
Dear Customer,

Due to an error found after publication had been completed, AASHTO has made the following erratum change to the AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete, Second Edition (GFRP-2B):

<table>
<thead>
<tr>
<th>Page Number</th>
<th>Affected Article</th>
<th>Errata Change To</th>
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<tbody>
<tr>
<td>2-12</td>
<td>Figure C2.5.5.2-1</td>
<td>One value of ( \phi ) was incorrectly given as 0.70 and has been replaced with the correct value, 0.75.</td>
</tr>
</tbody>
</table>

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.

We apologize for any inconvenience this may have caused.

AASHTO Publications Staff
July 2019
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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, \( \phi \), shall be taken as:

- For compression-controlled and tension-controlled reinforced concrete sections as specified in Article 2.6.3:
  \[
  \phi = \begin{cases} 
  0.55 & \text{for } \varepsilon_f = \varepsilon_{fu} \\
  1.55 - \frac{\varepsilon_f}{\varepsilon_{fu}} & \text{for } 0.80\varepsilon_{fu} < \varepsilon_f < \varepsilon_{fu} \\
  0.75 & \text{for } \varepsilon_f \leq 0.80\varepsilon_{fu}
  \end{cases} 
  \] (2.5.5.2-1)

where:

- \( \varepsilon_{fu} \) = design tensile strain of GFRP reinforcing bars (Eq. 2.4.2.1-1)
- \( \varepsilon_f \) = tensile strain in extreme tension GFRP at nominal resistance

- For shear and torsion
  \( \phi = 0.75 \)

- For compression-controlled sections with spirals or ties, as specified in Article 2.6.4
  \( \phi = 0.75 \)

- For bearing on concrete
  \( \phi = 0.70 \)

- For compression in strut-and-tie models
  \( \phi = 0.70 \)

- For tension in strut-and-tie models
  \( \phi = 0.55 \)

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 \( \phi \) 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 \( \phi \) 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 \( \phi \), 0.55 and 0.75, a section controlled by concrete crushing is defined as a section in which \( \varepsilon_{fu} \leq 0.80\varepsilon_{fu} \), and a section controlled by GFRP rupture is defined as one in which \( \varepsilon_{fu} = \varepsilon_{fu} \). 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.
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.

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.