"ONCE-IN-A-LIFETIME:

THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY PLANS THE REPLACEMENT OF THE ORIGINAL ROEBLING SUSPENDER ROPES ON THE GEORGE WASHINGTON BRIDGE" PART 2

BY: CLIFFORD W. ZINK

The Roebling workers who closed nearly 36 miles of 2 7/8 inch suspender ropes on their 80-Ton Rope Machine in Trenton, N.J., in 1929 would be amazed and proud to know that their product has been supporting the George Washington Bridge for 83 years and counting (Fig. 1). And they would be pleased to know that new replacement ropes will replicate the original ones they made.

As noted in the first article on the GWB published in the May-June issue of WRE, the Port Authority of New York and New Jersey (PANYNJ) is planning to replace all of the GWB's 296 suspender ropes and to clean and rehabilitate its main cables. In a recent conversation with PANYNJ engineers, Chief Engineer Peter Zipf said, "This will be an eight-year program for us, starting in 1914. It's an intriguing, step by step process that will start with utility work and be completed by 2022."

Othmar Ammann, PANYNJ's first Chief Engineer, designed the Hudson River Bridge, as GWB was then called, in the late 1920s with four 36-inch main cables to support two decks, the upper deck to be completed first and the lower deck to be added about 25 years later when traffic projections indicated it would be needed. PANYNJ erected the lower deck in 1962, and now with 14 lanes and 300,000 vehicles a day, the GWB is the world's busiest major crossing (Fig. 2).

Robert Kumapley, PANYNJ"s Lead Structural Engineer for the GWB Suspender Rope Replacement Project, explained that "Since the bridge opened in 1931, only 25 of the original suspender ropes have been replaced. 19 were replaced when the lower deck was added in 1961, and in 1999, six were replaced so that we could test them for their capacity."

When PANYNJ engineers began planning the replacement of the original suspender ropes in 2009, they noted that the average age of replacement time on comparable bridges is 70 years. Similar Roebling suspender ropes on the Golden Gate Bridge were replaced in 1977 after 40 years of service. Bernard Yostpille, PANYNJ's Chief Structural Engineer, noted that "The fog and mist

Fig. 1: More than 90 percent of the original 2 7/8 inch Roebling suspender ropes remain on the George Washington Bridge after 83 years of service.
Photo Courtesy Scott Schumaker.

Fig. 2: With 14 lanes and 300,000 vehicles per day, the GWB is the busiest major crossing in the world.
Photo Courtesy of Hugo Bouzon.

Fig. 3 (above): Charles C. Sunderland, left, at his retirement from the Roebling Company after more than 50 years of service in 1952, with Ferdinand W. Roebling III, great grandson of Company founder and Brooklyn Bridge designer John A. Roebling.
Trenton Public Library.

Fig. 4 (above): Charles G. Roebling, the third son of John A. Roebling, President of the John A. Roebling's Sons Company from 1976-1918, patented a 37-wire strand in 1915 similar to the strands on the GWB suspender ropes.
Hamilton Schuyler.

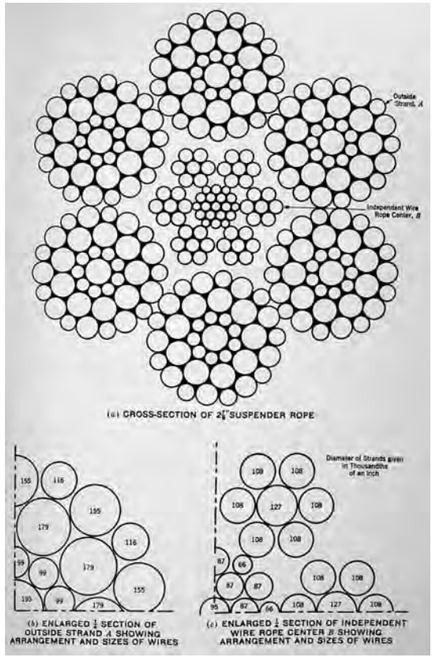

Fig. 5 (right): The 2 7/8 inch, 6 x 37 GWB suspender ropes have a 6 x 7 independent wire rope center, and contain ten different sizes of wire.
Engineering News-Record, 1931.

at the Golden Gate create a more corrosive environment than we have on the Hudson River. We've also maintained our ropes to a high level to get a little more life out of them."

For the original suspender ropes, Charles Sunderland (Fig. 3), the Roebling Company's Chief Bridge Engineer, specified a 6 x 37 configuration with an independent wire rope center to maximize their service on the bridge. Sunderland joined the Roebling Company in 1901 and worked under Charles G. Roebling (Fig. 4), the third son of John A. Roebling, the designer of the Brooklyn Bridge and the founder of the family wire rope business. Charles Roebling graduated from Rensselaer Polytechnic in 1871 and served as the president of the family business from 1876 until his death in 1918.

"This is a structural engineer's dream."

- Andrea Giorgi Bocker, GWB Resident Engineer

According to Donald Sayenga, an historian and a former sales executive at Bethlehem Steel's wire rope division, John A. Roebling "achieved the first American advancement in wire rope theory" in the late 1840s. "Realizing that the defects of six-strand ropes could be corrected by combining wires of different diameters in the strands, he devised a three-size construction that is now known as Warrington construction. By starting with a seven-wire strand made of one wire size, Roebling added an outer layer of 12 wires of two different alternating sizes," in order to improve roundness and to decrease hollow space within the strand.

Fig. 7: Roebling workers preparing the first four 3,500 ft. long, 2 7/8 inch Roebling ropes for crossing the Hudson to support the footbridges for building the GWB's main cables, 1929. *Smithsonian.*

Fig. 6: The Roebling Company manufactured the GWB suspender ropes on its 1893 Roebling 80-Ton Rope Machine at its Trenton Works. The Colorado Fuel and Iron Company (CF&I), which acquired the Roebling Company in 1952, altered the machine in 1968 to produce five-inch wire rope, the biggest at the time, for Big Muskie, a Bucyrus-Erie excavator at a strip mine in Ohio. The American Society of Mechanical Engineers designated the 80-Ton Rope Machine as a National Mechanical Engineering Landmark in 1989.
C.W. Zink.

In 1915, Charles Roebling followed up by patenting "an improved wire rope" with six 37-wire, "novel strands" composed of five different sizes of wire – a center of one size, a first layer of nine smaller wires, a second layer of nine wires a little smaller than the center wire, and an outer layer of 18 wires of two additional alternating sizes. Charles' patent application left the center of the rope unspecified but claimed that "the arrangement of wires in the strand… avoid to a great extent air spaces or voids and thus secure an increase in metallic area for a given diameter of strand, and a corresponding increase in tensile strength of the strand."

When the Roebling Company won the contract in 1927 for furnishing and installing the cables and suspender ropes on the Hudson River Bridge, Charles Sunderland was the Company's Chief Engineer and closely supervised the entire project. A native of Yorkshire, England, Sunderland became Chief Engineer of the Roebling Bridge, Tramway and Wire Rope Departments in 1910.

Fig. 8: Roebling bridgemen compacting the main cables on the GWB, 1931. The 2 7/8 inch footbridge ropes are visible in clusters on each side of the cables supporting the footbridge on the New York side span. *PANYNJ.*

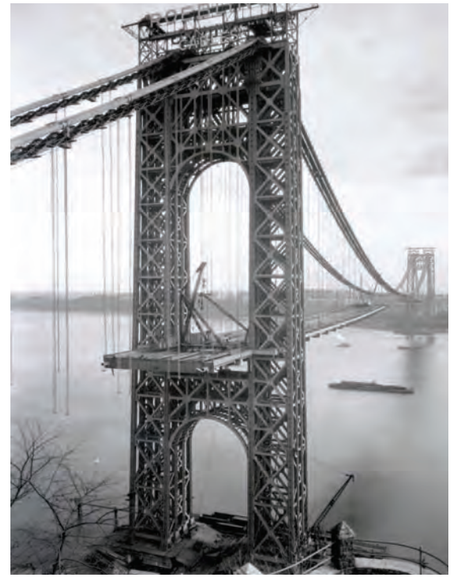

Fig. 9: With a "ROEBLING CABLES" sign on top of the New Jersey tower, workers hang the bridge deck from the 2 7/8 inch suspender ropes, 193[illegible]
PANYNJ

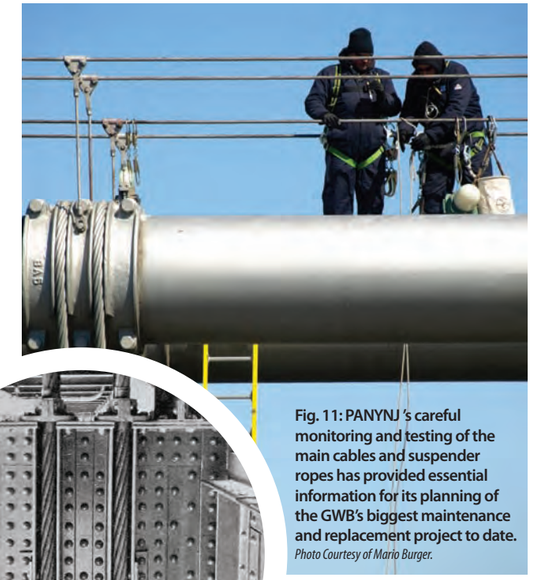

Fig. 11: PANYNJ 's careful monitoring and testing of the main cables and suspender ropes has provided essential information for its planning of the GWB's biggest maintenance and replacement project to date.
Photo Courtesy of Mario Burger.

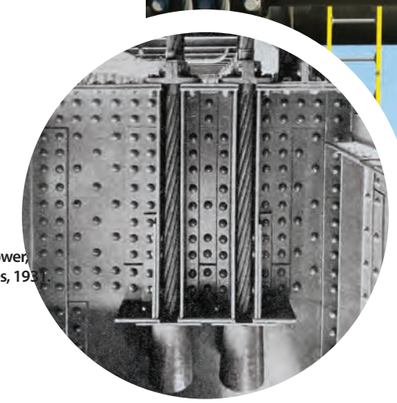

Fig. 10: Below the GWB bridge deck, the lower suspension connections of the 2 7/8 inch suspender ropes with the cross beams is an area subject to corrosion from moisture and road salts.
Engineering News-Record, 1931.

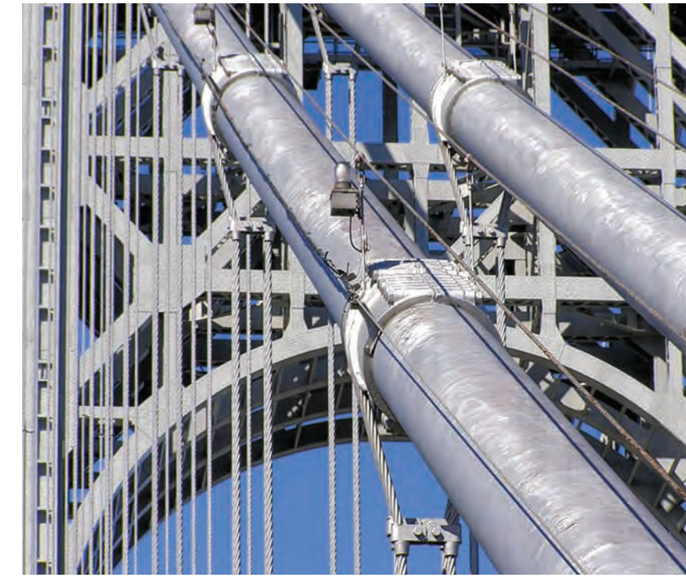

Fig. 12: The GWB Suspender Rope Replacement Project includes installing new suspender ropes that match the original Roebling ropes, cleaning and rehabilitation work on the main cables and the strands in the anchorages, and installation of new energy-efficient LED necklace lighting.
Photo Courtesy of Mario Burger.

"The configuration of the 37-wire strands around the center rope provides high capacity resistance to erosion and fatigue.... This design is inherently very appropriate, and we will use the same configuration for the replacement ropes."

- Bernard Yostpille, PANYNJ's Chief Structural Engineer

For the Hudson River Bridge's 2 7/8 inch suspender ropes, Sunderland specified a 6 x 37 rope with strands similar to Charles Roebling's patent, and a 6 x 7 independent wire rope center composed with two wire sizes in the outer strands and a 19-wire center strand with three wire sizes (Fig. 5). At the Roebling Company's Kinkora Works steel and wire plant in Roebling, N.J., ten miles south of Trenton, steel workers used scrap steel and pig iron to make the wire for the suspender ropes and for the bridge cables, and wire drawers drew it into the 11 different sizes needed for the strands, the rope center, and the bridge wire.

Rope shop workers at the Company's main plant in Trenton made the strands and closed them into 7,200-ft. long, 2 7/8 inch ropes with a 25 inch lay on the 80-Ton Wire Rope Machine, which Charles Roebling built in 1893 to make 30,000-ft. long, 1 ¼ inch ropes for cable cars (Fig. 6). The Company transported the GWB ropes back to the Kinkora Works, where workers cut them into prescribed lengths, prestressed them with 200,000 lbs of tension on the unique Prestretcher there, and shipped them to the bridge site in 760 to 3,500-ft. lengths (Fig. 7).

As described in the first article, Charles Sunderland developed the Prestretcher to enable the Company to use the ropes initially to support the footbridges for building the main cables (Fig. 8). When the Roebling bridgemen completed the cables, they cut the ropes into the required suspender rope lengths, socketed them on site, and installed them to support the bridge deck (Figs. 9 & 10).

After more than eight decades of service, tests on the ropes removed in 1999 and on ropes still in place indicate that the Roebling suspender ropes retain much of their original load bearing capacity (Fig. 11). According to Bernard Yostpille, "Corrosion is the basic problem with suspender ropes, especially where they connect with the roadway, where water and road salts create a corrosive environment. The ropes have a safe carrying capacity, but it gradually reduces over time, and the replacement project is underway before the safety factor becomes an issue."

As to the design of the replacement ropes, Yostpille said, "The configuration of the 37-wire strands around the center rope provides high capacity resistance to erosion and fatigue. The strand wires are tightly nested, which minimizes voids and moisture intrusion. This design is inherently very appropriate, and we will use the same configuration for the replacement ropes."

"During construction," Yostpille explained, "A temporary duplicate set of ropes will be methodically staged to take the tension out of the ropes to be replaced. This work will be monitored with strain gauges and the deck will stay in the same position. The sequencing of the rope replacement will be left up to the contractor."

The 296 ropes loop over the main cables and weigh from 1,500 to 10,000 lbs., depending on their length. If laid end-to-end, the ropes would stretch 32 miles. If the 283 wires in each rope were laid end-to-end, they would stretch 9,100 miles, more than 1/3 the circumference around the Earth's equator. When asked if the replacement ropes will be manufactured in the U.S., the PANYNJ engineers replied, "Too early to tell."

PANYNJ announced the $1 billion GWB Suspender Rope Replacement Project last December, to be financed with revenues from its 2011 toll increase, and estimated that it would create 3,600 jobs. The overall project includes cleaning and rehabilitation of the main cables to address some corrosion and loss of galvanized coating on the wires, work on the cable strands in the anchorages to address some minimal number of broken wires, and installation of a new energy-efficient LED system for the bridge's signature necklace lighting (Fig. 12). PANYNJ Commissioners approved $15.5 million for planning and design, and engaged Amman and Whitney, co-founded by Othmar Ammann in 1946, as the consulting engineer for the project.

Andrea Giorgi Bocker, the resident engineer in charge of construction at the GWB, told The New York Times in December, "This is a structural engineer's dream." Ms. Bocker's father managed the GWB while she was growing up, and visiting him at the bridge led her to become an engineer. "Suspension ropes aren't replaced every day," she said. "In the case of the George Washington Bridge, it's happening for the first time in its 80 year life. So it's a once-in-a-lifetime opportunity for an engineer to be part of." ▌

Clifford Zink is an industrial and engineering historian and preservation consultant, and the author of *The Roebling Legacy*.