★ GEORGE WASHINGTON BRIDGE ★

BUILT AND OWNED by THE PORT OF NEW YORK AUTHORITY

O. H. AMMANN, *Chief Engineer*
E. W. STEARNS, *Assistant Chief Engineer*
ALLSTON DANA, *Engineer of Design*
MONTGOMERY B. CASE, *Engineer of Construction*

GENERAL DIMENSIONS

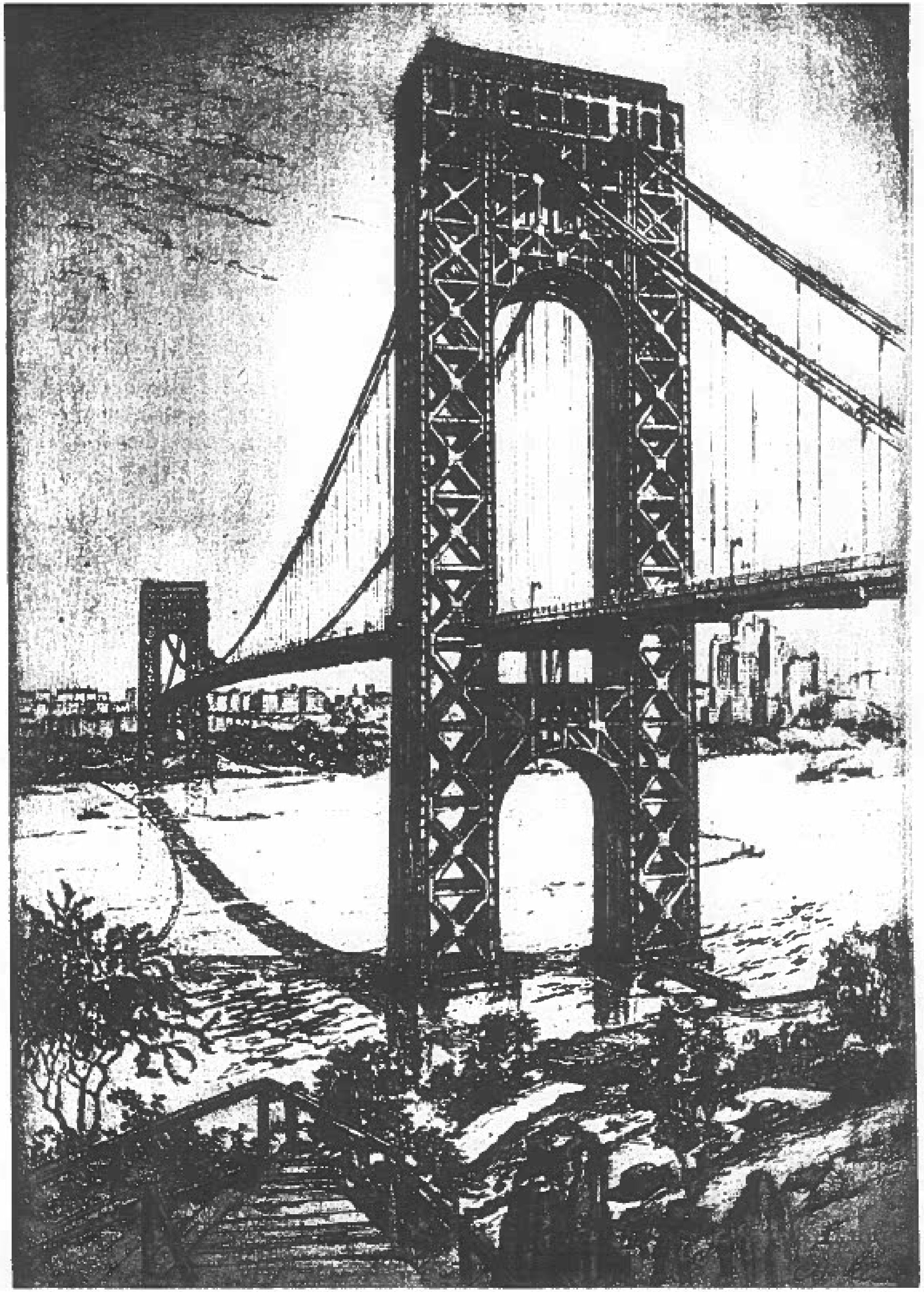
Length of main span, center-to-center of piers	3500 ft.
Length of suspended side span, New Jersey side	610 ft.
Length of suspended side span, New York side	650 ft.
Length between anchorage splay castings	4760 ft.
Total length, Plaza to Plaza	7600 ft.
Roadway height above mean high water at mid-span (present structure)	approximately 250 ft.
Clear height above mean high water at mid-span, normal temperature (final structure)	213 ft.
Height of masonry piers for towers, above mean high water	15 ft.
Height from top of masonry piers to top of cables at towers	576 ft. 3 in.
Height from top of masonry over observation galleries on towers	585 ft. 7 in.
Width of roadway (present structure)	
Two lanes, each 28 ft. 9 in., totalling	57 ft. 6 in.
Width of roadway (final structure); three lanes, totalling	86 ft.
Width of sidewalks; two, each 8 ft., totalling	16 ft.
Maximum overall width of suspended structure	120 ft.
Distance center-to-center wind chords (future stiffening trusses)	106 ft.
Depth of (future) stiffening trusses center-to-center chords	29 ft.

GENERAL DATA

Weight of steel in present structure:	
Towers (structural steel) by McClintic-Marshall	42,175 tons
Suspended span and floor by McClintic-Marshall	19,190 tons
Anchorage girders, eye-bars, etc. (2510 tons by McClintic-Marshall)	6774 tons
Saddle castings	800 tons
Cables (by John A. Roebling's Sons Company):	
Number of cables	4
Number of strands per cable	61
Number of wires per strand	434
Total number of wires per cable	26,474
Average diameter of each wire, after galvanizing	0.196 in.
Diameter of cables	36 in.
Area of one cable	800 sq. in.
Diameter of suspender ropes	2⅞ in.

Type of roadway surface:
7½-in. concrete slab, reinforced with steel bulb beams.

Number of field rivets:	
Per tower	475,000
In floor and wind truss	312,500
Date of signing of contract with McClintic-Marshall Corporation	Nov. 4, 1927
Tower erection begun	June 25, 1928
Tower erection completed	June 20, 1929
Cable spinning begun (by John A. Roebling's Sons Company)	Oct. 18, 1929
Cable spinning completed (by John A. Roebling's Sons Company)	Aug. 7, 1930
Suspended span erection begun	Oct. 28, 1930
Suspended span erection completed	Feb. 17, 1931
Bridge opened for traffic	Oct. 25, 1931
Estimated total cost of present structure, including right of way	$60,000,000



A MONUMENT IN STEEL.
George Washington Bridge, the longest-span suspension bridge in the world, as seen from the New Jersey side of the Hudson River.

★ GEORGE WASHINGTON BRIDGE ★

THE GEORGE WASHINGTON BRIDGE is the first bridge across the Hudson River in the vicinity of New York City. Because of the dense volume of traffic across that river, human minds have of course speculated for generations upon the possibility of a bridge. Forty years ago the subject was active, and interesting treatises were written, several by bridge-engineering specialists and one by a Board of United States Army Engineers, demonstrating both that such a span was theoretically possible, and that practical details could be evolved for its manufacture and erection.

Equally as essential, however, as an engineering solution, there were required financial justification for the great investment and a body of contractors having the machinery, capital, and courage to assume the risks.

Five years ago (1927) The Port of New York Authority, created by the States of New Jersey and New York to develop transportation facilities in the Metropolitan area, studying the tremendous growth of vehicular traffic and the cost and delays incurred in conveying it across the river by existing facilities, decided that a bridge for this type of traffic could be paid for by the tolls that would willingly be paid. Therefore The Port of New York Authority assembled an engineering staff of unusual ability in this special field, prepared the plans for the world's greatest span, and applied to the financial community for a loan of fifty million dollars, secured by a lien on bridge revenues, which sum, with ten million more advanced as a loan by the two states, it was estimated would cover the essential costs.

It is interesting to note that at this stage, when banking houses were considering the lending of this enormous sum for the construction of a span twice greater than any ever built, McClintic-Marshall by reason of its highly-developed plants, ample capital and long, successful experience in the erection of major structures, was sought out by interested investment houses who wished to determine whether the uncertainties, from the contractor's viewpoint, were too great, or whether a contractor of the calibre of McClintic-Marshall approved the plans and would tender for the opportunity, and the risks, of constructing such a span.

When the money was provided and formal tenders received McClintic-Marshall was the lowest bidder, and was awarded the contract to furnish, fabricate, and erect the steel towers and floor system. This was so far as known the largest tonnage ever purchased for a single bridge, and except for the Panama Canal lock gates, also furnished and erected by McClintic-Marshall, the largest single purchase of structural steel in this country's history. In the remainder of this foreword, and in connection with the illustrations which follow, there will be given the salient features of the structural design, and of the equipment and methods employed by McClintic-Marshall for the shop manufacture and the erection of the 60,088 tons of steel comprised in this single contract for the towers and floor.

Design of Towers

The two towers of the George Washington Bridge are located with their centers 3500 ft. apart, one on a rocky point on the New York side, the other slightly off the New Jersey shore, on piers carried down to rock. The span of 3500 ft. is double that of the Philadelphia-Camden Bridge (1750 ft.) and nearly double that of the Ambassador Bridge over the Detroit River (1850 ft.), the latter designed and built by McClintic-Marshall and opened to traffic in 1929, and at that time the longest span in the world.

Each tower of the George Washington Bridge comprises two legs, one on each side of the roadway, the two legs being joined under the roadway and again, well above the roadway, by arched portals. Total height of legs is 600 ft. 7 in. above mean high water.

Each leg is made up of eight individual columns, braced together, of which one row of four is parallel to and close to the roadway, and under the cable saddles (in the vertical plane of the cables); and the other row of four is outside of the row under the cables.

The bridge floor is carried by four 36-in. wire cables, two on each side of the roadway. The two cables on each side are only 9 ft. apart, and the two groups are 106 ft. apart, on centers. The inner rows of four tower columns in each leg are therefore 106 ft. apart, and are plumb as viewed along the axis of the bridge. The outer row of four columns is spaced 47 ft. 6 in. from the inner row, at the bottom, and 38 ft. 3 in. at the top.

Viewed in side elevation, none of the columns is plumb. The four columns in each row form three spaces of 18 ft. 8 in. each, at the bottom, and batter in to three spaces of 12 ft. 6 in. at the top. Obviously the rate of batter is three times as great for the outer as for the inner columns as viewed in side elevation. The illustrations reveal clearly these inclinations of the columns.

The four columns in the inner row are tied together by bracing, continuously from bottom to top; the four columns in the outer row are similarly tied together, and again each inner-row column is tied to its outer-row counterpart by continuous bracing. Also, at each alternate panel-point of these bracings there is a horizontal plane of bracing connecting the eight columns of each leg into a unit. The two legs of a tower, however, are not tied together except by the arched portals below and above the roadway, referred to above.

These tower legs, comprising eight straight-line, inter-braced, separate columns, are radically different from the shafts of other suspension-bridge towers of recent construction, in all of which the shaft has comprised a group of attached cells, with the inner or core cells usually plumb and of constant dimension from bottom to top, and the outer or bracing cells tapering or flaring toward the bottom to provide not only stability, but also a high degree of flexibility.

The George Washington Bridge towers, however, were designed to render possible the fulfillment of an architectural design which contemplates that they will be encased in granite with concrete backing. Because of its cost, this masonry encasement is now omitted and the time of its addition is entirely indefinite. The general design and all the details of the towers as constructed are, however, adapted to it; and the Port Authority engineers are to be congratulated that their towers, having been designed subject to this prescription of adaptability to future encasement, are as self-sufficient and attractive in appearance as the common verdict pronounces them to be.

As stated above, each leg receives the load of a pair of cables, centered over the inner row of four columns, at the extreme top. Below this point, however, an increasing proportion of this load is transferred outward through the bracing to the outer row of four columns. The unusual situation is thus created, that the columns of the inner row are less heavily loaded, and of lighter section, at the bottom than at the top. The transfer of load is sufficient nearly to equalize the loads on the inner and outer rows, at the bottom. This transfer is due to the fact that it is impossible for the inner columns to shorten under load without forcing the bracing and the outer columns to shorten proportionately. After calculation by a special application of the mathematics of indeterminate structures, this transfer was verified by laboratory experiments on a small-scale celluloid model, under similar loads and reactions.

The complex intersections of the tower bracing, as indicated above and shown in the illustrations, necessitated the carrying of some heavy and fundamental stresses through rivet heads in tension, a detail against which there is much inherited prejudice, though today fast losing its force. To verify the soundness of this detail, large test pieces simulating such a joint were fabricated and tested in tension to destruction. In these tests it was found that a group of rivets in tension withstood more load than an equal group either of turned bolts in tension, or of rivets in single shear.

The individual column units (of which eight comprise a tower leg, or 16 a tower) are of a unique cross-section. Four plates are boxed together into a closed square cell, a very efficient form for strength in any direction; each plate is extended beyond the corner of this square to form a wing, with an edge angle. The eight wings provide for simple connections of the several planes of bracing, and for the attaching of the future masonry encasement. The first illustration, on page 19, gives a complete picture of the make-up of one of these columns. The square cell is about 3 ft. on a side, and the overall of wings is 5 ft. 9 in. All tower bracing is obviously of box section about 3 ft. in width to connect to the column wings in line with the square central cell.

The area of each individual column is about 717 sq. in. at the bottom. The largest individual sections, the inner columns under the cable saddles at top of tower, are 1296 sq. in. The total vertical load on the top of each tower leg is 56,000 tons.

Each individual column rests on a structural pedestal flared to 13 ft. 9 in. square on the bottom. The column tops are surmounted by a grillage of heavy girders to receive the cable saddles. The latter are steel castings, machine-grooved to receive the individual cable strands. These girders and castings were a part of the contract for the wire cables; their weight is excluded from this record, except as noted on page 18.

The total weight of structural steel in the towers from masonry to under side of saddle grillages is 40,498 tons, of which about 60 per cent, comprising the columns and some bracing, is of silicon steel and about 40 per cent of carbon steel. The unit stresses for design, taking into account "congested" or quite improbable full live loading on upper and lower decks, are respectively 20,000 lb. per sq. in. in tension for carbon steel, and 27,000 lb. for silicon steel; and in compression $20{,}000-60\frac{l}{r}$ for carbon and $27{,}000-80\frac{l}{r}$ for silicon steel, with upper limits of 17,000 and 23,000 lb. per sq. in., respectively.

Fabrication of Towers

Fabrication, as is usual in the McClintic-Marshall shops, was essentially a straight-line procedure, with some lateral but no retrograde movements, raw material coming in at one end and finished bridge members passing out at the other.

The incoming material consisted of rolled-steel plates, angles, and other structural shapes, each piece ordered from the mill especially to form a definite component of a definite bridge member, and each ordered of the size shown by the finished detail drawing plus a little extra length for final trimming. Each piece was marked on arrival, and stored for its intended purpose. In turn it was made perfectly straight, then taken to the machine where, in accordance with the detail drawing locating every required hole, it was punched or drilled for riveting to other component parts.

Most of the George Washington Bridge material was first punched with 13/16-in. holes. It then advanced to fitting skids where, by means of a portion of these holes, several plates and angles were bolted together to constitute a column or other member. This member was then transferred laterally to a table under a "gantry" or rolling crane, carrying tools to ream out the 13/16-in. holes (for shop rivets) to their full diameter of 1 1/16 in. This process remedied the minute mismatching of the original sub-punched holes, and made all holes perfectly cylindrical.

From the reamers, the pieces advanced to other skids, where they were riveted up. The rivets were 1 in. in diameter, so as to fit easily into the 1 1/16-in. holes. They were heated in oil furnaces for easy upsetting. After insertion in the work they were gripped between two cups on the opposite ends of a yoke riveter, which by pneumatic pressure up to 70 tons squeezed the rivet material until the shank expanded to fill the hole completely, and a perfect head was obtained on each end. Rivets in difficult locations were riveted with pneumatic hand riveters such as are used in all cases in the field.

Sometimes it is convenient to divide a bridge member into longitudinal portions, and rivet these portions before assembling them for reaming and riveting of the complete member. This was the process followed with the George Washington Bridge columns, as clearly shown by the first illustration of column fabrication.

The columns advanced next to the milling machine, where the end irregularities were faced off to exact square or exact bevel, and to exact length. For the typical columns this presented no unusual problem for the usual rotary milling machines, other than that of the length of time required to cut with accuracy over members 5 to 6 ft. square over extreme corners. The upper sections of the inner columns, where flared out to distribute the loads from the cable saddles, were of great area and spread, and an improved type of milling machine was considered worth the investment if it would substantially reduce the time for this milling.

McClintic-Marshall therefore developed and installed for the George Washington Bridge a special milling machine, shown in several of the illustrations. This machine had a rather small milling head which traveled over all parts of a heavy frame. It could thus reach and mill all parts of any area up to 22 ft. wide by 12 ft. high, and could mill simultaneously both ends of a member 83 ft. long. Since the milling head wasted almost no time in passing over the void spaces of the column section, as a large rotary miller would have done, but could be kept at work all the time on the actual cutting of steel, it greatly reduced the time for milling the large columns.

The special McClintic-Marshall milling machine was erected in the entering end of a covered building especially designed for bridge assembly, in which complete bridge trusses up to 550 ft. in length can be assembled, reamed and painted under cover.

Accurate control of length of the several columns as milled was essential in order that all eight columns of a leg might come out to level bearing at the top. This was accomplished by accurate readings of length over all corners of each piece with correction for temperature, compensating the over-run or under-run of each in the milled length of the next above. A field survey after erection to the tenth level showed all 16 columns of a tower in agreement within 3/16 in. This variation was then corrected in the milling of the upper two lengths, making the tops perfectly level.

The columns, after milling, were then laid end to end, all the splice plates and splice angles for connection of one length to the next were fitted in place, and the connecting holes were reamed out. With the exception of holes required for bolting at this stage, the splice holes were sub-punched in the outer ply of material only, and through these holes as guides, the remainder of the holes were drilled from the solid. Absolute perfection of matching when erected, and quick and perfect field riveting were thus assured.

After detaching the splice material for clearing out the drillings, it was reassembled to the lower column section and riveted. The shop painting was then completed, under the protection of the assembly building.

The towers comprised in all 464 separate pieces of column, assembled, milled and finished as above described; also 32 pedestals and eight top grillages, as well as a great number and variety of bracing members. The finishing of the latter differed from that of the columns in that their field connections to the column shafts were not assembled for reaming, but were reamed through metal templets, assembled first to the column and then to the bracing member, producing an identical group of holes in each for field mating.

The 464 pieces of column averaged about 48 ft. in length and 60 tons in weight; the heaviest single members (0–1) weighed 80 tons. The special sections near the top of the inner row were among the heaviest, and because of the necessity of grouping these for milling, the shop cranes had to handle to and from the assembly skids and milling machine, assemblages up to 157 tons—a very unusual performance for a structural shop.

Erection of Towers

The first steel was set on the New Jersey side on June 25, 1928, and on the New York side on August 6. The towers were turned over to the cable contractor June 20, 1929. This interval included a four-month cessation of work, between November 28, 1928, when point 10 was reached, and March 26, 1929, when erection was resumed. Work was suspended for this period because the erection was going so far ahead of schedule that winter work was not justified.

The steel went by rail from the shop to ground storage in the New York lighterage area. Thence it was reloaded on cars as requisitioned from the bridge site, the cars placed on carfloats and towed to the bridge. The New Jersey tower being in deep water, the carfloats tied up to the pier; on the New York side they tied to a temporary wharf from which the material was unloaded by a stiffleg derrick, and set inshore to within reach of the traveler booms.

Each tower was erected by a traveler comprising two stiffleg derricks on a two-story underframe. The underframe occupied all of the rectangular space between the two legs of a tower, being in plan about 80 ft. transverse to the bridge, by 64 ft. The derrick masts were located 13 ft. in from the riverward corners of the underframe. Each had a stiffleg back to its inshore corner of the frame, and a transverse stiffleg reaching three-fourths of the 80-ft. distance across to the other mast. The transverse stifflegs of the two derricks therefore framed through each other, as the illustrations show. The derricks worked independently, each erecting a leg of eight columns; each 86-ft. boom had a capacity of 83 tons at 67-ft. radius, 79 tons at 77-ft. radius, and 40 tons at 86-ft. radius. The diagonal distance from foot of mast to base of farthest column was 77 ft. for the outer or light row, and 49 ft. for the inner or heavy row.

Each traveler was operated by two 7-drum engines weighing 75 tons each (probably the largest portable engines ever used on a construction job), located in fixed positions on the ground, 150 ft. landward from the center of the tower. All signals were by electric light, one red and one white to each drum or pair of drums. White light signalled to go ahead, red light to lower, no light signalled stop. Each 7-drum unit was powered by two 150-hp., 440-volt, 3-phase a. c. motors. These motors could be operated independently or, by throwing one lever, could be coupled together to deliver 300 hp. on one pair of drums.

Two drums of each 7-drum engine operated jumping falls at two corners (one side) of the traveler, each falls comprising 18 parts of 1-in. cable. The remaining five drums powered the derrick on the corresponding side of the traveler. One operated the auxiliary load falls, two parts of 7/8-in. cable on a 15-ton boom extension jib. Two operated the main-load falls, and two the boom falls. In each of these latter cases both ends of the 7/8-in. line were brought to the engine and were pulled simultaneously, the two drums being geared together. The effect of this was to produce two 6-part falls for the load, instead of one 12-part falls, and two 11-part falls for the boom instead of one 22-part falls, reducing frictional loss, lead-line pull, drum capacity, and hoisting time. The maximum time of hoist was 17 min.

The upper story of the traveler underframe was so trussed as to rest upon and load two transverse trusses, which comprised the lower story. These transverse trusses were placed slightly riverward from the two riverward inner tower columns and slightly shoreward from the corresponding shoreward tower columns, and were 106 ft. in length, or the same as the distance, center-to-center, of the inner columns, to which they were attached and delivered all load. Each of the four attachments was a kicker leg or toggle, sloping toward and resting on a bracket which was one of the regular column diaphragms, reinforced; there was a clamp to take care of the horizontal component of the reaction.

At each jump of the traveler, the batter of the main columns reduced the front-to-rear dimension of the tower legs, and consequently the distance between the two transverse trusses of the traveler underframe. Therefore the upper story of the traveler underframe was fixed to the riverward truss only, of the lower story, and rolled across the shoreward truss at their point of contact. These successive changes in the depth of the supporting base were the sole reason for constructing the traveler underframe in two stories.

After the traveler was set up on the pier, the first very important and delicate operation was the setting of the 16 independent structural column bases. These were 13 ft. 9 in. square and weighed 55 tons each; and upon their exact and level setting depended the accuracy of the entire structure. The procedure adopted was to set each pedestal on steel pads with bronze shims, and adjust it to perfect level; then to remove it, lay down a bed of one-to-one mortar and strike it off carefully 1/8 in. high, using a screed bar sliding over accurately-located rails. Then, when the pedestal was reset and, if necessary, given a slight additional load and vibrated with a heavy pneumatic riveting hammer, it displaced the excess mortar till it took perfect position on the pads. Most of the excess mortar flowed out from under the pedestal as it came to bearing; part escaped upward into the pedestal pockets, through relief holes drilled for this purpose through the bottom slab of the pedestal. After the mortar had set up, the steel pads and bronze shims were removed, and stiff mortar was rammed into the spaces they had occupied.

Upon these pedestals, the traveler then erected the entire first story (0–1) of each 8-column leg and the inside 4-column rows of the next story (1–2) and the bracing connecting point 2 to point 1 of the outer 4-column row.

The traveler next was "jumped" till the boom steps came over point 2. The illustration on page 39 shows this jumping. The booms were swung back to distribute equally the load of 320 tons to the four corners. The jumping load was carried by cat-head girders resting on the inner rows of main columns; when the jump was completed and the load transferred through the traveler underframe to the toggles and thence to the main columns, these cat-heads were unbolted and hung to one side.

Next the outer 4-column row (1–2) was erected and the bracing finished to point 2. Then the inside 4-column row of story (2–3) was erected and braced, and another jump made. This was the typical schedule, repeated to the top of the towers. An average jump, when only tower legs (no portal bracing) were involved, would follow five days after its predecessor.

At levels 2, 6, and 8, temporary struts were used to space the inside corner columns across the 106-ft. gap, until the erection of portal permitted their removal. The New York lower portal was erected by runner lines and falls hung from the traveler underframe, after the traveler had "jumped" above the portal position; the New Jersey portal, by swinging a traveler boom back inside its stifflegs.

After the tower legs were completely erected, one derrick was moved over onto each leg, and the two took down the traveler underframe and erected the upper portal. One of these derricks was again moved so that its mast was centered between the riverward columns and on the axis of the bridge, and its boom was lengthened to 105 ft. It then took down the other derrick, erected for the cable contractor his 36 wire ropes of 2⅞-in. diameter for support of cable-spinning footbridges, erected his grillage girders and saddles for both legs, and finally erected his construction tower or strand-handling runway.

Riveting followed closely behind the travelers. For outside riveters portable scaffolds were provided, with safety roofs and rails, and 60 ft. of height-adjustment by hand-ratchet winch. The most satisfactory forge was a coal forge with extra-size pan. Each tower required the driving of 475,000 field rivets, or 24 rivets per ton of tower steel.

Compressor house, tool house and other facilities were maintained at the base of the towers. To take care of future sightseeing, if found advisable, two permanent elevator shafts were provided in each tower; in one of these shafts on each side of the river the elevator was installed with cage-enclosure and was used throughout the job for the hoisting of men and supplies to the various levels; on completion of the bridge the permanent cage-enclosure was added.

After the bridge was in service for a few months, McClintic-Marshall received a further order to furnish and install covered observation galleries on the tower tops, amounting to 400 tons of additional steel.

Design of Floor

The towers, cables, suspenders, and anchorages of the George Washington Bridge were designed and built of full capacity for a double-deck bridge, of which only the upper deck has now been constructed. The loading assumed for the future lower deck is that of a 4-track electric rapid-transit railway. The upper deck is divided into two roadways 28 ft. 9 in. between curbs, which have been concreted and are in service; a central roadway of the same width, for which the steel framing is in place but which will not be concreted until traffic develops to require it; and two concrete sidewalks about 8 ft. in effective width, both completed.

The upper or present deck is carried by transverse floor beams of silicon steel, spaced 60 ft. apart. Their span is 106 ft., center-to-center of attachment to the suspender ropes, which attach in two groups of four ropes each at each end. These floor beams are 118 ft. overall, 10 ft. 6 in. deep, and weigh in general 62 tons each, the four adjacent to the towers being 6 tons heavier.

Eight lines of carbon-steel, plate-girder stringers, 60 ft. long, frame into these floor beams; they vary in depth from 64 in. to 68 in. On these stringers rest transverse 16-in. I-beams, blocked up to the roadway crown. On these are supported longitudinal 6-in. bulb-beams, 15 in. on centers, which constitute the major reinforcement for the concrete slabs. Curbs and roadway guards are longitudinal girders, riveted to the transverse I-beams.

The floor beams are pierced, under the center of the suspender attachments, to pass the wind-chord, a silicon steel box girder, 30 in. by 30 in. The wind laterals connect to this chord and pass under the stringers, to which they attach for support only. These wind-chords are designed to act also as the top chords of two vertical stiffening trusses, 106 ft. apart, for future construction; the verticals of these trusses will support the future transverse floor beams of the lower deck. The depth of the trusses will be 29 ft., or 1/120th of the main span. The great weight of the main cables makes practicable the absence of a stiffening truss for present highway loading, and the shallow and light design of stiffening truss for the future double-deck structure. It also makes possible a relatively light wind-bracing system for the present deck, a large proportion of the wind load being transferred through the cables to the towers.

Fabrication of Floor System

The general principles of sub-punching, assembling, reaming and riveting the various elements of the floor system, are the same as above described for the towers. On pages 25 to 28 are shown successive steps in the fabrication of one of the 62-ton floor beams. There were 74 of the floor beams, and 154 pieces of wind-chord, the latter requiring milling and assembled reaming of splices. Three railway cars were required to transport each floor beam, with swivel bolsters to permit them to swing around curves in the track while on their way from shop to bridge.

Erection of Floor System

Erection of the floor was carried on simultaneously at four different points, travelers working both ways from each tower. There were 8646 tons of carbon steel, 8131 tons of silicon steel, 2341 tons of beams and tie-rods in the roadway slabs, 69 tons of cast steel and cast iron, and 3 tons of bronze, making a total of 19,190 tons. Rapid erection was required, as the completion of this work determined the date of opening the bridge to public use.

Each of the travelers on the center span was, in reality, two A-frame travelers, coupled side by side. By picking the only heavy lifts (the main floor beams weighing 62 to 68 tons) with the two booms, lighter, shorter and faster booms could be used, and a smaller number of parts was required in the main-load falls. After each floor beam had been set, the two booms operated independently, each filling in one-half of the panel. Thus the hoisting consumed about half the time that would have been required if a single long and heavy boom had been used. By having two raising gangs on each of these double travelers, competition was created, tending to speed up the work. If one gang finished its half before the other, it helped fill in the other half, and the two travelers were moved as one unit. These A-frame, cable-backstay travelers were easily adjusted to compensate for changes in grade, it being necessary merely to move the sheave at the end of the backstay to a different pin hole in the connecting link.

The double travelers for the main span had been used singly to erect previous large bridges. The tops of two A-frames of the New York traveler were tied together with steel cable, and side guys or "quarter-falls" were used on the upstream side of the upstream A-frame and on the downstream side of the downstream A-frame, to increase the stability while picking steel from a carfloat, subject to tide and current. The shoes at the bottom of the "quarter-falls" were bolted to the top flange of the floor beam, these being the only tie-downs required at the front of the traveler. The two front sills were fastened together with a removable link which transferred shear only. Although the engine was sufficient counterweight to take care of the figured uplift, a rear tie-down was provided for safety, and to take out vibration. The New Jersey traveler A-frames were similar, but stifflegs were used instead of "quarter-falls."

The two 150-hp., 4-drum electric engines used on the New York center-span traveler were part of the 7-drum units used for the tower traveler. The four drums were utilized, one each for the main-load falls, boom falls, auxiliary-load falls, and traveler-moving falls. The engines used on the New Jersey center-span traveler were two 150-hp., 3-speed, 3-drum gasoline engines. These drums were utilized, one each for the main-load falls, boom falls, and auxiliary-load falls, this traveler being moved by manila falls from the "niggerheads." All booms were swung by point lines, operated from swinger engines.

One single-boom traveling stiffleg derrick was used on each side span, these derricks being available from the tower travelers. With the main span partially raised before erection was begun on the side spans, there was no appreciable change of grade during erection of side spans, so there did not have to be any adjustment for change of grade in the traveler stifflegs.

The engine for each side-span traveler was one of the tower traveler engines, still located on the ground. A swinging engine, mounted on the traveler, swung the boom by means of a bull wheel.

Floor steel, like the tower steel, was brought to the bridge site on carfloats. Almost directly under the panel where a main-span traveler was working, was anchored a barge to which the carfloat was moored during working hours. The steel was picked direct from this carfloat and set in place with no rehandling. It was not permissible to have the carfloats moored to these barges overnight, and they had to be towed out every morning and returned to the dock in the evening by the erector's tug.

Four anchors were used on each barge, and the position of the barges was adjusted by slacking off and taking up on the anchor cables. When a barge had thus been shifted out toward the center of the river, so that it was nearly abreast of the outboard anchor, all four anchors were in turn shifted by tugs.

The carfloats containing the steel for the side span were moored to the dock or to the tower foundation, respectively, and the steel unloaded by a stiffleg derrick which was located on the bridge deck directly above. The steel was then loaded on trucks and carried back to the side-span traveler, using the bulb-beams as rails.

Due to the large size of the bridge cables, and the great stiffness of the towers, the entire steel deck could be erected by the traveler as it moved out, without excessive distortion of bridge profile. Thus it was not necessary to make successive passes of the floor travelers, as has been necessary on other large suspension bridges.

In each panel the floor beam was erected first, and hung from the 16 suspenders, then the wind-chords, stringers, bracing, cross-beams, bulb-beams and tie-rods, in the order named. The main-load falls were used only on the floor beams and the wind-chords, all other steel being set with a 2-part auxiliary falls. The wind-chords could have been raised with the auxiliary falls, but the main falls were used to get the delicacy of motion required to make the connection readily.

There was no difficulty in closing the main span. The connection of span at each tower was a sliding surface, wind shear and half the vertical load of the adjacent panel being taken into the towers on sliding shoes. The New Jersey side was pulled towards the tower with turnbuckles, and jacks were set on the New York side. The closing chords were dropped in with 1/8-in. clearance, the connection made, and the jacks and turnbuckles removed.

During the early stages of erection, before short suspenders had a restraining influence, the possible lateral motion at the end of the span, due to wind, was estimated to be sufficient to cause the ends of the windward stringers in the panel adjacent to the tower to run off their seats. To prevent this, the wind-chords were fixed to the columns, thus transferring not only the wind shear, but also wind moment, the span forming a horizontal cantilever truss. After the suspenders were short enough to restrain the end, this tie was removed.

There were 312,500 field rivets driven. Air was furnished by compressors located on the ground near the towers. Wind-chord splices were not riveted until the two adjacent chords were in a straight line, the same position they had been in when they were reamed, assembled, at the shop. About ten panels of the main span were erected before the first splice was riveted.

On October 28, 1930 the cables had been compacted and enough suspenders were in place for the erection of floor steel by McClintic-Marshall to begin. Erection and riveting were completed, and the bridge was ready for the pouring of floor slabs by another contractor, on February 17, 1931.

The bridge was dedicated on October 24, 1931 and opened to the public the following morning, eight months ahead of the date announced by The Port of New York Authority when construction of the bridge was authorized.

Besides the foregoing work, performed under direct contract from The Port of New York Authority (60,088 tons fabricated and erected), McClintic-Marshall fabricated 3787 tons and erected 8851 tons of anchorage steel, anchorage floor, tower grillages, slabs, rollers, and saddle castings—all permanent main-bridge steel—for other contractors; and also furnished 2784 tons and erected 1408 tons of temporary-equipment steel for the cable contractor. On the elaborate New York approaches to the main bridge, McClintic-Marshall furnished and erected under subcontracts 4865 tons of permanent and 82 tons of temporary steel.

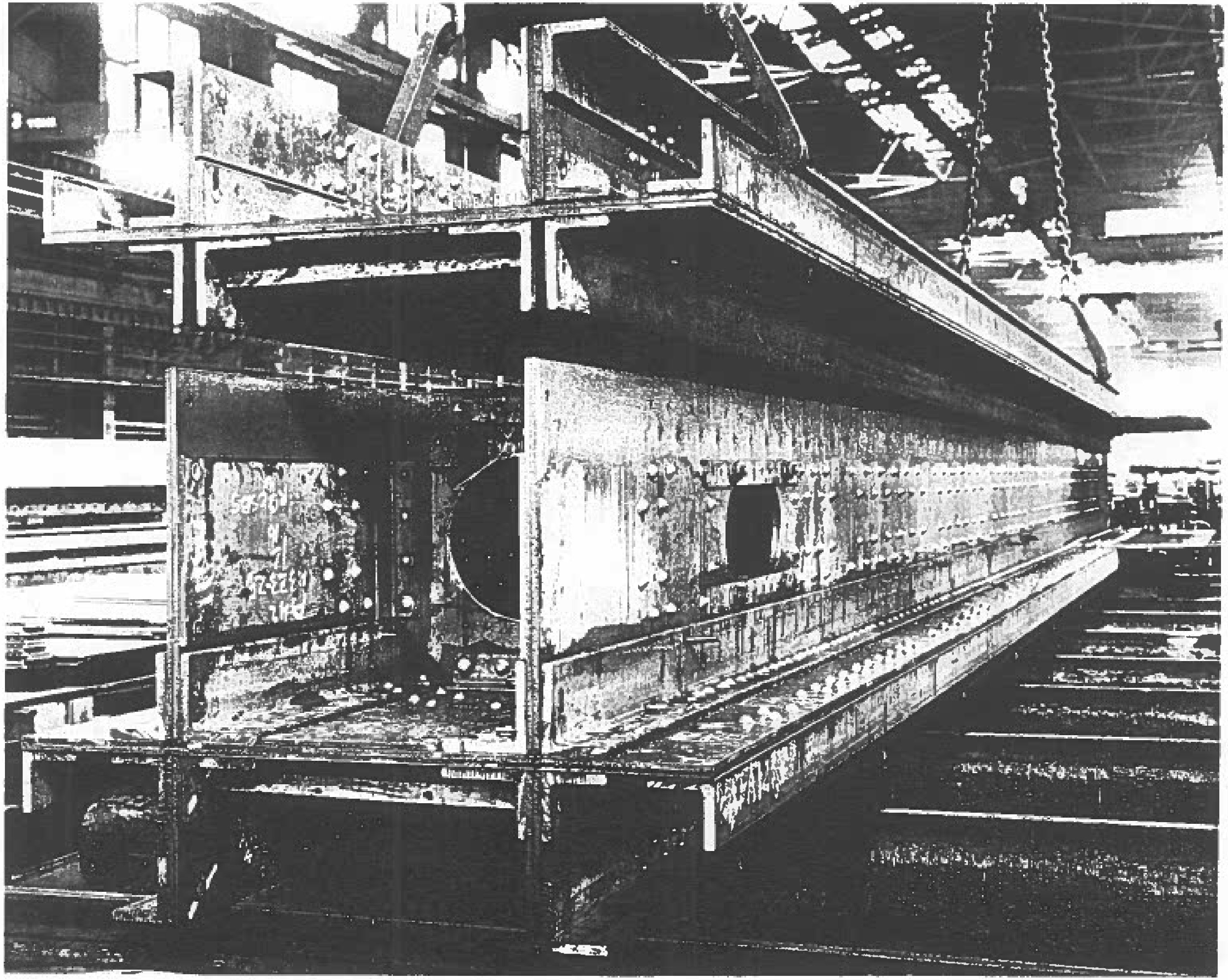
The total contribution of McClintic-Marshall to the George Washington Bridge project, in steel fabricated or erected, or both, was therefore 76,670 tons.

In February, 1931 McClintic-Marshall Company was purchased by and became a subsidiary of the Bethlehem Steel Corporation, its name being changed to McClintic-Marshall Corporation. Retaining the facilities and personnel with which it has made its name on the George Washington Bridge and scores of previous bridges, skyscrapers, and notable structures of every sort, with an augmented staff, and additional facilities expanding its capacity to 1,000,000 tons of fabricated steel per year, and with the support and cooperation of the great Bethlehem organization, the McClintic-Marshall Corporation is looking forward to still more difficult and notable tasks.

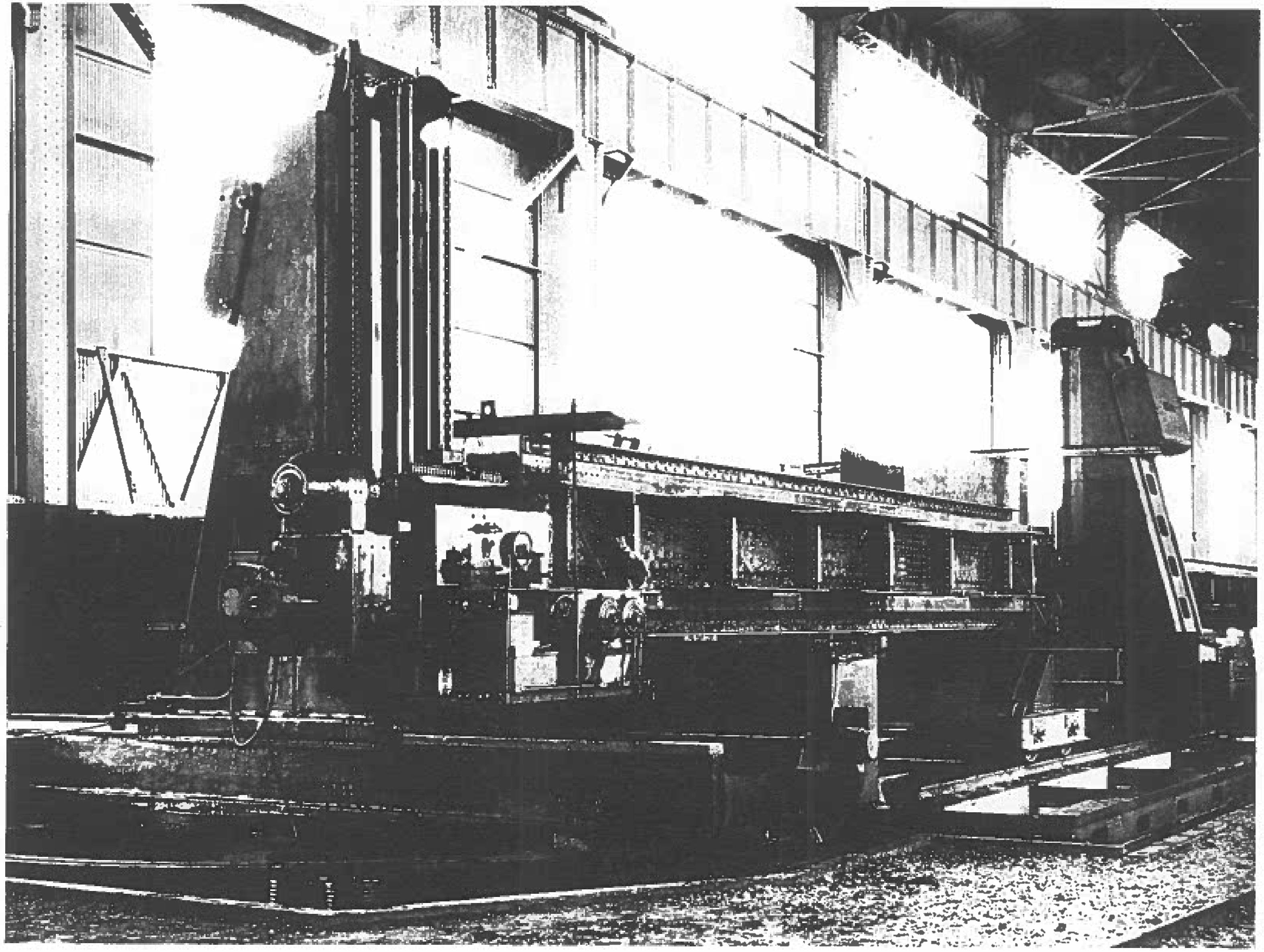
★

Acknowledgment is made to The Port of New York Authority for permission to reproduce among the following pages many of its progress photographs.

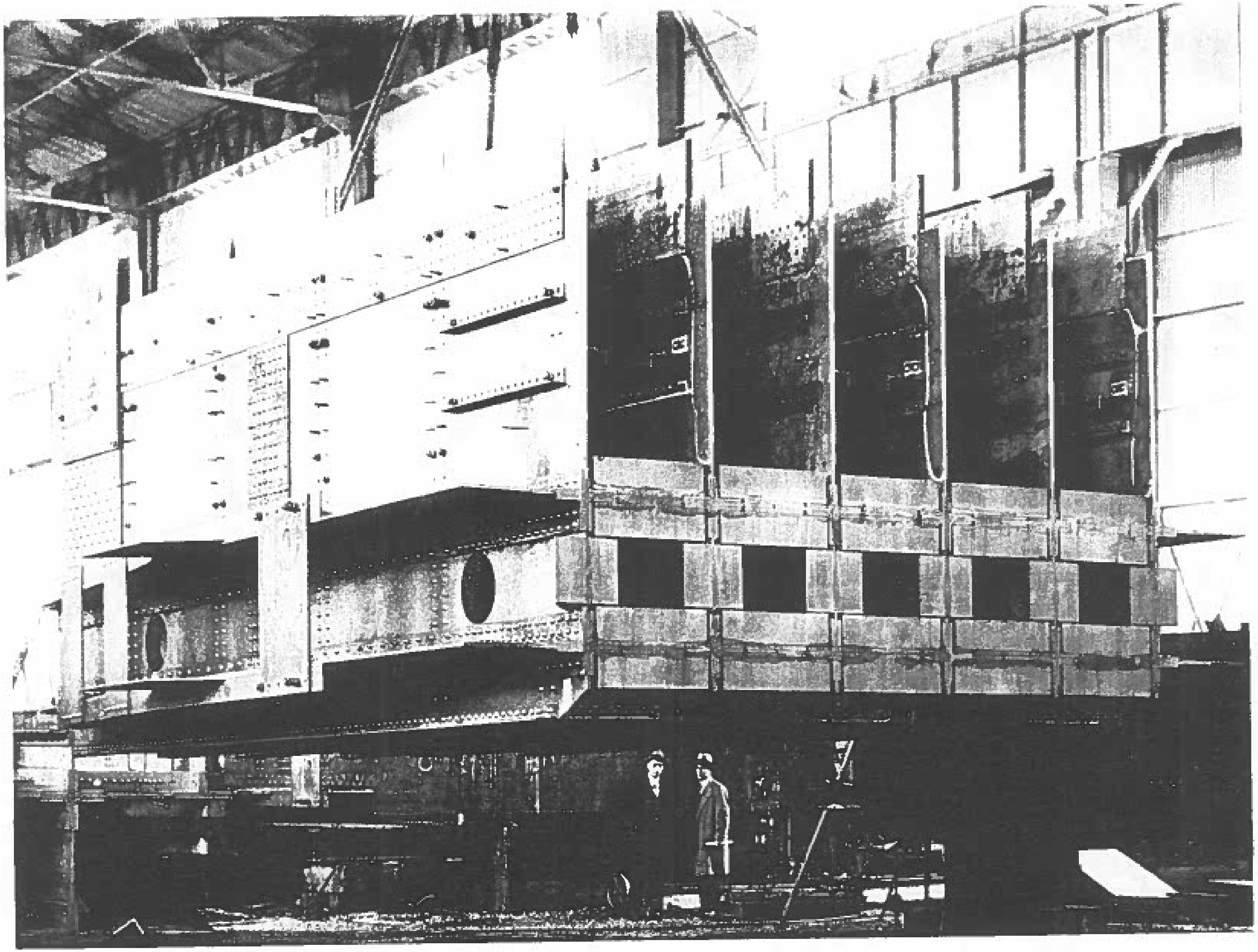
★



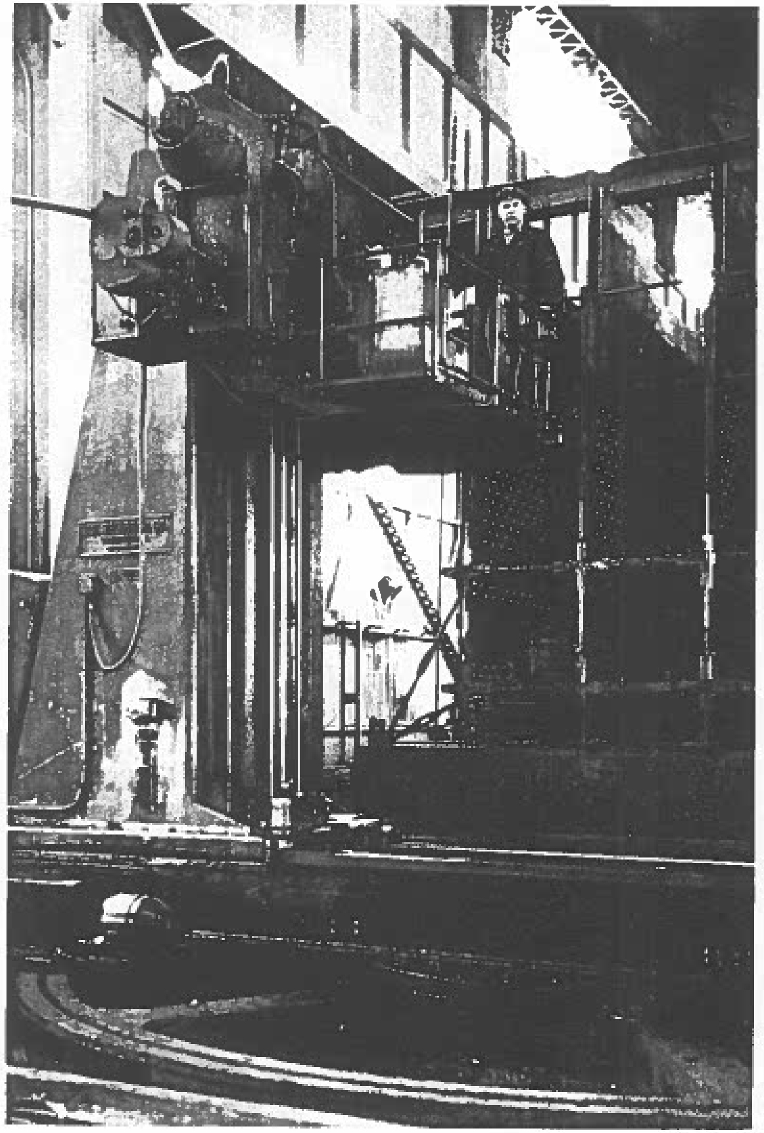
THIS ILLUSTRATION gives a clear idea of the unusual make-up of the main columns. A column is being assembled in the shop for completion of riveting, and the crane is lowering one flange into place. Four such columns are directly under each cable saddle and four more outside of and braced thereto, making eight columns for each tower leg, or 32 for the bridge.

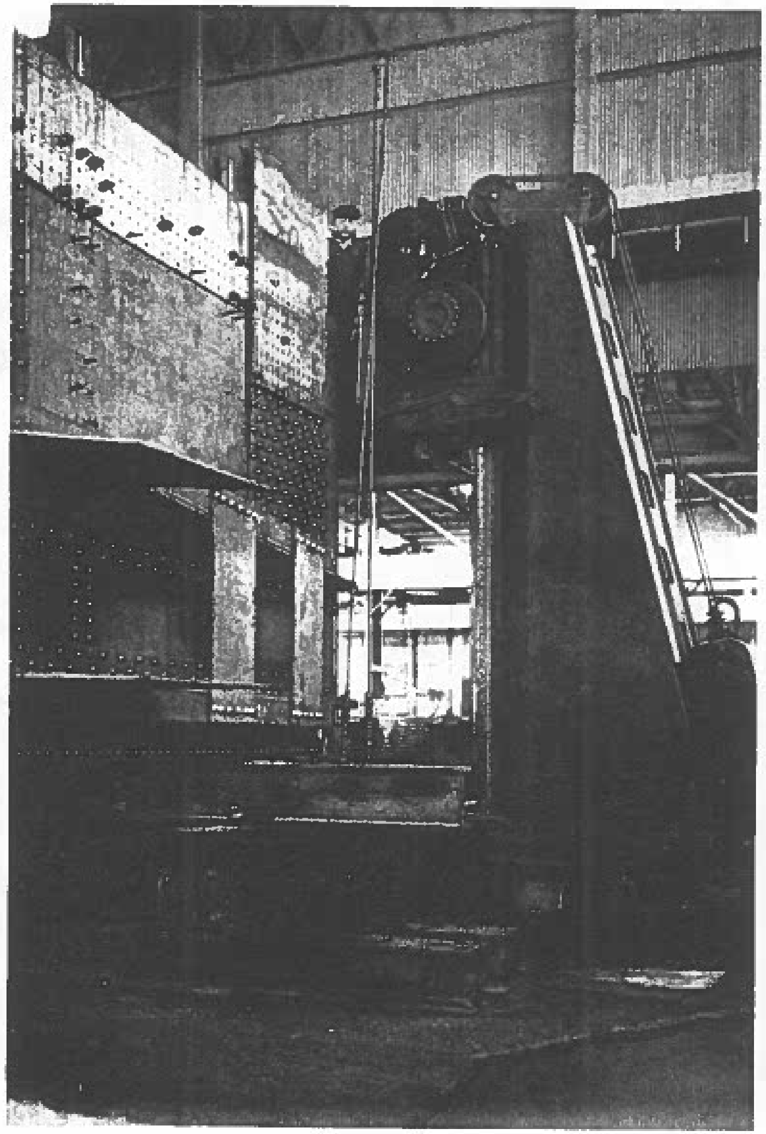


AFTER ASSEMBLING AND RIVETING, all columns were milled square at each end and exactly to length. This is a general view of the large double-end milling machine squaring a column section.

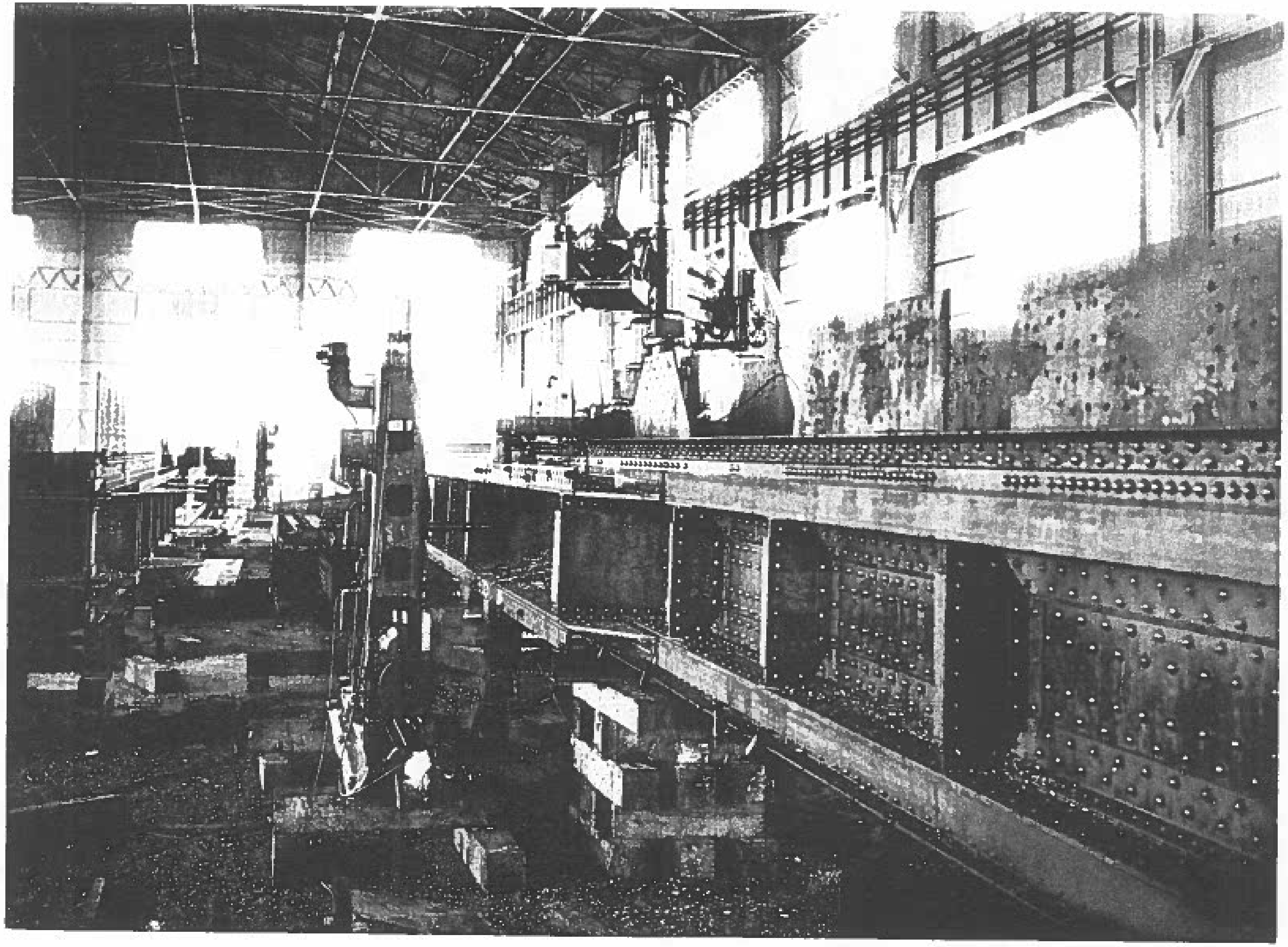


VIEW OF TOWER COLUMN SECTION 11–12, immediately under the grillage for cable saddle. To insure a plane surface for the saddle it was necessary to assemble and mill this as a unit, handling 157 tons with shop cranes. Then it was disassembled for shipment and erection.



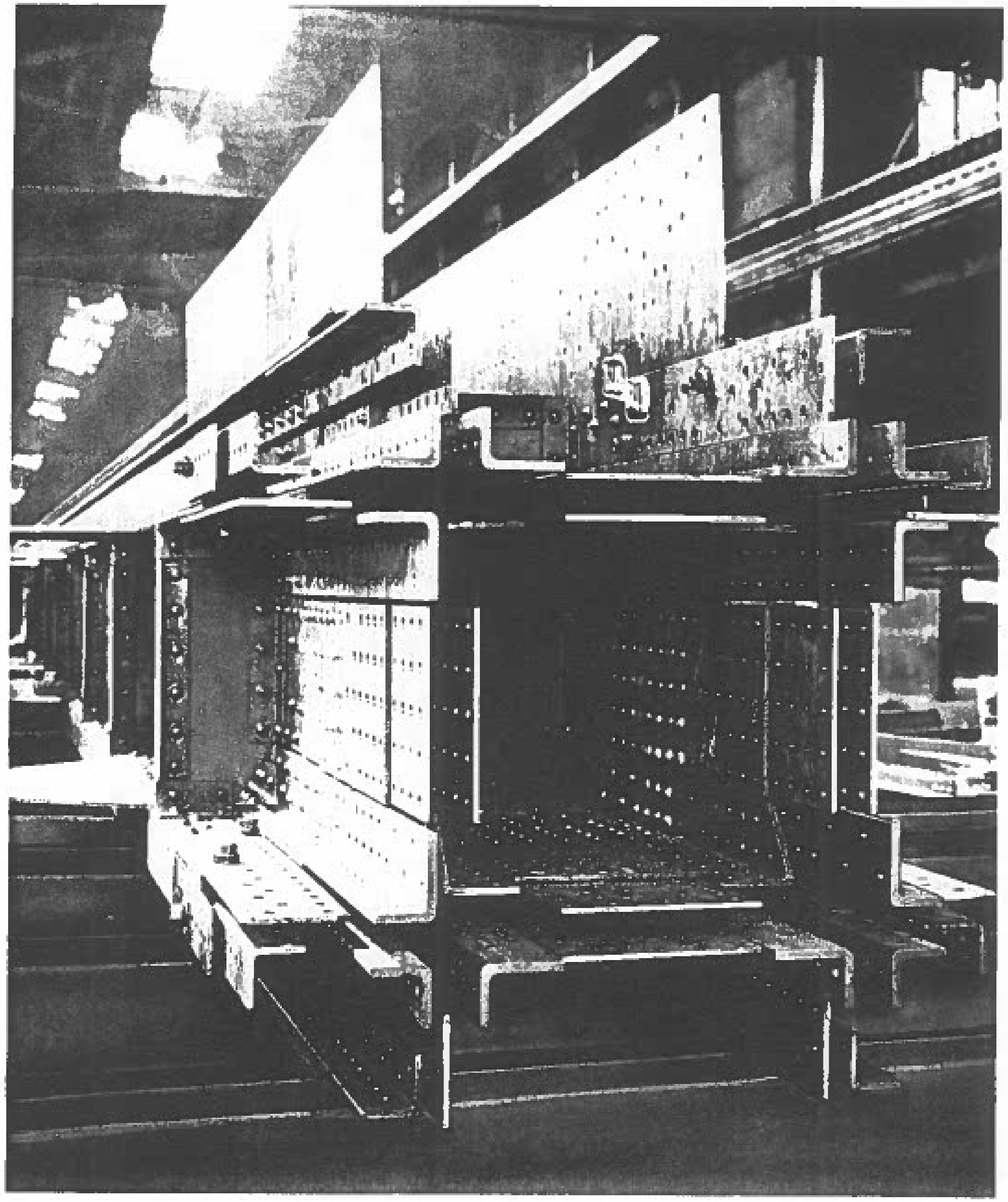


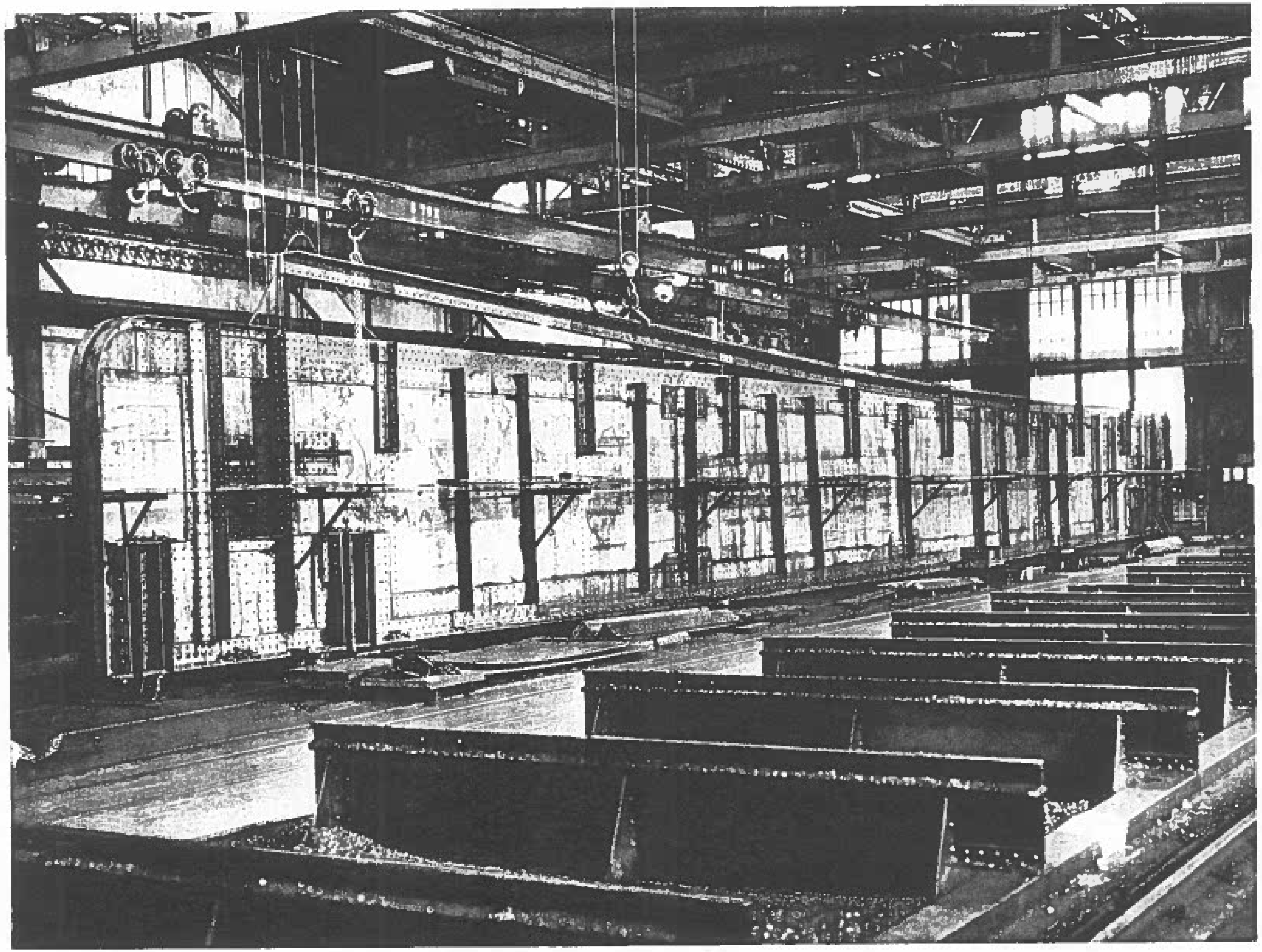
THIS MACHINE FOR MILLING THE HORIZONTAL COLUMN JOINTS is unique, and was designed especially for the George Washington Bridge. The cutting-head, shown near the top of the right-hand view, is relatively small and therefore free from deflection; it travels over a rigid back-up frame, and can mill all parts of an area 12 ft. by 22 ft. at each end of a member up to 83 ft. in length. For the entire bridge, nearly 1000 surfaces were milled on this machine. It is now permanently installed at McClintic-Marshall's Pottstown Works.



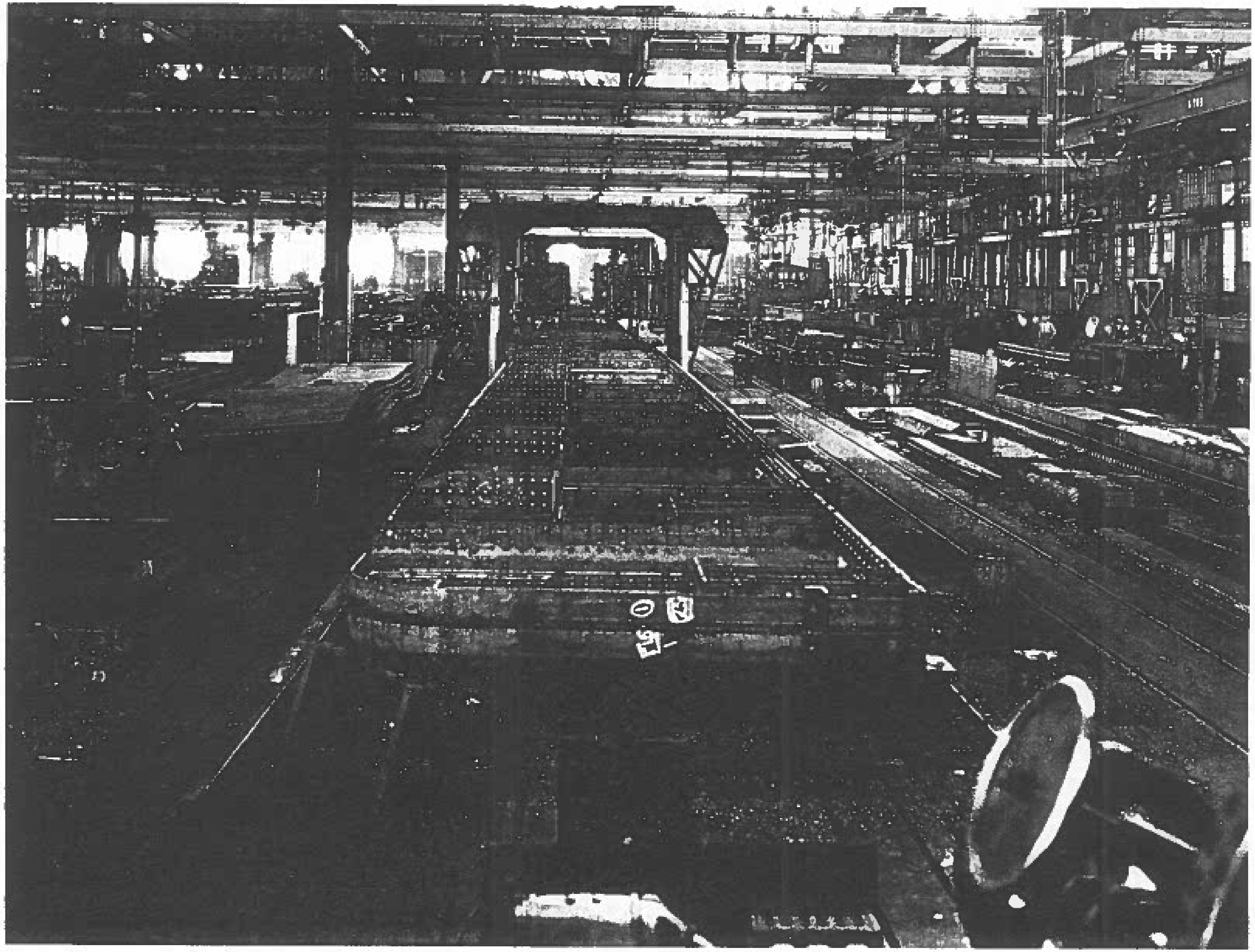
AFTER MILLING THE ENDS SQUARE, column sections were assembled end-to-end and the connection holes reamed with the splice material in place. The illustration shows the radial drills reaming holes in surfaces now horizontal, and one of the portable horizontal drills reaming holes in a vertical face. Many holes were sub-punched in the outer ply of material only, and drilled through the remainder. Nearly 1,000,000 splice holes were thus reamed or drilled in the two towers.

A COLUMN END after the splice had been reamed and the two-column sections parted for shipment. The splice material is opened up for cleaning; the illustration gives an indication of the make-up of the main-column material.

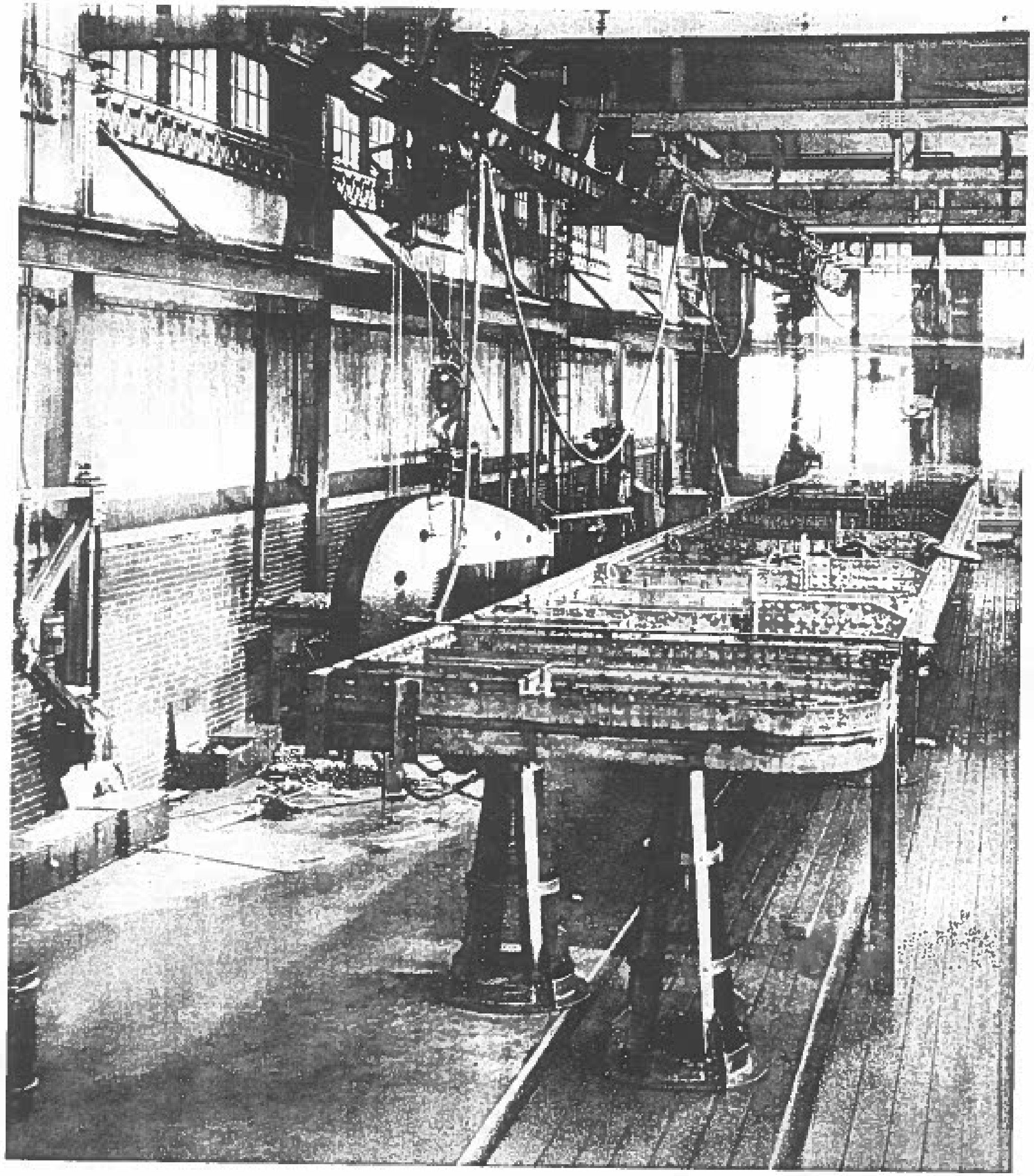




THE ASSEMBLING OF A FLOOR BEAM. The flanges have been separately assembled, reamed, and riveted, and are here being fitted to the web-plate in a vertical position. Stiffeners and other details are being added. The floor beam is upside down with respect to its position in the bridge.

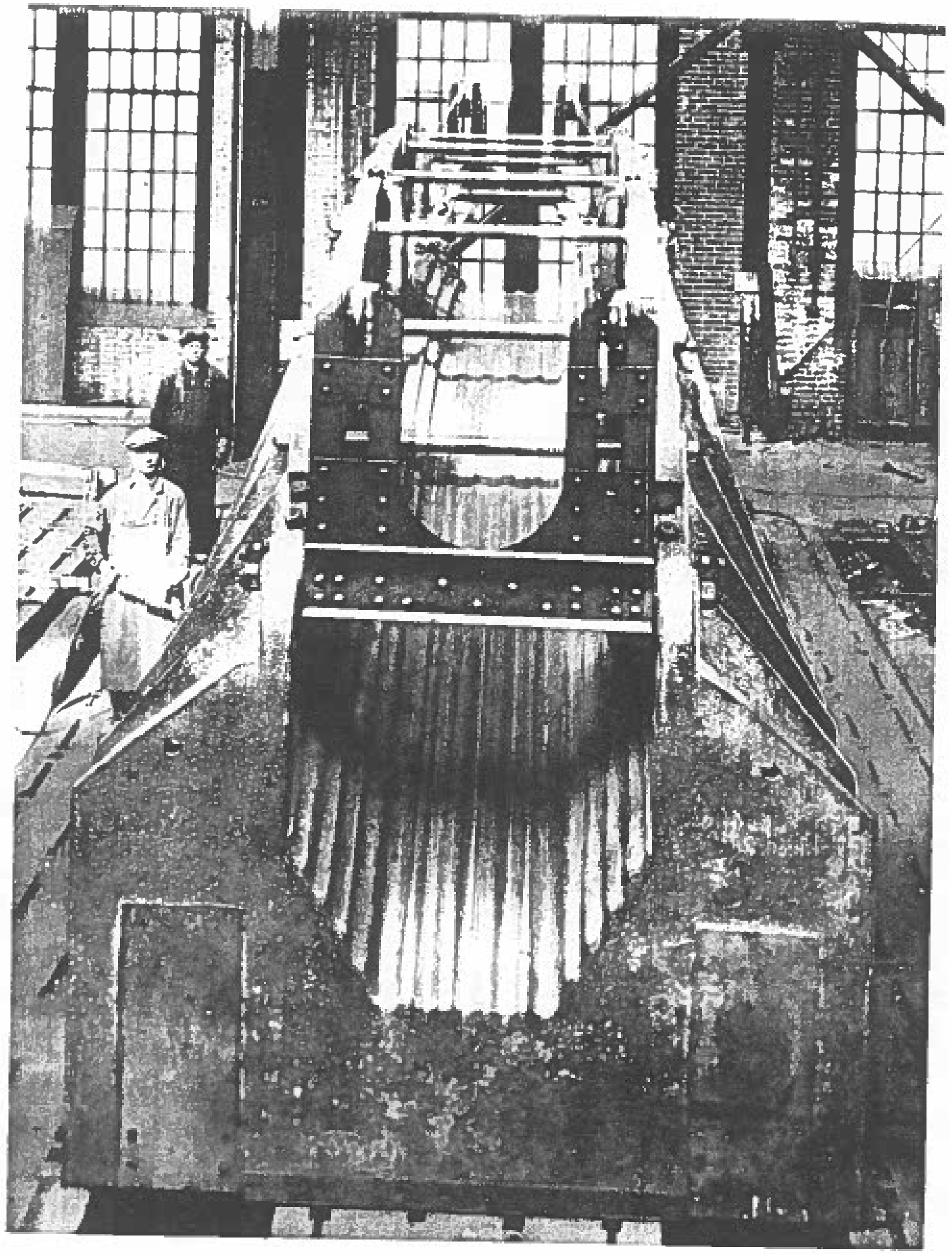


AFTER ASSEMBLING as in the previous illustration, the floor beams were laid flat under traveling gantries, as shown here. Radial drills carried by the gantries then reamed all holes to size.



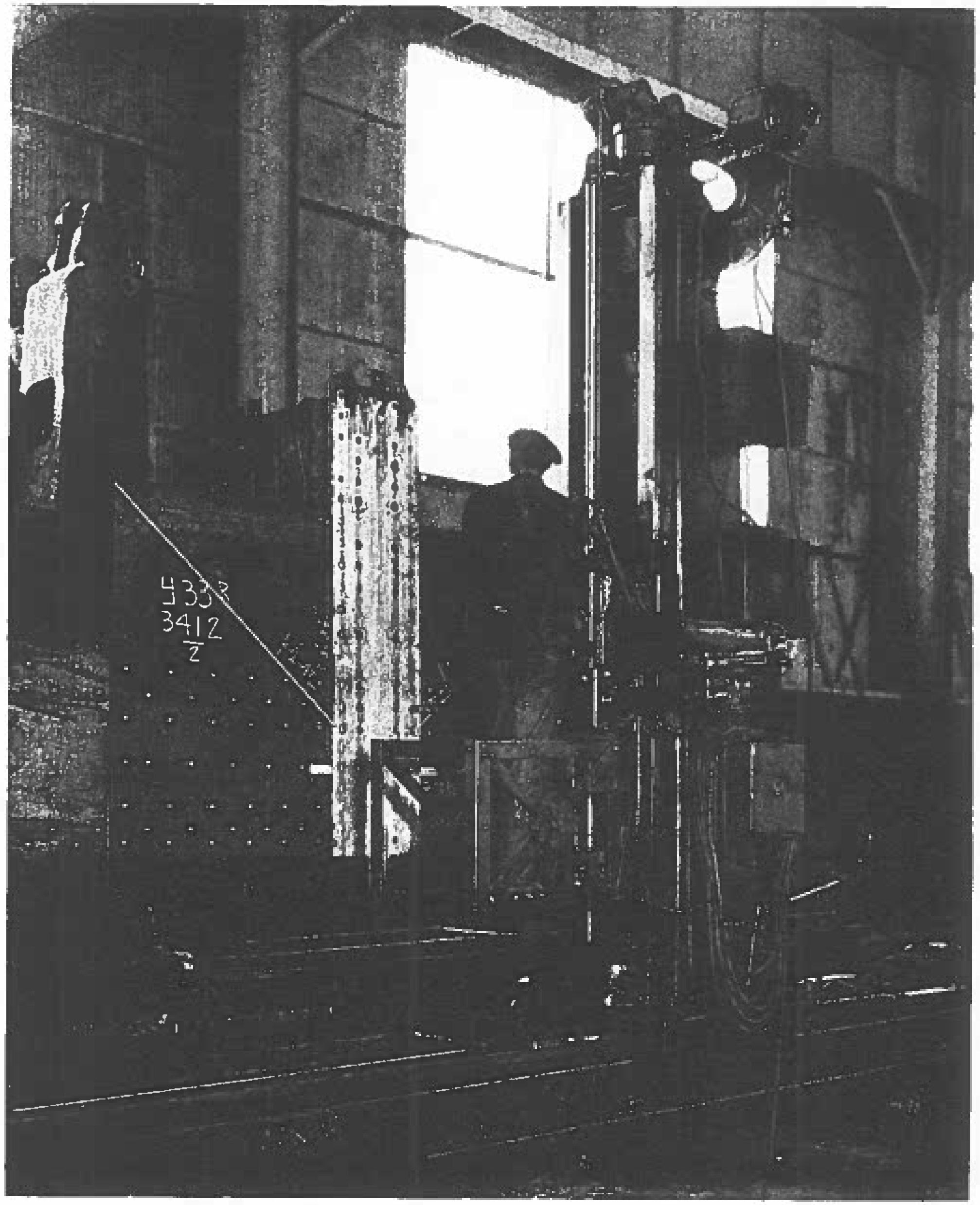
AFTER REAMING, the floor beams were carried by the shop cranes to pedestals, on which they were laid horizontally for riveting. Deep-yoke riveters were required to reach the rivets in the center of the 10-ft. webs. Most rivets were 1 in. in diameter, and were heated to uniform temperature in oil-burning furnaces.

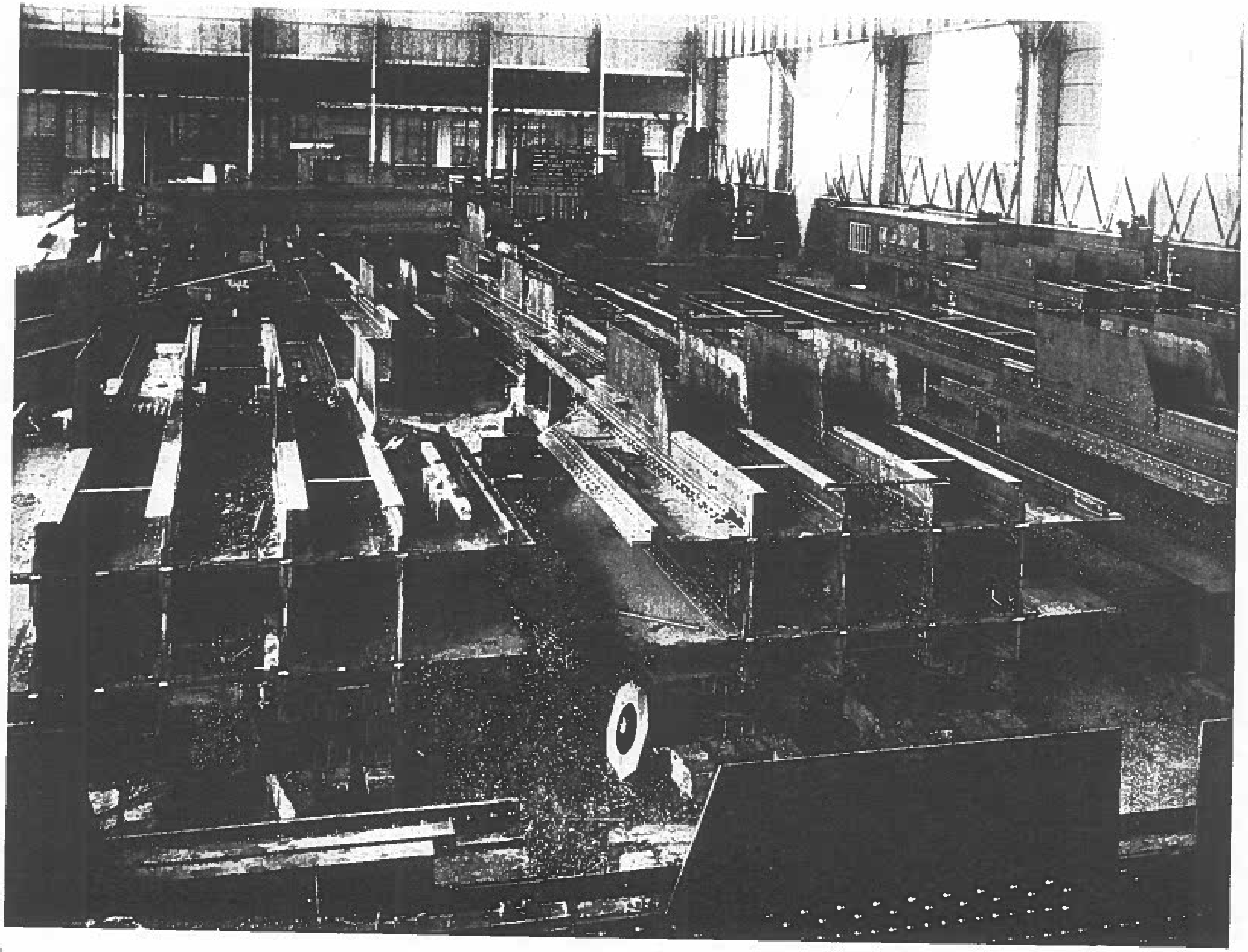
COMPLETED FLOOR BEAM loaded on three cars for shipment from Pottstown Works to New York. Note stiffeners for attachment of wire-rope suspenders; also opening through web for wind-chord. Length, 118 ft.; depth, 10 ft. 6 in.; weight, 62 tons.



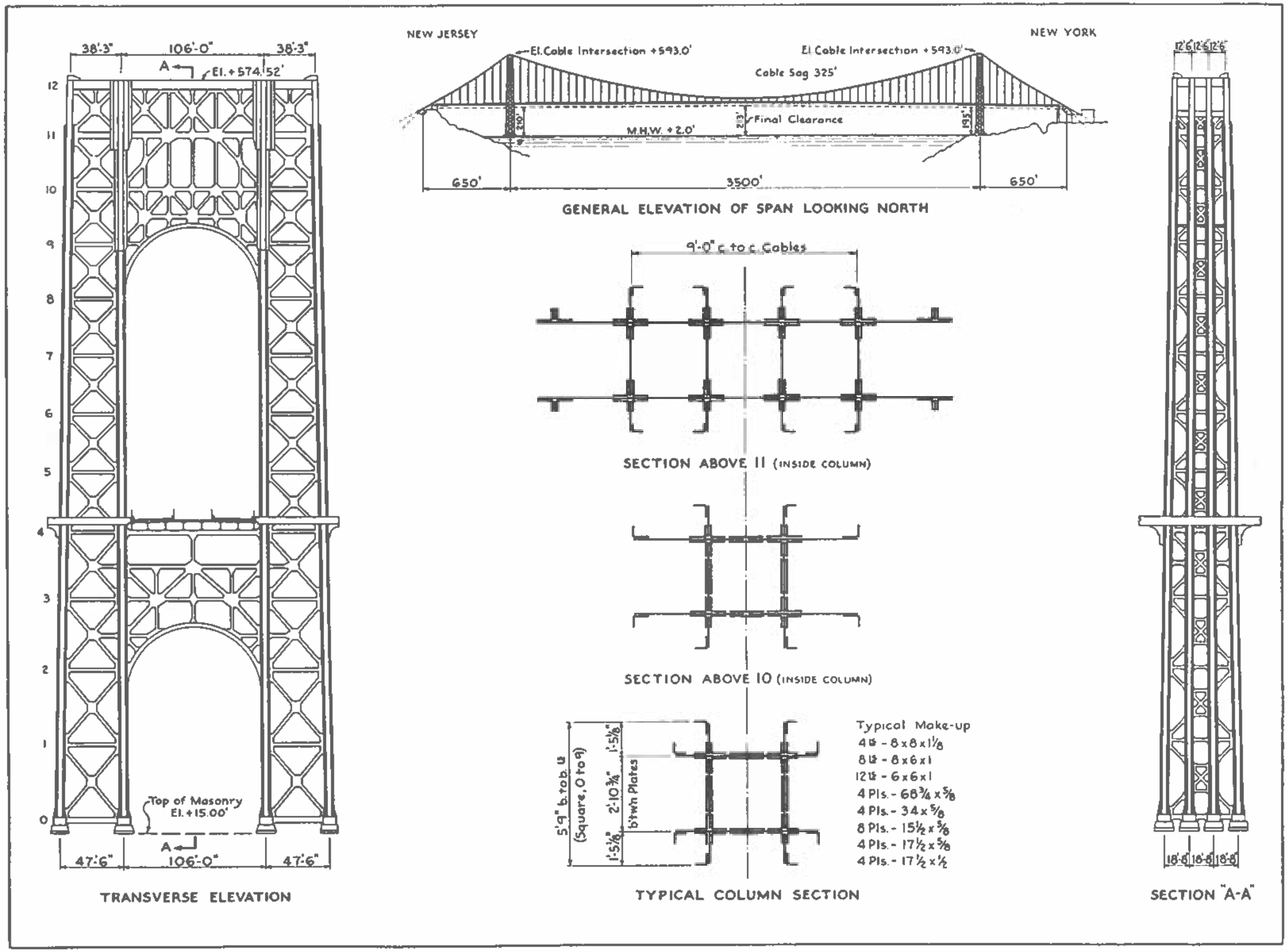
ONE OF THE CAST-STEEL CABLE SADDLES, showing the machined grooves for individual cable strands. These were furnished at the bridge site by the cable contractor and erected by McClintic-Marshall. Weight of complete saddle, 170 tons; heaviest section, 52 tons.

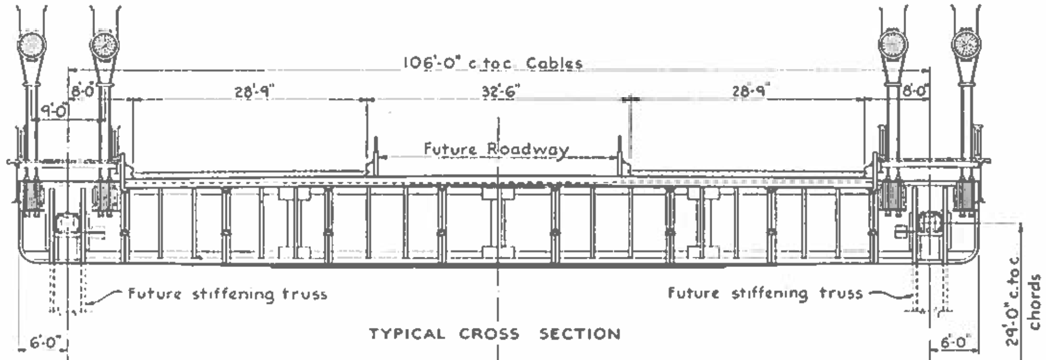
WIND-CHORDS WERE ASSEMBLED end-to-end for reaming of splice material, as illustrated for tower columns on page 23. All holes for connection of floor beams and bracing were drilled through steel templets with hard bushings in the holes; the same templets being used for drilling of the mating parts, absolute accuracy of field matching of open holes was assured. The exact setting of these templets in successive position on the two mating members is a process requiring a high degree of accuracy, in which McClintic-Marshall shopmen have had long and successful experience. The illustration shows some of the precautions taken in laying out, to set the templet to the correct position and at the correct angle.



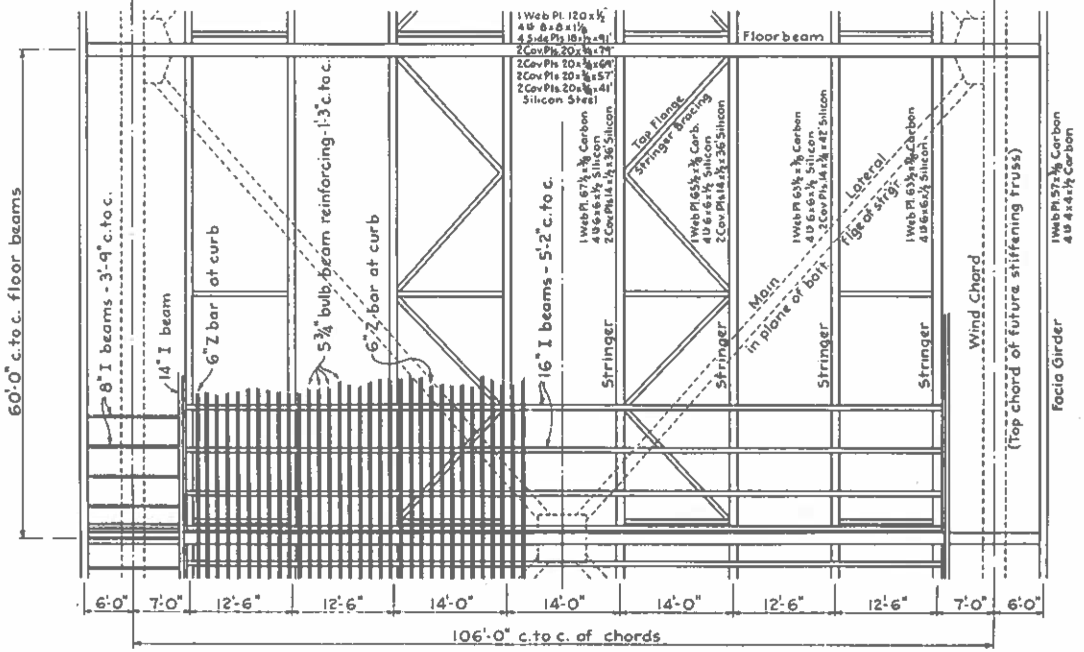


A PORTION OF THE UPPER-COLUMN SHAFT MATERIAL, preparatory to shipment. McClintic-Marshall's Pottstown Works has a covered storage runway in which complete bridges are milled, assembled, reamed, painted, and stored.

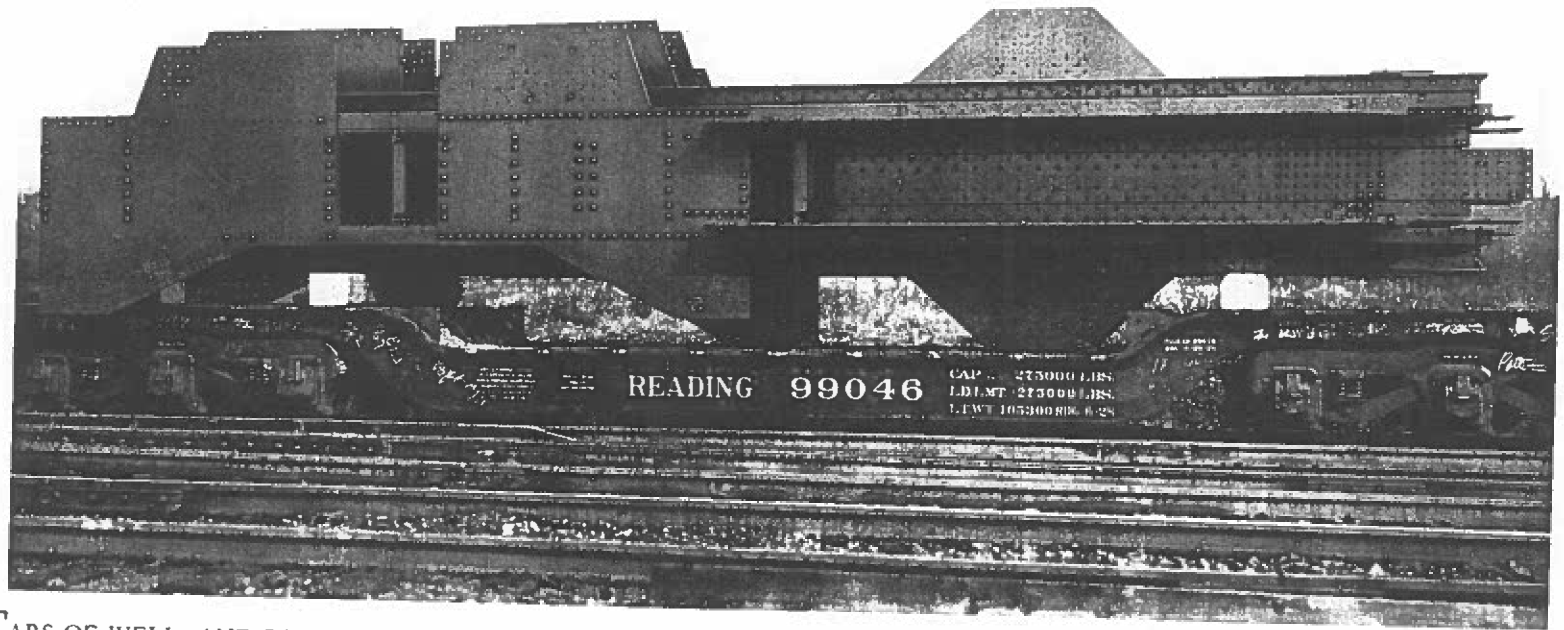

38'-3"
106'-0"
38'-3"
A
El. + 574.52'
12
11
10
9
8
7
6
5
4
3
2
1
0
Top of Masonry El. + 15.00'
A
47'-6"
106'-0"
47'-6"
TRANSVERSE ELEVATION
NEW JERSEY
NEW YORK
El. Cable Intersection + 593.0'
El. Cable Intersection + 593.0'
Cable Sag 325'
Final Clearance
M.H.W. + 2.0'
210'
213'
195'
650'
3500'
650'
GENERAL ELEVATION OF SPAN LOOKING NORTH
9'-0" c. to c. Cables
SECTION ABOVE 11 (INSIDE COLUMN)
SECTION ABOVE 10 (INSIDE COLUMN)
5'-9" b. to b. ⌊s
(Square, 0 to 9)
1'-5⅛"
2'-10¾"
1'-5⅛"
b'tw'n Plates
Typical Make-up
4 ⌊s - 8 x 8 x 1⅛
8 ⌊s - 8 x 6 x 1
12 ⌊s - 6 x 6 x 1
4 Pls. - 68¾ x ⅝
4 Pls. - 34 x ⅝
8 Pls. - 15½ x ⅝
4 Pls. - 17½ x ⅝
4 Pls. - 17½ x ½
TYPICAL COLUMN SECTION
12'-6" 12'-6" 12'-6"
18'-8" 18'-8" 18'-8"
SECTION "A-A"



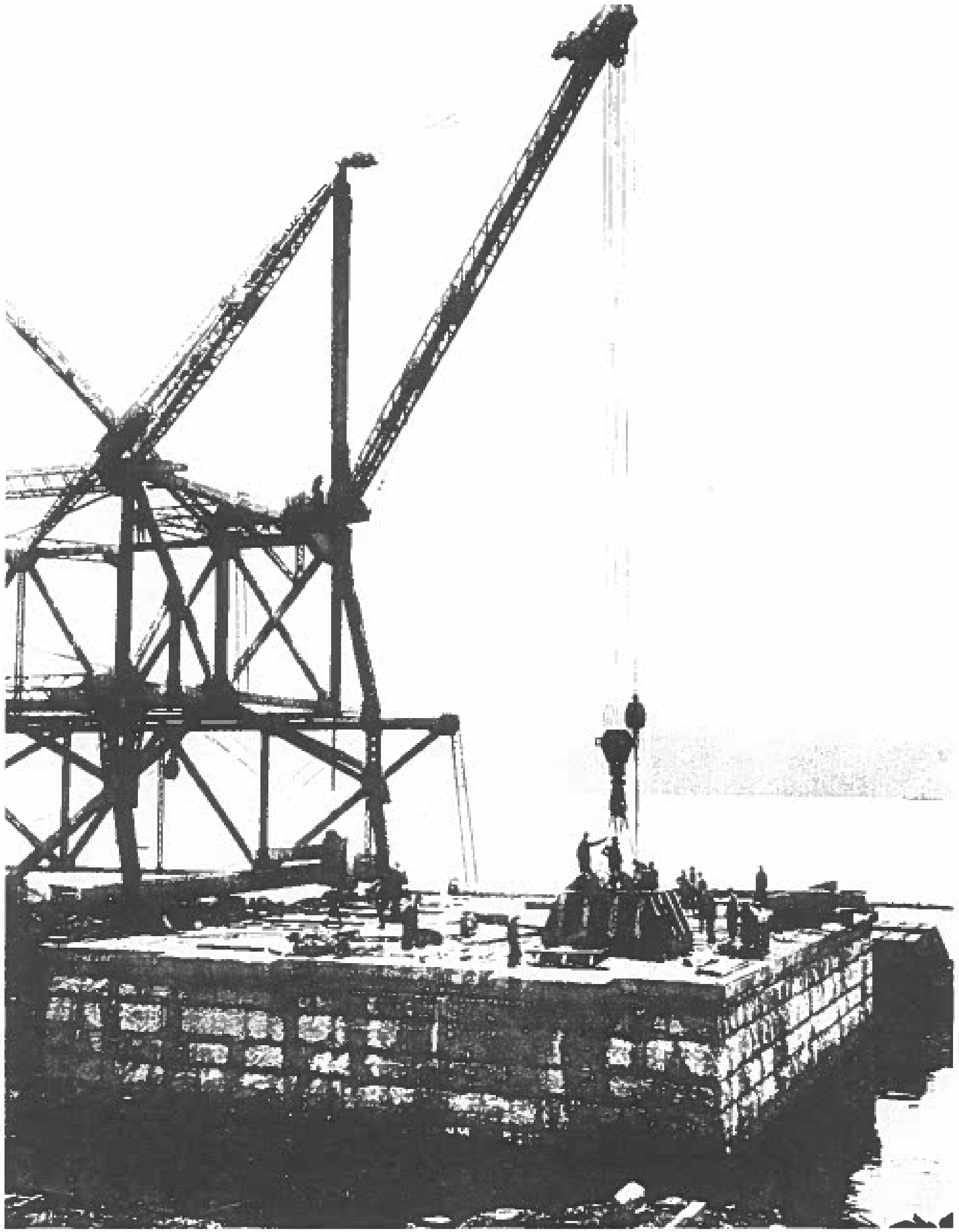
TYPICAL CROSS SECTION



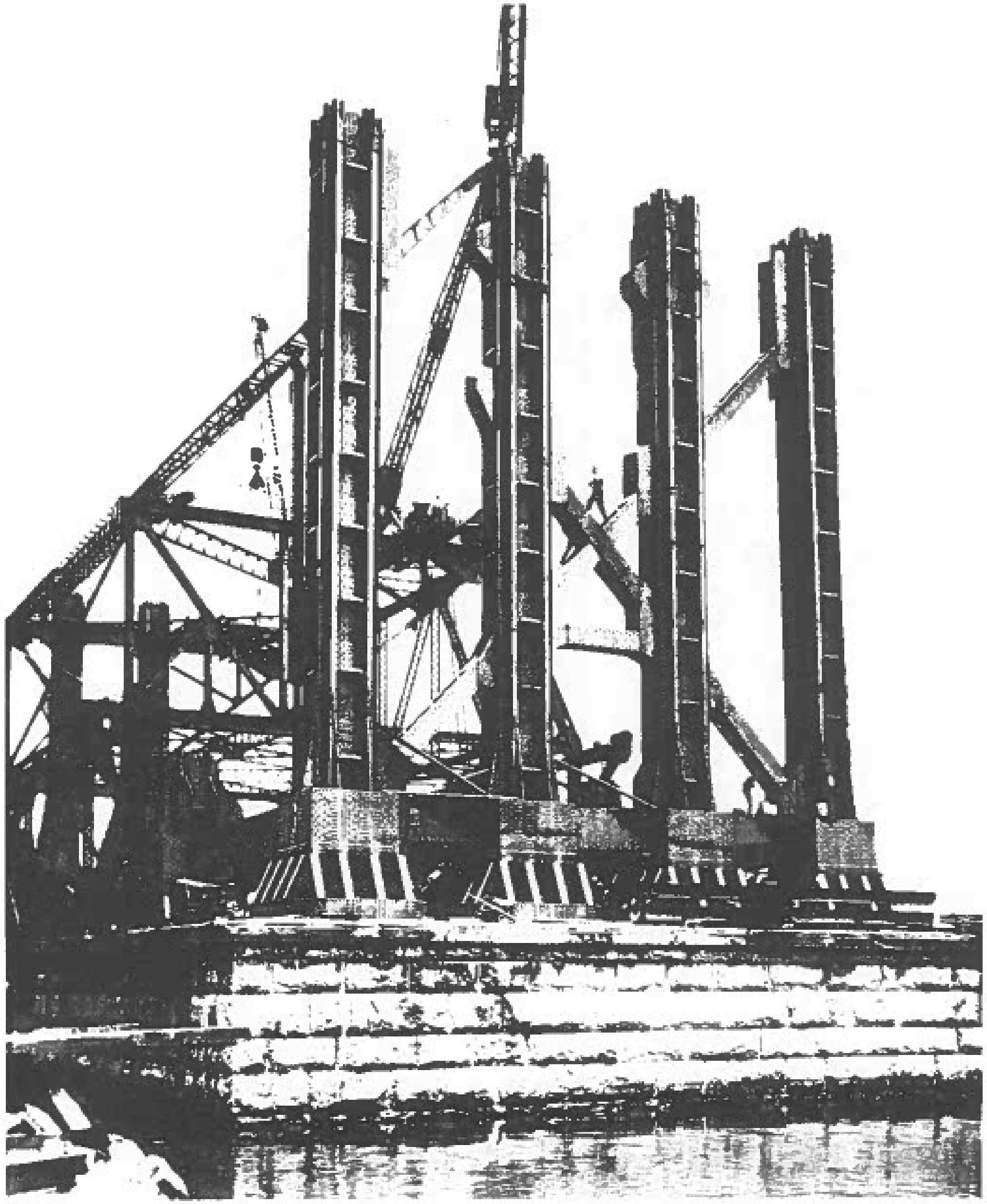
TYPICAL PANEL OF FLOOR STEEL



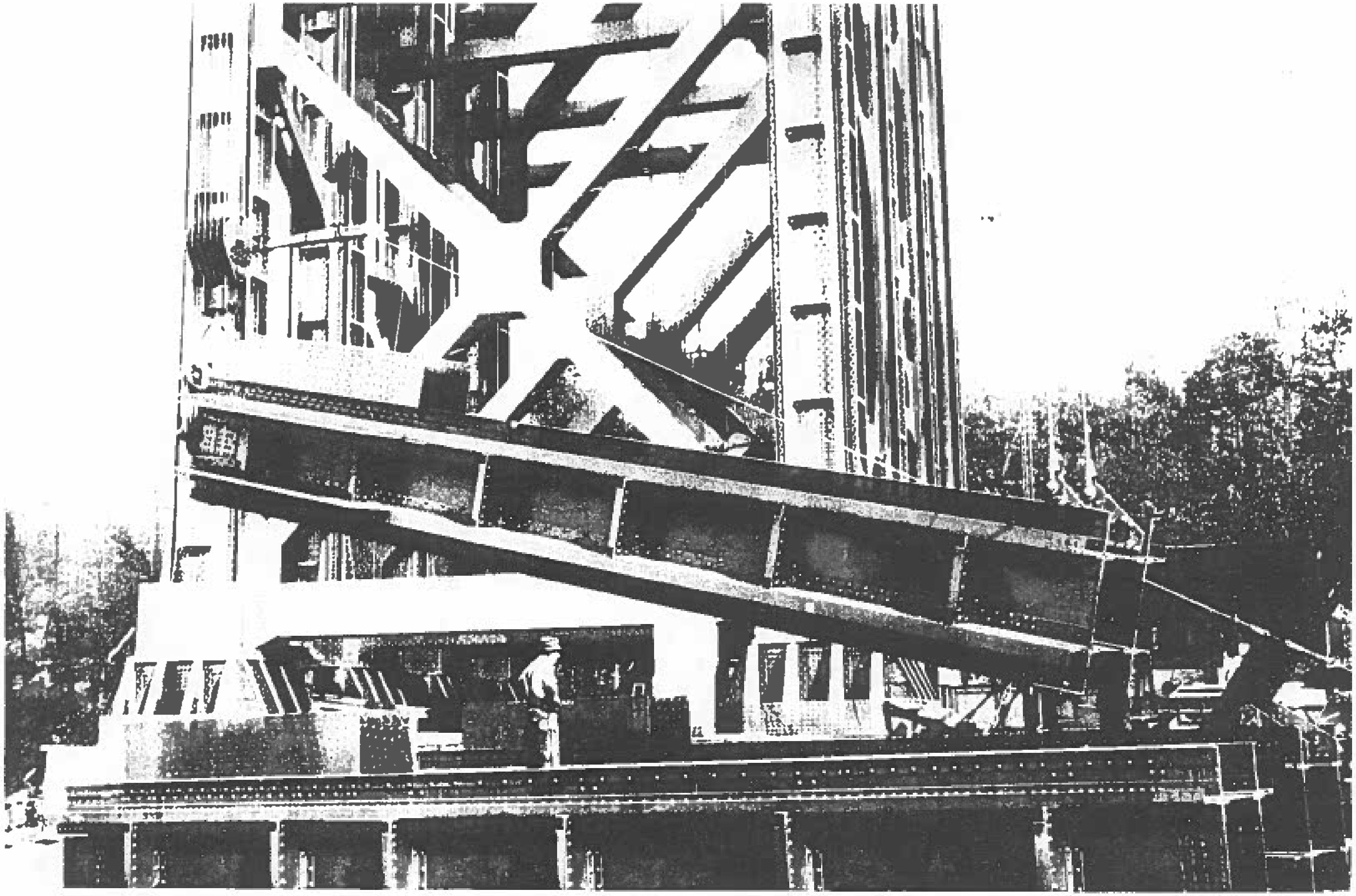
CARS OF WELL- AND DEPRESSED-TYPES were gathered together from several Eastern railroads, to transport the unusually deep sections of the upper-tower shafts. Here a top section is seen on a depressed car, bringing it barely within shipping clearances.



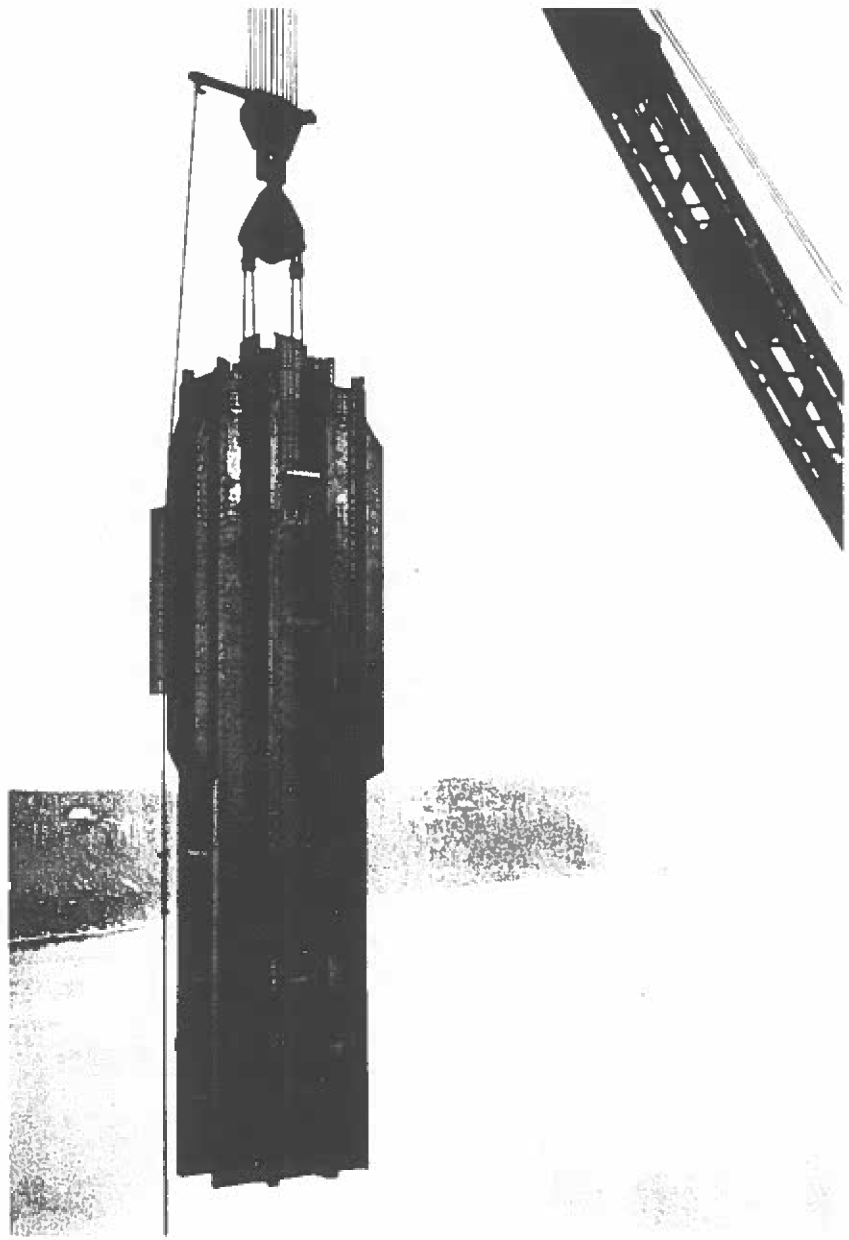
BEGINNING OF STEEL ERECTION, showing the placing of one of the thirty-two 55-ton column pedestals. In erecting these pedestals, steel pads, set to exact elevation, were used to insure the accurate setting of each pedestal on a bed of cement mortar. This illustration shows the details of one of the two traveler derricks and of both tiers of the traveler underframe.



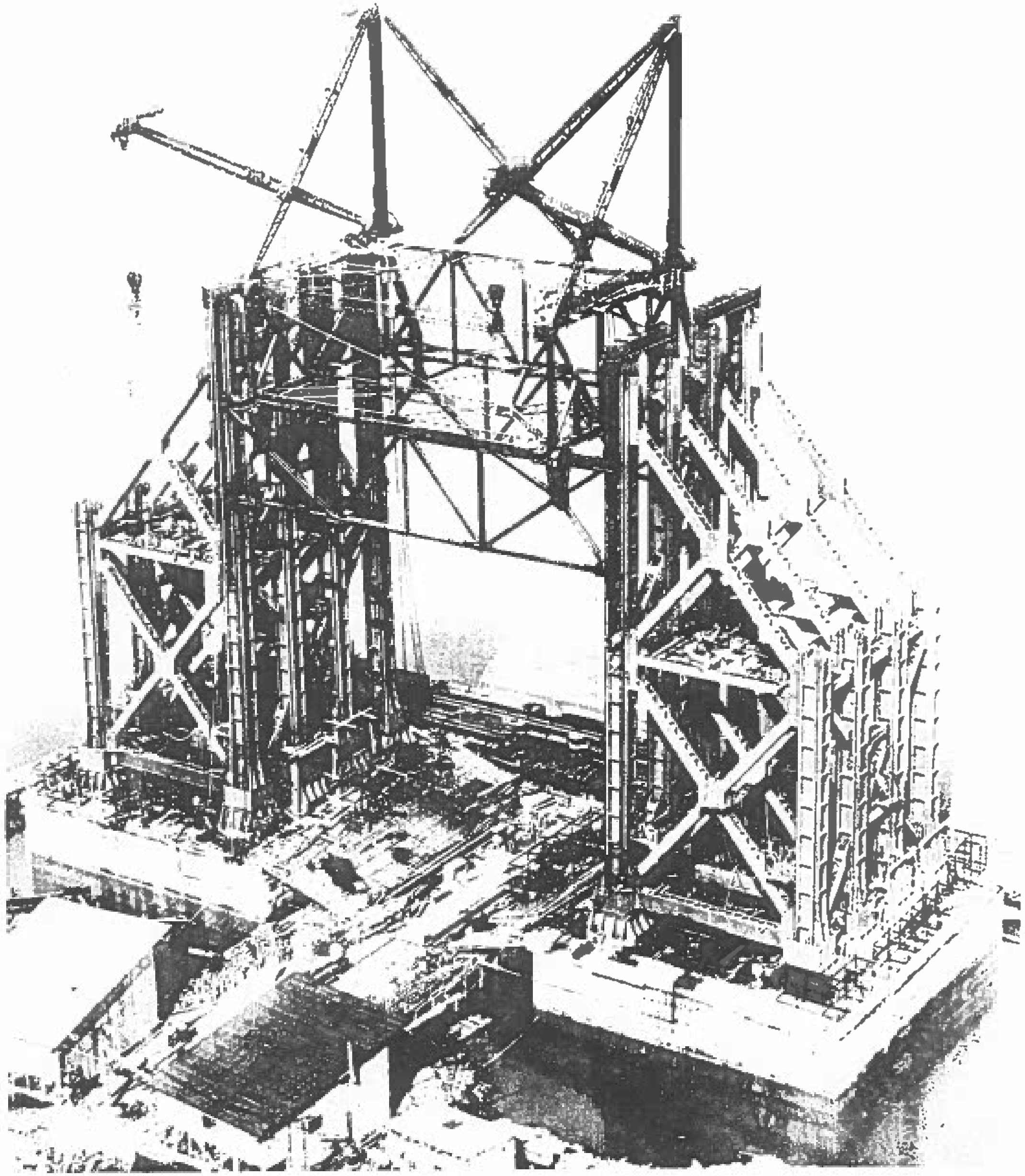
THIS ILLUSTRATION, taken from the downstream end of the New Jersey pier, shows the beginning of tower erection by creeper traveler. The creeper traveler has been erected, and its two booms, having set all the pedestals, are now erecting the first sections of tower columns (16 per pier, four shown in foreground and two at far end). Duplicate travelers were operated in competition, one on the New York and one on the New Jersey tower.



COLUMN MATERIAL WAS PASSED INSHORE from the carfloats, on the New York side, by an unloading derrick. In raising this material, a section was picked clear of its support with main (12-part) falls from one traveler boom at its upper end, and a hitch from the unloading derrick boom at its lower end. When clear of obstructions, the first falls was run ahead, turning the piece on a special pinned hitch until it was in vertical position; then the lower falls was released and the upper falls hoisted and set the piece. On the New Jersey side, the pier being in the water, the traveler falls up-ended the columns on the carfloats.

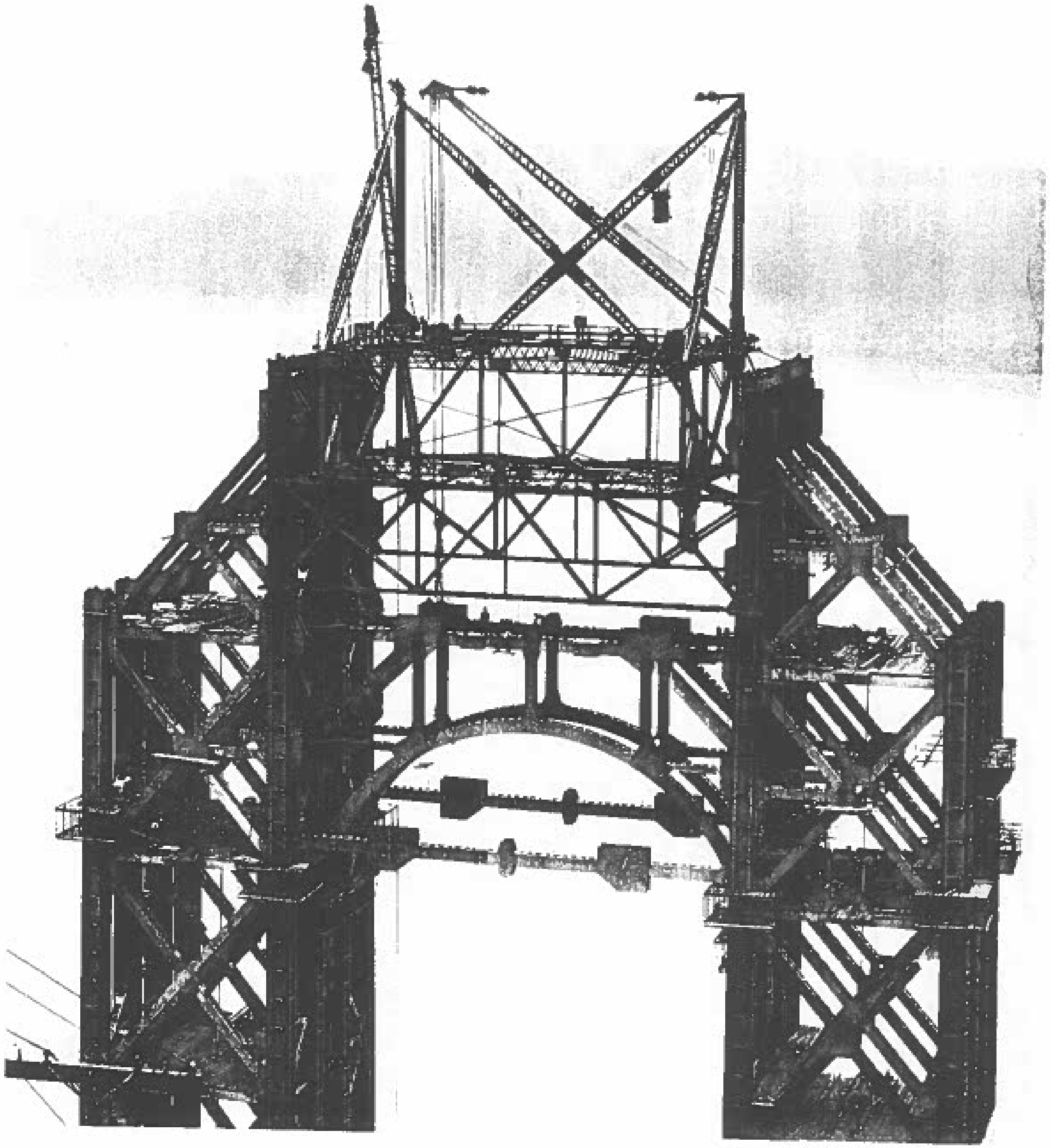


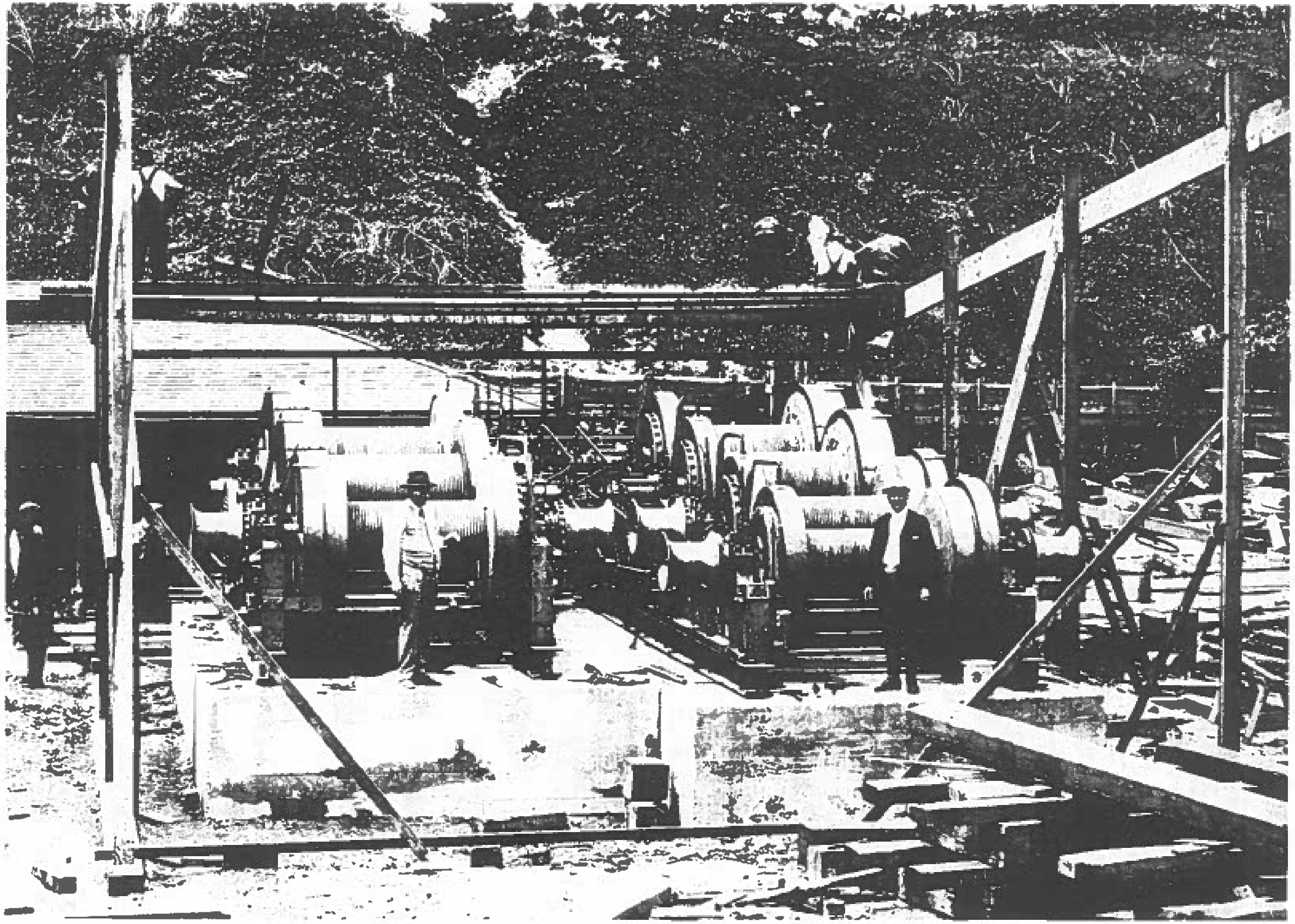
AN 80-TON COLUMN SECTION for the New York tower being hoisted to place by one traveler boom.



A FURTHER STAGE IN ERECTION of the New Jersey tower. The traveler has just been "jumped," and is hanging from four sets of falls from the cat-heads; supporting toggles are being pressed in against the columns, to rest on special brackets similar to the one shown near upper end of column section on page 38. Booms are swung back to equalize the load of 320 tons on the four cat-heads. The 80-ton load at each corner is lifted by an 18-part falls. The 150-hp. engines are in the sheds down in the foreground.

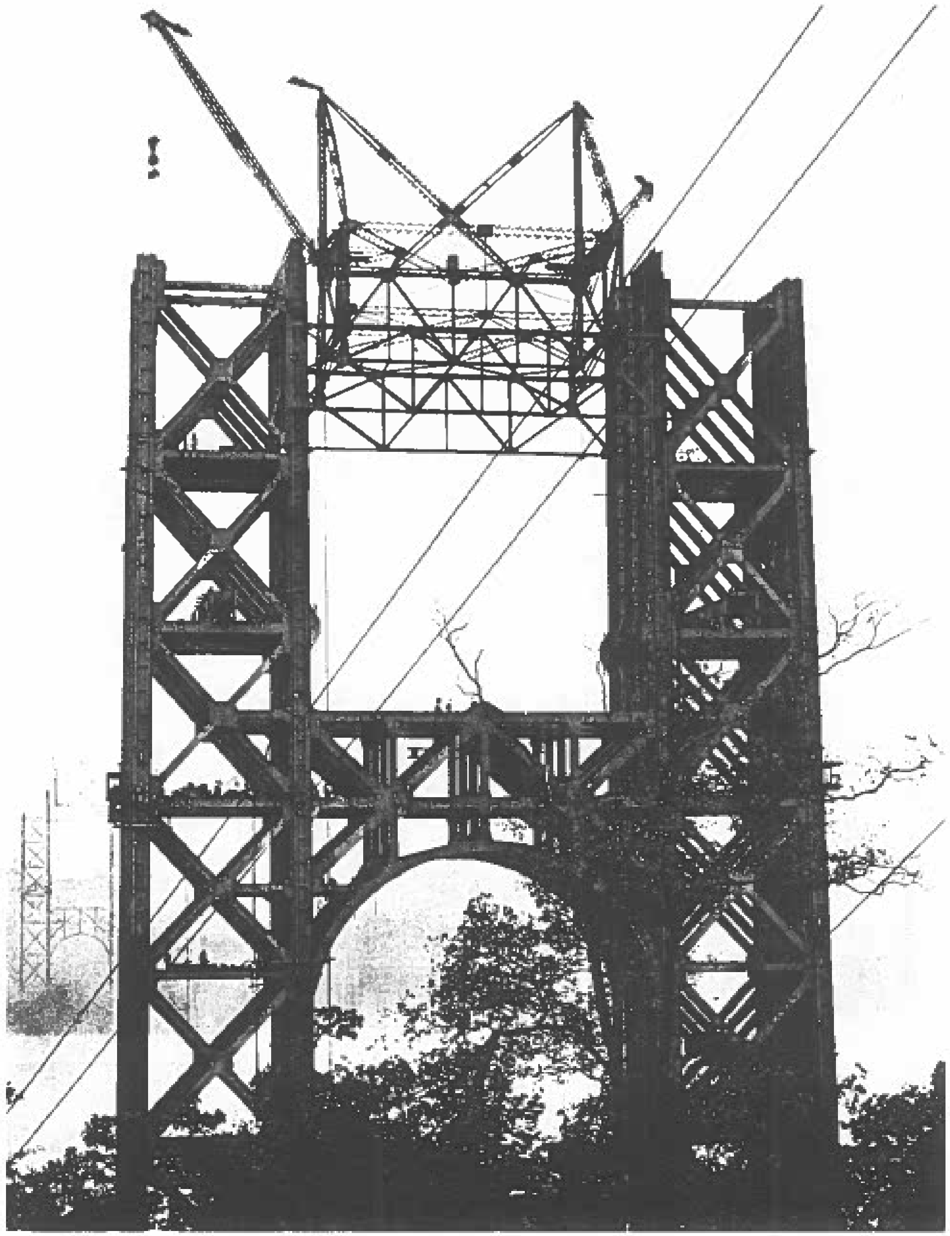
FURTHER PROGRESS on the New Jersey tower. Temporary position of front and back spacing struts, level 2. These will be inserted again at levels 6 and 8. Having passed above the position of lower portal, the traveler has paused to place this lower portal below itself. This steel is being handled by one boom which has been temporarily brought around between its stifflegs. On the New York tower, falls were attached to the traveler underframe for this purpose.

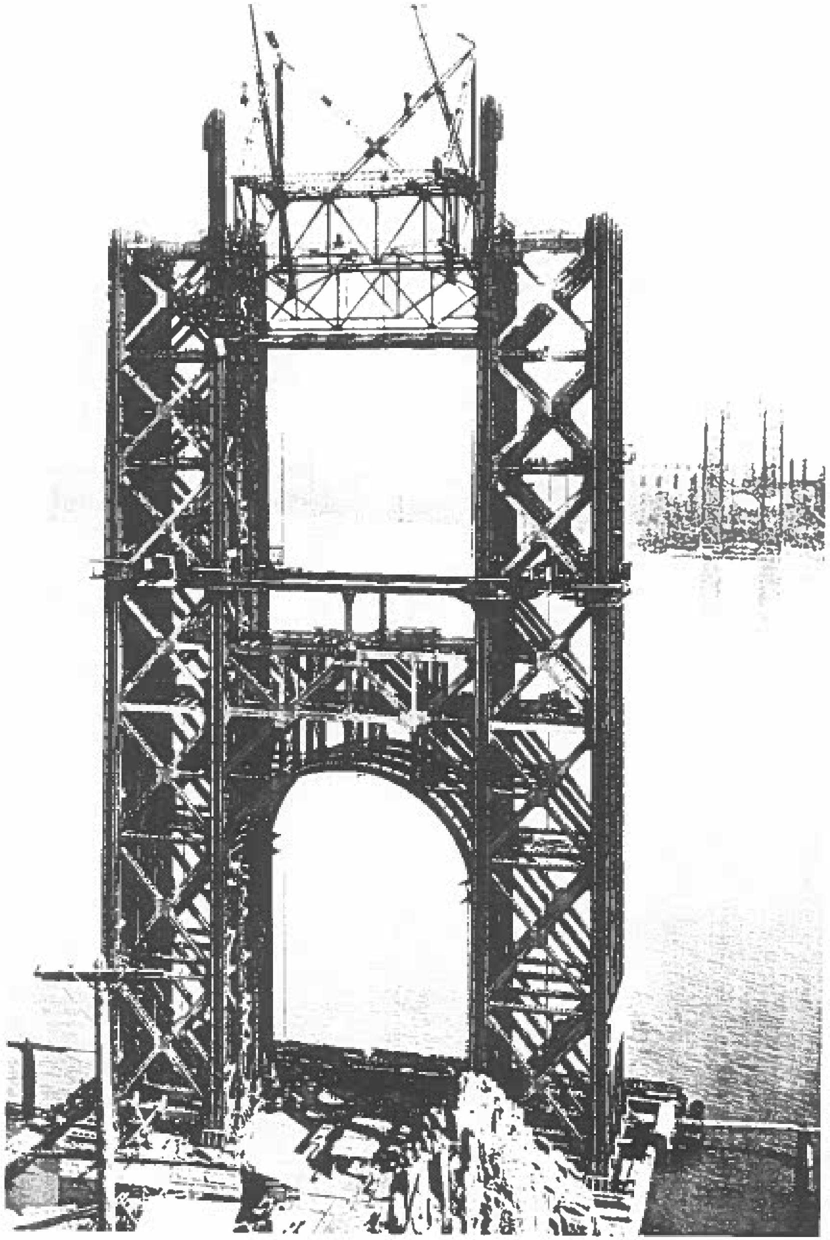




EACH DERRICK on each tower traveler was operated by a 7-drum hoisting engine, powered by two 150-hp. motors. The main-load falls were reeved continuously to two drums, the boom falls to two, the two sets of traveler-jumping falls to one each, and the auxiliary load falls to the seventh. These engines were installed permanently on the ground, and operated in accordance with electric-light signals sent from the traveler deck.

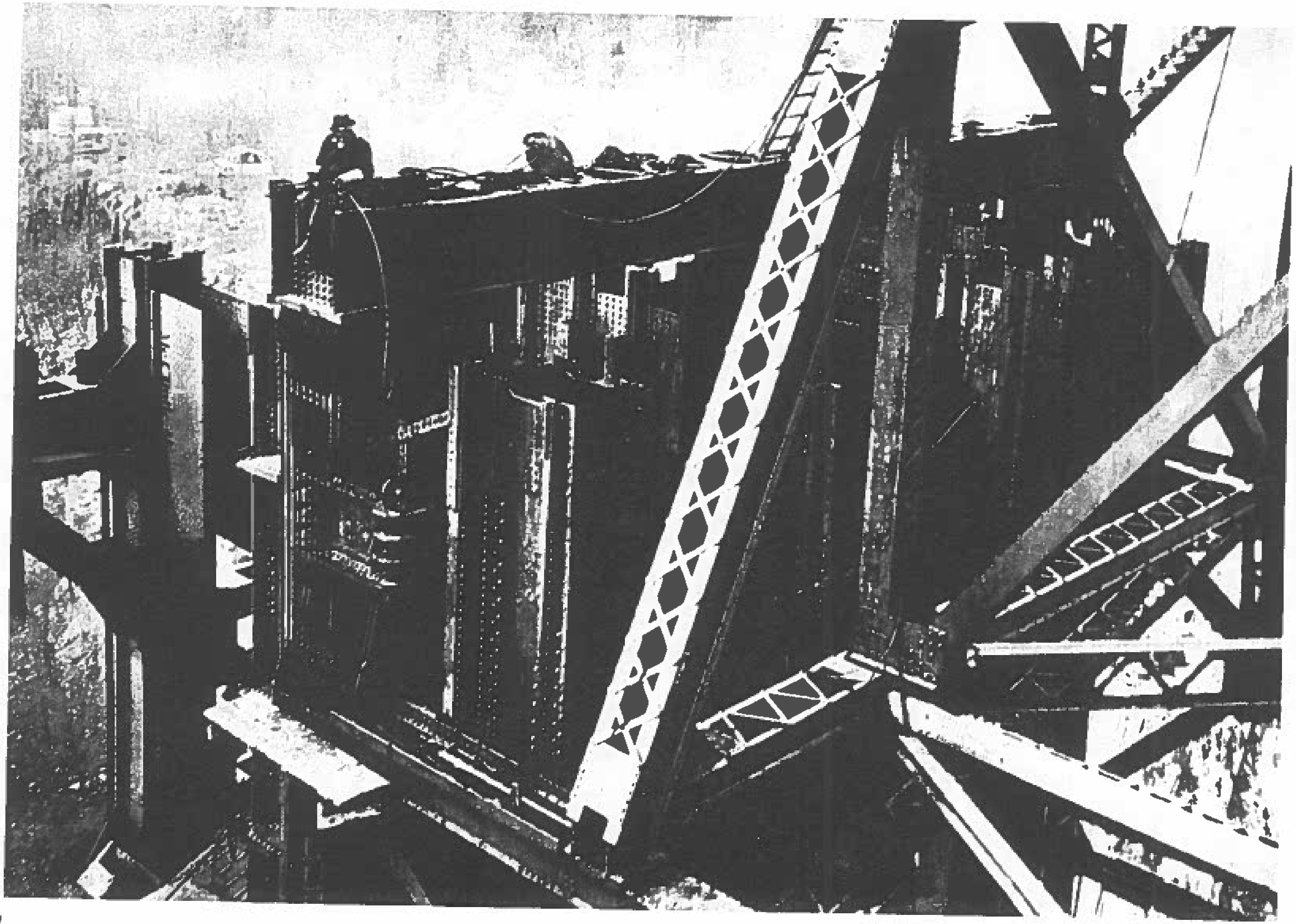
AN INTERMEDIATE STAGE of tower erection. The New York traveler in foreground has just set the two *outer* rows of columns (5-6) and their bracing; it will set the *inner* rows of columns (6-7) before "jumping" to the next position. In the distance, the New Jersey traveler has just finished the outer rows (6-7) and is commencing the inner rows (7-8). The general construction of the traveler is made clear by this and the following illustration. The two lower, transverse trusses are carried by main columns. As the latter lean toward each other from bottom to top of tower, the main-traveler frame rolls across the rear transverse truss at each jump of the traveler. Length of booms, 86 ft.; capacity, 83 tons at 67-ft. radius.



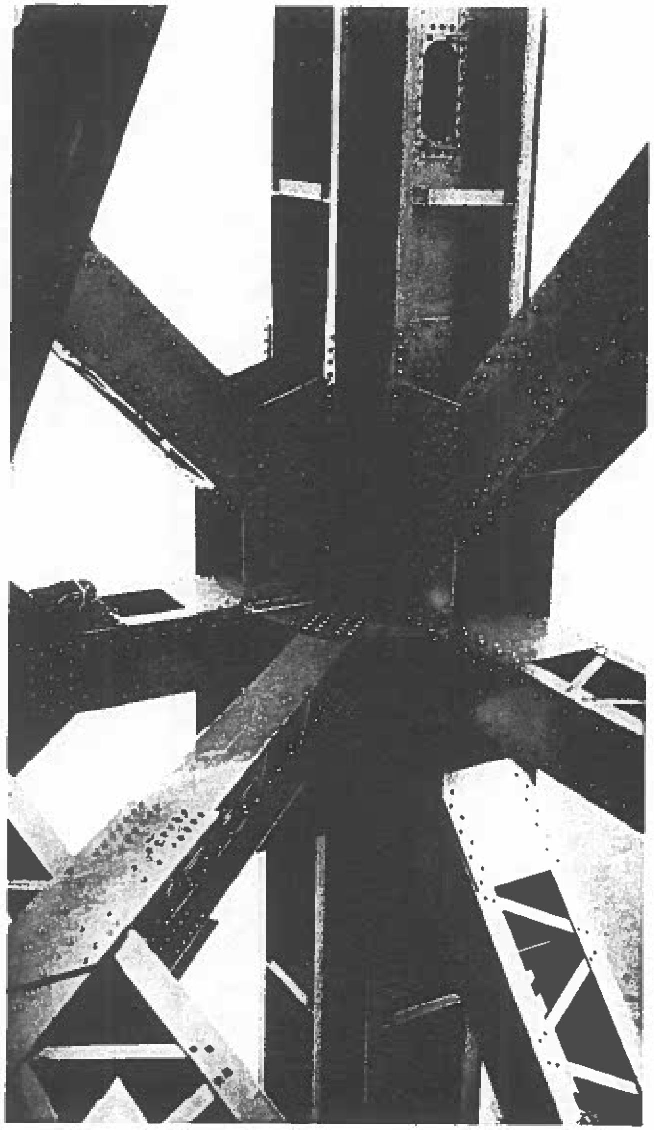


PROGRESS OF NEW JERSEY TOWER.

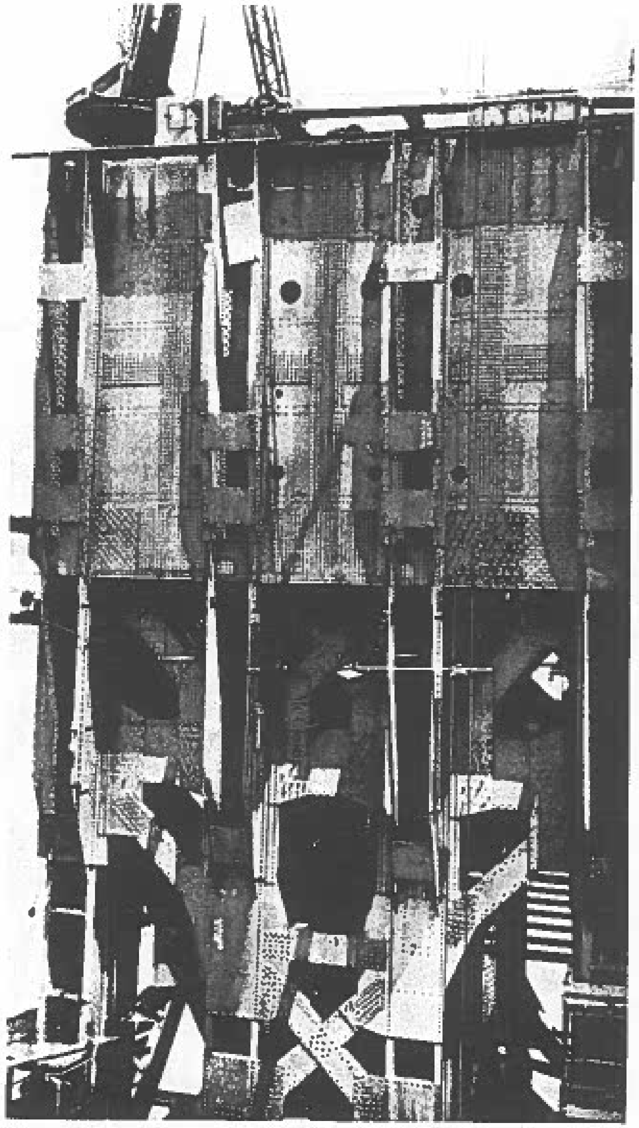
This view is the opposite of that shown on the left-hand page. The New Jersey traveler has completed the eight outer rows (6-7) and is proceeding with the inner row (7-8) before jumping. Temporary spacing strut is in position at point 6. The New Jersey tower was begun first, and remained ahead during the summer and fall of 1928. When point 10 was reached on both sides, work was suspended till the spring of 1929.



THIS ILLUSTRATION SHOWS MORE CLEARLY the rigging for "jumping" the traveler. The cat-head girders from which the falls are suspended are clearly shown in the two preceding views, supported on the main-tower shafts. Eighteen-part falls at each corner of the creeper frame led to two of the engine drums. After a jump, when the transverse trusses were again secured to the main columns and the falls slacked off, the cat-heads were hung out of the way of column erection until they were hoisted to new position for the next jump.

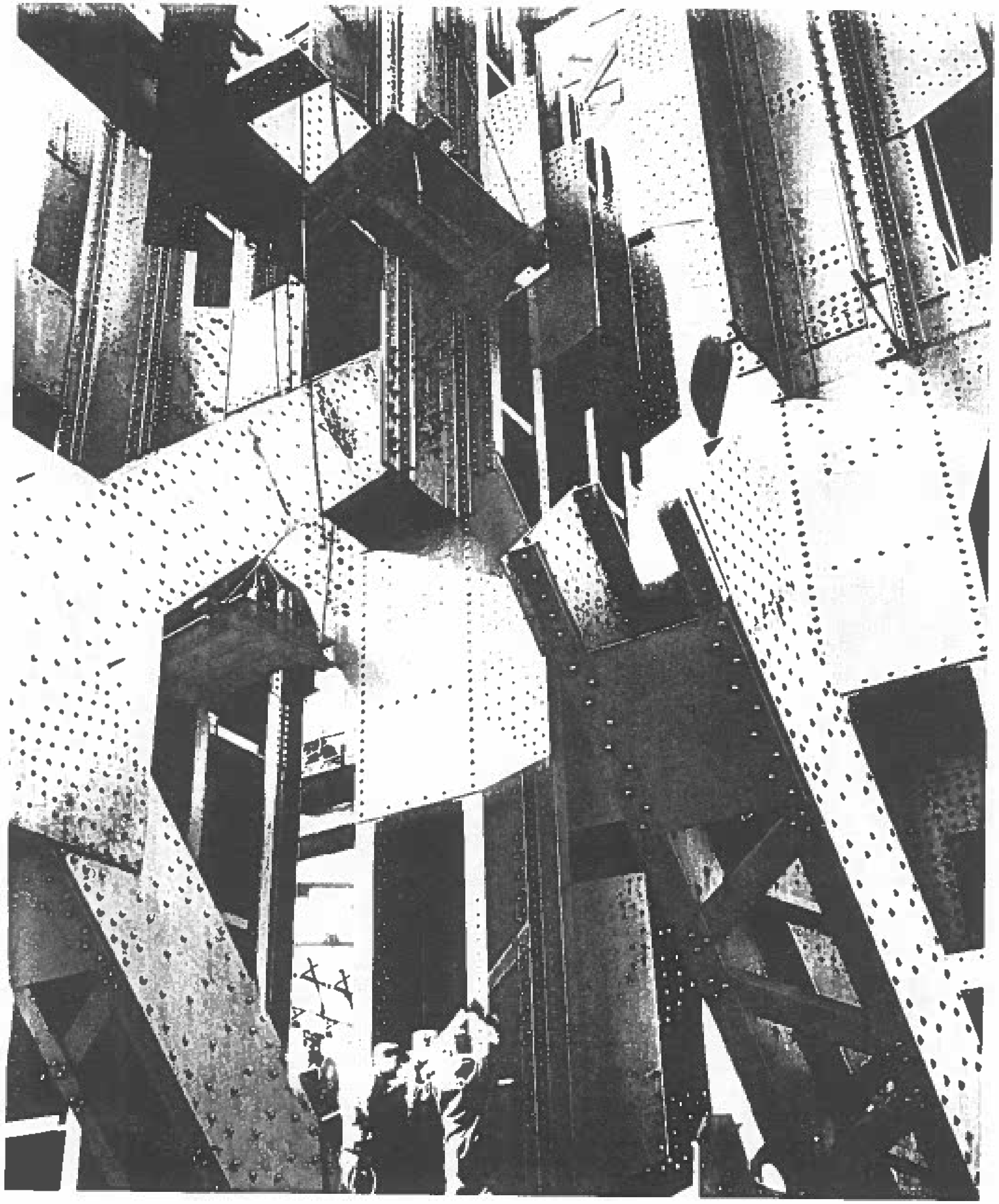


TYPICAL INTERSECTION on a corner column. Bracing attachments in three planes at one point. Transverse bracing connections are especially heavy, because they transfer a great deal of load from the inner to the outer columns.



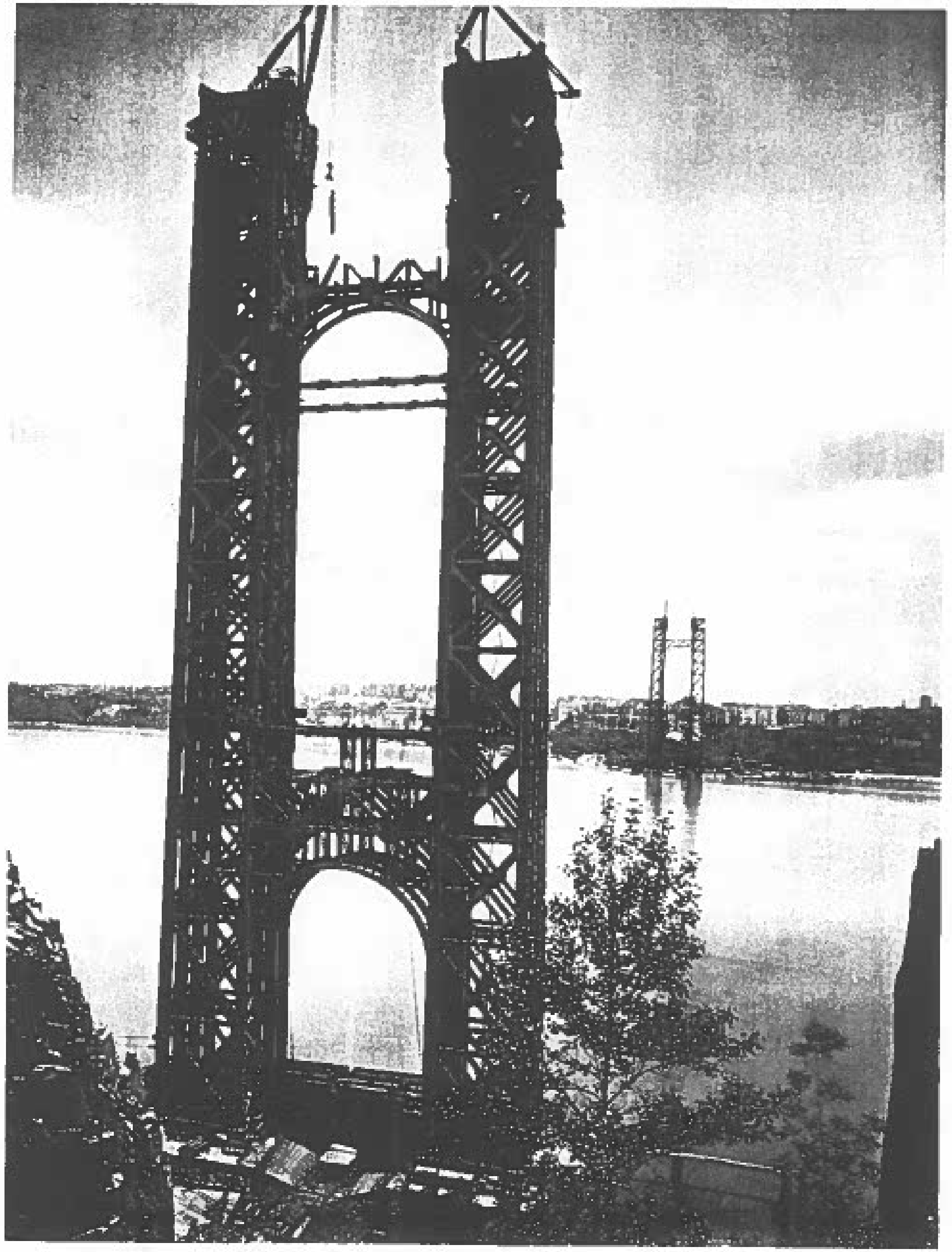
UNDER THE CABLE SADDLES. It is here that the vertical load will be delivered into the column shafts by the main cables. The complexity of the field connections and the necessity for great accuracy in laying out and drilling the holes at the shop are apparent.

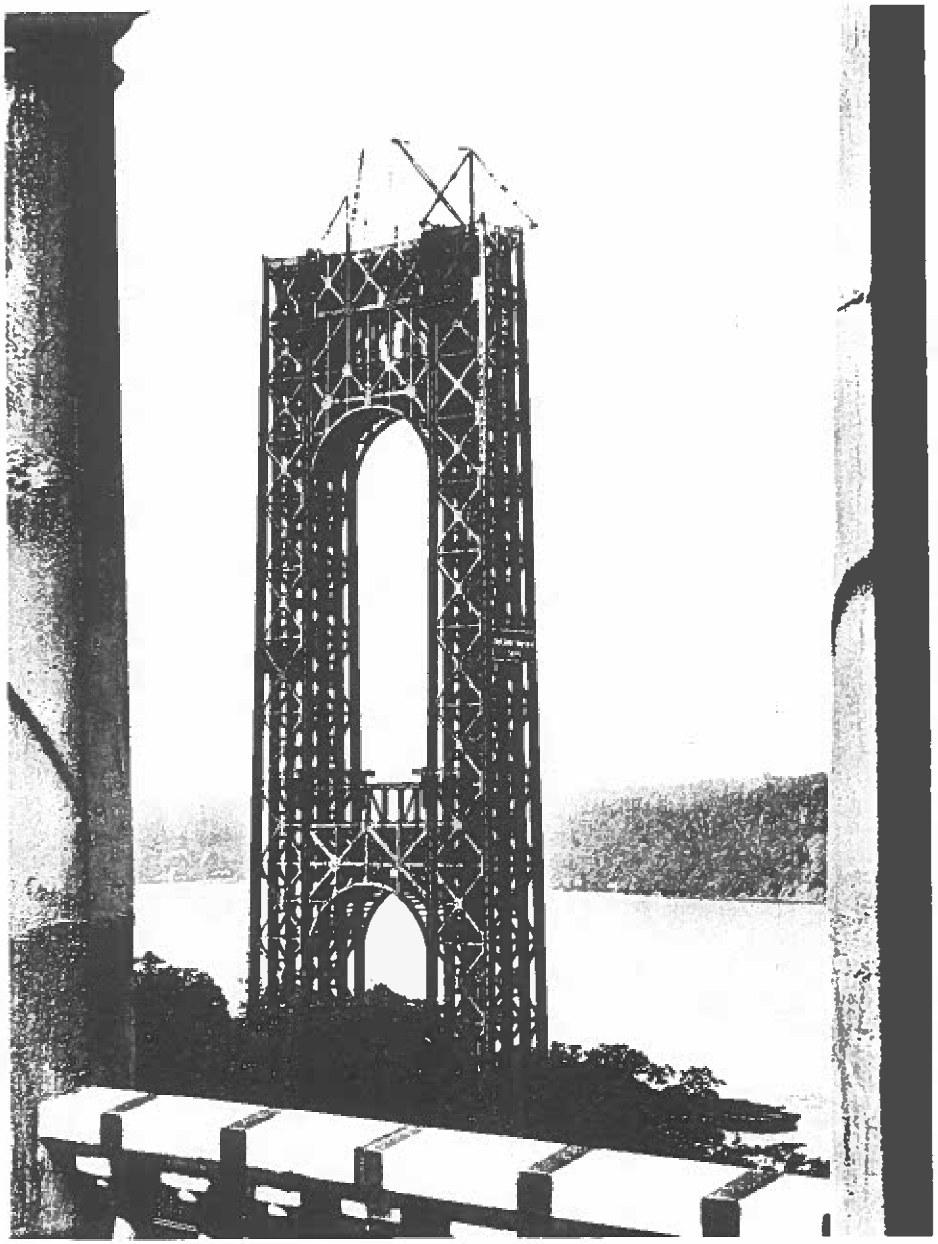
TOPPING OUT THE NEW YORK TOWER. There are 20,249 tons of steel in these 16 columns and their bracing. The taper of the towers has caused the upper tier of the traveler underframe to roll, by successive stages, over the lower tier and project behind the tower as shown.



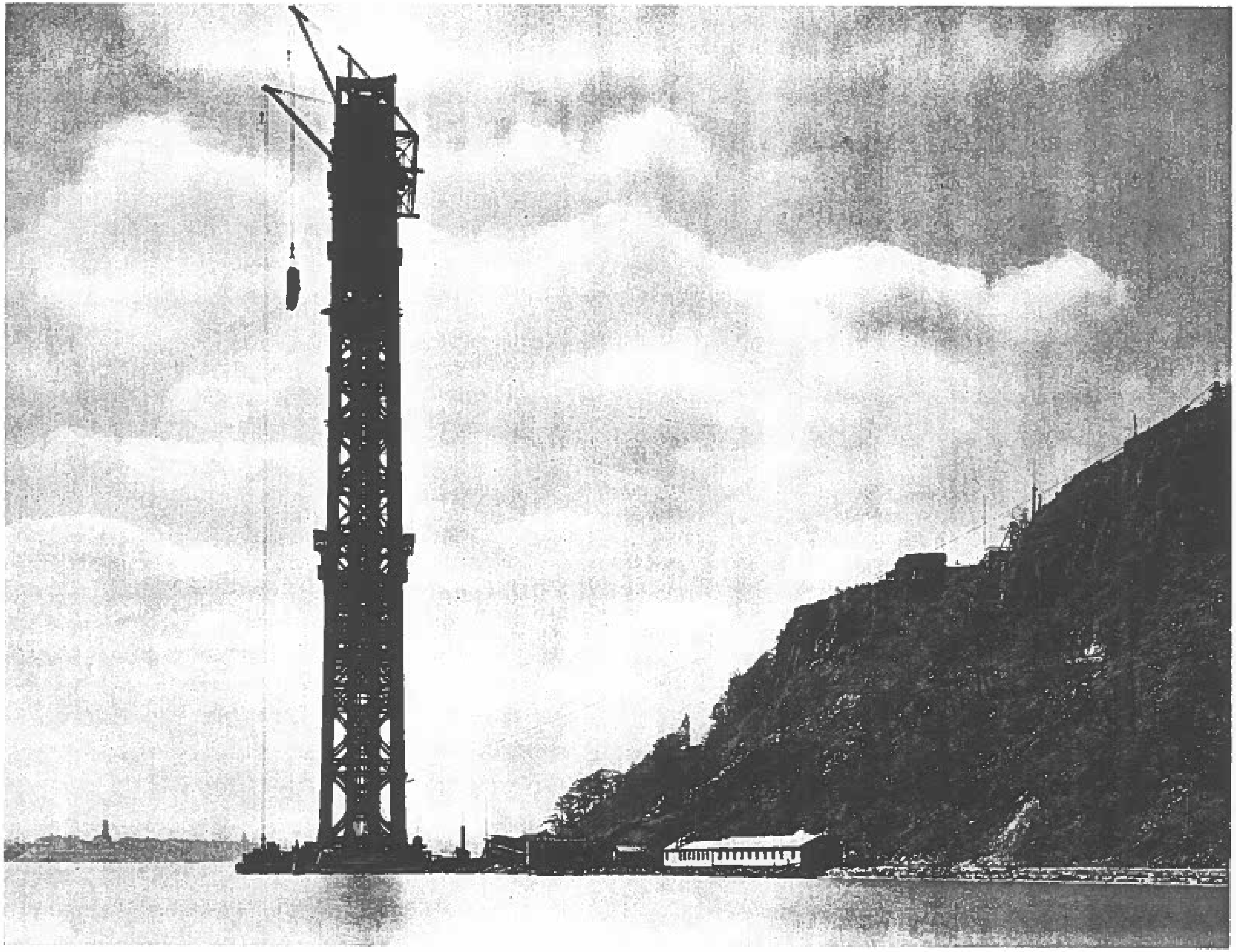
CONNECTIONS OF STEELWORK near top of tower. In the two upper stories the four columns of the inner row are expanded and interconnected so that they form practically a boxed plate-girder to receive the reaction from the pair of cable saddles. All of the diagonal members shown are connected by holes reamed to metal templers at the shop.

THE TRAVELER HAS REACHED THE TOP, the derricks have been moved over onto the tower shafts, and the traveler underframe has been dismantled and lowered. The two derricks are now building up the arched portal, commencing at level 8, and extending to the top of tower. Temporary struts borrowed from lower portal steel are still seen in position at level 8.

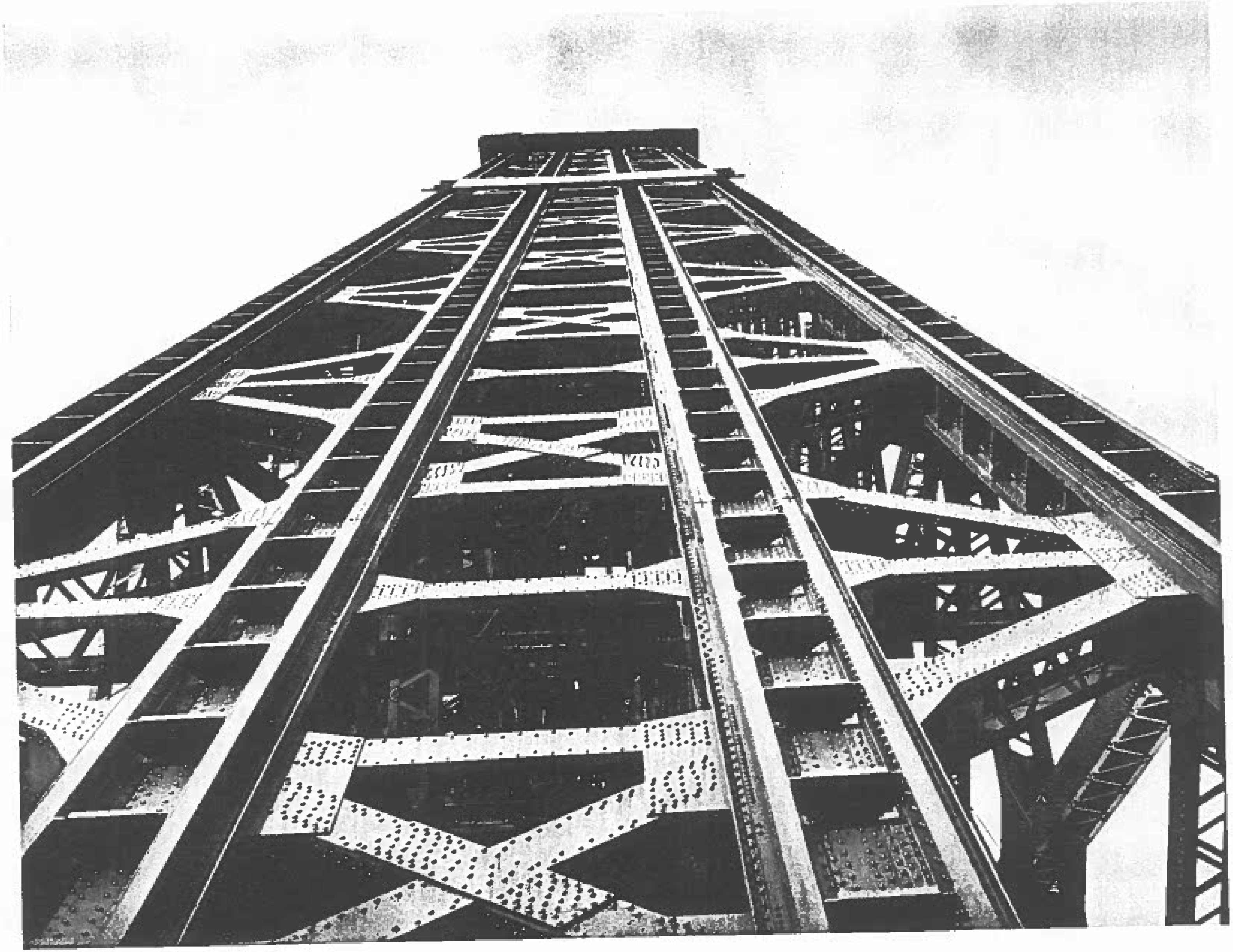




COMPLETION OF THE NEW YORK TOWER. The upper portal arch is being completed and the cable saddles will then be erected by one of these derricks, located on the center line of the bridge.

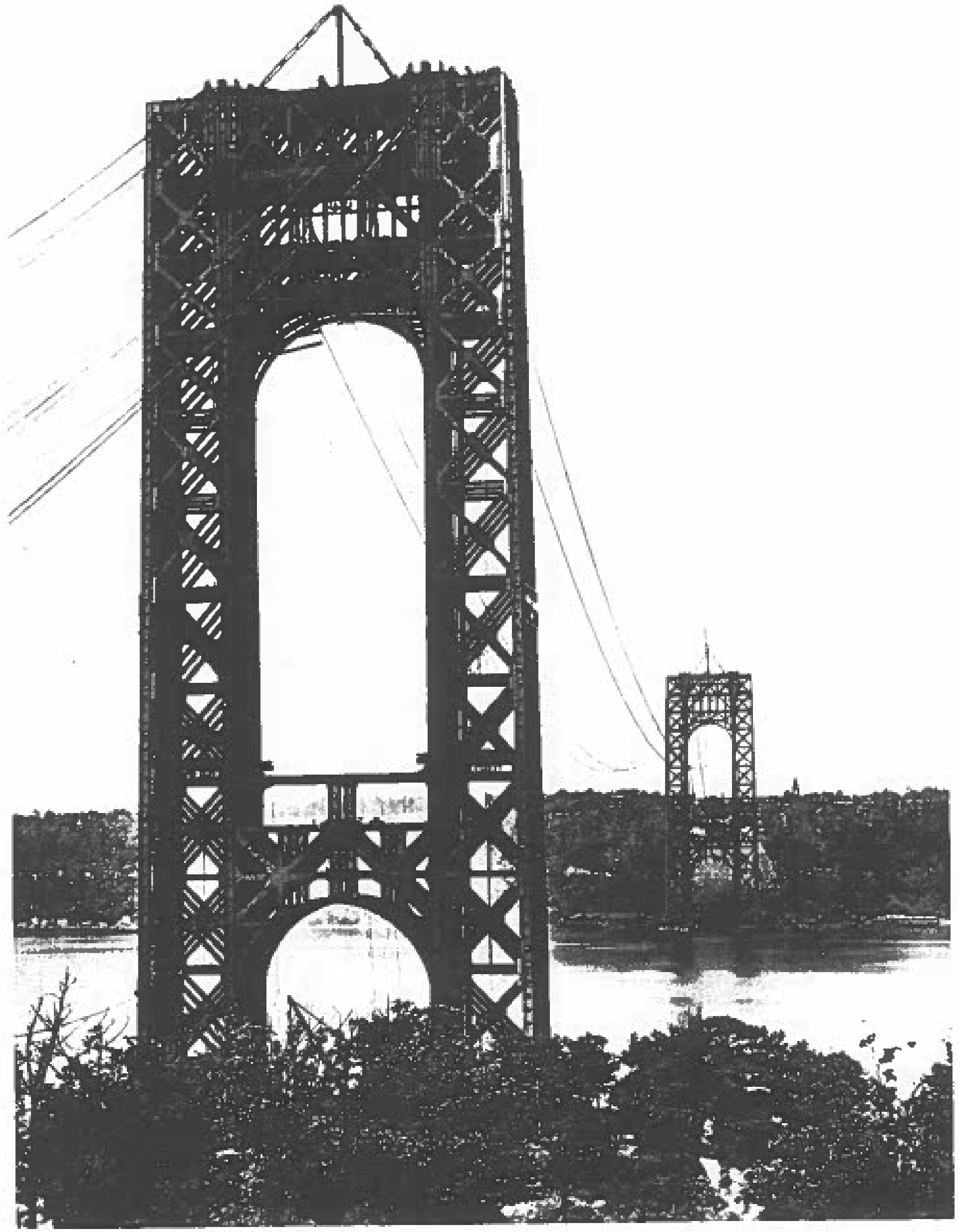


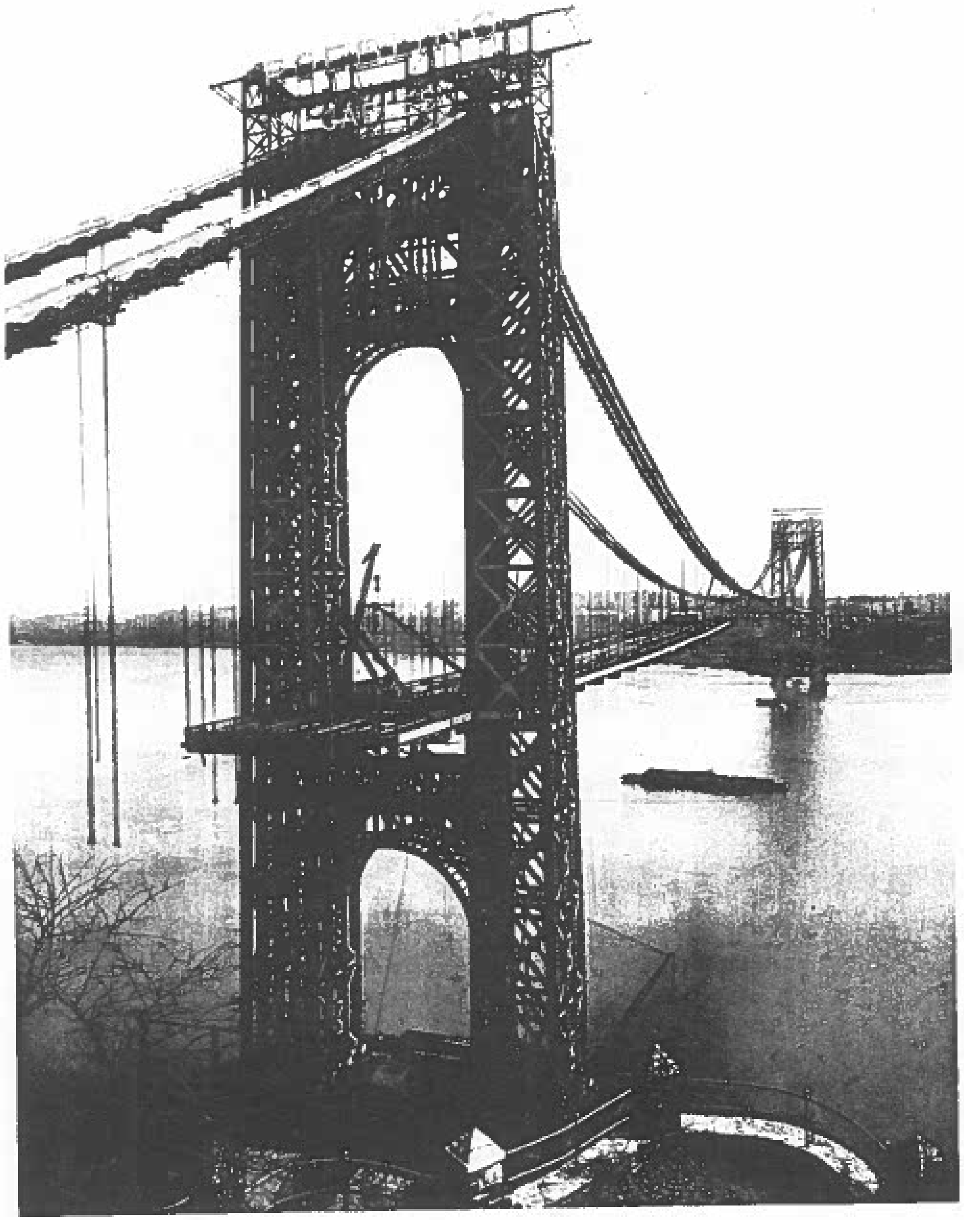
TOPPING OUT THE NEW JERSEY TOWER. It took 17 minutes to raise the last column section from the water to the top of tower. The erection of tower steel began June 25, 1928, and was completed June 20, 1929.



"WORM'S-EYE VIEW" of one of the completed towers, 560 ft. high above piers. Five feet higher than the Washington Monument.

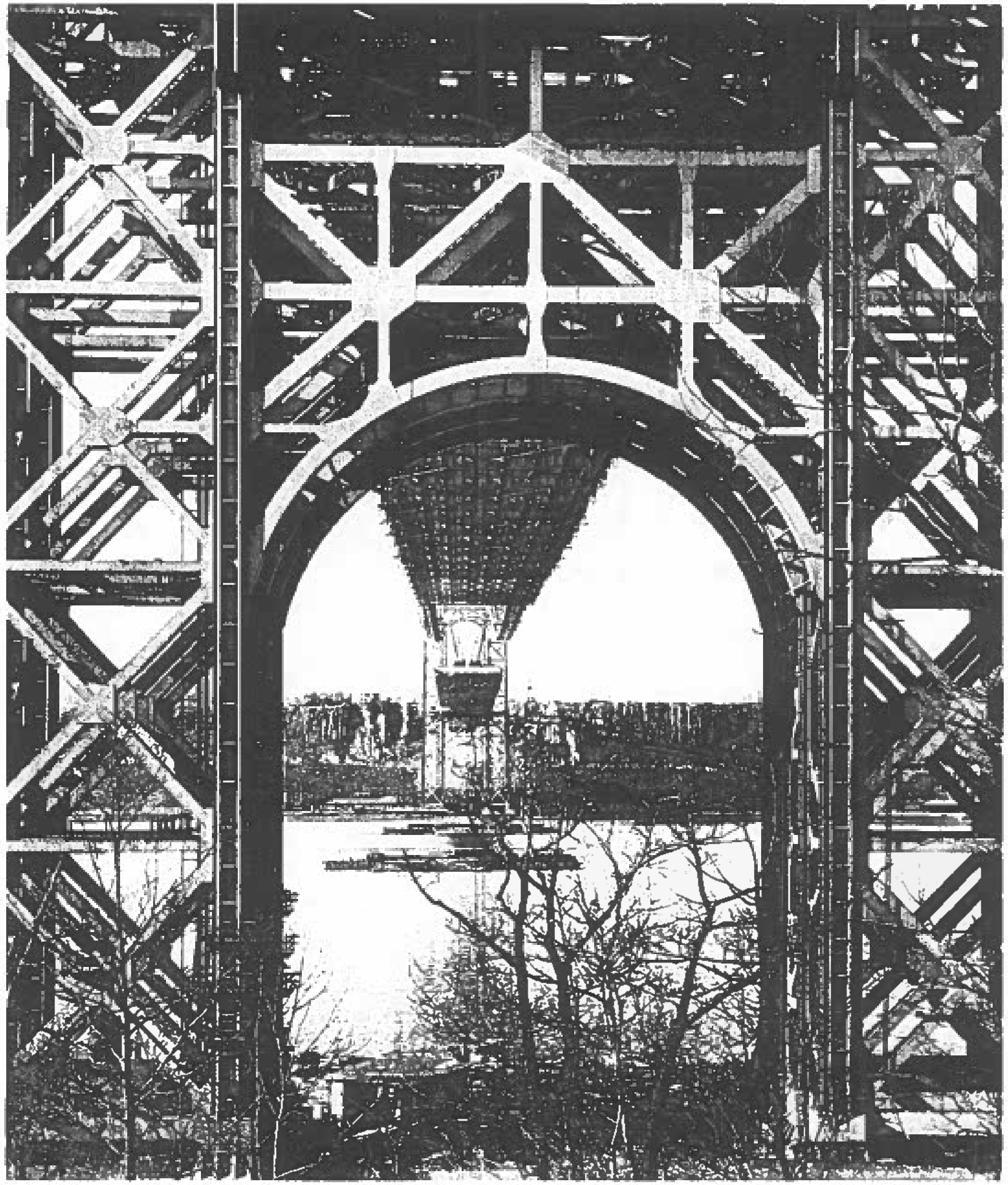
ONE DERRICK ON EACH TOWER was taken down, after moving its mate to the center line of the bridge. McClintic-Marshall was then employed by the Roebling Company to hoist its foot-walk ropes and erect much of its cable-spinning equipment. Picking the foot-walk ropes from the river bottom was a delicate undertaking (38 tons at 104-ft. reach). McClintic-Marshall's operations at the site were then suspended for over a year while the cables were spun and the suspender ropes placed. Fabrication of the floor and wind truss was proceeding at Pottstown during this interval.



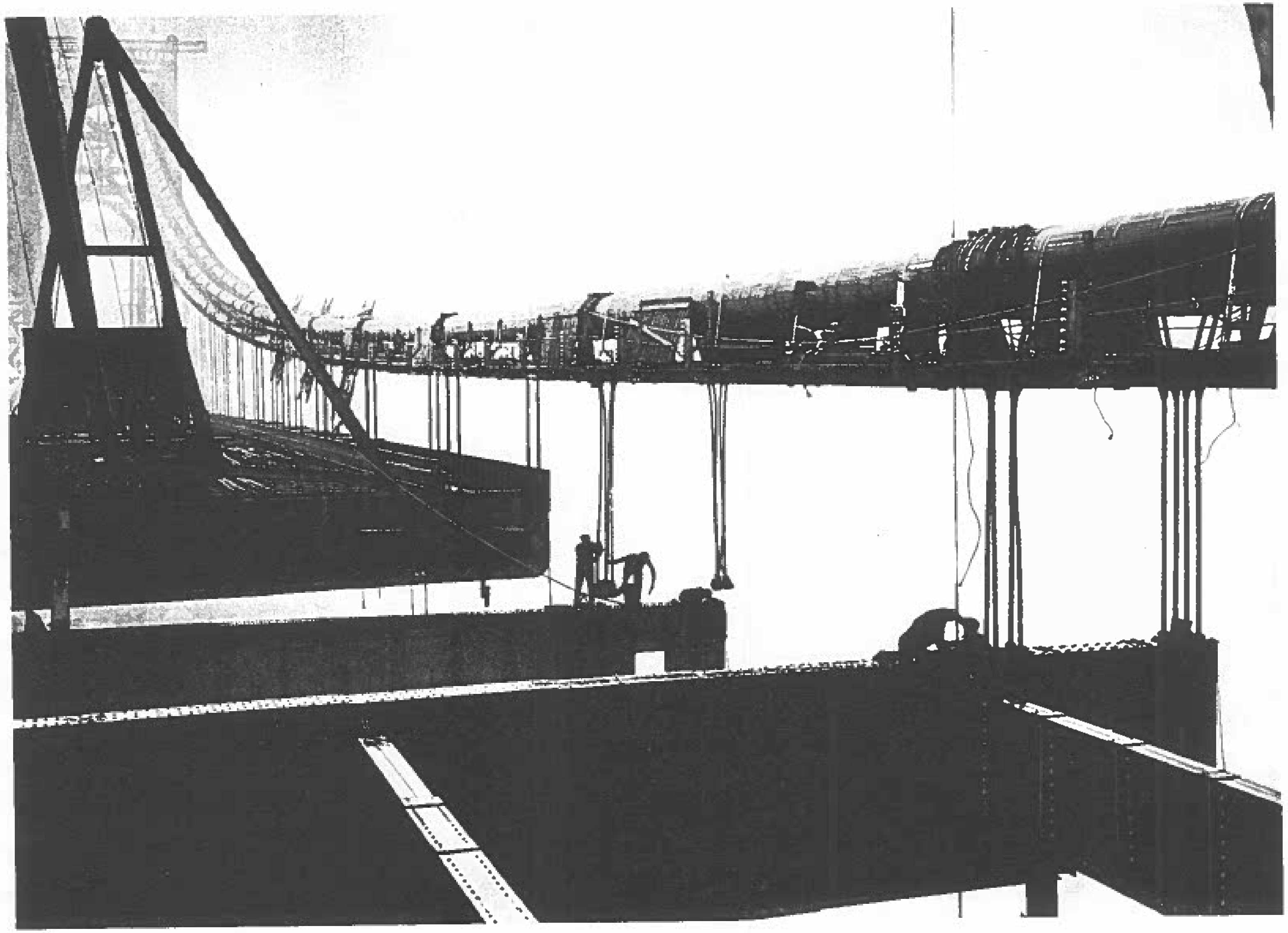


ERECTION OF FLOOR SYSTEM, as seen from the New Jersey side, showing the twin travelers on main span and single travelers on side span. The great weight of the main cables, and the design of the towers for a future double-deck bridge, permitted complete erection at one pass without overstress of the cables or towers from distortion. This is quite unusual in suspension-bridge erection.

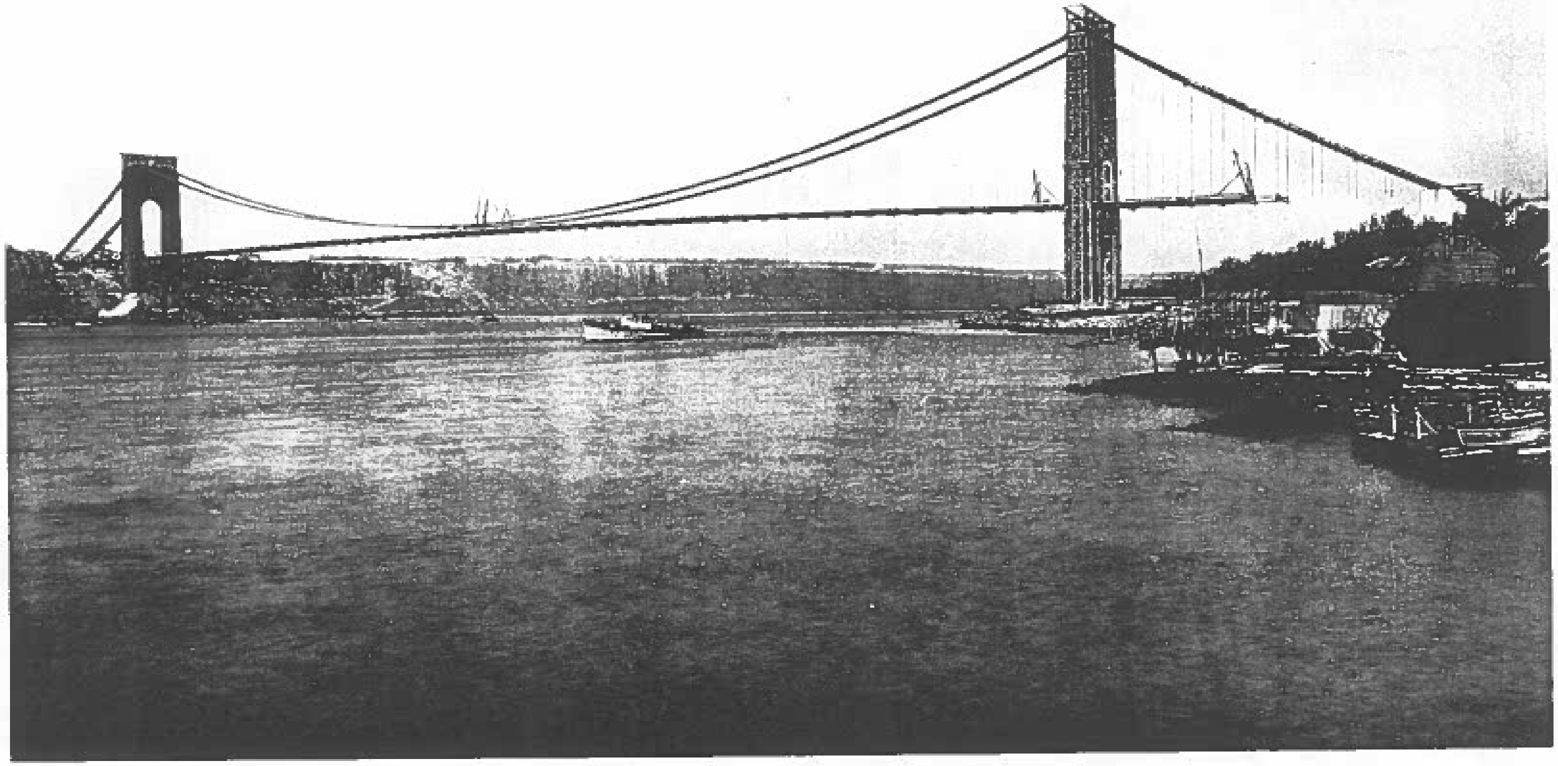
LOOKING THROUGH THE tower toward the Palisades, and showing the erection of the floor.



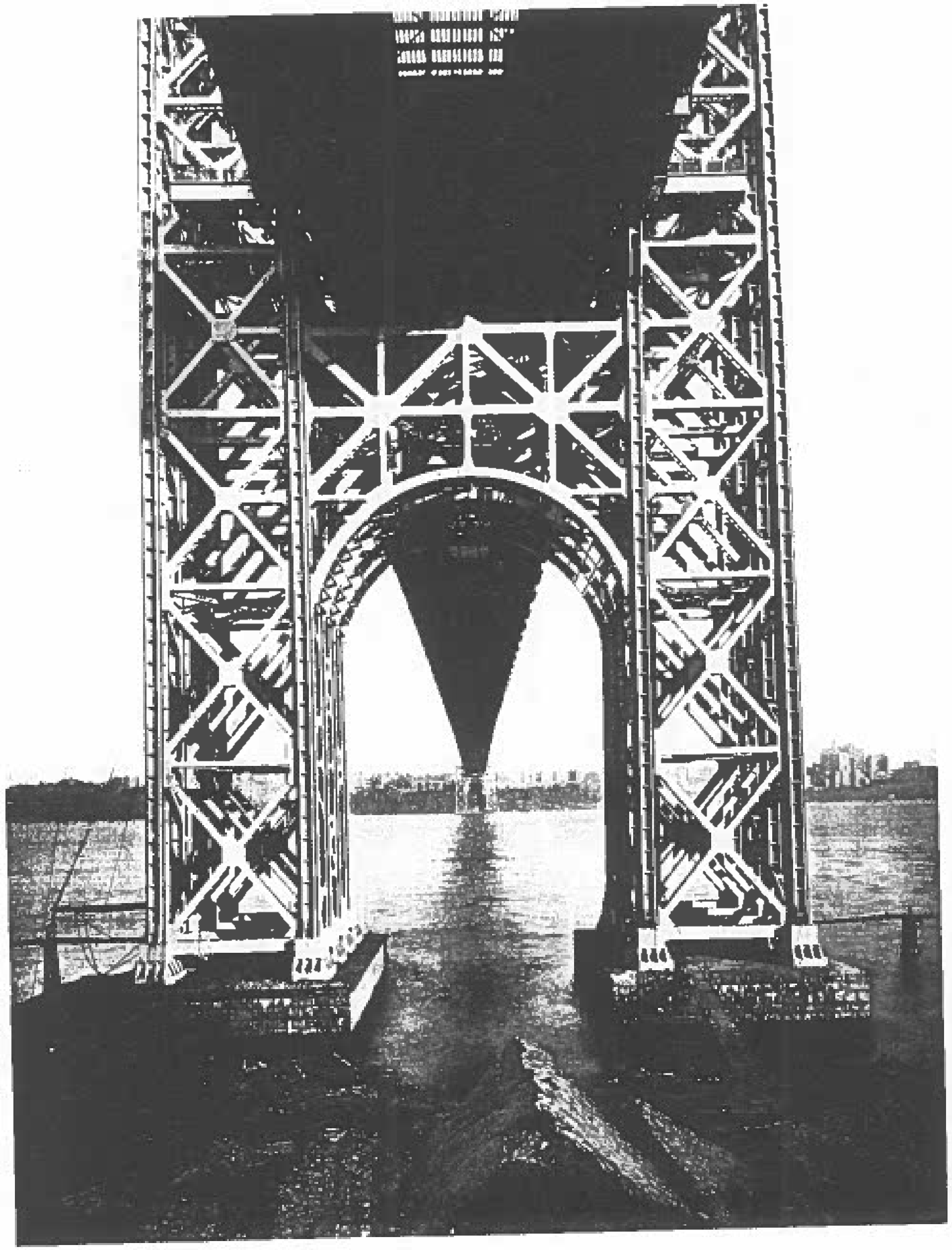
ERECTION OF THE FLOOR, showing the twin travelers progressing toward a meeting at mid-span. All steel has been placed, including floor beams, wind-chords, stringers, curbs, transverse rolled joists, and longitudinal bulb-angle reinforcement for floor slabs.



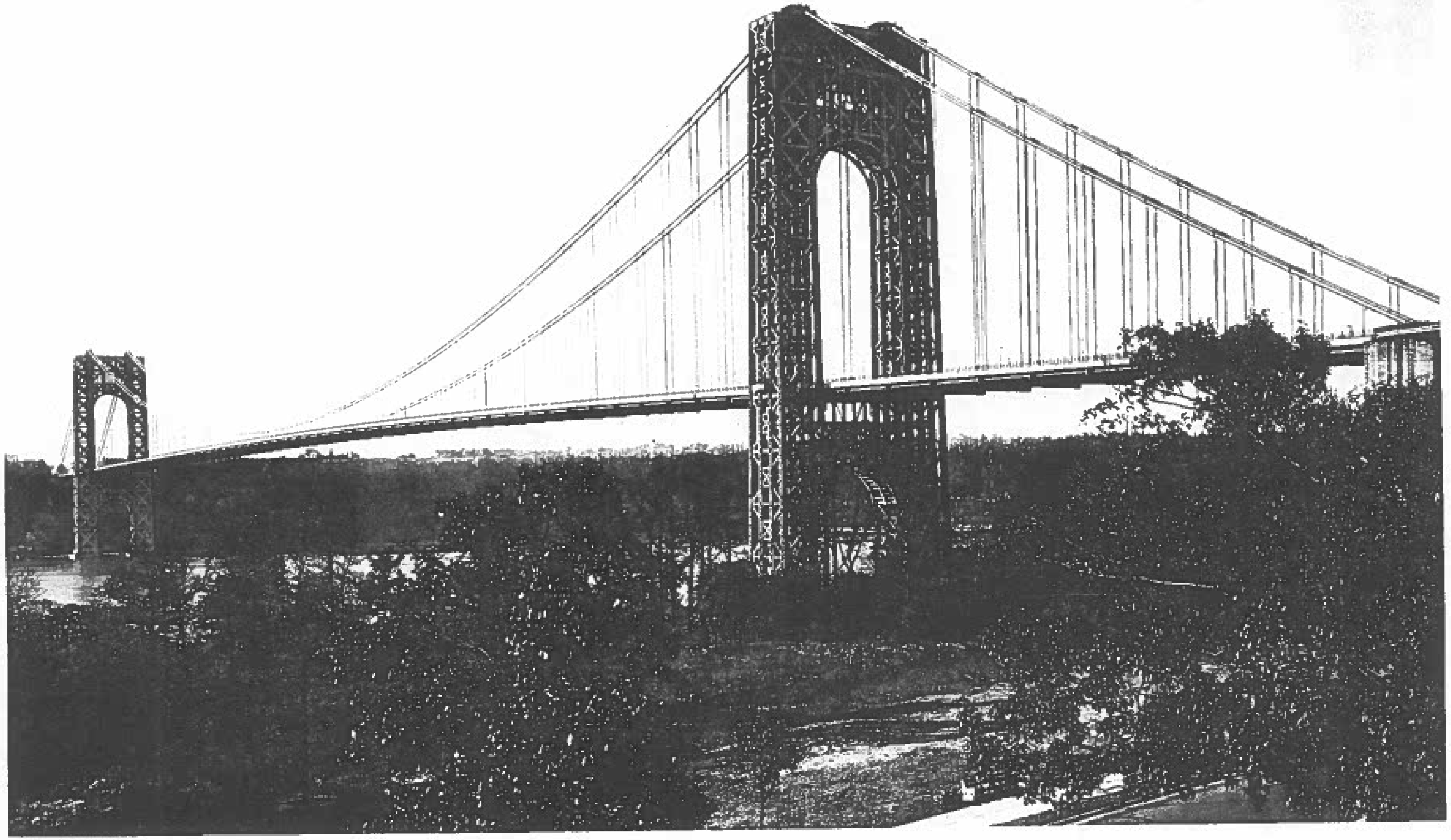
ERECTION OF FLOOR BEAM at center of main span. Bridgemen preparing to fit suspender sockets under floor-beam stiffeners. Wind-chord is shown projecting through the last previous floor beam.



NEARING COMPLETION of the George Washington Bridge. All main-span steel is in place and the side-span travelers are approaching the anchorages. The photograph reproduced here was taken December 31, 1930. Floor-steel erection began October 28, 1930, and was completed February 17, 1931.



THE FINISHED TOWERS AND FLOOR of the George Washington Bridge, showing the completed steelwork as seen from the New Jersey shore.

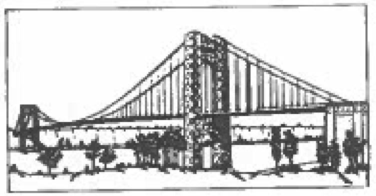


★ GEORGE WASHINGTON BRIDGE ★

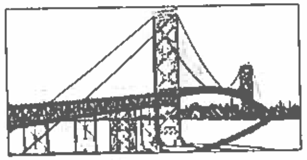
★ POTTSTOWN WORKS OF McCLINTIC-MARSHALL CORPORATION ★

The plant at which the steelwork for the George Washington Bridge was fabricated. McClintic-Marshall operates similar plants in the most important territories. Pottstown Works is a plant of recent construction and most refined equipment. No class or size of structural steelwork is beyond its capabilities. It includes facilities for indoor assembling, reaming, and painting of complete bridge trusses up to 550 ft. in length. This plant has an area of 55 acres, and a capacity of 186,000 tons per year. The total capacity of all plants of McClintic-Marshall Corporation is one million tons per year.

BRIDGES BY McCLINTIC-MARSHALL

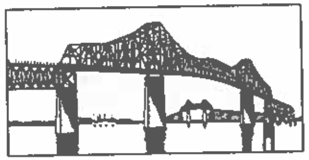


GEORGE WASHINGTON BRIDGE, 1927–1931
Over Hudson River, Fort Washington, New York City, to Fort Lee, N. J.
Built and owned by The Port of New York Authority
Highway, with provision for Electric Railway
Main Span, 3500 ft.
63,875 tons of steel by McClintic-Marshall.

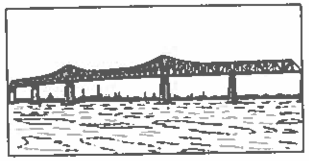


AMBASSADOR BRIDGE, 1927–1929
Over Detroit River, Detroit, Mich., to Windsor, Canada
Owned by Detroit International Bridge Co.
Highway; Main Span, 1850 ft.; 24,000 tons
Designed and built by McClintic-Marshall.

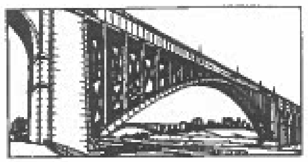
MT. HOPE BRIDGE, 1928–1929
Over Mt. Hope Bay from Bristol to Portsmouth, R. I.
Owned by Mt. Hope Bridge Co.
Highway; Main Span, 1200 ft.; 7500 tons
Robinson and Steinman, Consulting Engineers.



COOPER RIVER BRIDGE, 1928–1929
Over Cooper River at Charleston, S. C.
Owned by Byllesby Corp.
Highway; Cantilever Spans of 640 ft. and 1050 ft.
7650 tons of steel by McClintic-Marshall
Waddell and Hardesty, Consulting Engineers.

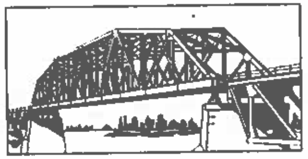


OUTERBRIDGE CROSSING, 1927–1928
Over the Arthur Kill from Perth Amboy, N. J., to Tottenville, S. I., N. Y.
Owned by The Port of New York Authority
Highway; Cantilever Span, 750 ft.; 16,100 tons
Waddell and Hardesty, Consulting Engineers.

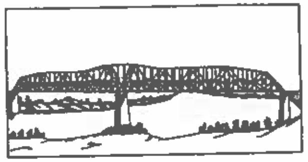


HIGH BRIDGE, 1928
Over Harlem River, New York City
Owned and designed by New York City Department of Plant and Structures
Conduit and Footway; Plate-Girder Arch; 425 ft.; 2000 tons.

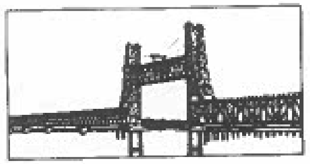
MAUMEE RIVER HIGH-LEVEL BRIDGE, 1930–1931
Over the Maumee River at Toledo, Ohio
Owned by the City of Toledo, Ohio
Highway; Main Span, 785 ft.; 8000 tons
Waddell and Hardesty, Consulting Engineers.



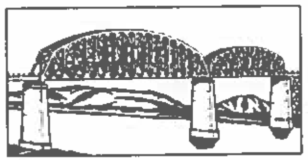
ILLINOIS RIVER BRIDGE, 1930–1931
Over the Illinois River at Chillicothe, Ill.
Owned by Atchison, Topeka and Santa Fe Railway
Main Span, 440 ft.; Solid Floor, Double Track; 7600 tons
Designed and built by McClintic-Marshall.



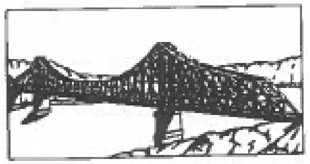
SCIOTOVILLE BRIDGE, 1915–1916
Over the Scioto River at Sciotoville, Ohio
Owned by Chesapeake & Ohio Northern Railway
Continuous, Double Track. Two Spans of 775 ft.; 14,700 tons
Gustav Lindenthal, Consulting Engineer.



CARLTON BRIDGE, 1927
Over the Kennebec River at Bath, Me.
Owned jointly by the State of Maine and the Maine Central Railway
Railway and Highway; Six-deck Truss Spans and 234-ft. Lift Span; 7700 tons
Waddell and Hardesty, Consulting Engineers.



A. H. SMITH MEMORIAL BRIDGE, 1923–1924
Over the Hudson River at Castleton, N. Y.
Owned and designed by the New York Central Railroad
600-ft. and 400-ft. Double-Track Spans and Viaducts; 22,700 tons.



BEAVER BRIDGE, 1908–1909
Over the Ohio River at Beaver, Pa.
Owned by the Pittsburgh and Lake Erie Railroad
Double Track, Cantilever; 769 ft.; 16,000 tons
Albert Lucius, Consulting Engineer.