Modern History of Wire Rope

by Donald Sayenga

It wasn't until recent history (the 1600-1700s) that most of the technical breakthroughs in the modern history of wire rope were achieved in Europe. This was followed by a remarkable 40-year period, between 1849-89, when a majority of the basic forms of wire rope still in use today all over the world were devised in the United States.

Early German and English Ropes
The first operative wire ropes of the modern era, employed in vertical shafts as hoisting cables in the Harz Mountain silver mines of Germany from 1834 to 1854, were not very complicated inventions. Three lengths of wrought-iron wire, all the same size, were twisted around each other by hand to make a strand. Next, three or four identical strands were twisted around each other in a similar manner to make a rope. The process was similar to prehistoric techniques for making ropes of hemp fibers.

These handmade ropes, known as Albert Ropes (after William Albert, the Harz mining official who pioneered the practice) were not very flexible because the wires were relatively large and stiff. But, they gave good service compared to chains or hemp ropes, where large hoists, drums, and sheaves were in use. Chains tended to part without warning, and hemp rope rotted in the damp mineshafts. Unfortunately, the tedious process of making Albert Ropes discouraged trials in other applications. Several versions were tested, but none contained an internal core for support of the outer strands. First attempted in 1834, they were abandoned after the 1850s.

Meanwhile, at the same time the Germans were achieving wire rope success in the Harz mines, a London inventor named Andrew Smith was experimenting with various ways to apply wire ropes to ship's rigging. He manufactured several kinds of wire rope for this purpose, using the ropewalk techniques of the hemp cordage industry. In 1840, a new rapid transit system known as the Blackwall Railroad opened for business in London. Smith substituted his wire ropes for the hemp haulage on the Blackwall Railroad.

In the meantime, another Englishman, Robert Newall, learned about the Albert ropes. He devised a way to make wire ropes in a factory using machinery rather than the hand-twisting method. His ropes were tested with success on the Blackwall Railroad, but Smith opposed Newall's efforts during a patent fight in the mid-1840s, in which Newall prevailed. The companies established by Smith and Newall later merged, remaining in business to the present.

Smith soon left England for California and the Gold Rush. Newall's style of wire rope--comprised of six strands, each containing its own fiber core, all twisted around a central fiber core--soon dominated the English market. Their major English contribution to the industry, however, was the idea of making strands on a machine known as a strander.

Wire Ropes and American Railroads
Word about the English and German experiments spread quickly to the United States. Prior to the advent of the high-pressure steam locomotive, the early railroads overcame higher elevations with a combination of hemp rope hoists and gravity descent, operated much like a modern ski-lift system.

In Pennsylvania, a cross-country transportation system known as the Allegheny Portage RR agreed to test a handmade wire rope in 1842 as a substitute for hemp ropes, which tended to rot after little more than one year of service. The test was a success, so the Portage converted to wire ropes. The new wire ropes attracted attention at the Morris Transportation System in New Jersey, and at several anthracite coal transportation companies including the Delaware & Hudson Co. in New York and the Lehigh Co. in Pennsylvania. These wire ropes were made by a surveyor named John Roebling. Although he twisted the wires together by hand, like the Albert ropes, he adopted the six-strand-plus-core arrangement favored by Smith and Newall. Roebling's ropes, however, were made entirely of wire, utilizing a core that was identical to the six outer strands, each comprised of 19 wires.

Roebling soon learned that his process for twisting 19 wires together created a strand that tended to become hexagonal rather than round. He launched a series of experiments with machine-made ropes looking for a way to make strands that were rounder. Meanwhile, one of his customers, the Lehigh Co., moved forward rapidly, building its own wire-rope factory in 1848. This factory (now owned by Bridon International--the same company that absorbed the original Smith and Newall companies in the UK), is still in business near Wilkes-Barre, Pa. And Roebling gave up surveying to concentrate on ropemaking, building a large factory in Trenton, N.J., in 1849.

Roebling's Three-Size Construction
At the time that his factory began operations in Trenton, Roebling achieved the first American advancement in wire-rope theory. 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 (now known as Warrington construction). By starting with a seven-wire strand made of one wire size, Roebling added an outer layer containing 12 wires of two different alternating sizes.

After numerous tests, Roebling's three-size ropes provided slightly better service in some applications. Although the original aim of the invention was to create improved roundness, the new strands yielded a side-effect of even greater significance. Because there was less hollow space within the strand itself, the greater fill-factor permitted the strands to be made by what is known as the equal-lay principle, whereby each wire in an outer layer is cradled by two wires in an inner layer, creating greater support without the effect of internal crossovers. The importance of the equal-lay principle did not become obvious until the introduction of modern high-speed stranders in the 1850s.

Unfortunately, in an accident with his own machinery, Roebling's arm and shoulder were mangled in 1849. Several years passed before he regained full mobility. During this period, he diverted his attention to the construction of wire-cable suspension bridges, for which he is most famous today. This diversion prevented him from fully exploiting the merits of three-size construction. When it was introduced again later, under the name Warrington, many people thought three-size construction was an English invention. Roebling never patented his achievement, so the history of his invention remains obscure.

Meanwhile, during Roebling's recovery, English ropemaking techniques were introduced in California. The inventor, Andrew Smith, had returned to Great Britain in 1853 but his son, Andrew H. Smith, remained in California to seek his fortune in the gold fields. After starving for several years, he moved to San Francisco, changed his name to A.S. Hallidie and launched a wire-rope business in 1857. Hallidie devoted himself to the concept of improvements in wire rope tramways for the gold and silver mines of California and Nevada.

Hallidie's mining tramways were a success in the 1860s. He also built numerous wire-cable suspension bridges and he devised his own version of equal-lay stranding, known as California Cable, using triangular-shaped wires. In some ways, Hallidie's method was superior to Roebling's three-size method, except that triangular wire is costly and difficult to manufacture. All this aside, Hallidie is better known for adapting his mining tramway cables to the streets of San Francisco in 1872 and the birth of the city's famous cable-car system.

Thomas Seale's Patent
The original Hallidie cable car on Clay Street was an instant success as a transportation system. Overnight, competitors went into business on other hilly streets nearby. Cable cars differed from overhead tramways because the ropes were subjected to more severe service conditions. Constant starting and stopping of the cars with a sliding grip, combined with numerous deflection sheaves required to allow the underground cable to conform to the surface profile of the streets, destroyed wire ropes in

short order. San Francisco quickly became the world's largest wire rope market.

One of Hallidies major transportation competitors was wealthy Leland Stanford. He had been involved in numerous successful ventures including the transcontinental railroad. Stanford intended to make his new California Street cable car line the city's finest. To this end, he hired an earthmoving contractor named Thomas Seale to be his superintendent. Born in Ireland, Seale had come to California with his brother during the gold rush, where they attained considerable wealth by grading streets near the San Francisco waterfront. The Seale brothers owned a huge ranch adjacent to Stanford's ranch in Palo Alto.

Roebling's three-size construction ropes were not very suitable for cable-car service because the alternately small-sized outer wires invariably wore out first, breaking up and tangling machinery in the underground tubes. English inventors were experimenting with elliptical- and triangular-shaped strands to solve this problem. These so-called flattened strands did provide improvement when tested, but they were very expensive to produce. Ultimately, the enormous demand for wire rope in San Francisco stimulated intense competition between Roebling's company and Hallidie, driving prices downward.

The cable car demand next spread all over the United States as other cities installed cable cars in the 1870s and 1880s. The three existing American manufacturers could not cope with the demand, which brought many other companies into the ropemaking arena. In San Francisco, the dilemma of short-rope service was tackled by Thomas Seale, whose solution soon became the accepted answer to the problem of severe outer wear combined with multiple reverse bending over small-diameter sheaves.

Seale's patent (#315,077 April 7, 1885) is based upon rearranging the three wire sizes into an entirely different pattern so that all the largest wire sizes are side-by-side on the exterior of the strand. The aim was to achieve increased abrasion resistance without losing flexibility. More important, the patent also described, for the first time, the basic concept of equal-lay stranding, which is inherent in the Roebling three-size approach, but had not been previously explained as the solution to internal cross-wire nicking.

Unfortunately, Seale's notes are gone and details of how he devised his famous construction remain unknown.

James Stone's Filler Wire Patent
Most of the wire rope companies, including Roebling's, adopted Seale's principles, even though it became apparent that Seale-type strands, although much more abrasion-resistant, had a tendency to be slightly less flexible and therefore less fatigue-resistant. Further analysis of the problem was launched by James B. Stone, who was rope-mill superintendent for Washburn & Moen in Worcester, Mass., in the 1880s. (Washburn & Moen later became known as American Steel & Wire and, after 1900, became an important part of the conglomerate known as United States Steel.)

Stone had already invented high-speed stranding equipment for the rope mill. He also had studied several cable-car systems in detail and concluded that four different sizes of wire, not three, would be needed to create the most perfect fill factor for strand concentricity. The smallest of the wires, known as filler wires, were to be inserted into the rope for cushioning purposes.

After toying with that concept, Stone realized that six fillers provided a key to making round, equal-laid strands at high speed from 19 wires of nearly the same size. James Stone's patent (#416,189 December 3, 1889) described what is now known as 6 by 25 filler wire construction.

The significance of the American developments in wire rope construction cannot be understated. Today, James Stone's 6 by 25 wire rope is the most widely-used wire rope construction in the world for general purpose applications. Thomas Seale's patented form of wire rope is also widely-used, particularly in any kind of application where severe abrasion is encountered, and John Roebling's three-size Warrington construction remains popular for small-diameter ropes where the filler wire principle cannot be applied.

A.S. Hallidie's municipal cable cars were supplanted by electromotive traction railways, which, in turn, were driven out of business by General Motors and Ford everywhere except in their original home in San Francisco. Motorists trapped in commuter traffic jams perhaps occasionally question the wisdom of driving the cable cars out of business, but the innovations in fundamental wire rope construction derived from American transportation experiments have benefited wire rope users everywhere