Thirty Years of Prestressed Concrete Railroad Bridges

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Traces the progress in prestressed concrete railroad bridges from simple short span structures built in the 1950s to the advanced designs and complex structures of the 1980s.

Engineers who design structures for railroads are often considered more conservative than those who design structures for highways or other facilities. Two explanations may be offered for this observation. First, railroad structures must sustain considerably greater loads than highway bridges or other structures. Also, because there are generally fewer opportunities for detours, rail traffic is likely to be disrupted significantly when a bridge is taken out of service for even a short time. Considering these factors, it is understandable that railroad bridge engineers are cautious about implementing untested or unproven structural techniques.

As far back as the Civil War, and before, railroad bridge engineers built bridges that might not be tried today (Fig. 1).[1] However, experience has shown that, given sufficient testing of a new concept, it will not be long before that concept is adopted by the railroad engineer.

While construction was commencing in 1950 on the Walnut Lane Bridge (the first major prestressed concrete bridge to be built in the United States), the Portland Cement Association in September of that year was load testing a prestressed concrete railway trestle slab in their research and development laboratories near Chicago, Illinois.

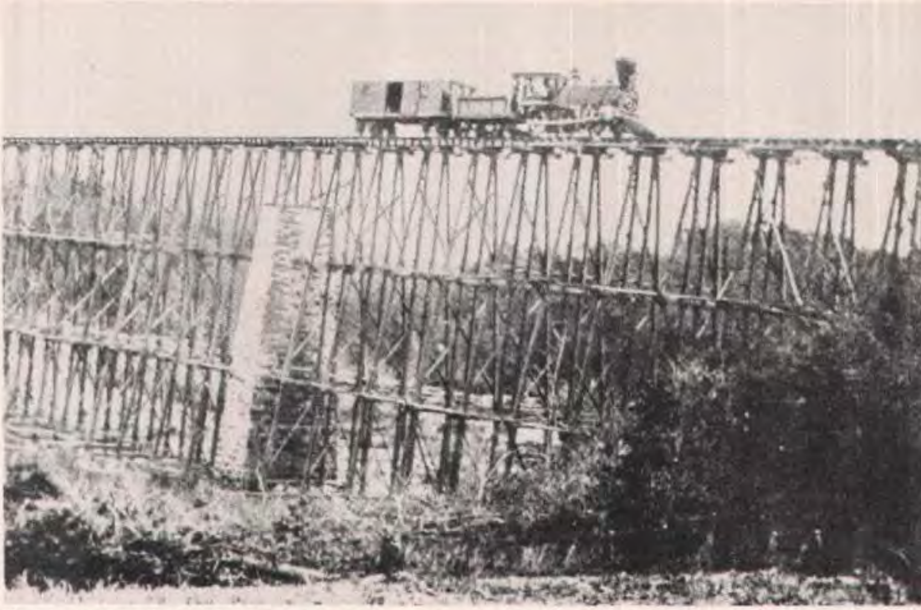

Fig. 1. Cedar Creek trestle, Raleigh and Gaston Railroad, North Carolina.

In October 1953, full scale load tests were made by the Association of American Railroads on a 19 ft (5.8 m) prestressed concrete trestle slab at the U.S. Bureau of Reclamation in Denver, Colorado. A summary of this research work is given in Refs. 2 and 3.

By March 1954, trains of the Chicago-Burlington & Quincy Railroad began operating near Hunnewell, Missouri, over the first prestressed concrete railroad bridge in the United States [Figs. 2 and 3(a)]. While only a modest 19 ft (5.8 m) long slab was used as part of a multispan structure, this slab represented another first for the prestressed concrete industry in the United States.

Between 1954 and 1957, railroad engineers took advantage of continued research by the Association of American Railroads and the experience of highway bridge engineers.[3,4] They designed and constructed still longer spans, using primarily slabs and boxes. The structures had waterproofing, ballast and track placed directly on the slab or box. This type of construction was particularly suited for replacement of existing timber trestles with minimum interruption to train operations.

Fig. 2. Bridge No. 38.64 on the CB&Q Railroad near Hunnewell, Missouri.

An excellent description (together with pertinent design details) of some of the prestressed railroad bridges built in the United States in the fifties is given in Ref. 5. Fig. 3 [(a) through (g)] shows typical sections of those early bridges.

The early prestressed concrete railroad structures were constructed in spans of 20 to 30 ft (6.1 to 9.1 m), matching existing timber spans. More often than not, these superstructures were supported on prestressed concrete piles driven through the existing track structure, with construction scheduled to minimize interruption of traffic.

The 703 ft (214 m) Salkehatchie River trestle in Yemassee, South Carolina [Fig. 4], was built by the Atlantic Coast Line as one of the first major prestressed concrete slab railroad trestles in the United States. It replaced a short steel span and a creosoted timber trestle. Further details of this structure appear in Ref. 5.

By 1957, the Santa Fe Railroad had completed two bridges with two 70 ft (21.3 m) spans at the Air Force Academy. Designed by Skidmore, Owings & Merrill of Chicago, Illinois, each of the 70 ft (21.3 m) spans contained four modified T-shaped girders post-tensioned with eleven 16 x 0.25 in. (6 mm) cables. Designed for Cooper's E-72 loading, each girder weighed 60 tons (54 t) [Figs. 5 and 3 (b)]. For more details see Ref. 5.

In 1959, the Great Southwest Railroad completed two structures with 67-ft (20.4 m) spans over the Dallas-Fort Worth Turnpike and State Expressway 360 in Arlington, Texas. Designed for Cooper's E-50 loading by Powell and Powell, Consulting Engineers, Dallas, Texas, each span consisted of six modified Type C Texas Highway Department girders. The girders were pretensioned with 44 $\frac{7}{16}$-in. (11 mm) strands and weighed 19.5 tons

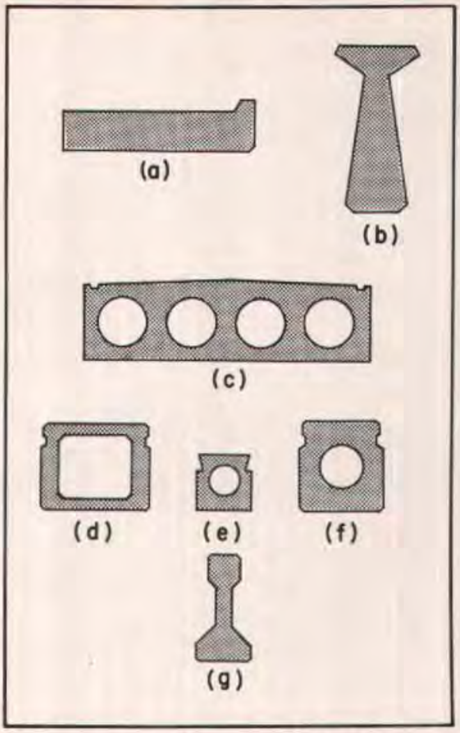

Fig. 3. Cross sections of various early railroad bridges: (a) Chicago, Burlington & Quincy Railroad; (b) Atchison, Topeka & Santa Fe Railway (Colorado); (c) Galveston Terminal Railroad; (d) Atchison, Topeka & Santa Fe Railway (California); (e) and (f) Chicago & North Western Railway; and (g) Great Southwest Railroad.

(18 t) each [Fig. 6 and 3(g)]. Ref. 5 provides more details of this structure.

In 1966, the Frisco Railway opened its third trestle using prestressed concrete box girders with the ties resting directly on the boxes.[6] The first trestle, built near Gattman, Mississippi, in December 1963, was a seven-span structure (Fig. 7) with a total length of 145 ft (44.2 m). It was designed for Cooper's E-65 loading with AREA diesel impact. The box girders are approximately 20 ft (6.1 m) long, 3 ft (0.9 m) wide, and 2 ft 9 in. (0.8 m) deep, and are prestressed

Fig. 4. Atlantic Coast Line's Salkehatchie River trestle in Yemassee, South Carolina.

Fig. 5. Santa Fe grade separation railroad crossing at the Air Force Academy, Colorado Springs, Colorado.

with 36 ⅜-in. (10 mm) 270 ksi (1062 MPa) strands. The two girders in each span are 5 ft (1.5 m) on center and are anchored to the piers at one end and free to move at the other. Installation of the deck required only about one hour per span. Four spans were changed one afternoon between trains and the remaining three the next morning (Fig. 8).[6]

The 1966 project, near Potts Camp, Mississippi, comprises 24 spans of trestle approaches to the Main Tippah River crossing. Most of these are 27 ft (8.2 m) spans designed for Cooper's E-80 loading with impact, and required 3 ft (0.9 m) wide by 3 ft 3 in. (1.0 m) deep box girders. The prestressing force was developed with 31 ½-in. (13 mm) diameter, 270 ksi (1062 MPa) strands.[6]

Fig. 6. Lifting into place a precast prestressed girder on the Great Southwest Railroad over the Dallas-Fort Worth Turnpike, Arlington, Texas.

Each pier is composed of three modified 22-in. (559 mm) PCI-AASHTO hollow-core square piles with cast-in-place reinforced concrete caps. The beams rest on neoprene bearing pads between precast concrete guide blocks attached to the pier cap by means of an epoxy adhesive.

Fig. 7. Frisco Railroad trestle, Gattman, Mississippi.

Fig. 8. Girder being placed on the Frisco Railroad trestle, Gattman, Mississippi.

In 1968, the Canadian Province of Saskatchewan constructed its first prestressed box girder railroad bridge for the Albert Street subway project in Regina. A four-span twin railway bridge designed by Reid, Crowther and Partners, Ltd., used boxes fabricated by Con Force Products, Ltd. (the forerunner of Genstar Structures Limited) which were 45 in. (1.1 m) deep by 48 in. (1.2 m) wide with a maximum span of 53 ft 2 in. (16.2 m). Fig. 9 shows the bridge under construction.

Fig. 9. Albert Street subway, Regina, Saskatchewan.

The girders were designed for Cooper's E-70 loading plus impact. The required prestress force was achieved with 42 ½-in. (13 mm) 270 ksi (1062 MPa) strands with the bridge being laterally post-tensioned with eight ½-in. (13 mm) strands per span. The final force for the post-tensioning was 25 kips (111 kN) per strand. Prairie West Construction Ltd., the general contractor, erected each bridge, excluding lateral post-tensioning, in two days.[7]

While not a railroad structure in the true sense, a precast prestressed tunnel provided a solution to constructing a four-lane divided highway over a curved railroad track, with a skew of more than 74 degrees, and at the same time provided flexibility for future expansion — with no disruption of railroad traffic (Fig. 10).[8]

Designed for the Connecticut Department of Transportation by Hayden, Harding & Buchanan, of Boston, Massachusetts, the tunnel was completed in 1970 by the general contractor, White Oak Corp., with Blakeslee Prestress providing the prestressed concrete. The total structure length, including wingwalls, is 800 ft (244 m). The center-to-center dimension between footings is 42 ft 6 in. (13 m) with a clear vertical height from top of track to underside of arch of 20 ft 4 in. (6.2 m).


Fig. 10. Precast railroad tunnel, Berlin, Connecticut.

The structure consists of 94 pairs of arch units, each approximately 6 ft (1.8 m) wide, 18 in. (457 mm) thick, and with a chord length of 35 ft 8 in. (10.9 m) along its centerline axis. Units on the outside of the curve were fabricated ⅝-in. (16 mm) longer than the inside units to compensate for the curvature effect.

Each section contains 12.5 cu yds (9.6 m^3) of concrete, 2500 lbs (1134 kg) of reinforcing bar cages, and three post-tensioning tendons. The sections were cast on their sides using two-part, custom-built forms with one side fixed and the other movable on rails.

The footings are considerably further apart than needed for tunnel clearances, allowing for installation without using sheeting or delaying train operations. The arch sections were also set without interfering with trains. Fig. 11 shows the tunnel under construction.

Fig. 11. Precast railroad tunnel, Berlin, Connecticut.

Fig. 12. Canadian Pacific Railroad, Regina, Saskatchewan, after completion.

Having seen the success of the previously constructed Albert Street subway prestressed concrete railroad bridge, in 1969 the City of Regina, Saskatchewan constructed a modified standard I-girder bridge[9] carrying the Canadian Pacific Railroad over a limited access road in the city with spans of 45, 63, 63, and 45 ft (13.7, 19.2, 19.2, and 13.7 m). Fig. 12 shows the bridge upon completion.

The bridge was designed for the city by Reid, Crowther & Partners Limited; Con Force Limited provided the girders to the general contractor, Poole Construction Limited, all of Regina.

The I-girders are similar to the standard AASHTO-PCI girder, but are really a Con Force Limited P-40 with the top and bottom flanges the same width (Fig. 13). Design loading on these bridges is Cooper's E-72 plus impact. The 44 ft 2 in. (13.5 m) girders used 12 ½-in. (13 mm) 270 ksi (1062

Fig. 13. Canadian Pacific Railroad, Regina, Saskatchewan, under construction.

Fig. 14. Pretensioned box girder being lifted into place on the Southern Pacific Railroad, Kyrene Bridge over New Superstition Freeway, Tempe, Arizona.

MPa) strands and the 63 ft (19.2 m) girders used 22 ½-in. (13 mm) 270 ksi (1062 MPa) strands of which 14 were straight and 8 draped.

A laminated neoprene and steel bearing, used at both ends of each girder, performed exceedingly well. A composite cast-in-place, 4000 psi (27.6 MPa) 8½-in. (216 mm) thick concrete deck was placed atop these girders, and No. 5 mild steel reinforcing bars were placed in both directions at middepth of the top slab. Diaphragms were placed on each girder at the bearing point, one-quarter point, and at midspan.

In 1969, the Arizona Department of Transportation awarded a contract for what was then believed to be the world's longest pretensioned concrete box girder for railroad bridges.[10]

The two-span structure, which carries the Southern Pacific Railroad's Kyrene Bridge over New Superstition Freeway in Tempe, Arizona, is 17 ft (5.2 m) wide and 250 ft (76.2 m) long. It is constructed of four box girders per span, each measuring 3 ft 5 in. (1.0 m) wide, 6 ft 8 in. (2.0 m) deep, and 100 ft 6½ in. (30.6 m) long and weighing 89 tons (81 t) (Fig. 14). Fifty-six ½-in. (13 mm) 270 ksi (1062 MPa) strands totaling over one mile (1.6 km) in length were used for each girder. Fig. 15 shows the prestressing steel and mild steel reinforcement in place prior to concreting.

The structure was designed by the Arizona State Highway Department's Structure Section, under the direction of Martin Toney, and Ronald Brechler. The boxes were fabricated by TPAC, a Division of the Tanner Companies, for the general contractor, Tanner Bros. Contracting Company of Phoenix. Awarded in the spring of 1969, the completed cost was \$50 per sq ft (\$538 per m^2), a modest sum for railroad bridges even at that time (Fig. 16).

Fig. 15. Prestressing steel and mild steel reinforcement for box girder. Southern Pacific Railroad, Kyrene Bridge over New Superstition Freeway, Tempe, Arizona.

Fig. 16. Completed structure. Southern Pacific Railroad, Kyrene Bridge over New Superstition Freeway, Tempe, Arizona.

Fig. 17. L & N Railroad over Charlotte Avenue, Nashville, Tennessee.

Fig. 18. L & N Railroad over Charlotte Avenue, Nashville, Tennessee.

At the same time, the L&N Railroad was renovating a bridge over Charlotte Avenue in Nashville, Tennessee, by using precast prestressed concrete box beams.[11] Since only two of the four tracks could be taken out of operation at one time, the bridge was built in stages. Each stage required an average of only two weeks to complete, an advantage of prestressed concrete. Fig. 17 shows the bridge under construction.

Each stage consisted of erecting four 3 ft (0.9 m) wide, 54 in. (1.4 m) deep, precast prestressed box beams per span for a total of eight per stage. Each stage is separated by a 22 in. (559 mm) wide, 4 ft (1.2 m) deep precast filler beam, also prestressed. The recesses formed by the filler beams provided space for a cast iron drain trough between the tracks. The walkway is isolated from the track superstructure by joint material to prevent transfer of live load stresses. Ballast curbs were formed by the inside edge of the walkway slab and a partial curb cast on the outside track beams at the precasting plant after strand release (Fig. 18).

All the beams were designed to maximize the use of the standard forms for AASHTO box sections. However, dimensional requirements made it necessary to use special void forms. The box beams are about 50 ft (15.2 m) long and weigh approximately 29 tons (26 t) each. The filler beams, although smaller in size, are solid and weigh about the same.

Each group of beams was laterally tensioned before moving to the next stage. This tensioning was done with a pair of 1-in. (25.4 mm) diameter tie rods, one at 15 in. (381 mm) and the second 30 in. (762 mm) below the top of the beam, and about 15 ft (4.6 m) on centers. By staggering and crossing two rows of tie rods at the filler beams, each stage was tied to the previous group, resulting in a continuous lateral tensioning for the full 54 ft 4 in. (16.6 m) bridge width. The limited room for erection required the use of segmental tie rods connected by threaded couplings.

The structure was designed by Henry Forte, in association with Barge, Waggoner & Sumner, for Metropolitan Government of Nashville, Tennessee; prestressed concrete was supplied by Dixie Concrete Pipe Co., also of Nashville.

Fig. 19. Canadian Pacific Railroad Dixie Road grade separation, Mississauga, Ontario.

The Dixie Road grade separation at the Canadian Pacific Railroad in Mississauga, Ontario, which was opened to traffic in 1969, is composed almost entirely of precast prestressed concrete, allowing most of the major work to be completed in six months despite severe Canadian winter weather (Fig. 19).[12]

Two spans of precast prestressed box beams, 3 ft (0.9 m) wide, 41 in. (1.0 m) deep and 57 ft 4 in. (17.5 m) long, are used to carry the three railway tracks over the four-lane highway. The design loading was Cooper's E-70 with impact. Deflecting 32 of the 46 ½-in. (13 mm) diameter, 270 ksi (1062 MPa) strands in the web of the box beams, using 6000 psi (41.4 MPa) concrete, and prestressing to 30 kips (133 kN) per strand resulted in a very shallow bridge. This allowed the use of a gravity storm sewer system in the depressed highway rather than a pumped system and added to the economy of the project.

The 16 girders per span, weighing 33 tons (30 t) each, were connected laterally with 1¼-in. (32 mm) tie rods torqued to 30 kips (133 kN) tension. These rods are at the diaphragms located at both ends and at the third points. Joints between beams are filled with an epoxy adhesive. A butyl membrane was placed over the girders, followed by 18 in. (457 mm) of granular ballast.

The retaining wall consists of 2000 lineal ft (610 m) of reinforced precast concrete panels 10 ft (3.0 m) wide, 8 in. (203 mm) thick and varying in height from 9 to 26 ft (2.7 to 7.9 m).[12] Fig. 20 shows the retaining wall in place. The panels are supported by 167 precast T-shaped pylons, 3 ft (0.9 m) wide at the front face, 2 ft (0.6 m) wide at the back, and spaced 12 ft (3.7 m) apart (Fig. 21). A continuous neoprene bearing strip separates the panel from the pylon. Small infill panels sit on top of the pylons between the large panels to complete the wall.

Footings, 6 ft 6 in. (2.0 m) by 6 ft (1.8 m) by 3 ft (0.9 m) deep, were cast and ducts were provided through the pylons and footings to line up with holes drilled into the shale below. Post-

Fig. 20. Dixie Road grade separation precast retaining wall.

Fig. 21. Dixie Road grade separation precast retaining wall.

tensioning tendons were then fastened into the rock using CCL rock anchors. The longest pylons used 18 ½-in. (13 mm) diameter, 270 ksi (1062 MPa) prestressing strands running through two ducts in each pylon. As the earth was backfilled behind the wall, a prestressing force was applied in three stages, thus serving to reinforce the pylons against bending in addition to providing stability against overturning.

An elevated sidewalk under the bridge consists of vertical precast panels connected at the top to the pylons by 1¼-in. (32 mm) diameter steel rods. A horizontal cast-in-place concrete slab forms the walkway.

Designed by McCormick, Rankin & Associates, Ltd., Port Credit, Ontario, the structure is owned by the County of Peel and the Canadian Pacific Railroad. Precast concrete was manufactured by

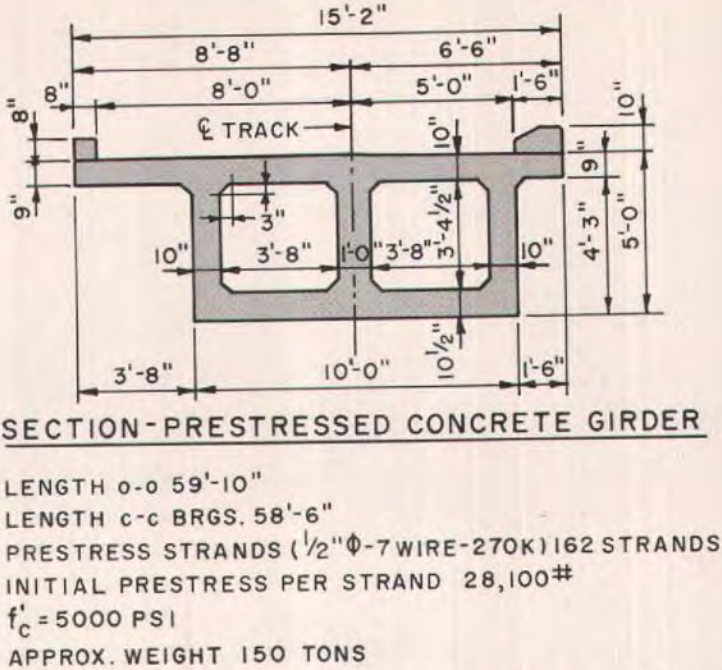

Fig. 22. Cross section of L & N Railroad over St. Louis Bay, Bay St. Louis, Mississippi.

A.B.C. Structural Concrete Ltd., Brampton, Ontario, with post-tensioning by Canadian Lift Slab, Ltd., Milton, Ontario, for the general contractor, Armstrong Bros. Co., Ltd., Brampton, Ontario.

In 1967,[13] the L&N Railroad completed construction of its bridge over St. Louis Bay in Bay Saint Louis, Mississippi, on the Mississippi Gulf Coast. Fig. 22 shows a cross section of the railroad bridge. The structure was designed by Hazelet & Erdal of Louisville, Kentucky (Frank B. Wylie, Jr., principal-in-charge, and Caroll S. Brown, project engineer). Construction was by Brown & Root of Houston, Texas. Fabrication was by Prestressed Concrete Products, Mandeville, Louisiana.

The total length of the bridge is 10,170 ft (3100 m), which includes a 289 ft (88.1 m) swing span. The bridge contains 163 prestressed girder spans (Fig. 23). Each span consists of a 60 ft (18.3 m) long by 5 ft 1 in. (1.6 m) deep by 15 ft 2 in. (4.6 m) wide box girder weighing 149 tons (135 t).

Fig. 23. L & N Railroad over St. Louis Bay, Mississippi.

Fig. 24. L & N Railroad over St. Louis Bay. Precast cap on prestressed piles.

Receiving the girders are 78 precast three-pile caps, 5 ft (1.5 m) wide, 5 ft 6 in. (1.7 m) high, and 16 ft 6 in. (5.0 m) long, which contained shear lugs to permit adjacent girder expansion. Eighty-five four-pile caps, 5 ft (1.5 m) wide, 5 ft 6 in. (1.7 m) high, and 12 ft (3.7 m) long, utilized shear lugs to maintain lateral and longitudinal fixity. A closeup of this connection is shown in Fig. 24.

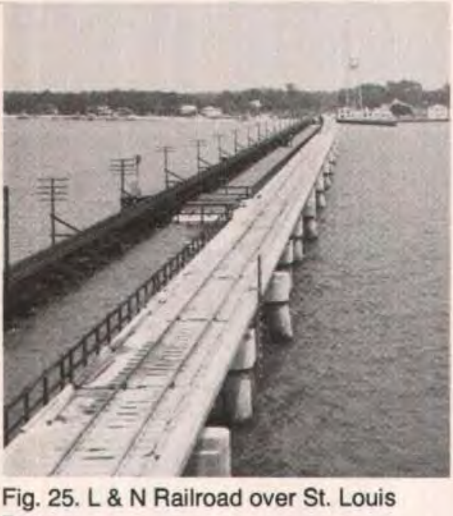

Fig. 25. L & N Railroad over St. Louis Bay.

Alternating three- and four-pile bent clusters were designed to resist lateral and longitudinal forces, respectively. Each precast, post-tensioned cylinder pile has a 4 ft 8 in. (1.4 m) outside diameter with a 5 in. (127 mm) wall and varies in length from 70 to 120 ft (21.3 to 36.6 m) for a total lineal footage of 54,915 ft (16738 m). The depth of pile tips to good foundation varied from 60 to 110 ft (18.3 to 33.5 m) with an average of 80 ft (24.4 m) below mean sea level.

A total of 2720 curb sections for ballast retention and pretensioned precast concrete railroad ties were also used. Every precast component of the structure was prefabricated at the plant; only the pile-filling concrete and cap-to-pile connecting concrete were site-cast (Fig. 25).

The same team was selected to design a new bridge over Biloxi Bay in Biloxi, Mississippi. The bridge was completed in 1979. This 6062 ft (1848 m) long bridge includes a 382 ft (116 m)

Fig. 26. L & N Railroad over Biloxi Bay, Biloxi, Mississippi. Substructure elements.

Fig. 27. L & N Railroad over Biloxi Bay, Biloxi, Mississippi. Overview of construction.

Fig. 28. Long Island Railroad grade crossing elimination, Hicksville, New York.

swing span with 93 prestressed I-beam spans consisting of 372 60-ft (18.3 m) long beams and 675 80- to 110-ft (24.4 to 33.5 m) long, 2 ft (0.6 m) square prestressed piles supporting precast pier caps (Fig. 26). Prestressed concrete fabrication was by Biloxi Prestressed Concrete, Inc., Biloxi, Mississippi, for the general contractor, Scott Bridge Company, Opelika, Alabama. Fig. 27 shows the bridge during construction.

Fig. 29. Long Island Railroad grade crossing elimination, Wantagh-Seaford detour tracks.

Meanwhile, back east, the Long Island Railroad was one of the few northeastern railroads to use prestressed concrete extensively. The Hicksville grade crossing elimination project (Fig. 28), designed in 1959, was the last of the Long Island Railroad's projects utilizing all cast-in-place concrete, which was typical of railroad viaducts in the area. The spans were 25 ft (7.6 m).

All the Long Island grade crossing eliminations are constructed in stages with two tracks of railroad relocated by a detour (Fig. 29) parallel to the existing alignment. With the right of way thus vacated, construction proceeds in the line of the original railroad bed.

Long Island's first rail project using prestressed concrete, completed in 1970, was a project to eliminate crossings at grade in the communities of Wantagh and Seaford in Nassau County (Fig. 30). The tracks are supported on prestressed box beams, 3 ft (0.9 m) wide by 2 ft 9 in. (0.8 m) deep on a span of 29 ft (8.8 m) (Fig. 31). The boxes are cov-

Fig. 30. Long Island Railroad Seaford Station.

Fig. 31. Long Island Railroad grade crossing elimination, Wantagh-Seaford.

ered with butyl rubber waterproofing with asphalt plank protection, then ballast and track. Fig. 32 shows a closeup of the platform tee beams.

A total of 67,000 sq ft (6224 m^2) of box beams were used for the viaducts; the station platforms used 33,000 sq ft (3066 m^2) of prestressed double tees.

The structure was designed by the New York State Department of Transportation, and turned over to the Long Island Railroad. The fabricator was

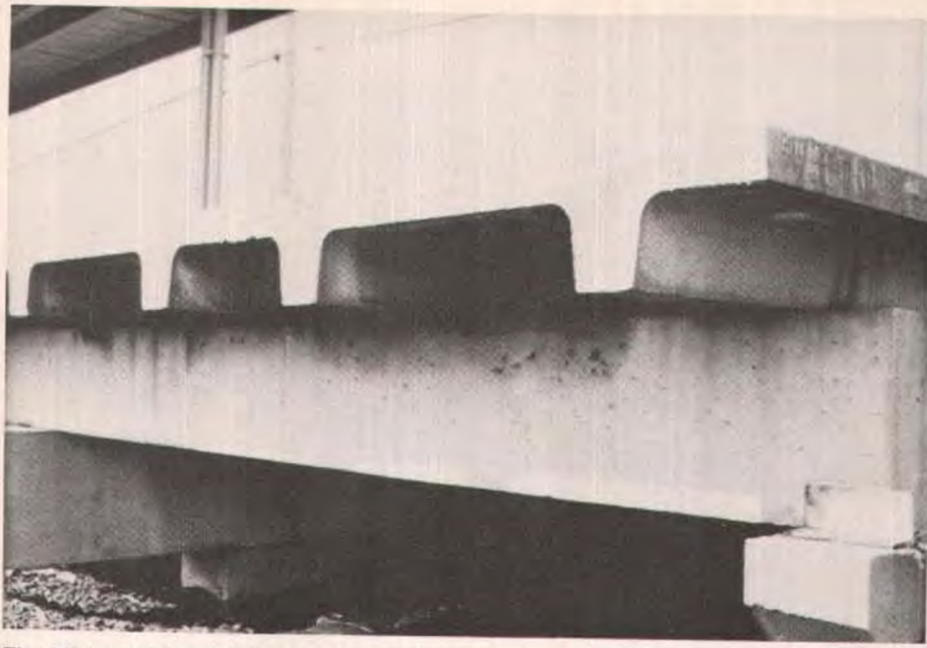

Fig. 32. Long Island Railroad grade crossing elimination, Wantagh-Seaford platform tee beams.

Fig. 33. Long Island Railroad grade crossing elimination, Amityville-Lyndhurst typical girder.

Grand Prestressed, for Del Balso Construction Corp.

The Wantagh-Seaford project was followed by Amityville-Lyndhurst grade crossing elimination project. This project was the first use of prestressed concrete I-beams (Fig. 33) with cast-in-place concrete slabs for the Long Island Railroad. The I-beam depth is 5 ft 10 in. (1.8 m) with two girders for the average span length of 70 ft (21.3 m) (Fig. 34). There are several spans over roads where the span is 102 ft (31 m) and four beams were used to support the track slab. The rails are attached directly to the slab by Landis fasteners (Fig. 35), eliminating maintenance problems of ties and ballast and drainage. The total length of the viaduct is 17,535 ft (5345 m).

The station platforms are supported on prestressed I-beams having depths of 4 ft 6 in. (1.4 m) and 5 ft 10 in. (1.8 m)

Fig. 34. Long Island Railroad grade crossing elimination, Amityville-Lyndhurst viaduct.

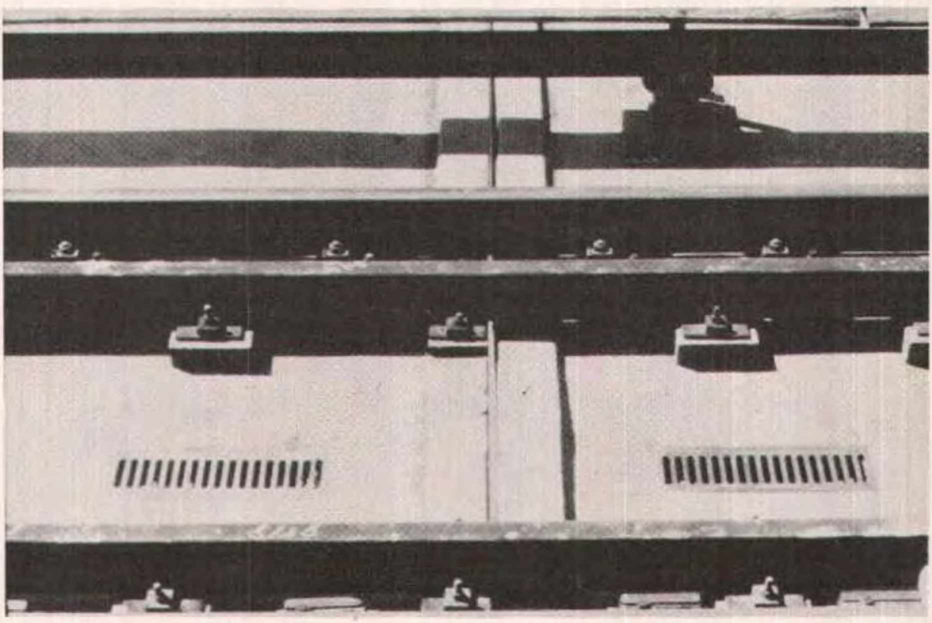

Fig. 35. Long Island Railroad grade crossing elimination, Amityville-Lyndhurst track structure.

Fig. 36. Long Island Railroad grade crossing elimination, Amityville-Lyndhurst station.

with the canopy over the platform consisting of four precast prestressed tee beams with flange widths of 6 ft (1.8 m) and web depths of 2 ft 8 in. (0.8 m) supported on structural steel girders and columns.

Completed in 1975 (see Fig. 36), Amityville-Lyndhurst was designed by Charles Sells of Pleasantville, New York, for the New York State Department of Transportation and the Long Island Railroad, with Grand Prestress providing the prestressed members for Hendrickson Brothers, Inc. and Horn Construction Co. Inc., a joint venture.

Following the Amityville-Lyndhurst grade crossing elimination was the Merrick-Bellmore grade crossing elimination project designed by McFarland-Johnson Engineers, Inc., of Binghamton, New York, for the New York State DOT and the Long Island Railroad. Its construction is similar to Amityville-Lyndhurst, using I-beams 5 ft 10 in. (1.8 m) deep with spans varying from 61 to 75 ft (18.6 to 23 m). Over the streets, 86 ft (26.2 m) spans were used with three beams supporting the track slab (Fig. 37).

The total length of this viaduct is 4850 ft (1478 m). The canopy construction was modified for this viaduct with cast-in-place concrete piers used to support precast prestressed concrete planks with a width of 4 ft (1.2 m) and a depth of 12 in. (305 mm) (Fig. 38). Platform spans varied from 30 to 43 ft (9.1 to 13.1 m). Construction was completed in 1977 by Horn Construction Co., Inc., with prestress fabrication by Grand Prestress.

Because of problems with pigeons roosting on the sloped bottom flanges of the I-beams utilized in Amityville-Lyndhurst, the railroad requested a precast shape with vertical sides for the

Fig. 37. Long Island Railroad grade crossing elimination, Merrick-Bellmore station.

Fig. 38. Long Island Railroad grade crossing elimination, Merrick-Bellmore station.

Fig. 39. Long Island Railroad grade crossing elimination in operation, Massapequa Park Station, New York.

Massapequa Park grade crossing elimination project (Fig. 39). Two 5 x 5 ft (1.5 x 1.5 m) prestressed box beams were chosen to support the track slab (Fig. 39). Spans vary from 63 to 75 ft (19.2 to 23 m) for a total viaduct length of 1425 ft (434 m). The station platform is supported by two 3 x 5 ft (0.9 x 1.5 m) prestressed box beams with spans varying from 67 ft 6 in. to 89 ft 10 in. (20.6 to 27.4 m) (Fig. 40). The canopy was constructed in essentially the same manner as the Amityville-Lyndhurst stations, with precast prestressed tee beams supported on concrete piers. Figs. 40 and 41 show underside views of the structure.

Massapequa Park was designed by Charles H. Sells of Pleasantville, New York, for the New York State DOT and the Long Island Railroad. Kenville Prestress fabricated the prestressed members for the general contractor, Hendrickson Brothers, Inc., and Horn Construction Co., Inc., a joint venture. Construction was completed in late 1980.

Another project, suspended during the design phase in order to allow consideration of depressing the entire railroad through the city of Mineola, consists of a mainline viaduct 7350 ft (2240 m) long, and a branch line viaduct 4000 ft (1219 m) long, both utilizing three custom-designed girders per track 4 ft 5 in. (1.3 m) deep on cast-in-place piers. The track slab would be the same as the previous projects without ballast. Station platforms would also be prestressed tees. The design was by Goodkind & O'Dea for the New York State DOT and the Long Island Railroad. Fig. 42 shows an artist's model of the project.

In addition to the piles, pier caps, I's, tees and boxes that have been presented here, some railroads are upgrad-

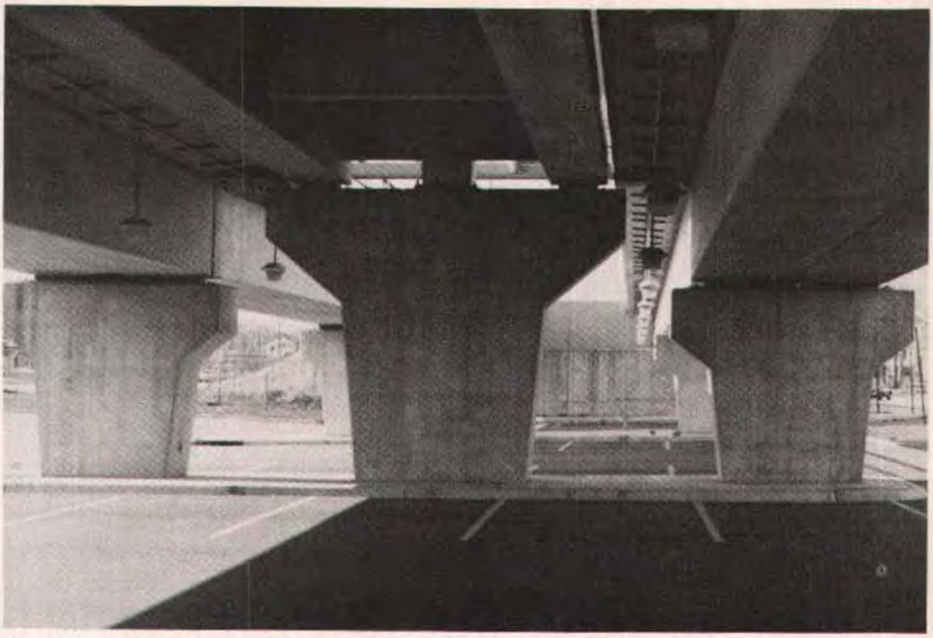

Fig. 40. Underside view of Long Island Railroad grade crossing elimination, Massapequa Park Station, New York.

Fig. 41. Long Island Railroad grade crossing elimination, Massapequa Park Station, New York. Note canopy construction of precast prestressed tee beams supported on concrete piers. The project was completed in late 1980.

Fig. 42. Long Island Railroad proposed Mineola grade crossing elimination project.

ing some of their old steel bridges by replacing timber decks which have outlived their purpose with precast slabs. The Santa Fe and Mopac railroads have utilized these extensively and a number of railroads have adopted this as a method of upgrading miles of trestle, with many miles to go.

Just as bridge engineers in the United States have adopted segmental construction for highway bridges, the future looks bright for railroad bridge designers to design longer spans by using segmental construction, as has been done in Australia and elsewhere.

Exemplifying the versatility of precast prestressed segmental construction, a dual track railway bridge was completed near Sydney, Australia, in early 1972 (Fig. 43).[14] The Como Railway Bridge spans the Georges River 13 miles (21 km) south of Sydney and about 75 ft (23 m) upstream from the bridge which it replaces, owned by the Department of Railways, New South Wales. It was designed by Donovan H. Lee & Partners, London, and constructed by John Holland, Constructions, Ltd., Sydney.

The bridge consists of seven simply supported 159-ft (48.5 m) spans giving an overall span length of 1113 ft 2 in. (339 m). The dimensions approach world records for concrete railway bridges both in overall length and size of span. [Bridges with longer spans are the 160-ft (48.8 m) single span skewed bridge at Rotherham, England, by the same designer, and the five-span LaVoulte Bridge over the Rhone River in France. The French bridge has piers at 194 ft (59.1 m) centers supporting rigid frames with inclined legs at 184 ft (56.1 m) centers.]

Because of the poor soil conditions, 92 inclined composite piles up to 166 ft (50.6 m) long were used to support the south abutment and piers (Fig. 44). Each pile consists of 12 by 12 in. (305 x 305 mm) steel H-sections connecting to

Fig. 43. Overview of Como Railway Bridge near Sydney, Australia.

21-in. (533 mm) square prestressed concrete piles.

Each span consists of twin precast post-tensioned box girders made from six segments about 7 ft (2.1 m) wide by 12 ft 6 in. (3.8 m) deep. The deck is formed by cast-in-place post-tensioned cantilever slabs.

Segments were railed to the bridge (Fig. 45) from an on site casting yard (Fig. 46).

Six segments for each span were placed on a 13-ft (4 m) deep steel falsework truss supported on two piers and temporary steel bent between the two piers with 18 in. (457 mm) spaces between segments (Fig. 47). Tendons were then pulled through the floor ducts prior to stressing (Fig. 48).

The 18 in. (457 mm) concrete joint was completed and upon reaching 5000 psi (34.5 MPa), 37 of the 55 tendons were stressed and then restressed after 10 days to recover losses. The remaining 18 tendons were stressed after the deck was cast.

Fig. 44. Driving prestressed concrete piles (Como Railway Bridge).

Fig. 45. Precast segments being moved into place (Como Railway Bridge near Sydney, Australia).

Fig. 46. An on site casting yard was set up to manufacture box segments for Como Railway Bridge.

Fig. 47. Falsework truss and temporary steel bent (Como Railway Bridge).

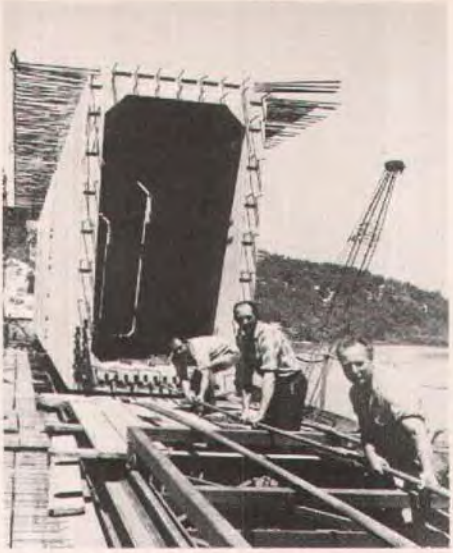

Fig. 48. Pulling tendons prior to stressing (Como Railway Bridge).

The old single track wrought iron bridge replaced by the Como Railroad Bridge can be seen in the background of Figs. 45 and 49.

During the same period, the Eastern Suburbs Railway in Sydney, Australia, completed two viaducts at Rushcutters Bay (Fig. 50) and Woolloomooloo (Fig. 51).[15] These segmentally constructed viaducts (Fig. 52) carry two tracks of heavy rail transit as shown on the typical section (Fig. 53). They were designed for the Department of Railways, New South Wales, by Snowy Mountains Engineering Corporation, with Fowell, Mansfield, Jarvis and Maclurcan as architectural consultants.

Loading was to a standard N.S.W.G.R. electric train loading reduced to a uniform distributed load of 2.15 kips per ft (0.003 kg/m).

Fig. 49. Completed Como Railway Bridge with old wrought iron bridge in background.

Fig. 50. Eastern Suburbs Railway at Rushcutters Bay, Sydney, Australia.

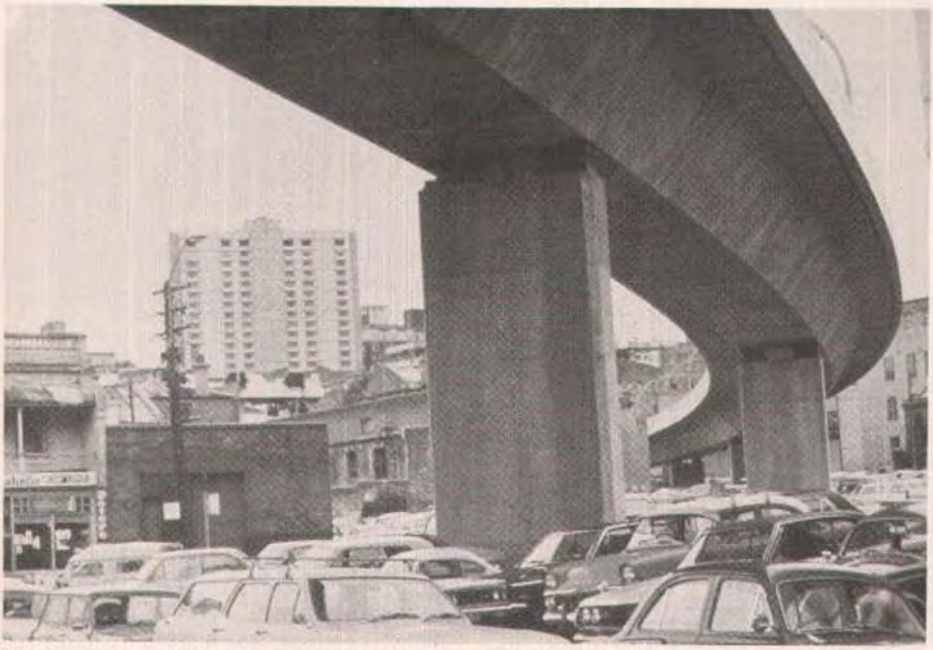

Fig. 51. Eastern Suburbs Railway at Woolloomooloo, Sydney, Australia.

Fig. 52. Segmental units being placed at Woolloomooloo viaduct.

As part of a flood control project in Arlington, Virginia, four new railroad bridges (Fig. 54) for the Richmond, Fredericksburg & Potomac Railroad were constructed from 1976 to 1980 utilizing 172 precast prestressed concrete box girders, all 6 ft (1.8 m) high by 4 ft (1.2 m) wide, with approximately a 68 ft (20.7 m) span. The design loading was Cooper's E80 plus impact. The total bridge area is approximately 146,000 sq ft (13563 m²). The design was by DeLeuw Cather & Company, with fabrication by Shockey Bros., Inc. of Winchester, Virginia.

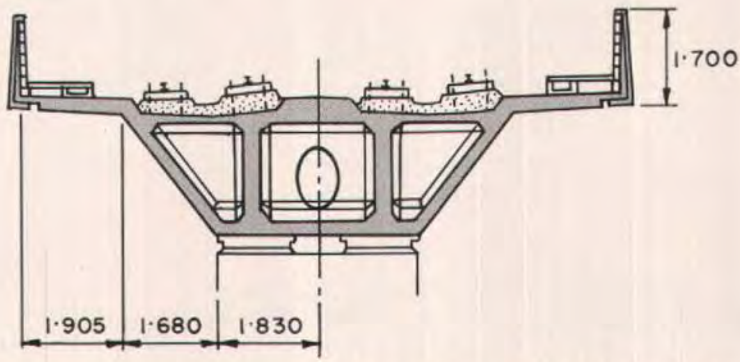

Fig. 53. Typical section of Woolloomooloo viaduct (Eastern Suburbs Railway).

Fig. 54. Flood control project, Arlington, Virginia.

Fig. 55. Prestressed concrete railway truss in Japan.

Fig. 56. Byker Viaduct, England.

As reported by Ben C. Gerwick, Jr.,[16] the Japanese have constructed their first prestressed concrete truss bridge for a railway line (Fig. 55). Segments are match-cast in the plant using a new admixture (Sigma 1000) and low pressure steam curing. They are joined by post-tensioning.

Several prestressed concrete bridges for mass transit structures have been built with fairly long spans. While the loads do not approach normal railroad loads, they are greater than typical highway loadings.

Typical of these, in addition to the previously described Rushcutters Bay and Woolloomooloo viaducts in Sydney, is the Byker Viaduct in northeast England, which is an epoxy glued segmental railway bridge on a highly curved alignment (Fig. 56). Constructed partly as balance-free cantilevers and partly by continuous cantilevering, the

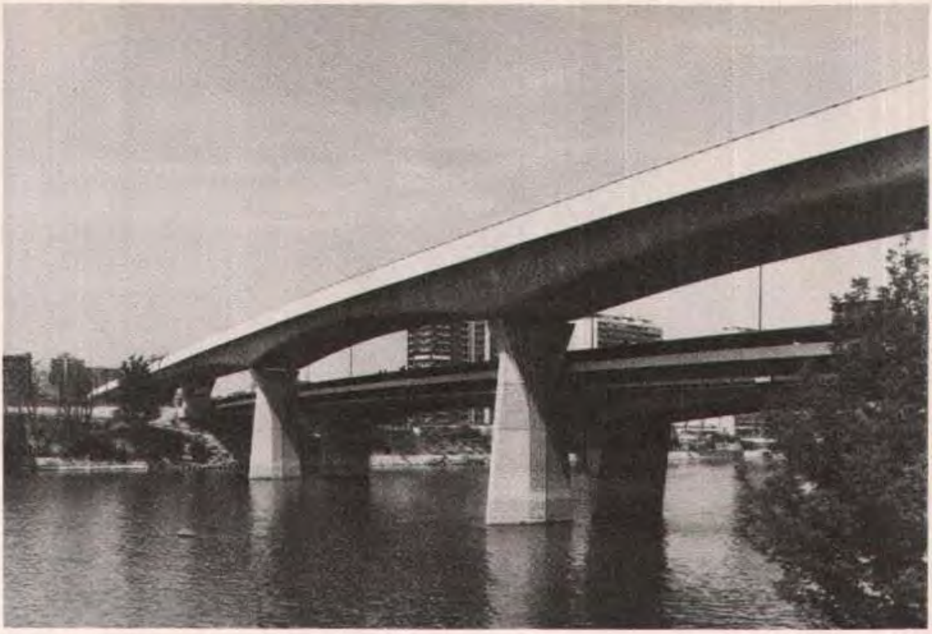

Fig. 57. Clichy Railroad Bridge, France.

longest span is 226 ft (69 m). A detailed description of the project appeared in the March-April 1981 PCI JOURNAL.[17]

The Clichy Railroad Bridge (Fig. 57), completed in 1979, has seven spans for a total bridge length of 2000 ft (619 m), with a center span of 280 ft (86.6 m). The Marne LaVallée Viaduct (Fig. 58) includes a bridge over the River Marne and a long trestle with a sharp horizontal curvature. The bridge has spans of 157 ft 6 in. (48 m), 246 ft (75 m) and 124 ft 8 in. (38 m) for a total length of 528 ft (161 m). The trestle is 4490 ft (1367 m) long with an average span of 105 ft (32 m). Both projects were designed by Jean Muller of Figg & Muller Engineers, Inc., Tallahassee, Florida.

One of the world's first all concrete cable stayed railway bridges was recently opened in England by British Rail.[18] It was designed by the Southern Region of British Rail in conjunction

Fig. 58. The Marne LaVallée Viaduct, Paris, France, was built with precast box girders assembled in balanced cantilevers using a launching gantry.

Fig. 59. British Rail over M25 Motorway, Lyne, England.

with Stressed Concrete Design Ltd., for the Department of Transportation, and contains two continuous skewed spans of 180 ft (54.9 m) with an overall width of 38 ft (11.6 m) (Fig. 59). The structure has solid post-tensioned edge beams and reinforced concrete deck with two concrete towers rising 72 ft (22 m) above the edge beams to support the bridge. Construction started in June 1976 and was completed in two years with only minimum interruption to rail traffic.

Readers interested in obtaining more recent information on railroad structures may consult Refs. 19 and 20.

And so, after 30 years, railway bridge engineers have advanced from a 19 ft (5.8 m) prestressed slab to a two-span 180 ft (54.9 m) cable stayed bridge. How far can the spans of railway bridges reach with prestressed concrete? This question is left to be answered to the courage of the bridge railway engineers and those contractors who can adapt the state-of-the-art of bridge construction practice to the construction of railway bridges. It is undoubtedly clear that we have only scratched the surface in this area and that many opportunities lie ahead to be tapped.

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