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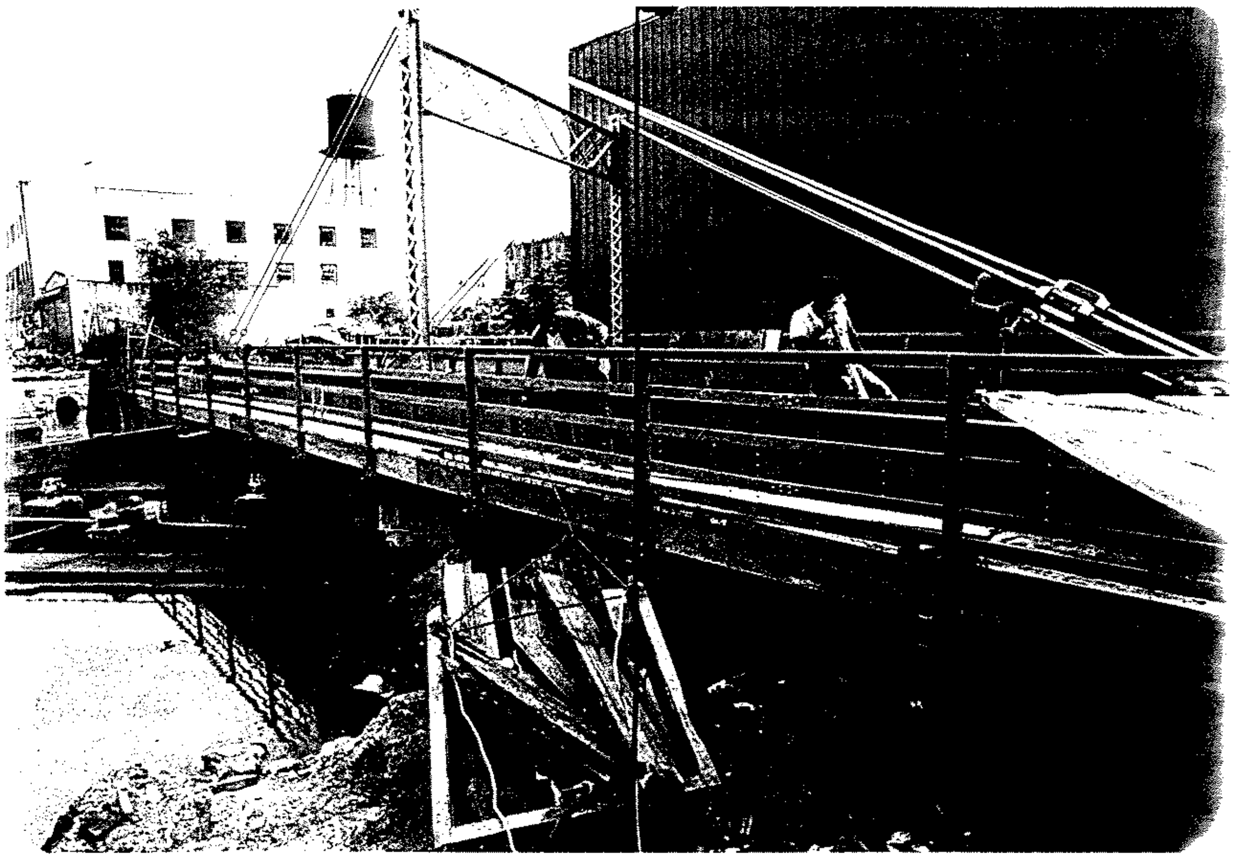
M.S.Hershey, New York City, Bridge Div.

CARROLL STREET BRIDGE REHABILITATION



NEW YORK CITY DEPT. OF TRANSPORTATION
BUREAU OF BRIDGES

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CARROLL STREET BRIDGE REHABILITATION

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THE CARROLL STREET BRIDGE REHABILITATION

I INTRODUCTION

It is a very exciting and challenging time to be working for the New York City Bureau of Bridges. In the Maintenance Division that I am in charge of, we have experienced an explosion of growth during the last three years. The reason for this growth was the realization at last that the 845 city-owned bridges were in a woeful state of disrepair and neglect due to the absence of maintenance programs for decades.

The biggest challenge arising out of this need and growth to date was the in-house rehabilitation of the Carroll Street Bridge.

In the spring of 1988, the First Deputy Commissioner of the newly created Bureau of Bridges requested the Maintenance Division to consider an in-house reconstruction of the Carroll Street Bridge over the Gowanus Canal in Brooklyn. The Carroll Street Bridge is a movable retractile* structure which ground to a halt in 1985 and had not been operated since then. The bridge was kept in the open position to allow vessels to navigate the canal and in the process severed a popular land link between the communities of Park Slope and Carroll Gardens.

During this outage period, the bridge was designated a city historic landmark by the Landmarks Commission. This meant that any work done to restore and repair the bridge would have to do so without altering the bridge's appearance. This would require that the bridge be rebuilt as a replica of the original using the same or similar materials. It also meant that substandard features in the existing structure would be maintained and would not be eligible for state and federal funds.

After reviewing the existing condition of the structural, mechanical, electrical and traffic control systems on the bridge and reviewing the consultants' Bridge Rehabilitation Project Report (BRPR), I determined that the bridge could be restored in time for the centennial birthday on September 25, 1989. The rehabilitation of the bridge would involve replacement of all structural elements with the exception of the two main steel plate girders and timber piles.

Photos showing the original deteriorated structure, rehabilitation period and finished bridge are included in the Appendix.

* There are only two existing retractile-type bridges in New York City and only four in the entire country. Carroll Street is believed to be the oldest extant retractile bridge in the United States.

II BRIDGE CONDITION PRIOR TO REHABILITATION

The condition of the various bridge components prior to rehabilitation were as follows:

1) Description of Bridge

The Carroll Street Bridge was built in 1889, as a retractile steel plate girder type bridge with steel eye-bar stays. The bridge structure, approximately 105 feet long and 28 feet wide, consists of two riveted steel plate girders, 20-inch riveted floor beams, 8-inch rolled beam stringers, a wood plank deck and a transverse steel bent supporting longitudinal steel eye-bar stays. The girder is a continuous two span member: one span has an average length of 60 feet and the other, 45 feet. The entire structure moves along steel rails at a skew to the longitudinal axis to allow for the passage of canal traffic. The eye-bar stay system helps support the dead load of the bridge when the bridge retracts to allow for the passage of waterway traffic.

Photo No. 1 shows deteriorated condition of the bridge on blocking prior to rehab.

Curb-to-curb width of the roadway on the bridge is 17 feet and the entire roadway width is used as travel lane, with no provision for parking. The bridge has only one traffic lane (east-bound). Each side of the bridge has a four foot timber sidewalk.

2) Carroll Street

Carroll Street is a one-way, one lane, east-bound commercial city street. On both sides of the street, about eight feet of the roadway width is used for parking leaving an average of 15 feet of roadway for travel. The street has no shoulders, but there are sidewalks of varying widths on both sides of the street. The average daily traffic count at last survey was 1,900 vehicles per day. Prior to being taken out of service, the bridge was posted with an eight ton limit.

3) Waterway Traffic

The bridge is opened for waterway traffic (closed to vehicular traffic) about four times a day on the average during the winter and the average duration of each of these openings is about eight minutes. The City of New York Department of Transportation requires a minimum of six hour advance notice between May 1 and September 30 from the waterway users, for the bridge openings. At other times it opens on signal. During maintenance operations and on occasions when the bridge machinery is inoperative, the bridge is left in the opened (closed to vehicular traffic) position.

Bayside Fuel Oil Depot Corp. is the major user of the waterway. The company owns and operates a wharf on the west bank of the Gowanus Canal just north of the Union Street Bridge for the receipt of petroleum products by self-propelled barges. The maximum-sized vessel in use is approximately 180 feet in length and 30 feet beam.

Prior to having to take the bridge out of service, an in-depth inspection revealed the following conditions:

4) Bridge Deck

o Wearing Surface and Deck Drainage:

The entire deck of the bridge is of timber construction. The wearing surface consists of two 2" layers of timber planks. The top layer is decayed and splintered in some areas. Some parts of the wearing surface have broken off the structural deck. In some areas, the bottom layers are exposed.

o Structural Deck:

The structural deck consists of 4" thick timber planks which are in fair condition, with the exception of some decayed edges. The timber is old and untreated.

o Sidewalk Rails:

The sidewalk rail on the south side is in fairly good condition. The northern sidewalk rail is damaged by vehicular traffic collisions at the abutment end. Here, the first two up-rights are broken at the deck level. The rest of the rail is in fairly good condition. The existing sidewalk rails cannot sustain the recommended AASHTO loadings.

o Sidewalk:

The sidewalk is of 2" thick timber planks. Some parts of the wearing surface are broken off the deck. The surface of the sidewalk deck tends to be slick when wet.

5) Bridge Approaches

o At both approaches, there is ponding of water during storms. This ponding is due to the clogged condition of the catch basins. Ground settlements at the approaches also contribute to the ponding. There are potholes and cracks in the pavements at both approaches.

6) Superstructure Condition

o Drawing 1, in the Appendix, shows the framing plan and a typical cross section of the existing bridge superstructure, including the sidewalks.

o The steel bearing plates at the east abutment embedded in the timber bulkhead are heavily corroded and worn out. The bearing plates are not secured firmly into the timber.

o The eye-bar stays, consisting of 2" rods, are in fairly good condition. However, there is corrosion at the eye-bar connection to the girders, due to accumulation of dirt and moisture.

- o Two king posts, connected at the top by a sway frame, carry the eye-bar stays. The posts and the sway frame are in fair condition. The sway frame however, is bent slightly out of alignment due to vehicle damage.

- o The original wedge operating machinery is not operable as a result of deterioration and missing components.

- o The main girders show evidence of collision damage on their east ends, which can be attributed to both vehicular and to marine vessel impact.

7) <u>Substructure Condition</u>

A) General

- o The substructure of the bridge, in general, is in very poor condition with deteriorated timber abutments and wing walls.

- o At the west bank (the side to which the bridge retracts), the timber retaining wall around the embankment is decayed and damaged and the top section is missing in one area (refer to Photo No. 2). The low height of this wall makes it susceptible to periodic floodings which submerge the rails. There is settlement of the rails especially in the area of the tracks supported on timber cribbing rather than on pile supports. The bottom of the girders graze the top of the pulley guides because of this settlement. The end of the rail at the east face of the embankment is broken due to boat collisions, causing some of the wheels to be left only partially supported.

B) ABUTMENTS (Bulkheads)

a) <u>East Abutment</u> -- The bridge is supported on this bulkhead when in the closed position spanning the canal.

- o <u>Abutment Joint with Deck</u> -- The joint is open, thus allowing dirt and moisture to accumulate on the floor beam. This condition promotes corrosion.

- o <u>Bridge Seat</u> -- The timber seat is weathered and cracked. There is also some splintering due to boat collisions. When the bridge opens and pulls away from the seat, the outer timber beam of the seat moves away from the abutment leaving a 1/2" gap between the two beams of the seat.

- o <u>Abutment</u> -- The timber wall of the abutment is badly decayed. There is a hole in the north wall due to the decayed condition. This condition has caused a loss of fill material from the embankment which in turn has undermined the north sidewalk and caused it to settle.

b) <u>West Abutment</u>

- o Abutment Joint with Deck -- This is an open joint, which allows transverse movement for the opening/closing of the bridge. The joint also allows water and dirt to accumulate on the floor beam. This causes extensive corrosion to the ends of the stringers and the west face of the floor beam.

- o Bridge Seat -- The rails on which the carriages are seated show signs of settlement and become submerged at high tide. This condition makes the bridge inoperable when the water freezes.

- o Wing Wall -- The wing wall at the abutment is of stone masonry and there is some loss of mortar. There is evidence of movement in the north wing wall.

C) Foundation Piles

A close examination of the abutment piles without removal of existing timber structural elements was not feasible. Based on past experience and observations of the performance of timber elements below the low water level, it was assumed that the piles would not show major signs of deterioration.

A test exploration was conducted to inspect the timber piles. The pile inspected was sound under vigorous hammering, and no dry rot or other deterioration was found.

8) Operating Machinery

A) History and Operation

The bridge operating machinery consists of an electric driven winch and a system of sheaves, wire ropes, rope attachments, carriage trucks and rails.

Two wire ropes are attached to and wrapped around the winch drum. One rope leaves the drum at the top, passes around the opening sheaves and is attached to the opening end of a dead man (terminal fitting). The other wire rope leaves the winch drum from the bottom, passes around the closing sheaves and is attached to the closing side of the terminal fitting. The terminal fitting is fixed to and moves with the bridge. The bridge sits on four carriage trucks which roll along rails much like a train. Each truck is connected to the bridge and is mounted on the bottom flanges of the main girders.

In the opening operation, the winch motor turns a drive shaft connected to speed reduction gears. The gears rotate the drum shaft at a slow constant speed. The wire rope pulls the bridge along the tracks while being wound counter-clockwise around the drum. At the same time, the closing wire rope is automatically paid out along its route from the drum to the closing end of the terminal fitting.

In the closing operation, the winch motor is reversed with the closing wire rope winding onto the drum while the opening wire rope is paid out in a clockwise direction.

B) Inspection

Following is a list of defects found during visual inspection of mechanical components while the machinery was both idle and operating:

a) Sheaves

Four of the six sheaves are original equipment in operation for over 75 years. Their grooves are well worn, corrugated and have become oversized.

b) Wire Rope Guides

Most guides are original equipment and have been found to be bent, broken and misaligned.

c) Carriage Trucks

The four trucks are also original equipment installed in 1905. Most wheels are seized and do not turn. The bridge is consequently being dragged along the rails causing additional stresses to the winch, wire ropes, rope attachments, sheaves and rails.

The truck bodies, however, appear to be in good condition with minor corrosion and no missing rivets.

d) Rails

Most rails and tracks are original equipment and in poor condition. Rails show extensive abrasion and wear mostly due to the effects of Item c) above. Uneven settlement has also caused additional stresses on the operating machinery. The profile of the three sets of tracks do not align.

A level survey was made of the top of rails of all tracks. The results of this survey indicated that the tracks dip over the non-pile supported areas where timber cribbing remains from a bulkhead that predates this bridge prior to 1889.

e) Wire Ropes

Excessive wear is suspected due to the aggravated conditions under which the rope is forced to operate.

The worn sheaves cause the rope to flatten in the grooves causing accelerated wear and loss of rope capacity.

The rope has stretched and sagged to a point where it can jump out of sheave grooves at the start of an operating cycle. The stretching causes uneven winding around the winch drum.

f) Wire Rope Attachments

The terminal fitting underneath the bridge has a significant amount of rust. Rope strands around this critical fitting have separated and flattened, allowing rust to penetrate into the interior. The U-bolt type clips used to form the loop around the fitting have twisted out of alignment.

9) Electrical Components

The condition of the electrical components of the bridge are summarized below:

A) The control (operator's) house is in poor condition and offers little protection against vandalism. The glass case of the electric meter was smashed and other damage to the electrical equipment was evident.

B) The electrical boxes, panels, switches and other devices are all in worn but usable condition. (The bridge was successfully operated during the inspection.) The location of the various electrical items is rather haphazard, which is an indication of changes made during the long life of the installation.

C) The motor starter has its associated resistor bank encased in a possibly combustible material, which minimizes ventilation. The controller requires operator judgement concerning the proper acceleration of the motor.

D) The motor is old and has no readable name plate. The motor brake requires frequent adjustments.

E) The navigation lights are not operating because the automatic take-up reel is broken and the cable is dragged back and forth as the bridge operates. Bridge navigation lights are also subject to vandalism.

F) The general impression received at the time of inspection, is that the electrical facilities, while operative, are rather old, worn and with uncertain future life.

10) Control (Operator's) House

The control, or operator's, house was found to be in generally poor condition. Specific observations are:

A) Cracked and spalled masonry walls with some evidence of foundation settlement at one corner.

B) Evidence of failure of the winch foundation, requiring expedient field repairs to permit the continued operation of facility.

C) Damaged and broken toilet facilities (vandalism).

D) Roof leakage resulting in cracked and water-stained ceiling.

E) Damaged and broken windows and window frames requiring boarding up for security purposes (vandalism).

III RECONSTRUCTION

1) Foundation

One of the major decisions faced was how to ensure the foundation of the bridge was adequate. Inspection of the existing timber piles indicated that they appeared to be intact and virtually as solid as when they were originally installed in 1889. A comparison of recent surveys with original rail elevations showed good correlation with settlement in local areas but not overall. The settlement had occurred in an area where piles had not been placed under the timber rail supports. Original drawings show a 16 foot wide area where timber cribbing formed a previous bulkhead which was no longer at the channel interface but approximately 28 feet inboard of the present bulkhead. (See Drawing 2 in the Appendix.)

The original continuous timber pile caps were installed in a double layer and served as the rail support transferring the moving load as the bridge opens to the piles. In the area of the abandoned bulkhead, the timber pile cap had been installed directly on the timber cribbing. Over the years, this cribbing apparently settled relative to the piles forcing the timber pile cap to bridge the span between pile groups and resulted in a "dip" in the rail.

There was no question that the timber pile caps needed to be replaced. They were deteriorated and not uniformly level. Consideration was given to installing new timber pile caps to preserve exactly the historic appearance and structure of the bridge. It was evident, however, that this would probably not provide a sufficiently rigid rail support over the abandoned bulkhead area and would settle again in the future.

It was decided to design a reinforced concrete pile cap that would serve as rail supports and span the abandoned bulkhead without allowing rail settlement. The existing timber pile cap was removed and a 3' x 3" deep reinforced concrete cap was placed over each group of rails. A two to four inch layer of greenheart timber was installed over the concrete pile cap and covered by a 1/2" steel bed plate on which the rails sit. The area between rails was graded and covered by a bed of gravel to prevent growth of weeds (Photo No. 7).

2) Operator's House

By the spring of 1988, the existing operator's house was on the verge of collapse. The house was located adjacent to a trash transfer station and the brick operator's house walls had been struck by trucks entering and leaving. There was no way to salvage the existing structure and it was decided to dismantle the building down to the foundation. Because of the landmark status, the existing face bricks were salvaged and stored so they could be used on the rebuilt house.

This small building houses the main drive motor, resistors, electric service meter and winch drum. The opening/closing cable winds around the winch drum and passes out back of the house through a series of sheaves and guides before it attaches to the bottom of the bridge structure at the terminal fitting.

Since this bridge is not staffed except for vessel openings, it was a frequent target for vandals and was broken into many times. After the bridge ceased to operate in 1985, vandals gutted and damaged the entire contents, leaving nothing inside that could be salvaged.

The bridge operator house is a five-sided polygon (25' long x 16' wide x 13' high). The construction consists of a 12" thick reinforced concrete slab, with cinder block walls on the interior of the bridge operator house. Brick facing (bricks from the original bridge operator house) on the exterior of the bridge operator house includes four arched window frames and one door opening. The roof is constructed of 2 x 10 timber joists with asphalt shingle overlay and stone coping placed around the top perimeter of the bridge operator house.

3) <u>Rebuilding the Bulkheads and Abutments</u>

The bridge maintenance division employs approximately 18 carpenters but it had been many years since any substantial timber fender or bulkhead work had been attempted. Rehabilitation of the bulkheads included approximately 125 linear feet on the west abutment and 110 linear feet on the east abutment. Depth of repair was down to low water level and was done with 12" x 12" timber. On the east abutment which was constructed as a cribbing, it was necessary to excavate inboard to sound timber and splice to these members. (See photo No. 6 in the Appendix.)

Work schedules had to be adjusted to take advantage of low tide, which changes daily. Much of the work was done from a timber raft that was built specifically for this job. The raft floated in the canal and could be lifted out when not in use or tied out of the way of barges using the canal. The canal had to remain unobstructed and navigable during the entire construction period.

4) <u>Rebuilding the Superstructure</u>

Except for the two longitudinal girders, the entire superstructure was to be replaced. All existing stringer to girder connections had to be measured precisely and field drilled to match existing holes. All steel was cut to final dimensions and fabricated in our shops. The timber deck was replaced in kind. (Photo No. 5 shows the new steel in place prior to deck installation.)

The superstructure elements that were entirely replaced and installed during this project included the following:

- o Eleven W21 x 83 floorbeams totaling 175 feet in length.

- o Seven rows of W8 x 48 stringers totaling 640 feet in length.
- o New timber deck installed in three layers consisting of 4 x 12 at bottom, 2 x 10 middle layer topped by 2 x 8 wearing course.
- o Transverse stiffening frame connecting cable stay posts.

During most of the construction period, the superstructure was supported on blocking until the new rails could be installed. All trucks were removed from the bridge and brought back to the shop. The ironworkers and machinists completely dismantled the trucks and refurbished or replaced all worn or deteriorated parts. The truck wheels were machined to remove flat spots. Three of the wheels were excessively out of round and were instead replaced by new ones. All wheels, shafts and bearings were refurbished in our machine shop.

The refurbishing of trucks included the following:

a) One six-wheel truck consisting of two sets of three wheels each
b) One four-wheel truck consisting of two sets of two wheels each
c) One two-wheel truck consisting of two single wheels
d) One single-wheel truck

A total of six rails were installed: a triple rail, double rail and single rail to support the various trucks.

An examination of the truck mounting hardware indicated that at one time they had the ability to swivel (like a caster) with respect to the bridge girders. This had been altered, however, at some time and were now not adjustable but bolted directly to the girder bottom flanges. Some time after the trucks were installed over the new rails, two problems became apparent; the bridge was not oriented at the correct skew angle to the rails and the trucks were not all parallel to each other, which they would have to be to stay on the rails.

The skew angle problem was caused by barges hitting the end of the bridge while it was up on blocks during construction. This was an additional challenge for us because, at first, we were not sure how difficult it would be to reorient the bridge. After considering various options including jacking with air bags and greased bearing plates, the solution proved not to be as difficult as we feared. While on blocks with the wheels off the rails, we were able to slowly coax the bridge into its proper alignment through the application of horizontal jacking forces.

The second difficulty (trucks not parallel) was solved by remounting one of the trucks. To do this, we fabricated a new mounting plate and drilled new holes in the existing bottom girder flange.

5) <u>Rebuilding the Electrical System</u>

The entire electrical system on the bridge was replaced and included:

a) New 200 A service to bridge -- 3 phase, 4 wire

b) A new 25 HP wound rotor induction motor including new foundation and reducer

c) New resistor banks

d) Pier and navigation lighting

e) Traffic gate lighting and bridge horn

f) New submarine cable and panel boxes

g) Automatic take-up reel (spring loaded retractable feeder rail)

h) Main disconnect switch and circuit breaker panel

i) 200 A motor disconnect switch

j) New control board with relays and exciter contactors

k) Refurbished drum controller and desk panel console

l) New bridge house lighting

m) Two historic street lighting lampposts

n) All wiring for above systems

IV REHABILITATION COST

The cost of rehabilitating the Carroll Street Bridge came to 1.5 million dollars and took less than one year. This proved to be a savings of both time and money. With normal letting of New York City engineering design, consulting and construction contracts, this process would have taken three to five years and probably cost nearly three million dollars.

A small portion of the work was done by a contractor to take advantage of his availability at the time. This work included pouring the reinforced concrete pile caps and installing dolphin clusters to protect the bulkheads. The following table illustrates the comparisons of the actual in-house costs incurred and the estimated contracted out costs.

In-house vs. Contract Cost Comparision

ITEM	IN-HOUSE COST
Design Cost	54,261
Labor Cost	1,104,428
Engineering Supervision	46,901
Contractor	111,255
OTPS (Materials)	110,000
OTPS (Equipment & Vehicles)	30,477
Consultant Cost	27,900
TOTAL IN-HOUSE COST	$1,485,222

ITEM	CONTRACT COST
Preliminary Design Consultant	269,000
Final Design Consultant	230,000
Supervision of Design Consultant - NYC DOT	100,000
Other City, State Fed Agencies*	NA
Construction Contract	1,800,000
Supervision of Construction - Consultant	200,000
Supervision of REI Consultant - NYC DOT	20,000
Consultant Contract Processing	25,350
TOTAL CONTRACTOR COST	$2,644,350

* There is an additional cost to city agencies other than DOT, state agencies and federal agencies associated with capital construction contracts. Estimates of these costs were not available for this analysis.

The various labor titles that worked on the bridge rehabilitation and average crew sizes were as follows:

Labor Title	Crew Size*
Engineers	2
Ironworkers	10
Machinists	2
Carpenters	6
Electricians	4
Painters	3
Laborers	4
Masons	4

* Average crew size indicated. All trades were not engaged constantly on this project but were utilized for the appropriate stages dictated by the project schedule.

V *CENTENNIAL CELEBRATTION*

On Saturday, September 23, 1989, the Carroll Street Bridge was restored to service two days prior to its one-hundredth birthday. This was a day of celebration for both the Department of Transportation and the local communities. The Park Slope and Carroll Gardens neighborhoods were again joined by the Carroll Street Bridge.

People who lived near the bridge for up to sixty years, as well as school children, dignitaries and DOT commissioners, were in attendance. Food and drink were provided by Monte's, a local Italian restaurant, and was highlighted by a "100 foot" hero (or "sub") sandwich which stretched across the bridge. Photo No. 9 shows the bridge on the day of the celebration.

Reconstruction of the Carroll Street Bridge was perhaps a once in a lifetime opportunity to tackle a complete project of this complexity and magnitude with in-house engineering and skilled trades personnel. The community, the Department of Transportation and the Bureau of Bridges all rose to the challenge and accomplished a proud achievement for the City of New York.

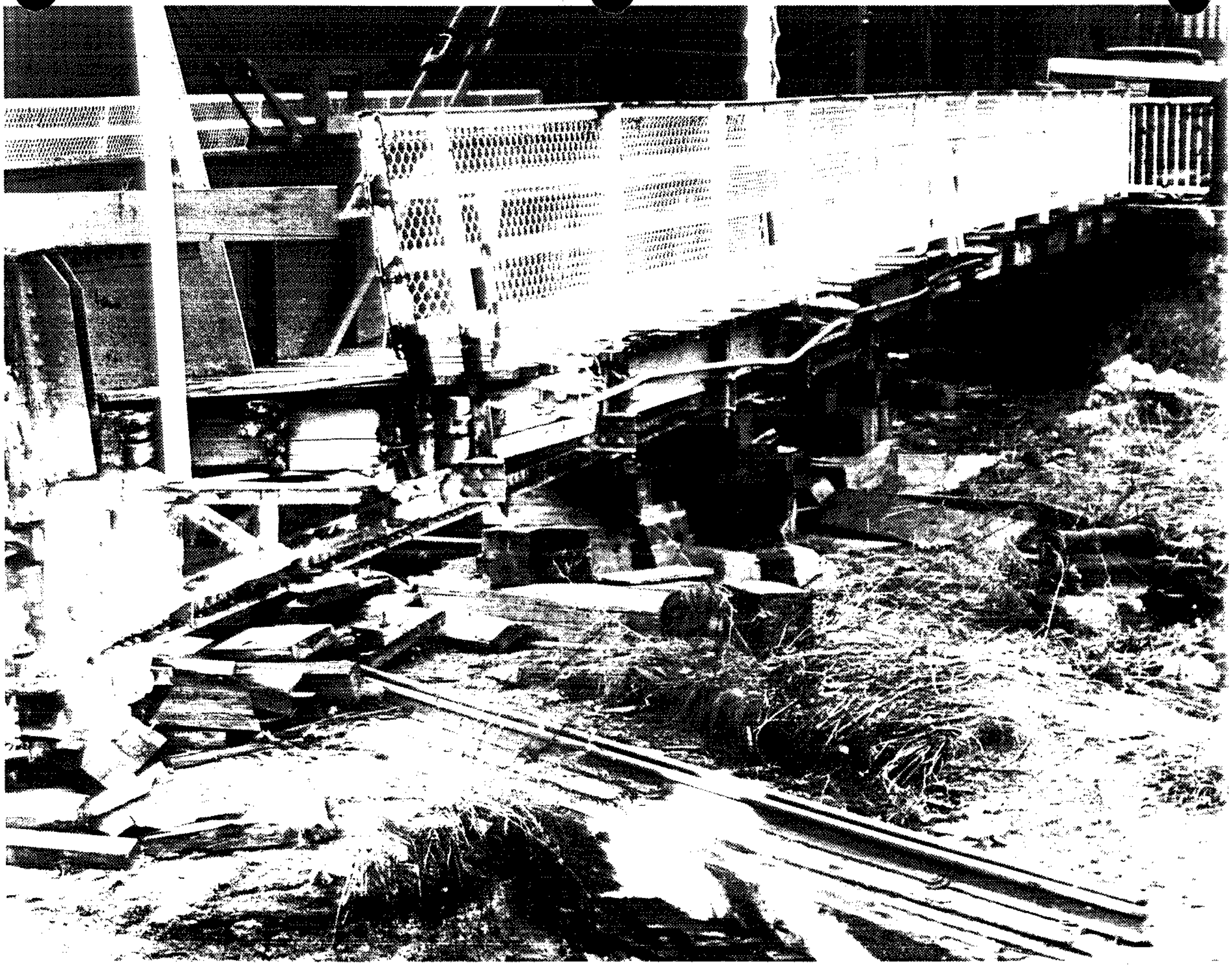


Photo No. 1 Deteriorated Bridge On Blocks

Photo No. 2 Damaged West Bulkhead And Sheave

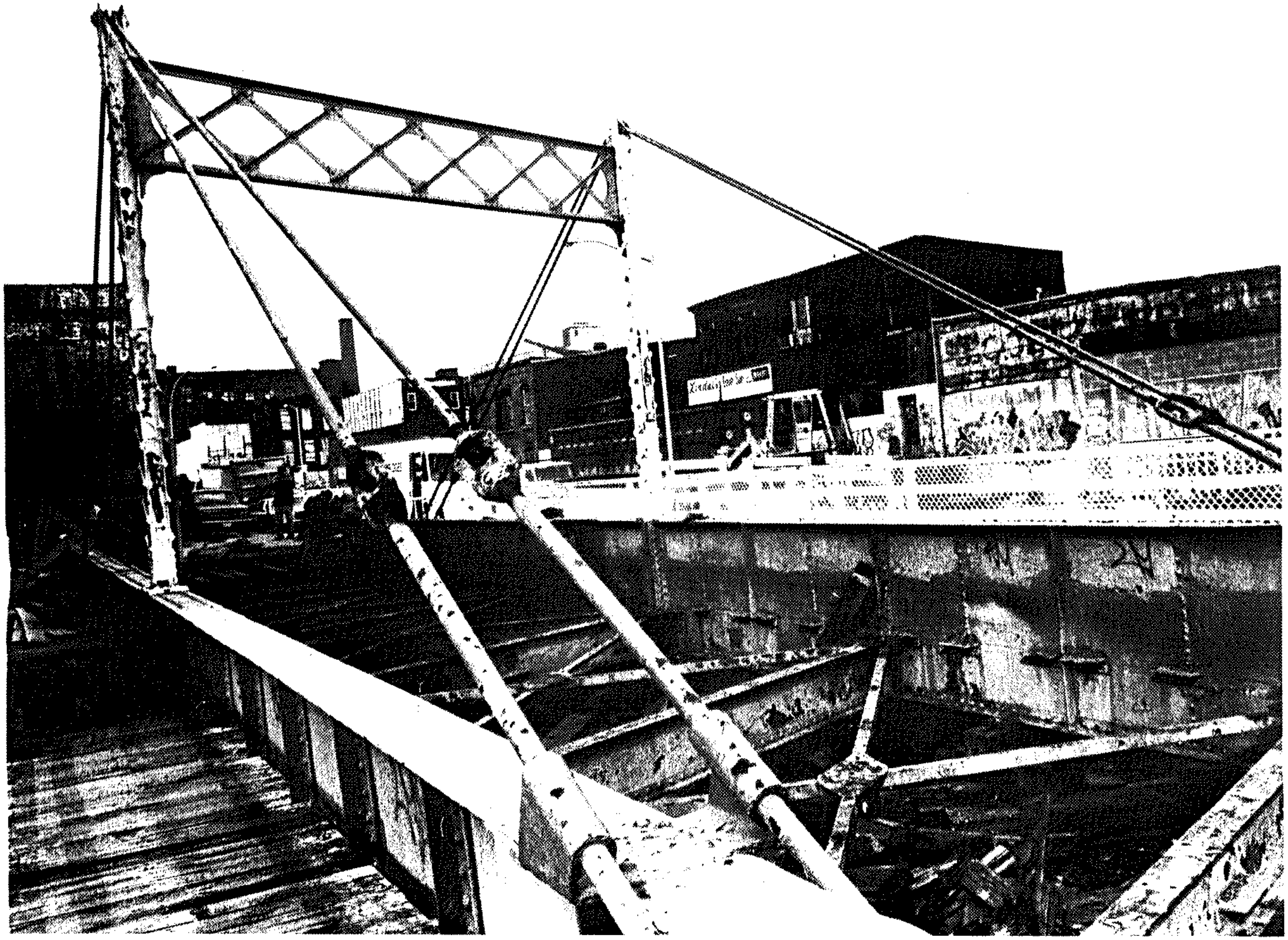


Photo No. 3 Bridge With Deck Removed

[NOTE: Photo's #4 and #5 missing from the original document.]

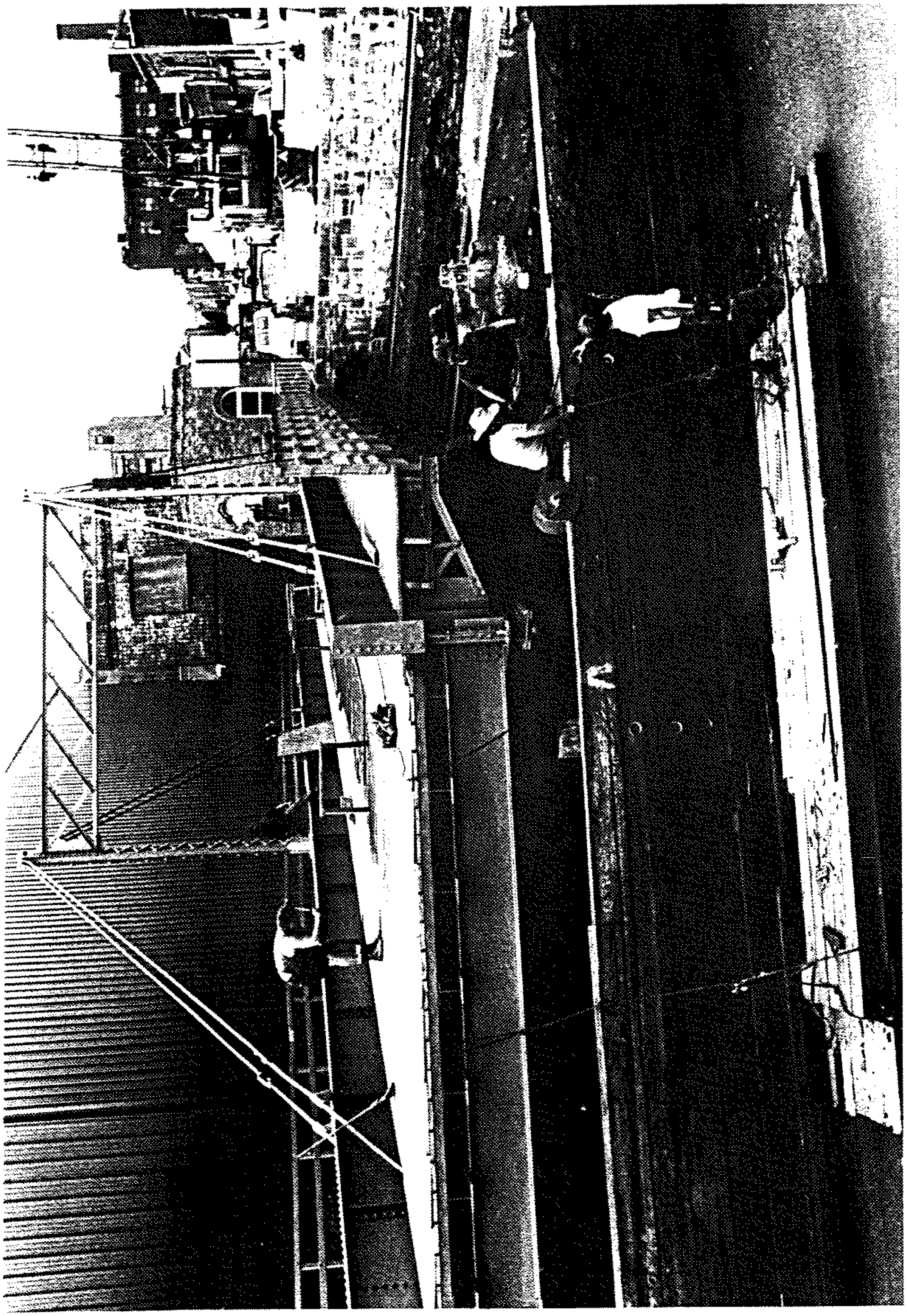


Photo No. 6

West Bulkhead And Deck Installation

Photo No. 7 Placing Gravel Bed

Photo No. 8 Installation Of Sheave

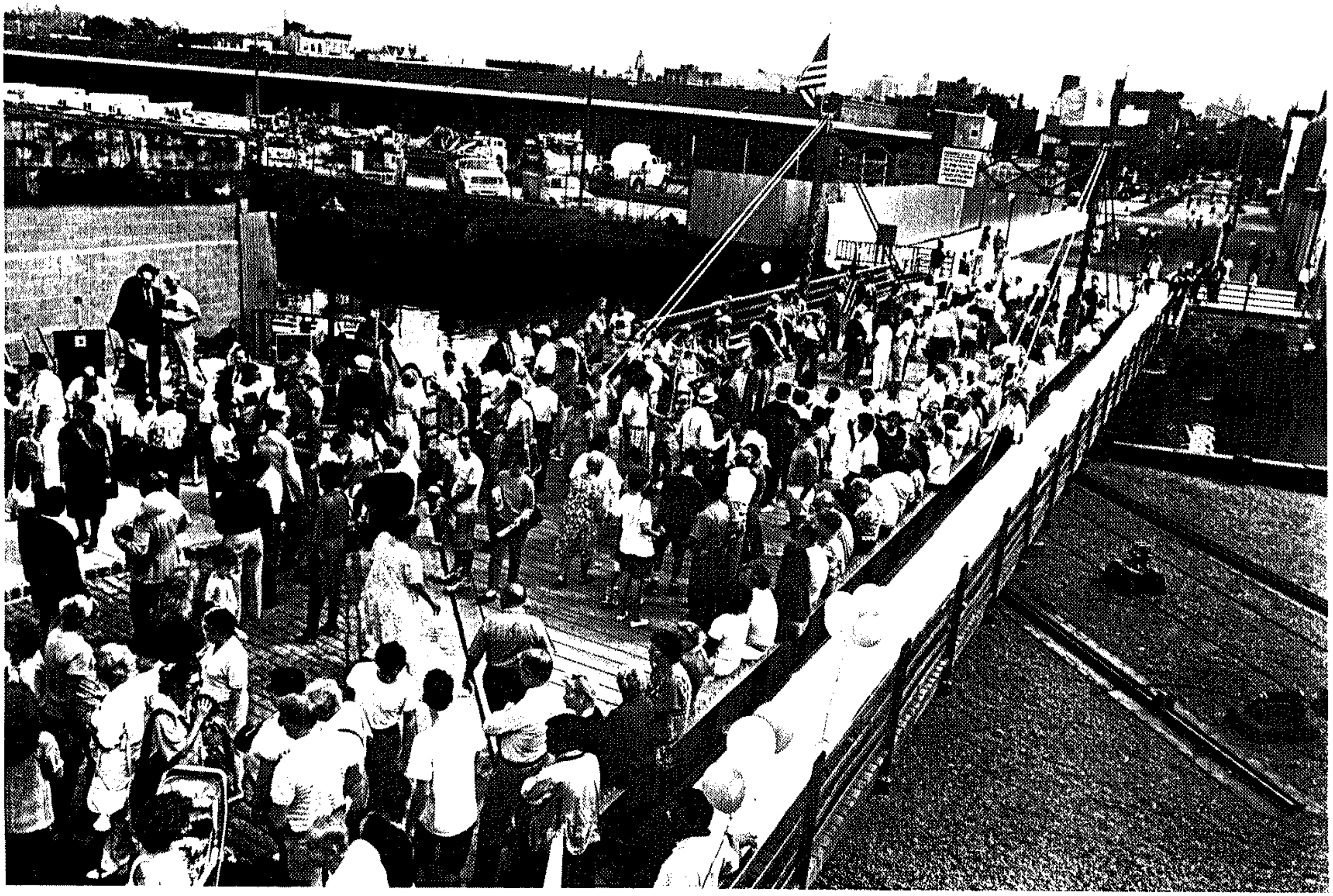
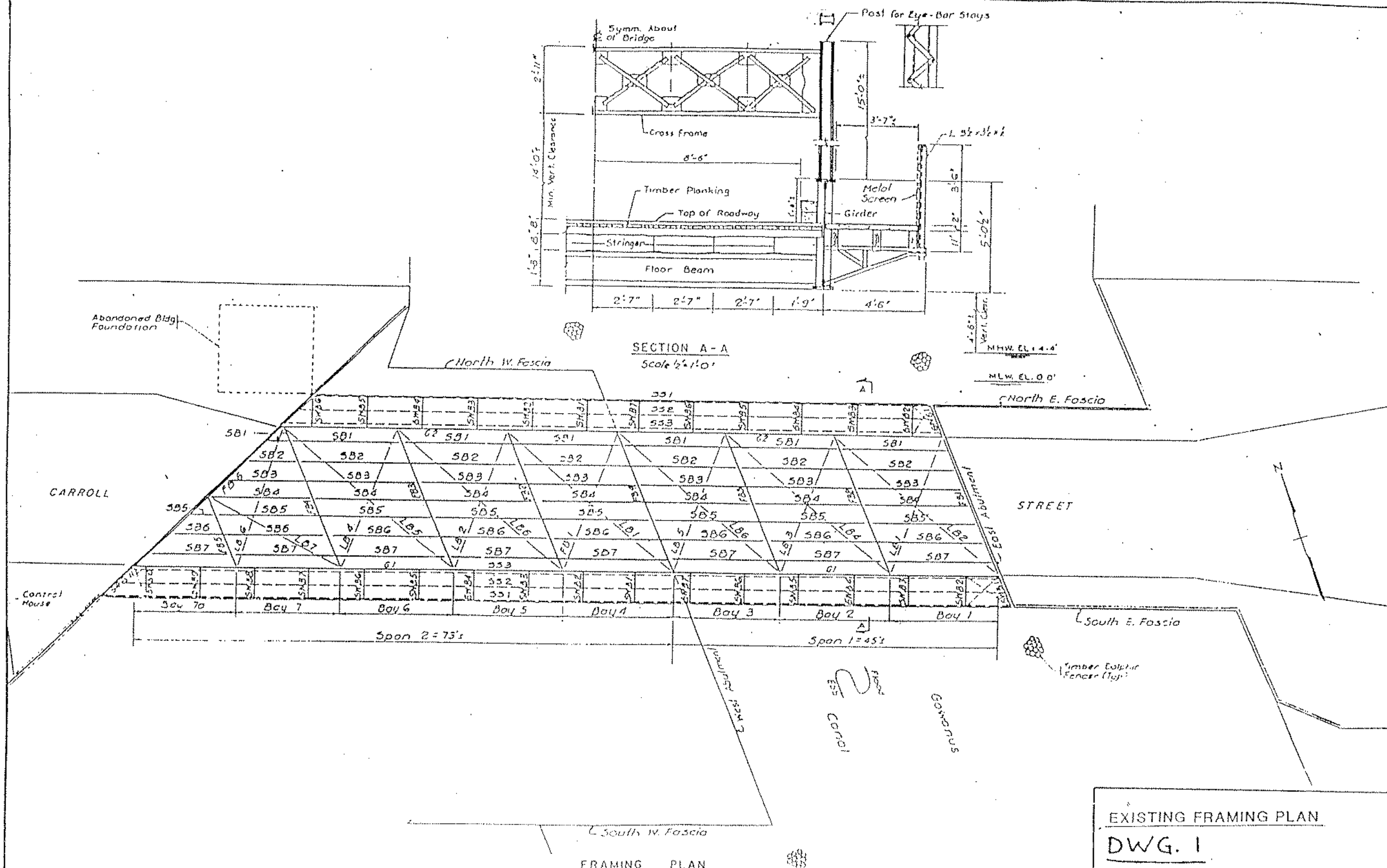


Photo No. 9 Centennial Celebration

A P P E N D I X

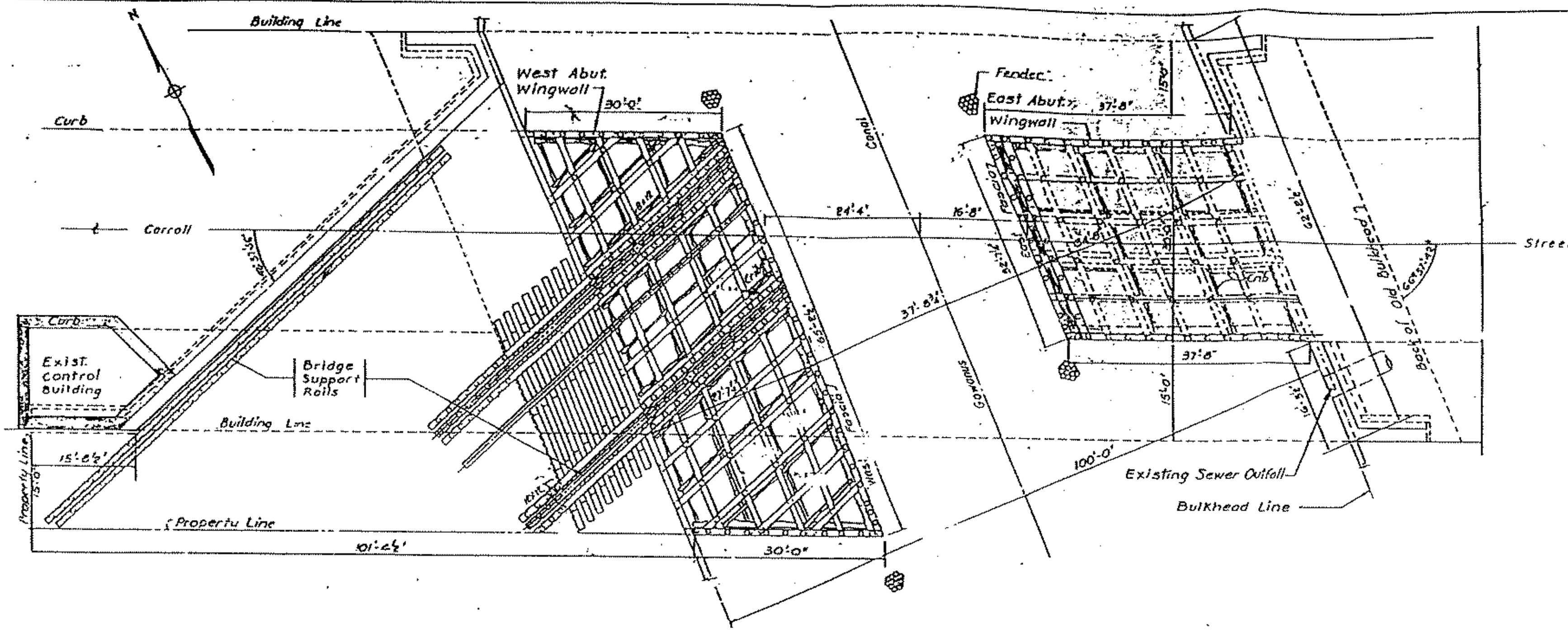


SECTION A-A
Scale ½" = 1'-0"

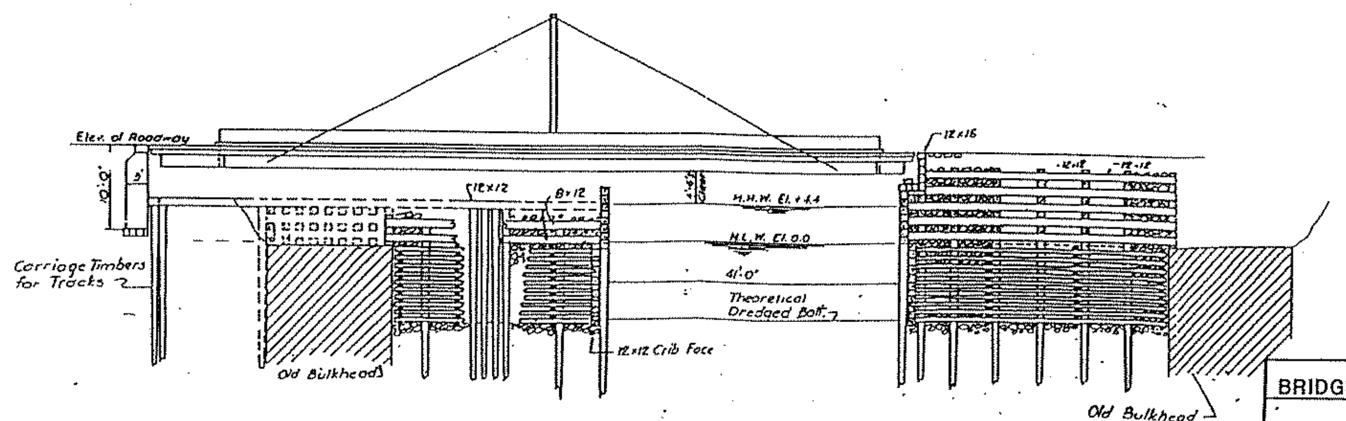
FRAMING PLAN
Scale 3/16" = 1'-0"

EXISTING FRAMING PLAN

DWG. 1



BULKHEAD PLAN
Scale ⅛" = 1'0"



LONGITUDINAL SECTION THROUGH CENTER OF CARROL STREET
Scale ⅛" = 1'0"

BRIDGE SUBSTRUCTURE PLAN

DWG. 2