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Design Challenges for Severely Skewed Steel Bridges

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Abstract : There is an increasing need for medium- to long-span steel bridges with complex geometry due to site restrictions in developed areas. One of the solutions to grade separations in congested areas is to use longer spans on skewed supports that avoid at-grade obstructions limiting impacts to the foundation. Where vertical clearances are also a constraint, continuous steel girders can be used to reduce superstructure depths. Combining continuous long steel spans on severe skews can resolve the constraints at a cost. The behavior of skewed girders is challenging to analyze and design with subsequent complexity during fabrication and construction. As a part of a corridor improvement project, Walter P Moore designed two 1700-foot side-by-side bridges carrying four lanes of traffic in each direction over a railroad track. The bridges consist of prestressed concrete girder approach spans and three-span continuous steel plate girder units. The roadway design added complex geometry to the bridge with horizontal and vertical curves combined with superelevation transitions within the plate girder units. The substructure at the steel units was skewed approximately 56 degrees to satisfy the existing railroad right-of-way requirements. A horizontal point of curvature (PC) near the end of the steel units required the use flared girders and chorded slab edges. Due to the flared girder geometry, the cross-frame spacing in each bay is unique. Staggered cross frames were provided based on AASHTO LRFD and NCHRP guidelines for high skew steel bridges. Skewed steel bridges develop significant forces in the cross frames and rotation in the girder websdue to differential displacements along the girders under dead and live loads. In addition, under thermal loads, skewed steel bridges expand and contract not along the alignment parallel to the girders but along the diagonal connecting the acute corners, resulting in horizontal displacement both along and perpendicular to the girders. AASHTO LRFD recommends a 95 degree Fahrenheit temperature differential for the design of joints and bearings. The live load and the thermal loads resulted in significant horizontal forces and rotations in the bearings that necessitated the use of HLMR bearings. A unique bearing layout was selected to minimize the effect of thermal forces. The span length, width, skew, and roadway geometry at the bridges also required modular bridge joint systems (MBJS) with inverted-T bent caps to accommodate movement in the steel units. 2D and 3D finite element analysis models were developed to accurately determine the forces and rotations in the girders, cross frames, and bearings and to estimate thermal displacements at the joints. This paper covers the decision-making process for developing the framing plan, bearing configurations, joint type, and analysis models involved in the design of the high-skew three-span continuous steel plate girder bridges.

Keywords : complex geometry, continuous steel plate girders, finite element structural analysis, high skew, HLMR bearings, modular joint
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