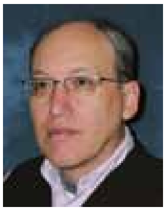
Longitudinal Reinforcement to Resist Shear



by Dr. Dennis R. Mertz

With the acknowledgement of the modified compression-field theory as a sectional resistance model for concrete members, it was realized that a certain amount of longitudinal reinforcement is required to develop the shear resistance. Article 5.8.3.5—Longitudinal Reinforcement of the *AASHTO LRFD Bridge Design Specifications* requires sufficient longitudinal reinforcement on the tension side of the member to preserve equilibrium as shown schematically in Fig. C5.8.3.5-1 of the commentary.

Any reinforcement on the tension side of the member may be considered to resist this longitudinal tension force: prestressed or nonprestressed reinforcement as suggested in Eq. 5.8.3.5-1 of the LRFD Specifications, which is reproduced here:

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

Equation 5.8.3.5-1 is derived taking a free-body diagram of the diagonally cracked section and summing moments about the resultant of the concrete compression force as shown in Fig. C5.8.3.5-1 of the LRFD Specifications.

Thus, the amount of longitudinal prestressed and nonprestressed reinforcement required (A_{ps} + A_s) is a function of the applied moment (M_u), applied axial load (N_u), and applied shear (V_u) force effects. The amount of steel required is also a function of the nominal shear resistance provided by transverse reinforcement (V_s) and the angle of inclination of the compressive stresses (θ) from the shear resistance determination. The required longitudinal reinforcement increases as the angle of inclination of the compressive stresses (θ) decreases and as the nominal shear resistance provided by tensile stresses in the concrete (V_c) increases. For a more complete explanation of the terms of the equation, see Article 5.8.3.5 of the LRFD Specifications.

This provision does not necessarily require additional reinforcement above that typically included to resist the other force effects. In cases where more reinforcement is provided than absolutely necessary—for example, where strands are added to yield a symmetrical strand pattern—the requirement may be easily satisfied. Also, as previously stated, all reinforcement on the tension side of the member can be counted upon for this resistance. Therefore, in prestressed concrete members, nonprestressed reinforcement not typically included in the moment resistance (such as steel used to form the reinforcement cage), can be considered for this provision, if necessary. However, the longitudinal reinforcement must be developed fully to consider it fully. If not, the tensile resistance must be reduced by assuming a linear variation over the development length for nonprestressed reinforcement or a bi-linear variation over the transfer and development length for prestressing steel. This situation is more likely to occur at the inside edge of the bearing area.

If the longitudinal reinforcement requirement of Eq. 5.8.3.5-1 cannot be satisfied by the developed steel on the tension side of the member, either additional transverse reinforcement or additional longitudinal reinforcement must be provided.

For load and resistance factor rating, Article 6A.5.8, Evaluation for Shear, of the *AASHTO Manual for Bridge Evaluation* specifies that sufficient longitudinal reinforcement must be present or some of the calculated nominal shear resistance must be discounted. A

Annual Survey

Each year, the AASHTO Highway Subcommittee on Bridges and Structures conducts a survey of the state bridge engineers to collect information on their bridge-engineering practices. Originally conceived to collect LRFD implementation information, the survey has evolved into more general topics and issues. Take a look at the latest survey and those over the past years at http://bridges.transportation.org/Pages/FAQ.aspx.

This year's questions identified the number of states that accept electronic submittals of shop drawings; have identified complex bridges; use Load and Resistance Factored Rating method for new bridges, existing bridges, and the overweight permit process; use elastomeric bearings; use different axle loads for design of concrete decks on longitudinal girders; and use life-cycle cost analysis.

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.