Charles Ellet, Jr., the pioneer American suspension bridge builder

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ABSTRACT: Charles Ellet, Jr. (1810-1862) was a multi-talented engineer who was far ahead of his time and who made important contributions in the fields of long span suspension bridge-building; river training and flood controls in western rivers; transportation planning and economics; canal and railroad building; and demonstrating merits of iron-clad steam rams in naval warfare. Ellet built the first permanent wire suspension bridge in the U.S. over the Schuylkill River in 1842, first suspension bridge across the Niagara Gorge in 1848, and the first suspension bridge with a span over 1,000 feet at Wheeling, Virginia in 1849. This paper highlights Ellet's contributions in building and promoting suspension bridges in the U.S.

1 WHO WAS CHARLES ELLET, JR.

According to Gambrel (1931) Charles Ellet, Jr. (Figure 1) was born at Penn's Manor, Bucks County, PA, sixth of the fourteen children of Charles Ellet, a Quaker farmer, and Mary, daughter of the high sheriff of Philadelphia. Ellet did not get proper guidance from his eccentric litigious father, who opposed Ellet's determination to become an engineer.

Ellet left home at 17, working as a rodman on the Susquehanna survey. Then, in 1828, he joined Chesapeake & Ohio Canal Co. in Maryland as an unpaid assistant in the field and office, and finally as an assistant engineer for a salary of $800 per year. He learned some mathematics and French on his own with little formal instruction.

In March 1830, with his mother's financial help, he went to France. There he was able to schedule a meeting with General Lafayette and the American Ambassador to France. With their references, he was able to attend the Ecole Polytechnique. There he learned the theory of designing wire suspension bridges. He decided to travel by foot through southern France and

Figure 1. Charles Ellet, Jr. (Stuart 1871)

Switzerland. On this trip he wrote of inspecting many suspension bridges on the Rhone, Loire, Garonne, and Seine. He made notes on these bridges and observed firsthand a suspension bridge being constructed across the Loire, and witnessed the manner in which the wire cables for these bridges were manufactured (Lewis 1968).

On his travels through Switzerland, he most likely visited what Tyrrell (1911) claims is the first wire suspension bridge in Europe. The bridge at Geneva over the river Fosse was constructed in 1823 with two equal spans of 132'-6" by Colonel Dufour. The author, after reading the development of wire suspension bridges in France by Peters (1987), believes that it was Marc Seguin and his four younger brothers who built the Geneva Bridge in 1823. According to Peters (1987), "Dufour drew up a measured cross-section through the double moat on the reverse of the sketch Seguin had sent to Pictet. The sketch showed the whole extent of the proposed bridge site. Dufour carefully noted the differences in elevation of the abutment emplacements which Seguin had lacked".

He returned from France to the U.S. in early 1832. In 1834, he proposed a suspension bridge across the Potomac, and later he proposed suspension bridges across the Mississippi River at St. Louis, and across the Connecticut River at Middletown in 1848.

In 1842 he built the first permanent wire suspension bridge in the U.S. over the Schuylkill River at Fairmount in PA. He built the first pedestrian bridge over the Niagara Gorge in 1848, and the longest suspension bridge in the world with a span of 1,010 ft. at Wheeling, Virginia over the Ohio River in 1849.

His plan for controlling flood and improving navigation in western rivers such as the Mississippi and the Ohio by impounding surplus waters in an upland reservoir was more than 75 years ahead of his time as can be judged by the fact that Ellet's reports were reissued in 1927-28 for the Flood Control Committee of the 70th Congress.

Visiting Europe during the Crimean War (1855), Ellet urged Russia to employ "ram-boats" for the removal of the blockade of the Port of Sebastopol (Lewis 1968). Returning to the U.S., he urged his ram-boat scheme to the successive secretaries of the navy, and circulated his pamphlet "Coast and Harbor Defences" in 1855. His scheme was ignored until 1862 when the boat Merrimac demonstrated the efficacy of the ram. Two weeks later he was commissioned a colonel, and he was asked by the Secretary of the Navy to prepare a ram fleet to clear the Mississippi. He sustained a bullet wound and died as his boat touched shore at Cairo, Illinois on June 21, 1862.

Ellet was a prolific writer and had 46 publications to his credit. Besides the flood control, he also wrote several articles on transportation economics and rate making.

In his book on Charles Ellet, Jr., Lewis (1968) has summarized Ellet's personality as follows: "One notable characteristic of Ellet's personality throughout life was his almost superhuman drive in the initial pursuit of an idea or a task, and then often he would become weary and drop it. Undoubtedly greater permanent accomplishments would have been his had he directed his efforts towards fewer endeavors. Ellet was destined always to be the inventor, and as is frequently the case, was forced to witness others achieve the recognition for his innovations."

2 CHAIN AND WIRE SUSPENSION BRIDGES IN THE U.S. BEFORE ELLET

According to a report prepared by Austin N. Hungerford of San Francisco and published in a Bulletin of the American Iron & Steel Association (Engineering Record 1904) one of the early chain bridges was "built by James Finley in 1801 across Jacob's Creek in Western Pennsylvania according to a system on which Finley received a patent several years later.

The same article provides the circumstances under which the first wire suspension bridge for pedestrians was built in the U.S., and most likely in the world. Joseph White and Erskine Hazard built a rolling mill and a wire factory at the Falls of Schuylkill River. Robert Kennedy and Conrad Carpenter agreed to build a bridge at this location under an act passed on February 22, 1809 using the Finley patent which would permit White and Hazard to levy tolls. They built a 3-span bridge in 1809 with two equal spans of 153 ft. in length. In January of 1811, the bridge failed under the weight of a large drove of cattle. Finley investigated the bridge failure and determined that an "ill-judged clip or coupling piece broke, with which two parts of the chain were joined together".

Frustrated with the failure, White and Hazard decided to build a wire suspension bridge across the Schuylkill River at Fairmount for foot passengers only, and limited 8 persons on the bridge at any time. They fastened suspension wires at one of the top windows of the mill, stretched them across the river and tied them to some large trees on the other side. They provided steps to descend down to the ground from the bridge. According to Schuyler (1931) the cable used were made of six 3/8 inch wires. The bridge had a single span 408 ft. and a passageway of only 18 inches. The bridge collapsed under a weight of snow and ice in 1816, the same year it was built.

In January 1817 an act was passed by the Legislature which authorized the Schuylkill Falls Bridge Co. to sell all its corporate rights to certain persons "who will undertake to erect a permanent bridge" at this point. The third bridge was designed by Louis Wernwag, built by Isaac Nathans, and opened in December 1817. This was a 340 ft. span covered wooden arch truss bridge and became known as the "Colossus".

3 FIRST U.S. WIRE SUSPENSION BRIDGE OVER SCHUYLKILL RIVER

In 1839, Ellet published a pamphlet titled, "A Popular Notice of Wire Suspension Bridges". In this article Ellet described particular advantages of wire cables, and covered the history and development of wire suspension bridges in the U.S., France, and England, and indicated the potential of bridging the Mississippi near its confluence with the Missouri, the Ohio River, and the Niagara River below the Falls using the wire suspension bridges. One of Ellet's motives for publishing the article on wire suspension bridges was to make the people of Philadelphia aware of the advantages of a new bridge system.

The real opportunity for Ellet to build the first wire suspension bridge in the U.S. came when the Collossus Bridge over the Schuylkill River burned down on September 1, 1838. The cornerstone of that bridge was laid with Masonic ceremonies on April 28, 1817.

Ellet submitted his plan for a wire suspension bridge to the county and learned that five other plans were also submitted (Lewis 1968). In July 1839, he learned from his mother in Philadelphia when Ellet was visiting his brothers in Illinois, that his plans had been selected by the Commissioners under the Free Bridge Act of 1839 for the replacement of the "Colossus". However, the City of Philadelphia decided to construct the bridge in the Spring of 1841.

According to Steinman (1945) the contract was awarded to a local contractor, Andrew Young, to build the bridge according to Ellet's plans. He sought help from Roebling for building the bridge. However, the County Board rescinded Young's contract, and awarded it to Ellet in June 1841 to erect a wire suspension bridge of his own design with a span of 358 ft.

Following the French practice for the Schuylkill Bridge, Ellet laid wires in separate strands side by side with iron bars fastened across them from which the suspenders were hung. Roebling preferred the system where the suspenders were hung from clamps surrounding the cables, which were generally in planes sloping at angle from the vertical, with systems of auxiliary stay cables radiating from the towers to successive panel points of the floor system (Tyrrell 1911). Roebling believed that by laying the wire in compact cables some of the integral resistance of solid bar could be obtained. Ellet's reasoning was that it was impracticable to combine the wires into a cable of large diameter, but the wires should be laid in cables of small diameter, adding to their number as additional strength was required (Steinman 1945).

The Schuylkill River Bridge (or Fairmount Bridge) (Figures 2 and 3) was opened to traffic in the Spring of 1842. The bridge was 26 ft. wide and included 18 ft. carriageways and two four-foot footwalks. It cost Ellet $53,000 to build the bridge whereas his quoted price was $50,000. He considered the loss well-justified as he received favorable publicity in newspapers and periodicals all over the country for building the first permanent suspension bridge in the U.S.

In 1853, Ellet wrote a letter to the county commissioners who were responsible for the care and management of the Fairmount Bridge, and requested them to examine the point of fastening which was hidden from sight, and offered his services. When Ellet received no response, he directed public attention to the issue of inspection of the Fairmount Bridge through the columns of the Philadelphia "Ledger". For greater safety, he suggested to add a new cable on each side of the bridge, and attach it to an independent anchorage. Scientific American (1855) endorsed this idea whole heartedly noting the failures of many suspension bridges in different parts of the

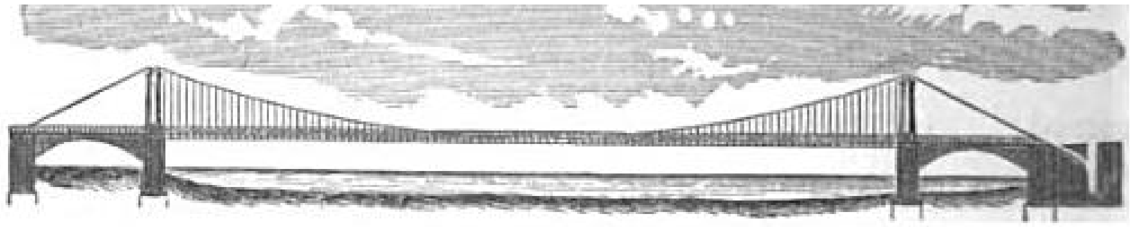

Figure 2. Line Diagram of the Schuylkill River Bridge (Stuart 1871)

Figure 3. Schuylkill River Bridge at Fairmount (Sayenga 1983)

country in the preceding six months. Because of increased traffic and vehicles with heavier loads, the bridge was replaced in 1874 with a double-deck truss span.

4 NIAGARA SUSPENSION BRIDGE

In 1845, Charles B. Stewart, a prominent civil and military engineer and who later became the first state engineer and surveyor of New York State, and eventually engineer-in-chief of the U.S. Navy (Steinman 1945), invited leading American and European engineers to build a bridge over the Niagara River between the falls and "Whirlpool". Only four engineers, namely Ellet, Roebling, Samuel Keefer, and Edward W. Serrell responded saying that the project was feasible. Each of them later constructed a suspension bridge over the Niagara River (Stuart 1871).

In response to the inquiry from Stuart, Ellet sent a reply dated October 12 1845 from Philadelphia which is reproduced below (Stuart, 1871):

> *"In the case which you have presented, I can, however, say this much with all confidence: A bridge may be built across the Niagara below the Falls, which will be entirely secure, and in all respects filled for railroad uses. It will be safe for the passage of locomotive engines and freight trains, and adapted to any purpose for which it is likely designed, and properly put together; there are no safer bridges than those on the suspension principle, if built understandingly, and none more dangerous if constructed with an imperfect knowledge of the principles of their equilibrium. To build a bridge at Niagara has long been a favorite scheme of mine. Some twelve years ago I went to inspect the location, with a view to satisfy myself of its practicability, and I have never lost sight of the project since. I do not know in the whole circle of professional schemes a single project which it would gratify me so much to conduct to completion."*

When two companies, one in the U.S., and the other in Canada with the power to connect with each other were formed in 1846, and when sufficient money was raised by selling stock to build the bridge, Stuart invited plans and estimates from prospective bidders. Ellet submitted his response from Philadelphia dated February 13, 1847 which is reproduced below (Stuart, 1871):

Charles B. Stewart,
Commissioner of the Niagara Bridge Company

Dear Sir, I promised to give you my views of the practicability and probable cost of the proposed bridge across Niagara river below the Falls. Immediately after inspecting the site, in eighteen hundred and forty-five, I gave the whole subject a careful investigation, and made a fair, but not extravagant, estimate of the cost of such a structure as I thought would be appropriate and of adequate strength.

This estimate amounted to two hundred and twenty thousand dollars for a railroad bridge competent to sustain the weight of locomotive engines and heavy freight trains, and one hundred and ninety thousand dollars for one suitable for common travel, with a railway track in the centre, to be crossed by passenger and burthen cars drawn by horses.

When I made my estimate, I had in view a work of the first order, and as I do not wish to be in any way connected with one of a lower grade, I cannot offer to reduce my proposition. But I will now repeat, that a secure, substantial and beautiful edifice, not one, however, equal to the claim of the locality – for nothing can match that – but a noble work of art, which will form a safe and sufficient connection between the great Canadian and the New York railways, and stand firm for ages, may be erected over the Niagara river for the latter sum named. If it should be built by me, or under my charge, it will cost about that sum, and I trust it will be worth the money.

With my best wishes for the success of the enterprise in all its magnificence,

I remain dear sir,
Yours truly,
Charles B. Ellet, Jr.,
Civil Engineer

On November 9, 1847, the Director of the American and the Canadian Niagara Bridge Companies made a contract with Ellet for the construction of a railway and carriage bridge over the Niagara River, two miles below the falls for $190,000. The 28-foot width of the bridge would accommodate two footways each 4 ft. wide; two carriageways, each 7'-6" wide; and one railway track in the middle 5 ft. wide. The approximate length of the span was about 800 ft.

The ultimate strength of cables was 6,500 tons. The weight of each train was limited to 24 tons to be drawn by a locomotive with a maximum weight of 6 tons. The towers were to be made of stone. The bridge was to be tested for 200 tons, and had to be completed by May 1, 1849 (Stuart, 1871).

Ellet was ready to begin construction early in 1848. He needed to build a foot bridge prior to the construction of the main bridge. This required connecting the two sides (the U.S. and Canada) of the river by a cable. Ellet, using his ingenuity and flair for publicity, offered a prize of $5 to the first boy who would fly a kite to the opposite shore.

Ellet used the kite string to draw over large cords, and then hemp ropes, and finally he pulled the first wire cable across and suspended over the gorge (Lewis 1968).

Ellet sent a letter to Stuart (1871) describing the first basket ride over the Niagara (Figure 4) which is included here:

Niagara Falls, March 13th, 1848.
Charles B. Stuart.

Dear Sir, - I raised my first little wire cable on Saturday, and anchored it securely both in Canada and New York. To-day (Monday) I tightened it up, and suspended below it an iron basket which I had caused to be prepared for the purpose, and which is attached by pulleys playing along the top of the cable.

In this little machine I crossed over to Canada, exchanged salutations with our friends there, and returned again, all in fifteen minutes.

The wind was high and the weather cold, but yet the trip was a very interesting one to me – perched up as I was two hundred and forty feet above the Rapids, and viewing from the centre of the river one of the sublimest prospects which nature has prepared on this globe of ours.

My little machine did not work as smoothly as I wished, but in the course of this week I will have it so adjusted that anybody may cross in safety.

Truly yours,
Charles Ellet, Jr.

The details of Ellet's Niagara proposed Suspension Bridge are as follows (Scientific American 1848b):

No. of cables for bridge	16
No. of strands in each cable	600
No. of strands in the ferry cable	37
Diameter of the cable	½ inch
Height of stone tower	68'-1"
Height of wood tower for ferry	50'
Base of the stone tower	20' x 20'
Top of the stone tower	11' x 11'
Span of the bridge	800'
Total weight of the bridge	650 tons
Height from the water	230 ft.
Depth of the water under the bridge	380 ft.

Ellet built a 7'-6" wide light suspension footbridge hung on wooden towers as a service bridge to carry men and materials across the gorge. The last plank in the floor was laid on July 29, 1848 and railing was completed only one-third of way, Ellet drove over and back in a buggy drawn by a high spirited horse (Lewis 1968).

After the footbridge was completed, Scientific American (1848c) described the crossing of the bridge by pedestrians as follows: "Foot passengers now walk across from the dominions of Uncle Sam to the dominions of Queen Victoria for 25 cents. This is a great work, not only physically but morally. It will promote intercourse and good will among the republicans and royalists. Difference of opinion regarding governments should never make men enemies".

The cost of the footbridge was about $30,000 and toll collected by Ellet for 10 months was about $5,000. There arose a dispute between the Directors and Ellet about who keeps the toll. There ensued a litigation between the two parties, and a compromise was reached by which Ellet relinquished his contract; and his connection with the work was terminated on December 27, 1848 (Stuart 1871).

The Niagara Bridge Co. hired John Roebling to construct the bridge and after a seven year interval, using Ellet's footbridge as a scaffold, Roebling completed the railroad suspension bridge across the Niagara in 1855. Roebling's two level Niagara Railway Suspension Bridge is covered in detail by Gandhi (2006).

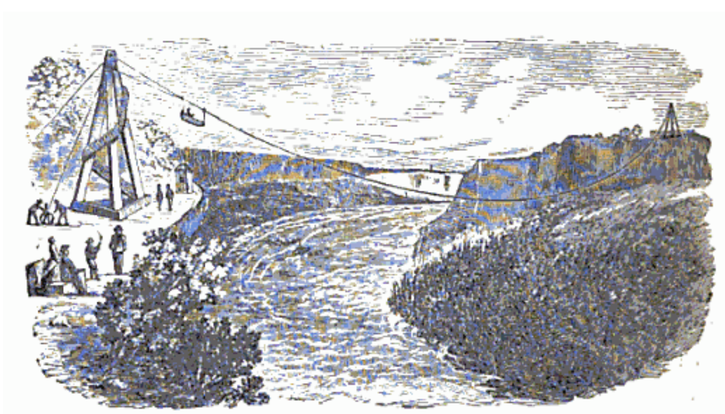

Figure 4. Ellet's basket ride over Niagara River (Stuart 1871)

5 SUSPENSION BRIDGE OVER THE OHIO RIVER

In 1847 the Virginia legislature authorized the construction of a wire suspension bridge over the Ohio River between Wheeling, Virginia (now W. Virginia) and Zane's Island. Ellet informed the directors of the company formed to build the bridge that the directors should review the proposals submitted by others, and if they were not satisfied, then he (Ellet) would submit his proposals (Lewis 1968).

In July 1947, the directors informed Ellet that they had reviewed the plans submitted by Roebling, and they did not approve those plans. As a result Ellet was selected to build the bridge. The details of the bridge are given below (Scientific American 1848a):

Span between centers of towers	1,010 ft.
No. of strands of the wire (No. 10)	9,000
Minimum strength of each strand of wire	500 lbs.
Height of bridge above the low water mark	87 ft.
Width of the bridge floor	24'-0"
Width of footway on each side	3'-6"
Width of the carriageway in the center	17'-0"
No. of cables	12
Length of each cable	1,350 ft.
Timber used	white pine and white oak
Estimated Construction cost of the bridge	$210,000

The 1,010 ft. span would make the Wheeling Bridge the longest suspension bridge in the world. The bridge was designed for carriages only, and not for carrying railroads. Construction of the bridge started in the summer of 1848, and was completed in December of 1849 (Figure 5). To signify the opening of the Bridge to the general public, Ellet crossed the bridge in a horse and buggy (Scientific American 1849a).

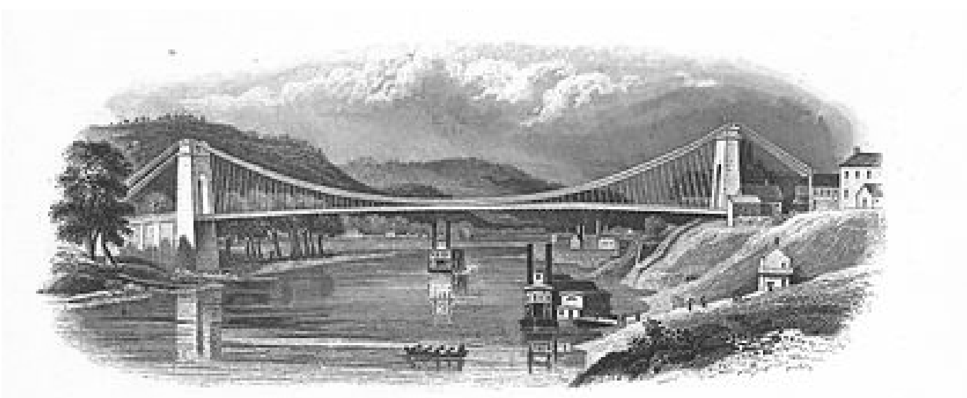

Figure 5. Image of the Wheeling Bridge as it appeared in court documents (U.S. Supreme Court 1851)

Figure 6. Tower and anchorages Wheeling Bridge (Gralian 2014)

The bridge as built had 12 cables of iron with each cable four inches in diameter and having 550 strands of wire. The cables rested on iron rollers placed on the top of the towers, and the cables were anchored into heavy masonry of wingwalls at each end of the bridge (Figure 6). The length of the deck supported by the cables was 960 ft., and the weight of each linear foot of deck was 546 lbs. The dead load of the bridge including the weight of the 12 cables, bolts, casting, suspenders, etc. was 920 lbs. per linear foot or 441 tons (Scientific American 1949b). The actual cost of the Wheeling Bridge was $225,000 (Scientific American 1850a).

6 LAWSUIT AGAINST WHEELING BRIDGE

6.1 *Lawsuit for obstruction to marine traffic*

In August of 1849, while the bridge was still under construction, a lawsuit was filed by the State of Pennsylvania on behalf of the steamboat interests of Pittsburgh against the Wheeling and Belmont Bridge Company. A motion was filed before the Supreme Court Justice Robert C. Grier for an injunction to stop the construction of the bridge. In the December term, the case was heard by the Supreme Court, and by an order of the Court, the case was referred to Chancellor Walworth, of New York, to act as special commissioner to gather the facts of the case (Lewis 1968). In July of 1850, Chancellor Walworth submitted to the Supreme Court that the bridge was a nuisance to boats with high funnels and chimneys (Scientific American 1850b). The lawyer for the bridge company, William W. Hubbel, responded that Chancellor Walworth had not yet heard all of the evidence nor the arguments, and had made no report on the subject (Scientific American 1850c).

In February of 1851, the Supreme Court intimated that a decision in the Wheeling Bridge case would not be rendered that term as the records from which to elicit a comprehensive brief were too voluminous. In addition, a copy of the testimony needed to be delivered into the hands of each of the judges, and as the evidence constituted a volume of 1,000 pages, it was preposterous to hope for an opinion until the subsequent term commencing in December of 1851 (Scientific American 1851a).

In reporting news from Alton Telegraph, Illinois on the Wheeling Bridge, Scientific American (1851b) noted that there were six railroads interested in crossing the Ohio at Wheeling, and there were six steamboats owned at Pittsburgh having long funnels who would not lower their funnels for the benefit of the passengers of these six railroads. The Supreme Court had to decide between the rights of the people of the U.S. and those of the boat owners. And, if the people could not have continuous railroads across the great rivers, that they should be informed of it in a timely manner.

6.2 *U.S. Supreme Court decision in favor of steamboat operators*

At the December 1851 term, Justice McLean delivered the majority opinion, with Chief Justice Taney and Justice Daniel dissenting. On March 1, 1852 the Court ruled the bridge to be an obstruction to the navigation of the Ohio River, and ordered that the bridge be elevated no less than 11 feet over the channel of the river, and "that unless this or some other plans shall be adopted, which shall relieve the navigation from obstruction on or before the first of February next (1853) the bridge must be abated" (Lewis 1968).

Ellet was successful in convincing the Supreme Court that a draw in the bridge would remove the obstruction to the boats with tall chimneys. After delivering an opinion against the bridge, the Court directed William J. McAlpine, one of the most well-known engineers of that period from New York City to report to the Court in May 1853 concerning the feasibility of a draw.

McAlpine presented eight different plans for modifying the existing suspension bridge, which he characterized as totally unfit for railroad purposes. All of these plans involved great expenses, the best costing no less than $156,243.50. He concluded that owing to the peculiar nature of the navigation and the principles upon which steamboats running on the Ohio River were built, that were was no doubt that the bridge as it was presented great obstructions (Scientific American 1852c).

The Supreme Court rendered its final decision in the case on May 27, 1852; and agreed that a draw in the bridge over the west channel of the river would adequately eliminate the obstruction to the navigation, if it were completed by February 1, 1853 (Lewis 1968).

While the Supreme Court was waiting for the report from McAlpine regarding the feasibility of a draw, Ellet (1852) sent a letter to Scientific American and presented six leading facts related to the case. The key points were that (1) Boats with chimneys less than 60 ft. in height could pass under the bridge at all times; (2) There were only 7 out of 270 more recently constructed boats with chimney heights varying from 70 to 80 ft. navigating the river, and all these seven boats had been built after the plans of the bridge were published two years before the construction of the bridge; and (3) The Supreme Court ruled for tearing down a bridge which cost more than $200,000 to build, all for the benefit of these seven boats.

The Chief Justice Taney in his dissent reasoned that the U.S. Courts had no jurisdiction over the matter, as the court has no law to guide them, and the jurisdiction exercised was without precedent. Scientific American (1852a) agreed with the Chief Justice and added that only Congress had the power over this case. The bridge was in the State of Virginia over an inland river, and Congress had made no laws for deciding such a case.

6.3 *Supreme Court injunction and Ellet's refusal to comply*

After the failure of the Wheeling Bridge in May 1854, Ellet was served by the Supreme Court on July 3, 1854 with an injunction, restraining him from rebuilding the bridge, except at a certain elevation (meaning at a higher elevation). Ellet declared that if he was not obstructed by the Court, he would have started the repairs and the bridge would have been open by July 1854 (Scientific American 1854). In the end, the Bridge Co. and Ellet ignored the injunction, and the repairs were completed by the middle of July for a cost of $37,000, and the bridge was opened to regular traffic. In 1860, Roebling spent $55,000 more in repairing the bridge. As of 1968, the Wheeling Bridge was the oldest existing suspension bridge in America (Lewis 1968).

6.4 *Congress bypasses Supreme Court decision*

The citizens of Wheeling, Virginia appealed to congress to legalize the Wheeling Bridge, and both houses of Congress passed the bill by a large margin. The bill required the steamboats on the Ohio River to shorten their pipes. The Supreme Court had ordered the bridge to be taken down or alterations of a most expensive character to be made, such as building a draw bridge in the middle of a suspension bridge so that the steamboats with high chimneys could pass under the bridge without shortening the height of their chimneys (Scientific American 1852d). On August 31, 1852 President Millard Fillmore signed the bill into a law that declared the bridge a portion of a post road, and therefore not subject to the decree of the Supreme Court.

7 FAILURE OF THE WHEELING BRIDGE AND ROEBLING'S OBSERVATIONS

On May 17, 1854 the Wheeling Bridge collapsed due to high winds. Based on the eyewitness account of a reporter for the Wheeling "National Intelligencer" the failure mode was similar to that of the Tacoma Narrows Bridge before it collapsed in 1940 (Lewis, 1968). The floor was torn by the force of the wind into three sections: the eastern portion measured 500 ft.; the western 300 ft., leaving the central part about 200 ft. long. Ten out of twelve cables broke in succession from the anchorage; one cable composed of 150 wires broke in the center (Stuart 1871). At that time, Roebling was constructing the Niagara Railway Suspension Bridge, which was opened to traffic on March 18, 1855

In his final report to the presidents and directors of the Niagara Falls Suspension and Niagara Fall International Bridge Companies, Roebling (1855) addressed the failure mechanism of the Wheeling Bridge, as follows: "Weight is a most essential condition, where stiffness is a great object, provided it is properly used in connection with other means. If relied upon alone, as was the case in the plan of the Wheeling Bridge, it may become the very means of its destruction. That Bridge was destroyed by momentum acquired by its own dead weight, when swayed up and down by the force of the wind". Roebling used stays in his design to prevent uncontrolled motion of his bridge.

8 ELLET AND ROEBLING

They were the two giants of the 19th century in terms of developing and perfecting the art of designing and building the longest suspension bridges in the world. Roebling single-handedly developed the wire rope industry by finding the use of wire ropes in mining, bridge-building, and other industries. They both started in the surveying industry and ended up building suspension bridges. The Roeblings became rich and survived as industrialists for over 100 years (Schuyler 1931) because of the single-minded pursuit of John Roebling in developing the wire rope industry, and the successive generations diversifying into relative industries and taking advantage of the strong foundation built by John Roebling.

Although Ellet had 13 brothers and sister, the Ellet family did not coalesce around Charles Ellet, Jr. who was impulsive and argumentative, and not a great team builder. He achieved national fame as a brilliant suspension bridge builder, but this fame did not translate into creation of wealth for him or his family because of his changing interests into other fields, notably, controlling flooding in western rivers, economics of railroad and transportation operations, and the ramboat scheme which ultimately led to not only his death but the death of his 19-year old son.

It is unfortunate that in each of the three head-to-head competitions for the construction of the Schuylkill, Niagara, and Wheeling Bridges with Roebling, Ellet won all three of these assignments but today the average person does not know his name and his achievements in the U.S. The name of Roebling is known all over the world among bridge engineers. Sayenga (1983) has presented and compared the live and times of both Ellet and Roebling in his interesting book.

9 CONCLUSIONS

Ellet was a brilliant thinker and thought about solving the problems of a young and growing nation, namely the U.S., at the national level. On some issues, such as flood control in western rivers, he was 75 years ahead of his time (Petterson, 1914), and his ideas were not considered seriously by the people in power due to his young age. It was he who developed the art of building wire suspension bridges in the U.S., and stimulated the thinking of Roebling in the same subject. If he had stayed with his first interest of building long wire suspension bridges for the rest of his life, his name would have been as famous as Roeblings today.

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