products are produced with thermosetting resins and have at least a 50% volumetric fraction of continuous basalt, carbon, or glass fibers.

The production process is typically pultrusion, although the guideline does not exclude different production processes that can be proposed by the manufacturers. The definition of the production process includes the type of surface quality of the bar, provided by the individual manufacturer to improve its bond.

The cross sections of the longitudinal bars and stirrups can be circular or rectangular in shape. The nominal diameter of the circular sections shall vary from 5 to 32 mm (0.2 to 1.3 in.), including the two extreme values. The width of the rectangular cross sections, coinciding with the maximum size of the section, should not be larger than 40 mm (1.6 in.).

The manufacturers must provide:

- The production process in the plant, in terms of organization and quality control, ensured by appropriate production control tests (FPC, Factory Production Control); and
- The physical-morphological and mechanical characteristics of the bars, determined through suitable type tests (TT, Type Testing).

In-place acceptance checks on the bars:

- Are mandatory and the responsibility of the construction manager; and
- Must be carried out within each batch and must cover all types of products supplied.

The sampling must be done by the construction manager or a delegate who must ensure, by means of appropriate acronyms and indelible labels, the traceability of the samples regarding the supply and location, and intended use on site.

FRP bars that can be used for the purposes of the DGL must meet the requirements in the QGL on identification, qualification, and acceptance and must also have:

- A characteristic value of the tensile strength of not less than 400 MPa (58,000 psi); and
- An average value of the tensile modulus in the longitudinal direction of not less than 100 GPa (14,500 ksi) for bars with carbon fibers and 35 GPa (5000 ksi) for those with glass or basalt fibers.

The design of RC structures with passive FRP bars must meet strength and operation requirements.

Special attention is required in structural analysis because the almost total absence of ductility of RC structures with FRP bars must be taken into due consideration. In particular, elastoplastic or elastic models with redistribution structural analyses cannot be adopted.

As a rule, specific fire resistance checks of the structural elements must be carried out, in accordance with current fire regulations. They shall take into account the value of the glass transition temperature, T_g.

Some structural types, such as bridge slabs and more generally those that do not bound closed volumes within which a fire can flare up, are affected to a limited extent by fire resistance problems and do not require specific checks.

The DGL provides design rules for bending stresses (both for ULS and SLS), axial and bending, punching, shear, and torsion. Construction details and minimum reinforcement ratios are also provided.

New Zealand

There has been limited use of GFRP reinforcing bars within New Zealand to date. The use of GFRP bars for temporary structures such as soft-eyes in tunnel construction is a normal practice, although it should be noted that the number of tunnels constructed in New Zealand is relatively low due to the small size and population of the country. However, the GFRP reinforcement has had very limited use in permanent structures.

There is no New Zealand standard or design code permitting the use of GFRP bars, nor is there a New Zealand specification for GFRP bars. This has likely been a limiting factor in adoption. The jobs that have used GFRP


Fig. 1: Precast FRP-RC retaining walls at Kaikoura, New Zealand

reinforcement have generally been designed based on ACI 440.1R-15. However, without the support of a national code, engineers are naturally reluctant to select GFRP as a reinforcement solution. It is predicted that New Zealand engineers who wish to make use of GFRP bars will continue to rely on ACI guides and codes for the design of GFRP RC structures for the foreseeable future.

University research projects

Canterbury University and the University of Auckland both have strong structural engineering departments with an interest in GFRP reinforcing bars and have undertaken research projects at both masters and PhD levels. With New Zealand's location on the Pacific rim and with earthquakes being a regular occurrence in the country, the universities also have significant experience in research related to seismic engineering design. It is anticipated that both universities will continue to support research projects for GFRP reinforcing bars, with a focus on seismic applications.

Recent project examples

For both, the Auckland Central Interceptor Tunnel and Auckland Central Rail Link Tunnel projects, GFRP reinforcing bars were selected for the soft-eye construction to allow a tunnel boring machine (TBM) to cut through the concrete wall without damage to the machine from cutting steel reinforcement.

Various recent electrical substations have been constructed using GFRP reinforcement in the ground slabs supporting electrical equipment with high electrical fields, thus taking advantage of the nonconductive and nonelectromagnetic properties of GFRP.

The Kaikoura State Highway and Rail Line had to be repaired after an earthquake of magnitude 7.8 struck the South Island of New Zealand, close to the town of Kaikoura in 2016. This caused major damage to the main North-South state highway and railway line. The highway and railway are in the coastal area. The reconstruction of these assets was the largest infrastructure repair project in the history of New Zealand (Fig. 1). Due to the coastal location and associated risk of corrosion, GFRP bars were selected to reinforce all precast retaining wall sections of the rebuild.

Many historic buildings damaged by earthquakes have been reinforced using GFRP bars. Also, historic buildings identified to be at risk of damage in future earthquakes have been reinforced with either GFRP bars or a combination of GFRP and steel reinforcement. A historic wharf built in the 1940s is also under repair, using GFRP reinforcing bars to eliminate corrosion in the intertidal zone.

References

1. Cardoso, D.C.T.; Carnio, M.A.; Forti, N.C.S.; and Christ, R., "Recommended Practice IBRACON: Fiber-Reinforced Polymer (FRP) Reinforced Concrete Structures," first edition, IBRACON, São Paulo, Brazil, 2021. (in production)

2. "Guide for the Design and Construction of Concrete Structures Reinforced with Fiber-Reinforced Polymer Bars," CNR-DT 203/2006, CNR (National Research Council), Rome, Italy, 2007, 35 pp.

3. CAN/CSA S806-12, "Design and Construction of Building Structures with Fibre-Reinforced Polymers," CSA Group, Toronto, ON, Canada, 2012, 198 pp.

4. ACI Committee 440, "Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer (FRP) Bars (ACI 440.1R-15)," American Concrete Institute, Farmington Hills, MI, 2015, 88 pp.

5. ASTM D7957/D7957M-17, "Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement," ASTM International, West Conshohocken, PA, 2017, 5 pp.

6. NORMA BRASILEIRA ABNT NBR 6118:2014, "Projeto de estruturas de concreto—Procedimiento (Design of Concrete Structures—Procedure)," Associação Brasileira de Normas Técnicas, Rio de Janeiro, Brazil, 2014, 256 pp. (in Portuguese)

7. He, Z., and Qiu, F., "Probabilistic Assessment on Flexural Capacity of GFRP-Reinforced Concrete Beams Designed by Guideline ACI 440.1 R-06," *Construction and Building Materials*, V. 25, No. 4, 2011, pp. 1663-1670.

8. ACI Committee 440, "Guide for Test Methods for Fiber Reinforced Polymer (FRP) Composites for Reinforcing or Strengthening Concrete and Masonry Structures (ACI 440.3R-12)," American Concrete Institute, Farmington Hills, MI, 2012, 23 pp.

9. ISO 10406-1:2008, "Fibre-Reinforced Polymer (FRP) Reinforcement of Concrete—Test Methods—Part 1: FRP Bars and Grids," International Organization for Standardization (ISO), Geneva, Switzerland, 2008, 40 pp.

10. Iranian National Building Codes Compilation Office, MMS9:2016, "Iranian National Building Code, Part 9: Reinforced Concrete Buildings Design," Ministry of Housing and Urban Development (MHDU), Tehran, Iran, 2016.

11. *fib* Bulletin No. 40: "FRP Reinforcement in RC Structures," International Federation for Structural Concrete (*fib*), Lausanne, Switzerland, 2007, 160 pp.

12. Aiello, M.A.; Ascione, L.; D'Antino, T.; Frassine, R.; Lignola, G.P.; Poggi, C.; and Prota, A., "Reinforced Concrete with FRP Bars: The Italian State of Technical Normative," *Structural*, No. 237, Sept.-Oct. 2021, www.structuralweb.it/cms/it4-magazine.asp?pag=articoli.asp&idCopertina=105.

Selected for reader interest by the editors.

دوره آموزشی تکنسین (فن ورز) بتن خودمتراکم

Self-Consolidating Concrete (SCC) Testing Technician

ASTM C1610 - ASTM C1611 - ASTM C1621 - ASTM C1712 - ASTM C1758

دوره آموزشی آزمون های بتن خودمتراکم تازه اختلاط (SCC)

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