Eqs. 5.8.3.5-1 and 5.8.3.5-2 shall be taken to apply to sections not subjected to torsion. Any lack of full development shall be accounted for.

Longitudinal or transverse reinforcing steel, or a combination thereof, with specified minimum yield strengths up to 100 ksi, may be used in elements and connections specified in Article 5.4.3.3.

over the transfer and development length of Article 5.11.4.2 may be assumed.

This provision allows the use of longitudinal and transverse reinforcing steel with specified minimum yield strengths up to 100 ksi for elements and connections specified in Article 5.4.3.3; however, the use of higher strength longitudinal reinforcing steel may not be practical due to longer required development lengths.

5.8.3.6—Sections Subjected to Combined Shear and Torsion

5.8.3.6.1—Transverse Reinforcement

The transverse reinforcement shall not be less than the sum of that required for shear, as specified in Article 5.8.3.3, and for the concurrent torsion, as specified in Articles 5.8.2.1 and 5.8.3.6.2.

C5.8.3.6.1

The shear stresses due to torsion and shear will add on one side of the section and offset on the other side. The transverse reinforcement is designed for the side where the effects are additive.

Usually the loading that causes the highest torsion differs from the loading that causes the highest shear. Although it is sometimes convenient to design for the highest torsion combined with the highest shear, it is only necessary to design for the highest shear and its concurrent torsion, and the highest torsion and its concurrent shear.

5.8.3.6.2—Torsional Resistance

The nominal torsional resistance shall be taken as:

$$T_n = \frac{2A_o A_t f_y \cot\theta}{s} \tag{5.8.3.6.2-1}$$

where:

A_o = area enclosed by the shear flow path, including any area of holes therein (in.^{2})

A_t = area of one leg of closed transverse torsion reinforcement in solid members, or total area of transverse torsion reinforcement in the exterior web of cellular members (in.^{2})

θ = angle of crack as determined in accordance with the provisions of Article 5.8.3.4 with the modifications to the expressions for v and V_u herein (degrees)

5.8.3.6.3—Longitudinal Reinforcement

The provisions of Article 5.8.3.5 shall apply as amended, herein, to include torsion.

The longitudinal reinforcement in solid sections shall be proportioned to satisfy Eq. 5.8.3.6.3-1:

C5.8.3.6.3

To account for the fact that on one side of the section the torsional and shear stresses oppose each other, the equivalent tension used in the design equation is taken as the square root of the sum of the squares of the individually calculated tensions in the web.

Torsion addressed in this Article, St. Venant's Torsion, causes an axial tensile force. In a nonprestressed beam, this force is resisted by

$$A_{ps} f_{ps} + A_s f_y \geq \frac{|M_u|}{\phi d_v} + \frac{0.5 N_u}{\phi} + \cot\theta \sqrt{\left(\left|\frac{V_u}{\phi} - V_p\right| - 0.5 V_s\right)^2 + \left(\frac{0.45 p_h T_u}{2 A_o \phi}\right)^2} \quad (5.8.3.6.3\text{-}1)$$

In box sections, longitudinal reinforcement for torsion, in addition to that required for flexure, shall not be less than:

$$A_\ell = \frac{T_n p_h}{2 A_o f_y} \quad (5.8.3.6.3\text{-}2)$$

$$T_n = \frac{2Ao(Al*fy+Aps*fps)}{ph \text{ Cot}(\theta)}$$

where:

p_h = perimeter of the centerline of the transverse reinforcement located in the outer-most webs and the top and bottom slabs of the box girder (in.)

A_ℓ shall be distributed around the outer-most webs and top and bottom slabs of the box girder.

longitudinal reinforcement having an axial tensile strength of $A_\ell f_y$. This steel is in addition to the flexural reinforcement and is to be distributed uniformly around the perimeter so that the resultant acts along the axis of the member. In a prestressed beam, the same approach (providing additional reinforcing bars with strength $A_\ell f_y$) can be followed, or the longitudinal torsion reinforcement can be comprised of normal reinforcing bars and any portion of the longitudinal prestressing steel in excess of that required for cross-sectional flexural resistance at the strength limit states.

For box girder construction, interior webs should not be considered in the calculation of the longitudinal torsion reinforcing required by this Article. The values of p_h and A_ℓ should be for the box shape defined by the outer-most webs and the top and bottom slabs of the box girder. Warping torsion is known to exist in cross-section *d* shown in Table 4.6.2.2.1-1 but many structures of this type have performed successfully without consideration of warping.

The longitudinal tension due to torsion may be considered to be offset in part by compression at a cross-section resulting from longitudinal flexure, allowing a reduction in the longitudinal torsion steel in longitudinally compressed portions of the cross-section at strength limit states.

5.8.4—Interface Shear Transfer—Shear Friction

5.8.4.1—General

Interface shear transfer shall be considered across a given plane at:

- An existing or potential crack,
- An interface between dissimilar materials,
- An interface between two concretes cast at different times, or
- The interface between different elements of the cross-section.

C5.8.4.1

Shear displacement along an interface plane may be resisted by cohesion, aggregate interlock, and shear-friction developed by the force in the reinforcement crossing the plane of the interface. Roughness of the shear plane causes interface separation in a direction perpendicular to the interface plane. This separation induces tension in the reinforcement balanced by compressive stresses on the interface surfaces.

Adequate shear transfer reinforcement must be provided perpendicular to the vertical planes of web/flange interfaces in box girders to transfer flange longitudinal forces at the strength limit state. The factored design force for the interface reinforcement is calculated to account for the interface shear force, ΔF, as shown in Figure C5.8.4.1-1, as well as any localized shear effects due to the prestressing force anchorages at the section.