engineering issues such as planning and management, infrastructure, irrigation and drainage, watersheds, hydraulics and waterways, cross media (environmental issues), and standards development.

Liaisons with ASCE Sections/Branches

The initial EWRI Section/Branch Activities Council was asked to foster and promote local activities in the environmental/water resources areas via the ASCE network. For example, the ASCE Texas Section and its Environmental, Hydraulics and Water Resources Groups and its 17 Branches were asked to actively seek formal links with EWRI and exchange communications with the EWRI Section/Branch Council.

MEMBERSHIP DUES

The initial annual dues for an institute for an ASCE member were free for the first institute and $20 if EWRI is an additional Institute. A non-ASCE member could join EWRI for an annual membership fee of $85.

STRATEGIC PLAN

With the commencement of EWRI operations in October 1999, a new strategic plan was needed. A group of 20-25 EWRI leaders met in January 2000 in San Antonio to develop the new plan. The 2000 Strategic Plan included Goals, Objectives, and Action Items. This strategic planning session was conducted at the same time as the beginning of the ASCE Strategic Plan for 2000, so that the EWRI plan could be congruent with the Society plan. The goals and objectives of that EWRI Strategic Plan 2000 (Keyes & Rogers 2002) follow.

EWRI STRATEGIC PLAN 2000

Goal 1: Expand and diversify the membership base

Objectives
1.1 Increase membership by 2000 members by 2003
1.2 Increase younger member involvement
1.3 Increase student involvement
1.4 Establish liaison mechanism with sections and branches
1.5 Conduct member survey for products and services
1.6 Develop four continuing education courses
1.7 Place all products on the web
1.8 Enable web communications

Goal 2: Partnering with external Groups

Objectives
2.1 Identify worldwide collaborative partnerships, both internally and externally

Goal 3: Improve the advancement and transfer of technology

Objectives
3.1 Develop more timely and integrated publications appealing to a broader audience and

resulting in increased sales
3.2 Develop timely and targeted conferences and workshops that result in increased attendance and conference exhibitors
3.3 Develop more standards and manuals of practice
3.4 identify member’s needs and develop new programs and services to meet these needs
3.5 Develop continuing education programs that promote lifelong learning
3.6 Encourage and reward innovative programs
3.7 Enable web communications

Goal 4: Strengthen EWRI's public policy role

Objectives
4.1 Implement procedure for formal public involvement and policy development
4.2 Mitigate and respond to regional and national disasters and emergencies
4.3 Expand delivery systems for information transfer to members and the public
4.4 Enable web communications

Goal 5: Implement and improve the 1999 EWRI business plan

Objectives
5.1 Encourage and reward innovative programs
5.2 Hold strategic planning and self-evaluation sessions annually

20 Years Later

The decision to form institutes has been a success for ASCE. There are currently nine (9) institutes within the ASCE governing structure and three Technical Directors now serve on the ASCE Board of Direction. Since EWRI was formed, five additional institutes formed include:

- Coasts, Oceans, Ports, and Rivers Institute (COPRI)
- Construction Institute (CI)
- Engineering Mechanics Institute (EMI)
- Transportation & Development Institute (T&DI)
- Utility Engineering & Surveying Institute (UESI)

The Environmental & Water Resources Institute (Institute) of ASCE has prospered through its first 20 years. Currently, the Institute has approximately 25,000 members. The Institute is financially stable and continues to build its reserves.

Annual congresses have been held at many cities around the United States from Orlando (initial Congress) to Honolulu and Anchorage to Omaha and Providence. Numerous specialty conferences have been held throughout the United States on diverse topics ranging from low impact development to computational methods. The Institute has conducted several international conferences in countries ranging from Morocco to India to Colombia. EWRI members have served on the Board of Governors of the World Water Council for six (6) years and many members have participated in the World Water Forum events held every 3 years. The Institute has also participated in the annual World Water Week sponsored by the Stockholm International Water Institute and in Civil Engineering Conference in the Asian Region (CECAR) conferences.

The Institute supported the formation of the American Academy of Water Resources Engineers (AAWRE) and continues to provide support through programs and ceremonies at the annual EWRI Congress.

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American Society of Civil Engineers web site https://www.asce.org

John Roebling's Innovations in Western Pennsylvania

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ABSTRACT

John A. Roebling (1806–1869) is recognized for his contributions in the development of the cable suspension bridge in North America. Roebling's expertise with wire cables had its origins with his innovative manufacturing and use of wire rope to replace hemp ropes on the Allegheny Portage Railroad near Johnstown in 1842. Subsequent projects in Pittsburgh included a wire cable supported suspension aqueduct across the Allegheny River (1845) and a cable suspension bridge across the Monongahela River (1846). Roebling's success with wire rope and cable in western Pennsylvania established his reputation leading to the increased use of wire rope and cable on other more prominent projects.

INTRODUCTION

John A. Roebling is recognized as the first successful wire rope manufacturer in the United States (Sayenga 1999). His contributions to the U.S. wire rope and cable industry and to the field of civil engineering began in western Pennsylvania. An immigrant to the U.S., Roebling settled in the wilderness west of the Allegheny Mountains near Pittsburgh in the early 1830s. Roebling came to the U.S. with formal training as an engineer, yet his initial profession in western Pennsylvania was as a small farmer. Unsuccessful at this, Roebling reentered the engineering profession at the dawn of the industrial expansion of the U.S. Roebling's innovative engineering skills and entrepreneurial spirit combined with his perseverance and a habit of being at the right place at the right time, enabled him to foresee the potential applications of wire rope and turn those ideas into reality (Rose 2006). Not far from his home in Saxonburg, Roebling's initial trials with wire rope occurred in the early 1840's on the Allegheny Portage Railroad near Johnstown. This was followed in the mid 1840's with two wire cable suspension structures in Pittsburgh. The success of Roebling and his wire ropes and cables greatly benefited from the growing industrialization of the United States in the mid 19th century. In a symbiotic way, Roebling's developments in the uses and manufacture of wire rope helped facilitate that same growing industrialization (Rose 2006).

GERMAN EDUCATION AND IMMIGRATION TO THE UNITED STATES

Born on June 12, 1806 in Műhlhausen, Germany, John Augustus Roebling studied architecture and civil engineering in Berlin. He served a three year obligatory civil service assignment for the Prussian government building and repairing roads (Sayenga 1999). Becoming disillusioned with the social and political climate in Germany, in May of 1831, 24 year old Roebling, his brother Carl and about 50 members of visionary philosopher Johann Etzler's followers began their journey to establish a utopian farming community in the United States (Sayenga 1999, McCullough 1972). Philosophical disagreements during the journey led the Roebling brothers and a handful of followers to split from the main group upon arrival in Philadelphia and they headed west to Pittsburgh (McCullough 1972, Sayenga 1999). At Pittsburgh, Roebling and his brother purchased some 28.3 km^2 (7,000 acres) of land about 40 km

(25 miles) to the north in Butler County for $1.37 an acre (McCullough 1972).

McCullough (1972), (Sayenga 1999) and Rose (2006) describe Roebling's 1832 layout, settlement and early development of Saxonburg. While Roebling tried his best to promote Saxonburg to fellow Germans (Downes 1935), after about five years, Saxonburg's growth had only produced a moderately functioning community with a number of typical merchants and farmers; however, Roebling's utopian farming community never fully materialized (McCullough 1972). In May 1836, John Roebling married Johanna Herting, the daughter of a fellow settler, and in the following year, his first son, Washington A. Roebling was born. In the summer of 1837, Roebling's older brother Carl died. This event, combined with his need to support his family and a renewed interest in engineering and the economic opportunities of growing U.S. industrialization, led Roebling to focus on engineering rather than the utopian farming community that brought him to the U.S. initially (McCullough 1972). Figure 1 shows the location of Saxonburg and other locales in Pennsylvania.

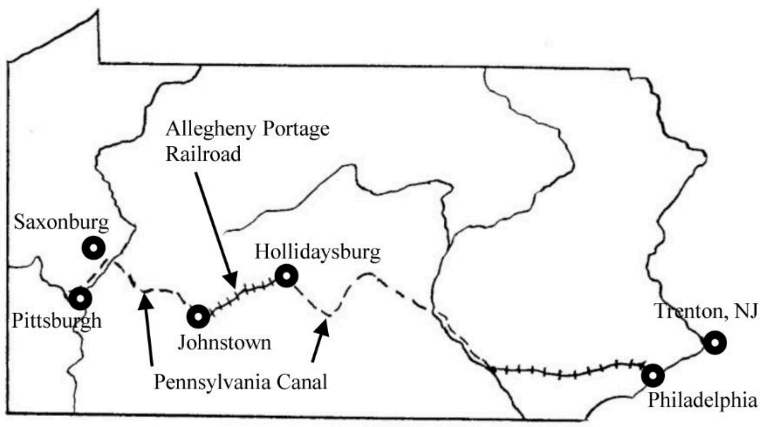

Figure 1. Map of Pennsylvania showing location of Saxonburg and other Roebling Sites (after Shank 1976).

RETURN TO ENGINEERING AND THE PENNSYLVANIA PUBLIC WORKS

With his education, he easily gained work as a surveyor on several minor canal projects. An assignment on the Beaver Division of the Pennsylvania Canal brought Roebling into the employment of the Pennsylvania Public Works where he become associated with the engineer Charles Schlatter (Sayenga 1999). Roebling learned English easily stayed abreast of many of the latest technological developments through reading. He also established correspondence with others with similar interests including bridge designer Charles Ellet and U.S. patent agent, Dr. Thomas Jones (Sayenga 1999). In 1839, Roebling's association with Charles Schlatter, led to a job on a team surveying one of three routes being considered for a new state owned railroad between Pittsburgh and Harrisburg (Sayenga 1999). Here he became familiar with the Allegheny Portage Railroad (APRR) between Hollidaysburg and Johnstown, as shown in Figure 1.

WIRE ROPES FOR THE INCLINES OF THE ALLEGHENY PORTAGE RAILROAD

Completed in 1834, after Roebling's arrival and settlement in Saxonburg, the APRR was a critical link in the Pennsylvania Main Line Canal between Harrisburg and Pittsburgh. Created by acts of the state legislature between 1824 through 1826, the Pennsylvania Main Line Canal was intended keep Pennsylvania economically competitive with neighboring New York, where the

Erie Canal was operating and Maryland where the C&O canal was being constructed (Shank 1976). A route from coastal Philadelphia in the east to Pittsburgh on the Ohio River was needed to keep Pennsylvania prominent in western trade. Although canal routes could be laid out following rivers for most of the distance, the major difficulty was crossing the Allegheny Ridge. A portage railroad system was constructed similar to portages in use on eastern canals. The length and elevation changes on the Allegheny Portage Railroad however, greatly exceeded what had been previously accomplished. Figure 1 shows the path of the Pennsylvania Main Line Canal and the location of the Allegheny Portage Railroad across the ridge.

According to Sylvester Welch's 1833 report on the APRR to the Board of Canal Commissioners, the 59 km (36.7 mile) Portage Railroad from Hollidaysburg to Johnstown involved a series of ten inclined planes and eleven relatively level sections between the inclines to transport rail cars over the crest of the Allegheny Ridge to continue by canal on to Pittsburgh (Welch 1973). Weinhold (1998) presents a detailed description of the inclined planes of the APRR. At the canal basins in Hollidaysburg and Johnstown, sectional canal boats could be hauled out of the canal in sections, placed on flat rail cars, hauled over the ridge, and then returned to the canal on the other side. At each incline, a double track was utilized to enable a counterweight mechanism to raise one set of rail cars up the incline while lowering another set down the parallel track. Stationary steam engines at the top of each incline helped drive the movement.

Sayenga (2001) notes that from its inception, the APRR was a financial burden on Pennsylvania. Shut down for several months each year due to the harsh winters, the fees collected never offset operating expenses. One of the highest expenses was for the hemp ropes used on the inclined planes. The hemp ropes had 159 mm to 178 mm (6 ¼ to 7 in) circumferences with lengths varying from 1024 m (3360 ft) to 2021 m (6632 ft) (Welch 1973). The average life of a hemp rope was only about 18 months or about two seasons of use. Observing the poor performance of the ropes and having read about wire ropes being used in Europe and Charles Ellet's 1839 paper on wire cable suspension bridges, Roebling believed the problems on the APRR could be addressed by replacing the hemp ropes with wire ropes. Although some references have attributed Roebling's idea to have resulted from witnessing a fatal accident due to failure of a hemp rope at one of the inclines (Schuyler 1931), Cummings and Sayenga (1984) indicate that by the time Roebling observed the APRR, safety devices were in use to prevent such accidents and no records of any deaths could be found to support that theory.

Roebling (1844) notes he began experimenting with wire rope making on his Saxonburg farm in 1839. In 1841, he approached the canal board about installing one of his wire ropes, at his own expense, but they showed no interest at the time. He finally was able to convince Thomas Young, who operated a private boat slip at the Johnstown canal basin to replace a hemp rope with a wire rope to pull section boats out of the basin to be transferred to the APRR. Figure 2 shows a map of the Johnstown canal basin and boat slip. Roebling's first wire rope was approximately 200 m (656 ft) long with a diameter of 19 mm (3/4 in) (Sayenga 1982a). In this first rope, Roebling tested his idea of using a bundle of parallel wires pulled uniformly in tension and tightly wrapped with wire as a protecting cover. Roebling tested this type of rope at Johnstown even though both wire cable suspension bridge designer, Charles Ellet, and U.S. patent agent, Dr. Thomas Jones, had recommended Roebling not use a wrapped parallel wire rope. Both felt the wrapping would break apart or deteriorate due to the movement the rope would experience as it passed around the sheaves used at the boat slip (Sayenga 1982a, 1999).

Sayenga (1999) indicates that the parallel wire, wrapped rope was put in service at Johnstown in April 1842 and apparently gave signs the wrapping was failing quickly due to the running nature of the cable. The poor performance at Johnstown possibly combined with the opinions of Ellet and Jones caused Roebling to reflect on his wrapped, parallel wire idea. His original patent application was for wrapped wire rope constructed of parallel wires. He modified his patent application for unwrapped wire ropes constructed with individual wires arranged in a spiral or helical format and constructed on a traditional ropewalk (Roebling 1842). Roebling felt that wrapped parallel wire ropes still held potential in non-moving applications for suspension bridges and ship rigging. When used in applications where wire ropes must be run over pulleys and sheaves, Roebling (1844) later noted that "A collection of parallel wires bound together by wrappings … is no rope and is not fit for running".

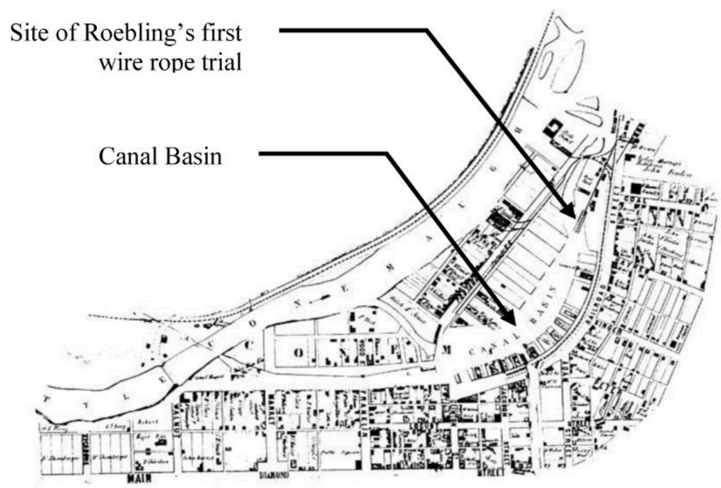

Figure 2. Map showing Johnstown Canal Basin (c. 1850) with rail incline into basin. (Courtesy of Johnstown Area Heritage Association, used by permission)

Even with the poor performance of Roebling's first wire rope at Johnstown, Roebling was not deterred. He continued to write the canal board proposing to use wire ropes in place of hemp ropes on the inclines. A reorganization of the canal board in February 1842 resulted in Roebling's friend Charles Schlatter, who now worked for the canal board, to be promoted. In his new position, Schlatter was able to get authorization for Roebling to perform a trial wire rope installation on the APRR. Roebling would install the wire rope at his expense and be paid if his rope lasted longer than a typical hemp rope (Sayenga 2001). The plane chosen for the trial was No. 3, the shortest at about 500 m (1640 ft) and having a rise of about 40 m (130 ft). Roebling proposed to construct the wire rope as one single rope onsite. The canal board would not allow this. The rope needed to be a continuous loop of about 1040 m (3400 ft) long. The longest space available was in the meadow behind his farm so it was there in Saxonburg that Roebling set up his ropewalk. A small building was constructed, as shown in Figure 3, to store wire before use (Sayenga 1982a). The meadow, however, could not accommodate the required length, so Roebling made three identical ropes which were shipped to the site of incline No. 3 and spliced together. The wire used was obtained from Robert Townsend of the Juniata Wire Works in Fallston, PA (Sayenga 1982b). Roebling is reported to have become acquainted with Townsend and his Beaver County wire drawing enterprise during his earlier surveying work (Sayenga 2001).

Figure 3. Roebling's Saxonburg workshop, moved about 200 yards from original location and restored by Saxonburg Historical and Restoration Commission (Photograph by author).

One of Roebling's reasons for initially proposing parallel wire ropes was his belief that the individual wires should not experience any twisting that might cause a reduction in strength (Sayenga 1982b). Roebling felt that stranding the wires in a way similar to hemp ropes, would cause the wire to be damaged by the inherent twisting that would occur. To overcome this, he developed a procedure to remove any undesirable twist from the wires being used to form the strand. According to Sayenga (1982b), first a frame was constructed and on it seven pulley sheaves were attached. Hemp ropes were draped over each sheave with a weight acting downward to maintain tension. The other end of each rope was attached to a swivel intended to relieve twisting of individual wires resulting from the process. Seven men then attached a coil of wire to each swivel. An eighth man clamped all the wires together as the seven men moved away from the frame with their wire coils and passing six of the coils around the seventh which served as a central core wire. In this way a 7 wire helical strand was formed. The initial 7 wire strand then served as the core as two additional groups of six wires were added by the same process. The end result was the creation of a 19-wire strand. Seven of these 19-wire strands were prepared and then each coiled at one end of the meadow. Then two men stretched out one of the 19-wire strands as the central core and pairs of men took the other six and again passed them to create the final 7x19 rope (Sayenga 1982b). According to Sayenga (1982b), Washington Roebling in his *Early History of Saxonburg* noted that "about eight men were needed for strand making, but sixteen or eighteen were required for laying up the rope."

Sayenga (1982a, 1982b, 1999) discusses Roebling's wire rope trials on the APRR. Difficulties with installation of Roebling's wire rope on plane No. 3 resulted in Roebling's friend Schlatter hiring Roebling as an employee of the APRR on September 15, 1842. This action allowed Roebling to fully oversee the installation and testing of the wire rope. One of the most critical elements was in splicing the wire rope in the field. Sayenga (1999) indicates this was quite a significant achievement since no one had ever spliced a wire rope before. If the three sections of rope were not spliced properly, failure of the test rope on plane No. 3 could occur defeating Roebling on his second attempt using wire ropes. The field splicing proved successful but other difficulties remained. The mechanism used to attach rail cars to the old hemp ropes tended to slip on the smoother wire ropes, so a new attachment device was developed (Sayenga 1999). The next difficulty involved inadequate traction between the machinery driving the incline and the new wire rope. The grooves in the sheaves were designed for the larger diameter hemp ropes. These ropes flattened considerably in the grooves giving sufficient friction between the rope and the sheaves. The contact surface between the new wire rope and the groove was smaller and the wire rope tended to slip requiring a doubling of the groove length to develop sufficient traction between the groove and wire rope (Sayenga 1999).

Roebling's attention to detail and his continual involvement in the manufacture, splicing, installation, and testing of the wire rope on plane No. 3 helped ensure its success. When the traction problem arose, Roebling was allowed to oversee modifications of the machinery to help ensure the successful performance of the test rope. As Sayenga (1999) notes, probably no other Roebling wire rope ever had so much of Roebling's attention. This may have been the critical element in Roebling's success. If this second wire rope had not been successful, Roebling's future destiny could have varied from what eventually took place. The wire rope on plane No. 3 outlasted even Roebling's projections, lasting a full 5 seasons of service.

The success of the wire rope on plane No. 3 changed the mind of John Snodgrass, the skeptical APRR superintendent. He ordered a second wire rope test on the much longer plane No. 10 and gained board approval to modify machinery on plane No. 2 to accept wire rope in place of hemp. In 1844, a plan was presented for gradually switching over to stranded wire ropes on all inclines on the APRR as the hemp ropes needed replacement. The difficulty in achieving this was limited by financial constraints more than anything else. State finances were strapped and the APRR after 10 years of service, along with the Pennsylvania Main Line Canal were not only losing money but were also quite rapidly becoming obsolete as railroad expansion westward progressed. Figure 4 shows a piece of wire rope found during archeological exploration at the Allegheny Portage Railroad National Historic Site near Gallitzin, PA and on display as part of the Roebling exhibit at the facility.

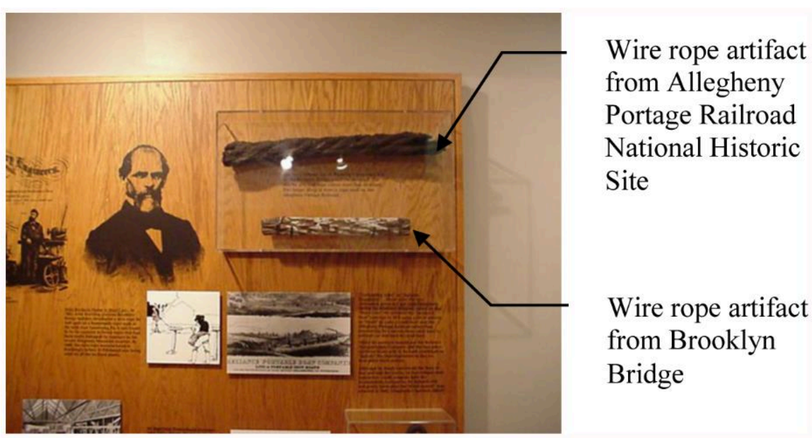

Figure 4. Roebling exhibit at the Allegheny Portage Railroad National Historic Site near Gallitzin, PA (Photograph by author).

Gradually wire ropes replaced hemp ropes on all the APRR inclines. According to Sayenga (1999), until 1849, all of Roebling's wire ropes were made on the ropewalk behind his Saxonburg farm. Some mechanical devices were developed to improve the process, but wire rope making in Saxonburg was still labor intensive and subject to the uncertainty of the western Pennsylvania weather. None of the subsequent wire ropes produced for the APRR performed as well as the first successful rope installed on Plane No. 3. That critical first successful wire rope had Roebling's undivided attention. Even though Roebling was responsible for the first wire ropes used, the APRR was still a business and Roebling's wire ropes were not used exclusively, as other manufacturers began producing wire ropes, as well (Sayenga 1999). In fact, a competing manufacturer supplied some of the wire ropes for the APRR (Cummings and Sayenga 1984). One result of this growing competition was Roebling's eventual decision to relocate to Trenton in 1849 (Sayenga 1991).

Roebling's success with wire rope making did not go unnoticed largely because Roebling knew the importance of marketing. While Roebling was manufacturing his wire ropes for the APRR, he was simultaneously writing letters to other canal companies and boards seeking to supply wire rope for their inclines and boat slips as well. He also wrote articles on wire rope for technical journals. His 1843 article in the *American Railroad Journal* and reprinted in the *Journal of the Franklin Institute*, discussed the implementation of his wire ropes on the APRR. In the article he indicated the difference between stationary rope or rigging where the rope remains tied off at two points to resist tension, and a running rope where the rope carrying tension passes over sheaves, or guides, etc. As wire rope was relatively new to many readers, Roebling addressed the major concerns regarding its long term durability due to corrosion and oxidation. He noted that running wire rope tends to rust no more than iron rails or chains when in use. During periods of no usage, oxidation increases. For wire rope used in stationary applications, Roebling discussed periodically oiling or tarring for protection. He also addressed the need for modified attachment mechanisms when using wire rope as compared to using hemp rope.

Roebling was not the only one promoting the advantages of wire rope. In an article in the *Journal of the Franklin Institute* (1845), the editors noted the success of wire rope on two of the ten inclines of the APRR. They cite the written report of APRR superintendent John Snodgrass discussing the performance of these two wire ropes, the economics of replacing the hemp rope on plane No. 6 with a wire rope, and the advantage of wire rope over hemp rope in wet conditions.

Roebling's letters and published articles on wire rope led to mining and canal companies expressing interest in acquiring Roebling's wire rope for trials in their own operations. In addition to providing wire ropes for the APRR, orders for wire ropes from the Lehigh Coal and Navigation Co., the Delaware and Hudson Canal, and ship rigging interests in New York City kept the Saxonburg rope makers quite busy during the warmer months of the year such that between 1841 and 1849, Roebling produced approximately 100 wire ropes in his Saxonburg meadow (Sayenga 1999).

THE PITTSBURGH AQUEDUCT

While Roebling's wire ropes were being constructed and installed on the APRR and elsewhere, Roebling fortunately had a second opportunity to further develop his expertise with wire on a project in Pittsburgh. The canal basin in the city of Pittsburgh was connected to the Pennsylvania Main Line Canal by a wooden aqueduct constructed in 1828-29 across the Allegheny River, near what is today 11th Street. According to Kussart (1938), by 1842, the old wooden aqueduct was no longer safe for boats. Several attempts to have repairs made failed due to state financial difficulties, as the expenses associated with the canal and APRR nearly drove the Commonwealth into bankruptcy. An act of the state Legislature authorized the city of Pittsburgh to make repairs or have the aqueduct rebuilt at their own expense and in return, be entitled to all tolls collected to cover the repair costs (Gibbon 2005). Minor repairs were completed in early 1844, but these were not adequate. The economic importance of the canal convinced city leaders to replace the aqueduct and a $100 prize was offered for the winning