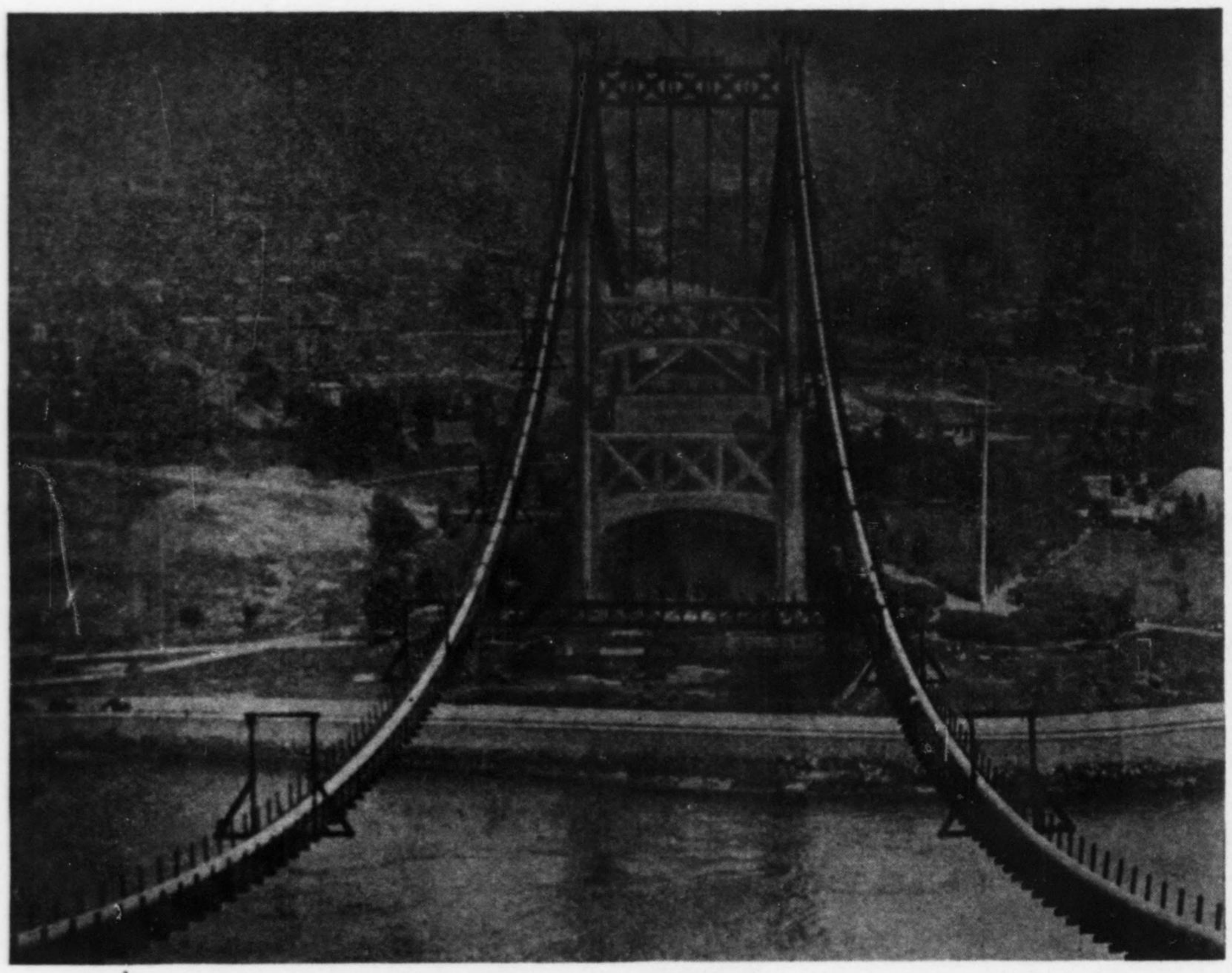
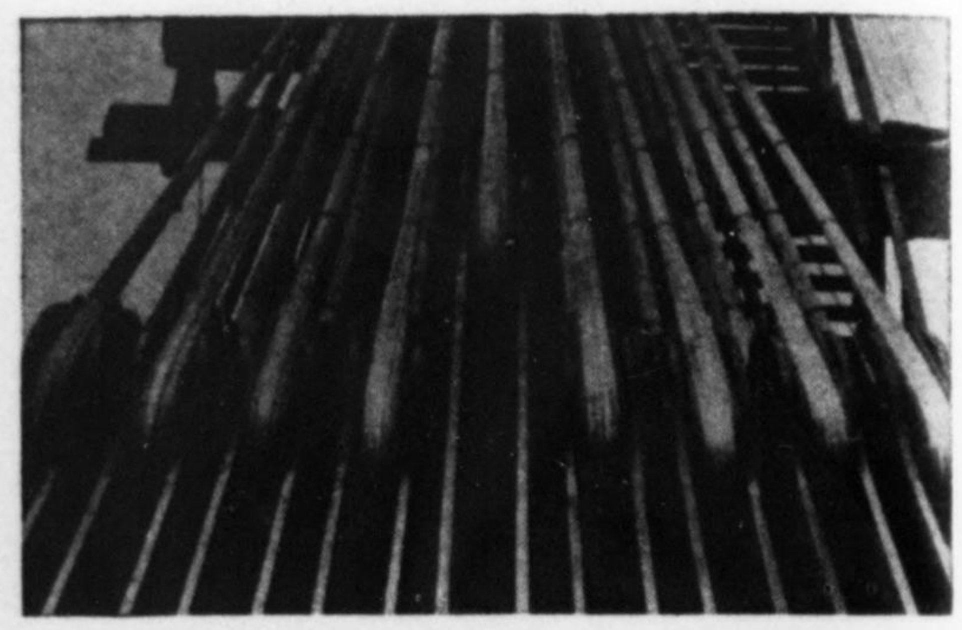
Widest Two-Cable Suspension

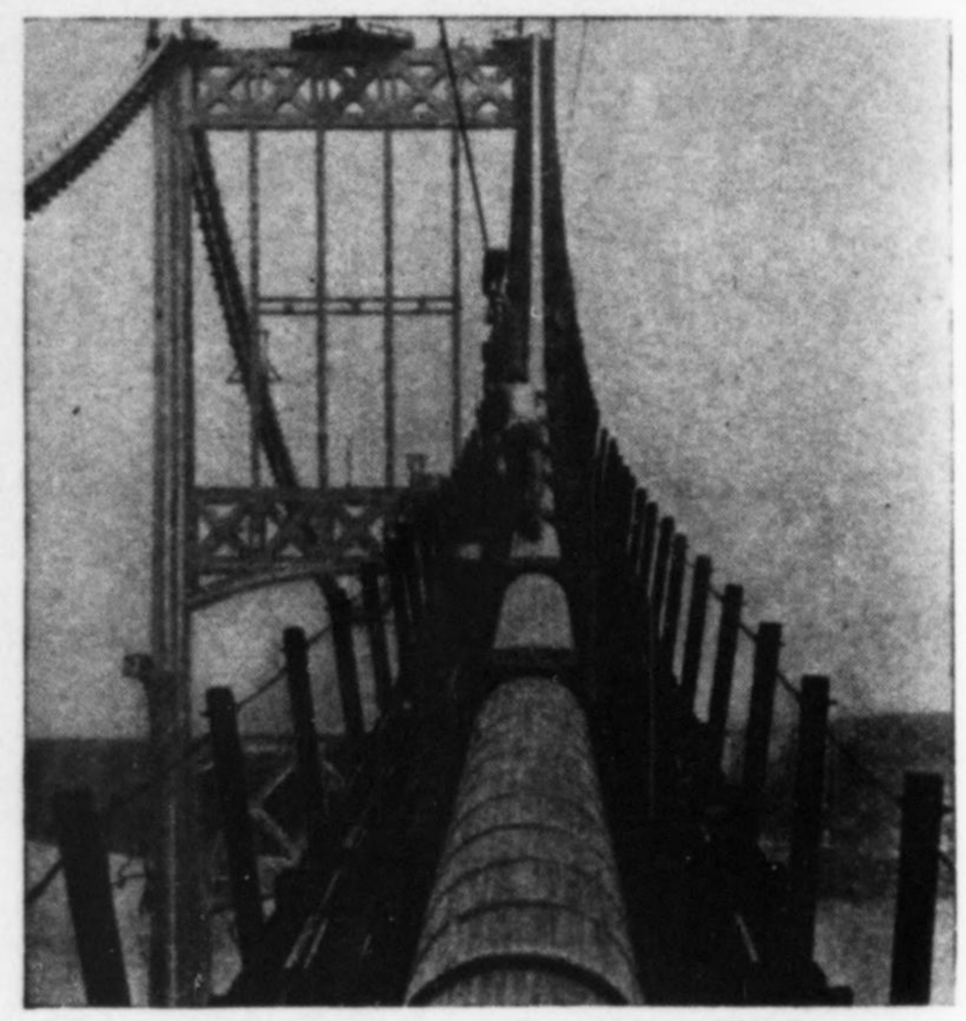
SPANS HELL GATE



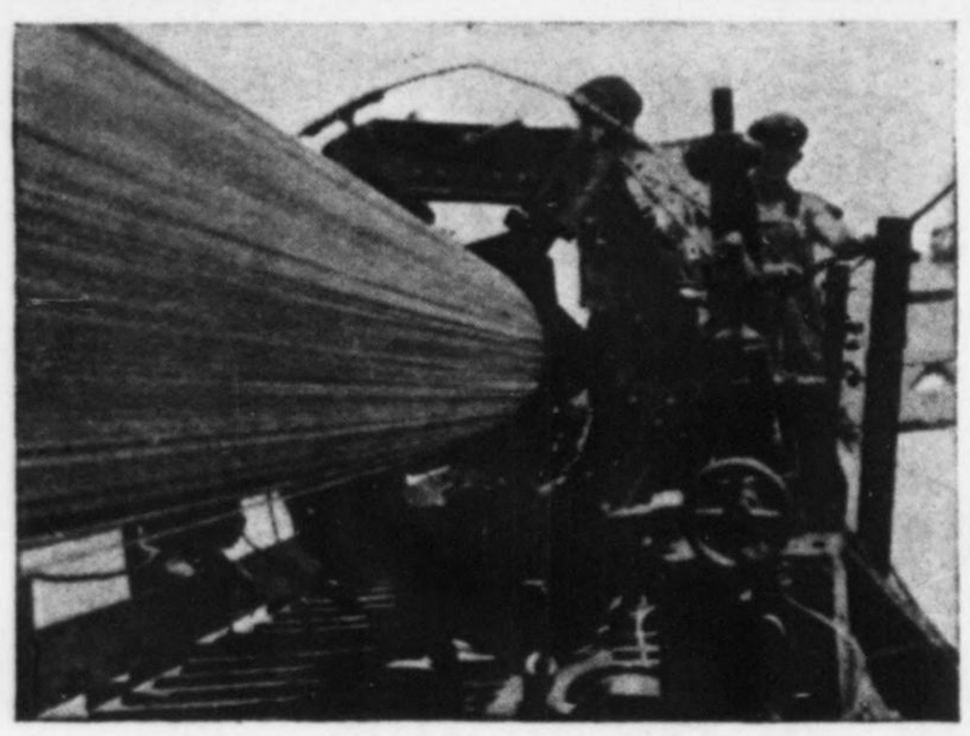
Looking from Ward's Island tower at the 1380 ft. center span as it crosses Hell Gate.



These splayed strands are connected to the eyebar anchors.



This cable has been compacted and is to be wrapped. In place already are several cable bands from which hang the suspender ropes. Note temporary catwalk used for erecting the cable.

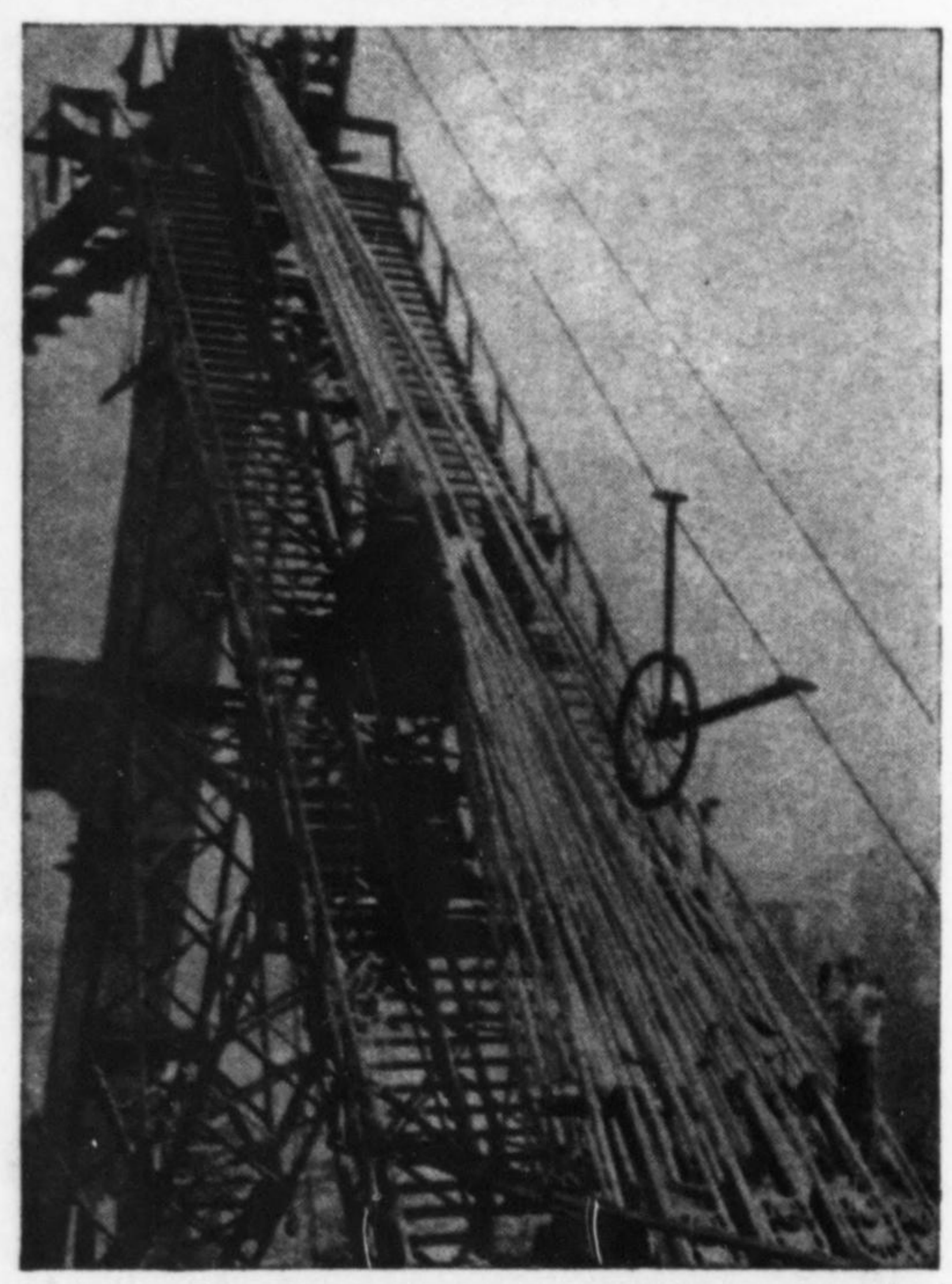


The compacting machine squeezes parallel wires into circular cable.

FROM two cables, spaced 98 feet apart, hangs the 8-lane, 87-foot roadway of the East River Crossing of the Triborough Bridge nearing completion in New York City. Each parallel-wire cable, 20$\frac{5}{8}$ inches in diameter, was spun in 37 strands of 248 wires each — 9,176 per cable.

The side spans approximate 705 feet in length from towers to cable bent posts, which deflect the cables downward at a 45 degree slope to enter the gravity-type anchorages. Embedded in these anchorages are the girder grillages and eyebars which anchor the splayed cable strands.

These cables complete with suspender and hand ropes, cable and splay bands, bearing blocks and strand shoes were erected by American Bridge Company, who also fabricated the eyebars and structural steel grillage for the cable anchorages. American Steel & Wire Company supplied the galvanized steel wire for the cables and the pre-stressed suspender ropes. For any of your needs in steel structures, the resources of the American Bridge Company are at your disposal.



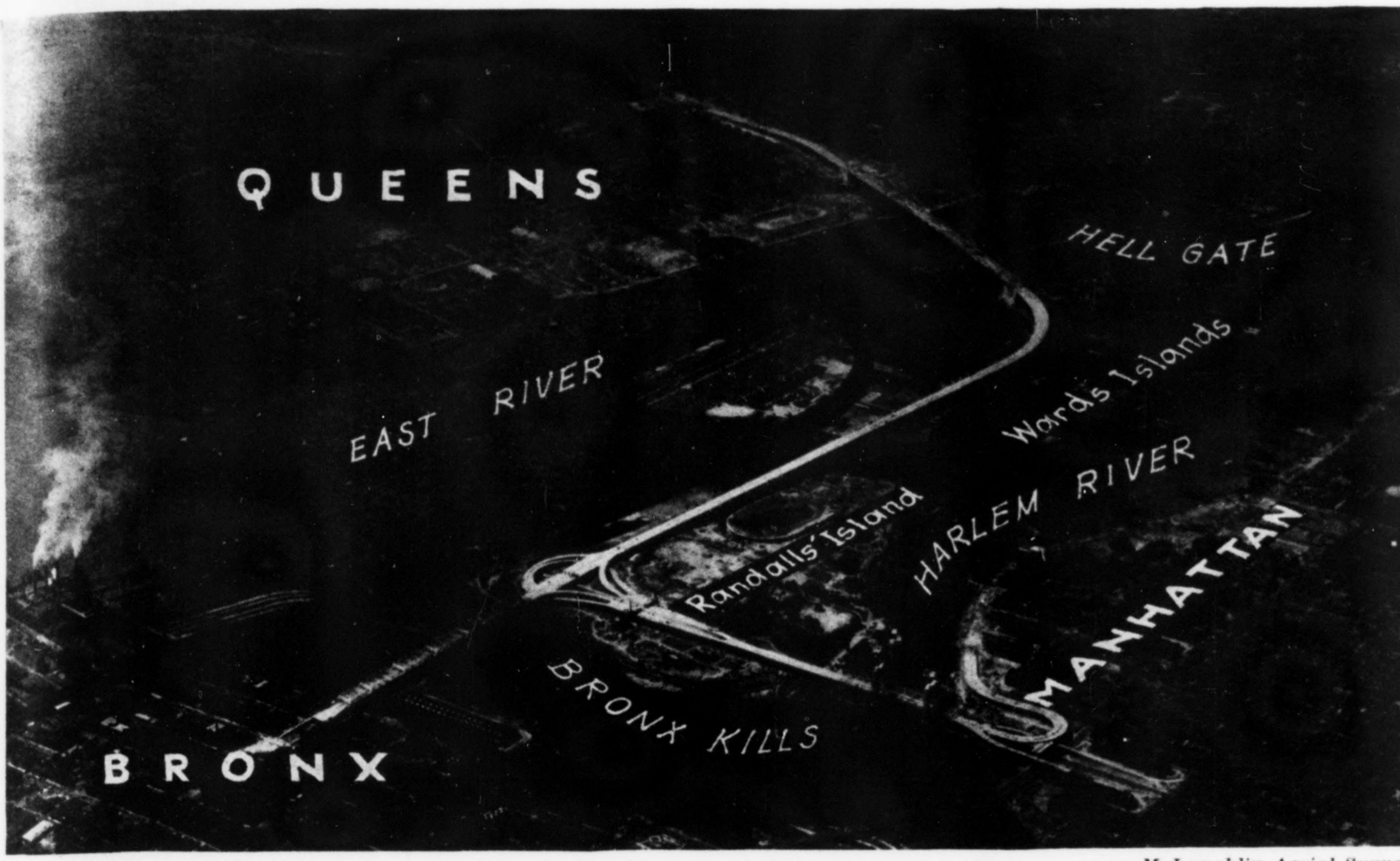
Spinning individual wires into strands as the wheel mounted on V-shaped frame travels up the side span at Astoria anchorage. At the bottom, strands circle strand shoes, which later connect to the eyebar anchors.

AMERICAN BRIDGE COMPANY · *Pittsburgh, Pa.*

Columbia Steel Company, San Francisco, *Pacific Coast Distributors*

United States Steel Products Company, New York, *Export Distributors*

UNITED STATES STEEL



McLaughlin Aerial Surveys

THE TRIBOROUGH BRIDGE at New York City was opened on July 11

$60,300,000 Bridge Project at New York Completed and Put into Service

THE TRIBOROUGH BRIDGE, connecting the New York City boroughs of Manhattan, Bronx, and Queens, was opened to traffic on July 11. The bridge, built at a cost of $60,300,000, crosses the Hell Gate channel from Astoria to Ward's Island, crosses Ward's Island and Randall's Island on a high viaduct, and connects with the Bronx by a fixed span over the Bronx Kills. Manhattan traffic leaves the viaduct at a circle giving complete separation of opposing traffic and continues on a viaduct to a lift span over the Harlem River, and thence to viaducts connecting with the new East River Drive and the streets of Manhattan. Also shown in the photograph are the new bathing pool in Astoria Park, between the new bridge and the Hell Gate arch, the new Ward's Island sewage disposal plant, and the new stadium on Randall's Island, where the Olympic tryouts began on the day the bridge was opened.

Engineers and Contractors

Engineers for the Triborough Bridge Authority include: O. H. Ammann, chief engineer; E. W. Stearns, assistant chief engineer; Allston Dana, engineer of design; H. W. Hudson, engineer of construction; J. C. Evans, engineer of approaches; E. Warren Bowden, assistant to the chief engineer; George L. Lucas, engineer of inspection; R. E. Robinson, deputy engineer of construction; Arthur I. Perry, principal assistant engineer. The field engineer's staff included J. E. Tonnelier, Homer R. Seely, H. C. Curtin, and R. T. Wheadon. The consulting engineering firm of Ash, Howard, Needles, and Tammen designed the Harlem River lift span.

Among the 60 contractors, the following list includes those whose contracts were for more than $400,000: American Bridge Co.; Arundel Corp.; Brown Electric Co.; Cauldwell-Wingate Co.; Corbetta Construction Co.; P. T. Cox Contracting Co.; A. M. Hazell, Inc.; Del Balso Construction Co.; Johnson, Drake & Piper; J. Leopold Co.; McClintick-Marshall Corp.; William P. McDonald Construction Co.; Porier & McLane Corp.; Frederick Snare Corp.; Taylor-Fichter Steel Construction Co.; Tulli & DiNapoli Co.; Albert A. Volk Co., and Woodcrest Construction Company.

Cost of the Project

Expenditures by the city before the Triborough Bridge Authority was set up:		
Construction	$3,300,000	
Real estate	2,100,000	
Expenditures by the city since the Triborough Bridge Authority was set up:		
Real estate for approaches	$10,700,000	
Total city expenditures		$16,100,000
Expenditures by the Triborough Bridge Authority:		
For the bridge itself,		
Construction	$20,100,000	
Real estate	6,300,000	
		26,400,000
For bridge approaches,		
Construction	$13,200,000	
Real estate	4,600,000	
		17,800,000
Total expenditures of Triborough Bridge Authority		44,200,000
Total cost of bridge and approaches		$60,300,000

Large Construction Program For Argentine Approved

A comprehensive program of road construction in Argentina, prepared by the national highway department, has just been approved by the President of the Republic.

The project calls for a total expenditure of $90,000,000, to be spent over a period of five years. The plan, as approved, includes work which has been completed since 1934. About one-half of the total appropriation has already been obligated by past and present highway construction. The remainder is to be spent during the balance of this year and in 1937 and 1938.

It is anticipated that the highway department's program will be completed by the end of 1938 and that proceeds from the gasoline tax will more than cover the amount required.

Clarification Sought Of Tri-county Decision

The Tri-county Power and Irrigation District of Nebraska has asked the U. S. Supreme Court for a clarification of its decision that water from the Platte River may not be used outside the watershed of that river. The district is seeking to determine whether canals carrying water from the Platte River may run outside the watershed and then return the water to the watershed. About 15 miles of canal, already constructed, weave back and forth across the divide in order to obtain better ground conditions. It is estimated that, due to the necessity for levees and concrete lining of ditches in the unfavorable ground, it would cost nearly $300,000 to reroute the ditches entirely within the Platte watershed.

ENGINEERING NEWS-RECORD

August 8, 1935

Fairchild Aerial Surveys

FIG. 1—PARALLELING the famous Hell Gate railroad arch and its approaches, the new Triborough Bridge will join Queens, the Bronx and Manhattan to the great advantage of vehicular traffic. In the background beyond Manhattan is the George Washington Bridge over the Hudson.

New York's Triborough Bridge

Joining three boroughs of New York City across famous Hell Gate and adjacent waters, it includes 3½ miles of bridge structure and 14 miles of connecting roads—Suspension span of 1,380 ft. carried by two cables 98 ft. apart

THE TRIBOROUGH BRIDGE in New York City, advancing at a rapid pace toward scheduled completion next summer, ranks with the most notable projects in the country. Its length is nearly 3½ miles, exclusive of some 14 miles of boulevard connections which are a part of the project. Four river crossings, of which one is a 1,380-ft. span suspension bridge, are connected by steel-girder viaducts in spans of 65 to 140 ft. The 98-ft. cable spacing on the suspension bridge is exceeded only by the 106-ft.-width center to center of the pairs of cables on the George Washington Bridge over the Hudson River, and the only comparable bridge that is carried by two cables alone is the Philadelphia-Camden bridge with an 89-ft. width. The $42,000,000 cost of the Triborough Bridge ranks it above the $35,000,000 Golden Gate Bridge and second only to the $75,000,000 San Francisco Bay Bridge among current bridge undertakings. And in economic importance it probably exceeds all but the last-named structure, for by providing an uptown connection between the boroughs of Manhattan, the Bronx and Queens, the Triborough Bridge will relieve materially the congested East River crossings from 57th St. south to the Brooklyn Bridge. As a byproduct, the new bridge will also open up for development as city parks two large East River islands; plans already are drawn for such a park on one of them.

Elements of the project

The Triborough Bridge, with its approaches and connections, is shown in Fig. 2. In accordance with an agreement with the city, the Triborough Bridge Authority, the quasi-public body that is building the project, bears the entire cost of the work on the bridge structures, the approaches and connections, as well as 100 per cent of the land cost for bridges and approaches and 35 per cent of the land cost for the connections.

On the Queens side the approach viaduct rises from the surface at 29th St. on a 3.6 per cent grade to the East River crossing at Hell Gate, which is a suspension bridge, of 1,380-ft. main span and 705-ft. side spans. This is followed by a viaduct structure on Wards Island, over Little Hell Gate and onto Randall's Island to the junction of the Bronx and Manhattan branches. The Bronx approach is a series of truss spans over the Bronx Kills and the N.Y.,N.H.&H.R.R. yards, connecting with a system of concrete ramps to grade in a plaza between 134th and 135th Sts. The Manhattan branch is a plate-girder viaduct as far as the Harlem River, which is crossed by three truss spans, including a 310-ft. vertical lift. West of the Harlem River, a pair of ramps descends to grade in a plaza east of Second Ave. on the line of 125th St., while another ramp curves south to grade at 122d St., where connection is made with a new East River Drive.

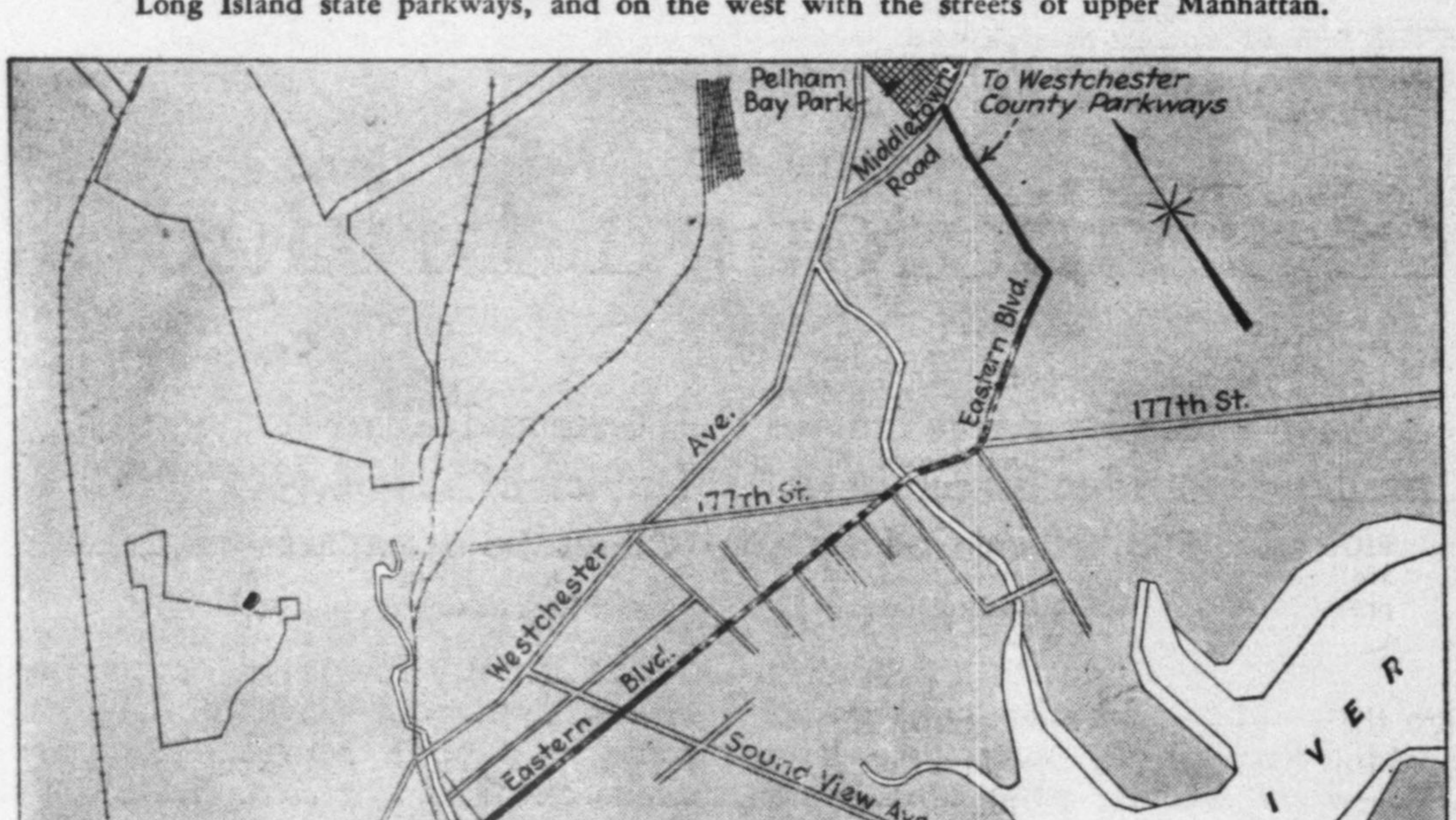
Highway connections are being constructed in each of the three boroughs. The Bronx connection, over 6½ miles long, consists of an improvement of Southern Blvd., Whitlock Ave. and Eastern Blvd. as far as Pelham Bay Park. From the bridge plaza at 135th St. and Cypress Ave., Southern Blvd. and Whitlock Avenue (as far as Leggett Ave.) will have a 60-ft. roadway and two 20-ft. sidewalks. Whitlock Ave., from Leggett Ave. to Hunts Point Ave., is being widened to provide two 40-ft. roadways separated by a landscaped mall 60 ft. wide. The roadways are flanked by two 15-ft. sidewalks. From Whitlock Ave. the connection continues along Eastern Blvd. to Middletown Road as a 60-ft. roadway with two 20-ft. sidewalks.

The Queens connection will also have a total length of about 6¼ miles. From the bridge approach east to St. Michael's Cemetery, the connection will consist of two 42-ft.-wide depressed express roadways separated by a safety strip and flanked by two marginal surface streets, each of which will have a 40-ft. roadway and a 15-ft. sidewalk (*ENR*, March 1, 1934, p. 279). The present Astoria Ave. will form the south marginal roadway. The depressed roadways will be bridged at a number of north and south streets, to provide for the uninterrupted movement of surface traffic. Where the roadway passes under the New York Connecting Railroad at 42d St., it has been necessary to provide new, deeper piers for the railroad viaduct so as to place the footings below the depressed highway.

The depressed roadways are brought to grade at 70th St. opposite St. Michael's Cemetery, where they divide into the Astoria Blvd. branch and the Grand Central Parkway branch. The latter continues as two 32-ft. roadways separated by a safety strip, skirting Flushing Bay and joining with the Grand Central Parkway Extension at Northern Boulevard (*ENR*, March 1, 1934, p. 279). Astoria Blvd. is being widened, regraded and paved for a width of 130 ft. Two 42-ft. roadways will be separated by a 16-ft. mall and flanked by two 15-ft. sidewalks.

The Manhattan connection will parallel the Harlem River waterfront from East 122d St. to 92d St. and York Ave., in a new boulevard similar to Riverside Drive along the Hudson River. It will consist in general of a 125-ft. drive having two 32-ft. roadways, separated by a safety strip, a 15-ft. sidewalk along the west side, and a mall, 40 ft. wide, along the river side. The length of the Manhattan connection, to be known as the East River Drive, will be 1½ miles. The total length of the connections in the three boroughs will, therefore, be about 14 miles.

FIG. 2—TRIBOROUGH BRIDGE PROJECT in New York includes 3½ miles of bridge structure and 14 miles of approach boulevards. On the north (in the Bronx) it connects with the Westchester County parkways, on the south (in Queens) with the Long Island state parkways, and on the west with the streets of upper Manhattan.



History of the project

The history of the Triborough Bridge project is not so long as that of some other big bridges but it is quite as interesting and varied. One of the first suggestions for a Triborough Bridge was made in 1916 by Edward A. Byrne, then chief engineer of the New York City Department of Plant and Structures; this early project contemplated facilities for both highway and rapid transit. No progress was made until 1925, when the city appropriated $17,000 for surveys, borings and plans, which were made. In 1927, another appropriation of $150,000 was made for further borings and plans. In 1929, a $3,000,000 appropriation was made for final plans for a self-sustaining highway toll bridge, to be financed by city corporate stock. In the fall of the same year, a contract was awarded for the viaduct foundations on Ward's Island and for the two suspension-bridge tower foundations. There followed a further appropriation of $5,000,000 and the letting of contracts for the Ward's Island anchorage (1930) and the Queens anchorage (1931). In 1932, these foundations were completed, but shortly thereafter municipal financing dried up, just as plans were under way for advertising for contracts on the steel towers of the suspension bridge.

For two years the foundations stood stark and bare until, in the spring of 1933, the project was transferred from the Department of Plant and Structures to a Triborough Bridge Authority created by the state legislature as a prerequisite to securing federal financing from the Reconstruction Finance Corp. Before the body could start functioning, however, the Public Works Administration was formed, and application was made for a loan of $35,000,000 and a grant of 30 per cent of the cost of labor and material used in the project, which was approved in the fall of 1933. The loan and grant together total about $42,000,000.

Work was resumed, with a contract let for fabrication and erection of the suspension-bridge towers, when the PWA raised questions as to the possibility that the bridge could not be completed within the funds appropriated. The outcome was the appointment by the mayor of a new personnel for the Authority, and shortly thereafter O. H. Ammann, who had recently so successfully completed the George Washington Bridge, was appointed chief engineer.

A complete check of the design of the project was made which indicated that some $48,500,000 would be required to execute the original plans. A redesign was made, changing materially the character and appearance of the structures and effecting a saving of about $10,000,000. Later the Manhattan connection from 92d St. was added at a cost of about $6,000,000. The latest estimated total cost of the project is $42,400,000, for which funds are said to be available.

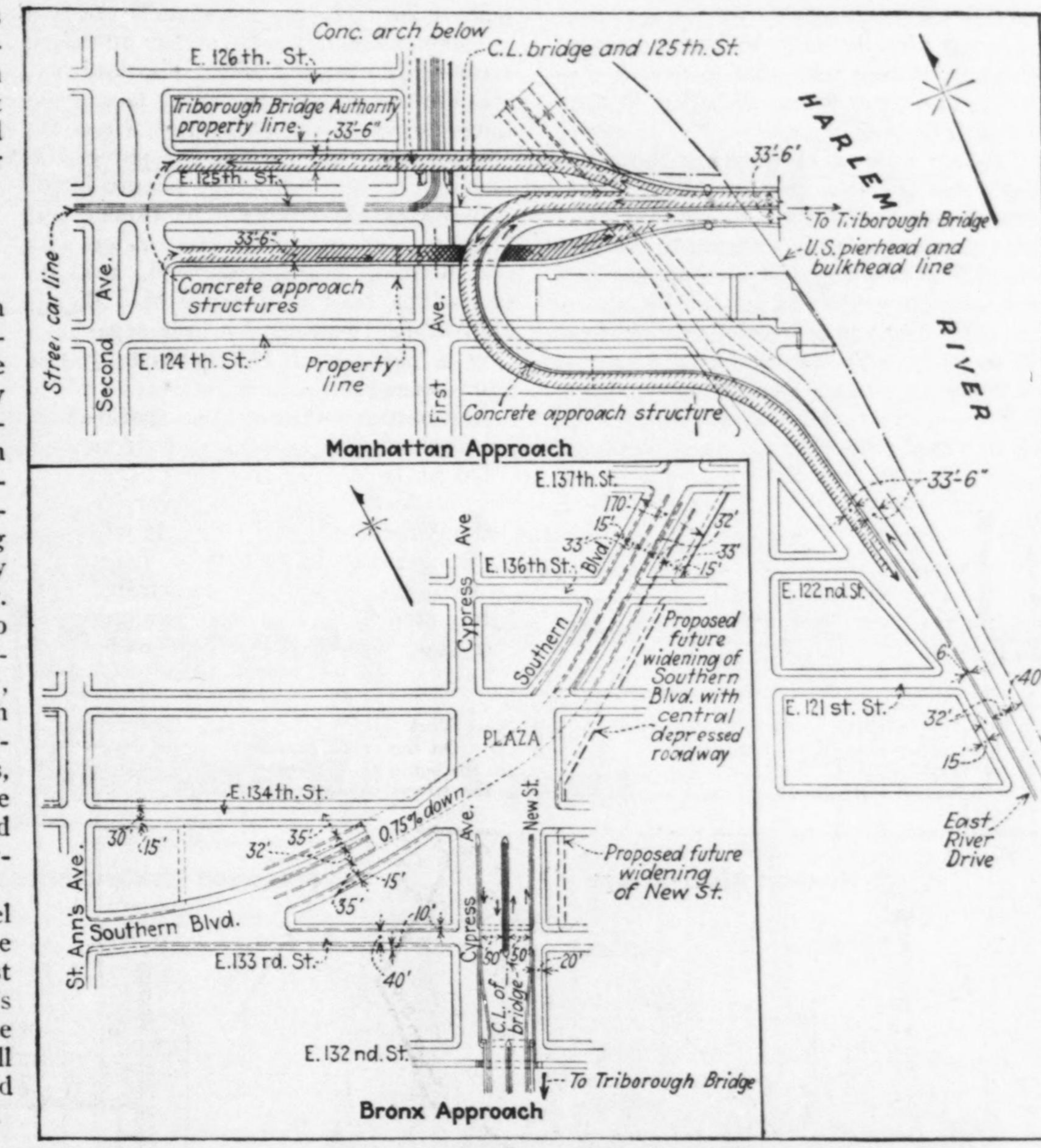


FIG. 3—APPROACHES to the Triborough Bridge from Manhattan and the Bronx are based upon the principles of no crossings at grade and no left turns across approaching vehicle lanes. Dashed lines in Bronx approach indicate future construction.

Original design

When considering the present design of the Triborough Bridge structures, particularly the suspension bridge and the viaduct on Ward's Island, it is necessary to understand the elements of the original design, since those elements which had already been constructed or contracted for were important considerations in the redesign. Fig. 4, showing the suspension-bridge towers originally planned, is a key to such understanding. It will be noted that four cables and two decks were contemplated. Four roadways (granite blocks on steel plates), 36 ft. wide between curbs, were each planned for four lanes of traffic, or sixteen lanes in all. Four stiffening trusses, 24 ft. deep with 18-ft.-long panels, were provided. The tower foundations and the anchorages were built for this four-cable layout.

The viaduct sections planned were steel arches on granite-faced piers, with the exception of a series of nine spans just west of the suspension bridge on Ward's Island; these spans were planned to be concrete arches faced with granite. All viaduct foundations on Ward's Island were finished before work was stopped.

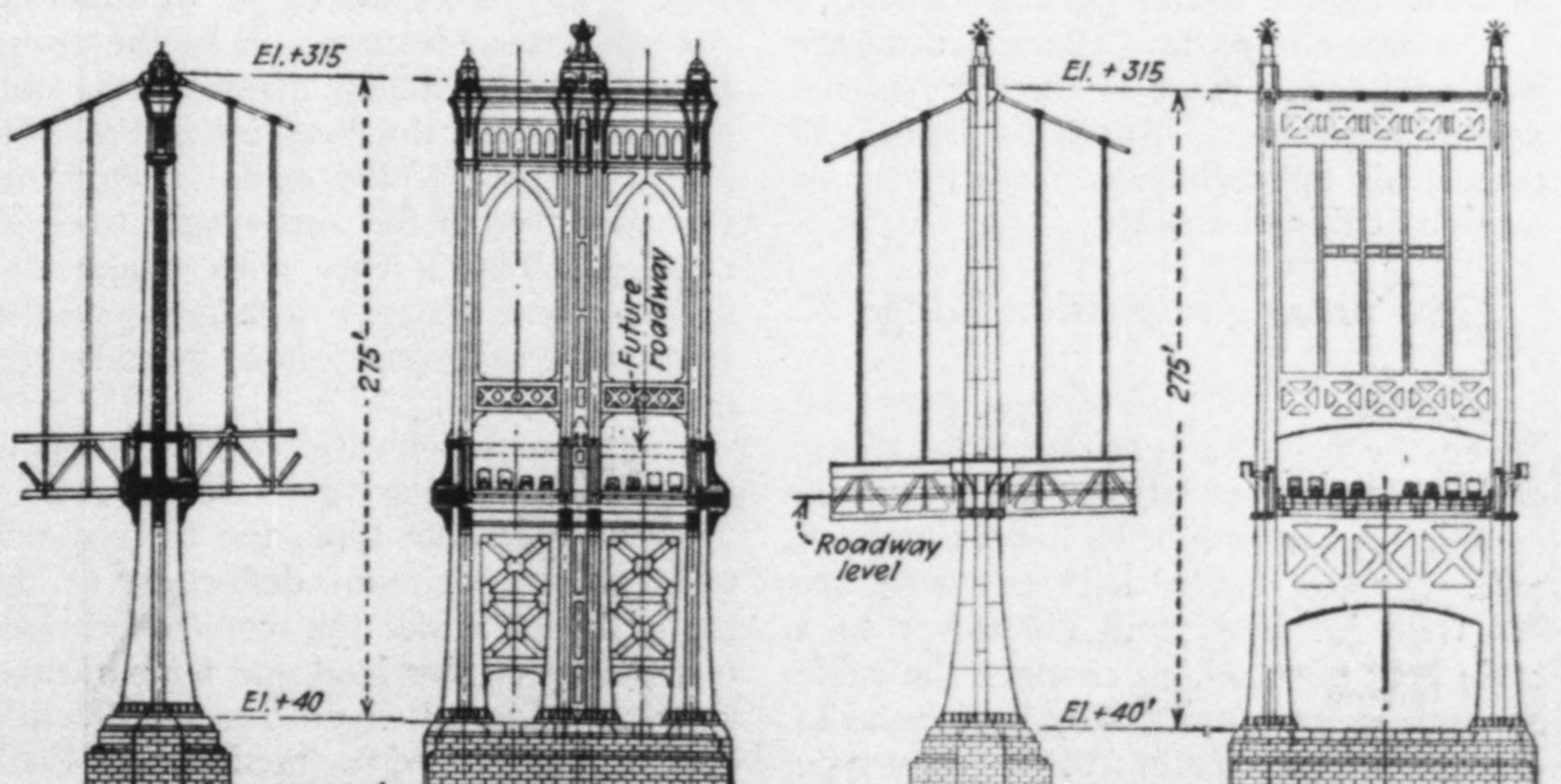
The new design

The starting point for the redesign was a consideration of potential traffic capacity. This was placed at 20,000,000 vehicles per year, or 54,800 per day at the end of 25 years. Based on 600 vehicles per lane per hour (the Holland Tunnel has carried as many as 1,000 per lane per hour), eight lanes would accommodate over 57,000 vehicles per 12-hour day. Also, as on all bridges and tunnels, the amount of traffic that the approaches could handle was really the determining factor, and no approaches that could reasonably be provided would care for more than 54,800 vehicles per day. It was concluded that a structure of two decks and sixteen lanes was unwarranted, and since the object was to cut some $10,000,000 off the ultimate cost, it was recommended that the upper deck be eliminated and that eight lanes be provided on a single deck.

The original design, as a matter of fact, had proposed eight lanes for its lower deck, but each of these was only 9 ft. wide, which was considered inadequate. Greater roadway width required elimination of the pairs of columns, stiffening trusses and cables along the center line of the bridge. Detailed study of the problem indicated that such elimination was practicable and would materially aid in reducing the cost of the structure. Although the contract had been let for the original towers and the erector and fabricator were busy with detail plans, very little actual fabrication had been done, so that a minimum of scrapping would be necessary.

Further cost savings were sought in the viaduct, and steel truss and girder spans on concrete piers were substituted for the steel and concrete arches. Practically all of the granite facing proposed in the original design (some 1,850,000

FIG. 4—REDESIGN of the suspension-bridge towers to effect necessary economy changed them from four-column to two-column type.



cu.ft.) was eliminated. Of the seventeen footings already built on Ward's Island, the new design was able to utilize thirteen. The other four will be left in place but will be graded over.

As a result of eliminating the upper deck and the two central cables on the suspension bridge, the four-column tower was changed to a two-column tower with simplified bracing and an entirely new appearance. Also the panel lengths of the stiffening trusses were increased from 18 to 28 ft., thus decreasing the number of suspender ropes and fittings; stiffening trusses were decreased from 24 to 20 ft. in depth; floorbeams were increased in depth, but the original design of a girder continuous over four supports was eliminated; the floor was changed from granite blocks on steel plates to a concrete deck on steel cross-beams. These changes reduced the estimated cost of the East River superstructure by about $2,000,000, including $1,000,000 saved by eliminating the center pair of cables.

The other important change in design was an improvement of the intersection at the junction on Randall's Island, to permit all toll-collection facilities to be located at this one point.

The present suspension bridge

Spanning 1,380 ft. across the East River, the suspension bridge, upon which cable-spinning operations were recently completed, has both of its towers on land. Side spans, of loaded backstay type, are 704 ft. 8 in. long from the tower to a cable bent post, which changes the cable inclination from practically horizontal to 45 deg., when it enters the gravity-type anchorage. The two $20\frac{5}{8}$-in.-diameter parallel-wire cables, 98 ft. apart c. to c., have a sag of 138 ft. (1:10) between the tops of the towers and the center of the main span. The towers, made up of two cellular columns held apart by three cross-braces located below the roadway, above the roadway and at the top of the towers, are 270 ft. 8 in. high from the concrete pier to the base of the saddle casting. The stiffening trusses with Warren web systems are 20 ft. deep and hinged at the towers. The bridge was designed for a dead load of 20,000 lb. and a live load of 4,000 lb. per lin.-ft. Under such loading the maximum tension in each cable is 22,700,000 lb., and in any suspender rope it is 100,000 lb.

Foundations—Tower piers and anchorages are founded on rock and are located on the shore. The Wards Island anchorage, weighing 115,000 tons, contains 59,000 cu.yd. of concrete. The Queens anchorage, because of a greater depth to rock, required 74,500 cu.yd. of concrete. An interesting feature will be the architectural treatment, the masses being outlined to suggest the direction of the cable pull, the splay of the cable strands and the resistance of the anchorages to overturning. The V-cuts with which this architectural design is attained will also serve as expansion joints, to minimize cracking.

Towers—An elevation and sections of one of the towers are given in Fig. 6. Of fixed-base flexible type, the towers will undergo a maximum deflection at the top of 14 in., under the worst conditions of unbalanced live load and temperature. Column material is silicon steel, while carbon steel is used for the bracing. Each column is of cruciform shape, built up of plates and angles into the conventional cellular form. Most of the material, both angles and plates, is $\frac{3}{4}$-in. thick. About 5,500 tons of steel is required for the two towers.

The cross-braces between the legs are in the form of X-braced-panel trusses of carbon steel attached to the legs by deep silicon-steel gussets. Chords and web members are box-shaped, with the bottom chords curved except in the top truss. Between the top and intermediate bracing, four vertical architectural members, 93 ft. long and of built-up I-section, are utilized to accentuate the vertical lines of the towers. The top connections of these members are sliding joints, to free them from any bending from tower deflection. Also, at about mid-height, they are braced apart by a light box strut of four angles, to steady them in the wind.

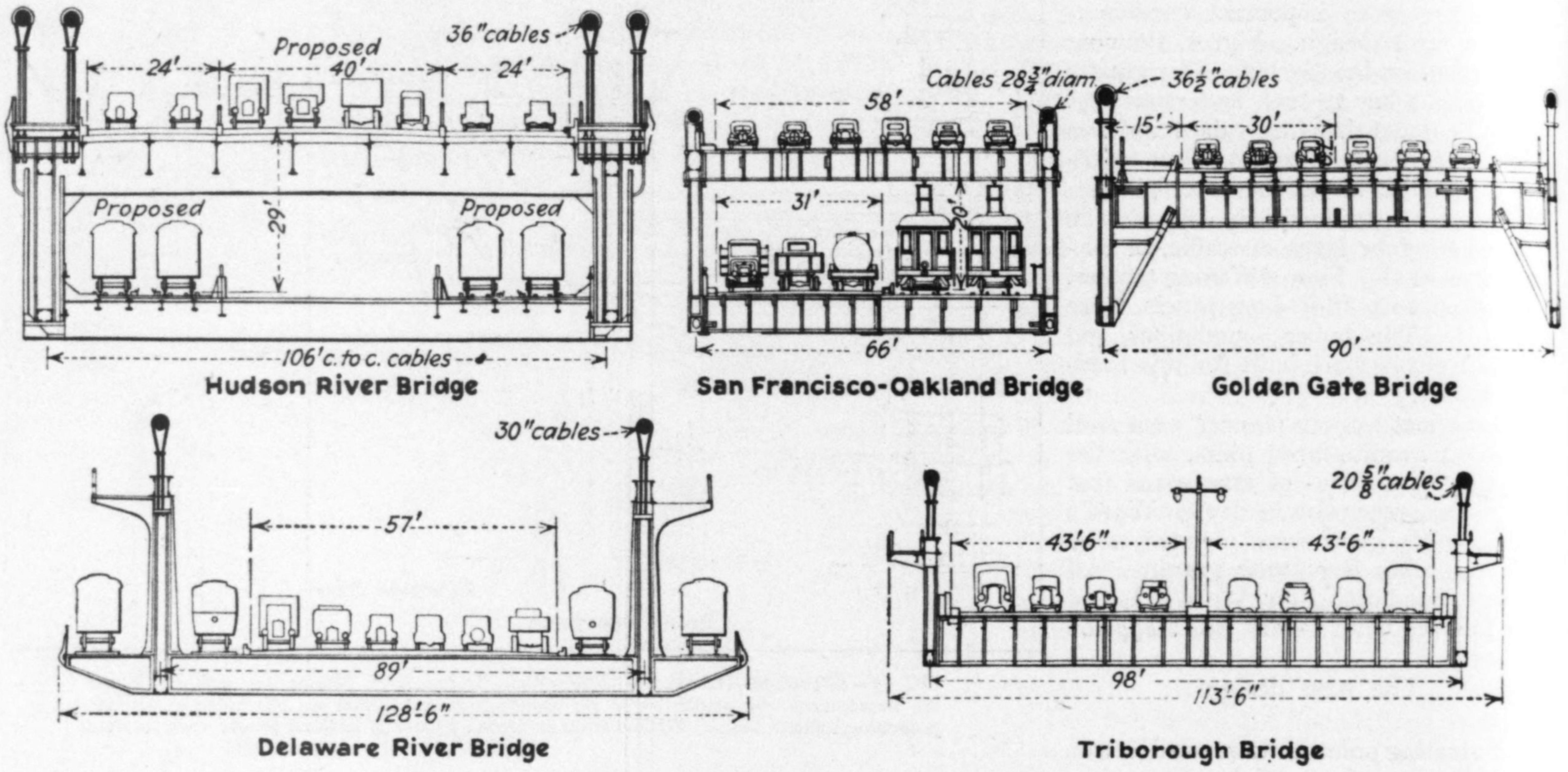


FIG. 5—COMPARISON with roadway widths of other large two-cable suspension bridges places the Triborough Bridge in first place.

Special details on the towers occur at roadway level and at the stiffening-truss connection 20 ft. above the roadway. At the latter location, box girder brackets with holes for 12-in. pins are provided for the rockers which support the ends of the stiffening trusses. At roadway level in the center of the tower cross-brace, horizontal brackets made up of five 21-in. wide-flange sections set transversely between $1\frac{1}{2}$-in. plates top and bottom furnish a connection for the floor lateral systems of the main and side spans. The actual connection is made by a 10-in. pin; a flat bronze plate around the pin is used to support the laterals on the brackets.

The tops of the towers are to be finished with an architectural lantern 30 ft. high surmounted with aviation lights.

Cables and Stiffening Trusses—The cables are of parallel-wire type, spun in the field. Of a diameter of $20\frac{5}{8}$ in. after compaction, each cable contains 37 strands of 248 wires each, every wire galvanized and of 0.196-in. diameter. The cross-sectional area of wire in each cable is 277 sq.in.

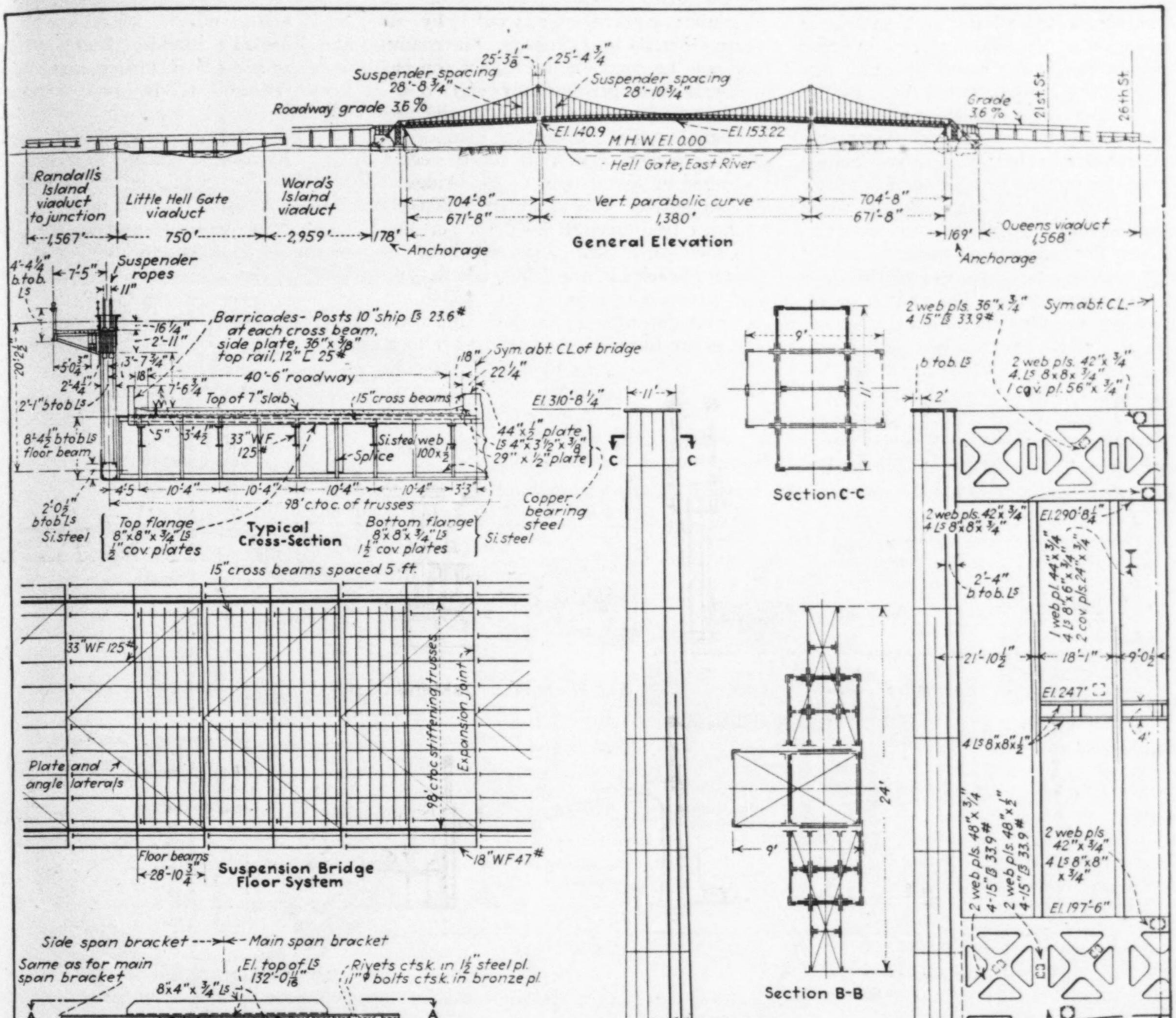


FIG. 6—STRUCTURAL DETAILS OF TRIBOROUGH BRIDGE IN NEW YORK.

The stiffening trusses, as previously noted, comprise an important element of the redesign. By reducing them in depth from 24 to 20 ft., some material was saved in the trusses themselves, and by lengthening the panels from 18 to 28 ft. fewer suspender ropes and floorbeams were required. Offsetting these savings were extra material required in the truss web system, since the panels had to be subdivided to reduce the stresses, and heavier floor stringers because of the longer spans. Nevertheless, the net saving was appreciable. The chords of the stiffening trusses are silicon steel, of plate and angle-box section, with maximum net section of 72 sq.in. in the top chord and 78 sq.in. in the bottom chord. Diagonals are carbon steel. As previously noted, the stiffening trusses are designed for a live load of 4,000 lb. per lin.-ft. of bridge. Wind is assumed at 1,200 lb. per lin.-ft. of bridge, of which 1,095 lb. is floor wind load and the rest comes from the cables.

Floor System—The floor steel comprises one of the most remarkable features of the bridge because of the great width. Floorbeams are plate girders 96 ft. long and 8 ft. 4½ in. deep. Of silicon steel, they are spliced at the third points. There are 46 rivets of ⅞-in. diameter in each end connection, and the end shear is 396,000 lb. The rolled-section stringers, which are placed under the edge of each traffic lane, carry an end shear of 86,000 lb. Stress expansion joints are located at every second panel point.

The roadway that is carried on this floor system consists of two 43½-ft. pavements with a curb island between. The pavement, a 7-in. concrete slab, is carried on steel cross-beams placed on top of the stringers. Inclined monolithic curbs at the sides of each roadway are flanked by a 3-ft. 4½-in. steel barricade.

Viaduct

Some 13,500 ft. of viaduct are included in the project divided about as follows: 1,570 ft. in Queens, 3,000 ft. on Ward's Island, 4,570 ft. on Randall's Island, 3,500 ft. in Manhattan, and 1,000 ft. in the Bronx. The majority of this is of the same design—namely, three lines of deck plate girders on concrete piers in spans from 60 to 140 ft. providing two four-lane roadways as on the suspension bridge. Framing between the longitudinal girders consists of floorbeams spaced 20 to 25 ft., into which are framed the I-beam stringers that support steel cross-beams under the 8½-in. concrete roadway slab. The piers are of three-column type joined at the top with reinforced-concrete ties having a curved soffit. Pier shafts are octagonal in cross-section, a design that was adopted for the sake of appearance but which showed some saving in material over a rectangular section. The tallest shaft is 65 ft. Reinforcing consists of 1-in.-diameter vertical roads and a ⅝-in. diameter continuous spiral. In general, separate footings are used, although those put in for the original arches on Ward's Island and used in some instances for the new design are combined.

The 1,500-ft. viaduct approach in Queens, leading to the suspension bridge, is on a 3.6 per cent grade. The only special characteristic is a two-span continuous girder layout near the north end. This provides a 141-ft. clear span for a street crossing, and some economy of material was possible by making it continuous with the adjacent 98-ft. span. The piers are supported on concrete piles with the exception of the six nearest the anchorage, which are on spread footings.

North of the suspension bridge all of the project is viaduct with the exception of two of the river crossings. The Little Hell Gate, which separates Ward's and Randall's islands, is crossed by a series of six 125-ft. girder spans having a clearance of 62 ft. over mean high water.

Randall's Island junction

On Randall's Island the branch to Manhattan intersects the viaduct, which continues on north to connect with the Bronx approach. The junction (Fig. 7) is an elevated concrete structure made up of a continuation of the viaduct from Ward's Island, widened to 137 ft. to provide for toll collection and surrounded by two concentric circular ramps, arranged so that there are no crossings at grade and no left turns, regardless of the origin or destination of the traffic. There are also two ramps located centrally on the Manhattan branch, which provide direct access from all the boroughs to the new Randall's Island city park. It was the incorporation of these ramps, which permit toll entrance but free exit, that made the design of this junction difficult as compared with an ordinary three-way intersection. The ramps have a maximum grade of 6 per cent; elsewhere in the intersection the maximum grade is 4 per cent.

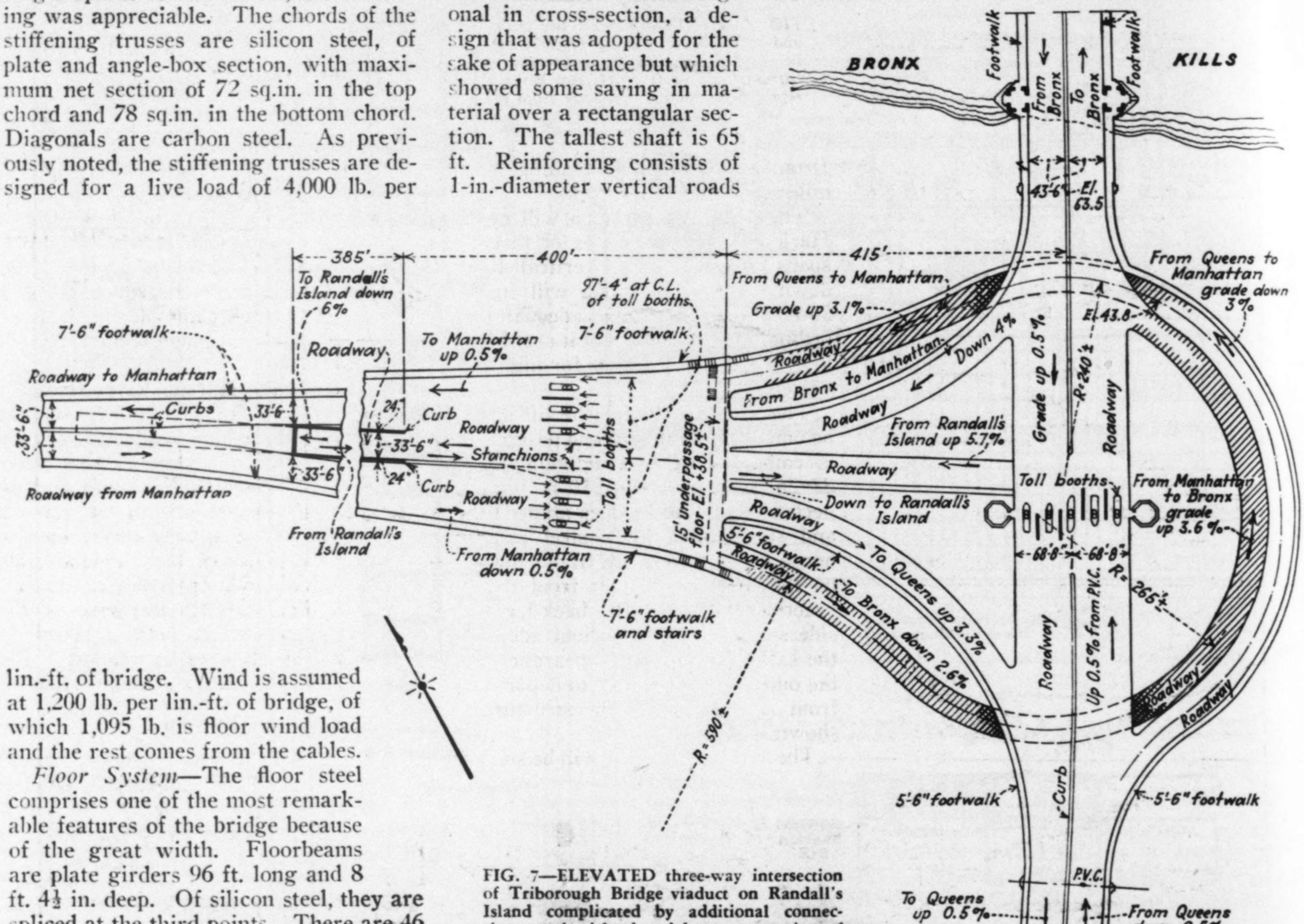


FIG. 7—ELEVATED three-way intersection of Triborough Bridge viaduct on Randall's Island complicated by additional connections to the island and by concentration of toll-collecting facilities within the intersection area.

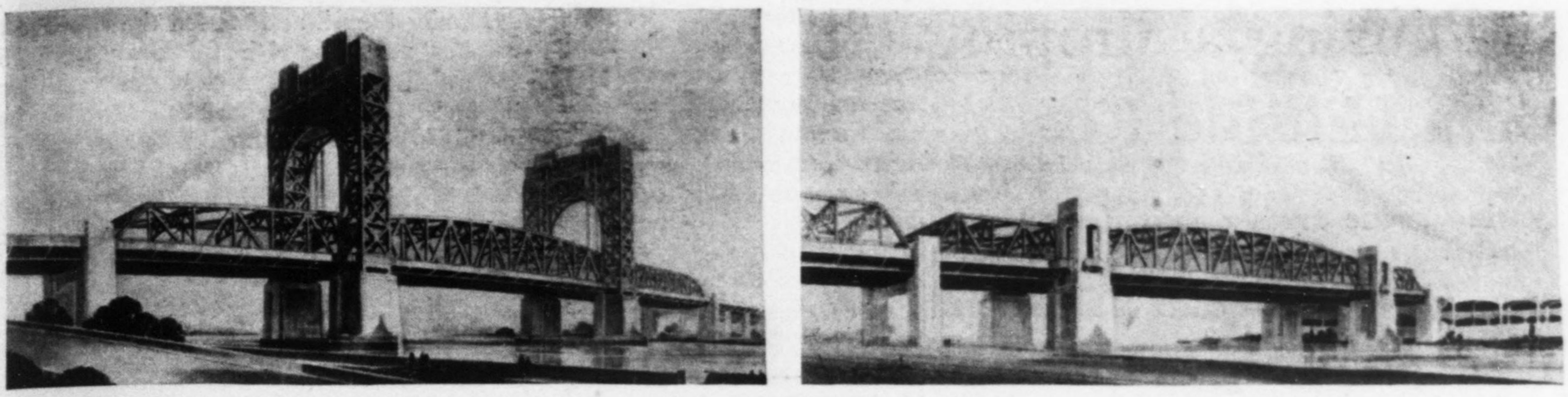


FIG. 8—HARLEM RIVER lift span (left) and Bronx Kills crossing (right), the latter being also designed for conversion into a lift span. Towers of Harlem River Bridge represent a notable departure from previous designs.

The arrangement of the roadways at the junction is such as to provide safe and easy divergence and convergence of traffic. Curvatures have been limited to 240-ft. radius and, where possible, are over 400 ft

Tolls are to be collected at two points. All vehicles passing between Queens and the Bronx will pay toll in the area of the junction where the two roadways of the main viaduct are combined and widened to 137 ft. All other vehicles will pay toll in an area on the Manhattan branch where it has been widened to 195 ft.

Bronx and Manhattan approaches

From the junction, the Bronx approach continues north for a short distance on Randall's Island to a bridge over the Bronx Kills, while the Manhattan viaduct on Randall's Island continues west to a bridge across the Harlem River. These Bronx and Manhattan approaches, as distinct from the connections noted previously, contain some interesting structures.

The Bronx Kills crossing, carrying two roadways of four lanes each and outside footwalks, consists of three steel truss spans—a 350-ft. span over the channel and two shorter approach spans reaching to piers on the shores. The main channel span adjacent to the Bronx shore is located to serve future locks and is designed for conversion into a vertical lift, which would be larger and heavier than any existing lift span, having a net roadway floor area of about 31,000 sq.ft. and a weight of about 2,900 tons.

Beyond the river crossing, over the yards of the N.Y.,N.H.&H.R.R. will be four truss spans (three of 272 ft. and one of 170 ft.) supported on concrete piers founded on rock. The approach structure north of 132d St. (in general, of concrete construction) will reach the ground level at the south side of a plaza area between 134th and 135th Sts. east of Cypress Ave. and will provide direct access to the Bronx connection, extending some 6 miles to Pelham Bay Park.

The Manhattan branch will cross the Harlem River by means of three truss spans, one a 310-ft. vertical lift. In down position the span will furnish a 55-ft. vertical clearance, adequate for the ordinary river traffic, but it may be raised to give 135-ft. clearance for high-masted vessels.

The steel towers for the lift span will be unusual both in size and design. Each is composed of two individual towers, 22x26 ft. in plan and 210 ft. high, connected at the tops by deep arched bracing and surmounted by a steel machinery house. The towers are wholly supported on the piers as distinct from the usual practice of resting the back-leg on the side spans. This expedient adopted for the sake of improved appearance causes the outline of the bridge to depart widely from former lift-span structures, as shown in Fig. 8.

The vertical-lift span will be suspended by 96 wire ropes of 2¼-in. diameter passing over 15-ft.-diameter sheaves at the tops of the towers. Power for the hoisting operations will be supplied by four 200-hp. electric motors housed at the tops of the towers. The span is said to be the largest lift span yet designed when measured in terms of the deck area provided for traffic (20,000 sq.ft.). It is not, however, the heaviest span, every effort having been made to reduce its weight and cost, as for example by the use of asphalt plank pavement laid on steel plate for the floor.

West of the Harlem River Bridge the three-lane offbound roadway separates into two three-lane roadways, one continuing west to a plaza east of Second Ave., the other curving south and back east to a connection with the new East River Drive. Similarly, three-lane roadways are provided for onbound traffic. This Manhattan approach is shown in Fig. 3 From the Harlem River to First Ave. and to a point south of 124th St. it consists of plate-girder viaduct. Elsewhere it is of concrete construction.

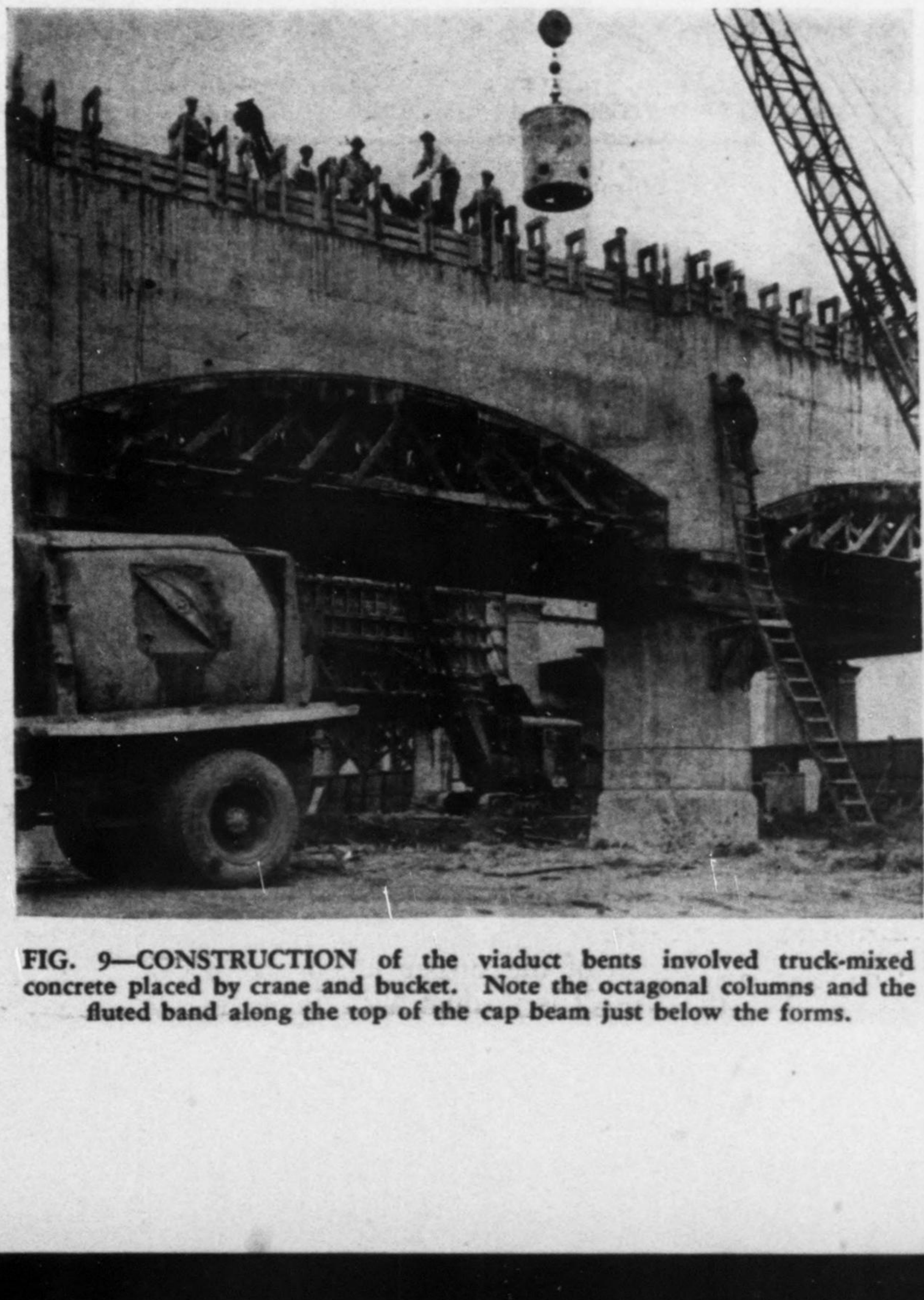


FIG. 9—CONSTRUCTION of the viaduct bents involved truck-mixed concrete placed by crane and bucket. Note the octagonal columns and the fluted band along the top of the cap beam just below the forms.

Personnel

For the Triborough Bridge Authority O. H. Ammann is chief engineer, Edw. W. Stearns assistant chief engineer, Allston Dana engineer of design, J. C. Evans engineer of approaches, H. W. Hudson engineer of construction, Aymar Embury II architect. A. I. Perry principal assistant engineer, and E. W. Bowden assistant to the chief engineer. R. F. Wheadon is assistant to the engineer of construction, and J. H. Curtin, H. R. Seely and A. J. Fearing are resident engineers.

Leon S. Moisseiff and Daniel E. Moran act as consulting engineers and Charles P. Berkey as geologist. Ash-Howard-Needles & Tammen prepared the design for and act as consultants on the lift bridges.

For the Federal Emergency Administration of Public Works, Wharton Green is resident project engineer and Charles E. Trout deputy resident project engineer.

March 23 of this year, when it reached a crest of 59.36 ft. There can be no question as to its stability and ability to protect the city to a 62-ft. river stage. Some negligible seepage occurred through the expansion joints. This trouble could have been eliminated by the use of copper in the joints at the time of construction.

The French drains, which carried considerable seepage, presumably coming through the strata underlying the wall, as well as through the joints, caused some water to seep through the backfill and accumulate in two or three low places. While this caused no damage, it gave rise to many false rumors to the effect that the wall was failing. This trouble will be corrected by the construction of a sewer along the wall to carry this drainage to the pumping stations. There was also considerable seepage through the railroad fills, which consist mainly of slag and cinders. Sandbags were placed to counteract this to some extent. This seepage flows to the nearest sewers and is pumped out.

Provisions have been made to open the sewer gates and to flood the city gradually if the river stage ever rises above 62 ft. Thus it is apparent that fears of the city washing away from a rush of water over the wall is unfounded.

It is fitting to mention here that the city council, at its meeting on April 1, 1936, passed a motion to the effect that recognition be given to Mr. Hudson, by erecting a tablet to his memory.

Lift Span Erected by New Procedure

Harlem River crossing of Triborough Bridge in New York hoisted from barges to pier tops before end panels of 310-ft. trusses are erected—Counterweight movement controlled by jacks

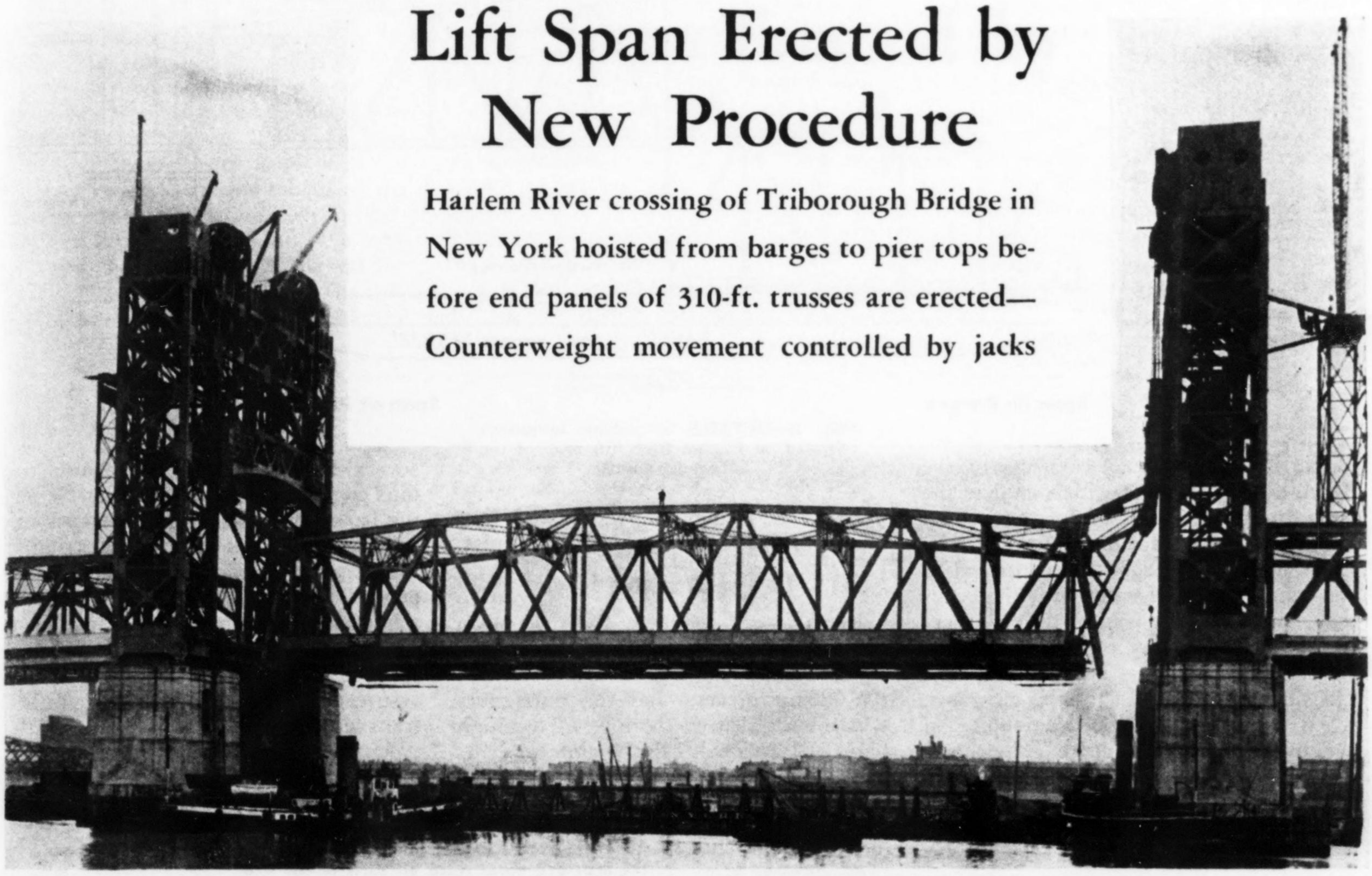


FIG. 1—RAISING the Triborough lift span by temporary outrigger connections to the lifting girders. The end panels of the trusses, missing in this picture, were erected as the next operation, to permit the span to be landed on the pier shoes.

LAST SUNDAY, May 3, the last stream crossing in New York's great Triborough Bridge project was closed when the 310-ft. lift span over the Harlem River in the Manhattan approach was floated into position between its towers, raised first to pier level and from there to its normal high position 135 ft. above the river. With the span in the up-position, the roadway wearing surface of asphalt plank and the concrete sidewalk slabs will be installed, to complete the bridge on schedule time.

The operations followed in erecting this huge span, which weighed 1800 tons as lifted, are noteworthy, and in some particulars departed from usual practice. One controlling factor was the 50-ft. height of the piers above the water, coupled with the fact that the lifting girder connections to the lift span had to be made at the bottom chord level. The contractor elected to float the span in at low level rather than to build the falsework on his barges high enough to clear the piers, and since the span was about 25 ft. longer than the clear distance between the piers, this presented another complication. By leaving off the end panels of the span until it had been raised clear of the piers, using temporary outrigger connections extending above the level of the top chords, these difficulties were overcome.

Largest in roadway area

The Harlem River lift span, joining Randalls Island on the east with Manhattan on the west, is believed to be the largest yet built when measured in terms of its roadway area which is 20,000 sq.ft. The span is 310 ft. and the trusses are spaced 75.5 ft. on centers, to accommodate two 30-ft. roadways separated by an island. Two 8.5-ft. sidewalks are carried outside the trusses. The weight of the completed span will be 2,050 tons. The 133.5 ft. towers, contrary to usual practice, are supported on the piers independent of the side spans, an arrangement adopted in the interests of architectural appearance. Each tower consists of two x-braced four column legs, 20x23.5 ft. in plan and 95.5 ft. on centers braced apart at the top by trusses 20 ft. deep. Machinery houses on the top of each tower enclose three 200 hp. motors, one of which is a synchronous motor through which the span is maintained level during lifting. Also, within these enclosures are located the four

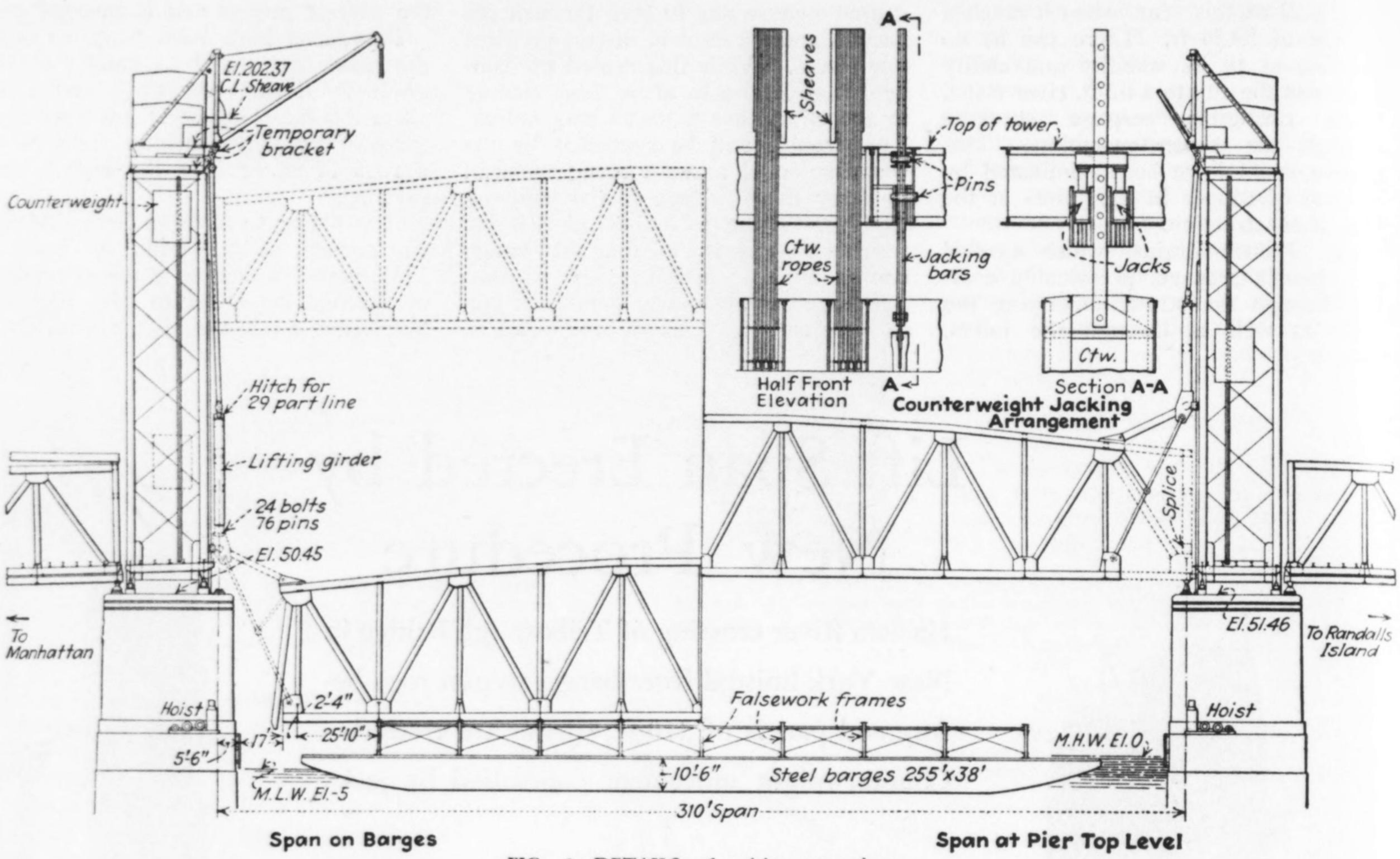


FIG. 2—DETAILS of raising operations followed on Harlem River lift span of the Triborough Bridge.

15-ft. dia. sheaves each carrying twelve $2\frac{1}{4}$-in. dia. wire ropes which engage the span through a lifting girder that moves up and down the face of the tower. The other ends of the ropes are attached to the counterweight located over the roadway; in its up position the counterweight is masked by the trusses across the top of the tower. The lift span provides a 55-ft. vertical shipping clearance when down and 135 ft. when up. An article describing the entire Triborough Bridge project was published in the issue of Aug. 8, 1935, p. 177.

Floor steel erected at rail-head

Steel for the lift span was received by rail at the Hudson River piers in Weehawken, N. J., on the opposite side of Manhattan Island from the bridge site. As it was unloaded, the steel for the floor members, bottom chords and lower lateral bracing, except the two end panels, was assembled in final position on falsework consisting of nine steel A-frames set up on two steel car floats 255 ft. long and 38 ft. wide fastened together side by side, 43 ft. on centers. The truss members and bracing were stowed on top of this platform, and the partially completed span towed four miles around the lower tip of Manhattan to a berth adjacent to the bridge. Here a guy derrick was erected on the Randalls Island approach span and the lift span assembly completed, minus the two end panels but including temporary outrigger connections extending upward and outward from the ends of the trusses. These outriggers were necessary because the span on the barges was only 13 ft. above the water and thus about 40 ft. below the top of the pier.

Towed in at low level

In this semi-complete state the span was towed into position between the towers, and a connection made between the lifting girders and the outriggers whose ends cleared the tops of the high piers. Previously the counterweights had been poured and were suspended several feet below their up-position from pins engaging temporary lifting or jacking bars. The counterweight ropes were in place but slack and not carrying the lifting girders, each of which was suspended from a 29-part line attached to a hoist set on the pier. The machinery, geared to the main sheaves, had been assembled locking the sheaves together, to assure that the span would remain level transversely while it was being lifted.

After the connection was made between the outriggers on the span and the lifting

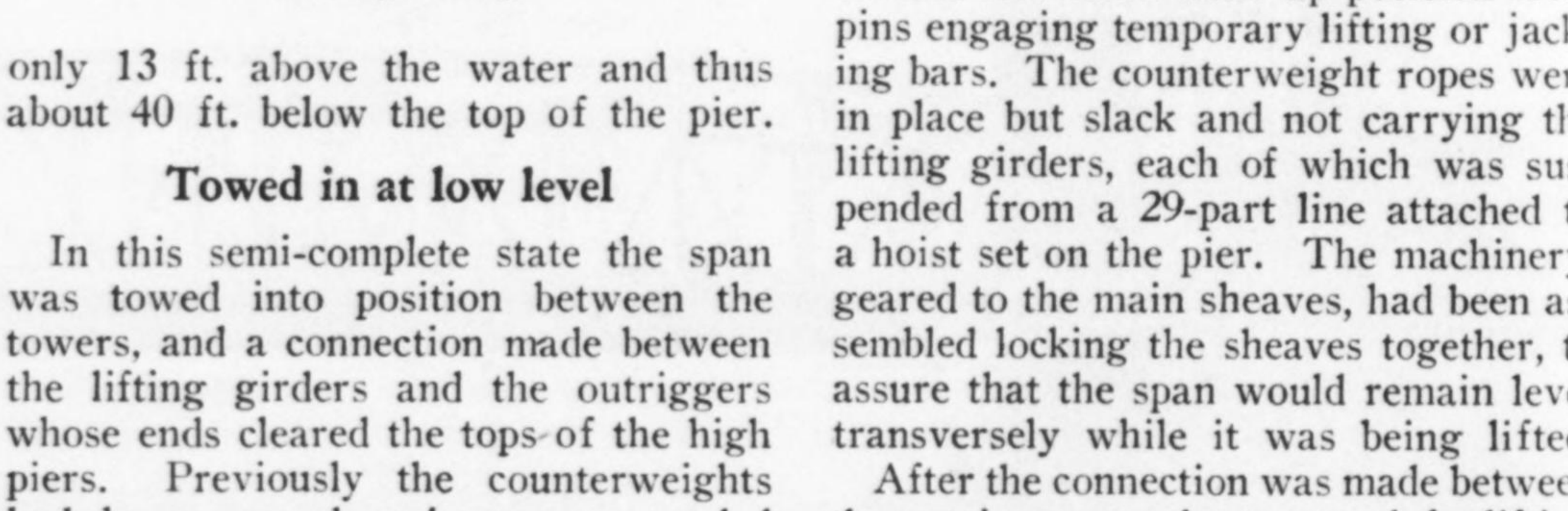


FIG. 3—LIFT SPAN approaching completion on barges in the berth adjacent to Randall's Island. The barges were moved from time to time so that the derrick on the approach could reach all parts of the span.

girders, water was pumped into the barges to lower the span as an aid in making the slack counterweight ropes taut; this operation coincided with a falling tide which aided the lowering of the span and therefore also the lifting girders. Finally the counterweights themselves were lowered (using four 350-ton jacks on each operating against jacking girders attached to the lifting bars) until their weight was suspended on the counterweight ropes. In this condition the counterweights balanced all but 65 tons of the span load; this difference in weight was intentional, to eliminate any tendency for the span to move up without a definite force being applied. This span overbalance and friction were required to be overcome in lifting the span from the barges with the hoists on the piers.

After the span had been raised (in about 16 min. elapsed time) so that the bottom chords were level with the shoes on the piers, the end panels of the trusses were erected by lines from derricks on top of the towers, and the span was lowered slightly to bearing on the shoes. This permitted release of the outrigger connections, following which the Manhattan lifting girder was lowered (by jacking the counterweight up to its normal high position) until the permanent connection to the bottom chords could be made. This jacking operation raised the counterweight a total distance of 45 ft., pins being inserted in the lifting bars after each 2 ft. lift, to carry the load while the jacks were being reset. The counterweight was then lowered slightly putting the full load on the ropes. The operation of transferring the lifting girder connection to the bottom chords was then repeated on the Randalls Island end of the span.

As a final operation the span was raised to its normal high position, using the temporary hoists and the 29-part lines that were attached to the centers of the lifting girders. The contractor was allowed to block the channel for 6 hr. and was required to have the span raised to its up-position in 48 hr. The time required to set the span on its shoes on the piers was 5½ hr. A storm on May 4 delayed final raising of the span until the morning of May 5.

It is believed that the Harlem River Bridge is the first lift spa.. to be completely assembled on floats, and also the first to be floated into position below pier level. The low level assembly was adopted to reduce the weight of falsework and to give better stability. Also, since the towers are independent of the approach spans, high level cantilever erection would have necessitated considerable temporary anchorage. In addition, cantilever erection would have interfered with the completion of the work at the tops of the towers and would have been more hazardous during the winter.

Personnel

The erection of the bridge was carried out by the Taylor-Fichter Steel Construction Co., New York. S. D. Kapelsohn, general superintendent. Clinton D. Hanover, Jr., and H. O. Adelman assisted in the development of the erection procedure. For the Triborough Bridge Authority, H. W. Hudson is construction engineer and Homer R. Seely, resident engineer. The lift span was designed by Ash, Howard, Needles and Tammen, consulting engineers, New York.

Letters to the Editor

Welding Technique

Sir—In reading through the February 27 issue of *Engineering News-Record* we were very interested in the editorial "Don't Forget the Welders" on page 328. We were particularly interested in the last sentence of your editorial which read "A weld is only as good as the welder."

The welding industry has long recognized the importance of the welder and his qualifications but we believe that that is o..ly part of the story. There are five additional factors of importance, and grouped together, they are generally considered under the heading "Procedure Control." If the six steps of Procedure Control are followed there can be no result but a good weld. Procedure Control is not a new term nor are the factors which it covers by any means new.

The six steps of Procedure Control for welding are as follows:

A. Check of the Welders
  1. Experience
  2. Qualification Test
  3. Special Check
B. Selection and Inspection of Material
  1. Material to be Welded
  2. Welding Rod
  3. Welding Flux
  4. Gases
  5. Welding Apparatus
C. Design and Layout of Welded Joint
  1. Spacing
  2. Welding Procedure
D. Preparation for Welding
  1. Alignment
  2. Cleaning
  3. Packing
E. Welding Technique, Organization and Construction
  1. Organization
  2. Welding Technique
  3. Construction Detail
F. Inspection and Test
  1. Inspection
  2. Testing

Consideration of the above factors together with proper supervision will assure a thoroughly sound and satisfactory job for any type of welded construction. Our letter is not intended as a criticism but we believe it preferable to state that "a weld is as good as the procedure control and its application in the hands of the organization performing the welding" rather than to place the entire responsibility upon the welder himself.

R. W. Boggs
The Linde Air Products Co.
New York, N. Y.
March 31, 1936.

THE EDITORIAL in question did not place "The entire responsibility upon the welder." Quite the contrary, for it stated that "prequalification tests for welders should be accepted as a permanent part of all welding routine." Adherence to the above procedure control steps will unquestionably produce a sound weld. It is to be noted that steps A, D and E are direct corollaries of the welder's ability, however. —Editor.

Soil Tests and Foundation Design

Sir—Bruce M. Dack's letter published in your issue of April 9 emphasizes the futility of detailed earthquake-resistant design when erroneous assumptions as to foundation conditions are made. It might also be added that normal designs for vertical loads are frequently invalidated by unnecessary foundation settlements.

Tests can be made which reveal the elastic characteristics of soils under oscillating loads, simulating earthquake conditions, as well as for normal static loading. The results of these tests have been and are being used by progressive engineers in order to obtain adequate and economical foundations.

The common error into which all too many engineers and architects fall is the failure to distinguish between soil testing and foundation engineering. In order to be useful, a soil test must be located and conducted under the supervision of a competent engineer who has an intimate knowledge of the sub-surface structure, including variations in moisture and density which affect the supporting value of the soil as well as the types of soil present. A test made with incomplete understanding of the situation is likely to be unrepresentative of the conditions to be met by the proposed structure.

The importance of accurate interpretation of the test results must not be underestimated. This study must be undertaken with due consideration to the type of soil and the structural features of the proposed building, in the light of our best knowledge of soil mechanics. The understanding of stress in soils has advanced so rapidly that it is not too much to say that even now it is possible and economical to improve greatly the precision of foundation design both for normal and earthquake loading, and in the near future it is hoped that a more consistent accuracy of design throughout the structure may be common practice.

William W. Moore
Los Angeles, Calif.
April 14, 1935.