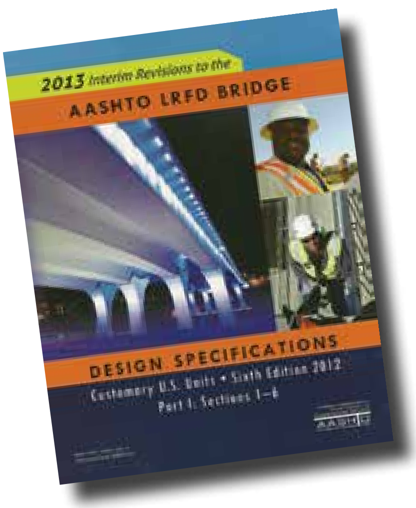
AASHTO LRFD

Sectional Design Model: Maximum or Concurrent Force Effects?

by Dr. Dennis R. Mertz



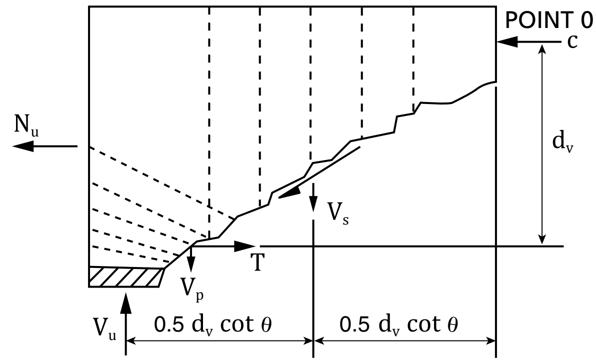
Since the discussion in the Fall 2013 issue of *ASPIRE*™ regarding how cracked concrete carries shear, readers raised questions about the application of several equations in Article 5.8.3, Sectional Design Model, of the AASHTO *LRFD Bridge Design Specifications*. In several equations, the variables M_u and V_u appear along with N_u and in one case T_u. Are these concurrent values, maximum values, or what?

Applying the modified-compression field theory model, the net longitudinal tensile strain in the section at the centroid of the tension reinforcement, ε_s, is estimated using *LRFD Specifications* Equation 5.8.3.4.2-4, shown below. This strain is then used to determine β, the factor indicating the ability of diagonally cracked concrete to transmit torsion and shear, and θ, the angle of inclination of the diagonal compressive stresses.

$$\varepsilon_s = \frac{\left(\dfrac{|M_u|}{d_v} + 0.5N_u + |V_u - V_p| - A_{ps}f_{po}\right)}{E_sA_s + E_pA_{ps}}$$

The variables, β and θ, and their influence on shear resistance, are discussed in the Fall 2013 issue. Equation 5.8.3.4.2-4 includes M_u and V_u along with N_u.

For all the section design models, in determining the required longitudinal reinforcement due to the interaction of the force effects, the variables M_u and V_u appear again along with N_u and in one case T_u. This interaction is illustrated in the free-body diagram, adapted from the *LRFD Specifications*, shown above.



Summing moments about point 0 in the figure as detailed in *LRFD Specifications* Article C5.8.3.5, yields Equation 5.8.3.5-1, shown below, as used for sections not subject to torsion.

$$A_{ps}f_{ps} + A_sf_y \geq \frac{|M_u|}{d_v\phi_f} + 0.5\frac{N_u}{\phi_c} + \left(\left|\frac{V_u}{\phi_v} - V_p\right| - 0.5V_s\right)\cot\theta$$

For sections subject to combined shear and torsion, Equation 5.8.3.6.3-1, shown below, is used.

$$A_{ps}f_{ps} + A_sf_y \geq \frac{|M_u|}{\phi d_v} + \frac{0.5N_u}{\phi} + \cot\theta\sqrt{\left(\left|\frac{V_u}{\phi} - V_p\right| - 0.5V_s\right)^2 + \left(\frac{0.45p_hT_u}{2A_o\phi}\right)^2}$$

The three equations discussed here represent a single point in time, as shown in the free-body diagram. Thus, the force effects should be concurrent values due to a common load condition. In general, when checking shear, the maximum shear is used with the other concurrent force effects; when checking moment, the maximum moment is used with the other concurrent force effects. Theoretically, at each section, each of the maximum force effects should be checked with its other concurrent forces though this is not typically done.

Equation 5.8.3.4.2-4, for ε_s, is applied at sections along the beam (typically 1/10th points) to determine the shear resistance of each section. For each section, the maximum shear and the other concurrent force effects at that section are used in the equation.

Equations 5.8.3.5-1 and 5.8.3.6.3-1, for the required longitudinal reinforcement, are again applied for sections along the beam to determine the required reinforcement at each section. Again, for each section, the maximum shear and the other concurrent force effects at that section determine the required longitudinal reinforcement.

The various strength limit-state force effects (in other words, the sum of the factored force effects from the governing strength limit-state load combination), M_u, V_u, N_u, and T_u, in the LRFD equations, do not represent the maximums for the section due to different load conditions. They represent the maximum force effect under consideration along with the other concurrent values for the single governing load condition at each section.

EDITOR'S NOTE

If you would like to have a specific provision of the AASHTO LRFD Bridge Design Specifications *explained in this series of articles, please contact us at www.aspirebridge.org.*