Rigid Frame Bridges

Ranked by bridge historian David Plowden as a key reinforced concrete bridge engineering advance of the twentieth century, comparable to the later development of prestressed concrete, the rigid frame bridge was pioneered by German engineers and the Brazilian Emilia Baumgart. According to Plowden, it was introduced to the United States primarily through Westchester County engineer Arthur G. Hayden's Swain Street Undercrossing, the first of many short-span rigid frame bridges Hayden built for the Bronx Parkway Commission in 1922-1923 (Plowden 1974:321).

Unlike other reinforced concrete spans, in which the superstructure and the substructure were not designed as a continuous unit, the rigid frame bridge as built by Hayden and his associates was a continuous structure "from footing to handrail" (as the *Engineering News-Record* editorialized in April 1926) (Hayden 1926). An instructive 1933 booklet prepared by the Portland Cement Association noted that in a rigid frame structure, "the bearing is replaced with concrete that continues monolithically from the abutments into the deck, [so that] the altered structure becomes a frame with rigid corners." Observing that "it is generally simpler and more economical to build a concrete bridge continuous than otherwise," the Association also found that "the moments are small in the sections near the center of the deck of the rigid frame bridge compared with the corresponding moments in a simply supported deck of the same span length." The result was that "frame sections can be reduced and the bridge floor made exceptionally shallow at the center of the span" (Figure 20).

The Portland Cement Association declared in their 1933 *Analysis of Rigid Frame Concrete Bridges* that because the rigid frame structure could be built with a shallow section, "substantial reductions are obtained in volume of embankment fill or excavation, and in area of land required for the approaches." Maintenance expense was also advantageous because the rigid frame bridge was a monolith, in which "the various details where the deck bears on the abutments are eliminated." The Association declared that rigid frame reinforced concrete highway bridges with solid decks were economical up to a span length of about 70 feet, while for longer spans "the ribbed deck construction is preferred on account of its lightness" (Portland Cement Association 1933:4). As of September 1933, the longest rigid frame concrete span in the world was the 224-foot main span of the Herval bridge in Brazil.

PLATE 15: **Typical Concrete Multiple-Span Beam Bridge: Bridge Crossing Railroad Tracks at Fallston**

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1930)

During the early 1930s, rigid frame bridge design and analysis was the subject of specialized treatises such as Arthur Hayden's *The Rigid-Frame Bridge* (1931) and Hardy Cross's and Newlin Dolbey Morgan's *Continuous Frames of Reinforced Concrete* (1932). These texts stressed the fact that the supporting members in a rigid frame bridge provided flexure and worked as a unit with the superstructure, while such members in the non-rigid frame structure simply carried a deck at a certain desirable clearance above a roadway or watercourse. Victor Brown and Carleton Conner in their 1931 work *Low Cost Roads and Bridges* observed that "rigid frame bridges constructed of concrete possess great inherent strength and rigidity which insure their safety;" from the nature of their construction, "any overloading of one part of the bridge simply causes the stresses to be transferred to other parts until a balance is obtained" (Brown and Connor 1933:156).

By 1939, the authoritative Taylor, Thompson, and Smulski text *Reinforced-Concrete Bridges* included "multi-span rigid frames in which the girders forming the superstructure are rigidly connected with elastic vertical supports" as one of four main choices available to the engineer designing a multiple span reinforced concrete girder bridge. The other options were "a number of simply supported girder spans, a combination of girders provided with cantilevers and short spans supported by these cantilevers," and "continuous girders supported by independent piers." Recommending the rigid frame design for use "where vertical supports of the bridge are elastic, as in viaducts," the authors enumerated several advantages of rigid frame bridges over simply supported girder spans: (1) rigid frame structures required less steel and concrete; (2) the center of the span could be much shallower; (3) fewer expansion joints were required; (4) deflection and vibration were considerably reduced; (5) no bearings were required at the supports, and; (6) "owing to rigid connections between the vertical supports and the horizontal members, the stability of the vertical supports in rigid frames is much greater than that of independent piers" (Taylor et al. 1939:150-151).

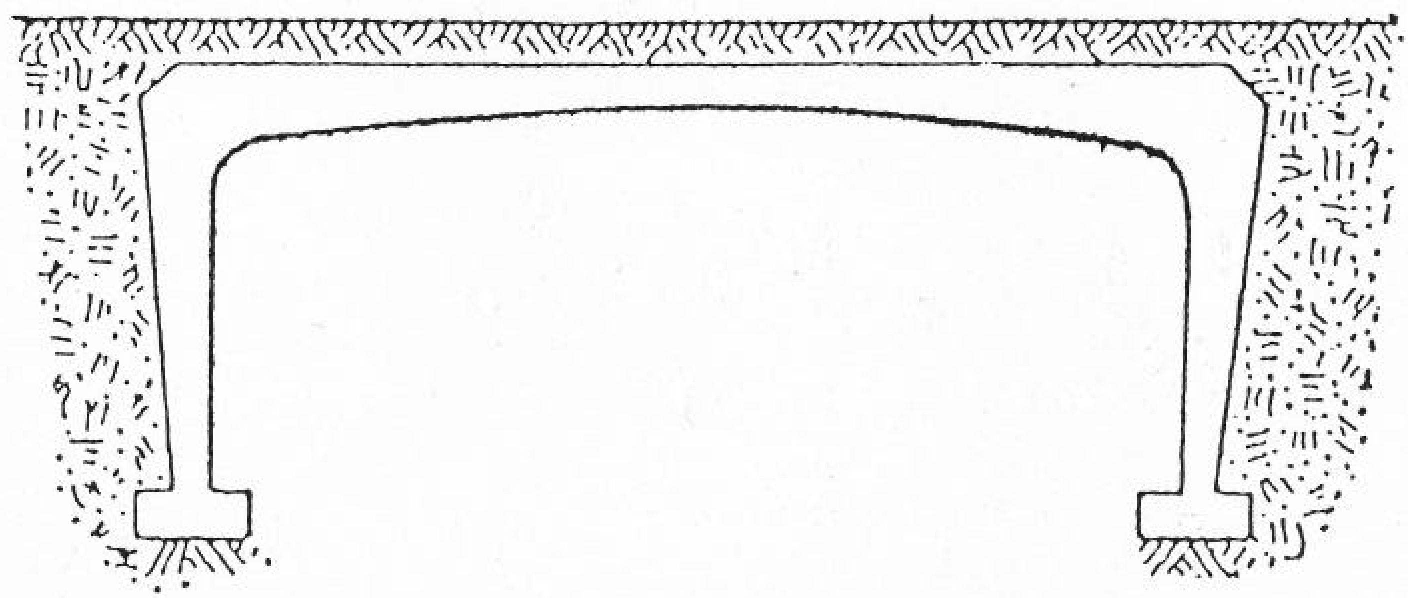

FIGURE 20: Concrete Rigid Frame Bridge Schematic

SOURCE: Cross and Morgan 1932

Taylor et al. also noted certain disadvantages of rigid frame bridges, including the following: (1) rigid frames were suitable only at sites where unyielding foundations could be ensured, for uneven settlement produced a "bad effect" on their strength; (2) placing of steel reinforcement in the concrete required considerable skill; (3) the sequence of concrete placement and removal of formwork was sometimes more complicated; and (4) design of rigid frame bridges was somewhat more complex because such structures were "statically indeterminate," and analysis was not as straightforward as in the case of statically determinate, simply supported spans. In the hands of a competent engineer, the authors asserted, these disadvantages disappeared (Taylor et al. 1939:150-151).