Heavy Movable Structures, Inc.

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Rehabilitation of the Stratford Avenue Bridge Over the Yellowmill Channel

by

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"REHABILITATION OF THE STRATFORD AVENUE BRIDGE OVER THE YELLOWMILL CHANNEL"

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AUTHOR BIOGRAPHY

Mr. Nasim is registered professional engineer in New York, New Jersey and California and holds a Master's degree in Civil Engineering from Cornell University. He has been involved in the structural engineering and construction review of several major bridge projects in the United States and abroad.

Mr. Nasim was the project engineer for the "Rehabilitation of the Stratford Avenue Bridge over the Yellowmill Channel", responsible for the structural design, detailing, plan preparation, cost estimate and specifications for the project.

His experience includes the structural engineering for cable stay bridges, concrete segmental bridges, curved steel girder bridges, steel box girder bridges, arch bridges, highway bridges (prestressed concrete and steel girder) and seismic retrofit engineering of many structures in California.

He is a member of the American Society of Civil Engineers (ASCE) and the International Association for Bridge and Structural Engineering (IABSE).

REHABILITATION OF THE STRATFORD AVENUE BRIDGE OVER THE YELLOWMILL CHANNEL

BY: MOHAMMED N. NASIM, P.E.[1]

INTRODUCTION:

The rehabilitation of the Stratford Avenue Bridge includes the removal and replacement of the existing superstructure of the bridge over the Yellowmill channel and the restoration of the existing substructure. The existing four span structure being replaced consists of a double leaf rolling bascule main span with three fixed approach spans. It was constructed around 1927 and is situated in a historical area of Bridgeport, Connecticut. The structural design of the replacement structure is the subject of this paper.

The proposed movable structure is a 122 feet twin double leaf rolling bascule span, containing four separate leaves in the northwest, southwest, northeast and southeast quarters. The north half leaves are independent, structurally and mechanically from the south half leaves. The proposed construction will match the historical look of the existing structure. The double leaf scheme permits smaller leafs and corresponding smaller wind loads on the open leaf. This type of bridges are more aesthetically pleasing than other movable bridges. The general plan and elevation is shown in page 9. A major feature of the proposed structure is the microsilica lightweight concrete deck.

The proposed approach spans consist of spread precast prestressed concrete box beams. The new approach spans resemble the original spans through the coloring of concrete, replicating of the parapet barrier and through simulating the change in depth of the existing west approach spans towards the bascule span. The change in depth was accomplished by using deeper fascia units in the second span of the west approach. The haunch in the second span presents a gradual

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transition in structure depth to the depth of the bascule span. Also, existing ornamental features are being recreated in the new structure to maintain historic significance.

The construction is being accomplished in two stages. Construction performed on the portion north of the centerline of the bridge while traffic is maintained on the south half and vice versa.

BASCULE SPAN STRUCTURAL SYSTEM:

Each leaf of the proposed 122 feet double leaf rolling bascule span, is composed of two, 81 feet long parabolically haunched welded plate girders. The framing plan is shown on page 10 and the typical cross section on page 11. Each girder has a curved, 7 feet radius segmental portion at the center of roll, which bears on the track girder. The track girders are embedded in concrete with the tread plate exposed. The tread plate on the track girder positions the pintles, which insert into the openings in the tread plate of the segmental portion of the bascule girder. The forged steel pintles press fit into the track girder tread plate. Anchor bolts attach the bottom flange of the track girder to concrete to increase the stiffness of the track girder. The rack frame is partially embedded in concrete and supports the pinion bearing. All new structural steel is of 50ksi yield strength.

The bascule girders are composite with the 7.5 inch microsilica lightweight concrete deck. The leafs are connected at their forward ends with a live load hinge designed to lock the leafs for equal deflection under unbalanced live load. The live load hinge also termed as the center lock permits transverse centering and realigning of the leafs.

The floorbeams are perpendicular to the vertical profile of the bridge, facilitating connection of the stringers. Floorbeams are spaced at 13'-7", stringers spaced at 6'-3 $^1/_2$". The stringers are continuos over the floorbeams and composite with the lightweight concrete deck.

The statical system for live load is shown in Fig 1. As the rear end span lock is only present at the west bascule pier, a non linear analysis was carried out on GTSTRUDL (a computer program for structural analysis) to simulate this condition. This was performed to obtained more realistic live load reactions and deflection at center of span.

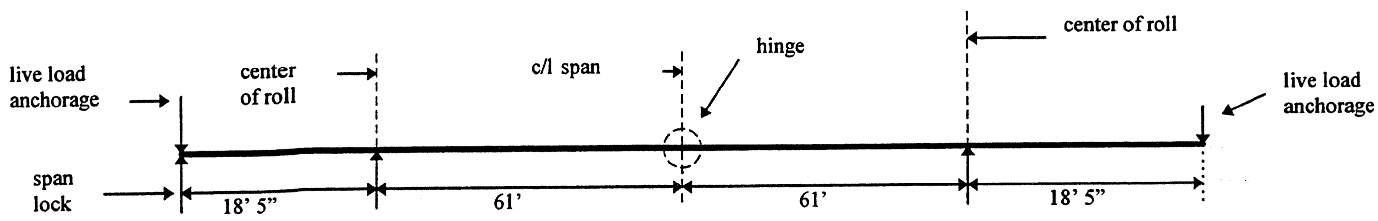


Figure 1, Statical System of the Double Leaf Bascule Span

The bascule structure opens to an angle of 71 degrees providing unlimited vertical clearance. The corresponding translational roll is 8'-8" away from the channel.

The machinery floor is attached to the floorbeams and moves with the bascule span. Access to the machinery floor is from the gate houses and an emergency entrance has also been provided from the sidewalk above the machinery floor area.

This structure contains an "under deck" counterweight concealed in the pit of the bascule pier, giving the bridge a more handsome look compared to an overhead counterweight. The counterweight concrete is supported by two floorbeams with mild steel reinforcement passing through the webs of the floorbeams. The mild steel reinforcement in the counterweight is provided to control width of cracks possibly resulting from the heat of hydration of the massive concrete pour. In the open position, top and bottom floorbeam bracing connect the counterweight floorbeams to bascule girder to transfer the weight of the counterweight to the bascule girders. The connection plates of the counterweight floorbeams were assessed for adequacy with finite element modeling to determine the level of stresses occurring during the various positions of the leafs.

MICROSILICA LIGHTWEIGHT CONCRETE DECK:

Most movable spans have steel grating or steel plate decks. Steel grating allows corrosion inducing materials to fall through, accelerating the deterioration of the underlying structural members. The Yellowmill bridge has a 7.5 inch lightweight concrete deck containing microsilica for reduced permeability enabling increased corrosion protection to the mild steel reinforcement and to the underlying structural steel framing. Also, the concrete deck permits improved rideability. The weight issue has been mitigated through the use of lightweight concrete with a maximum unit weight of 115 pcf and a minimum 28 day concrete strength of 4000psi. The light weight aggregates specified are blast furnace slag, shale or slate. The deck acts composite with the stringers and the bascule girders.

Typical composite design assumes all of the dead weight of the concrete deck to be sustained by the girder alone. This is not quite true for the bascule girder in this case. Due to the first opening of the leaf, the self weight of the deck is unloaded from the girder. This is due to the reduction of the component of the self weight perpendicular to the girder as the leaf's open. When the leaf closes back, the dead load is taken compositively by the girder and deck. Thus the dead load is partly taken by the deck also, depending on the angle of opening. If the leaf opens to 90^0, then all of the self weight of the deck will be taken compositively.

In the open position the deck is held to the steel framework by shear studs which also serve the dual purpose of ensuring composite action. Friction between the steel flange and concrete deck was not relied upon.

Open joints in the deck exist at the centerline of the channel and where the bascule span abuts the bascule pier sidewalk.

The design proposes a posttensioned precast concrete barrier to ease possible opening of the bascule leafs during construction for navigational needs.

BASCULE SPAN APPROXIMATE QUANTITIES

Cost of movable structure is approximately $800.00 per sqft.

Structural Steel: 80 lbs per square foot of the plan area ($250.00 per sqft).

Ratio of cost of structural steel to total cost of movable structure: 30%

Ratio of cost of lightweight concrete deck and contained mild steel to total cost of movable structure: 3%

Ratio of cost of machinery(excluding electrical) to total cost of movable structure: 16%

Ratio of cost of electrical work to total cost of movable structure: 18%

Low bid for the project, including approaches and roadway work $12.36 million.

Cost of removal of existing structure about $25.00 per sqft plan area (about 5% of total cost of new structure, including approaches).

It is to be noted that most of the cost for this project is in the superstructure and not as much in the substructure due to the scope of construction work.

BALANCING ANALYSIS:

Although the final responsibility for balancing of the bascule structure lies with the contractor, a thorough analysis was made to determine the size of the counterweight and to ensure that the designed structure can be adequately balanced. Theoretically balancing means, ensuring that the center of gravity of the structure (everything except the counterweight) and that of the counterweight alone are in a straight line through the center of roll of the leaf. The bascule leaf must be "balanced" under dead loads for proper opening and closing. Practically, to aid the seating of the bascule span, the center of gravity is pushed forward towards the center of roll to achieve a dead load reaction at the live load anchorage.

A 3 dimensional GTSTRUDL model was prepared containing each member of the bascule leaf and the concrete deck. The weight of the concrete counterweight was applied at the counterweight center of gravity. The model was rotated through each degree of opening to check the adequacy of the counterweight dimensions and of the counterweight concrete density.

Each leaf as designed, requires a 625 kips concrete counterweight with a unit weight of about 207 pcf. The density for the counterweight concrete can be achieved by using steel punchings, scrap metal, or billet steel. Pockets in the counterweight accommodate cast iron balance blocks provided to compensate for a possible 3.5% underrun and 5% overrun in the weight of the span, excluding the counterweight. The balance blocks have hooks for lifting and weight no more than 100lbs. The dead load reactions at the center of roll for the two girders of each leaf were not identical due to the cross slope of the cross section.

LIVE LOAD ANCHORAGE FRAMING

The live load anchorage structure is to sustain the live load reactions from the bascule span. Each girder tail end, has a live load shoe that bears upon a bearing attached to the live load anchorage girders. The uplift from the bascule leaf is controlled by the load case with bridge closed and counterweight independently supported with live loads thereon.

The uplift is transferred to the existing anchor bolts in the live load anchorage area by the live load anchorage girder. The existing anchor bolts are being reused to attach new live load anchorage framing, resulting in significant cost savings by preventing demolition at the bascule piers as the anchor bolts derive their tensile resistance by engaging a mass of masonry. It is anticipated that repairs to the shanks of some of the anchor bolts may be required to upgrade the carrying capacity.

The live load anchorage framing also contains the span lock machinery. This bridge contains the span lock only at the west bascule pier. The west leaf girders contain a bottom shoe at their tail end against which the span lock bar bears.

CONSTRUCTION OF THE BASCULE LEAF

The AASHTO movable specification load case with the counterweight independently supported, lends the live load anchorage framing for construction purposes without any additional strengthening for erection loading. The live load anchorage framing is installed prior to the installation of the bascule leaf and then subsequent to the erection of the track girders, the bascule girders are placed. The bascule girders are placed on the track girders and supported at the tail end by the live load anchorage framing. Temporary lateral bracing of the bascule girders is provided from the pit pier. The assembly of the remaining framing is then completed. After completion of the erection of the steel framing and placement of the machinery, the concrete slab is cast in stages. The deck casting stages can be coordinated with the simultaneous casting of the concrete counterweight or the casting of the counterweight can be started after casting of the deck slab reaches the center of roll.

It is however possible, that the entire leaf steel framing assembled off site and lifted into place, favoring navigation during erection. One leaf's steel framing weighs about 91 tons.

A novice approach for the concrete counterweight is precasting in segments and posttensioning. This approach can speed up construction, favorable in situations with heavy navigation during erection. This choice is however, better left to the contractor.

SEISMIC DESIGN

The bascule span structure has been designed for a 0.14g ground acceleration in the closed position, and 0.07g acceleration coefficient in the open position. As in a fully balanced span, the center of gravity of the dead loads acts at the center of roll, the longitudinal seismic reaction is transferred at the support of the pinion bearing by the rack frame. However due to the flexibility of the rack frame, part of this reaction is taken by the pintles and transferred to the substructure. The stiffeners of the bascule girder are designed to transfer the transverse seismic loads.

REPAIRS TO THE EXISTING SUBSTRUCTURE

The foundation timber piles were thoroughly assessed to determine adequacy under the new structure loads. The piles were found to be capable of sustaining the proposed loads partly due to the fact that the original structure was designed for two active trolley tracks that have now been removed and that the approach spans of the existing structure were deeper and covered with concrete. As the existing pile capacities could not be found, the existing pile loads were determined and compared to the new loads to evaluate adequacy.

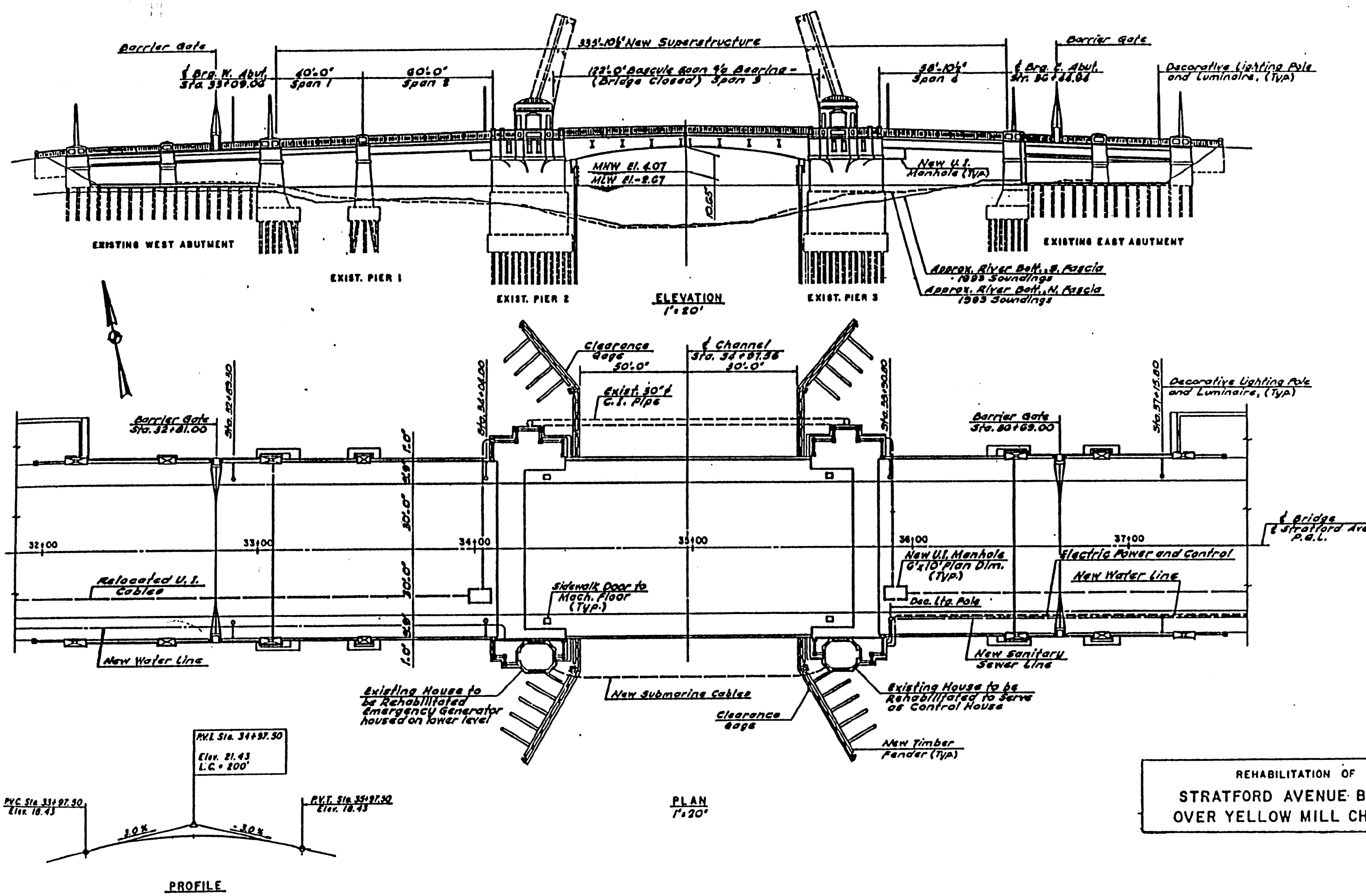
The repairs at the pit bascule pier include the removal of the debris and thorough cleaning through sand blasting and recoating with a copolymer cementitous mortar patch for water proofing. All cracks will be epoxy injected.

Also all existing castings embedded in concrete are being reused for bearing of new track girders and rack frames.

OPERATION OF THE LEAFS

All four leafs contain separate set of new machinery and are all centrally controlled. Operation will be by rack pinions (two per leaf) engaging a stationary rack. Each leaf is provided with 40 HP AC motor.

Normal operation time for raising or lowering the bascule leaves, exclusive of the time necessary to lock or unlock the span is 70 seconds. Emergency operation is 3 minutes with a 20HP two speed AC motor.



REHABILITATION OF
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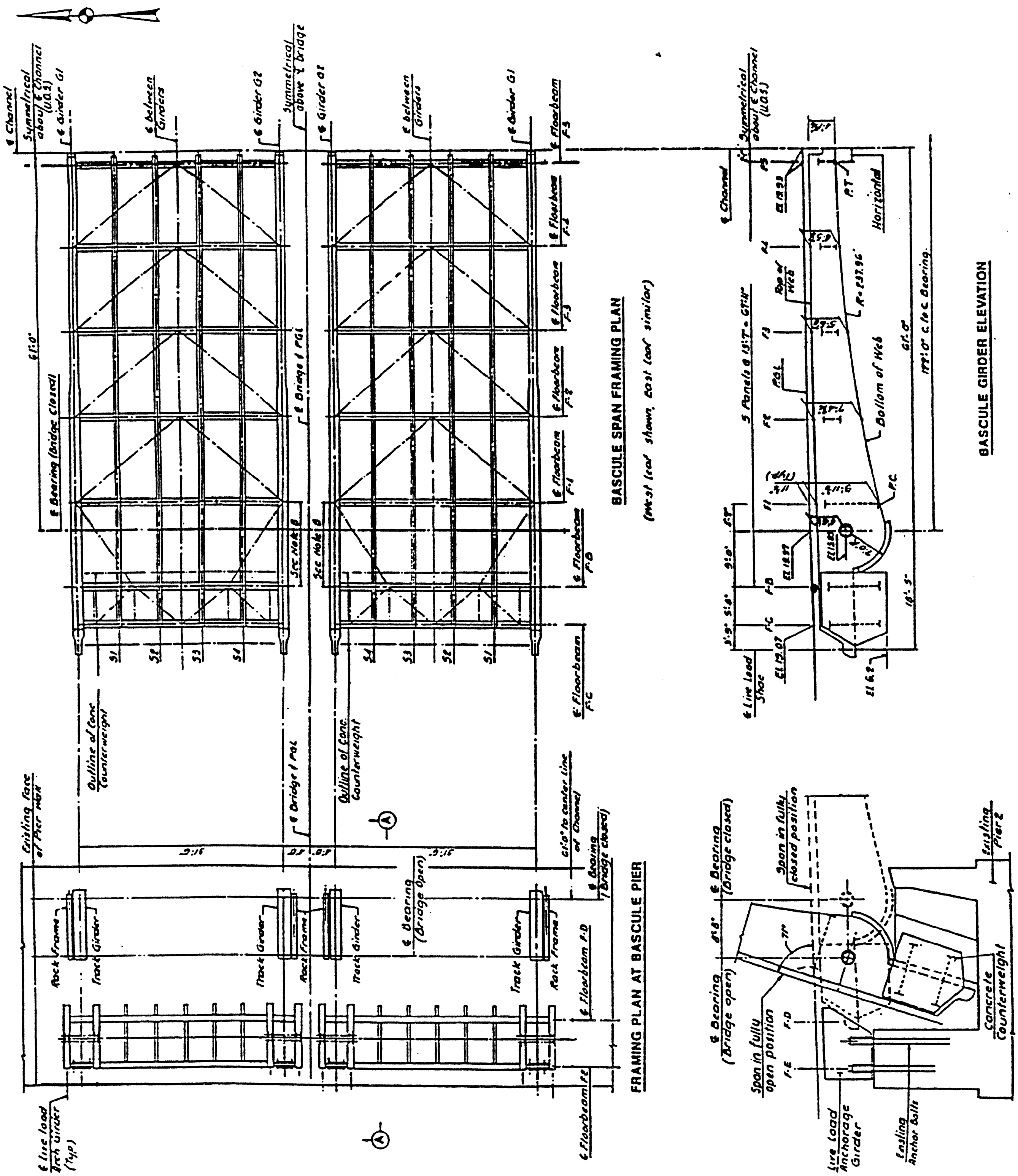
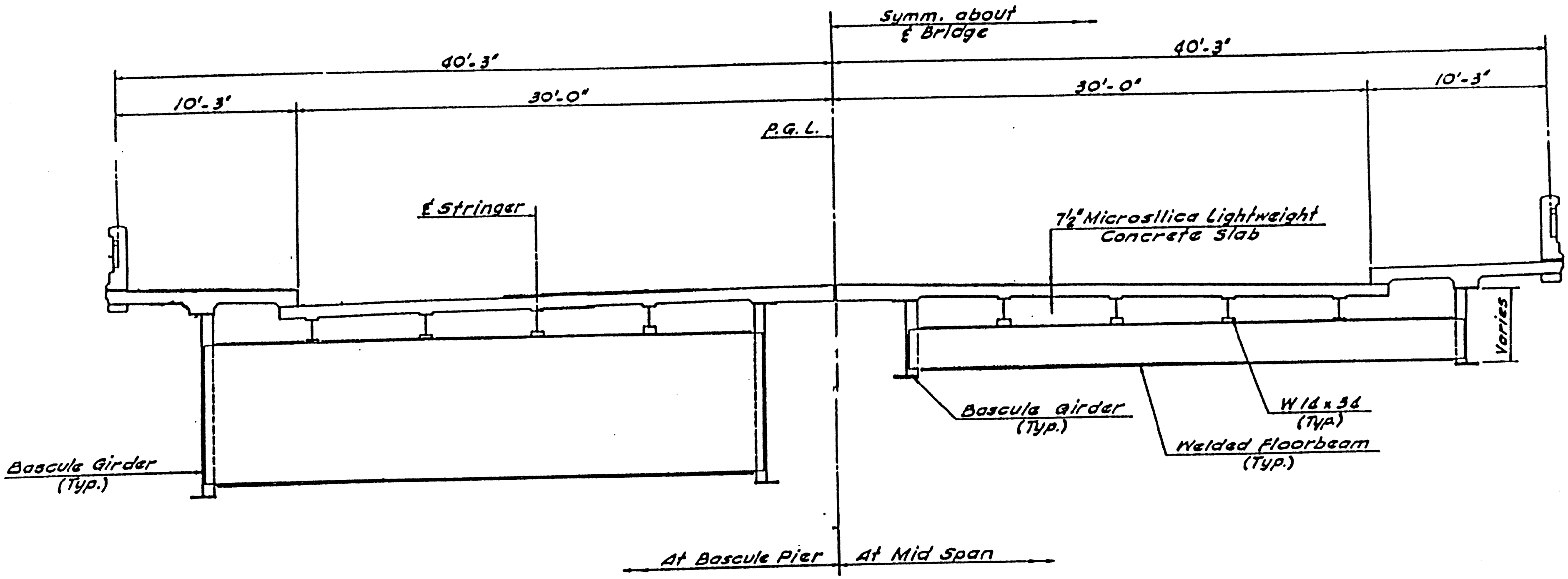

BASCULE SPAN FRAMING PLAN
(West leaf shown, east leaf similar)
BASCULE GIRDER ELEVATION
FRAMING PLAN AT BASCULE PIER
SECTION A - A



BASCULE SPAN CROSS SECTION