To Whom It May Concern,

I am writing to confirm that Rebar X Glass Fiber Reinforced Polymer (GFRP) rebar complies with the building codes such that the simpler details provided in this document are very suitable as a substitute for conventional steel rebar to control cracks at the end of ICF panels.

Rebar X has unique characteristics that cannot be found in Steel reinforcement and other Fiber Reinforced Polymer (FRP) rebars. FRP rebars have a much lower Poisson's ratio(nu) than steel. Which when combined with design considerations, allows for simpler detail for ***temperature and shrinkage reinforcement*** to control cracks at the end of ICF panels.

1. Understanding Poisson's Ratio and Its Importance

Poisson's Ratio measures the amount a material contracts (deforms) laterally when stretched longitudinally – notwithstanding the rare auxetic materials which would display a negative Poisson's ratio.

- **Steel Reinforcement:** With a higher Poisson's Ratio (.28 to .33), steel expands in diameter under tension. This dimensional change can reduce bond performance, potentially leading to rebar **slippage** in the concrete. Engineers often compensate for this with **bent bars or hooks** to ensure mechanical anchorage.

- **Rebar X (GFRP)** maintains a **lower Poisson's Ratio (~.23)**, meaning it retains its original diameter throughout loading and up to failure. Rebar X achieves **tensile strengths exceeding 1000 MPa**, approximately **twice that of steel**, without altering its cross-section. The clear advantages include:

    - **Improved Bond Strength and Reduced Slippage**: The lower lateral contraction of GFRP under tension helps the bar maintain a tighter grip within the surrounding concrete. Steel, with its higher Poisson's ratio, shrinks more in diameter under load, which can be enough to cause the bar to slip from the concrete, leading to the need for specific bent bar anchorage designs.

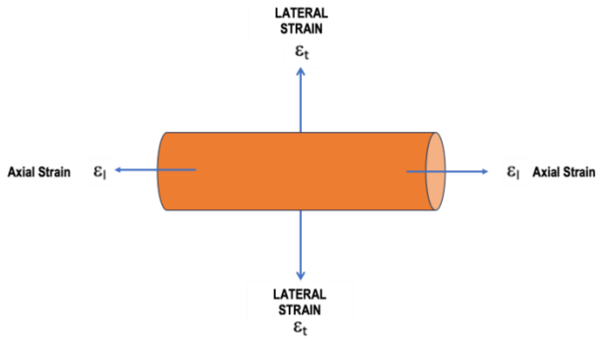
    - **Better Anchorage in Concrete:** Because GFRP holds its diameter better under stress, it provides a more consistent and reliable bond along its length, which can simplify some aspects of structural design and potentially reduce the need for certain types of mechanical anchorages.

    - **Reduced Risk of Concrete Cracking/Spalling:** By not "necking" down as much under load, GFRP may put less localized lateral stress on the surrounding concrete during extreme loading events, potentially reducing the risk of splitting cracks in the concrete cover directly caused by the rebar's lateral movement.

Independent **post-installed pull-out testing** has confirmed this superior bond behavior.

Poisson's Ratio as it relates to the GFRP Bar

Poisson's ratio is the ratio of the relative contraction strain (transverse, lateral or radial strain) normal to the applied load - to the relative extension strain (or axial strain) in the direction of the applied load.



Poisson's Ratio (ν) is expressed as: $\nu = - \varepsilon_t / \varepsilon_l$

ε_t = transverse strain = $\Delta r / r$ where Δr is the radial strain (usually) contraction
r = initial radius (mm, in, ft, m, etc)

ε_l = longitudinal or axial strain = $\Delta l / L$ where Δl is the change in length
L = initial length (mm, in, ft, m etc)

The lower the value of Poisson's ratio, the more advantageous for achieving greater grip, slip resistance, and bond to concrete – as is inherently provided by GFRP. As mentioned prior, ν is approximately 0.23 in rebar composite materials while exhibiting a value of 0.28 to 0.33 for steel.

2. Technical Design Considerations

For structural reliability, the **required embedment (development) length** must always be satisfied as a function of bar diameter.

- Where full development length is not possible, **90° bent bars** may be installed at corners to ensure adequate anchorage and load transfer.
- Pirate Rebar's high bond strength enables **simplified reinforcement detailing** for **temperature and shrinkage control** in ICF panels and footings.

These simplified details are supported by results from **concrete pull-out tests**, confirming excellent bond performance.

3. Minimum Concrete Cover (Clear Cover)

A **minimum concrete cover** is required to protect reinforcement, maintain durability, and ensure long-term bond integrity. This is referenced as **clear cover** and is best defined as the "least (minimum)distance between reinforcement and the outer surface of concrete.

The governing standard is provided in ACI CODE-318-19 Table 20.5.1.3.1-Specified concrete cover for cast-in-place non-prestressed concrete members.

Table 20.5.1.3.1-Specified concrete cover for cast-in-place nonprestressed concrete members

Concrete exposure	Member	Reinforcement	Specified cover, in.
Cast against and permanently in contact with ground	All	All	3
Exposed to weather or in contact with ground	All	No. 6 through No. 18 bars	2
		No. 5 bar, W31 or D31 wire, and smaller	1-1/2
Not exposed to weather or in contact with ground	Slabs, joists, and walls	No. 14 and No. 18 bars	1-1/2
		No. 11 bar and smaller	3/4
	Beams, columns, pedestals, and tension ties	Primary reinforcement, stirrups, ties, spirals, and hoops	1-1/2

ACI establishes the clear (concrete) cover in the table above as either 1.5" or 0.75" based on exposure and contact with ground.

The qualifying equations to determine whether there is sufficient core thickness are given:

ACI assumes there are three possible controlling factors for minimum spacing:

S_{clear} : this value is the spacing (clear spacing) between parallel bars (rebar) and is the maximum of the following:

- d_b (bar diameter)
- 1 inch
- 4/3 D_{agg} (aggregate diameter)

$S_{clear} >= \max(d_b, 1.0 \text{ in.}, 4/3 D_{agg})$

Note that while ACI does not specify orthogonal bar spacing, the "1 in. minimum clear spacing" requirement applies to **both parallel and crossing bars** in practice, even though ACI only defines it for "parallel bars.

The following terms below to further calculate the required core thickness:

Term	Meaning	Controlled by
s_{clear}	Gap between bars	ACI 318 25.2.1
c	Cover to bar surface	ACI 318 Table 20.6.1.3.1
$c_{CL}=c+d_b/2$	Centerline distance	Geometry
$t_{min}=2c+d_b+s_{clear}$	Required Wall/Core thickness	Derived geometry
ICF Typical cover	¾" to 1 ¼" protected	Field practice/tolerance

By way of example, lets utilize a 4-inch core, #4 FRP (1/2" bar)

$s_{clear} = 1.0"$

$d_b = 0.5"$

$t_{core} = 4.0"$

Solving for cover:

$c = (4 - 0.5 - 1.0)/2 = 1.25"$

The code minimum for ICF (not exposed to weather or ground) would be ¾"; therefore, fits the 4" core.

The conclusion from the analysis and compliance to ACI is that **ICF-protected faces** with **#4 or #5 FRP** and **¾–1″ aggregate**, a **4″ core with c≈1.2–1.25″** is **code-compliant and practical**.

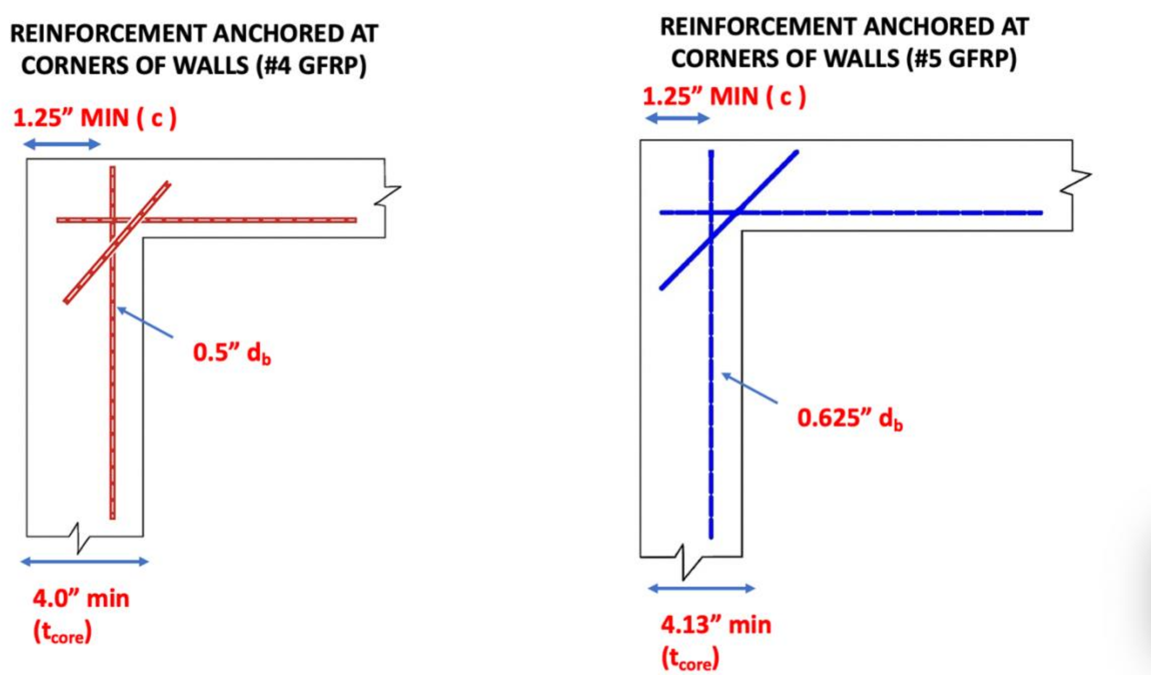


Figure 1

Conclusion

Based on the review of test data and design considerations and code requirements, the detail provided above is applicable for Rebar X GFRP bars because of their high bond strength to concrete based on the test results achieved by pullout tests and ACI 318.

Reinforcement designed to control cracks shall be extended by the end of walls. At least one cross bar per horizontal layer of bars of Rebar X straight bars need to be placed at each corner at a spacing equal to or less than the spacing of horizontal reinforcement. In any case, a clear concrete cover of 1.5" shall be provided over the Rebar X bars. See in Figure 1.

Rebar X meets structural standards and is code-compliant across the following jurisdictions:

- Florida: 2023 Florida Building Code (8th Ed.)

Please contact me with any questions.

See stamp below.

Sincerely,
Engr Collins, Steven, PE

*Engineer's seal covers design only. Engineer assumes no liability for product defects, fabrication, installation, or construction means and methods.