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Rehabilitation of a Bascule Bridge Without Interruption of Marine or Vehicular Traffic

by

Paul M. Blair, P.E., A.G. Lichtenstein & Associates, Inc.

REHABILITATION OF A BASCULE BRIDGE WITHOUT INTERRUPTION OF MARINE OR VEHICULAR TRAFFIC

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Heavy Movable Structures, Inc.

Prepared by

Paul M. Blair, P.E.
A. G. Lichtenstein & Associates, Inc.
Framingham, Massachusetts

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The Fore River Bridge carries four lanes of Route 3A highway traffic over a 175 foot wide navigation channel and was originally constructed in 1933. This twin double leaf deck truss Scherzer rolling lift bascule is the largest bascule bridge in Massachusetts. (See Photos 1-7.) Route 3A carries heavy Northbound commuter traffic from the South Shore to the Boston area in the morning and heavy return traffic to the South Shore in the afternoon. Due to the excessive length of the detour route in the event of a traffic closure and the heavy traffic volume carried by Route 3A, this bridge is a vital link for the communities served. (See Figure 1.) The repeated operational problems and other defects such as cracks in the Scherzer segmental girder tread plates and tread connection angles, poor concrete condition in the approach deck slabs and the substructure and the need for replacement of the fender system led the owner to program a major rehabilitation of the bridge. Rehabilitation was preferred over replacement. The rehabilitation of the structure within the existing envelope required much less environmental permitting (a water quality permit was required for fender work). The existing superstructure was in fair to good condition in most areas. The structure, being more than fifty years old, would have also required evaluation of historic significance. The primary attraction of rehabilitation over replacement was the cost and time savings. There is an oil distribution facility upstream of the bridge which is one of only two such facilities in the state which supply winter heating oil.

The Engineer's Construction Cost Estimate for the total Rehabilitation Project was $36,000,000.00. $16 million of this cost is associated with the bascule span, $3 million with the fendering and $17 million with the approach span work. The bridge is 79 feet 4 inches wide and 1324 feet long. An additional 1090 feet of retained fill embankment carries the approaches down to grade. A replacement structure was estimated to cost approximately $80,000,000.00 without Right of Way acquisition.

Closure of this structure to either vehicular traffic or navigation was extremely undesirable to the local communities and the State Highway Department. Discussions with representatives of the local communities and with mariners lead to the following conclusions:

- The existing four lane roadway carried two full lanes of traffic Northbound in the A.M. peak hours and two full lanes of traffic Southbound in the P.M. peak hours, but the reverse directions were lightly travelled during peak traffic hours.
- Mariners could accept a one or two week long closure of the navigation traffic in the Winter with advance notice to the operator of the oil distribution facility and other commercial vessels to permit rescheduling of vessels.

These constraints formed the basic design parameters along with the proposed rehabilitation work as follows:

- The existing open grating deck had experienced some serious skidding accidents and was slated for replacement with filled grating.

- The approach span deck slabs were in poor condition and required replacement on one approach and extensive repairs and a new overlay on the other approach.
- The sixty three year old Electrical and Mechanical Systems were in poor condition, had caused operational faults resulting in emergency repairs and were slated for complete replacement.
- The existing non air-entrained concrete substructure was heavily deteriorated due to runoff of water laden with deicing salts from the roadway and required repairs. The owner also wished to retrofit the structure to meet current AASHTO seismic design requirements. The use of seismic isolation bearings was selected during design to reduce the loads on the repaired substructure during a seismic event.
- The existing timber fenders were in poor condition and the owner wished to replace the existing fendering with a system designed to meet current AASHTO design requirements for vessel impact.
- Pedestrian traffic and operator access to the towers had to be maintained at all times during construction.

The method selected to maintain traffic and navigation was to put all traffic on one pair of double leaves and to do the bulk of work on the movable leaves which were under repair in the open position with a maximum of one two week closure to navigation (in the winter) for each of the two pairs of double leaves. This method required separating the twin leaves on each side of the river structurally (there were connection plates between the floorbeam ends) and modifying the existing controls and wiring to raise both of the twins together on the same side of the river, shore one leaf on each side of the river in the open position and then deactivate the shored leaves while the adjacent twin leaves continued to operate and carry vehicular traffic.

This method was feasible because the existing roadway was sixty feet wide (thirty feet on each of the twin leaves) and there were eight foot sidewalks on each side of the road. The additional width available for use on one set of twin leaves allowed placement of temporary barricades on the active leaves (two feet each, a total of four feet) with sufficient room remaining to carry three 11 foot lanes of traffic with a 3 foot strip of extra width needed to provide for the horizontal geometry necessary to safely carry traffic through the work area at the posted speed of 35 m.p.h..

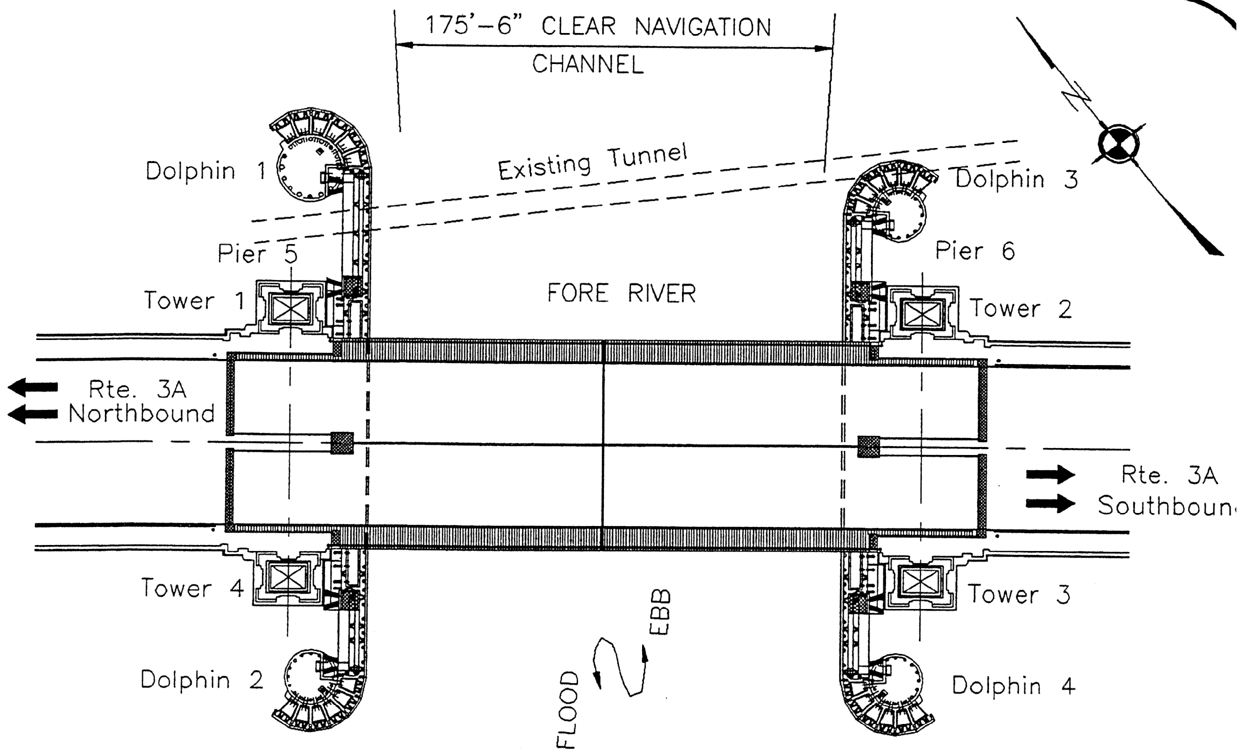
The detailed sequence of construction was as shown in Figure 4. The use of the existing sidewalk area as a travel lane increased the loads on the fascia trusses in the bascule and adjacent approach spans. Carrying three lanes of traffic in an area that had previously carried two lanes also caused an overall increase in live load. This increase in load created a need to reinforce selected members in the deck trusses of the bascule and approach deck truss spans as shown in Figures 5 and 6.

The Scherzer tread plates were found to be overstressed in line bearing (as is often the case on older Scherzers) but due to the large radius of the segmental girder, an increase in plate thickness was not required. The existing treads on the segmental and track girders were replaced with higher yield strength new ASTM A-588 tread plates of the same thickness.

The seismic design of the structure yielded few modifications to the superstructure. The existing interleaving shear locks at the bascule center floor break were replaced with standard worm gear driven shear locks that have a tight tapered fit to provide reliable, maintainable shear transfer across the floor break. New live load rests were constructed on the span side of the segmental girders. The approach piers were patched and also reinforced for seismic loadings. The applied seismic loads on the piers were reduced through the use of isolation bearings on the approaches.

One particularly interesting feature of the design was the use of a combination of neoprene energy absorbing bumpers and float-in frangible concrete boxes to construct the new fendering. The new design is modular and capable of completely absorbing the energy of a large tanker in a vessel impact, while maintaining low hull pressures to minimize the likelihood of a tanker hull breach. See Figures 2 and 7.

FIGURE 1 – SITE PLAN



GENERAL PLAN – FENDERING

FENDERING CONSTRUCTION SEQUENCE

1. CONSTRUCT PRECAST ELEMENTS AT SEPARATE STAGING AREA.
2. REMOVE PORTIONS OF EXISTING FENDERING WHICH CONFLICT WITH PLACEMENT OF THE NEW DOLPHINS.
   CONSTRUCT TEMPORARY FENDERING SYSTEM TO BRIDGE GAP BETWEEN EXISTING AND NEW FENDERING AS NECESSARY.
3. PLACE THE DOLPHINS IN ACCORDANCE WITH THE FOLLOWING PROCEDURES:
   A. MOVE PRECAST CAISSON FROM CASTING AREA TO FLOATATION DEVICE AND MOVE CAISSON INTO POSITION.
   B. SINK THE CAISSON INTO PLACE, USING A GUIDE DEVICE AS REQUIRED, UNTIL THE PRECAST CONCRETE ELEMENT STOPS MOVING FROM ITS OWN WEIGHT. LEVEL THE CAISSON.
   C. JET THE INTERIOR OF THE CAISSON TO DISPLACE ADDITIONAL BOTTOM SEDIMENT AS REQUIRED AND SINK THE CAISSON TO THE DESIRED TIP ELEVATION.
   D. DRIVE THE PIPE PILES INSIDE THE CAISSON TO THE REQUIRED TIP ELEVATIONS AND FILL WITH CONCRETE.
   E. CONSTRUCT CONCRETE CORBEL ON OUTSIDE OF CAISSON.
   F. PLACE TREMIE POURS INSIDE THE CONCRETE CAISSON.
      ANY WATER CONTAMINATED WITH SILT OR CEMENT PARTICLES WHICH IS PUMPED OUT DURING CONCRETE TREMIE PLACEMENT SHALL BE FILTERED AND DISCHARGED IN A MANNER APPROVED BY THE ENGINEER.
   G. PLACE EXTERIOR FRANGIBLE BOXES, TIMBER PILES, TIMBER WALERS, AND NEOPRENE FENDERS AS SHOWN ON THE PLANS.
   H. THE MAXIMUM ALLOWABLE PRESSURE DIFFERENTIAL SHALL BE 3 FEET OF SEAWATER ON THE FRANGIBLE BOXES AND 6 FEET OF SEAWATER ON THE VERTICAL BOXES.
4. POUR ENGINEERED LIGHTWEIGHT FILL TO CLOSE OPEN AREAS OF EXISTING PIERS.
5. WORKING IN SEGMENTS, REMOVE EXISTING TIMBER FENDERING AND FLOAT IN NEW PRECAST FRANGIBLE BOXES AND ATTACH TO FACE OF PIER. TEMPORARY FENDERING MUST BE USED AT ALL TIMES DURING CONSTRUCTION TO BRIDGE GAPS BETWEEN NEW AND EXISTING FENDERING.
6. PLACE NEW FRANGIBLE BOXES AND COMPLETE UPPER PORTION OF DOLPHIN CONSTRUCTION.

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FIGURE 2

PLAN OF TWIN DOUBLE BASCULE SPAN

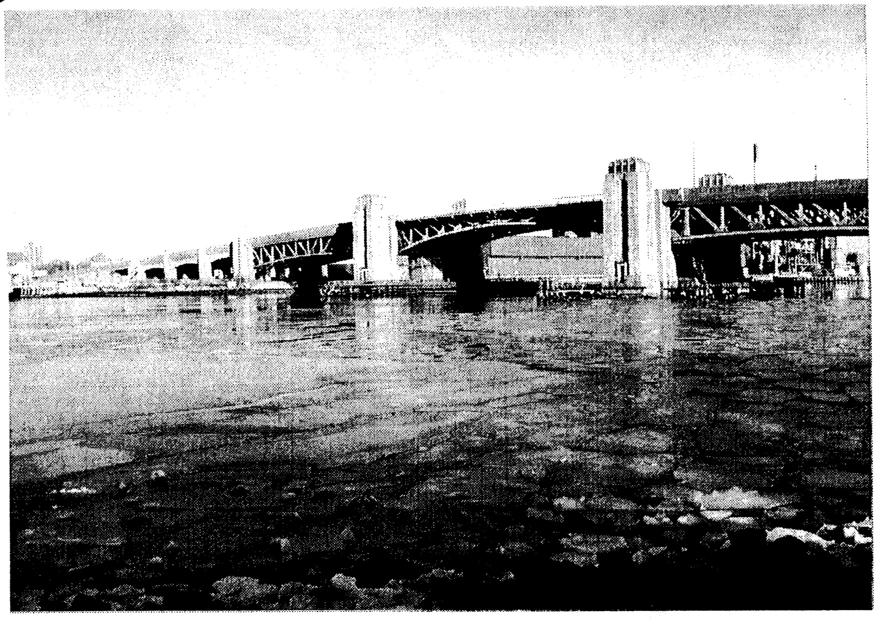

PHOTO 1 – EASTERLY ELEVATION

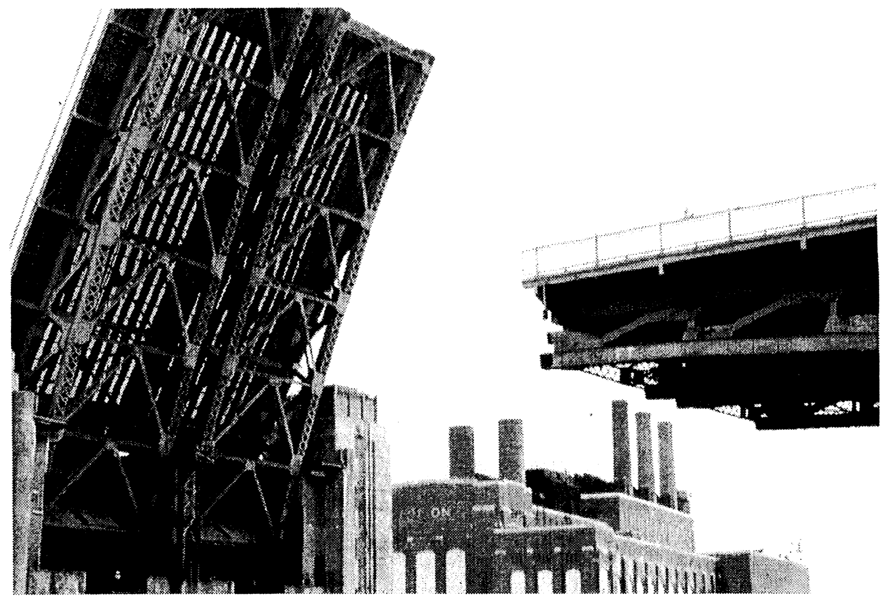

PHOTO 3 – SOUTHERLY SET OF TWIN LEAVES OPEN

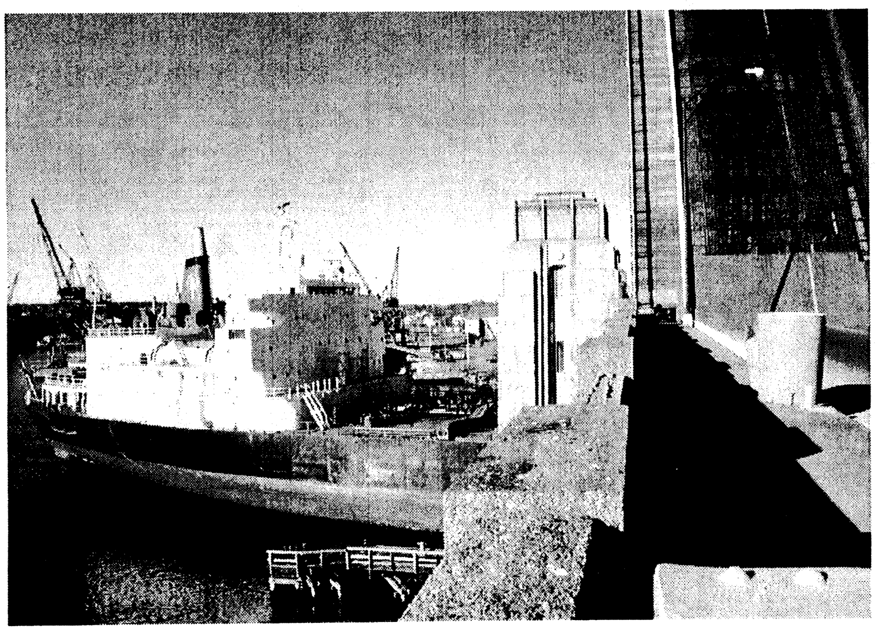

PHOTO 2 – OIL TANKER TRANSITTING CHANNEL

PHOTO 4 – TYPICAL TRAFFIC CONGESTION
DURING AN OPENING

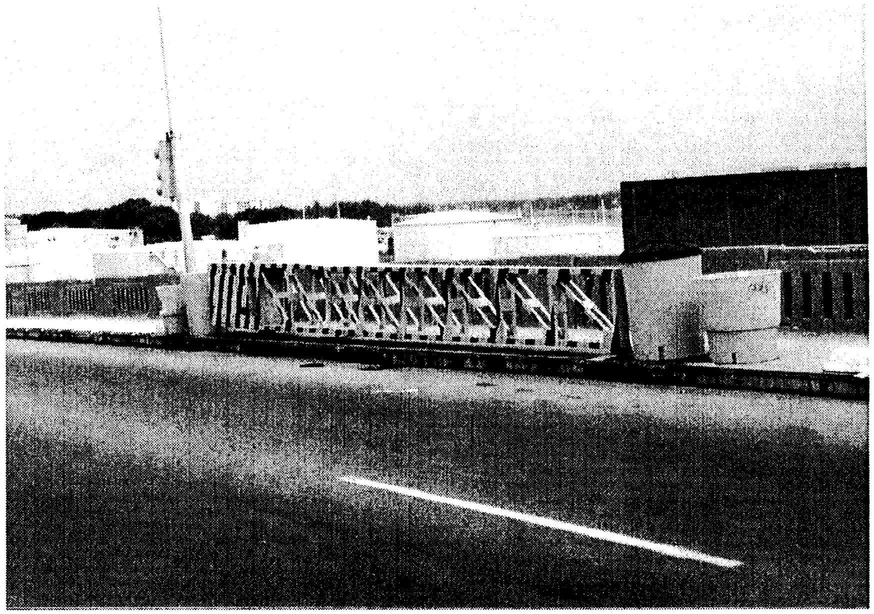
PHOTO 5 – EXISTING BARRIER GATES

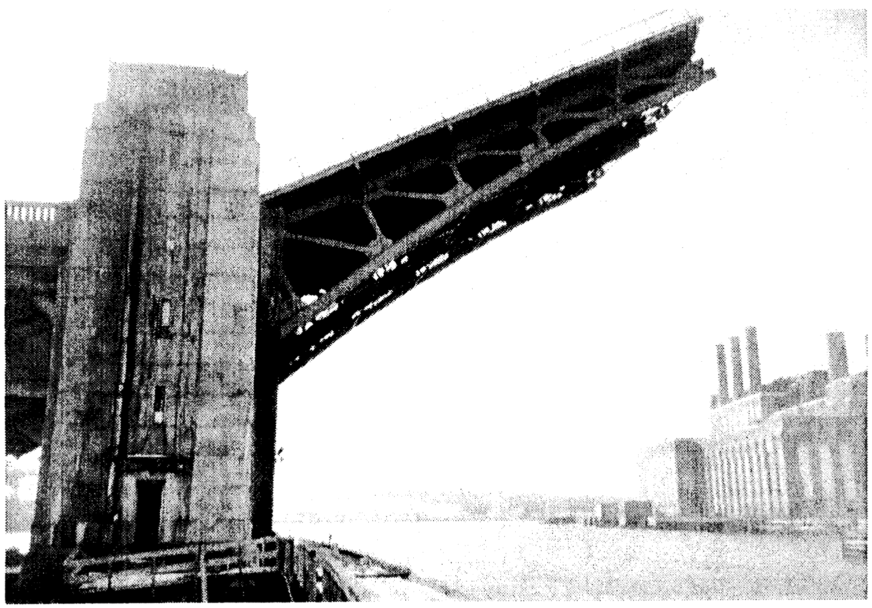
PHOTO 6 – BASCULE DECK TRUSS

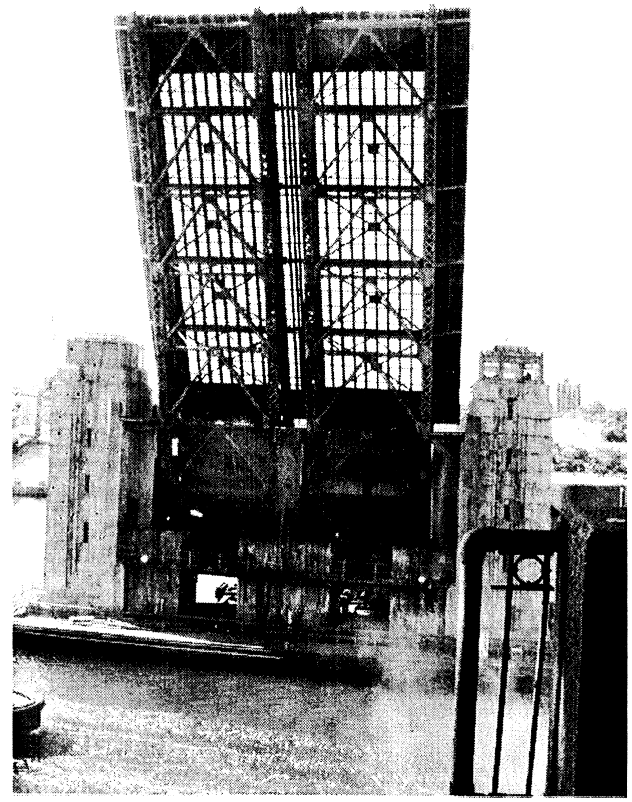
PHOTO 7 – UNDERSIDE OF OPEN
PAIR OF TWIN LEAVES

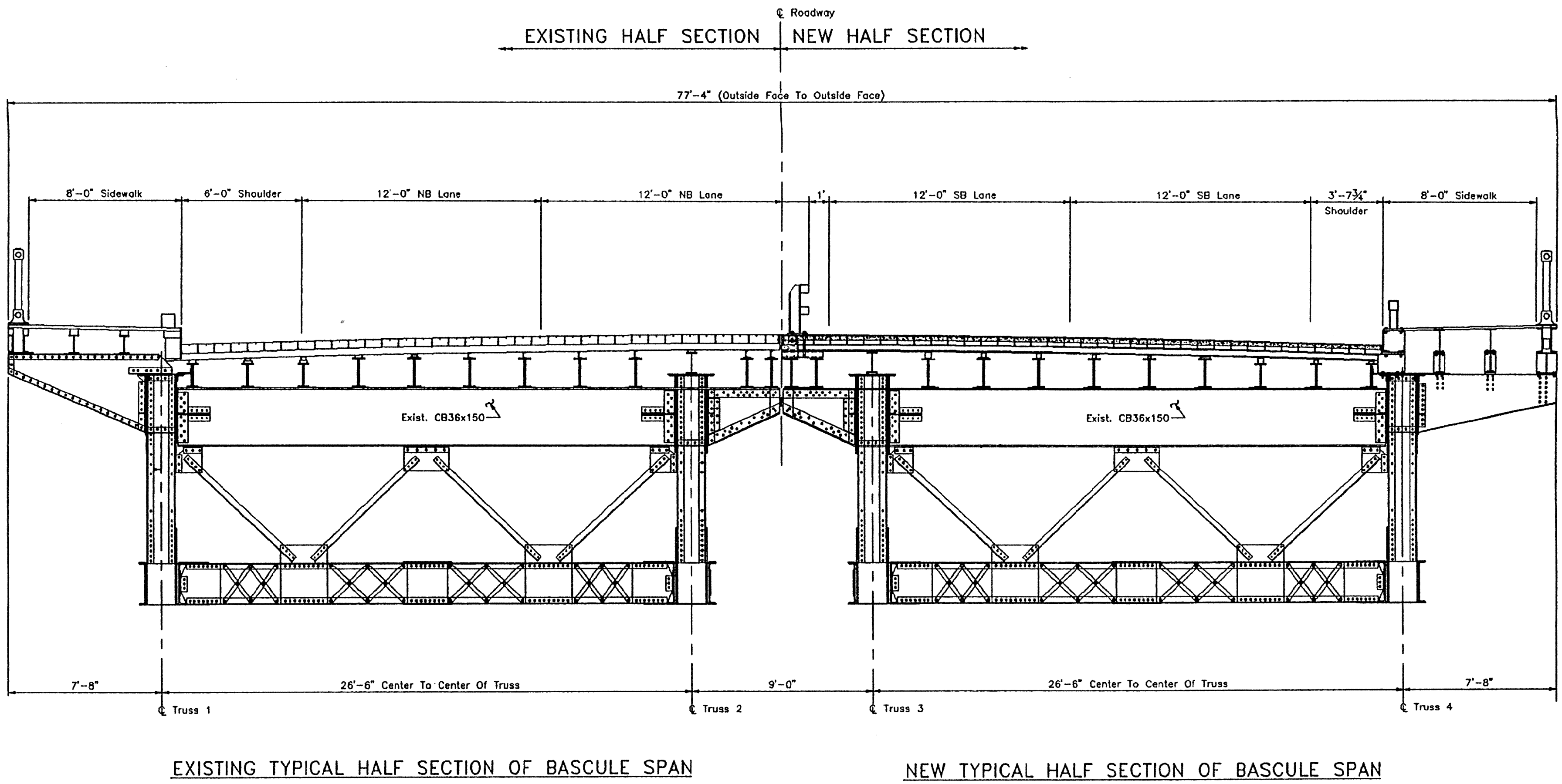

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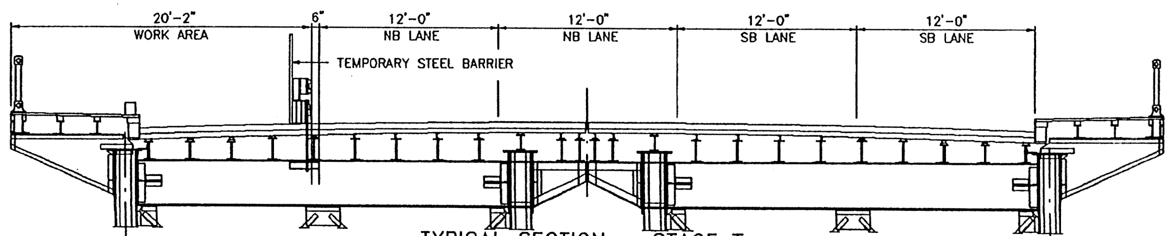
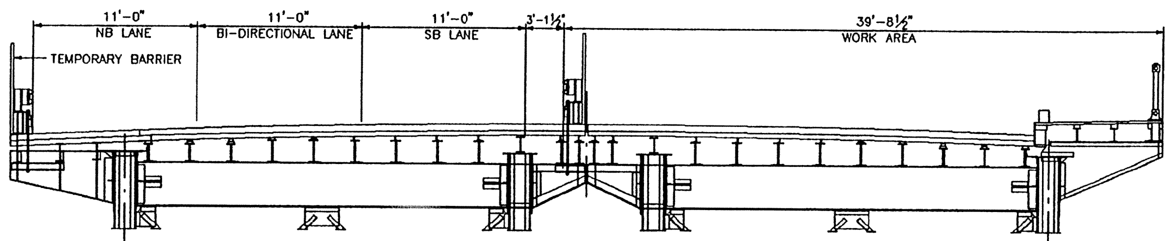
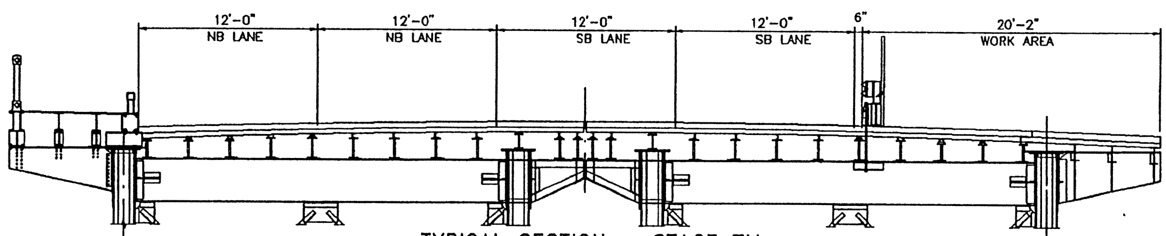
FIGURE 3
NEW AND EXISTING TYPICAL SECTIONS AT BASCULE



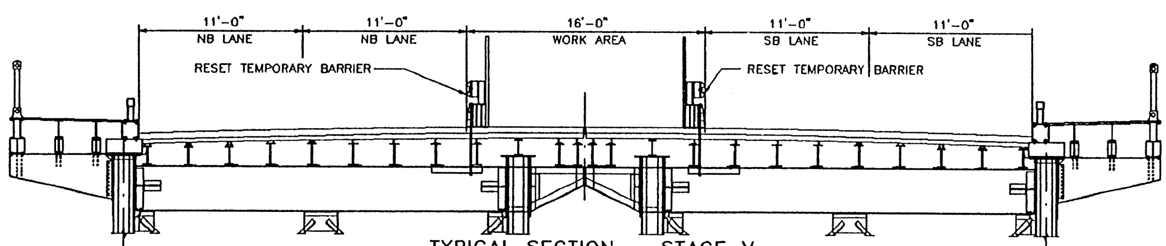
TYPICAL SECTION - STAGE I



TYPICAL SECTION - STAGE II SHOWN (STAGE III OPPOSITE HAND)



TYPICAL SECTION - STAGE IV



TYPICAL SECTION - STAGE V

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FIGURE 4
STAGES OF CONSTRUCTION

STAGE I (4 MONTHS)

- 1 lane Northbound and adjacent sidewalk closed. Maintain four 12 foot lanes of traffic.
- Sidewalk reconstructed as a travel lane - Balance maintained using temp. seawater ballast tanks.
- Exterior trusses and selected members reinforced to carry additional vehicular load during construction.
- Construct Operator Access Catwalk below deck.
- Place temporary steel barriers to allow one pair of twin leaves to be open while the other pair carries traffic.
- Modify bridge controls to allow separate operation of twin leaves.

STAGE II (7 MONTHS)

- Replace Electrical and Mechanical Systems on Western pair of twin leaves with leaves shored in the open position.
- Maintain three 11 foot lanes of traffic on the Eastern pair of twin leaves. Center lane is an alternating bi-directional lane which carries the Northbound peak traffic in the morning and the Southbound peak traffic in the afternoon. Maintain pedestrian traffic via shuttlebus during sidewalk closure.
- Maintain balance on operational and shored leaves with seawater ballast tanks during construction.
- Demolish open grating deck on shored Western leaves.

STAGE III (6 MONTHS)

- Maintain three 11 foot lanes on the reconstructed Western pair of leaves (sidewalk area temporarily serves as travel lane). Maintain pedestrian traffic via shuttlebus.
- Reconstruct Eastern pair of twin leaves similarly to Stage II work.

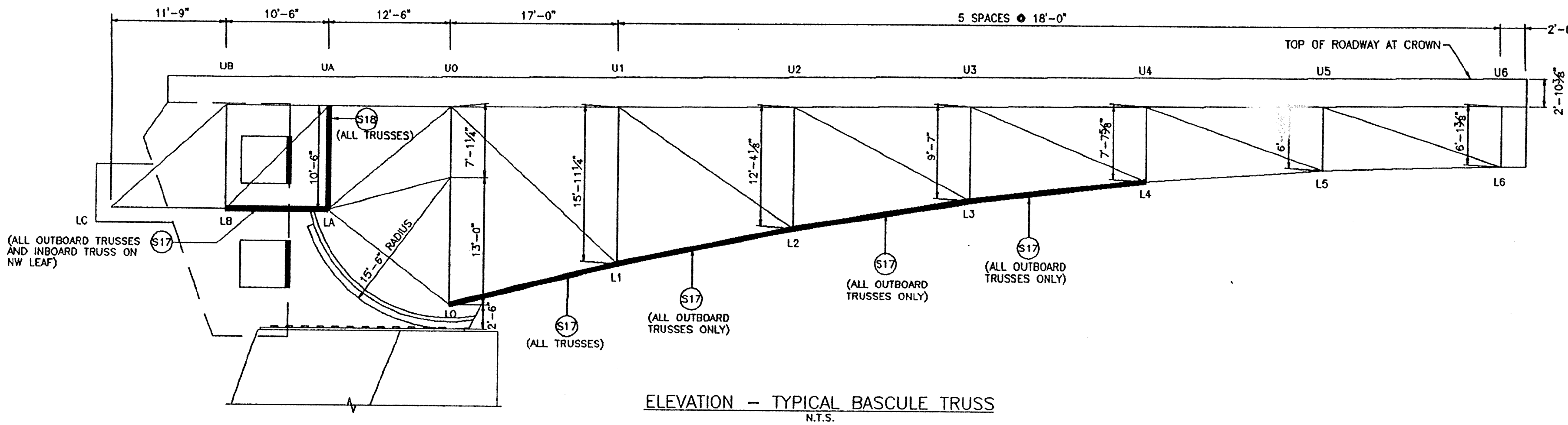
STAGE IV (3 MONTHS)

- Complete Western sidewalk and miscellaneous cleanup work on Western leaves.
- Maintain four 12 foot lanes of traffic.

STAGE V (4 MONTHS)

- Complete placement of permanent median and median barriers.
- Maintain four 11 foot lanes, two on each pair of twin leaves.

FIGURE 4 CONT'D



ELEVATION – TYPICAL BASCULE TRUSS
N.T.S.

LEGEND:

—— EXISTING MEMBER TO REMAIN

▬▬ EXISTING MEMBER TO BE REINFORCED

REPAIR SCHEDULE FOR REPAIR ITEMS S17 AND S18		
STAGE	LOADING CONDITION (ENTIRE SPAN LENGTH)	TRUSS TO BE REPAIRED
I	PEDESTRIAN RAILING, SIDEWALK STRINGERS, SIDEWALK SLAB, CANTILEVER SIDEWALK BRACKET AND CURB REMOVED IN WORK AREA AND LEAF IS IN THE TO OPEN POSITION.*	OUTBOARD TRUSS ON NE AND SE LEAVES.
II	ROADWAY DECK, WEARING SURFACE, PEDESTRIAN RAILING, SIDEWALK STRINGERS, SIDEWALK SLAB, CANTILEVER SIDEWALK BRACKET AND CURB REMOVED IN WORK AREA AND LEAF IS IN THE TO OPEN POSITION.*	INBOARD AND OUTBOARD TRUSSES ON NW AND SW LEAVES.
III	ROADWAY DECK, WEARING SURFACE, TEMPORARY STEEL BARRIER, TEMPORARY SIDEWALK STRINGERS AND TEMPORARY OPEN GRID DECK AND LEAF IS IN TO THE OPEN POSITION.*	INBOARD TRUSS ON NE AND SE LEAVES.

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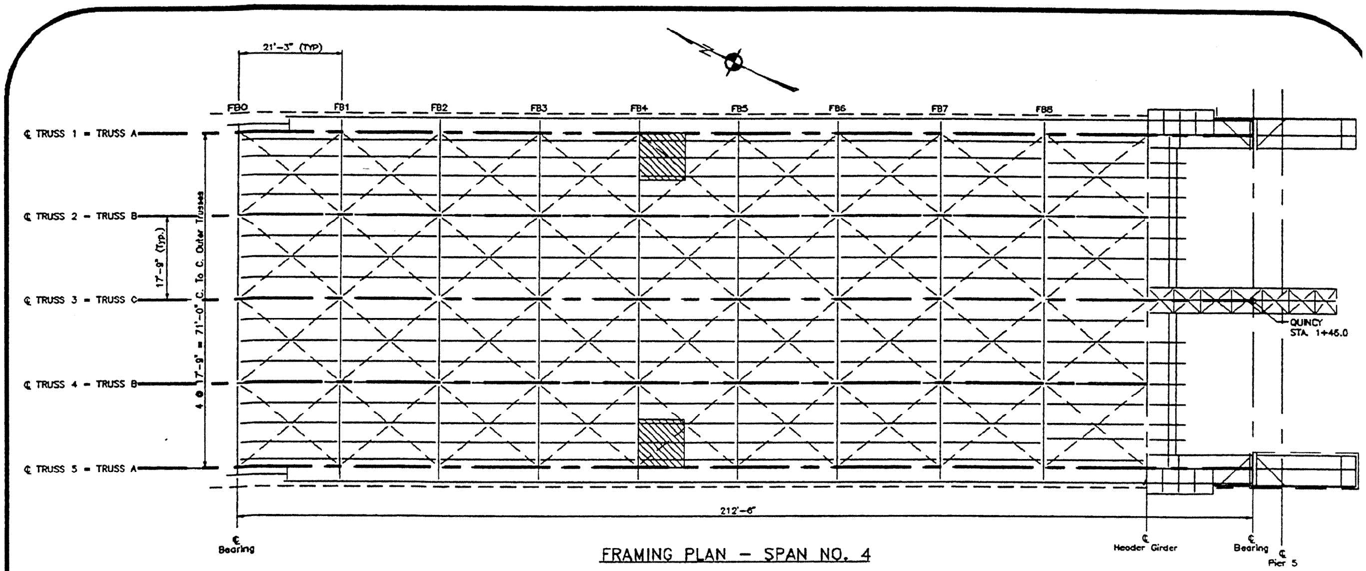
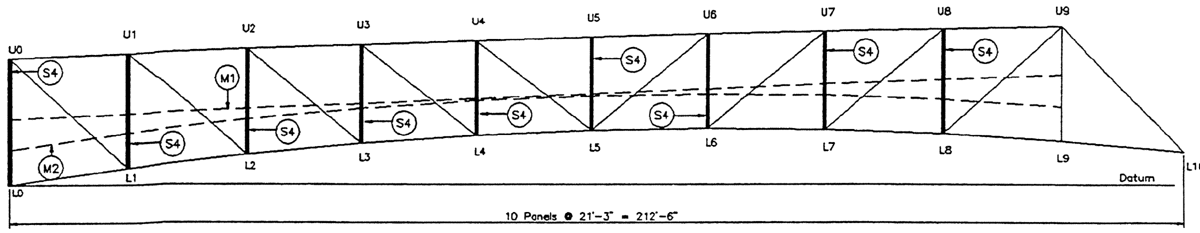
FIGURE 5

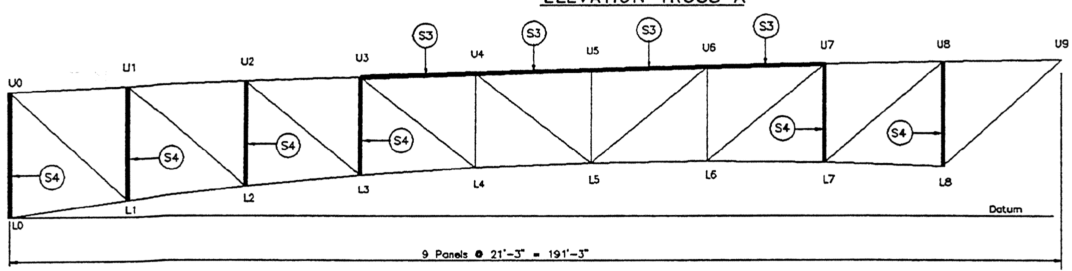
BASCULE SPAN DECK TRUSS REINFORCEMENT



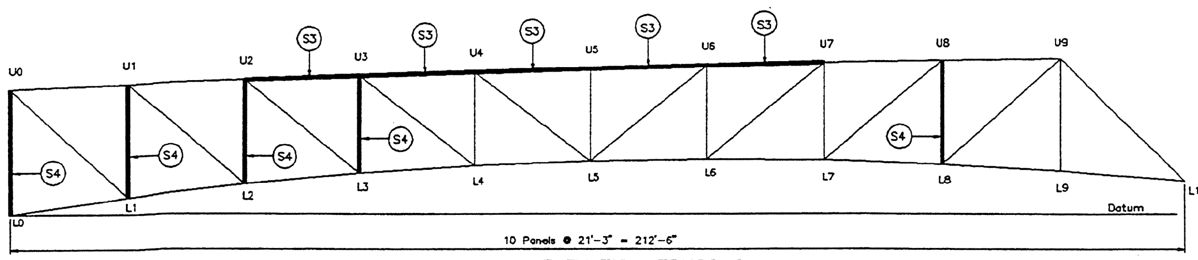
FRAMING PLAN – SPAN NO. 4



ELEVATION TRUSS A



ELEVATION TRUSS B



ELEVATION TRUSS C

REPAIR SCHEDULE FOR REPAIR ITEMS S3 AND S4

STAGE	LOADING CONDITION (ENTIRE SPAN LENGTH)	TRUSS TO BE REPAIRED
I	PEDESTRIAN RAILING, FASCIA CONCRETE, SIDEWALK SLAB, SIDEWALK STRINGERS AND CANTILEVER FLOORBEAM REMOVED.	EAST TRUSS A (1)
II	PEDESTRIAN RAILING, FASCIA CONCRETE, SIDEWALK SLAB, SIDEWALK STRINGERS AND CANTILEVER FLOORBEAM REMOVED.	WEST TRUSS A (5)
II	PEDESTRIAN RAILING, WEARING SURFACE AND ROADWAY DECK REMOVED OVER ENTIRE WIDTH OF WORK AREA.	WEST TRUSS B (4)
III	PEDESTRIAN RAILING, WEARING SURFACE AND ROADWAY DECK REMOVED OVER ENTIRE WIDTH OF WORK AREA.	EAST TRUSS B (2)
V	WEARING SURFACE AND ROADWAY DECK TO BE REMOVED OVER ENTIRE WIDTH OF WORK AREA AND BOTH LANES ADJACENT TO WORK AREA TO BE CLOSED TO TRAFFIC.	TRUSS C (3)

LEGEND:

—— EXISTING MEMBER TO REMAIN

▬▬ EXISTING MEMBER TO BE REINFORCED

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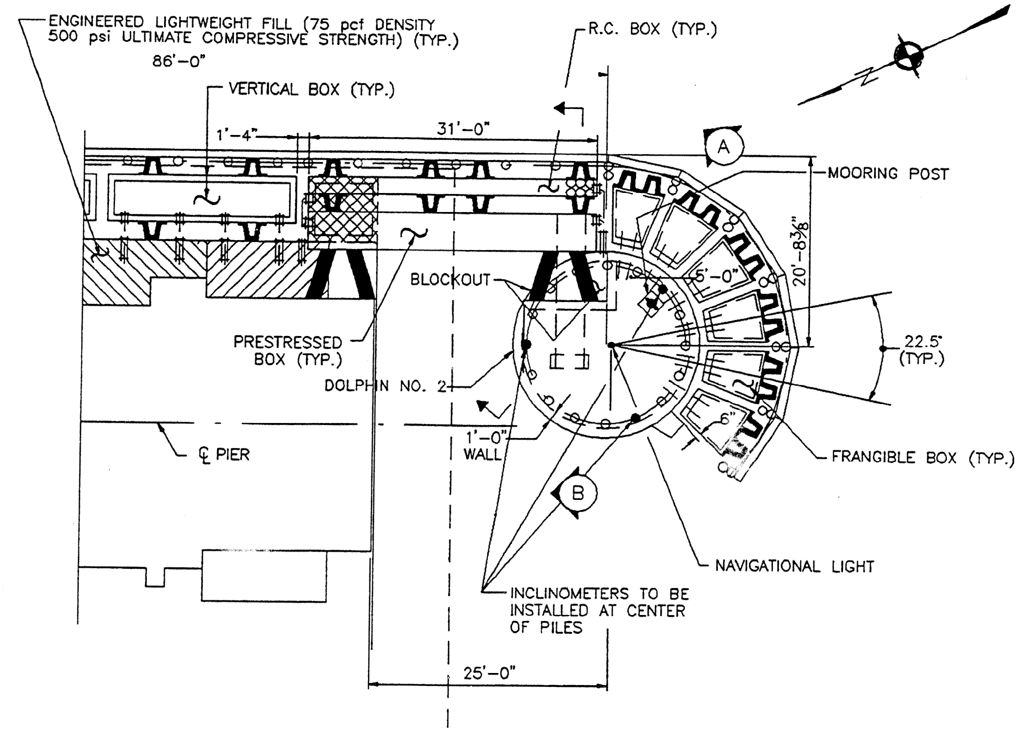
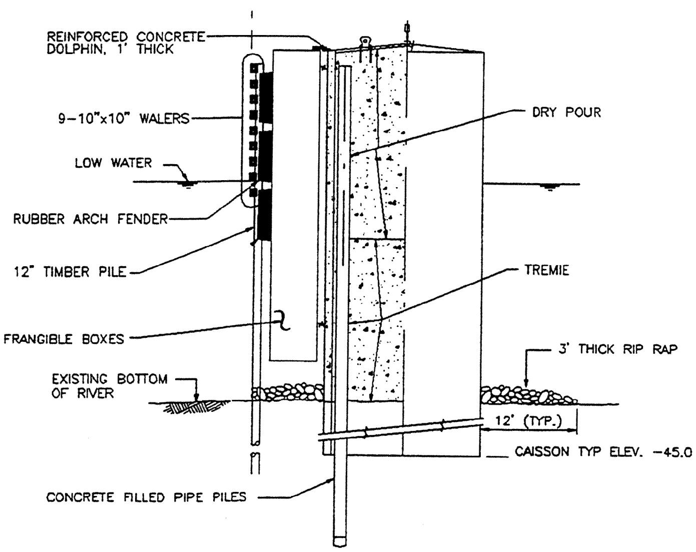
FIGURE 6

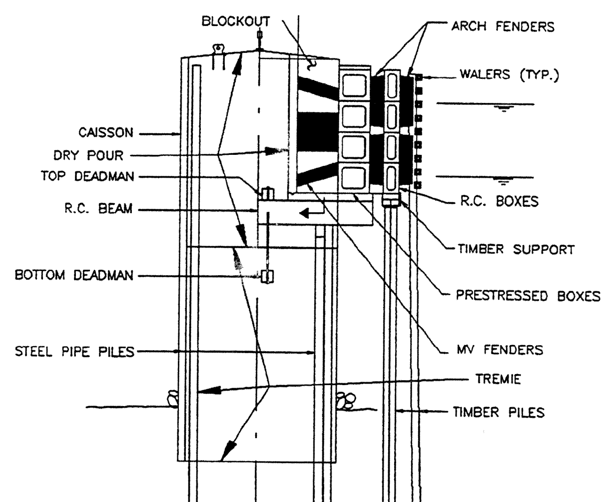
APPROACH SPAN
DECK TRUSS REINFORCEMENT



FENDERING REPLACEMENT PLAN



TYPICAL DOLPHIN SECTION (A)



TYPICAL DOLPHIN SECTION AT BLOCKOUT (B)

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FIGURE 7
NEW FENDERING