PDHonline Course C674 (8 PDH)

Othmar Ammann and the Great Gray Bridge

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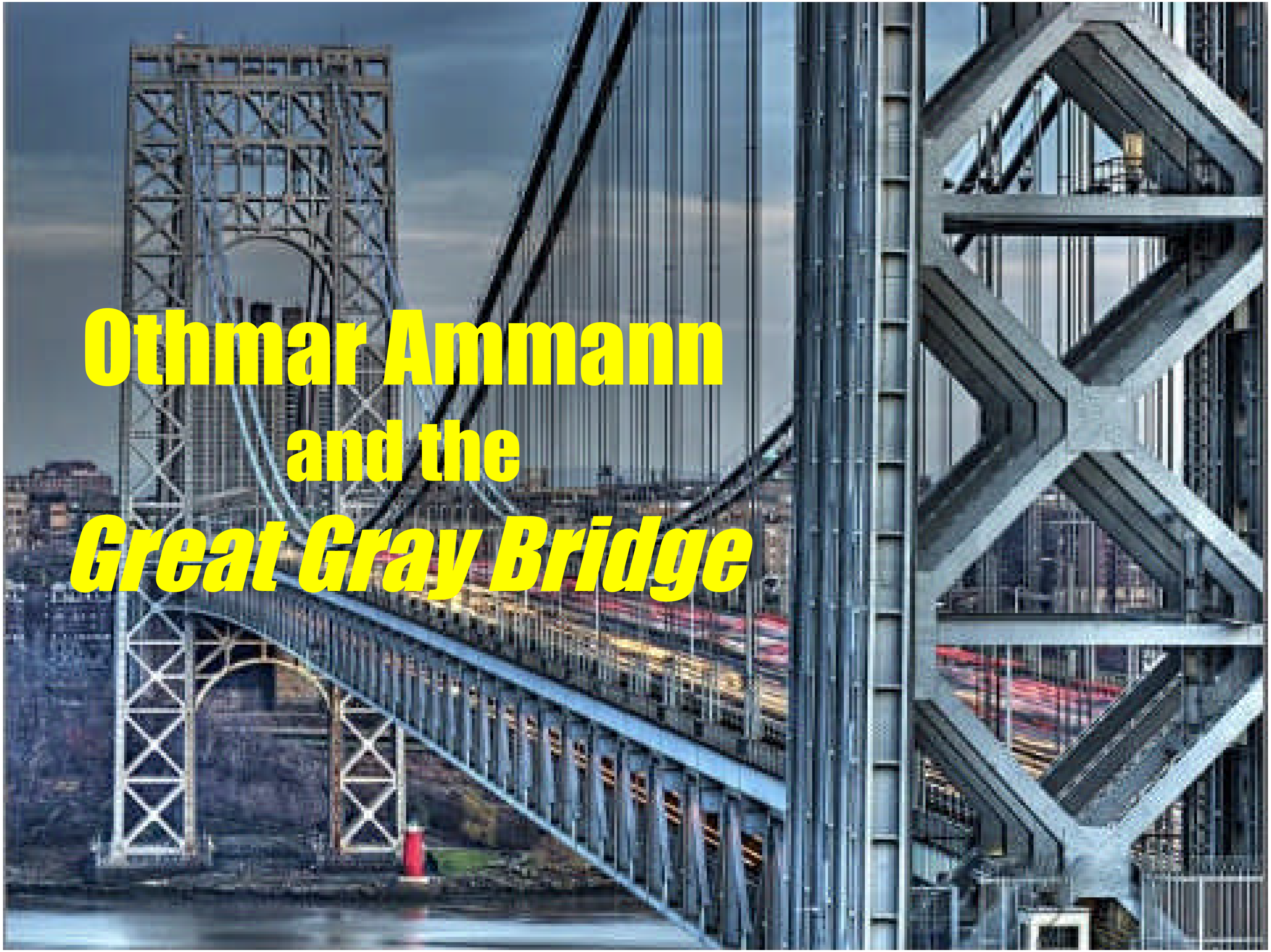


Othmar Ammann and the *Great Gray Bridge*

Table of Contents

Part 1

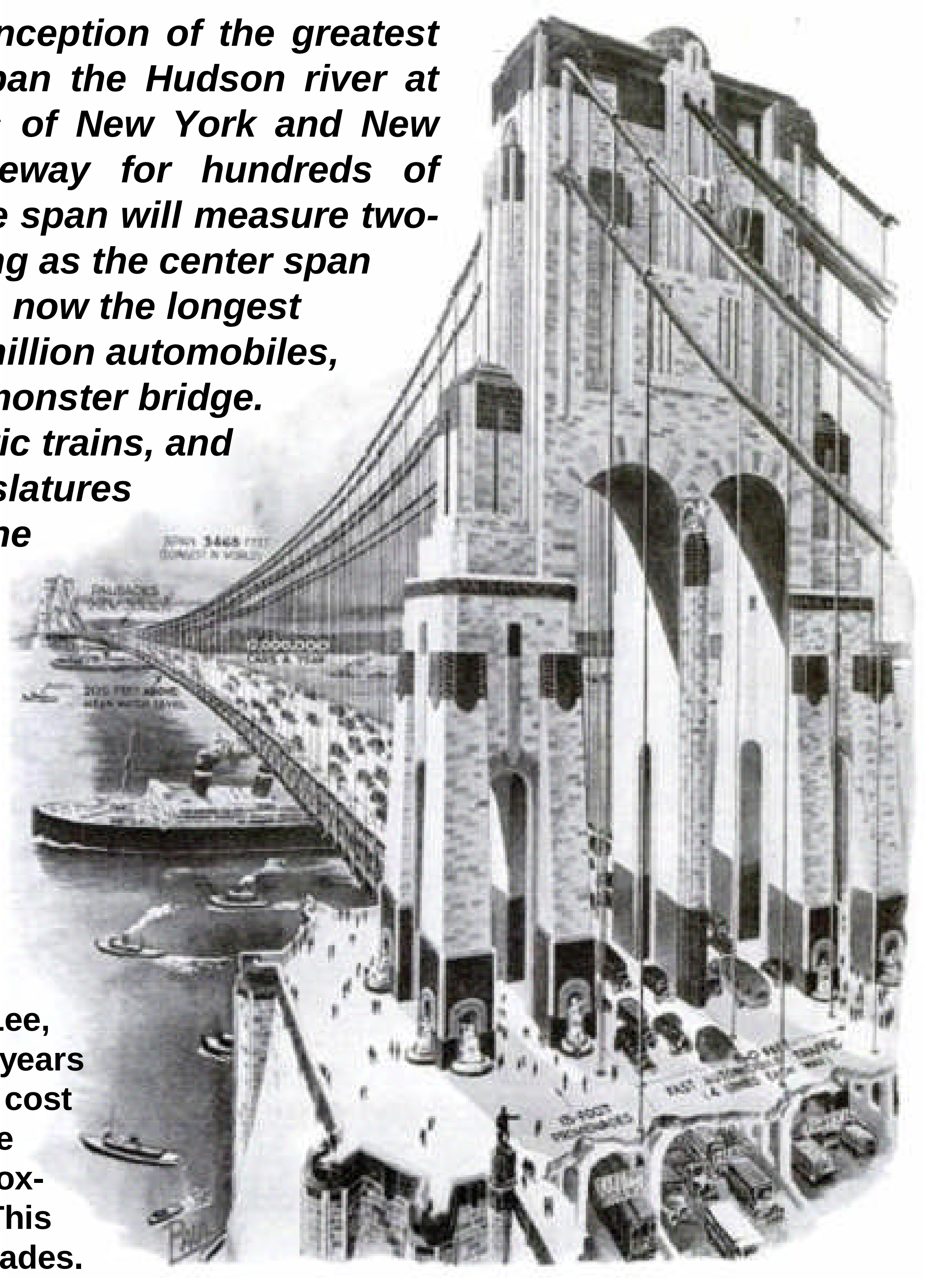
It is Blessed

The Greatest Bridge in the World

"Here is presented our artist's conception of the greatest bridge in the world, which will span the Hudson river at New York City, Uniting the states of New York and New Jersey and providing a passageway for hundreds of thousands of commuters. Its single span will measure two-thirds of a mile, almost twice as long as the center span of the Philadelphia-Camden bridge, now the longest bridge in the world. About twelve million automobiles, it is estimated, will pass over this monster bridge. There will be tracks, also, for electric trains, and pathways for pedestrians. The legislatures of the two states have authorized the bridge with the consent of the War Department, and plans are now being worked out. O.H. Ammann, bridge engineer, and Professor William H. Burr of Columbia UniversIty will soon submit official designs. Cass Gilbert is to plan the architectural features."

Popular Science, **April 1926**

<u>Right</u>: caption: "The proposed bridge between Fort Washington, NY and Fort Lee, NJ, will be of gigantic proportions. Four years will be required for its construction. The cost will be $40 million, to be met by tolls. The NJ side of the proposed location is approximately 50-feet higher than the NY end. This may require a rock-cut through the Palisades.



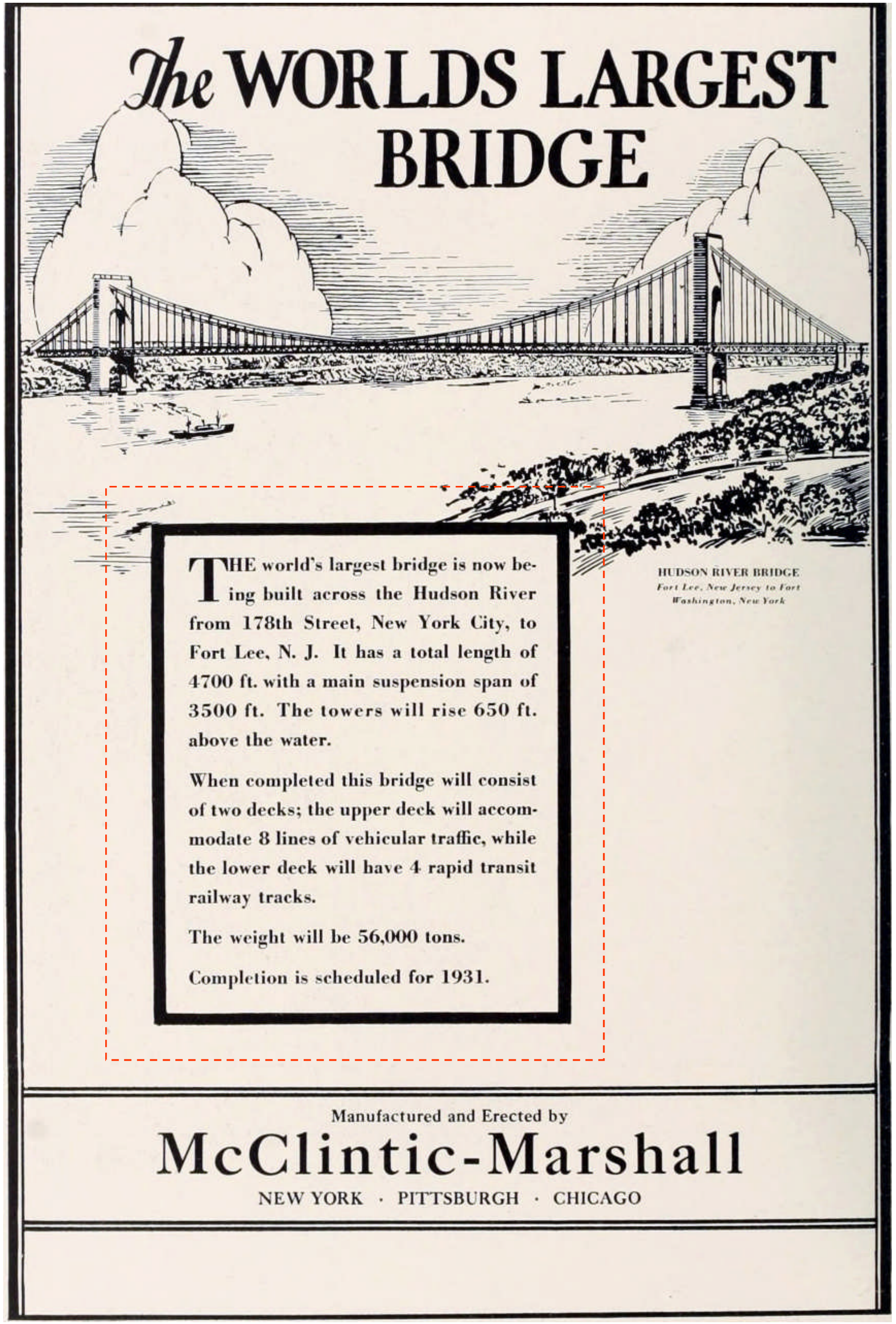
Top Left: caption: New Jersey tower under construction October 1, 1928”

Top Right: caption: “Rock-cut through New Jersey Palisades complete”

Left: caption: “Manhattan-bound traffic passes through the Palisades rock-cut”

"…But such a giant bridge does not exist, you say. True! It will, however, be a monumental reality within a few years. In 1932, the new Hudson River Bridge, dwarfing all other structures of its kind, will stretch across the Hudson from Fort Washington, in New York City to Fort Lee, in New Jersey, giving New York a great new gateway to every part of the United States…"

***Popular Science,* February 1929**



The WORLDS LARGEST BRIDGE

THE world's largest bridge is now being built across the Hudson River from 178th Street, New York City, to Fort Lee, N. J. It has a total length of 4700 ft. with a main suspension span of 3500 ft. The towers will rise 650 ft. above the water.

When completed this bridge will consist of two decks; the upper deck will accommodate 8 lines of vehicular traffic, while the lower deck will have 4 rapid transit railway tracks.

The weight will be 56,000 tons.

Completion is scheduled for 1931.

HUDSON RIVER BRIDGE
Fort Lee, New Jersey to Fort Washington, New York

Manufactured and Erected by
McClintic-Marshall
NEW YORK · PITTSBURGH · CHICAGO

<u>Left</u>: caption: "The world's largest bridge is now being built across the Hudson River from 178th Street, New York City, to Fort Lee, N.J. It has a total length of 4,700 ft. with a main suspension span of 3,500 ft. The towers will rise 650 ft. above the water. When completed this bridge will consist of two decks; the upper deck will accommodate 8 lines of vehicular traffic, while the lower deck will have 4 rapid transit railway tracks. The weight will be 56,000 tons. Completion is scheduled for 1931."

“Imagine all the men, women and children of Baltimore, Md., leaving their homes on a sultry August morning and piling into automobiles to rush away from the heart of the city. Then picture the huge procession of automobiles – about 200,000 cars in a line that would reach two-thirds of the way from New York to Chicago! – passing in that one day across a suspension bridge of a single span 3,500 feet long, and you have gained an idea of the tremendous traffic to be borne on a summer Saturday by the greatest bridge in the world…”

Popular Science, **February 1929**

“…Realize, next, that all of these cars with their four fifths of a million passengers, besides hundreds of buses and electric trains, thousands of pedestrians, and the mammoth weight of the bridge itself, will be supported by four cables over a distance of fourteen city blocks, 200 feet above the water, and you have a conception of the boldness and magnitude of one of the most wonderful engineering feats ever attempted…”

***Popular Science,* February 1929**

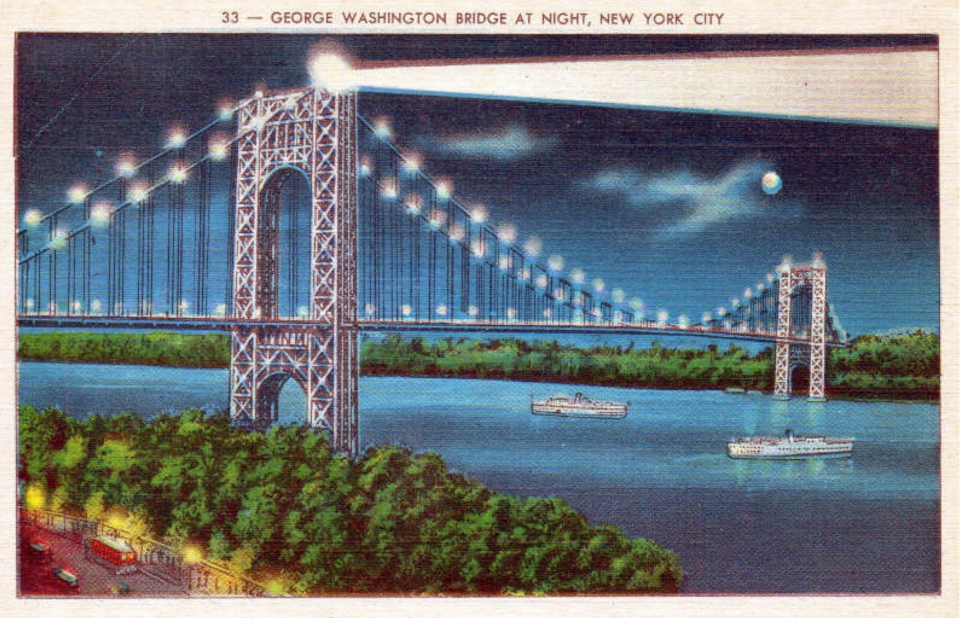
Above: caption: “Giant of World’s Bridges Rising in New York. Artist’s drawing of the New Hudson River Bridge, now under construction. Compared with other famous structures; note comparative size of Brooklyn Bridge.”

“…The main span of this titan among bridges will be twice as long as that of the 1,750-foot Philadelphia-Camden crossing which, since its opening in 1926, has held the record of being the world’s longest suspension span. And the famous Brooklyn Bridge, with its 1,595 feet, will seem almost insignificant beside it…”

***Popular Science*, February 1929**

<u>Above</u>: postcard for the *Delaware River Bridge* (a.k.a. *Ben Franklin Bridge*)


32 — GEORGE WASHINGTON BRIDGE, NEW YORK CITY


33 — GEORGE WASHINGTON BRIDGE AT NIGHT, NEW YORK CITY

“…Fourteen traffic lanes, including eight roadways, two sidewalks, and four electric railway tracks, will accommodate the unprecedented traffic. It is expected that 40,000,000 automobiles will eventually cross it in a year! Its total cost will reach $60,000,000. The height of its finished cable towers – 635 feet – will exceed that of the Washington Monument by eighty feet and that of the Singer Building, in New York, by twenty-three feet. They will hold a 90,000-ton fabric of steel and concrete in mid-air – twice the weight of the steamship ‘Leviathan!’ The carrying cables will have a capacity of 350,000 tons, compared with 120,000 tons for the cables of the Delaware Bridge and 45,000 tons for those of the Brooklyn Bridge. It is estimated that in the first year of operation, 8,148,000 vehicles, containing some 19,000.000 passengers, will move across the new span, in addition to 1,500,000 pedestrians and nearly half a million buses!...”

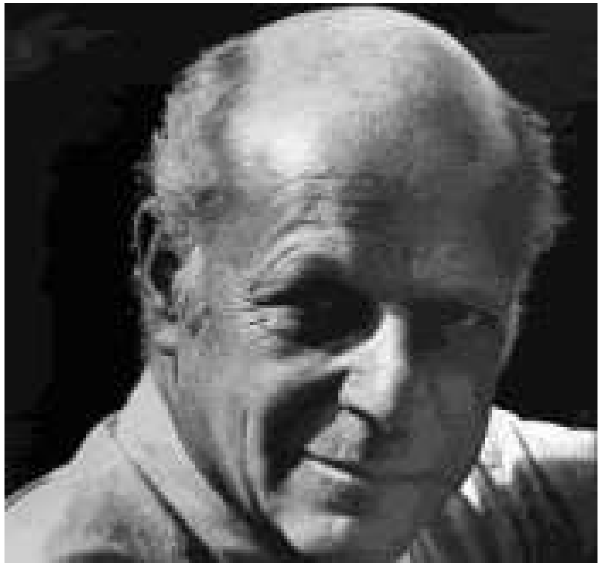
***Popular Science,* February 1929**

A Spiritual Conception

"…The beauty and symmetrical appearance of a suspension bridge, of which the Brooklyn structure remains the greatest example, despite its age, lies in the graceful curve of the huge cables, dipping down from one tall tower toward the center of the river, then rising again to pass over the supporting tower on the opposite shore. The simplest curve in nature, the catenary, is that formed by a hanging chord. When the cord supports a uniform horizontal load, as in a suspension bridge, it changes its shape somewhat, and approximates a parabola, but the change is so slight, and so skillfully disguised by bridge designers that the eye fails to see it…"

***Popular Mechanics,* August 1925**

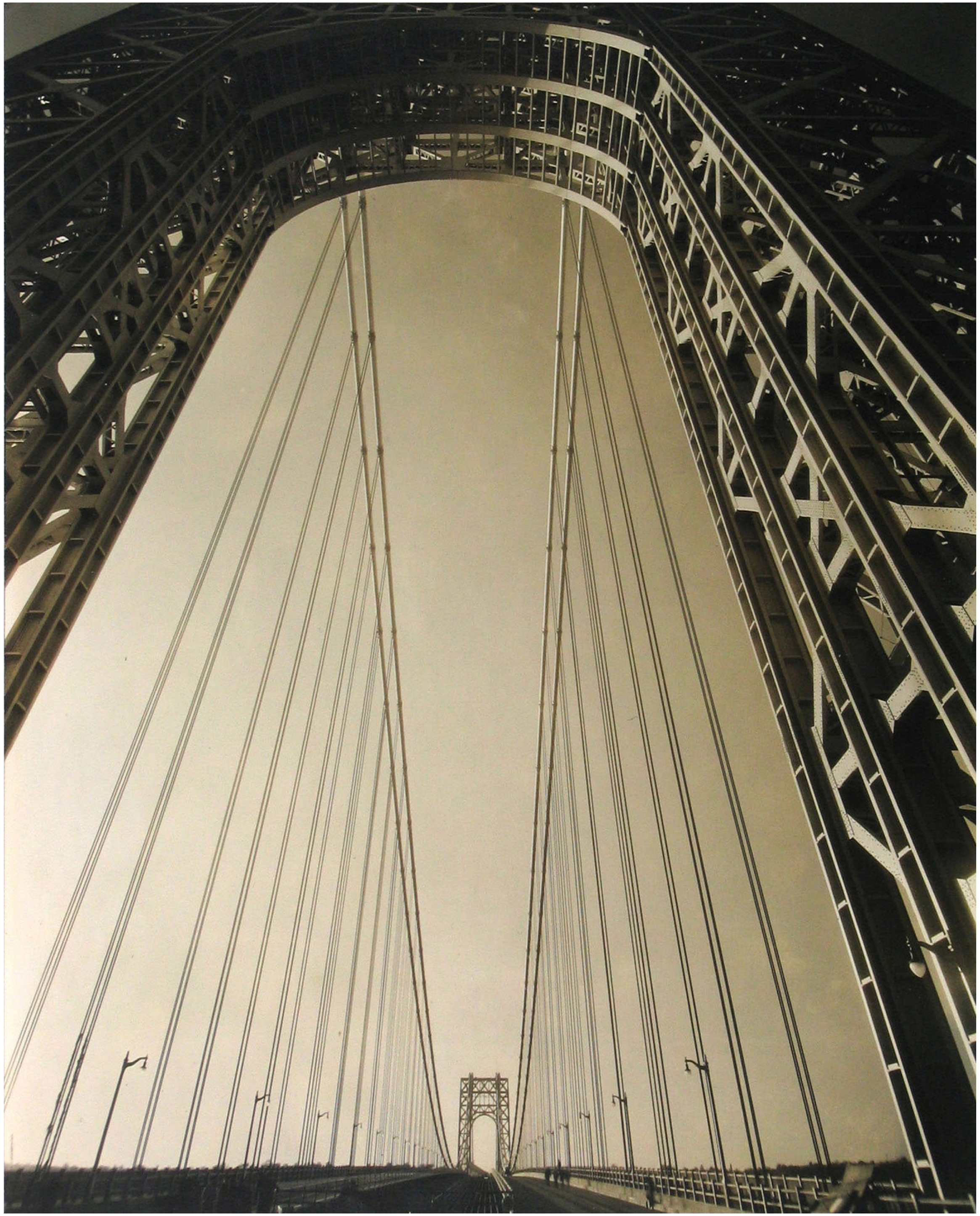
RE: *John A. Roebling* – designer of the *Brooklyn Bridge* and many other suspension bridges in the mid-*19th Century*, referred to the balance of forces present in a suspension bridge as "A Spiritual Conception."



"…I have walked across it late at night when it was shrouded in fog, and during the brilliant sunshine hours of mid-day. I have driven over it countless times and passed under it on boats. Coming to New York City by airplane, sometimes I have been lucky enough to fly right over it. It is difficult to imagine a more gracious welcome or dramatic entry to the great metropolis"

***William Schuman*, Composer**


CANADIAN COLONIAL AIRWAYS
NC 21750



"The George Washington Bridge over the Hudson is the most beautiful bridge in the world. Made of cables and steel beams, it gleams in the sky like a reversed arch. It is blessed. It is the only seat of grace in the disordered city. It is painted an aluminum color and, between water and sky, you see nothing but the bent cord supported by two steel towers. When your car moves up the ramp, the two towers rise so high that it brings you happiness; their structure is so pure, so resolute, so regular that here, finally, steel architecture seems to laugh. The second tower is very far away; innumerable vertical cables, gleaming across the sky, are suspended from the magisterial curve that swings down and then up. The rose-colored towers of New York appear, a vision whose harshness is mitigated by distance."

Charles-Edouard Jeanneret-Gris,
French Architect (a.k.a. *Le Corbusier*)

“Mere size and proportion are not the outstanding merit of a bridge, a bridge should be handed down to posterity as a truly monumental structure which will cast credit on the aesthetic sense of present generations”

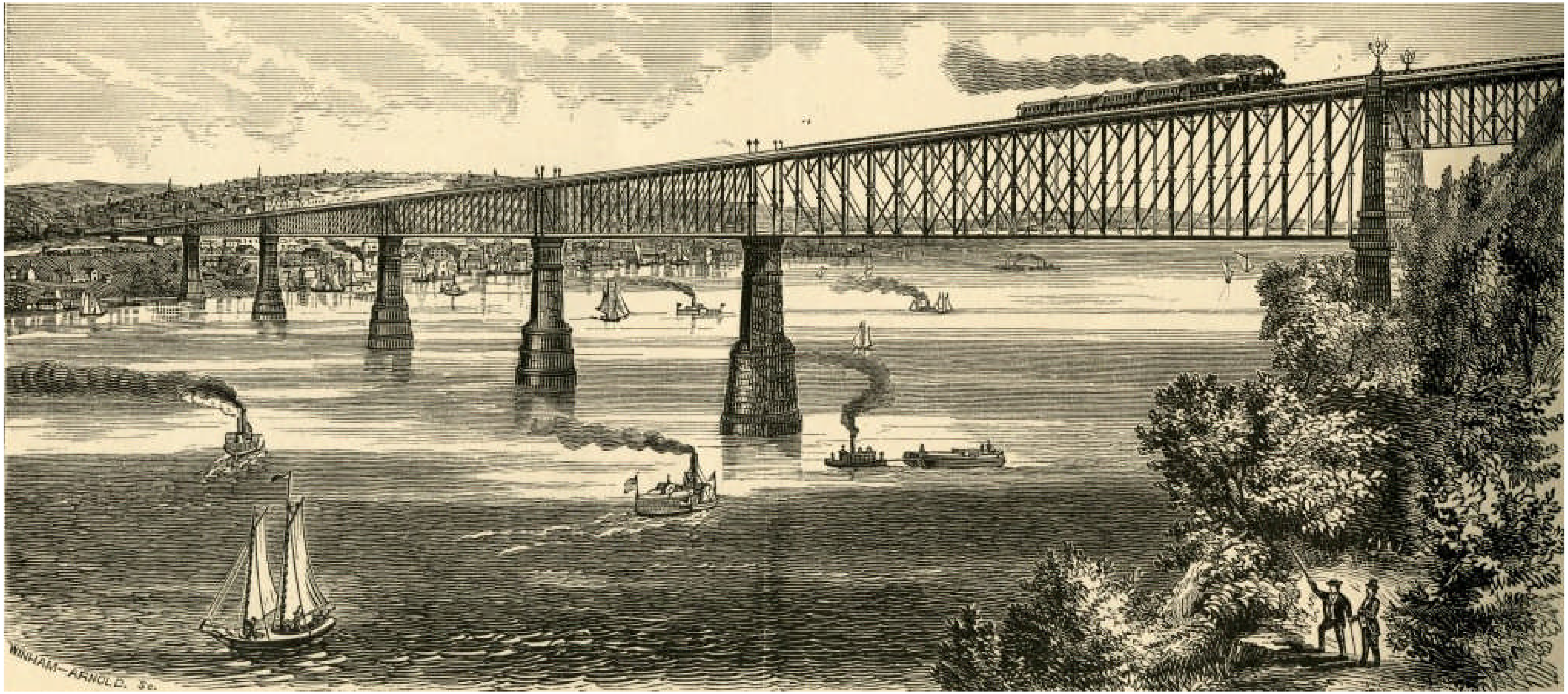
***O.H. Ammann,* 1934**

Location, Location, Location

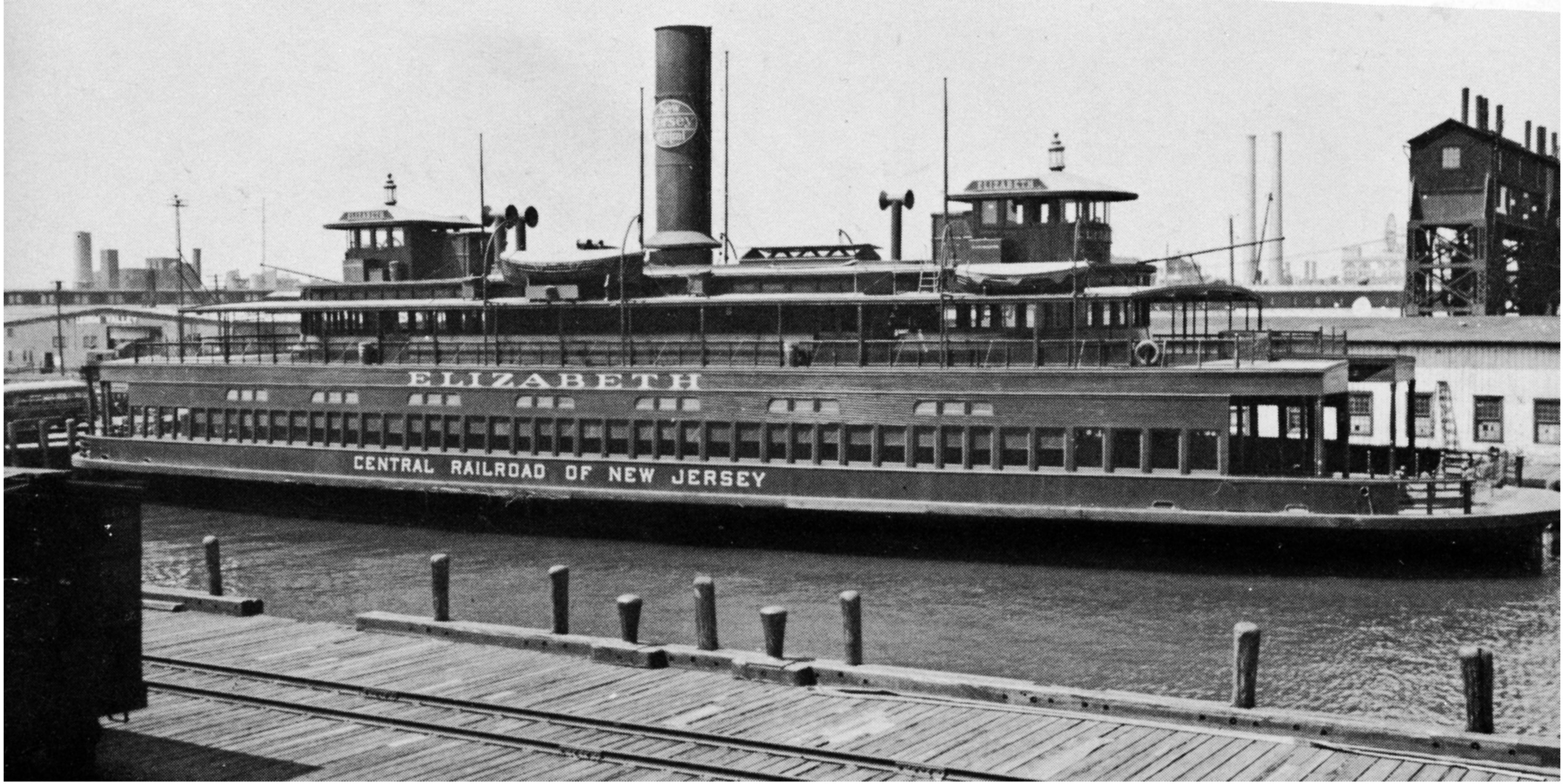
"A highway tunnel under the Hudson River at New York City, connecting the highway system of New York and New Jersey, is proposed by the Bridge and Tunnel Commissions of the two states instead of a bridge. There is but one bridge across the Hudson, south of Albany. That is at Poughkeepsie, 75 miles above New York City. The project for a bridge from Manhattan Island to the New jersey shore has been agitated for a hundred years, but the great height at which it would have to be built to give sufficient clearance for shipping, and the value of the land that would have to be taken for terminals, would make a serviceable bridge cost $50,000,000, the commissions estimate, while a tunnel with two tubes, each having a 17-ft. roadway, could be built for $11,000,000. The average number of vehicles crossing the Hudson in ferry-boats is 19,660 per day. All but 2,000 of these cross below Twenty-third Street, and to make the highway tunnel accessible to this traffic it will have to be built below that point. A tunnel such as proposed would have a capacity of 5,000,000 vehicles a year, or about the number now crossing the river. Mechanical ventilation and means for maintaining perfect cleanliness are included in the plans."

Popular Mechanics, **1914**

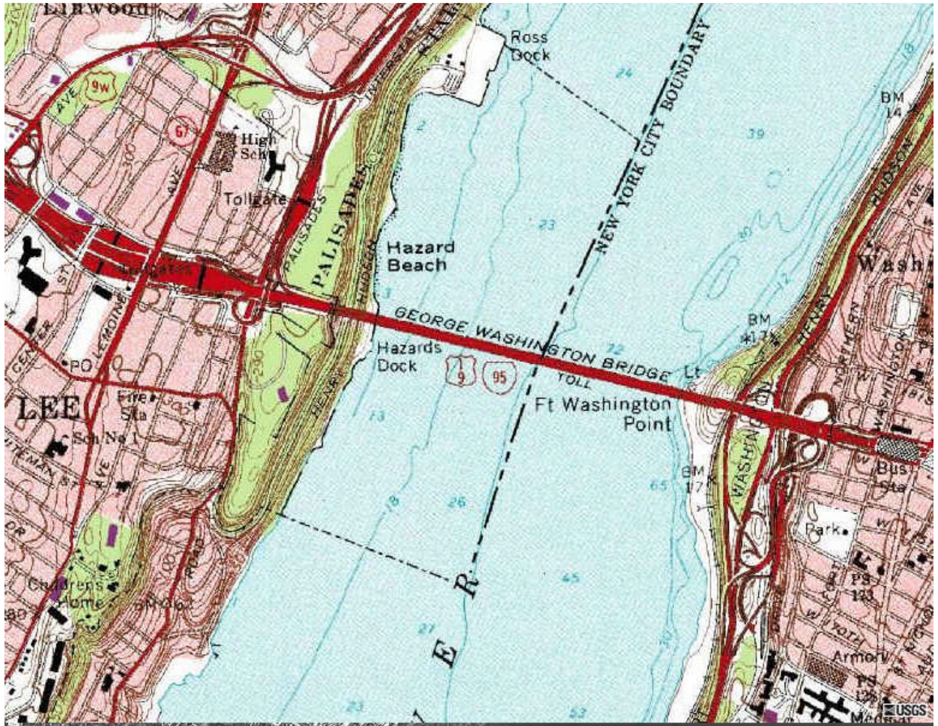
RE: as early as 1906, the governors of the states of *New York* and *New Jersey* proposed a bridge over the *Hudson River* between *179th Street* in *Manhattan* and *Fort Lee*. That year, the governors appointed an *Interstate Bridge Commission* for the purpose of constructing one or more trans-Hudson bridges at the joint expense of the two states.



Above: caption: “Hudson River Bridge at Poughkeepsie, New York.” The *Poughkeepsie Highland Railroad Bridge* spans the *Hudson River* connecting *Poughkeepsie* and *Highland, New York*. Designed by *John F. O’Rourke*, it was built as a double track railroad bridge by the *Union Bridge Company* of *Pennsylvania*. Construction began in 1886 and the bridge operated from 1889, when it was completed, until 1974. At the time, it was the only fixed railroad crossing of the Hudson River between *New York City* and *Albany*, providing freight trains a more direct route between *New England* and the *Midwest*. Today, the bridge is operated by the *New York State Historic Park System* and is open to pedestrian and bicycle traffic only.



Above: the ferry *Eliizabeth* of the *Central Railroad of New Jersey* was one of a fleet of ferries carrying passengers and vehicles across the *Hudson River* between *New York City* and the railroad's massive *Communipaw Terminal* in *Jersey City, NJ*. Direct railroad connections offered passenger train service locally in *New Jersey* to destinations such as *Baltimore, Maryland*, *Washington D.C.* and throughout *Pennsylvania.*



"From the purely engineering point of view, it is the most economical crossing from Manhattan over the Hudson River that it is possible to select, it being the narrowest part of the river, with comparatively small land damages on either side. The approaches over land are short, that from New York reaching 179th Street over Fort Washington Park, and that from New Jersey over the proposed limits of Palisades Park. The foundation problems are not likely to be of great magnitude as far as can be judged in the absence of borings. The rock is on the surface at Fort Washington point, involving no foundation work whatever, beyond leveling off the same. Furthermore, the channel span need not, in our engineer's opinion, be over 1,400 feet or thereabouts, which will give abundant passage for all river traffic, the north limit anchorage for large vessels being below this crossing. This site has not been bored, but in our engineer's opinion, from the apparent geological condition, ten million dollars will cover the cost of a bridge at this point for highway and speed trolley service, being in their opinion one-third the cost of a bridge lower down the river."

***Interstate Bridge Commission*, 1910**

"…It should be an inspiration to us to recall that here, at Fort Washington in 1776, our forebears made one of the most valiant stands against insurmountable obstacles of the entire Revolutionary War. Here, at Jeffrey's Hook, Washington and his generals once struggled to block this channel against a hostile fleet with the sunken hulls of ships. Here, in a defense unmatched for heroism, 3,000 Americans sacrificed all for a great cause. We may rejoice that this great bridge marks a site so sacred in patriotic memories…"

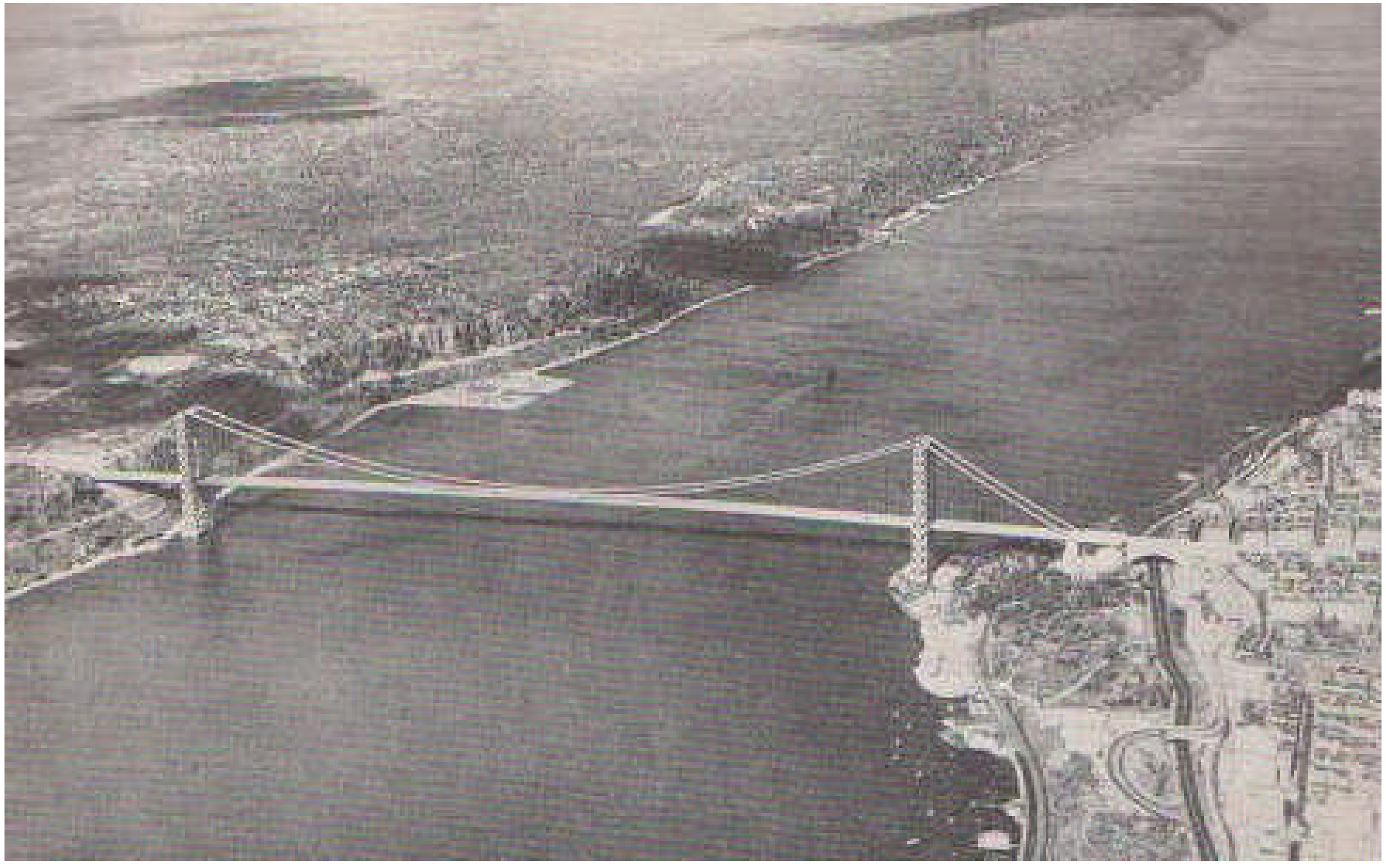
Franklin D. Roosevelt, **Governor of the** ***State of New York***

RE: excerpt from his dedication speech on October 25th 1931 (left)

An Important New Link

“Separating New York from New Jersey, the great Hudson River has long been an obstacle to transport. The opening of the great George Washington Suspension Bridge in 1932 completed an important new link in the highway systems of the two states. For several generations the City of New York and its environs have enjoyed a reputation for giant bridges…The George Washington Bridge spans the Hudson River between Fort Washington and Fort Lee and is one of New York’s newest bridges…”

***Wonders of World Engineering,* November 1937**



<u>Above</u>: caption: “The Hudson River is spanned by the George Washington Bridge between Fort Washington Park, Manhattan, and Fort Lee, on the New Jersey shore. The bridge is carried on two towers which centers are 3,500 feet apart. The anchor span on the Manhattan side is 650 feet long, and that on the other side is 610 feet long. Thus the total length is 4,760 feet. The complicated circles of ramps and approach roads connecting Riverside Drive and neighboring streets with the bridge can be seen on the Manhattan bank.”

***Wonders of World Engineering,* November 1937**

A Grand River

"…The Hudson is a grand river. The reach that sweeps down into New York City, between majestic, partly wooded heights, is in keeping with its noble upper reaches. A fine piece of engineering, above all a giant bridge, seldom spoils the appearance of its surroundings, but rather serves to enhance them. The new George Washington Bridge across the Hudson is an example of this. It sets off the grandeur of the great river…"

Wonders of World Engineering, **November 1937**

FOR some fourteen miles the Island of Manhattan stretches along the Hudson, from The Battery to the Harlem River. To the observer afloat, the New York side presents a view of almost unbroken crags of masonry ranged in serried ranks of streets, sparsely relieved by touches of nature.

On the New Jersey side, Jersey City sprawls northward to meet the famous old port of Hoboken with its background of hills. From here on, Weehawken and other smaller communities meet the gaze, subdued by ever mounting hills until at Fort Lee, opposite upper Manhattan, New York City, the hills take on the precipitous form of The Palisades. Here, early in the War of Independence, the colonists erected a fortification called Fort Constitution, but later renamed Fort Lee, in honor of General Charles Lee. In the vicinity of the fort a village gradually assembled taking the same name.

The natural beauty of the surroundings and their proximity to the ever-growing metropolis of New York early made for frequent passage of the intervening and mighty Hudson. From very early times crude flat boats worked by hand with big sweeps provided ferriage which was badly hampered in winter by ice. With the coming of steam, service was steadily improved and for many years boats of the latest type have been in operation. With the passing of the years, New York spread northward to completely cover Manhattan while the territory back of Fort Lee, and above, into that part of New York State to the northward, spread a vast population dependent upon the city for a livelihood, supplies and amusement.

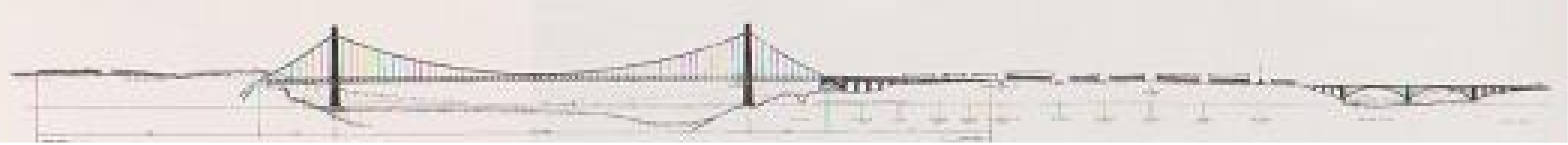
Approaching New York City from the North on the Hudson, the New York State line halts on the west side, 12 miles above Fort Lee where it meets New Jersey. To the army of commuters and others who go to and from the metropolis, the Fort Lee crossing speedily became a traffic artery of prime importance.

"…179th Street is opposite Fort Lee, where the built-up area on the Jersey City bank begins to open out to a certain extent, the river being flanked by high rocky bluffs and half-wooded cliffs. It was at 179th Street that the site of the Hudson bridge was finally fixed, in surroundings where the boldness of man's engineering resource was set off by the grandeur of the cliff-flanked river…"

***Wonders of World Engineering*, November 1937**

Left: caption: "George Washington Bridge - view from the New Jersey, 1931"

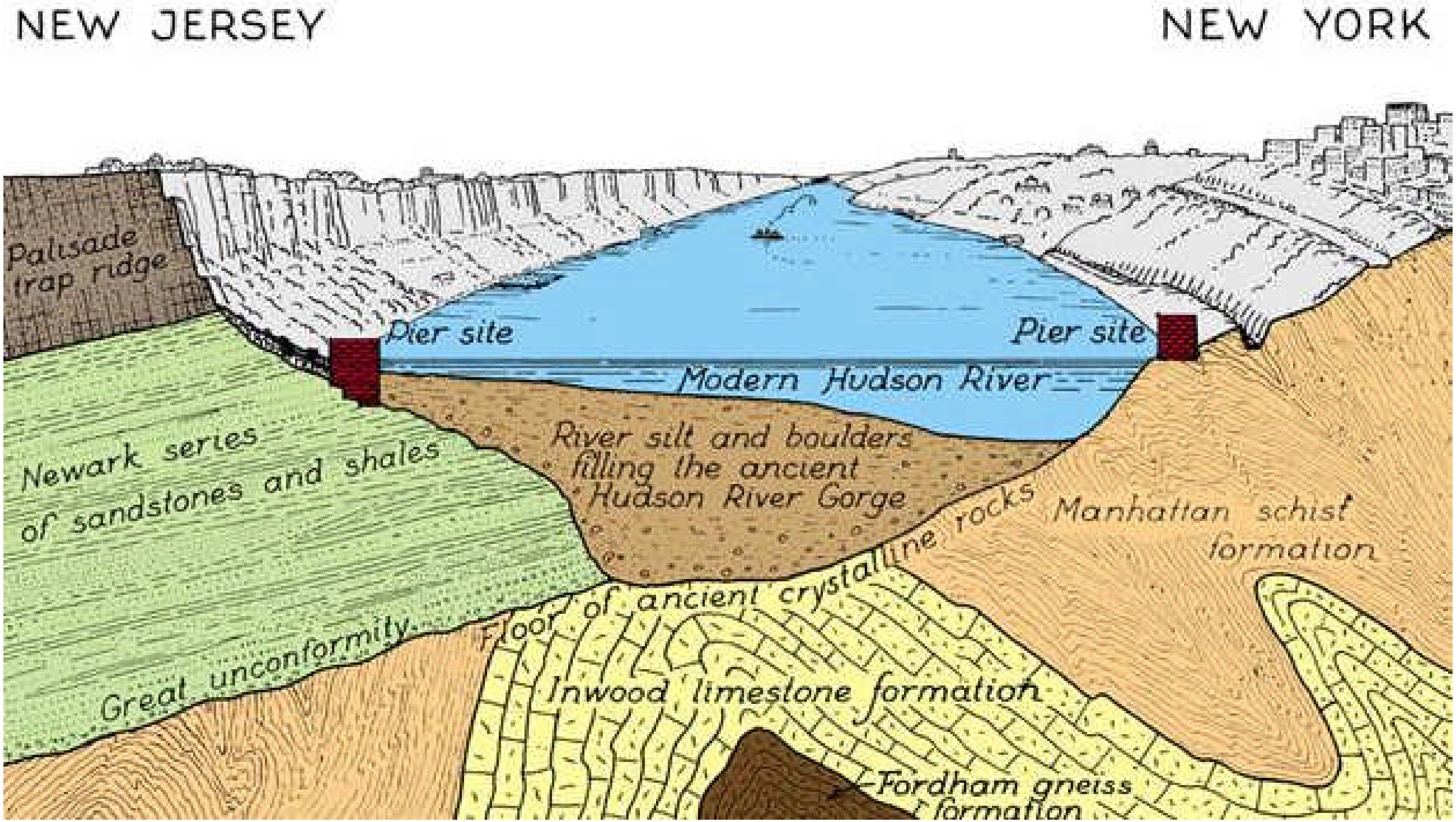
Right: caption: "Aerial view of the George Washington Bridge under construction"



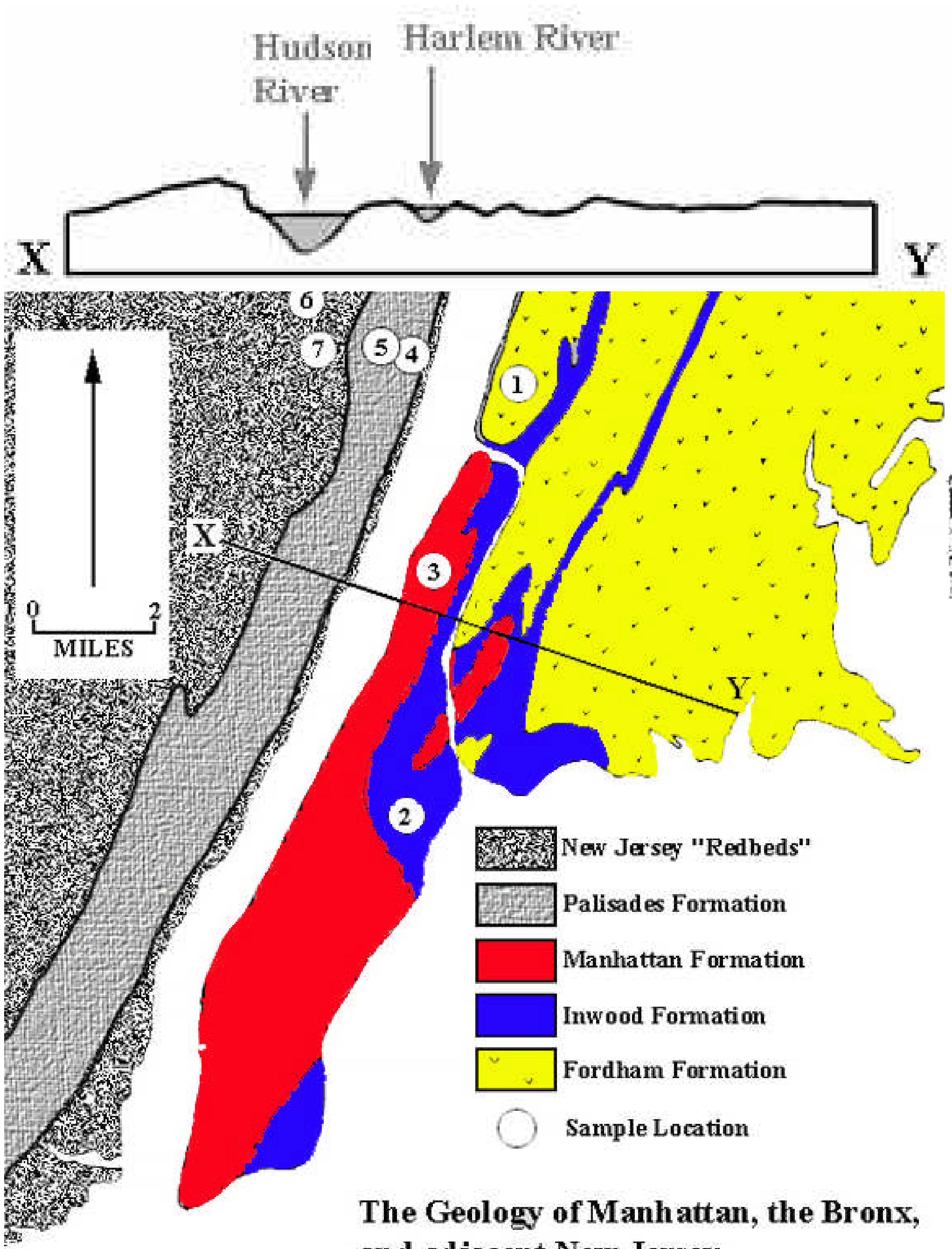
"…On the side of the New York pier lies a deep stratum of hard crystalline schist, resting in its turn on strata of limestone and gneiss. The underlying rock on the New Jersey side consists of sandstone and shale, with the Manhattan schist a long way below it, a big fault being situated beneath the river bed towards the New Jersey side. The bed of the Hudson River consists of silt, with boulders filling up the ancient gorge, and the New Jersey pier had to be sunk through this silt until it reached the underlying shale. The schist on the Manhattan side, however, rises right to the surface below the heights of Fort Washington Park, which face Fort Lee across the river. Above the stratum of shale on the New Jersey side lies one of ancient volcanic rock, and in this the western anchorage of the bridge cables were embedded…"

***Wonders of World Engineering*, November 1937**

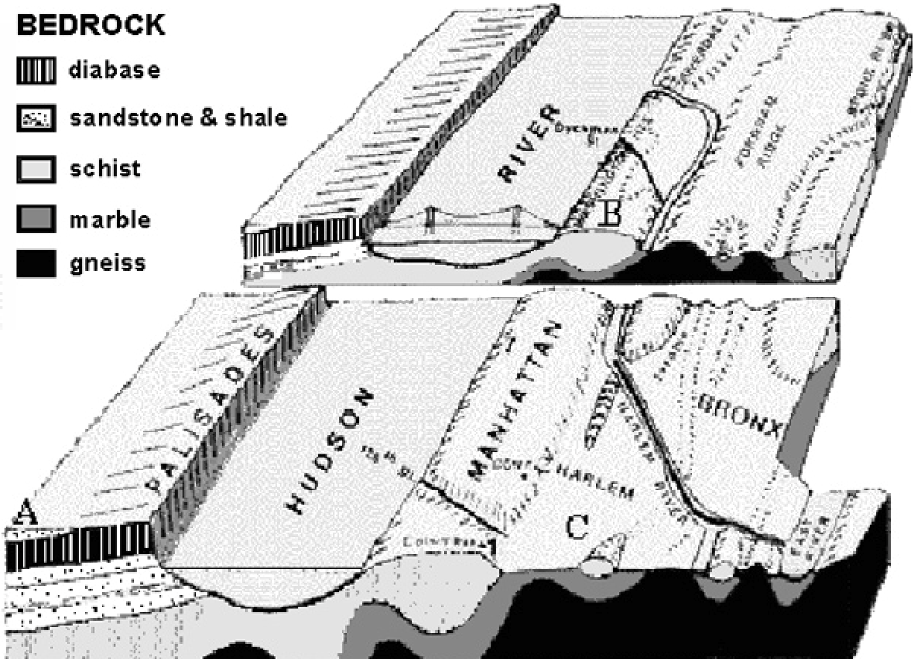
Above: caption: "Scaled drawing of the GWB and surrounding land form"



Above: caption: “Interpretive geologic section across the Hudson River in the vicinity of the George Washington Bridge showing westward tilted strata”



The Geology of Manhattan, the Bronx, and adjacent New Jersey



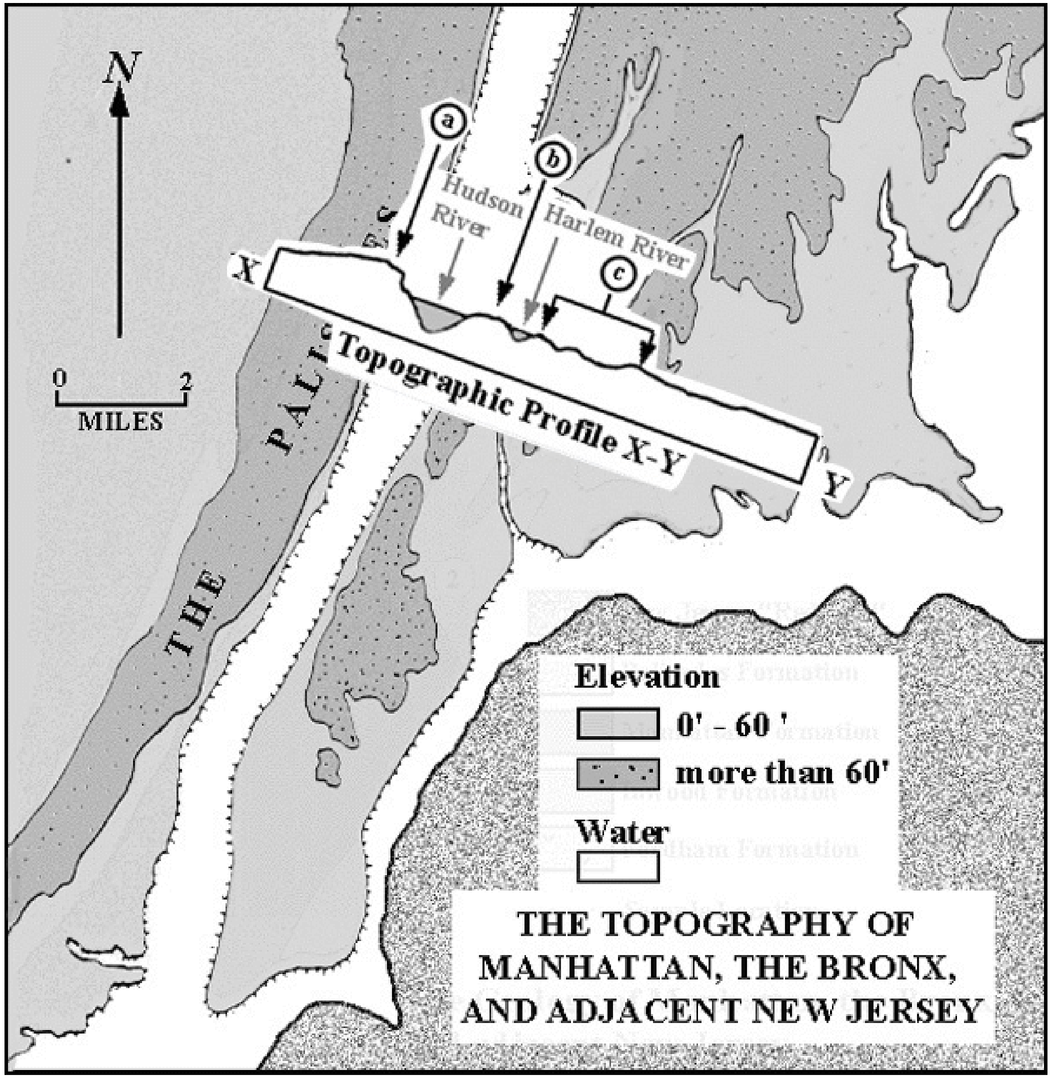
"…The strata on the New Jersey side lie at an inclination varying from 10 to 15 degrees downwards from the edge of the riverside heights. This natural accident is a favorable one, as it precluded the possibility of the rock sliding riverwards at some future date and carrying the foundations, anchorages and approaches with it. The New Jersey shore, known at this point as the Palisades Cliffs,, rises to a height of about 300 feet above the level of the river…"

***Wonders of World Engineering,* November 1937**

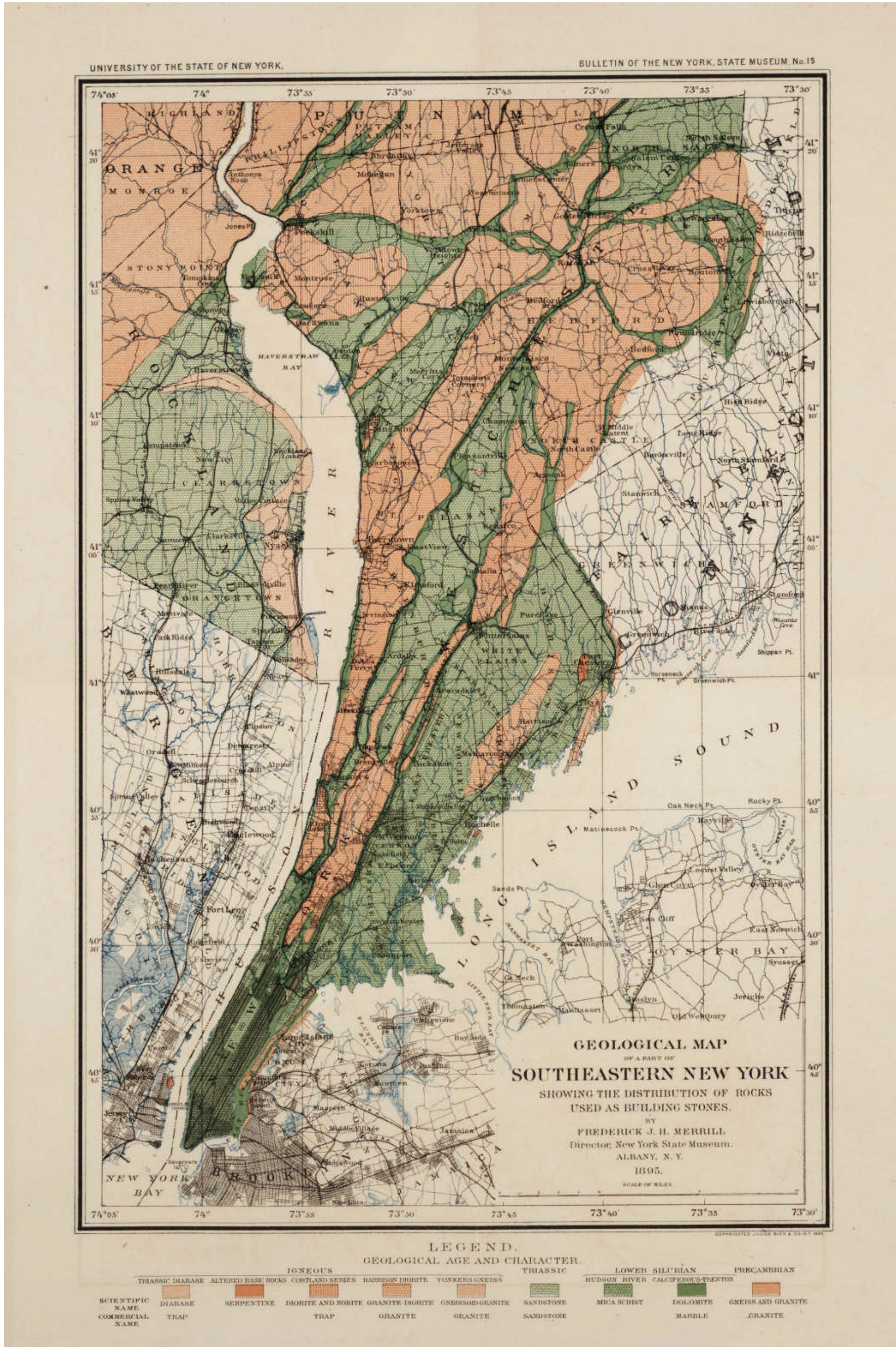
Above: caption: "Block diagram showing topography and bedrock geology"

"…Another engineering job of the first magnitude was the construction of the great piers on which the cable towers stand, especially on the Jersey side, where they are located in the river about fifty feet from the water's edge. Borings showed that the rock pitched sharply away from the shore to a depth of seventy-nine feet. Not only was this rock uneven, but it was covered with a fifty-five foot layer of mud. This problem was solved by sinking huge cofferdams – four-sided boxes open at the top and bottom and strong enough to resist terrific outside pressure as the water within was being pumped out. In this manner, the rock floor was exposed and then solid blocks of concrete were built inside the caissons. These blocks form the bases of the two legs on which the New Jersey tower rests. And the legs need to be sturdy, for each of the cable towers contains 20K tons of steel – the weight of 10K automobiles!..."

***Popular Science*, February 1929**



Left: caption: “Simple topographical map of Manhattan, the Bronx, and the Palisades of New Jersey. Elevations of land surfaces are indicated. With the exception of mid and lower Manhattan, much of the region is characterized by a series of elongated hills (called ridges) and valleys that are roughly parallel to (a) each other, (b) to the length of Manhattan, and (c) to the Hudson and parts of the Harlem and East Rivers. The Palisades is an elongated ridge that parallels the shore of the river. The east-side of the ridge is a sheer cliff that rises hundreds of feet. The west-side of the ridge slopes gently downward to the west. The topographic profile X-Y illustrates the asymmetric character of the Palisades ridge and also shows details of the topography of northern Manhattan and the South Bronx.

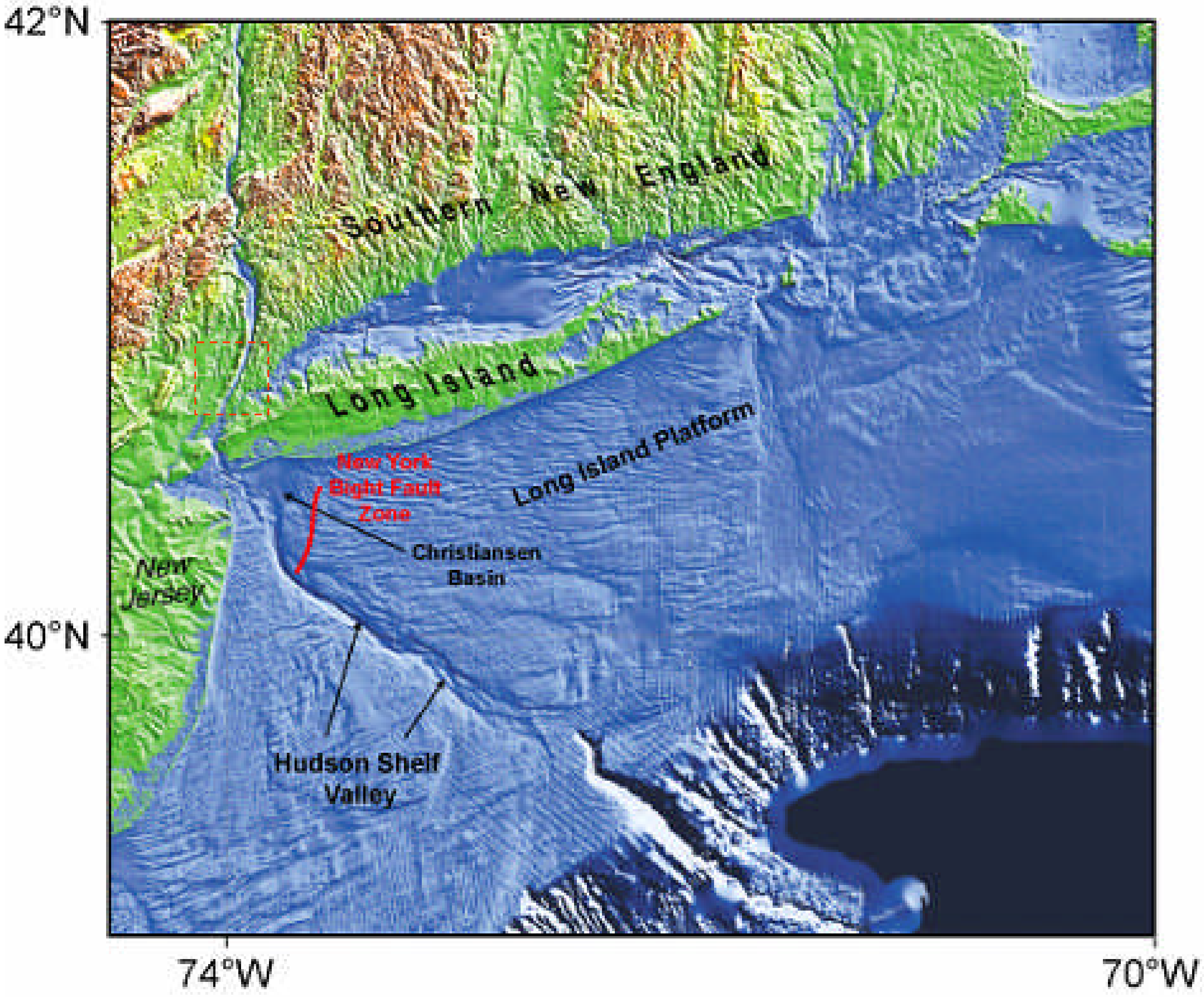


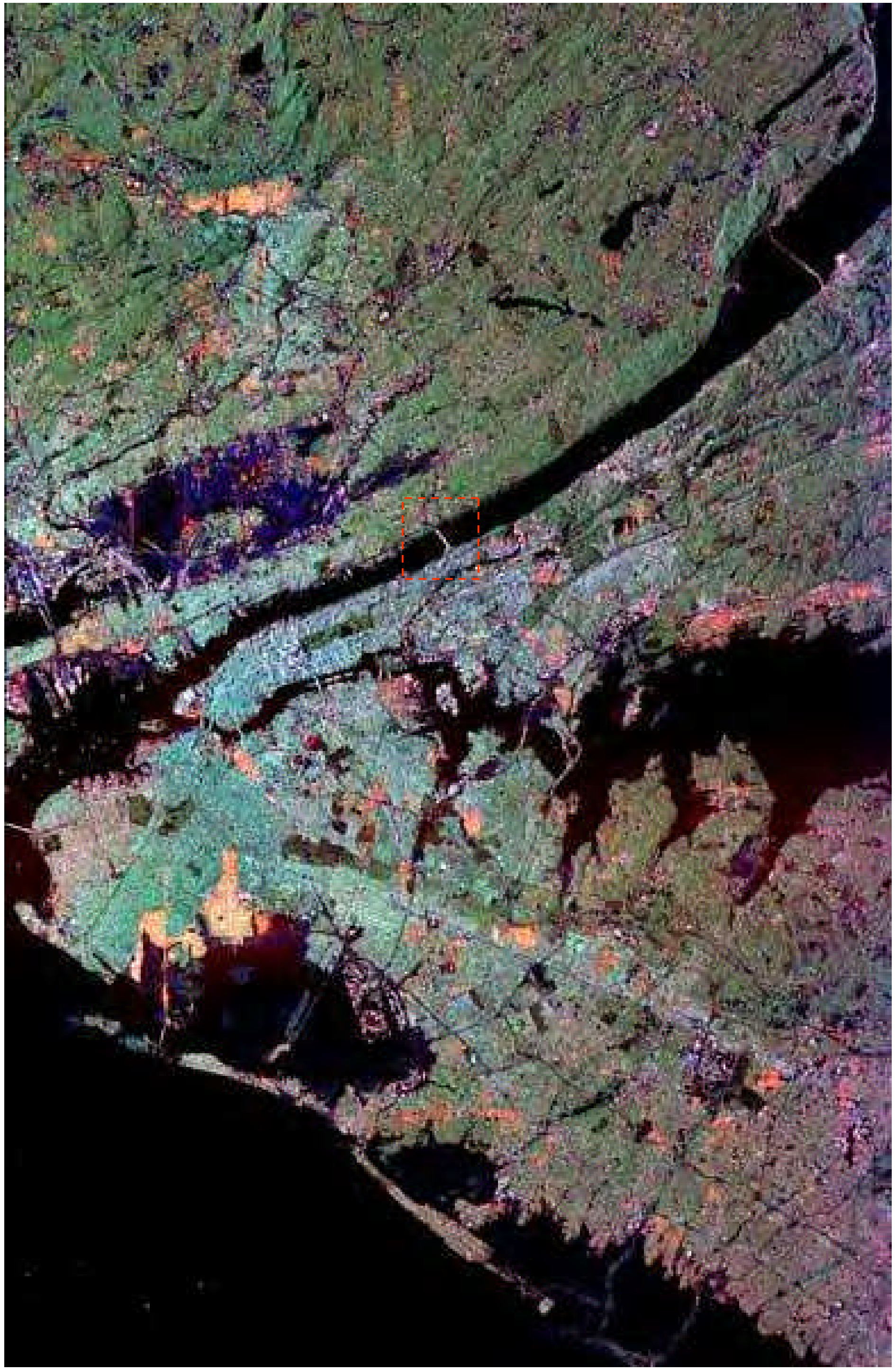
"…Dr. Charles Bakey was the expert chosen to explore the nature and strength of the rocks, and he was afterwards retained as Consulting Geologist. Berkey's examinations showed that the rock formations on the New Jersey side varied in strength so as to withstand a pressure ranging from 3,000 lbs. to 24,000 lbs. per sq. in. The average strength he estimated at about 14,000 lbs. per sq. in., more than thirty times the pressure to be imposed upon it by the base of the New Jersey tower…"

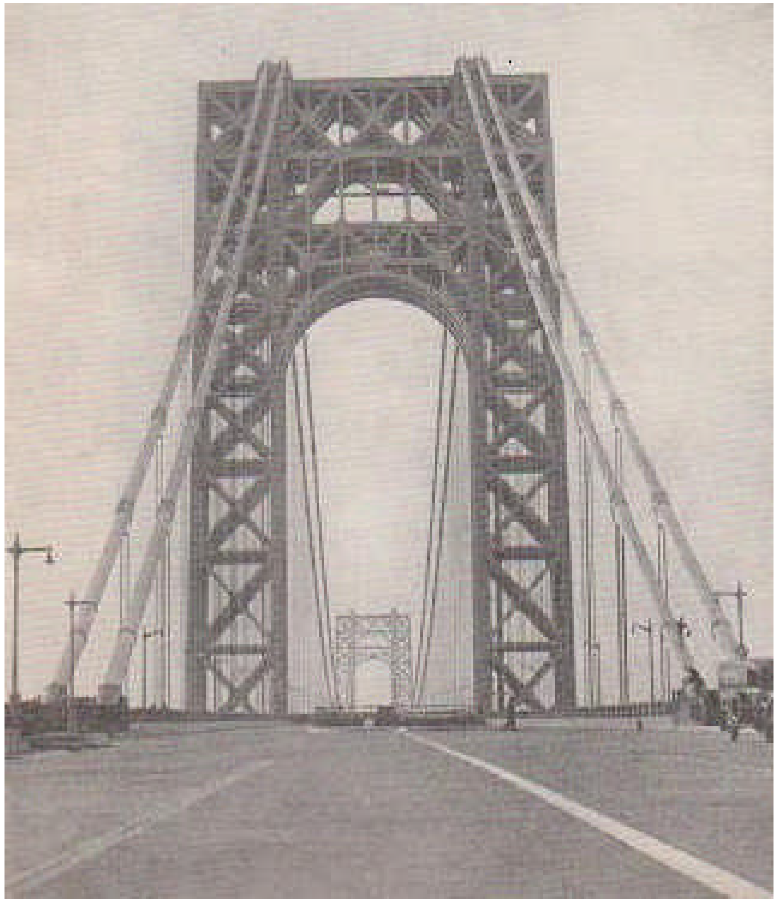
***Wonders of World Engineering*, Nov. 1937**

<u>Left</u>: Geological map of the Southeastern region of New York State

<u>Above</u>: Palisades Cliffs (*Fort Lee, NJ*)


42°N
Southern New England
Long Island
Long Island Platform
New York Bight Fault Zone
Christiansen Basin
New Jersey
40°N
Hudson Shelf Valley
74°W
70°W





"…O.H. Ammann, who produced the preliminary design of 1923, was appointed Bridge Engineer, and he chose his colleagues and staff well and carefully. His bridge gives a clear headway of 213 feet above the river in the middle…"

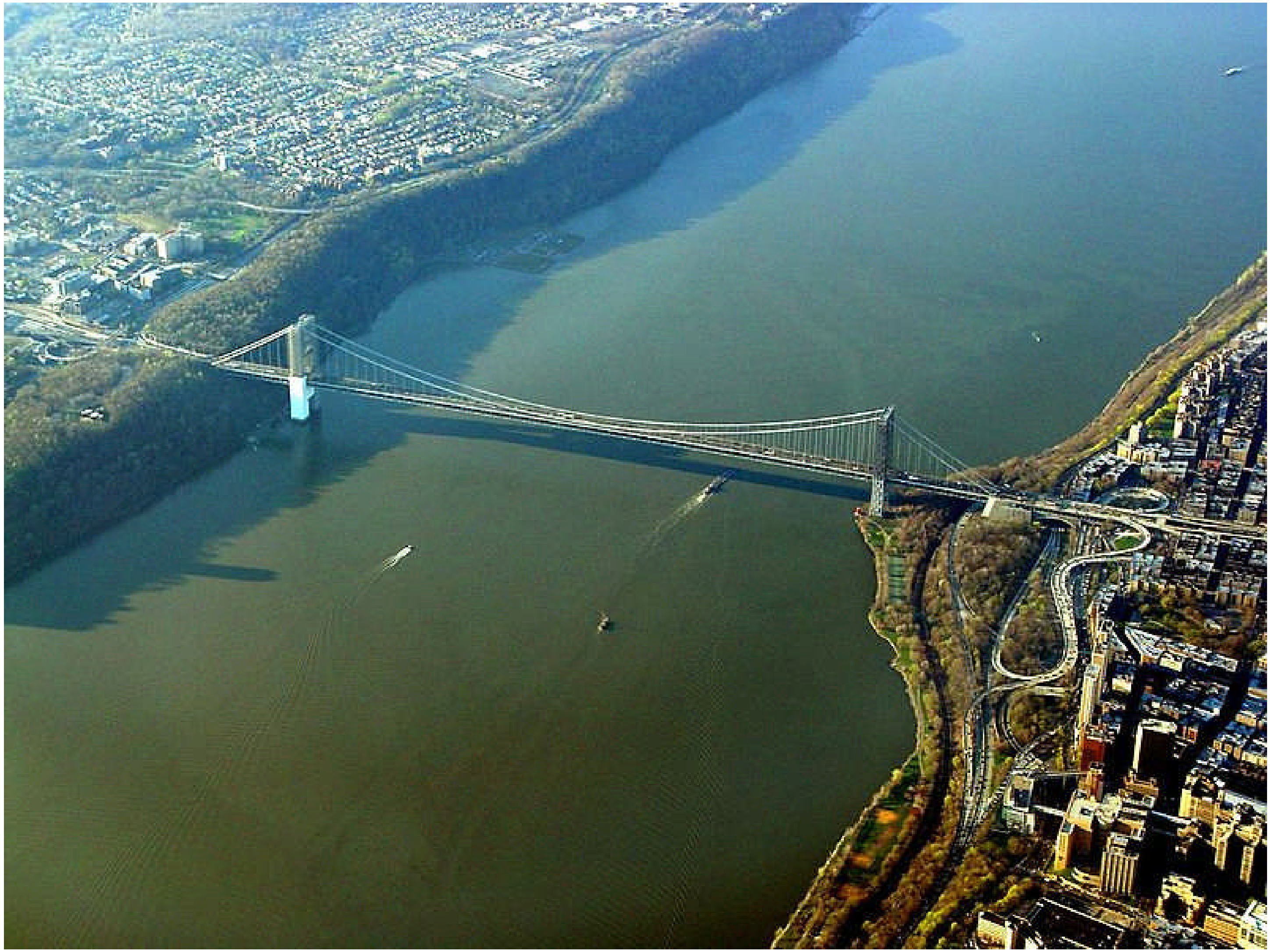
***Wonders of World Engineering,* November 1937**

Left: caption: "The roadways of the bridge converge at either end into a great marshalling space or 'plaza.' There are three roadways across the bridge itself. The central roadway, 30 feet wide, is flanked on either side by two 28 ft. 9 in. wide roads and by two 10 ft. 9 in. sidewalks, forming promenades along the outermost edges of the deck."

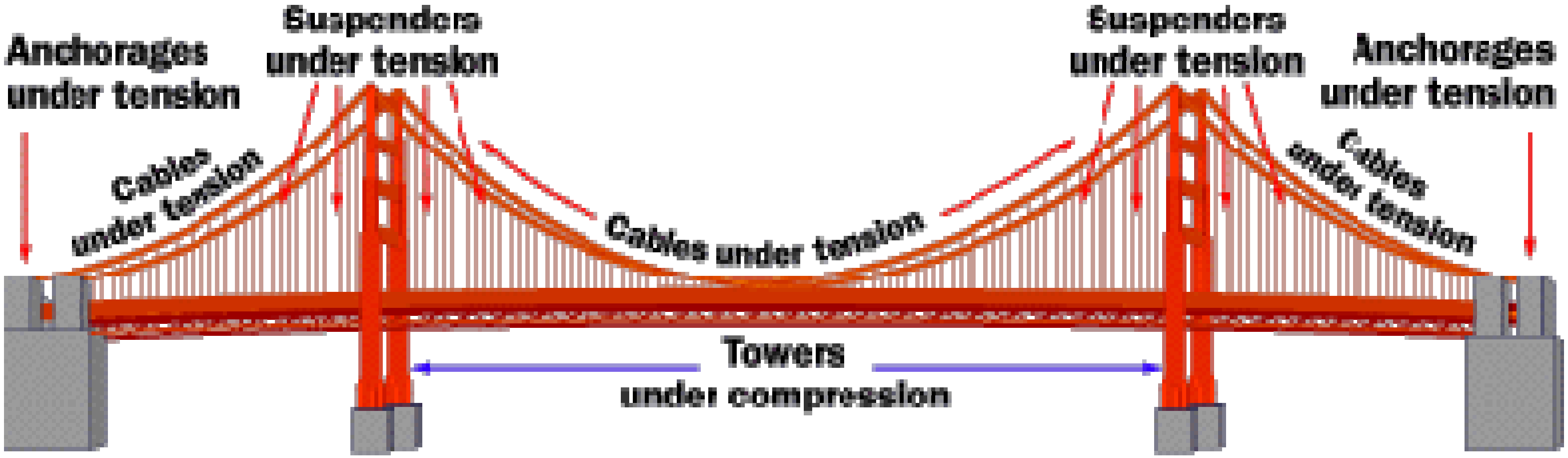
"…the bridge has a total length, between anchorages, of 4,700 feet. The total length of the bridge and its approach ramps is, however, nearly double this, for it amounts to 8,716 feet, or over a mile and a half. The headway just inside the Manhattan pier is 195 feet, and at a similar point on the New Jersey side it is as much as 210 feet clear, for the New Jersey shore is higher at its summit than that of Manhattan…"

Wonders of World Engineering, **November 1937**

Above: caption: "Spanning the Hudson River between the Washington Heights section of Manhattan and Fort Lee, New Jersey, the George Washington Bridge carries I-95, US 1 and US 9. US 46 also runs over the New Jersey portion, ending unannounced at the state line. The bridge feeds a toll-free section of I-95 maintained by the New Jersey Turnpike Authority. The bridge itself is a facility of the Port Authority of New York and New Jersey, as is the George Washington Bridge Bus Station."

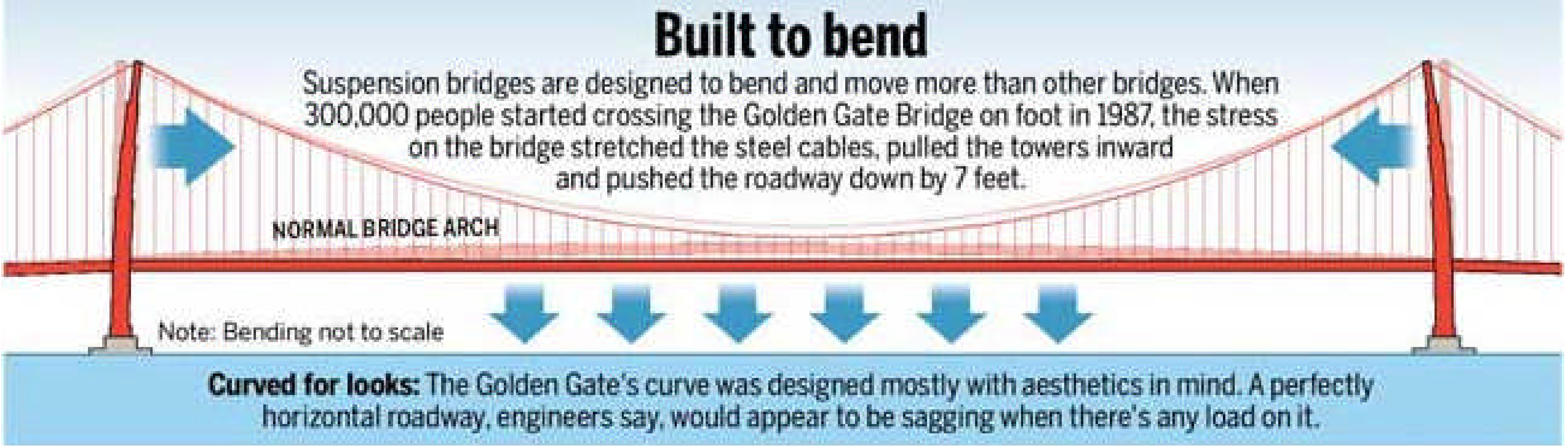


Built to Bend

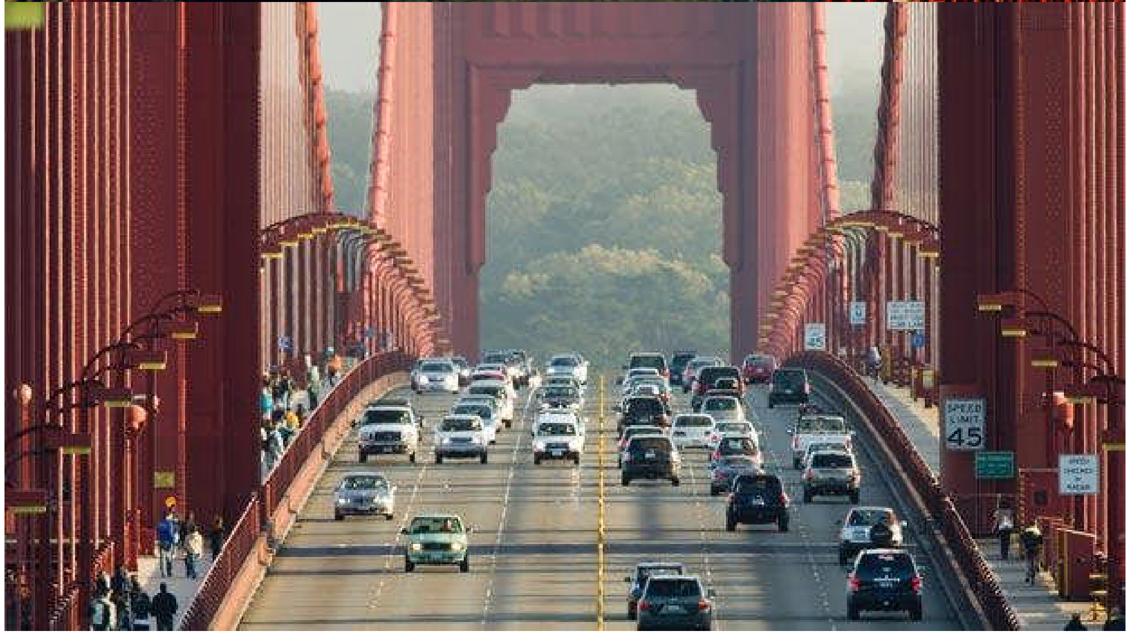


"…How much will such a huge suspension bridge sag, and how will wind and weather affect it? Here is the engineer's answer: the bridge floor will have a camber or arch of eleven feet, giving a clearance, under normal temperature and without a load, of 206 feet above mean high water at the center of the bridge and 195 feet at each tower. This provides the required elasticity, so that the structure will be able to adjust itself to expansion and contraction in its cables under summer heat and winter cold. But under normal circumstances, for example, on a very hot day when the bridge is burdened with an unusually heavy load, there will be a flattening out of the camber at the center of the span. In this manner, the floor will drop about ten feet and still have an emergency safety margin."

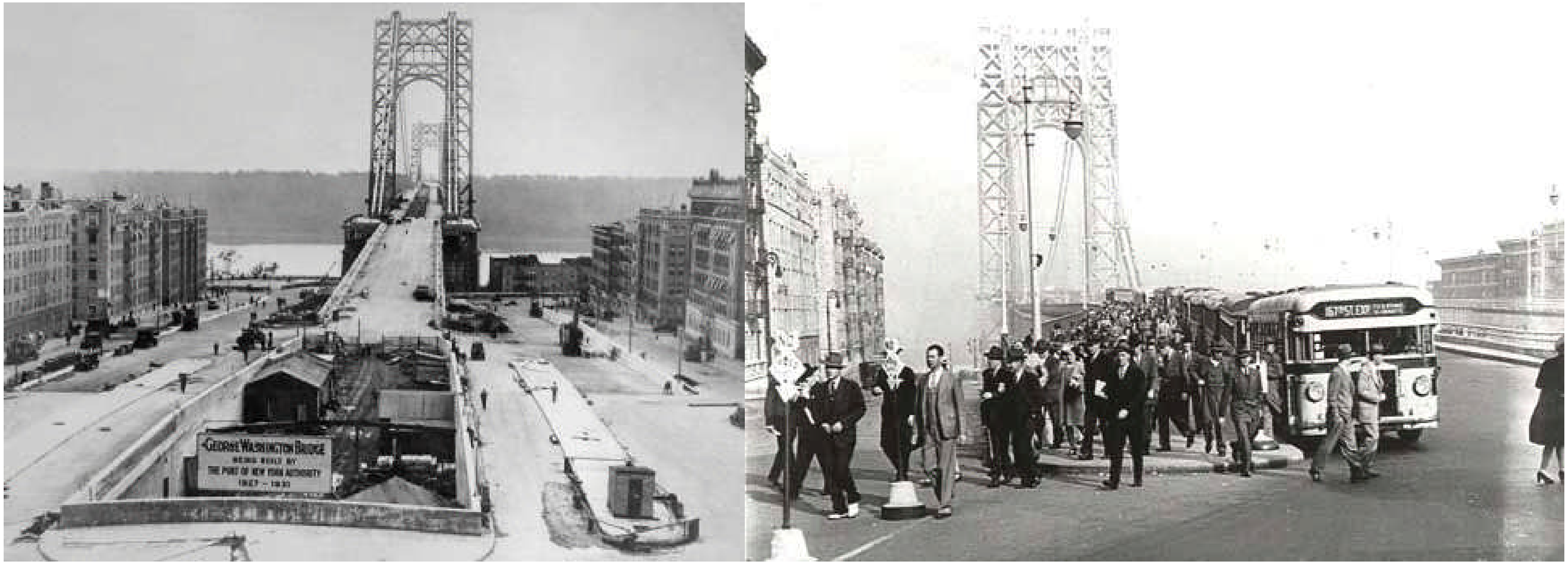
***Popular Science*, February 1929**



On May 24th 1987, 300K people were stuck in human gridlock for hours while getting a rare chance to cross the 1.7-mile *Golden Gate Bridge* on foot to celebrate the bridge's 50th Anniversary (1937-1987). Officials quickly closed the bridge (half-a-million other people waiting to cross never got the chance). The enormous, unprecedented weight caused the middle of the bridge to sag seven feet. Engineers said afterward that the bridge was never in danger of collapsing. On fully loaded suspension bridges the size of the Golden Gate, it's normal to have deflections of up to ten-feet. Suspension bridges are designed to bend and move more than any other bridge type. As such, the bridge was designed to move sixteen feet vertically and twenty-seven feet laterally without causing permanent damage. Assuming the average person weighs about 150 pounds and occupies about 2.5 square-feet in a crowd, there would have been about 5,400 pounds for every lineal foot of bridge that day - more than double the weight of cars in bumper-to-bumper traffic. Originally, the bridge was engineered to hold 4K pounds per lineal foot. During the mid-1980s, the concrete deck was replaced with a lighter steel framework, boosting that capacity to 5,700 pounds per lineal foot. The designers of the Golden Gate Bridge over-engineered the bridge to accommodate at least an additional 150 percent weight burden. Even if the crowd had exceeded that safety buffer, the deck would have deformed rather than break.


SPEED LIMIT 45

May 24th 1987

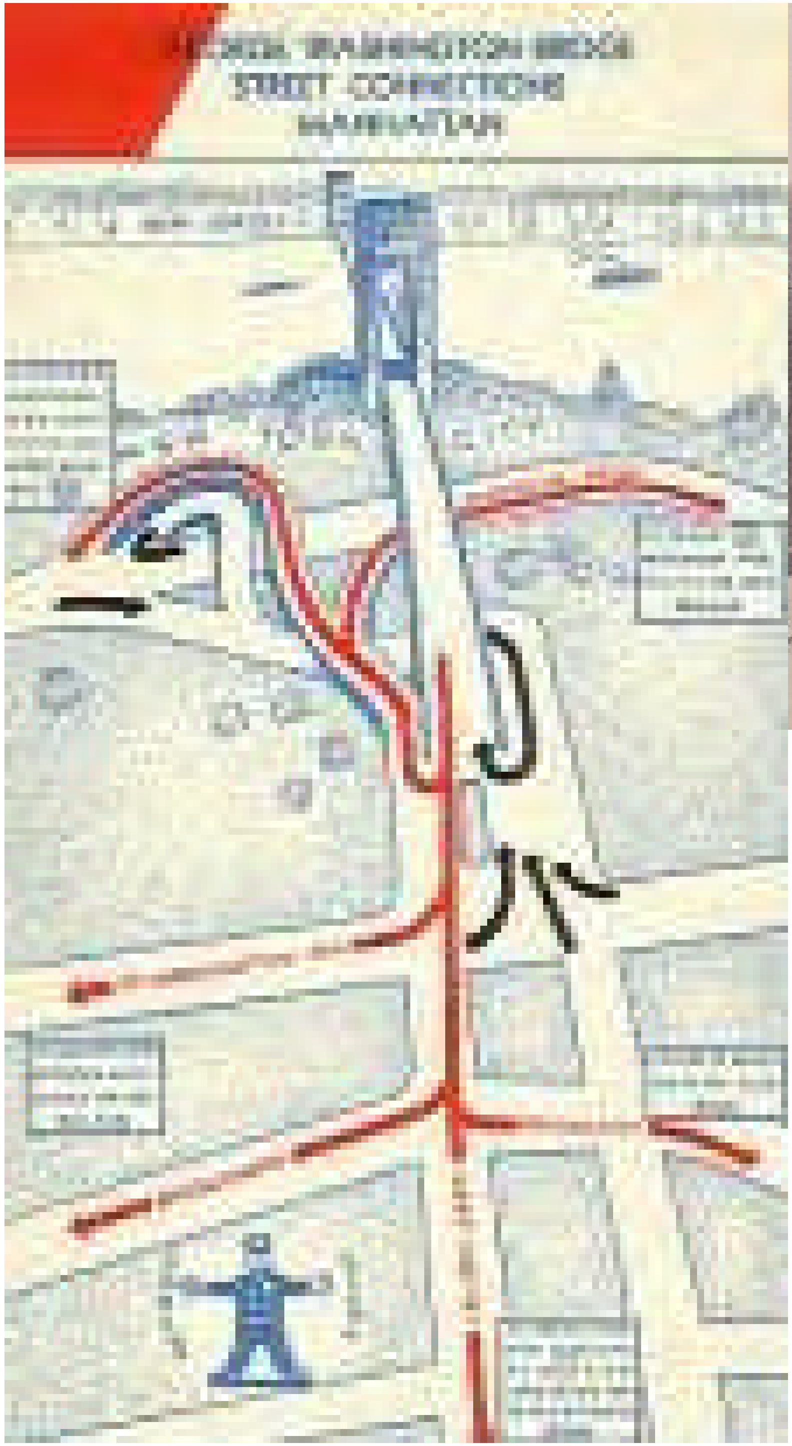


“…At either end of the bridge is a broad circulating area or ‘plaza’ for the marshalling of traffic, which converges on the bridge from all directions. The plaza on the New York side lies between 178th and 179th Streets, whose western ends it has swallowed up. In addition to the main ramps leading to these plazas, there are tunnels for road traffic and for rail connections, though the lower deck of the bridge, designed to carry the rails, was not made part of the first building program…Provision is made on the lower deck for four electric railway tracks in connection with the New York Rapid Transit system…”

***Wonders of World Engineering,* November 1937**

<u>Left</u>: caption: “10/19/1931 - New York - THE ROAD’S CLEAR...That will be the signal when the new Washington Memorial Bridge over the Hudson River is opened with appropriate ceremony. In the meantime, here's a new and unusual view of the structure from the New York end, showing the underground approach as well as the one on the surface and the exit. That’s NJ in the distance.”

<u>Right</u>: caption: “NJ commuters arriving by bus at the Manhattan bridge plaza transfer to NYC Subway”



<u>Above</u>: caption: "On the Manhattan side the approaches to the George Washington Bridge are arranged is such a way as to expedite the circulation of traffic and to give access from many neighboring streets."

<u>Left</u>: *Port of New York Authority* pamphlet showing *Washington Heights* area street connections to the GWB (ca. 1937)

Top Left: caption: “Manhattan bridge plaza bus terminal (Washington Heights)”

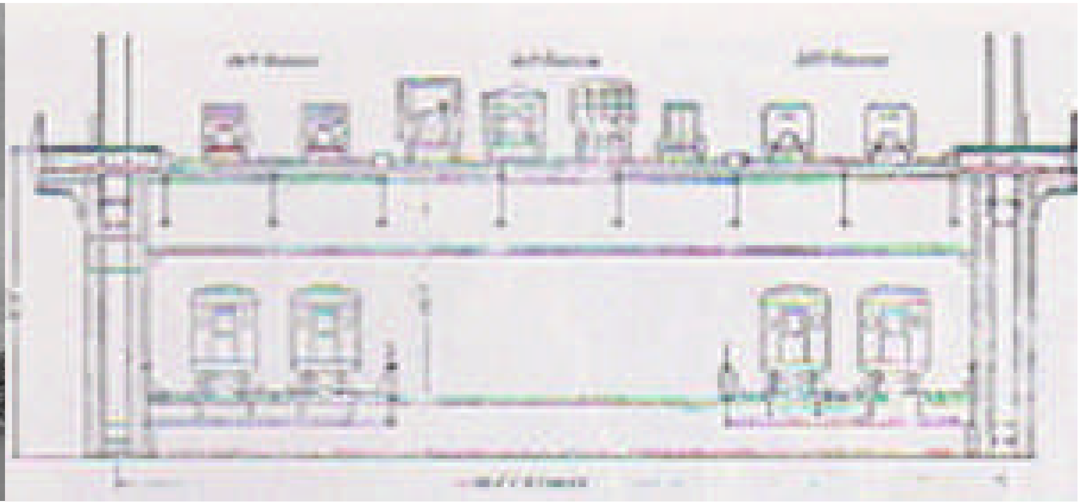
Top Right: caption: “New Jersey bridge plaza terminal (Fort Lee)”

Left: caption: “The 178th Street and 179th Street tunnels connected the George Washington Bridge with the Bronx. This 1952 photo shows the eastern portal of the 179th Street Tunnel. The tunnel has since been replaced by the Trans-Manhattan expressway.”

Top: caption: “This photo, also taken in 1952, carried traffic from the eastbound 178th Street Tunnel into the eastbound Washington (Heights) Bridge. This viaduct is still in use.”

Bottom: caption: “View from 2001 shows the Highbridge interchange looking west. Note the arched portal for the former 179th Street Tunnel on the right side of the photo. The old tunnel is now used as storage space. The 178th Street Tunnel was built before World War II, and the 179th Street Tunnel followed in the early 1950s. The two tunnels are both intact, but the ventilation buildings were demolished to make way for the Trans-Manhattan Expressway in the early 1960s, rendering the tunnels useless.”

At a More Leisurely Rate

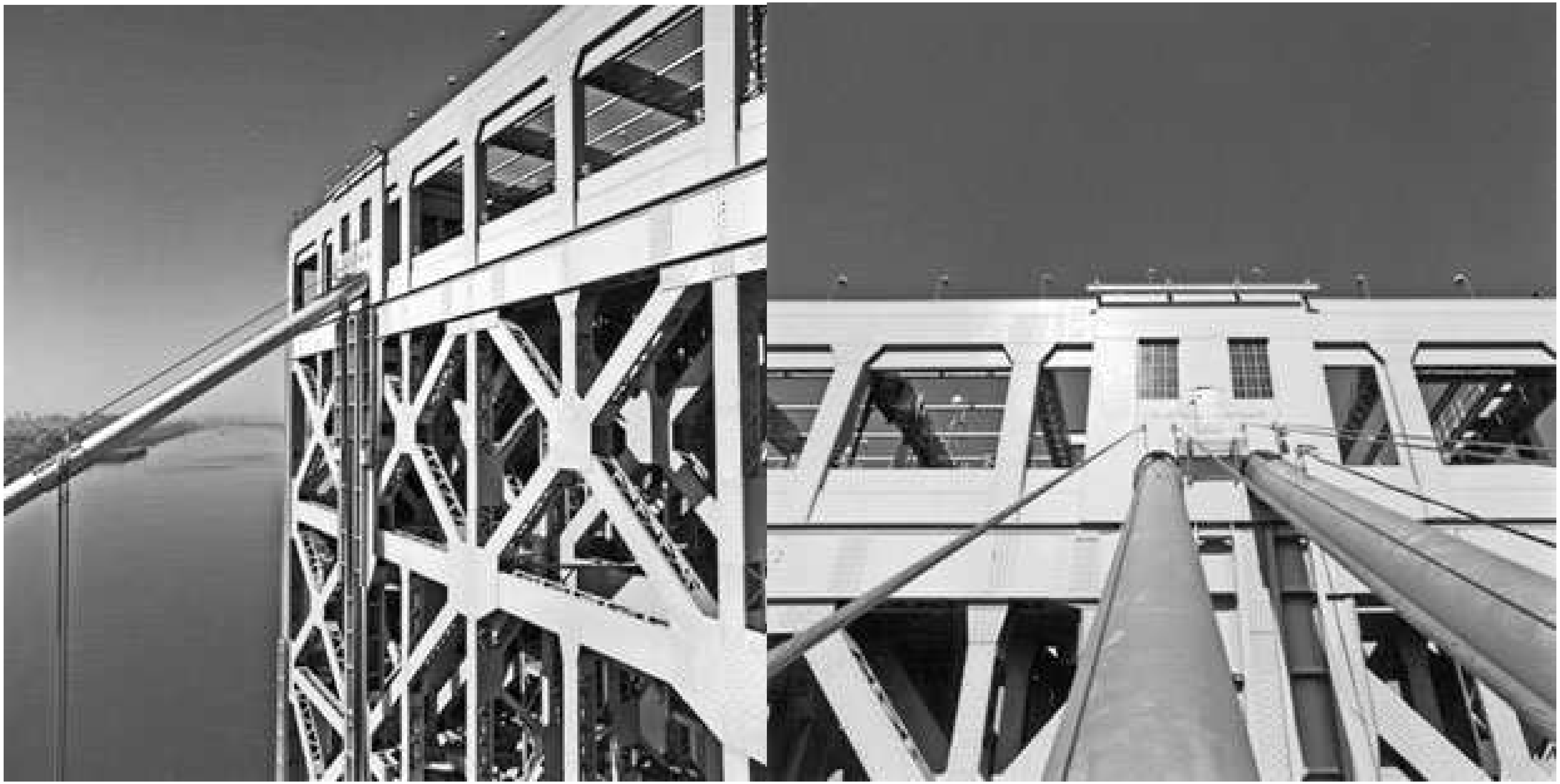


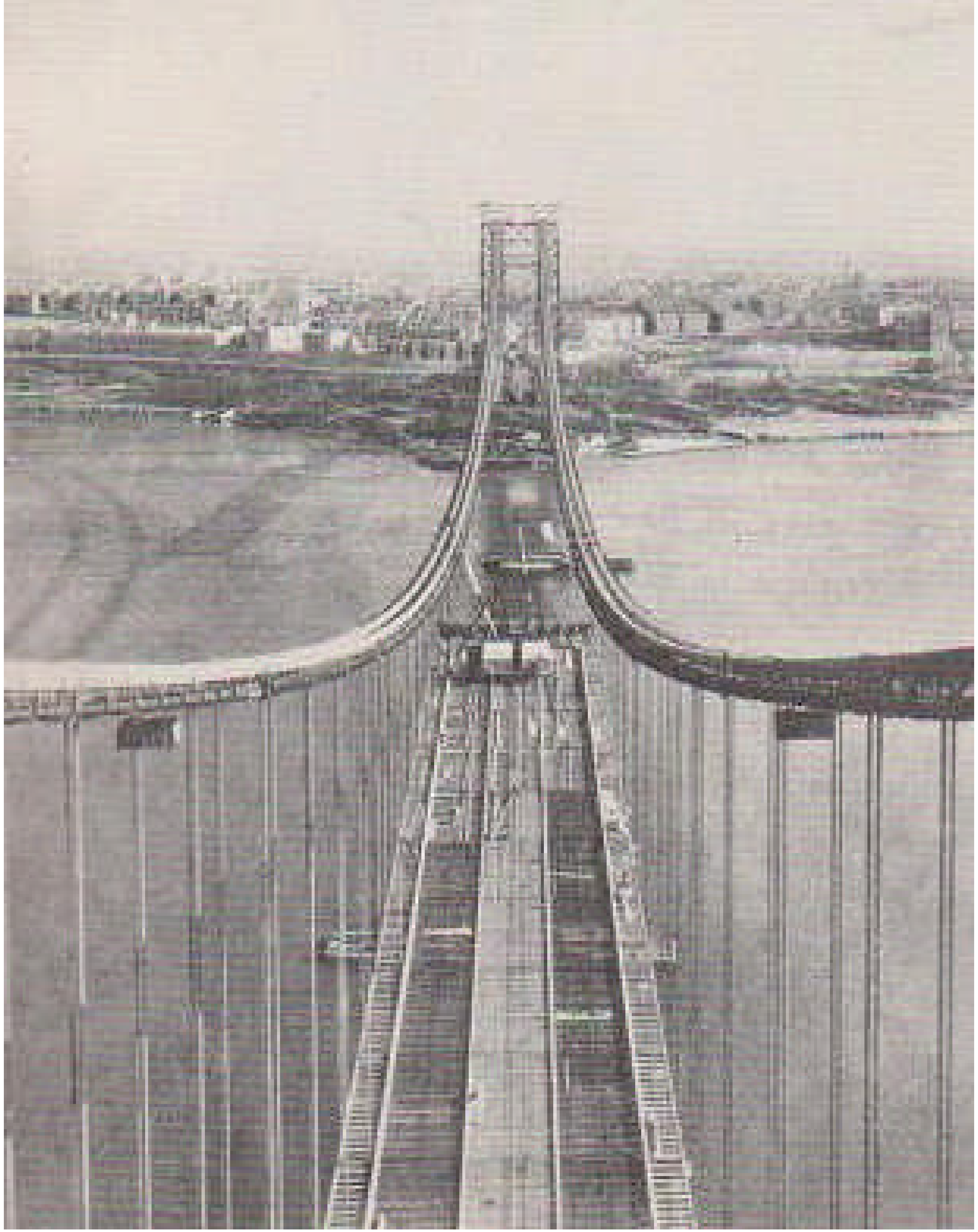
“…When the bridge was opened for traffic in 1932, the central carriageway on the upper deck, and the lower deck, with its electric lines, remained to be built. The aim of the engineer was not to complete the structure before opening it, but to relieve existing motor traffic congestion as rapidly as possible. Having provided a through way over the river for the most urgent requirements, he intended to complete the less badly needed features at a more leisurely rate. There is nothing new in this policy. It was observed, for instance, in the building of the Simplon Tunnel under the Alps between Brig (Switzerland) and Domodosolla (Italy), a single track tunnel having been opened some time before its companion was buiilt…”

***Wonders of World Engineering,* November 1937**

Left: caption: “The George Washington Bridge in 1932, one year after it opened, looking west across the Hudson River toward New Jersey. Note the lack of stiffening trusses on the deck. These trusses would not be added until the lower level was completed in 1962. Also note the exposed cable saddles atop the towers. An enclosure atop the towers was later added to protect the cable saddles.”

Right: caption: “A second deck could provide rapid transit or more auto lanes”





<u>Left</u>: caption: Building the Road Deck. Work proceeded simultaneously from either tower and the floor was completed on the central span in less than four months. This photograph was taken from the tower on the New Jersey side of the bridge.”

***Wonders of World Engineering*, November 1937**

Deflection Theory

“Based on comparison and on the theories we find in textbooks and other treatises on suspension bridges, we should expect the stiffening system of the George Washington Bridge to weigh from 13,000 to 14,000 pounds per foot and be eleven stories high. Actually, it weighs only 1,100 pounds per foot in the initial stage with only one deck for highway traffic and will weigh 2,350 in the final stage with two decks.”

O.H. Ammann

RE: engineering research and testing which allowed for a shallow stiffening truss due to the bridges’ own great dead-weight.

<u>Left</u>: initial single deck

"…With the Manhattan Bridge, Moisieff – a brilliant mathematician of Latvian origin, introduced the 'deflection theory' to America. The theory was formulated in Austria by Joseph Melan, an expert in reinforced concrete arches. Moisieff developed the theory's principles, applied them to long-span suspension design, and in so doing gave rise to all the slender bridges that proceeded…"

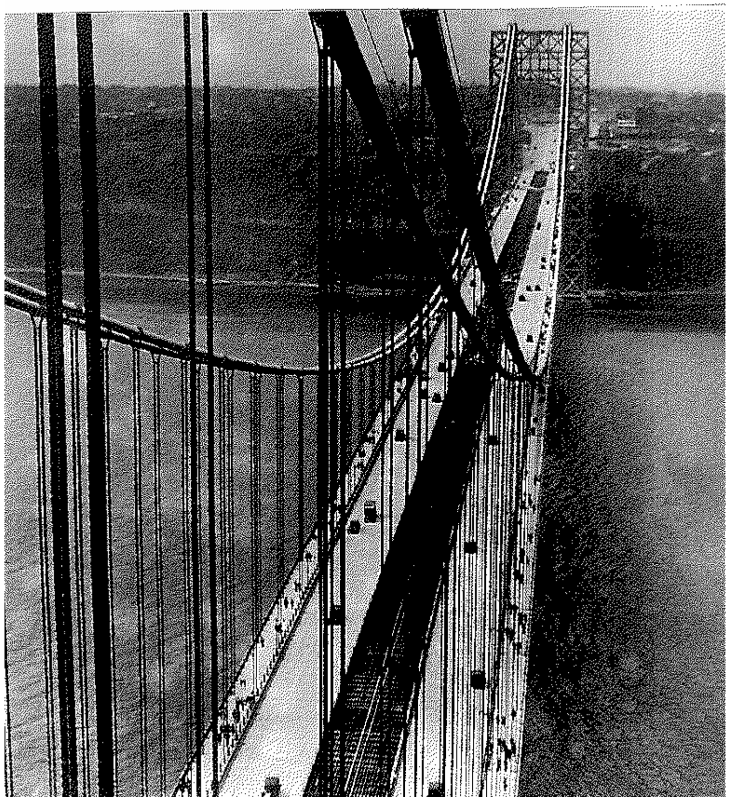
***Darl Rastorfer*, Author**

“…Deflection theory holds that as the deadweight of a suspension bridge increases per linear foot, the need for deck stiffness decreases, largely because the gravitational pull on monumental suspension cables, suspender cables, and un-stiffened decks alone is nearly sufficient to provide a level of resistance against the force of wind and moving traffic, eliminating the need for excessive add-on devices like stiffening trusses or cable stays…Moisieff translated this phenomenon into a series of mathematical formulas essential to the theory’s rational application. The equation’s overall impact on form, exemplified by the Manhattan Bridge, was profound. Every aspect of the bridge – even the towers – is delicate and made aerial in appearance by the reduction of hundreds of tons of iron and steel that otherwise would have been required by established design practice. Considerable cost savings accompanied this reduction, making the bridging of previously unbridgeable spans (such as the Hudson River) genuinely economical for the first time…”

***Darl Rastorfer,* Author**

"…Ammann's design for the Hudson River would be the first to rely on deflection theory for a suspension bridge of such great length – its clear span more than twice as long as the Manhattan Bridge's. Improvements in the quality and strength of materials contributed to the engineering, but Ammann's innovative application of the deflection theory was the most significant force in determining the bridge's form. The boldness of the design is magnified by the fact that the Manhattan Bridge had the stabilizing benefit of a double-deck span tied together with stiffening trusses…Ammann enhanced the rigidity of his road deck structure with a pair of deep girders to give the deck its ribbon-like appearance…"

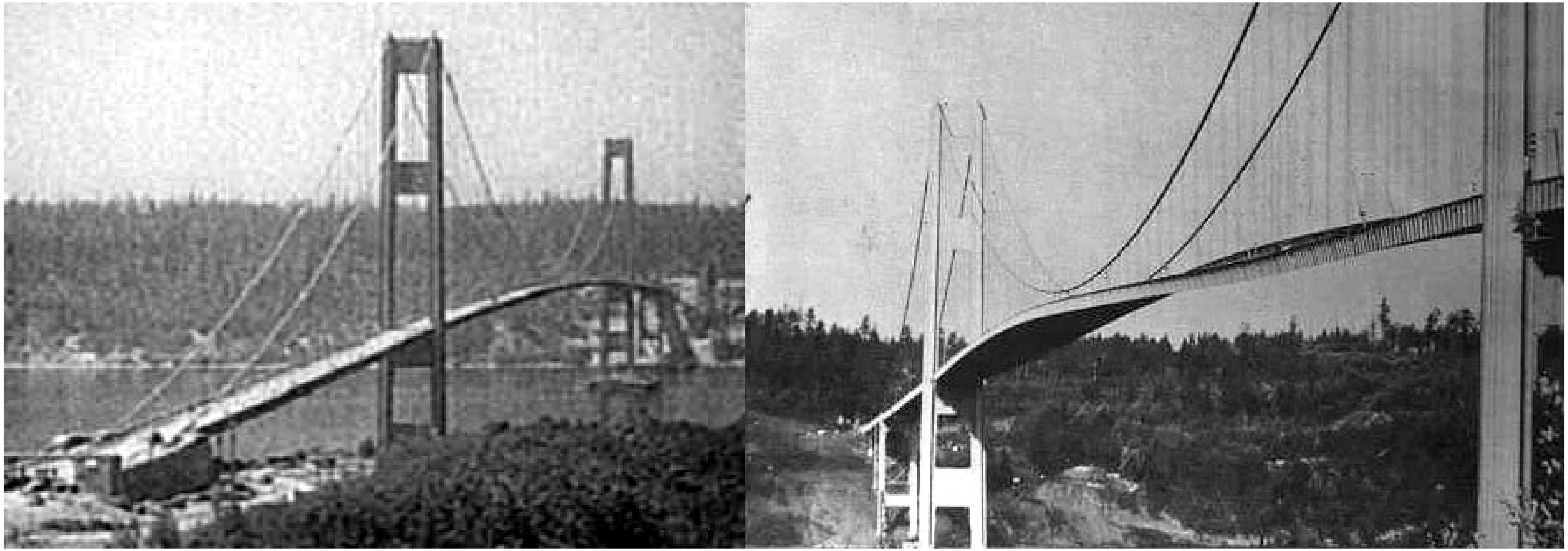
Darl Rastorfer, **Author**



‘We may now refute the conception held even by engineers that the length of span is the major economic factor in the construction of a large bridge, in that it is supposed to influence the cost about in proportion to the square of the span. Traffic capacity and the cost of foundations and approaches are apt to be far more important economic factors than were length of span.”

O.H. Ammann

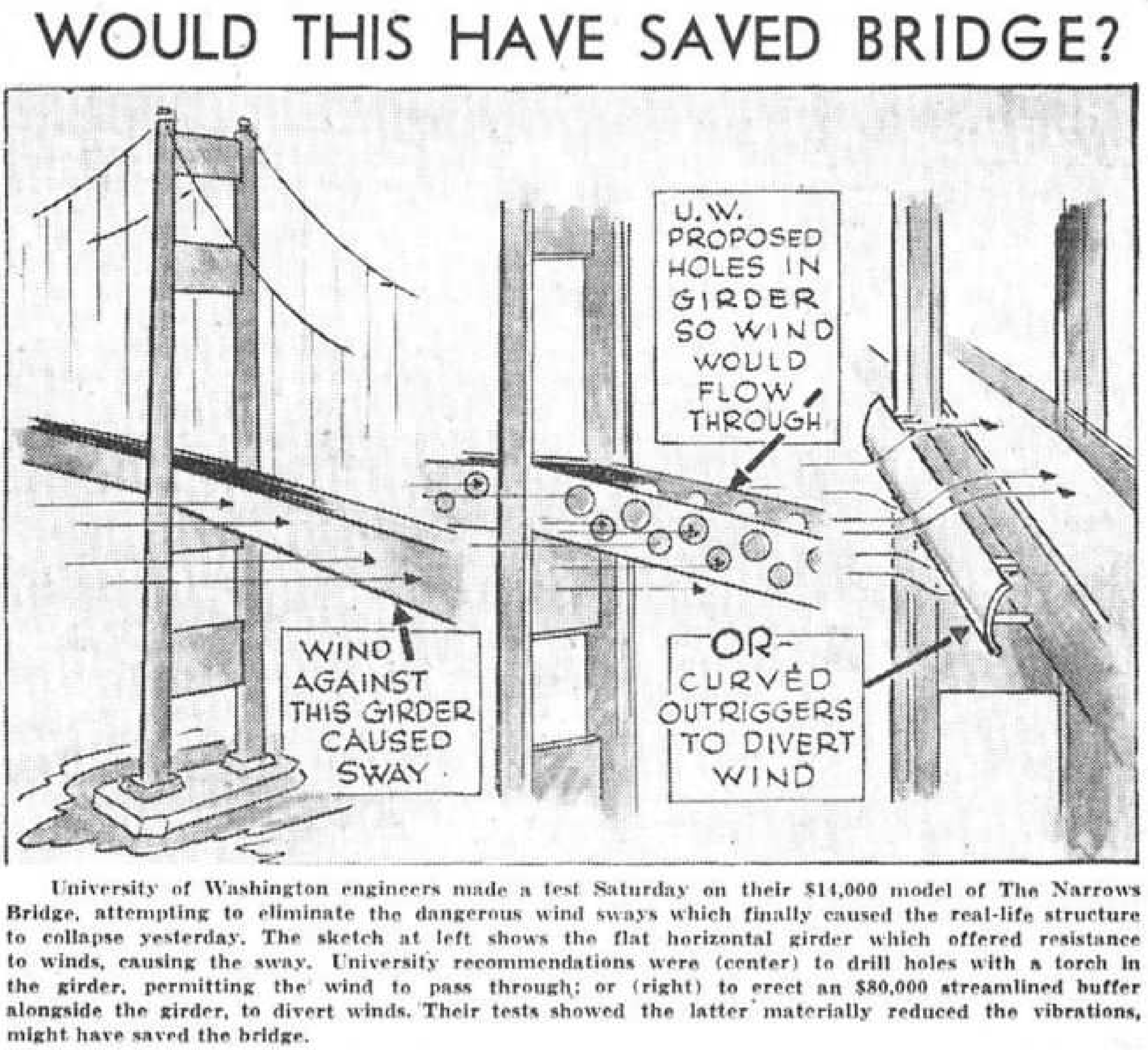
RE: feasibility and economy of long-span suspension bridges proven-out by the design and construction of the GWB using *Deflection Theory*.



"…In 1940, however, the extremes of Ammann's innovation were dramatically demonstrated in the wind-driven collapse of the aptly nicknamed 'Galloping Gertie,' otherwise known as the Tacoma Narrows Bridge. After his investigation of that famous failure, which had been captured on film for the nation to see, Ammann wrote, 'Its smaller weight and extreme narrowness has drastically revealed that this practice has gone too far.'"

Smithsonian **magazine, October 1999**

<u>Above</u>: the *Tacoma Narrows Bridge* (left) opened to traffic on July 1st 1940. *Leon Moisieff* designed the extremely narrow and long bridge using minimal stiffening and a plate girder truss. On November 7th 1940, the bridge failed due to excessive oscillations during a sustained 42 mph wind storm. Ammann served on the *Board of Engineers* examining the failure. Moisieff died a broken man in 1943.



WOULD THIS HAVE SAVED BRIDGE?

University of Washington engineers made a test Saturday on their $14,000 model of The Narrows Bridge, attempting to eliminate the dangerous wind sways which finally caused the real-life structure to collapse yesterday. The sketch at left shows the flat horizontal girder which offered resistance to winds, causing the sway. University recommendations were (center) to drill holes with a torch in the girder, permitting the wind to pass through; or (right) to erect an $80,000 streamlined buffer alongside the girder, to divert winds. Their tests showed the latter materially reduced the vibrations, might have saved the bridge.

The Price of Human Progress

“The Tacoma Narrows bridge failure has given us invaluable information...It has shown that every new structure that projects into new fields of magnitude involves new problems for the solution of which neither theory nor practical experience furnish an adequate guide. It is then that we must rely largely on judgment and if, as a result, errors, or failures occur, we must accept them as a price for human progress”

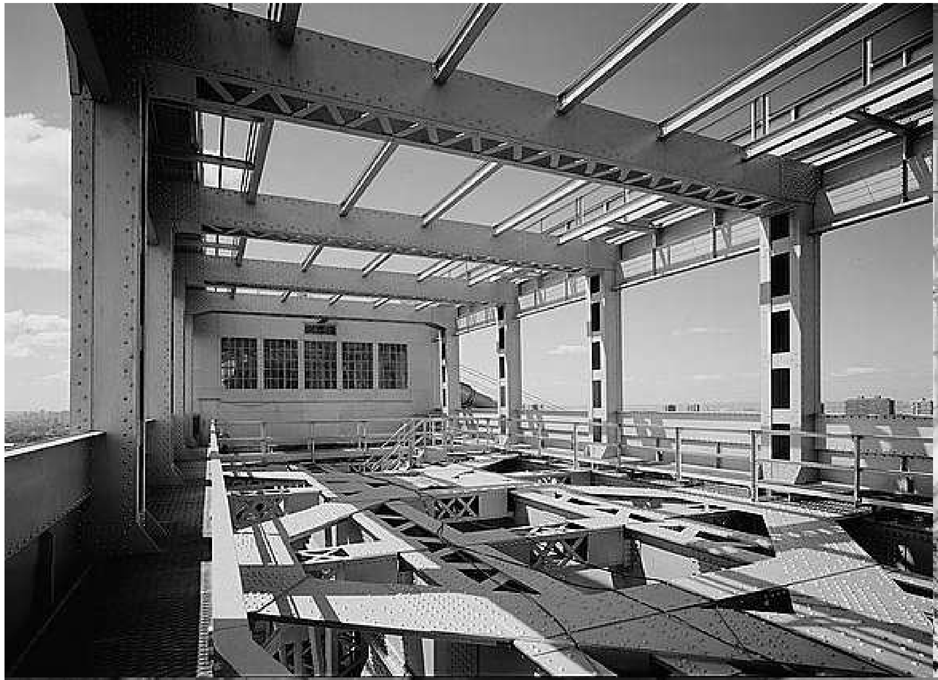
O.H. Ammann

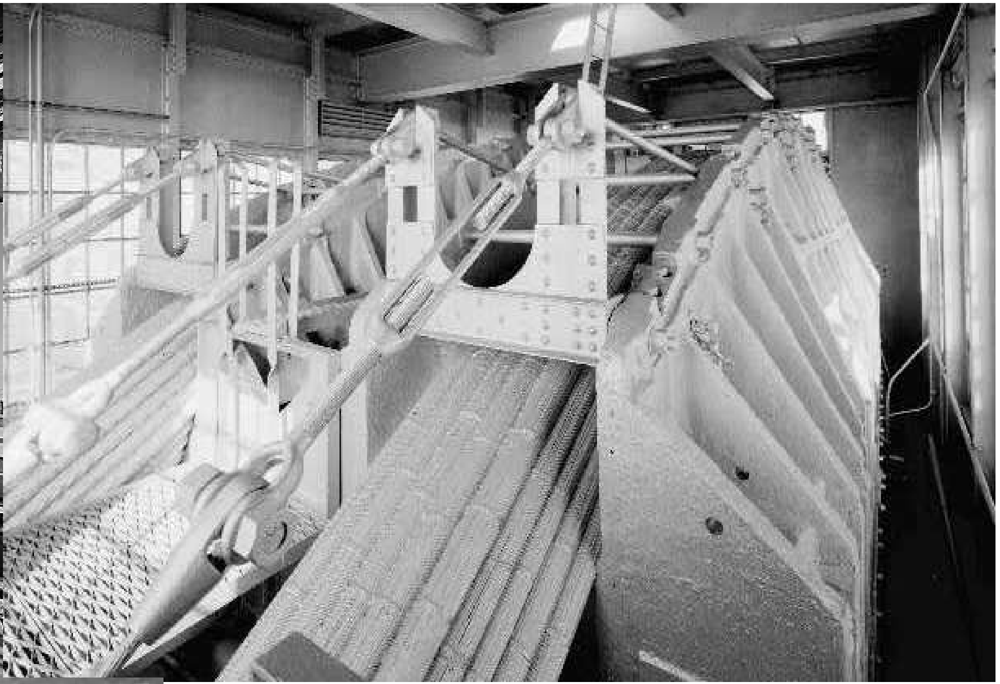
“…The cables of the George Washington Bridge are made up of stranded steel wire, over which squeezers were passed after they were in position. Each cable is a yard in diameter. They are arranged in two pairs, one pair on either side of the carriageways. The center of each pair of cables, that is, the point midway between the two, is 106 feet from the center of the neighboring pair. The centers of the cables in each pair are 9 feet apart. Thus the centers of the outside cables on either side of the bridge are 115 feet apart. These cables are supported on saddles mounted in the tops of the steel towers at a height of 591 feet above mean water level, and are 15 feet above roadway level in the middle of the span…the deck is supported from the cables by vertical suspenders…”

***Wonders of World Engineering*, November 1937**

Left: caption: “View of cable pair from pedestrian walkway (at bottom of their curve)”

Right: caption: “View of cable pair from tower”

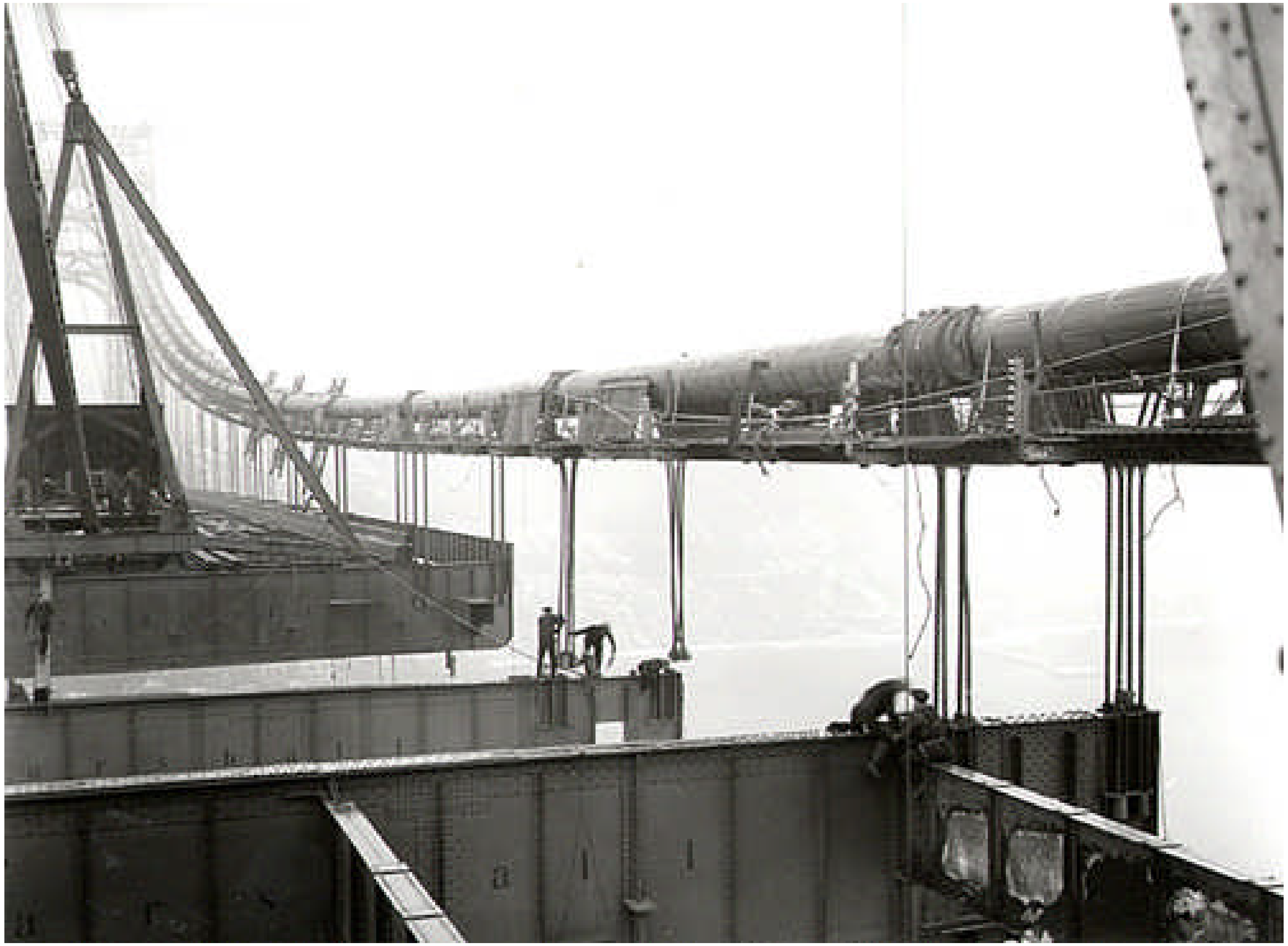


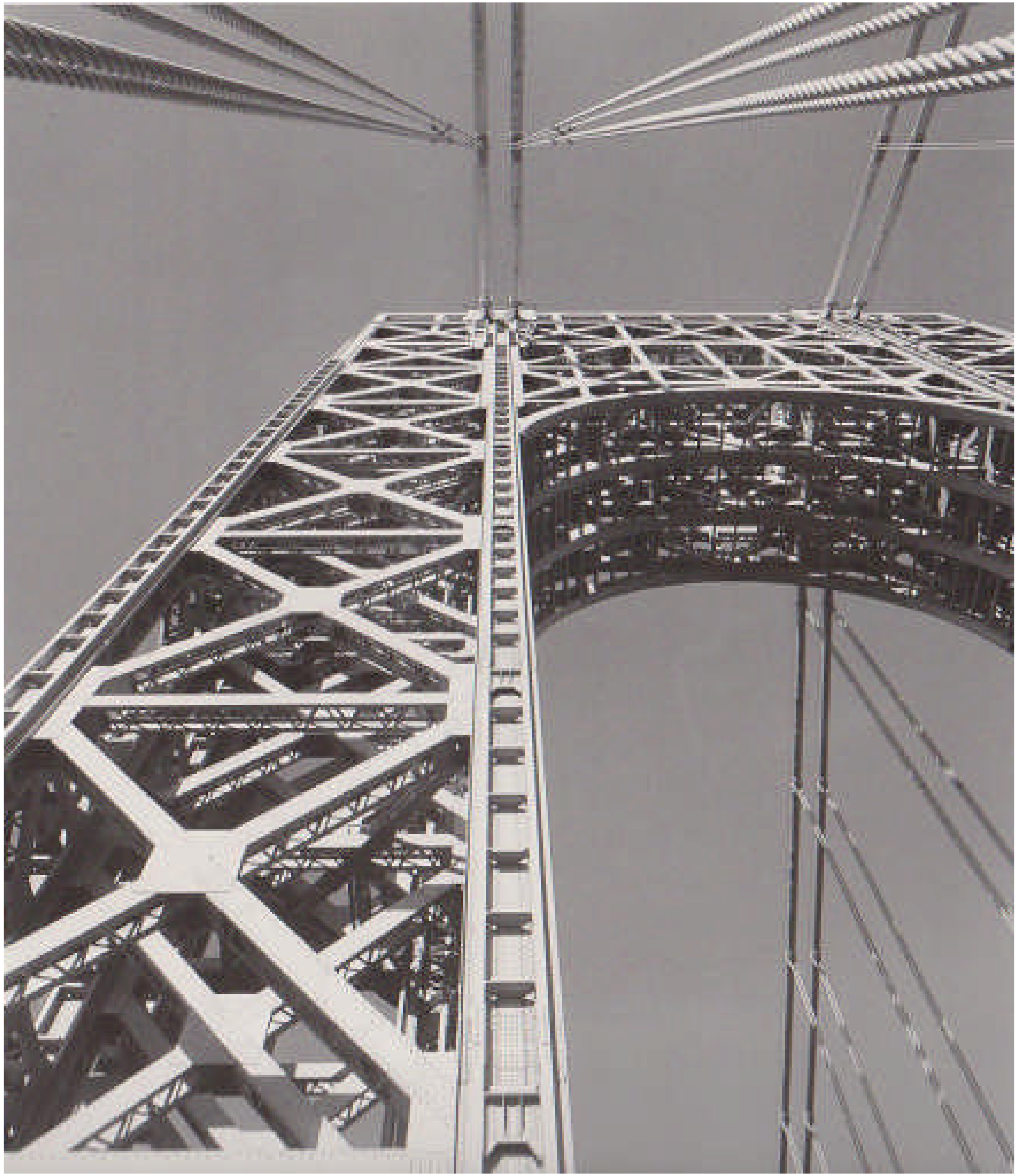


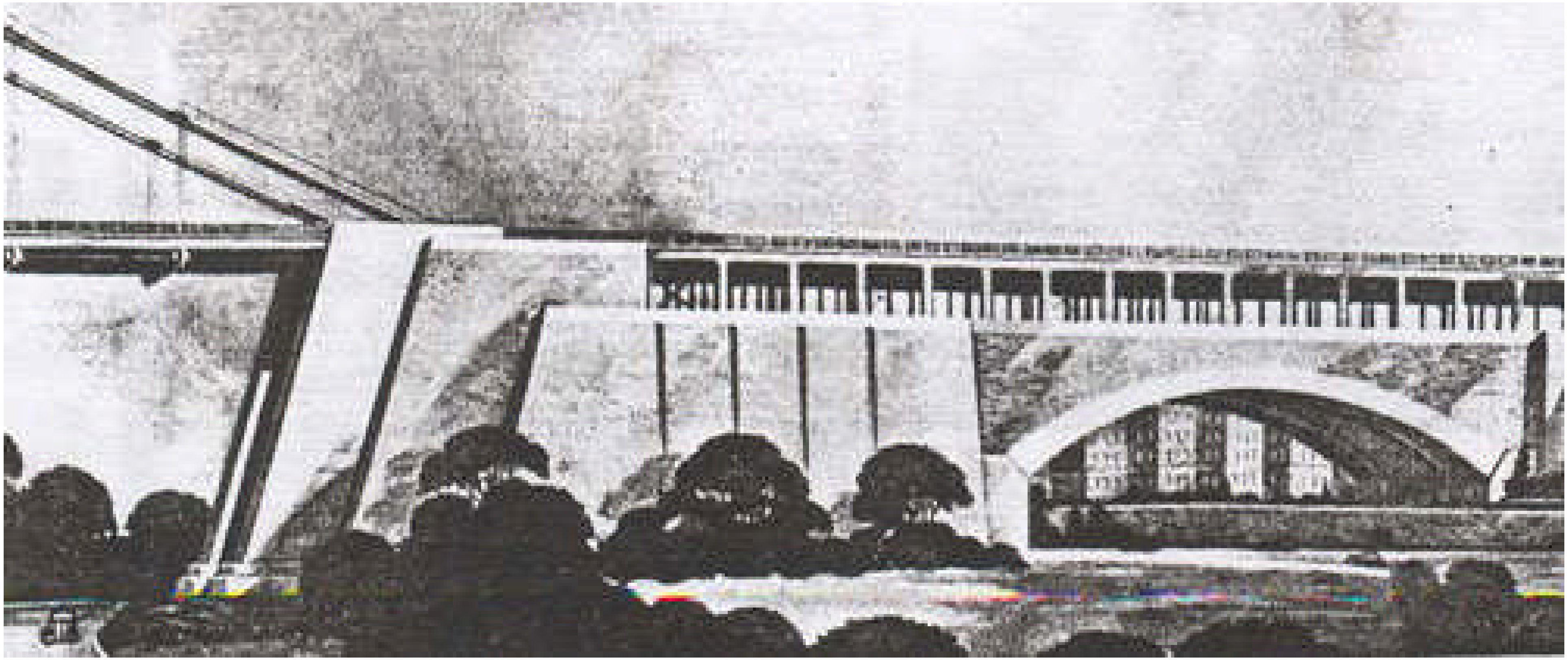
Top Left: caption: “Detail of top of New York Tower, Saddle Level, looking Southwest”

Top Right: caption: “Detail of Saddle at top of New Jersey Tower showing Cables ‘A’ and ‘B’”

Left: caption: “Close-up detail showing rollers beneath New Jersey Tower Saddle”







“…The anchor chains, to which the huge cables are secured at the ends of the bridge are embedded in concrete for a distance of 112 feet at the New York end and 150 feet at the New Jersey end; they are connected with anchor girders running at right angles at their lowermost ends. The two anchorages differ from each other considerably. That situated on Manhattan Island consists, in essentials, of an enormous block of concrete in which the anchor chains are embedded. On the New Jersey side, the chains and girders of the anchorage are secured in concrete-filled tunnels bored down into the natural rock formation, which here rises considerably above the levels of the bridge decks…”

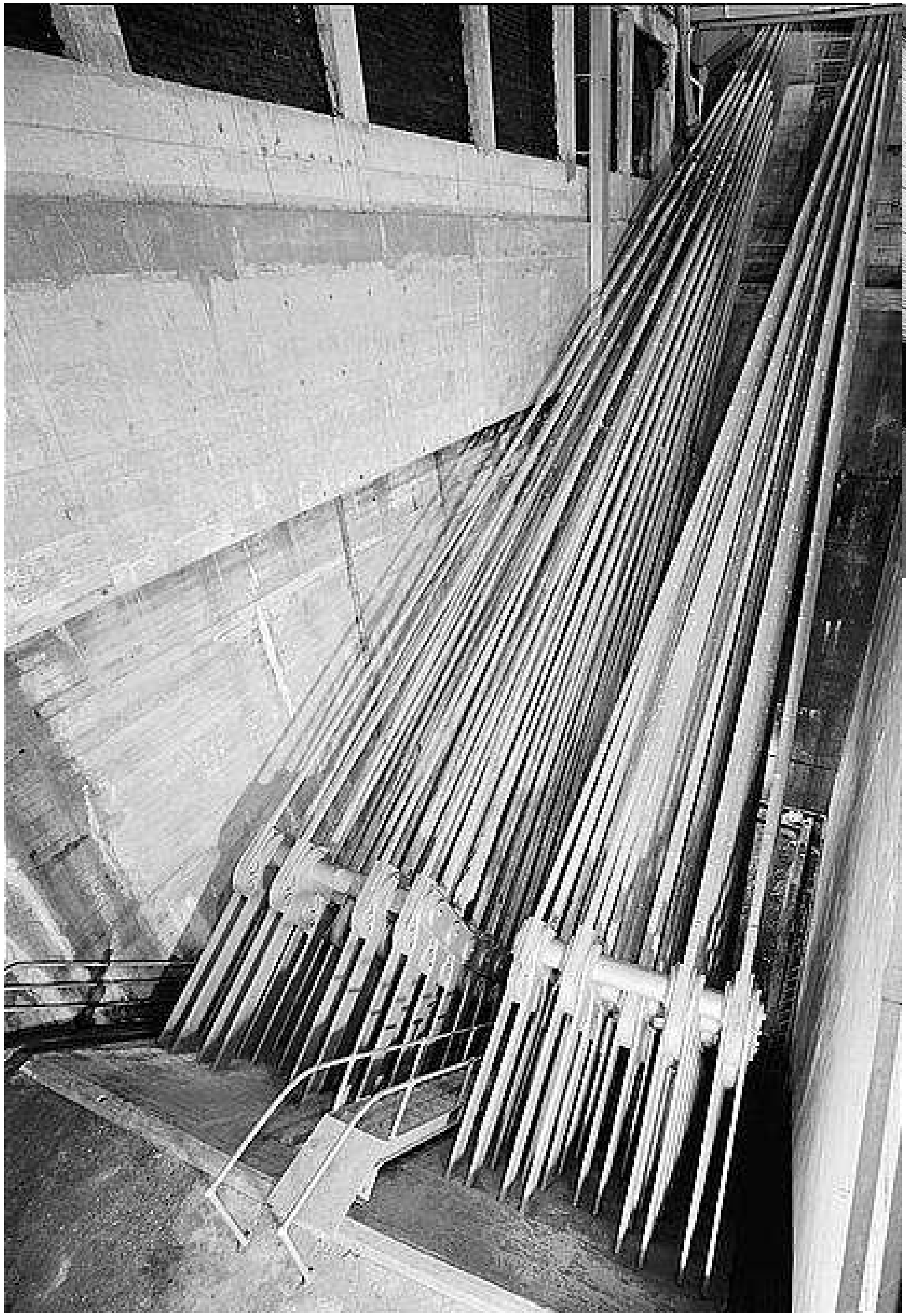
Wonders of World Engineering, **November 1937**

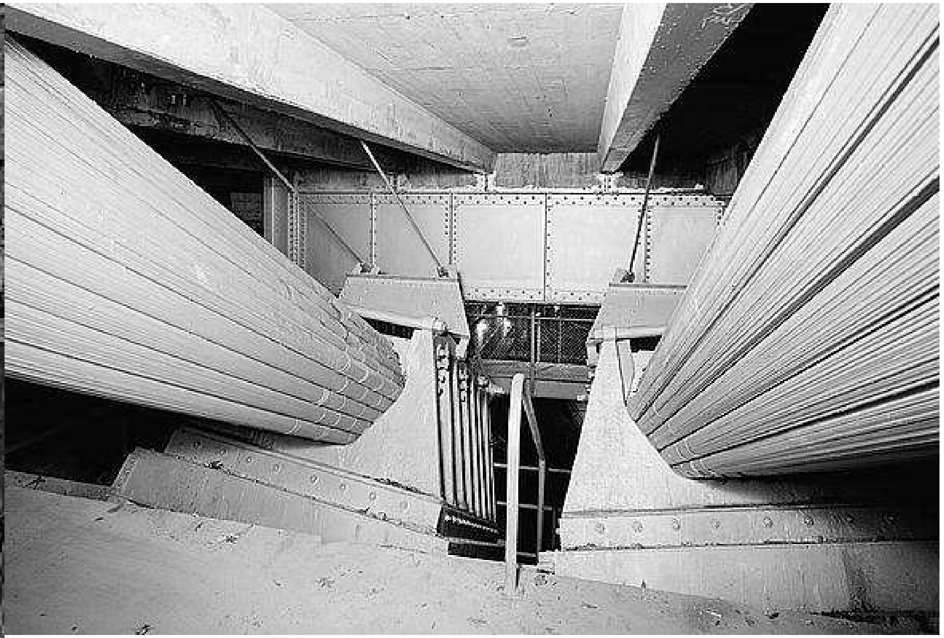
Above: caption: “Anchorage, George Washington Bridge, 1931”

Left: caption: "The anchorage of the George Washington Bridge on the Manhattan side is formed by a mass of concrete, with a volume of 110,000 cubic yards. This great concrete anchorage was completed in five and a half months, as many as 1,200 cubic yards being handled in one day of sixteen working hours."

<u>Above</u>: caption: "General view looking down on Harp section from stairs above, New Jersey Anchorage"

<u>Left</u>: caption: "North tunnel for New Jersey anchorage"





<u>Above</u>: caption: "Detail showing saddle for holding cable together just before it splays apart into Anchorage Bay, New Jersey end"

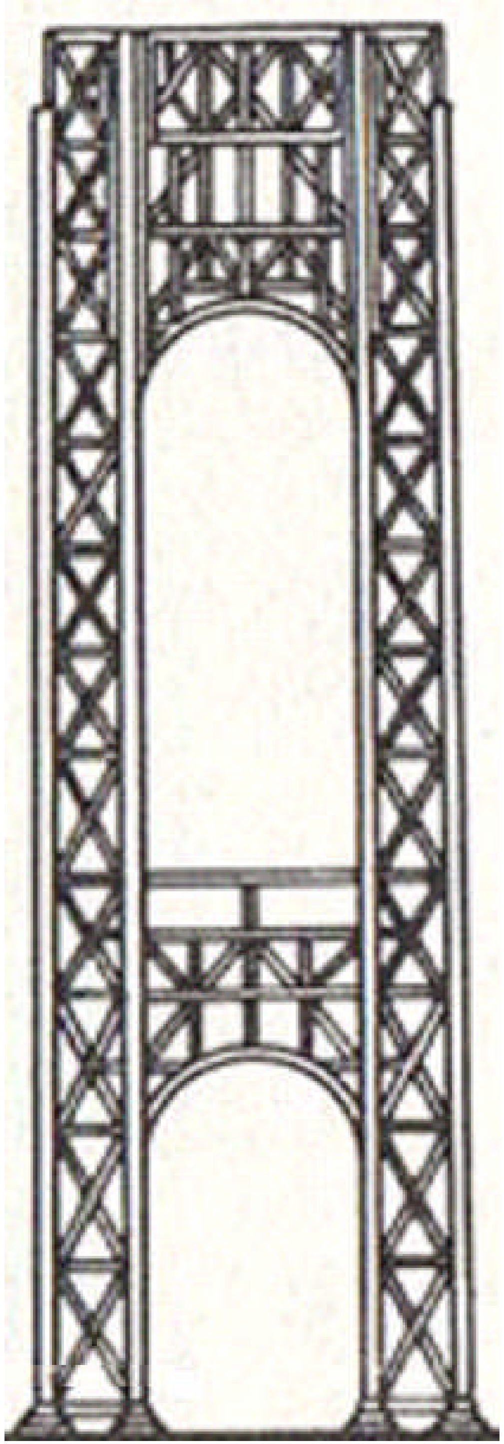
<u>Left</u>: caption: "General view of Cables 'A' and 'B' looking down on Harp, Southwest corner, New Jersey Anchorage"

"…As first inaugurated, the bridge thus took the form of a simple suspension structure, designed on a tremendous scale. The building of the lower deck, with its four railway tracks, involved the addition of two stiffening members set 106 feet apart and having a depth of 29 feet…"

Wonders of World Engineering, **November 1937**

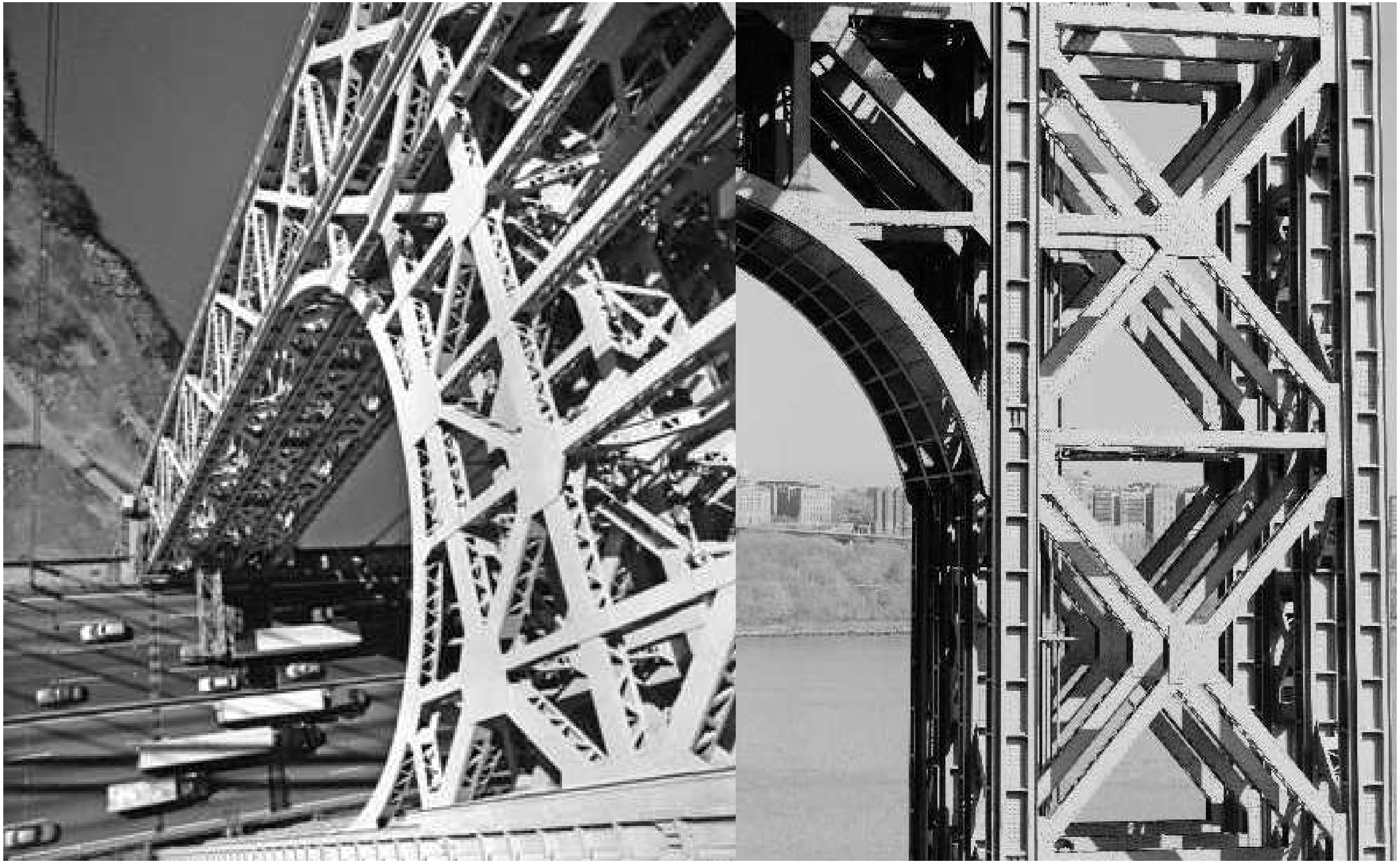
<u>Left</u>: caption: "New York Tower, looking West"


EXIT 1
H Hudson Pkwy
W 178 St
THRU TRAFFIC
95
1/4 MILE

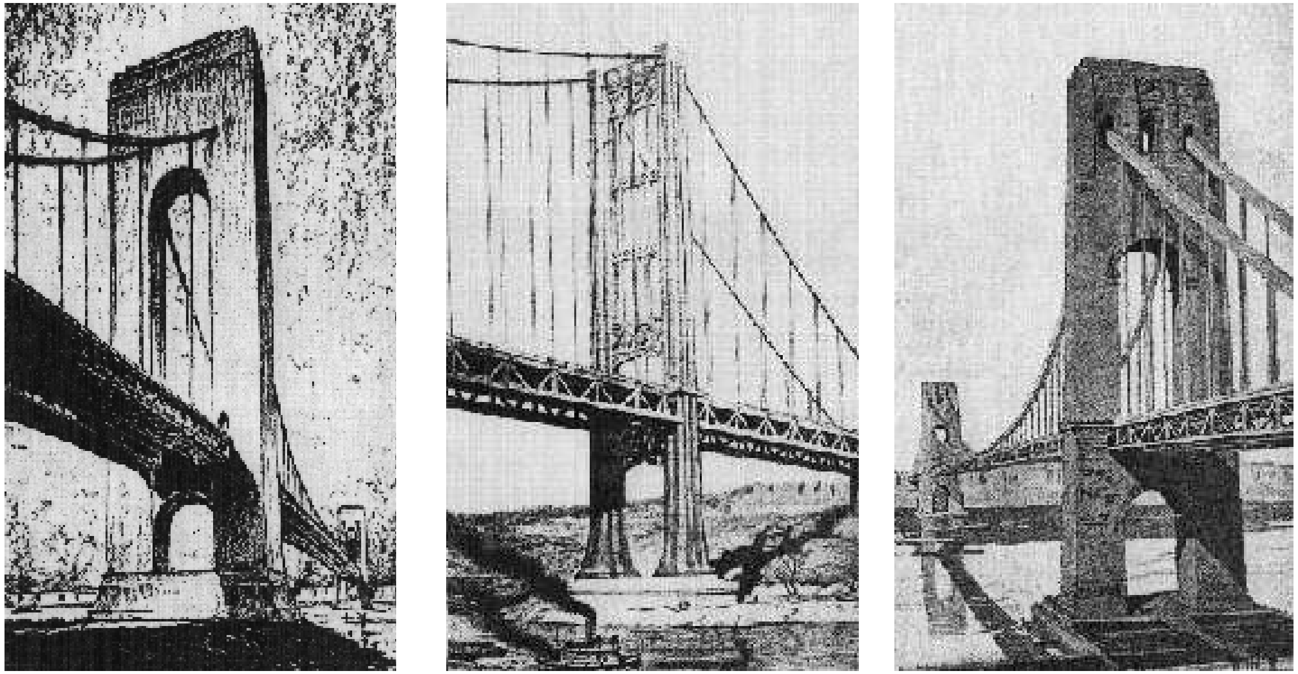


“…The two towers are of steel, with arch members below the bridge deck level and below the suspension cable saddles set in the tops…”

***Wonders of World Engineering,* November 1937**



Much Admired

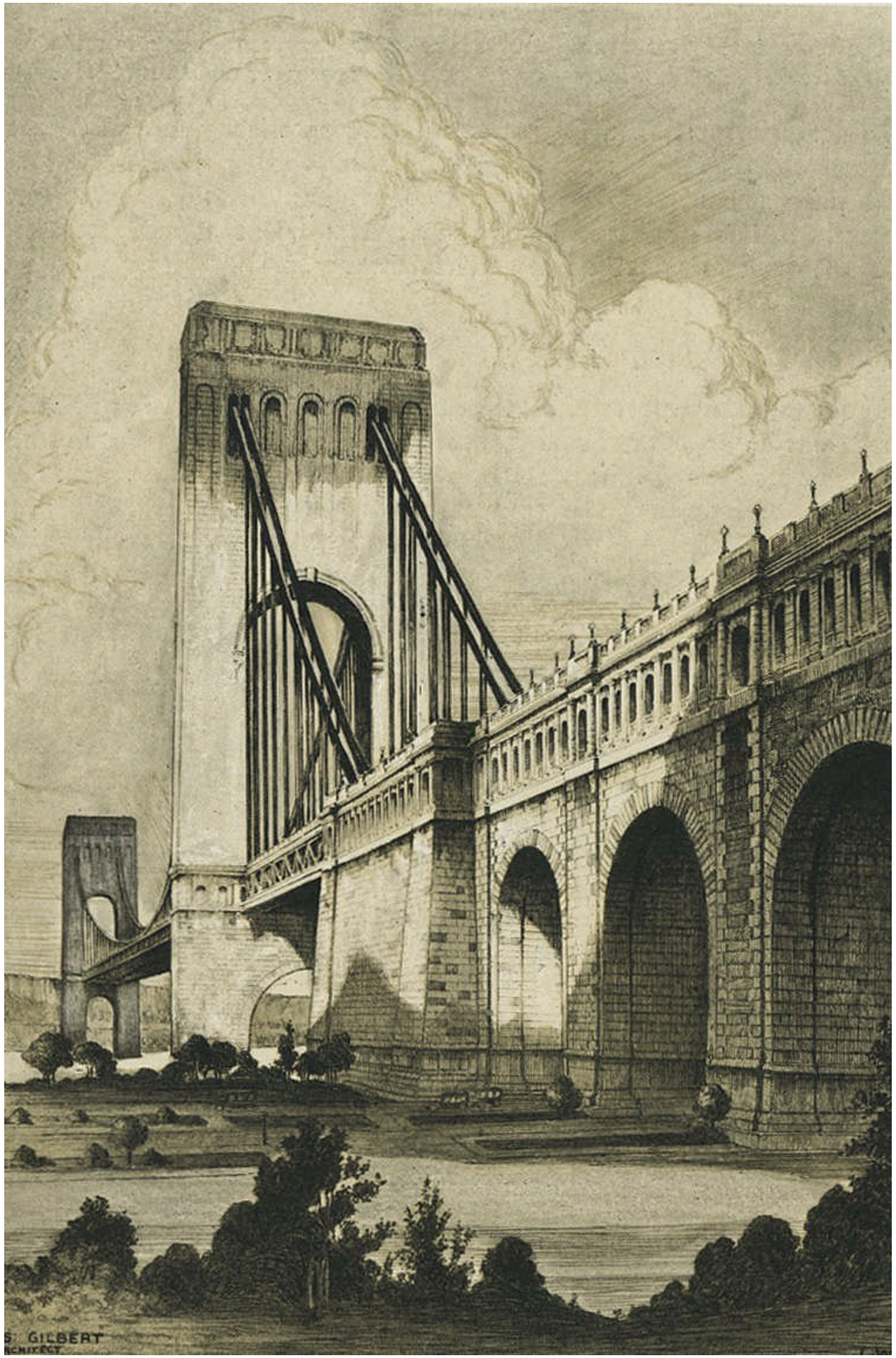


Ammann considered two suspension systems for the bridge; an eyebar chain and/or a wire cable system. Because he viewed both systems as equally effective, he tendered the suspension system for competitive bid. *John A. Roebling's Sons* won the contract for an aerial-spun wire cable suspension system. A number of tower designs that borrowed from Gothic, Baroque and Art Deco conventions were considered.

<u>Left</u>: The original Ammann design from 1923, which called for conventional suspension cables and masonry-encased steel towers

<u>Middle</u>: This design called for conventional suspension cables and slender steel towers

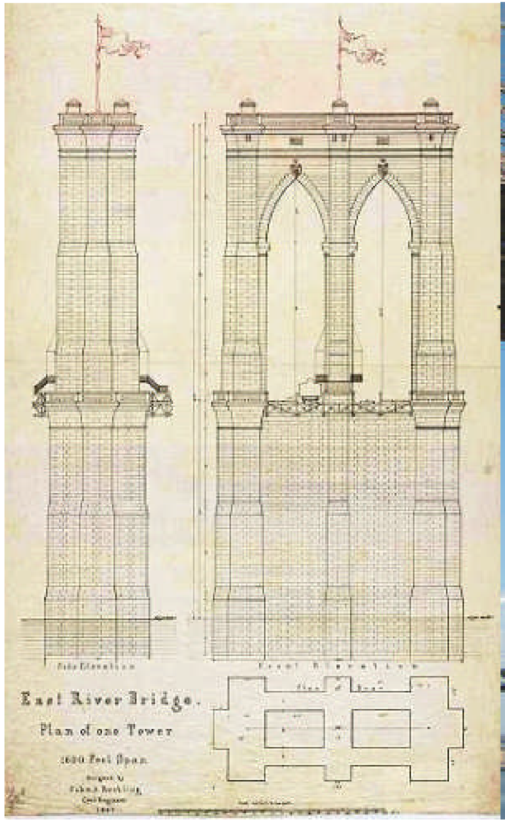
<u>Right</u>: This design called for an eyebar-chain suspension system and masonry-encased steel towers



"…It was originally intended, for aesthetic reasons, that these towers should be encased in masonry. The great masonry towers of the Roebling's East River bridge have been much admired, and it was a form of traditionalism which at first demanded the placing of stonework round the piers of the George Washington Bridge…"

Wonders of World Engineering, **November 1937**

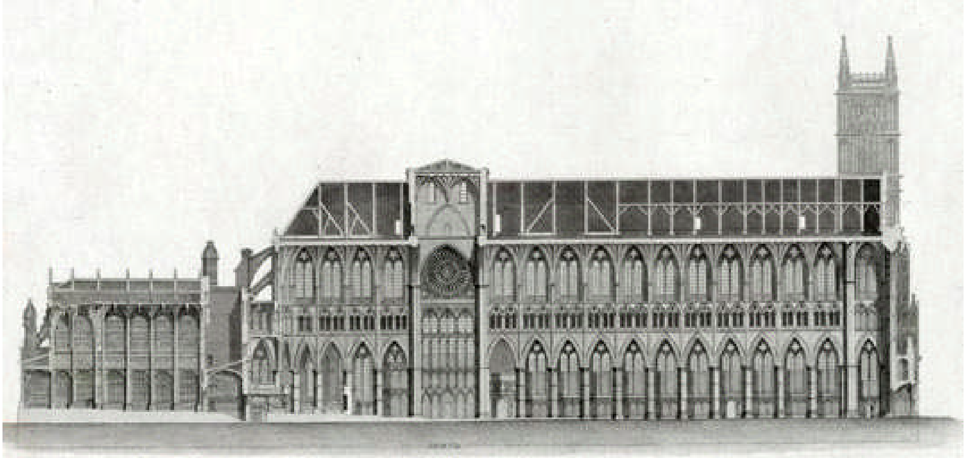
<u>Left</u>: caption: "Sketch of Architect's Drawing for the Hudson River Bridge, Manhattan to Fort Lee. A design with one arch instead of three across Riverside Drive (in the foreground) has since been adopted."


Side Elevation
Front Elevation
East River Bridge.
Plan of one Tower
1600 Feet Span.

"…Popular taste, however, seems sensibly to have approved the undoubted beauty and majesty of the open steelwork. Purpose, after all, is the great keynote in architectural and engineering beauty, and there is no denying the manifestation of purpose in those mighty towers above the Hudson. This aspect has been realized in the best work right down the ages. In great buildings, embodying the best traditions of Gothic, we see it everywhere. The loveliness of Westminster Abbey, for instance, is due to the fact that the salient features of its design do not merely serve their definite purposes, but also emphasize them. Though there is not much resemblance between Early English Gothic and modern American, as exemplified in the George Washington Bridge, they have this much in common, emphasis of purpose…"

Wonders of World Engineering, **November 1937**

Left: caption: "Tower side view"



“…To have covered the steel towers with stone facing would have made them appear colossal shams, just as if someone had lined Westminster Abbey with pitchpine matchboarding…”

Wonders of World Engineering, **November 1937**

Above: caption: “Westminster Abbey – South-side elevation”

Left: caption: “Westminster Abbey – West Towers and Buttresses”

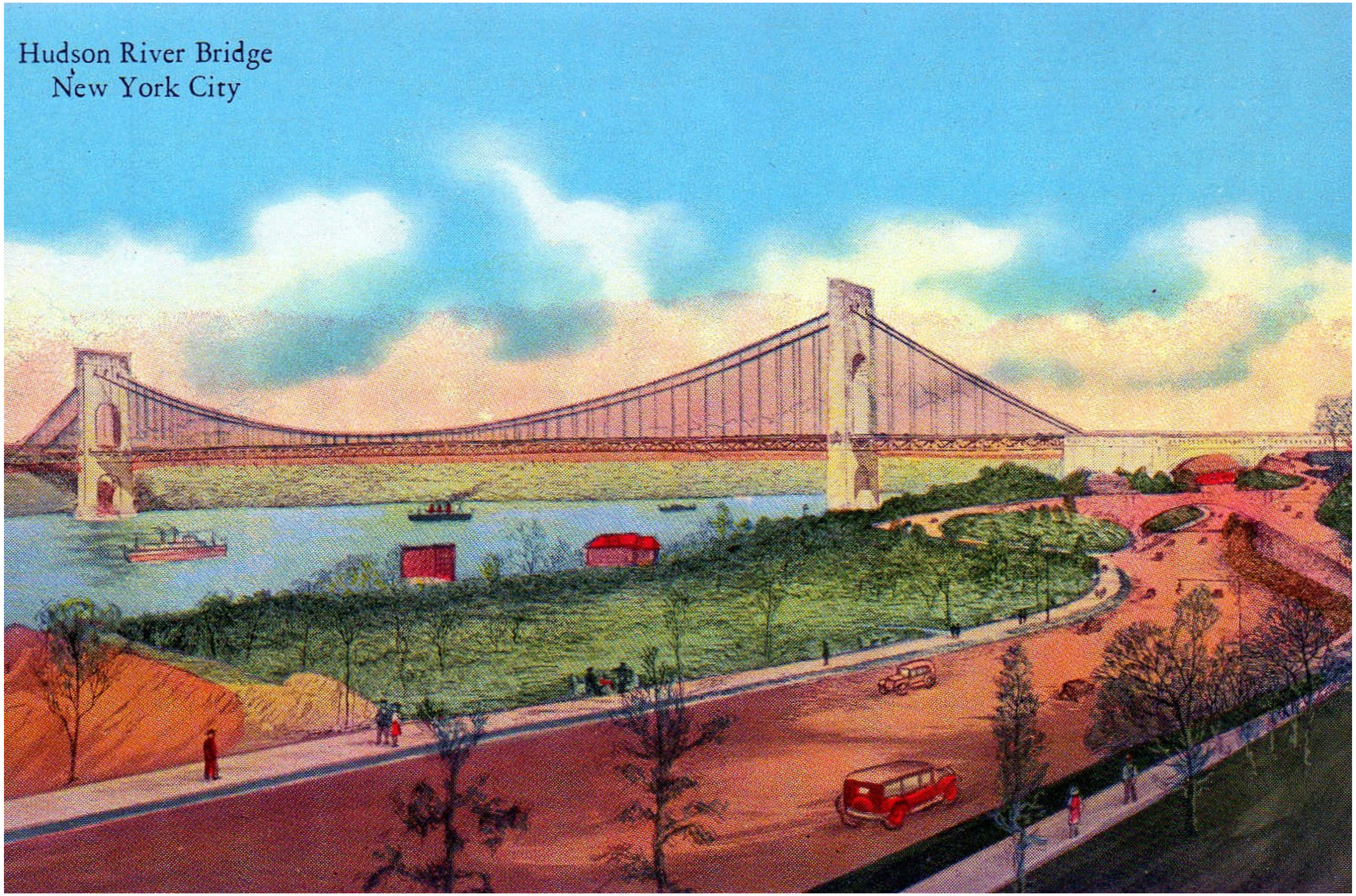
“It is hardly possible to enter into a discussion of the reasons and considerations which eventually led to the decision to build the towers initially as a steel frame designed to carry the entire load and to leave it for future consideration as to whether the frame is to be encased in or surrounded by stonefaced concrete”

O.H. Ammann

“The towers were to have been faced with stone molded and sculpted in ‘Beaux Arts’ style. Someone acted…‘Stop! No stone or decoration here.’…They dismissed the architect with his decorations.”

Le Corbusier

RE: the GWB’s towers were to be clad in a masonry envelope faced in pink granite chiseled with *Beaux Arts* flourishes, as well as statuary to cover the points where the cables pass through the roadway on their way to the anchorages. These plans, along with grand plazas for the bridge’s entrances with heroic statuary and a fountain on the *New York* side, were the work of *Cass Gilbert*, architect of the *Woolworth Building* (1913).

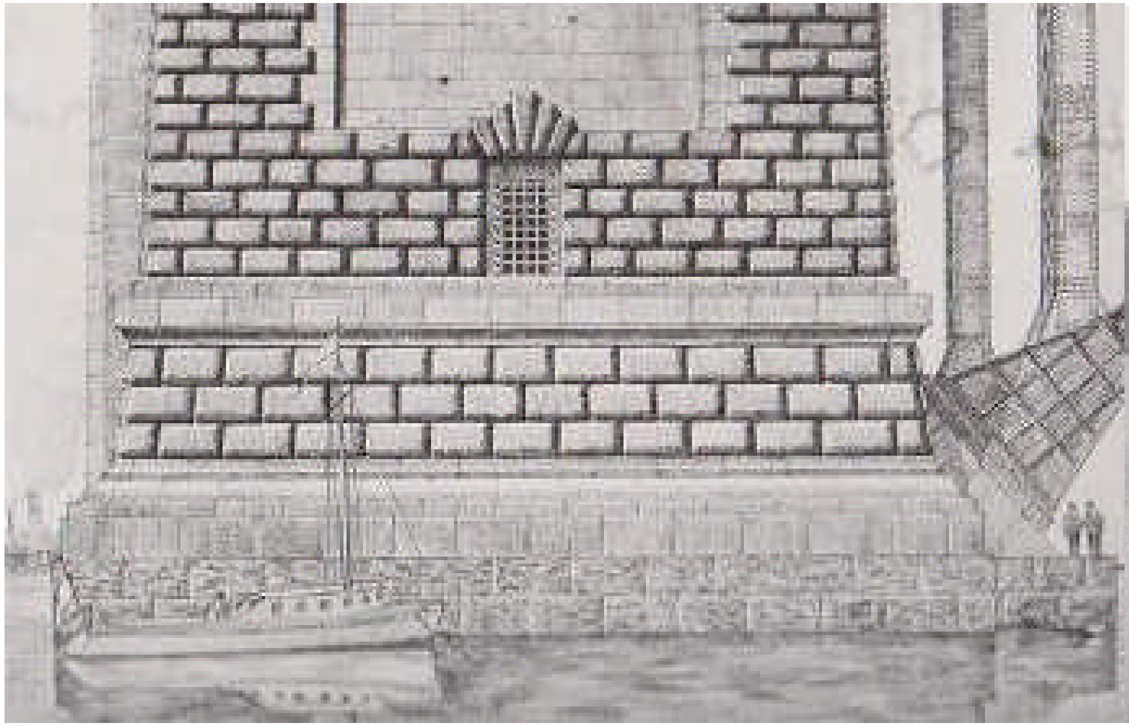

Hudson River Bridge
New York City

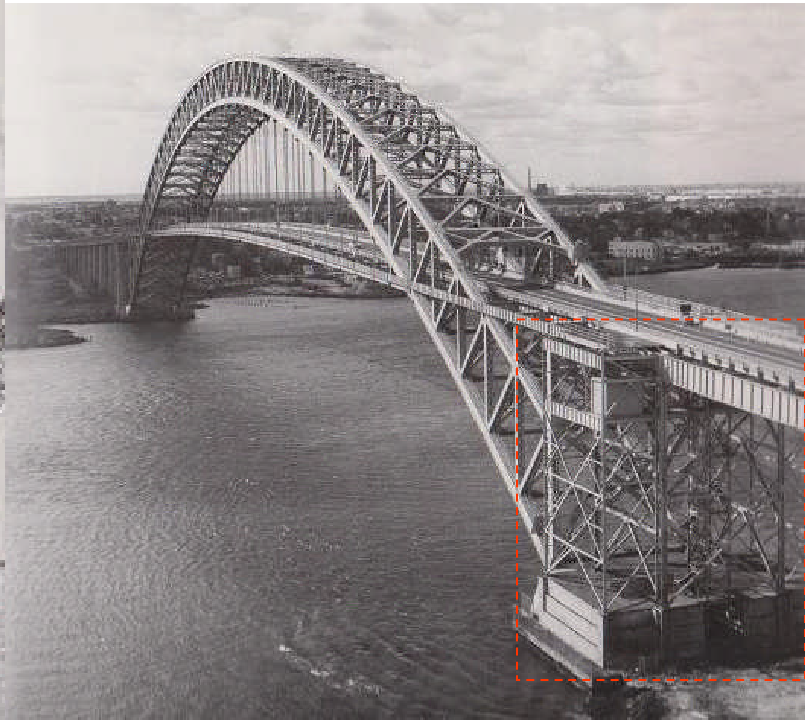
“The writer, who has conceived and is primarily responsible for the type and general form of the design, considers the steel towers as they stand to represent as good a design as may be produced by a slender steel bent, and that this lends the entire structure to a much more satisfactory appearance than he had anticipated. Nevertheless, he believes that the appearance of the towers would be materially enhanced by the encasement with an architectural treatment, such as that developed by the architect, Mr. Cass Gilbert…The writer is not impressed by the criticism, based solely on theoretical and utilitarian grounds, that the encasement would constitute a camouflage which would hide the true structure and its function. The covering of the steel frames does not alter or deny their purpose any more than the exterior walls and architectural trimmings destroy the function of the hidden steel skeleton of a modern skyscraper, except to the initiated.”

O.H. Ammann

RE: economic pressures and public opinion prompted Ammann to leave the exposed steel latticework of the towers exposed, thus allowing the *Port of New York Authority* to save approximately $1 million.

At Any Time in the Future





“The huge abutments of the arch, which are yet exposed in their crude construction, are eventually to be marked by massive pylons, and will thus further enhance the appearance of the structure in its setting in the landscape”

O.H. Ammann

RE: excerpt from his opening day speech for the *Bayonne Bridge* (November 1931)

Left: caption: “Study for the masonry surface designed for the ornamental abutments”

Right: caption: “Ornamental stonework was never erected above the bridge’s abutments, leaving the steel armature exposed”

"It cost 14 percent less to build than was budgeted and appropriated"

Morgan F. Larson, **Governor of the** ***State of New Jersey***

RE: excerpt from his opening day speech for the *Bayonne Bridge* (November 1931). Rather than forming the piers of solid concrete, Ammann made them of structural steel, making them wider (thus appearing sturdier) and, for aesthetic reasons, as support for Cass Gilbert's design of an ornamental stone encasement. Unlike the decision to eliminate the stone facing for the towers of the GWB (as a cost-saving measure during the depression) which was done well in advance of the bridge's October 1931 opening, supervisors for the *Port of New York Authority* simply placed the order for the stone on hold, citing fiscal restraint as the reason despite the fact that funds were in place to complete the design. The bridge opened without the stone to both Ammann and Gilbert's dismay. In the ensuing years, theirs and others pleas for completion fell on deaf ears and the piers remain in an unfinished state to the present day (above).

“Ours is a utilitarian age, of course, and one affiliated at the moment with a disease called a Depression. But it is also an age with a powerful urge toward experiment. Economic power is not wholly responsible for the change in the bridge piers. The economic arguments are strong, but something else: the effect of the steel beams on the landscape. The notion has got considerably diffused that what already has been achieved in carrying out the monumental design in steel provides an eyeful that could hardly be bettered by trying to make steel towers look like stone piers – even stone piers designed by the architect of the Woolworth Building and so much else that is fine and distinguished. Of course, we don’t intend to tie up the future to current notions of aesthetics and the stone dressing can be added at any time in the future.”

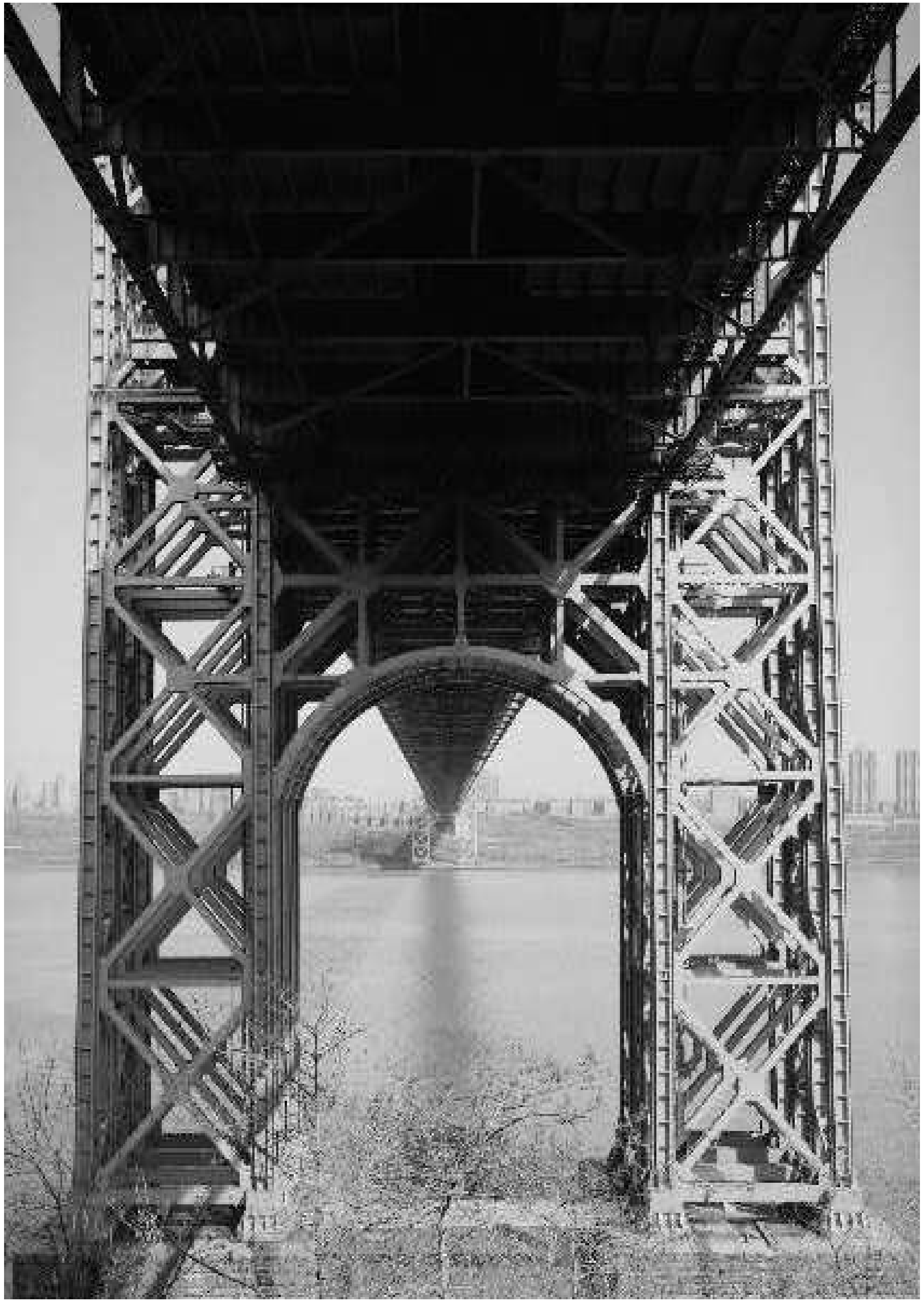
***The New York Times*, 1931**

Terra Firma

"…Creating the single New York tower foundation would be a relatively simple matter, basically smoothing out the rocky surface of Jeffrey's Hook, the promontory of Manhattan schist sticking out into the Hudson that is ten to twelve feet above mean high water. The two New Jersey tower foundations would be far more complicated: they had to be erected out in the Hudson River, because the Palisades descend directly to the river's edge…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

Left: caption: "New York Tower Foundations – Jeffrey's Hook"



“…In the building of the bridge, the engineers responsible found, from Berkey’s trial borings, that they could place the foundations of the great New Jersey tower on a bed of solid rock (shale and sandstone, whose surface was nowhere deeper than 100 feet. After a number of tentative proposals, they decided that the foundations should consist of a huge block of concrete situated under each of the two leg members of the superimposed steel tower. The vertical load exerted by the tower upon the foundation caused a maximum edge pressure of almost 400 lbs. per sq. in. The trial borings showed that even on the river side, the top of the rock bed would be struck well within the limit of 100 feet. It was met with at an average depth of less than 50 feet and the maximum depth came to only 75 feet. It was therefore decided that the use of open cofferdams was perfectly feasible…”

***Wonders of World Engineering,* November 1937**

Left: caption: “Detail showing Bridge Pier and Tower Base, New Jersey end”

"…even though it involved the use of cofferdams which, taking into consideration their depth and their area, were to be on a scale never before attempted*. *Had the builders of the George Washington Bridge decided to use separate caissons for the foundation blocks, they might well have experienced considerable difficulty in maintaining, through connections, an even degree of pressure distributed within the adjoining caissons, and thereby a single action beneath the pier as a whole. The open cofferdam allowed for easy and careful preparation of the rocky bed on which the foundations of the pier were to stand. The site of the foundations had to be dredged out before the sheet piling, forming the walls of the cofferdam, was sunk. These walls were placed in position, five feet outwards from the site of the walls of the future piers on all sides. Timber bracing had first, however, to be sunk inside the cofferdam area, the sheet piling following outside this preliminary work…"

Wonders of World Engineering, **November 1937**

<u>Above</u>: caption: "Groundbreaking – September 21, 1927"

“…As early as December 12, 1927, work was proceeding at a rapid pace on the foundations for the New Jersey tower. As chief bridge engineer Othmar Ammann would write his mother, ‘We are already working 75 feet below the water level. Until now, everything has progressed as planned and all the constructions are further ahead than anticipated.’ One reason things were going so well is that giant steel cofferdams were being utilized to create the forms for the New Jersey tower foundations instead of the caissons used in the construction of the Brooklyn Bridge. Unlike caissons, cofferdams were not pressurized, so the bends was not an occupational hazard…”

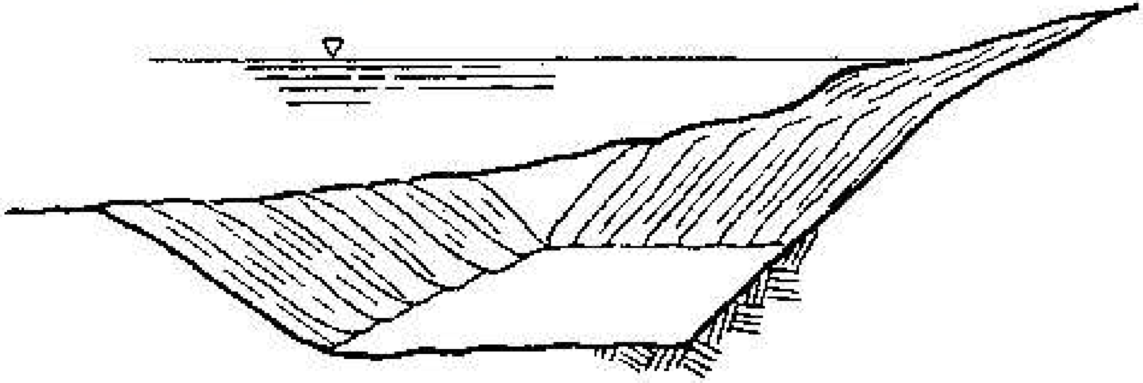
RE: excerpt from *The George Washington Bridge: Poetry in Steel*

“…Dredging was started in the beginning of May 1927, and within twenty days the dredgers had removed more than 75,000 cubic yards of silt from above the underlying rock-bed. The silt contained boulders, and several large, rocky obstructions were encountered in the course of excavating this otherwise harmless material. Divers were sent down to drill them for blasting. In this manner, the last traces of the major obstructions had been removed within a space of ten days. Some smaller boulders, however, still remained, and were encountered in the sinking of the sheet piles…”

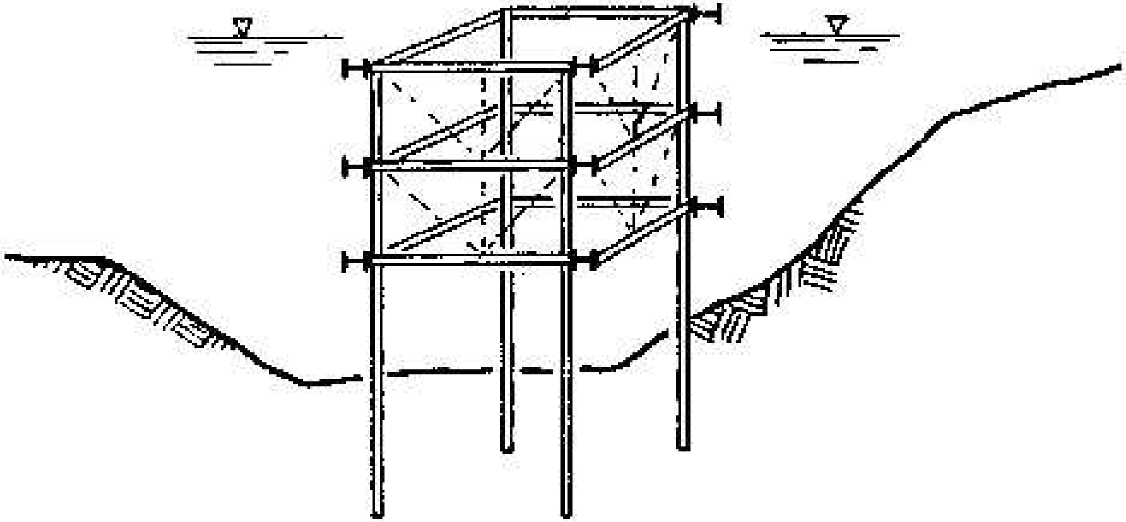
***Wonders of World Engineering,* November 1937**

Cofferdam Construction Sequence

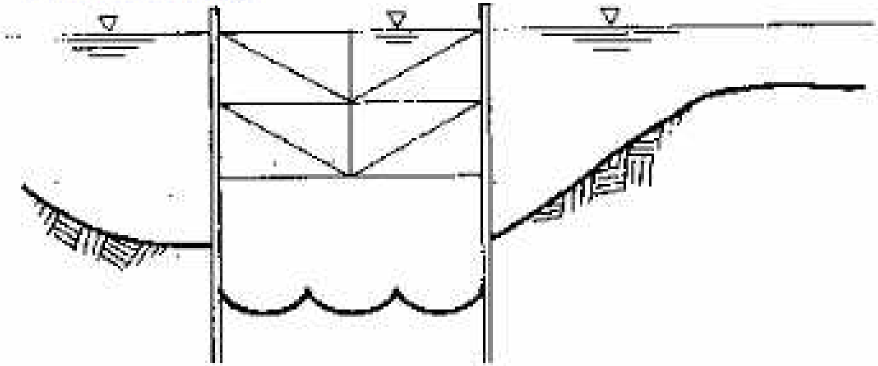
1. Pre-dredge to remove soil or soft sediments and level the area of the cofferdam.



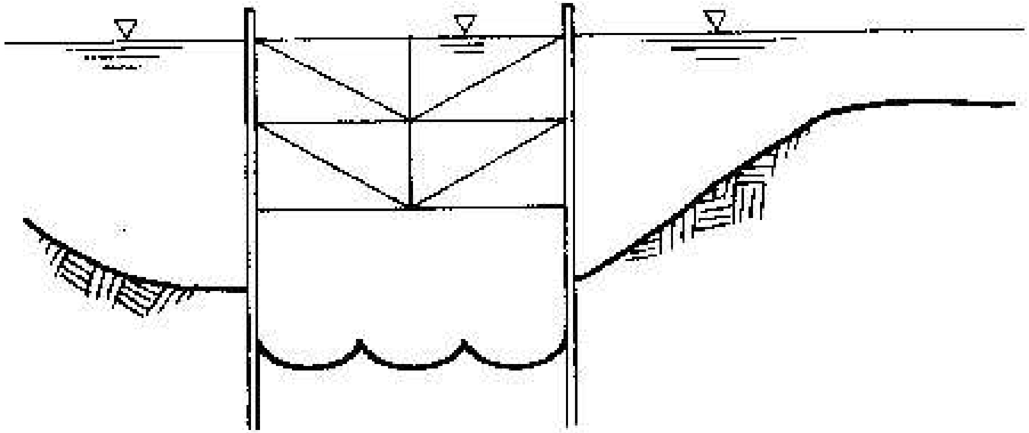
2. Drive temporary support piles
3. Temporarily erect bracing frame on the support piles.



4. Set steel sheet piles, starting at all four corners and meeting at the center of each side
5. Drive sheet piles to grade.
6. Block between bracing frame and sheets, and provide ties for sheet piles at the top as necessary.

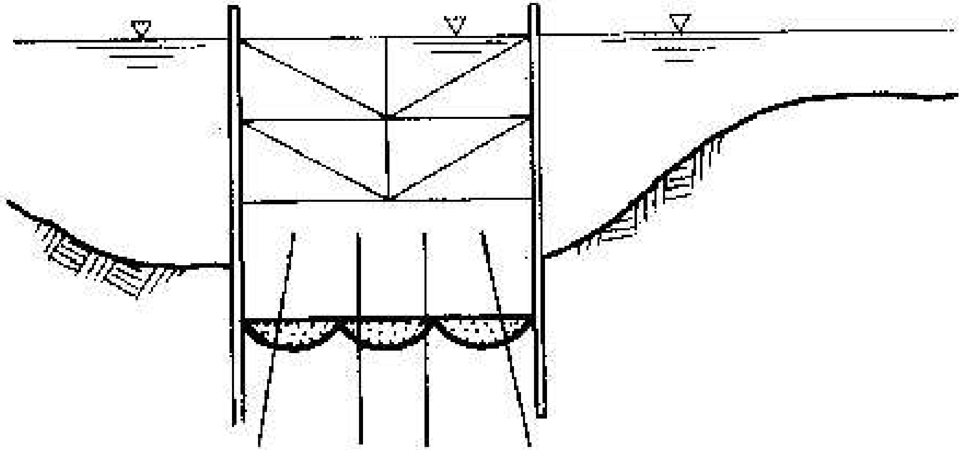


7. Excavate inside the grade or slightly below grade, while leaving the cofferdam full of water.

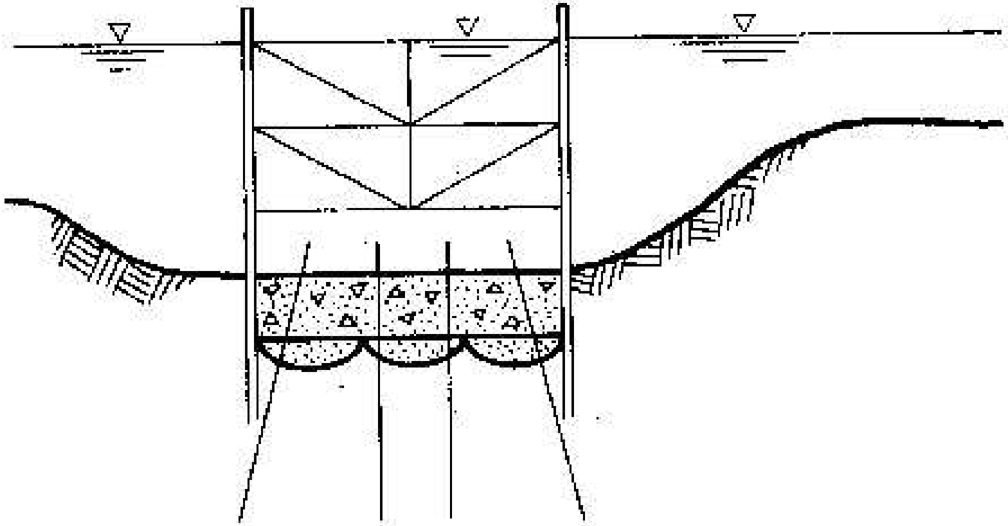


8. Drive bearing piles.

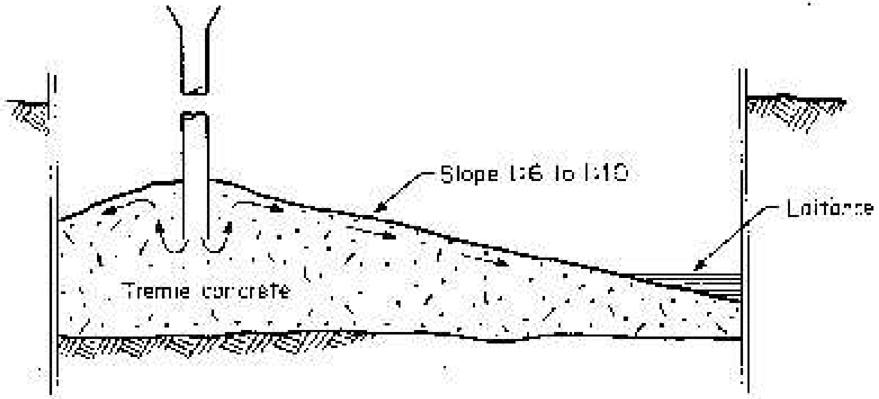
9. Place rock fill as a leveling and support course.



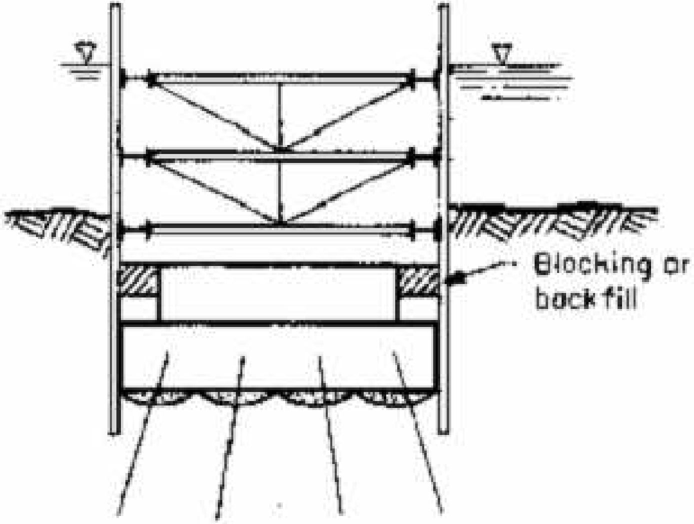
10. Place tremie concrete seal.

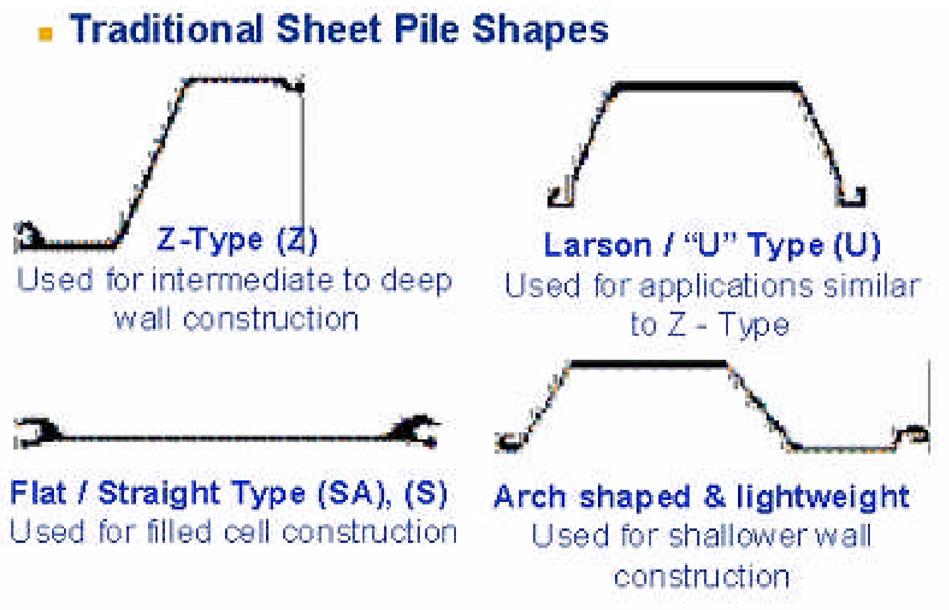


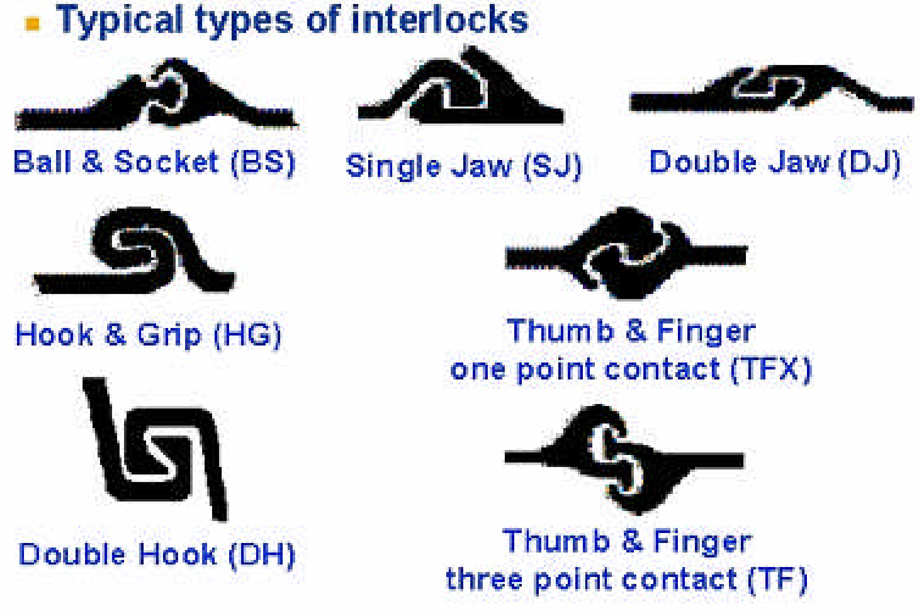
Tremie concrete seal.



11. Check blocking between bracing and sheets.
12. Dewater.
13. Construct new structure.







"…The site was ready for this process within two months of the start on dredging operations. For the building of the two cofferdams, one for each pier supporting a leg member of the tower, 1,558 tons of steel sheet piling were required. The cofferdams had double walls, and the pockets in these were filled with concrete along the sides facing across the river. Elsewhere the side pockets were filled with ordinary silt from the river bed…"

***Wonders of World Engineering*, November 1937**

“…Nevertheless, on December 23, disaster struck. The cofferdam for the New Jersey tower’s north foundation, receiving the full pressure of the Hudson River, buckled and three men drowned. Until the tragedy the north cofferdam had been considered so inviolable that only a small pump had been thought necessary to keep river leakage into the dam at a manageable level…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

"…One serious accident took place during the sinking of the cofferdams. This was caused by a blow-in at the upstream, shoreward corner of the northern cofferdam. It happened on December 23, 1927, luckily early in the morning when most of the men were out of the workings. Even so, those who were in the cofferdam lost their lives. No great difficulty, however, was encountered in repairing the material damage. Concreting followed, the concrete piers being faced with stone to a depth of seven feet below the water level…"

Wonders of World Engineering, **November 1937**

Left: typical modern-day cofferdam construction for a bridge pier

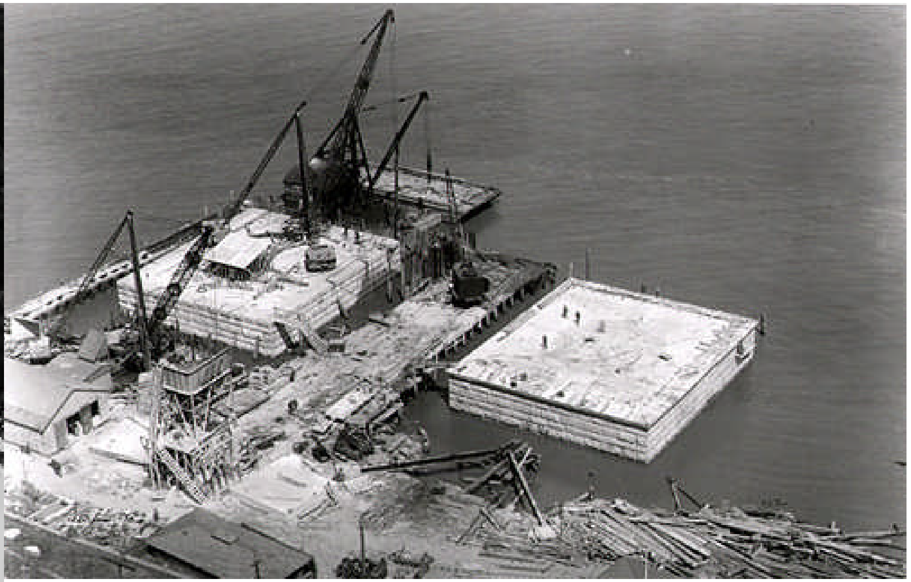
A Knowledge as Sure as Instinct

“There are unavoidable hazards connected with the work, but as a rule it is the green man who takes hold of the wrong rope, or steps on the unsecured bit of staging, or does something else which the experienced workman would have been warned by a knowledge as sure as instinct. Sometimes, though, accidents happen to the most cautious, the most experienced workmen. I have had a few narrow escapes myself.”

Ralph Modjeski, **Bridge Engineer**

"…In all, twelve men died in building the George Washington, including one when an explosive charge improperly placed in Palisades rock went off prematurely, but the deaths in the north cofferdam received the greatest amount of publicity and are likely the origin of a legend about the bridge: that during the pouring of the immense quantity of concrete that forms the New York anchorage, on the other side of the river, three workers fell in and were entombed forever…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

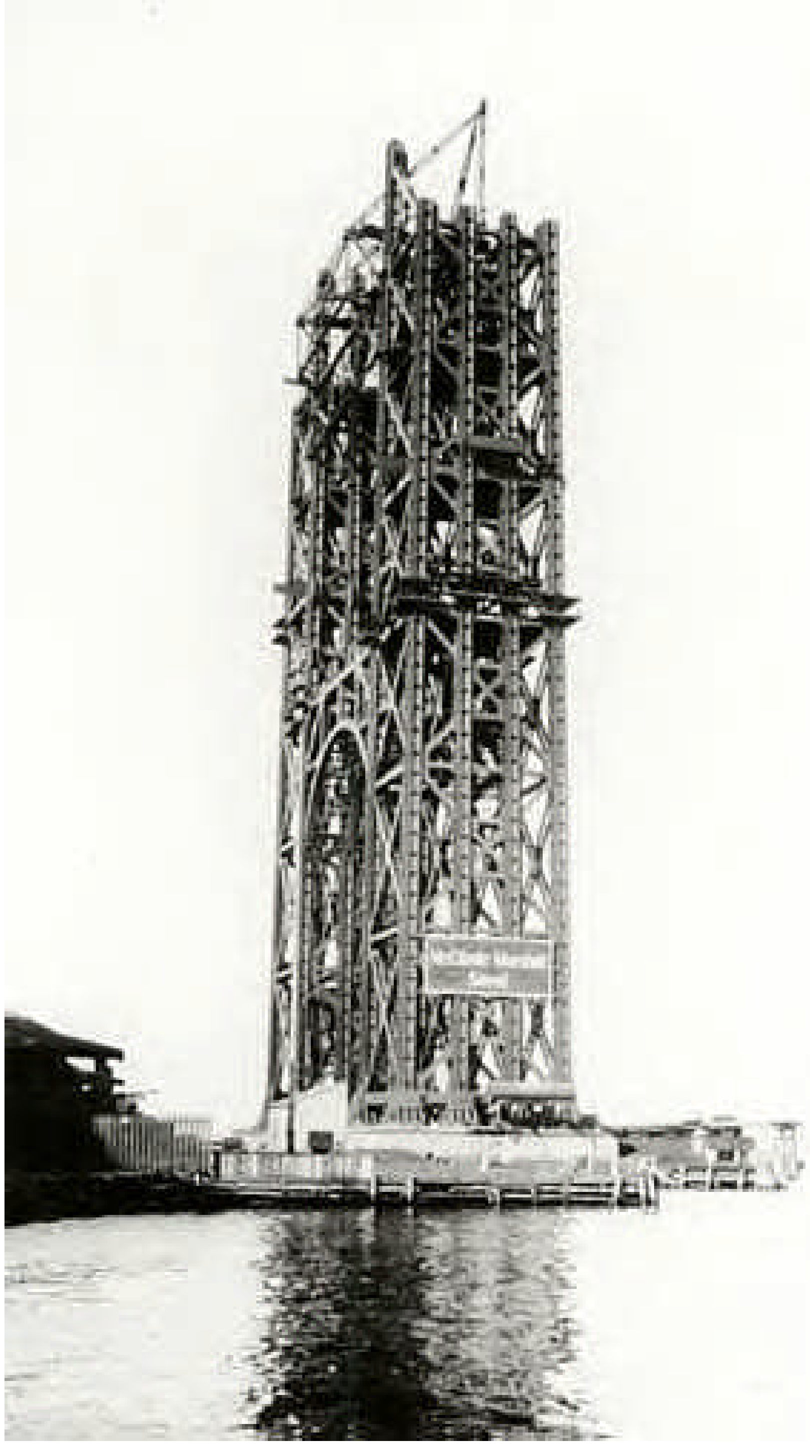


“…The two piers were ready for the erection of the steel tower bearings by April 1928, nearly a year after the preliminary dredging had been begun. Each of these piers consisted of an 89 feet by 98 feet concrete foundation block, on which a similar block 84 ft. 6 in. by 76 ft. was superimposed, the upper block being faced with stone. These piers rose to a height of 14 ft. 11in. Above mean sea level at Sandy Hook, at the mouth of New York Harbor…”

Wonders of World Engineering, **November 1937**

Above: caption: “Piers for the New Jersey Tower near completion”

Left: caption: “Detail of Tower Base, New Jersey end”



"…The foundations on both sides of the river were the first of six steps in the building of the bridge. Though several steps can proceed simultaneously, this order is typical for suspension bridges: tower foundations; towers; anchorages; the major, or barrel, cables; the suspender, or stringer, cables; and, finally, the roadway. Once the foundations of the George were in place, the tower footings had to be bolted to them, sixteen for each tower. With these mounted, the towers themselves could rise; although they seem to be single, unified units, each is made up of sixteen columns of steel. Pre-assembled sections were floated to the work sites on barges, and since the towers were erected simultaneously, heavy machinery and large crews of workers had to be available at both sites. The erection of the towers began in June 1928, with a friendly competition between those building the New Jersey tower and those building the New York tower as to who would finish first. Nine or ten teams of four riveters each worked on assembling each tower. Taking one year and over one million rivets to assemble, the towers were completed by June 1929…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

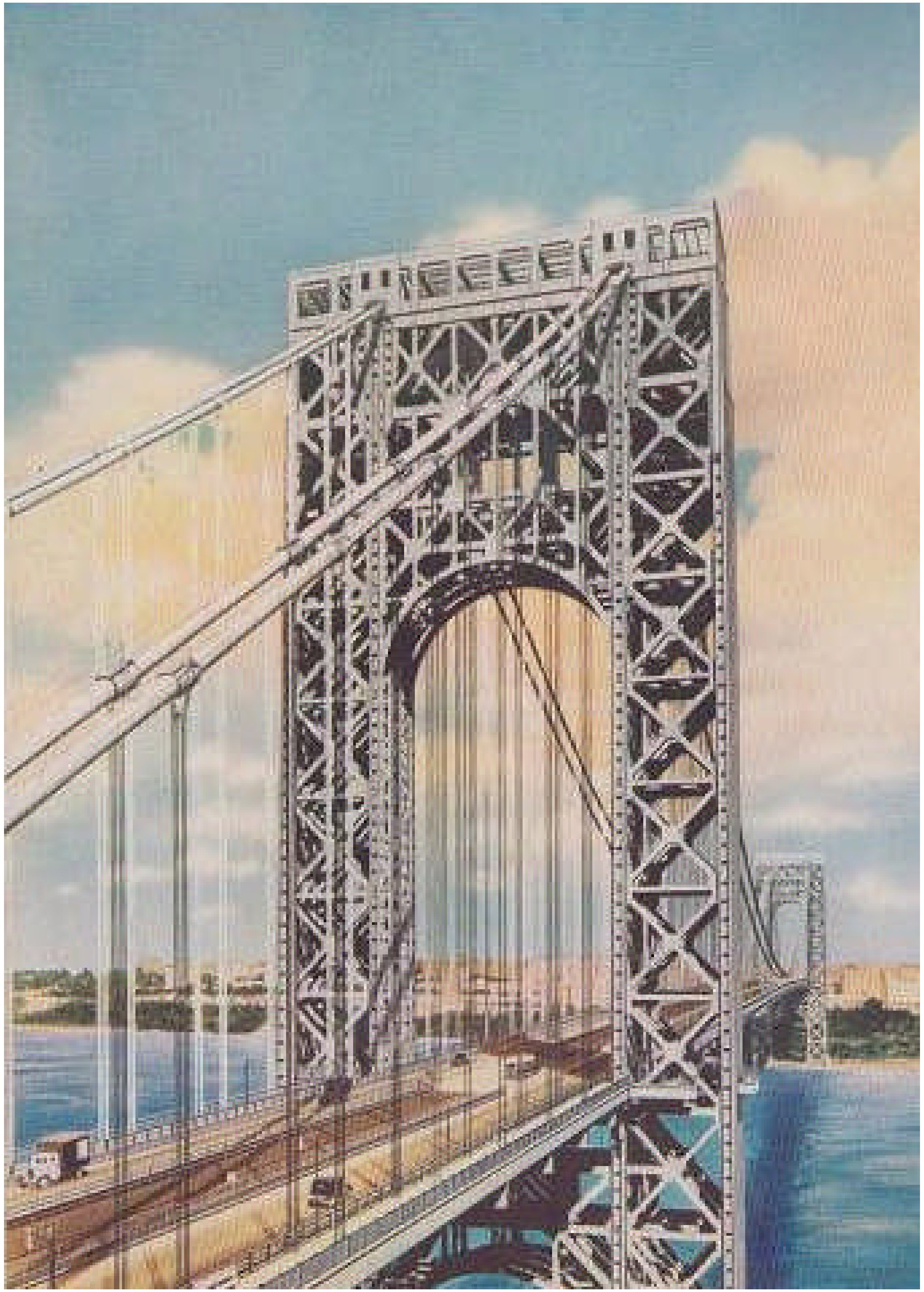
Left: caption: "New Jersey tower rising from its river foundation"

“…On the Manhattan side, as the strong stratum of schist rose well above high-water mark, there was no need for cofferdams, and it was possible for the 80 feet by 88 ft. 6 in. foundation blocks to be built up on the cleared space without difficulty. The upper part of each pier was reduced in size to 76 ft. by 84 ft. 6 in. to take the ornamental granite facing. This last, being a purely decorative feature, was not added until the autumn of 1932, the pier blocks having been ready for the superimposition of the towers since the spring of 1928, as on the New Jersey side…”

***Wonders of World Engineering*, November 1937**

Left: caption: “Manhattan Tower Piers – Jeffrey’s Hook (ca. 1928)

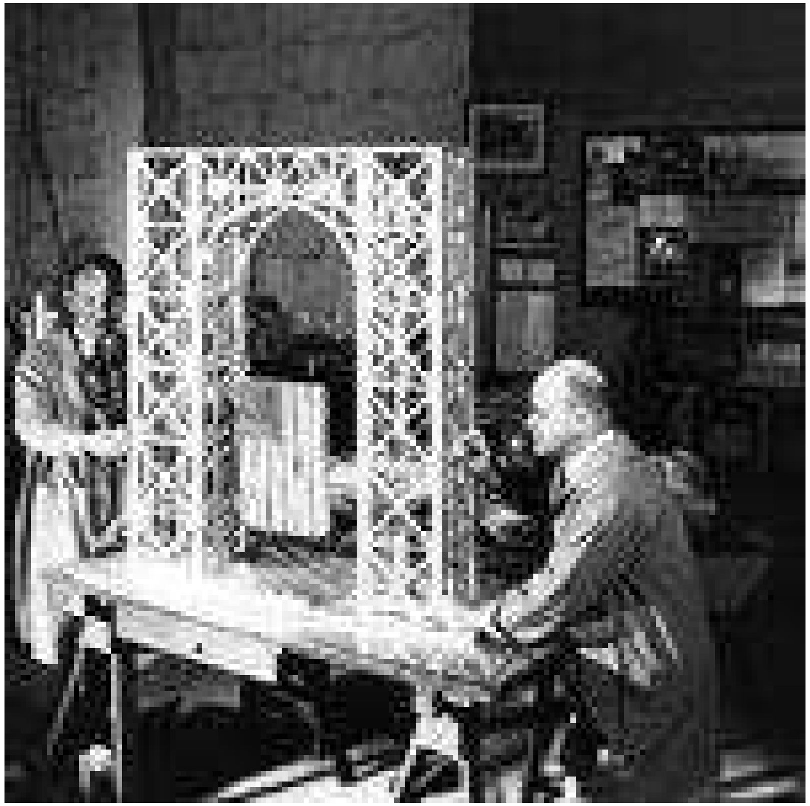
Right: caption: “ New York Tower base”

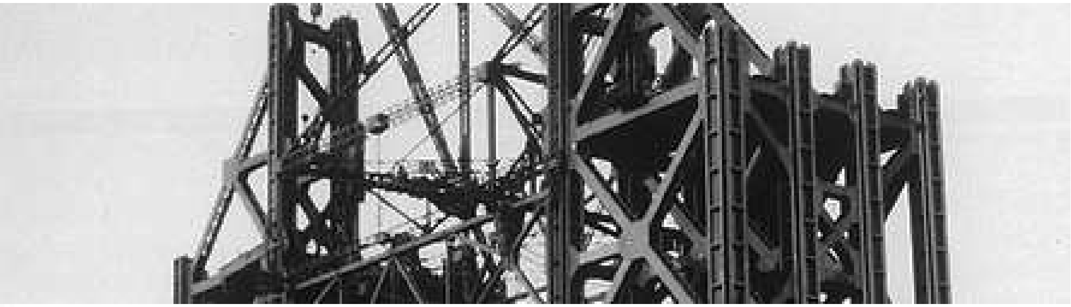


"…As they stand, these two magnificent towers contain 23,600 tons of silicon steel and 17,500 tons of carbon steel, giving them a total content of 41,100 tons of steel. Exhaustive experiments were carried out beforehand with celluloid models of the towers and with steel girder members, which were tested to breaking point, the results being carefully recorded…"

Wonders of World Engineering, **November 1937**

<u>Left</u>: caption: "Each of the two towers is 559 ft. 6 in. high from the top of its pier to the summit of the steelwork"

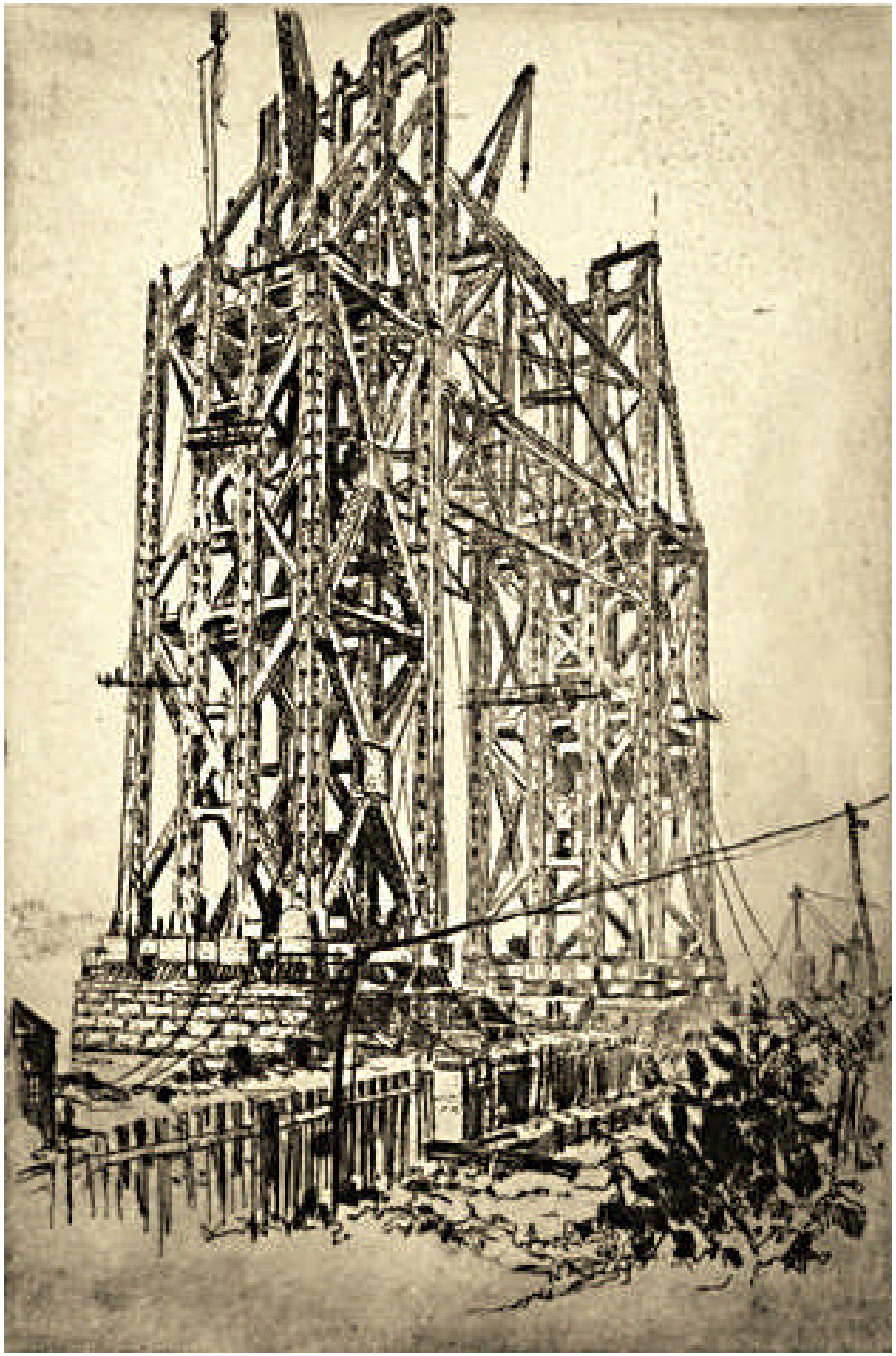




"…Erection of the two great towers began as soon as the foundation bearings were ready to receive them…the roadway passes through the New York tower at a level 16 ft. 6 in. lower than that at the New Jersey tower. The building of these towers took place simultaneously, though the men at work on the New Jersey tower had a start of six weeks because of the earlier completion of the New Jersey piers. Each tower rests on sixteen steel pedestals set on the tops of the piers. The first pedestal of the New Jersey tower was placed in position by derrick on June 23, 1928. The pedestals were complete for erection when they arrived for erection on the piers

***Wonders of World Engineering*, November 1937**

Left: caption: "New Jersey tower under construction September 12, 1928"



"Not far from where we lived, the great new George Washington Bridge across the Hudson to the New Jersey shore was slowly taking shape…This was steel at its very best and I could not resist the opportunity of recording the bridge at its various stages of construction in a series of etching plates."

Otto August Kuhler **(1894-1977)**

RE: *The Pillar* (1927), etching by Otto August Kuhler. One of a series of prints by the artist documenting the construction of the *George Washington Bridge.*

"…Each pedestal consists of a steel member 14 feet square and 6 ft. 6 in. high, secured to the top of the pier by six 2.5 inch anchor bolts over which it was lowered. From these sixteen pedestals, eight to a pier, the tower superstructure was built up progressively, the derricks being situated between the two legs of the tower, and on the legs themselves for the erection of the cross-arches. Much the same procedure was observed on both towers, but in the New York tower each pedestal, instead of arriving whole, came in two pieces and had to be assembled on the spot…"

Wonders of World Engineering, **November 1937**

RE: the *New Jersey* tower was located 76-feet into the *Hudson River*, while the *New York* tower was built on land (to avoid the steep drop from the Manhattan shoreline). Both towers are composed of twelve 50-foot-long sections and each tower leg houses a service elevator.

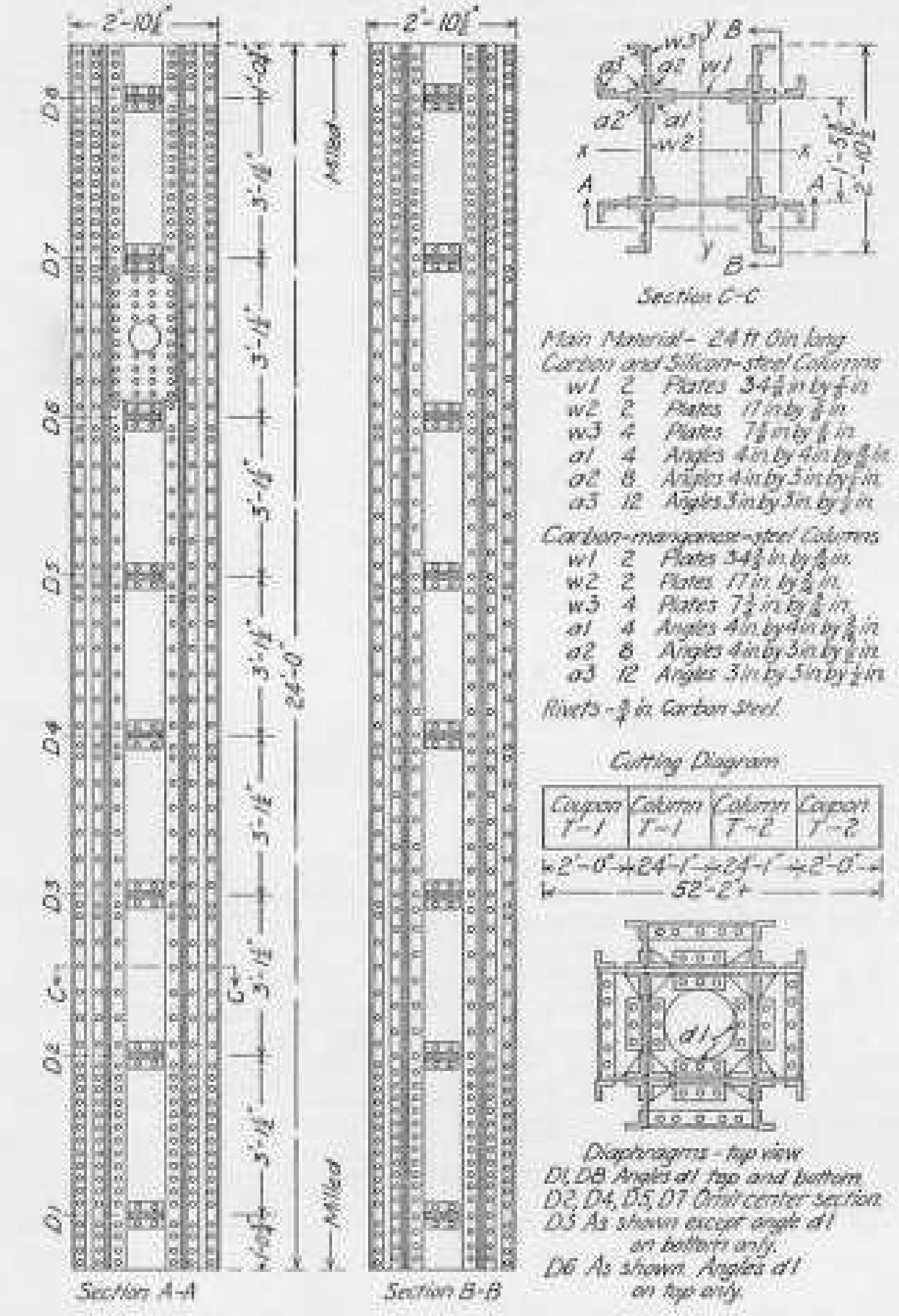


FIGURE 1.—*Dimensions of the test columns.*

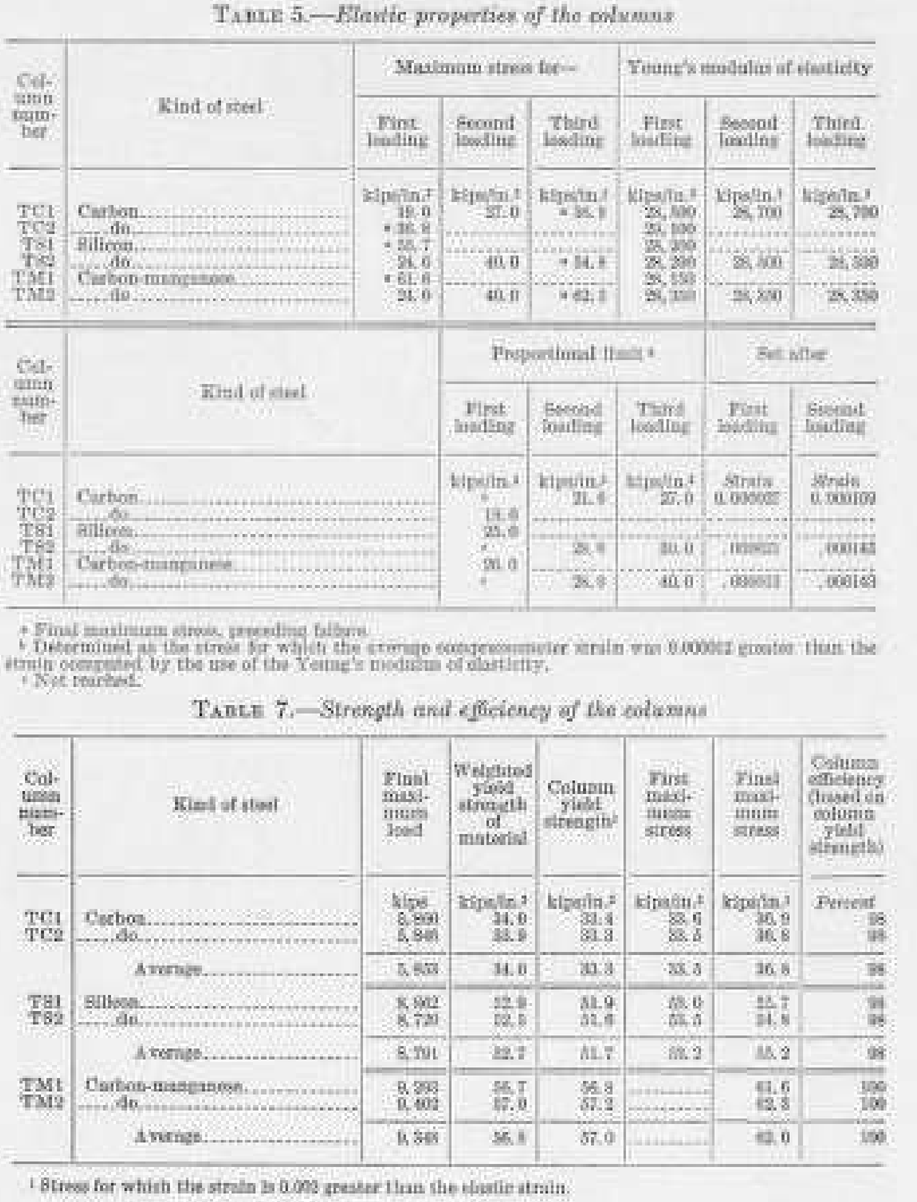


TABLE 5.—*Elastic properties of the columns*

Column number	Kind of steel	Maximum stress for—			Young's modulus of elasticity		
		First loading	Second loading	Third loading	First loading	Second loading	Third loading
		kips/in.²	kips/in.²	kips/in.²	kips/in.²	kips/in.²	kips/in.²
TC1	Carbon	19.0	37.0	a 36.9	28,800	28,700	28,700
TC2	do	a 36.8			29,100		
TS1	Silicon	a 55.7			28,300		
TS2	do	24.6	40.0	a 54.8	28,300	28,500	28,300
TM1	Carbon-manganese	a 61.6			28,150		
TM2	do	24.0	40.0	a 62.3	28,350	28,300	28,350

Column number	Kind of steel	Proportional limit b			Set after	
		First loading	Second loading	Third loading	First loading	Second loading
		kips/in.²	kips/in.²	kips/in.²	Strain	Strain
TC1	Carbon	c	31.6	27.0	0.000027	0.000109
TC2	do	19.0				
TS1	Silicon	25.0				
TS2	do	c	28.9	30.0	.000025	.000143
TM1	Carbon-manganese	20.0				
TM2	do	c	28.0	40.0	.000013	.000143

a Final maximum stress, preceding failure.

b Determined as the stress for which the average compressometer strain was 0.000012 greater than the strain computed by the use of the Young's modulus of elasticity.

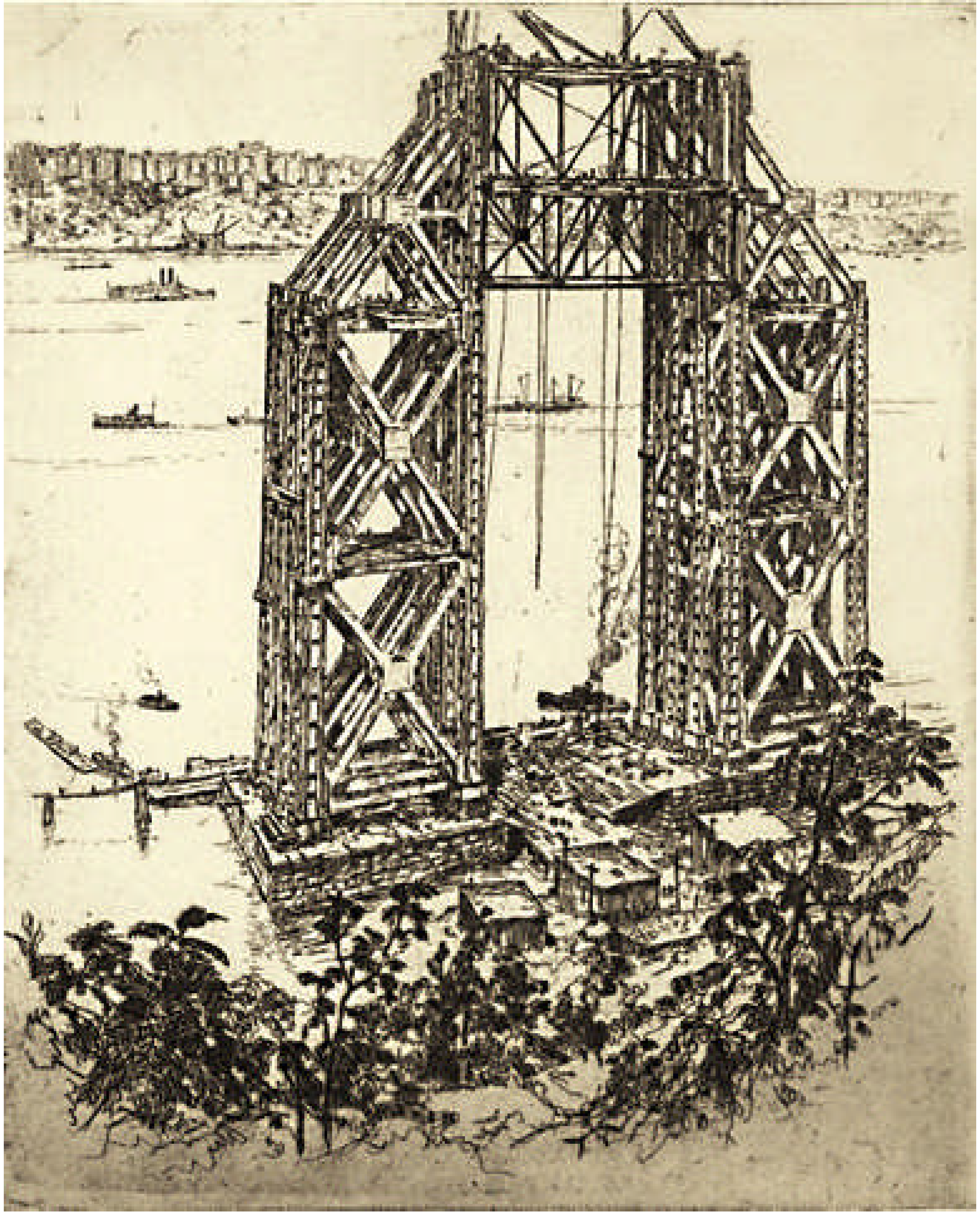
c Not reached.

TABLE 7.—*Strength and efficiency of the columns*

Column number	Kind of steel	Final maximum load	Weighted yield strength of material	Column yield strength[1]	First maximum stress	Final maximum stress	Column efficiency (based on column yield strength)
		kips	kips/in.²	kips/in.²	kips/in.²	kips/in.²	Percent
TC1	Carbon	5,860	34.0	33.4	33.6	36.9	98
TC2	do	5,846	33.9	33.3	33.5	36.8	98
	Average	5,853	34.0	33.3	33.5	36.8	98
TS1	Silicon	8,862	52.9	51.9	53.0	55.7	98
TS2	do	8,720	52.5	51.6	53.5	54.8	98
	Average	8,791	52.7	51.7	53.2	55.2	98
TM1	Carbon-manganese	9,293	56.7	56.8		61.6	100
TM2	do	9,403	57.0	57.2		62.3	100
	Average	9,348	56.8	57.0		62.0	100

[1] Stress for which the strain is 0.002 greater than the elastic strain.

<u>Above T&B & Left</u>: excerpts from: Tests of Steel Columns for the George Washington Bridge – U.S. Department of Commerce – National Bureau of Standards



<u>Left</u>: ***The Tower Grows*** **(1927) - etching by *Otto August Kuhler***

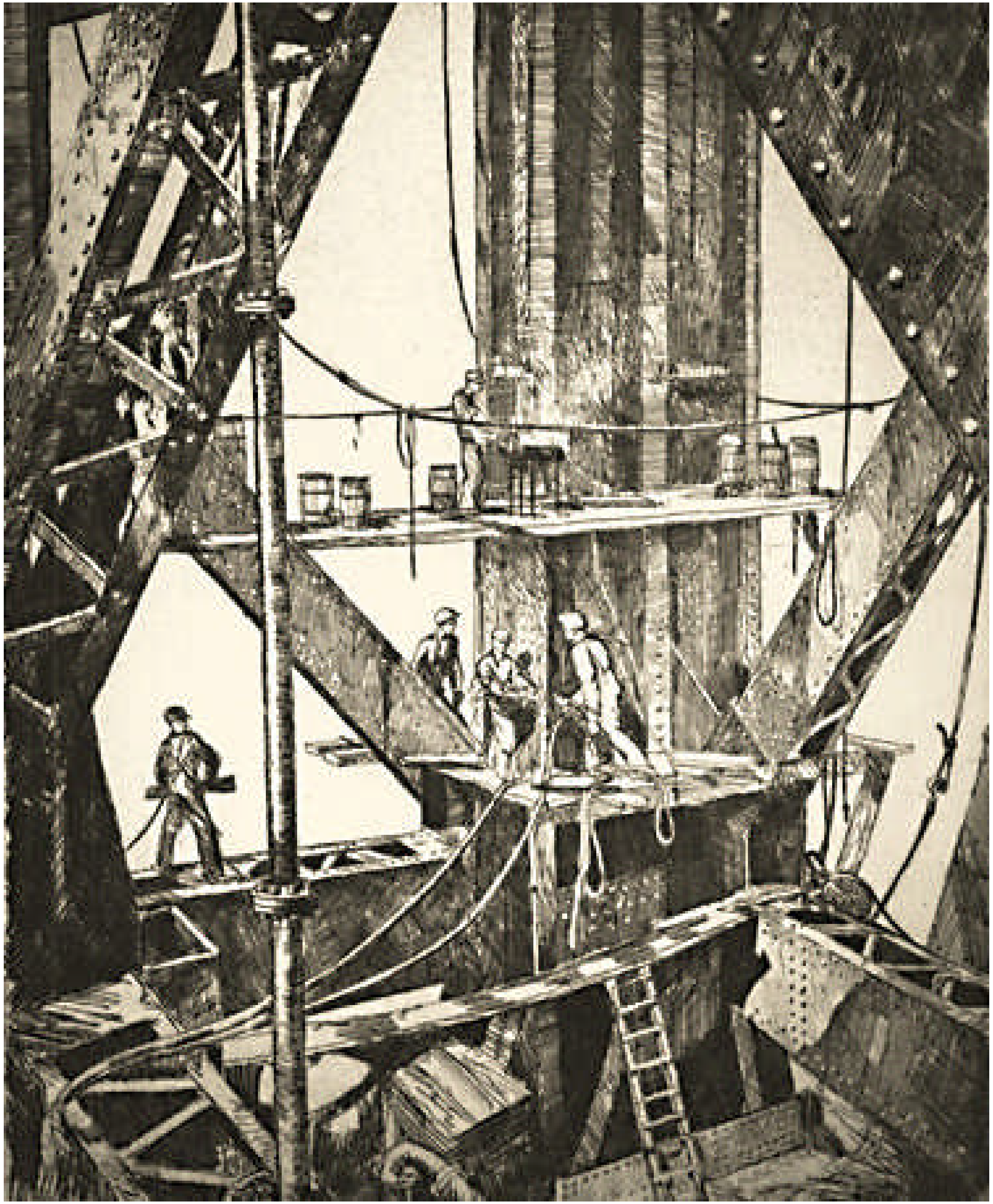
"…Erection and riveting of the tower superstructures were discontinued during the winter of 1928-29. The riveting of both towers, however, was completed by August 1929. On an average, nine or ten gangs, each gang consisting of four men, were engaged in the riveting of each tower, though sometimes thirteen gangs would be on the job at once. Each of the cable saddles on the towers consists of four huge castings, the heaviest weighing about 55 tons…"

***Wonders of World Engineering,* November 1937**

<u>Left</u>: caption: "New York & New Jersey towers rising from their foundations Winter, 1929"

<u>Right</u>: caption: "Towers near completion"

<u>Above T&B</u>: caption: "Tower Steel Erection"
<u>Left</u>: caption: "Workers inside tower"



Left: ***Riveters*** **(1928) - etching by *Otto August Kuhler***

A Stupendous Task

> ***“…The magnificent structure, when completed in 1932, will have been made possible through the unique engineering undertaking of deep-rock mining operations on one shore, and erecting a man-made mountain range on the other. For the engineers were confronted with the problem of anchoring it in the solid rock of the Palisades that rise on the Jersey bank of the river, and of constructing a huge cliff on the New York side to match the natural stone opposite it in everlasting power…”***

***Popular Science,* February 1929**

"…Building the New Jersey anchorage, much of which was underground, was a stupendous task. The miners employed on the excavation of the anchorage had to dig out 17,300 cubic yards of rock for the anchor chain tunnels alone. Between the surface of the ground overhead and the lower extremity of the tunnel system they sank a vertical shaft, with the usual type of pit headgear at the top, for the removal of the rock spoil. The bottom level was reached during June and July 1928. A cross gallery, containing tubs running on rails, was driven between the bottom of the shaft and the bottom of the tunnels, which were connected to it by spoil chutes. The shaft was 250 feet deep and seven feet by nine feet in section…"

***Wonders of World Engineering,* November 1937**

Left: caption: "Excavating South Tunnel for the New Jersey Anchorage"

“…The big cutting through the rock surface above, which was to take the approach road to the bridge from the environs of Jersey City, involved the removal of 197,500 cubic yards of spoil over a length of 830 feet and a width of 146 feet. The anchorage pits above the tunnels accounted for a further 6,500 cubic yards of rock. The anchor blocks are 69 feet long, 26 feet high by 27 feet wide; they contain anchors for the stiffening trusses. Work in the two anchorage tunnels proceeded alternately, the men working in one tunnel while the other was being cleared of fumes from blasting operations. The two tunnels thus progressed simultaneously and the same men worked in both…”

***Wonders of World Engineering,* November 1937**

Above Top: caption: “Palisades cliff-side before blasting”
Left: caption: “Preparing the cliff-side for blasting”
Above Bottom: caption: “Palisades cliff-side after blasting”

Built to Endure

“…The Jersey stone gives ample anchorage for the big cables – thirty-six inches in diameter – from which the bridge will be suspended. But on the opposite bank, anchorage required a mass of concrete almost an entire city block in area and as high as a fourteen-story building! Such immense anchors are needed, for each cable must be able to resist a pull of some 65,500,000 pounds, caused by its own weight and that of the structure it will help to carry…To erect the concrete anchorage on the New York side, a modern concrete plant had to be established in the midst of one of New York’s exclusive residential sections. Here two huge mixers grind out 1,000 cubic yards of concrete each day!...:”

Popular Science, **February 1929**

"…The building of the New York anchorage, as of the New York piers, was a simpler operation than that simultaneously in progress across the water, though it involved heavy enough work. It contains no less than 110,000 cubic yards of concrete…The entire mass was completed in a space of five and a half months, or over two months ahead of schedule…"

***Wonders of World Engineering*, November 1937**

Left: caption: "New York Anchorage under construction"

KOEHRING

Anchorage for the Longest Suspension Span

A bridge with a main suspension span of 3500 feet, the longest in the world, will soon cross the Hudson river at New York. Suspension will be maintained by four 36 inch cables supported on steel towers 635 feet above the water level.

Abutments on the Fort Lee approach are shown in preparation in the views at the right. Two Koehring Heavy Duty products, a power shovel for the rock excavation and a paving mixer for turning out the Dominant Strength Concrete, were used in this work.

The massive New York anchorage above, 200 feet by 300 feet ground dimension and 125 feet in height, contains 110,000 cubic yards of quality controlled concrete mixed by two Koehring Heavy Duty Mixers.

Another identification of the Koehring re-mixing action with a structure built to endure!

The revised edition of "Concrete — Its Manufacture and Use," a complete treatise and handbook on present methods of preparing and handling portland cement concrete, is now ready for distribution. To engineering students, faculty members and others interested we shall gladly send a copy on request.

KOEHRING COMPANY
MILWAUKEE, WISCONSIN
Manufacturers of
Pavers, Mixers—Gasoline Shovels, Cranes and Draglines
Division of National Equipment Corporation

<u>Left</u>: caption: "A bridge with a main suspension span of 3,500 feet, the longest in the world, will soon cross the Hudson River at New York. Suspension will be maintained by four 36 inch cables supported on steel towers 635 feet above water level. Abutments on the Fort Lee approach are shown in preparation in the views at right. Two Koehring Heavy Duty products, a power shovel for the rock excavation and a paving mixer for turning out the Dominant Strength Concrete, were used in this work. The massive New York anchorage above, 200 feet by 300 feet ground dimension and 125 feet in height, contains 110,000 cubic yards of quality controlled concrete mixed by two Koehring Heavy Duty Mixers. Another identification of the Koehring re-mixing action with a structure built to endure!"

RE: 1930 advertisement

“…On the New York bank of the river, along stately Riverside Drive, a mammoth steam shovel, droning and panting from behind a green board fence, picks up 15,000 cubic yards of rock at one time. Aloft, a 325-ton traveler crane grinds ponderously around, hoisting enormous amounts of material that form its own rising pedestal. An endless conveyor belt, crossing the New York Central railroad tracks, carries sacks of cement and gravel from river lighters. From across the water comes the constant boom of blasting as tunnels are bored and a man-made canyon is cut through the Palisades…”

***Popular Science,* February 1929**

Left: *Man Made Canyon* (1927) - etching by *Otto August Kuhler*

Part 2

The Hudson Challenge

A Serious Obstacle

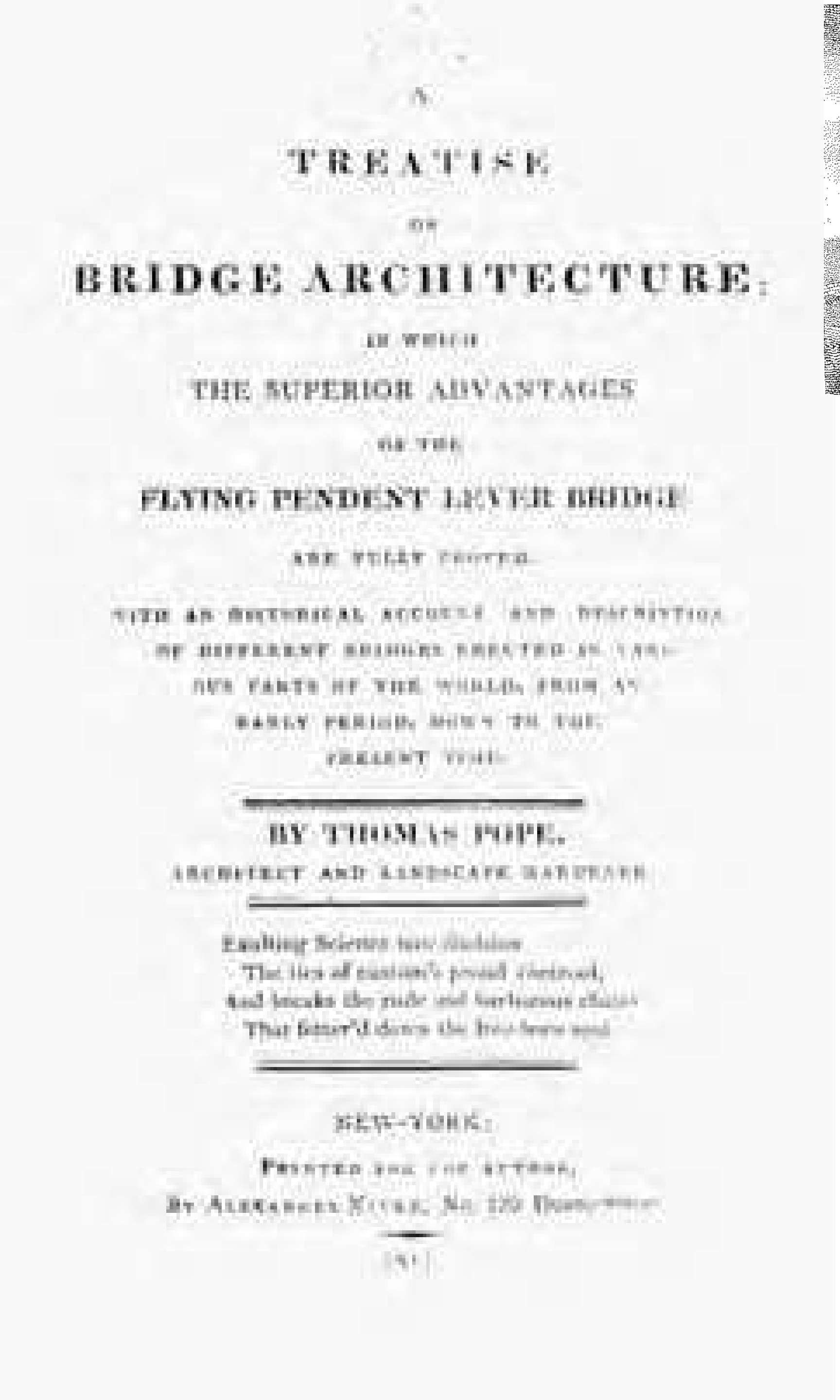
“…To those who planned America’s highways in the past the broad waters of the Hudson formed a serious obstacle. It is not surprising, therefore, that serious schemes for bridging it have been proposed…”

***Wonders of World Engineering*, November 1937**

“…The traffic situation in New York and vicinity labors under many disadvantages, and by far the greatest of them is the existence of the broad stretch of the Hudson River, cutting off Manhattan Island, the heart of New York, from the mainland and its vast network of railroads. Once this obstacle has been removed, the traffic problem will be solved. That has always been well understood. The outstanding question has been how best to accomplish this…”

***Popular Science,* April 1921**

One Grand Flying Leap



A
TREATISE
ON
BRIDGE ARCHITECTURE;
IN WHICH
THE SUPERIOR ADVANTAGES
OF THE
FLYING PENDENT LEVER BRIDGE
ARE FULLY PROVED.
WITH AN HISTORICAL ACCOUNT AND DESCRIPTION
OF DIFFERENT BRIDGES ERECTED IN VARI-
OUS PARTS OF THE WORLD, FROM AN
EARLY PERIOD, DOWN TO THE
PRESENT TIME.

BY THOMAS POPE,
ARCHITECT AND LANDSCAPE GARDENER.

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NEW-YORK:
PRINTED FOR THE AUTHOR,
BY ALEXANDER NIVEN, No. 120 [illegible]

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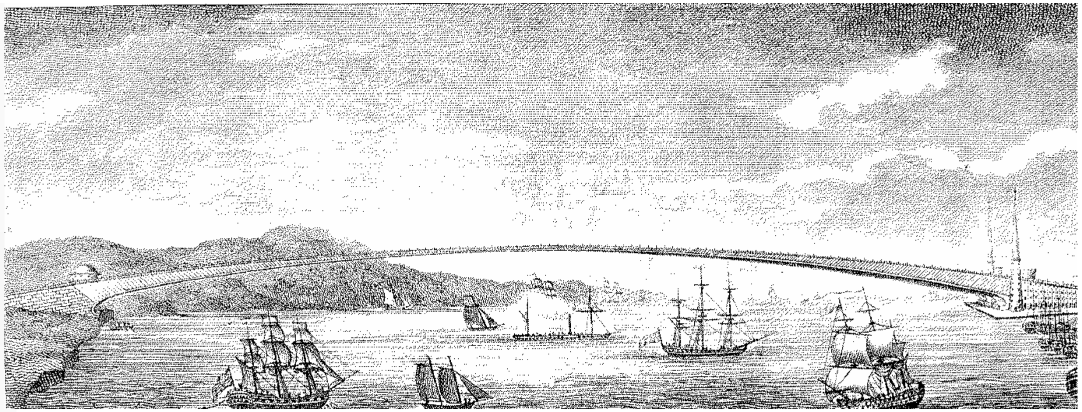


Like half a rainbow rising on yon shore,
While the twin partner spans the semi o’er
And makes a perfect whole that need not part
Till time has furnished us a nobler art
Thomas Pope

RE: shipwright, poet and visionary, in 1811 Pope published *A Treatise on Bridge Architecture* (left). In it, Pope proposed *Rainbow Bridge* – a wooden “Flying Pendant Lever Bridge,” to span the *East* and/or *North* (*Hudson*) *River/s* in “one grand flying leap” (the latter scenario illustrated above).

“…No matter when it was built, the first bridge to span the Hudson River from New Jersey to New York City was destined for fame. After the Civil War, a single span was determined most suitable for the wide, heavily trafficked river just west of the fast-growing metropolis. But materials and engineering skill lagged far behind the dream…”

Smithsonian **magazine, October 1999**

“We shall have a bridge across the Hudson into this city ere the century closes”

***The New York Times*, July 3rd 1888**

“…As long ago as 1868, when the Roebling’s celebrated Brooklyn suspension bridge was first being planned, similar proposals were being made for spanning the Hudson, for in that year the State of New Jersey passed an Act for the building of such a bridge. The Act allowed for a structure with a clear span of not less than 1,000 feet, with not more than two piers founded in the bed of the river itself, and a clear height of at least 130 feet over the fairway in the center. Though nothing was done at the time, in spite of the formation of a company for building the bridge, this and other early proposals are of considerable interest…”

***Wonders of World Engineering*, November 1937**

From Shore to Shore

“…Over twenty years later, the scheme was revived and a new Act was passed, this time by the State of New York. This second Act did not allow the founding of any piers in the river, which was, whatever the type of bridge to be adopted, to be cleared in a single gigantic span from shore to shore…”

***Wonders of World Engineering*, November 1937**

“…The bridge company now encountered the law entrenched, for it did not at the time want to build a suspension bridge, which seemed to be the only type possible under the ruling of the New York State Act. The primary purpose of the bridge – it was long before motor transport had any significance – was to link two railway systems. In the opinion of the company a suspension structure was unsuited to the great shifting weights of heavy steam locomotives which were expected to pass to and fro over the structure…”

***Wonders of World Engineering*, November 1937**

The North River Bridge Company

Beneath a tree on a college campus in *New Jersey* (top), there’s a cornerstone of a bridge that was never built (bottom). The stone is the only vestige left of a planned 6K-foot bridge that would have spanned the *Hudson River* from Manhattan’s *57th Street* to *New Jersey*. Originally laid on June 18th 1895 (at the corner of *Garden* and *12th Street/s* in *Hoboken*), the stone was later moved to its current location at the *Stevens Institute of Technology*.

"…Just five years after the completion of John Roebling's Brooklyn Bridge, then the world's longest suspension bridge, 38-year-old Austrian-born engineer Gustav Lindenthal put forth a plan for a suspension bridge across the Hudson. It was a grand concoction: six railroad tracks, more than a mile in total length. Its center span was to be nearly twice as long as that of Roebling's widely admired masterpiece. Great feats of engineering require greater feats of imagination. For both, Lindenthal was well qualified. With little formal education and a physique to match the size of his dreams, he had taught himself English and the rudiments of engineering. Immigrating to America in 1874, he quickly prospered in his adopted land, whose engineers had more use for quick thinking and practical energy than college degrees…"

Smithsonian magazine, Oct. 1999

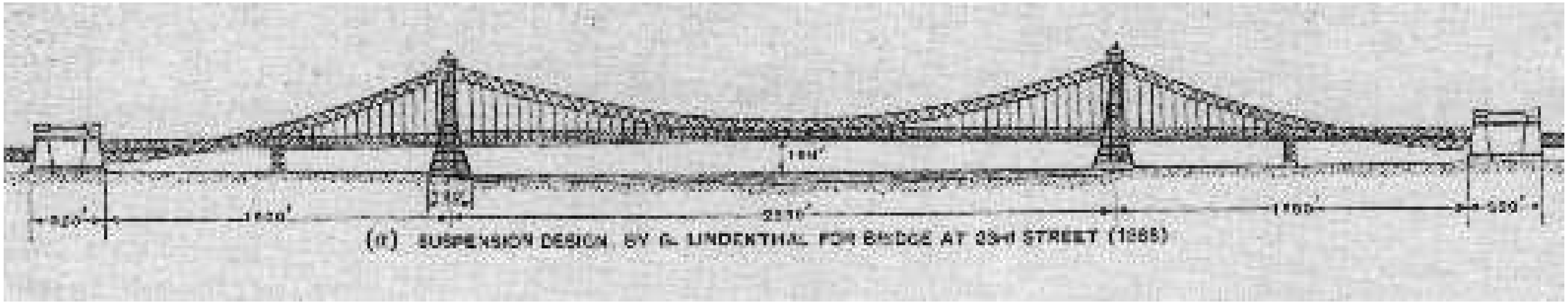
Left: _Gustav Lindenthal_ (ca. 1880s)

In 1885, *Gustav Lindenthal*, a self-educated bridge engineer who had established his reputation on two notable *Pittsburgh* spans, was approached by officials at the *Pennsylvania Railroad* regarding the feasibility of a railroad bridge across the *Hudson River*. At the time, the Pennsylvania Railroad was at a serious disadvantage since it did not have direct service into *Manhattan* as did its chief competitor; the *New York Central Railroad*. Because of the smoke that emanated from the steam locomotives of the day, the railroad favored a bridge across the Hudson rather than a tunnel. After giving serious thought to a cantilever design, Lindenthal decided on a suspension bridge (because it would allow wider distances between piers). However, the suspension bridge would have to have a main span of about 3K-feet; nearly twice the length of the main span of the *Brooklyn Bridge* which was completed just two years earlier (1883). Constructing such a bridge, along with its approaches and Manhattan terminal, was considered too expensive for one railroad to handle alone. In response, in 1887 Lindenthal organized the *North River Bridge Company* to seek financial support from several railroads. These railroads would share not only the bridge, but also the terminal facilities. The completion of the bridge would be a boon for these railroads, whose transcontinental tracks dead-ended on the *New Jersey* shore of the Hudson. Freight trains bound for *New York City* by rail-ferry would no longer be at the mercy of Hudson River traffic and/or foul weather nor would they have to make a 300-mile detour via *Albany* to get across the wide river.

“…The great arteries of circulation, the railroads, extend to the shores across the river, but, with only one exception, they do not bring their trains of freight and passengers directly into Manhattan. All the material carried by these outside lines must be transferred and rehandled before it is conveyed across the river to be distributed. This involves expense which is reflected in the cost of living. Long Island and Manhattan are connected by bridges as well as tunnels. Why have we waited so long before attempting to bridge the Hudson?...”

***Popular Science,* December 1920**

Left T&B: Hudson ferry terminal, Manhattan (ca. 1920s)

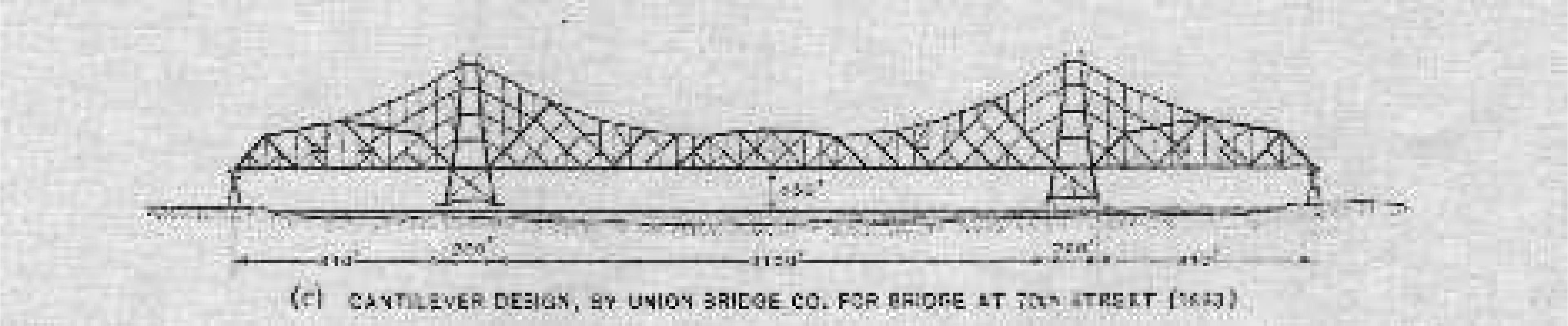


“…as close as convenient to the principal hotels”

Gustav Lindenthal

Above: caption: “Suspension design by Gustav Lindenthal for a bridge at West 23rd Street (1888).” In late 1887, Lindenthal published *The Proposed New York City Terminal Railroad, Including North River Bridge and Terminal Station, in New York City*, in which he described the parameters of the project. The proposed bridge featured a main span of 2,850-feet between towers, with side spans of 1,500-feet. Eyebar chains were to be suspended from 530-foot-tall steel-and-masonry towers, together supporting the deck 150-feet above the *Hudson River*. The six railroad tracks that were to be carried by the bridge required deep stiffening trusses. These tracks were to continue into *Manhattan* on high viaducts to a proposed terminal station near *Sixth Avenue* and *West 18th Street*. Lindenthal and the *Pennsylvania RR* wanted the bridge to exceed its rival - the *Firth of Forth Railway Bridge* (1890), in *Scotland*.

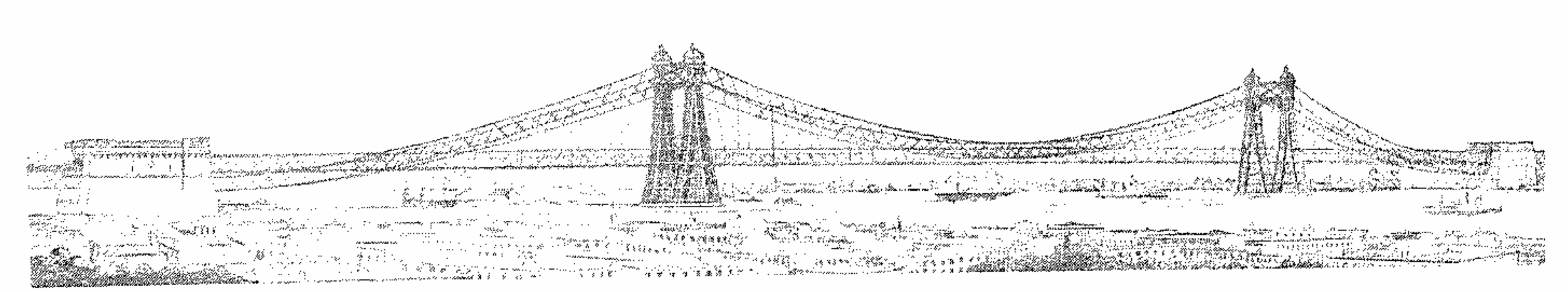
The complete *Hudson River* bridge and terminal project, which was to include a tunnel through *Bergen Hill* in *New Jersey*, was projected by Lindenthal to cost $23 million. An additional $14 million was to be set aside for right-of-way acquisitions. Because the expenses of operating the system were to be covered by the railroads (about $2 million per year in revenue would come from passenger fares alone) the proposal appeared financially sound. In 1888, a competing proposal for a cantilever bridge across the Hudson had been submitted to the legislatures of *New York* and New Jersey. This plan called for two piers in the middle of the Hudson River, a 1K-foot main span, and a 135-foot clearance above the river. However, *Engineering News*, defending the Lindenthal suspension bridge proposal, said that the cantilever bridge would compromise navigation along the Hudson and be less visually appealing than a suspension bridge.

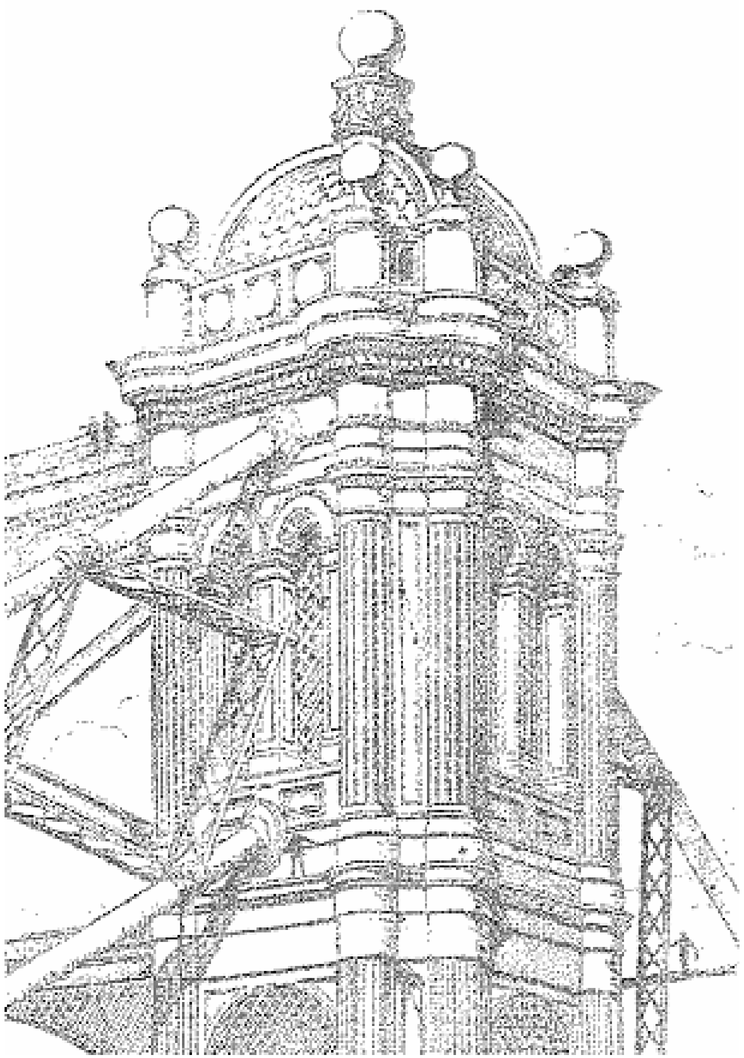


"…The proposal contemplates the erection of a cantilever, and stipulates for the placement of one pier in the river channel, neither of which should be permitted unless absolutely found necessary, even if the cost were considerably increased. If there be one place where a mere 'utility structure' should not be permitted, but where dignity and beauty of form should be a controlling feature, it is over the North (Hudson) River in New York, and in that and other respects the suspension type seems to us to have great advantages for the location…"

***Engineering News,* 1888**

<u>Above</u>: caption: "Cantilever design by Union Bridge Company for a bridge at West 70th Street (1893). The design featured a 2,100-foot-long main span, two 810-foot-long side spans, and a clearance of 150-feet"





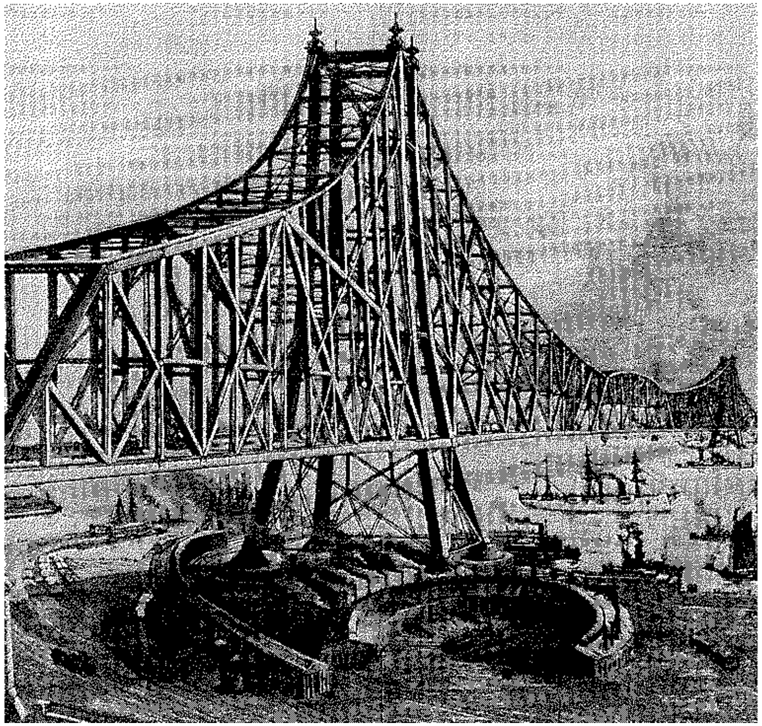
"It is certainly true that New York Harbor, acknowledged to be the most beautiful in the country, should be defaced by a utility bridge of shabby appearance, it would be an unpardonable offense against the civilization of mankind"

Gustav Lindenthal

RE: excerpt from *Engineering News,* February 1888

<u>Above</u>: caption: "Gustav Lindenthal's first proposal for a Hudson River Bridge. Note his characteristic eyebar bracing between cables."

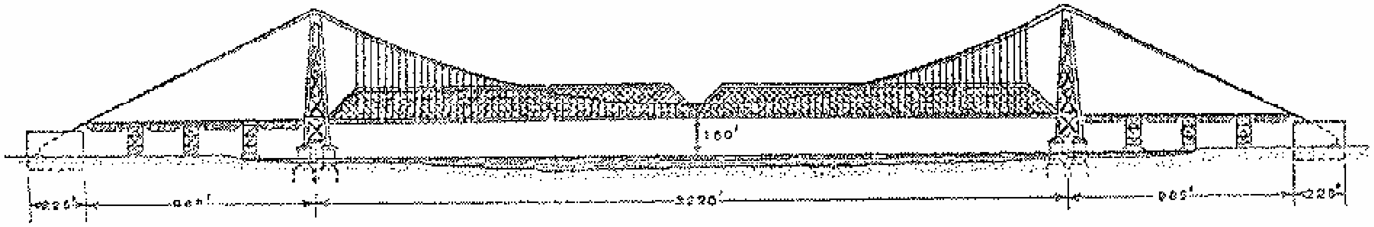
<u>Left</u>: caption: "Detail of 525-foot tower displays ornamental steelwork"

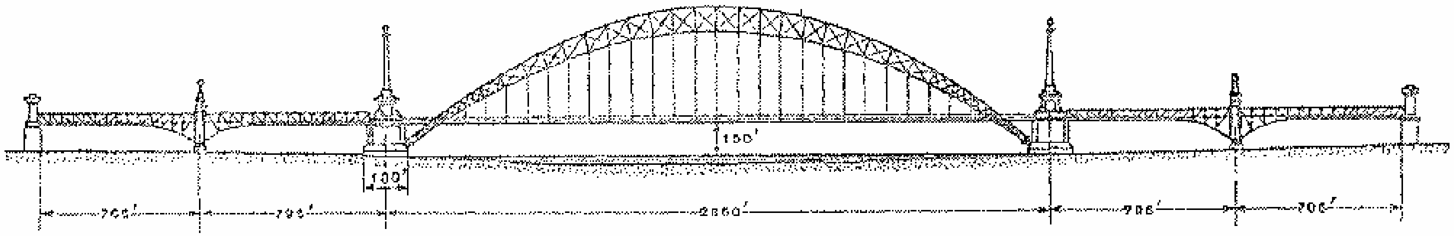


"…Again, the engineers called into consultation did not think that they could build a suspension bridge on such a scale as that demanded by the Hudson. The original plans had been for a cantilever bridge from 70th Street, Manhattan, carrying six railway tracks and having a clear span of 2,000 feet, the distance between the centers of the piers being 2,300 feet. The New York pier was to be on shore, and the New Jersey pier was to be situated 900 feet out…"

***Wonders of World Engineering*, November 1937**

Left: caption: "Proposed cantilever bridge over the Hudson River"





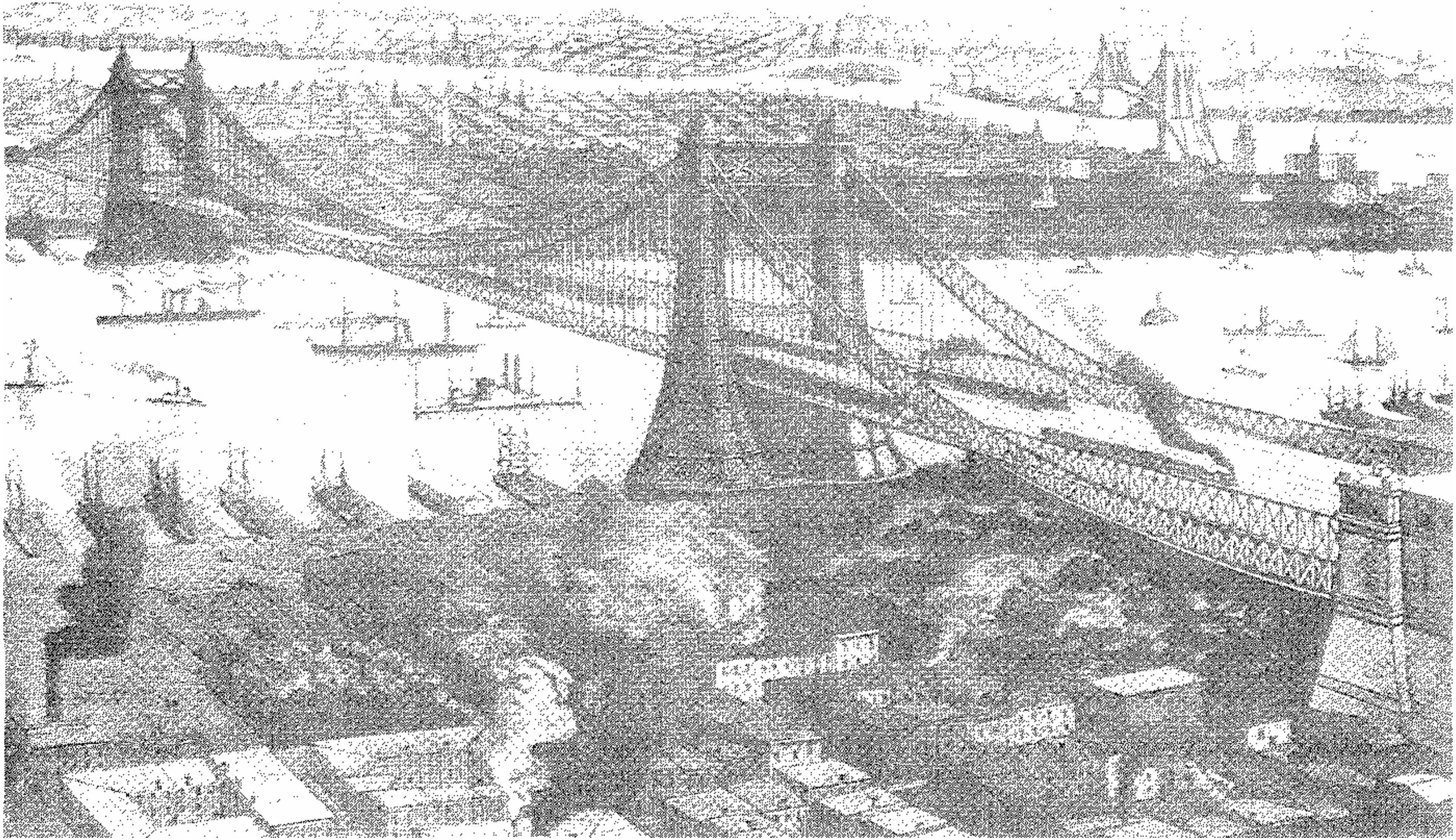
"…a suspension bridge spanning the North River without a pier would involve such elements of uncertainty as regards first cost, novelty in its magnitude as a hitherto untried engineering feat, and time of construction, to say nothing of the well-founded prejudice against the suspension principle for railroad purposes, as would render the enterprise impracticable from a financial standpoint"

***NY & NJ Bridge Company,* 1890**

RE: first plan submitted to the federal government for a six-track, 2,300-foot cantilever railroad bridge at *70th Street* in *Manhattan* – considered most practical and economical as compared to a suspension bridge.

<u>Above Top</u>: caption: "Suspension design by the Board of Engineers appointed by the U.S. Secretary of War (1894). The design featured a 3,220-foot-long main span, two 965-foot-long side spans and a clearance of 160-feet"

<u>Above Bottom</u>: caption: "Arch design by Max Am Ende (1889). The design featured a 2,850-foot-long main span, two 795-foot-long side spans, two 705-foot-long flanking spans, and a clearance of 150-feet"



Above: caption: “Lindenthal altered his design and it appeared in Scientific American, May 1891. It carries 10 railroad tracks.”

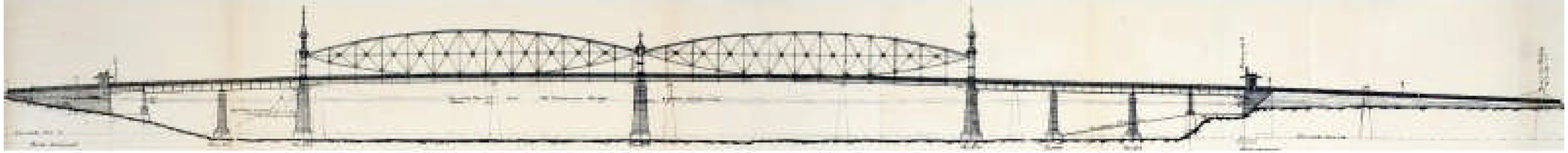
Financiering

"…the financiering of the bridge far exceeds in difficulty the engineering problems presented."

Gustav Lindenthal

RE: construction of a suspension bridge was proposed by Federal legislation, pending approval of plans by the *Secretary of War*. For a *Hudson River* bridge to be constructed, no piers would be allowed in the river. By 1890, the bridge proposal passed both houses of *Congress*. Ground was broken for the bridge on June 18th 1895, and the first foundation masonry was laid at the site of the *Hoboken* anchorage, across the Hudson River from *West 23rd Street* in *Manhattan*. Work did not progress much further because of the difficulties in financing the $37 million cost of the project. The bridge's construction would have cost $23 million, $40 million with related costs; about the same amount it cost to run all of *New York City* in 1888.


FOUNDATION
LAID JUNE



"…By the turn of the century, Lindenthal was renowned among his peers. His Seventh Street and Smithfield Street bridges in Pittsburgh were some of the most significant of their time. In 1902, Lindenthal became commissioner of bridges for New York City, a political appointment that gave him considerable power and prestige as an engineer and designer. But his dream bridge still had not been built. Despite endorsement of Lindenthal's Hudson River bridge plan by the War Department, a rival bridge concern had sued to stop the project. By the time the case was settled, the depression of the early 1890s had dried up most of the funds. Replaced as commissioner after the 1903 city elections, Lindenthal found himself in the odd position of peddling new Hudson River bridge designs to myriad interested groups - with no agreement on location, cost or funding. In the meantime, the city grew. By 1912, Lindenthal was busy completing plans for a railroad bridge - the world's longest steel arch bridge, in fact - across the dangerous channel between Manhattan and Queens called Hell Gate. To help with the task, the august designer took on a 33-year-old assistant not long arrived from Switzerland…"

Smithsonian **magazine, October 1999**

Above: caption: "Original (1881) elevation of the Smithsonian Street Bridge"

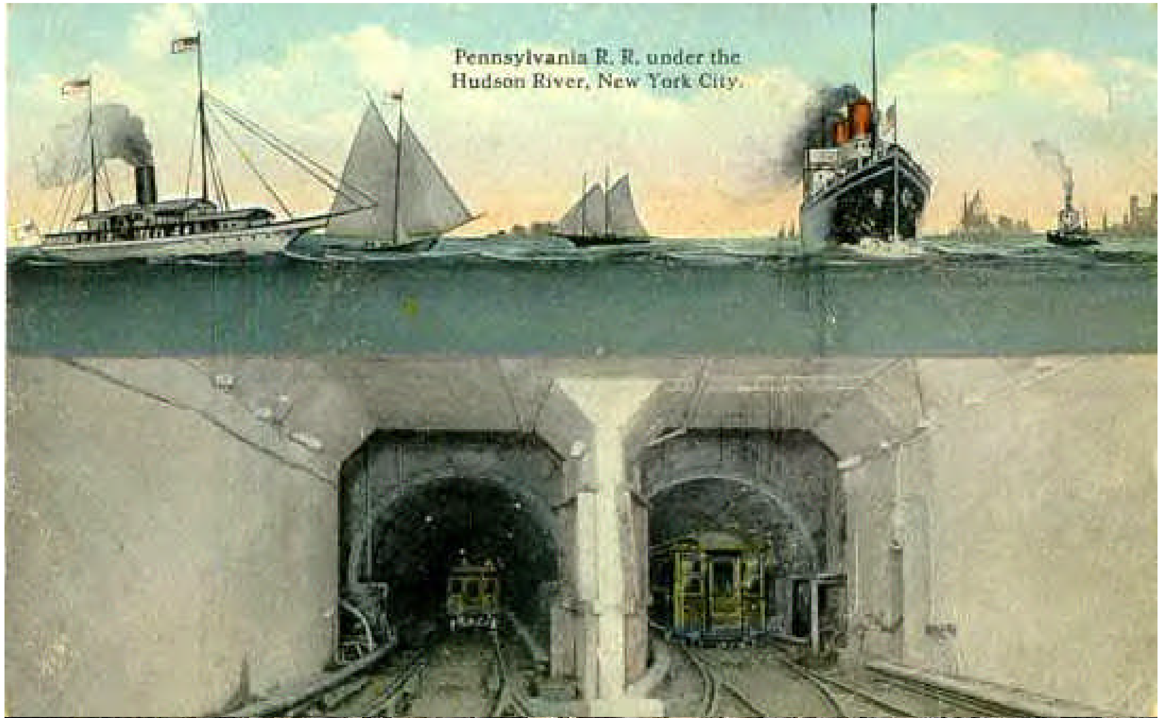
“Steinman, bridge engineering is easy. It’s the financial engineering that’s hard”

Gustav Lindenthal

<u>Above</u>: *Hell Gate Arch* (present-day)

<u>Left</u>: the engineering staff pose for a photograph near *Hell Gate Arch* during construction (October 1916). *Gustav Lindenthal* (highlighted) is the large man at center with *D.B. Steinman* fourth from left. *O.H. Ammann* is to Lindenthal’s right.

<u>Above</u>: engineering staff for the *Queensboro Bridge* (*Gustav Lindenthal* at far left). Construction of the *Hudson River* bridge was delayed by the financial panic of 1893 and, eventually, plans fell by the wayside. In the meantime, construction had begun on the *Manhattan & Hudson RR* tunnels (now *PATH*) into lower *Manhattan.* As the *19th Century* drew to a close, developments in tunneling and in electric-traction locomotives led the *Pennsylvania Railroad* to pull out of the Hudson River bridge project, opting instead to construct tunnels under the Hudson using electric trains. In 1910, the Pennsylvania RR completed construction on tunnels to link *Weehawken, NJ* and their new *Pennsylvania Station* in Manhattan. In 1902, after being appointed *New York City Bridge Commissioner* by Mayor *Seth Low*, Gustav Lindenthal shifted his attention from the Hudson River to the East River, concentrating on the *Williamsburg* (1903), *Manhattan* (1909) and Queensboro (1909) *Bridge/s* (the former then under construction). With *O.H. Ammann* serving as his first assistant, he would complete his crowning achievement – *Hell Gate Arch* (1917). But his dream of a Hudson River bridge would live on.



"The plan to bridge the Hudson from New York to the Jersey side of the river has at last been abandoned. Railroad constructors who have been at work on the project have had but poor results from their experiments with foundation borings and have been forced to give up their work. In no instance have they discovered bedrock within working depths below the water level. The indications are, however, that a tunnel between Manhattan and Jersey can be constructed at much lower cost than a bridge, and from the results obtained in the operation of existing subways, such a form of connection can be operated even cheaper than ferries."

***Popular Mechanics,* July 1910**


Pennsylvania Station, New York City.

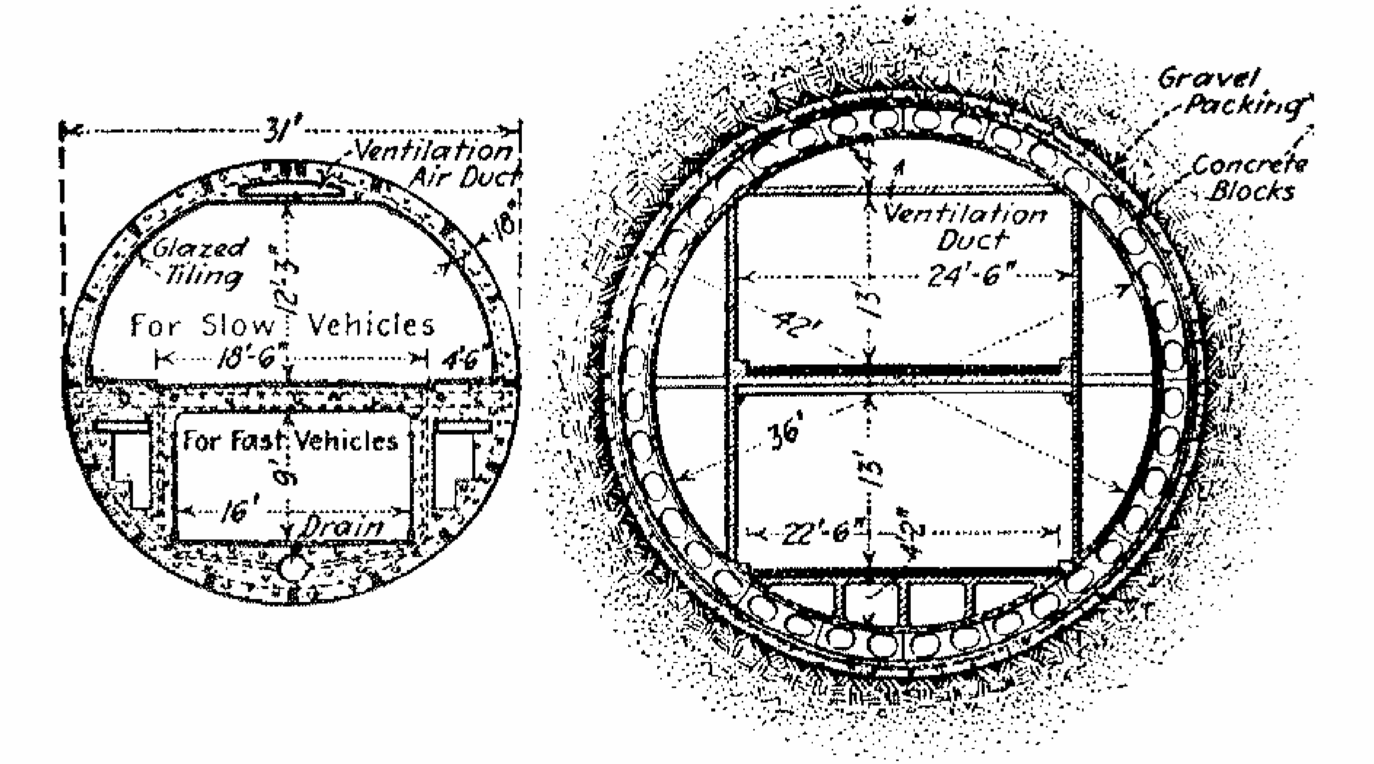
“To insure success, any plan for connecting Manhattan with New Jersey should include the cooperation of the railroads, at least so far as the handling of freight is concerned. Every one of the four existing East River bridges cost from 89% to 120% more than the original estimate at the time the bridges were authorized, and this is only in keeping with the sad experience which New York City and State have had with regard to other important engineering works that have been built with public funds. If the present grossly unfair treatment of the railroads shall come to an end, that is to say if they are once more permitted to operate according to true economic laws, and therefore should feel justified in facing larger expenditures to improve their systems, they will find the proposed railway connections with Manhattan an attractive proposal.”

***Gustav Lindenthal,* 1910**

RE: Lindenthal’s (left) revised proposal for a suspension bridge at *59th Street* accommodating both automobiles and sixteen railroad tracks

“Put two million eight hundred thousand on an island, give them houses, subways, surface cars, factories, stores, and all the equipment of a city - but fail to provide a means of reaching these people with the materials with which their factories can work, fail to give them fuel and food - and the vast population of the isolated island will perish. The means of conveying material, food, and fuel to the citizens of the island-city is of utmost importance. Manhattan island must be hooked up to the United States, and many plans have been suggested to accomplish this ambitious purpose…”

***Popular Science*, December 1920**



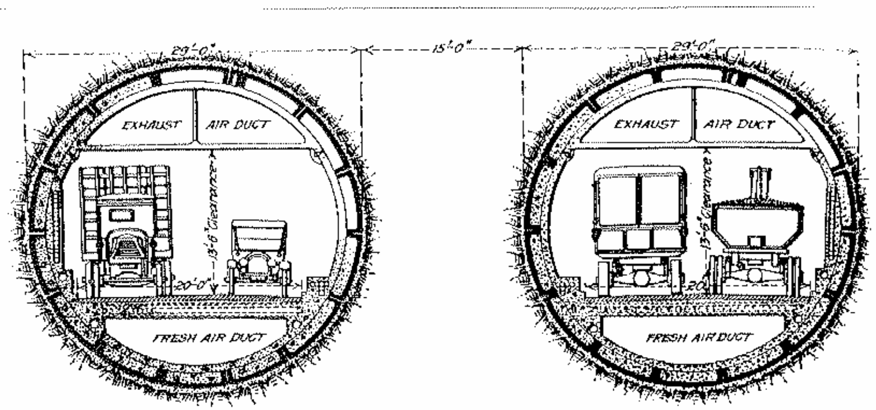
"…was due almost entirely to the city's inability because of the ice-choked river to transport thousands of tons of coal that were literally in sight on the other side of the river, and yet as unattainable as if they were still in the mines"

George Goethals

<u>Above</u>: caption: "Two unrealized proposals for Hudson River vehicular tunnels, by the firm of Jacobs & Davies in 1910 (left) and by *O'Rourke & Goethals* in 1919 (right)." During the winter of 1918, a "Coal Famine" occurred in *New York City* when barges containing the coal needed to heat homes and businesses could not get across the Hudson due to ice flows. Goethals was a proponent for a tunnel of his own design to be built under the Hudson

“That there is need for better connection between Manhattan and the western half of the Metropolitan District lying across the Hudson River is evidenced by the prodigious growth of Brooklyn and the Bronx, to which convenient interboro transportation facilities have been provided; and also by the fact that the States of New York and New Jersey have recently begun the joint construction of a vehicular tunnel between Jersey City and lower Manhattan. Because of these and many other economic reasons which are acute and press for closer connections between the two shores of the river, it now seems justifiable to consider a bridge across the Hudson…”

Baltimore & Ohio **magazine, January 1923**



‘If I had known it was tapping his strength so much, I would have urged him to be more careful, but he was so completely wrapped up in his work that I really do not know if any pleadings would have had any effect”

RE: comments made by the wife of Chief Engineer *Clifford Holland* (left) upon his tragic death from nervous exhaustion at age 41. The tunnel – which was completed soon after his untimely death – was named in his honor. Above, Holland’s design for a *Hudson River* vehicular tunnel made up of twin, ventilated tubes.

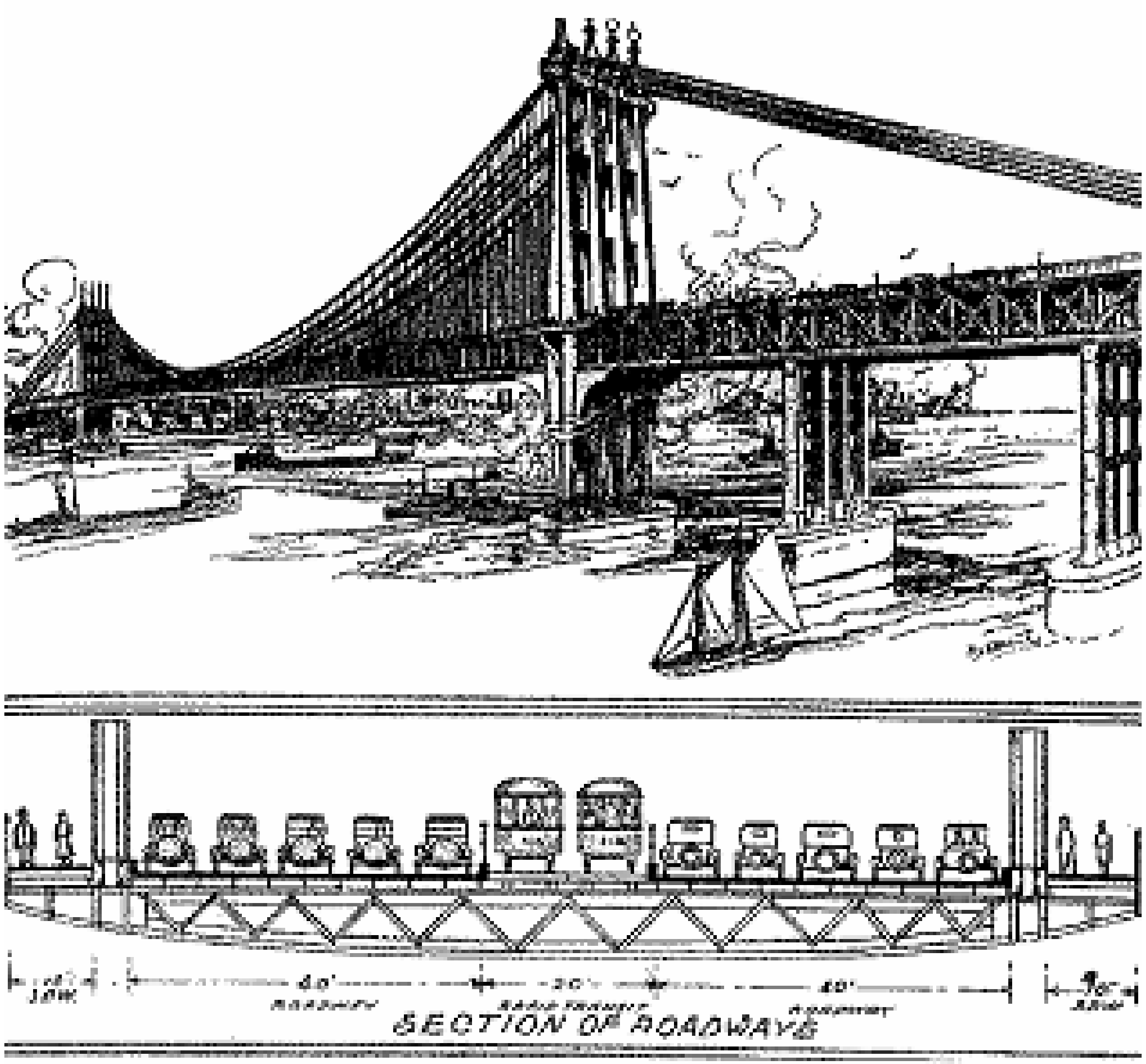
“…tiled ventilated vehicular bathroom, smelling faintly of monoxide and inviting claustrophobia”

Robert Moses

RE: his opinion of tunnels

“…But new forces were at work. With construction under way for what would be known as the Holland Tunnel, it was assumed that connecting the metropolis to its burgeoning New Jersey suburbs by underwater routes would be cheaper than a bridge (a notion proved wrong well before the tunnel’s 1927 completion). By that time, too, necessarily heavy (and expensive) railroad spans across the Hudson were steadily being eclipsed by less costly ones dedicated to a newly popular conveyance: the car. Already, in Philadelphia and Detroit, huge suspension bridges had been built for cars. The future was clear…”

Smithsonian **magazine, October 1999**



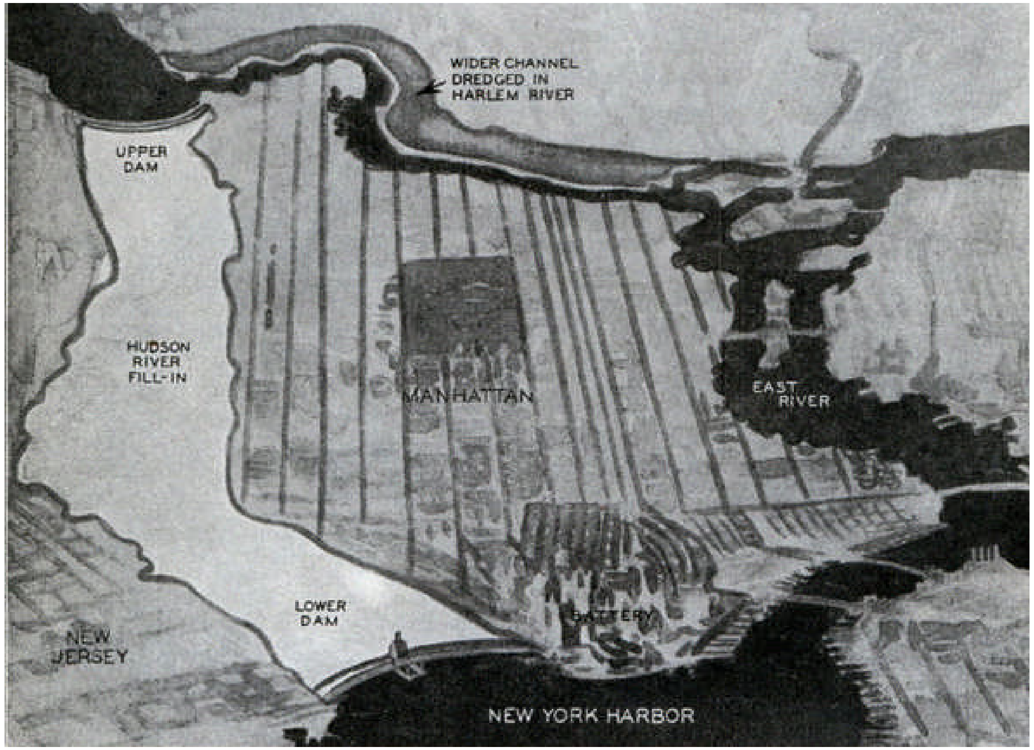
<u>Above</u>: caption: “Sketch of Charles Evan Fowler’s proposal for suspension bridges of 3,500-to-4,000-foot main span to cross the Hudson River at three locations (59th Street, 83rd Street and 178th Street) for a total cost of about $100 million, essentially the same design he proposed for a bridge between Detroit and Windsor, Canada.” (ca. 1925)


Detroit-Windsor Bridge
1803 ft. Span. Longest and Heaviest Bridge in the World

Plan B

“Plug up the Hudson river at both ends of Manhattan…divert that body of water into the Harlem river so that it might flow out into the East river and down to the Atlantic ocean…pump out the water from the area of the Hudson which has been dammed off…fill in that space…ultimately connecting the Island of Manhattan with the mainland of New Jersey…and you have the world’s eighth wonder - the reconstruction of Manhattan! That is the essence of the plan proposed by Norman Sper, noted publicist and engineering scholar. It is calculated to solve New York City’s traffic and housing problems, which are threatening to devour the city’s civilization like a Frankenstein monster. In keeping with the Norman Sper plan, the ten square miles of land which would thereby be reclaimed from the Hudson would not only provide for thousands of additional buildings, but also for avenues and cross streets which would greatly relieve the congestion in present thoroughfares. Today there are ten avenues laid out along the length of Manhattan. These are crossed by 125 streets. It is the lack of up-and-down arteries which has given rise to the existing traffic crisis. Sper would double the number of avenues…”

Modern Mechanix**, March 1934**



Left: caption: “This map vividly tells the story of the plan to dam the Hudson river and rebuild New York, ending the isolation of Manhattan Island. Water which now finds an outlet through the Hudson river would be diverted via widened Harlem river to the East river and then into outer harbor. What is now Manhattan Island would be grafted to New Jersey”

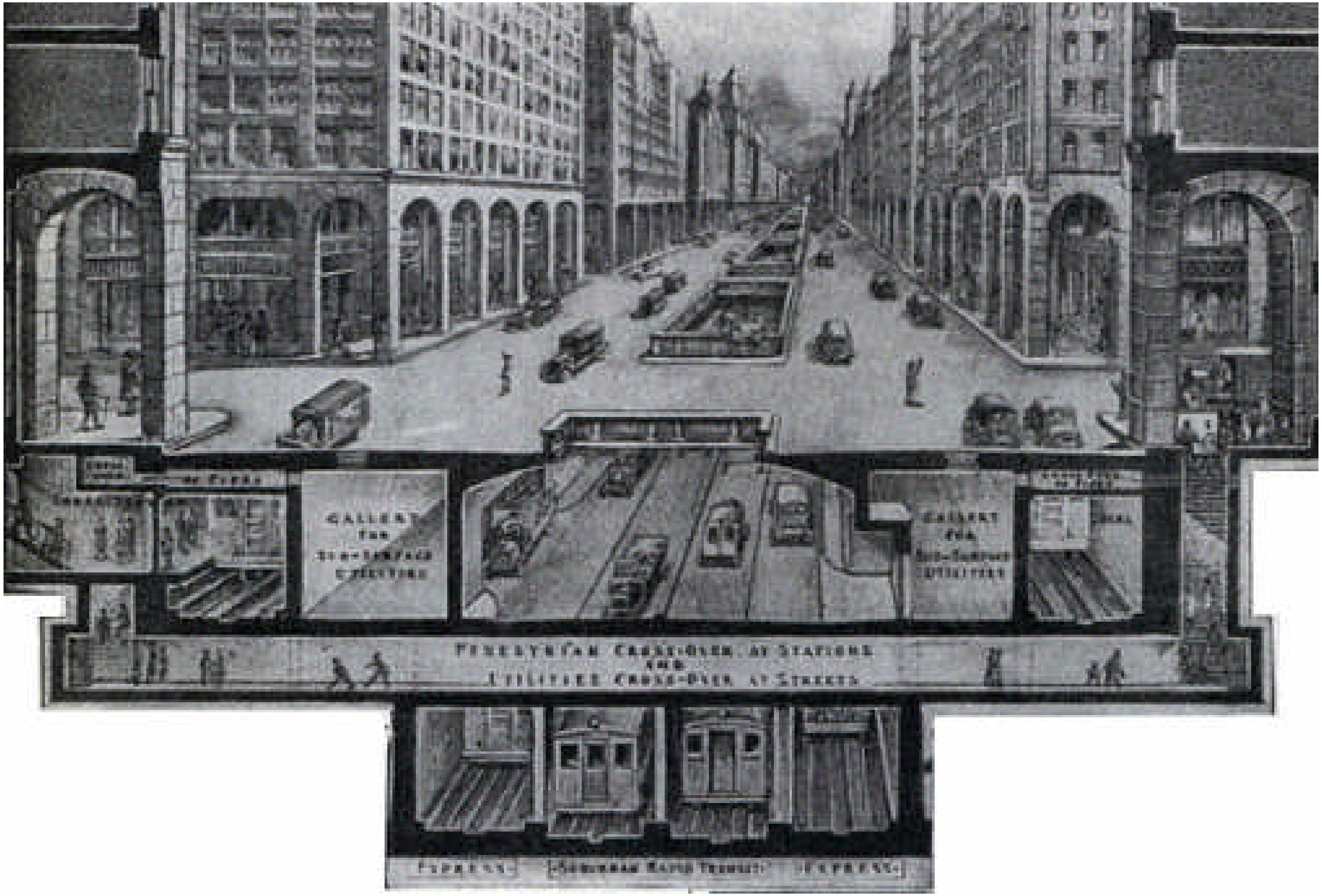
“…His suggestions go still further. No use waiting, he says, until the entire area is filled in before starting underground improvements. Build your tunnels, conduits, mail and automobile tubes, and other subterranean passages indispensable to comfort in the biggest city in the universe as you go along. Do it in the process of filling the basin left by the drawing off of the water. ‘When every possible subterranean necessity had been anticipated and built,’ Sper points out, ‘a secondary fill would bring the level up to within twenty-five feet of the Manhattan street level. Upon this level would rest the foundations and basements of the buildings that would make up the new city above, planned for fresh air, sunshine and beauty. Thus, below the street level would be a subterranean system of streets that would serve a double purpose. All heavy trucking would be confined to it, but primarily it would serve as a great military defense against gas attack in case of war, for in it would be room for practically the entire population of the city. If the Russians had the vision and the courage not only to build huge cities from the ground up, but to practically rebuild an empire, surely America should not be frightened at a project as big as this’…”

***Modern Mechanix*, March 1934**

Above: caption: "Manhattan Island as it looks today from the U.S.S. Macon. The lower dam, under Norman Sper's proposal, would start at the Battery, shown here, extend across the Hudson to the New Jersey shore. Reclamation of river bed would provide New York with ten square miles in which to expand. Necessity for expansion is graphically shown in this aerial photograph."

“…It would cost about one billion dollars to build, he figures. If you think such a project is beyond the abilities of modern engineers, asserts Mr. Sper, think of these achievements: The seemingly invincible Colorado river has been diverted to build the biggest dam in the world - Boulder dam. Fifty-foot tunnels were hewn out of the stubborn rock on either side of the river to make way for diversion of the water, which, in flood seasons, becomes a raging torrent. Look at the engineering wonders accomplished in construction of bridges. The two bridges now being built across San Francisco bay, one over the Golden Gate and the other from San Francisco to Oakland, defied problems which seemed unsurmountable even a few years ago. Consider the success of Colonel George Goethels in finishing the Panama Canal and opening it to traffic of the world’s largest ocean going vessels after others had failed. That virtually closed Mr. Sper’s case. Engineers uniformly agree that there are very few problems which can successfully defy the determination of civilization to conquer. As in many other instances, the project to dam the Hudson river and reclaim the river bed to provide New York with an additional ten square miles of land, would depend largely upon the ability of the government to finance such a project…”

***Modern Mechanix*, March 1934**



Above: caption: “Here is how the proposed new section of Manhattan would look when finished. Buildings in normal fashion on the surface, with beautiful, wide streets and only casual, block to block vehicular traffic. Below you find the numerous automotive, pedestrian and rail tunnels, all well ventilated and all having easy access to the street above.”

“…In the past, individual projects were considered in terms of millions of dollars and only recently in terms of hundreds of millions. Now comes Mr. Sper with a plan which must be considered in the light of a billion dollar expenditure. This single project would cost within approximately one-thirtieth of the total of the public debt of the United States government as it now stands. While such a figure is enough to stagger an ordinary financial mind, engineers point to the fact that the project would provide an immediate income of almost unbelievable dimensions. For instance, the land reclaimed could be sold outright or leased for 99-year periods to private concerns or to individuals and because of the desirability of the location, would bring extremely high rentals or sales prices. Then, too, the franchises for electric and telegraph conduits, steam heat tubes, street car and railway tubes would bring in millions of dollars annually. An annual income of a hundred million dollars a year would represent a return of ten percent on the investment of a billion dollars and engineering experts all agree that this would be only a trifle of the amount that could be realized from this great project. Thus, it is easy to comprehend the advisability of the Hudson river reclamation project from both an engineering and financial standpoint…”

***Modern Mechanix*, March 1934**

“…C. Keith Pevear, well-known Manhattan consulting engineer, who has been identified with various projects for municipal improvement said: ‘I have conferred with several marine engineers on the plan you have told me about. After several hours of spirited discussion - for we actually became very much interested in the various phases presented - it was our unanimous conclusion that the project is one which comes within the realm of possibility and could actually be accomplished. There were a multitude of problems, perhaps I should say obstacles, which cropped up in our discussion. We gave each one full consideration. Soundings and borings have disclosed that the bed of the Hudson river is rock with a silt, or mud covering. The foundation work in connection with the Holland Tunnel, the Pennsylvania Railroad Tunnel and the Washington Bridge showed that the Hudson had a rock bottom. The Manhattan rock structure goes under the Hudson river and proceeds west beyond the hills of Hoboken’…”

***Modern Mechanix*, March 1934**

“…Albert V. Sielke, formerly consulting engineer for the City of New York, and now executive of a New York engineering group which specializes in remodeling entire cities, stated: ‘I recall some years ago a man named Thompson had a plan to fill in the Harlem river and eliminate the East river entirely. So, since I was in the midst of the discussion on the Thompson plan, I have a fairly good idea of what the Hudson job involves. Furthermore, it was under my supervision that we made 135 acres of land along the Hudson river, filling it in from west Seventy-Second Street up to the Harlem River Canal, which is near Two Hundred and Twelfth Street. We used fill derived from subway construction work. No, I wouldn’t for a moment say that the Sper plan is an impossible one by any means. I would say, offhand, that the greatest difficulty would be in procuring enough fill, as you would have need for a tremendous volume of material to load up that valley.’ Jesse W. Reno, a pioneer in numerous vast engineering jobs and who is well-known for his salvage operations, and generally recognized as an engineering wizard, had this to say: ‘Getting down to the proposal to divert the Hudson river, there is an old saying that if you have money enough, everything else merely resolves itself into finding something to do with it. Provided with sufficient money and time, particularly money, the project could be carried through to completion with unquestionable success. It would take more than a billion dollars, I have estimated. On the other hand, it would be quite in keeping with President Roosevelt’s rehabilitation and N.R.A. plan and put an enormous army of men to work. I heartily endorse the plan - though I am fully aware of the almost insurmountable impediments which appear at first study of the idea.’”

***Modern Mechanix*, March 1934**

Part 3

Halfway to the Moon

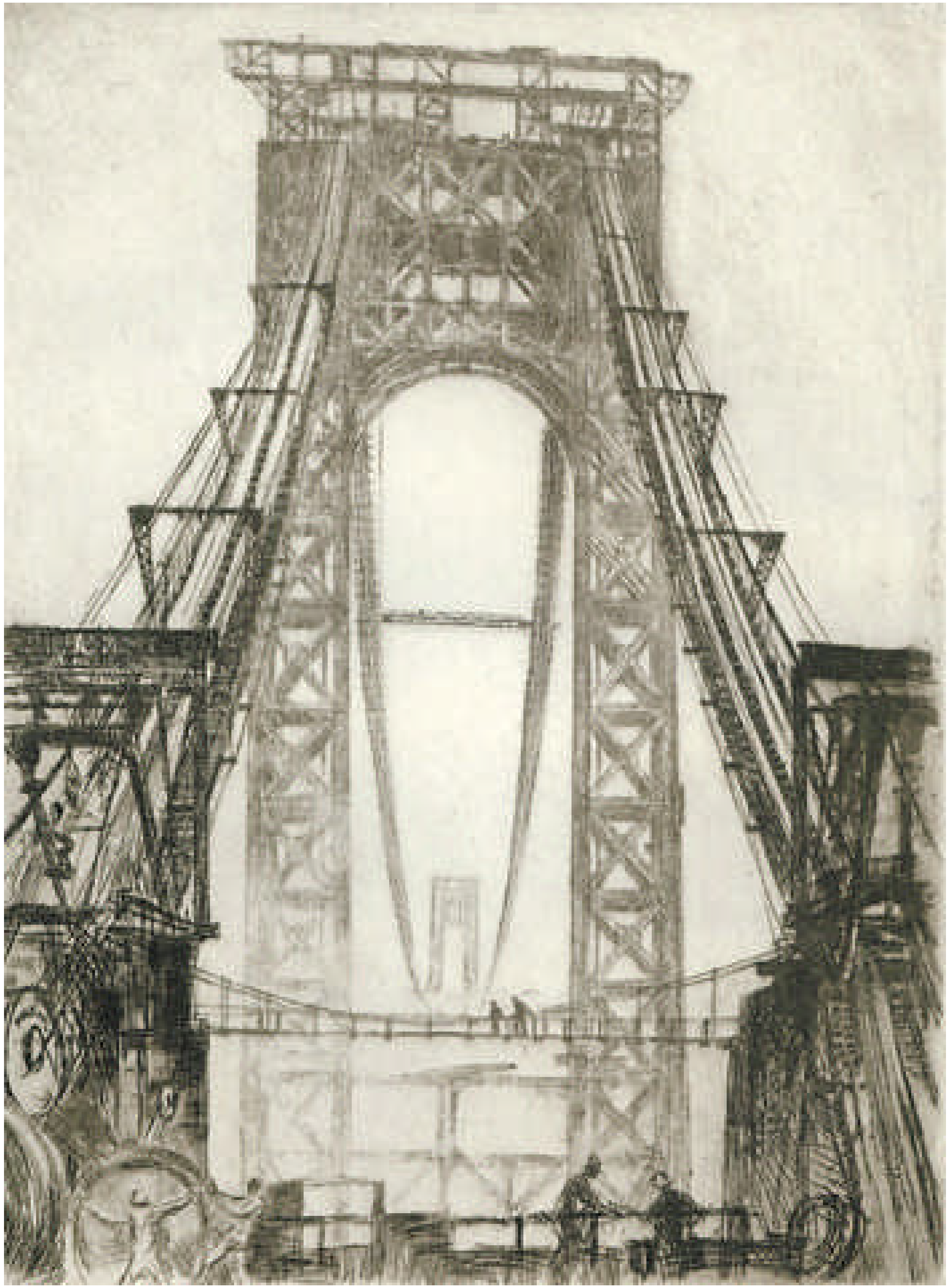
High Wire Act

"…There were suspension bridges before those the Roeblings built, it is true. Not until steel-wire cables were devised, however, was the modern suspension bridge a possibility. Nor did it become a reality until the Roeblings had built the Brooklyn Bridge…."

Fortune **magazine, 1931**

“…Next the four huge barrel cables had to be laboriously strung across the towers wire by wire, passing over the giant saddles in each tower and then being tied down in the anchorages. It took almost a year to methodically build the four main cables, each three feet in diameter. To carry out the process, footbridges between the towers had to be built and pulleys mounted on them over which the wires, only 0.196 inch in diameter, could move smoothly…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*



"…Spinning and stringing of the cables and slinging of the footbridges to be used during that process followed the completion of the towers. The footbridges were laid from aerial ropeway carriages passing from tower to tower and between the towers and anchorages. The spinning of the cables was completed on August 7, 1930. On March 19 of that year 87 tons of wire were spun in twelve hours. This was a record…"

***Wonders of World Engineering*, November 1937**

Left: *George Washington Bridge Under Construction* (1927) - etching by *Otto August Kuhler*

Eminently Qualified

John A. Roebling's Sons Company

TRENTON, N. J.

BRANCHES:

New York Boston Chicago Philadelphia Pittsburgh Cleveland
Atlanta San Francisco Los Angeles Seattle Portland, Ore.

"The John A. Roebling's Sons Company has been actively engaged in the design and manufacture for, and in the erection of suspension bridge cables, for a longer period than any other firm in this country. From a small beginning in 1841 at Saxonburg, PA., transferred to Trenton, N.J., in 1848, this company has designed and built many long and short span suspension bridges, and since its long ago construction of the famous Niagara and Brooklyn Bridges, it has maintained a continuous, active and progressive interest in suspension bridges. Eminently qualified by this exceptional background of tradition, experience and accomplishment, the Roebling Co. successfully undertook the long, difficult and costly research and design resulting in more than thirty new features and details for the new Hudson River Bridge…"

John A. Roebling's Sons Co.

ROEBLING'S

WIRE ROPE

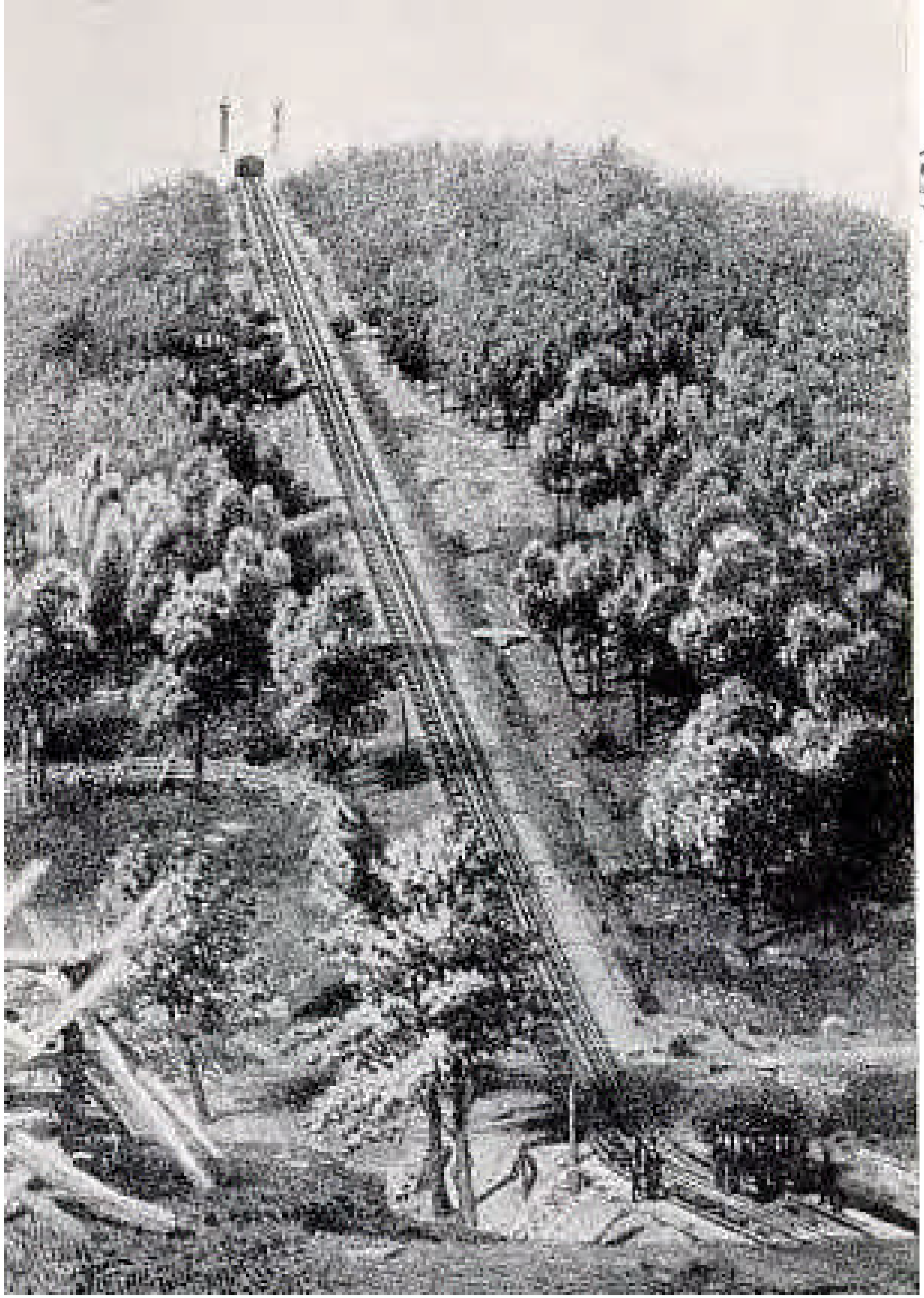
For Best

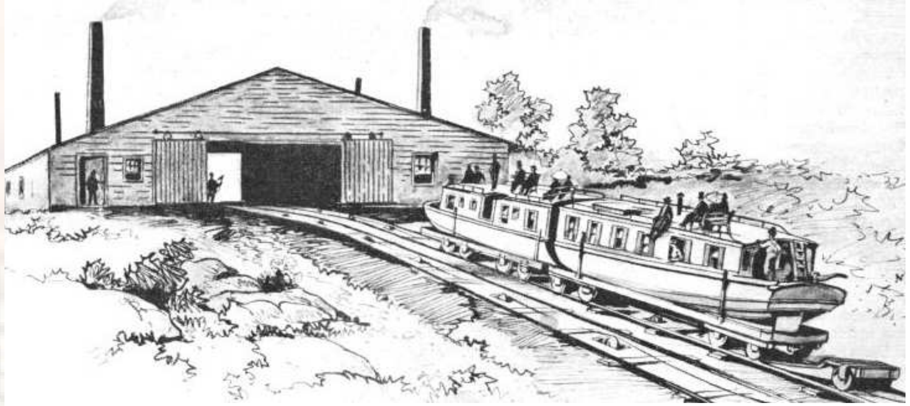
IRON or STEEL WIRE HOISTING, RUNNING or STANDING ROPES, or BEST GALVANIZED CHARCOAL WIRE ROPES FOR SHIP'S RIGGING,

Address, JNO. A. ROEBLING'S SONS, Manufacturers,
Trenton, N. J. or 117 Liberty St., N. Y.

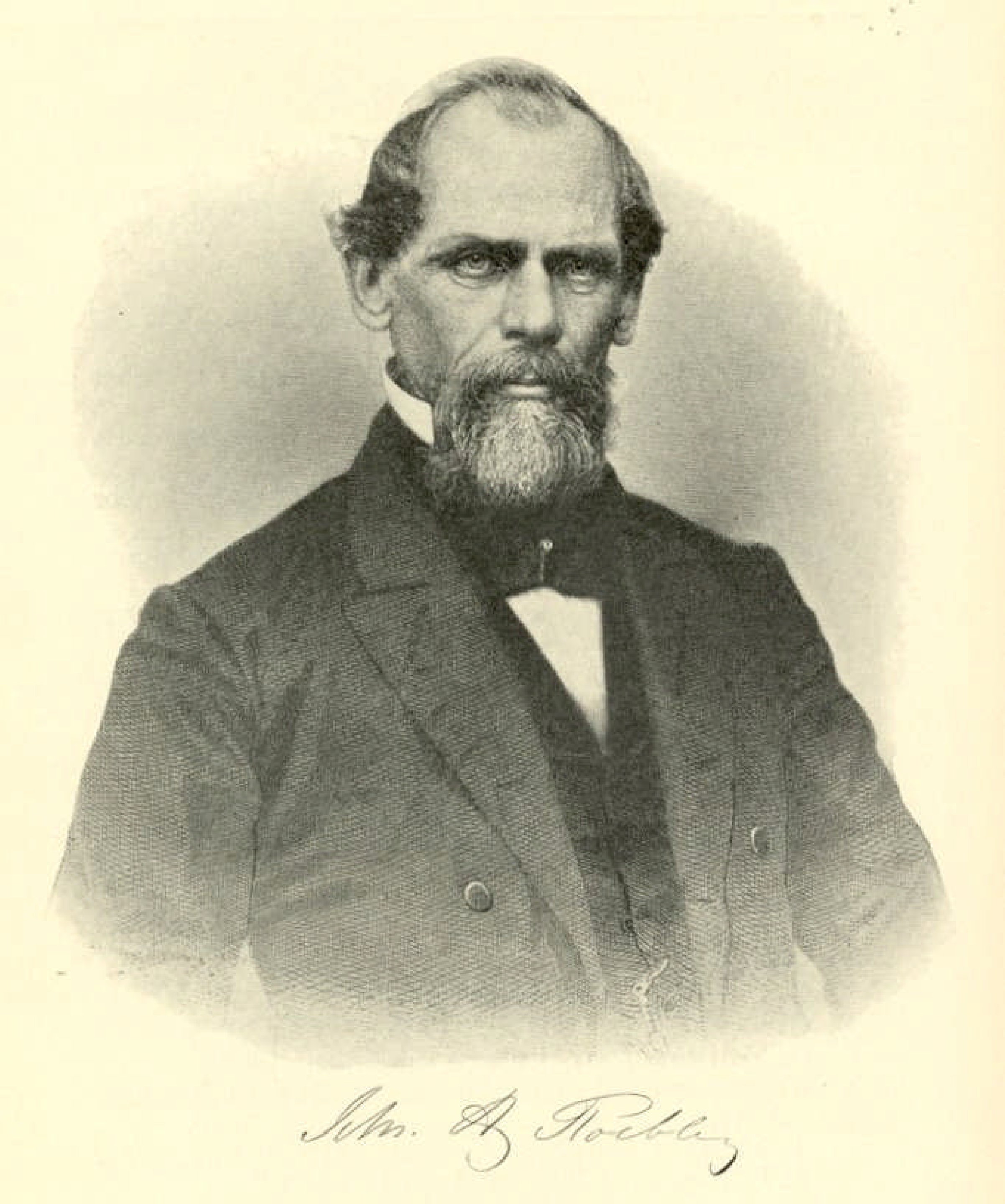
"The novelty of my process chiefly consists in the spiral laying of the wires around a common axis without twisting the fibers; and secondly, in subjecting the individual wires while thus laying to a uniform and forcible tension under all circumstances. By this method, the greatest strength is obtained by the least amount of material, and, at the same time, a high degree of pliability."

John A. Roebling

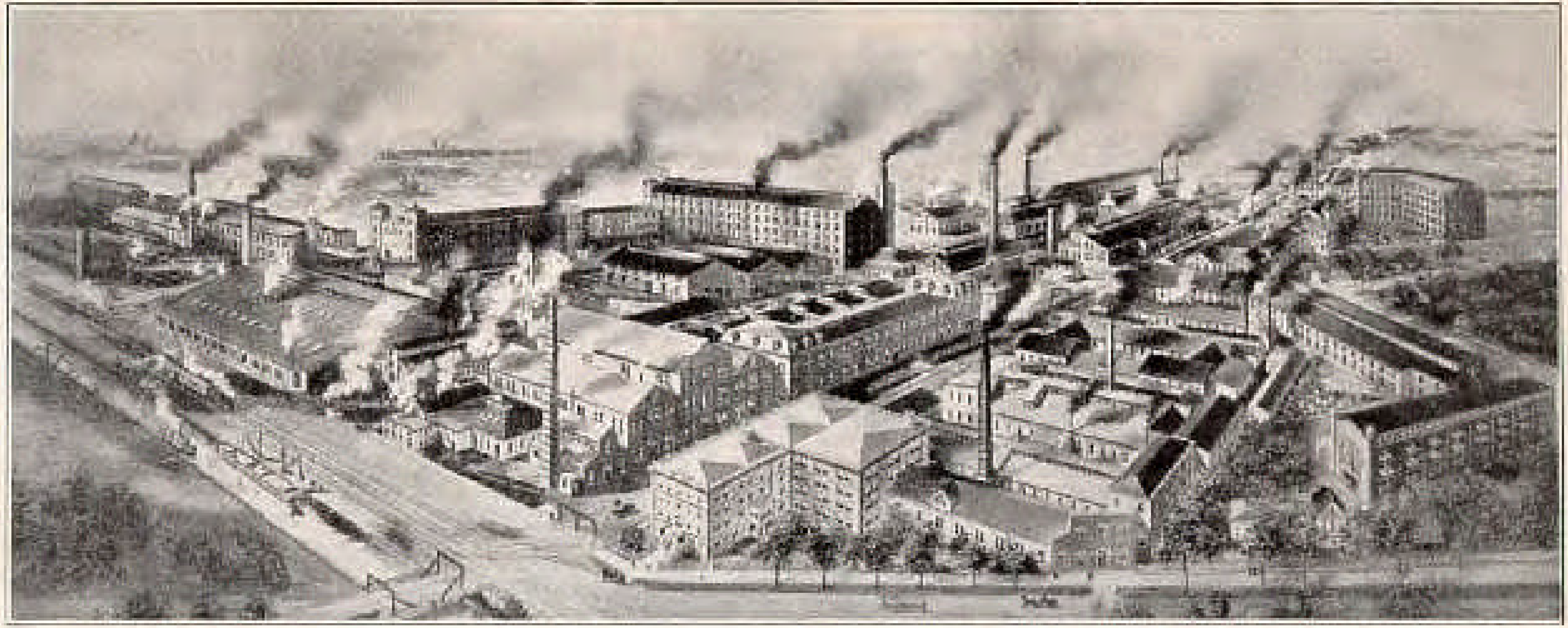




John Augustus Roebling **was born in** ***Prussia*** **in 1806, studied bridge engineering at the** ***Royal Building Academy*** **in** ***Berlin*****, immigrated to** ***America*** **in 1831 and co-founded the town of** ***Saxonburg*** **in** ***Butler County,*** **thirty-five miles north of** ***Pittsburgh, PA*****. Roebling's familiarity with the early efforts to make ropes out of wire led him to experiment with making a wire rope for the** ***Allegheny Portage Railroad*****, which used costly hemp ropes to haul canal boats over the mountains. Though he had no experience with making rope, he built a ropewalk on his farm and soon grasped the fundamental principles. Besides being an innovative engineer, Roebling was also an astute businessman. He installed his 7 x 19 wire rope on the Portage Railroad at his own expense, and with its success he began marketing his wire ropes for canals and for ships' tillers and rigging. The illustration above shows a sectional canal boat being hauled over one of the inclined planes of the Portage Railroad (left).**



“No man was ever great by imitation”
John A. Roebling



UPPER WORKS OF JOHN A. ROEBLING'S SONS CO., TRENTON, N. J.
One of three Roebling works.

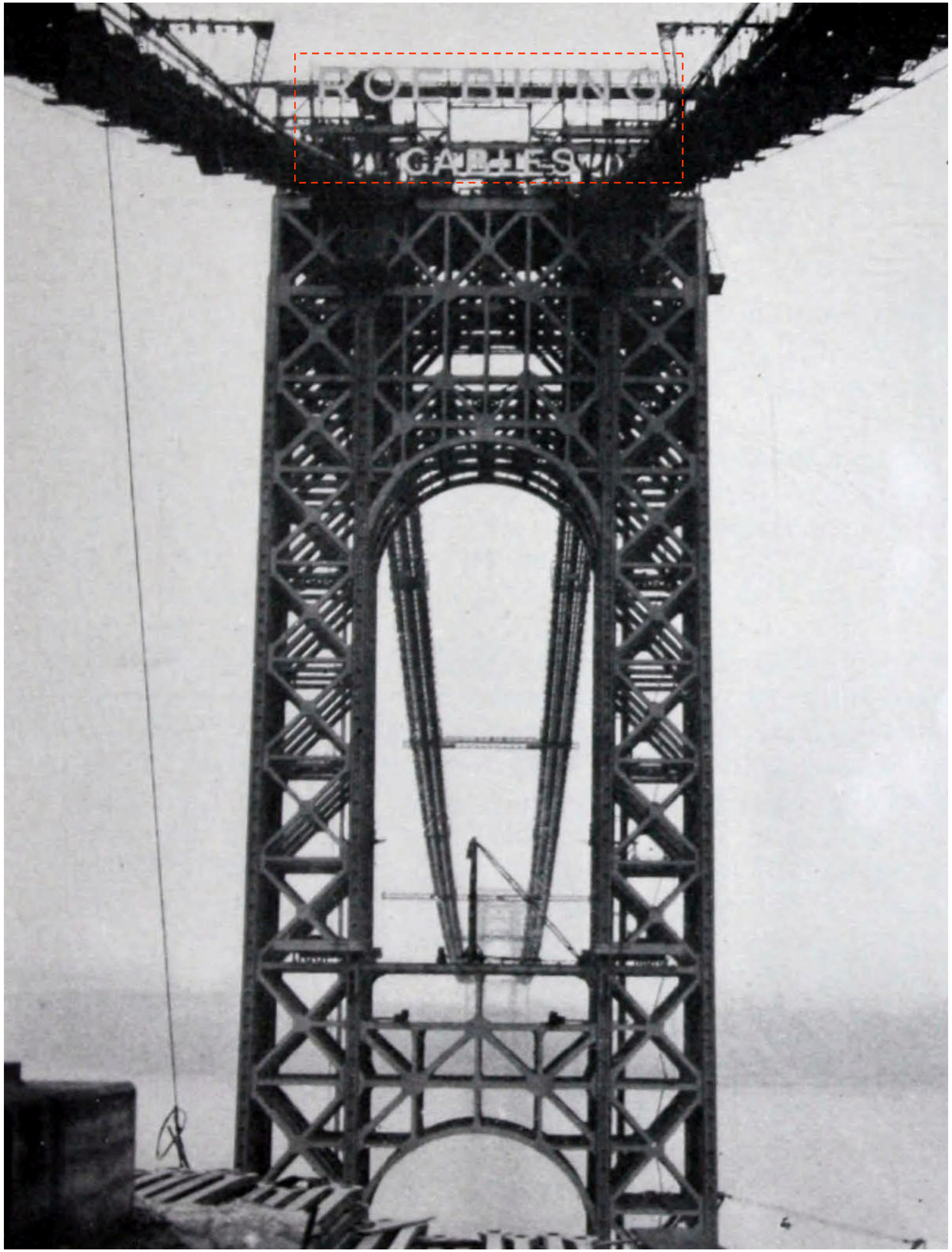
Roebling built his first suspension bridge, a canal aqueduct, in 1845 and he immediately patented the traveling wheel method he devised to lay individual wires into the aqueduct's seven-inch cables. In 1848, he moved his wire rope business to *Trenton, N.J*., to be closer to his customers. John Roebling, who died from injuries sustained in 1869 during the early stages of construction for the *Brooklyn Bridge*, left his wire rope business; the *John A. Roebling's Sons Company*, to his three sons: *Washington, Ferdinand* and *Charles.* Over the next fifty years they built it into the nation's leading manufacturer of wire rope.

Hudson River Bridge

ROEBLING
CABLES

“…Only a few years ago the construction of a span as long as that of the Hudson River Bridge was pronounced impossible by high authorities. Later it was admitted practicable, but believed to be unprofitable. Now it has become imperative, and a single span structure of unprecedented dimensions, capacity and cost has reached such a degree of highly successful erection that its early completion is well assured…It marks a very long stride in bridge construction, and demonstrates the advance of manufacture and erection fully equal to exacting requirements of engineering progress…”

John A. Roebling & Sons

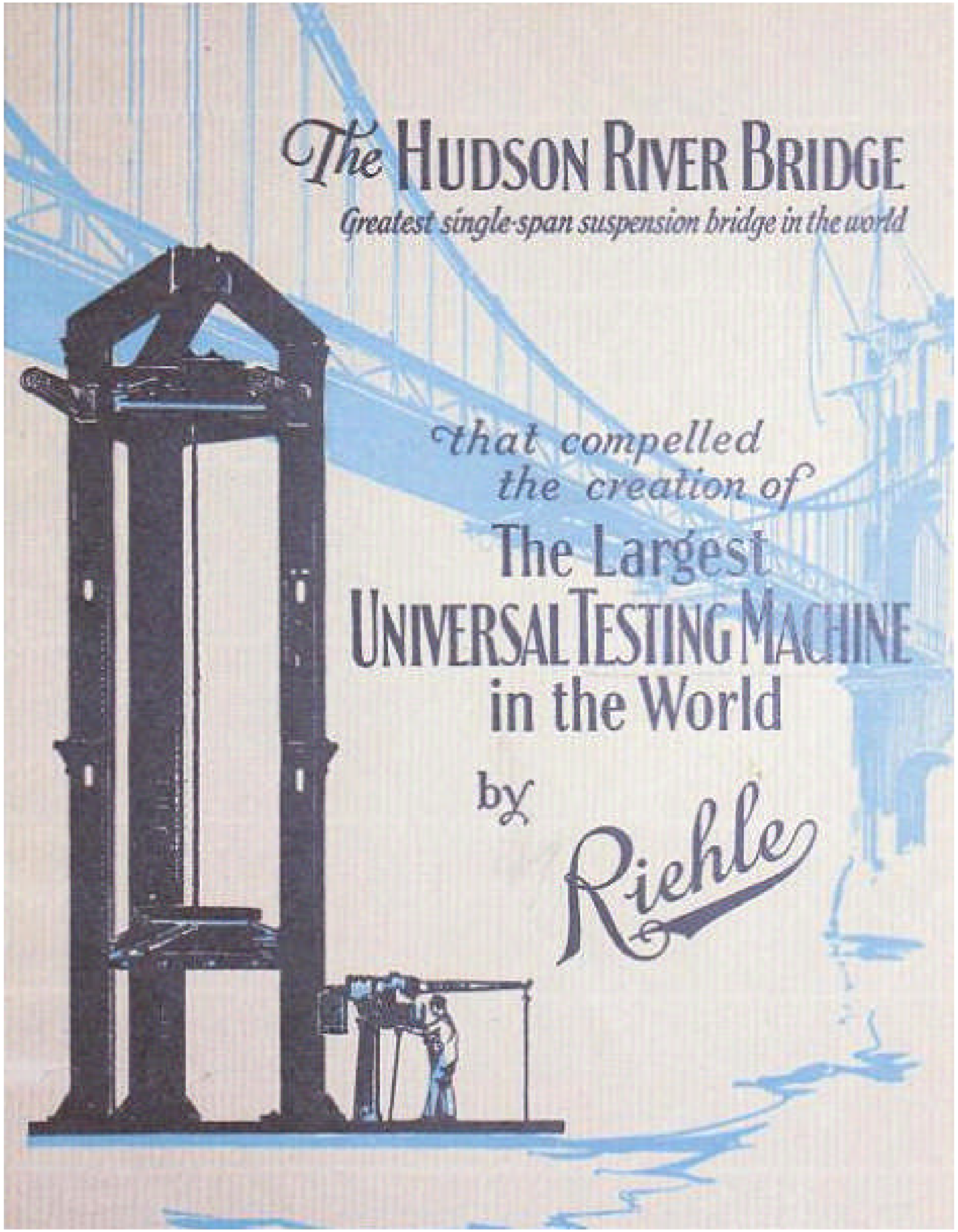


"…Competitive bids on alternative designs for parallel wire or eyebar cables gave, a difference in favor of the former, and the contract for wire cables was awarded, on its merits, to the John A, Roebling's Sons Company, Trenton, New Jersey, for $12,399,977.00 for the construction of the 28,600-ton cables, the fabrication and some of the erection of more than 7,000 tons of structural steel in the anchorages and approach floor, and for the fabrication and erection of 34 miles of 2.94-inch diameter rope…"

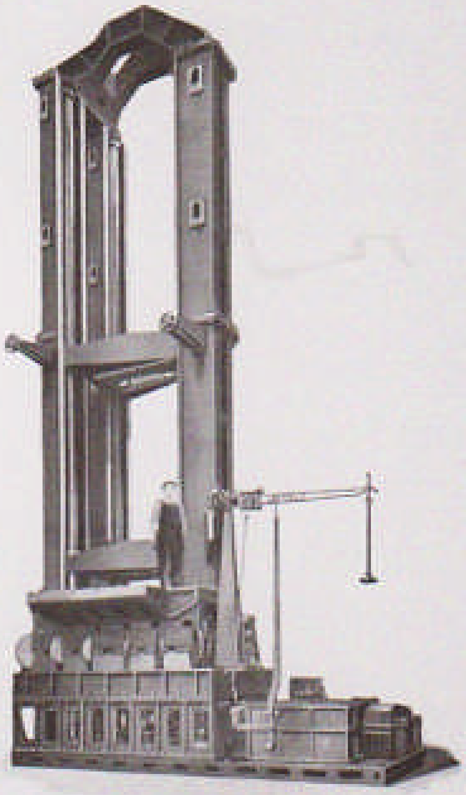
John A. Roebling's Sons Co.

Left: caption: "Wire spinning footbridges nearly one mile long under each pair of cables"

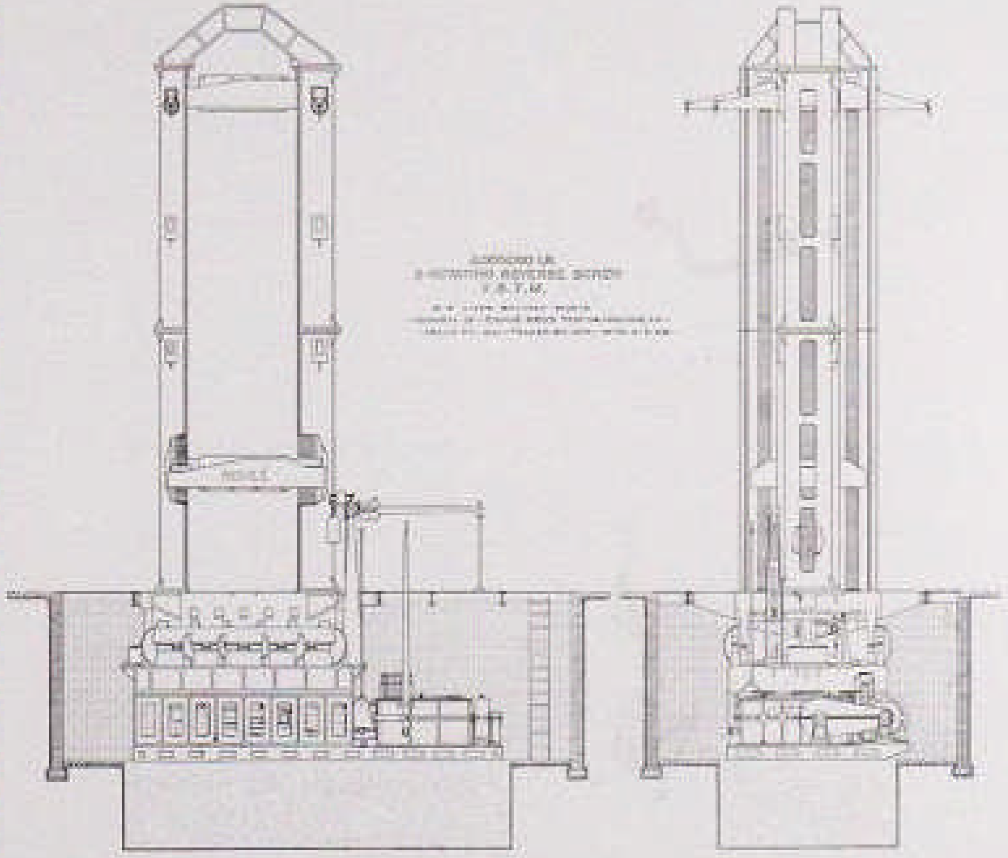
Research & Development



"It was only natural to expect that the design of a suspension bridge of the magnitude of the Hudson River Bridge would produce a host of problems…Chief among them were the management of the John A. Roebling's Sons Company of Trenton, N.J., the firm that built the cables for the famous Brooklyn Bridge. In the past seventy years they have made most of the wire rope and cables used in suspension bridges erected all over the continent. This experience and data pertaining thereto is their capital, but rich as it is, it included nothing covering a task of this gargantuan size. The problem of chief concern to Roebling was not that of producing or twisting wire, but that of proving to their own satisfaction what combination was the right one capable of bearing the enormous stresses and strains to be contended with. To test such gigantic cables as must be employed, there was not then in existence, a testing machine of a size sufficient for the purpose. No sooner was the need for such a machine apparent than Roebling's made plans to purchase one capable of exerting the tremendous pull of 2,000,000 lbs. To our organization fell the honor of creating this, the greatest universal testing machine in the world today…"



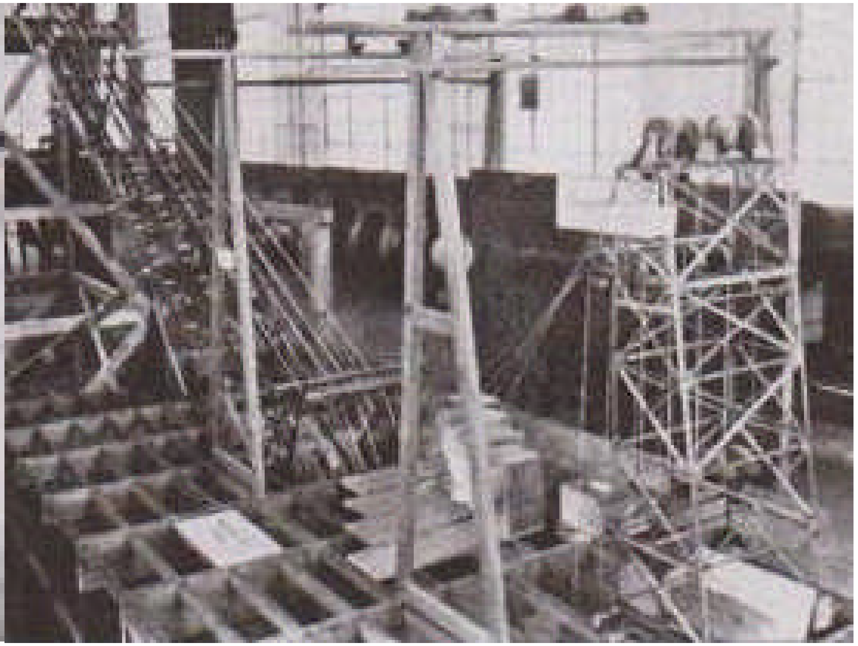
Actual photograph of 2,000,000 lb. Machine after assembly on Shop Floor



"…The Roebling Company is held responsible for the quality of materials, and safe and prompt completion of their contract in strict accordance with specifications of the Port of New York Authority. Requirements were high; difficulties great; time short; and there were no precedents of anywhere near equal magnitude; therefore the company assigned a corps from its permanent staff of engineering specialists to preliminary researches and verifications, including analyses, experiments, full-size and model tests, and the study and development of new and improved equipment and methods. This work was carried on for more than a year prior to the commencement of field operations

John A. Roebling's Sons Co.

<u>Left</u>: caption: "Strand friction test at Trenton plant of John A. Roebling's Sons Co. Full size strand built through, 2,000,000-pound testing machine to establish friction value between main tower saddles and strands."



"…The apparent impossibility of stringing the four cables simultaneously in the very short specified time caused the consideration of methods of stringing them in successive pairs; models tests and computations demonstrated so many difficulties in this method that improvements in spinning mechanism and operations developed that permitted the cables to be spun simultaneously much more rapidly than was ever before possible. Full size spinning apparatus was erected at the Kinkora plant and its operation was studied; new devices and improvements were developed until eventually a wire spinning speed 100% faster than ever before practiced was attained. A new spinning wheel was perfected that eliminates the hanger goose neck, the use of which definitely limits the tramway speed. A system of counterweight take-ups in towers maintains uniform tension in the wire while spinning, and affords a gauge for the instantaneous synchronization of the unreeling machines with the spinning wheels; a very important operation…"

John A. Roebling's Sons Co.

Left: caption: "Cable wire spinning wheel attached to tramway"

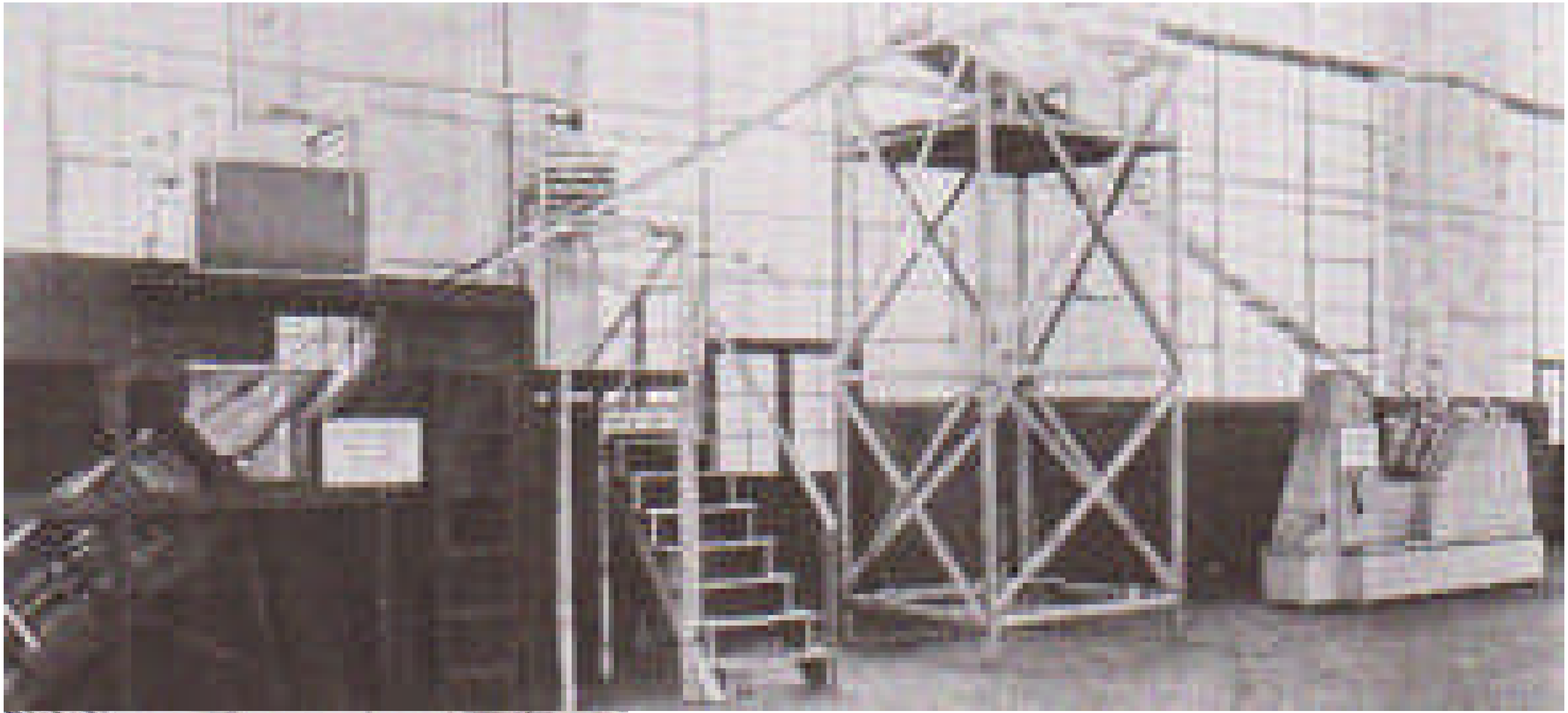
Right: caption: "1/20 scale model of counterweight tension tower and girder crane supported on floor steel, New Jersey"

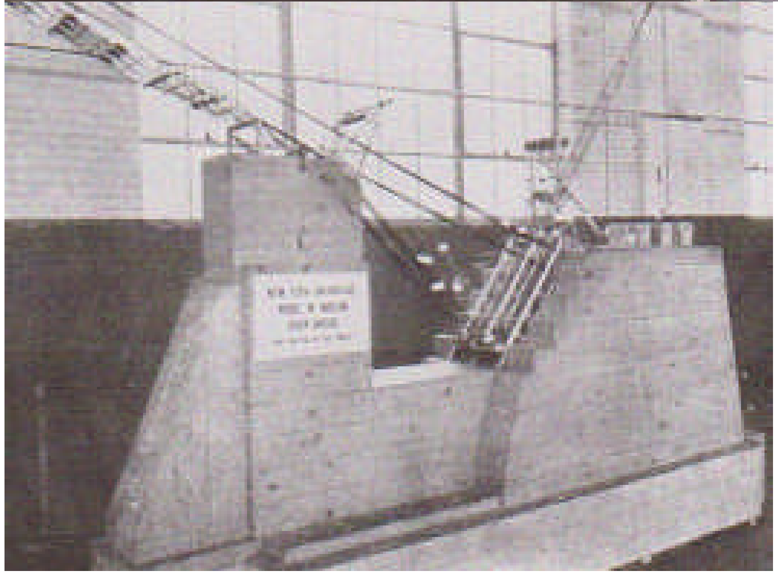
"…In former practice the cable wire reels were overhauled by the spinning wheels, and irregularities of unwinding or speed produced exceedingly troublesome variations of momentum. With reels weighing twice as much as formerly, this would be very serious, and had been obviated by mounting the reels on power driven and power braked unreeling machines that quickly engage and disengage, load and unload, start and stop the reels and regulate their speed instantly…"

John A. Roebling's Sons Co.

Above: caption: "1/24 scale model and sand bag loading of main cable for study of successive cable spinning operations"

Left: caption: "Unreeling machine from which all cable wire is spun under perfect control"





"…The arrangement of cable wire spinning apparatus, including the aerial tramway for operating the spinning wheel, its special support, tension tower and other details, were shown on a model of the New York anchorage together with one end of the side span footbridge…"

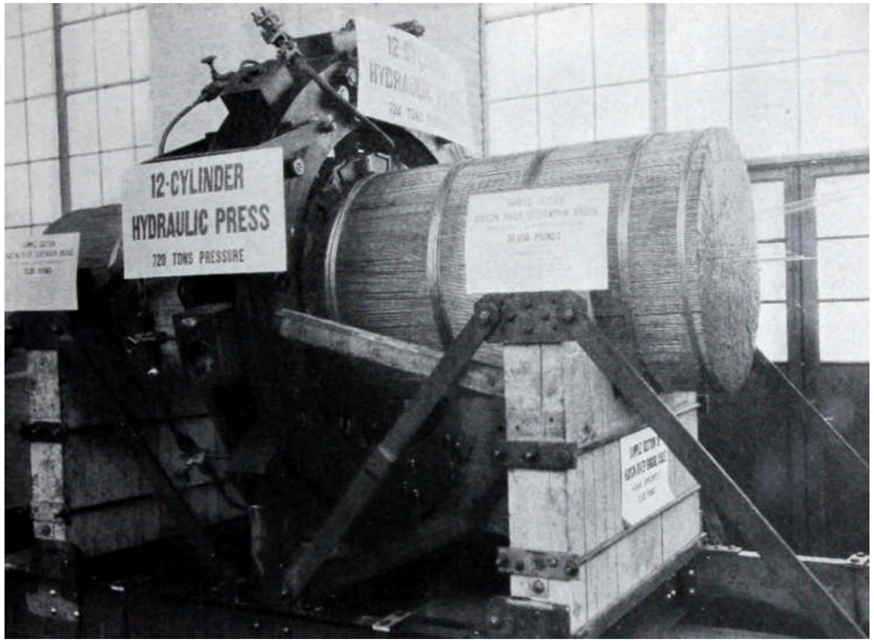
John A. Roebling's Sons Co.

<u>Above</u>: caption: "Model to 1/24 scale showing anchorage eyebars and strand connections, and portion of footbridge, with spinning equipment mounted on anchor block"

<u>Left</u>: caption: "Model of NY anchor block showing footbridge cables, wire tension tower, traction tramways and supports"

“…A 1/24 scale model of the New Jersey tunnel anchorage was made, and afforded opportunity to study the clearances of the girders and eyebars therein, and to develop their erection methods. The model, combined with the model of the New York block anchorage, assisted in the simplification of the spinning and strand adjustment studies. Arrangement and location of principal equipment was made on them, and the side spans of the construction footbridge were also reproduced, greatly assisting the draftsmen to visualize conditions and requirements…”

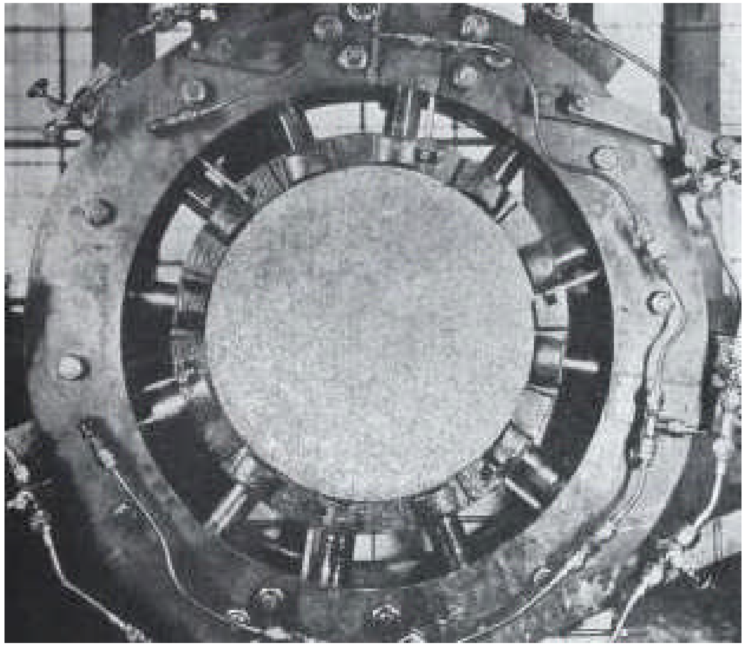
John A. Roebling’s Sons Co.



“…To study the effects of compression on a main cable composed of 26,474 wires, each 0.196 inch in diameter, a short length of cable with full size cross section was made and tested for friction, compression, distribution of stress and other features. Test wires were left protruding from the end of the cable to study their resistance to longitudinal displacement when under transverse pressure…”

John A. Roebling’s Sons Co.

Left: caption: “Full size cable section under circumferential pressure. Wires projecting from one end to be pulled.”



“…A full size yoke, to be used eventually for compacting the finished cable, was used to compress the experimental cable. It was provided with twelve radial hydraulic pistons, together exerting a balanced pressure of about 400 tons, that compress the 61 strands from their original hexagonal arrangement, with numerous voids between them, to a substantially solid cylinder approximately 36 inches in diameter, in which an indication of the original strand outlines is scarcely perceptible…”

John A. Roebling’s Sons Co.

Left: caption: “Full size cable section in compression machine, showing strands compacted as in finish cable”

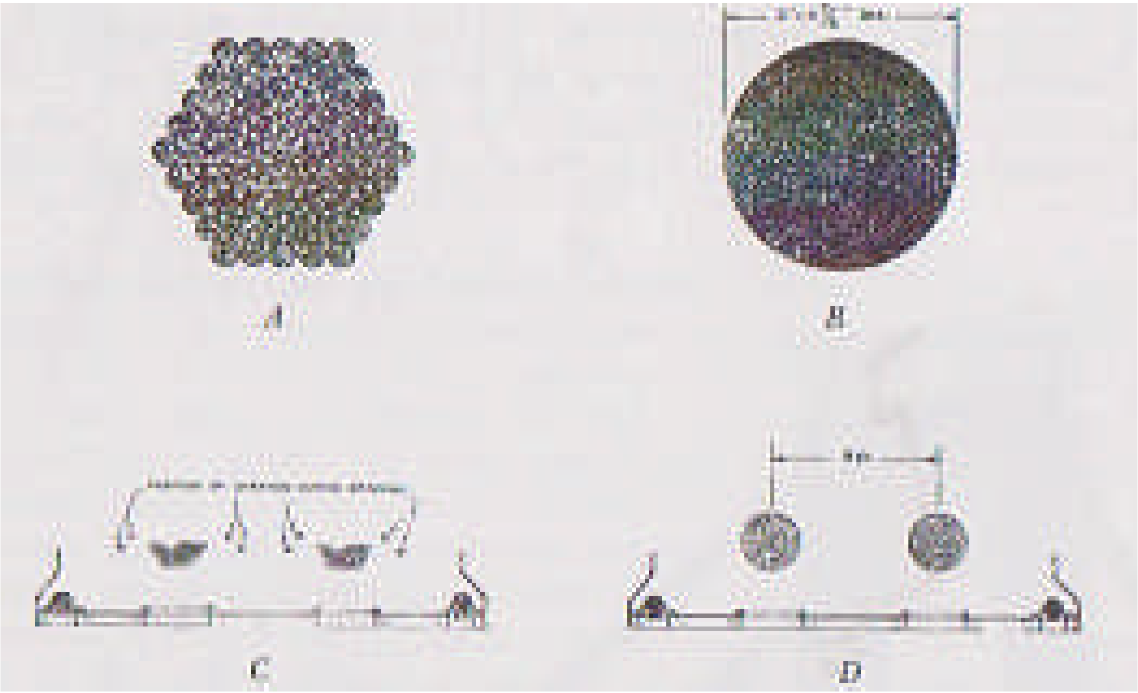
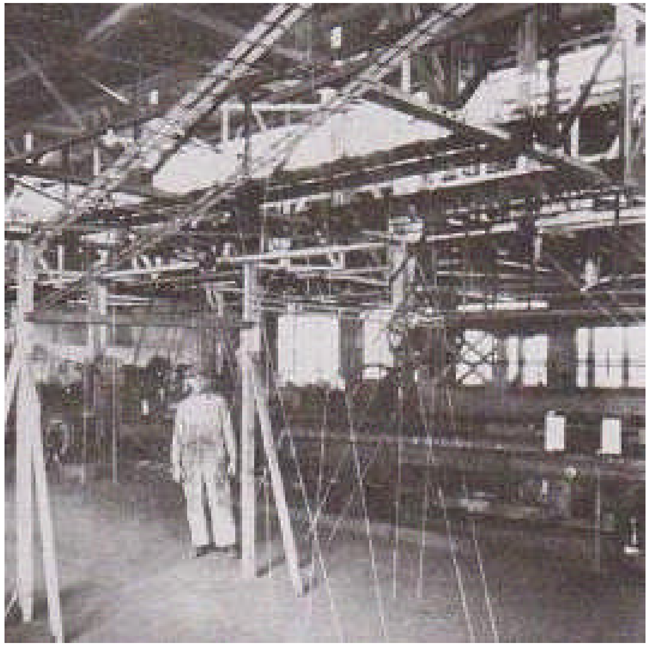


Figure A: Cross section of cable before compacting. Has 61 strands of 434 wires.

Figure B: Cable after compacting has a diameter of 2-feet 11-7/8-inches.

Figure C: Diagram of partly completed cables shows footbridge and position of strands during spinning.

Figure D: Compacted cables are placed 9-feet apart.



"…The displacement by wind of the temporary working platform or footbridge from which the main cables are strung is so great that in former work it has often interrupted operations, and the limits of permissible displacement had been nearly reached in the maximum span lengths attained. When these were doubled in the Hudson River Bridge, new provisions were desirable to make the footbridge more stable. Therefore elaborate investigations were made on the vibrations and distortions due to displacements and the damping effects of retarding elements. Many systems were tried, and finally an independent funicular system combined with horizontal transverse suspended compression booms, was developed that demonstrated the possibility of securing astonishing stability for the long span…"

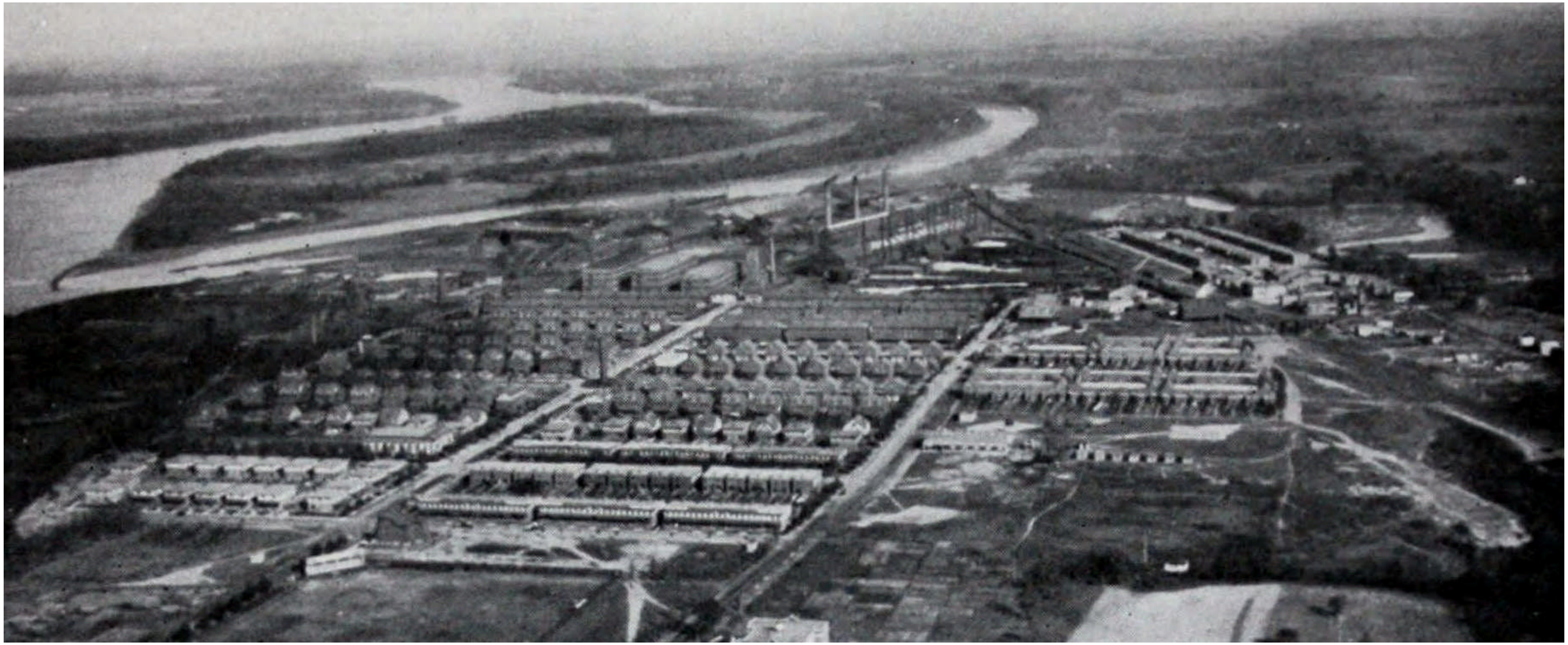
John A. Roebling's Sons Co.

Left: caption: "1/35 scale model of center span footbridge and storm system, showing compression boom"

Wire Manufacture

“…It is of interest that all of the wire for the GWB’s cables was contracted for with the Roebling Company. Roebling also provided the skilled workers who supervised the spinning of the GWB cables on-site. The New Jersey town of Roebling may still be found just off Route 130, immediately south of Trenton. Though the Roebling works are closed and covered over with vines - indeed, are a Superfund cleanup site - the citizens of Roebling live in the row houses that once made up that company town…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*



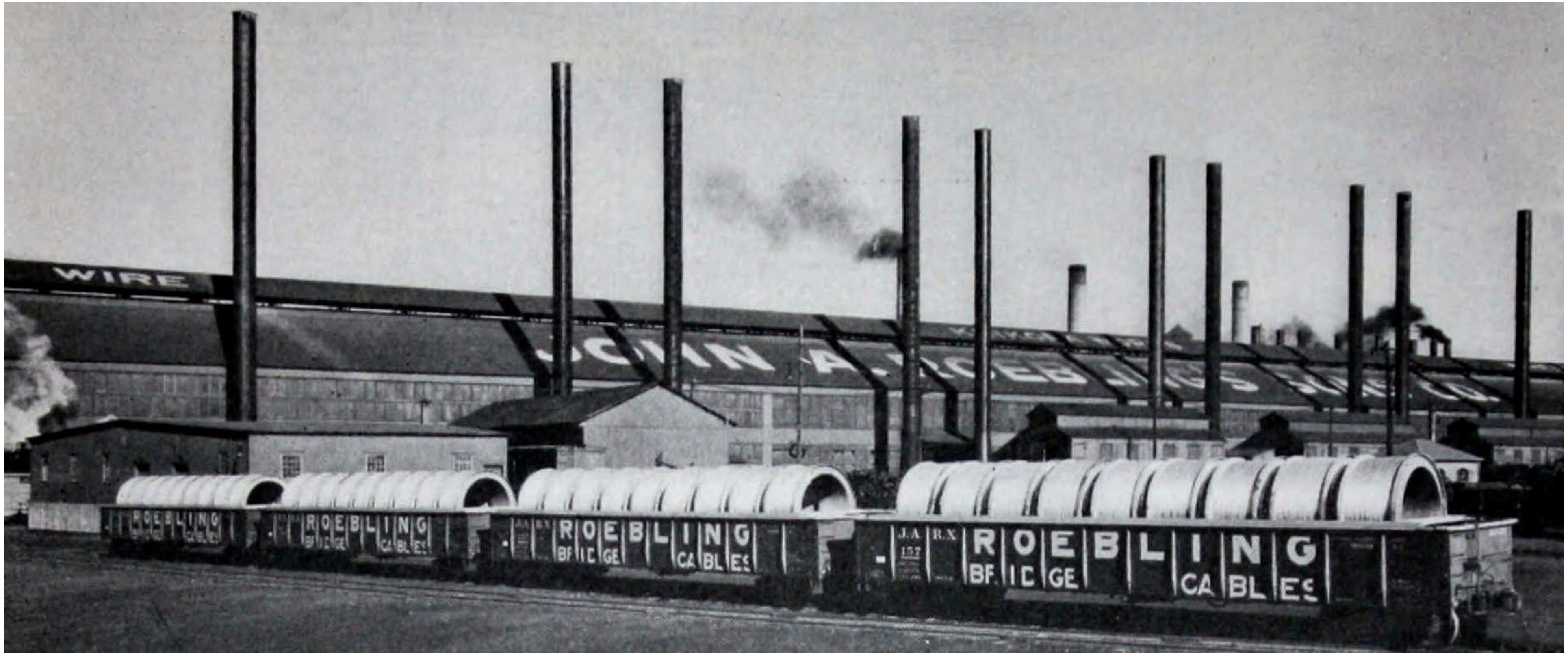
"…All of the cable wire and wire ropes for the Hudson River Bridge are manufactured in the three plants of the Roebling Company. These plants together cover an area of about 213 acres and employ about 4,000 skilled and semi-skilled workmen…"

John A. Roebling's Sons Co.

Above: caption: "Kinkora plant of John Roebling's Sons Co. where all wire for Hudson River Bridge is made. Village of Roebling, New Jersey in foreground."

“…The Bridge wire in the main cables of the Hudson River Bridge is of the same character as that used in all suspension bridges having Roebling cables, beginning with the Brooklyn Bridge, in which the wire has an ultimate strength of 160,000 pounds per square inch, and progressing chronologically with the Williamsburg Bridge, 200,000 pounds per square inch; Manhattan Bridge, 210,000 pounds per square inch; Bear Mountain Bridge, 215,000 pounds per square inch, and the Hudson River Bridge, with 225,000 pounds per square inch…”

John A. Roebling’s Sons Co.



"…The average strength of the last 4,000,000 pounds of cable wire tested for the Hudson River Bridge is 240,000 pounds per square inch. Tests on the first 45,000,000 pounds of wire furnished for this bridge show an average tensile strength of 235,000 pounds per square inch, and this steadily sustained increase in the strength of cable wire, and the fact that it is all standard cold drawn wire, of the same character that has successfully stood the test of services for many years, gives full assurance of the durability of the cables…"

John A. Roebling's Sons Co.

Above: caption: "36 reels, 288 tons, of bridge wire ready for shipment"

"…The superiority of the Hudson River Bridge cable wire over any wire previously furnished for a similar project is due to the quality of materials; extremely careful and highly skilled operations, and perfected galvanizing. Important items of improved wire manufacture are: the selection of raw materials; method and extreme care in the production; selection of heats; very close analyses of chemical constituents; close observation of refining and tapping temperatures; the rolling of ingots and billets that produce rods free from seams and surface defects. All the refinements in the production of the semi-finished steel and the rods, and the use of acid open hearth steel make for high wire quality and uniformity…"

John A. Roebling's Sons Co.

Above: caption: "Billets in storage pile ready to go into wire rod mill at Kinkora plant of John A. Roebling's Sons Co., Roebling, N.J."

WIRE ROPE

AND WIRE ROPE FITTINGS

MADE BY

JOHN A. ROEBLING'S SONS CO.

Manufacturers of

WIRE ROPE, STRAND, TELEPHONE, COPPER, FLAT
SPECIAL SHAPE AND MISCELLANEOUS WIRES,
INSULATED WIRES AND CABLES

Agencies and Branches:

New York Boston Chicago Philadelphia Pittsburgh Cleveland
Atlanta San Francisco Seattle Portland, Ore.

"…Manufacturers of steel for special purposes often demand a particular kind of scrap. A manufacturer of steel cables for elevators, bridges, and so on, continuously combs the country for scrap steel that has a low phosphorous content. Structural steel is of this type. It may astonish you to know that the cables which suspend the roadways of the new Hudson River Bridge at New York City are of steel which was made with fully sixty percent of material selected from the junk heap…"

***Popular Science,* September 1931**

Wire Drawing

“…One of the best examples of modern cable making was the construction of the cables that will support the new Hudson River Bridge. These cables must be capable of sustaining a dead weight of 350,000 tons, about six ships the weight of the ‘Leviathan’s’ size. To do this the four main cables – bundles of straight wire three sixteenths of an inch in diameter – are three feet thick each. Bridge wire used for the Hudson span comes from ingots of steel fourteen inches square and five feet long. After careful chemical analysis, selected ingots are reheated and rollers reduce them to sections two inches square. Clipped into thirty-foot billets, these in turn are worked smaller. Leaving the rolls, the steel is a round rod similar to a curtain rod, and three eighths of an inch in diameter. That is as far as the rolls can go towards turning steel into wire…”

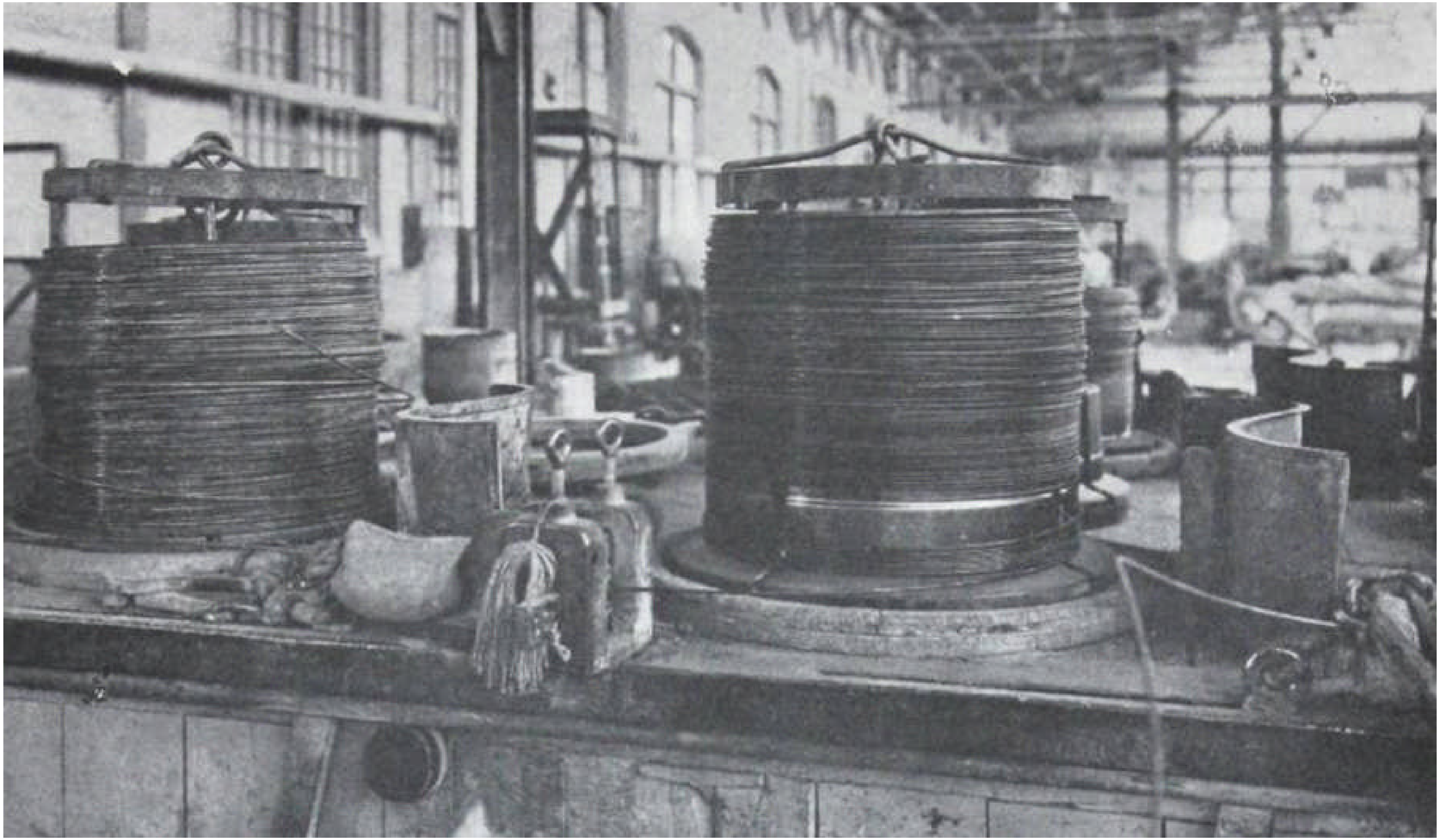
***Popular Science*, March 1930**

“…Next comes the die through which the wire is cold-drawn. But the rods are not squeezed through it. Instead, they are tempered, cleaned, and pointed so that an end can be thrust through a hole in the die. A ‘dog,’ a powerful mechanical hand, seizes the small tip and pulls through enough wire to be fastened about a drum. The drum then exerts enough pull to drag the steel through the hole. Passing through small holes each a little smaller than the last, the rod is reduced to wire of the required size. Four thousand feet of wire are drawn from each billet. This drawing of wire through a hole too small for it does not weaken the wire, as might be imagined, but actually strengthens it. The fibers of metal are drawn into a parallel position which resists any break. Mighty testing machines in the wire factory check up on that. A loud report like that of a canon means that a wire has finally broken in the testing machine, which can exert forces of as much as two million pounds. One of the single strands of wire used in the Hudson cables would require the combined pull of ten strong horses to break it…”

Popular Science, **March 1930**

“…The physical properties of the wire are highly developed by the cumulative meticulous care constantly maintained in every detail of the manufacturing processes. The actual wire drawing process insures great uniformity of diameter and physical qualities, which are practically the same from one end of a coil to the other. Coils of wire rod are cold drawn again and again through smaller and smaller holes in steel dies, until they are reduced to the required diameter of about 6 ¼ thirty-seconds of an inch, elongated to a length of 3,800 feet, and have their strength increased until a value of about 260,000 pounds per square inch is obtained. The strenuous work of drawing insures the great strength of material necessary to resist the drawing stresses, and the process is so efficient that the surface of the wire is perfectly smooth and the diameter is very uniform from end to end. The Roebling shops are equipped with 48 sets of wire drawing blocks suitable for the Hudson River Bridge cable wire, but only half of them are required to meet the erection schedule…”

John A. Roebling’s Sons Co.

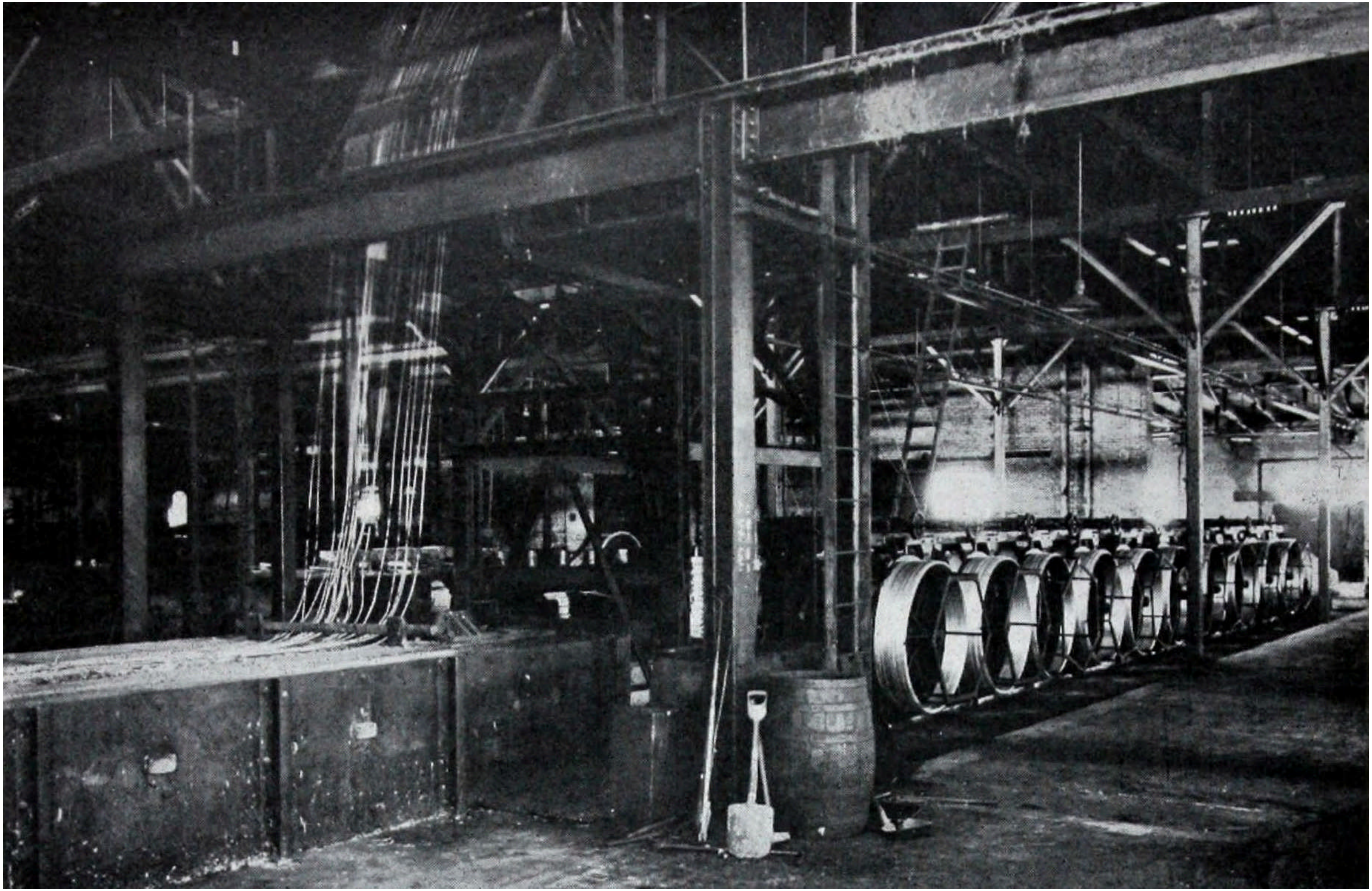


Above: caption: "Drawing bridge wire at the Kinkora plant, Roebling, N.J. (this wire drawing shop has a capacity of 5,000,000 pounds per month of bridge cable wire, and is producing 2,500,000 pounds per month to keep pace with the spinning of the Hudson River Bridge cables, and maintain an adequate reserve supply for them)."

Galvanizing

"…The most modern methods of galvanizing produce on the finish wire a uniform zinc coating that adheres most tenaciously. Twenty lines of wire are continuously passed through successive baths of melted lead to heat them, through dilute acid to clean them, and through molten zinc to galvanize them, after which they are drawn over an elevated drum, washed and finally coiled for testing and storage. During this process they are uniformly coated with a very durable, tenacious zinc skin from 1/1000 to 2/1000 inch thick that, so long as maintained continuous and intact, prevents the possibility of corrosion of the steel…"

John A. Roebling's Sons Co.



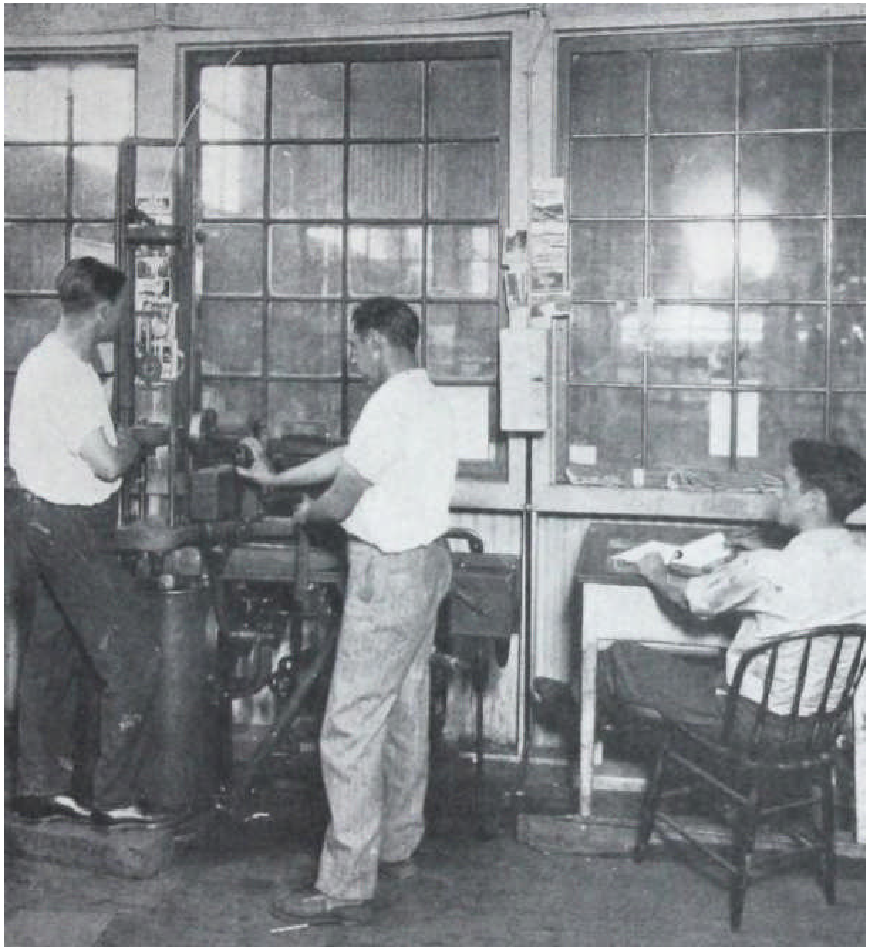
<u>Above</u>: caption: "Simultaneous galvanizing of twenty Hudson River Bridge cable wires, passing continuously and uninterruptedly through the zinc bath which deposits on them a coating of solid zinc from 1/1000 to 2/1000-inch in thickness."

"…The coils of galvanized cable wire for the Hudson River Bridge are delivered by electric crane trucks to a great storage warehouse, where thousands of tons are piled awaiting reeling and shipment. Each coil bears a metal tag giving the heat and other numbers by which its test record can be identified, and its records traced back through the rods, billets, blooms and ingots, to the raw products charged into the acid open hearth furnace…"

John A. Roebling's Sons Co.

Above: caption: "Section of Hudson River Bridge wire storage warehouse containing approximately 20,000,000 pounds of cable wire, each coil of which has been tested at both ends and accepted"

Wire Testing



"…In the Roebling Company's testing laboratory, specimens cut from <u>both</u> ends of every coil of Hudson River Bridge cable wire are broken in power machines which determine the ultimate tensile strength, ultimate elongation, and yield point, which at first exceeding the requirements of the specifications, show continual gradual improvement as the quality of raw materials and the care in every stage of manufacture is maintained, with greater and greater uniformity and skill developed by repetition so long continued…"

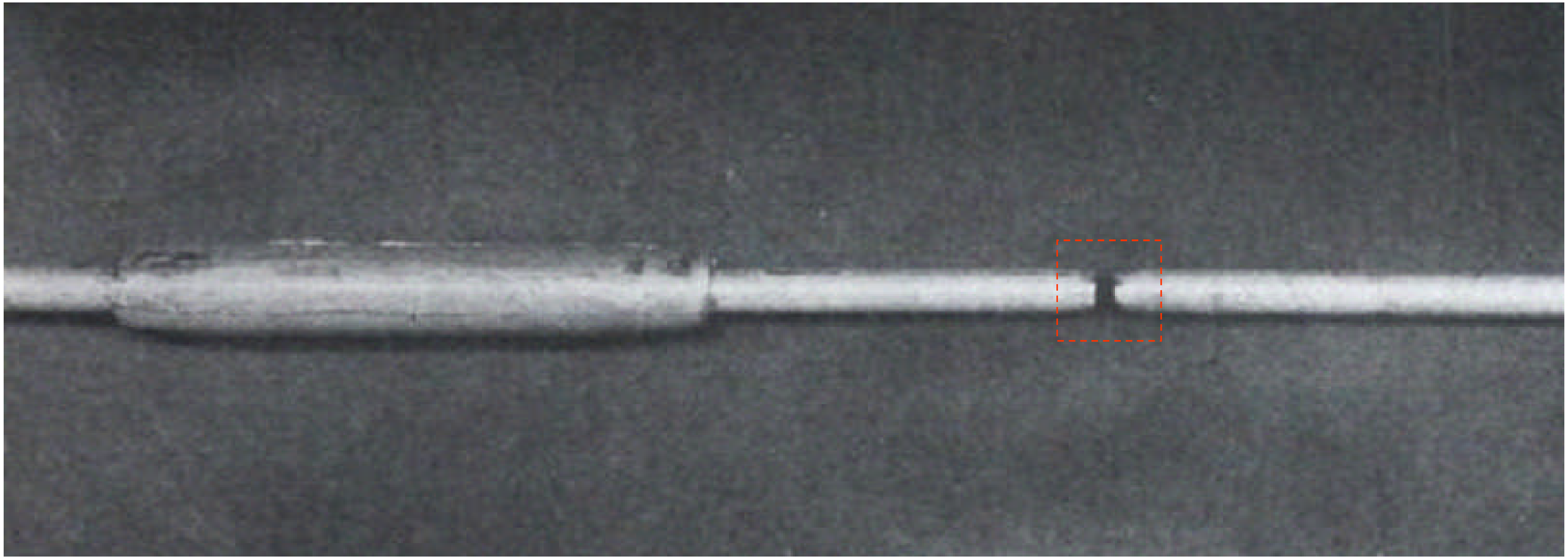
John A. Roebling's Sons Co.

<u>Left</u>: caption: "Method of testing bridge cable wire by the Roebling Company, for ultimate strength, ultimate elongation, and yield point"

"…The Port of New York Authority specifications for the Hudson River Bridge require an average minimum yield point stress of 153,000 pounds per square inch; the actual average up to January 1, 1930, is 182,000 pounds, thus establishing high quality and value, hitherto believed impossible for cold drawn bridge wire, which have been secured on the basis of 45,000,000 pounds production…"

John A. Roebling's Sons Co.

Wire Splicing



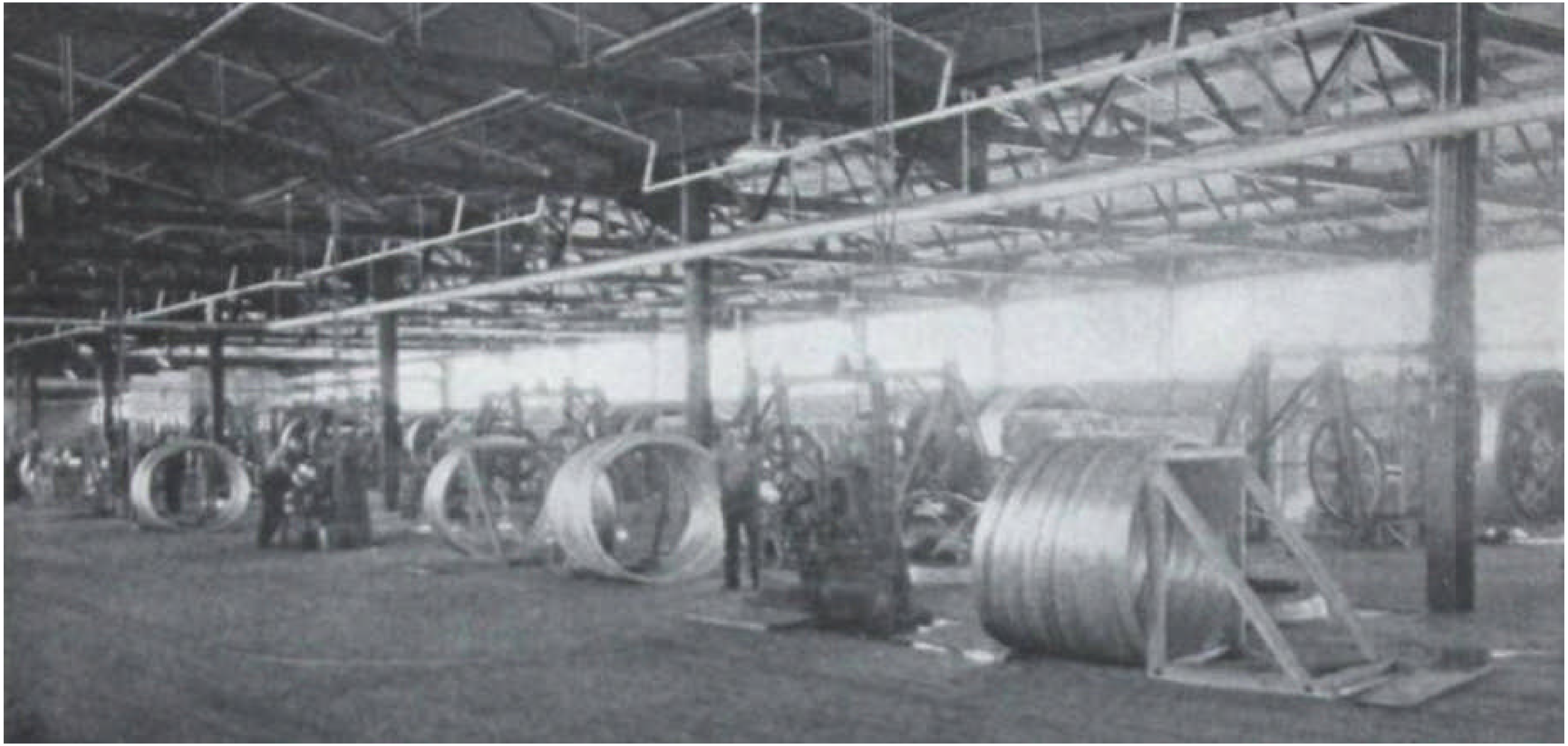
"…A very important feature of the cable wire is the improved cold pressed sleeve splice, which in a large majority of numerous tensile breaking tests has broken the wire beyond its splice. This assures practically unimpaired maximum strength, and unlimited lengths of wire made from any number of separate pieces that may be quickly spliced either in the shop or field…"

John A. Roebling's Sons Co.

Above: caption: "Failure of wire in splice test. Clean cup-and-cone break of wire outside of splice showing a better than 100% connection."

“…Unable with existing equipment to manufacture cable wires as long as were needed for the great span of the George Washington Bridge, over the Hudson River, the builders were confronted with the problem of producing a joining device that would not reduce the strength of the wires and that would be permanently secure from corrosion. The ends of the galvanized strands were finally threaded and screwed into high-carbon steel ferrules. Permanently to exclude the effects of moisture, each of the several hundred thousand threaded ends and ferrules was sprayed with molten zinc – securing a better protection at the joints than that provided by the galvanizing on the regular stretches of the gigantic wire cables…”

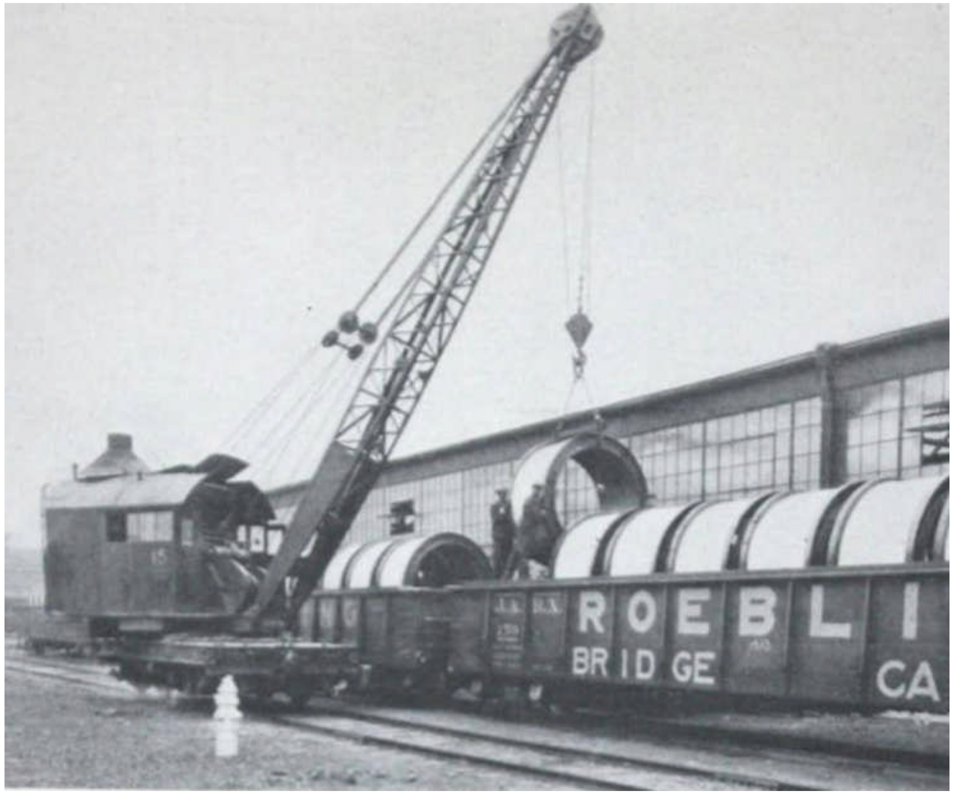
***Popular Science*, November 1932**



"…The 3,800-foot coils of tested and accepted finished cable wire are wound under uniform tension on mechanically driven structural steel reels holding 140,000 feet or more of continuous wire, the end of one coil being spliced to the beginning of another coil as the winding progresses…"

John A. Roebling's Sons Co.

<u>Above</u>: caption: "Bridge wire reeling stands in shop at Kinkora plant"



"…As fast as filled with cable wire, the reels weighing about 8 or 9 tons each are stored or loaded for shipment in special steel cars taking nine reels each. Steel cradles and clamps are provided on the car floors, which engage the reels and hold them securely against displacement in transit…"

John A. Roebling's Sons Co.

Left: caption: "Loading reels of bridge wire in special cars at Kinkora Plant for shipment to bridge site"

Plant & Equipment

“…No pains were spared by the Roebling Company in the selection of able and experienced engineers, superintendents and skilled employees, that have reached a total of about 400 men at the site, with a daily payroll of about $6,000. Abundant provisions made for their safety, efficiency and comfort, have resulted in notable zeal and loyalty, and in the rapid execution and high quality of the work performed. The plant and equipment installed are of high standard design and quality, and include many special appliances, all operated by electric power, and arranged to obviate delays from breakdowns or replacements, an abundance of reserve being always maintained. The average consumption of electricity for light and power is about 50,000 kw hours of 440-volt, 3-phase, 60-cycle current monthly. All material for the New Jersey side of the bridge is delivered by barges to the foot of the New Jersey tower and thence hoisted to the top of the Palisades by an inclined cableway arranged to raise or lower a load simultaneously with its transversing, so as to let it travel continuously at a uniform height above the sloping surface of the ground…”

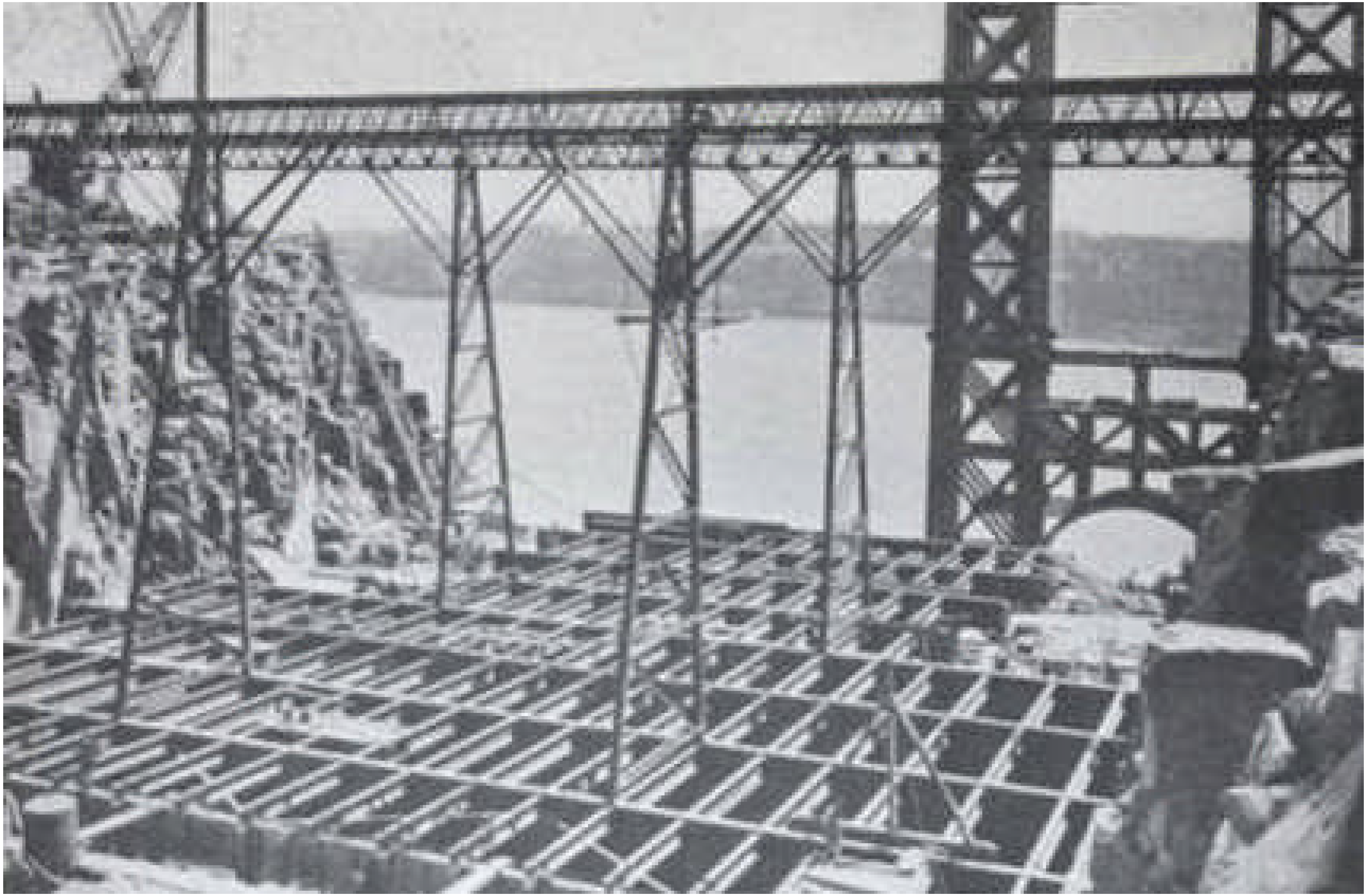
John A. Roebling’s Sons Co.

Above: caption: “Upper end of hoisting cableway on New Jersey shore, derrick mounted alongside of approach cut, commanding anchor block in cut”

"…A very complete construction plant and equipment was installed at the bridge site by the Roebling Company at a cost of more than $1,500,000 and, besides that directly required for the cable stringing operations, included a number of large and small offices, shops, warehouses and other buildings on both sides of the river, cantilever steel dock, a 600-foot and 750-foot Blue Center cableway, for transferring men, materials and equipment horizontally and hoisting them 300 feet, a 112-foot suspension service bridge, five boom derricks, one 10-ton girder crane of 54-foot span on a 268-foot runway commanding the New Jersey anchorage and storage yard, a 10-ton caterpillar crane and two 7 ½-ton skip hoists operated on the outer faces of the main towers…"

John A. Roebling's Sons Co.

Left: caption: "New Jersey approach cut and side span footbridge. Material handling crane in foreground"

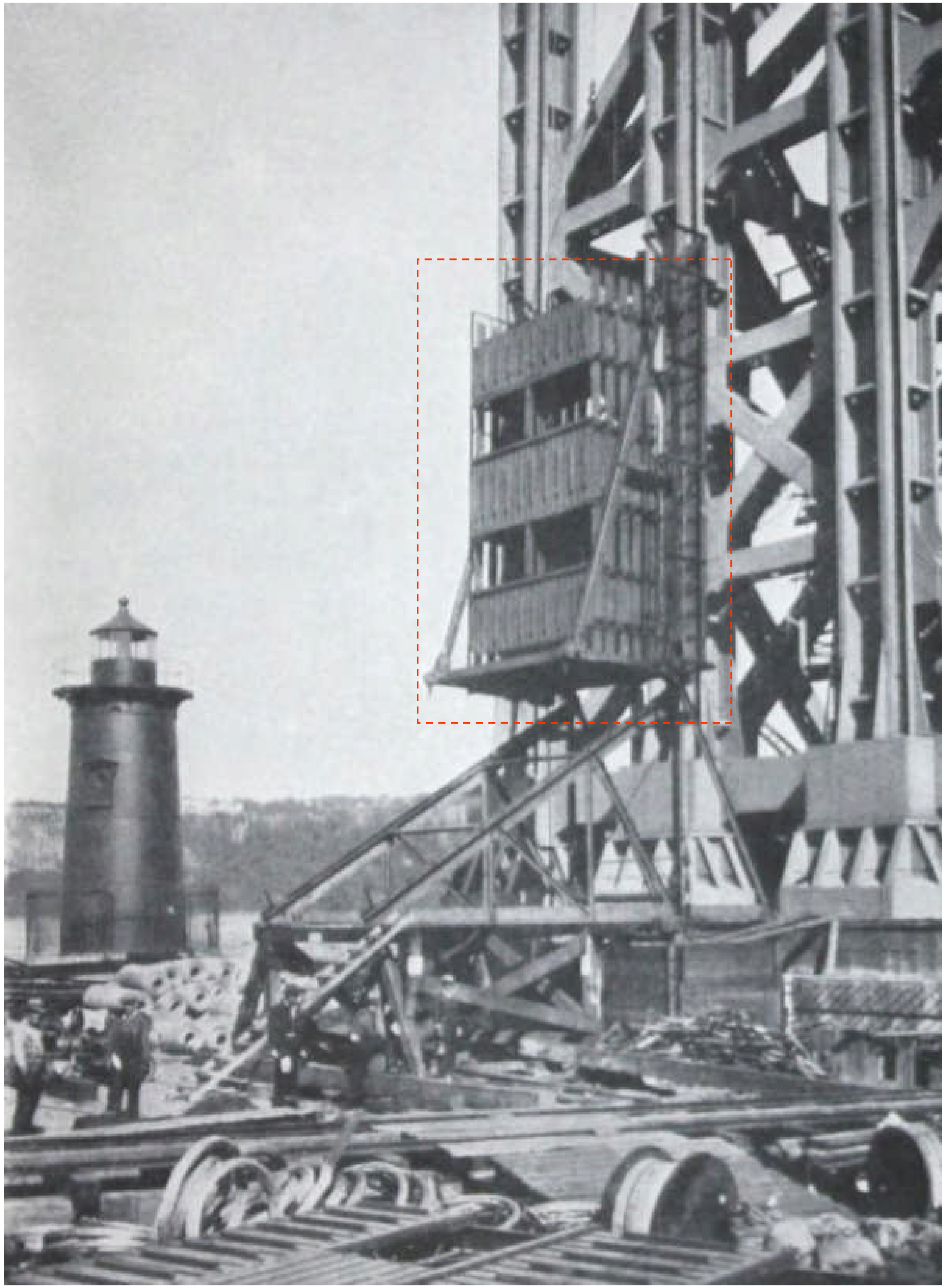


Above: caption: “New Jersey anchorage floor steel furnished and erected by the McClintoc Marshall Co., under Roebling contract. Also crane runway for handling reels of bridge wire and equipment at the New Jersey anchorage.”

"…The wide and deep rock cut in the top of the Palisades for the New Jersey approach to the bridge, and for its anchor pits, is spanned by the runway of a girder crane that serves the elevated storage yard north of the cut, and also carries a footbridge over the cut…"

John A. Roebling's Sons Co.

<u>Left</u>: caption: "Installing road framing for the New Jersey approach"



"…A special skip, traveling on vertical guide strands from its foot to the top of each tower, transported the footbridge sections and flooring to the temporary working platforms, whence they were delivered to the travelers that erected the footbridges…"

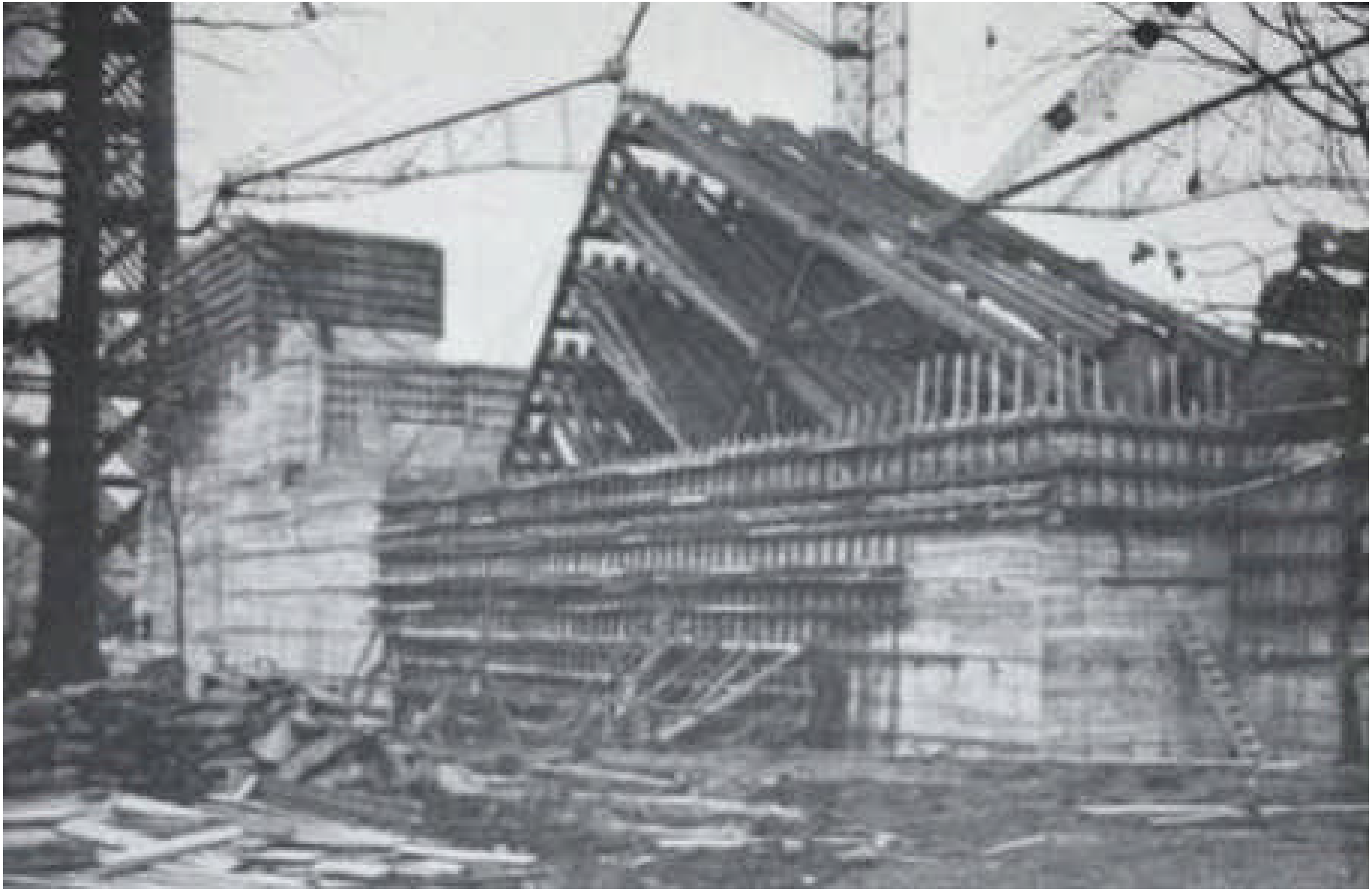
John A. Roebling's Sons Co.

Left: caption: "Loaded skip hoist on New York tower"

Anchorage Erection

“…All of the 727 tons of plate girders in the New York anchorage and the 1,426 tons of embedded eyebars in the anchor chains, were furnished by the American Bridge Co. under the Roebling contract. On the New York side of the river all the steel was set in the open on the concrete footings which later became integral portions of the huge masses of enclosing concrete that resist the upward and horizontal pull of the cables. The embedded steelwork was set by the Arthur McMullen Co., of New York, who built the New York anchorage and the New York tower foundations. The 122 lines of eyebars, two panels in each line, that were set before cable spinning was commenced, were temporarily supported in their required inclined positions on structural steel transverse bents that remained permanently in position after the eyebars had been sealed up in the great mass of anchorage concrete…”

John A. Roebling’s Sons Co.



<u>Above</u>: caption: “Embedded eyebars in New York anchorage. Furnished under the Roebling contract.”

“…Entering the anchorages over somewhat smaller saddles than those in the towers, the barrel cables were splayed out into their sixty-one component strands. These were wrapped around the first of a chain of huge eyebars that extended deep into the rock or concrete, finally attaching to a steel girder placed crosswise. Concrete was inserted to surround all of this steel in the 150-foot tunnels that were bored into both anchorages…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

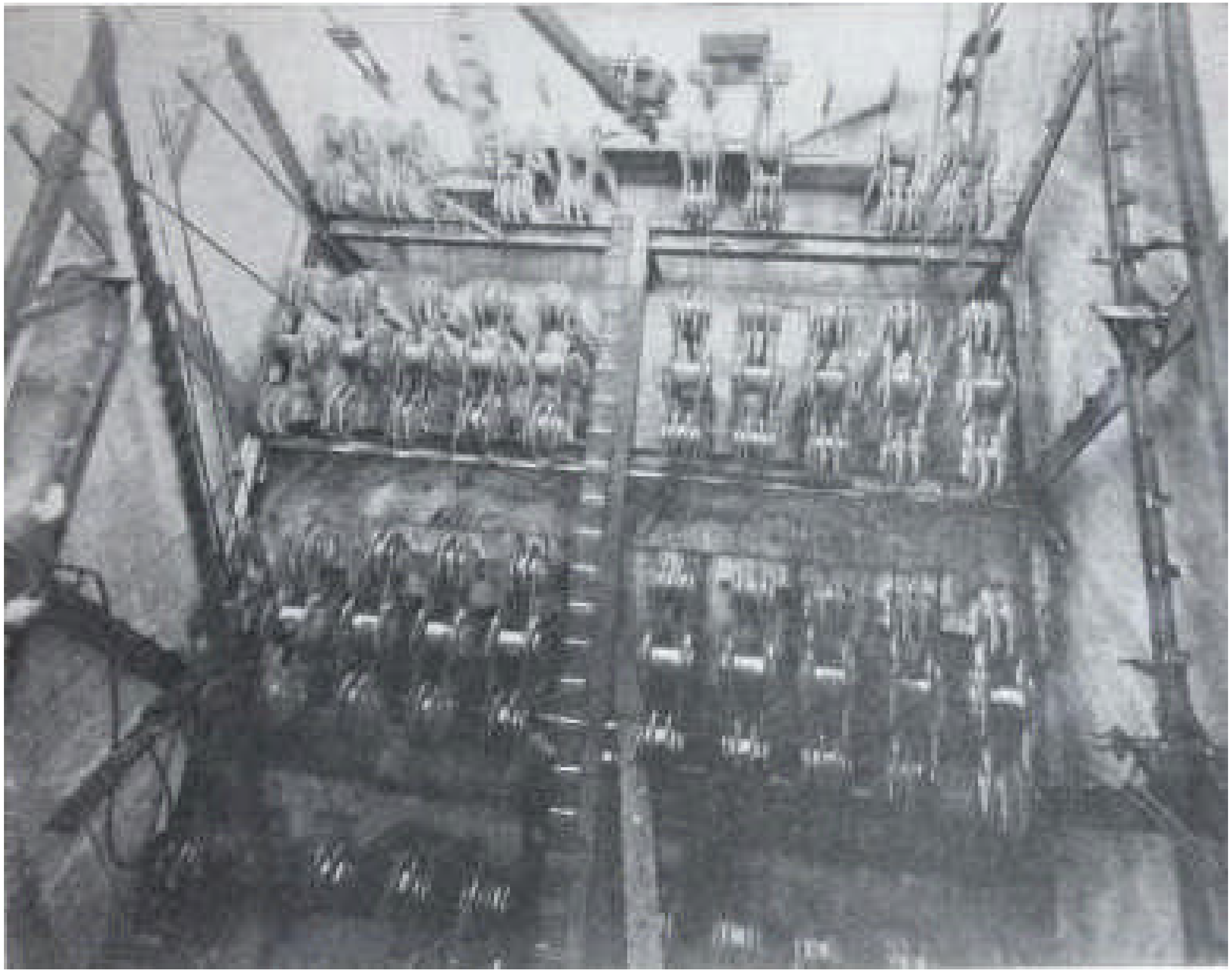
"…The installation in the two New Jersey anchorage tunnels of twenty 35-ton plate girders, and 1,464 10 x 1 ¾ and 10 x 1 7/8-inch eyebars, about 40 feet long, required the transportation and accurate placing of long, wide, and heavy members on steeply inclined surfaces and in very narrow quarters with small clearance. It was successfully accomplished with methods and equipment developed by study and experiment with large scale models. The girders were trucked ten miles to the top of the Palisades, delivered in the approach cut, derricked to the tunnel top, and there placed on skids and lowered to the bottoms of the tunnel by gasoline hoists. When the reaction girders reached the bottoms of the anchorage tunnels, they were hoisted to inclined positions at right angles to the anchor chains by tackles suspended from the steel bents provided for the subsequent temporary support of the eyebars, and were jacked transversely to their required positions and bolted in place ready to be pin-connected to the lower panel of eyebars. The erection of these girders and the eyebars, and their enclosure with concrete was one of the items of the Roebling contract…"

John A. Roebling's Sons Co.

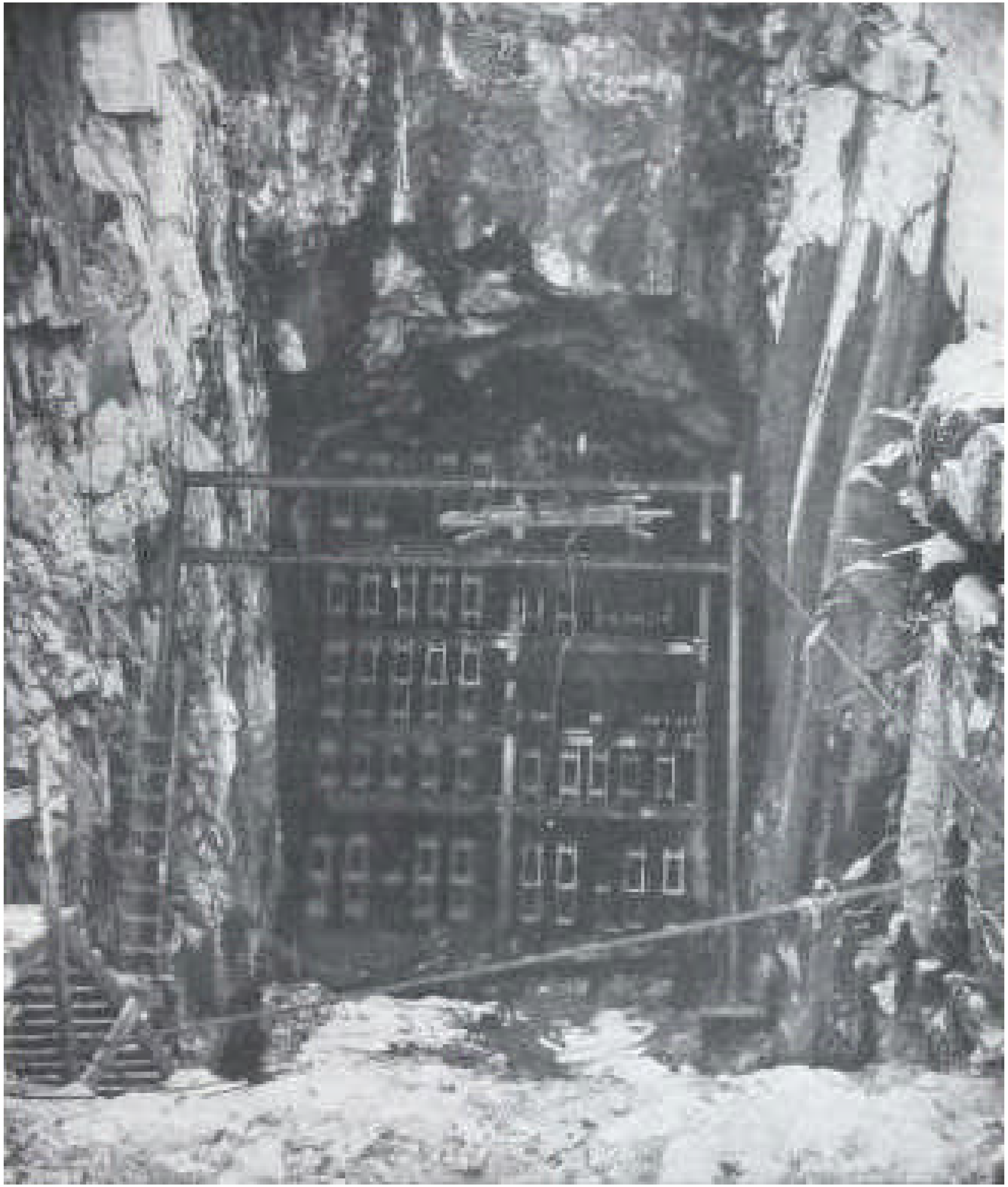
Left: caption: "Reaction girders on skids for lowering to position in anchorage tunnel"

“…Maximum clearance, that was especially needed at the New Jersey anchorage, for the connections of the strand shoes to the anchor eyebars, was secured by the expedient of successively connecting the eyebars in the upper tier to those in the next lower tier, only as fast as their respective strand shoes become ready for adjustment. Before strand adjustment was commenced, the upper ends of the eyebars projected only a short distance from the anchorage concrete to receive the upper tier bars that were assembled to them from the bottom up, thus always maintaining open working space above them…”

John A. Roebling’s Sons Co.



<u>Above</u>**: caption: “Lower panels of New Jersey anchorage eyebars for two main cables ready for successive connections with upper tier of eyebars that engage the strand shoes. Boom for handling equipment above. Pipes from hydraulic pumps, on the walls. Pressure tubes to strand pulling jacks at lower right corner.”**

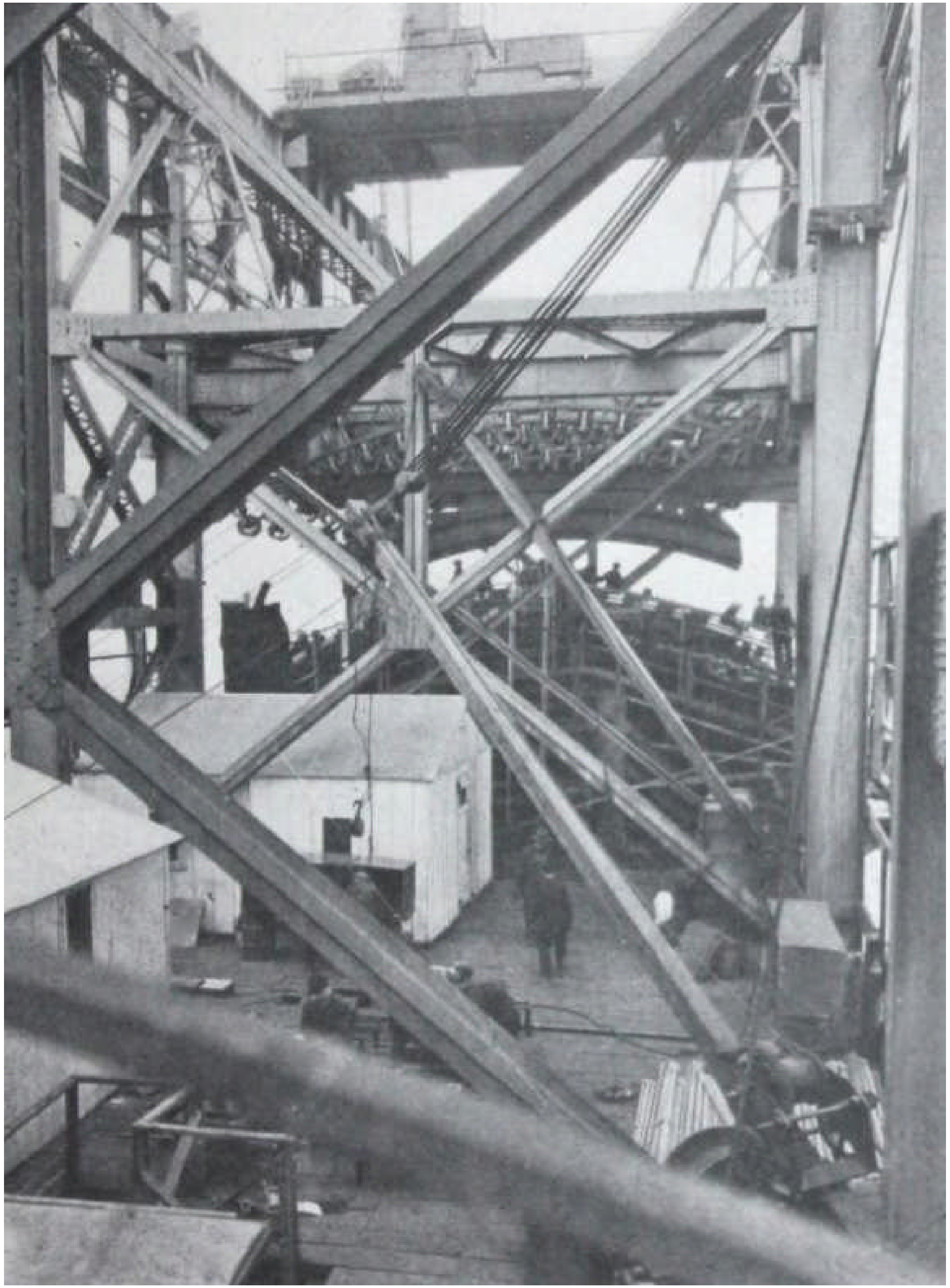


"…The 2,837 tons of eyebars for the New Jersey anchorage were delivered by lighters to the foot of the tower, unloaded by a derrick boom, and transported in sets of eight in slings hoisted to the top of the anchorage at the rate of 40 eyebars per hour by the inclined cableway. Part of them were lowered to position in the tunnels by whip lines from a gasoline hoist; the bars taking bearing on I-beam skids through rolling pins in their eyes. The eyebar erection was expedited by handling part of them with a 215-foot Blue Center cableway in the roof of the north tunnel. After the lower three panels of eyebars were set they were embedded in concrete that was chuted to position, completely filling the lower ends of the tunnels…"

John A. Roebling's Sons Co.

<u>Left</u>: caption: "End view of anchorage eyebars connected to reaction girders in tunnel"

Cable Spinning Apparatus



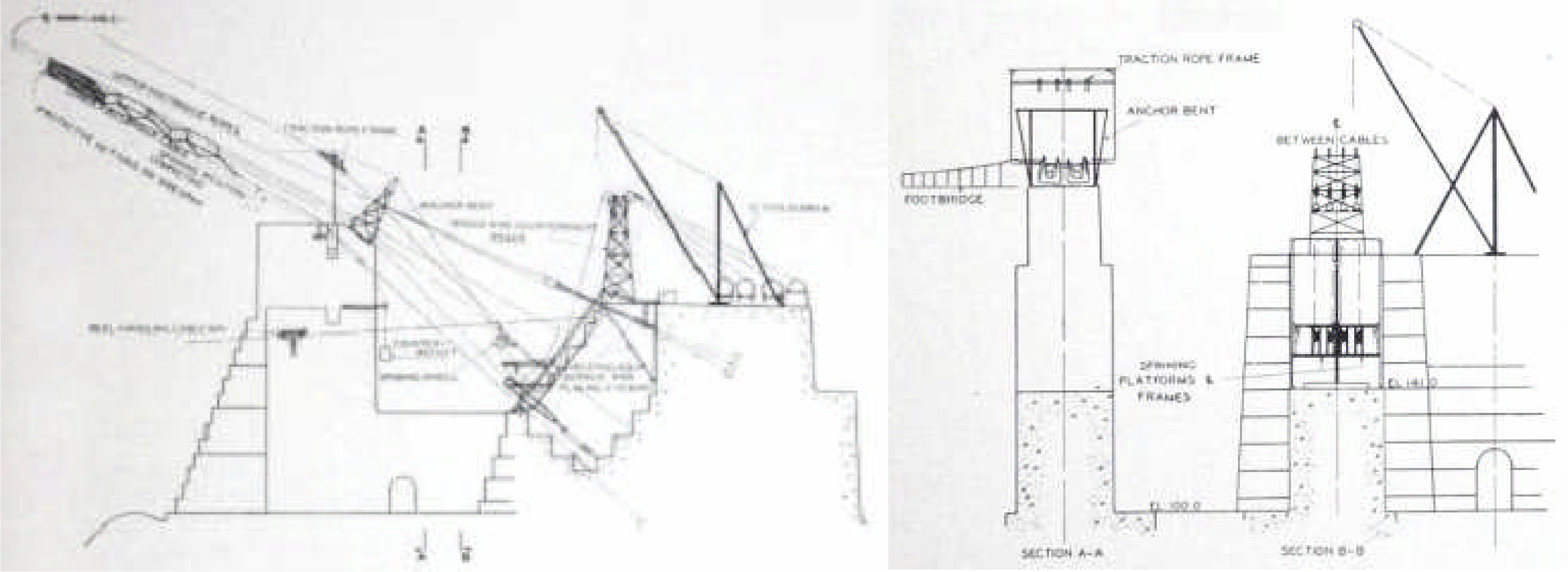
“…For handling cable stringing apparatus and for other erection service, there is installed on top of each main tower a structural steel framework about 50 feet high, called a construction tower, that supports the cable spinning tramways and other equipment, and has longitudinal girders 245 feet long that cantilever beyond the up and down stream faces of the tower, and serve as runways for the 130-ton girder cranes used for strand shifting and adjusting, instead of jacks, always heretofore used for this purpose…”

John A. Roebling’s Sons Co.

Left: caption: “Roebling construction tower, and 130-ton crane atop New Jersey tower”

"…The general arrangement of the wire spinning and strand adjustment plant is substantially the same on both sides of the river, except for variations due to different topography, and to those developed to conform to the tunnel anchorages in New Jersey and the concrete block anchorages in New York…"

John A. Roebling's Sons Co.



"…The completion of the New York anchorage blocks before cable work was commenced provided advantageous support at convenient locations for the important equipment, which was largely installed by the 125-foot boom steel derrick mounted on top of the main block to command its entire area and the adjacent ground area where materials were delivered to it by the inclined cableway. Nearly all this equipment was installed in duplicate for the north and south pairs of cables. The traction rope frame is similar to those installed on the tower tops…"

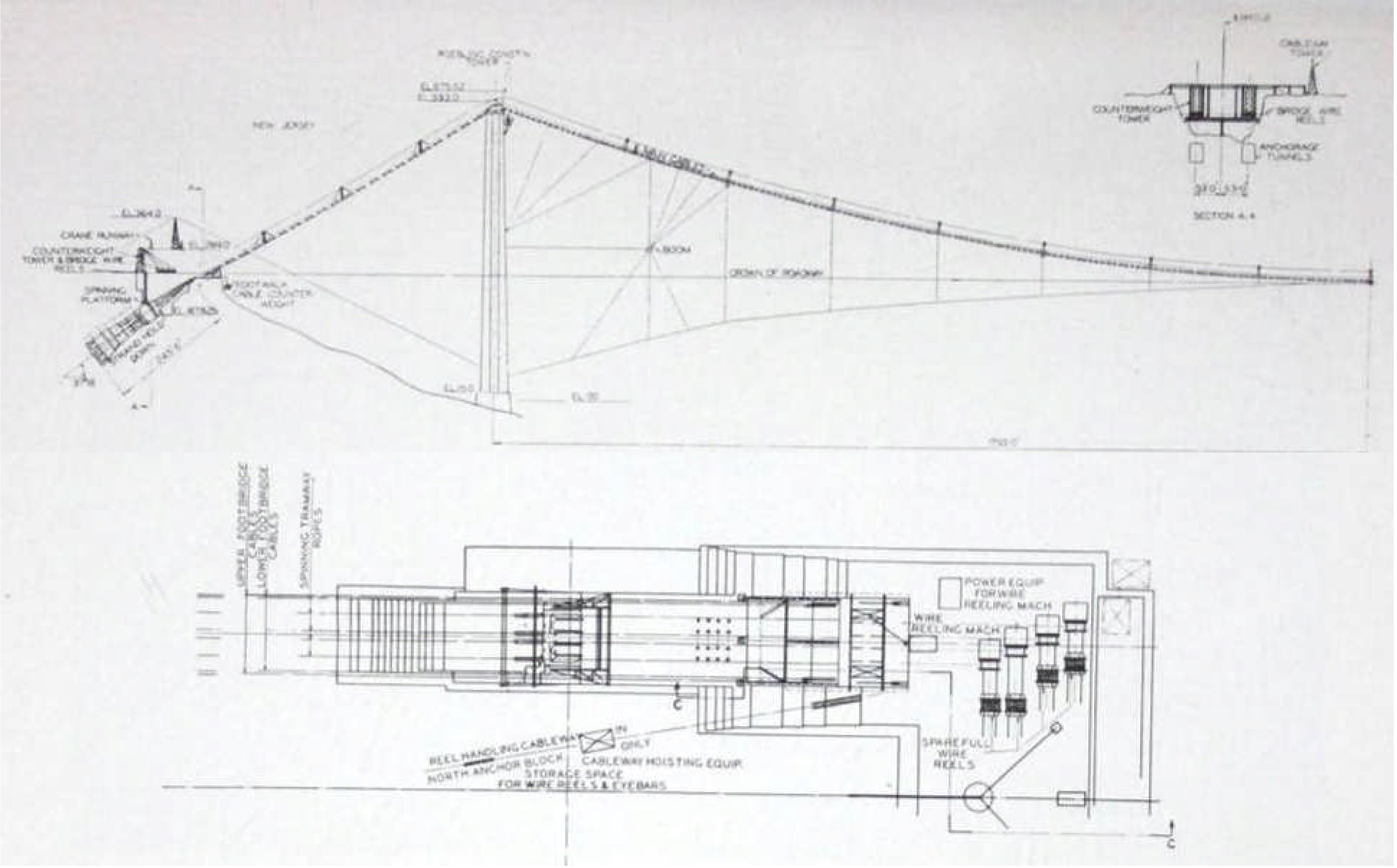
John A. Roebling's Sons Co.

Above L&R: caption: "Longitudinal and transverse sectional elevations of New York anchorage, showing end of side span footbridge and location of principal wire spinning equipment. Main cable anchorage eyebars and girders not shown."

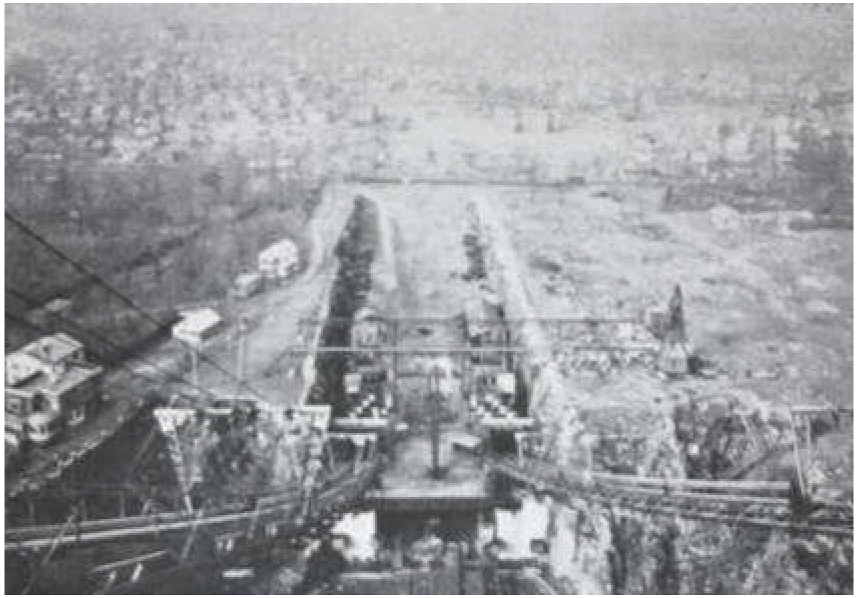
"…In New Jersey the cable wire reels and anchorage machinery and construction materials are handled by the girder crane that commands the approach cut and high level storage yard, and the relative position of tramways, unreeling machines and tension towers correspond to those shown in larger scale at the New York anchorage…"

John A. Roebling's Sons Co.

<u>Left</u>: caption: "NJ Spinning machinery"



Top: caption: “Semi-elevation of footbridge and storm system and longitudinal section through New Jersey anchorage tunnel”
Bottom: caption: “Location plan of cable spinning plant at New York anchorage”



"…At the New Jersey end of the bridge the construction plant was installed at three principal levels: storage yard, girder crane runway and cableway tower on top of the Palisades; unreeling machines, and some other equipment on the floor steel; and the remaining items in the anchor pits…"

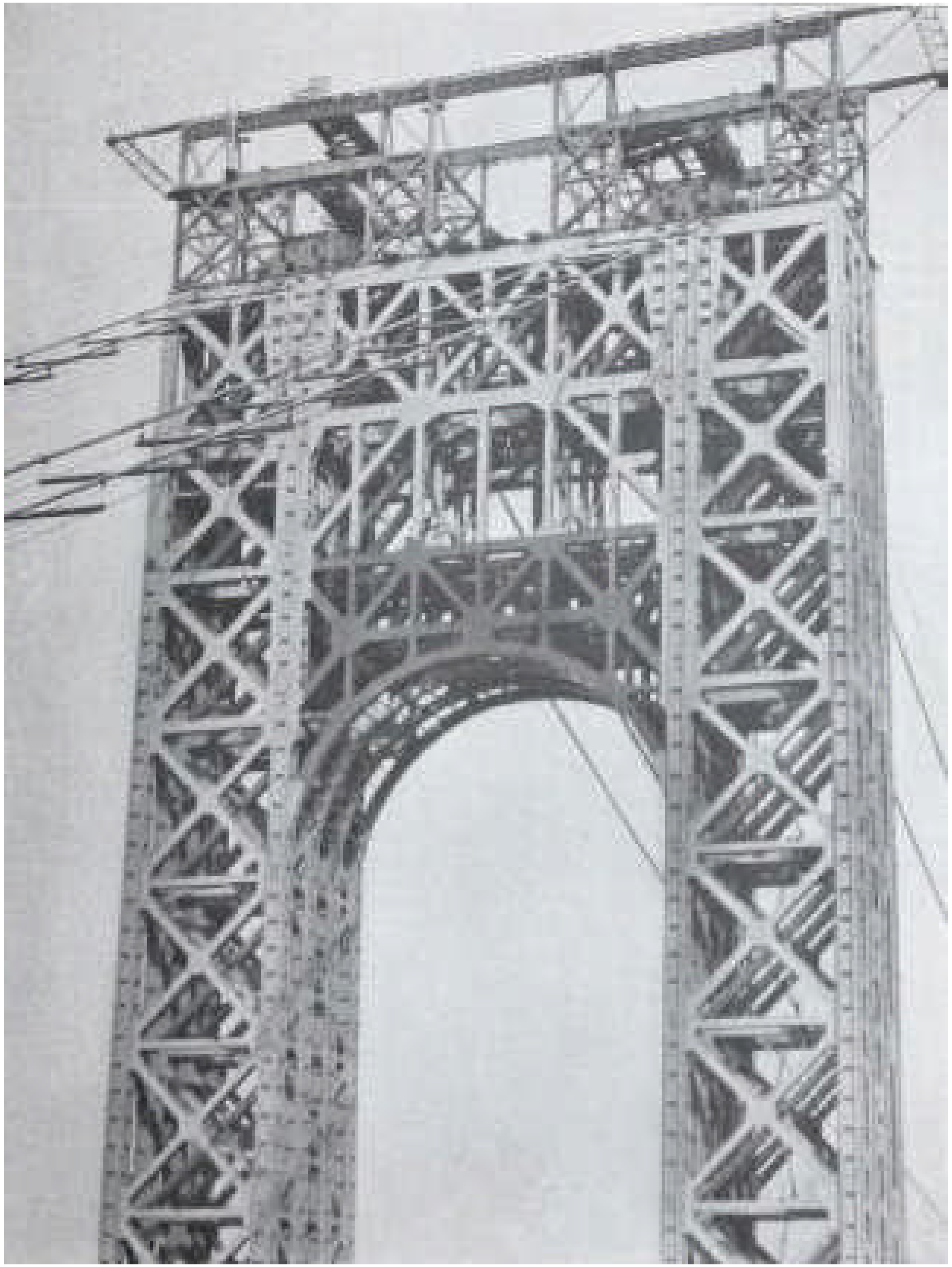
John A. Roebling's Sons Co.

Left: caption: "General view of New Jersey anchorage, showing reels of wire in spinning position"

“…For spinning and adjusting the cable wires, and for adjusting, transferring and connecting the cable strands, there was installed on each tower top an auxiliary construction tower with 130-ton electric traveling crane; at each anchorage two 150-ton pulling jacks and two 60-ton hoisting jacks. There were installed for each pair of cables two tramways, eight wire unreeling machines with two hydraulic electric centrifugal power units, two wire tension towers, two hydraulic-electric wire splicing machines, and twelve electrically operated come-along lamps…”

John A. Roebling’s Sons Co.

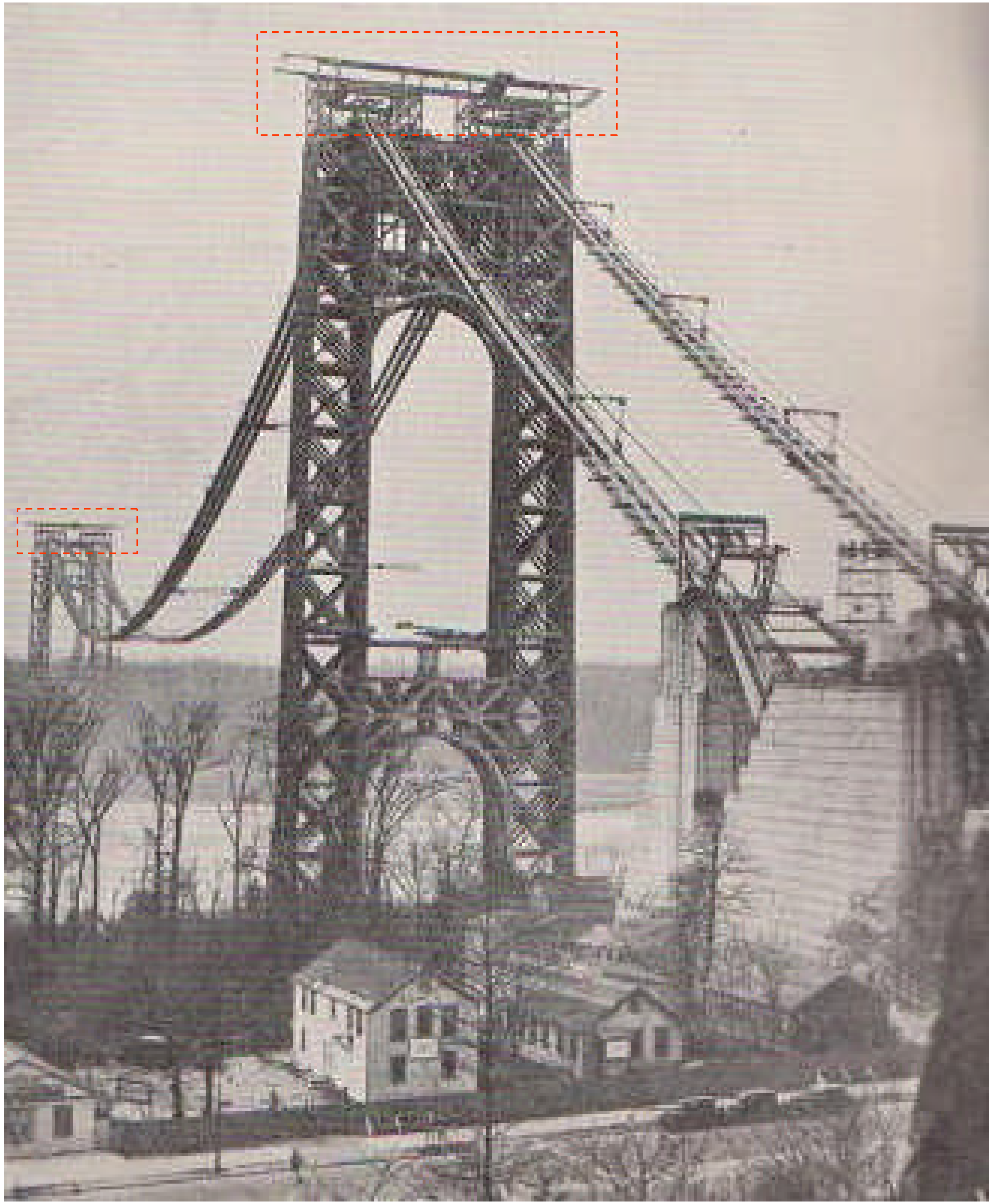
Left: caption: “Wire reels, unreeling machines, tension counterweight tower and stiffleg derrick on New York south anchorage block. Footbridge cables and their anchorage eyebars in foreground, Strand anchorage eyebars under footbridge cables. Inclined spinning frame and adjustable spinning platform over anchor pit.”



"…Integral with each construction tower is a transverse runway 245 feet long, cantilevering 21 feet beyond the north and south faces of the main tower for the 35 ½ foot span girder crane, with two electrically operated pairs of 65-ton fixed hoists for lifting the cable strands. A 7 ½-ton auxiliary hoist is also installed on each crane to operate whip lines or tackles on its cantilever extremities…"

John A. Roebling's Sons Co.

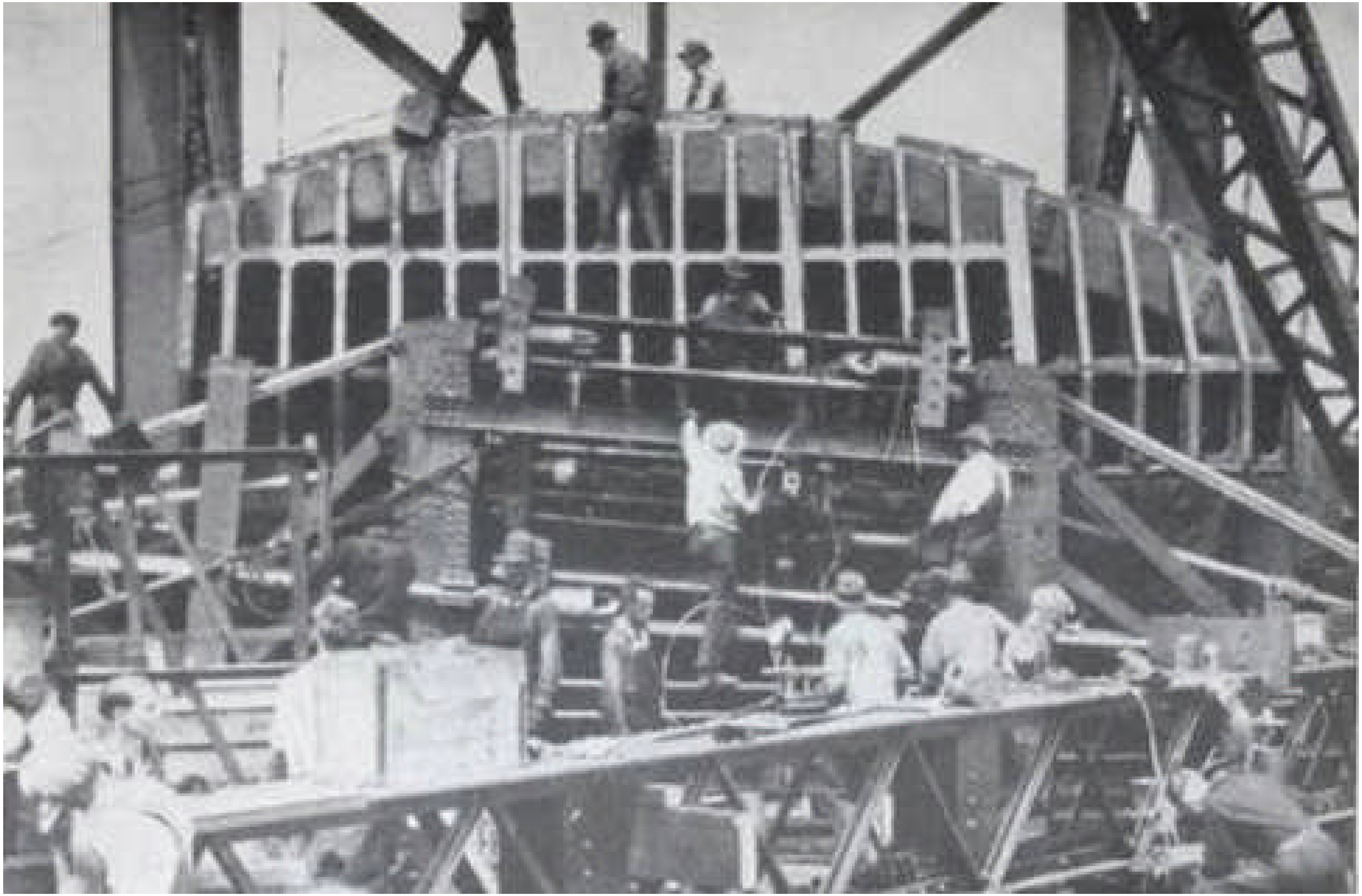
<u>Left</u>: caption: "Temporary construction tower and girder crane on top of New Jersey tower"



Cable Saddles

"…Each of the 55 x 210-foot steel towers, 635 feet high, carries on its deep upper girders four massive sectional 180-ton cast steel saddles, grooved to receive the lower exterior thirteen 4 ½-inch strands of one main cable. The erection and placing of these saddles required very powerful tackles, engines and boom derricks and was done with skill and safety; the hoisting engines, out of sight and hearing from the tower tops, being very accurately governed by the derrick man on the tower top, who controlled a set of electric signal lamps in the engine room. The McClintoc Marshall Co. hoisted and set these saddles, which were furnished and erected under the Roebling contract…"

John A. Roebling's Sons Co.

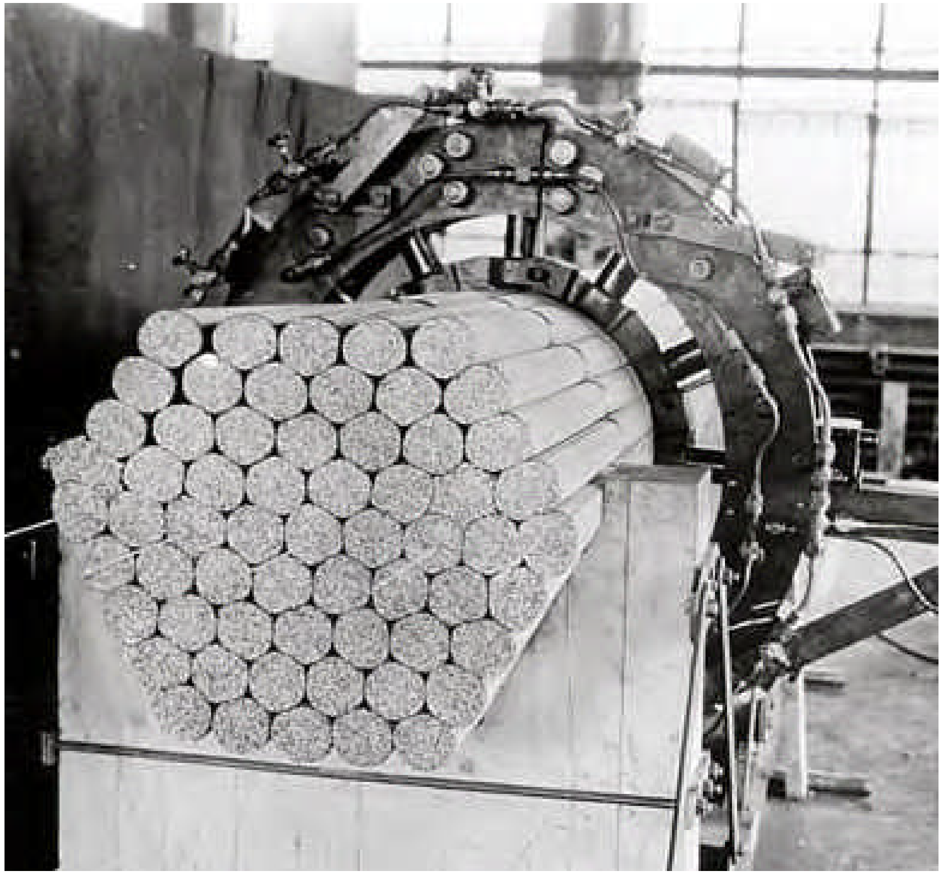


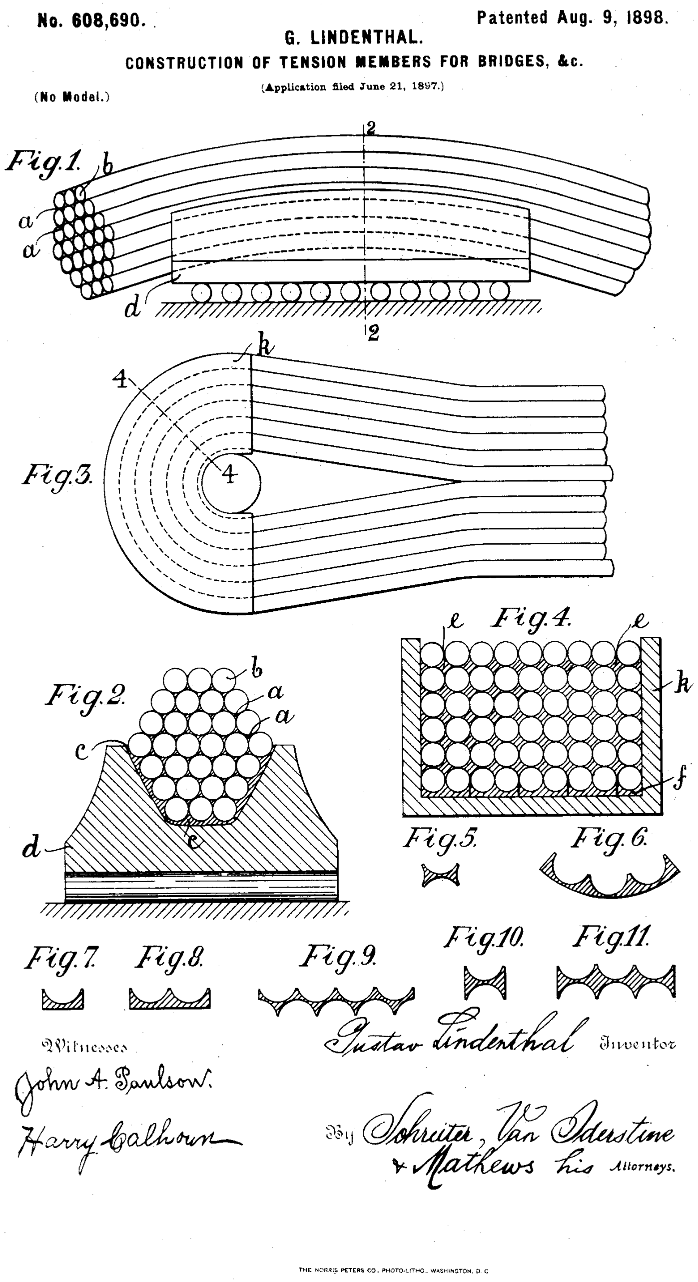
<u>Above</u>: caption: “180-ton sectional cast steel main cable saddle. Temporary structural supports, adjustment jack, and tension rods for footbridge cable ropes in foreground.”

“…The 61 strands of each cable are laid so as to have at the main saddle a hexagonal cross section, which, beginning on either side of the saddle, is eventually compressed to a circle by a massive yoke containing a number of powerful radial hydraulic jacks that will encircle the cable and, exerting an enormous force, will successively compact the cable wires and reduce to a minimum the interstices between them, after which the cable will be tightly wound by a protecting spiral wire…”

John A. Roebling’s Sons Co.

Above: caption: “New York tower main cable saddle”




No. 608,690. Patented Aug. 9, 1898.

G. LINDENTHAL.

CONSTRUCTION OF TENSION MEMBERS FOR BRIDGES, &c.

(Application filed June 21, 1897.)

(No Model.)

Witnesses

John A. Paulson.

Harry Calhoun

Gustav Lindenthal Inventor

By Schreiter, Van Ideustine & Mathews his Attorneys.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

<u>Left</u>: patent for: "Construction of Tension Members for Bridges"- awarded to *Gustav Lindenthal* (above) on August 9th 1898

"…Over the anchor blocks, where the shore spans of the cable are deflected, they rest in 22-ton cast steel saddles supported on sets of rollers on thick bed plates inclined from the horizontal. These saddles were set in positions carefully computed, and allowances made for the longitudinal displacements of the saddles for changing cable stresses, longitudinal movements, and temperature variations…"

John A. Roebling's Sons Co.

Left: caption: "22-ton anchorage cable saddle and roller bed"

Temporary Footbridge

“…The greatest spinning job the world has ever seen, the spinning of these strands into the cables of the Hudson Bridge, is now underway. It will be completed next October. To manage it, two temporary footbridges each twenty-five feet wide had to be slung from one anchorage to another, a feat in itself. The cables for the footbridges were the first to cross the river. They were fastened, first, to their anchorage on the New York shore. Then a barge, towed slowly across the river by tugs, paid out the cable by reels. Unwinding, it lay on the river bed where it would not interfere with passing steamers. Once across, the ropes were firmly fixed to the Jersey anchorages. Then cranes on the bridge towers reached down and hoisted the long steel cables to saddles on the tops. The same afternoon that the first cables for the footbridges spanned the river, there was lively discussion among the workmen – a hard-boiled, rollicking, fearless lot – as to who would have the honor of being the first to cross. A supervising engineer looked down one of the shining steel ropes and saw what looked like two buzzards roosting 400 feet out. They moved – and the engineer recognized them as two of his star workmen suspended on the naked wires 250 feet above the water. ‘We’re crossing to Jersey!’ they replied to his outraged hail. Threatened with instant dismissal, they returned to wait for the footbridges…”

Popular Science, **March 1930**
RE: the temporary $600K footbridge

“No ropes so long as would be required to support these walks had ever been built for such exacting service. It was necessary to stretch these ropes after fabrication to loads in excess of the maximum working load, in order to eliminate erratic or excessive sag.”

***Engineering News-Record*, 1930**

RE: the *Roebling Company* won the cable contract in 1927. *Charles C. Sunderland*, Roebling’s Chief Engineer, called the proposed bridge: “a sudden leap forward into a whole new range of magnitude.” One of Sunderland’s biggest challenges was supporting the 3,500-foot main span of the two footbridges needed to build the four massive cables. To solve this problem, Sunderland built a pre-stretcher operation at the Roebling Company’s *Kinkora Works* in *Roebling, N.J*. At the ends of the pre-stretcher’s 1,850-foot long track, hydraulic machines stretched the looped footbridge ropes with 200K pounds of tension, 25% higher than the required working load of 160K pounds. In 1930 ENR cited the Roebling pre-stretcher as: “one of the most important advances made in the suspension bridge field in many years.” For maximum efficiency, Roebling fabricated the nearly thirty-six miles of 2 7/8-inch footbridge ropes with six 37-wire strands and an independent 7x19 wire rope center for double-duty as suspender ropes after the main cables were complete.

"…All of the cable stringing operations are conducted from the tower tops, anchorages and their connecting footbridge, which must be maintained within about 2-feet horizontally and vertically, of its required position. It is very difficult to fabricate ropes 2.94 inches In diameter and predict their structural set within the close limits of permissible variation of footbridge elevations. Even moderate variations from the structural set of ropes a mile long would so change the footbridge floor elevation as to interfere with the accuracy and speed of stringing the main cables. The difficulty was overcome by subjecting the 108 long pieces of this rope to a stress of 200,000 pounds, which was maintained several hours, and then reduced to 80,0000 pounds, which was equivalent to the load tension of the suspended rope. It was measured under this stress; the stress released; the rope cut as marked, and the ends socketed at the shops. When erected in position no irregularity of structural stretch was visible, and they serve together uniformly and with only very slight initial adjustment…"

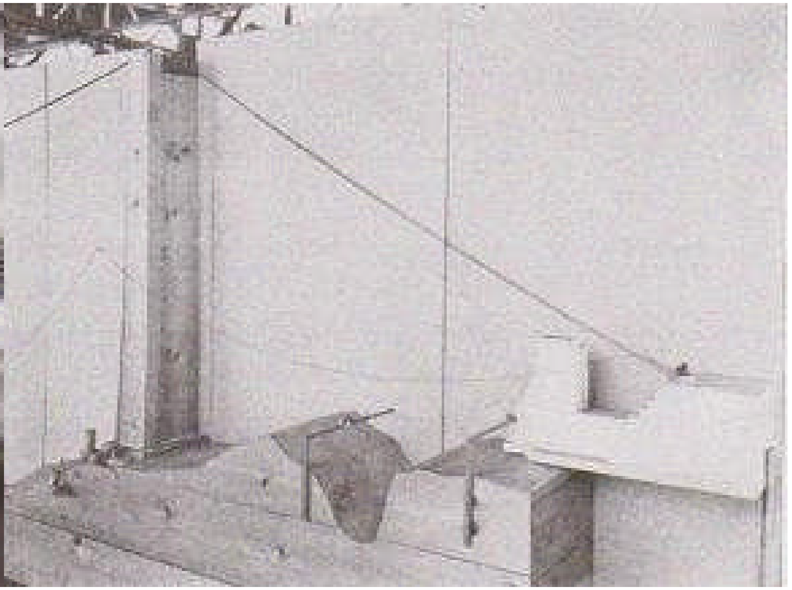
John A. Roebling's Sons Co.

Left: caption: "Footbridge cable ropes in position before final adjustment developed uniform stretch, producing great regularity and accuracy of catenary curves"

"The first machine in the world intended to modify factory made cables by placing a full length of wire rope under tension for an extended period bearing the working load until the wires rearranged themselves to eliminate their inherent looseness."

***Donald Sayenga,* Historian**

Left: caption: "John A. Roebling's Sons Company pre-stretcher at the Kinkora Works, Roebling, N.J., ca. 1929. The Company developed the innovative 1,850-feet long track to pre-stretch the footbridge ropes for the George Washington Bridge."



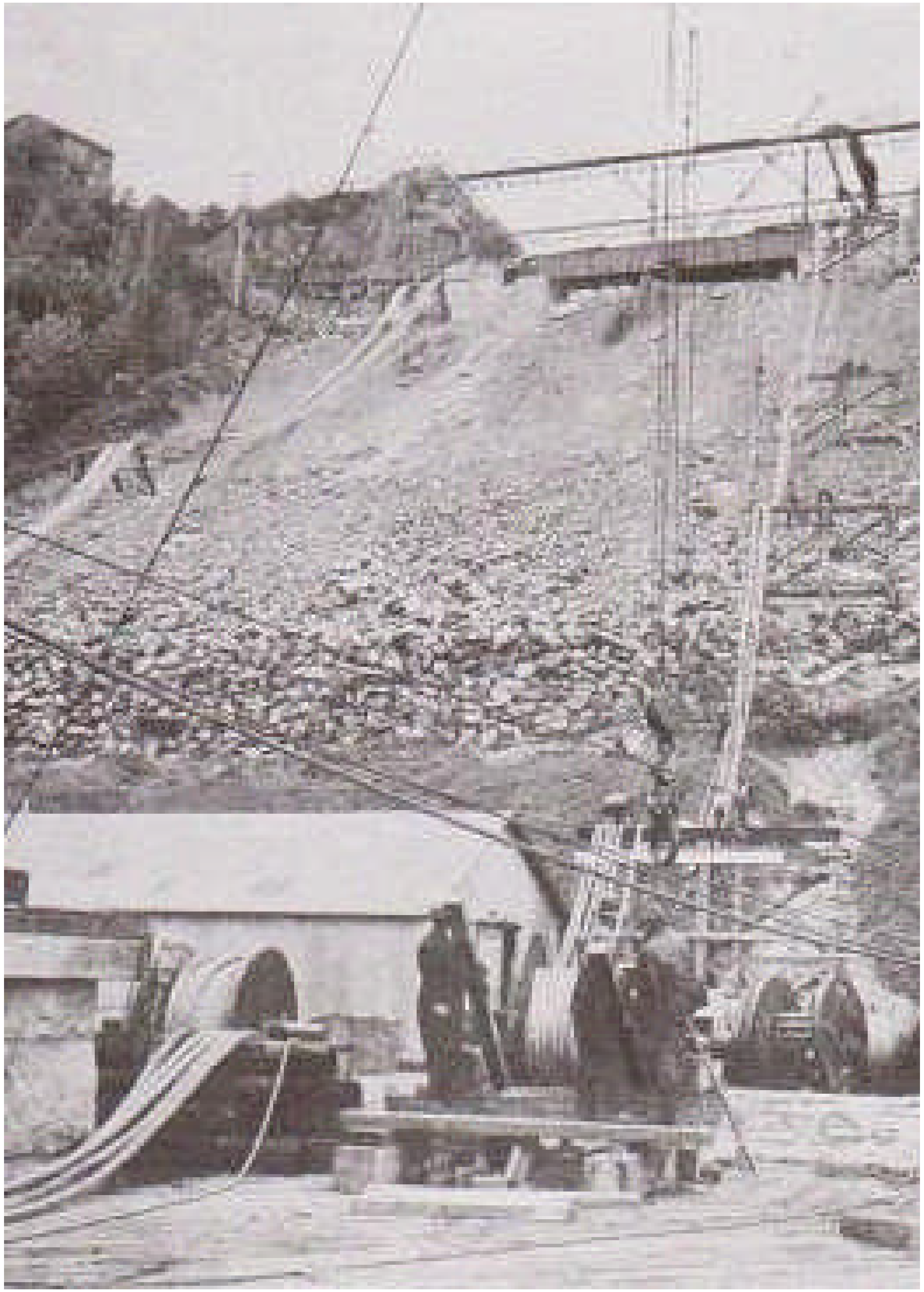
“…The footbridge is supported on thirty-six 2.94-inch twisted Blue Center ropes, each about a mile long and weighing approximately 78,000 pounds. As these had to be, for erection, positioned from anchorage to anchorage with the center section lying on the river bed, a very careful preliminary study was made with a length and weight scale model rope and a very accurate 1/100-scale profile of the river bottom. This demonstrated the amount and character of longitudinal displacement of the rope and the eccentric stresses developed in hoisting it more than 600 feet to the tower tops, and determined the hoisting method and special equipment that were adopted and proved very successful…”

John A. Roebling’s Sons Co.

Left: caption: “1/100 scale model of profile of ground surface and river bottom and footbridge cable hoisting apparatus”

Right: caption: “Model of footbridge cable rope hoisting equipment at New York side span”

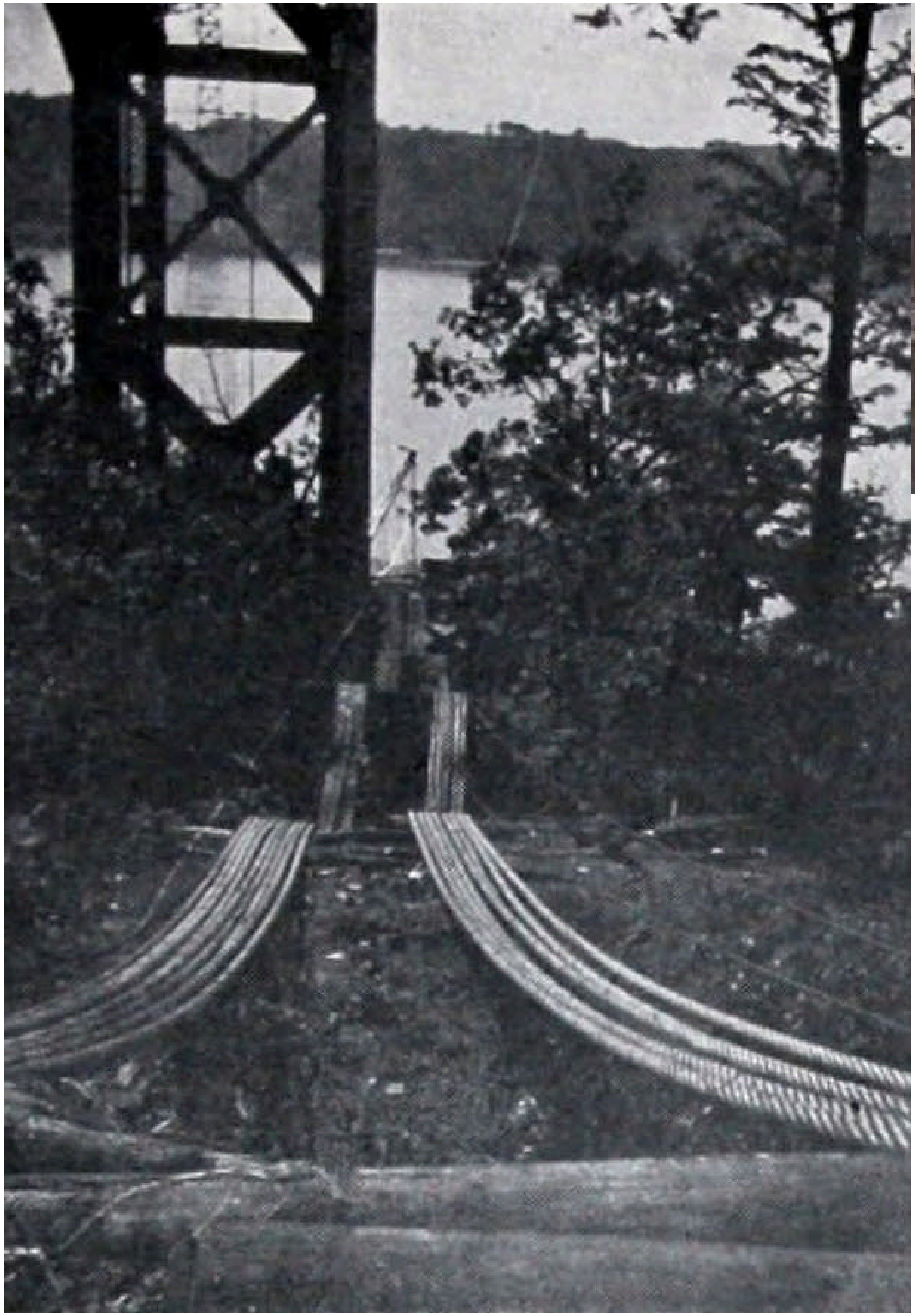
Positioning Footbridge Cable Ropes

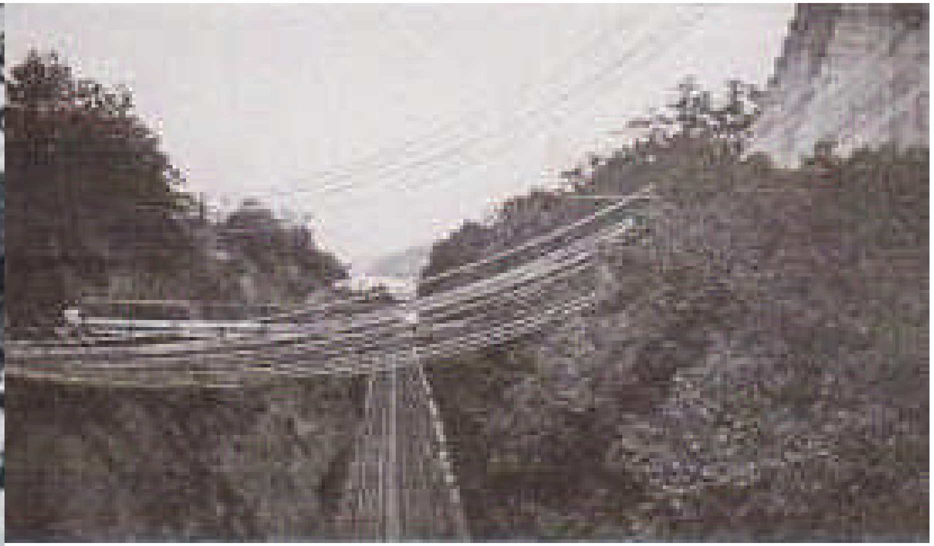


"…All the footbridge cable ropes except those for the west side span were unloaded from lighters near the foot of the east tower, the remainder being unloaded at the foot of the west tower. The side span ropes were positioned on both sides of the bridge axis from the shore lines to the anchorages, being supported on falsework trestle bents to keep them clear of rocks, etc., and the land ends were made fast to special anchors in the anchorage masonry. The hauling of the footbridge cable ropes up to the anchor pits was made difficult by their great length and weight, and the necessity of supporting them on falsework bents between which they sagged in deep loops forming nodes that greatly increased the required traction force…"

John A. Roebling's Sons Co.

Left: caption: "Hauling side span footbridge cable ropes to anchorage in Palisades"



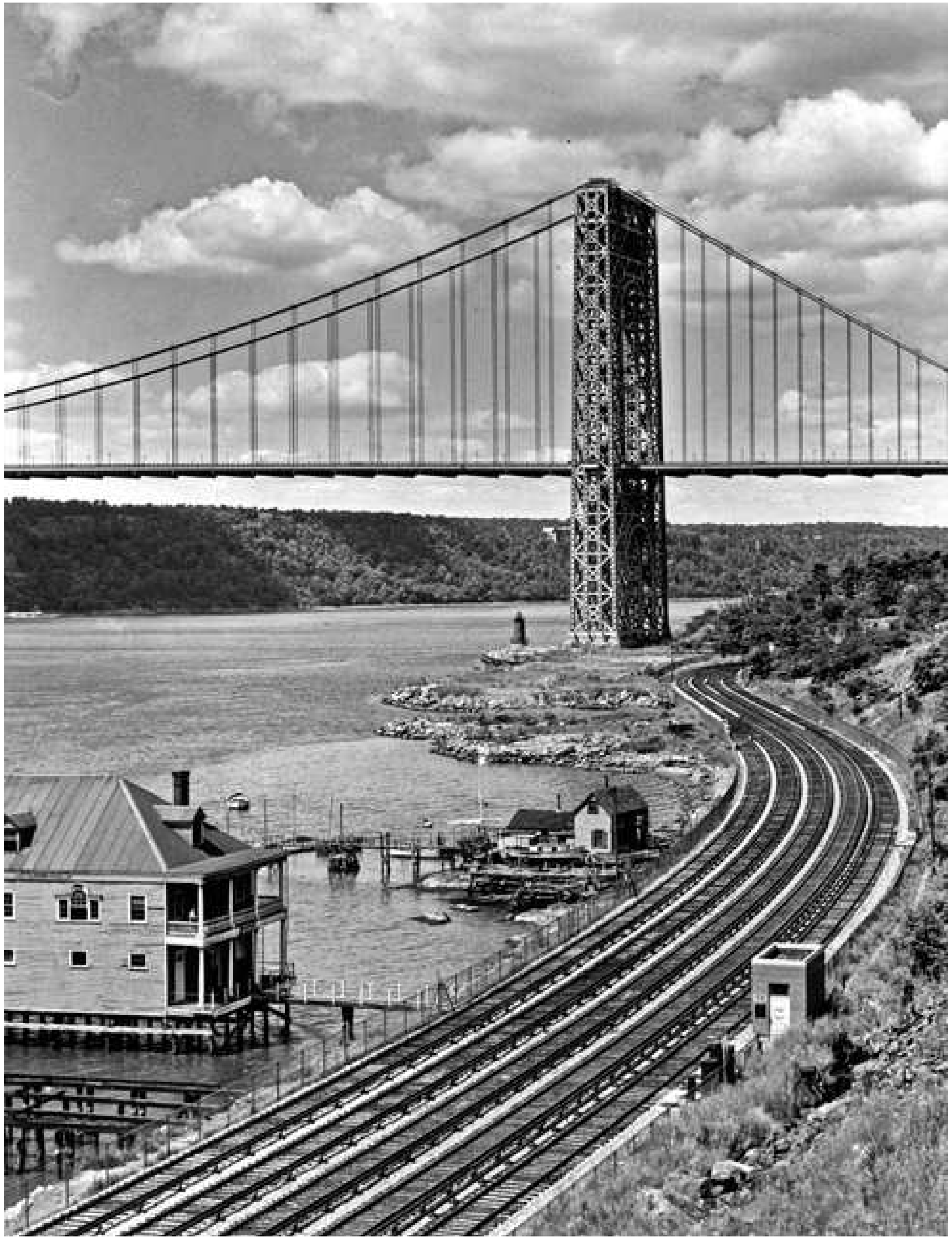


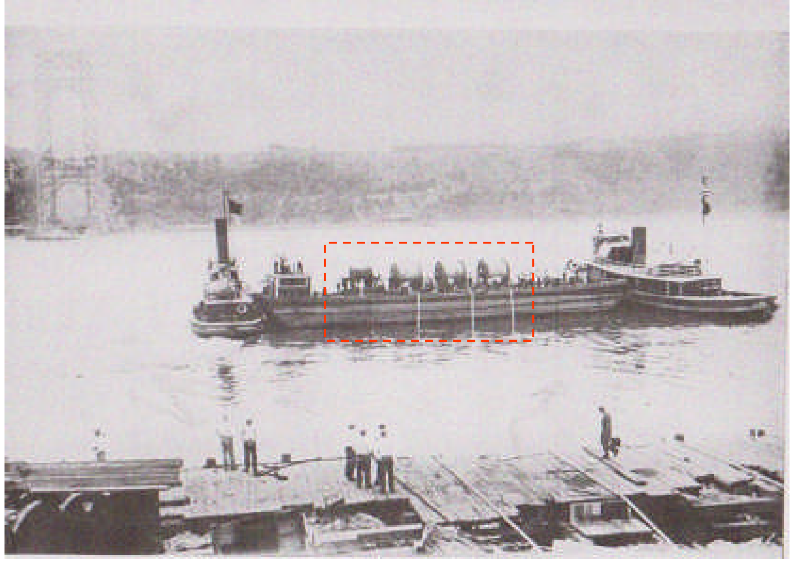
"…Especial difficulty was experienced in positioning the New York side span ropes over the 300-foot span and 160-foot rise above the deep, wide cut for the New York Central Railroad tracks…"

John A. Roebling's Sons Co.

<u>Above</u>: caption: "Cable ropes for New York side span of footbridge ready to be hoisted over deep railroad cut"

<u>Left</u>: caption: "Footbridge cable ropes positioned for hoisting to top of New York tower"





"…Each of two barges was equipped with four reel stands and reel brakes; the center span sections of the footbridge cable ropes on reels were placed in the reel stands, the socketed outer ends of the ropes were connected to the ends of the New York side span ropes, and the barges were towed across the river in about 20 minutes as the rope unreeled and dropped to the bottom of the river. The barges made alternate trips on opposite sides of the bridge axis, and when they arrived at the New Jersey shore the reel ends of the ropes were connected to the river ends of the side span ropes, making the footbridge cables continuous from anchorage to anchorage, but at an elevation 600 feet at the towers below the required height. Afterwards while navigation was controlled by a Coast Guard patrol for intervals of one hour or less, the footbridge ropes were successfully hoisted to the tower tops in less than an hour each, and were placed in their saddles and adjusted to the exact required length and sag…"

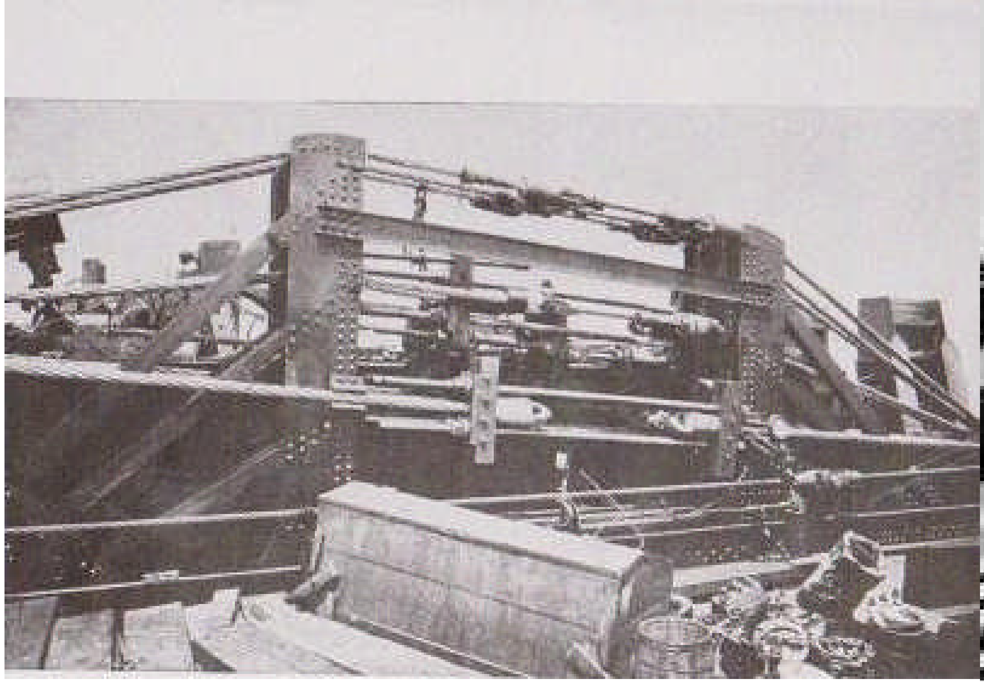
John A. Roebling's Sons Co.

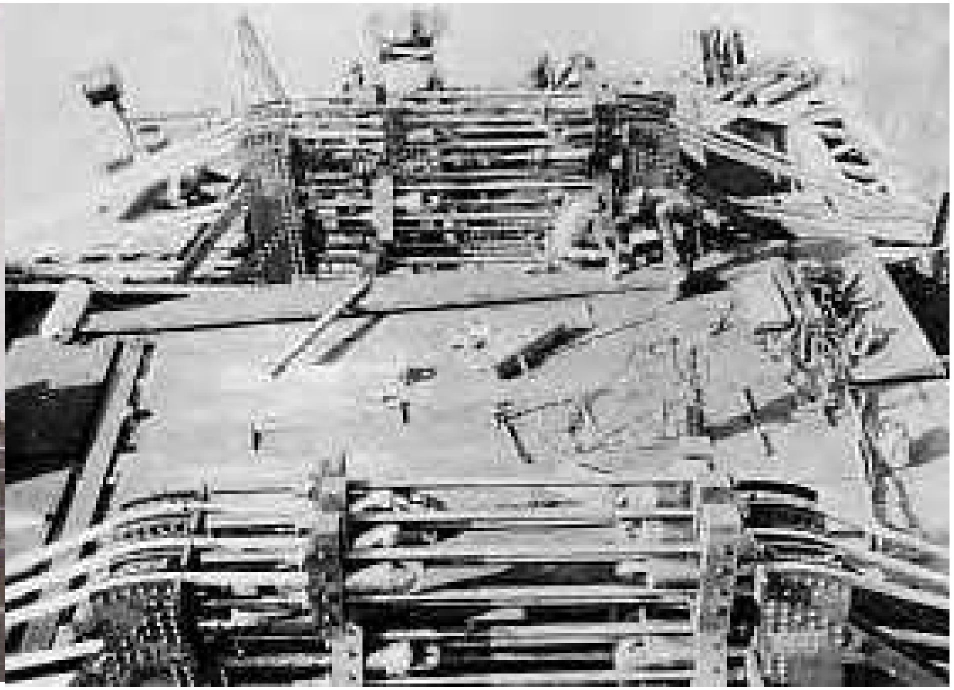
Above: caption: "Laying a set of center span footbridge ropes on the river bed"

"…Hoisting, at two points, a stiff heavy rope, nearly a mile long, fixed at both ends, and submerged on an unseen bottom for more than half its length, becomes a serious matter when it must be rapidly raised to a great height. Investigations had shown that heavy longitudinal stresses would deflect the fixed points of attachment of the hoisting tackles about 70 feet from each tower towards mid-channel, thus pulling the heavily stressed tackles far out of plumb into positions that would be unsafe for the long flat derrick booms already installed on the tower tops. Therefore, the ropes were attached by multiple connection plates to tackles suspended from very sturdy cat-head girders cantilevering a short distance beyond the tower tops. When the ropes had been hoisted high above the surface of the river and the tackles were attached to the connection plates, the cat-head tackles released, and the ropes hoisted the remaining distance and swung into position by the derrick booms…"

John A. Roebling's Sons Co.

Left:: caption: "Three-way connection plate permitting the hoisting tackle to be shifted from cat-head to derrick boom"



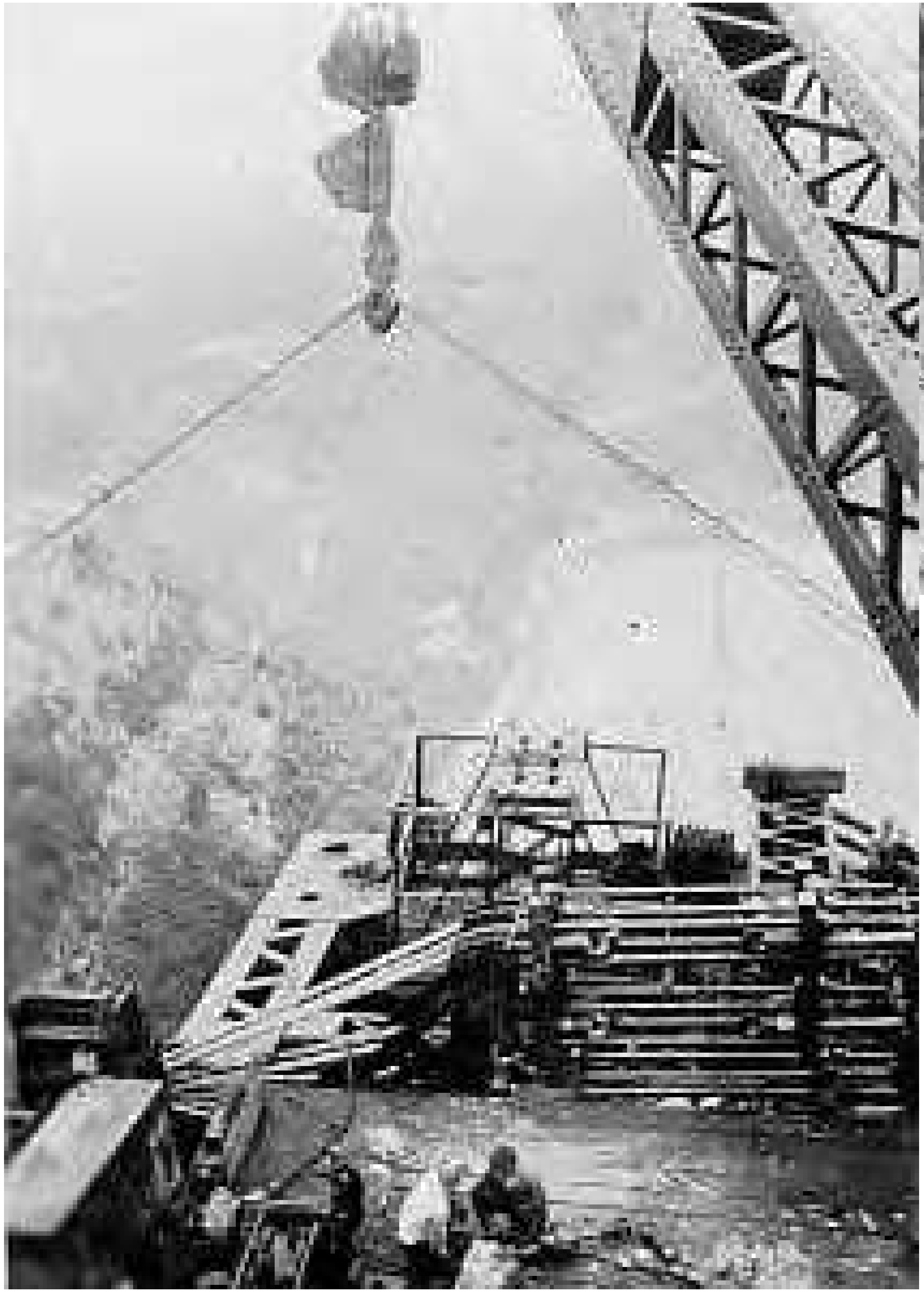


“…The footbridge cable ropes were supported on the tower tops on structural steel frames, the toggles connecting the socketed ends of the center and side span sections replaced by pulling jacks, and adjustments made and followed up by nuts on tension rods that joined the connections after the removal of the pulling jacks. The footbridge, although generally spoken of as a single structure, really functions as two parallel duplicate working platforms 22 feet wide, that reach from tower top to tower top, and from tower tops to adjacent anchorages, one under each pair of cables. The center spans were erected simultaneously by four steel travelers working back and forth from the tower tops. The floor platforms were placed just below the groups of cable ropes in order that the latter should take the place of the specified guard planks, thus eliminating an important area of exposure to the wind…”

John A. Roebling’s Sons Co.

Left: caption: “Footbridge cable ropes in adjustment and supporting frame on tower top. Some sections of rope still connected by hoisting toggles. Other adjusted sections completed by pairs of tension rods.”

Right: caption: “Footbridge rope tower saddles and adjustment equipment”



Above: caption: "Cutting the first completed footbridge rope with lifting beams and clamps"

Left: caption: "Lifting the footbridge rope over the footbridge tower saddle"

"…Eight one-inch Blue Center traction ropes 5,400 feet long were taken across the river in pairs, and spliced to make four endless tramway ropes that were hoisted to the tower tops as were the footbridge cable ropes, reeved over fixed sheaves at the anchorages, and installed on the center lines of the main cables. Each was driven by a 100-h.p. motor at the tower tops. Attached to these traction ropes were trolley carriages traveling on the footbridge cable ropes and carrying large traveler cages for the erection of the center span footbridge…"

John A. Roebling's Sons Co.

Left: caption: "Erecting traveler for center span footbridge. Note working platforms at different levels, floor sections on suspended platform, and safety rails."

Erecting Footbridge Floors

“…Special precautions were taken against fire throughout the building of the bridge. At first thought this may seem rather strange, considering that the structure is composed entirely of concrete, steel and masonry. Wood, however, is used extensively throughout the building process…”

***Wonders of World Engineering,* November 1937**

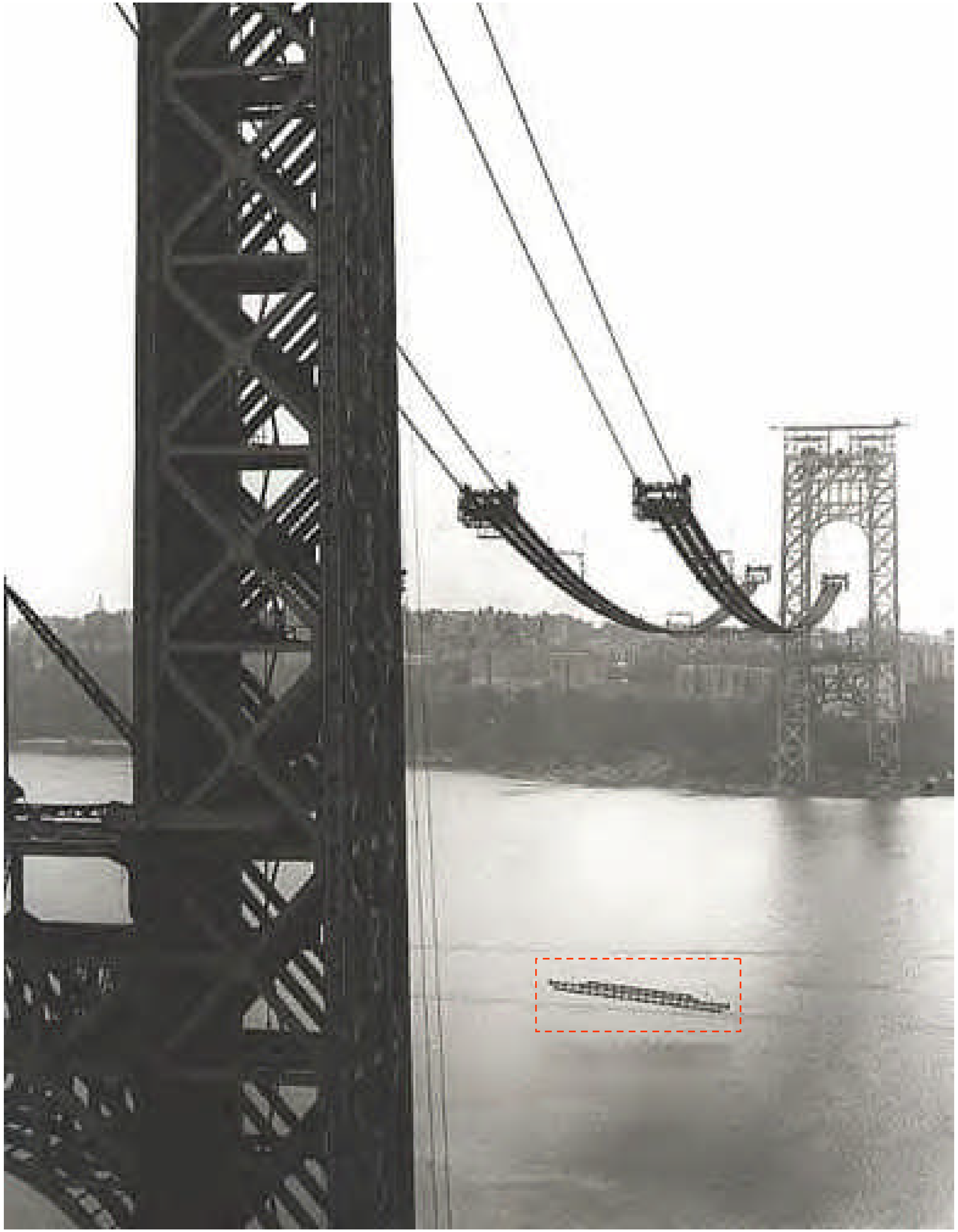
<u>Above</u>: caption: “Assembling the floor sections for the main span footbridge”


“…A temporary working platform was bracketed out from the river side of each tower just below the top, and to it were delivered the assembled 12 x 25-foot standard steel floor panels, covered with wood gratings under the strand positions and with heavy wire mesh under the cable centers. They were loaded in sets of ten on platforms suspended from the travelers, and the latter with their crews were lowered by the tramways from the tower tops to the center of the span, where the erection was commenced…”

John A. Roebling’s Sons Co.

Left: caption: “Footbridge during construction, while the cables were illuminated by flood lights on the tower tops for the protection of aeroplane traffic”

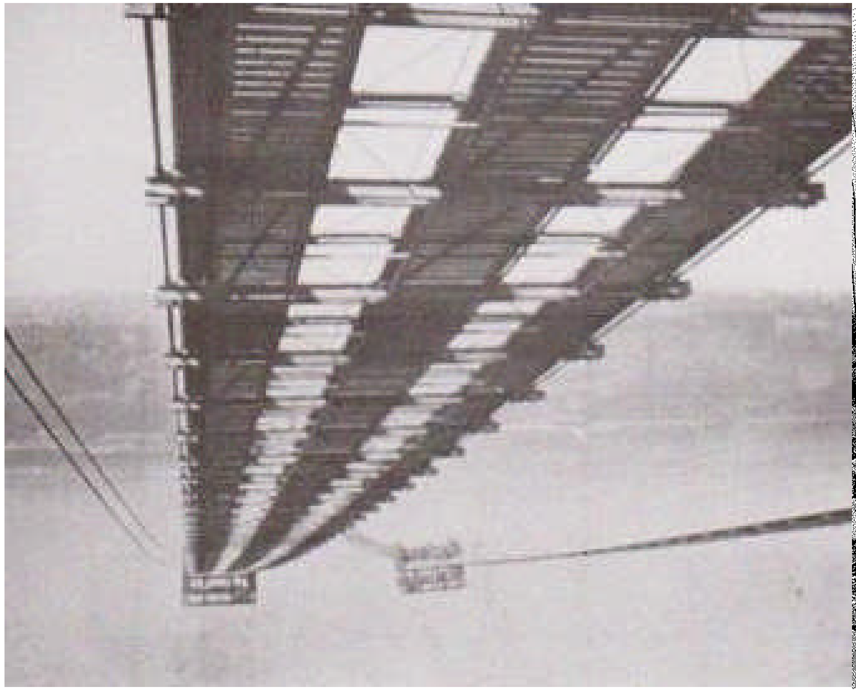
Right: caption: “Four traveling cages simultaneously erecting the center span north and south footbridges towards both tower tops”



"…Great rapidity of erection of the main span footbridge was attained by the installation and simultaneous operation of four erection cages that maintained the construction symmetrical at all times, loading the footbridge cables uniformly from the center to the towers. After the transverse bents supporting the traction tramways were successfully erected, the five 14-ton crossbridges were joisted to place from barges in the river…"

John A. Roebling's Sons Co.

<u>Left:</u> caption: "Erection of the main span footbridge showing four erection cages at work. Also one of the five 14-ton steel crossbridges being hoisted more than 300 feet from the river."

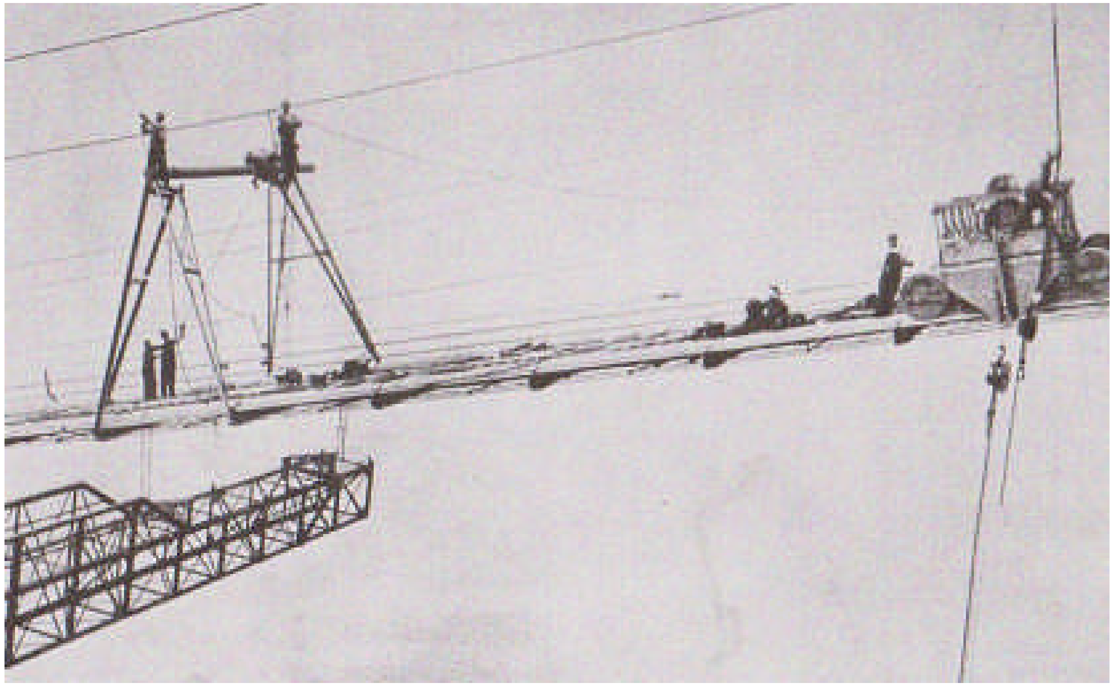


"…The traveling cages for the erection of the center span of the footbridge were equipped with special trolley wheels with laminated wood treads that ran on the groups of footbridge cable ropes without abrading them or in any way impairing their strength and durability for their permanent subsequent service as suspenders for the bridge floor and trusses. The arrangement of footbridge cable ropes above the footbridge floor enabled the erection cages to pass back and forth over the floor after it was erected in position…"

John A. Roebling's Sons Co.

<u>Left</u>: caption: "Details of main span footbridge construction, showing how erection cages could be run out over the semi-completed footbridge"

<u>Right</u>: caption: "Commuting between towers before footbridge erection"



"…The travelers also erected the transverse bents about 200 feet apart for the subsequent support of the spinning wheel traction ropes. Each traveler was equipped with 600 feet of 1-inch Blue Center rope on a drum, and as the erection of the footbridges advanced, these ropes were passed over fixed sheaves on the transverse bents and lowered to the surface of the river, where pairs of them were made fast to opposite ends of the five 14-ton crossbridges. The travelers were then hauled towards the towers and thus raised the crossbridges, which were hoisted and bolted in position in less than an hour each…"

John A. Roebling's Sons Co.

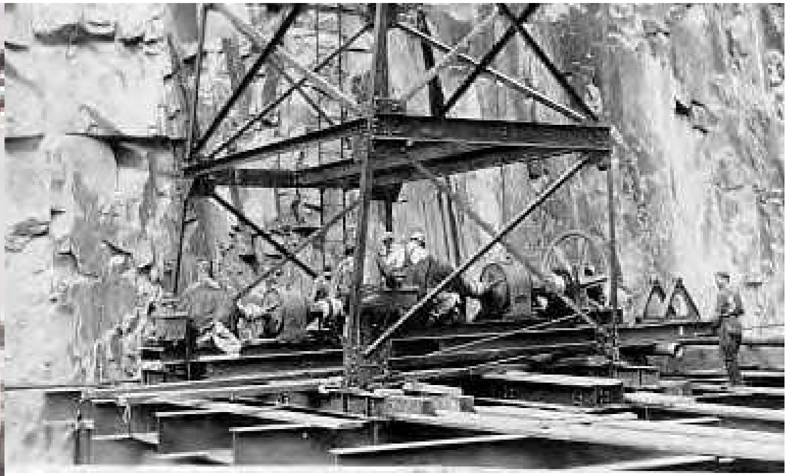
Above: caption: "Traveler carriage (with erection cage detached) hoisting one of the crossbridges from barge"

Side Span Floor Erection

"…On account of the steepness of the side span cables, their footbridges differed from those of the center span, and the floor panels were each made with three stepped sections 30-feet long parallel with the bridge axis, supported by 11-inch pipe floor beams 26-feet long and 30-feet apart, lying under and bolted to the lower cable ropes and suspended from the main groups of cable ropes. The steel longitudinal floor trusses have hook plates engaging the floor beams at the upper ends and pin-connected to the plates at the lower ends of the adjacent sections…"

John A. Roebling's Sons Co.

Left: caption: "Erecting floor beams for south footbridge of New Jersey side span"

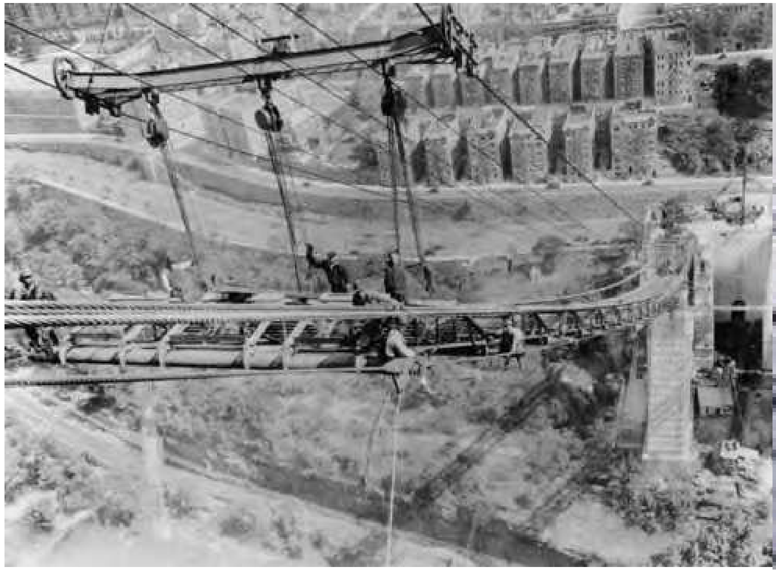


"…Sets of four to six floor beams, connected together by 30-foot tag lines, were loosely clamped over the lower footbridge cables, hauled up from the anchorage toward the tower tops, adjusted to accurate position by turnbuckles in the tag lines, and tightly clamped to the lower cable ropes…"

John A. Roebling's Sons Co.

Above: caption: "Tramway drive machinery"

Left: caption: "Side span footbridge. Floor beams attached to lower cable ropes. Note working platform in foreground traveling on overhead temporary tramway. Also, note upper group of footbridge cable ropes."

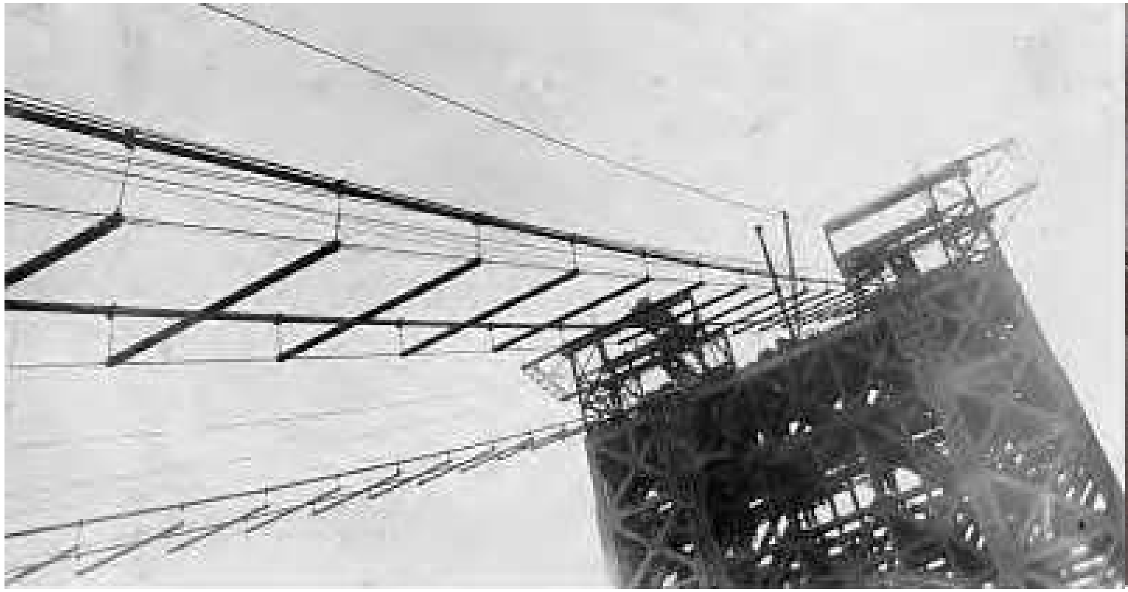


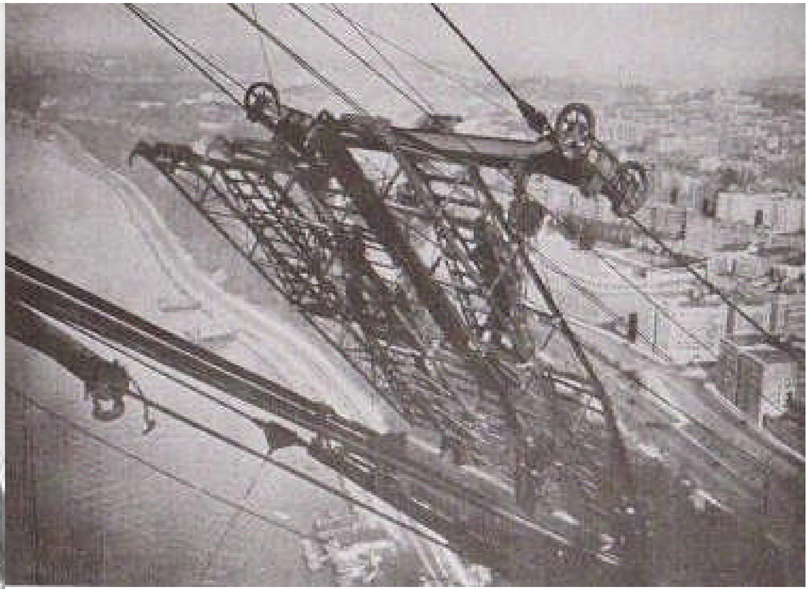
"…Over each footbridge there were installed two 1.75-inch Blue Center side span tramway cables on which traveled the wheels supporting a movable carriage the full width of the footbridge. Each of these four carriages was equipped with a chain hoist over the center line of each of the three floor sections…"

John A. Roebling's Sons Co.

Left: caption: "Assembling side span floor sections from platform suspended from 4-wheel carriage on tramway. Note hook plate connections to floor beam."

Right: caption: "Footbridge cables and pipes installation"



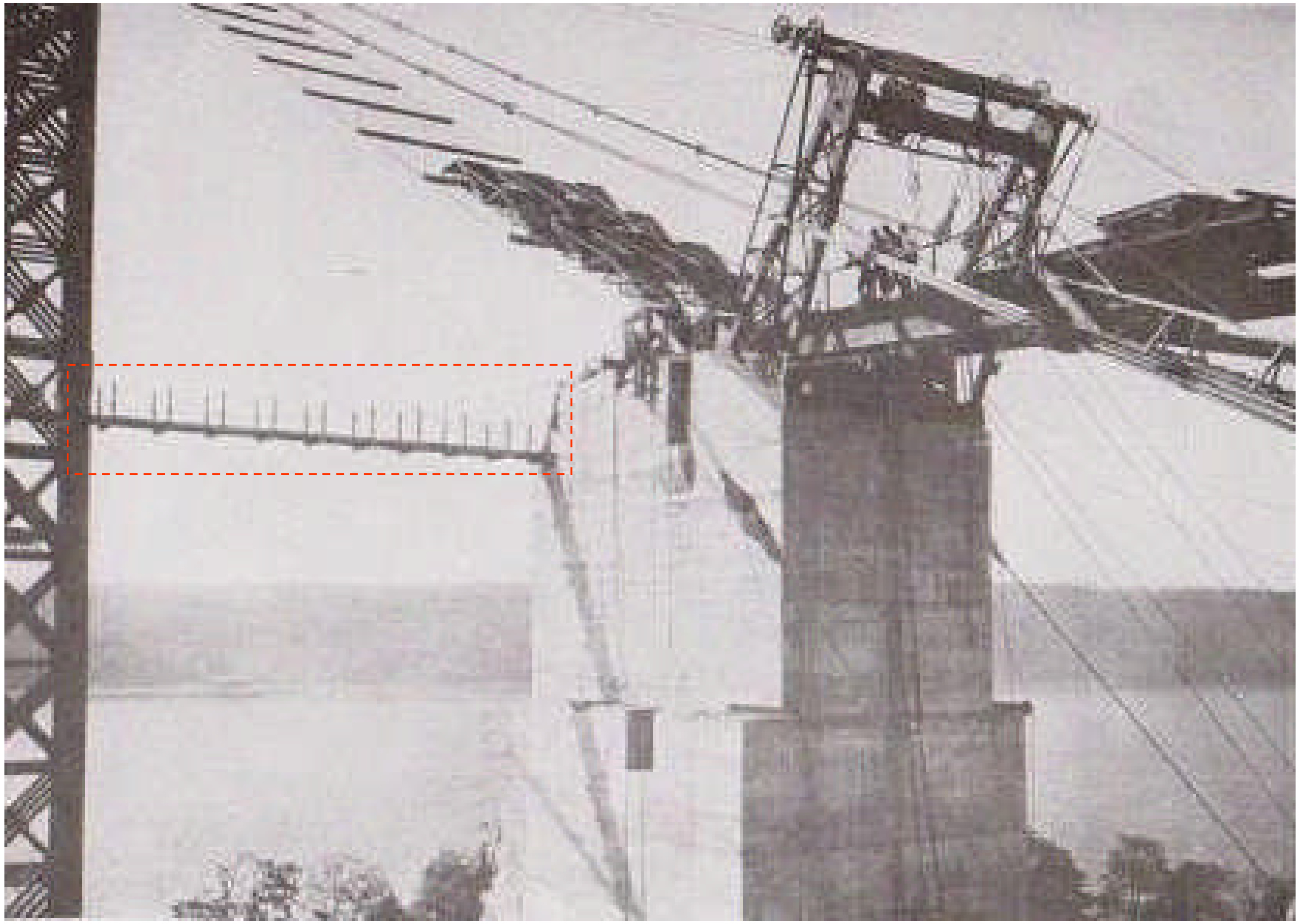


"…The three sections of one footbridge panel, connected together by their wooden floor platforms, were delivered at the anchorages to the carriages which were hauled up towards the tower tops by 0.75-inch Blue Center traction lines operated by electric hoists on the anchorages. Three men riding each carriage operated the chain hoists. The end hooks were lowered to engagement with the proper floor beams, and a gang following over the assembled sections made the pin connections at the rear ends…"

John A. Roebling's Sons Co.

Left: caption: "Side span foot-bridge pipes in place"

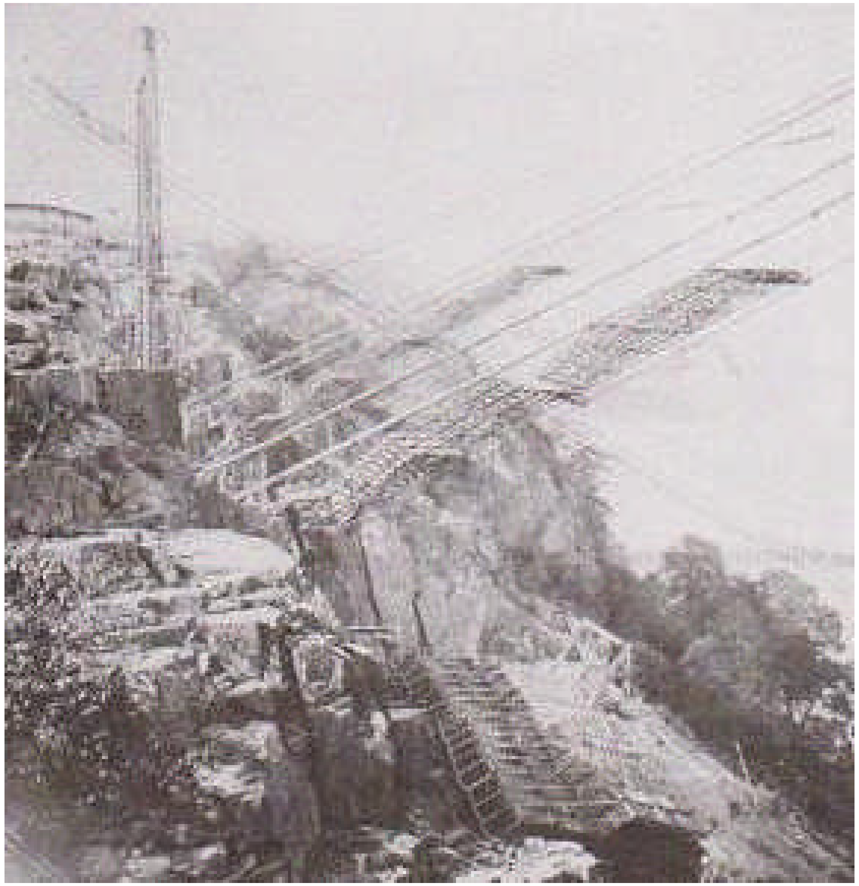
Right: caption: "Erecting last side span footbridge sections adjacent to New York tower by means of cableway"



“…The floor beams, trusses and platforms for the side spans of the foot bridge, were assembled on pairs of low level ropes, and the floor beams are suspended from the groups of footbridge cable ropes above. The trusses and floors were erected from light platforms carried under 4-wheel carriages running on temporary ropes above the footbridge cables…”

John A. Roebling’s Sons Co.

Above: caption: “Commencement of erection of north footbridge sections New York side span, showing floor beams suspended from cable rope groups. Note 125-foot span suspension service bridge with cables anchored to the concrete.”



"…As the erection of the side spans of the footbridge progressed from the anchorages to the tower tops, the work was always accessible, and was advantageously performed form the assembled portions and from the light travelers that handled the floor sections. The continuous working platforms thus provided just below the working points were most advantageous on the very steep inclines, and were an important factor of safety. No casualties occurred on this dangerous part of the work…"

John A. Roebling's Sons Co.

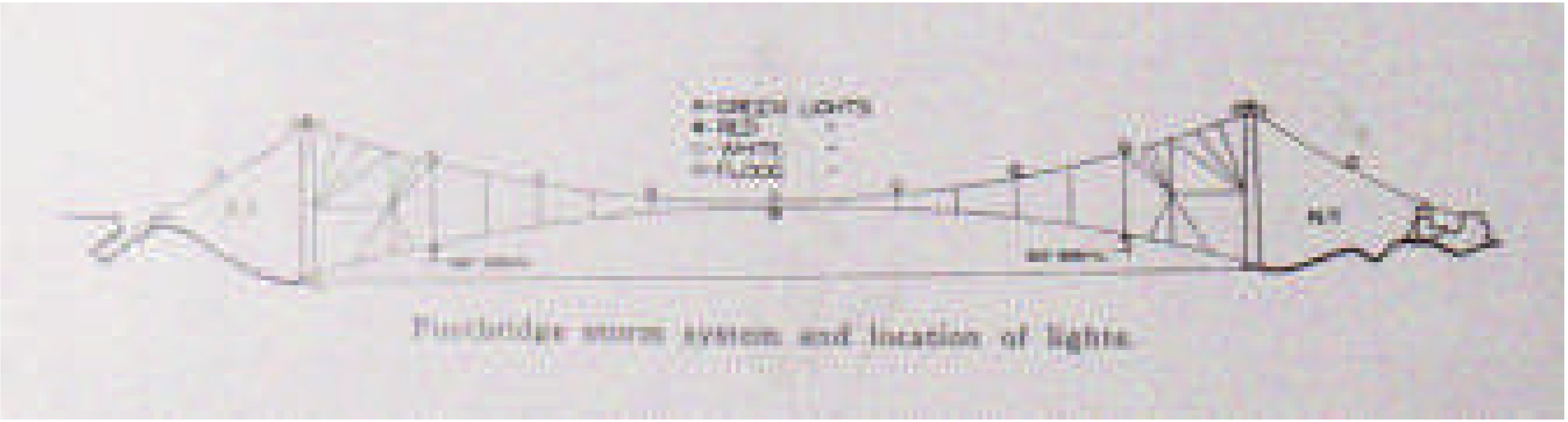
<u>Left</u>: caption: "Partly erected footbridge for the New Jersey side span. Note storage of floor sections in foreground."


"…Less than eight days were required for the erection, without accident, of the two footbridges. During the footbridge construction the company's launch cruised continually under the bridges to immediately render aid should it be needed…"

John A. Roebling's Sons Co.

<u>Left</u>: caption: "Completed footbridge from New York shore. Note Roebling construction towers on main towers, and tramway bents on footbridges."

<u>Right</u>: caption: "Aerial view of towers, anchorages & footbridges"

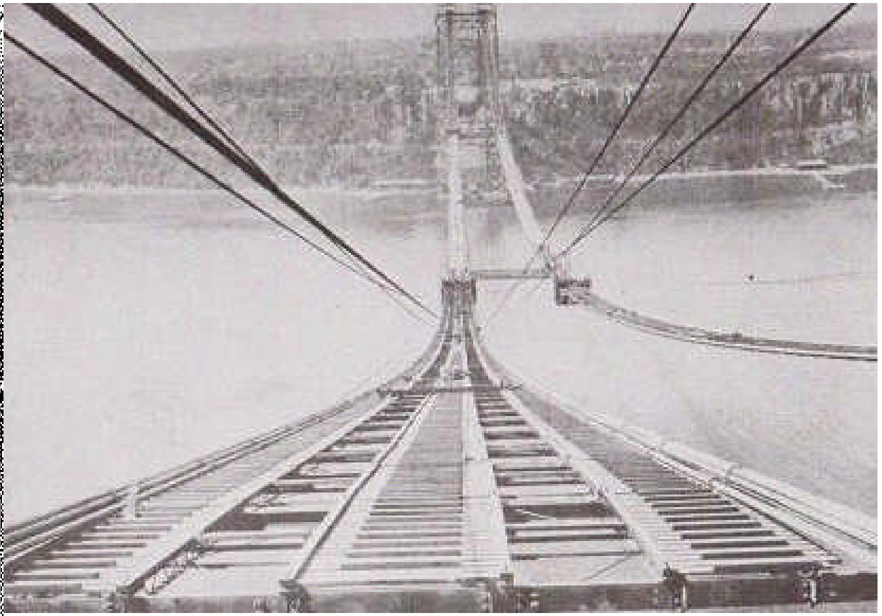


Footbridge storm system and location of lights.

“…The footbridge storm system cables were assembled immediately below, and supported from the footbridges, and their connections were made from the footbridge erection travelers. The booms and ropes were lowered to position. The counterweights in the towers were attached, and the adjustments were made by men in bo’sn’s chairs. The system reduces vertical and horizontal displacements from a 60-mile wind, to about 1 foot and 3 feet, respectively. It contains about 75,000 feet of 0.63, 1.75, and 2-inch rope. Besides providing an ample illumination with 200-watt lamps with domes, shades and reflectors for construction operations, the Roebling Co., maintains on the footbridge a complete system of all night traffic signal lights complying with United States and navigation requirements for aeroplane and marine traffic…”

John A. Roebling’s Sons Co.

Above: caption: “Footbridge storm system and location of lights”



Above: caption: “Center span footbridge before placing wire mesh under cables. Note cable ropes acting as guard planks.”

Left: caption: “North foot-bridge ready for cable-spinning operations”

The Spinning Job

“…When enormous cables for bridges are made, twisted wire rope cannot be used. Strands laid parallel to each other and ‘spun’ together by encircling wires are employed instead. The reason is that a rope made of strands containing fifty wires is only about eighty-five percent as strong as fifty wires laid parallel. When wire is crossed in twisting, the separate filaments rub against each other and thus lower the breaking point of the cable…”

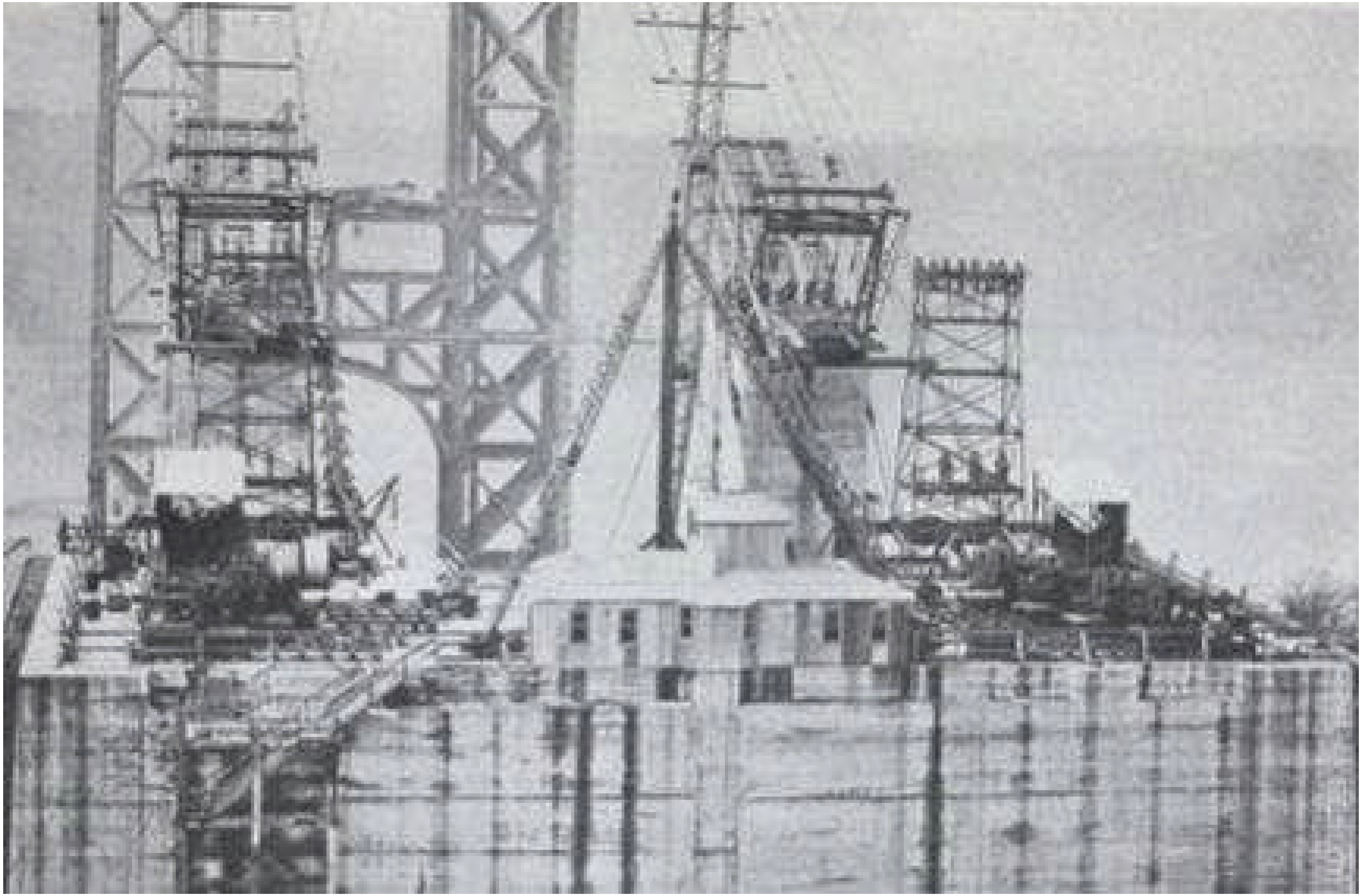
***Popular Science*, March 1930**

"…With the footbridges in place, the spinning job began. To spin a single cable, which consists of sixty-one strands, each made of 434 wires about the thickness of a lead pencil, a traveling wheel makes 26,474 trips across the river. It unrolls the wire from a reel fixed on one of the anchorages, and lays each successive wire next to the last. When a spool of wire gives out, wire from a new spool is spliced on. Completing a strand of sixty-one wires, the next wire is spliced on in the same way. Thus the wire in a main cable will consist of a single unbroken filament. When finished, the four main cables of the bridge will contain 107,000 miles of wire, enough to wrap four times around the earth at the equator. A zinc coat protects the wire from the weather. When all the wires of a main cable have been spun, a traveling machine crosses the footbridge, squeezing them together under enormous pressure into a compact three-foot circular cable. Thus the cables will support a road in the air, 200 feet above high water. They will last as long as the bridge, which has been designed as nearly permanent as engineers know how to make it, and they afford another striking example of the power of cables put to work for civilization…"

***Popular Science*, March 1930**

“…The traction rope is driven at a speed of 600 to 700 feet per minute by a power wheel operated by a 100-h.p. motor at the New Jersey end, and at one end is reeved in multiple around pairs of movable counter-weighted sheaves that take up slack, and maintain uniform tension. The previous use of the same rope for hauling the footbridge erecting travelers, very effectively produced complete initial stretch and eliminated elongations in the wire spinning operations that would have caused great delay and loss. A wire splicing press is installed at each end of each pair of cables, four in all. Each press has a circular yoke in which, at intervals of 120 degrees, are set three radial hydraulic cylinders operated at a pressure of 5,000 pounds per square inch to squeeze the nipple of their balanced dies with a force of about 100 tons, which causes the steel in the nipple to flow and produce a cold pressed joint that is as strong as the body of the wire…”

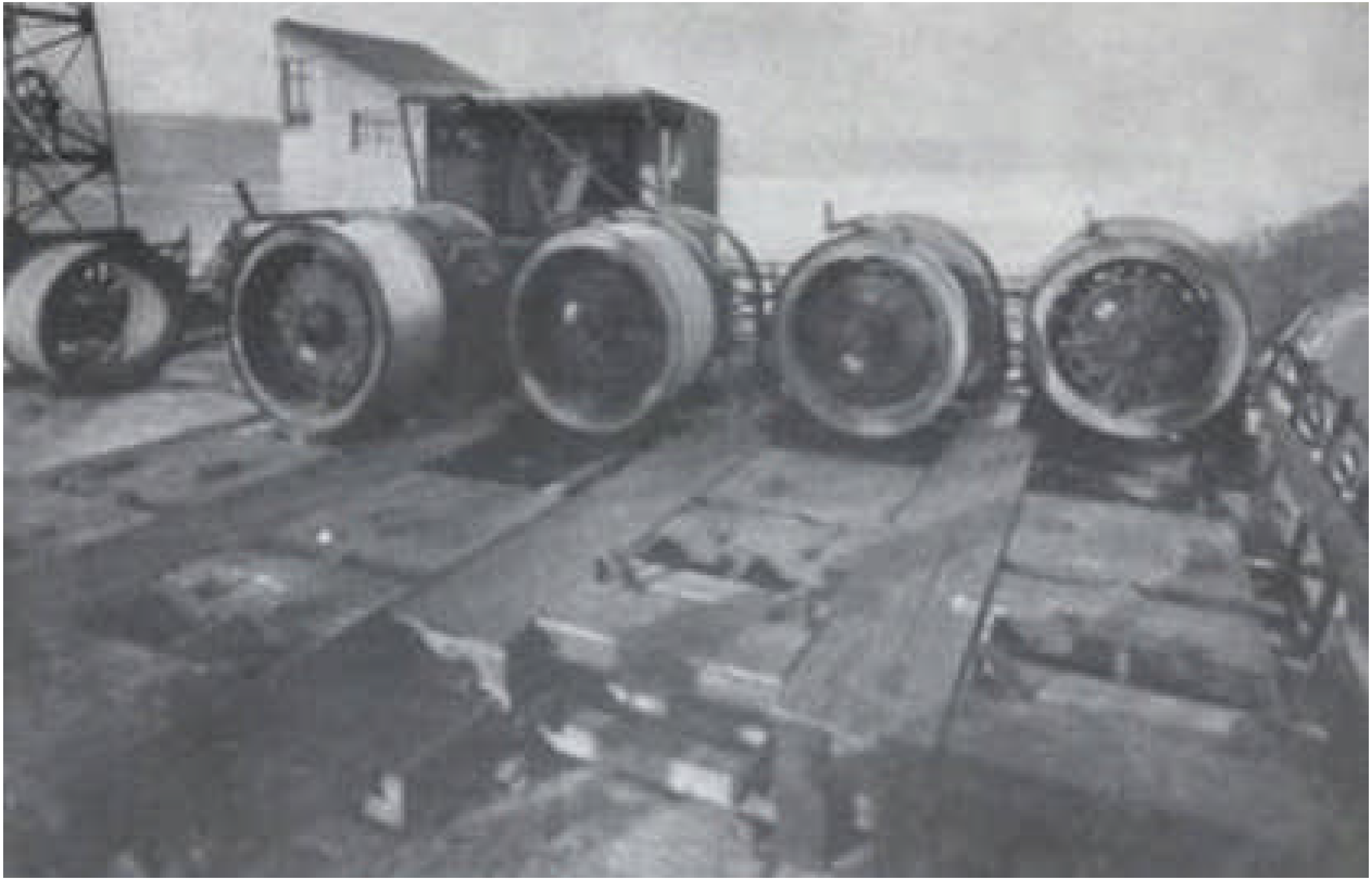
John A. Roebling’s Sons Co.



Above: caption: “Cable spinning equipment on New York anchor block. Traveling cages erecting north and south side span footbridges simultaneously.”

“…At each end of each cable there are installed two unreeling machines, sixteen in all. Each machine has a horizontal shaft with six adjustable radial arms, with their extremities fitted to engage the cylindrical inner surface of the wire reel that is moved over them parallel to the shaft; then the arms are extended to bear against the inner surface of the reel, thereby lifting it clear, and supporting it on the shaft. Each group of four unreeling machines is operated by one 100-h.p. electric motor. Watching the floating counterweight that maintains uniform tension in the wire, the machine operator regulates the speed of the unreeling machine to conform to the tramway speed…”

John A. Roebling’s Sons Co.



<u>Above</u>: caption: “Reels of cable wire mounted on unreeling machines at New York anchorage. Low level cats for shifting full and empty reels in foreground.”

“…In the plane of each main cable, and about twelve feet above its saddle, there is installed an aerial cable spinning tramway, with one-inch Blue Center endless traction rope reaching from anchor pit to anchor pit, that is supported at the tower and anchorage saddles where the curves change, and at intermediate points, on sets of special sheaves that permit the free passage at high speed, of the two attached wheel carriages, and prevent vertical and horizontal displacement of the very long traction rope that has sufficient tension to engage the overhead idler sheaves…”

John A. Roebling’s Sons Co.

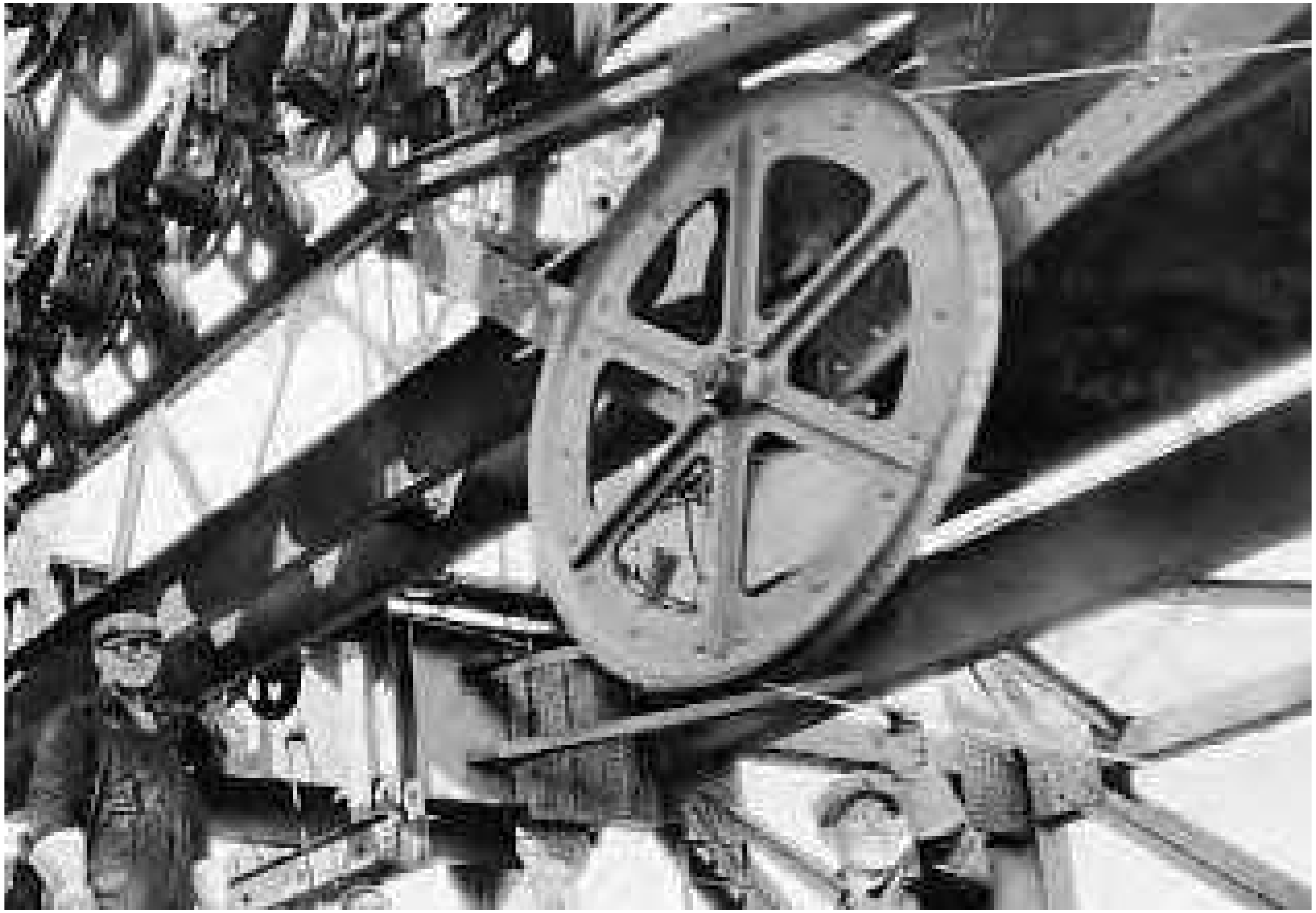
<u>Above</u>: caption: “Strand arms connected to anchorage eyebars. Adjusting strands at New York anchorage.”

Left: *Concrete and Cable* (1927) - etching by *Otto August Kuhler*

“…Attached near opposite ends of opposite parts of the traction rope are the two trussed carriages, each equipped with a spinning wheel four feet in diameter, that carries a bight of bridge wire on each trip back and forth across the river…”

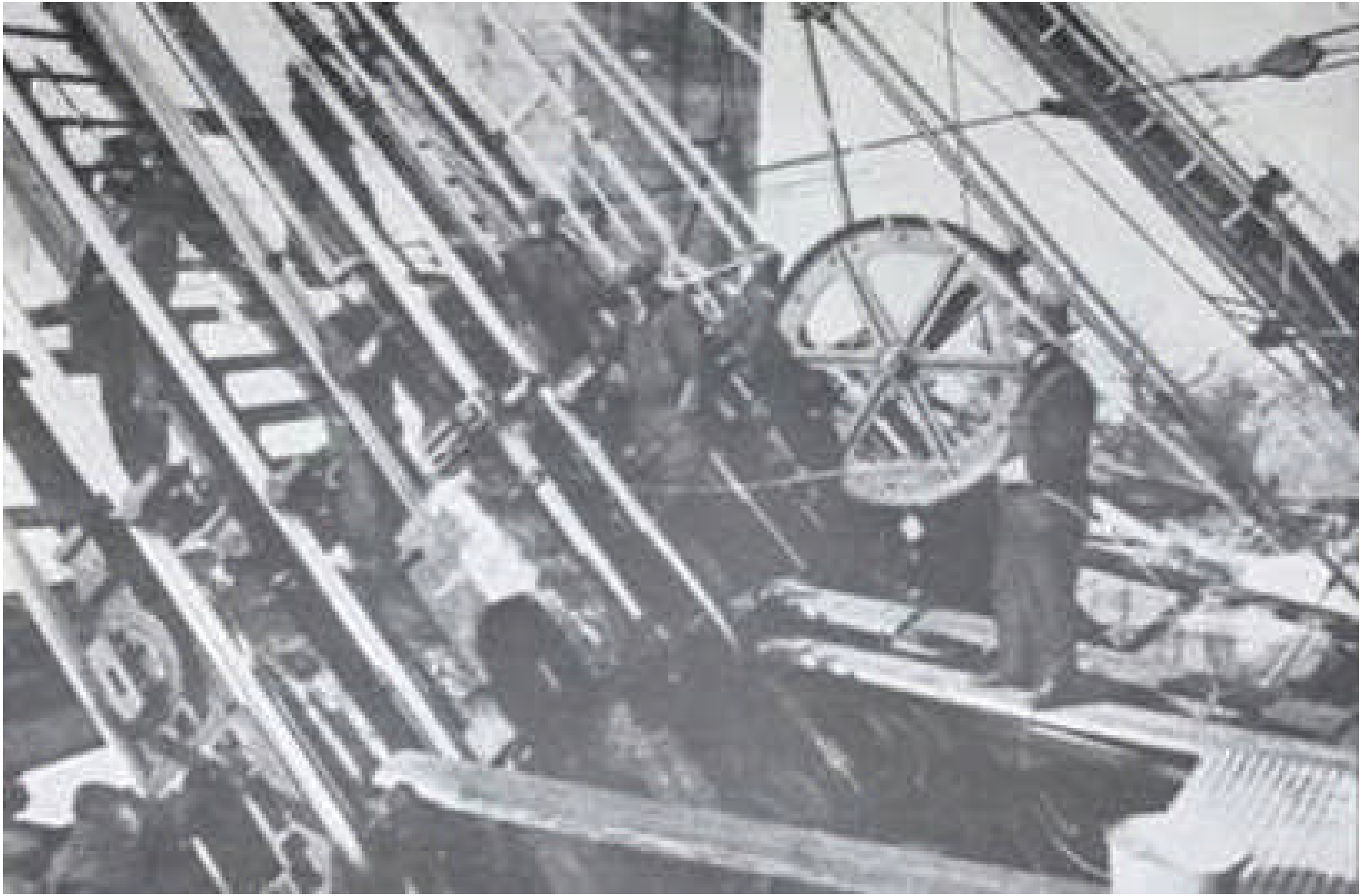
John A. Roebling’s Sons Co.

Left: caption: “Spinning wheel laying wires in uncompleted strand of center span. Seized, finished strands underneath.”



“…A bight of the slack wire adjacent to the shoe is engaged with the spinning wheel, and in about eight minutes is hauled across the river to the opposite anchorage, removed from the wheel and placed over the strand shoe there. The slack is pulled back across the river and its bight is picked up by the same spinning wheel and carried to the opposite strand shoe as before. Each and every one of the 434 parallel parts of a strand is an undivided portion of the same endless wire about 434 miles long, from many reels successively placed in the same unreeling machine; the end of each reel being field spliced to the beginning of the next reel. One spinning wheel is mounted on each part of the endless tramway rope that is reversed as soon as the wheels complete their trips from anchorage to anchorage, both wheels carrying wire simultaneously across the river in opposite directions for different strands of the same cable. Each spinning wheel lays out two miles of wire on each trip across the river, and it now takes about nine days to spin one strand, all spinning operations being duplicated at both anchorages. All the wires of every strand in the four cables are adjusted to exactly parallel a guide wire of the length and sag required for that strand. Each guide wire, identified by a copper wash, is of the same material, diameter and weight as a cable wire, and is about 5,199 feet long…”

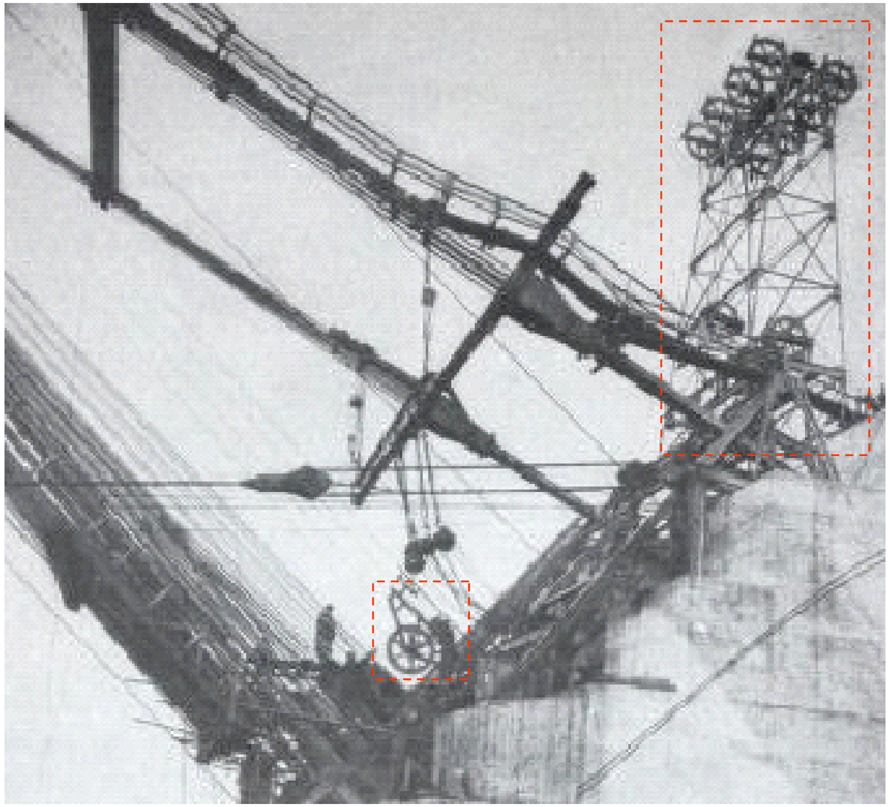
John A. Roebling’s Sons Co.



<u>Above</u>: caption: “Removing wire loop from wheel momentarily stopped for reversal at anchorage. Note permanent strand shoe and strand connected to strand arm in spinning position at lower left corner.”

“…At the end of each one-mile trip in either direction between the anchorages, the tramway is stopped, and the bights of wire are removed from its two spinning wheels on opposite sides of the river, New bights of wire are put on the wheels, and the tramway is reversed to complete the round trips of its spinning wheels that are always traveling in opposite directions…”

John A. Roebling’s Sons Co.



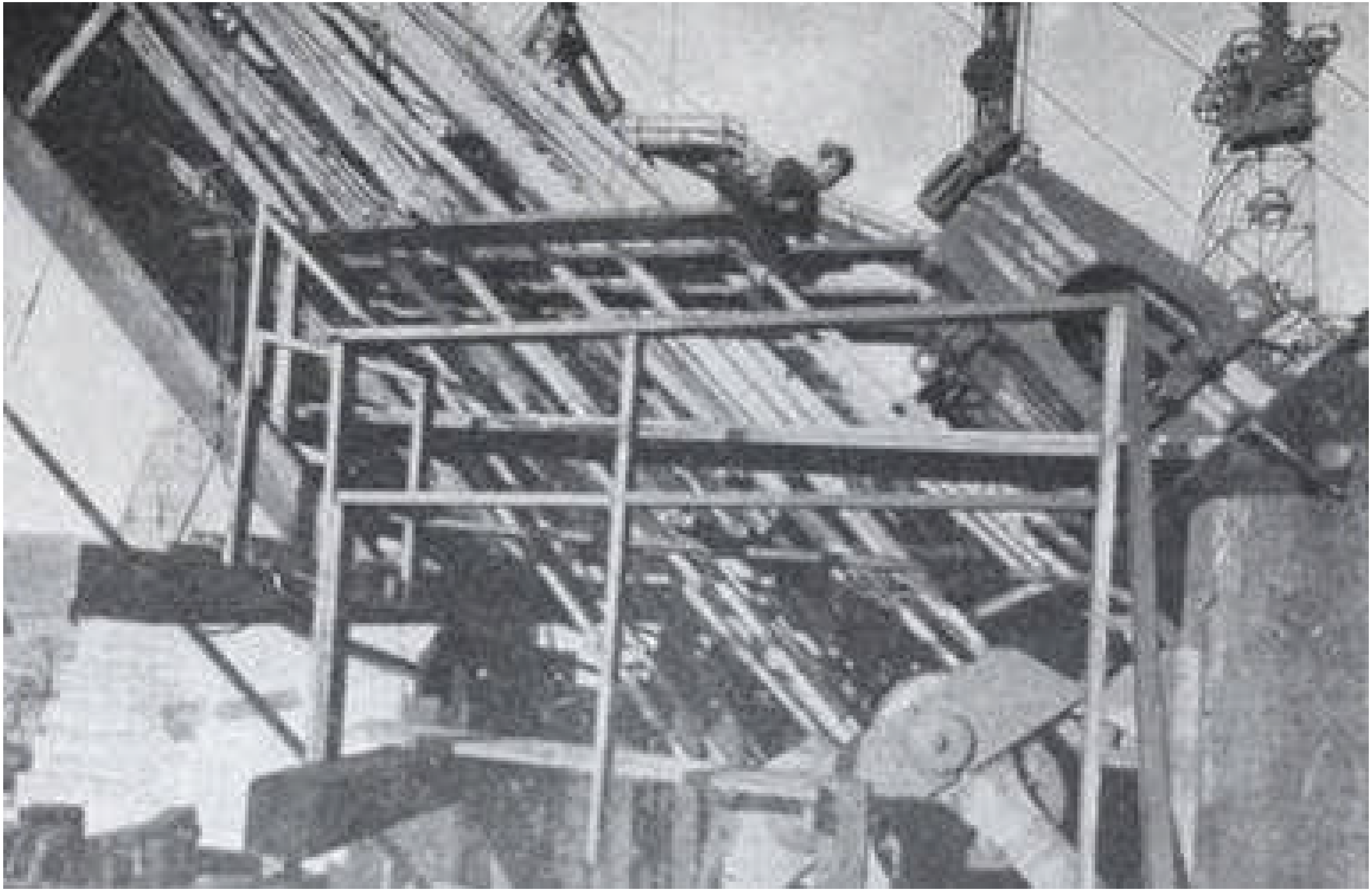
"…Stopping the tramway, shifting the bights of wire off and on both spinning wheels simultaneously, and starting the tramway in reversed direction, normally takes only a few seconds…"

John A. Roebling's Sons Co.

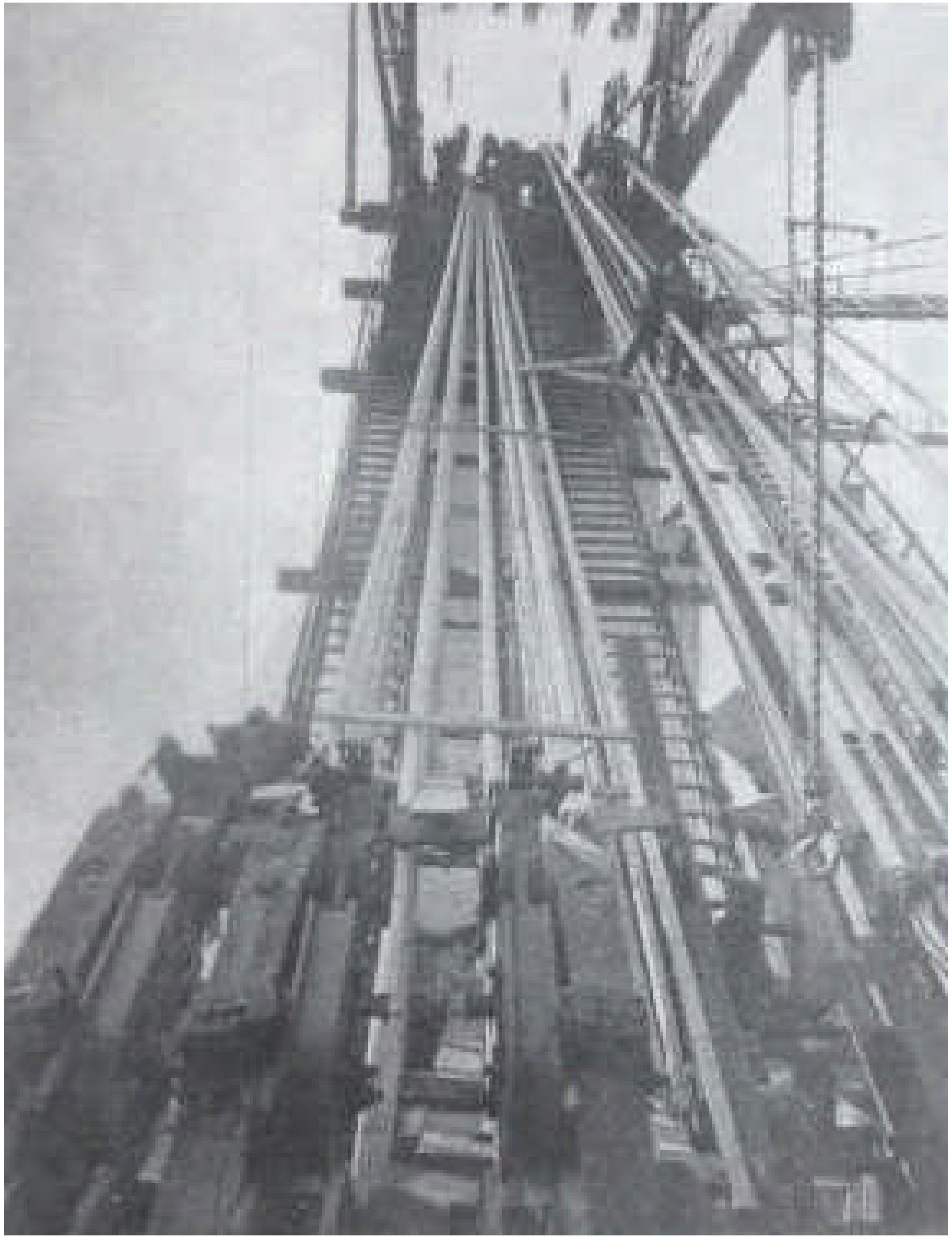
Left: caption: "The end of a tramway trip: shifting bights of wire at the spinning wheel in center of lower part of picture. Wire tension tower at right."

“…At each end of each strand, the parallel parts of its wire are separated into two equal groups that together form bights of the continuous wire and engage the strand shoe. The wires of each group form semi-strands that converge at a small angle, and where they intersect are seized together to form a single cylinder 4 ½ inches in diameter. These 4 ½-inch cylinders converge and merge into the 36-inch cylinder of the compacted cable…”

John A. Roebling’s Sons Co.



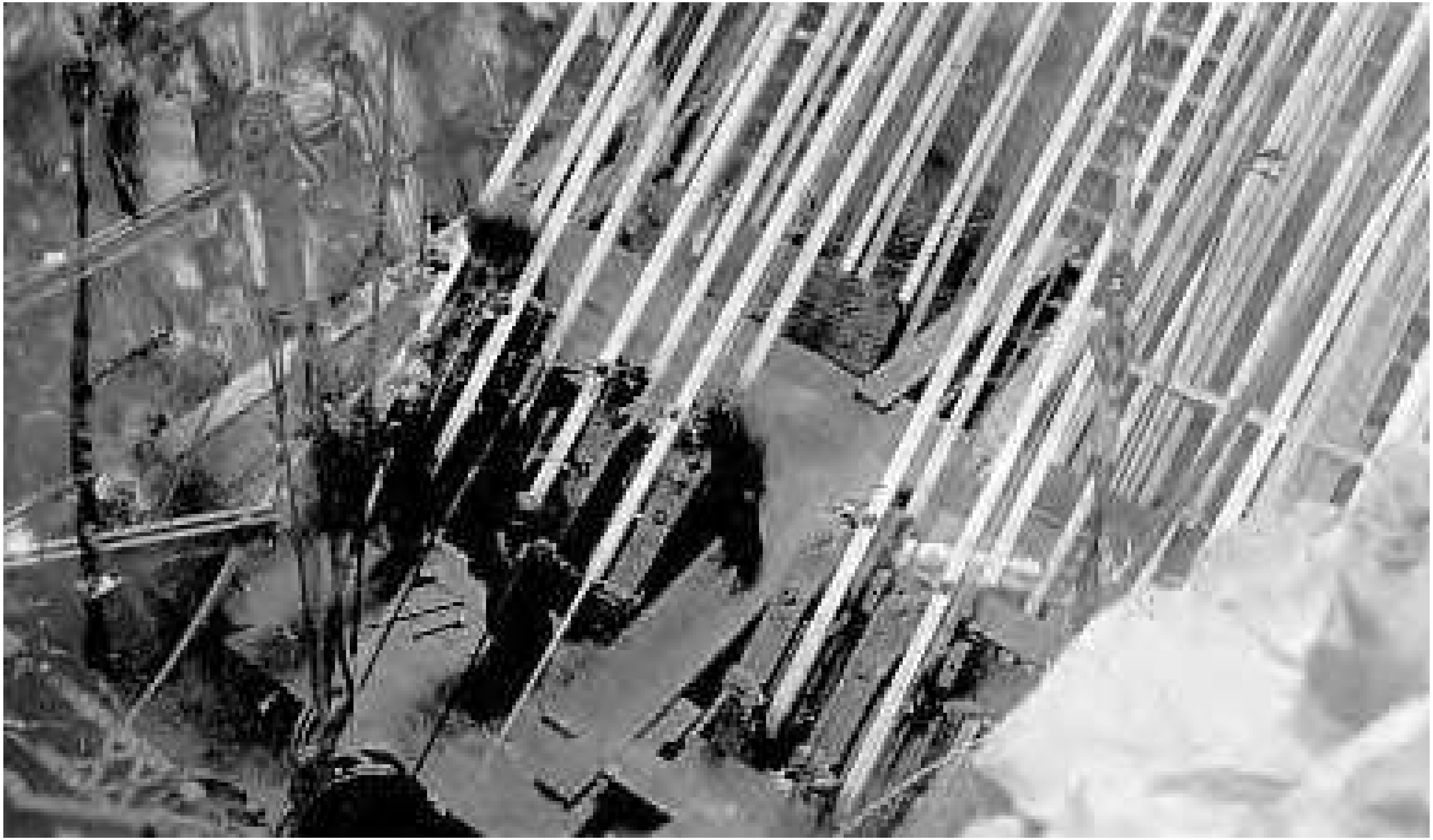
Above: caption: "Lower tiers of strands connected to eyebars in New York anchorage, and working platforms prepared for spinning higher and higher tiers of strands"



"…After all the 434 wires of each strand are spun, the two divergent parts of the strand between the anchorage saddle and the strand shoe are separately seized before the strand shoe is transferred from the strand arm to its eyebar connection…"

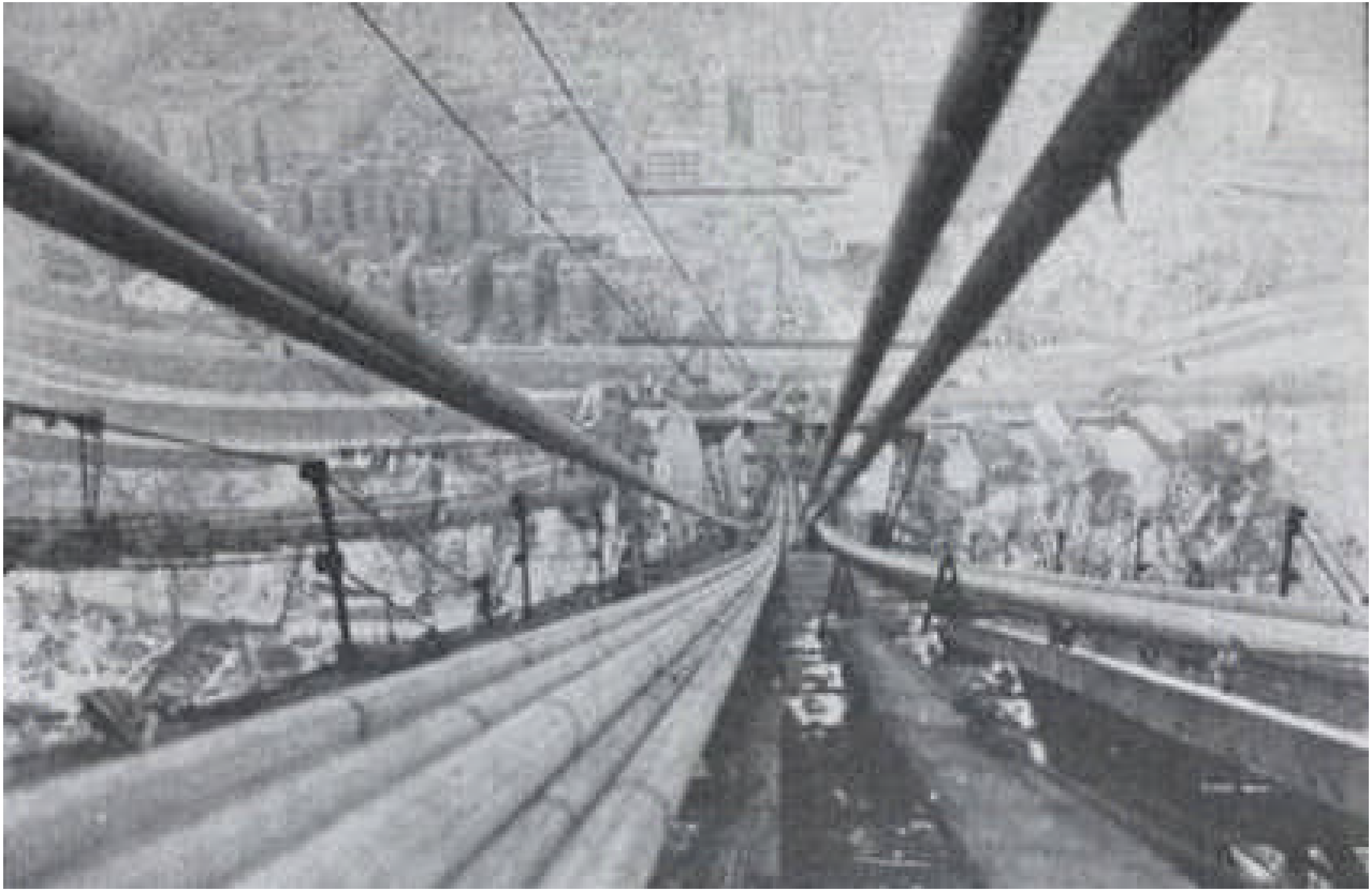
John A. Roebling's Sons Co.

Left: caption: "Completing the construction of the strands after the spinning is finished"



“…The profile of the footbridge was very carefully computed and adjusted so that it is very closely parallel to that of the cable, and is near enough to the latter to permit the men to work efficiently on the upper strands, and yet far enough from it to be free from contact with the lowest strands, thus eliminating the obstructions, uncertainties, changed stresses, delays, and dangers that would be caused by the contact of the cable strands with the footbridge…”

John A. Roebling’s Sons Co.



<u>Above</u>: caption: “Four strands completed and ready for adjustment with those already positioned in cable B”

"…The schedule calls for operations to be continuously maintained, in each working shift, in simultaneously spinning two strands for each of three cables, and adjusting two completed strands for the fourth cable. These balanced operations are in regular succession without delay, interference, or lost time, and are carried on from a foot walk between each pair of cables, and from one on each outer side of each pair, six walks in all, besides the alternating spaces under the cables which are covered with wire netting instead of the wooden gratings on which the men walk and work…"

John A. Roebling's Sons Co.

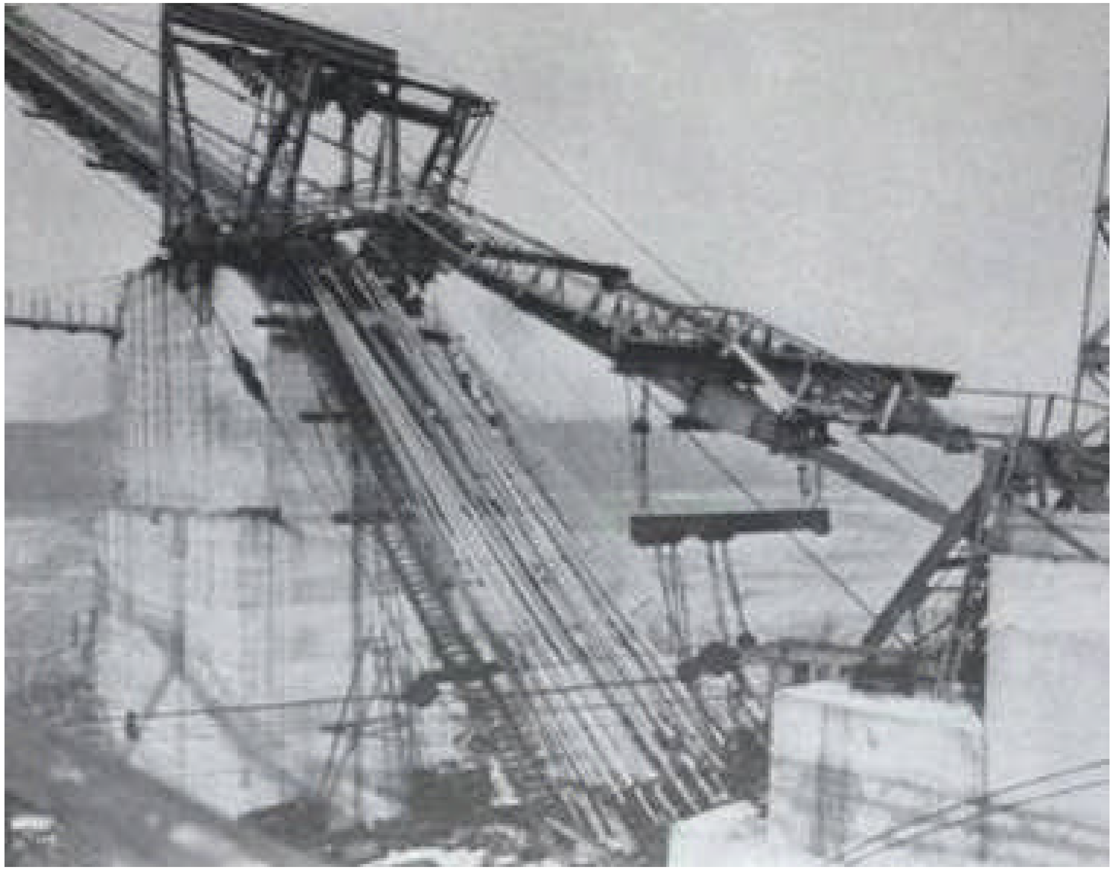
<u>Above</u>: caption: "Completed and incomplete strands on south center span footbridge"

Strand Adjustment and Attachment

"…The deflection of the side span strand from the center of its chord is measured by instrument readings as adjustments are made by the pulling jack on the basis of 1-inch jacking for 8-inches sag. Prior to the adjustment of the side span the center span of the strand is adjusted and verified by level readings on its center point. As soon as the center span adjustment is completed the second side span is adjusted like the first side span…"

John A. Roebling's Sons Co.

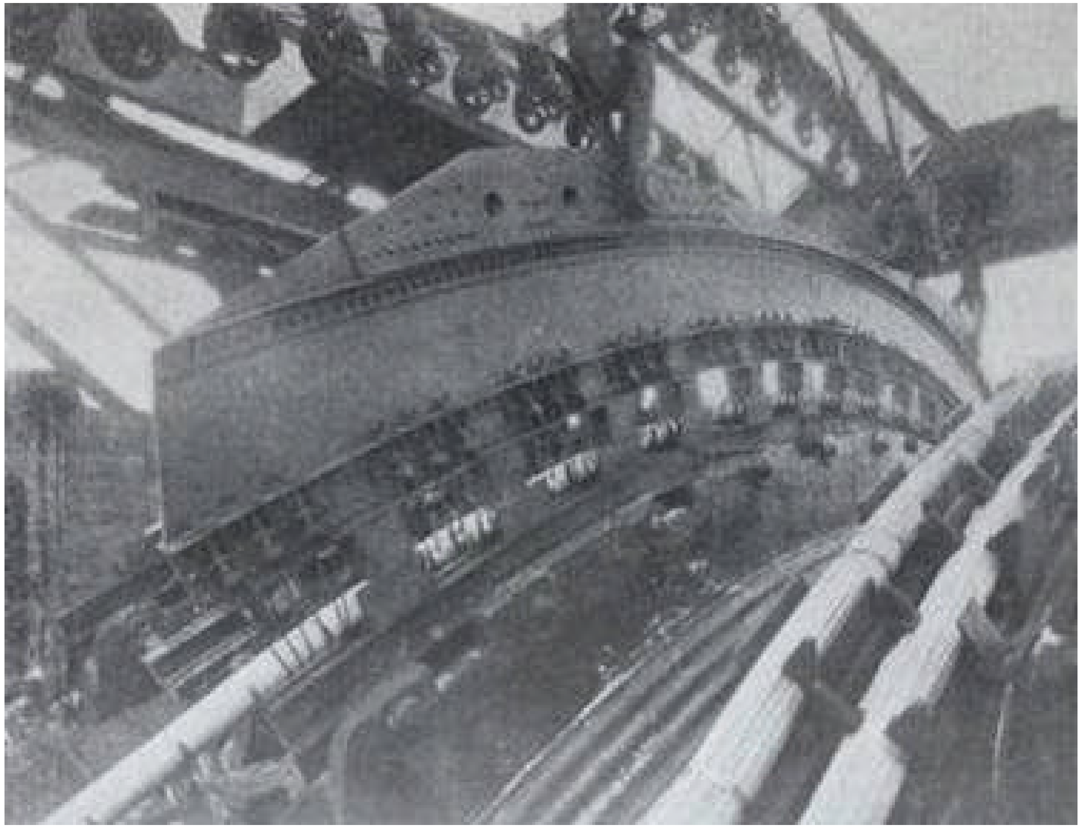
<u>Left</u>: caption: "General view of New Jersey side span footbridge, showing eight completed strands in each of the south main cables. Note transverse bent with tramway ropes and their supporting sheaves."



"…Special provisions are necessary at the anchorage for handling the heavy strand adjustment equipment, and to provide access between points at different elevations where various operations are in progress. Tackles are supported by a plate girder that is suspended from the footbridge cables, and transverse I-beams are clamped across the footbridge cables. Curved girders suspended from a transverse bent on the anchorage saddle blocks, carry the sets of special sheaves supporting the traction ropes of the cable spinning tramways…"

John A. Roebling's Sons Co.

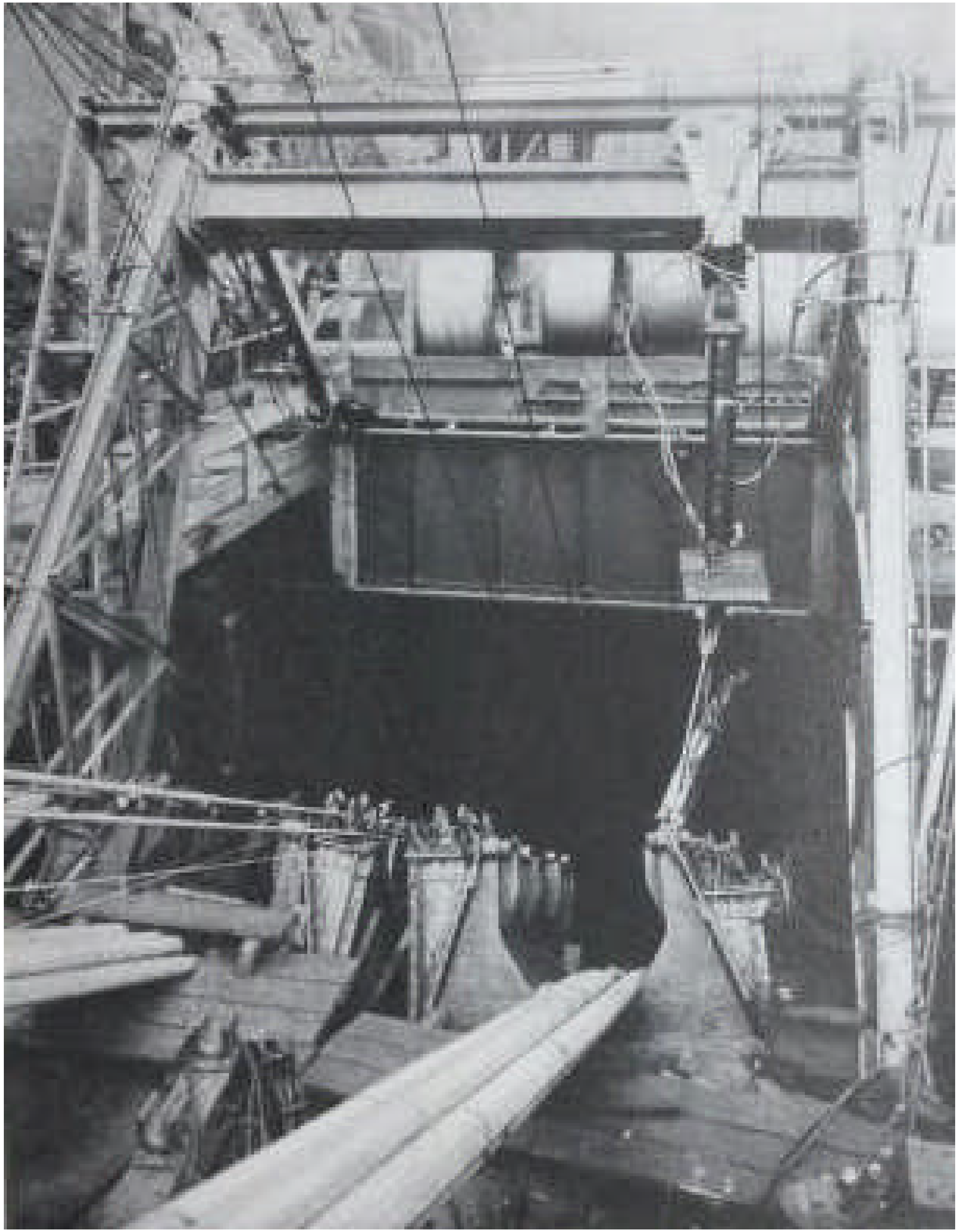
Above: caption: "Cable wire spinning and strand adjustment equipment on north side of New York anchorage"



"…All the wires in a strand are seized together at 5-foot intervals. At the main and anchorage saddles grommets made of 3/8-inch wire rope are placed under the strand and their loops are engaged with bolts in a curved lifting beam above the strand. The grommet bolts are screwed up to lift the strand clear of its forming saddle, and the strand is shifted about 2 ½ feet laterally to the center line of its saddle groove by traversing the crane hoist

John A. Roebling's Sons Co.

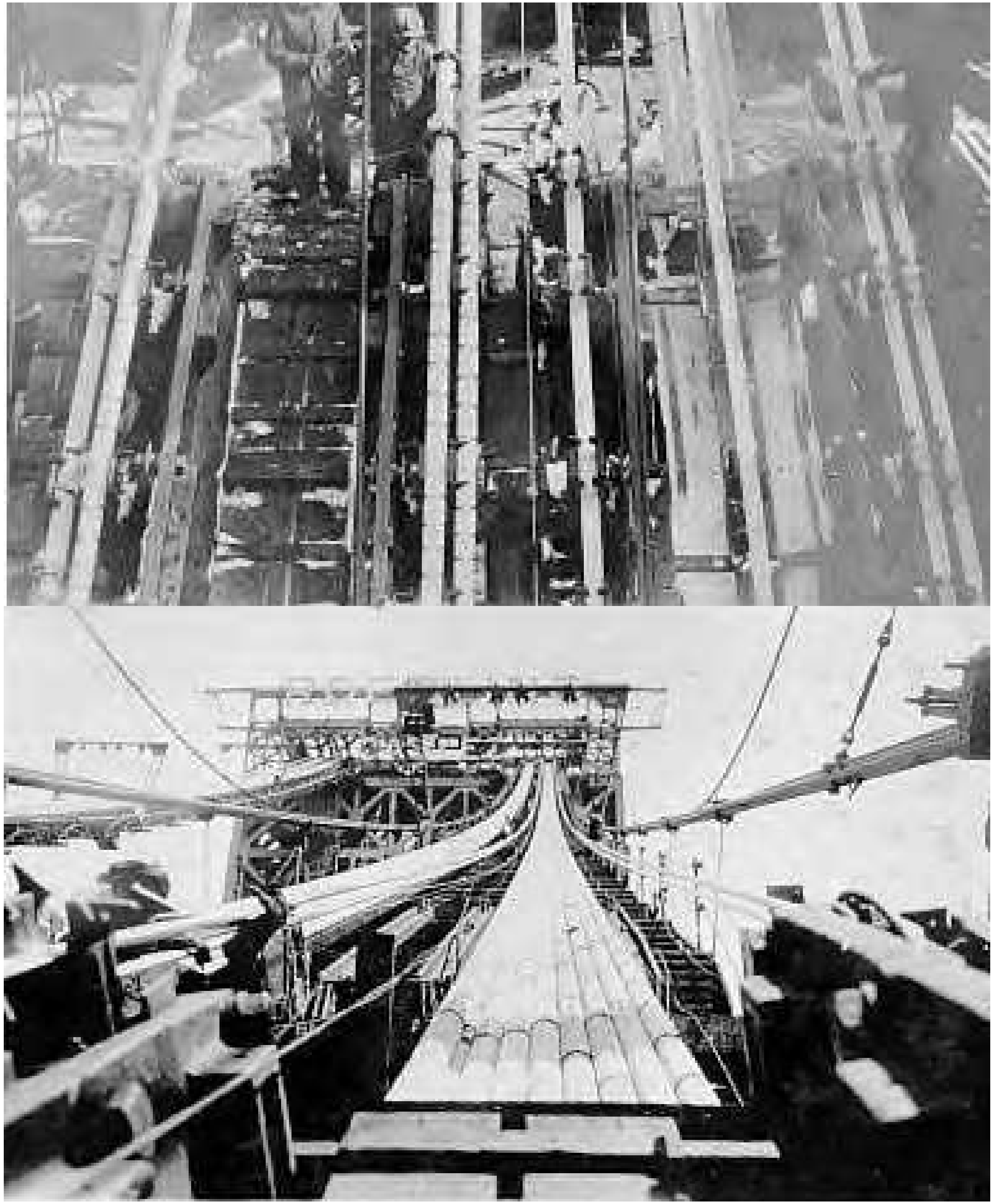
Left: caption: "Curved lifting beam for transferring strands from temporary spinning position to permanent location in cable saddle."

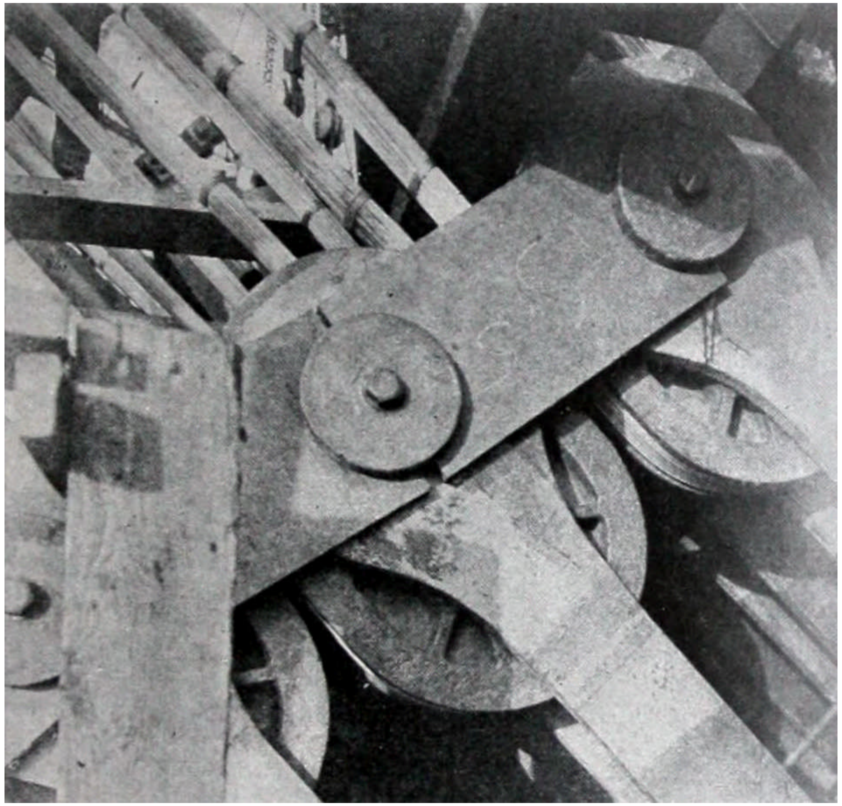


"…After a strand has been placed in its tower saddle, the anchorage saddle operator on the same side of the river lifts the strand with 60-ton hydraulic jacks, and moves it to lateral position with a hand winch. A 150-ton pulling jack moves the strand leg down for connection with the anchorage eyebars while the strand is being lowered into its saddles on this side of the river, and the same operations are repeated on the other side of the river…"

John A. Roebling's Sons Co.

Left: caption: "Hoisting jack and lifting beam for setting finished strands into anchorage saddle"

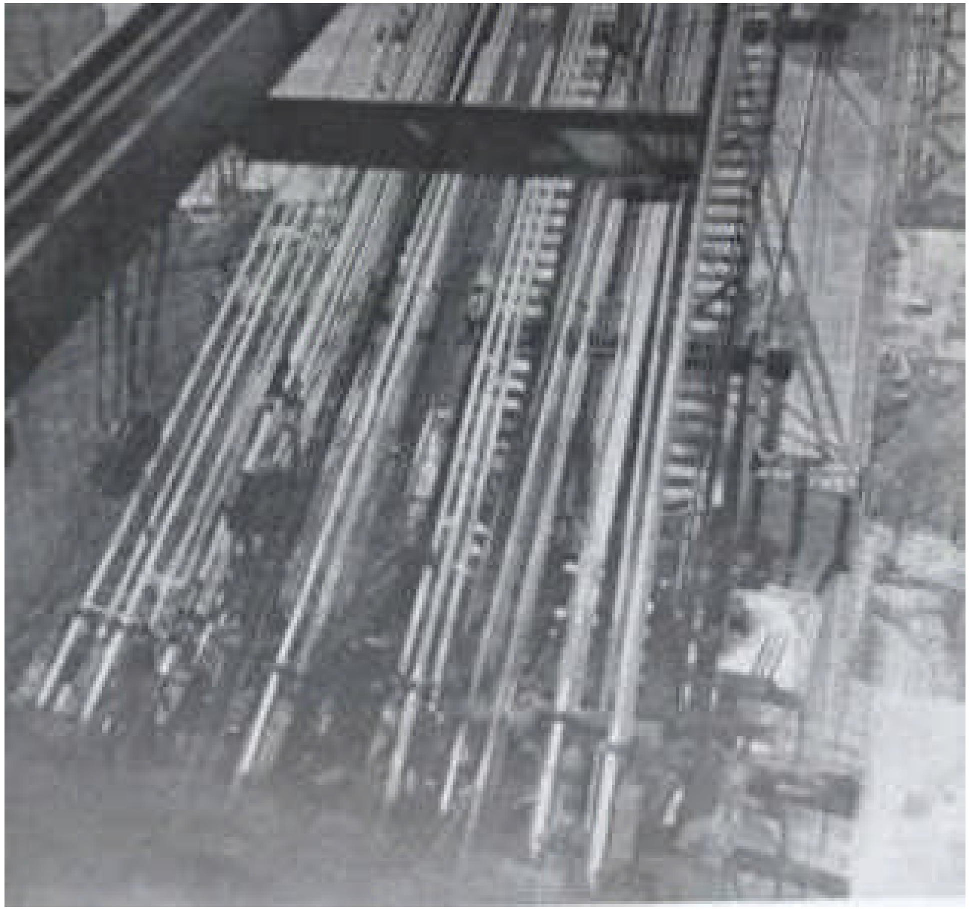




“…Just beyond their supports in the anchorage saddles, the main cables are each divided into 61 strands that diverge in both horizontal and vertical projections to their connections with the upper panel anchor eyebars. Each strand shoe is assembled between two eyebars and connected to them by a horizontal 10-inch pin, the ends of which project beyond the eyebars and engage half holes in spacer plates that are held in position by flat circular cap plates, secured by 1 ½-inch bolts passing through them and through the axes of the pins. The strand shoes have elongated pin holes permitting the exact adjustment of strand lengths by the insertion of shims in their bearings…”

John A. Roebling’s Sons Co.

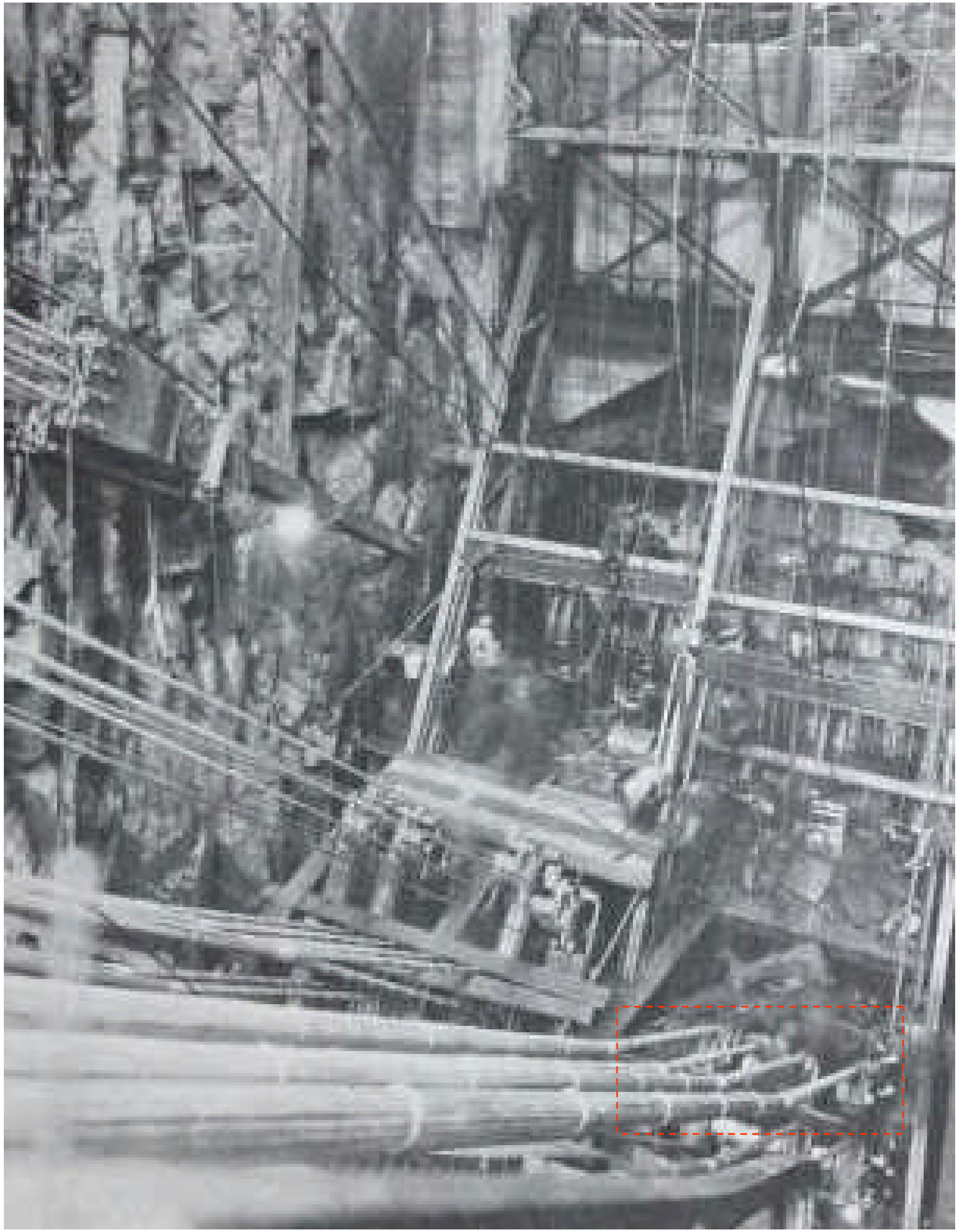
Above: caption: “Typical assembly of cable strands to anchorage eyebars”



"…In the New Jersey tunnel anchorage, and the New York block anchorage, the strand shoes are spaced very close together in both vertical and horizontal planes, but the spinning and adjustment operations are so carefully planned that necessary clearances are maintained for handling the heavy equipment, and for transferring the strand shoes from the strand arms, to which they are attached during spinning, to the eyebars. The attachment of the strand shoes to the strand arms is well shown in the view of the first set of strands at the New York anchorage…"

John A. Roebling's Sons Co.

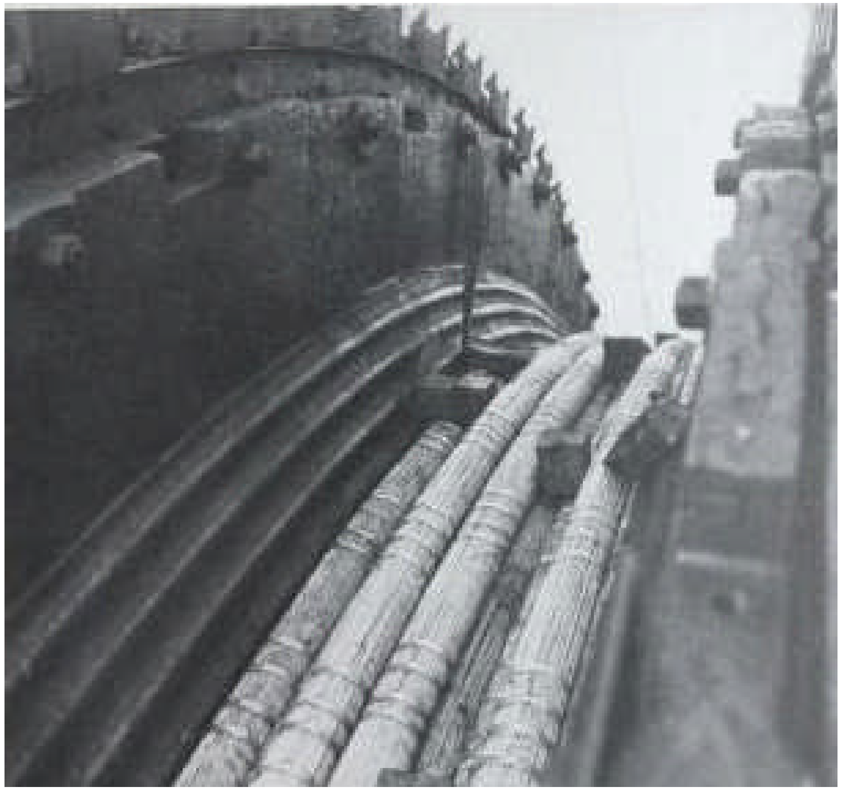
Left: caption: "View of the first strands at New York Anchorage. Spinning wheel at left just starting for opposite anchorage."



"…As each strand is completed its shoe is connected to its anchorage eyebar, and the strand arm to which it had been secured during the spinning operations is detached from the eyebar and transferred to position to receive the shoe for the next strand while the latter is being spun. These strand arms are very heavy offset steel castings, temporarily secured to the anchorage eyebars in such a way that they hold the strand shoe during the spinning of the strand, and then permit its permanent connection to the eyebar…"

John A. Roebling's Sons Co.

Left: caption: "General view of New Jersey south anchor pit, showing some finished strands, and four strands being strung"



"…The exterior lower strands of the cables are carefully placed in their respective grooves of the cable saddles, and the interior lower strands are accurately set in their required positions tangent to each other, making the most compact hexagonal arrangement possible. The several horizontal tiers develop, in service, heavy vertical pressures on the lower wires, that have been carefully investigated by the Roebling Company…"

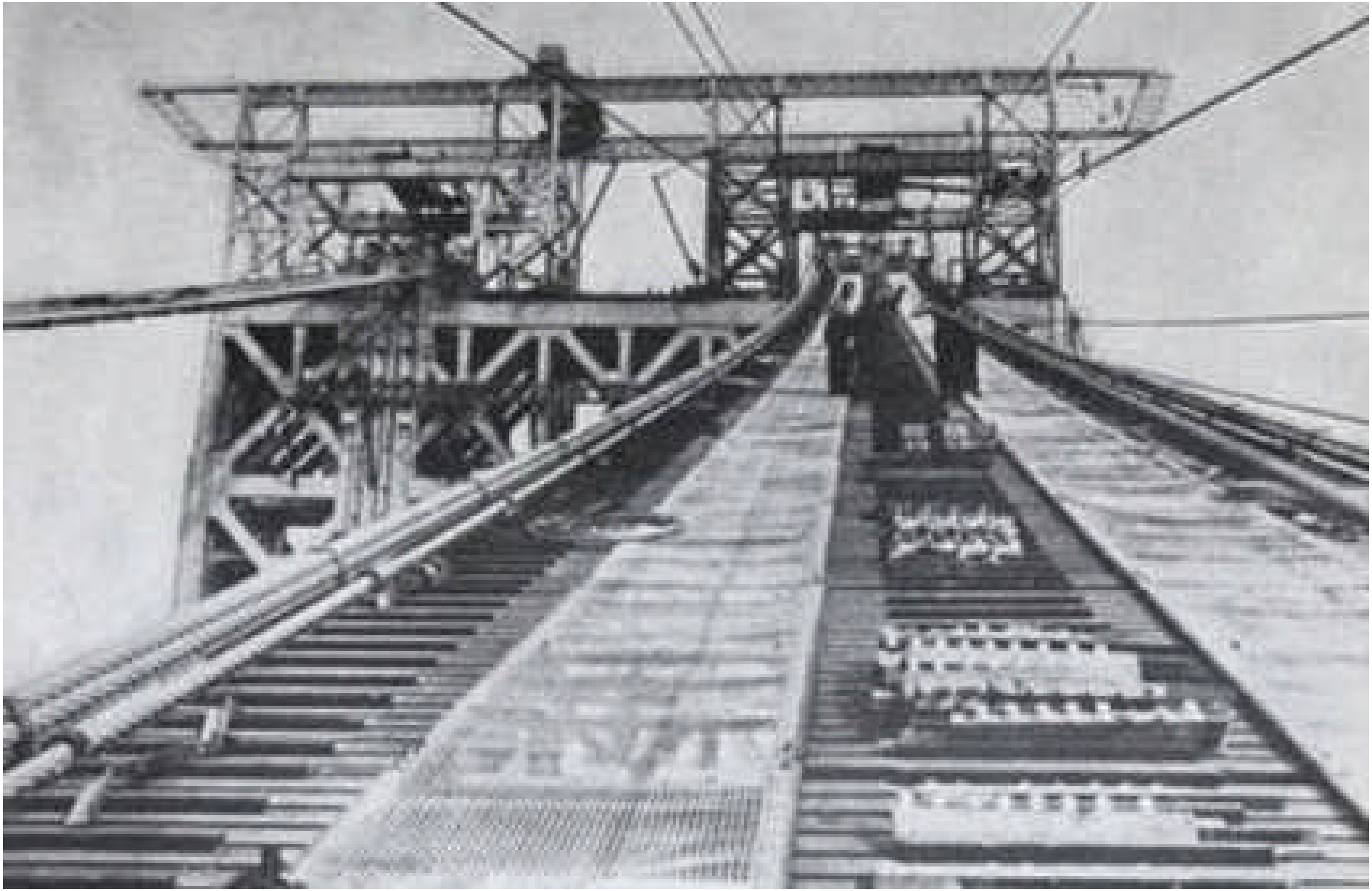
John A. Roebling's Sons Co.

Left: caption: "Eight finished strands in main tower saddle"

Electric Light, Power & Signal Systems

“…There is a very comprehensive and complete combination of eight principal electric signal systems covering and re-covering all important locations and key operations of the work, and providing for telephone communication, light, bell, buzzer, and annunciator drop signals, instantaneously controlling and synchronizing spinning and adjusting operations, making possible the unprecedented speed that has been attained in cable stringing, and eliminating cable spinning delays that are estimated to cost at least $125 per hour per cable in wages alone. The cost of labor and materials for the installation of the electric light, power and signal systems, exclusive of the cost of 86 electric motors up to 175 h.p. that furnish all power, was about $60,000, and a force of ten men is constantly employed on the maintenance of the electrical equipment…”

John A. Roebling’s Sons Co.



<u>Above</u>: caption: “Preparing upper end of center span footbridge for installation of electric signal system. Note Roebling construction tower on top of main tower in background.”

“…At the tower tops, at the anchorages, at the centers of the main and side spans, and at some other points on the footbridge there are located wind breaks and shelters, some of them heated in cold weather, where there are installed telephones and other equipment of the signal systems. The insulated electric wires are strung on steel posts adjacent to the hand rail ropes…”

John A. Roebling’s Sons Co.

Above: caption: "Groups of strands adjusted for each of the four cables. Note ample working space on both sides of cables, spinning tramways overhead, signal wires alongside hand rails, and signal station at left"

Above: caption: “Illumination of tower top and footbridge visible to millions of people within a radius of several miles”

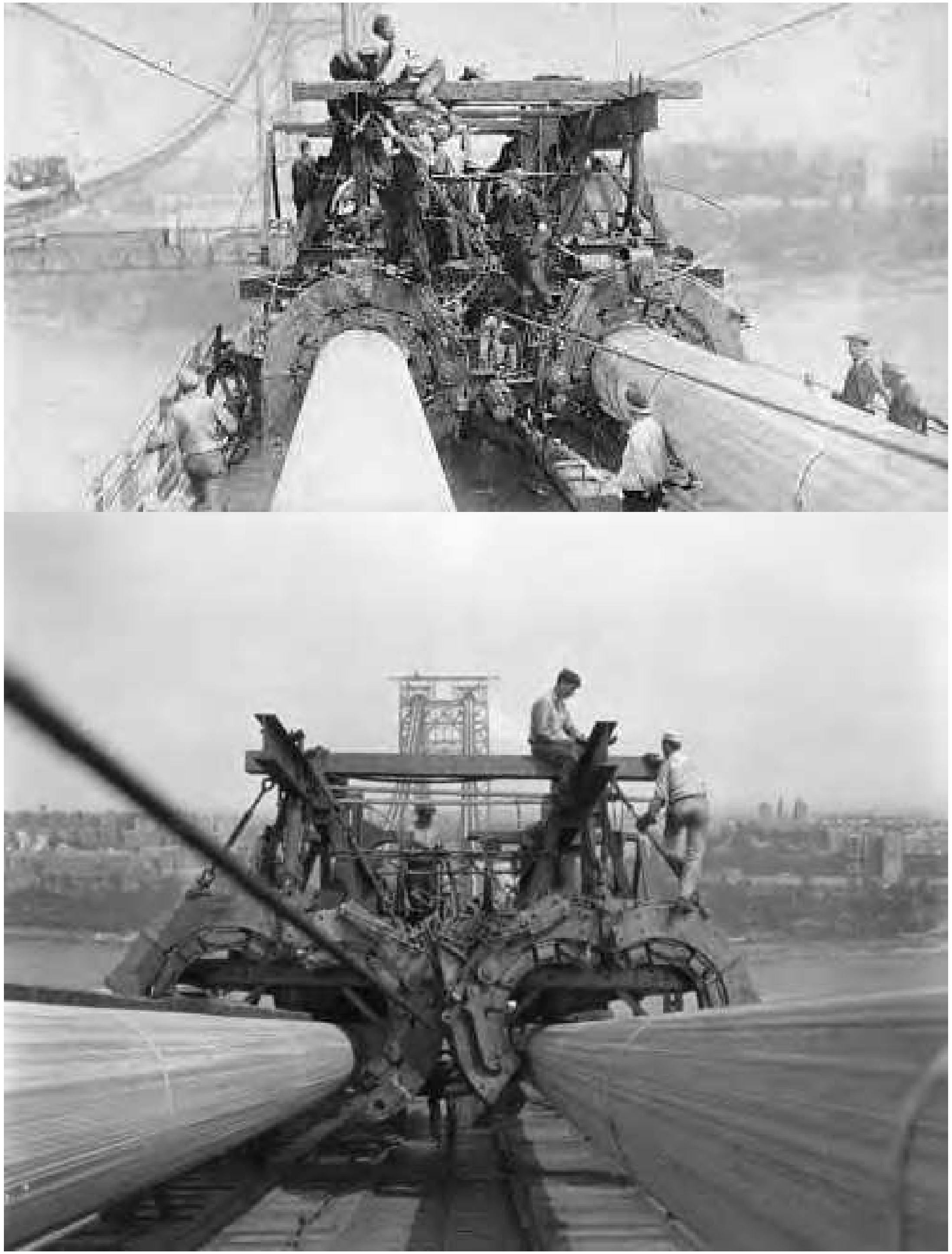
“…The spinning of the cables was completed on August 7, 1930. On March 19 of that year 87 tons of wire were spun in twelve hours. This was a record…”

***Wonders of World Engineering*, November 1937**

Cable Compacting

"…Once complete, the barrel cables had to be compacted by a machine called a squeezer, which, with a crew aboard, traveled over two barrels at a time compressing them into their rounded shape. Then the barrels had to be painted, wrapped in fine twice-galvanized wire, and painted again. The fact that just ten feet of a barrel cable weighs 34,000 pounds gives some sense of the strength and weight of the bridge's barrel cables…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*



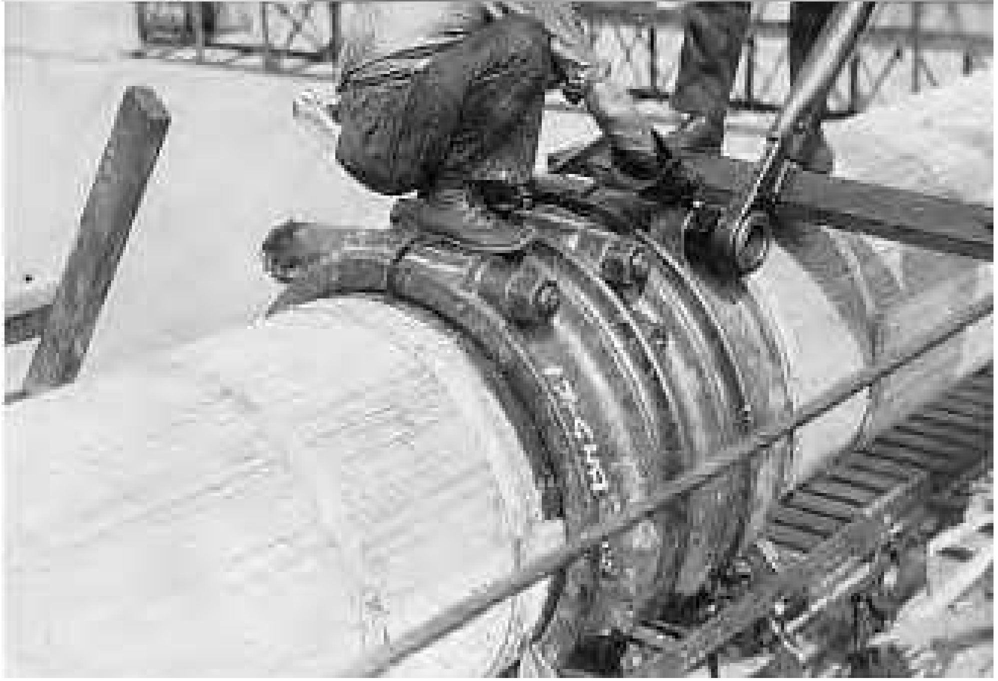
"…Today, faced with critical problems in every field, we are inclined to put our faith in mechanical panaceas, underestimating that most powerful of all machines, the human mind. These steel spans, these fine-spun cables are a vivid reminder that skill and scientific planning must be the keynote of all great achievements. Behind this mighty structure, that seems almost superhuman in its perfection, is an inspiring background of high intelligence…"

***Franklin Delano Roosevelt*, POTUS**
RE: excerpt from his October 25th 1931 opening day dedication speech
Left T&B: compacting the cables into a round configuration

“…Spliced into a continuous loop, 434 wires made up a strand three inches in diameter, and there were 61 strands in each barrel cable. If the 26,474 wires in each of the four barrel cables were laid out end to end they would, at 107,000 miles, girdle the planet at the equator more than four times and, together with the wire in the suspender cables, or stringers, would extend virtually halfway to the moon…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

Hanging the Deck



By 1930, Roebling had 175 men working on the cables. With innovations Sunderland and his engineering staff developed, the four cables were completed in October 1930, thirteen months ahead of schedule. They then disassembled the footbridges to prepare the footbridge ropes for their second incarnation. Cutting the ropes into 292 pieces of pre-marked lengths and socketing them at the bridge site, the Roebling crew installed them as the suspender ropes for suspending the bridge deck.

<u>Top</u>: caption: “Painting the main cables”

<u>Bottom</u>: caption: “Securing the cable bands”

"…Finally, beginning in September 1930, work on hanging the roadway from the stringers began. Like the towers, prefabricated sections 110 feet wide, 90 for the roadway and 10 for each walkway, were lifted by cable from large river barges anchored at all four corners so as to be motionless during the delicate operation. To keep the structure in balance, sections were alternately fastened in place beginning at both towers and moving toward the center and then outward from the towers to the anchorages…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

<u>Top Left</u>: caption: “Securing the suspender cables to the floor girders”
<u>Top Right</u>: caption: “Tying the suspender cables together”
<u>Left</u>: caption: “Closing the main scan gap with floor girders and beams”

<u>Above L&R</u>: caption: “Suspender cables ready for road deck attachment as viewed from within the anchorage”

<u>Above</u>: caption: “Floor framing nears anchorage”
<u>Left</u>: caption: “Floor framing approaches New York anchorage from side span”

"…Floor erection began on September 12, 1930, and was completed between the two towers by December 29. Floor erection of the side spans made rather slower progress. The work was completed on the New Jersey side on January 1, 1931 and on the New York side on January 21 of that year…"

***Wonders of World Engineering*, November 1937**

Above: caption: "Disassembling the foot-bridge"

Left: caption: "Floor steel in place"

Part 4

A Bridge Too Grand

An Undeniable Touch of Genius

“…could build a bridge across the Atlantic and have piers on a solid foundation even though in places the ocean is three miles deep…would be strong enough to carry the heaviest traffic and to resist the biggest gales that have ever blown. There is nothing at all impossible in such a project”

Gustav Lindenthal

RE: excerpt from article appearing in *Frank Leslie’s* magazine, 1920. Lindenthal believed that, with enough money, bridging the *Atlantic Ocean* was possible.

“…In the City of New York is a man who for thirty years has held a vision so splendid that few have had the imagination to appreciate it. He is Dr. Gustav Lindenthal, consulting engineer. His vision centers in a solution of New York’s transportation problem, one feature of which is building a great bridge across the Hudson River. It is an undertaking which offers far greater difficulties than were encountered in building any of New York’s present bridges…”

***Popular Science,* December 1920**

“…At last, after many delays, the latest of which was due to the war, the preliminary work necessary for the construction of the Hudson River Bridge is well under way. A staff of engineers which includes some of the most distinguished men in the country has been formed, and back of the great work is a group of leading financiers, railroad men and others who have a wide practical acquaintance with transit problems…with an undeniable touch of genius that Gustav Lindenthal conceived the problem of connecting Manhattan and New Jersey, not by a series of separate structures, but by one vast bridge whose proportions would be such that it could easily take care of the whole of the traffic which surges to and fro between Manhattan Island and the mainland…”

***Popular Science*, April 1921**

WEST JERSEY BRIDGE, NEW YORK CITY.

Unprecedented Dimensions

“…Mr. Gustav Lindenthal, the eminent bridge engineer, has evolved a design for a bridge across the Hudson at 57th Street, which will allow so great an increase in the facilities which make for the growth of Manhattan, that the bridge is of interest to the entire country…”

Baltimore and Ohio **magazine, January 1923**

“…It was not idealism or any striving for the spectacular that led to the conception of this bridge upon such a gigantic scale. Rather, its dimensions have been determined by the severest application of the principles of economy. In all construction engineering work, whether upon land or sea, it has been proved over and over again throughout the past decades that there is economy in concentration. We see it in the 900-foot steamer, the 400-ton locomotive, the 100-ton freight car, the multi-storied office building, and in the huge factories which are characteristic of American Manufacturing industry. Similar economies both in the first cost and the cost of operation, will be achieved by solving the vast traffic and transportation problem between the Western continent and Manhattan Island, by the construction of a single bridge of unprecedented dimensions…”

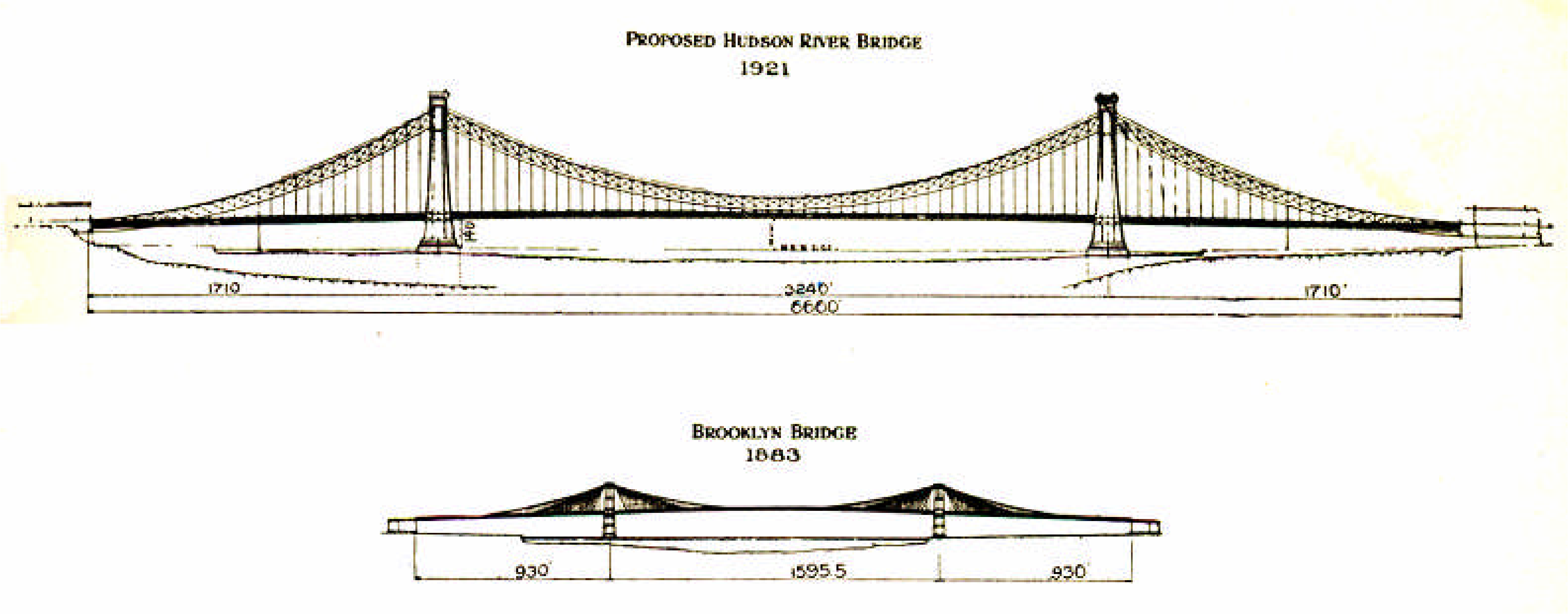
***Popular Science,* April 1921**

The Bridge Structure

“In a bridge, it is not possible to separate the architectural from the engineering features”

Gustav Lindenthal

<u>Above & Left</u>: view of one (of two) ornate, load-bearing portal entry/s to Gustav Lindenthal’s lenticular truss *Smithfield Street Bridge* over the *Monongahela River*



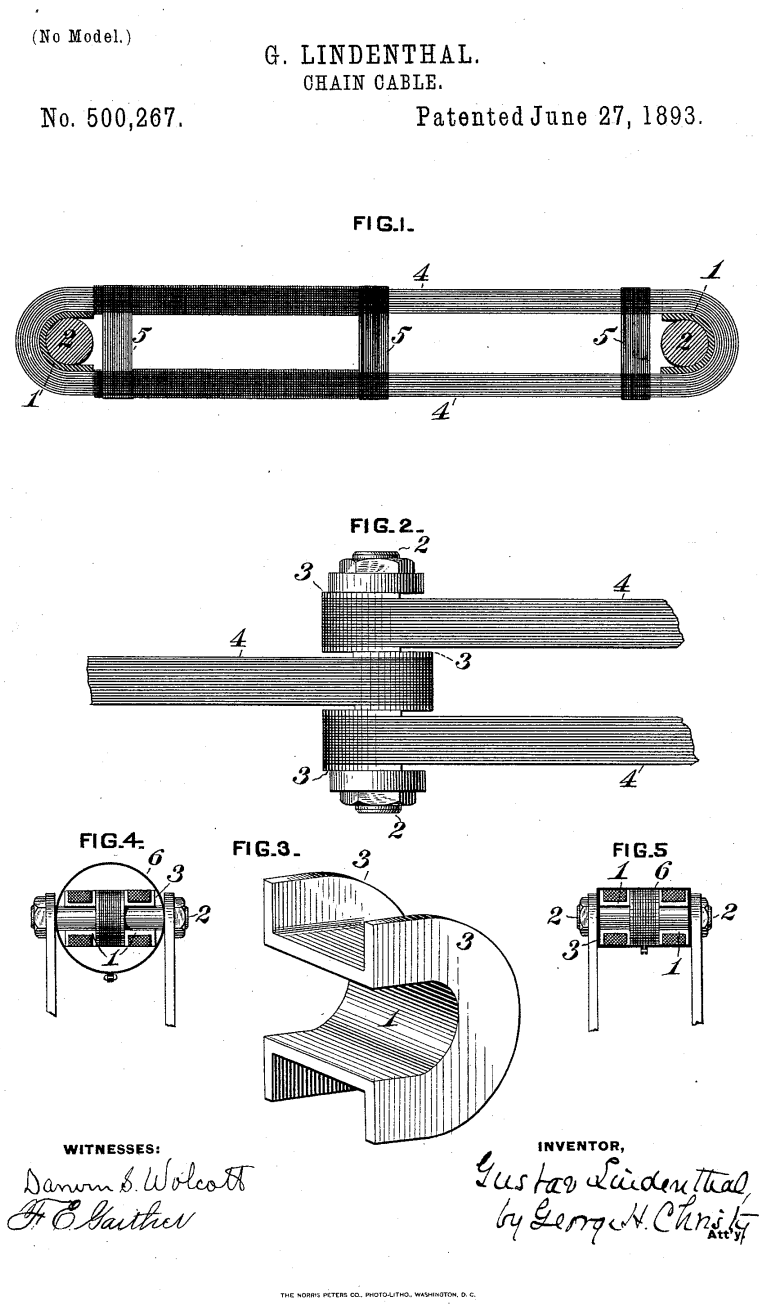
"…The bridge is of great magnitude. The river span is 3,240 feet between center of towers and the approach spans are each 1,590 feet to the face of the anchorage. The floorway of the bridge is 235 feet wide and is carried by two lines of suspension arches 160 feet apart horizontally. Each suspension arch consists of two chords 60 feet apart vertically with bracing between which provides stiffening under passing loads…"

Baltimore and Ohio **magazine, January 1923**

Above: caption: "A Side View of the Hudson River Bridge Compared with the Brooklyn Bridge. The span of the new structure will be 3,240 feet, almost twice the length of the Brooklyn span. From one anchorage to the other the new bridge will measure 6,660 feet, or nearly a mile and a quarter."

“…The principal stresses to which the bridge will be exposed will be those due to its own dead load. So great is this that, even with the bridge loaded to capacity, the live load would cause a comparatively negligible addition to the dead load stresses. The same is true of the wind loads. The great width of the extremely rigid floor system, coupled with the inertia of the bridge, serves greatly to simplify the problem of providing against wind stresses…”

***Popular Science,* April 1921**



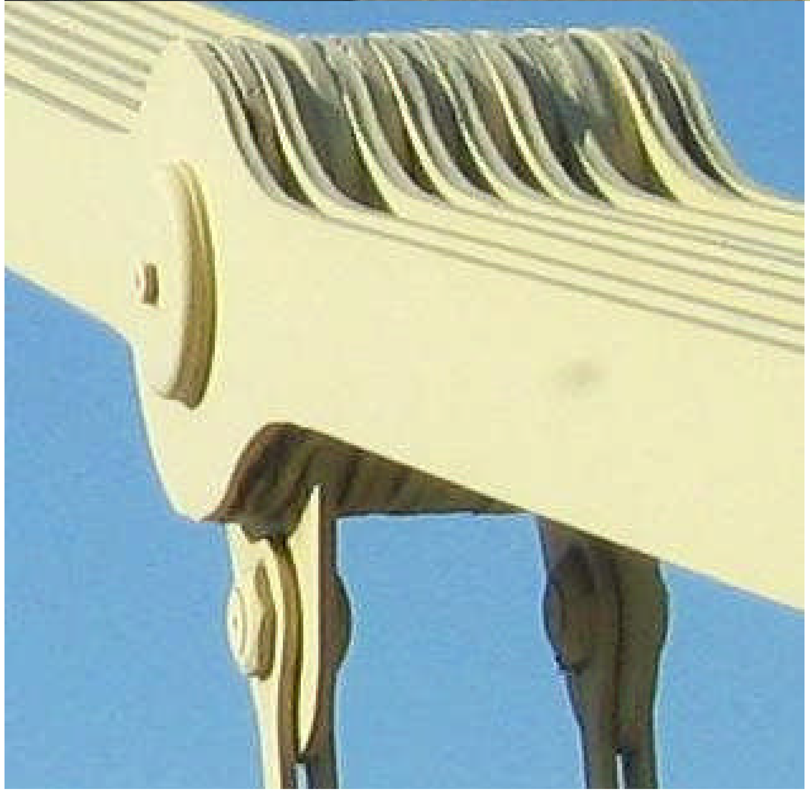
"…Each of the four cables will consist of three banks of steel eye-bars, enclosed in watertight bronze tubes, to protect them from the weather. Each pair will be braced together to form a deep stiffening truss. At every 40 feet will be suspended a massive plate-girder floor beam 32 feet deep and 200 feet long. Framed in between those will be the longitudinal stringers of the two decks…The floor will be watertight and will completely cover in the lower deck…"

***Popular Science,* April 1921**

Left: Gustav Lindenthal's patent for "Chain Cable" (June 27th 1893)

“…The floor system, which will be a double-deck structure 220 feet in width and 34 feet in depth, will be suspended from four cables arranged in pairs, with a horizontal distance between them, center to center, of 165 feet. Each pair will hang in the same vertical plane at a vertical distance of 60 feet center to center. Due to the fact that the cables will be braced by a system of vertical tension and diagonal compression members, each pair will be secured against deformation, and will serve the function of a stiffening truss. The width of each panel of this trussing will be 60 feet, and the floor of the bridge will be supported from each panel point by eye-bar suspender chains…each cable will consist of eighty eye-bars arranged in three banks. The diameter of each cable, as thus assembled, will be about 11 feet…As a protection against the weather, the cables will be enclosed in watertight bronze tubes, which will measure fifteen feet in exterior diameter. This will protect the cables from the weather and will provide sufficient clearance for the workmen to inspect the cables and paint them at the long intervals of many years when repainting becomes necessary. Incidentally, the bronze covering will add to the artistic and monumental appearance of the bridge…”

Popular Science, **April 1921**



"…Instead of wire cables with which we are familiar in the Brooklyn Bridge, chains of eye bars are used to form the chords. An eye bar is a bar of steel which has an eye or hole at each end which fits around the circumference of a steel pin and is in tension. Each chain consists of 20 to 30 eye bars 16 inches wide and 2 to 2 ½ inches thick, strung up side by side on pins, and each chord consists of three such chains fastened together at the pins so that there are twelve such chains in four chords forming the two suspension arches carrying the suspended floor-ways…"

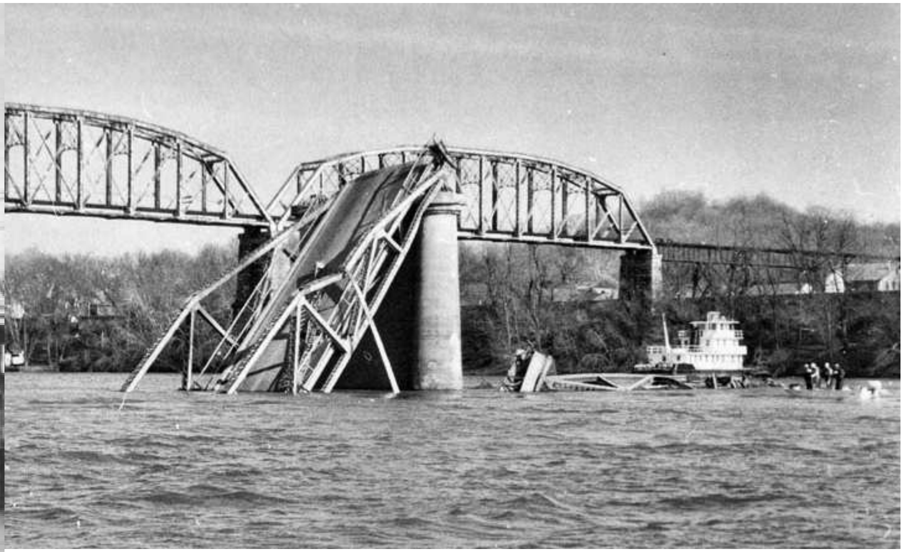
Baltimore and Ohio **magazine, January 1923**

Above & Left: one of the "Three Sisters" eyebar chain suspension bridge/s over the *Allegheny River*, *Pittsburgh, PA*

"…The eyebars are to be 60 to 70 feet long from center to center of pins and in order to cut down the weight of the bridge the tensile strength or pulling apart strain will be about twice that of ordinary steel but not higher than the best alloy steels of today…For economy and in order to reduce the area of the structure exposed to deterioration, each chord will be enclosed in an envelope of bronze, which will protect the painting from the elements and allow for proper inspection…"

***Baltimore and Ohio* magazine, January 1923**

Above L&R: eyebar chain suspension close-up/s



On December 15th 1967 at approximately 5:00 p.m., the *U.S. Highway 35* bridge, otherwise known as the *Silver Bridge* (top left) connecting *Point Pleasant, West Virginia* and *Kanauga Ohio* suddenly collapsed into the *Ohio River* (top right and left). At the time of failure, thirty-seven vehicles were crossing the bridge and thirty-one of those fell with the bridge. Forty-six individuals perished with the failure of one the bridge's eyebar chains and nine were seriously injured. Along with the numerous fatalities and injuries, a major transportation route connecting *West Virginia* and *Ohio* was destroyed. The bridge, opened in 1928, was dubbed "Silver Bridge" because it was the nation's first aluminum painted bridge. It was designed with a 22-foot roadway and one 5-foot sidewalk. Some unique engineering features of the bridge included high-tension eyebar chains, a unique anchorage system and "Rocker" towers. The Silver Bridge was the first eyebar suspension bridge of its type to be constructed in the U.S.

SILVER BRIDGE TUMBLES,

TOLL, 7 DEAD, 41 MISSING

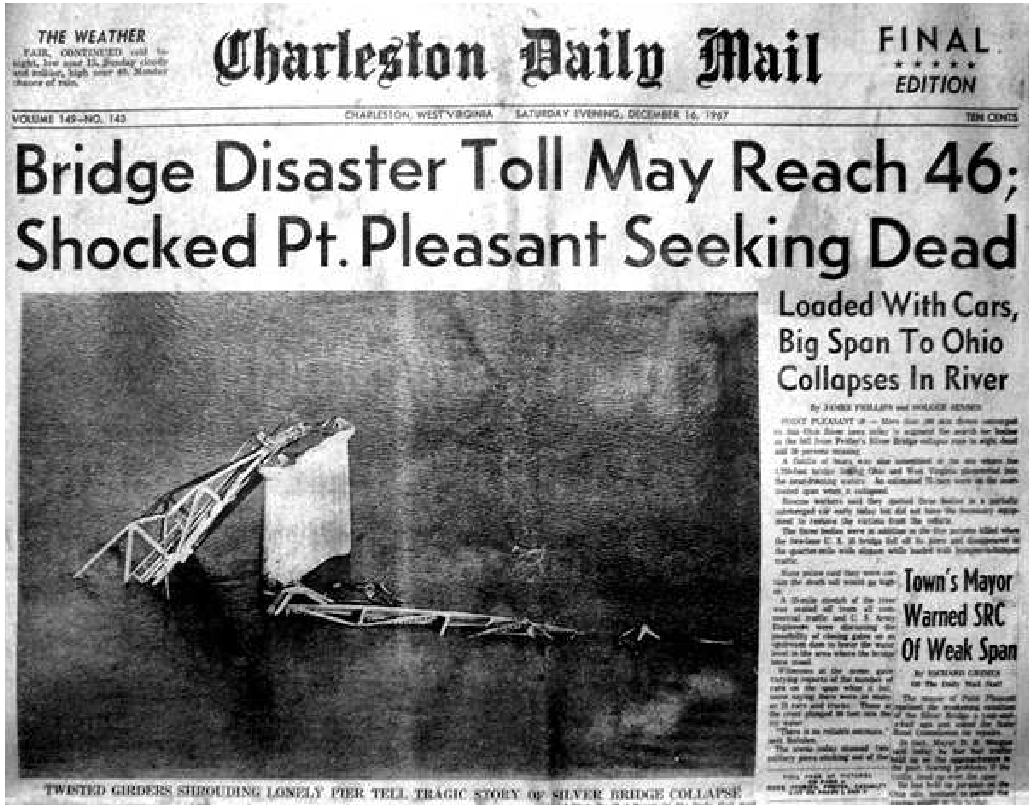
Point Pleasant Register

'I Couldn't Understand Why I Made It'

Five Survivors Give Accounts

Divers Begin Search For Untold Loss

Eye Witnesses Tell Of Tragedy



THE WEATHER

Charleston Daily Mail

FINAL ★★★★★ EDITION

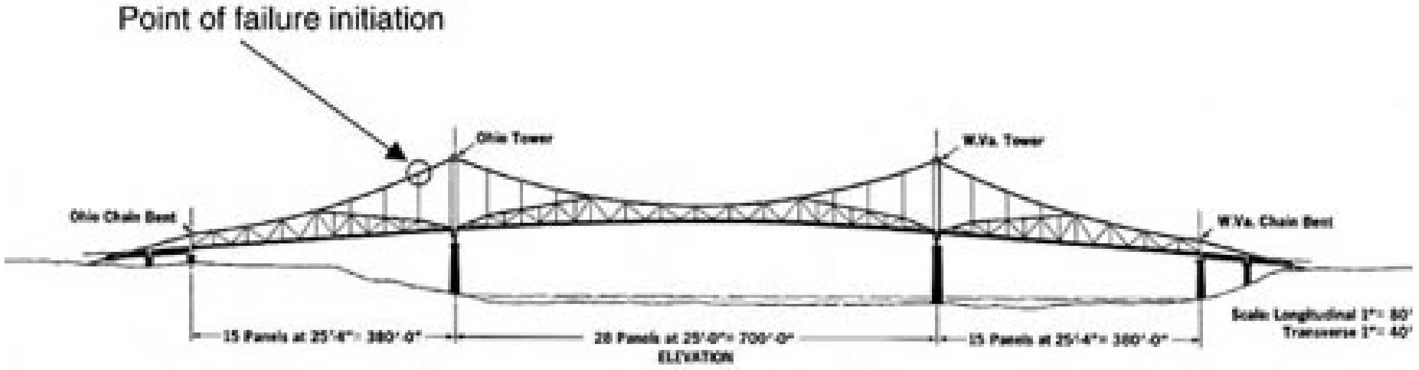
VOLUME 149—NO. 143 CHARLESTON, WEST VIRGINIA SATURDAY EVENING, DECEMBER 16, 1967 TEN CENTS

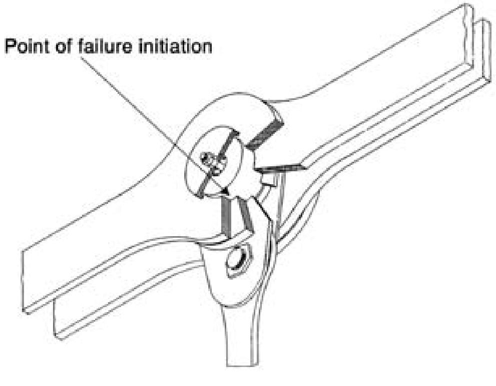
Bridge Disaster Toll May Reach 46; Shocked Pt. Pleasant Seeking Dead

TWISTED GIRDERS SHROUDING LONELY PIER TELL TRAGIC STORY OF SILVER BRIDGE COLLAPSE

Loaded With Cars, Big Span To Ohio Collapses In River

Town's Mayor Warned SRC Of Weak Span

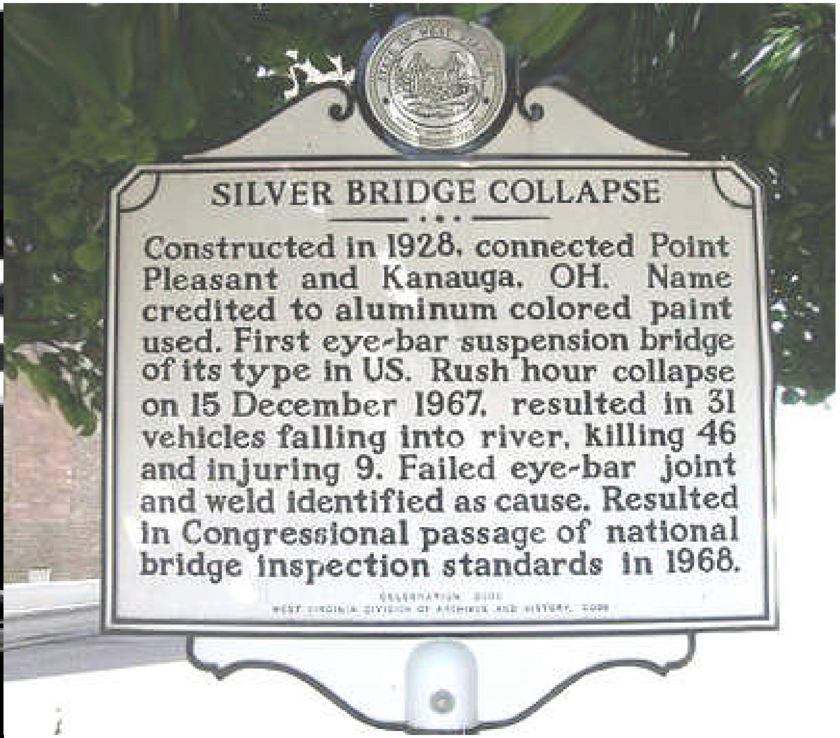




"…the cause of the bridge collapse was the cleavage fracture of the lower limb of the eye of eyebar 330 at joint C13N of the north eyebar suspension chain in the Ohio side span. The fracture was caused by the development of a critical sized flaw over the 40 year life of the structure as the result of the joint action of stress corrosion and corrosion fatigue. Contributing causes are:

- ***In 1927, when the bridge was designed, the phenomenon of stress corrosion and corrosion fatigue were not known to occur in the classes of bridge material used under conditions of exposure normally encountered in rural areas;***
- ***The location of the flaw was inaccessible to visual inspection, and;***
- ***The flaw could not have been detected by any visual inspection known in the state of the art today without disassembly of the eyebar joint"***

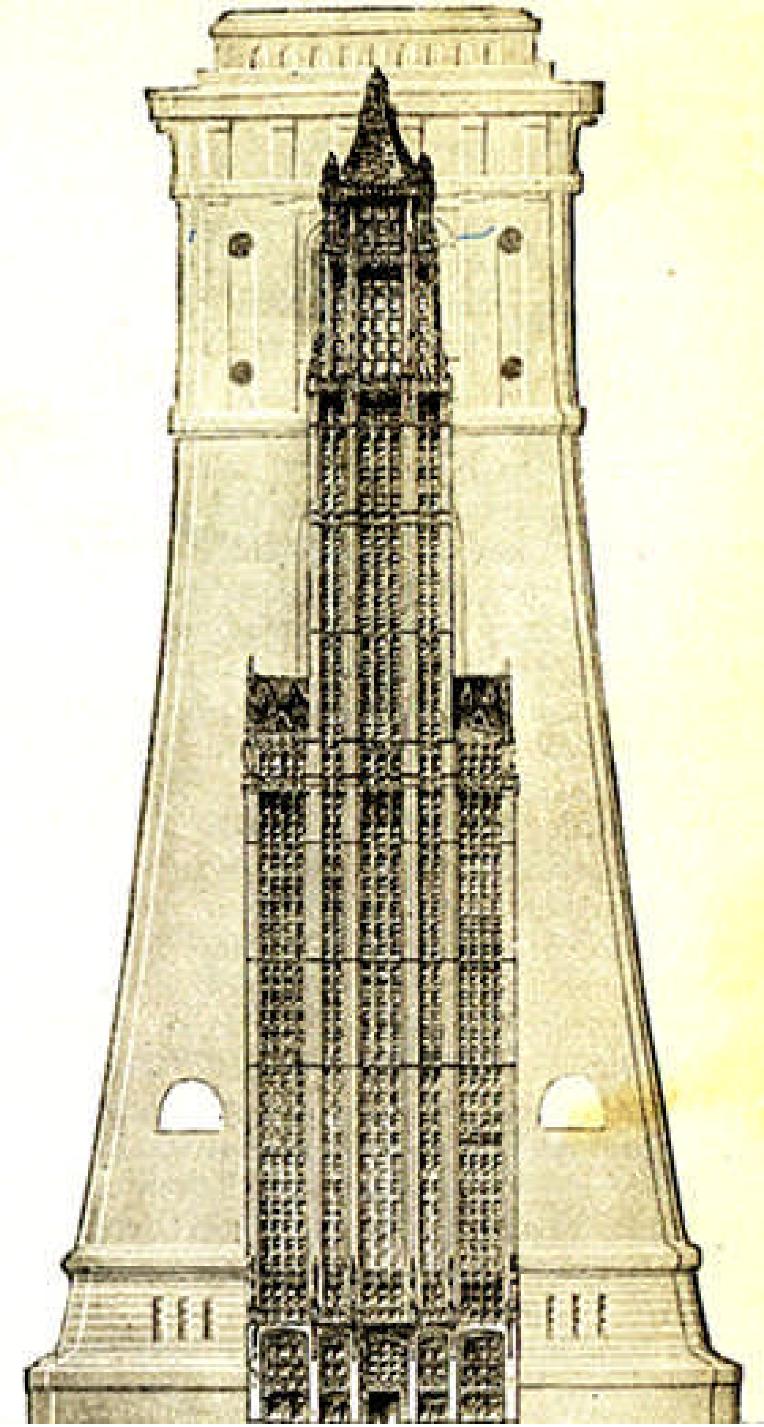
RE: excerpt from the *National Transportation Safety Board* (NTSB) report, 1970. The suspension system consisted of sets of two eyebars connected by pins at the junction between adjacent segments (right). The eyebars were made of a new, tempered, high-strength steel. Failure was initiated by the brittle fracture in the eyebar material at the first joint to the north of the tower on the *Ohio*-side in the suspension structure (left).



SILVER BRIDGE COLLAPSE

Constructed in 1928, connected Point Pleasant and Kanauga, OH. Name credited to aluminum colored paint used. First eye-bar suspension bridge of its type in US. Rush hour collapse on 15 December 1967, resulted in 31 vehicles falling into river, killing 46 and injuring 9. Failed eye-bar joint and weld identified as cause. Resulted in Congressional passage of national bridge inspection standards in 1968.

The *Silver Bridge* disaster was a wake-up call for the bridge-engineering community and the design, construction, inspection and maintenance of bridges changed radically as a result. Biannual inspections and material fracture toughness requirements were mandated, as well as other changes over the years, especially related to fatigue and brittle fracture. The change of most interest was the requirement that a bridge be robust, that is, that it should not totally collapse when a local joint or member fails. In the jargon of bridge-design standards, the system must not be prone to “progressive collapse.” The forces that a failed part is designed to carry must be able to be rerouted to another path. In other words, the structure must be “redundant.” If the *Point Pleasant Bridge* had been built with many eye-bars in each chain link, like the *Budapest Chain Bridge* (left), it would still be in service today, with fractured eyebars replaced as needed. Thus the cause of failure was not the fracture of the eyebar per se, but an error in judgment during design of the bridge whereby redundancy for a failed joint was not considered.



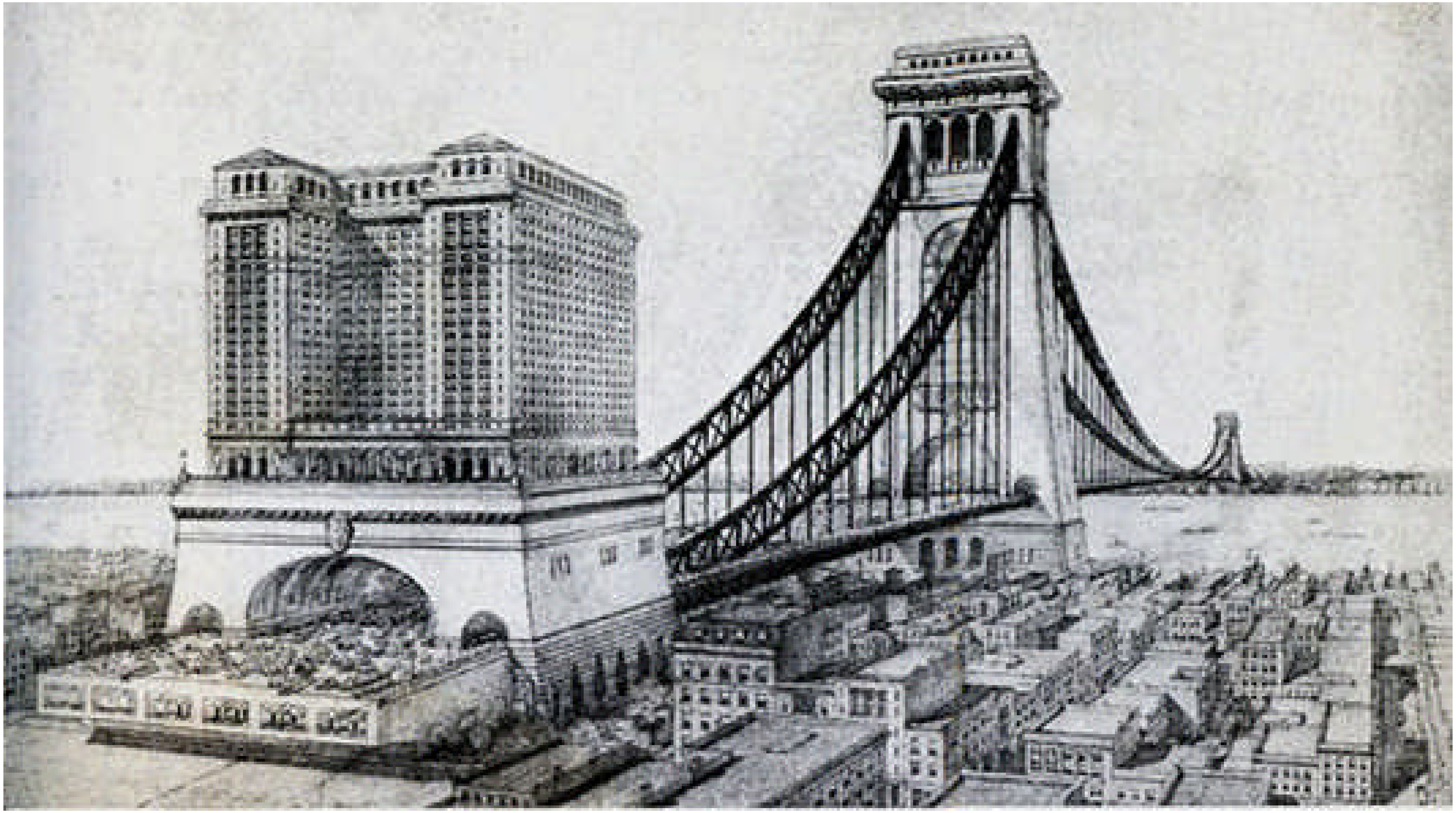
"…The other prominent features are the towers. In order to give the most economical sag to the chains the towers have to be of great height and strength. Their bases are to be 200 feet by 400 feet and their overall height 800 feet above water level. They are to be founded on rock which is from 100 to 200 feet below the water…Each tower will be built of steel encased in a shell of masonry for utility and as protection from the weather…"

***Baltimore and Ohio* magazine, January 1923**

Left: caption: "One of the two towers which will support the bridge - 825 feet high – compared with the famous Woolworth Building" (*Scientific American*, 1921)

“…At the towers the clear height from mean high water to the underside of the bridge will 140 feet, and at the center of the channel it will be 155 feet…The main towers, which will be built upon concrete foundations extending to bedrock, will be carried up to a height of 750 feet above mean high water, or practically to the same height as the Woolworth Tower. They will be built of steel and covered, from water level throughout their full height, with smooth-dressed, light-gray granite, which will serve as a protection to the steelwork against the weather and will, of course, add greatly to the architectural beauty of the whole bridge. The upper roadway of the bridge will pass through the towers by means of three arched openings, the center one measuring 155 feet in width by 100 feet in height, and the side openings being 30 feet in width. In view of the fact that there is a preponderance of sentient in favor of utilizing the monumental proportions of this bridge in working out a suitable war memorial, it is evident that this three-arched entrance, with its vast spread of granite wall space will lend itself most admirably to the purpose, providing ample space for heroic statuary and commemorative bronzes and tablets…”

***Popular Science,* April 1921**



“…The anchorages are in the rock on either shore and their function is to resist the pull of the chords. Masonry concrete blocks 400 feet long by 355 feet wide and some 240 feet high, will be required to properly anchor the chords…”

***Baltimore and Ohio* magazine, January 1923**

<u>Above</u>: caption: “The proposed bridge across the Hudson River – from the Architect’s drawing.” The structure atop the anchorage was to be a hotel/office building.

“…On the landward side the cables will swing down to masonry anchorages on each shore. These, like everything connected with the bridge, will be built on a gigantic scale, the pull of the cables necessitating the emplacement of an enormous mass of masonry to provide the necessary frictional resistance…The traffic pass through the center of these anchorages, and here again there will be a grand portal, consisting of one central arch and two flanking arches, which will lend themselves to war memorial decorations…”

***Popular Science,* April 1921**

A Living Monument

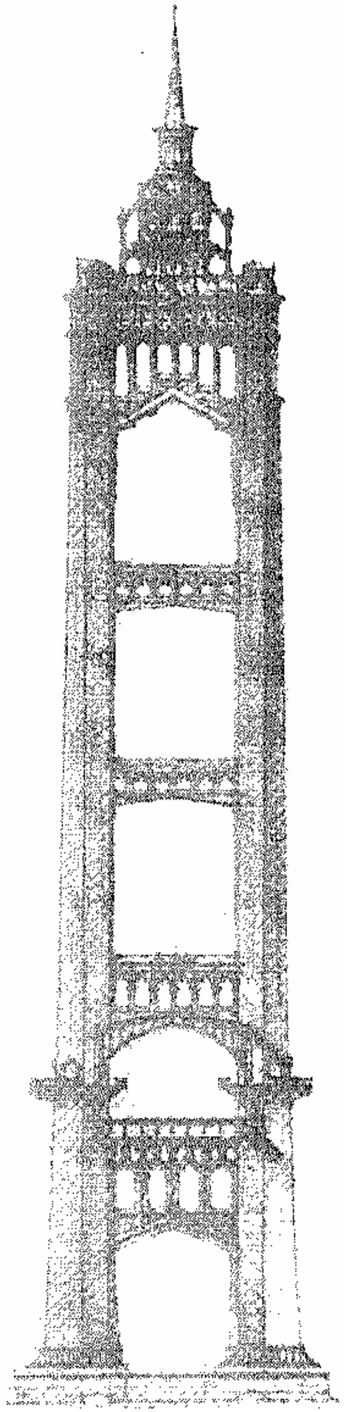
“…The building of a massive structure of steel across the Hudson would be a fitting monument to our Age of Iron. Its completion would mark a new wonder of the world, ranking as an engineering undertaking far above the construction of the Pyramids. Its service would be to the humanity of future generations, though nothing could be more appropriate as a monument to the heroes of the last war. In ancient times bridges were built as monumental structures. Why not have this modern enterprise a ‘Hudson River Memorial Bridge’?...What could be more splendid than a ‘Living Monument,’ rather than one purely ornamental and lacking a vital contribution to humanity?

***Popular Science*, December 1920**

"Will peal out anthems of Liberty to those who enter through this nation's gateway; and a beacon light that will send out beams as a symbol of Liberty to guide, welcome and inspire those who crossed the seas to come to our shores"

David B. Steinman

RE: in 1926, Dr. David B. Steinman proposed a suspension bridge across New York Harbor's *Narrows* to be funded by private investors as a memorial to WWI casualties. His "Liberty Bridge" (left) would have had a 4,620-foot clear span and 800-foot tall towers ornamented with Gothic tracery enclosing observation decks, beacon lights, and a clarion of bells. A business syndicate applied to *Congress* for a charter to build and operate the bridge. Then Congressman *Fiorello H. La Guardia* single-handedly blocked the proposal, stating his opposition to a private corporation profiting from a civic need.



"I don't want private capital to profit at the expense of the people"

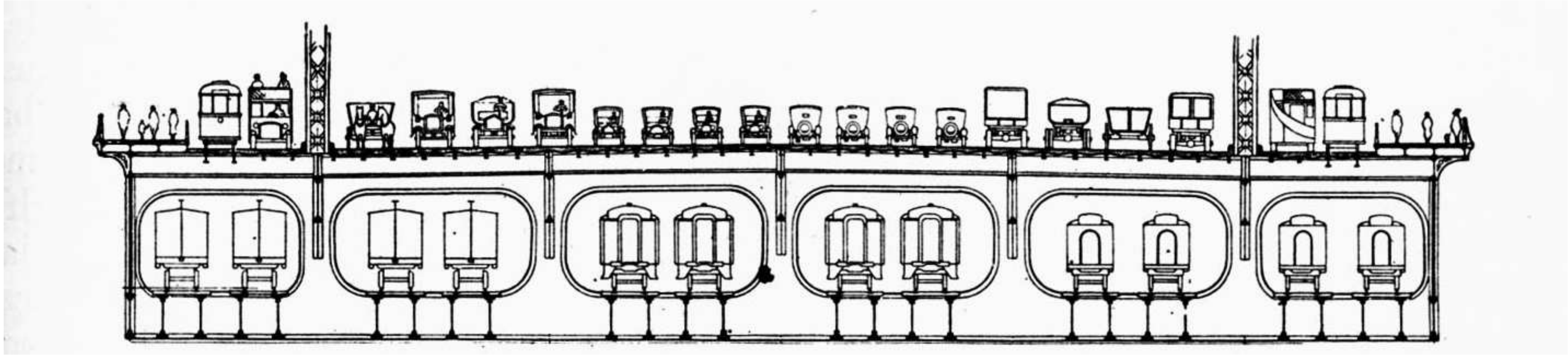
Congressman *Fiorello H. La Guardia*

<u>Left</u>: caption: "Liberty Bridge's elaborate 800-foot steel towers were to contain observation balconies, carillons and beacon lights." La Guardia's lone congressional dissent ended the efforts of a private company funded by wealthy New Yorker's – the *Interborough Bridge Company,* to obtain a federal charter for D.B. Steinman's *Liberty Bridge* across the *Narrows.* Later, as *New York City* mayor in the 1930s, he would advocate the plan as needed to help alleviate unemployment during the *Great Depression*. In the post-WWI years, it was a common political tactic to attach the word "memorial" to a project to assist its chances of getting approved and/or funded.

“Let the bridge stand on its own merit as a means of communication between the three boroughs for the purpose of transporting passengers and freight, but please don’t claim it to be a monument or a memorial. Every member who wants to put a pet project across thinks he could succeed by pinning it on the back of some dead soldier. Leave off the camouflage when you present the plan to the Board of Estimate. Just say that the proposed bridge is a needed public utility.”

Congressman *Fiorello H. La Guardia,* 1920
RE: the *Triborough Bridge*. As a WWI aviator, he resented greatly the political ploy of memorializing ad nauseum infrastructure projects to obtain federal approval/funding.

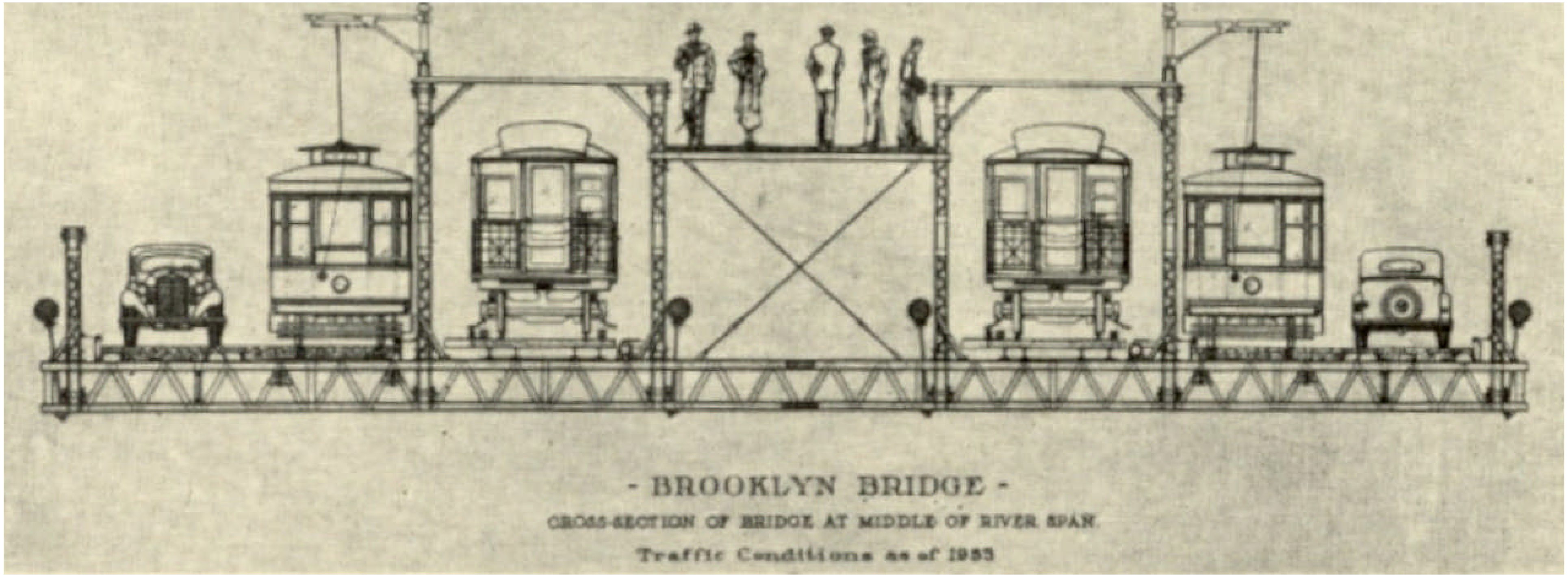
Bridge Capacity



"…So much for the bridge structure. Its capacity on the upper decks is four surface car lines, two fifteen foot sidewalks, and width of roadway sufficient for 16 lines of vehicles; on the lower decks, facilities for 12 standard gauge railroad tracks…"

Baltimore and Ohio **magazine, January 1923**

Above: caption: "Cross-Section of the Proposed Hudson River Bridge, at the Center of the Span. The central roadway, between the suspension cables, will be 155 feet wide, capable of accommodating sixteen lines of vehicular traffic. At each side, also, there will be room for trolley, bus, and pedestrians. Below that roadway will be provisions for twelve railroad tracks for passengers and freight trains. The extreme width of the bridge at the center of the span is 235 feet. In contrast, it may be mentioned that the Brooklyn Bridge accommodates only two rapid-transit railroad tracks, two trolley tracks, two lines of vehicles, and one roadway for pedestrians."



"…The bridge is to be built by private capital, and primarily to take care of the vehicular traffic of Manhattan and it is estimated that such traffic alone will support the bridge proper. It will cater to such other business as seems fitting under the charter and will furnish revenues which will add to the profit of the undertaking or reduce the cost to all users…"

Baltimore and Ohio **magazine, January 1923**

<u>Above</u>: caption: "Brooklyn Bridge. Cross-section of Bridge at Middle of River Span. Traffic Conditions as of 1933." This was the roadway configuration from 1898 to 1944.

“…Its upper deck will furnish facilities for vehicular traffic and other surface traffic. The lower deck, when and as desired, can furnish with economy facilities for three other great public needs.

1st – Tracks for rapid transit suburban trains from New Jersey.

2nd – Tracks for passenger trains, other than for commuters, to a union station in Manhattan.

3rd – Tracks for freight delivered direct to Manhattan.

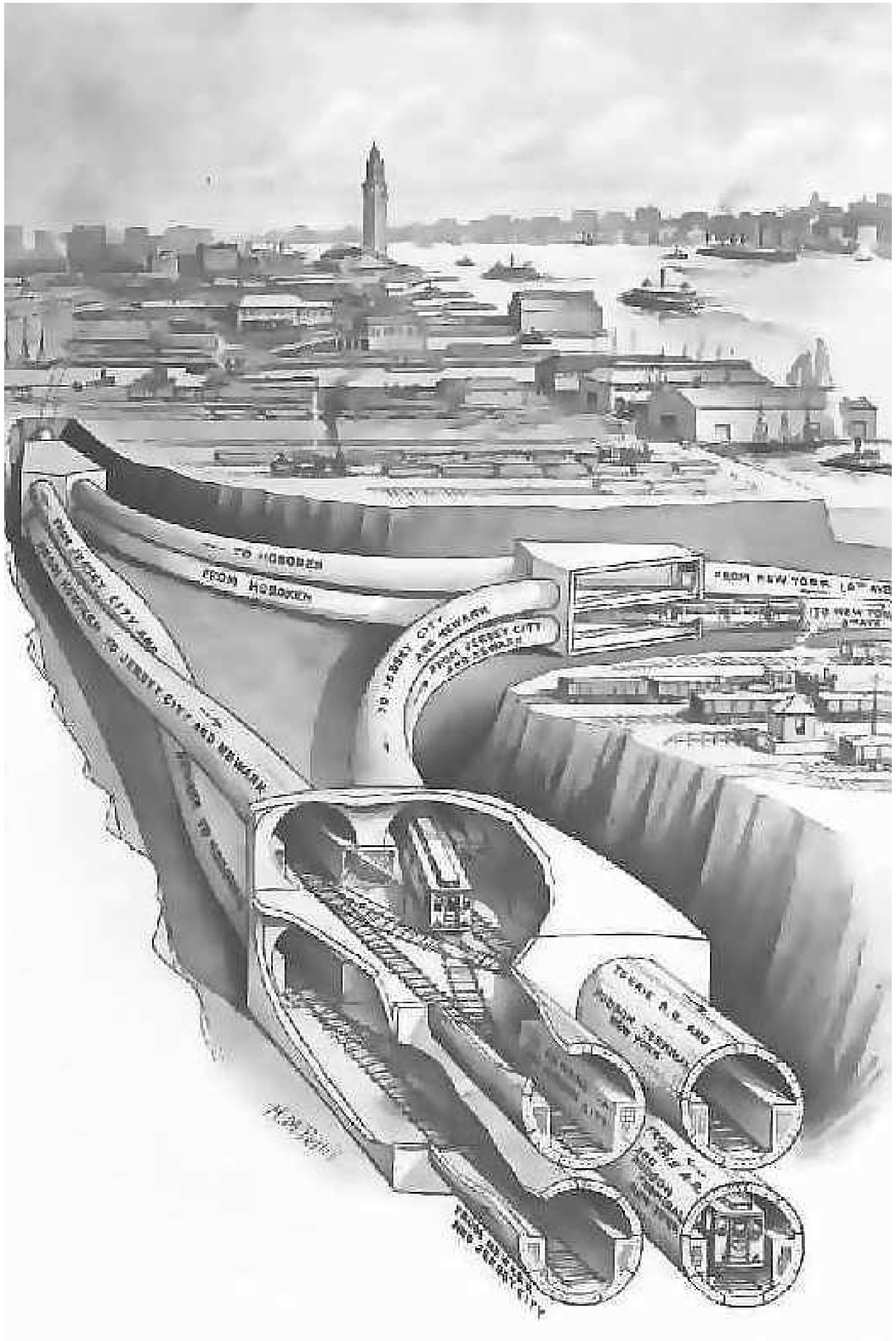
Each or any one of these three facilities can be an independent unit built and maintained and operated as a separate unit as and when economically justified, or a combination of two or all three of the facilities can be worked together with the economies resulting from such a combination…”

Baltimore and Ohio **magazine, January 1923**

“…The surface of the upper deck will be made watertight, so that the whole floor system, in addition to the towers and cables will be protected from the weather. This will result cutting down the cost of repairing (always a heavy part of the maintenance costs of a bridge) to a minimum. In fact fifteen percent only of the steelwork of the Hudson River Bridge will be exposed…”

***Popular Science,* April 1921**

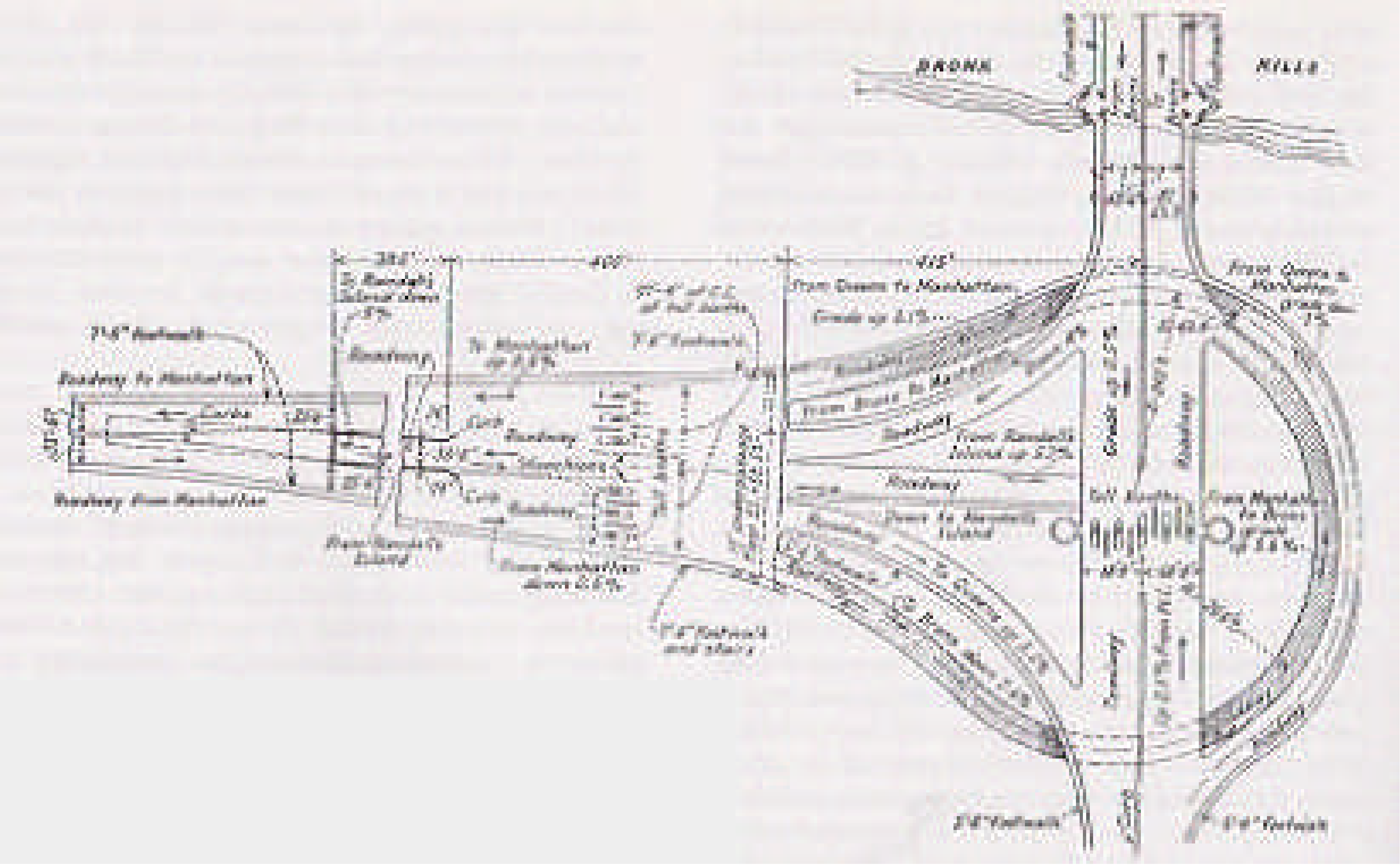
Surface Traffic



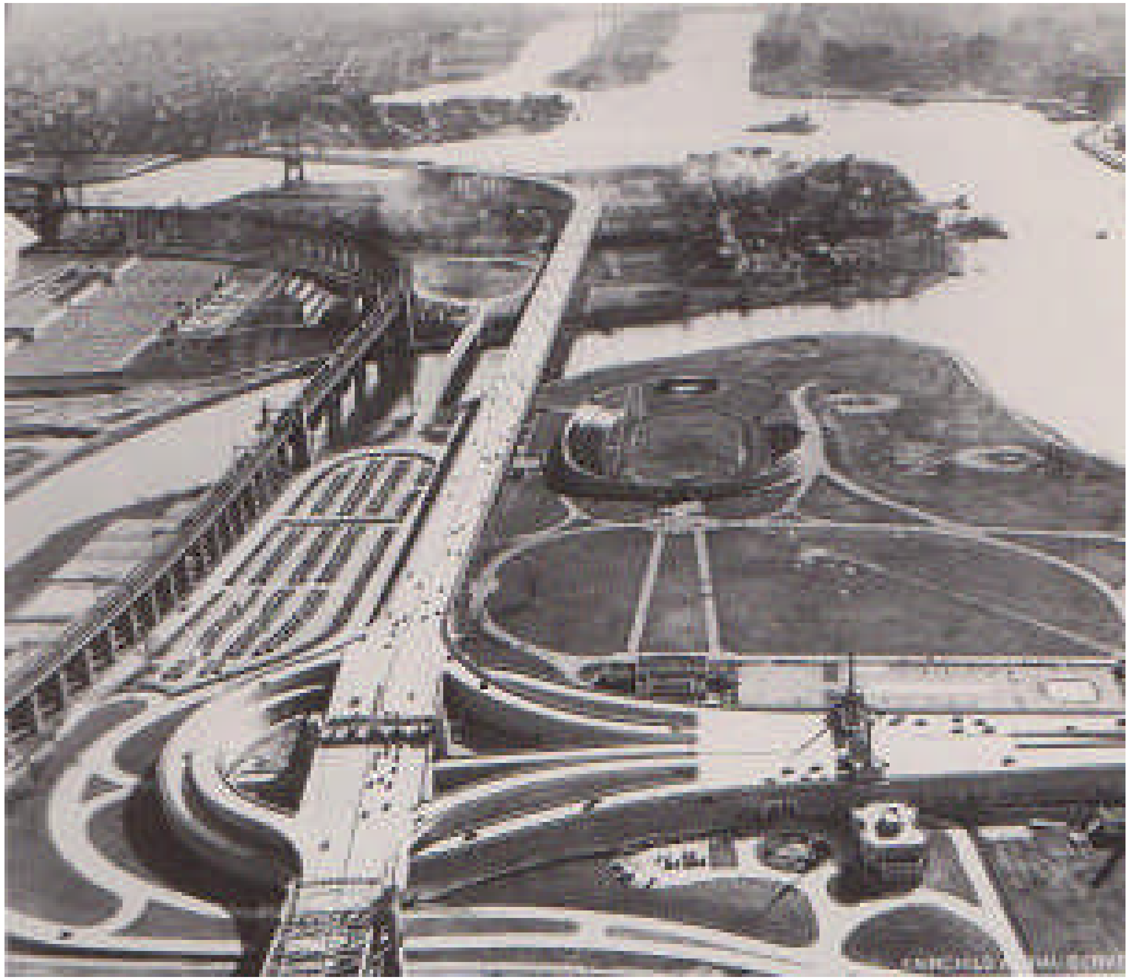
"…In taking care of vehicular and other traffic of the upper deck, the plan of approaches on either side of the bridge has been as carefully worked out as the busiest railroad junction. They provide that the tremendous traffic can be distributed into the street system on either side without causing congestion. The combined area into which the bridge pours its traffic is several times the width of the roadway on the bridge, with its sixteen lines of traffic, and by the use of flying junctions it is so arranged that the combined vehicular and surface traffic is delivered into the stream of street traffic on the proper side of the street for traffic moving in the same direction, and all traffic entering the bridge can do so without crossing at grade opposing traffic on the streets or the opposing streams of traffic leaving the bridge…"

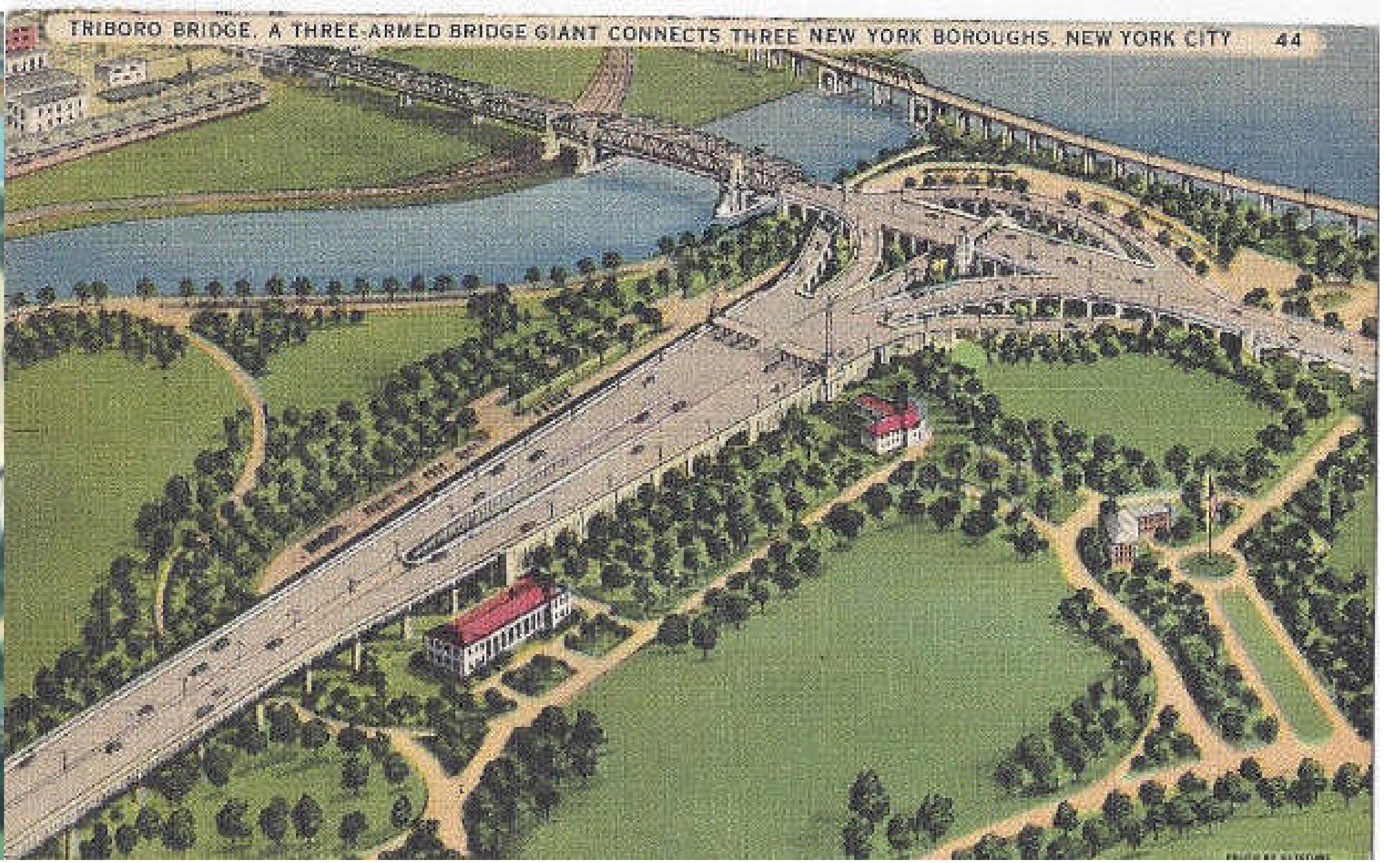
Baltimore and Ohio **magazine, January 1923**

Left: caption: "Double-decked Flying Junction: Just leaving the river tunnel and entering under Jersey City, a tube train from the east (Manhattan) is about to start heading southwards towards the second complicated flying junction between Erie / Exchange Place / Grove Street."



<u>Above</u>: caption: "The elevated three-way intersection of the triborough viaduct on Randall's Island was regarded as an engineering marvel in 1935. It is complicated by additional connections to the island and by the toll collecting facility"




TRIBORO BRIDGE, A THREE-ARMED BRIDGE GIANT CONNECTS THREE NEW YORK BOROUGHS, NEW YORK CITY
44

Rapid Transit

“…The plans for suburban trains from New Jersey have not yet been definitely worked out to a conclusion on account of the constantly changing status of rapid transit service in Manhattan. Suburban service has not been considered profitable and has few financial friends but it is a necessity of the Metropolitan life and it is inconceivable that an opportunity for the use of such an efficient and comfortable entrance into Manhattan will not have proper distributing means available. It has great possibilities of daily service to many people and our preliminary study is to collect a portion of the commuters from all the New Jersey railroads and distribute them into Manhattan from an elevated structure along West Street reaching from 57th to Cortland Street and also into such existing subways as have capacity available…”

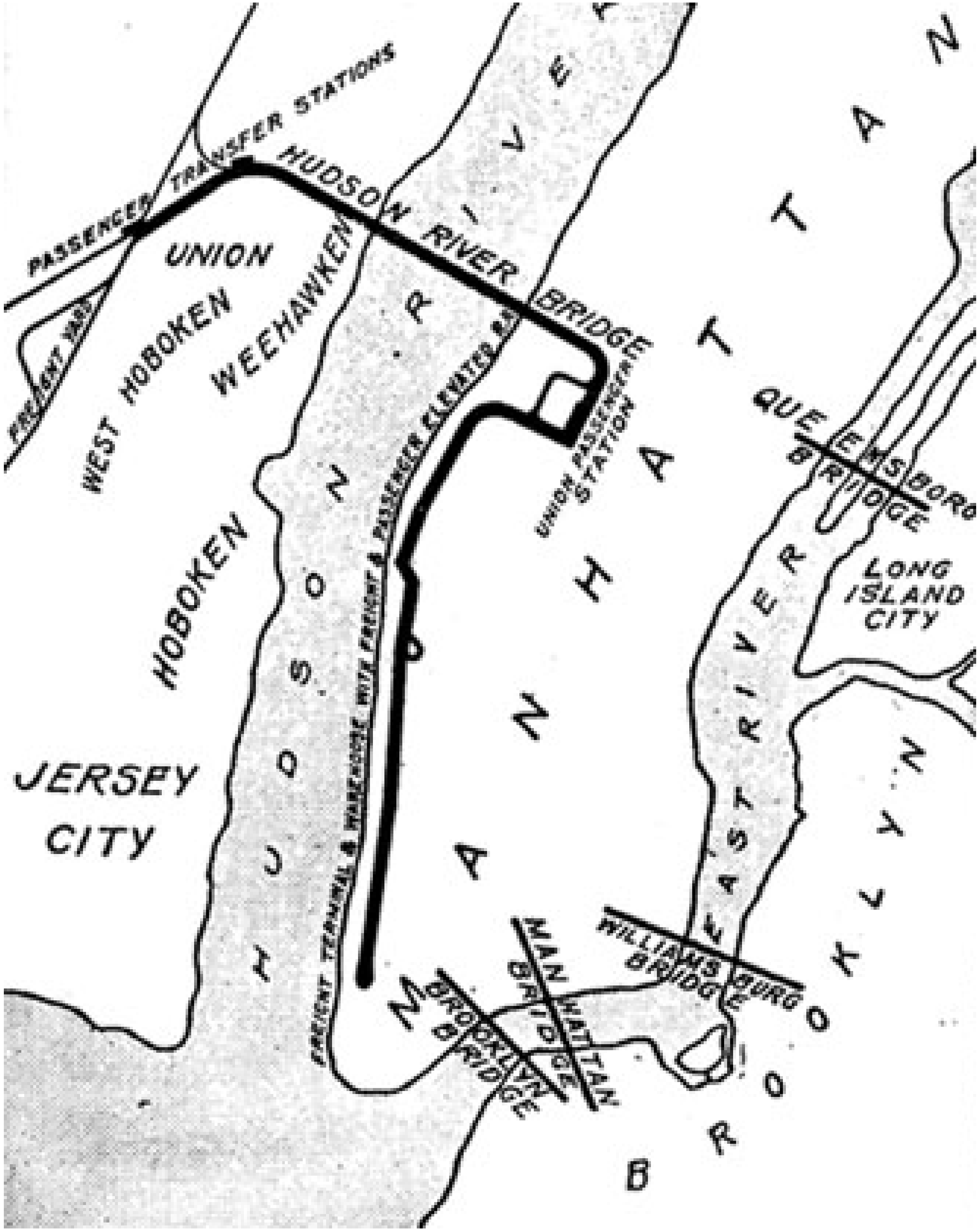
***Baltimore and Ohio* magazine, January 1923**

Union Station

“…The proposed Union Station is of the through station type, in which for the same trackage the train capacity is several times larger than for a stub station type. The tracks are under the street level and pass around a loop through the Union Station near 9th Avenue back to the bridge. It is expected to use the four tracks on the bridge to the station, normally, two in and two out or three in one direction and one in the other as desired…The station is designed to be modern and efficient and is planned with a very large capacity and is intended to serve all the railroads of New Jersey which may desire to give their passengers such service…it is also proposed to build above ground office buildings, hotels, etc., on the real estate acquired for the station and its approaches, so that the undertaking may benefit financially…due to the change in conditions brought about by the construction of the bridge and these particular facilities…”

Baltimore and Ohio **magazine, January 1923**

Freight Terminals

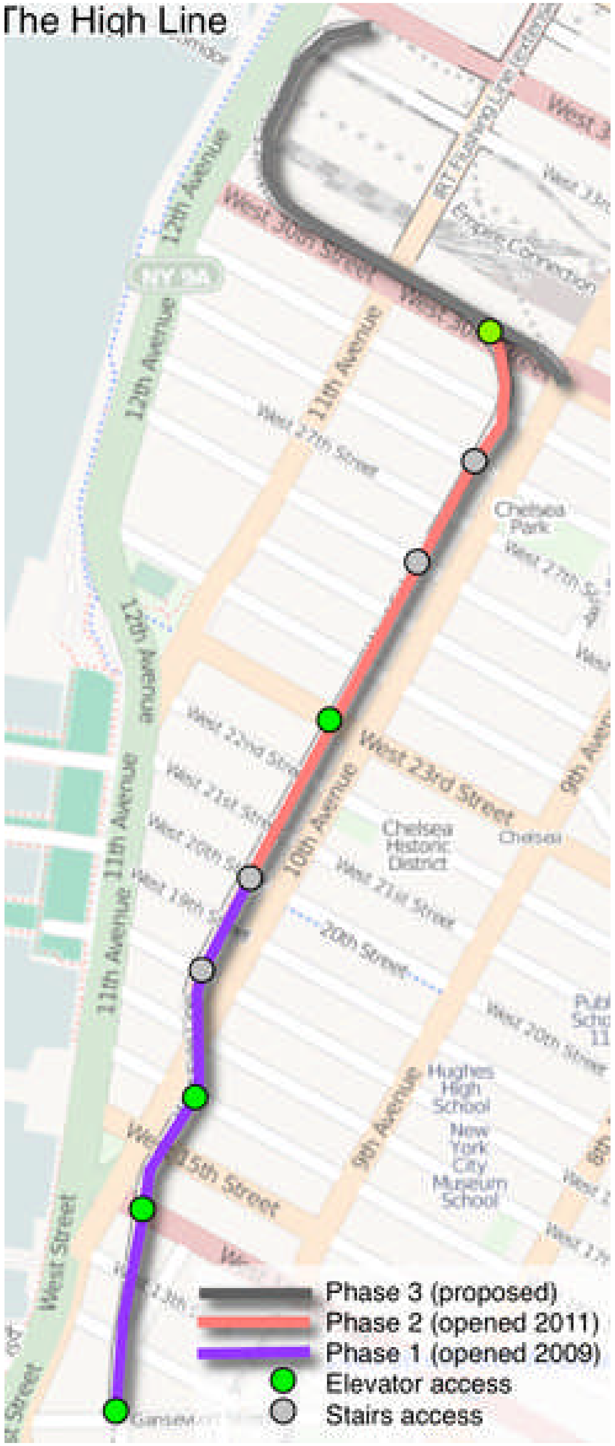


"…The freight terminal proposed in Manhattan consists of an elevated freight railroad located on blocks, lying on the east side of West Street from 46th Street to Cortland Street. These elevated running tracks are encased in an almost continuous building, extending from 42nd Street to Cortland Street, the building being 200 feet wide and five or more stories high and the cross town streets uninterruptedly through the building…"

***Baltimore and Ohio* magazine, January 1923**

Left: caption: "Map of proposed Hudson River Bridge showing Union Station & RR lines"

In 1847, the *City of New York* authorized street-level railroad tracks down Manhattan's *West Side*. For safety, the railroads hired men to ride horses and wave flags in front of the trains (a.k.a. the "West Side Cowboys"). Even so, many accidents occurred between freight trains and other traffic and *10th Avenue* became known as "Death Avenue." In 1929, the *City* and the *State* of *New York* and the *New York Central Railroad* agreed on the *West Side Improvement Project*, which included the *High Line*. The 13-mile project eliminated 105 street-level railroad crossings and added 32 acres to *Riverside Park*. It cost over $150 million. The High Line opened to trains in 1934. It originally ran from *34th Street* to *St. John's Park Terminal*, at *Spring Street*. It was designed to go through the center of blocks, rather than over the avenue, to avoid the drawbacks of elevated trains. It connected directly to factories and warehouses, allowing trains to roll right inside buildings (left T&B). The growth of interstate trucking in the 1950s led to a drop in rail traffic throughout the nation. In the 1960s, the southernmost section of the line was demolished.



In the mid-1980s, a group of property owners with land under the line lobbied for the demolition of the entire structure. In the 1990s, as the line lay unused and in disrepair (despite the fact that the riveted steel elevated structure was basically sound) it became known to a few urban explorers and local residents for the tough, drought-tolerant wild grasses, shrubs, and rugged trees such as sumac that had sprung up in the gravel along the abandoned railway. It was slated for demolition under the administration of then *New York City* Mayor *Rudolph Giuliani*. In 1999, the non-profit *Friends of the High Line* was formed. They advocated for the Line's preservation and reuse as public open space, an elevated park or greenway (similar to the *Promenade Plantée* in *Paris*). Expanding community support of public redevelopment for the High Line for pedestrian use grew and in 2004, the NYC government committed $50 million to establish the proposed park. The southernmost section (from *Gansevoort Street* to *20th Street*) opened as a city park on June 8th 2009. On June 7th 2011, the second High Line section from 20th Street to *30th Street.* The northernmost section (from 30th to *34th Street/s*) is owned by *CSX Transportation*, which in 2011 agreed in principle to donate the section to the city. The *Related Companies*, which own the development rights to the *West Side Rail Yards*, agreed not to tear down the spur that crosses *10th Avenue*.


FROM BLOC
YOU BELONG
LEATHER, TO

America’s Metropolis

“…The suggested system of financing the whole enterprise does away with the necessity of delaying traffic to collect tolls. Automobiles would have an easy access to Manhattan from New Jersey, and by making use of the present East River bridges would have a direct passage to Long Island. No less than eighteen tunnels under the North River would be required to accommodate the traffic which would pass over this single great bridge, and the cost of that number of tunnels would be at least two-thirds greater than the cost of the bridge…”

***Popular Science,* December 1920**

"…Figures of cost have been avoided as they are confusing except to an expert…To the believer in Americanism, it is clear that the public is entitled to health, comfort and happiness in the consideration of any economic question…To the student of political economy, the expenditures involved are proper for this day and generation as they are primarily for the creation and improvement of permanent property for the production of direct service to the people for their material welfare…when the bridge has been built the historian will record that in no other place in the world could the facilities it affords have possibilities of beneficially affecting the lives of so many people. Yet America's metropolis is even now so great in population and industry and its future so assured that its need for such facilities will continue to be unprecedented…"

Baltimore and Ohio **magazine, January 1923**

In Round Figures

“…The estimated cost of the bridge itself in round figures is 100 million dollars; the freight classification yard in New Jersey, 25 million dollars; the Union passenger station, accommodating the trains of all the roads that come in from the west and north, 30 million dollars; the double-deck elevated railroad down West Street to the Battery, 30 million dollars. The cost of the electrification and the equipment of the whole system is set down at 25 million dollars, making a total cost of 210 million dollars for the whole scheme…”

***Popular Science,* April 1921**

“…The yearly traffic across the Hudson River in round figures for the year 1920 was as follows: Passengers, 200 million; draft vehicles, 10 million; freight; coal, 12 million tons, miscellaneous freight, 8 million tons. The present rate of increase indicates that by 1930, or about two years after the bridge is completed, the total traffic across the river will be 250 million passengers, 22 million vehicles and 25 million tons of freight: and it is estimated that of this total, something over one-half will be diverted to the bridge…”

Popular Science, **April 1921**

The Vision of Thirty Years

“…But how is the money to be raised for such an enterprise? That is the question that has been the chief concern during the thirty years since the idea was realized to be a mechanical possibility. Mr. Lindnethal’s scheme is as unique as it is feasible. It overcomes what he considers to be the greatest obstacle in the way of accomplishing the actual building of the huge suspended roadway across the river. ‘The communities on each side can pay their share in the form of yearly rentals,’ says Mr. Lindenthal; ‘so also can the railroads. The respective shares can be adequately determined to cover operation, interest, cost of maintenance, and taxes.’ A separate terminal organization would act as agent and trustee for the Federal Government, while private capital, realizing the advantages to be conferred, can be relied upon to come forward with the required funds for building, equipping, and operating the vast project. Cooperation between the railroads, the City of New York, and the communities on the New Jersey side, and the Federal Government, will assure this method of bringing to life the vision of thirty years.”

***Popular Science*, December 1920**

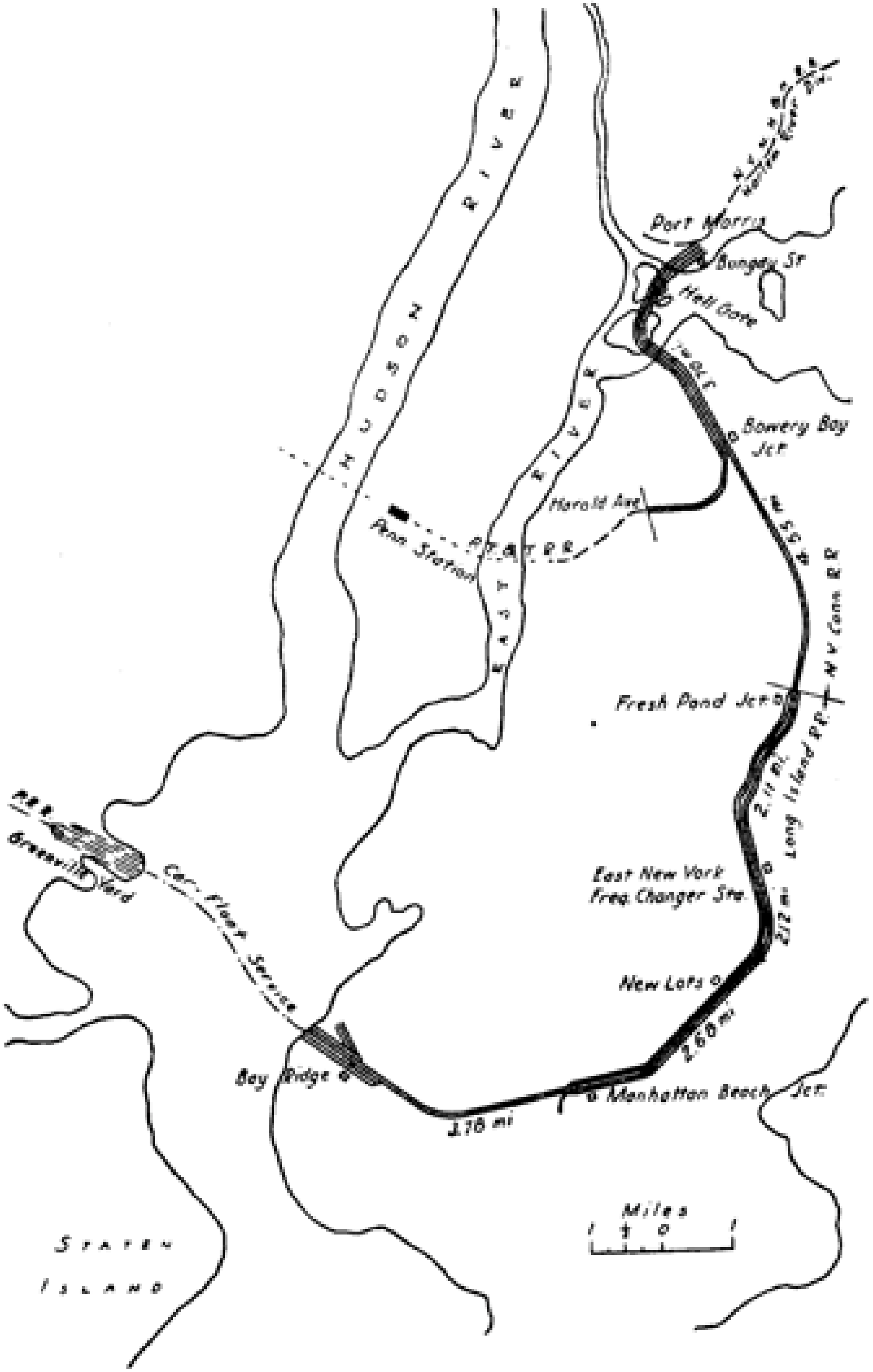
‘The art of bridge building is ancient, as old as mankind itself, perhaps even older; the science of bridge building is modern…Nowadays bridges are not built on faith…not another field of applied mechanics where results can be predicted with so much precision as in bridges of iron and steel”

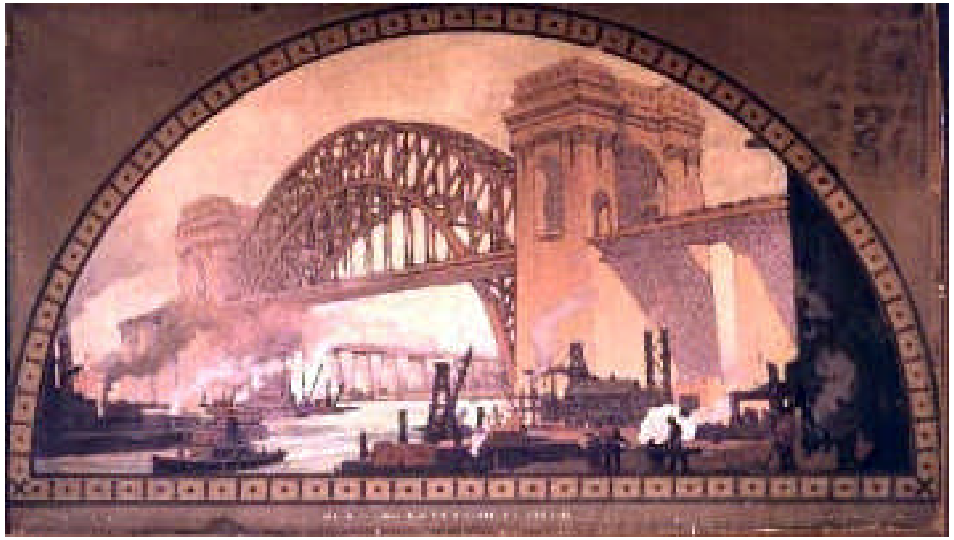
Gustav Lindenthal

Part 5

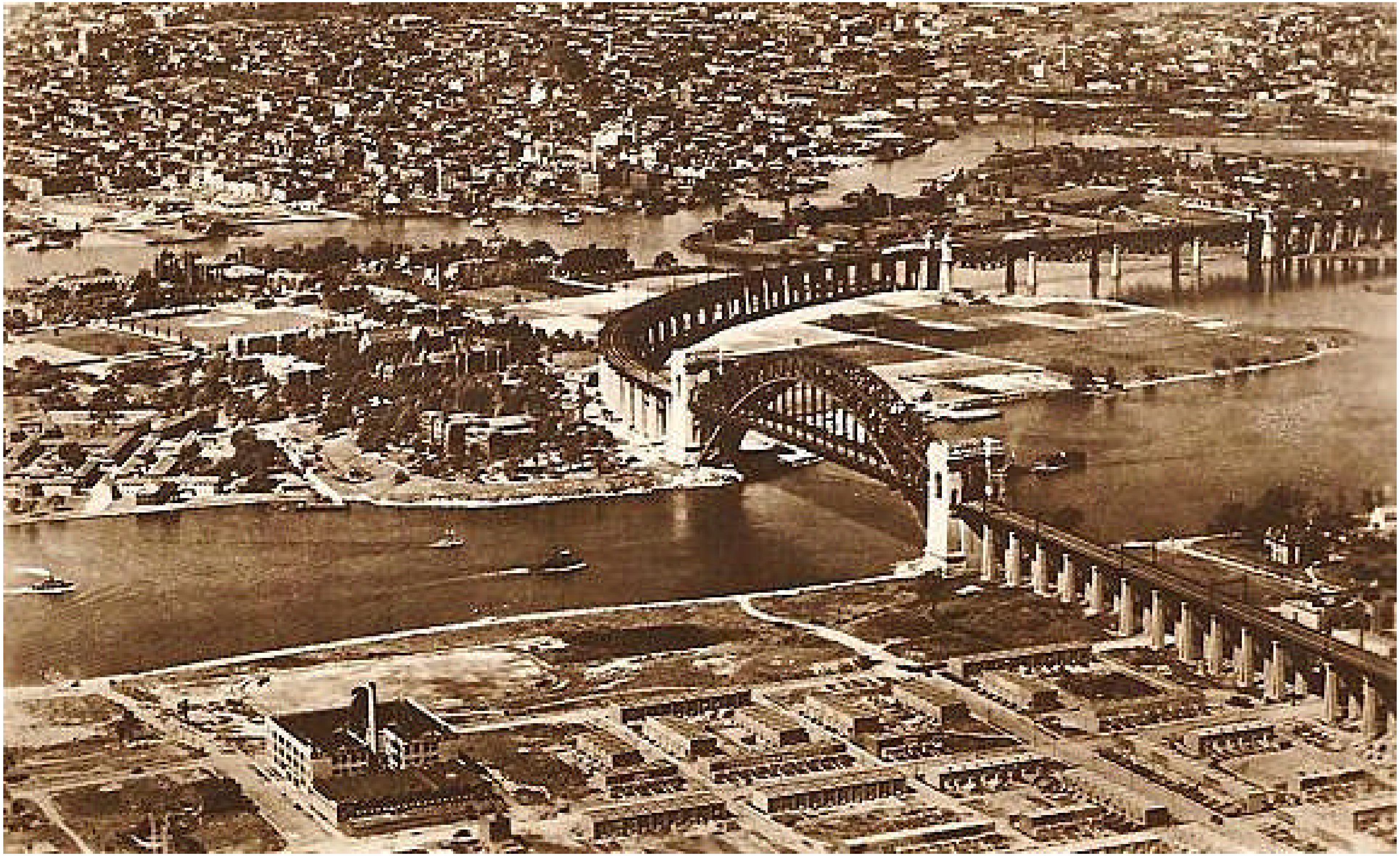
May the Best Bridge Win

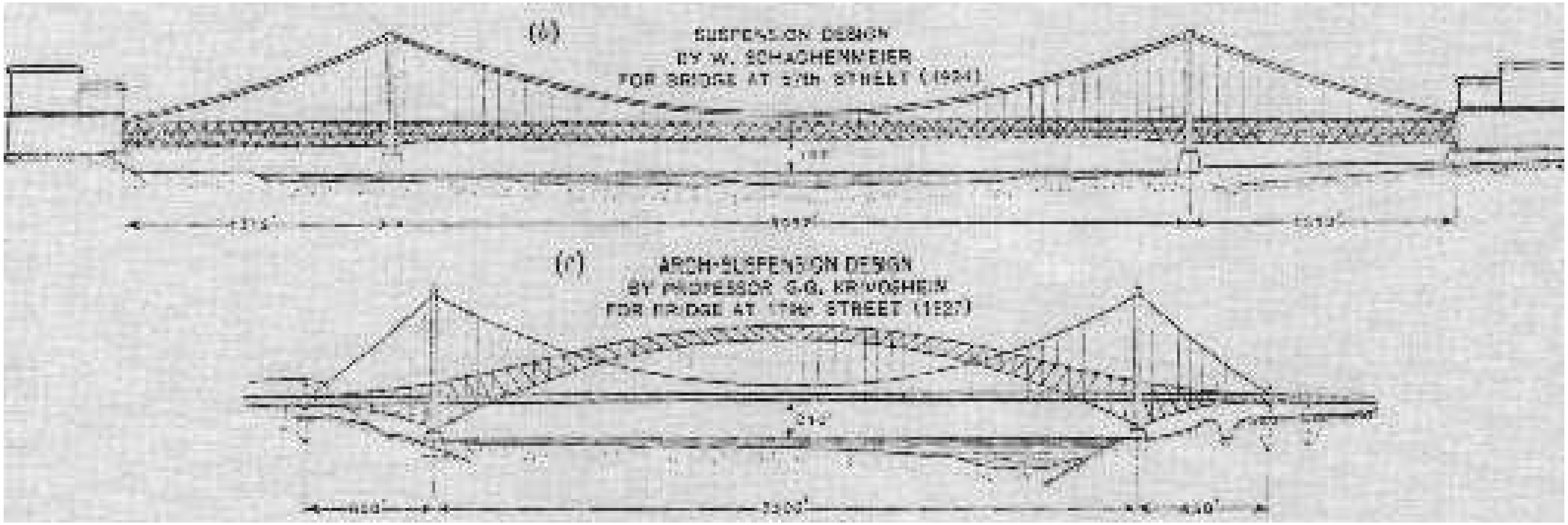
What Dreams May Come





Gustav Lindenthal's dream of constructing a *Hudson River* bridge from midtown *Manhattan* to *New Jersey* was designed to connect rail lines in New Jersey with those in *New York City* and *New England*. Part of this rail link was completed in 1917, when his *Hell Gate Arch* (above) – a component of a larger scheme known as the *New York Connecting Railroad* (left), opened for business.





<u>Top (b)</u>: caption: “Suspension design by W. Schachenmeier for a bridge at West 57th Street (1924). The design featured a 3,937-foot-long main span, two 1,312-foot-long side spans, and a clearance of 164 feet.”

<u>Bottom (c)</u>: caption: “Arch-suspension design by G.G. Krivoshein for a bridge at West 179th Street (1927). The design featured a 3,500-foot-long main span, two 650-foot-long side spans, and a clearance of 210 feet.”

“…Through all of this, Lindenthal’s dream for a span over the Hudson continued. But what was grand in 1888 had, through decades of deferment, become fantastical. By 1923, Lindenthal’s plan called for a bridge more than 200 feet wide, with two decks, one for 12 railroad tracks, the other for 20 vehicle lanes, including two for trolleys. Its massive concrete towers, at 825 feet high, would rise above even the ten-year-old Woolworth Building, then the world’s tallest skyscraper. The price: at least a cool $200 million (nearly two billion in today's dollars). Ammann deferentially warned Lindenthal that such a costly project would never be realized. But the old master sharply rebuked his assistant…”

Smithsonian **magazine, October 1999**

“G.L. rebuked me for my ‘timidity’ and ‘shortsightedness’ in not looking ahead for 1,000 years”

O.H. Ammann

RE: with opposition to the North River Bridge Company’s scheme growing, Lindenthal withdrew into a world of militant self-assurance. During WWI, without any engineering work available, Ammann took a position as manager of a clay mine in *South Amboy, N.J*. of which Lindenthal and future *New Jersey* Governor *George Silzer* were stockholders (Lindenthal recommended him). The mine was losing money but Ammann turned the situation around, impressing Silzer greatly. After three years, he resigned his industrial management position for the *Just Such Clay Company* in 1920 with the long-desired intention of returning with his family to his native *Switzerland* for a position with the *Swiss Federal Railway De-partment*. Lindenthal persuaded Ammann, albeit reluctantly, to return to his office to work on the *Hudson River* bridge project in early 1921. Ammann – and others in Lindenthal’s office, were awakening to the fact that the course set by their captain would lead them all to disastrous ruin.

"…In order for you to understand my situation for many months, in fact for the whole year, I will no longer conceal from you that the giant project for which I have been sacrificing time and money for the past three years, today lies in ruin. In vain I as well as others have been fighting against the unlimited ambition of a genius that is obsessed with illusions of grandeur. He has the power in his hands and refuses to bring moderation into his gigantic plan. Instead, his illusions lead him to enlarge his plans more and more, until he has reached the unheard of sum of half a billion dollars – an impossibility even in America…"

O.H. Ammann

RE: excerpt from a letter to his mother in *Switzerland* dated December 14th 1923. Forty-five years old, on March 21st 1923, Ammann left the employ of *Gustav Lindenthal* and set up an office in a loft building at *470 Fourth Avenue*, NYC. It was there – among spools of cloth, that he developed his own plan to bridge the *Hudson River*.

Dreamer in Steel

A protege to Lindenthal, *Othmar Ammann*, opposed his mentor’s ideas concerning a *Hudson River* bridge. Ammann argued that the Lindenthal plan would require expensive approaches in already congested midtown *Manhattan*, which would be politically controversial to say the least. As well, many midtown businessmen were opposed to Lindenthal’s grand scheme. Instead, Ammann pushed for a Hudson River bridge between *179th Street* in upper Manhattan and *Fort Lee, New Jersey* (above), which would accommodate both motor vehicles and light rail. The location of the bridge would be at high points in Manhattan and New Jersey, allowing enough clearance for tall ships without extensive approaches. Furthermore, the location was at a relatively narrow point on the lower Hudson River, simplifying construction greatly. Ammann believed that the crossing would be an easier political sell since it would require neither the approval of influential business leaders in midtown Manhattan nor the necessity of persuading railroads to use the bridge.

"…Slight in stature, with a quiet demeanor that hid a steely core, Othmar Ammann seemed the opposite of the large, bluff, practically educated Lindenthal. Ammann's degree, unlike any that Lindenthal might occasionally claim, was from a Swiss institute of technology considered one of the most prestigious in the world. Ammann was impressed by his mentor, one of the world's pre-eminent bridge builders - and the favor was returned…"

***Smithsonian* magazine, October 1999**

<u>Left</u>: *Othmar H. Ammann* - ca. 1904, the year he arrived in *America* to participate in the design of long span bridges

“My first serious interest in the problem of bridging the Hudson was awakened shortly after my arrival in New York on a visit to the top of the Palisades Cliffs from where I obtained a splendid view of the majestic river. For the first time I could envisage the bold undertaking, the spanning of the broad waterway with a with a single leap of 3,000 feet from shore to shore, nearly twice the longest span in existence. This visit came at that time as near to a dream to see the ambitious effort materialized. Nevertheless, for a young engineer it was a thrill to contemplate its possibility, and from that moment as my interest in great bridges grew, I followed all developments with respect to the bridging of the Hudson River with keenest interest.”

O.H. Ammann

There’s No Substitute for Experience

“Get all the experience you can…Learn from those who mastered your trade or profession before you, I have known many ambitious young men to fret themselves and waste their energies early in life because they could not achieve at once great things, for which, as a matter of fact, they were not prepared…It is true of other career’s as it is of the engineer’s – the first thing a man must decide is whether or not he has the ability to follow the calling he has chosen. Once convinced of this, it is a matter of hard work and experience; if the experience you need isn’t thrown your way, you must move heaven and earth to get it…Let me put it another way: study the career of any man of real achievement and you will almost certainly find that this is true: from the very start he was not only willing but eager to profit by the experience of others, How true it is that there is nothing absolutely new under the sun! However great a man’s achievement may be, it rests, in the final analysis, not upon radical departures from the experience of those who went before him, but upon the way in which he adapts their experience to his own purpose.”
O.H. Ammann

“…It took Ammann less than two weeks to find his first position in New York, where he was hired by the office of Joseph Mayer, a consulting engineer…During his brief tenure with Mayer, he had worked on no fewer than thirty steel bridges and watched with fascination as a team in the office developed the design for a Hudson River crossing at New York City…Ammann’s second position in America took him to Harrisburg, Pennsylvania. Here he joined a staff of one hundred engineers who supported the Pennsylvania Steel Company’s five-thousand man bridge-building division…The Pennsylvania Steel Company quickly took note of this intense, soft-spoken foreigner…With each resignation, Ammann was given assurances that a job was waiting for him if he chose to return…”

***Darl Rastorfer*, Author**

“…In the summer of 1905, Ammann took a one-month leave from his job and traveled to Zurich, where he and Lilly were married…seven months later they were expecting their first child. During the first months of Lilly’s pregnancy, Ammann resigned his position at Pennsylvania Steel, and the couple spent March through August moving three times for three different jobs, in a race to cover as much professional ground as possible…The first move was to Pittsburgh, where the engineer briefly worked with McClintoc-Marshall…Two months later, however, he resigned, and the Ammanns moved to Chicago so he could take a job with Ralph Modjeski…The Ammanns returned to Harrisburg in late 1906, a month before the birth of their first son, Werner…Ammann was named one of three first engineers for Pennsylvania Steel…”

Darl Rastorfer, **Author**

“…At the time, there were only a handful of acknowledged experts in long-span steel structures. Ammann had already worked with two: Mayer in New York and Modjeski in Chicago. Within a year of being reestablished in Harrisburg, he began a professional association with a third: Frederick C. Kunz of Philadelphia…Kunz took an immediate liking to the young engineer and soon made a pitch for Ammann to leave his position in Harrisburg and join Kunz and his partner, Charles C. Schneider, in their Philadelphia-based practice…Ammann eventually yielded to Kunz’s offers, but two years elapsed before he made the move. In the interim, he kept his position with the Pennsylvania Steel Company and spent evenings and weekends assisting Kunz…”

Darl Rastorfer, **Author**

“…Ammann wanted the challenge of assisting with the high-profile projects going through the Kunz & Schneider office. So in May 1909 he and his family packed their bags and moved from Harrisburg to a rented house on the outskirts of Philadelphia. There, Ammann set up a home office and became a full-time consulting engineer to Kunz & Schneider…”

***Darl Rastorfer*, Author**

"…it never occurred to Ammann and his wife that they would make the situation permanent. Their long range plan had always been to return to Europe. With that in mind, Ammann maintained close contacts with former teachers, classmates, and employers, periodically arranging opportunities for work in Germany or Switzerland. On several occasions a move was planned but then forestalled in favor of a more seductive possibility in America. The pressure to leave mounted when a second son, George Andrew ('Andy'), was born…They were keen to have their children educated in Switzerland, and Werner was now old enough to enter Kindergarten. So at the close of 1911, the engineer made a determined effort to tie off loose ends with Kunz & Schneider. The family hoped to leave the States in late spring, but the departure was again postponed when another leading American master of long-span design, Gustav Lindenthal, offered Ammann an irresistible job in New York…"

***Darl Rastorfer*, Author**

Call of Duty

“…On August 1…it was announced that the German army had taken position on the banks of the Rhone River across from Basel, World War I was about to grip Europe. Ammann was still a citizen of Switzerland and a reserve officer in its army. His eldest son, parents, and a brother were currently living in Basel. Patriotism and a concern for family and friends stirred him to immediate action. Ammann booked transatlantic passage before receiving written notice to report for active duty. He left for Switzerland on the morning of August 6, along with two other Swiss engineers who were working in New York…Lindenthal was not pleased with Ammann’s abrupt departure. The ever meticulous and thoroughly capable assistant had kept the Hell Gate project running smoothly and on schedule…”

***Darl Rastorfer*, Author**

The Ammann Touch

"…In Ammann's absence. Lindenthal promoted David B. Steinman to the position of first assistant…Outstanding in his own way, Steinman did not have the Ammann touch, and Lindenthal was soon leveraging his personal influence with the Ammann family. He appealed to Lilly and urged her to pressure her husband into suspending his stint of active military duty – Lindenthal was willing to pay whatever was necessary to secure his early discharge. As it happened, war did not erupt on the Swiss border and Ammann was released from service after three months. Werner returned to America with his father, and the family was reunited in New York on December 11, 1914…"

***Darl Rastorfer*, Author**

"…Lindenthal immediately reinstalled Ammann as first assistant. It is unclear whether an unhealthy competitive tension existed between Steinman and Ammann before the leave of absence. What is certain is that upon Ammann's return – and Steinman's subsequent demotion – a bitter rivalry took hold that would last throughout their careers…It was widely known that the mention of Steinman's name was strictly forbidden in the Ammann household…"

Darl Rastorfer, **Author**

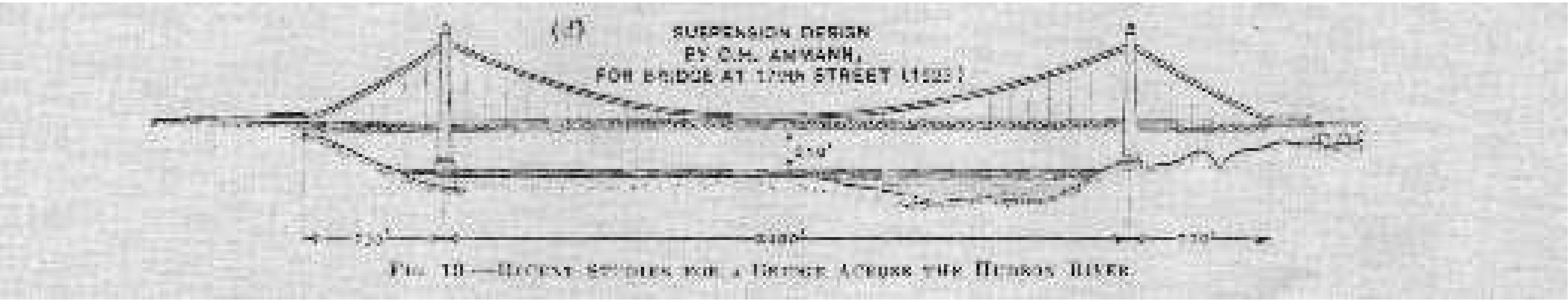
Left: Dr. David Steinman on the cable stays of the *Brooklyn Bridge* during its reconfiguration (1944-54). He grew up nearby - on the *Lower East Side*, rising to become one of the greatest bridge engineers of the *20th Century*.

On a More Moderate Scale

"…However, I have gained a rich experience and have decided to build anew on the ruins with fresh hopes and courage – and, at that, on my own initiative and with my own plans, on a more moderate scale. It is a hard battle that I have already been fighting for six months now, but the possibility of success is constantly increasing, so that I do not allow myself to be frightened in spite of the great hardships and my shrinking finances. I wait and hope that the New Year will finally bring my work to fruition."

O.H. Ammann

RE: excerpt from a letter to his mother in *Switzerland* dated December 14th 1923. Facing internal opposition while working for Lindenthal, Ammann struck out on his own, joining forces with newly elected Governor *George Silzer* of *New Jersey* (who knew him, and his abilities, well from the days when Ammann successfully managed the failing clay mine). Ammann officially unveiled his proposal on February 19th 1924 at a meeting of the *Connecticut Society of Engineers*.



“…Working on his own, Ammann had developed another scheme. Quietly, he wrote to the governor of New Jersey with suggestions for a smaller, cheaper suspension bridge to be built across the Hudson at 179th Street. The newly formed Port of New York Authority, which enjoyed both states’ cooperation and had a short time before rejected Lindenthal’s expensive monstrosity, was immediately interested - to Lindenthal’s understandable dismay…”

Smithsonian **magazine, October 1999**

Above: caption: “Suspension design by Othmar Ammann for a bridge at West 179th Street (1923). The design featured a 3,400-foot-long main span, two 700-foot-long side spans, and a clearance of 210 feet. With some modifications, this was the design adopted for the George Washington Bridge.”

“Mr. Ammann has been my trusted assistant and friend for ten years, trained up in my office and acquainted with all my papers and methods. But I know his limitations. He never was necessary or indispensable to me…Now it appears that Ammann used his position of trust, the knowledge acquired in my service and the data and records in my office, to compete with me in plans for a bridge over the Hudson and to discredit my work on which I had employed him. He does not seem to see that his action is unethical and dishonorable.”

Gustav Lindenthal

RE: excerpt from a letter to Governor Silzer of *New Jersey* (in response to his request that Lindenthal review a copy of Ammann’s prospectus). It was the discreet backing and encouragement from Silzer that had prompted Ammann to break from Lindenthal and pursue his own design. A Wilsonian Democrat elected Governor in 1923 previously, as a state senator, Silzer had backed the North River Bridge Company’s plans in the past, but as Governor he discontinued that support in favor of Ammann’s more practical scheme. In favor of large public works projects, Silzer needed to appease the Republican dominated legislature. Lindenthal’s scheme held no particular benefit for Republicans whereas Ammann’s bridge would connect to rural *Bergen County* – a Republican stronghold, and open it for development. Prior to his public announcement endorsing the Ammann proposal, Silzer sought to appease Lindenthal - his long-time friend and colleague, by asking him to review Ammann’s proposal.

“I estimate an engineer one-third by his character, one-third by his ability, and one-third by his experience”

Gustav Lindenthal

Eminently Doable

“…By the degree to which Lindenthal’s scheme seemed over-ambitious and overblown, Ammann’s seemed disarmingly restrained and eminently doable. The younger engineer’s proposal emphasized vehicular traffic, envisioning a wide roadway that would accommodate eight lanes of traffic and two pedestrian walkways on the upper deck, and four light rail lines on a lower deck that would be constructed in the future when capacity was reached on the original deck. The estimated price tag was a modest $40 million (the estimate for Lindenthal’s structure had grown by this time to $500 million); and, with a location at the northern end of Manhattan connecting with a sparsely populated section of Bergen County, New Jersey, Ammann’s site avoided the pitfalls of developing approaches and anchorages on land where real estate prices – and emotions – ran high…”

Darl Rastorfer, **Author**

“…By 1925, Ammann was bridge engineer for the Port Authority, charged with designing not only the 179th Street bridge (then known as the Hudson River Bridge) but also a bridge between Staten Island and New Jersey - both mainly for cars. Construction of the Hudson bridge began in the fall of 1927, with more than 100,000 miles of cable wire strung across the river by John Roebling’s company. By any standard, the bridge was monumental. With a 3,500-foot main span - nearly twice that of the next largest suspension bridge, built just two years before - its slender deck was to arch gracefully more than 200 feet above the Hudson. Its twin 604-foot towers would stand nearly 50 feet taller than the Washington Monument. And each of its four cables could support more than 90,000 tons - ten times more than each Brooklyn Bridge cable. For his design, Ammann owed as much to material advances since that 1883 wonder as he did to his own ingenuity. Improved steel ensured that when drawn to only 0.196 inch in diameter, each of the 26,474 wires that made one cable had a strength of at least 240,000 pounds per square inch - more than one and a half times that of the cable wires in the Brooklyn Bridge. And better machinery allowed the wires to be hung from the towers (a process called spinning) sixteen times faster than in 1883…”

Smithsonian **magazine, October 1999**

RE: the new bi-state *Port of New York Authority* had given lukewarm reception to motor vehicle projects, but thanks to the persuasiveness of Ammann and Silzer, there was enough support on both sides of the Hudson to construct the proposed bridge. In 1925, the Port Authority agreed to take responsibility for constructing the bridge, and employed Ammann as Master Bridge Designer and Chief Engineer. *Cass Gilbert*, the designer of the *Woolworth Building*, would consult on the bridge’s architectural treatment.

Soon after the *Port of New York Authority* announced the *Hudson River* bridge project in 1925, Ammann commissioned consultants for various designs. Initial plans devised by the Port Authority and the *Regional Plan Association* (RPA) called for a suspension bridge with a 2,700-foot-long main span with piers approximately 400-feet beyond the pier head lines. The final design would include a 3,500-foot-long main span. However, considering the length of the main span, the side spans are relatively short and are of differing length (650-feet on the *New York* side and 610-feet on the *New Jersey* side). In a revolutionary shift from prevailing suspension bridge design conventions, Ammann proposed eliminating the stiffening trusses that had been essential for suspension bridges previously. Instead of using trusses, Ammann (using *deflection theory*) concluded that the deadweight of the bridge deck and the four enormous cables would be sufficiently heavy to resist strong winds, thereby eliminating the need for trusses (each of the 106-foot-long floor beams weighed 66-tons). Even with a single deck only 10-feet deep and a depth-to-span ratio of 1:120, neither heavy traffic nor high winds cause the bridge to sway.

"We wanted to begin with something where we were most likely to succeed, and the smaller enterprise was the better one for the purpose. If we succeeded, the George Washington Bridge would surely come later. And so it did."

Julius Henry Cohen, **Council for the *Port of New York Authority***

RE: *Goethals Bridge* and *Outerbridge Crossing* – simultaneously built as the first project of the Port Authority (later renamed *Port Authority of New York and New Jersey*) and completed in 1928 (both opened on the same day). Neither was profitable until the opening of the *Verrazano Narrows Bridge* and the *Staten Island Expressway,* both in 1964.

Left: NYC bridge crossings (ca. 1937)

“A monument to the foresight, sagacity and vision of Mr. Outerbridge”

***Port of New York Authority,* 1928**

RE: naming of the southern bridge “Outerbridge Crossing,” in honor of *Staten Island* resident, bridge proponent and first chairman of the Port Authority *Eugenius Outerbridge*. He was guest of honor at the opening ceremonies of the bridge on June 20th 1928. The north bridge, first named the *Howland Hook Bridge,* then the *Arthur Kill Bridge,* was renamed “Goethals Bridge” in honor of *George Goethals* – first Chief Engineer of the PA who died shortly before the bridge/s were dedicated.

Keeping Faith

“The U.S. War Department recently had under consideration a plan, submitted by the North River Bridge Company of New York City, to build a railroad and highway suspension bridge across the Hudson River from Fifty-seventh Street in Manhattan to the New Jersey shore. It called for a double-deck structure with a single span of 3,240 feet, to be connected on the New York side with a great union passenger station. The new bridge would accommodate at least 40,000,000 vehicles, 400,000,000 passengers, and 25,000,000 tons of freight per year. Its cost is estimated at about $200,000,000. The designer of this gigantic project, who originated it some thirty-five years ago and has been working for its realization ever since, started his career in this country as a stone mason in the grounds of the Philadelphia Centennial Exposition at $2.50 a day. He is Gustav Lindemthal, who was 79 years old in May and says he expects to cross his beloved Hudson Bridge. In robust health, there seems to be no reason why this expectation should not be fulfilled…”

***Popular Science,* August 1929**

RE: *Gustav Lindenthal* (left) died in 1935

“Failure is only an epitaph for lack of preparation”
Gustav Lindenthal

"…In the relentless Great Depression, the bridge became a sort of savior in steel. Completed six months ahead of schedule, it cost less than the $60 million originally allocated. 'Fulfilling a dream of three-quarters of a century,' ran the ecstatic headline in the New York Times. On October 24, 1931, in front of thousands of spectators, New York governor (and soon to be President) Franklin Roosevelt and New Jersey governor Morgan Larson opened the bridge, newly named in honor of George Washington. In tribute to his mentor, Ammann drove with Gustav Lindenthal onto the bridge that the older man had spent his lifetime fruitlessly dreaming of…"

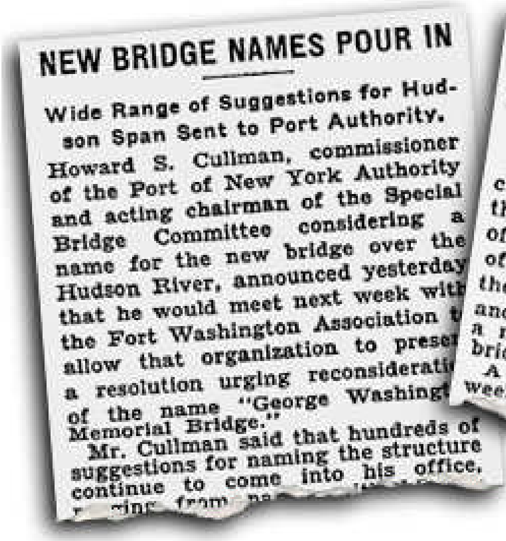
Smithsonian **magazine, October 1999**

Left: October 24th 1931

“In every patriotic sanctuary, there is at least one figure so serenely certain of enduring honor that the scrutiny of centuries can never shake its permanence. In dedicating the George Washington Bridge, we pay tribute not so much to the military triumphs of a great general, not to the attainments of a great executive, but to a more precious heritage. We offer homage to great ideals, exemplified in Washington’s career and stamped indelibly upon our national thought. Out of the wealth of vital principles demonstrated by his deeds, I feel that three are peculiarly significant and especially appropriate to this occasion. They are the worth of integrity, the need for intelligence and the fact of our independence…”

Franklin D. Roosevelt,* Governor of the *State of New York

RE: excerpt from his dedication speech. The six-lane *George Washington Bridge* was completed on October 25th 1931, eight months ahead of schedule, at a cost of $59 million and twelve lives. Officials on both side of the Hudson praised the bridge as the realization of a long-sought dream. More than 30K people witnessed the opening of the bridge and many more listened to the opening ceremonies on the radio. Governor *Franklin Delano Roosevelt* of *New York*, standing alongside Governor *Morgan F. Larson* of *New Jersey*, dedicated the bridge in honor of the first President.



NEW BRIDGE NAMES POUR IN

Wide Range of Suggestions for Hudson Span Sent to Port Authority.

Howard S. Cullman, commissioner of the Port of New York Authority and acting chairman of the Special Bridge Committee considering a name for the new bridge over the Hudson River, announced yesterday that he would meet next week wit the Fort Washington Association t allow that organization to prese a resolution urging reconsiderati of the name "George Washingt Memorial Bridge."

Mr. Cullman said that hundreds of suggestions for naming the structure continue to come into his office,

'CLEVELAND BRIDGE' URGED.

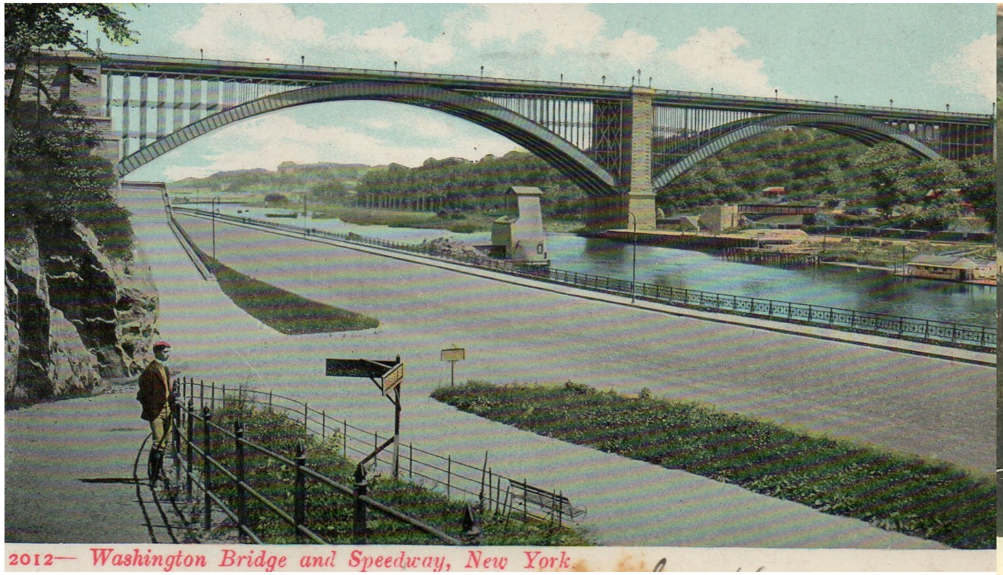
Name of Ex-President Proposed for New Hudson Span.

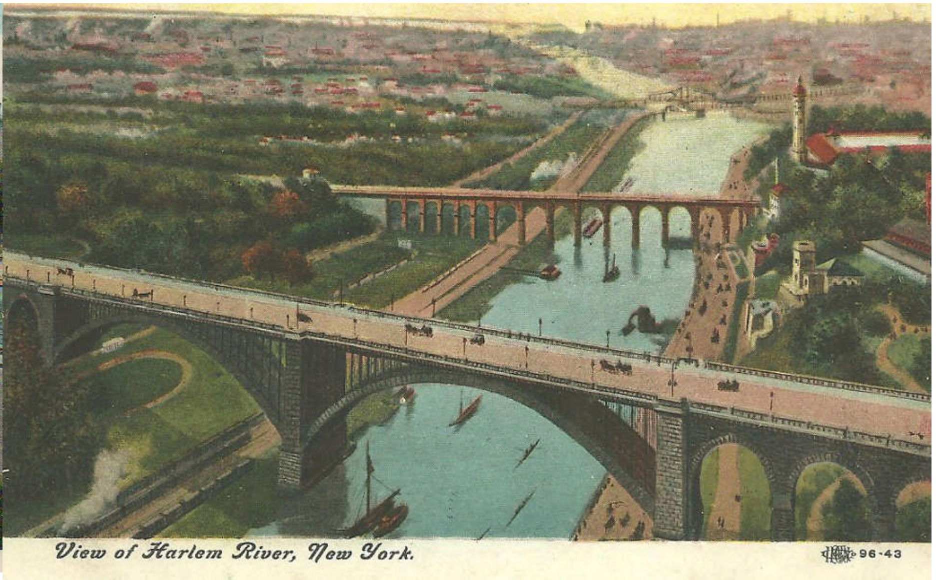
In a telegram to John F. Galvin, chairman of the New York Port Authority, David Robinson, secretary of the Grover Cleveland Association of New York, last night suggested the name of the former President and Governor of New York State as a name for the new Hudson River bridge.

A controversy was started last week over the announced intention

First named the *Hudson River Bridge*, other names for the bridge had been considered, including the *Palisades Bridge*, *Fort Lee Bridge*, *Columbus Bridge* and *Verrazano Bridge*, before the Port Authority decided upon the *George Washington Memorial Bridge,* in 1930 (after school children voted it their favorite). Later, the name was shortened to "George Washington Bridge."

The Other Washington Bridge

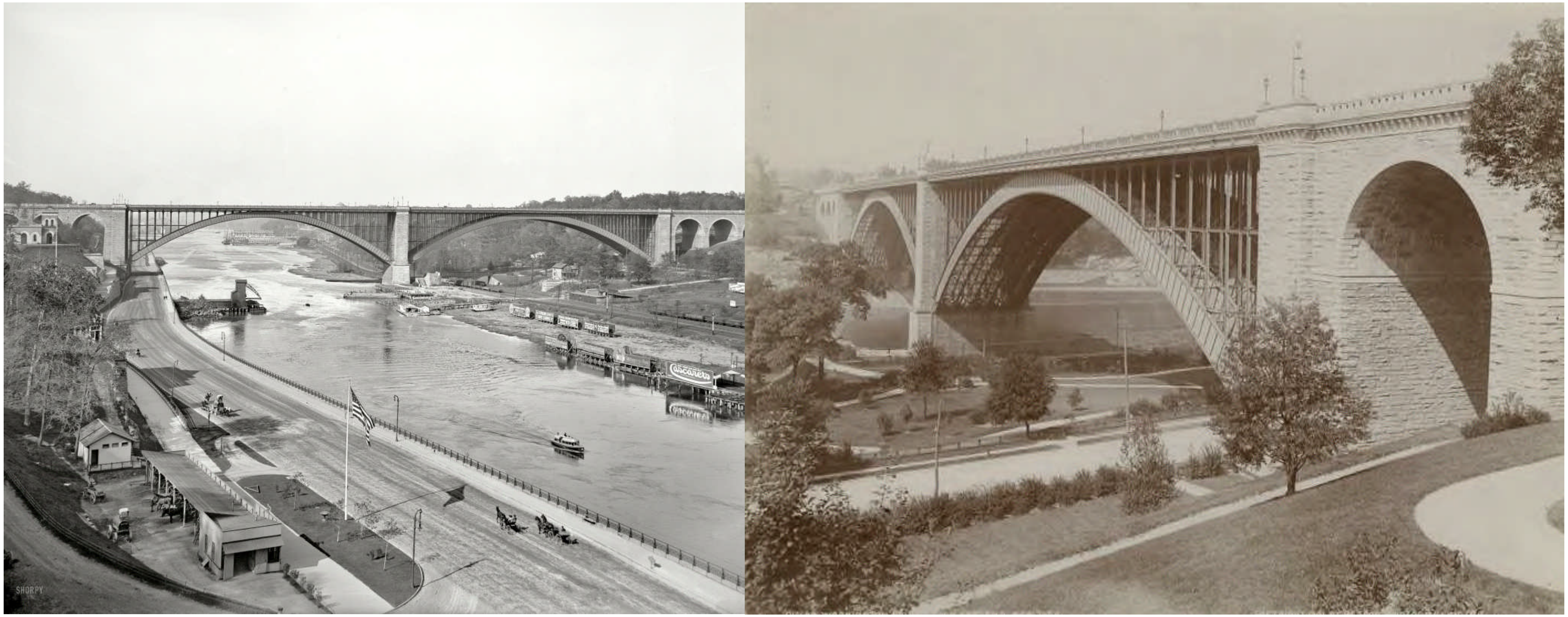

2012— Washington Bridge and Speedway, New York.

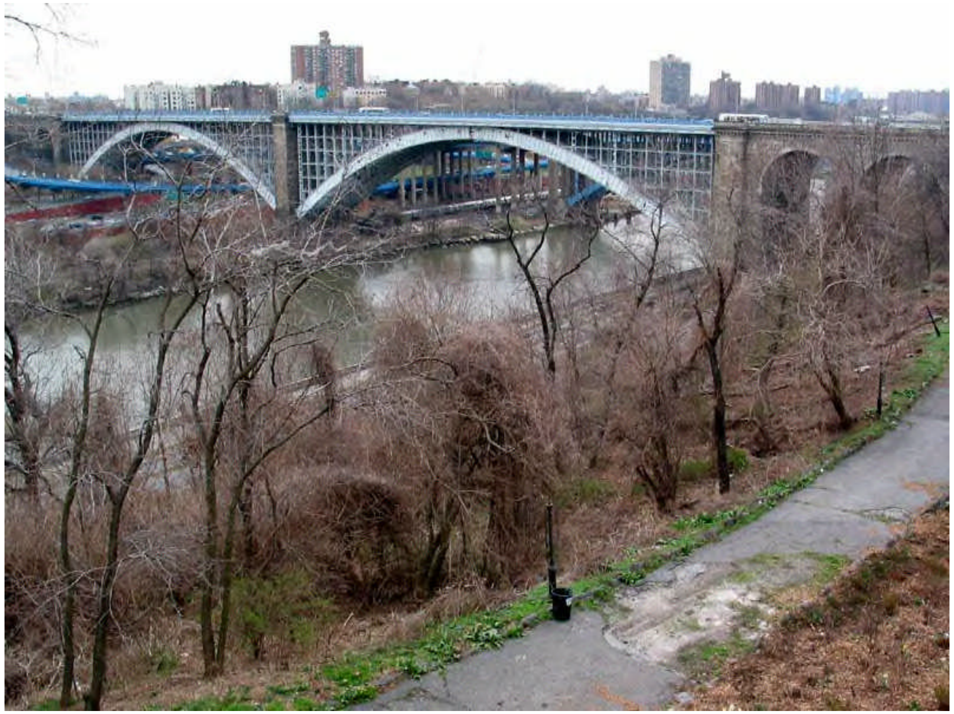

View of Harlem River, New York.

"One of the most imposing, beautiful and substantial to be found anywhere about the metropolis and is especially interesting as a perfect and consistent edifice in the arched style of bridge architecture…a marvel of rapidity of construction"

***The New York Times,* 1889**

RE: *Washington Bridge.* The bridge was erected (1886-1888) over the *Harlem River* from the *Bronx* to *181st Street* in *Manhattan* to provide a means of communication for residents on both sides. Unlike *Highbridge Aqueduct* (1842) to the south whose roadway was narrow, Washington Bridge was wide enough to accommodate both pedestrians and carriages in both directions. It was named "Washington Bridge" to honor the centenary of the inauguration of *George Washington* as the nation's first president. It is just north of the *Alexander Hamilton Bridge* (1963) which carries traffic over the Harlem River to/from the *Trans-Manhattan Expressway* which leads directly to/from the GWB.


Cascarets
SHORPY



When it opened in 1931, the *George Washington Bridge* not only connected *New York* with *New Jersey*, but also completed one of the earliest pieces of the tri-state arterial highway network recommended in 1929 by the *Regional Plan Association*. In its first year of operation, it was forecast that sixty million vehicles would use the bridge. For six years, the *Hudson River* span held the title of the world's longest suspension bridge. It was eclipsed by San Francisco's *Golden Gate Bridge* (1937) which has a main span of 4,200-feet.

Left: caption: "USS Nautilus passes under the GWB in 1956"

"…By the early 1960s, when the George Washington's lower deck was added (as specified in the original plans), Ammann had all but eclipsed his mentor. Ammann's other 1931 creation, the Bayonne Bridge connecting Staten Island and New Jersey which was, until 1977, the world's largest steel arch bridge - more than 600 feet longer than the previous record holder, Lindenthal's Hell Gate Bridge. Months before his death in 1965, Ammann gazed through a telescope from his 32nd-floor Manhattan apartment. In his viewfinder was a brand-new sight some 12 miles away: his Verrazano-Narrows suspension bridge. As if in tribute to the engineering prowess that made Ammann's George Washington Bridge great, this equally slender, graceful span would not be surpassed in length for another 17 years."

Smithsonian **magazine, October 1999**

<u>Left</u>: *O.H. Ammann* (ca. 1963)

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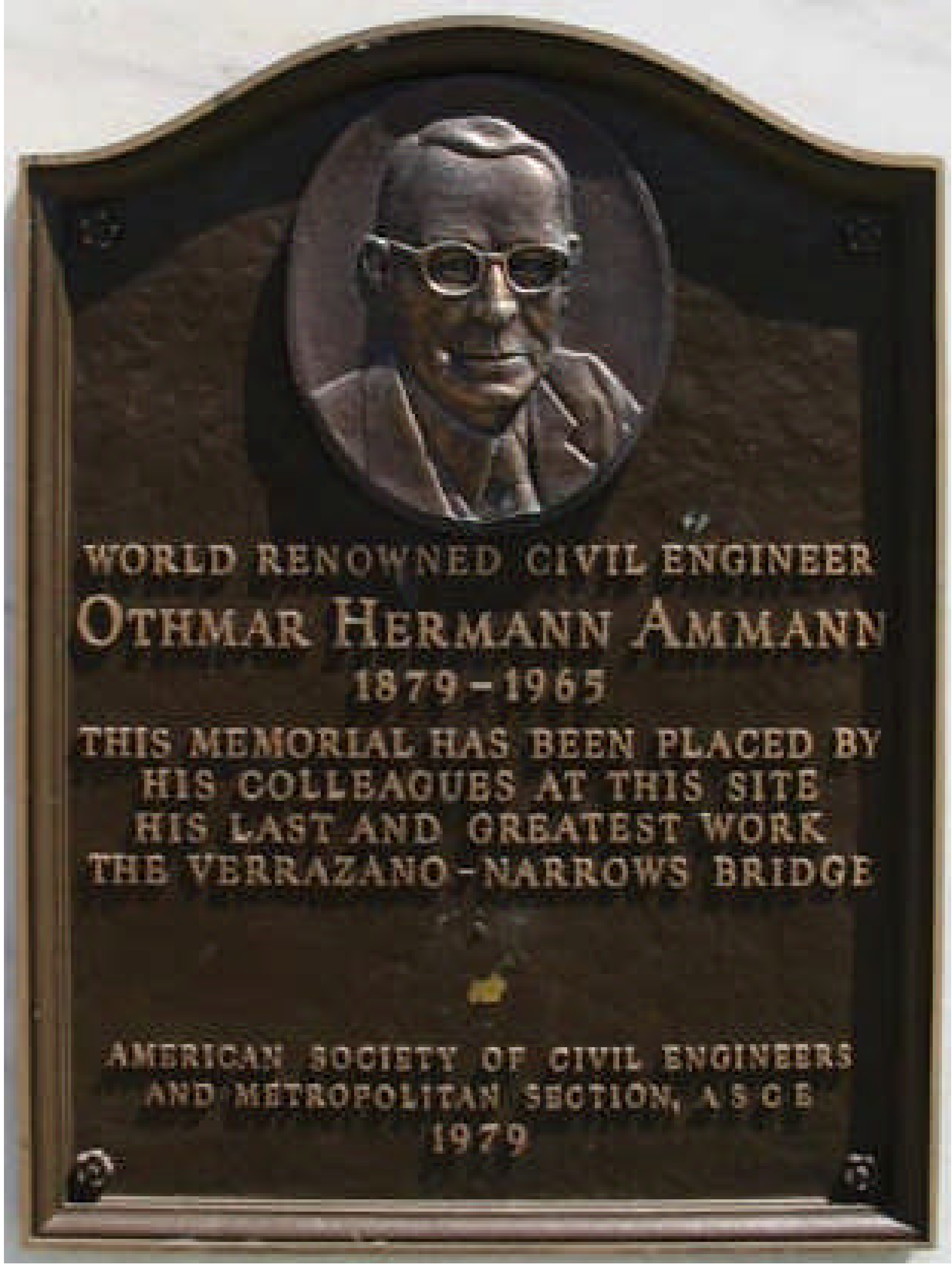
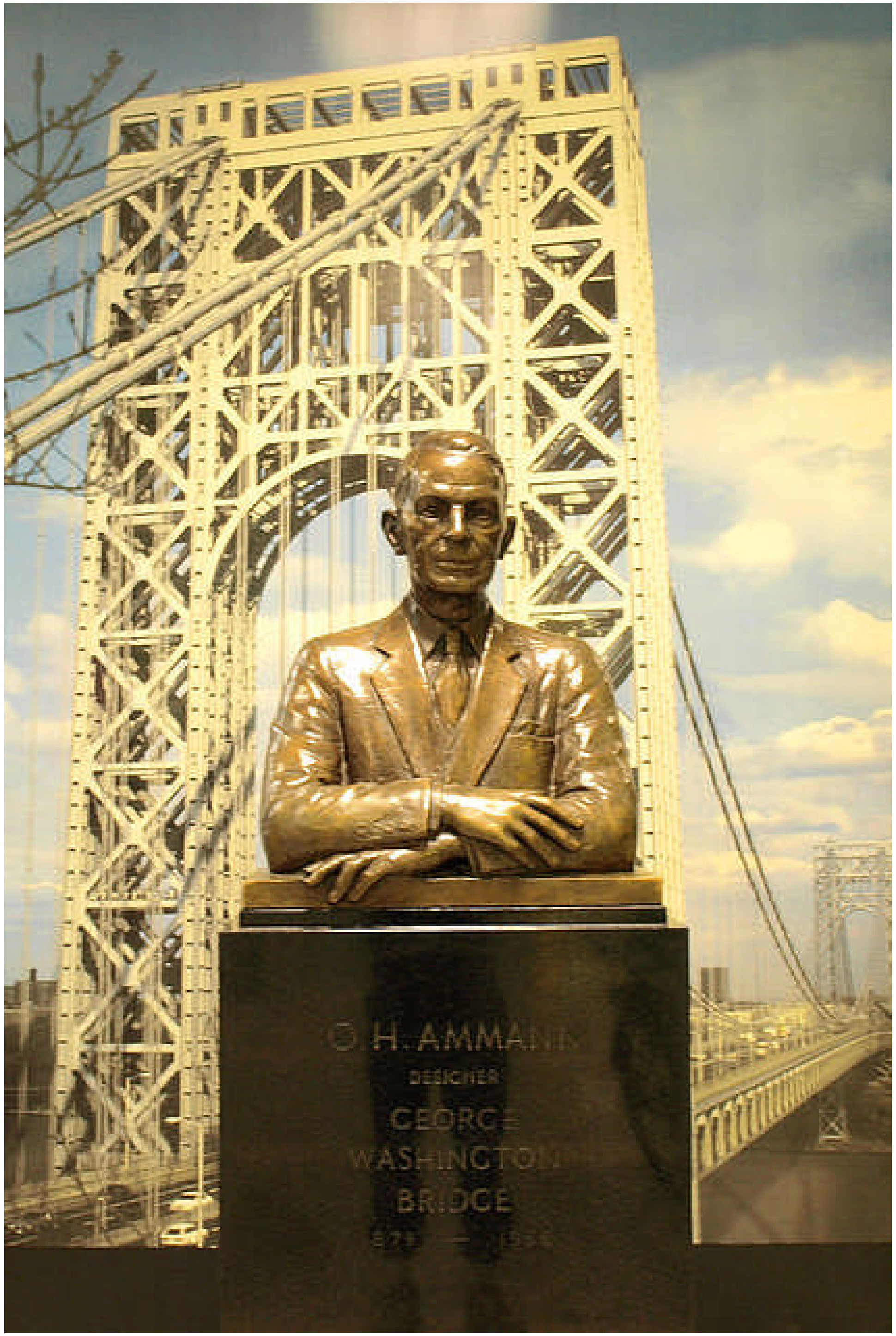
The Greatest Living Bridge Engineer



"I now ask that one of the significant great men of our time – modest, unassuming and too often overlooked on such grandiose occasions – stand and be recognized. It may be in the midst of so many celebrities, you don't even know who he is. My friends, I ask that you now look upon the greatest living bridge engineer, perhaps the greatest of all time."

***Robert Moses,* November 21st 1964**

RE: introducing *O.H. Ammann* at the opening day ceremonies for the *Verrazano Narrows Bridge*, Moses failed to mention Ammann by name – a fact not soon forgotten by a college freshman attending the ceremonies with his father: *Donald Trump*



“The rain was coming down for hours while all these jerks were being introduced and praised. But all I’m thinking about is that all these politicians who opposed the bridge are being applauded. Yet, in a corner, just standing there in the rain, is this 85 year old engineer who came from Sweden and designed this bridge, who poured his heart into it, and nobody even mentioned his name.”

Donald Trump

RE: recalling the opening ceremonies for the *Verrazano Narrows Bridge* whereby *O.H. Ammann* was never mentioned by name in Robert Moses’ speech praising him. It left an indelible impression on the ambitious young man (Trump mistakenly referred to *Sweden,* not *Switzerland*, as Ammann’s country of origin)

It’s a Crime

“In bridge designing, the aesthetics are quite as important as engineering details. It is a crime to build an ugly bridge.”
O.H. Ammann


OTHMAR
H. AMMANN
1879-1965
HELVETIA
20
HANS THÖNI
COURVOISIER

Part 6

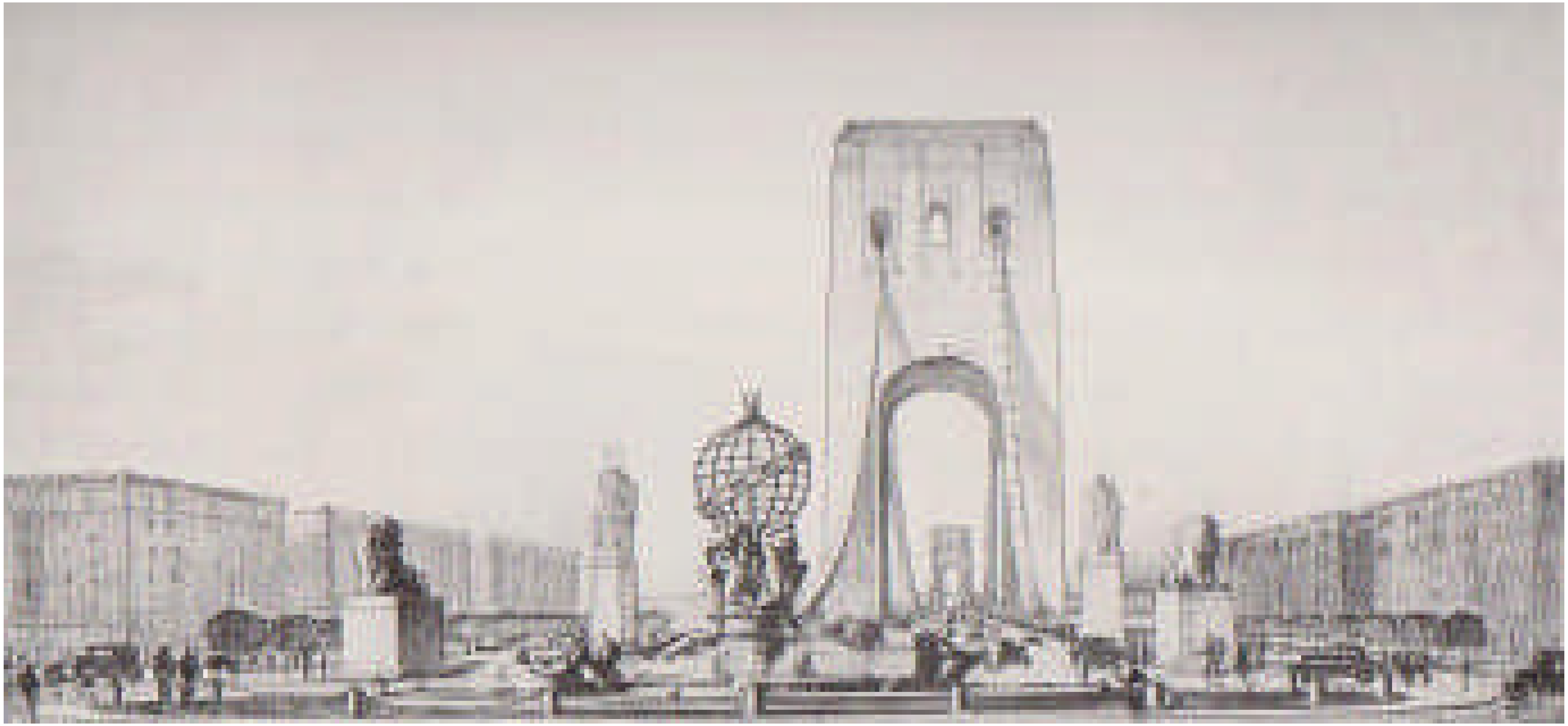
What Might Have Been

Pleasing to the Eye

“Economics and utility are no the engineer’s only concerns. He must temper his practicality with aesthetic sensitivity. His structures should please the eye. In fact, an engineer designing a bridge is justified in making a more expensive design for beauty’s sake alone. After all, many people will have to look at the bridge for the rest of their lives. Few of us appreciate eyesore, even if we should save a little money by building them.”

O.H. Ammann

Manhattan Plaza/Approach



<u>Above</u>: caption: “Study for a monumental plaza at the approach to the east tower.” Originally conceived as a grand public plaza, traffic would enter from multiple ramps all leading to an ornate central fountain flanked by statuary. Motor vehicles would circle the fountain en route to the bridge or disperse to adjacent streets by way of ramps. The erratic movements of high-speed/density traffic using such a plaza design would, no doubt, have caused delays, congestion and accidents.

The original plan for the *Manhattan* bridge approach had its genesis in the “City Beautiful” movement. It was to feature several ramps leading to a traffic circle, which would have been highlighted by a spectacular fountain. Although visually appealing, the design was not suited to the demands of modern traffic. Instead, a complicated series of ramps and overpasses was constructed. The final design of the Manhattan interchange was completely dissimilar to the earlier proposal. As built, it separates traffic flowing in opposite directions as well as relatively slow from fast moving traffic. Dedicated ramps disperse vehicles to a variety of connecting highways absent grade crossings and/or sharp left turns. The result is a hodge-podge of spiraling ramps, underpasses, overpasses (some three-stories high) that seems to be the antithesis of the original plaza scheme.

<u>Top</u>: caption: “Phase I demolition for the Manhattan plaza”
<u>Bottom</u>: caption: “Phase II demolition for the Manhattan plaza”

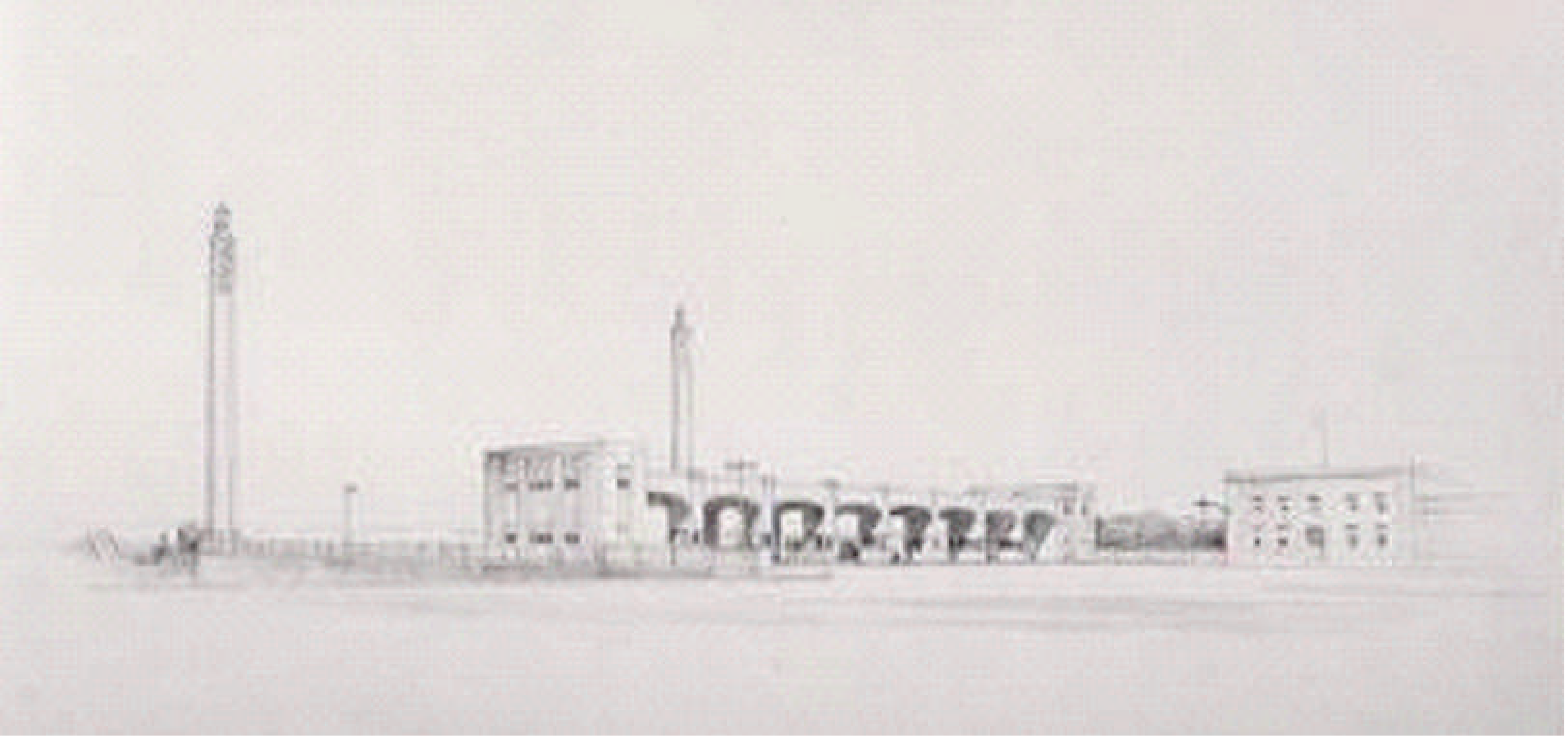
“…On the New York side, the layout of the approaches appears complicated in plan, though it works most smoothly. Most notable among the approaches is the great series of ramps, with up and down carriageways connecting the bridge with the world famous Riverside Drive, with their strange loops and magnificent concrete arches. Then there are tunnels, carrying 22-foot roadways, beneath 178th Street. In these tunnels elaborate precautions have been taken against contamination of the air by carbon monoxide gas given forth by the passing vehicles. Along the side of the tunnel run two great ducts, together as high as the tunnel itself, one carrying a constant flow of fresh air to the tunnel and the other carrying off the vitiated air…”

***Wonders of World Engineering,* November 1937**

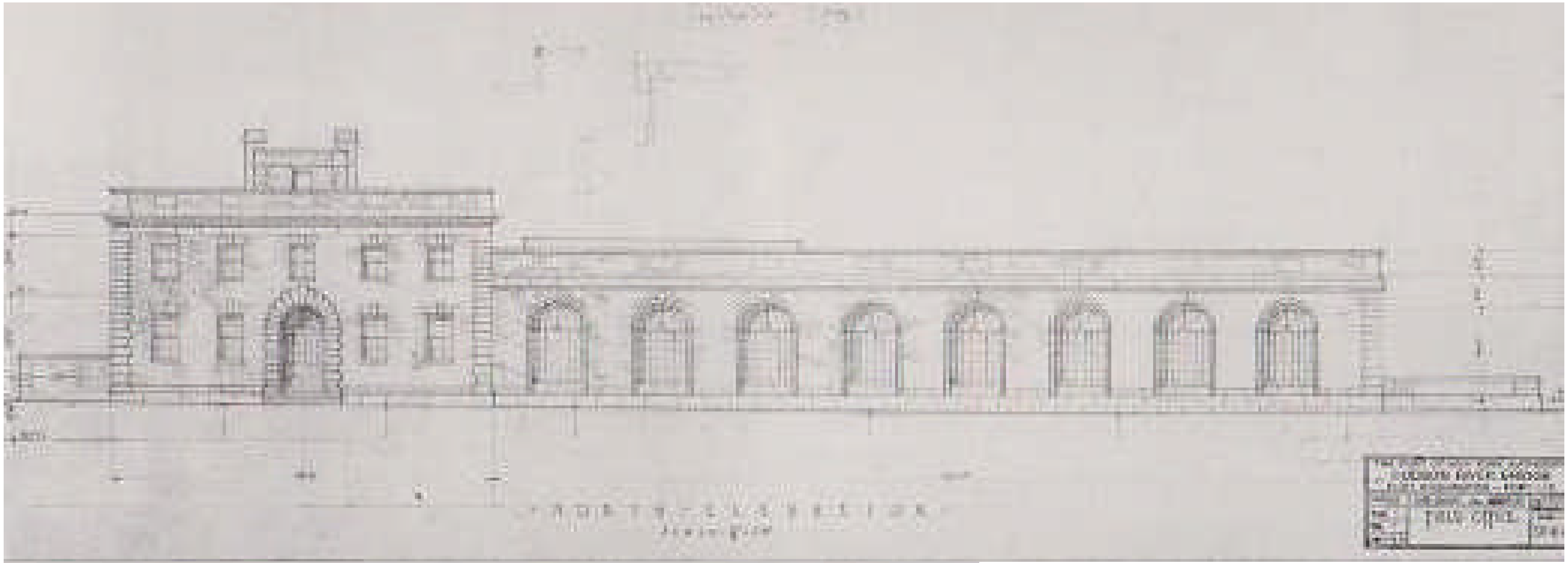
Fort Lee Plaza/Approach

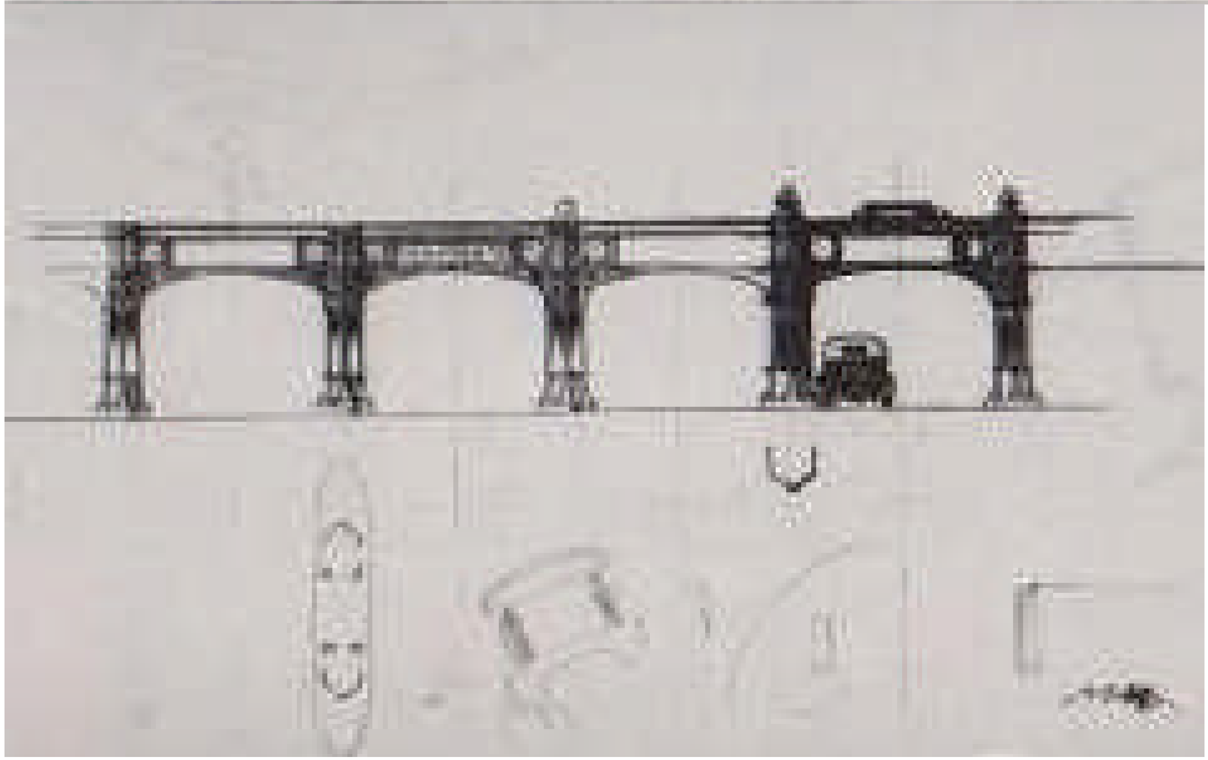
The *New Jersey* approach, part of which was carved out of the solid rock of the Palisades, was designed for beauty, efficiency and safety. The original architectural design of the toll plaza, maintenance facilities and floodlight towers recalled the stylistic forms of the past. Nearly all of these features were lost in the two toll plaza expansions during the early 1960s and early 1980s.

Left: caption: "New Jersey approach from top of New Jersey tower"



<u>Above</u>: caption: “Study for the New Jersey plaza showing toll booths and maintenance building.” Compared with the densely populated *Fort Washington* neighborhood on the *Manhattan* side of the bridge, *Fort Lee* was, for the most part, undeveloped. As such, the bridge plaza could be configured without restraint, with safety and efficiency in mind.





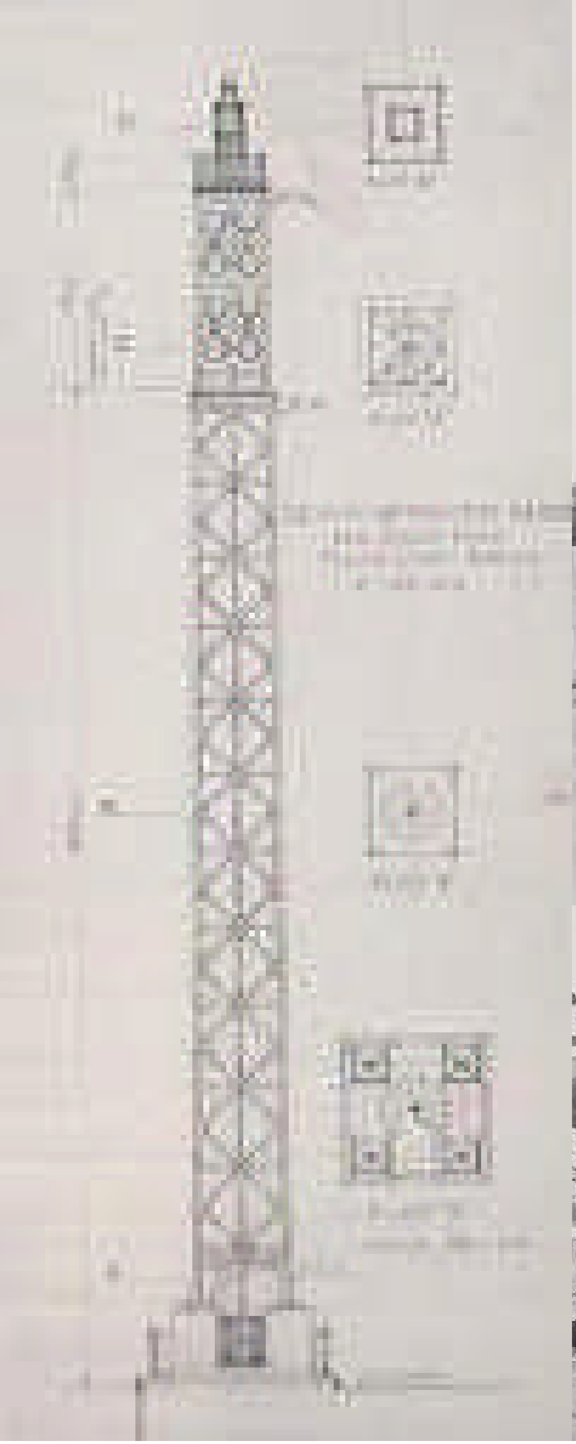
<u>Above</u>: caption: “Study for a maintenance facility designed in the classic style”

<u>Left</u>: caption: “Sketch study for toll facility”

"…The approaches to this bridge provide a distinct study in themselves. First there are the two great plazas for the marshalling of traffic at either end of the bridge. In these are situated toll booths through which all vehicles entering the bridge have to pass, and where their drivers pay the appropriate duty for using the bridge. Big floodlighting towers have been set up in the plazas to make their negotiation as easy by night as by day…"

***Wonders of World Engineering*, November 1937**

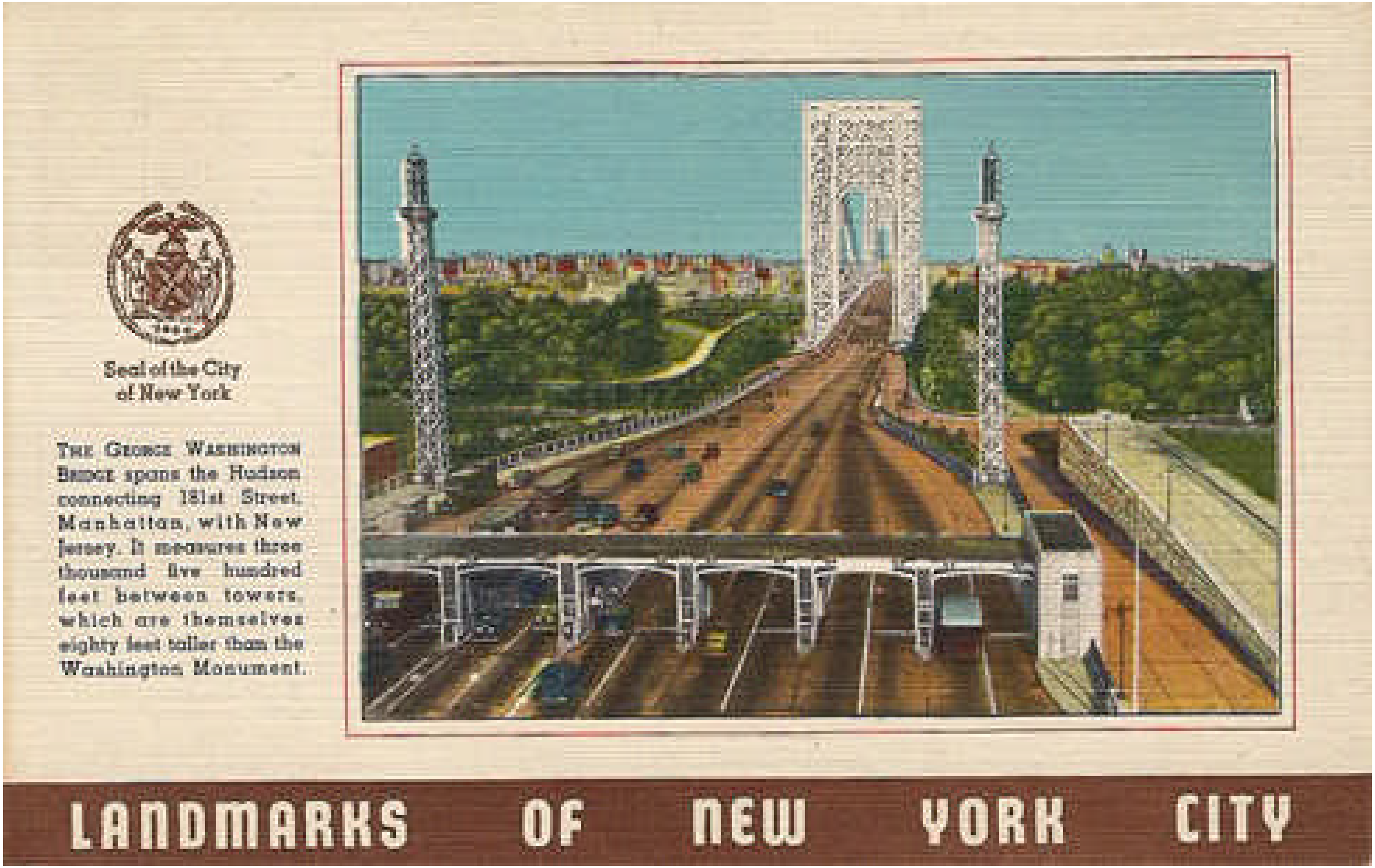
<u>Above</u>: original toll booths (*Fort Lee*). Note: only the *New Jersey Approach Plaza* contained toll booths – then and now.



Above: caption: “New Jersey plaza soon after the bridge opened”
Left: caption: “Detail of original toll booths”
Far Left: caption: “ Study for a floodlight tower”

"…At the beginning of the design process, the architect advocated building materials and stylistic forms that recalled grand civic architecture from the past; but as time went on they came to appreciate the uncontrived form of the bridge itself. Toll booths, floodlights, and support buildings took on a clean, machined appearance, harmonizing with the masonry foundations and exposed steel of the bridge. Gilbert's light towers for the toll plaza, with their open framing threaded with a spiral stair, sounded a playful note amid the bridge's overwhelming grandeur…"

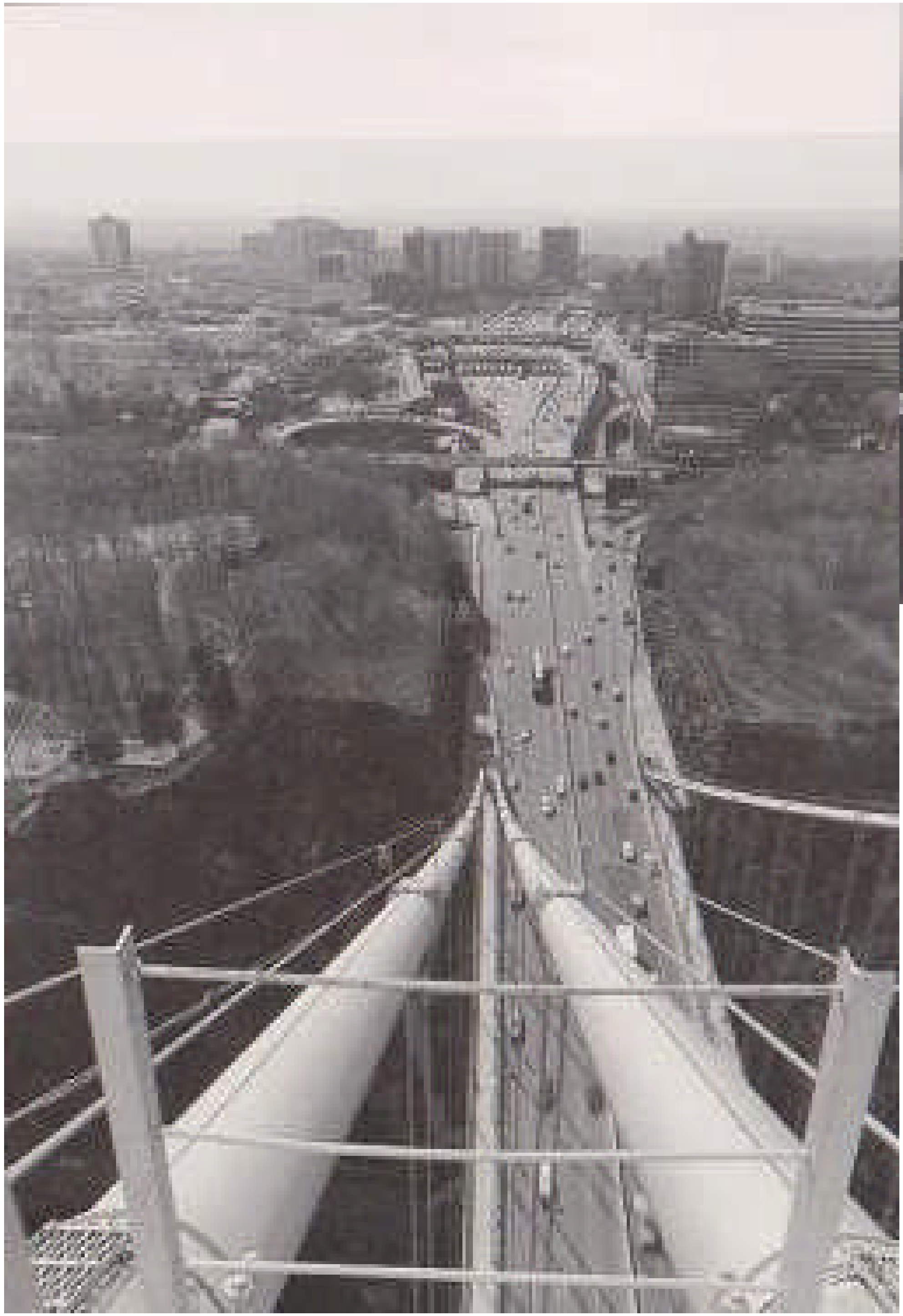
***Darl Rastorfer,* Author**



Seal of the City of New York

THE GEORGE WASHINGTON BRIDGE spans the Hudson connecting 181st Street, Manhattan, with New Jersey. It measures three thousand five hundred feet between towers, which are themselves eighty feet taller than the Washington Monument.

LANDMARKS OF NEW YORK CITY

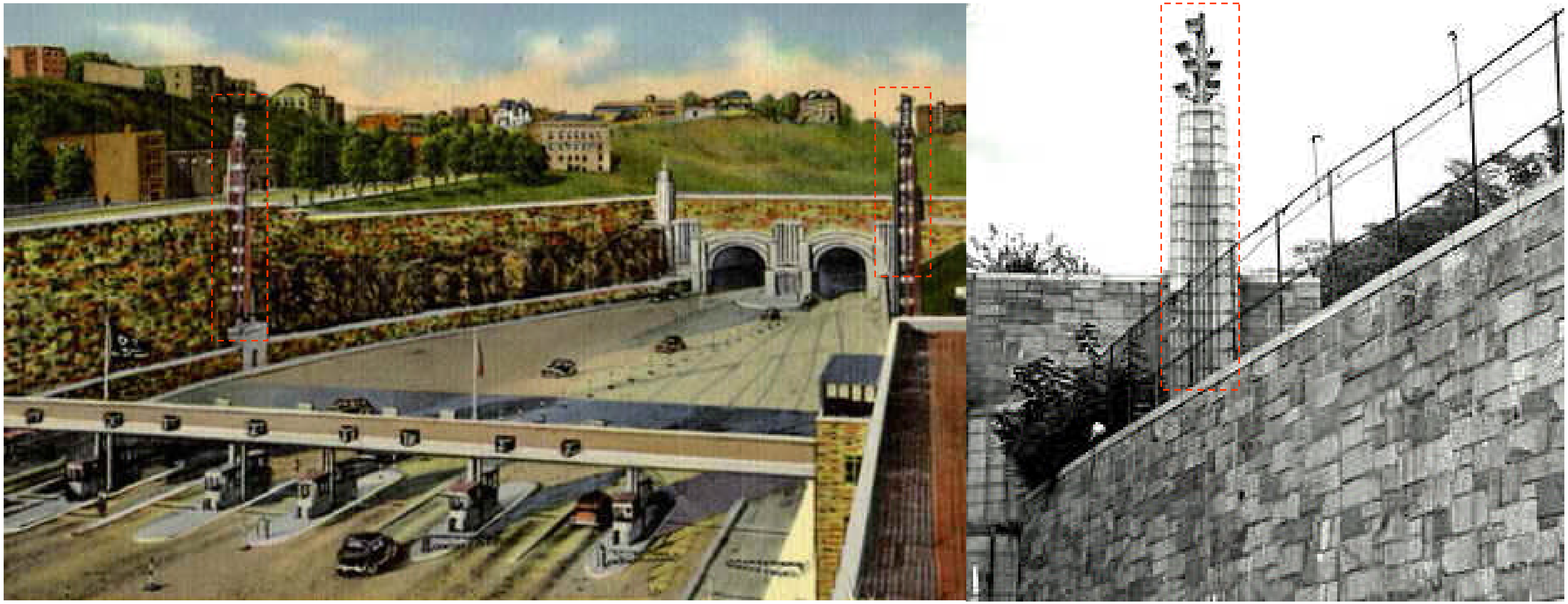


“…Unfortunately, none of Gilbert’s work at the George Washington toll plaza remains, having been lost in the facility’s expansion. He designed a similar series of floodlight towers for Ammann’s Lincoln Tunnel of 1934, however, and those towers are still in service and are well maintained…”

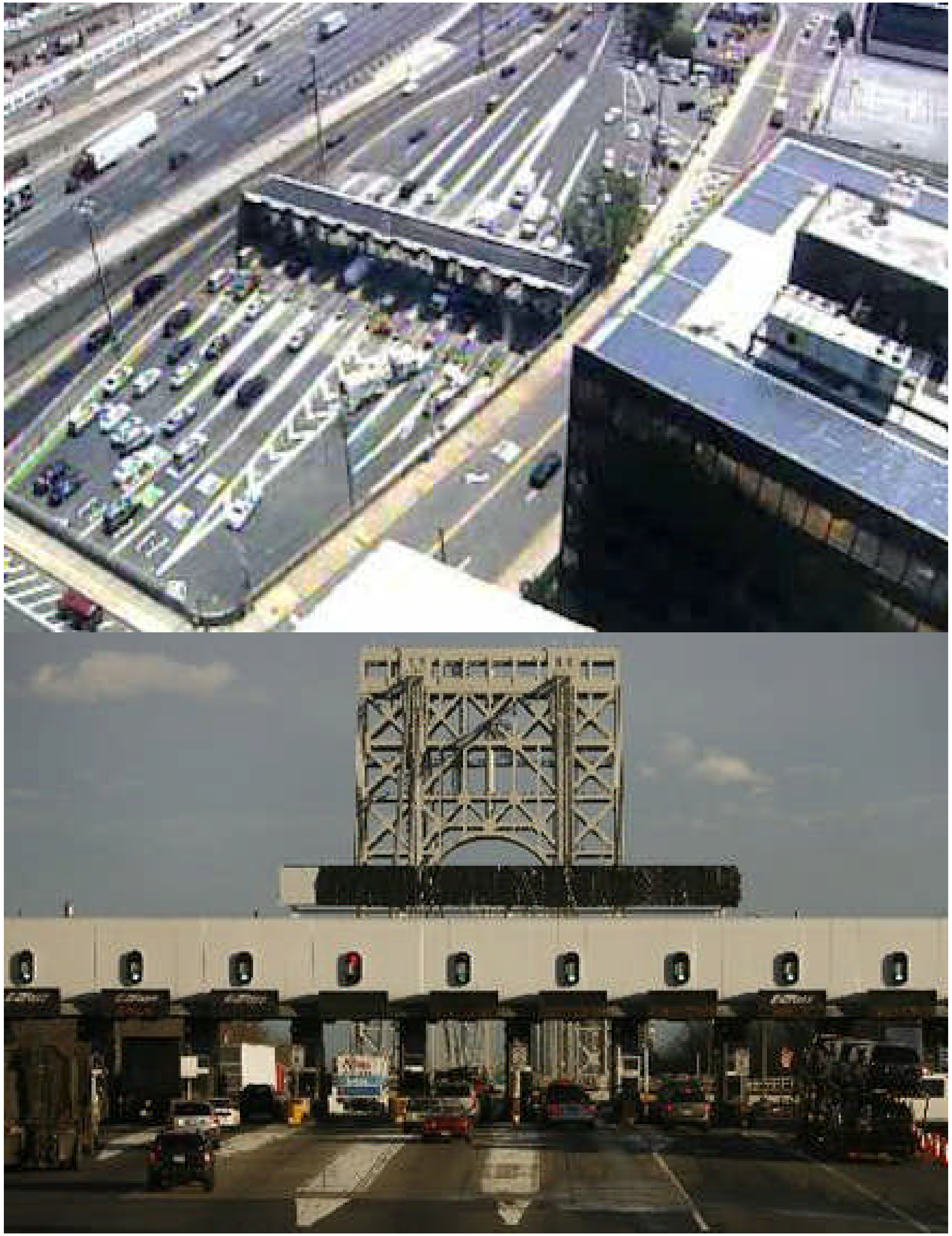
Darl Rastorfer, **Author**

Above: caption: “View from the west tower to the New Jersey approach plaza”

Left: caption: “The New Jersey approach and toll plaza”



Above: ***Lincoln Tunnel Toll Plaza*** **with Cass Gilbert's original floodlight tower/s (highlighted)**

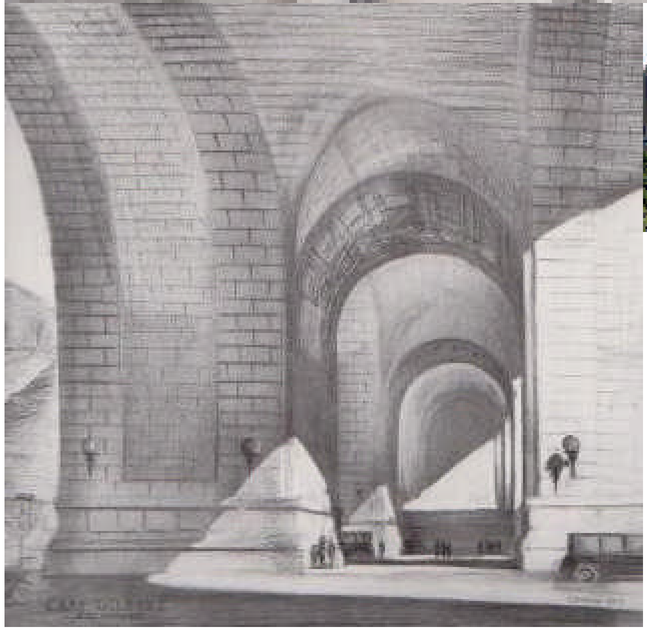


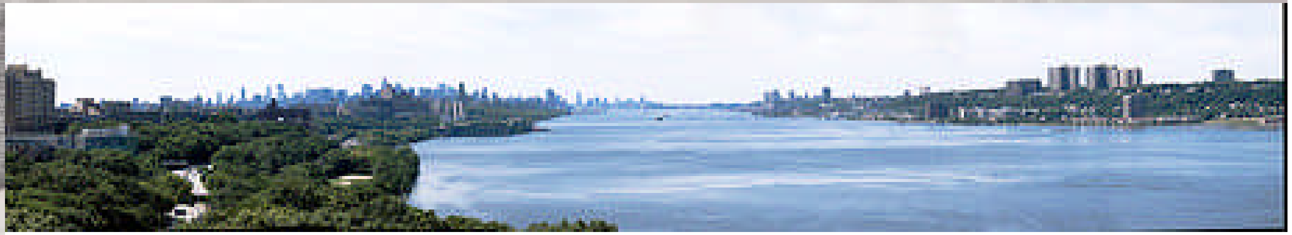
Manhattan Parkway Approaches

"…It so happened that the bridge's siting placed it in Manhattan's Fort Washington Park, the northern continuation of Riverside Park. Beginning on West Seventy-second Street, Riverside Park's winding paths, rustic retaining walls, and informally arranged plantings follow the English pastoral style. Frederic law Olmsted, the principal landscape architect for Central Park, was a guiding force in the design of both Riverside Park, which ends at 158th Street, and Fort Washington Park, which adjoins it and continues the scenic public parkland to the base of the George Washington Bridge. Today, both Riverside Drive and the Henry Hudson Parkway (often mistakenly called the West Side Highway) course their way through the parks…"

Darl Rastorfer, **Author**

<u>Top Left</u>: caption: "Aerial view of Fort Washington Park (foreground)"
<u>Top Right</u>: caption: "Approaching the GWB along Riverside Drive in 1938"
<u>Left</u>: caption: "Riverside Drive, George Washington Bridge and Hudson River, New York City"

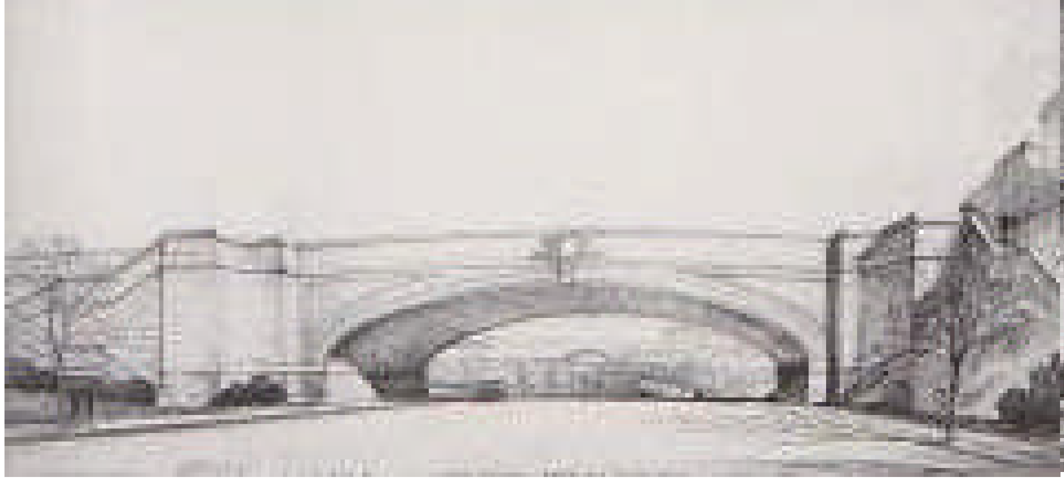




<u>Above Top</u>: caption: "Study for the landscape design at Fort Washington Park"

<u>Above Bottom</u>: view looking south from GWB pedestrian walkway – *Manhattan* parkland and *Riverside Drive* at left

<u>Left</u>: caption: "Study for the east tower's underpass"



"…Not surprisingly, Ammann and his design team regarded the Manhattan approach from the south as the most architecturally splendid, seeing the bridge as the focal point for all northbound traffic. Working with previously established landscape features, they sought to enhance the carefully composed visual corridor with crossover bridges, vehicular ramps, esplanades, tunnels, and retaining walls that were sympathetically detailed to harmonize with the surroundings. Of the many new roadway features designed in conjunction with the bridge, none was more painstakingly considered than the tunnel configuration at the front of the New York anchorage through which Riverside Drive passes. Both the exterior and the interior of the underpass were carefully studied, as were the number and arrangement of tunnel openings. As built, a single arched opening faced with brick gives passage to the parkway. New leisure and recreational facilities, such as esplanades and a yacht basin, were planned for the base of the east tower…"

Darl Rastorfer, **Author**

<u>Top Left</u>: caption: "Study for a crossover bridge above Riverside Drive"

<u>Top Right</u>: caption: "Study for a retaining wall and stairs adjacent to the Manhattan anchorage"

WEST SIDE EXPRESS HIGHWAY AND GEORGE WASHINGTON MEMORIAL BRIDGE, NEW YORK CITY 39

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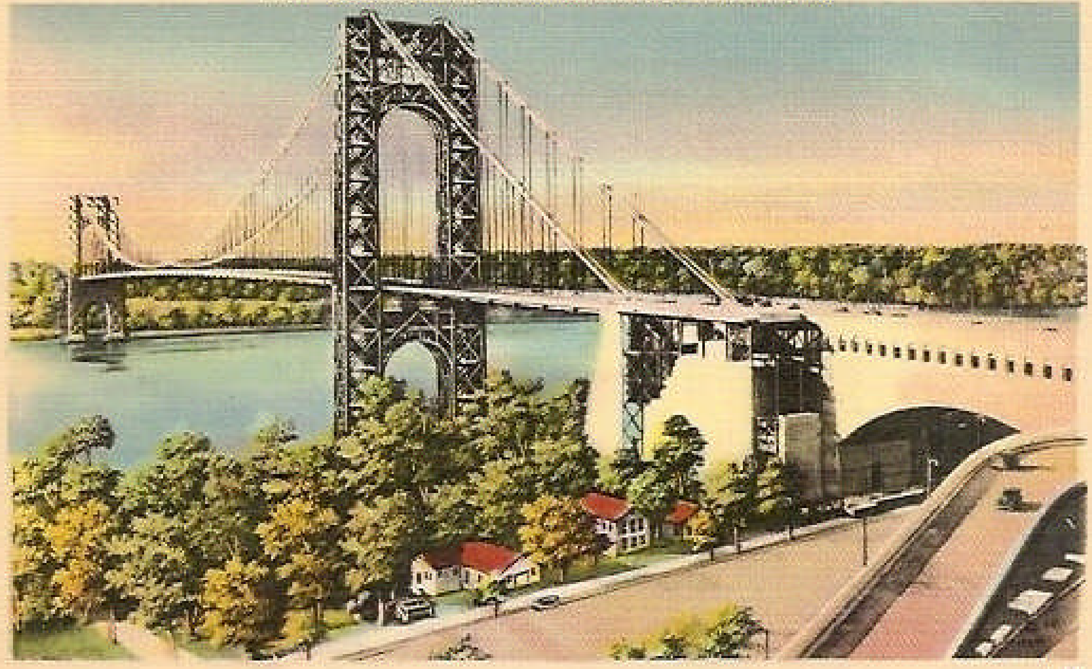
133 — GEORGE WASHINGTON BRIDGE NEW YORK.



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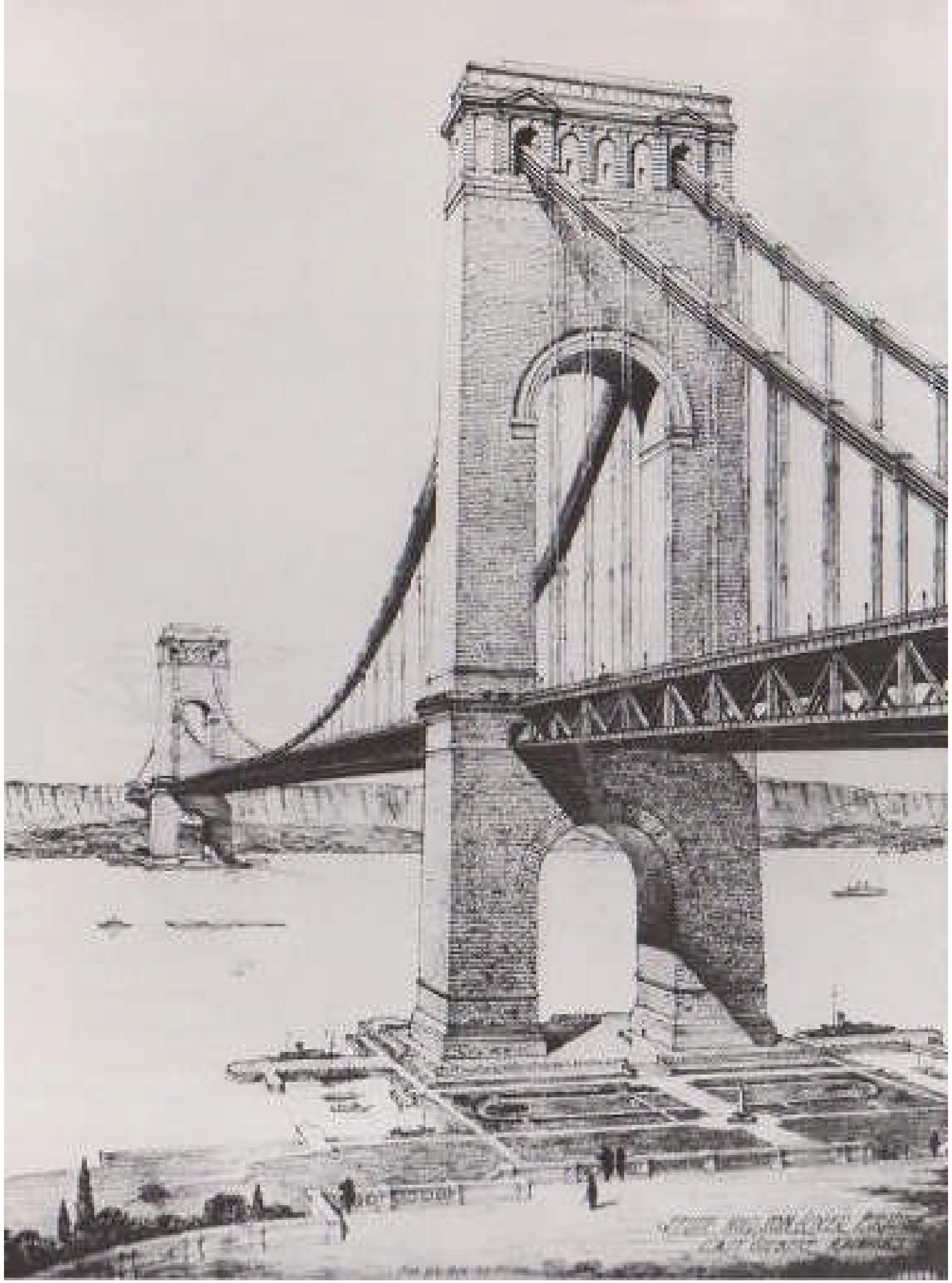
SLOW

Towers



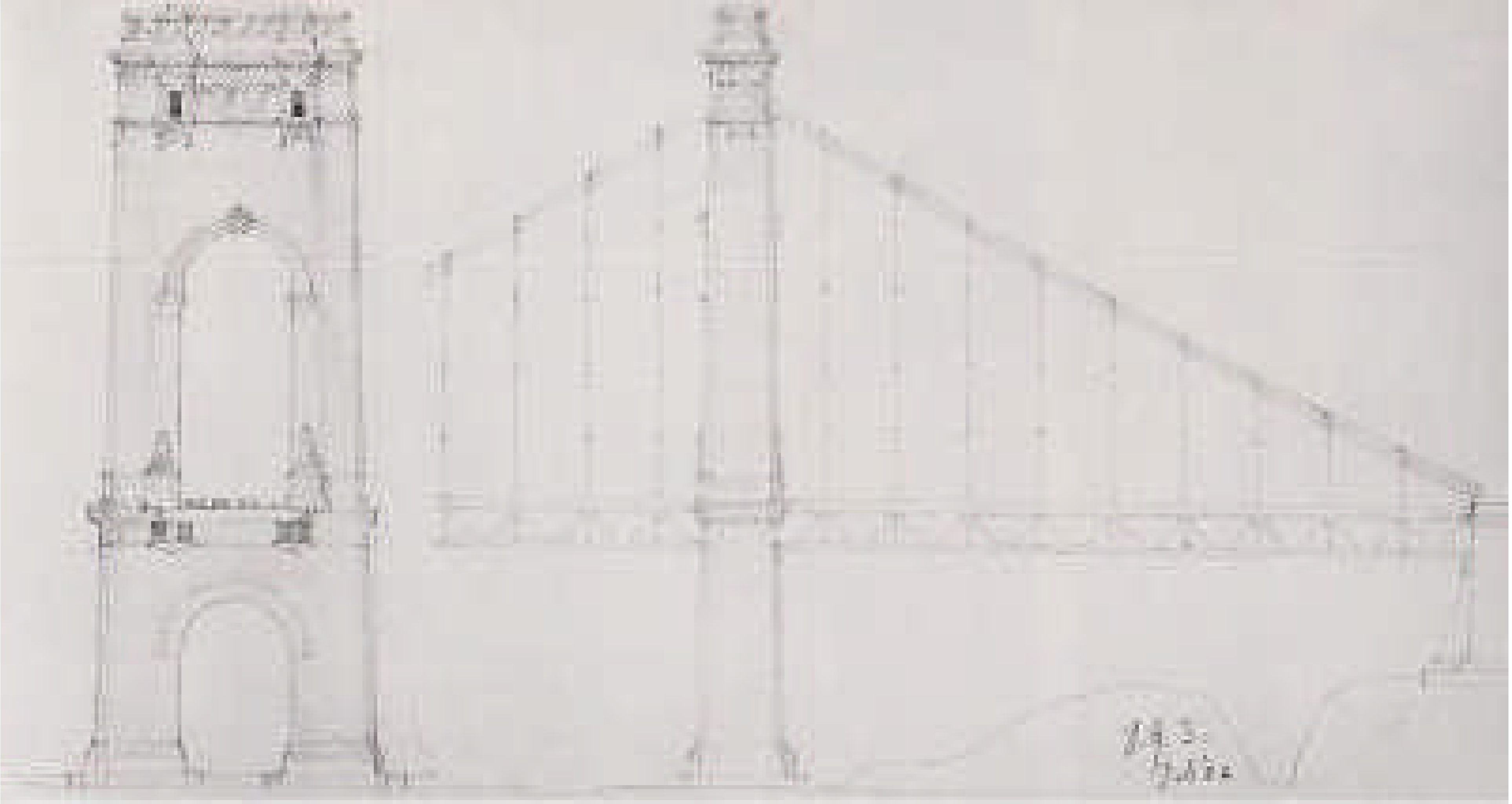
"…The George Washington Bridge is one of America's most conspicuous unfinished works of architectural engineering. Designed to be covered with granite, the closely knot network of steel making up the towers was meant to provide the armature on which would hang thousands of pieces of dimensional stone. Ammann chose stone to strike a harmonious balance between the architecture of the structure and the natural grandeur of the site…"

***Darl Rastorfer,* Author**

Left: caption: "Rendering of a design for cladding the bridge's towers with stone. Note the formal esplanade, garden, and yacht basin also under consideration."

“…The governing board responsible for approving all matters concerning the bridge project accepted preliminary plans for steel towers hung with stone. Consequently, the office of Cass Gilbert pushed forward under Ammann’s direction and prepared numerous schemes that studied varying approaches to massing and stylizing the sheathing. In the beginning of their studies, historical models were favored: classical, baroque, and Gothic. Design trends, however, were shifting in America…”

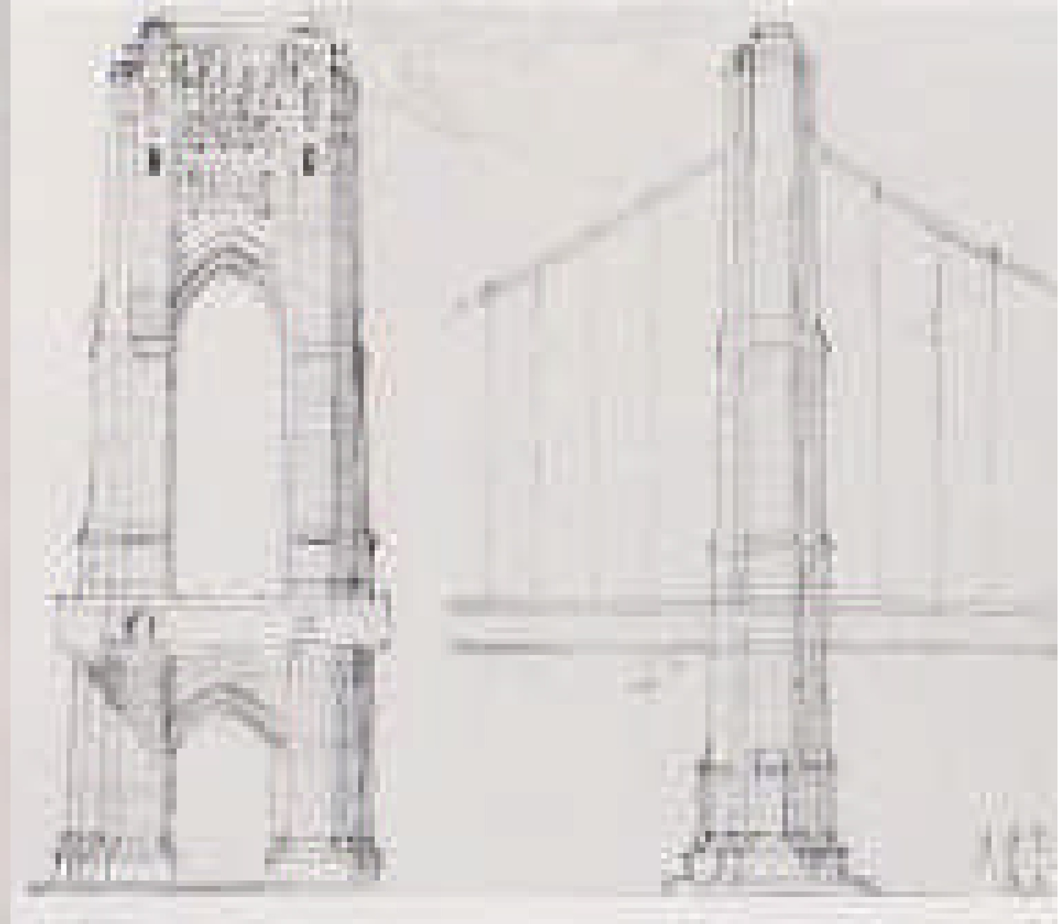
***Darl Rastorfer*, Author**

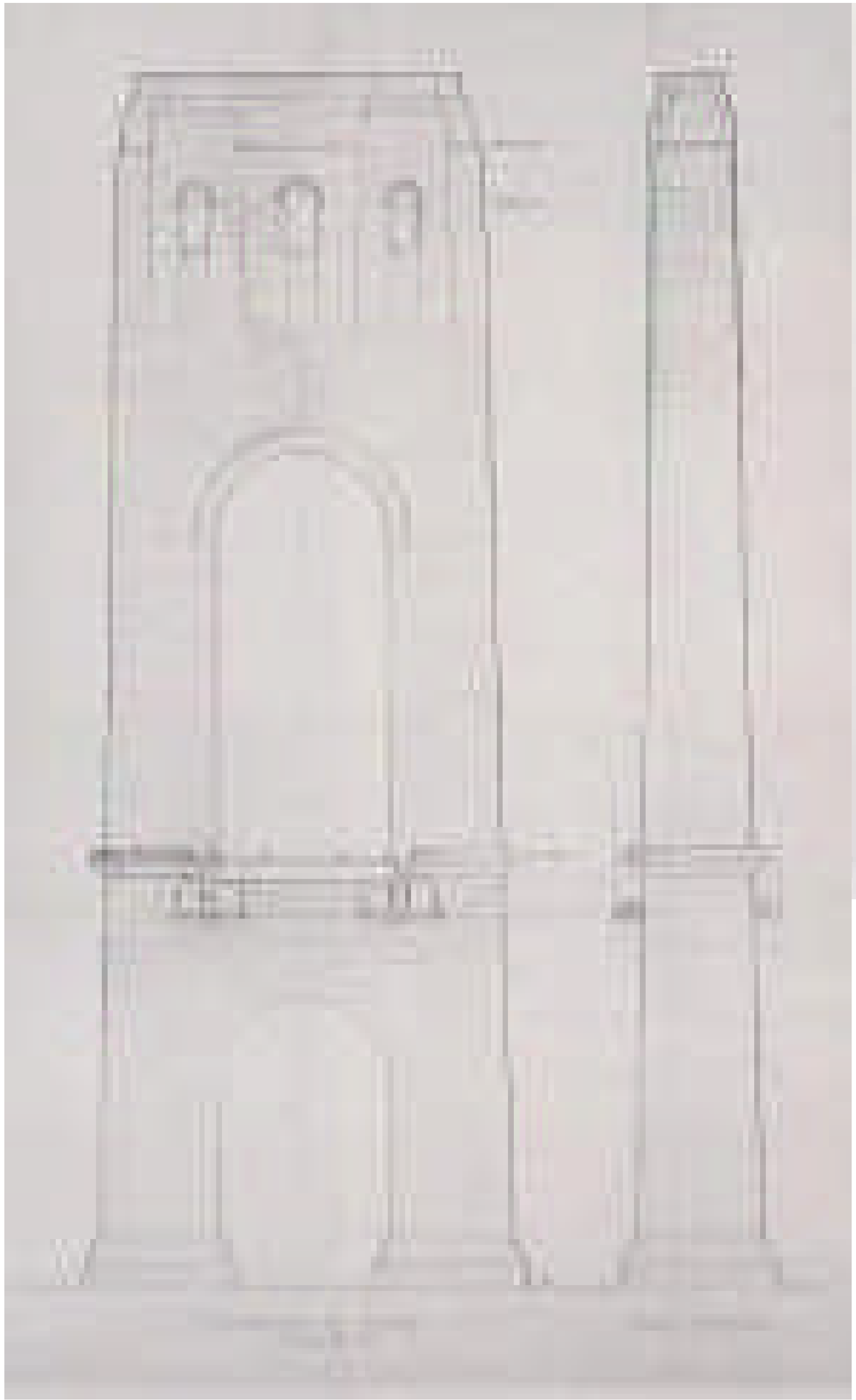


"…At the same time the bridge was on the drawing board, modernism was beginning to supersede revivalism in popularity…"

***Darl Rastorfer,* Author**

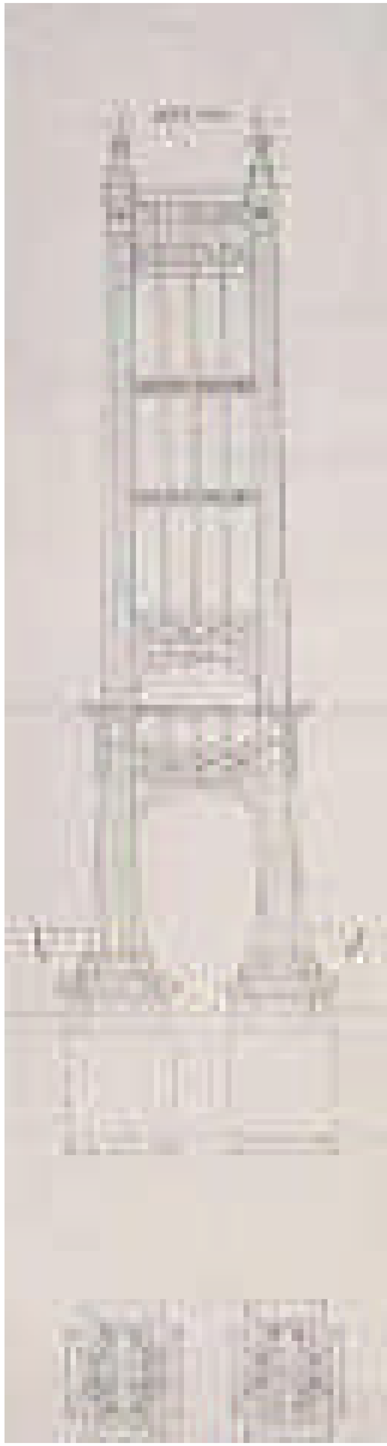
<u>Above</u>: caption: "Baroque style tower scheme"

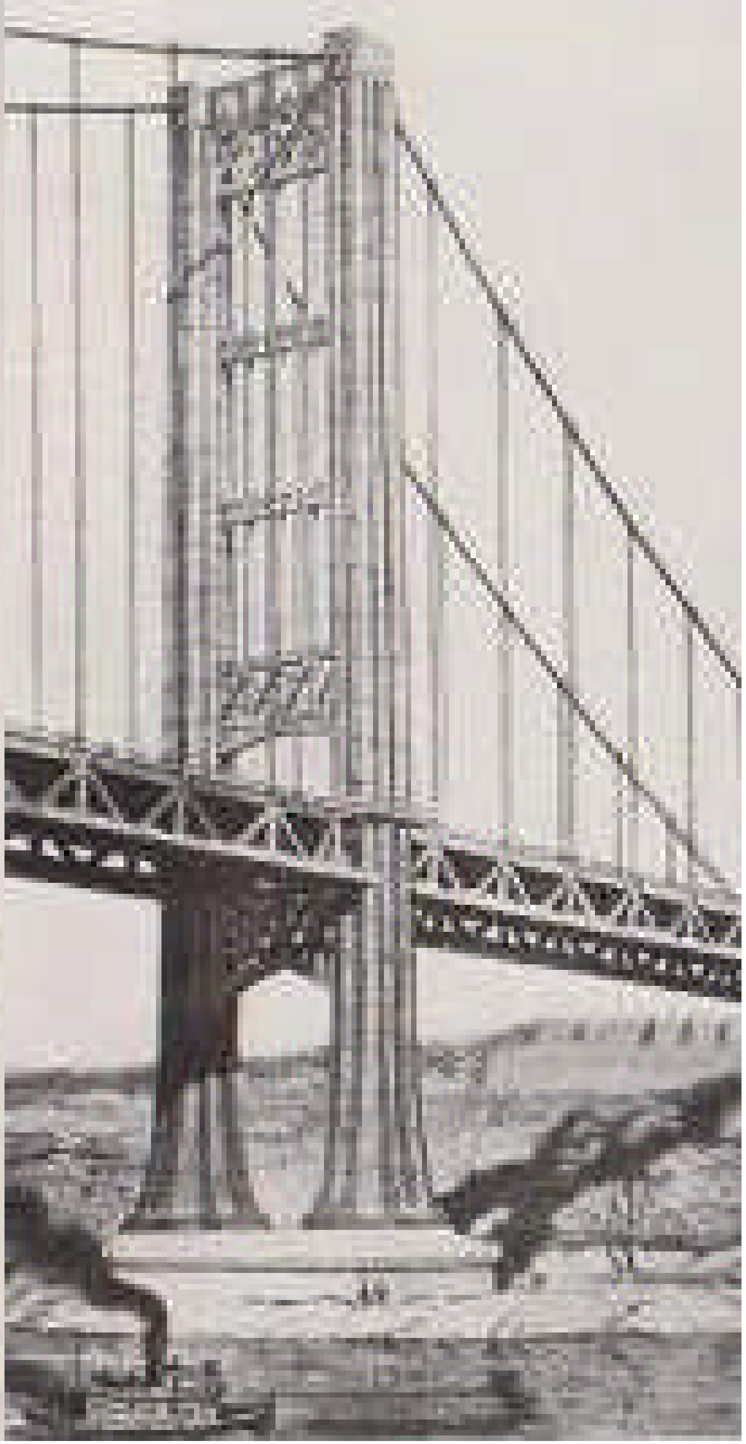




<u>Above</u>: caption: “Gothic style scheme”

<u>Left</u>: caption: “Art Deco style tower scheme”





"…while assiduously investigating patterns for decorative stonework, Ammann and Gilbert had also looked at several designs for exposed steel towers. Had they known that the project was destined to have steel towers, there is little doubt that they would have configured them in a slender shape rendered with a few heavy lines, similar to the design they considered…"

***Darl Rastorfer,* Author**

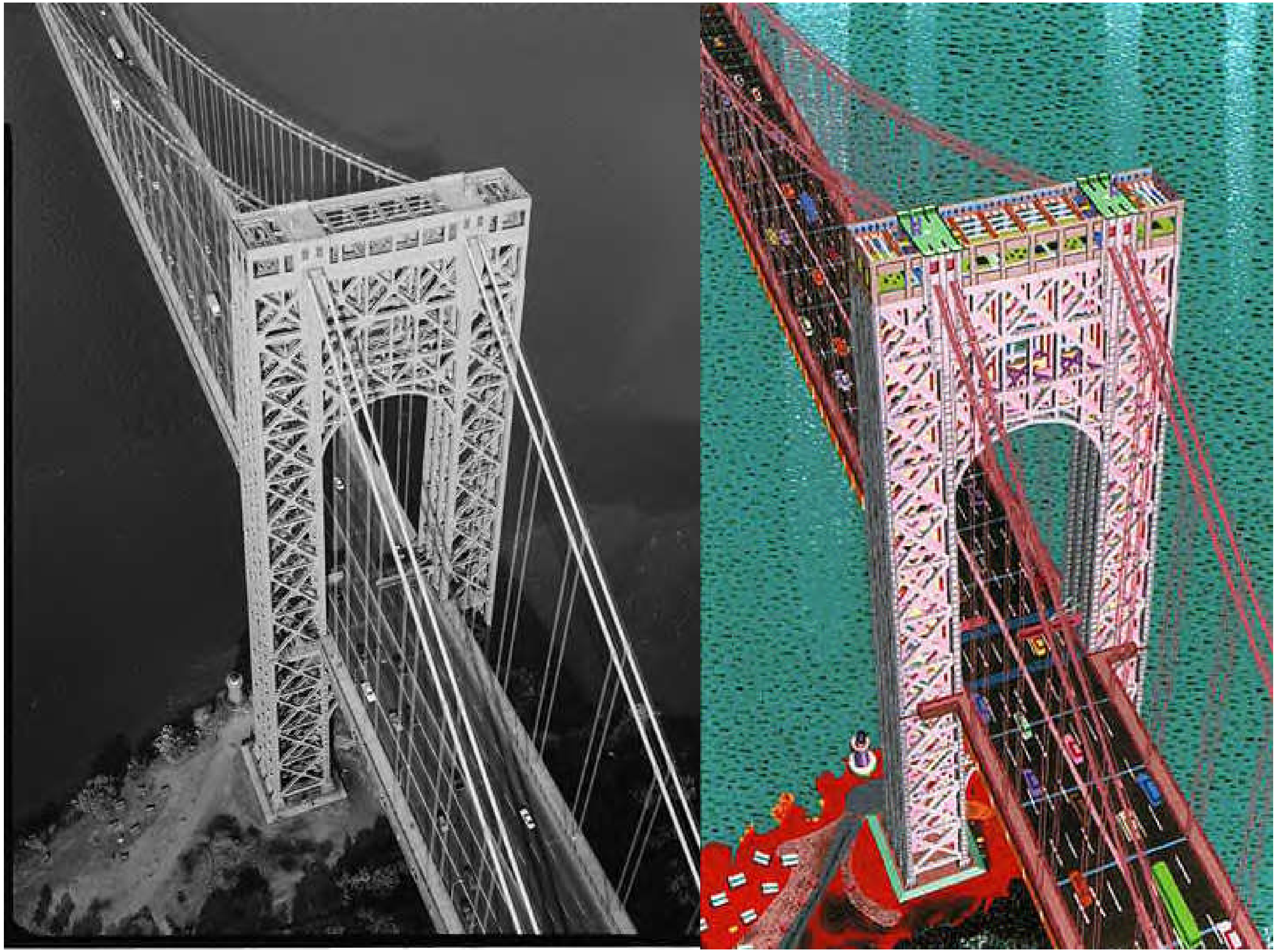
Far Left: caption: "Front elevation of the exposed steel tower scheme"

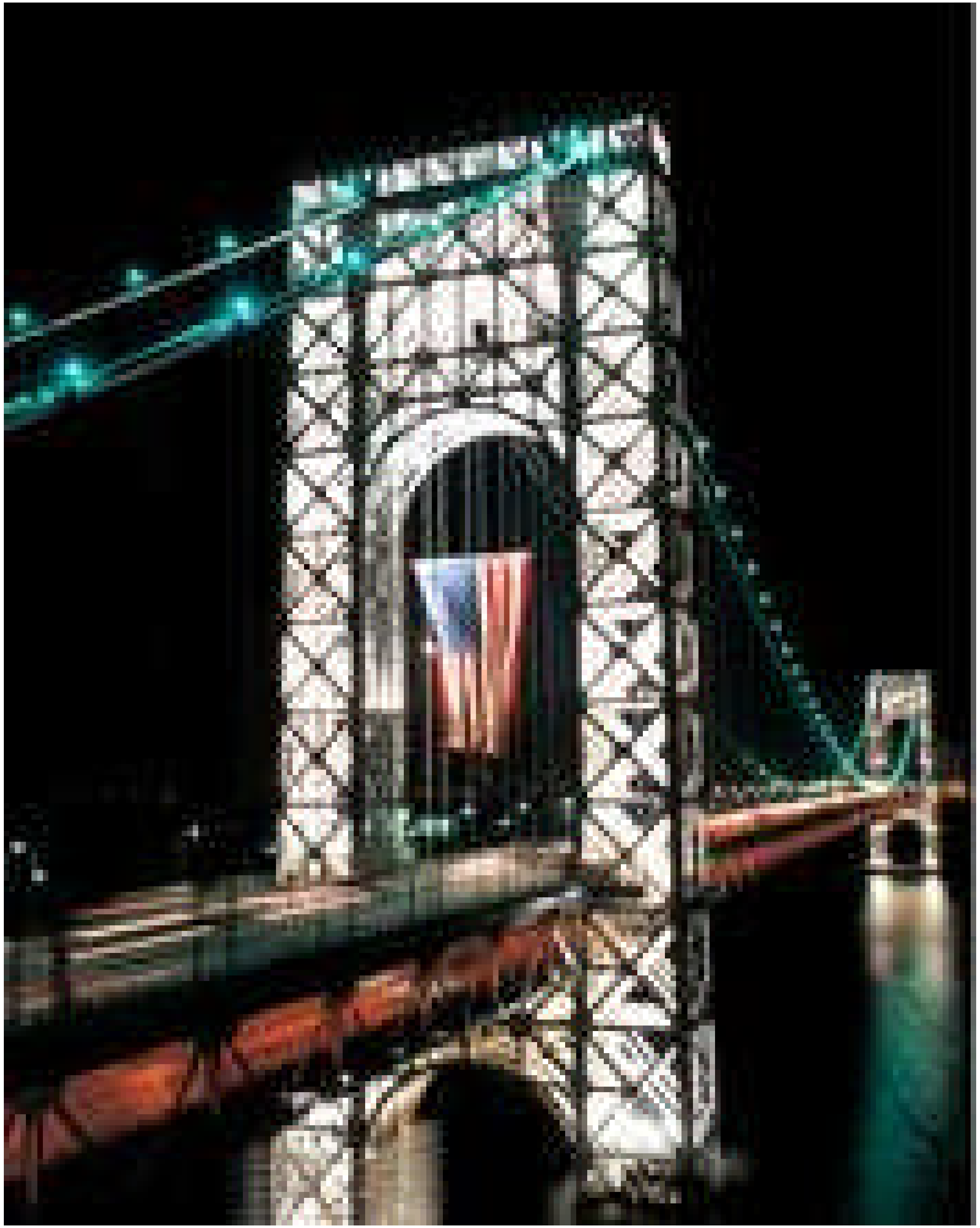
Left: caption: "Rendering of a scheme for an exposed steel structure"

"…Ammann and Gilbert objected passionately to the governing board's cancellation of the ornamental stone as a cost-saving measure. After offering arguments in their final pleas that even they must have considered farfetched, once it became clear that stone would not be provided for the towers neither engineer nor architect publicly expressed regret…"

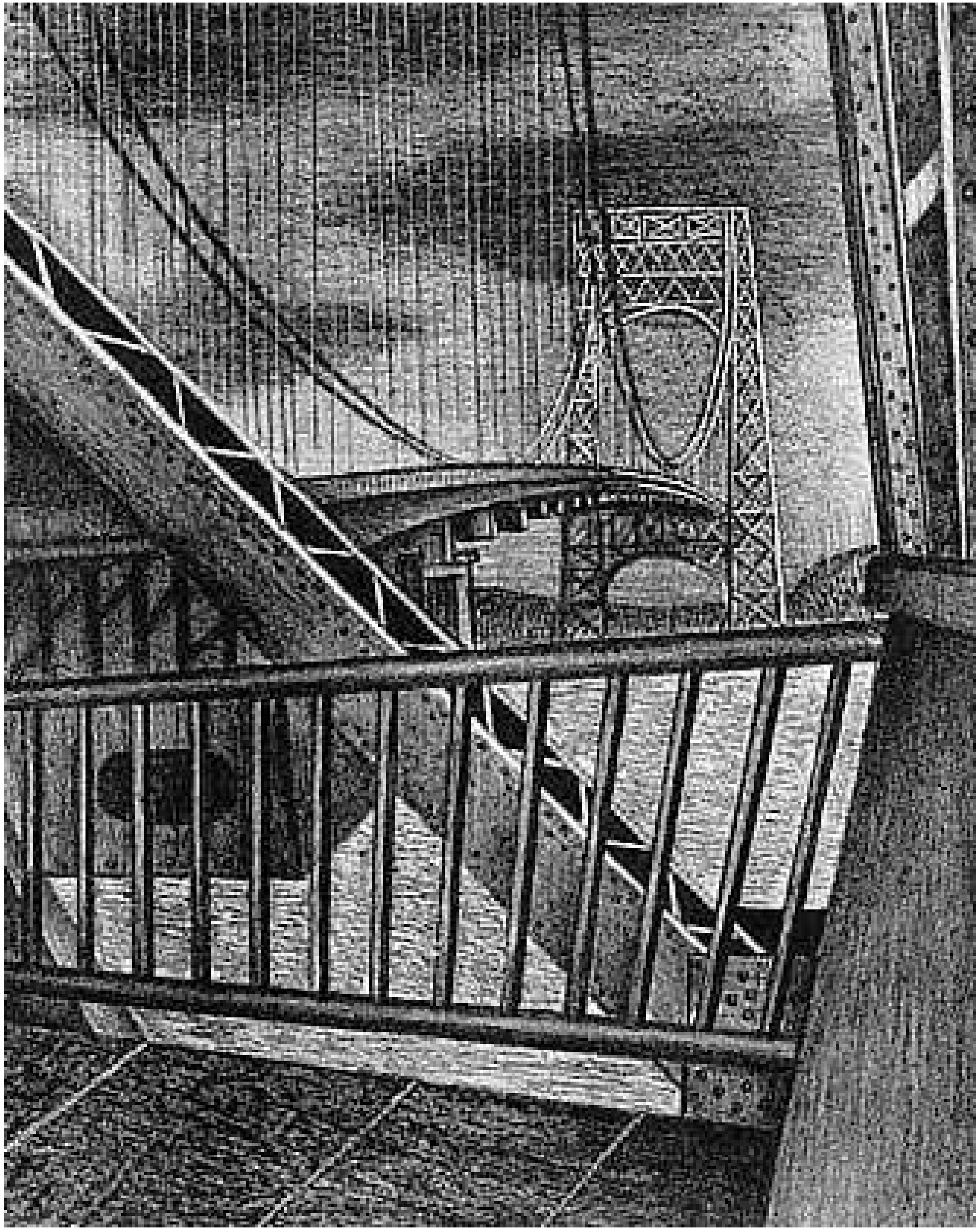
Darl Rastorfer, **Author**

Left: ***Cass Gilbert***, **Architect**





The *New Jersey* tower of the bridge stores the largest free-flying flag in the world. Flown on holidays over the roadway, the 475-pound U.S. flag, which measures 60-feet by 90-feet, features five-foot-wide stripes and three-foot-wide stars.



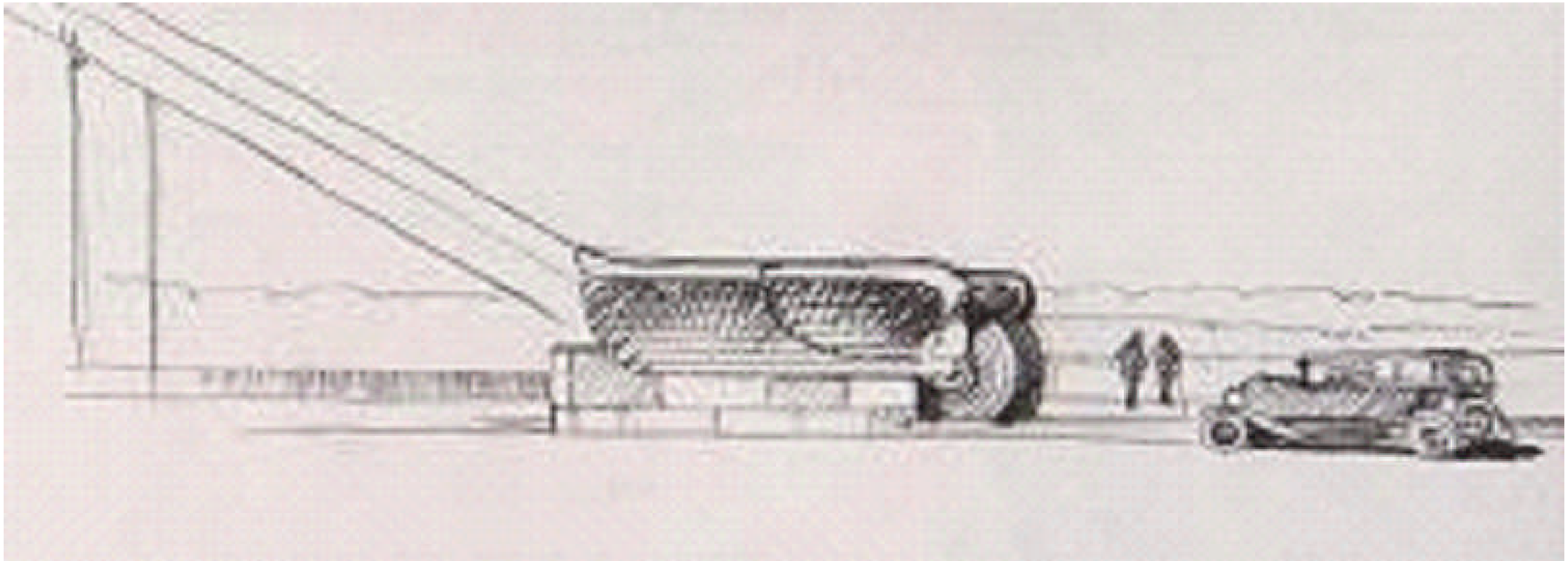
The Period at the End of a Sentence

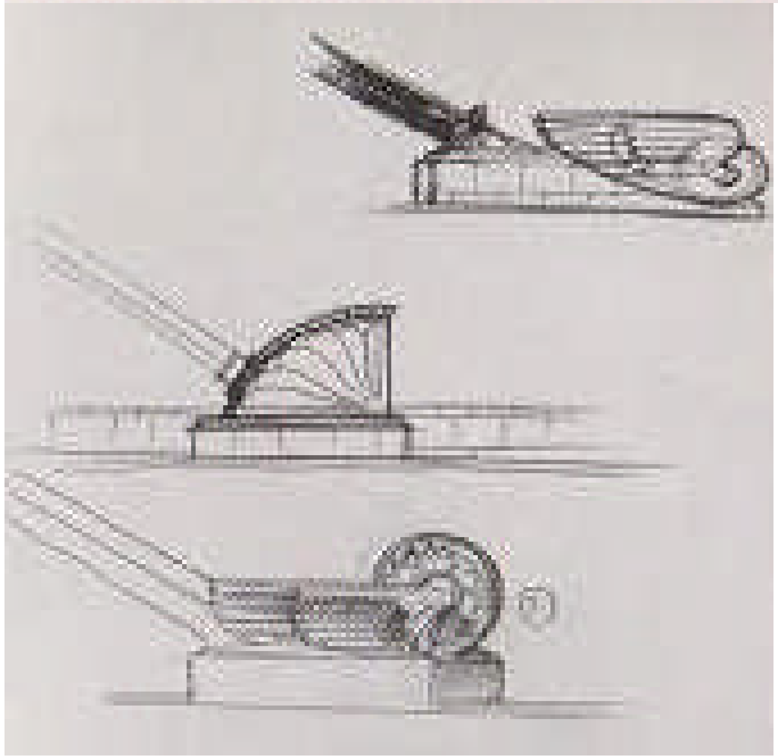
"…Because the anchorages at the George Washington are beneath the level of the road, the main suspension cables are threaded through the deck on their way to being anchored. It's both astonishing and curious to see the powerful cables simply disappear from sight. It was not, however, the intention of the project's consulting architect that the intersections of the cables and the road be left unarticulated. Indeed, Gilbert and his design team felt challenged to provide a pleasing and expressive architectural detail at these points…"
Darl Rastorfer, **Author**

“…Between 1925 and 1926, Gilbert’s design office prepared numerous preliminary studies for stylizing the cable ends. The general effect intended by the architectural treatment was twofold. First, a conspicuous sculptural form was prescribed because it would bring the cables to a deliberate point of termination before they disappeared from sight – metaphorically, the period at the end of a sentence. Second, the imagery and formal composition of the mass was meant to convey the dynamic tensile forces at work in the cables as they flex to support the weight of the road deck – an allegorical device to convey a genuine physical state…”

***Darl Rastorfer,* Author**

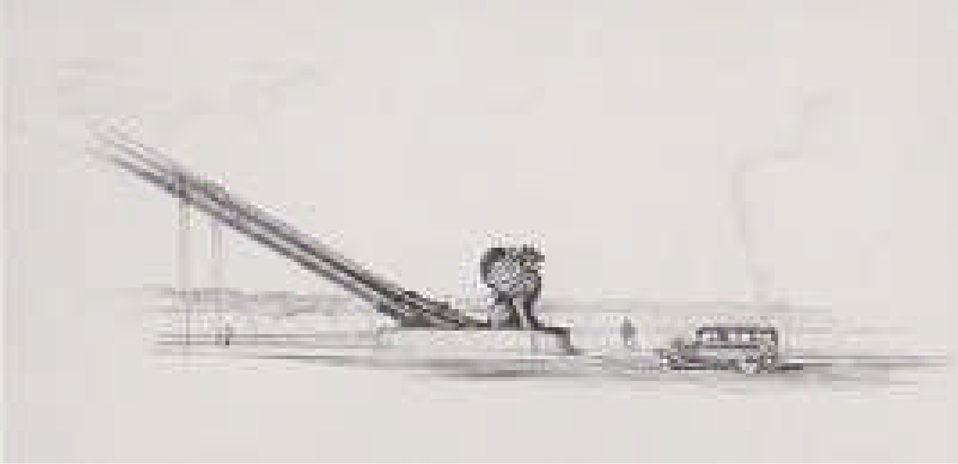
Left: caption: “Study for the bridge’s side-span statuary and stone tower”

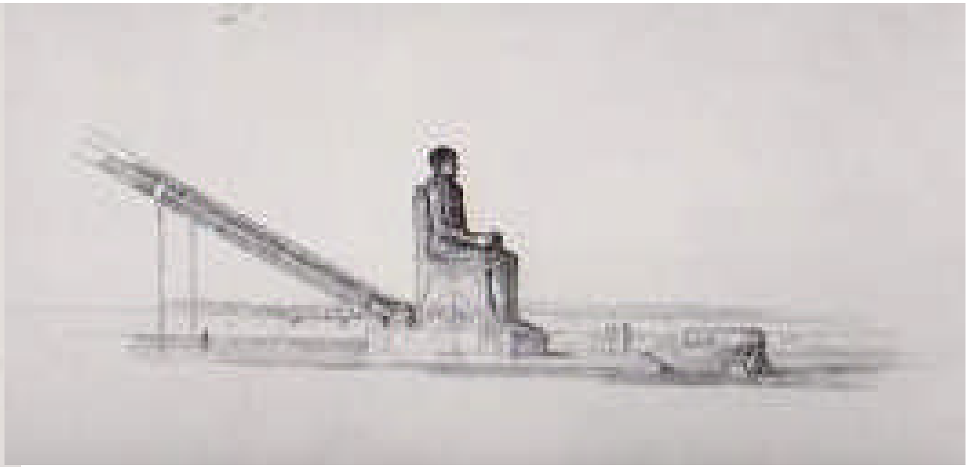




Above: caption: "'Winged Tire' scheme for cable end"

Left: caption: "Three studies for cable-end details with wings, fins, and tires"



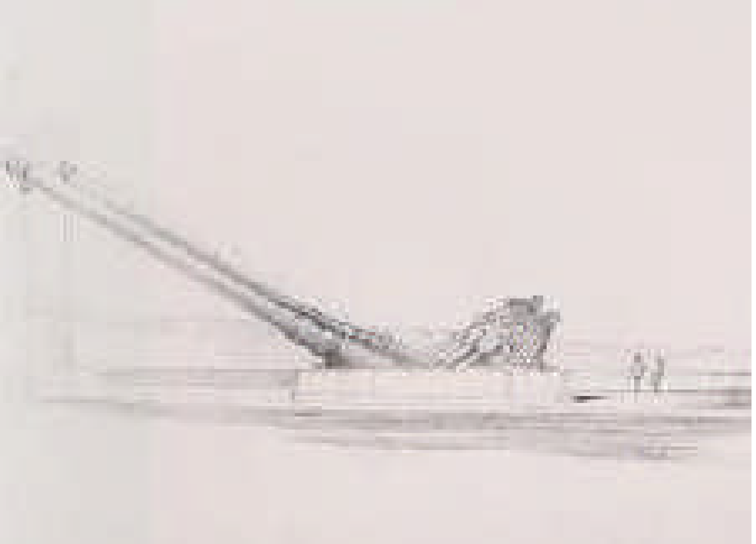


“…From the ‘Winged Tires,’ directed to resist the cables’ pull, to the ‘Laboring Group’ frozen in the struggle to hold back the cables in a never ending game of tug-of-war, all the proposed schemes were placed on long, low pedestals intended to soften the geometric transition between diagonal cable and horizontal road deck…”

Darl Rastorfer, **Author**

Left: caption: “Griffin scheme for cable end”

Right: caption: “Scheme for the cable end incorporating a replica of an Assyrian Colossus”

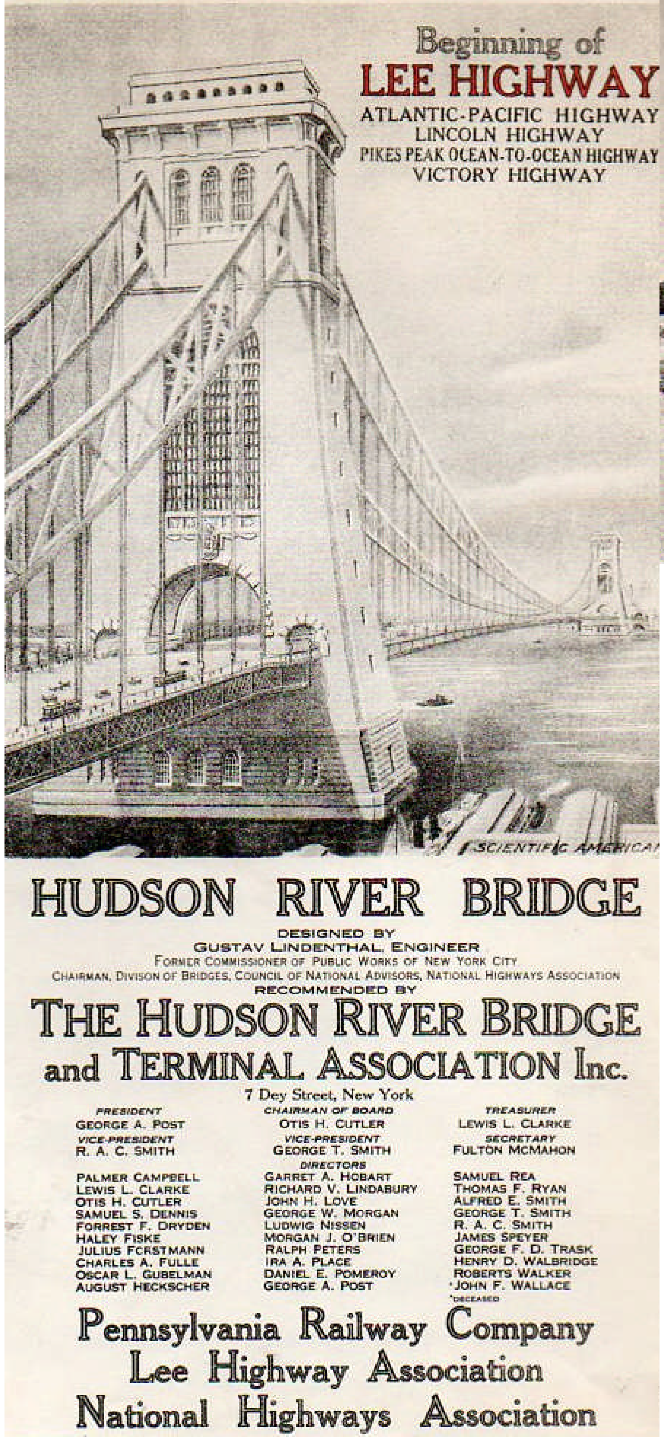


“…The stylized cable ends met the same fate as nearly all the bridge’s ornamental detailing: they were canceled due to unforeseen economic constraints. With a bow to pragmatism, a simplified steel fitting eases the juncture of cable and road surface

***Darl Rastorfer*, Author**

<u>Left</u>: caption: “‘Laboring Group’ scheme for cable end”

Six-Way Motor-Way



Beginning of
LEE HIGHWAY
ATLANTIC-PACIFIC HIGHWAY
LINCOLN HIGHWAY
PIKES PEAK OCEAN-TO-OCEAN HIGHWAY
VICTORY HIGHWAY

HUDSON RIVER BRIDGE
DESIGNED BY
GUSTAV LINDENTHAL, ENGINEER
FORMER COMMISSIONER OF PUBLIC WORKS OF NEW YORK CITY
CHAIRMAN, DIVISON OF BRIDGES, COUNCIL OF NATIONAL ADVISORS, NATIONAL HIGHWAYS ASSOCIATION
RECOMMENDED BY
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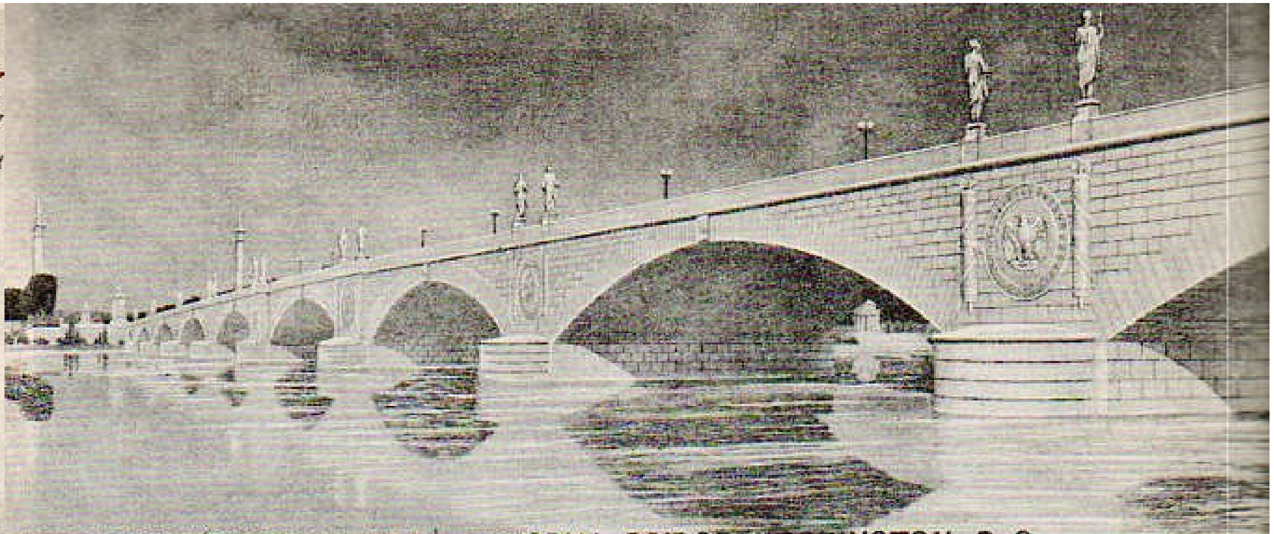
HENRY D. WALBRIDGE
ROBERTS WALKER
*JOHN F. WALLACE
*DECEASED

Pennsylvania Railway Company
Lee Highway Association
National Highways Association


ARLINGTON (LINCOLN-LEE) MEMORIAL BRIDGE, WASHINGTON, D. C.

"The Lee Highway Association, the National Highway Association and the National Foundation are cooperating to create a six-way motor-way connecting the National Metropolis with the National Capitol and extending southwest to the Blue Ridge Mountains, the Shenandoah Valley and the Caverns of Luray. The length will be 330 miles. This motor-way will cross the Hudson River on the Hudson River Bridge and the Potomac River on the Arlington Memorial Bridge, the one to be the greatest, the other the most beautiful bridge ever built by man – the National Bridge of Virginia, crossed by Lee Highway…The New York-Washington Six-way Motor-way will provide for slow, medium and rapid transit each way…Such a public work, monumental in character, will afford an adequate approach to these cities and an extension of their street and boulevard systems…"

RE: excerpt from brochure (ca. 1925). It was never realized.

Part 7

George & Martha

The What?

“I had been working on this book for some time when, at a party, a friend asked, ‘Will you be including a chapter on ‘the Martha’?’ ‘The what?’ I asked. I already knew that one of Fort Lee’s major streets, which leads to the bridge, is Martha Washington Way. I couldn’t imagine that this fact would be worth more than a brief mention. My friend laughed. ‘You don’t know about ‘the Martha’?’ he said, incredulous, and told me that when he was growing up in New Jersey the boys in his neighborhood would always refer to the Upper Level of the George Washington Bridge as ‘the George’ and the Lower Level as ‘the Martha.’ Another person at the party remembered distinctly the traffic reports that would say, ‘There’s a thirty-minute wait for the George, only ten for the Martha’…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

First Things First

“It was April 1950. I was a young civil engineer given the task to head a five-man Port Authority (PA) inspection team to tighten the bolts on the George, the short name we all used for the George Washington Bridge (GWB). Tighten the bolts? Yes, all 3,368 of the cable band bolts, each 28 1/2-inches long, 2 1/4-inches in diameter and holding in place the cable bands on the 36-inch main cables. The cable bands, in turn, support the vertical cables from which the main bridge deck is suspended…The bridge built in 1931, was nearing maturity at 19 years of age. Adjustments were necessary. The tension on the bolts after years of heavy traffic varied all over the lot. Some, it turned out, were virtually hand loose or painted light; others were way over-stressed. To loosen the over tightened nuts there were 5-foot long wrenches with 6- to 8-inch sockets that equaled the leverage of as many as four, 200-pound men. While the GWB was in no danger, the bolts needed to be tightened to avoid the theoretical possibility of a slipping of the cable bands. The task to be performed while 250- to 600-feet in the air was to adjust all 3,368 bolts to a constant tension of 29,000 pounds per square inch (psi)…”

Edward S. Olcott, **CE**

“…We operated special strain gauges that were measuring the 29,000 psi tension. Our workstations were specially designed cages that were rolled by winches along the main cables of the 600-foot high towers. Every day we climbed the cables to reach the cage, either from the tower or from the saddle at the middle of the main span. While we were there tightening bolts, there was talk about a lower level to the George being added…Now the 20-year old bridge was in great shape and ready to take on the job of carrying the additional load of a six-lane lower deck that the premier bridge engineer, O.H. Ammann had so brilliantly designed in the 1920s…Planning for a second GWB deck and its approaches was one of the Port Authority’s major post-World War II projects. I became the project coordinator on this job and loved every minute of it…”

Edward S. Olcott, **CE**

The World’s Biggest

“…The most challenging aspect of building the Lower Level was connecting it to a web of approaches and highways on both sides of the river, making certain motorists could reach their desired destination regardless of whether they took the Lower or the Upper Level. Depressed ramps and new tollbooths were constructed in Fort Lee at the approach to the Lower Level…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

“Considered by many the world’s most beautiful bridge, the George Washington Bridge between New York and New Jersey became, this fall, the world’s biggest as well. A second deck was opened, giving the Hudson River span a total of fourteen lanes that will enable 70,000,000 cars, buses, and trucks to cross it a year…The bridge, built in 1931, was designed to take a lower level when it was needed. New work cost $21,000,000. Approaches brought the added cost to $145,000,000.”

***Popular Mechanics,* Dec. 1962**

Left: network of new highways on the NJ side

The *George Washington Bridge* was first opened to traffic in October 1931. During its first full year of operation in 1932, more than 5.5 million vehicles passed over the bridge. As originally built, the bridge offered six lanes of bi-directional traffic (three lanes in each direction). As traffic demands increased with the post-WWII boom in car ownership (and the opportunity it offered for suburban life via the bridge), additional capacity became necessary. In 1946, the two center lanes of the bridge, which had been left unpaved (open grating) during the original construction, were paved over and opened to traffic, increasing capacity of the bridge by one-third. Thus, two additional lanes were provided on what is now the upper level making it an eight-lane roadway. A second, lower deck, which had been anticipated in Othmar Ammann's original plans, opened to the public on August 29th 1962. This lower level was nicknamed "Martha" (the upper deck was "George"). The additional deck increased the capacity of the bridge by 75%, making the GWB the world's only fourteen-lane suspension bridge; providing eight lanes on the upper level and six on the lower. It was expected that the lower deck, in and of itself, could handle 30 million vehicles per year.

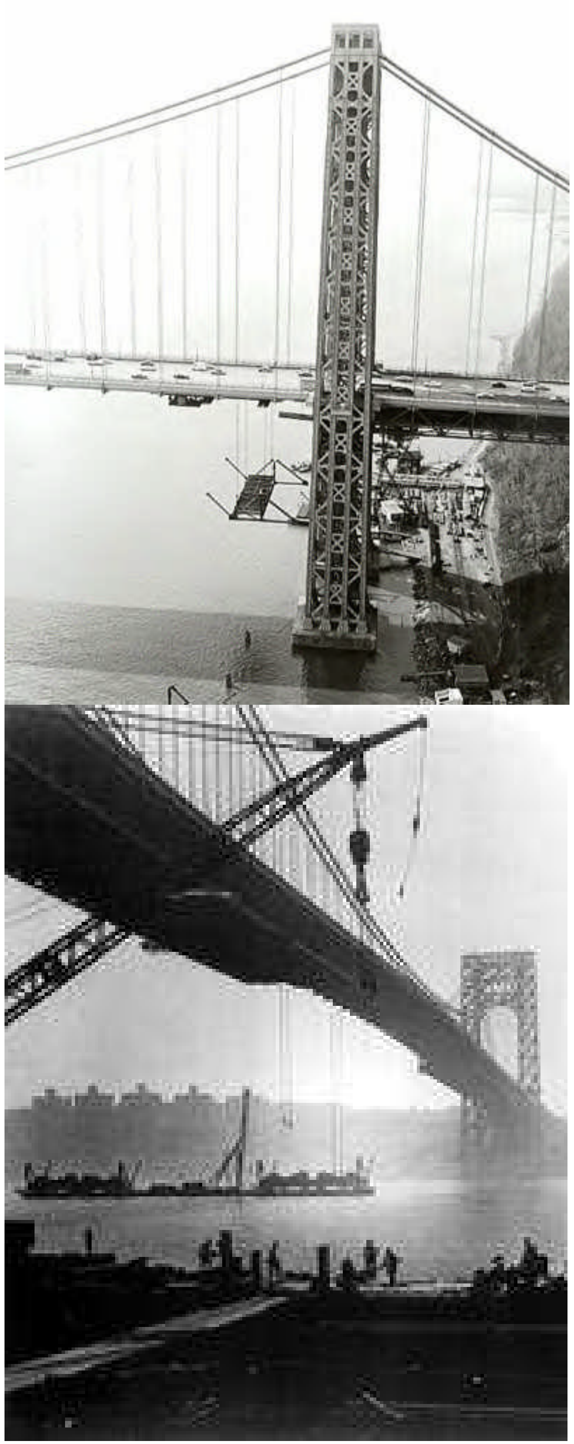
"…At one point in the 1920s, the bridge's chief engineer, Othmar Ammann, had considered only one barrel cable on each side of the George but had put two to ensure that a second level, if desired, could be added someday. It is remarkable that the Lower Level was added without any additional cabling. Both levels hang from the suspender cables that support the Upper Level and descend from the barrel cables. The Lower Level is simply bolted to the Upper Level by a crosshatch of steel girders…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

"…There are no walkways on the Lower Level, though this is, perhaps, as it should be. Roofed by the Upper Level and shut in by girders obstructing the view, it is something of a tunnel and would not be a pleasant place to walk or bike…The absence of walkways on the Lower Level, while understandable, is symptomatic. By 1962, Robert Moses' automobile-focused plans for New York City were being realized everywhere, and we would see their effect in Ammann's last bridge, the Verrazano-Narrows, where there are no pedestrian or bicycle walkways whatsoever…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

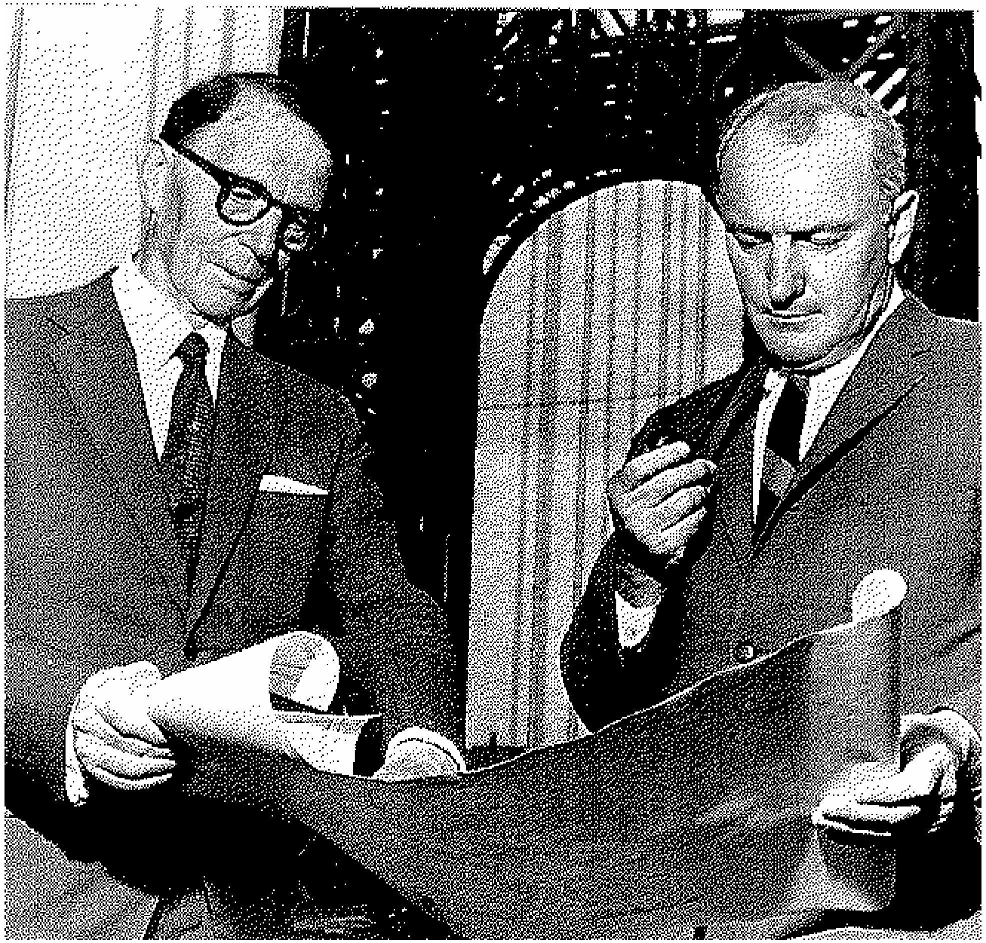
Left: caption: "Pedestrian walkway on the upper level of the bridge"



"Double-deck bridge's aren't new – San Francisco's Oakland Bay Bridge was built that way from scratch. But adding a second deck to an old bridge, especially one of this size (its 3,500-foot span is the third longest) is something else again. Bethlehem Steel engineers brought new, complex methods into play. They added the lower deck without closing down even temporarily, and without interrupting the upper-deck flow of 100,000 vehicles a day during four years of construction. Yards on both banks of the river assembled seventy-five huge 220-ton steel deck sections 108 feet wide and 90 feet long. They were raised on trolleys working on tracks under the structure…"

***Popular Mechanics,* December 1962**

Left T&B: raising lower-deck truss sections into place



"…Although Ammann had long ago left the Port Authority to found his own engineering firm, his foresight had proven remarkable. First, the Upper Level had to have been hung in 1931 with sufficient clearance between its underside and the bottom of each tower's main arch for another roadway to pass through - a roadway sufficiently elevated above the Hudson to meet Defense Department navigational standards. As it is, the Lower Level is 212 feet above the river at mid-span. Also, Ammann, in his original design, had seen to it that steel plates were attached to the Upper Level to which the girders supporting the Lower Level could be bolted…"

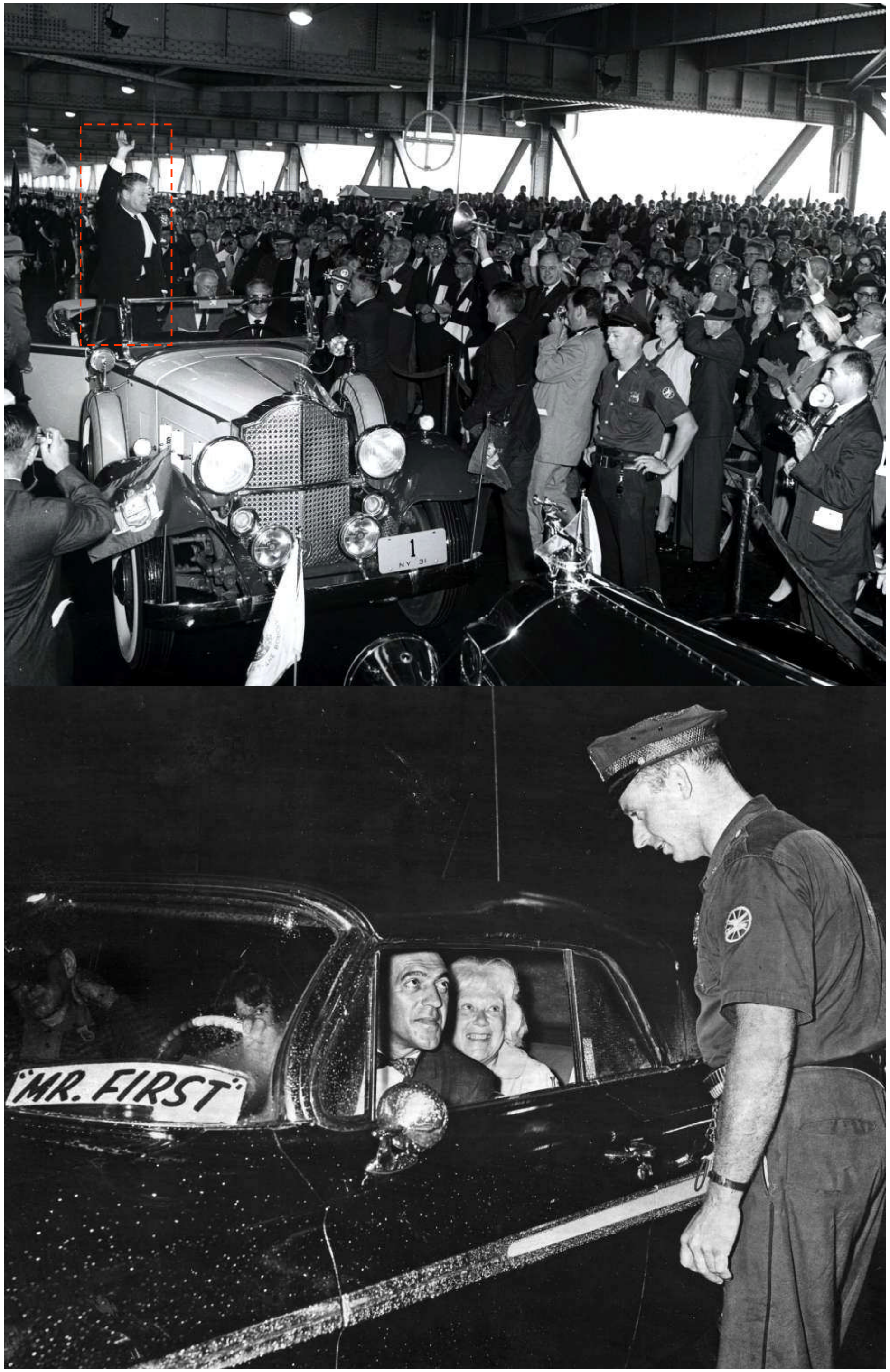
RE: excerpt from *The George Washington Bridge: Poetry in Steel.* At left, Ammann reviewing lower deck plans as consultant to the PA (ca. 1960).

Trusses were assembled in 60-foot chords for the 4,670-feet of deck and dry-fitted in Bethlehem’s Pottstown plant to insure final fit on-site. Each 220-ton truss section was raised into place starting from each tower toward the anchorage/s and, when the side span sections were complete, from each tower toward mid-span. Once all the trusses were secured in-place, concrete to form the 4.5-inch deck was pumped from the upper level via chutes through temporary holes punched in the deck (it took 5K square-yards of concrete to cover the entire area). On the lower deck, the concrete mix was distributed by motorized spreaders from mid-span landwards in each direction to keep the additional weight balanced. Once all the concrete was in-place, a 1.5-inch asphaltic wearing surface was laid and compacted with heavy rollers.


95
80
TP
NJ
KEEP RIGHT

“…When the Lower Level was added, it was discovered that the extra weight had raised a bump in both roadways. Port Authority engineer Charles Druding, general manager of the Lower Level project, knew that pulling down on adjoining suspender cables would jack up the roadway in the bump areas. But how? Inspecting the cables that needed to be pulled on, Druding discovered that they had handle-like wires attached. Ammann, in the 1920s, had foreseen the bumps and had provided the means of alleviating them…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel.* Construction of the $20 million lower deck began in 1959 and followed Ammann’s original design. Without interruption to the eight traffic lanes above, seventy-six structural steel sections were hoisted into place from below. The lower deck was designed with a minimum clearance of fifteen-feet between the upper and lower deck roadways. Even with the addition of the lower deck, the bridge had a clearance of 213-feet over the *Hudson River*. Stiffening trusses were incorporated into the design of the lower deck to provide additional stability against torsion. The additional weight required a slight adjustment to the cable saddle rollers.



"…The Lower Level was inaugurated on August 29, 1962, thirty-one years after the opening of the Upper Level. Governors Nelson Rockefeller of New York and Richard Hughes of New Jersey were driven from their respective states onto the Lower Level in convertibles of 1931 vintage that recalled the original inauguration…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel.* At left, *New York* Governor *Nelson Rockefeller* showed up for the 1962 opening of the GWB's lower level in a vintage 1931 *Packard* (top), the year the bridge first opened. Below, a motorist vies to be "Mr. First" (to cross the lower level).

The Joint Study

“In the opinion of the Port Authority, the public interest requires that the George Washington Bridge be able to accommodate rail rapid transit at any future time. It is solely because of this look to the future that the second deck of the Bridge would be designed to permit conversion of two vehicular lanes to rapid transit use. Rail rapid transit across the Hudson does not appear to be an immediate prospect…The new lower deck of the George Washington Bridge would support a double-track rapid transit line, should the two center lanes be converted to trackage use…A rail rapid transit plan was studied and direct track connections with four New Jersey commuter railroad were found to be physically feasible…”

RE: excerpts from *Joint Study of Arterial Facilities - New York, New Jersey Metropolitan Area*, published by the *Port of New York Authority* in 1955

"…Originally, Ammann had thought that were a Lower Deck ever built, it would be for light rail. By 1962, virtually all thought of using the Lower Level for trains had been abandoned. Six of the eight lanes were paved for automotive traffic, the two center ones left vacant with the vague thought that they might someday be used for rapid transit tracks. The lanes remain vacant to this day, covered with a thick steel mesh to prevent a vehicle, in a freakish accident, from going over the inside barriers and crashing through to the river. Shortly after the Lower Level opened, a truck did go over a barrier, but the mesh held…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*


EXIT 1
H Hudson
Pkwy
W 178 St
THRU
TRAFFIC
95
1/4 MILE

“…The most famous accident on the George Washington took place on Christmas Day 1965, when a plane crash-landed on the Upper Level. A 19-year-old pilot from the Bronx, Philip Ippolito, was out for a pleasure ride with a friend in a small plane he had rented at the Ramapo Valley Airport in Spring Valley, New York. They flew down the Hudson, developing what they thought was engine trouble just off midtown Manhattan. Ippolito turned the plane around, thinking he might be able to make it back to the airport. But the engine was now sputtering. Earlier, in flying over the George Washington Bridge, Ippolito had noticed that traffic was light, as it usually is on a Sunday. With his engine now close to failing altogether, he glided toward the bridge and managed a long sweeping curve over the lowest point of the south barrel cables. The plane, with a 34-foot wingspan, set down between widely spaced westbound cars and trucks. The plane’s wing clipped a truck, causing almost no damage to it, but the plane was pretty well demolished when it spun out of control and then smacked into the concrete divider. There was no fire because the plane’s problem, as it turned out, was that it was out of fuel; its gas cap was missing. Ippolito and his passenger were able to disembark without assistance and were taken to the hospital…Both men were released from the hospital two days later…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

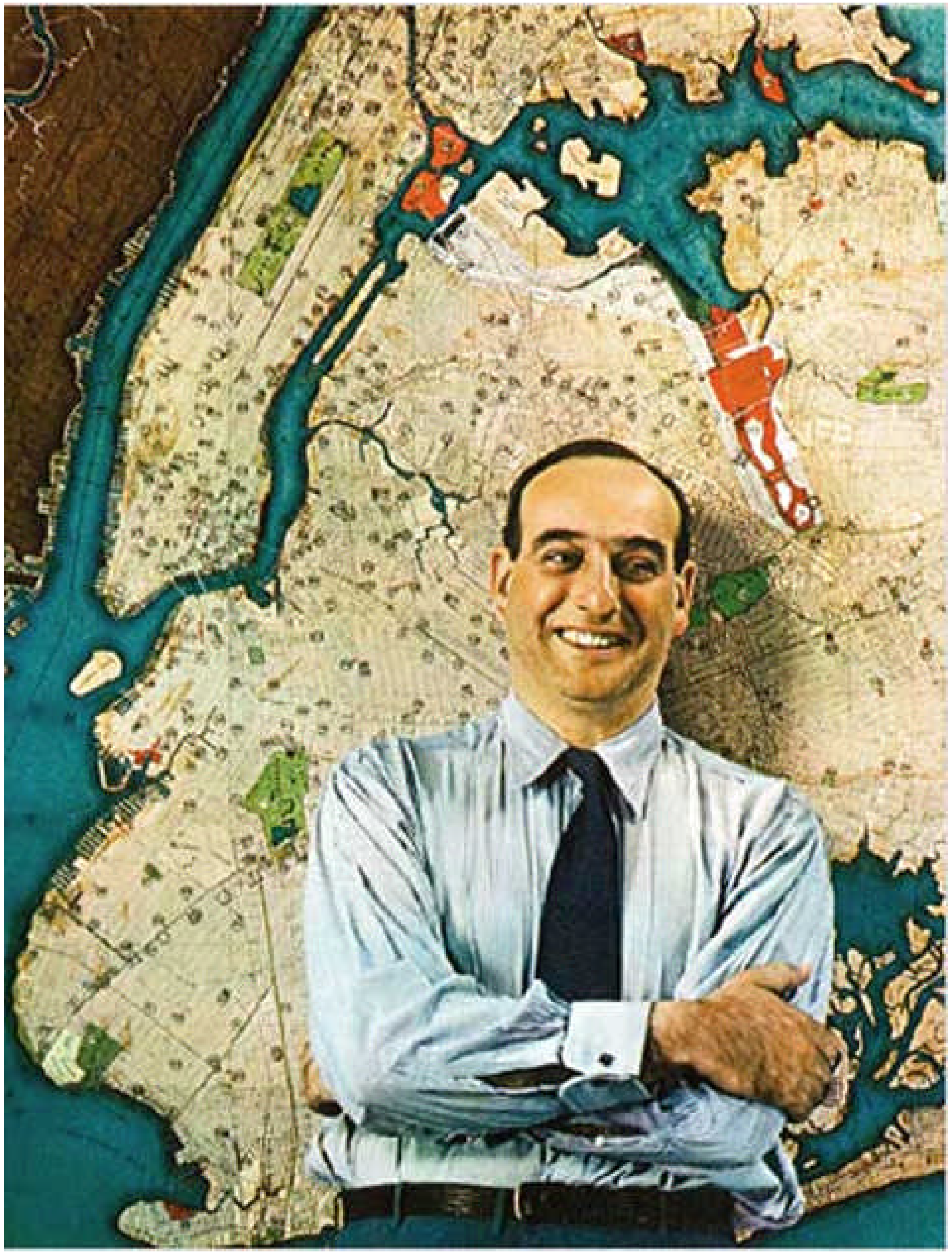
“…I asked Vicky Kelly, director of Tunnels, Bridges, and Terminals for the Port Authority, why, given the congestion on the bridge, the two vacant lanes on the Lower Level have not been made available for use - which would give the bridge sixteen lanes in all, making it still more busy than any bridge in the world. She told me that it’s a question of capacity on the New York side. The off-loading of even more traffic onto the West Side Highway and the Cross Bronx Expressway would be untenable. Nevertheless, she agreed that someday these two lanes might have to be made available for use - but almost certainly for automotive traffic, not mass transit…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

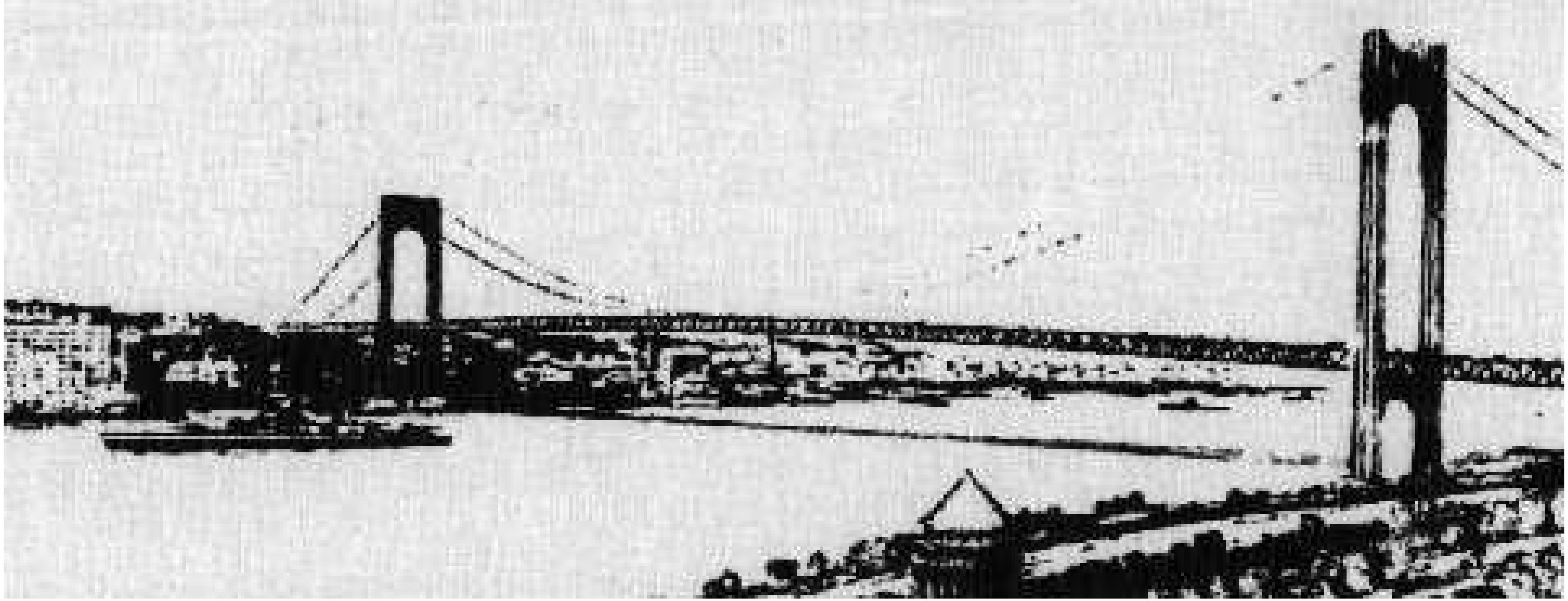
The 125th Street Bridge

“…There was a brief period in the 1950s when, instead of adding the Lower Level, a bridge across the Hudson at 125th Street was considered. Such a bridge would have routed traffic across Manhattan to the Triborough Bridge, but it would have disrupted city life far more than has the Lower Level of the George Washington Bridge, more than fifty blocks farther uptown. And it would have cost a great deal more…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel.* In 1955, after nearly a decade of explosive traffic growth, *Robert Moses* chaired the *Joint Study of Arterial Facilities* between the *Port of New York Authority* and the *Triborough Bridge and Tunnel Authority*. The Joint Study was developed to spearhead construction of new bridges and expressways, One of the alternate proposals (and the one adopted) called for the addition of a six-lane lower level to the *George Washington Bridge*.



In the mid-1950s, another crossing of the *Hudson River* was proposed, this time between *West 125th Street* and *Edgewater, New Jersey*. Together with the proposed *Cross Harlem Expressway*, the bridge was to provide additional access from *New York City* and *Long Island* to northern *New Jersey*. In 1954, the *Port of New York Authority* commissioned *Othmar Ammann* to design a new suspension bridge across the Hudson River at West 125th Street. Instead of constructing the Hudson River bridge, the Port Authority shifted its attention - under the influence of Joint Study chairman *Robert Moses* (left) - to the construction of the *Verrazano-Narrows Bridge* in the late 1950s. Moses sought financial support from the Port Authority to have his bridge constructed while the Port Authority needed the support of the *Triborough Bridge & Tunnel Authority* (TBTA) to bail out its money-losing crossings between *Staten Island* and New Jersey.



<u>Above</u>: the suspension bridge, which was designed with a 4K-foot main span and a 6,300-foot distance between anchorages, would have had a truss-stiffened deck with two six-lane roadways, rigid-frame steel-plate towers with hemispheric struts, and four suspension cables. The proposal, whose features were to be similar to those for Ammann's *Verrazano-Narrows* and *Bronx-Whitestone Bridge/s*, never advanced beyond the preliminary design stages.

“Under the Joint Study, close attention was given to a new bridge in the vicinity of 125th Street, Manhattan. Traffic to be accommodated by such a new major Hudson River crossing, however, would require extensive and costly expressway facilities in Bergen County and across northern Manhattan, and extensive connections through Queens and on Long Island. It would also call for expensive new Harlem River and East River crossings. We therefore recommend that further consideration of a fourth major Hudson River crossing be deferred until the George Washington Bridge, Narrows Bridge and Throgs Neck Bridge projects have been completed and the traffic patterns at that time can be studied.”

RE: excerpt from a joint study of present and future traffic volumes on existing facilities conducted by the *Triborough Bridge and Tunnel Authority* and the *Port of New York Authority*, 1955

Trans-Manhattan Expressway

“The 179th Street Tunnel, built by the Port of New York Authority at a cost of $9,000,000, provides a two-lane, subsurface westbound connection between the Harlem River Drive, the 181st Street (Washington Heights) Bridge, the Cross Bronx Expressway and the George Washington Bridge. The two-lane 178th Street Tunnel, which the Port Authority built and opened in 1940, will be used for eastbound traffic from the George Washington Bridge. Construction was begun March 17, 1949, and the tunnel’s reinforced concrete shell was completed on June 21, 1951. The $5,300,000 Highbridge Interchange, the connecting link between the George Washington Bridge (via the approach tunnels), the Cross Bronx Expressway and the Harlem River Drive, features a soaring two-lane viaduct supported on a single row of long slender columns. The construction of the interchange required extensive reconstruction in Highbridge Park, including promenades, walks, playgrounds, and a new pumping station. As the westerly terminus of the Cross Bronx Expressway, the old Washington (Heights) Bridge over the Harlem River has been widened, and provisions have been made for future additional capacity.”

Robert Moses, **1952**

Above: *178th Street Tunnel* (left) and *179th Street Tunnel* (right), present day. Immediately after WWII, *Robert Moses* constructed a bypass - a predecessor to the *Trans-Manhattan Expressway* - through the *Washington Heights* section of upper *Manhattan* that would connect the bridge with highways in the *Bronx*. Between 1938 and 1952, two two-lane tunnels were constructed from the GWB to the approaches of the 1888 *Washington Bridge* and the *Harlem River Drive* (which was then under construction). Eastbound traffic used the 178th Street Tunnel, while westbound tunnel used the 179th Street Tunnel. The tunnels were designed in traditional Moses-style, utilizing stone-faced arch portals and “Whitestone” light-posts. Viaducts with single circular supports that connected the tunnels with the Washington Bridge are still in use today. Originally, traffic bound from the tunnels to the *Cross Bronx Expressway* was to cross the *Harlem River* over the Washington Bridge. However, after less than five years, the traffic demands were too much on the two, two-lane tunnels and the older Washington Bridge. A new solution would be sought to meet the future demands of interstate traffic. Furthermore, the ventilation buildings of the old tunnels were situated such that they would be functionally obsolete for future expansion of the lower deck of the GWB.

“The New York approaches to the lower deck of the George Washington Bridge would provide an interchange with the Henry Hudson Parkway (NY 9A) and Riverside Drive, as well as to the local Washington Heights area, by means of extensive modification of the existing approaches. At present, express traffic across Manhattan to and from the George Washington Bridge is handled by means of the Port Authority’s 178th Street and 179th Street Tunnels. To augment these tunnels, an east-west expressway would be provided against Manhattan Island. Occupying the entire block between 178th and 179th Streets, the expressway would connect with the Cross Bronx Expressway by means of a new Harlem Bridge. The new bridge would be built by the State of New York as part of the Cross Bronx Expressway under construction. On the Manhattan side of the Harlem River in Highbridge Park, direct connections would be provided with Amsterdam Avenue and with the Harlem River Bridge which, when the extension south to 125th Street is completed, will be an additional north-south artery in Manhattan.”

RE: excerpt from a joint study of present and future traffic volumes on existing facilities conducted by the *Triborough Bridge and Tunnel Authority* and the *Port of New York Authority*, 1955

The construction of the *Trans-Manhattan Expressway* (highlighted on map at left) was undertaken in conjunction with the lower level of the GWB. The ventilation buildings, which were along the right-of-way for the proposed expressway, were demolished to make way for the twelve-lane roadway. In the meantime, the original tunnels were left abandoned. Originally planned in 1955 as an open-cut design, the twelve-lane Trans-Manhattan Expressway (TME) opened to traffic in 1962 as part of a $60 million program to improve access roads for the GWB, whose lower deck also opened that year. The expressway is one of the few examples in *New York City* (and one of the earliest in the U.S.) where air rights over major highways were used. Upon completion of the expressway, the *Port Authority Bridge Plaza Bus Terminal* (serving northern *New Jersey* communities) and four high-rise apartment buildings (*Bridge Apartments*) opened above the TME.

<u>Above</u>: caption: “Looking east along the route of the Trans-Manhattan Expressway in the Washington Heights section of Manhattan, as shown in this 1960 photo. The Washington (Heights) Bridge, which lies in the background, would be accompanied two years later by the Alexander Hamilton Bridge.”

“The New York State Department of Public Works is currently constructing the Cross Bronx Expressway, which includes the magnificent old Washington Bridge across the Harlem River. This bridge was widened and repaved, and a center divider was installed. It will before long have to be doubled in capacity by virtually adding another bridge next to it.”

***Robert Moses*, 1952**

RE: when the *Highbridge Interchange* connecting the 1888 *Washington Bridge* with the GWB (via the *178th* and *179th Street* tunnel/s) opened in 1952, Robert Moses - *New York City Construction Coordinator*, anticipated that it would not be long before a parallel span would have to be constructed alongside the Washington Bridge. In his 1955 report: *Joint Study of Arterial Facilities*, Moses determined that the Washington Bridge would not be able handle the anticipated traffic demands from the then-proposed lower level of the GWB. He proposed a new eight-lane arch span - the *Alexander Hamilton Bridge*, directly south of the existing Washington Bridge. The bridge was to link to two other new expressways proposed by Moses: the *Cross Bronx Expressway* and the *Trans-Manhattan Expressway*. As part of the Interstate highway system signed into law in 1956, the new bridge was to carry the “I-95” (Interstate) designation. The Federal government covered 90% of the bridge’s $21 million cost (the bridge itself cost $7.5 million to construct; the remainder was allocated for the interchanges). Plans for the bridge and its interchanges had been finalized by 1958.

“…The tunnels under 178th and 179th streets were abandoned, and the twelve-lane Manhattan Expressway was built. It was connected to the Cross Bronx Expressway over the newly constructed Alexander Hamilton Bridge that spanned the Harlem River. In addition, a new bridge headquarters building was erected in Fort Lee and a bus station was built at the eastern end of the bridge, basically to accommodate commuters to and from New York…”

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

Construction of the *Alexander Hamilton Bridge* (top, in foreground) began in early 1960. In the spring of 1962, the two parallel arches comprising the main span were joined high above the *Harlem River*. The new bridge opened to traffic on January 15th 1963, the same day that the controversial *Cross Bronx Expressway* was completed. However, the interchange ramps between the bridge and the *Major Deegan Expressway* did not open until 1964 (bottom). *Ernest Clark*, who designed the Cross Bronx Expressway under Moses, described this interchange as “concrete spaghetti…the word ‘interchange’ does not begin to adequately describe the construction in this area.”

"…Also, four apartment towers were built over the Manhattan Expressway to compensate for the apartment buildings taken down to allow its construction. All of these projects proceeded simultaneously with the building of the Lower Level itself, a remarkable feat of co-ordination…"

RE: excerpt from *The George Wash-ington Bridge: Poetry in Steel*. At left, four 32-story apartment buildings and a modernistic bus station (above and to the left of the apartments) were constructed above the TME via the granting of air-rights.

"…when the huge towers of the Bridge Apartments above the twelve-lane Manhattan Expressway, the road that carries bridge traffic across Manhattan, were built, they were considered an immense novelty and a fashionable address. Today we question how anyone could have imagined that homes built above a giant highway might be fit places to live. But Americans had not developed much of an environmental consciousness by 1962. Now we wonder to what extent the people living there are victimized by noxious air rising into their apartments - even though there are huge ventilators underneath the buildings that are supposed to convey elsewhere the exhaust fumes of the 300,000 vehicles that daily cross the bridge…"

RE: excerpt from *The George Washington Bridge: Poetry in Steel*

“The depressed Trans-Manhattan Expressway connecting the George Washington Bridge and the Alexander Hamilton Bridge across the Harlem River will be fully opened to traffic with the completion of the Cross Bronx Expressway. This is the first expressway to be built across Manhattan, and we hope that the Lower Manhattan and Mid-Manhattan expressways, both of which have been the victims of inordinate and inexcusable delays caused by intemperate opposition and consequent official hesitation, will follow. These crosstown facilities are indispensable to be effectiveness of the entire metropolitan arterial objective of removing traffic through congested city streets.”

Robert Moses

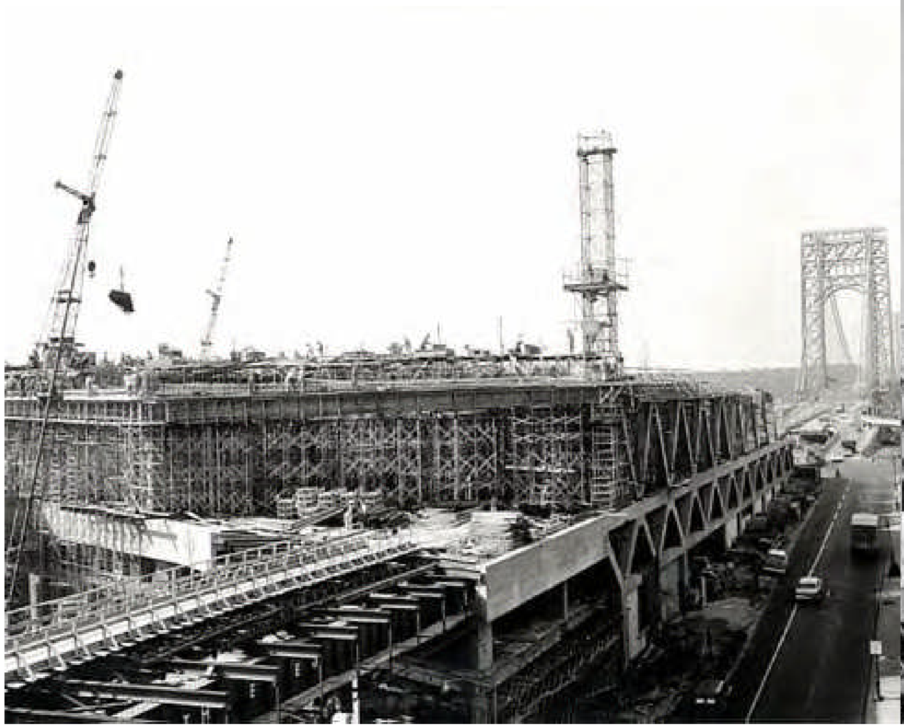
Left: caption: “Mid-Manhattan Expressway (proposed), looking east, circa 1959”

Erector Set Deco

“…There were only nine years between the germ of the idea in 1953 and the ribbon-cutting ceremony in 1962. Equally amazing was that the project was authorized for $183 million but came in at $145 million! These were not times of deflation, either. Actually, the $183 million figure was a little distorted. In 1957, Austin Tobin, the legendary executive director of the Port Authority from 1942 to 1972, went to the New York City Board of Estimate with a $182 million job. When he emerged several hours later he said, ‘Call it $183 million. They insisted we put a roof on the bus station.’ Thus, the origin of what became known as the Nervi-roof on the GWB bus station designed by the Italian architect…”

Edward S. Olcott, **CE**

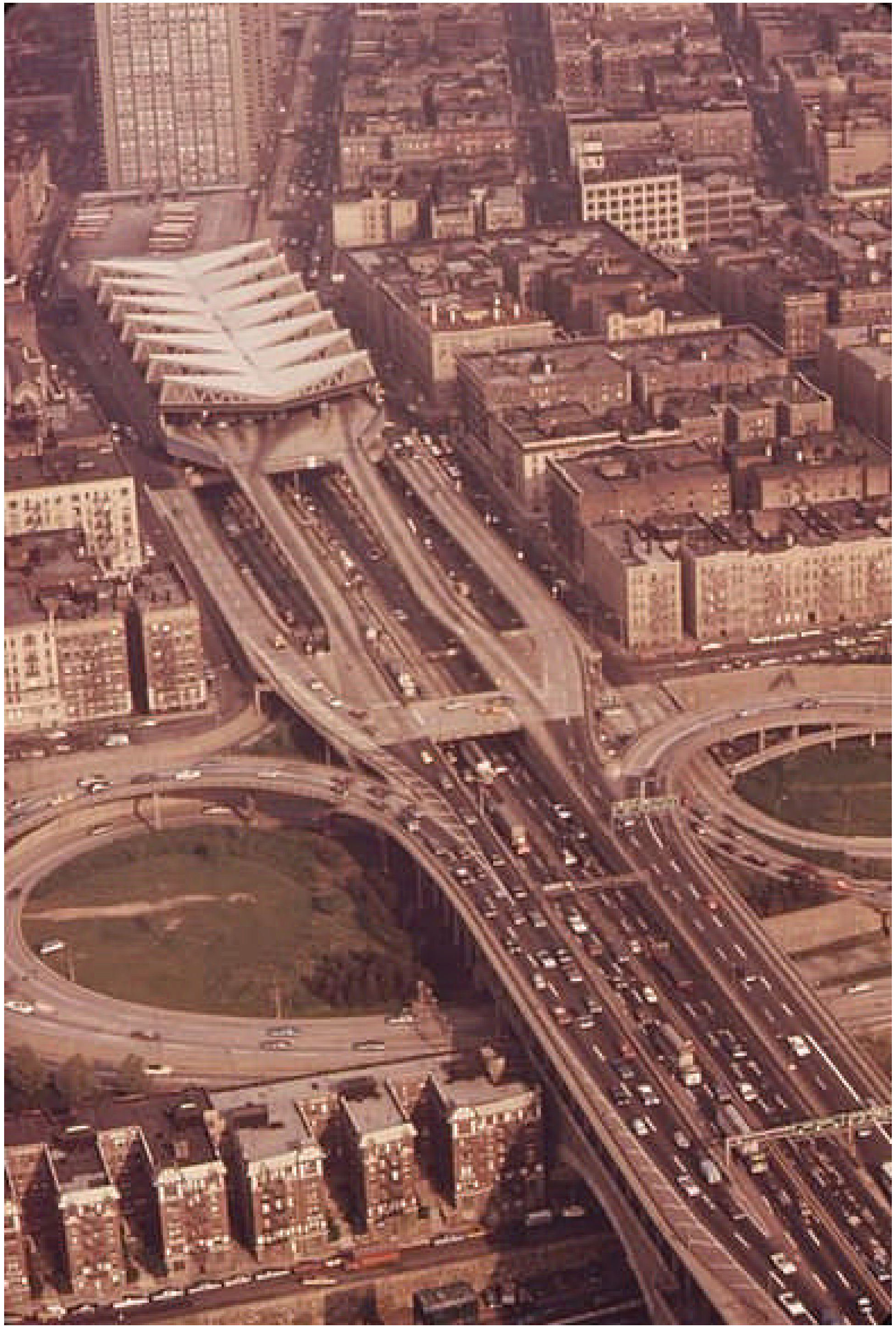
Opened on January 17th 1963, The *Bridge Plaza Bus Station* (left) replaced numerous sidewalk bus loading areas that existed in the *166-167th Street/s* area of *Washington Heights* with comfortable and convenient facilities for passengers. The station was the first example in the *United States* of the work of *Dr. Pier Luigi Nervi*, the noted Italian engineer-architect of the *Palazzetto dello Sport* (1960 Olympic Stadium) in *Rome, Italy* (right). The station's concrete roof comprises twenty-six triangular sections poured in-place, fourteen of which slope upward from a row of columns in the center of the building. Each triangular 92-by-66-foot section is made of twenty-five concrete panels. The sides of the raised roof sections (and of the bus station itself) are exposed concrete structural members forming openings to facilitate ventilation of the bus platforms and the *Trans-Manhattan Expressway* beneath the building. These concrete supporting members complement the design of the steel cross-bracing in the GWB's towers. The station received the Concrete Industry Board's 1963 award as the structure in the metropolitan area that represents the best in conception, originality and applicability of concrete, both in design and construction.



“…call it ‘erector set deco’…The structure – a station and attached parking lot, one of Nervi’s few completed projects outside Italy – is a superb example of the poetry he wrought from ferro-concrete, exploring, as he put it, ‘the mysterious affinity between physical laws and the human senses’…The building is on par with Saarinen’s TWA terminal at Kennedy Airport, another reinforced concrete masterpiece that seems ready to leave the ground. But unlike Saarinen’s building, which has achieved iconic status, Nervi’s is under-appreciated…”

ArchNewsNow


TWA



“The George Washington Bridge Bus Station is located on a two-block site in the Washington Heights area of upper Manhattan. The station, which features a direct link to the upper level of the George Washington Bridge, is between 178th and 179th streets and Fort Washington and Wadsworth avenues. In 2012, 4.7 million passengers on 327,000 bus trips passed through the terminal…To improve the atmosphere and level of service in and around the bus station, the Port Authority is advancing an initiative with a private entity to significantly upgrade the space…The proposed air rights development would add approximately 1.3 million square feet of first-class office space to the terminal, improve the efficiency and quality of transportation, enhance pedestrian and bus passenger circulation, and upgrade the retail space…”

***PANY&NJ*, 2013**


RETAIL
4

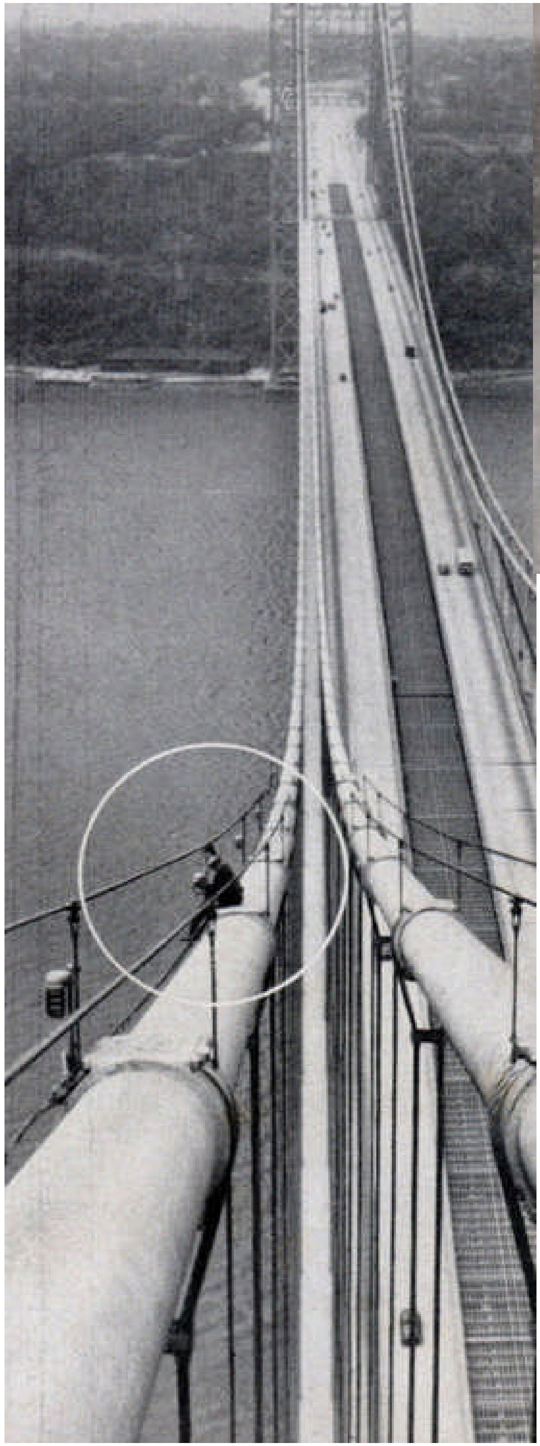

RETAILER

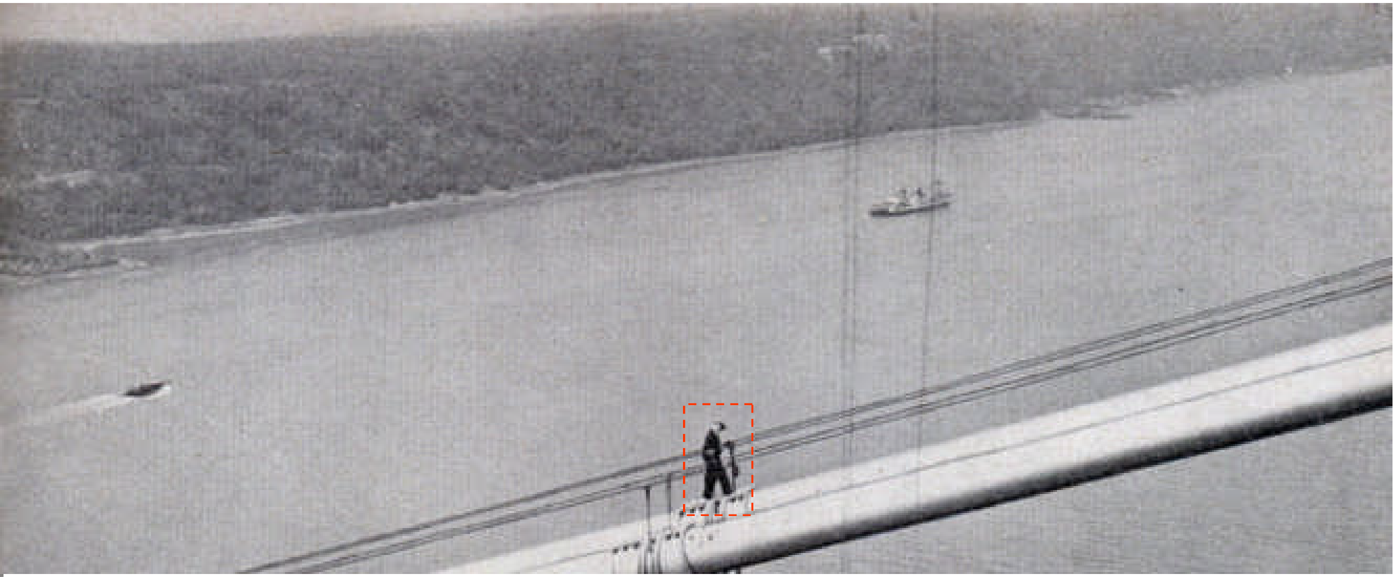
Legacy

“The ‘Hudson River Bridge,’ as the George Washington Bridge was called in the early days, was twice the length of any existing span, and it required an intricate system of access roads to handle large volumes of traffic. The bridge’s two steel towers, embedded deep in rock and concrete, soar 604 feet into the sky, each as tall as some of Manhattan’s great skyscrapers. They contain more than 43,000 tons of steel. Rope cables were strung from anchorages on each shore and draped in an arc between towers, like a giant silver braid. When thirty-six of them had been placed, catwalks were erected to provide walking platforms. Cable spinning required two spinning wheels on each side of the river that traveled back and forth to create strands about the diameter of a pencil. The strands were spun into four great cables, each a yard in diameter. Steel suspender ropes were then hung from the cables, each containing some 107,000 miles of wire. Within this silver web, steel sections were put in place to form the roadway, which progressed from each shore until the last section joined the other in the middle. Finally, the concrete was poured, the lanes were laid down, and the bridge was painted.”

RE: excerpt from: ***Perpetual Motion*****,** ***A History of the Port Authority of New York and New Jersey***

Keeping the Bridge Lights Burning

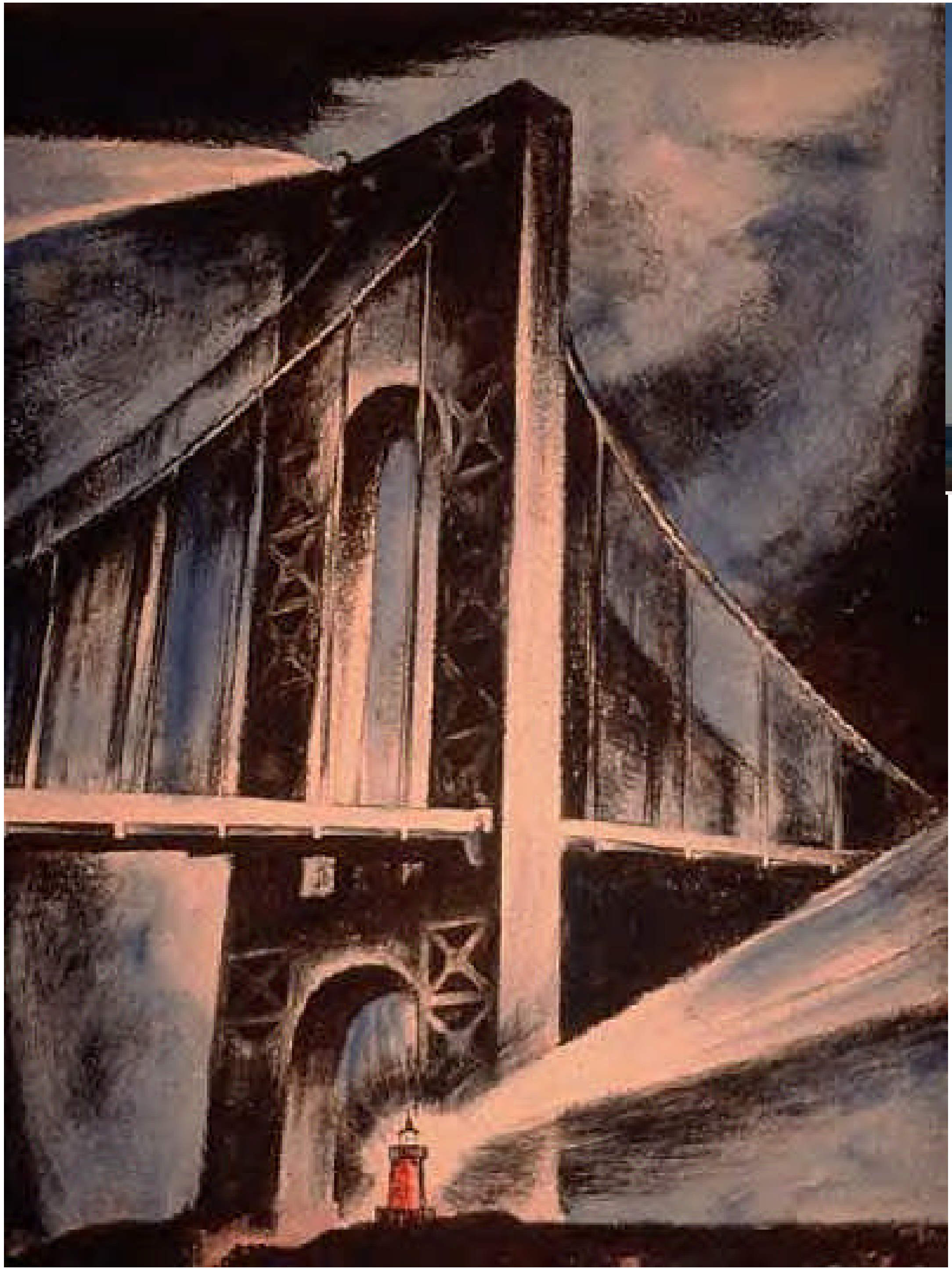




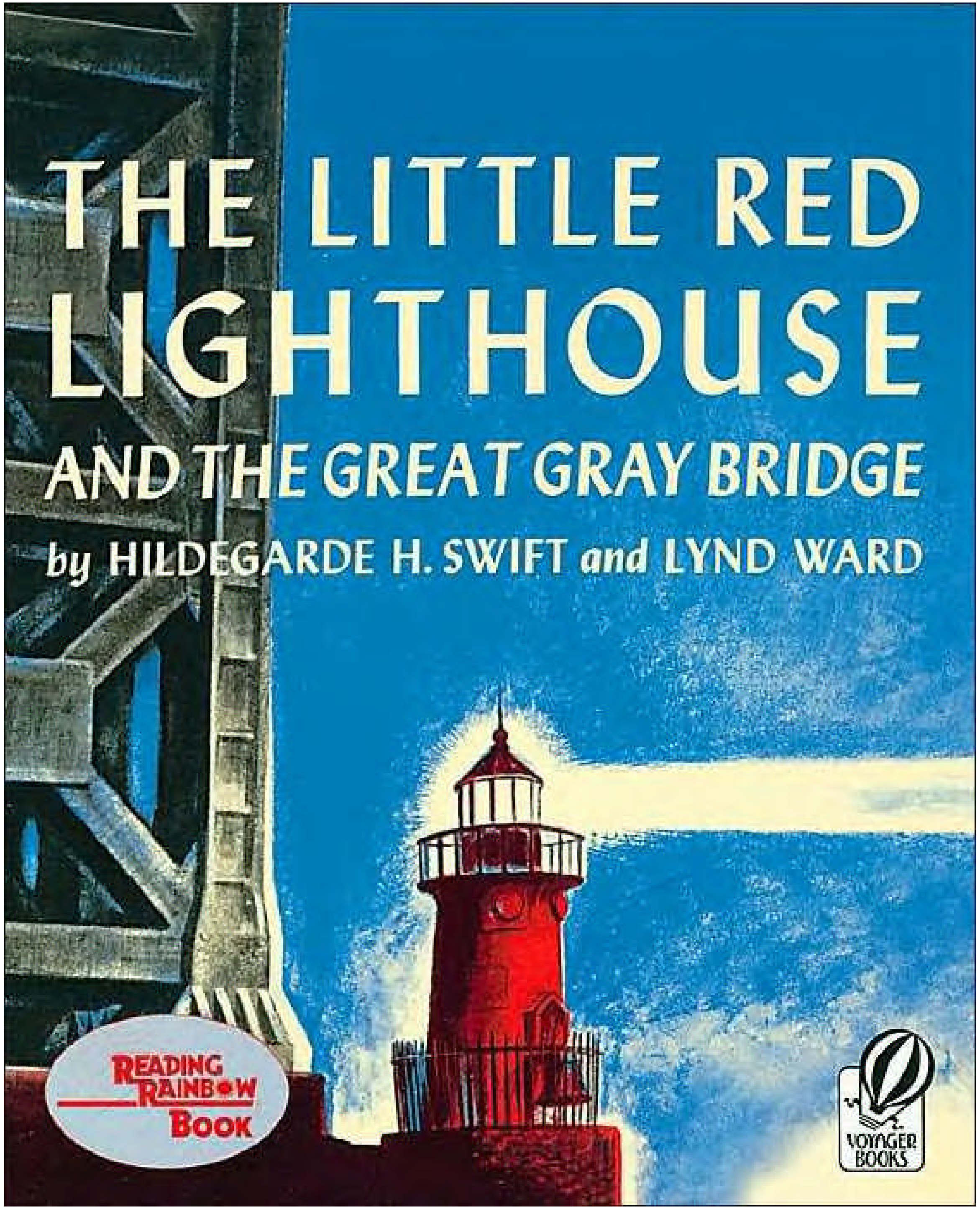
“Combining the jobs of human fly, electrician, and lamplighter, John J. Kiernan watches over the 2,700 electric lamps which light the great George Washington Bridge across the Hudson River. In his work of inspecting equipment and replacing burned-out bulbs, he climbs cables, rides along wires in a bo’sun’s chair, dangles high above the river, at times more than 500 feet in the air. His day begins with an inspection of the aircraft warning lights at the top of the great towers; it ends with an examination of the countless navigation lights dotting the anchorage piers. In between, the steel-nerved Kiernan walks miles uphill and down on the monster metal cables which support the 3,500-foot span. To guard against sudden gusts carrying him from these gigantic tight ropes, he loops a safety belt over outrigger cables, sliding it along as he advances. A veteran ‘steeple-jack electrician,’ Kiernan has been keeping the bridge lights burning since 1931.”

***Popular Science,* November 1940**

The Little Red Lighthouse



The Little Red Lighthouse and the Great Gray Bridge, **by *Hildegarde Swift,* is a children's story about the red lighthouse that stands guard next to the *Manhattan* (East) tower of the *George Washington Bridge*. The story remains a favorite for children.**


THE LITTLE RED LIGHTHOUSE
AND THE GREAT GRAY BRIDGE
by HILDEGARDE H. SWIFT and LYND WARD
READING RAINBOW BOOK
VOYAGER BOOKS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