Kiev Suspension Bridge 1846 – 1853

John Vignoles

INTRODUCTION

Design and Construction of Kiev Bridge

The Tsar Nicholas I Chain Bridge across the River Dnieper at Kiev was designed and constructed by Charles Blacker Vignoles. Opened in 1853, it was the first multi-span suspension bridge in Europe. Commissioned as a design and construction project, it has many parallels with civil engineering projects today. Designed in the UK, the project office was in Warsaw, the client was in St Petersburg, and the construction team was in Kiev.

The paper describes the design and construction process followed, drawing on information from Vignoles' journals and letters, and also from other contemporary documents.

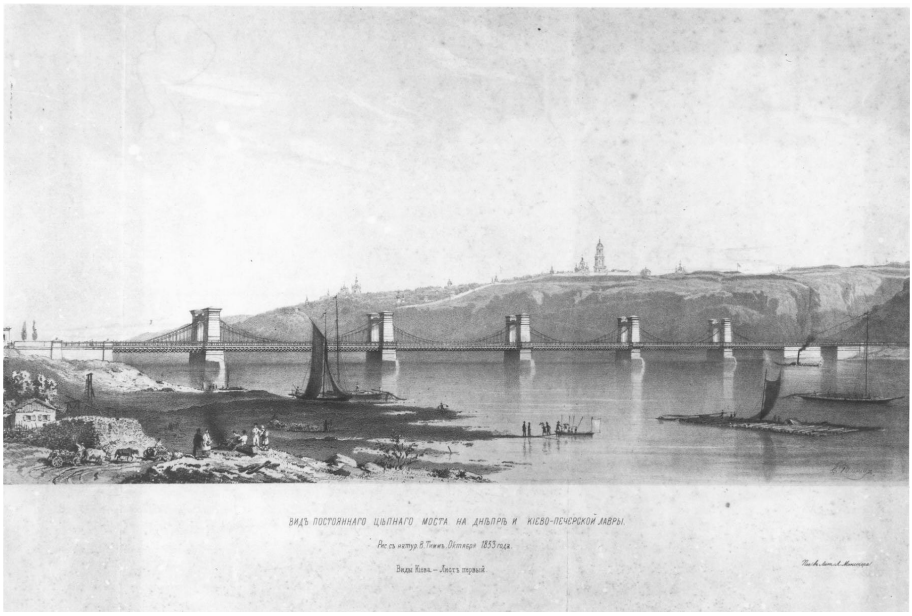

Figure 1. Engraving of Kiev Bridge viewed from upstream from a watercolour by JC Bourne.

The paper also makes use of material derived from recently discovered sketches and progress photos taken by JC Bourne and Roger Fenton. This was probably the first time photography had been used to record construction progress.

Invitation

Charles Blacker Vignoles, (1793 – 1875), was a civil engineer of considerable experience. Although his work was mainly in England and Ireland, he had been considering the possibilities of work in Russia for some years. In 1840 he had acted as guide to General Tcheffkine, the Russian director-general of roads and bridges. Recently, he had been corresponding with the British Consul General in Warsaw, Colonel du Plat of the Royal Engineers, who had developed a business understanding with two Birmingham-born brothers, Alfred and Donald Evans, who were based in Warsaw, and interested in investing in Russia (at that time, the Kingdom of Poland was ruled as part of Russia, and the Russian Court spent part of each year in residence there).

In September 1846, Colonel du Plat advised Vignoles that the Tsar Nicholas I of Russia wished to build a bridge over the river Dnieper at Kiev. In December 1846, on his return from a short break in Paris, he found waiting for him a firm invitation to prepare a design proposal, which was to be submitted to the Tsar in St Petersburg by the end of January 1847.

The Task

The River Dnieper at Kiev was slow-moving and sluggish in summer, and frozen in winter. It was a main highway for barge traffic, mainly timber but also other commodities. During the summer, when the river was free-flowing, the 2 200 ft wide river could be crossed by a bridge of boats. During the winter, the river could be crossed over the ice. There was no permanent crossing available all the year round, as the bridge of boats could not survive the intermediate freeze/thaw period, when the river currents could be extreme. This was a strategic problem, and was common to many of the rivers in Russia at that time.

The Proposal

Vignoles' proposal **(fig.1)** was for a bridge of four main spans of 440 ft and two side spans of 225 ft; the five piers were to be constructed in the river within timber-piled cofferdams. The crossing incorporated a swing bridge to enable barge traffic to pass when the river was in flood. The deck of the crossing was to be constructed in timber, and hung from suspension chain links.

While Vignoles had no experience of constructing such a bridge, he was well acquainted with the principles involved. There were a number of suspension bridges in England with which he would have been familiar, and the Budapest bridge across the Danube, designed by his colleague William Tierney Clarke, was at that time under construction **(table 1 and fig.2)**.

In the few days at his disposal, Vignoles proceeded to work in a number of different directions. He discussed the strengthened Montrose bridge deck with Rendel; he did a search of the bridge drawings at the Institution of Civil Engineers (ICE); and he wrote to various ironmasters concerning the provision of links for the suspension chains. He also had a consultation with Tierney Clarke, who undertook to give him information on the design and construction of the Budapest Bridge.

Finally, Vignoles produced a memorandum of the principles involved and an abstract of quantities to brief his partners in Warsaw.

Table 1. Comparison list of suspension bridges.

Bridge	Engineer	Construction Date	Main Span	Crossing length
Menai	Thomas Telford	1818 - 1826	580 ft	1710 ft chain cables.
Hammersmith	Tierney Clark	1824 - 1827	410 ft	590 ft
Marlow		1829 - 1832	217 ft	437 ft
Norfolk Bridge, Shoreham	Tierney Clark	1830 - 1833	284 ft	
Montrose	Rendel	1828 - 1830	432 ft	
Clifton	IKBrunel and others	1836 – 1864	702 ft (final design)	
Hungerford Footbridge	IKBrunel	1841 – 1845	676 ft	1366 ft
Budapest	Tierney Clark	1839 – 1849	666 ft	1262 ft

On 24 December, Vignoles went to see Mr Cheffins, who provided a draughting and printing service, to prepare drawings; and he commissioned John Cooke Bourne to do a water colour sketch of the crossing for the proposal. On the morning of 3 January 1847, we read in CBV's journal that he:

> …received finally the Geometrical and perspective Drawings of the Kiev Bridge magnificently finished and mounted in the manner required and enclosed in a splendid Box.
>
> (Vignoles Diary, BL, 3 January 1847)

It remained only to pay Mr Cheffins for the work and to make agreements with his office manager Mr Cummins to conduct business in his absence.

PROPOSAL SUBMISSION

Journey to Warsaw

Armed with the proposal, Vignoles set off for Russia accompanied by two of his sons, Hutton aged 24, and Henry aged 20. Leaving London on the evening of 3 January 1847, he travelled by steamer to Flushing, by train to Mainz, by ferry across the Rhine, by train to Heidelberg, and then by travelling-carriage to Stuttgart. While in Stuttgart, he had an audience with the King of

Wurtemberg, and received an introductory letter from him to the Tsar. Vignoles then travelled by carriage for three days and nights, arriving in Vienna in the early hours of 16 January.

On 18 January, the party set off for Warsaw, travelling first by train to Leipzig, and then by coach through Breslau and Cracow. There was snow on the ground, and the roads were not clearly defined. On one occasion they lost their way. Unable to communicate with the local people, they were put on the right road when they found the village priest and asked the way in Latin, their only common language. On 22 January, they reached Warsaw, nineteen days out from London, after a journey of some 1 500 miles.

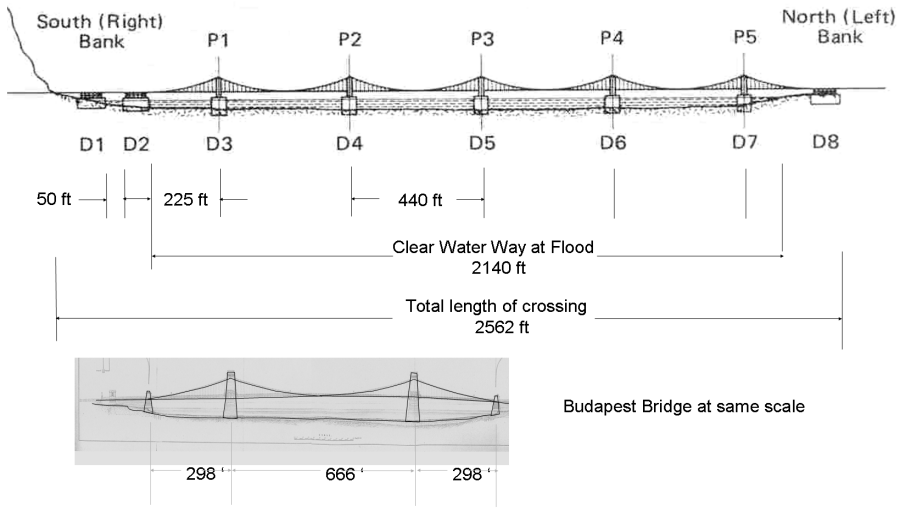

Figure 2. Final layout of Kiev Bridge with Budapest Bridge at same scale.

In Warsaw

On arriving at Warsaw, Vignoles met Col. du Plat and the Evans brothers, and discussed the form of their partnership. Vignoles then settled down to establish the budget and firm up the wording of the proposal, which had to be translated into French, the lingua franca of the Russian court at that time. While in Warsaw, he also found time to dine with the Prince Governor, and to visit the Vistula Suspension Bridge and the railway station and workshops.

Journey to St Petersburg

After a pause of several days, the journey recommenced. They travelled by coach to the Russian border at Kowno (modern day Kaunus), and then by sleigh to St Petersburg where they arrived on 1 February some twenty-one days after leaving London (at one point the temperature was so cold in the coupe that a bottle of sherry froze and separated into the constituent parts of ice and alcohol).

Along the journey, they crossed a number of large rivers. At each crossing Vignoles surveyed the bank to consider how a bridge could be provided.

In St Petersburg

On 12 February, Vignoles was introduced to Count Kleinmichel, the Minister of Public Works, who favourably received the proposals, and asked that Vignoles provide copies of the design for the bridge *on the American principle* showing the depth of water at various seasons and also the transverse section of the river. Count Kleinmichel also requested that Vignoles should consider presenting proposals for bridging three of the rivers he had just crossed.

Vignoles occupied himself with preparing these schemes whilst awaiting an audience with the Tsar. In addition, he visited the St Petersburg to Moscow Railway works which was under construction. The Chief Engineer was Col Whistler, an American Engineer. On 16 February he showed the plans to the Tsar, who asked him to prepare a working proposal.

On 10 March 1847, Vignoles and his younger son, Henry, were back in London, travelling via Warsaw and Berlin; while in Warsaw he signed a partnership contract with Col. Du Plat, the Evans brothers, and a Polish Contractor, Mr Blomberg, who would undertake the construction. Hutton Vignoles went on to Moscow and Kiev on a provisional reconnoitre for materials.

On 7 April 1847, Vignoles received a letter giving official acceptance of his proposal for the Kiev crossing at a budget price of about £239 000 Sterling. (1 670 000 Roubles).

DESIGN DEVELOPMENT

Back in London, Vignoles worked on the structural design, for which he took reponsibility. He made visits to Montrose, Shoreham and Hammersmith Bridges and made extensive measurements at each one; and he visited iron works to look at the chain link material. He looked at steam pile driving machines; and investigated the cost of shipping freight to Kiev via the port of Odessa. He discussed architectural details and commissioned Mr Bourne to draw a revised proposal. Meanwhile Vignoles commissioned Mr William Coulthard to set up a design office at Preston to prepare the drawings for the foundation construction. In this work he was assisted by his son, William Robson Coulthard, by Hutton Vignoles, now back from Kiev, and by John England; these three would all work on the bridge construction. On 16 June 1847 the final proposal was complete, and a portfolio prepared for submission to the Tsar.

THE DESIGN APPROVAL AND SITE VISIT

Journey to Warsaw

In July 1847, Vignoles returned to St Petersburg to get the final design approved, accompanied by his other two sons, Charlie, who was 27 and Olinthus, then aged 19. They travelled by sea to Hamburg, by rail to the Polish border and by carriage to Warsaw.

Site Visit

Vignoles then went to Kiev for his first view of the site. While there, he commissioned searches for timber and stone, and also for a foundry which could make piling shoes. The journey involved over eighty hours travelling in each direction for a visit of two days.

Partnership Agreement

Back in Warsaw, Vignoles consulted with his partners about the agreement. The risks and rewards rested with Vignoles and Col. du Plat, who was the senior partner in the venture. The Evans brothers declined to take a share in the risk, but agreed in all other repects to assist him, and to endeavour to get Mr Blomberg either to continue on the original terms or to take an extra price for doing the work as contractor.

Design Approval

Vignoles then returned to St Petersburg, where he was to remain for six weeks negotiating the design with the 30-man Bridge Commission appointed by the Tsar. Various dimensional changes were requested, and the suspension calculations were challenged. It soon became clear that no-one was prepared to take reponsibility for approving the works. At the beginning of September Vignoles arranged a meeting with the Tsar who asked to confirm that his calculations were satisfactory, and to take account of the dimensional changes requested.

On 22 September, Vignoles met the Tsar on site at Kiev, and the various amendments were agreed. Eventually, at the end of September, Vignoles received a contract, signed on behalf of the Tsar by Count Kleinmichel and General Gottman, the local Governor of the XXth Arrondissement – the Kiev district. Vignoles writes in his diary "Thus after 9 months of tedious discussions this affair of the Kiev bridge was brought to a satisfactory conclusion".

Before leaving Kiev, Vignoles appointed a local engineer to investigate materials. He also commissioned a local builder to build him a family residence for his site establishment.

Works contract

Returning via Warsaw, Vignoles agreed the terms of contract with Mr Blomberg to supply the labour force and construct the works at Kiev, including the procurement of locally available materials of timber and stone. Before leaving for London, Vignoles had a Power of Attorney drawn up to enable Blomberg to order and mobilise the work. He also engaged a Polish Engineer to go to Kiev and carry out a preliminary survey.

PROCUREMENT AND MOBILISATION.

On 7 October, Vignoles arrived back in England and started to make preparations for the start of work on site in the New Year.

Ironwork and Temporary Works Machinery

All ironwork and temporary works machinery would be obtained in the UK, with payment direct from Russia. On 16 October, a contract was placed with Musgrove of Bolton to supply the ironwork. The first shipment was loaded at Liverpool and shipped out to Odessa in December, followed by a second one in January.

Design Check

Also in October Vignoles spent three days in Ireland consulting on the mathematics of the design with Mr Bergin and his nephew Edward Whiteford at Trinity College Dublin and with Professor Robinson in Armagh (as Professor Robinson would accept no fee, Vignoles presented him with a Whitworth slide-lathe).

Procurement of Suspension Links

Vignoles had been much exercised over the chain procurement. The diary records numerous discussions and letters to ironmasters, the earliest being in December 1846. A series of tests of the raw material had been made at Thorneycrofts. On 18 November 1847 Vignoles records attending full-size tests on hammered links in Birmingham. The drawings for the links were sent out on 18 December to a number of ironmasters, and finally on 23 January 1848 we find Vignoles checking the contract for the supply of rods and chains with Fox Henderson, who were also the link suppliers for the Budapest bridge.

Project Finance

On 10 December Vignoles arranged for a first financial drawdown from his bankers and had discussions with Col. Du Plat regarding his share of capital for the finances. Although a form of stage payments had been agreed with the client, cash flow was always a concern. Before leaving London, Vignoles would arrange a Power of Attorney for his office manager, based at No. 4 Trafalgar Square, to manage his affairs in his absence.

Piling Engines

In December 1847, Vignoles asked Mr Frost, newly appointed as river works engineer, to investigate and procure some piling engines which he had seen working at Perth; and on 16 January 1848, two weeks before departure for Kiev, Vignoles travelled up to Newcastle to visit the Nasmyth steam pile drivers at work on the foundations for the Newcastle High Level bridge.

Foundation Drawings

On 15 December, the foundation drawings were completed. The Preston office was closed and the design assistants travelled to London to join the party for Kiev. Mr Coulthard (Senior) was to remain in England on a salaried basis, to provide a design service to the site as required.

1848 - SITE ESTABLISHMENT AT KIEV

Site establishment

At the end of January 1848, Vignoles set off to Kiev, where he intended to establish his own residence, as he had ten years previously at Dinting Vale for the Woodhead tunnel. He took with him his daughter Camilla, who was estranged from her husband; she had agreed to keep house for him.

On the 19 February the site team assembled at Kiev. Vignoles was to be Chief Engineer; with Hutton and Henry Vignoles, John England, and William Robson Coulthard as Assistant Engineers. As well as Mr Frost and his son, there were two Mechanical Engineers, Coulishaw and Bell, and George Pemberton who was a blacksmith. Mr Dacre White was to be reponsible for the shipping import at Odessa. Mr Whiteford, the maths scholar from Trinity College Dublin joined the team as General Assistant. The contractor's Agent was Mr Schweitzer and Captain Kirchenpauer was construction engineer.

Construction Records

John Cooke Bourne joined the team to produce record drawings and sketches and photographs (calotypes) as required. At the close of each season, a set of photographs were placed in an album for the client.

Construction Programme (fig.3)

Vignoles anticipated that the bridge would be handed over in September 1851, four years after signing the contract. Due to events, however, the bridge was not completed until September 1853.

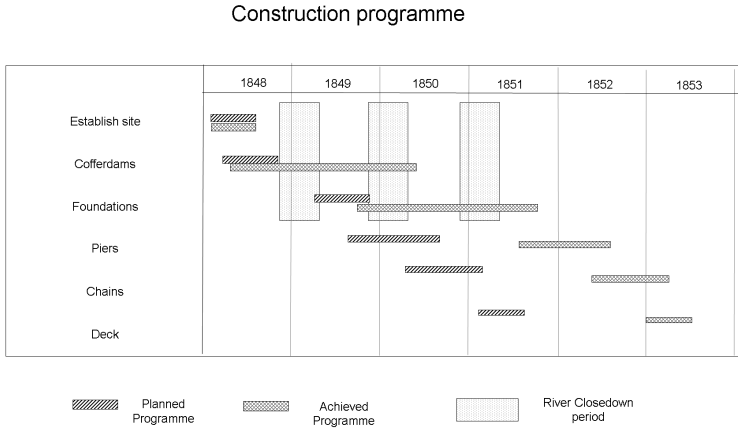

Figure 3. Planned and achieved construction programme.

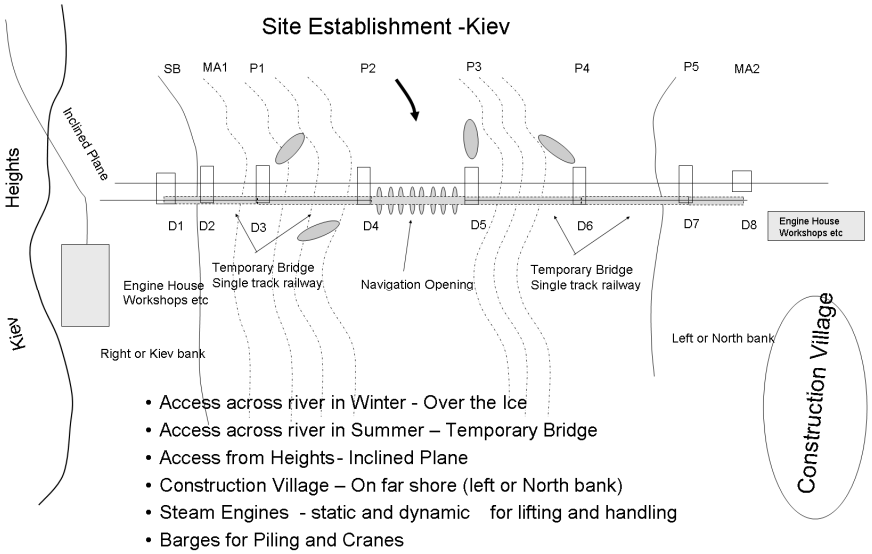

Figure 4. Layout of works at Kiev

Initial Site Works.

On arrival in Kiev, the team found that the river was frozen over. This enabled them to work relatively dry-shod surveying the line of the bridge, establishing foundation positions, and drilling down to prove the ground. They found hard clay on the right bank under the heights, and sand over the remainder of the river. Much time was spent preparing plans and sections of the river, and deciding the bridge alignment. Vignoles appears to have carried out much of the direction of the works himself, and his journals are full of detail during this period.

Description of Works (fig.4)

Work also proceeded to establish the construction camp on the North or left bank and to set up and source stone and timber for the works. The course of the supply railway down from the heights was also determined, and the necessary inclined plane surveyed and constructed by the end of the year.

Letter to Robert Stephenson

On 16 May 1848, CBV wrote to Robert Stephenson, congratulating him on the successful lift of the first Conway Tube, and requesting his assistance with a Parliamentary Hearing on the NW Railway (Lancaster to Settle), as he could not leave Kiev at that time.

He also says:-

> The very large work I am engaged in here for the Emperor of Russia has nothing novel in it to the English Engineers. I have been busily engaged in matters which in this country

require all my personal care and superintendance, but I am happy to say that except in magnitude, there are no difficulties to be encountered. It is chiefly a question of time and I am fortunate in having got an experienced and honest contractor. Of course, everything except Brick, Stone and Timber must come out from England, even leather and cordage, but I trust my arrangements to carry on everything smoothly and at present the season is favourable.

(Vignoles correspondence, Letter No. 1218.)

RIVER WORKS 1848

Temporary bridge and cofferdams.

Once the river had thawed sufficiently, piling for the temporary bridge supports and for the cofferdams started. The temporary bridge was built to carry a railway across the works, with pile bents at 54 ft centres, and sidings at each cofferdam. There were seven cofferdams in number, some in deep water and some in shallow. The basic construction was of two concentric rings of timber piles, with the space between filled with puddle clay, and tied together with iron straps. **(fig.5)**.

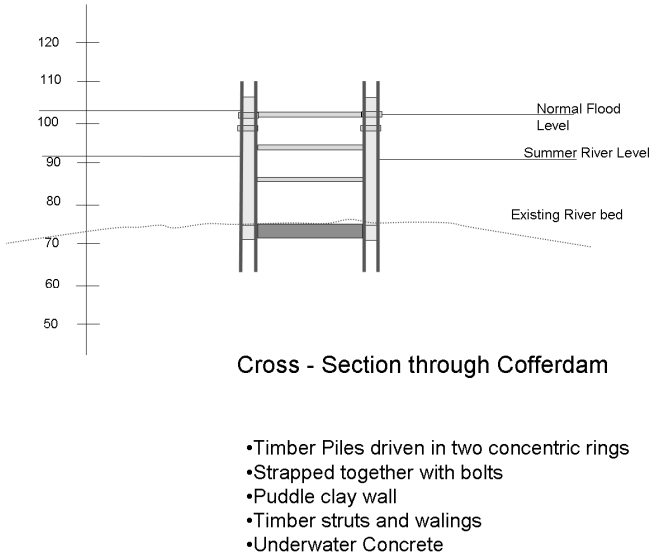

Figure 5. Details of deep water cofferdams.

That summer they experienced their first bout of cholera. The workmen left for home, and the contractor was reduced to borrowing soldiers from the garrison to man the piling engines. Sadly, Mr Whiteford was taken ill and died the same day.

In July, Vignoles returned to London for a couple of months, leaving Hutton in charge. While there, he commissioned a large-scale model of the bridge and also inspected the suspension chains. The first stone for foundations on the shore was laid in Sept 1848. Vignoles returned to Kiev in October. The cofferdam piling was completed before the winter freeze set in. There was a difficult moment when the river was partially frozen. The river currents increased, the last river barges of the season swept down out of control, and carried away a portion of the temporary bridge **(fig.6)**. However, by dint of laying straw on the river surface the remaining gaps between the ice floes were sealed, and the works were closed down for the winter.

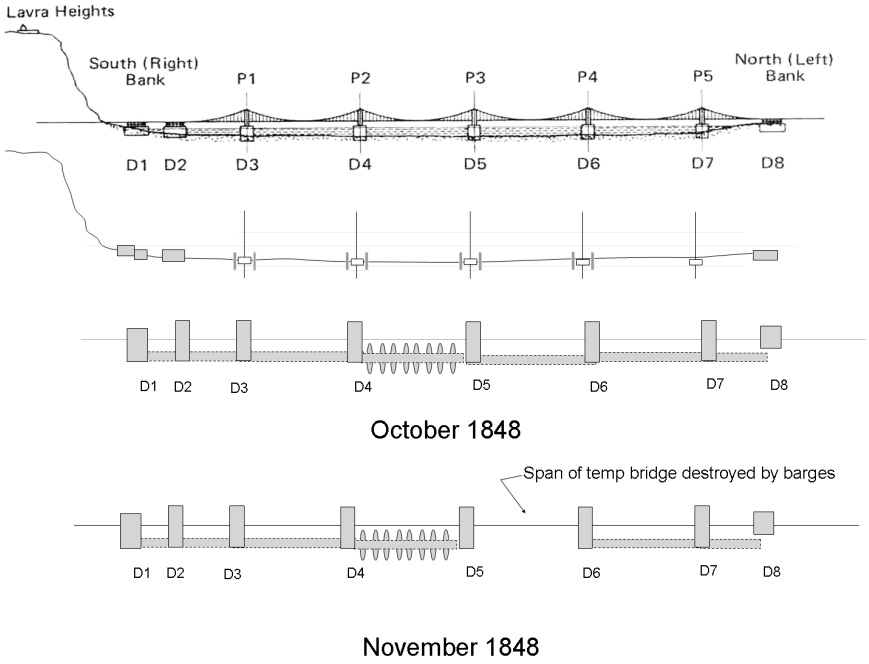

Figure 6. River works 1848.

Forward Planning

At home meanwhile, the procurement of the chains was progressing; and the construction methods for the piers were being developed by Coulthard. At Kiev, the engineers were set to work detailing the stones for the piers, producing cutting schedules, and also scheduling up the timbers for the bridge deck to be put aside for seasoning.

Interim Payments

In January 1849 was the first of many concerns regarding cash flow. To keep the flow of supplies and materials from England , Vignoles took out a personal loan from his solicitor.

RIVER WORKS 1849

Setback on the Riverworks.

During the winter, work restarted on the cofferdams, completing the clay puddle walls and installing the waling frames. To protect the dams from damage during the thaw, additional rows of piles were driven at the upstream side to act as icebreakers.

In April, when the ice thawed, large ice floes collided with the piers of the temporary bridge causing damage to some spans which had to be replaced. In May, the melting of the snow upstream caused the river to rise to a high flood level. A number of large barges failed to pass the bridge, and were wrecked, causing yet more damage. The river continued to rise, and two days later, coffer dam no.4 was swept away and coffer dam nos. 3 and 5 were severely damaged **(fig.7)**.

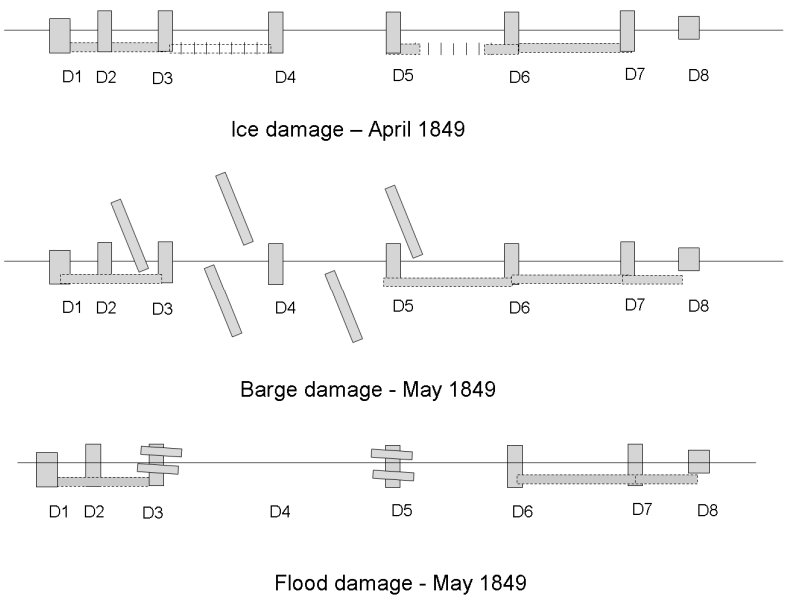

Figure 7. Damage to river works spring 1849.

Vignoles summarises the events in a report on 11 May 1849 to his partner Col. du Plat.

He opens the report:

> "I must beg you to summons your philosophy, for this letter has to recount a series of formidable disasters… [Although] the flood…has risen 19 feet above the level of last summer, we are apprehensive it may rise higher".

He describes the wrecking of the barges, and goes on to make the following points:

- the upstream end of Cofferdams nos. 3 and 4 rose 2 and a half ft above water level which was 5 and a half feet above the top of the dams, ie 8 ft out of ground.
- part of dam no 4 shot up vertically like a whale about 25 to 30 ft, and was carried away 2 versts downstream.
- all hands filled barges with stone and sank them on dam no 3 and drove it back down under water.
- being worried for dam no 5 also, more barges were loaded with stone and sunk across it.
- all day, all night and next morning water rose steadily.
- the remainder of dam no. 4 began to show above water, and a second piece sprang up, and in the afternoon a third piece likewise, being the remainder of the dam.
- being worried that dam 5 was still lifting in spite of the load on it, more barges were sunk on it.
- soundings show a water depth of 51 ft to 56 ft around dam no. 5, which indicates 10 to 14 ft of scour.
- dam no. 6 seemed secure, as did the temporary bridge up to dam no. 5.
- the river bed must have deepened considerably between dam no. 2 and dam no. 4.

Examining the wreckage of cofferdam no. 4 , he found that:

- the counter piles were sound and unbroken complete with shoes.
- any bay piles which had knots in, the knots had crushed in driving, which will have lessened hold in the ground.
- none of the piles were broken
- walings and tie bolts had held dam well together.

Vignoles concluded that the cofferdam as a whole had been well fixed in the ground. This would explain the delay after the first 2/5ths tore off, before the remainder went.

In the report, Vignoles proposed the following course of action, which he believed would be adequate provided there was not a repeat of the scouring event:-

- To reconstruct the cofferdams as 3 rows of piles, all squared timber free from shakes and knots, and to drive 12 to 14 ft below present river bed. This would require timbers at least 56 ft long.
- To fill the scour holes with concrete inside as well as outside, after first paving the inside with clay.

- To make a clay puddle material mixed with dung and brick rubbish and stone chippings and fill two separate puddle walls between the three rows of piles.
- To ensure that the dam walls are well braced together and weighed down.

Vignoles gave instructions to the site staff to secure the works and prepare to redrive the cofferdams with longer length piles, using Nasmyth's steam piling engines. Unfortunately, the boilers which had left Odessa the previous November had not yet arrived. They were found lying in a ditch.

On 4 June, Vignoles he returned to England for a typically busy few weeks. He attended the ICE for a discussion on rolling bars for suspension bridges; (he got married again); he visited the Britannia Bridge tubes at Bangor; he visited Coulthard to discuss the swing bridge designs. The first part of August he was present in Ireland for Queen Victoria's visit to Dublin. On 16 August he was back in London leaving for Warsaw via Hamburg and Berlin. He was back in Kiev on 5 September.

While at Bangor, Vignoles discussed the river problems with IK Brunel, Robert Stephenson, and Cubitt among others. He also consulted with Herr Hubbe, the Hamburg Port Authority engineer, who advised the use of fascine mattresses. After viewing an installation in Holland, Vignoles appointed two Dutch engineers to come to Kiev and reinforce the river bed around the cofferdams with willow mattresses. **(fig.8)**. By the end of October, the cofferdams were securely remade.

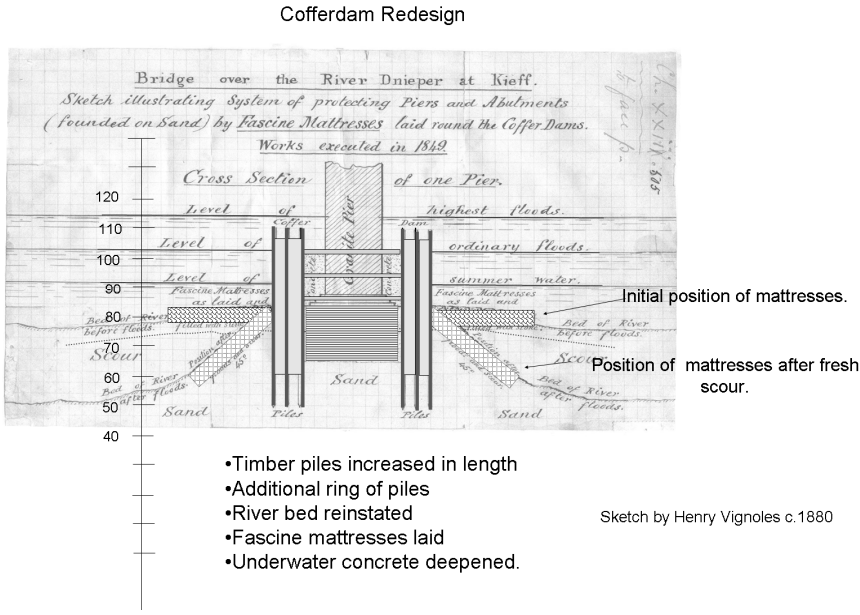

Figure 8 Details of redesigned cofferdams, based on a sketch by Henry Vignoles (c.1880).

Eyewitness account of a pontoon bridge

In September 1849 the team had a visit by Lady Mary Shiel, who was travelling overland to Persia. In her account of her journey, she declares herself very content with the hospitality she received from Mr Vignoles and household, and comments on the reaction to the disaster. She also describes her experience crossing the public pontoon bridge, which was downstream from the site:

> Returning from inspecting Mr. Vignolles's curious works, we drove in a carriage over the Russian strange contrivance for connecting the two banks of the Dnieper. This consisted of thick planks floating in the water, placed closely side by side, like a raft, across the whole breadth of the river, and braced by bands of rope together. At each movement of the wheels and of the horses, these planks sank into the water, sometimes to an alarming depth; but though the passage looked hazardous, it was free from danger.
>
> (Shiel, Chapter 2).

Inclined Plane Experiments

In October 1849, Vignoles carried out a series of experiments to see if the operation of the inclined plane could be automated, using empty waggons as counterweights. The incline consisted of two gradients of 1 in 14 and 1 in 4, separated by a curve in plan. To overcome the friction in the pulleys, it was shown necessary to use five loaded wagons to recover one empty one. Vignoles notes that:

> I conclude that the number of waggons and the number of men to work the plane from the top of all is too great… we have to… place [the large wheels] on the top of the steep part of the plane and work the upper part by letting the loaded waggons down the 1 in 14 with the brake and pull up the empty waggons with horses; paving between the rails.
>
> (Vignoles Diary, BL, 24 October 1849)

Erection of Scale Model in St Petersburg

In December, Vignoles went to St Petersburg to supervise the erection of the 1:1 000 scale model, which was installed in the Winter Palace. A second model was to be exhibited at the 1851 and 1854 Great Exhibitions, where it remained on show until it was destroyed by fire in 1866.

WORK ON SITE 1850

Site Establishment

Early in the year, there was more concern about expenditure. It was decided to abandon the domestic set-up as it was too expensive, and to send Camilla home. The site establishment was then run as part of the office, and the finances managed accordingly.

Foundation Construction (fig.9)

When the thaw of 1850 came, work could restart on the cofferdams. Now the construction plant came into its own. There were two static steam engines, one on each bank, and five mobile ones. The cofferdams were pumped down, the leaks plugged, and attempts made to bottom them out with a mixture of clay puddle and concrete. The cement for the concrete was made in the yard. The cement installation consisted of 8 large roasting ovens, which could turn out 500 cub ft of cement each day.

Labour Problems

During the summer of 1850 the work dragged on. There were big problems with the leaks, and much working time was lost because of saints' days and holidays. As a consequence, there was little progress on the bases of D3, D4 and D5. In October the main contractor Mr Blomberg died. Fortunately for Vignoles, the agent on site, Mr Schweitzer, agreed to carry on the work.

Completion of North Bank Foundations

The bases of the shallow water foundations, in dams D6 and D7, were concreted before the winter of 1850 closed in.

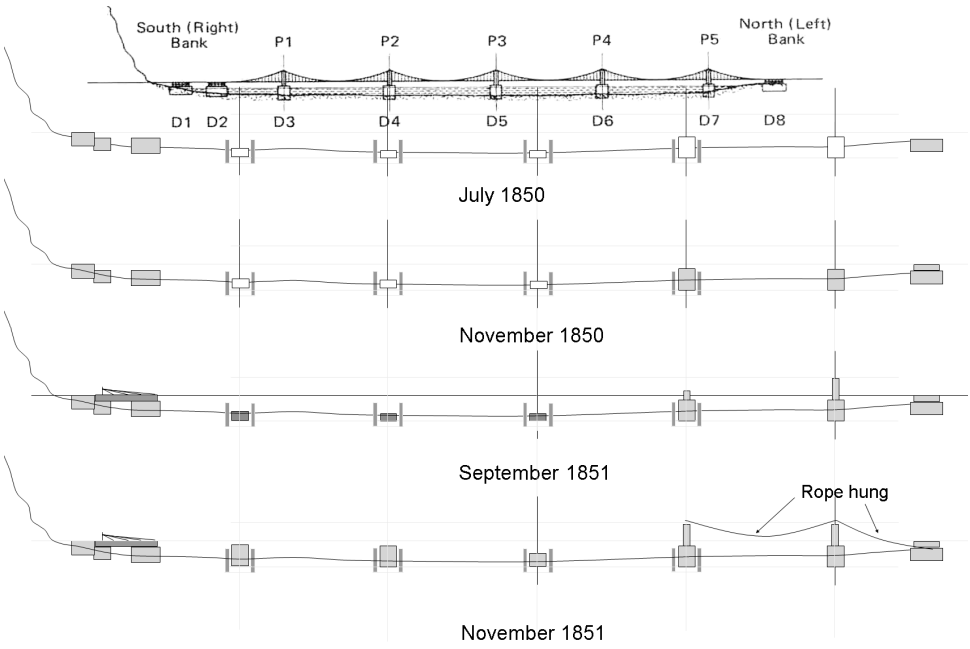

Figure 9. Foundation construction progress 1850 to 1851.

WORK ON SITE 1851

Foundation Completion

During the summer of 1851 every effort was made to complete seal the deep water cofferdam bases. The final one was sealed by mid-September.

Progress on Structure (fig.9)

By the end of 1851 much progress had been made. The roadway was complete on the swing bridge, the bases to D3, D4 and D5 were completed, and their piers (P1, P2 and P3) were built to above flood level. Also piers P4 and P5 were completed up to arch level. When the Tsar visited site, Vignoles arranged to hang ropes between P4, P5 and the abutment to indicate the suspension chains. Work could then continue through the winter on completing the Portals to Piers 1, 2 and 3.

CHAIN LIFTING AND DECK ASSEMBLY 1852 TO 1853

Start of Chain Lifting (fig.10)

Summer 1852 saw the chain lifting process commence. This involved positioning trestles at points along the span and using block and tackle to winch the chains up to level. A fair amount of supervision was needed for this, and there are frustrated remarks in Vignoles's journal about the time it took and the skills required.

Progress Photos

In August 1852 Roger Fenton and Bourne together and separately recorded the chain lifting process. Copies of these together, with a series of photos taken the final year, have recently been located in Kiev by Professor John Hannavy (Hannavy, 2004).

Winter Working

Chain lifting continued throughout the winter. Advantage was taken of the ice to lift the deep water chains while the river was frozen, using sheer legs on the ice.

Deck Installation

The deck was constructed from timbers. Two deep longitudinal trusses were suspended from the chains on links. The detail can be clearly seen in some of the photographs. The method used was described by Vignoles in a paper at the ICE in 1867.

Cash Flow

There was again concern about cash flow. Vignoles used a life insurance as security to raise money to pay the workforce. He brought this in gold coin when he travelled to site in August 1853.

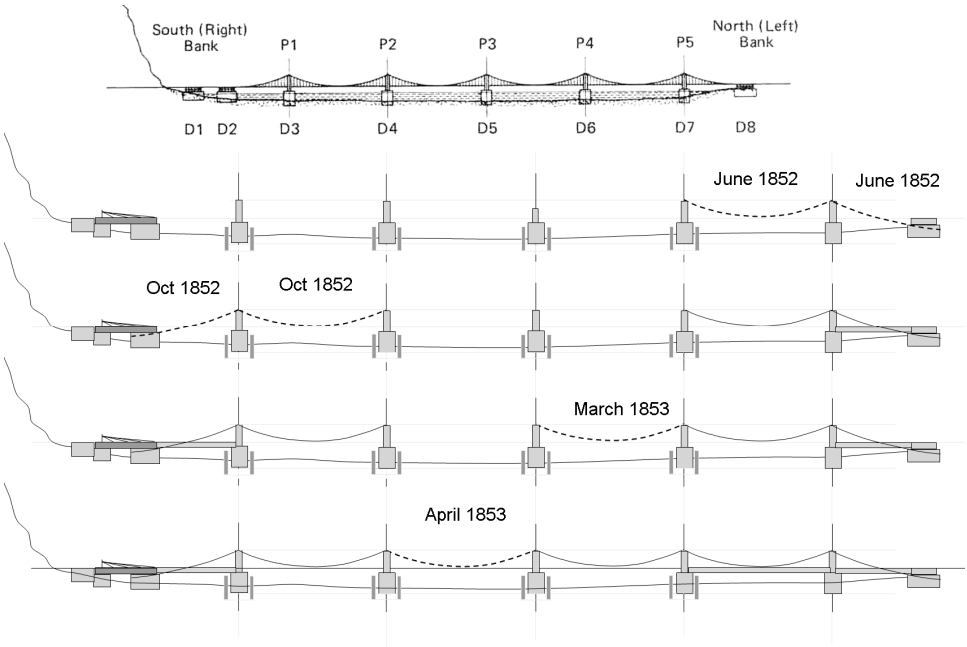

Figure 10. Construction sequence 1852-1853.

Test Loading

As part of the acceptance trials the bridge was test-loaded. A temporary deck was laid over the running surface, and the bridge spans were loaded with 60 000 cubic ft of sand, which was brought in by the barrow-load, and this can be clearly seen in some of the photographs. Before the spans were unloaded a heavy rainstorm ensued which soaked the dry sand, increasing the effect of the load considerably. A flurry of activity ensued, and the load was removed span by span – not an easy task!

Completion

Finally, on 10 October 1853 the bridge was opened by Grand Duke Nicolas, the third son of Tsar Nicholas I. There was a full ceremony of blessing and crowds thronged the bridge. A week later, Vignoles disbanded his establishment and left Kiev never to return. Hutton Vignoles also left Kiev, going to represent his father on a railway project on the Rhine. A skeleton staff remained to deal with outstanding items, carry out the maintenance, and draw up the final account, finally returning to England in 1855.

Vignoles published an impressive set of statistics to accompany the scale model in the 1854 Great Exhibition **(fig.11)**. This gives the final cost of the project as about £432000 sterling.

The account was not settled until after the end of the Crimean War. Vignoles spent some months in St Petersburg pursuing outstanding payments both for his unfulfilled designs and for the bridge itself. In January 1858, he received a final payment in part settlement of his claims. In February 1858 there is a note in the Journal regarding settling the accounts of Mr Palmer, his solicitor, Mr Coulthard, his design assistant, and Mr Bourne, his photographer. In March 1858, he notes that he has: "sent to Douglas Evans at his request a discharge infull...signed by me, releasing him from further [liability] for all sums on Kieff a/c which had passed through his hands since 1848."

Exhibited (at the request of the Directors) in the Crystal Palace, Sydenham, 1854.

MODEL

OF THE

KIEFF SUSPENSION BRIDGE

RECENTLY ERECTED ACROSS THE

RIVER DNIEPER

NEAR THE

CITY AND FORTRESS OF KIEFF

BY ORDER OF

HIS IMPERIAL MAJESTY NICHOLAS I. EMPEROR

OF

RUSSIA

CHARLES VIGNOLES, F.R.A.S., M.R.I.A., ENGINEER.

First Stone laid September 9th, 1848.—*Opened October 10th*, 1853.

THE MODEL BY JABEZ JAMES, A.INST.C.E., MECHANICAL ENGINEER.

Scale of the Model, One Inch to Eight Feet—equal to $\frac{1}{96}$th (0.0104166) of real length.

THE SUSPENSION CHAINS AND BOLTS EXECUTED BY MESSRS. FOX, HENDERSON & CO., LONDON WORKS, BIRMINGHAM.
THE OTHER IRON WORK EXECUTED BY MESSRS. MUSGROVE & SONS, GLOBE WORKS, BOLTON-LE-MOORS.

PRINCIPAL DIMENSIONS, &c.

Extreme Length, 854 yards—(nearly Half-a-Mile), or (366 *Russian sagènes*—776 *French mètres.*)	2,562 feet	Chord of chains of large openings, clear of piers	416 feet.
Extreme breadth, 17½ yards, or (7½ *Russian sagènes*—16 *French mètres.*)	52½ „	Versed sine of ditto	30 „
Spans: Each of the four large openings, from centre to centre of the river suspension towers or piers	440 „	Total length of all the suspended platforms, clear of piers	2,090 „
Spans: Each of the two side openings, from centre of the suspension tower to the face of the abutment	225 „	Total weight of all the platforms and rods, clear of piers (48lb. per square foot)	2,350 tons.
Spans: Swivel bridge opening, in the clear	50 „	Weight of chains and pins, suspended clear of the piers	1,076 „
Clear Water Way at highest floods	2,140 „	Total weight of the four chains and pins only (length of each chain, 2,280 feet)	1,678 „
Height of platform above ordinary summer water-line	30 „	Minimum sectional area of the four chains, excluding pins and overlaps	328 sq.in.
Greatest rise of floods (after the melting of the snows in the spring) above the ordinary summer water level	20 „	Total weight of iron of all kinds used in the works	3,500 tons.
Greatest depth of water in the channel at summer level	40 „	Total quantity of timber used, including temporary works	500,000 c. ft.
Ditto at highest floods	60 „	Total quantity of masonry, brickwork, and concrete in the works	1,500,000 „
Extreme height from deepest river foundations to the top of caps of the suspension towers or piers	112 „	Proof load per available square foot of suspended platform	63 lbs.
Breadth of the portals passing the suspension towers	28 „	Total proof load calculated to be laid on the bridge for trating	2,350 tons.
Height of ditto	35 „	Actual load laid on the bridge for the test, 60,000 cubic feet of sand, which being much wetted by heavy rain during the test weighed 1 cwt. per cubic foot, being equivalent to the weight of 50,000 infantry soldiers or about	3,000 „

TOTAL ABSOLUTE EXPENDITURE ABOUT £432,000 STERLING.

Figure 11. Statistics sheet from 1854 Exhibition.

Bridge in Use.

The Tsar Nicholas 1 Bridge stood for many years. In 1920 the bridge deck was destroyed in the Whites versus Reds wars, and the crossing reverted to a bridge of boats. In pictures of the destroyed bridge the willow tree growth from the fascine mattresses can be clearly distinguished. Various schemes were put forward for reconstruction, which was eventually done, as the foundations were still good. However the bridge was finally destroyed during the Second World War.

CONCLUSION

Back in London, CBV concentrated on overseas railway work, on the Rhine, by Lake Geneva, in Bahia – where he was represented by his son Hutton - in Spain, and in Poland. He continued his interest in photography, and when in London he found time to attend ICE discussions on many subjects; also his name lives on in the flat-bottomed rail which bears his name. He had intended to present a paper on the bridge construction to the ICE. However, as he remarked while contributing to the discussion on suspension bridges in 1867, "Procrastination is the thief of time"; apart from discussions on one or two pertinent details, the only published piece of writing is the publicity he wrote for the exhibition catalogues **(fig.11)**.

The story of the building of the Kiev Bridge brings out the character of CBV in many ways. His determination to take on such a venture, his perseverance to see it through, his willingness to take risks with his own money, his ability to stimulate and enthuse his team of assistants, his pride in his workmanship, his wide knowledge and interest in every aspect of engineering, his showmanship and feeling for publicity - these qualities are all typical of the man and indeed of the age. Similar examples are to be found time and again in his journals, demonstrating that he was indeed a worthy member of the engineering fraternity, he was rewarded by being selected President of the ICE in 1869 to 1871.

Vignoles died in 1875 at the age of 82. The Kiev Bridge survived him for 45 years.

ACKNOWLEDGEMENTS

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REFERENCES

British Library (BL)

Journals of Charles Blacker Vignoles (Eight Volumes comprising Add. Ms 34528 to 34535, Add. Ms 35071)

Add. .Ms 34530 Vol III 1842-1845
Add. Ms 34531A Vol IVa 1847-1848
Add. MS 34531B Vol IVb 1849-1850
Add. Ms 34532 Vol V 1851-1853
Add. Ms 34533 Vol VI 1854 - 1856
Add. Ms 34534 Vol VII 1857 - 1859.

Vignoles Diaries (four volumes comprising Add. Ms 58203 to 58206)
Add. Ms 58205 Vol III 1846
Add. Ms 58206 Vol IV July - November 1851.

Portsmouth Record Office
Letters of Charles Blacker Vignoles (Ref 1072A)

Clarke, Tierney, 1852. "An account of the suspension bridge across the river Danube linking Pesth with Buda", In ICE library.

Fox, Sir Charles, 1865. "On the size of pins connecting flat links on the Chains of Suspension Bridges", *Proceedings of the Royal Society*, Vol XIV, pp. 139-44.

Hannavy, John, Winter 2004. "John Cooke Bourne, Charles Blacker Vignoles and the Dneiper Suspension Bridge at Kyiv", *History of Photography*, Vol. 28, No. 4, pp. 334-47.

Report of discussion, 1849. "Tests on Rolled Suspension Bridge Bars", *Minutes of the Proceedings of the ICE*, Vol. 8, Paper 802, pp. 273-81.

Report of discussion, 1867. "Suspension Bridges of Great Span", *Minutes of the Proceedings of the ICE*, Vol. 26, pp. 270-1.

Shiel, Lady Mary, 1856. *Glimpses of Life and Manners in Persia,* London: John Murray.

Smith, Denis, 1992. "The works of William Tierney Clark", *Newcomen Society*, Vol. 63, 1991-92, pp. 181-207.

Vignoles, KH, 1982. *Charles Blacker Vignoles: Romantic Engineer,* Cambridge: CUP.

Vignoles, OJ, 1889. *Life of C B Vignoles, FRS, Soldier and Civil Engineer,* London: Longmans, Green.