Why GFRP is Becoming Material of Choice in 2023: From Code to Field

Borna Hajimiragha
CEO
MST Rebar Inc.

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Outline

1. Cost Of Corrosion In Canada & USA
2. Example of Corrosion
3. Why GFRP
4. Recent Changes in Code & Standard
5. Benefits
6. Field Examples
7. Greener for the environment

The cost of corrosion study (IMPACT Study) Reveals $52 billion USD

Annual cost only in Canada!

USA > $0.6T

$Billions could be saved by using GFRP

Example of Steel Corrosion

Designed for 100 years

Last less than 50 years

Start to corrode after 8 years

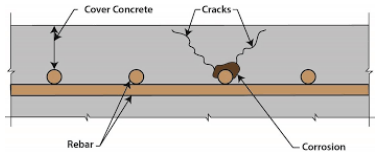
Why Steel Rebar Corrode

Built **1600 years ago** by Roman Empire (6th Century)

Without Steel Rebar

Built in **2000** in North America

With Steel Rebar



Evolution/History of Rebar

Black Bar

1920s

Galvanized & ECR

1970s

Fiberglass Rebar

1990s

Steel rebar corrodes so as StainLESS Rebar

Engineers take additional measures to mitigate corrosion of steel reinforcement in concrete: use of corrosion inhibiting admixtures, use of epoxy-coated or galvanized steel, use of sealers and membranes on the concrete surface, providing additional concrete cover, etc.

Those measures only delay the issue of corrosion and are effective to a limited extend!

Pergamon

CEMENT AND CONCRETE RESEARCH

Cement and Concrete Research 31 (2001) 713–718

Corrosion inhibitors in concrete
Part III. Effect on time to chloride-induced corrosion initiation and subsequent corrosion rates of steel in mortar

S.M. Trépanier[a,*], B.B. Hope[b], C.M. Hansson[c]

[a]Halsall Associates Limited Consulting Engineers, 2300-2300 Yonge Street, P.O. Box 2385, Toronto, Ontario, Canada M4P 1E4
[b]Civil Engineering Department, Queen's University, Kingston, Ontario, Canada
[c]Mechanical Engineering Department, University of Waterloo, Waterloo, Ontario, Canada

Received 26 April 1999; accepted 26 January 2001

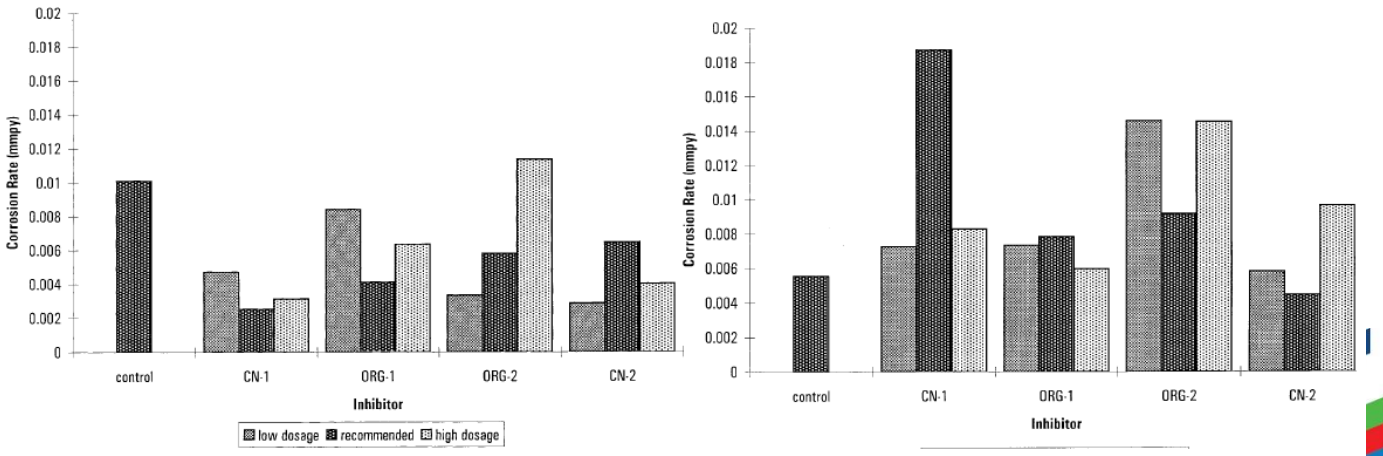


Fig. 3. (a) Nominal corrosion rates for samples with W/C 0.50. (b) Nominal corrosion rates for samples with W/C 0.70.

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Solution!
New Great Success Story Used Globally & Made In North America

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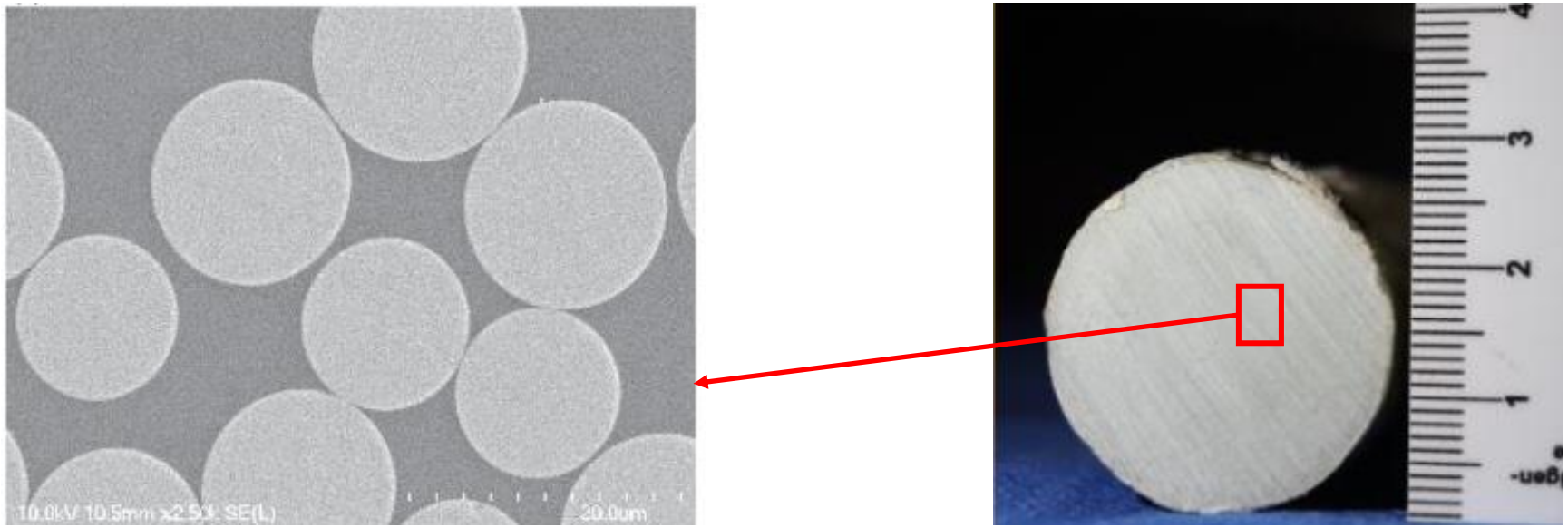
GFRP Rebar

Glass Fiber Reinforced Polymer (GFRP) Bars

Fiber: E-CR glass fiber
Resin: Vinyl ester

Process makes a HUGE difference

Interface makes a HUGE difference



Source: Benmokrane et al. (2019)

Why GFRP is Gaining Traction in last 10 years!

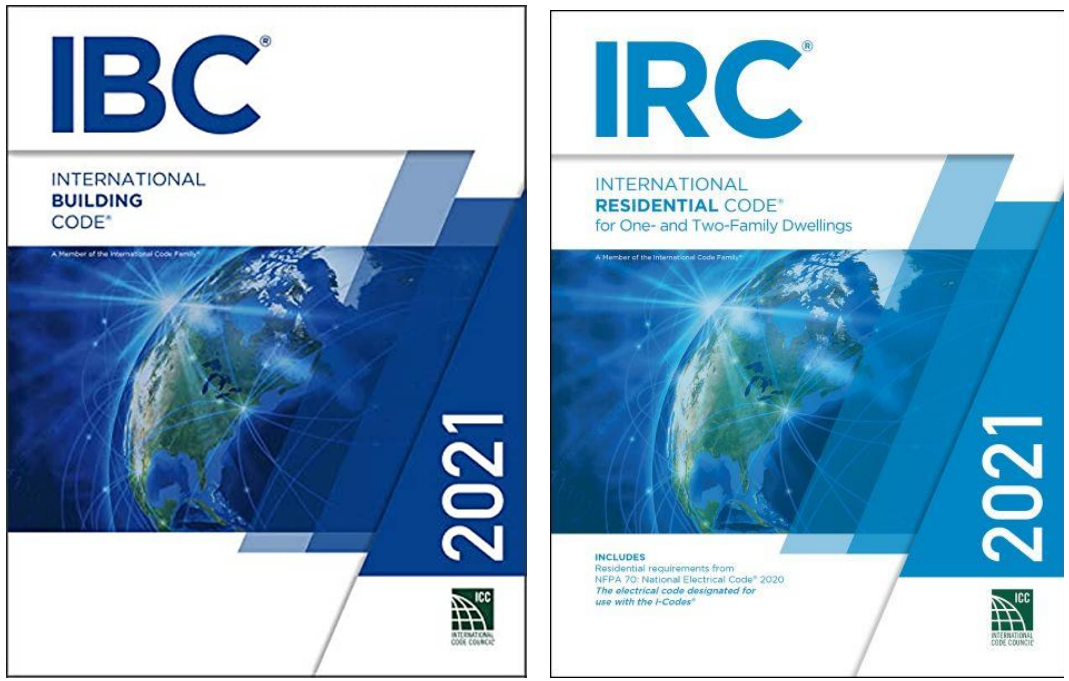
- **TRUST:** Proven history of Fiberglass Rebar since 1990
- **SLOW:** Construction Industry is slow in adaptation
- **ENGINEERING & CODE:** Finalized in the last 10 years
- **INCREASE IN PRODUCTION:** Capacity to match steel
- **Service Life:** +100 years of true service life
- **Support:** Many DOT's, Ministries, Government

Mid 1990

2020

Pic Ref
Kodiak West Virginia
https://www.fiberglassrebar.us/

Building Codes in the USA



As of today, predominant building codes in the U.S.A. are the International Building & Residential Codes, latest Edition of 2021. Neither codes in 2021 included provisions for use of FRP reinforcing bars in reinforced concrete structures.

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Building Codes in the USA

How can we **overcome** regulation **barriers** to **safely** use FRP rebars in concrete construction:

- Building code compliance in accordance with IBC Section 104.11, which allows innovative materials that are not defined in the building code to be safely used when independently evaluated in a research report.
- Building code change proposal to include FRP rebars in Chapter 19 (Concrete) of the IBC.

Building Codes in the USA

ES ICC EVALUATION SERVICE®

www.icc-es.org | (800) 423-6587 | (562) 699-0543 *A Subsidiary of the International Code Council®*

ACCEPTANCE CRITERIA FOR FIBER–REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS

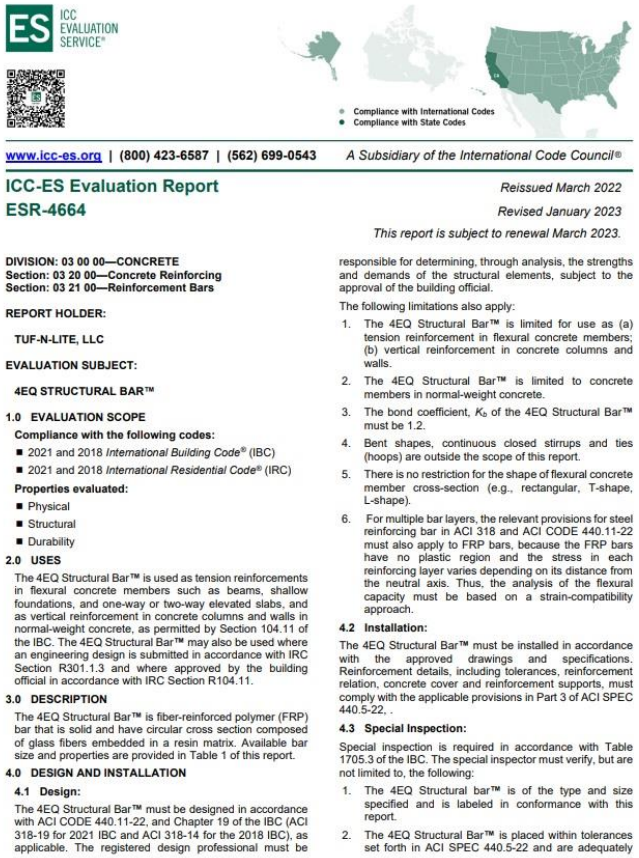
AC454

Approved October 2022

Previously approved April 2021, December 2020, June 2020, February 2017, June 2016, May 2015 and June 2014

(Previously editorially revised February 2021)

PREFACE



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ICC-ES Evaluation Report
ESR-4664

Reissued March 2022
Revised January 2023
This report is subject to renewal March 2023.

DIVISION: 03 00 00—CONCRETE
Section: 03 20 00—Concrete Reinforcing
Section: 03 21 00—Reinforcement Bars

REPORT HOLDER:

TUF-N-LITE, LLC

EVALUATION SUBJECT:

4EQ STRUCTURAL BAR™

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2021 and 2018 *International Building Code®* (IBC)
- 2021 and 2018 *International Residential Code®* (IRC)

Properties evaluated:

- Physical
- Structural
- Durability

2.0 USES

The 4EQ Structural Bar™ is used as tension reinforcements in flexural concrete members such as beams, shallow foundations, and one-way or two-way elevated slabs, and as vertical reinforcement in concrete columns and walls in normal-weight concrete, as permitted by Section 104.11 of the IBC. The 4EQ Structural Bar™ may also be used where an engineering design is submitted in accordance with IRC Section R301.1.3 and where approved by the building official in accordance with IRC Section R104.11.

3.0 DESCRIPTION

The 4EQ Structural Bar™ is fiber-reinforced polymer (FRP) bar that is solid and have circular cross section composed of glass fibers embedded in a resin matrix. Available bar size and properties are provided in Table 1 of this report.

4.0 DESIGN AND INSTALLATION

4.1 Design:

The 4EQ Structural Bar™ must be designed in accordance with ACI CODE 440.11-22, and Chapter 19 of the IBC (ACI 318-19 for 2021 IBC and ACI 318-14 for the 2018 IBC), as applicable. The registered design professional must be responsible for determining, through analysis, the strengths and demands of the structural elements, subject to the approval of the building official.

The following limitations also apply:

1. The 4EQ Structural Bar™ is limited for use as (a) tension reinforcement in flexural concrete members; (b) vertical reinforcement in concrete columns and walls.
2. The 4EQ Structural Bar™ is limited to concrete members in normal-weight concrete.
3. The bond coefficient, K_b of the 4EQ Structural Bar™ must be 1.2.
4. Bent shapes, continuous closed stirrups and ties (hoops) are outside the scope of this report.
5. There is no restriction for the shape of flexural concrete member cross-section (e.g., rectangular, T-shape, L-shape).
6. For multiple bar layers, the relevant provisions for steel reinforcing bar in ACI 318 and ACI CODE 440.11-22 must also apply to FRP bars, because the FRP bars have no plastic region and the stress in each reinforcing layer varies depending on its distance from the neutral axis. Thus, the analysis of the flexural capacity must be based on a strain-compatibility approach.

4.2 Installation:

The 4EQ Structural Bar™ must be installed in accordance with the approved drawings and specifications. Reinforcement details, including tolerances, reinforcement relation, concrete cover and reinforcement supports, must comply with the applicable provisions in Part 3 of ACI SPEC 440.5-22, .

4.3 Special Inspection:

Special inspection is required in accordance with Table 1705.3 of the IBC. The special inspector must verify, but are not limited to, the following:

1. The 4EQ Structural bar™ is of the type and size specified and is labeled in conformance with this report.
2. The 4EQ Structural Bar™ is placed within tolerances set forth in ACI SPEC 440.5-22 and are adequately

One of the code compliance options is obtaining a research report in accordance with IBC Section 104.11.

Acceptance Criteria AC454, first issued in **2014**, final revision **2022** was used for the evaluation.

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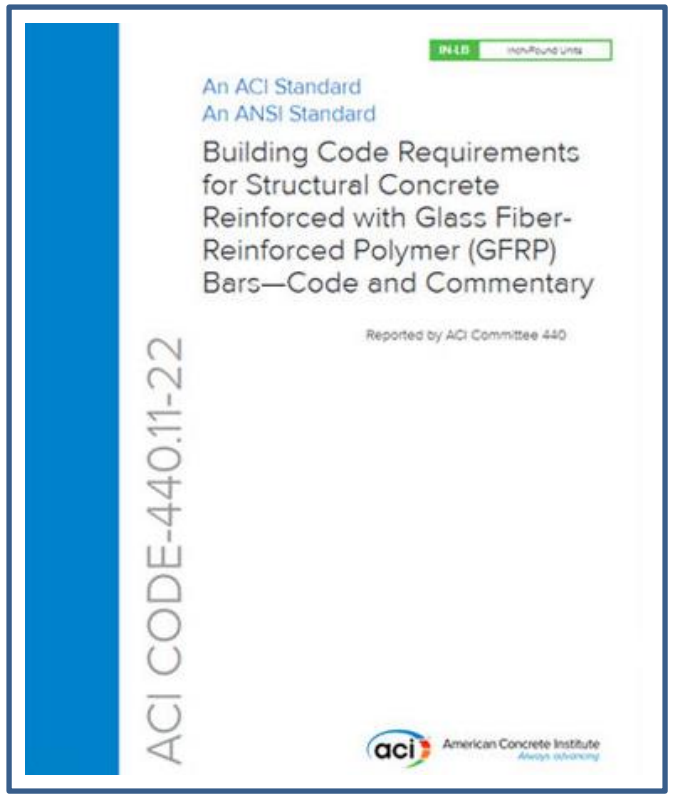
Building Codes in the USA



One of the major advances in FRP rebar industry was ACI developing first FRP rebar code book ACI Code 440.11 in September 2022; and revising FRP Spec 440.5 in 2022.

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Building Codes in the USA

S174-22

IBC: 1901.2, 1901.2.1 (New), ACI Chapter 35 (New), ASTM Chapter 35 (New)

Proposed Change as Submitted

Proponents: Stephen Szoke, representing American Concrete Institute (steve.szoke@concrete.org); Jerzy Zemajtis, representing NEx, An ACI Center of Excellence for Nonmetallic Building Materials (jerzy.zemajtis@nonmetallic.org); John Busel, representing American Composites Manufacturers Association (jbusel@acmanet.org); Scott Campbell, representing NRMCA (scampbell@nrmca.org); Doug Gremel, representing Owens Corning Infrastructure Solutions (douglas.gremel@owenscorning.com); Carl Larosche, representing ACI (clarosche@wje.com); William O'Donnell, representing DeSimone Consulting Engineers (william.odonnell@de-simone.com); Matthew D'Ambrosia, representing MJ2 Consulting (matt@mj2consulting.com); Keith Kesner, representing CVM (kkesner3006@gmail.com); antonio de luca, representing Thornton Tomasetti

2021 International Building Code

1901.2 Plain and reinforced concrete. Structural concrete shall be designed and constructed in accordance with the requirements of this chapter and ACI 318 as amended in Section 1905 of this code. Except for the provisions of Sections 1904 and 1907, the design and construction of slabs on grade shall not be governed by this chapter unless they transmit vertical *loads* or lateral forces from other parts of the structure to the soil.

Add new text as follows:

1901.2.1 Structural concrete with GFRP reinforcement. Cast-in-place structural concrete internally reinforced with glass fiber reinforced polymer (GFRP) reinforcement conforming to ASTM D7957 and designed in accordance with ACI CODE 440 shall be permitted only for structures assigned to Seismic Design Category A.

Add new standard(s) as follows:

ACI

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331-3439

CODE 440-22 — Structural Concrete Buildings Reinforced Internally with Fiber Reinforced Polymer (FRP) Bars – Code Requirements

Another major advances in FRP rebar industry was ACI submitting code change proposal for 2024 IBC to include a reference to Code 440.11-22.

2024 IBC is expected to include 440.11-22, making it a code-book-by-reference.

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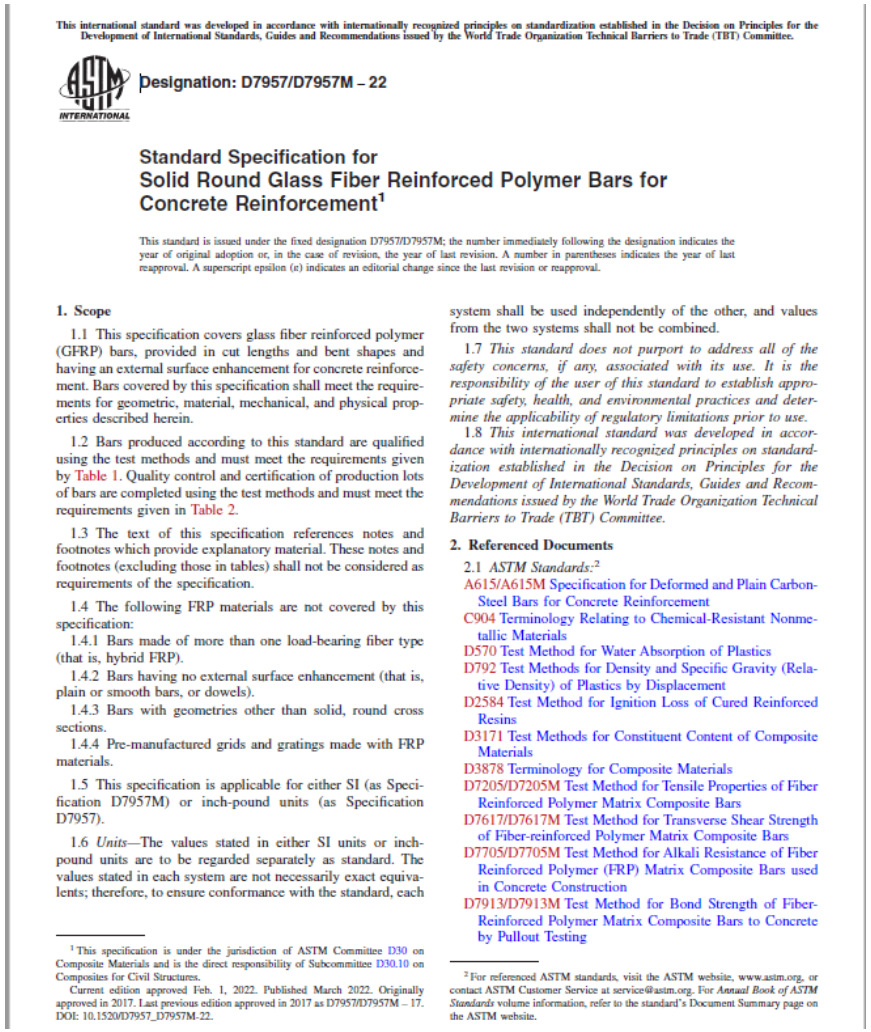
Material Specifications



This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D7957/D7957M – 22

Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D7957/D7957M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers glass fiber reinforced polymer (GFRP) bars, provided in cut lengths and bent shapes and having an external surface enhancement for concrete reinforcement. Bars covered by this specification shall meet the requirements for geometric, material, mechanical, and physical properties described herein.

1.2 Bars produced according to this standard are qualified using the test methods and must meet the requirements given by Table 1. Quality control and certification of production lots of bars are completed using the test methods and must meet the requirements given in Table 2.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables) shall not be considered as requirements of the specification.

1.4 The following FRP materials are not covered by this specification:

1.4.1 Bars made of more than one load-bearing fiber type (that is, hybrid FRP).

1.4.2 Bars having no external surface enhancement (that is, plain or smooth bars, or dowels).

1.4.3 Bars with geometries other than solid, round cross sections.

1.4.4 Pre-manufactured grids and gratings made with FRP materials.

1.5 This specification is applicable for either SI (as Specification D7957M) or inch-pound units (as Specification D7957).

1.6 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials
D570 Test Method for Water Absorption of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
D7617/D7617M Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars
D7705/D7705M Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction
D7913/D7913M Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing

[1] This specification is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.10 on Composites for Civil Structures.
Current edition approved Feb. 1, 2022. Published March 2022. Originally approved in 2017. Last previous edition approved in 2017 as D7957/D7957M – 17. DOI: 10.1520/D7957_D7957M-22.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

ACI Code 440.11-22 refers to ASTM D7957-22 for material specifications

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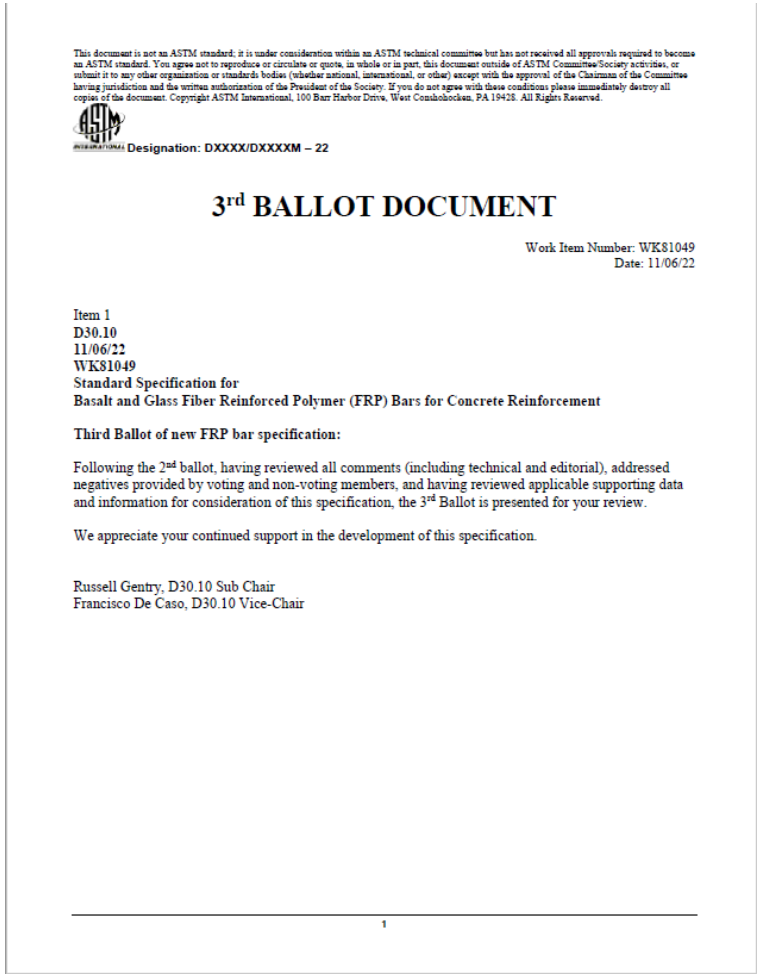
Material Specifications



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Designation: DXXXX/DXXXXM – 22

3rd BALLOT DOCUMENT

Work Item Number: WK81049
Date: 11/06/22

Item 1
D30.10
11/06/22
WK81049
Standard Specification for
Basalt and Glass Fiber Reinforced Polymer (FRP) Bars for Concrete Reinforcement

Third Ballot of new FRP bar specification:

Following the 2nd ballot, having reviewed all comments (including technical and editorial), addressed negatives provided by voting and non-voting members, and having reviewed applicable supporting data and information for consideration of this specification, the 3rd Ballot is presented for your review.

We appreciate your continued support in the development of this specification.

Russell Gentry, D30.10 Sub Chair
Francisco De Caso, D30.10 Vice-Chair

1

ASTM subcommittee D30.10 is working on approving a standard for material specifications of the new generation of GFRP bars

High Mod Bars ONLY : 60GPa

Higher Tensile and Shear properties

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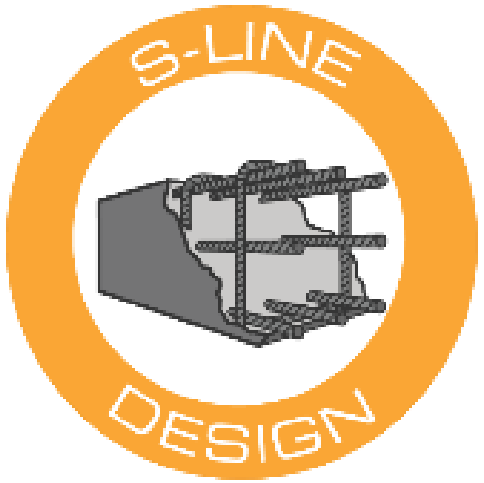
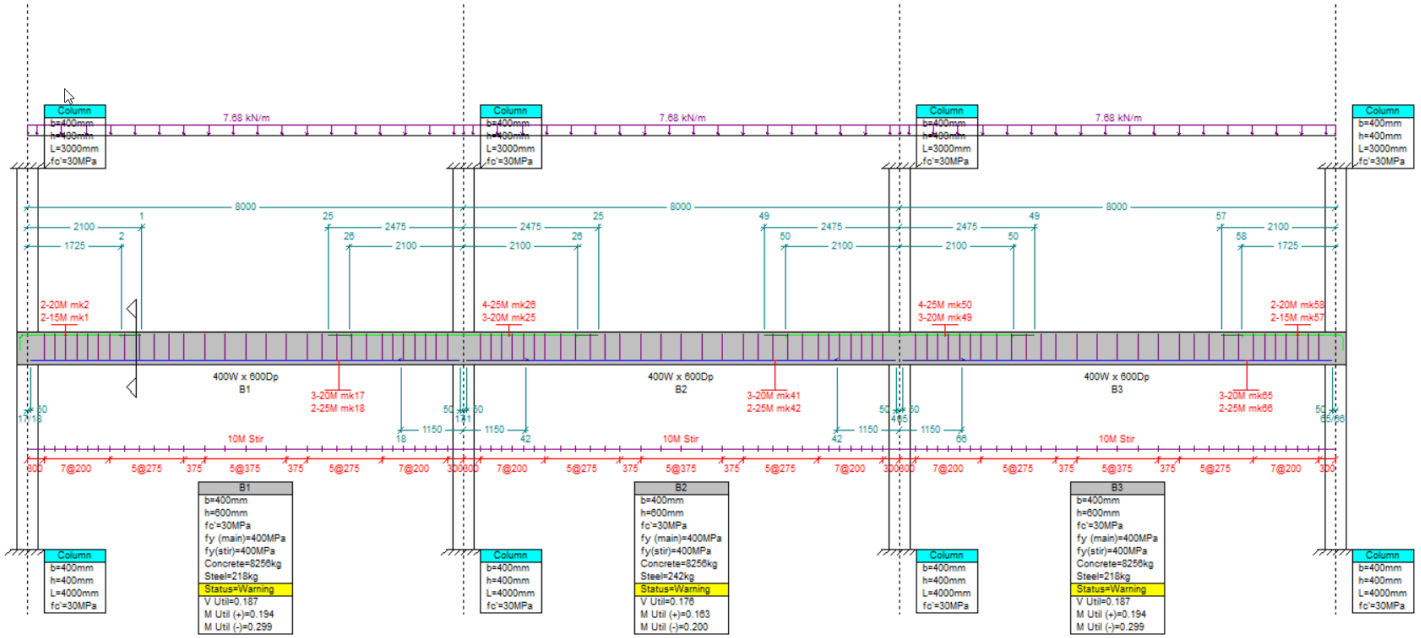
Altair S-CONCRETE, including S-LINE



S-LINE

Continuous beam design



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THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

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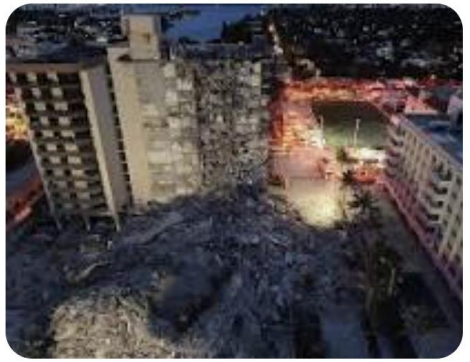
Field experience + Code + Trust = Change

- ✓ **Halton Region**
- ✓ **Brampton Region**
- ✓ **FDOT**
- ✓ **ODOT**
- ✓ **MTO**
- ✓ **MTQ, MDOT, TXDOT and Others are heavily using it**

A contributing factor under investigation is long-term degradation of reinforced concrete structural support in the basement-level parking garage under the pool deck, due to **water penetration and corrosion of the reinforcing steel**. The problems had been reported in 2018 and noted as "much worse" in April 2021.



https://en.wikipedia.org › wiki › Surfside_condominium_...

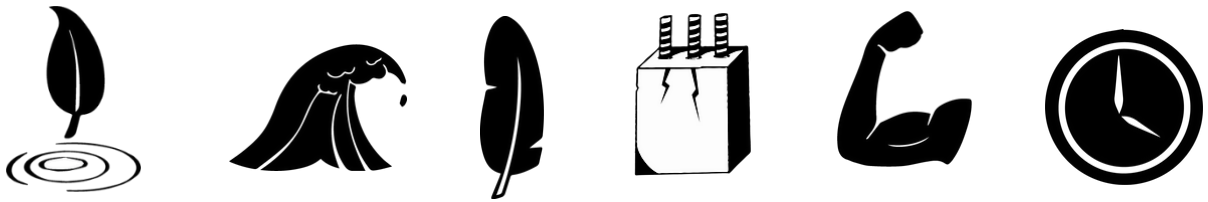
Surfside condominium collapse - Wikipedia

Why Consider GFRP

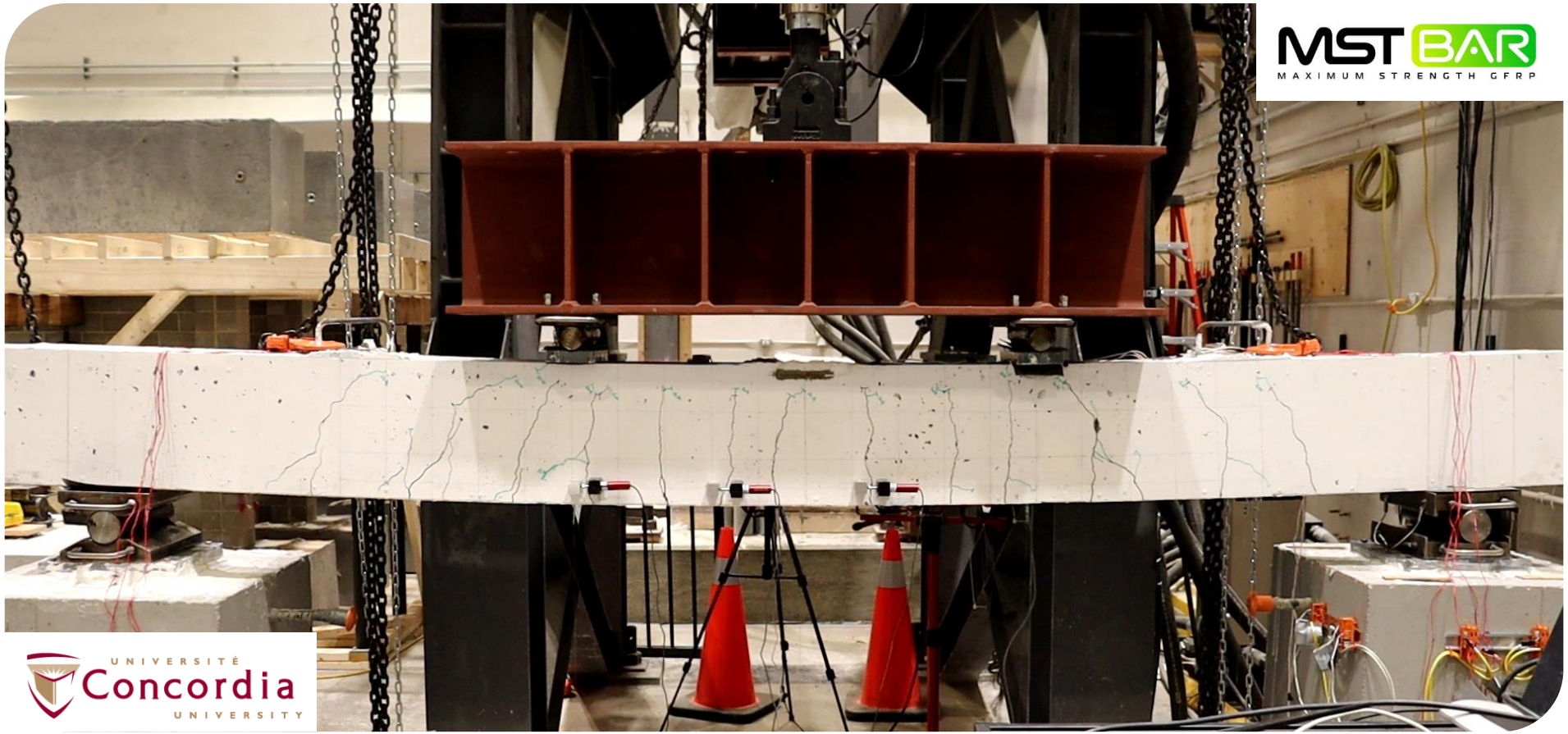
- ✓ **Ministries of Transportation and DOTs in Canada & US are using it**
- ✓ **Code approved ICC, ASTM, CSA, AASHTO & ACI**
- ✓ **Reduce construction accidents- ‘’OSHA: 61% of Construction accidents are due to steel rebar impalement ‘’**
- ✓ **Reduce back injuries - ¼ of the weight**
- ✓ **Easier to install - Non-Conductive (Thermal & Electrical)**
- ✓ **Reduce unnecessary cost of corrosion protection**
- ✓ **Reduce long term maintenance**
- ✓ **Keep the environment clean**

All The Benefits of GFRP

- **Corrosion Resistance = Risk Insurance**
- **Weight - 4 X Lighter Than Steel**
- **Bonding Strength**
- **Ease Of Cutting - No Sharp Edge**
- **Fire Rated- Over 3 Hours**
- **Strength – 3 X Steel**
- **Fatigue Strength**
- **Economical Curing – No Need For Fresh Water**
- **Conductivity – No Grounding Required**
- **Thermal Non-conductive – Suitable For Use In Hot & Cold Environments**
- **GREEN – Significantly Less Energy to produce compare to Steel**



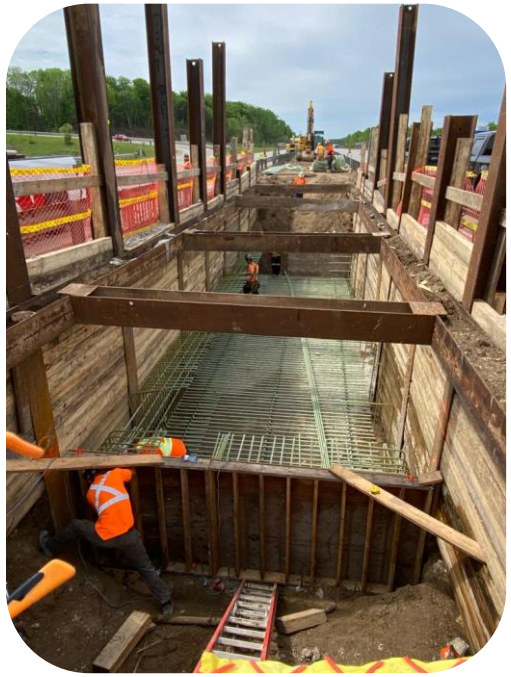
Fatigue test performed as a part of the PhD program of Islam Elsayed Nagy at Concordia University under the supervision of Prof. Khaled Galal



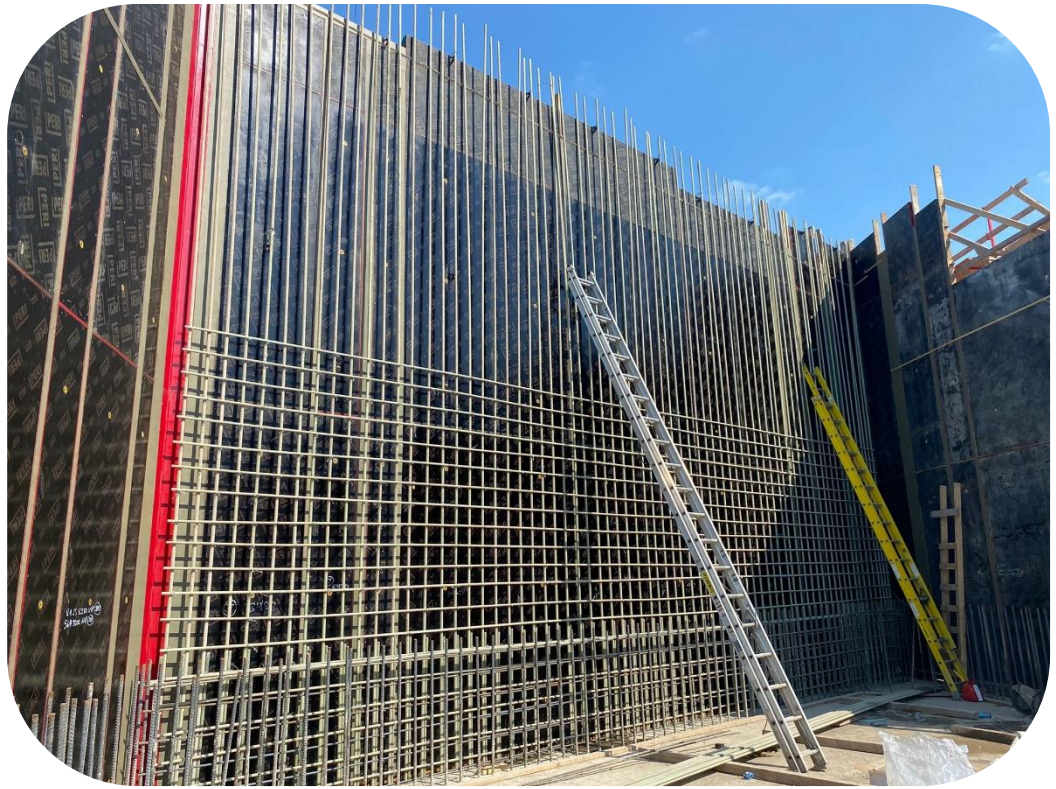
MST-BAR is Heavily Involved in Civil Projects for the Past 10 Years

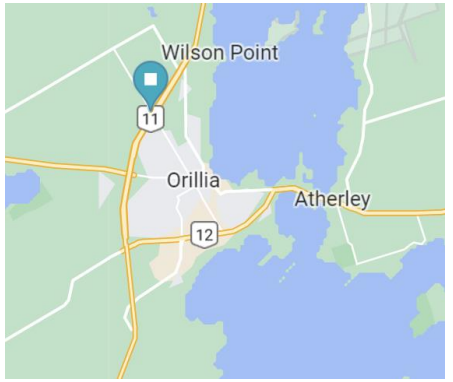
All MST-BAR bridge

MTO is using MST-BAR on 100s of bridges, but this is the only Steel free one!



- MST-BAR cost similar to black steel rebar
- Life expectancy +100 years
- $18M bridge finishing under budget
- Locally made material
- Delivered faster than Steel
- Lighter Bridge with less Injury




Wilson Point
11
Orillia
Atherley
12

Easier and Safer to Use

THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

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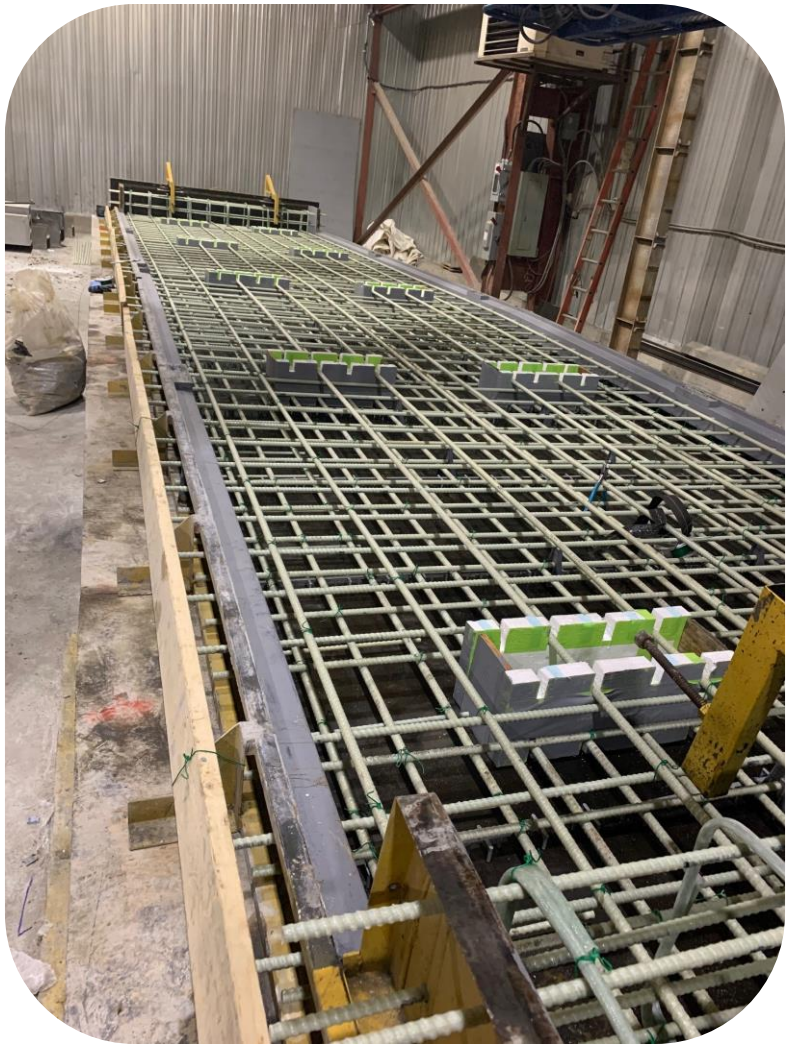
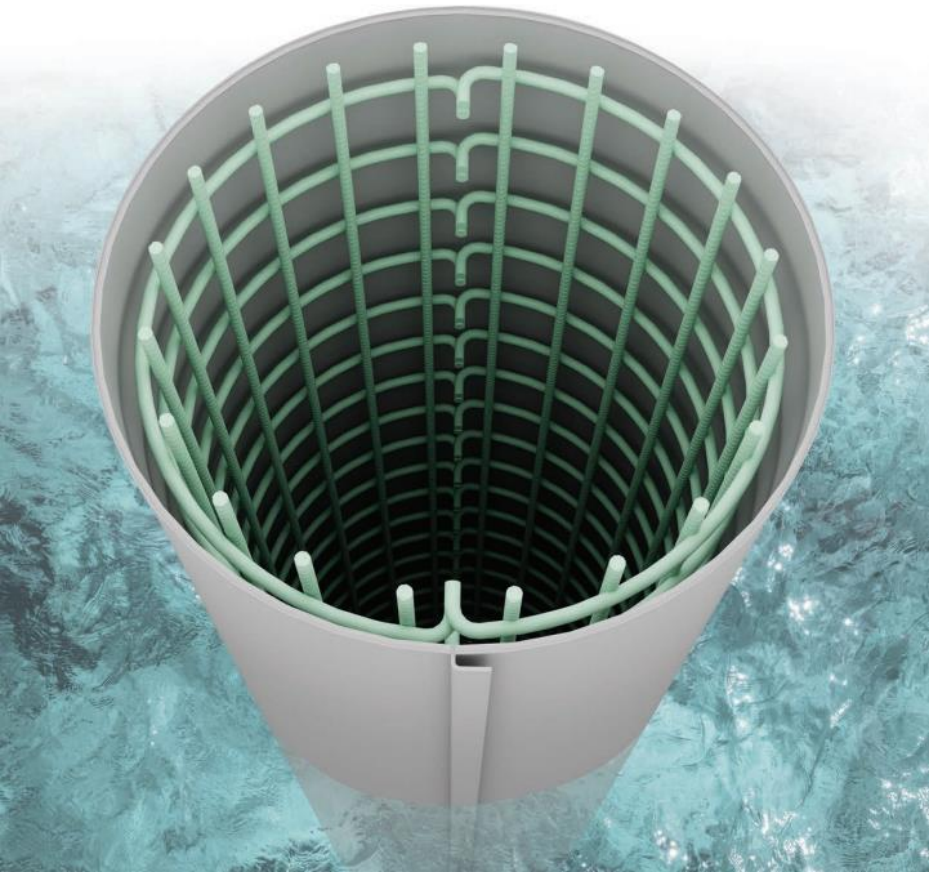
STAPLES



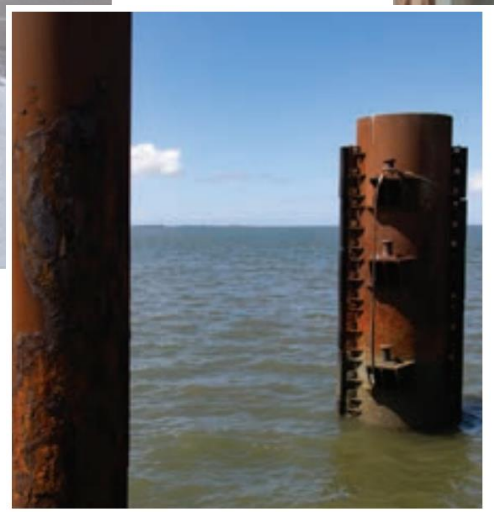
MST PILE REPAIR KIT

FOR PIERS, PILES, COLUMNS AND BEAMS

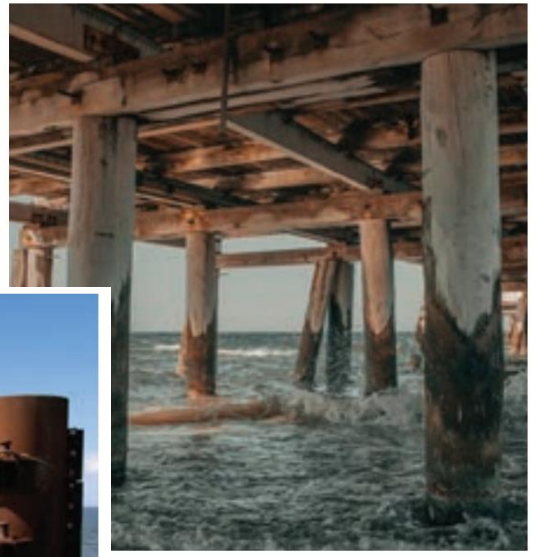


In marine situations, piles made of steel, concrete, and wood frequently sustain structural deterioration at the waterline.

Concrete



Steel



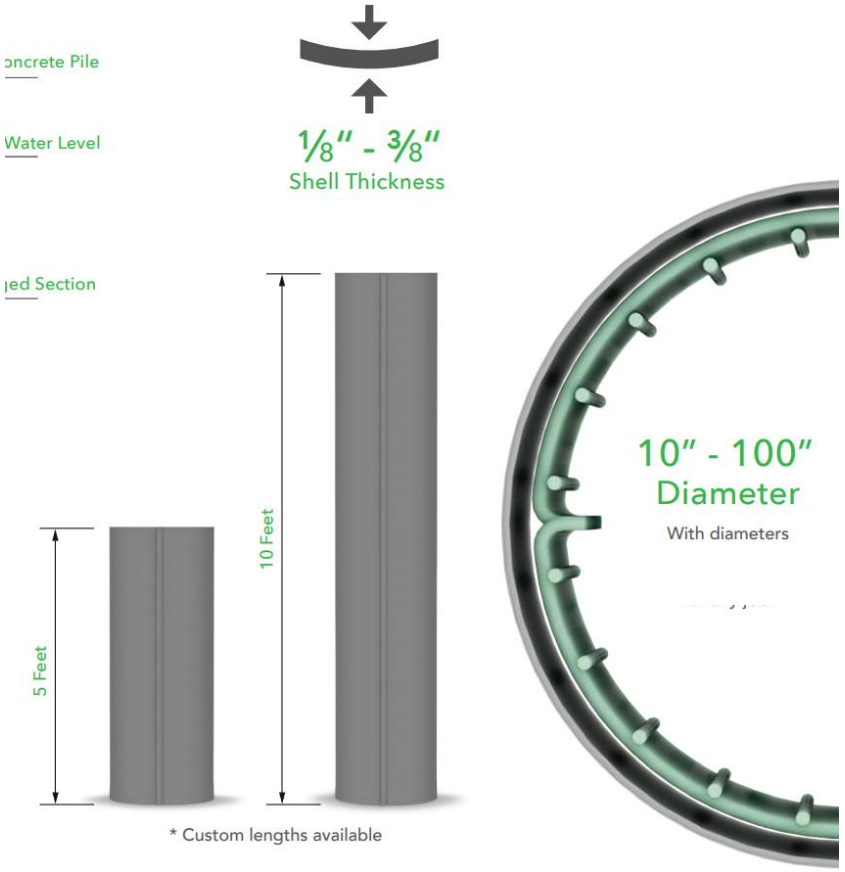
Timber

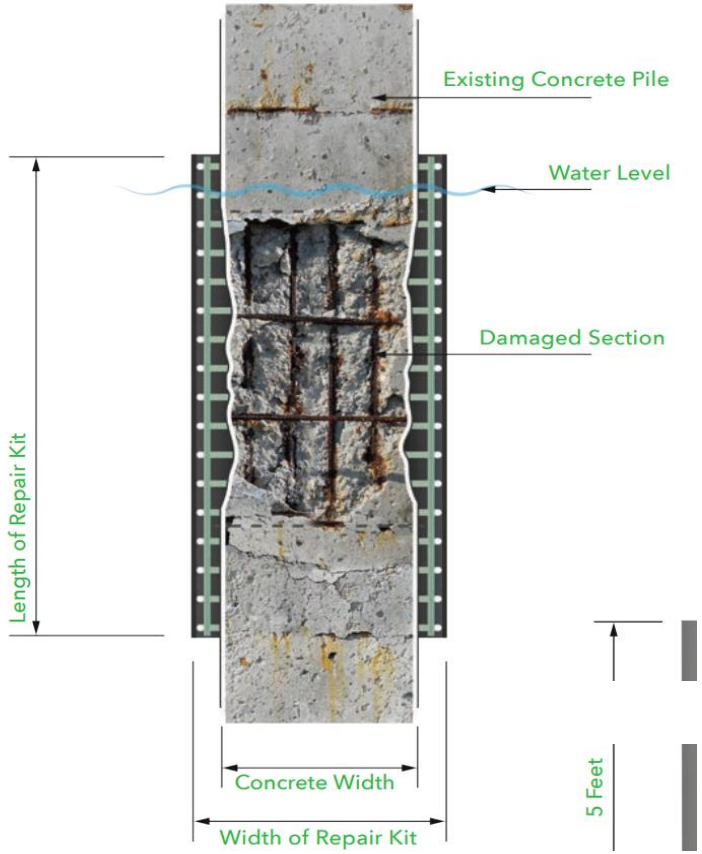
MST Pile Repair Kit

The Kit combines GFRP rebar inside a high strength fiberglass outer jacket

with a pigmented resin surface coat to include ultraviolet inhibitors.

The jacket provides protection to all pile materials.





MST Pile Repair Kit

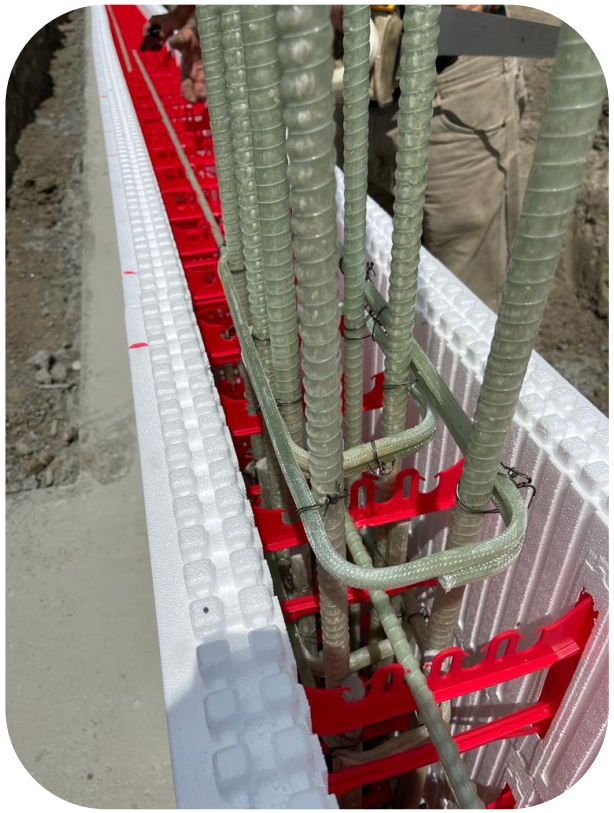
Project Case: South Corridor in Panama City.

MST Rebar Inc. provides the necessary
Assessment, Engineering and Training for proper installation and QC.

Benefits

- **No Rust!**
- **No Divers!**
- **Lower cost!**
- **Not prone to freeze and thaw**

Residentials



Residentials

Residentials

Residentials

Why GFRP?

1/4 the weight → 1/4 CO2 from transportation

Longer life → less demolition → less concrete → less CO2

Better thermal isolation → less energy loss

No rust → no repair → no replacement

Less maintenance → less traffic jam → less CO2

Lower energy is required to produce MST-BAR than conventional steel

Chloride is not a durability concern for GFRP RC → no need for fresh water to make concrete

MST BAR
MAXIMUM STRENGTH GFRP

4X More load!

Thank You!