SECTION 4
STRUCTURAL ANALYSIS AND EVALUATION

4.1 GENERAL REQUIREMENTS

Section 4 discusses the preferred methods of structural analysis, design, and evaluation of bridges. The section is limited to the modeling of structures and the determination of member stresses, forces, and deformations. The primary analysis goals for the Designer are to satisfy force equilibrium and to identify a load path to adequately transfer the loads to the foundations.

Bridges are to be analyzed in accordance with AASHTO 4.5.2.2, except for extreme limit states or with approval from Unit Leader in coordination with the State Bridge Engineer.

In most cases, the Designer should use simple models using distribution equations from AASHTO and reasonable assumptions. Complex structures may require refined analysis, but refinement should not be used unless necessary. Any cost savings realized by refined analysis may be negated by the additional efforts needed for the independent design check and the rating. Each bridge design must consider the need for a satisfactory bridge rating, further supporting the need for simpler, more straightforward calculations versus refined analysis.

4.2 CODE REQUIREMENTS

AASHTO lists multiple acceptable methods of analysis options, allowing the Designer to choose their preference. Staff Bridge does not require, prefer, or forbid any specific method. The Designer must be knowledgeable about the design specifics and the analysis parameters of the chosen approach.

The Designer must validate all computer software before it is implemented into the design. Using a software program does not relieve the Designer of the responsibility to properly apply and interpret results. Staff Bridge does not support a preapproved list of software but reserves the right to disallow any software on a regular or case-by-case basis. A list of specialized software shall be noted in the Structures Selection report and shall be approved by the Unit Leader in coordination with the Software SMEs.

4.3 MODELING METHODS

AASHTO allows the contribution of continuous composite barriers in service and fatigue limit states for the calculation of the structural cross section of the exterior girder. Staff Bridge's preference is not to use the composite section for new designs, but these sections may be considered in the evaluation or design for rehabilitation. The Designer should not consider continuous composite barriers in section properties without approval from Unit Leader in coordination with the Bridge Rail SMEs.

Uplift at bearings is not allowed unless approval is obtained from Unit Leader. Hold downs or anchorages are required if uplift is permitted in the design. There may be additional requirements for bearings when uplift is permitted, as outlined in Section 14 of this BDM.

Calculations are to follow a clear and detailed process. Spreadsheets should show all equations, assumptions, design parameters, and references. When modeling integral abutments, the Designer is to model the connection between the superstructure and the substructure as a pin connection. The reason for this is that integral abutments are not intended to transfer moment from superstructure to substructure. Modeling the connection this way prevents moment from being transferred into the substructure elements and eliminates the need for negative moment design at the deck level.

Time-dependent material effects shall be modeled as outlined in Section 5 of this BDM. Using code prescribed equations for these effects will account for the impacts of creep, shrinkage, and relaxation.

Redistribution of moments in continuous bridges is allowed.

Unit Leader must review and approve non-standard resistance factors for unique materials prior to implementation.

Staff Bridge allows the use of cracked section properties in the analysis of both superstructure and substructure. The Designer should be aware that in some situations the use of 0.5 value for γ_{TU}, γ_{CR}, and γ_{SH} load factors no longer applies in conjunction with cracked section properties. ***AASHTO 3.4.1***

When using moment magnification, the calculations shall follow AASHTO. ***AASHTO 4.5.3.2.2***

4.4 DEAD LOAD DISTRIBUTION

Non-composite dead load should be distributed to the girders based on tributary width for straight bridges. Non-composite dead load on curved I-girders may be distributed uniformly to all girders, as long as intermediate diaphragms or cross frames are provided and have been designed as primary members per AASHTO. CDOT allows composite dead loads to be distributed evenly to all girders; however, the Designer must use engineering judgment in determining the distribution of heavier concentrated line loads such as utilities, parapets, sidewalks, barriers, etc. ***AASHTO C4.6.1.2.4b***

4.5 LIVE LOAD DISTRIBUTION

Theoretically, live load distribution factors (LLDF) change for each variance in the cross section; this could result in more refinement than necessary. The Designer must decide how often to calculate the LLDF along the span. All LLDF used in the design must be included in the Bridge Load Rating Package, developed in accordance with the CDOT Bridge Rating Manual.

AASTHO Table 4.6.2.2.1-3 provides simplified values to be substituted when calculating the LLDF in corresponding tables in AASHTO 4.6.2.2. The State Bridge Engineer has approved Table 4.6.2.2.1-3 for use to simplify calculations. ***AASHTO 4.6.2.2***

When calculating LLDF, a refined analysis may be required whenever a variable falls outside the “Range of Applicability” as provided in the various LLDF tables of AASHTO. Approval from Unit Leader may be obtained to waive the need for the refined analysis if the value of the parameter is close to the ***AASHTO 4.6.2.2.1*** limit provided in the LLDF tables. Lever Rule may be used as a conservative alternative.

LLDFs for culverts and three-sided boxes shall be calculated as outlined in Section 12, Buried Structures and Tunnel Liners, of this BDM.

The use of our 5" minimum deck over side by side girders allows the designer to utilize the distribution factors based on F type (AASHTO Table 4.6.2.2.1-1) girder arrangements per AASHTO 5.12.2.3.3(f). For normal traffic bridges utilizing adjacent box girders, shear keys shall not be used.

4.5.1 Exterior Girder Live Load Distribution

The LLDF of specific multi-girder cross sections reported in AASHTO were calculated without consideration of interior diaphragms or cross frames within spans, or the effects of those members on the exterior girders. AASHTO Equation C4.6.2.2.2d-1 shall be checked for exterior girders when rigid cross frames are present between girders that would cause the entire superstructure to behave as a rigid body.

AASHTO C4.6.2.2.2d

4.6 SKEW EFFECTS ON BRIDGES

Staff Bridge prefers bridge skews less than 50 degrees. Bridges with large skew angles can produce differential deflection between adjacent girders and unpredictable transfer of load from interior girders to exterior girders. Simple analysis will not be enough to correctly calculate deflection and load based on diaphragm and deck stiffness variations; therefore, Staff Bridge prefers a refined analysis to correctly model the effects of the large skew angles. AASHTO provides correction factors for LLDF for shear; care must be taken to not apply adjusted factors manually when software models the skewed supports and makes adjustments automatically. Refer to Figure 4-1 for the definition of skew angles.

AASHTO 4.6.2.2.3c

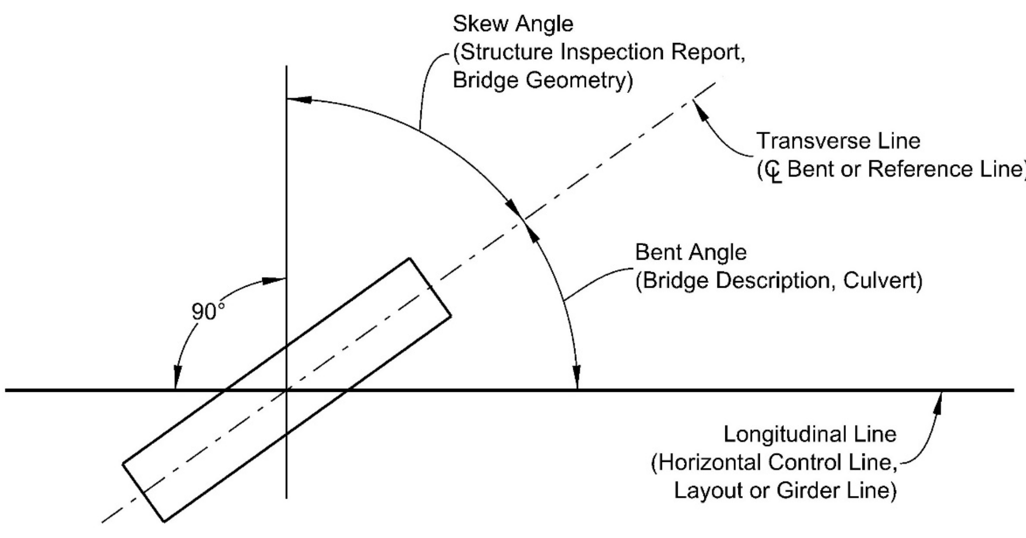

Figure 4-1: Skew Angle Definition

4.7 FOUNDATION STIFFNESS AND SOIL-PILE INTERACTION

AASHTO 4.5.4

The following guidelines supplement the general information given in AASHTO regarding modeling foundation boundary conditions.

For non-complex bridges with a length of 300 ft. or less that do not require a seismic analysis, Designers may use an assumed depth to fixity method to model pile and drilled shafts for lateral foundation analysis. In this case, the length used for determining lateral force effects, un-braced length, beam-column buckling analysis, and field welding requirements (BDM Section 10.5.3), may be based on engineering judgment founded on successful past practice.

For complex bridges, such as curved, highly skewed, and where an individual substructure stiffness varies significantly from the group, any bridge over 300 ft, or bridges that require a seismic analysis, CDOT prefers that Designers account for foundation stiffness in a more refined manner. This may be accomplished with the use of direct soil springs, equivalent spring constants, or equivalent depth to fixity calibrated with a soil/structure interaction analysis.