



BASTECH

DESIGN MANUAL

Document Number: DM-1 (Version 2)

Date Issue: December 14, 2022

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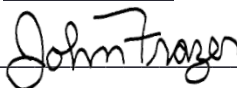
THIS MANUAL IS PROPERTY OF BASALT ENGINEERING LLC. USE ONLY FOR DESIGN WITH BASTECH® BASALT FIBER REINFORCED POLYMER (BFRP) BAR FOR USE AS INTERNAL STRUCTURAL REINFORCEMENT OF CONCRETE. ALL DESIGNS MUST FOLLOW PROCEDURES AS DETAILED IN THE IBC, UBC, IRC AND OTHER APPLICABLE LOCAL CODES AND AS DESCRIBE HEREIN. THE OWNER AND REGISTERED DESIGN PROFESSIONAL ARE RESPONSIBLE FOR DETERMINING, THROUGH ANALYSIS, THE STRENGTHS, DEMANDS AND REQUIRED SERVICE CONDITIONS OF THE CONCRETE STRUCTURAL ELEMENTS TO BE REINFORCED WITH BASTECH® BFRP BAR, WHICH ARE SUBJECT TO THE APPROVAL OF THE CODE OFFICIAL OR DESIGNATED PARTY.

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Approval Authorized Signature

This document outlines the design principles, criteria, design material properties and other applicable provisions for the design of concrete reinforced with Bastech® Basalt Fiber Reinforced Polymer (BFRP) reinforcement bar (rebar). This document has been approved and release by:

Name: John Frazer

Signature: 

Date: March 1, 2021

Quality Policy

Basalt Engineering LLC is committed to providing quality, reliability and integrity to exceed our customer's expectations. Refer to our Quality Manual (QM-1), which outlines Basalt Engineering's Quality Management System (QMS) to demonstrate it's ability to consistently provide quality, reliable, integrity products that meet and exceed our customer's expectation.

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Document Control and Revision Log

Superseded Document:	DM-1 (Version 1)
Reason for Revision:	Update to comply with ACI 440.11-22
Effective Date:	December 14, 2022

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1. INTRODUCTION

1.1. Purpose

The objective of the design manual is to satisfy the design requirement of the ESR (evaluation service report) No. ESR-4648 in recognition of the Acceptance Criteria AC454 issued by the International Code Council Evaluation Service (ICC-ES) Acceptance Criteria for Fiber-Reinforced Polymer (FRP) Bars for Internal Reinforcement of Concrete Members (AC454) [1], Section 8.0; for the use of Bastech®, a Basalt Fiber Reinforced Polymer (BFRP) reinforcement bar (rebar) for use as internal structural reinforcement of concrete for the construction of structures and elements in residential, commercial, industrial, road and civil engineering applications.

This document contains Bastech® experimental and design material specifications, design equations in accordance to ACI CODE 440.11-22 [2], applicable references to other design documents and building codes, installation and handling instructions.

1.2. Design Manual Holder Information



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2. Bastech® REBAR

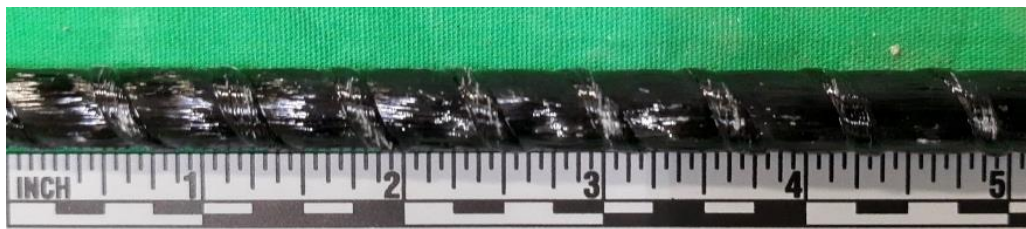
2.1. Bastech® Rebar Description

Bastech® is a Basalt Fiber Reinforced Polymer (BFRP) reinforcement bar (rebar), composed of high strength and modulus basalt fibers, resistant to an alkaline environment in an epoxy resin, finished with a continuous helically wound surface element providing adequate bond to concrete.

Bastech® is intended for use as internal structural reinforcement of concrete for the construction of structures and elements in residential, commercial, industrial, road and civil engineering applications.

Bastech® is available in straight in the following standard (nominal) sizes as represented in Figure 1.:

- #3 (3/8 in. nominal diameter), M10 (10 mm nominal diameter); and
- #5 (5/8 in. nominal diameter), M16 (16 mm nominal diameter).



(a)



(b)

Figure 1 - Bastech® FRP straight bar (a) #3 - M10; and (b) #5 - M16

Scale in inches

2.1.1 Uses

The Bastech® basalt fiber- reinforced polymer (BFRP) 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 and normal-weight concrete. The Bastech® BFRP bar may be used where an engineering design is submitted in accordance with Section R301.1.3 and where approved by the building official in accordance with Section R104.11.

2.2. Bastech® Rebar Properties

The standard experimental properties of Bastech® Rebar are provided in Table 1, this are mean values based on experimental test specimens. These values are not guaranteed properties and only represent average properties. Refer to Section 3 of this document for Bastech® Rebar design properties, which includes guaranteed material design properties. Guaranteed material properties, together with safety/reduction values must be used for design purposes as per ACI CODE 440.11-22 [2].

Table 1 - Bastech® standard material properties

Reference	Property	Unit	Bar Size	Bar Size
		SI US	M10 (3)	M16 (5)
ASTM D2584	Fiber Mass Content	%	78	74
ASTM E1640	Mean Glass Transition Temperature (DMA)	°C	n/a	119
		°F	n/a	246
ASTM E2160	Mean Degree of cure	%	99	98
ASTM D7205	Mean Measured Cross-Sectional Area	mm ²	83	228
ASTM D792		in ²	0.129	0.353
ASTM D7205	Mean Ultimate Tensile Strength	MPa	1187	911
		ksi	172	132
	Mean Tensile Modulus of Elasticity	GPa	56	52
		Msi	8.2	7.5
	Mean Ultimate Tensile Strain	%	2.1	1.8
ASTM D7705-A	Mean Alkaline Resistance (Tensile Load Retention)	%	n/a	96
ASTM D7913	Bond Strength	MPa	n/a	7.63
		ksi	n/a	1.11
ASTM D7617	Guaranteed Transverse Shear Strength	MPa	226	199
		ksi	33	29
ASTM D4475	Mean Horizontal Shear Strength	MPa	57	48
		ksi	8.2	7.0
ASTM D570	Mean Moisture Absorption at 24 hrs.	%	n/a	0.17
	Mean Moisture Absorption at Saturation		n/a	0.75

n/a – not available

3. DESIGN PROVISIONS

3.1. General Design Considerations

The design of reinforced concrete structural elements using Bastech® rebar shall be done in accordance to ACI CODE 440.11-22 [2] and shall comply with the applicable provisions of IBC [3], IRC [4] and other applicable local codes as required. The owner and registered professional engineer are responsible for determining, through analysis, the strengths, demands and required service conditions of the concrete structural elements to be reinforced with Bastech® rebar, which are subject to the approval of the code official or designated party.

Computations of the strength of reinforced concrete cross sections with Bastech® rebar are performed based on the following assumptions:

3.2. Bastech® Rebar Design Properties and Factors

The design properties and factors summarized in

TABLE 2 – DEMENSIONS AND PROPERTIES

BAR DESIGNATION NUMBER	NOMINAL DIAMETER (in)	NOMINAL CROSS SECTIONAL AREA (in ²)	GUARANTEED ULTIMATE TENSILE FORCE (kip)	MEAN TENSILE MODULUS OF ELASTICITY (ksi)	MEAN ULTIMATE TENSILE STRAIN (%)	GUARANTEED TRANVERSE SHEAR STRENGTH (ksi)	GUARANTEED BOND STRENGTH (psi)
3 (M10)	0.375	0.11	15.0	8200	2.1	33	1100
5 (M16)	0.625	0.31	33.6	7500	1.8	29	1100

are based on ACI CODE 440.11-22 [2], and applicable provisions of ACI 318 [5], where equations (Eq.) (1) and (2) give the Bastech® rebar tensile properties to be used in all design equations.

The design tensile strength shall be determined by (ACI CODE 440.11-22, Sec. 20.2.2.3 [2]):

$$f_{fu} = C_E f_{fu}^* \quad (1)$$

where

f_{fu} = design tensile strength of FRP, considering reductions for service environment;

C_E = environmental reduction factor shall be 0.85 for concrete both exposed and not exposed to earth or water;

f_{fu}^* = nominal tensile strength of a FRP bar defined as the guaranteed tensile load divided by the nominal cross-sectional area.

The design rupture strain shall be determined as:

$$\varepsilon_{fu} = C_E \varepsilon_{fu}^* \quad (2)$$

where

ε_{fu} = design rupture strain of FRP reinforcement;

ε_{fu}^* = ultimate rupture strain of FRP reinforcement defined as the guaranteed tensile load divided by the product of mean elastic modulus and nominal cross-sectional area.

TABLE 2 – DEMENSIONS AND PROPERTIES

BAR DESIGNATION NUMBER	NOMINAL DIAMETER (in)	NOMINAL CROSS SECTIONAL AREA (in ²)	GUARANTEED ULTIMATE TENSILE FORCE (kip)	MEAN TENSILE MODULUS OF ELASTICITY (ksi)	MEAN ULTIMATE TENSILE STRAIN (%)	GUARANTEED TRANVERSE SHEAR STRENGTH (ksi)	GUARANTEED BOND STRENGTH (psi)
3 (M10)	0.375	0.11	15.0	8200	2.1	33	1100
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3.3. Design Methodology

The design of concrete structures reinforced with Bastech® BFRP shall be done as per ACI CODE 440.11-22.

4. INSTALLATION OF Bastech® BAR

4.1. Instructions Details

The design and installation of Bastech® rebar for concrete reinforcement must be in accordance with the published ICC-ES report ESR-4686, ACI SPEC 440.5-22 [6], the approved quality documentation, this design manual, as well as applicable codes that include IBC [3], IRC [4] and other local codes, as required.

Complete construction documents, including plans and calculations verifying compliance with the evaluation report must be submitted to the code official for each project at the time of permit application. The construction documents must be prepared and sealed by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

The use of Bastech® rebar for concrete reinforcement of flexural and shear members can be used in any cross-section (e.g., rectangular, T-shape, L-shape). For flexural reinforcement, the use of multiple that Bastech® rebar layers and bar bundling is permitted. For multiple bar layers, the minimum spacing should be in accordance with ACI CODE 440.11-22, Sec. 25.2 [2].

Fire-resistance rating of that Bastech® rebar reinforced concrete assembly is outside the scope of the evaluation report, and concrete assemblies with that Bastech® rebar are limited to type VB construction under the IBC.

Special inspection as required by Table 1705.3 of the IBC for steel-reinforced concrete construction, is also applicable to that Bastech® rebar reinforced concrete construction.

4.2. Handling Requirements

Handling requirements of Bastech® rebar including methods to cut, hoisting and other relevant requirements are provided within ACI SPEC 440.5-22 [6].

4.3. Environmental Considerations

Bastech® rebar shall be installed at ambient temperatures with in a range of 32° F to 105° F (0° C to 40° C). Bastech® rebar shall be stored above the surface of the ground on platforms, skids, or other supports as close as possible to the point of placement. If Bastech® rebar shall be stored outdoors for over 30 days, the rebars shall be covered with a cover that will protect from ultraviolet rays.

4.4. Product Identification

Bastech® rebar are labeled in accordance with the approved quality management system (QMS) procedures, where labels include at minimum the manufacturer name and address, product name, manufacturing traceability identification, and ICC-ES evaluation report number. Prior to installation, verify that Bastech® rebar is legitimate.

5. REFERENCES

- [1] AC454, "Acceptance Criteria for Fiber-Reinforced Polymer (GFRP) Bars For Internal Reinforcement Of Concrete Members" ICC-ES. (December 2020).
- [2] ACI CODE 440.11-22, "Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars—Code and Commentary". Reported by ACI Committee 440. American Concrete Institute. Farmington Hills, MI. (2022).
- [3] IBC, International Building Code. ICC. (2021 and 2018)
- [4] IRC, International Building Code. ICC. (2021 and 2018).
- [5] ACI 318, American Concrete Institute, "Building code requirements for reinforced concrete" Reported by ACI Committee 318. American Concrete Institute. Farmington Hills, MI. (2014).
- [6] ACI SPEC 440.5-22, "Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars". Reported by ACI Committee 440. American Concrete Institute. Farmington Hills, MI. (2022).