4. STRUCTURAL ANALYSIS AND EVALUATION

The analysis of bridges and structures is a mixture of science and engineering judgement. In most cases, simple models with conservative assumptions can be used to arrive at the design forces for various elements. For example, for straight beam bridges with small skews, beam line models with approximate distribution factors can be used to arrive at the design moments, shears and reactions. For more complex structures or for situations where refinement offers significant benefits, a more refined analysis (e.g., grid or 3-D) may be justified. Situations where this might be appropriate include, curved bridges, bridges with large skews, or when evaluating the critical element of a bridge with marginal live load capacity.

In all but the most complex bridges, time-dependent behavior will not be modeled. The impacts of creep, shrinkage, and relaxation will be accounted for by using code prescribed equations for these effects.

Satisfying force equilibrium and identifying a load path to adequately transfer the loads to the foundations is the primary analysis goal for designers.

The remainder of this section contains guidance on a variety of topics. Topics include load distribution, load rating, and LRFD exceptions.

4.1 Load Distribution [4.6.2]

The LRFD Specifications encourage the use of either refined or approximate methods of analysis. An approximate method of analysis can be utilized to determine the lateral live-load distribution to individual girders for typical highway bridges. Lateral live-load distribution factors are dependent on multiple characteristics of each bridge. There are specific ranges of applicability for the use of approximate methods of analysis. Extending the application of such approximate methods beyond the limits requires sound and reasonable judgement. Otherwise refined analytical methods should be used.

4.1.1 Dead Load Distribution

Deck, Future Wearing Surface, Railing, Barriers, and Medians

For beam bridges the dead load of the deck is distributed to the beams based on their respective tributary widths. Superimposed dead loads (future wearing surface, railings, barriers, and medians) are to be distributed equally to all beam lines.

For concrete slab bridges (reinforced or post-tensioned) the weight of the barrier loads shall be distributed to the edge strip. For design of the interior strip, the weight of the barriers shall be distributed across the entire width of the slab and combined with other superimposed dead loads.

Miscellaneous Loads - Conduits, Sign Structure,etc.

Conduit loads supported by hangers attached to the deck and sign structure loads shall be distributed equally to all beams.

4.1.2 Live Load Distribution

Equations and tables for live load distribution factors are provided in the LRFD Specifications. For typical beam bridges distribution factors are provided for: Interior beam flexure (single lane, multiple lanes, and fatigue), Interior beam shear (single lane, multiple lanes, and fatigue). The lever rule and distribution formulas shall be used to determine the amount of live load carried by the exterior beam. LRFD C4.6.2.2.2d provides a formula for computation of an additional distribution factor for bridges that have diaphragms or cross-frames. Use of the rigid cross-section or pile equation distribution factor is not required for design of exterior beams.

4.1.2.1 Steel and Prestressed Concrete Beams

Unlike the Standard Specifications, the live load distribution factors for beam bridges are dependent on the stiffness of the components that make up the cross section [LRFD Equation 4.6.2.2.1-1]. Theoretically, the distribution factor changes for each change in cross section. However, this is more refinement than necessary. For simple span structures a single live load distribution factor (computed at midspan) may be used. For continuous structures a single distribution factor may be used for each positive moment region and for each negative moment region. For bridges with consistent geometry (same number of beam lines in each span, etc.) the largest positive moment distribution factor may be used for all positive moment locations. Similarly, the largest negative moment distribution factor may be used for all negative moment regions.

For skewed superstructures, LLDF for end shear throughout the length of the girder shall be used.

4.1.2.2 Slab Spans and Timber Decks [4.6.2.3]

Concrete slabs and timber decks shall be designed using a one-foot wide longitudinal strip. The LRFD Specifications provide equations for distribution factors that result in equivalent strip widths, E, that are assumed to carry one lane of traffic. The equivalent strip width to a live load distribution factor shall be converted for the unit strip by taking the reciprocal of the width. LLDF = 1/E

4.1.3 Sidewalk Pedestrian Live Load [3.6.1.6]

Unlike the Standard Specifications, no reduction in sidewalk pedestrian live load intensity based on span length and sidewalk width is provided in the LRFD Specifications.

The vehicular live load shall be placed on the sidewalk and in adjacent traffic lanes with no pedestrian live load on the sidewalk.

4.1.4 Pedestrian Bridge Live Load

Note that bridges designed for only bicycle or pedestrian traffic use a slightly higher pedestrian live load (0.085 ksf).

4.2 LRFD Exceptions

The LRFD Specifications are comprehensive. In addition to an updated design methodology, the new specifications also include information that has not been included in the Standard Specifications. For example, the LRFD Specifications contain guidance for vessel impact loads that previously were contained in the *Guide Specification and Commentary for Vessel Collision Design of Highway Bridges*. However, not all AASHTO design guidance has been incorporated in the LRFD Specifications. A few special topics have not yet been incorporated into the new specification. Information on these topics is given below.

4.2.1 Curved Bridges

The commentary to Article 1.1 of the LRFD Specifications states that curved girder bridges are not covered and were not part of the calibration database used in assembling the specifications. The definition of what constitutes a curved bridge is not presented in the LRFD Code. This can be found in the scope section of the 2002 AASHTO Document *Guide Specifications for Horizontally Curved Highway Bridges.* When computing primary bending moments for structures, with the characteristics detailed in Table 1.4a of the Guide Specification, curvature effects shall be ignored.

4.2.2 Railroad Bridges & Bridges or Structures Near Railroads

Railroad bridges are to be designed according to the most current American Railway Engineering and Maintenance-of-Way Association (AREMA) Specifications.

Designers should be aware that railroads may have specific criteria for structural design of items carrying their tracks or in the vicinity of their tracks. Design criteria varies from railroad to railroad.