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ERRATA for AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete, Second Edition

Dear Customer,

Due to errors found after publication had been completed, AASHTO has made the following errata changes to the *AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete*, Second Edition (GFRP-2B):

Date	Page Number	Affected Article	Errata Change To
July 2019	2-12	Figure C2.5.5.2-1	One value of φ was incorrectly given as 0.70 and has been replaced with the correct value, 0.75.
February 2020	6-4	Table 6.6.4-1	“Minimum Inside Bend Diameter” should read “Minimum Inside Bend Radius”

Please substitute the original pages of text with the enclosed pages, which will remain clearly distinguishable as errata pages once they have been inserted due to the large errata page header. Text in ***bold italics*** indicate revisions made since the previous errata was released in July 2019. The previous errata changes are included

We apologize for any inconvenience this may have caused.

AASHTO Publications Staff
February 2020

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The cracked moment of inertia and ratio of neutral axis depth to reinforcement depth for singly reinforced, rectangular cross sections without compression reinforcement bent in uniaxial bending may be computed using Eq. 2.5.3-3.

2.5.5—Strength Limit State

2.5.5.1—General

The strength limit state issues to be considered shall be those of strength and stability.

Factored resistance shall be the product of nominal resistance as determined in accordance with the applicable provisions of Articles 2.6, 2.7, 2.8, 2.9, 2.10, and 2.11, unless another limit state is specifically identified, and the resistance factor as specified in Article 2.5.5.2.

2.5.5.2—Resistance Factors

The resistance factor, ϕ, shall be taken as:

- For compression-controlled and tension-controlled reinforced concrete sections as specified in Article 2.6.3:

$$\phi = \begin{cases} 0.55 & \text{for} \quad \varepsilon_{ft} = \varepsilon_{fd} \\ 1.55 - \dfrac{\varepsilon_{ft}}{\varepsilon_{fd}} & \text{for} \quad 0.80\varepsilon_{fd} < \varepsilon_{ft} < \varepsilon_{fd} \\ 0.75 & \text{for} \quad \varepsilon_{ft} \leq 0.80\varepsilon_{fd} \end{cases} \qquad (2.5.5.2\text{-}1)$$

where:

ε_{fd} = design tensile strain of GFRP reinforcing bars (Eq. 2.4.2.1-1)

ε_{ft} = tensile strain in extreme tension GFRP at nominal resistance

- For shear and torsion 0.75
- For compression-controlled sections with spirals or ties, as specified in Article 2.6.4 0.75
- For bearing on concrete 0.70
- For compression in strut-and-tie models 0.70
- For tension in strut-and-tie models 0.55

C2.5.5.2

A reliability analysis on FRP reinforced concrete beams subject to flexure using load combination 2 from ACI 318-05 (for live to dead load ratios between 1 and 3) resulted in reliability indexes between 3.5 and 4.0 when ϕ is set to 0.65 and 0.55 for compression-controlled and tension-controlled sections, respectively (Gulbrandsen, 2005). More recently, a comparative reliability analysis of steel- and GFRP-reinforced concrete beams resulted in ϕ with a lower limit of 0.70 instead of 0.55 for tension-controlled sections, and an upper limit of 0.75 instead of 0.65 for compression-controlled sections (Jawaheri Zadeh and Nanni, 2013).

Because tension-controlled concrete members reinforced with GFRP bars do not exhibit ductile behavior, a conservative resistance factor of 0.55 has been retained.

While a concrete crushing failure mode can be predicted based on calculations, the member, as constructed, may not fail accordingly. For example, if the concrete strength is higher than specified, the member can fail due to GFRP rupture. For this reason and to establish a transition between the two values of ϕ, 0.55 and 0.75, a section controlled by concrete crushing is defined as a section in which $\varepsilon_{ft} \leq 0.80\varepsilon_{fd}$, and a section controlled by GFRP rupture is defined as one in which $\varepsilon_{ft} = \varepsilon_{fd}$. The resulting relation between resistance factor for flexure and tensile strain at failure in the GFRP reinforcement is illustrated in Figure C2.5.5.2-1.

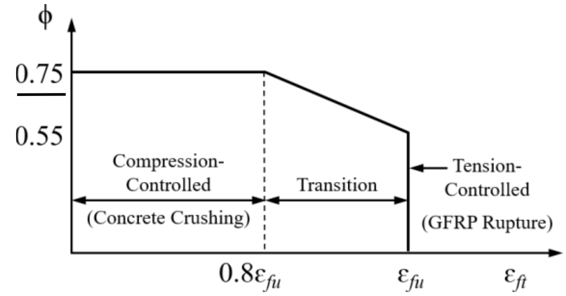

Figure C2.5.5.2-1—Variation of ϕ with Tensile Strain at Failure, ε_{ft}, in GFRP Reinforcement

2.5.5.3—Stability

The structure as a whole and its components shall be designed to resist sliding, overturning, uplift and buckling. Effects of eccentricity of loads shall be considered in the analysis and design.

Buckling of precast members during handling, transportation, and erection shall be investigated.

2.5.6—Extreme Event Limit State

The structure as a whole and its components shall be proportioned to resist collapse due to extreme events, specified in Table 3.4.1-1 of the *AASHTO LRFD Bridge Design Specifications*, as may be appropriate to its site and use.

C2.5.6

The lack of ductility and limited potential for moment redistribution after cracking should be carefully considered under this limit state where the resistance factor is typically specified as 1.0. In fact, different from steel RC members, neither the formation of plastic hinges nor moment redistribution can be assumed for GFRP RC members. Large deformations and limited rotations may still be possible for tension-controlled GFRP RC members due to concrete cracking and loss of stiffness. However, it is difficult to reliably quantify related beneficial effects.

2.6—DESIGN FOR FLEXURAL AND AXIAL FORCE EFFECTS—B-REGIONS

2.6.1—Assumptions for Service, Fatigue, and Creep Rupture Limit States

The following assumptions may be used in the design of GFRP reinforced concrete components for all compressive strength levels:

- The strains in the concrete vary linearly, except in components or regions of components for which conventional strength of materials is inappropriate.
- Where transformed section analysis is used to assess the time-dependent response to permanent loads, an age adjusted effective modular ratio of $2n_f$ is applicable.

C2.6.1

Examples of components for which the assumption of linearly varying strains may not be suitable include deep components such as deep beams, corbels, and brackets.

Transformed section properties are used in the working stress methods based on elastic and time-dependent analysis, for instantaneous and creep effects, respectively. The methods are applicable for service and fatigue limit states. Approximate analysis using gross section properties may be adequate in some designs provided that volume change effects are recognized.

displacement and to keep the reinforcing at the proper distance from the forms within tolerances. Use steel tie wires, bar chairs, supports, or clips fully coated with epoxy or plastic. Plastic ties and supports approved by the Owner's representative may also be used.

6.6.2.2—Tolerances

Place, support, and fasten GFRP reinforcement as shown on the Project Drawings. Do not exceed the placing tolerances specified in ACI 117 before concrete is placed. Placing tolerances shall not reduce cover requirements except as specified in ACI 117.

6.6.2.3—GFRP Reinforcement Relocation

When it is necessary to move GFRP reinforcement beyond the specified placing tolerances to avoid interference with other reinforcement, conduits, or embedded items, the resulting reinforcement arrangement shall be submitted for approval.

6.6.2.4—Concrete Cover

Unless otherwise specified by the Owner, the concrete cover for GFRP reinforcement shall be as indicated in Table 6.6.2.4-1 applicable to all exposure conditions except those required for additional fire protection. Tolerances on specified concrete cover shall meet the requirements of ACI 117.

Table 6.6.2.4-1—Concrete Cover Requirements for GFRP Reinforcing Bars

Description	Specified Cover
Slabs Top and bottom reinforcement for No. 10 GFRP reinforcing bars and smaller	1.0 or 1.5 bar diameters
Beams, formed Stirrups Principal reinforcement	 1.5 in. 2.0 in.

6.6.3—GFRP Reinforcement Supports

Reinforcement supports shall be made of electrically insulating material or, if ferrous, coated with electrically insulating material, including epoxy or another polymer.

Unless otherwise specified by the Owner, the reinforcement supports shall be as follows:

- Concrete supports that have a surface area greater than or equal to 4.0 in.^{2} and compressive strength and durability properties equal to or greater than the specified compressive strength of the concrete being placed.

a lower density than concrete and need to be secured from migrating up during concrete placement.

- Wire reinforcement supports that are zinc-coated (galvanized), coated with electrically insulating material, or made of electrically insulating material (including GFRP) to support GFRP reinforcement.
- Reinforcement and embedded steel items used with GFRP reinforcement shall be stainless steel, stainless steel clad, zinc-coated (galvanized), or coated with non-metallic materials.
- When precast concrete reinforcement supports with embedded steel tie wires or dowels are used with GFRP reinforcement, steel wires or dowels shall be zinc-coated (galvanized) or coated with electrically insulating material, or stainless steel.
- Reinforcement used as supports with GFRP reinforcing bars shall be coated with epoxy or another electrically insulating polymer, or made of GFRP.
- Tie wire shall be plastic- or polymer-coated wire.

6.6.4—Bending or Straightening

If the plans require bent GFRP reinforcing bars, the bends shall be incorporated during bar manufacturing. Field bending or straightening of GFRP reinforcing bars shall not be permitted.

For factory-formed bends, the minimum inside bend diameters shall conform to the requirements of Table 6.6.4-1. In addition, the beginning of the bend shall not be closer to the concrete surface than the minimum diameter of bend.

Table 6.6.4-1—Minimum ~~Diameter~~ *Radius* of Prefabricated GFRP Bends

Bar Size Designation	Minimum Inside Bend ~~Diameter~~ *Radius*
No. 2 through 8	3 bar diameters
No. 9 and 10	4 bar diameters

6.6.5—GFRP Reinforcement through Expansion Joints

Do not continue GFRP reinforcement or other embedded GFRP items bonded to concrete through expansion joints. GFRP dowels that extend through a joint or waterstop shall be unbonded or bonded to only one side of a joint or waterstop.

6.7—REPAIR OF GFRP REINFORCING BARS

Any damage to a GFRP reinforcing bar resulting in visible fibers (other than at cut ends) or any cut or defect greater than 0.04 in. deep shall be cause for rejection of the bar. All visible damage to the GFRP reinforcing bars exceeding 2 percent of surface area per foot of bar and not resulting in rejection by the Design Professional shall be