The Howe Bridges on the Nikolayev Railway

by

Kamil Nizamiev and Dario Gasparini, PhD
Case Western Reserve University


St Isaac's Square,
St Petersburg, Russia
View from St Isaac's
Cathedral

Equestrian statue of Czar Nicholas I
St Isaac's Square,
St Petersburg, Russia
Completed in July 7, 1859

Survey by Tzar on Nikolaev Railroad, Verebja Bridge (Ramazanov, 1851)

The B & O Railroad

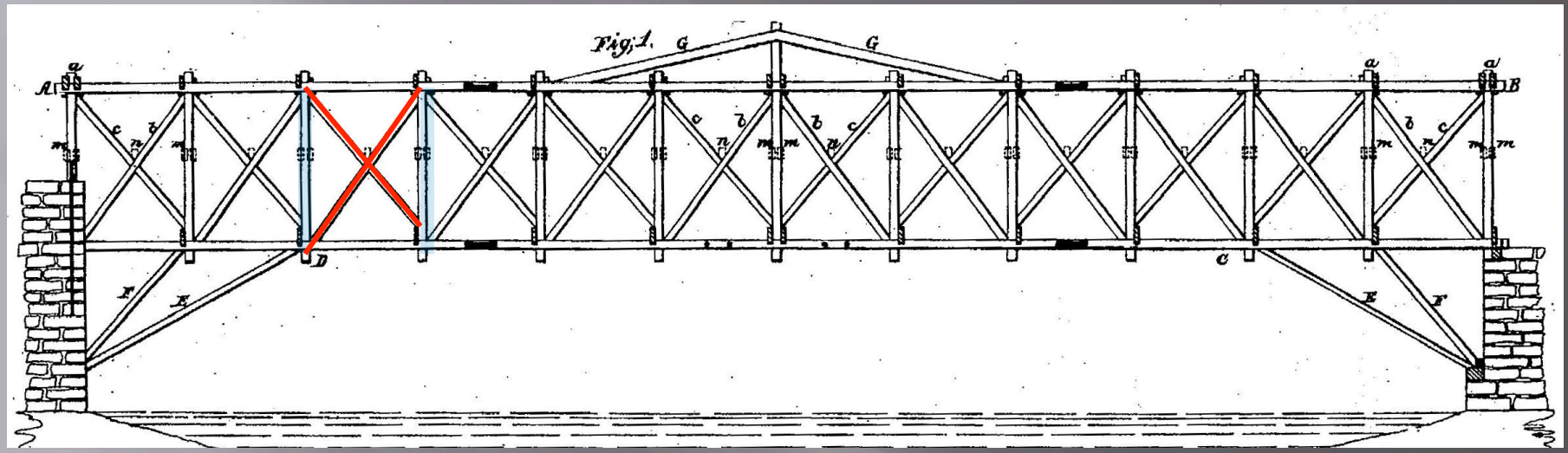
Board of Engineers 1828-1830

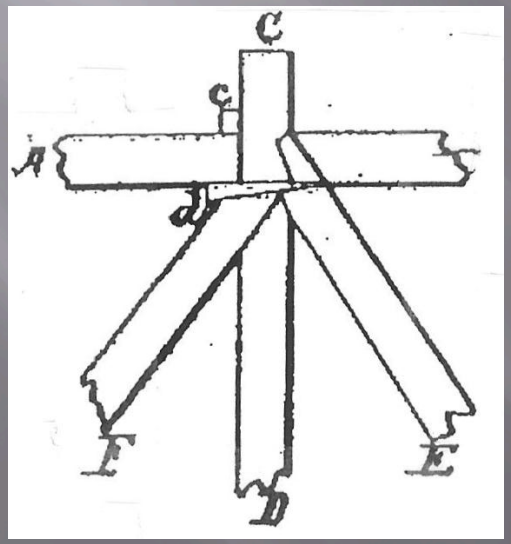
Jonathan Knight
Stephen H. Long (Dartmouth ‘06)

Assistant Engineers

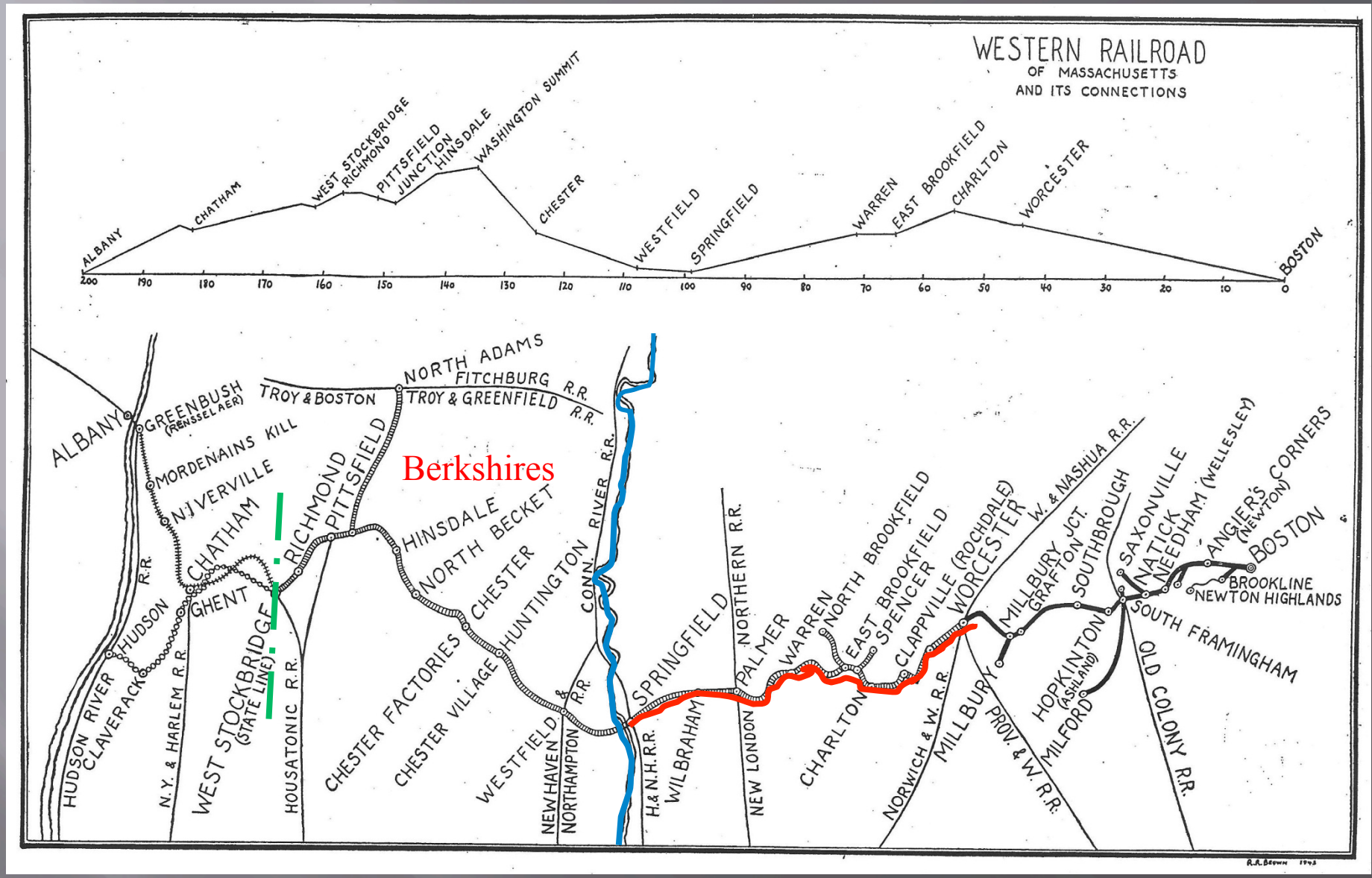
William G. McNeill (USMA ‘17)
George W. Whistler (USMA ‘19)

S. H. Long Patent 5862X of March 6, 1830





Used wedges to apply a pre-compression in the diagonals; both diagonals active in adding to stiffness.



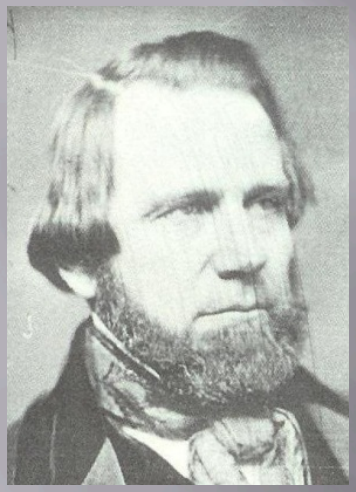
October 1839 – Western Railroad open from Worcester to Springfield; all but one of the bridges east of the Connecticut River were Long trusses.

Chronology: Western Railroad, America, 1831~1839 (Eastern Part)

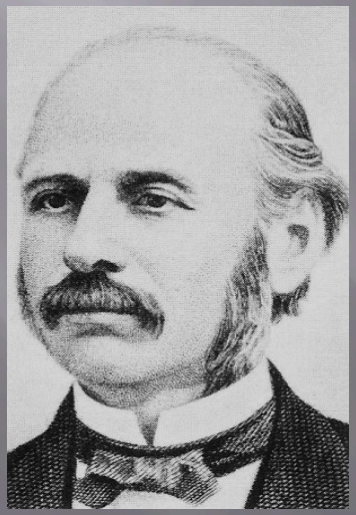
Western Railroad engineers

G. W. Whistler (USMA ’19) - Chief engineer 1836-1842
W. G. McNeill (USMA ‘17) - Chief engineer 1836-1840
W. H. Swift (USMA ‘19) - Resident engineer 1836-1839

The inventor and the builder

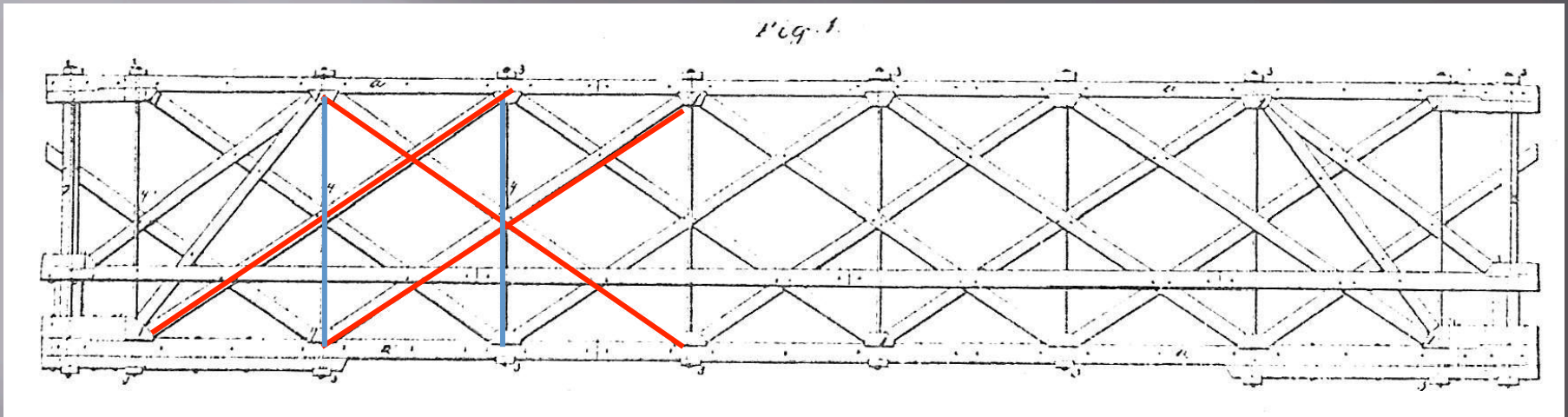


William Howe (b. 1803 Spencer, MA)



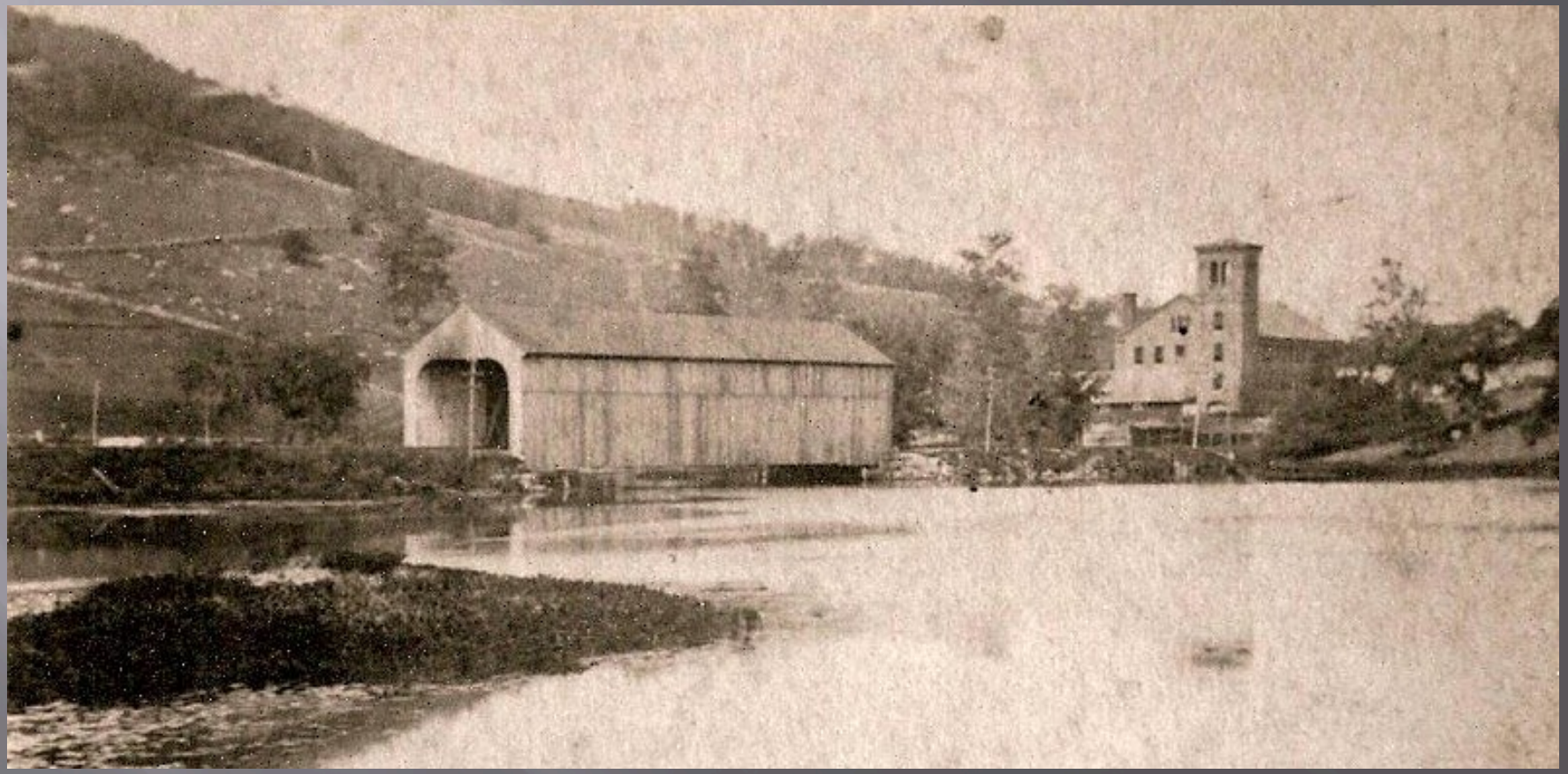
Amasa Stone (b. 1818 Charlton, MA)

William Howe truss patent number 1711, August 3, 1840

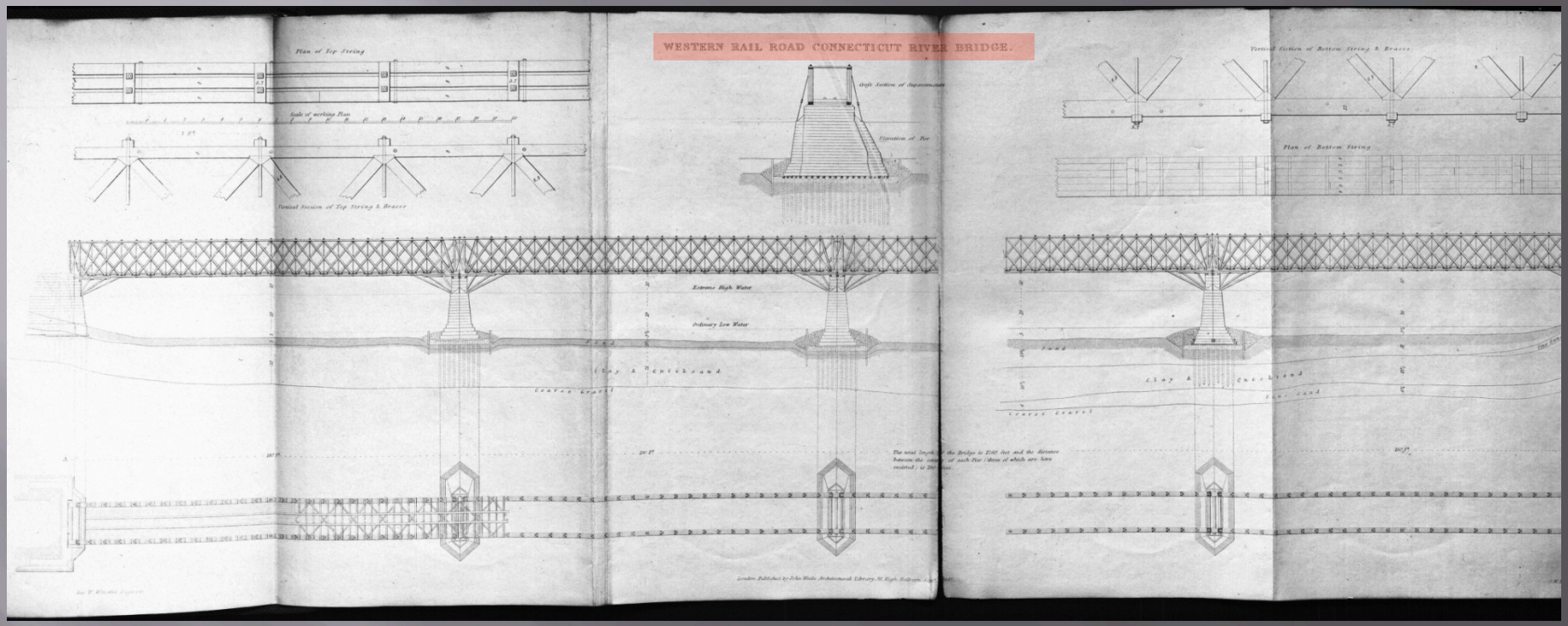


Node blocks keyed into the chords
Wrought iron verticals post-tensioned by tightening nuts

First bridge built by William Howe and Amasa Stone for the Western Railroad at Warren MA, 1838-1839; a "Howe" truss?

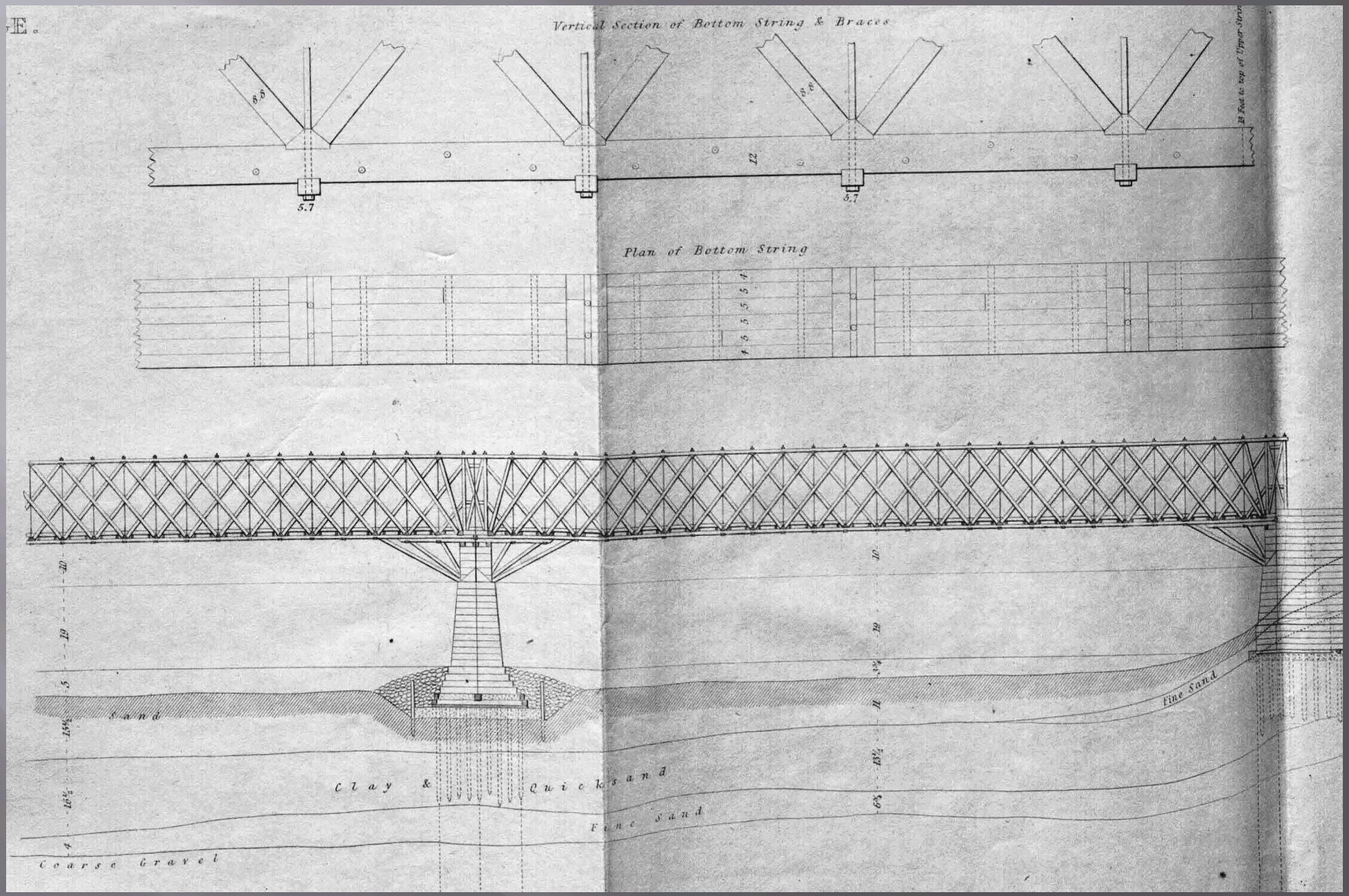


Connecticut River Bridge



A single track, continuous through Howe truss “1264 feet long, of 7 spans, 180 ft. each”

Chronology: Western Railroad, America, 1831~1839, Connecticut River Bridge



- **Design of the Connecticut River Bridge**

Span lengths -180ft
Depth/span ratio - 1/10
Continuity over supports – Seven continuous spans
Chord sizes –constant along length
Lower chord – Four 5 x 12 and two 4 x 12
Upper chord – Three 8 x 8
Sizes of wrought iron rods – constant along the length
Two, 2 inch (?) diameter rods
Sizes of main and counter diagonals – constant along length
Main diagonals and counters - 8 x 8

- **Construction of the Connecticut River Bridge**

"…the several frames for each opening must be accurately fitted and put together in the carpenter's yard. When the piers and abutments have been carried up to the proper height to receive the [falsework] platform, the frames are then taken to pieces and re-erected in their permanent position." (Weale 1843)

- **Weather and fire protection**

The trusses are "covered in on both sides and top, and thoroughly whitewashed. The entire flooring of the Connecticut River Bridge is covered with tin, painted of a dark color." (Reports 1843)

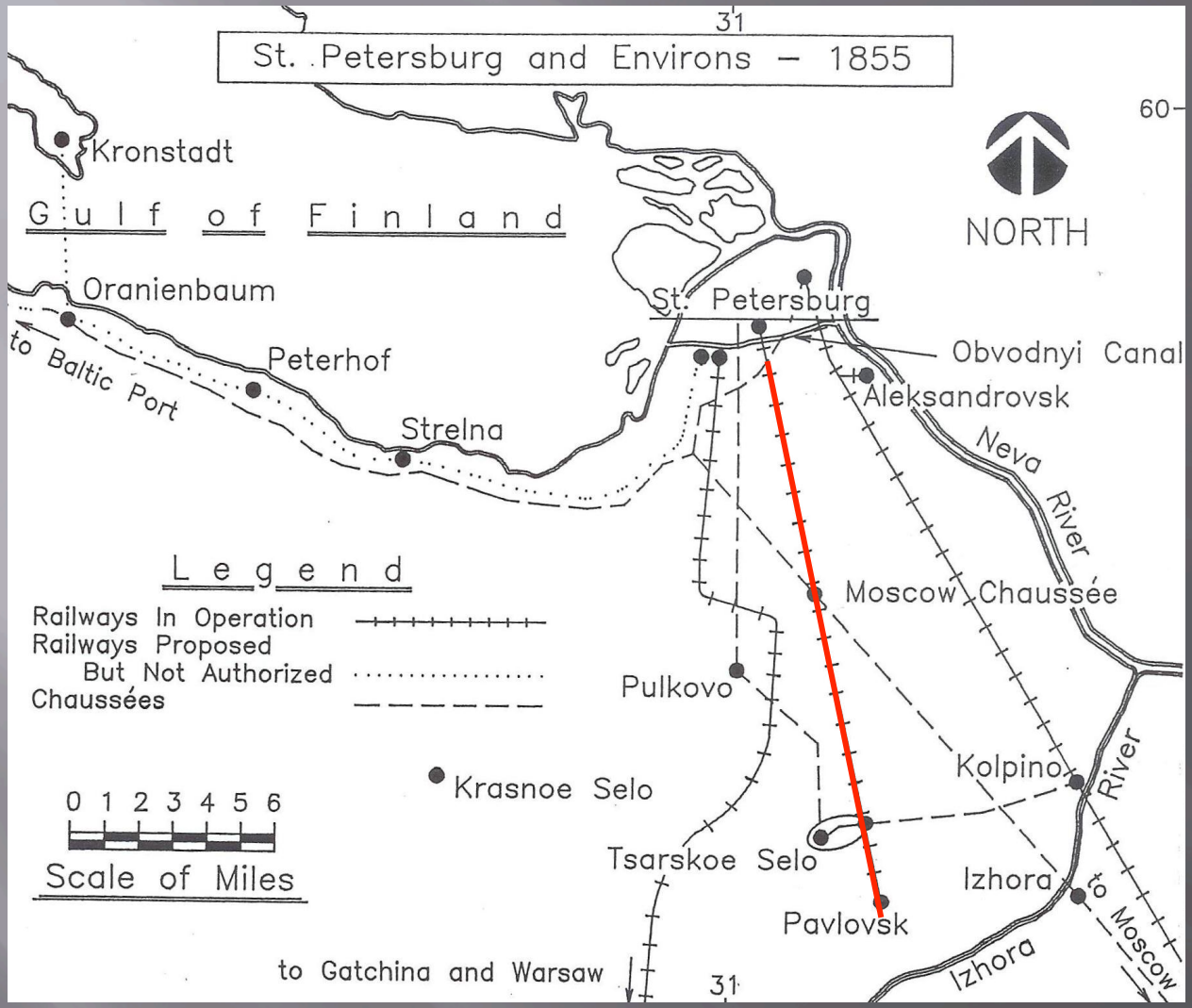
Completion on July 4, 1841 (Reports 1843)

- **Significance of the project**

"The Connecticut River Bridge and those westward of it on the Western road, are of truss frames, of Howe's more recent patent." (Reports 1843)

"There are on the Albany road 17 wooden railroad bridges…. the whole are built after Howe's plan, and the truss frames are covered in and whitewashed." (Reports 1843)

Chronology: Tsarskoye Selo Railway, Russia, 1836-1837, First Public Railway



Haywood 1998

A short, 17 mile, demonstration railroad was completed by Franz Anton Ritter von Gerstner by 1837. It utilized a broad (6 feet) gauge.

Chronology: Moscow –Saint Petersburg Railroad Discussion, 1839

In April 1839 Tsar Nicholas I ordered two officers from the Corps of Transport Engineers to travel to America to study railways.

Col. P. Melnikov – Professor of mechanics at the Institute of Transport Engineers
Col. N. Kraft – Professor at the Institute of Transport Engineers

They were in America from June 1839 to June 1840, met with Whistler, and submitted a report in 1841. On January 1842 Melnikov and Kraft both recommended that the Russian government retain Major Whistler.

The Russian Minister in Washington, A.A. Bodisco, was instructed to enter into negotiations with Whistler. Major Ivan F. Bouttatz was sent to America to buy steam excavators, steam pile drivers, and steam locomotives and, if Whistler accepted the position, accompany him to Russia.

Chronology: Western Railroad, America, 1842

The Western Railroad began operations from Boston to Rensselaer on January 4, 1842. Whistler accepted the position in Russia and resigned from the Western Railroad in May 1842.

Whistler and Bouttatz purchased a steam excavator from the firm of Eastwick and Harrison of Philadelphia and a small locomotive from Ross Wynans of Baltimore.

He and Bouttatz left for Russia on June 16, 1842 and arrived in Russia on July 30, 1842.

Chronology: London, England, 1842, Journal by John Weale

THE

THEORY, PRACTICE, AND ARCHITECTURE

OF

BRIDGES

OF STONE, IRON, TIMBER, AND WIRE;

WITH

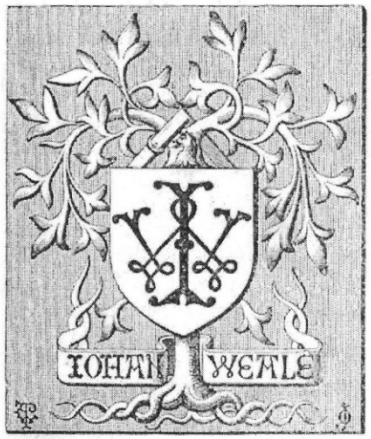
EXAMPLES ON THE PRINCIPLE OF SUSPENSION:

ILLUSTRATED BY

One Hundred and Thirty-eight Engravings

AND NINETY-TWO WOOD-CUTS.

VOL. I.



London:

ARCHITECTURAL LIBRARY, 59, HIGH HOLBORN.

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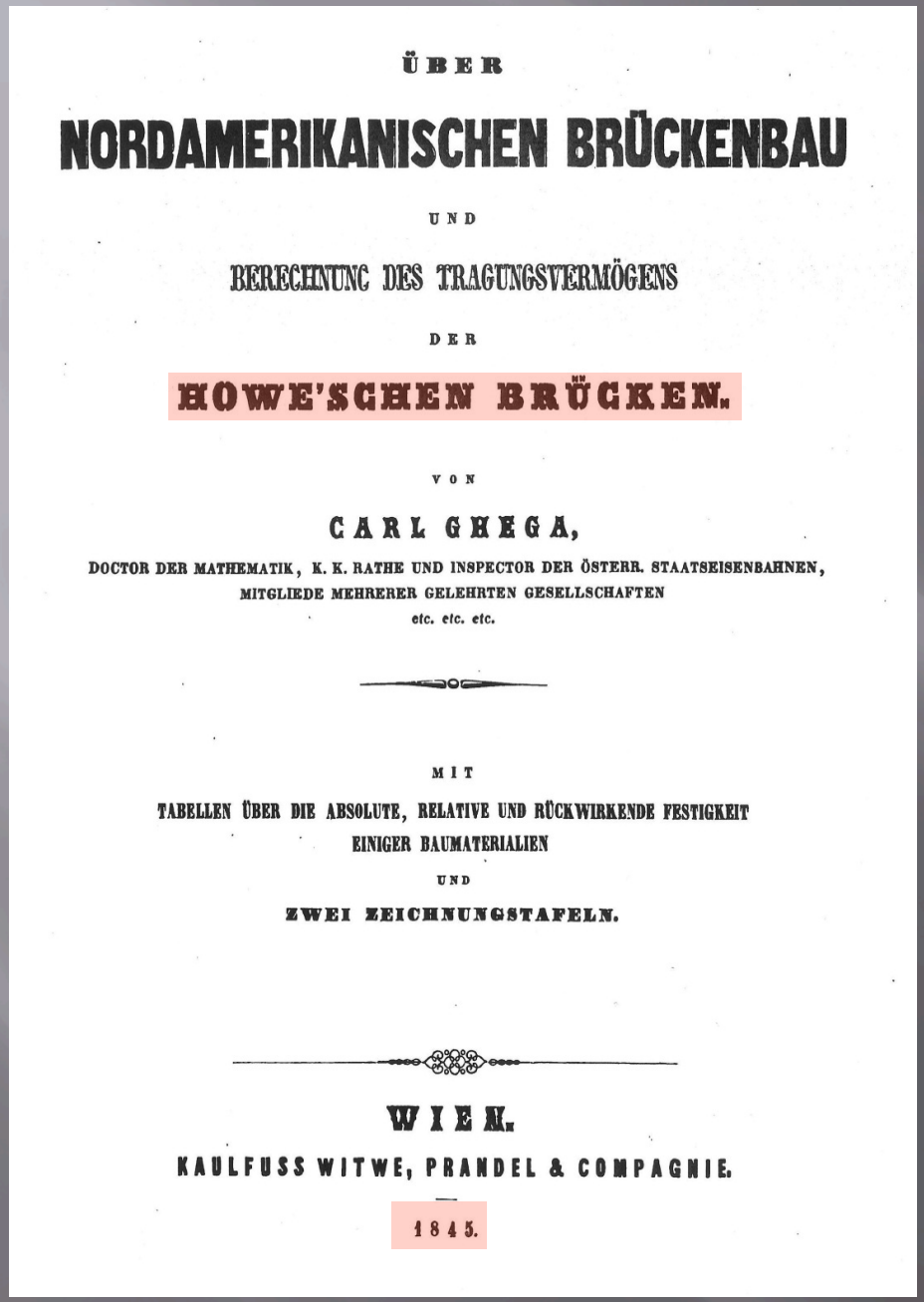
Plate 122 shows the Connecticut River Bridge. Weale acknowledges that the drawings were given to him by Major G.W. Whistler

Chronology: Vienna, Austria, 1842, Article by Carl von Ghega



ÜBER

NORDAMERIKANISCHEN BRÜCKENBAU

UND

BERECHNUNG DES TRAGUNGSVERMÖGENS

DER

HOWE'SCHEN BRÜCKEN.

VON

CARL GHEGA,

DOCTOR DER MATHEMATIK, K. K. RATHE UND INSPECTOR DER ÖSTERR. STAATSEISENBAHNEN,
MITGLIEDE MEHRERER GELEHRTEN GESELLSCHAFTEN
etc. etc. etc.

MIT

TABELLEN ÜBER DIE ABSOLUTE, RELATIVE UND RÜCKWIRKENDE FESTIGKEIT
EINIGER BAUMATERIALIEN

UND

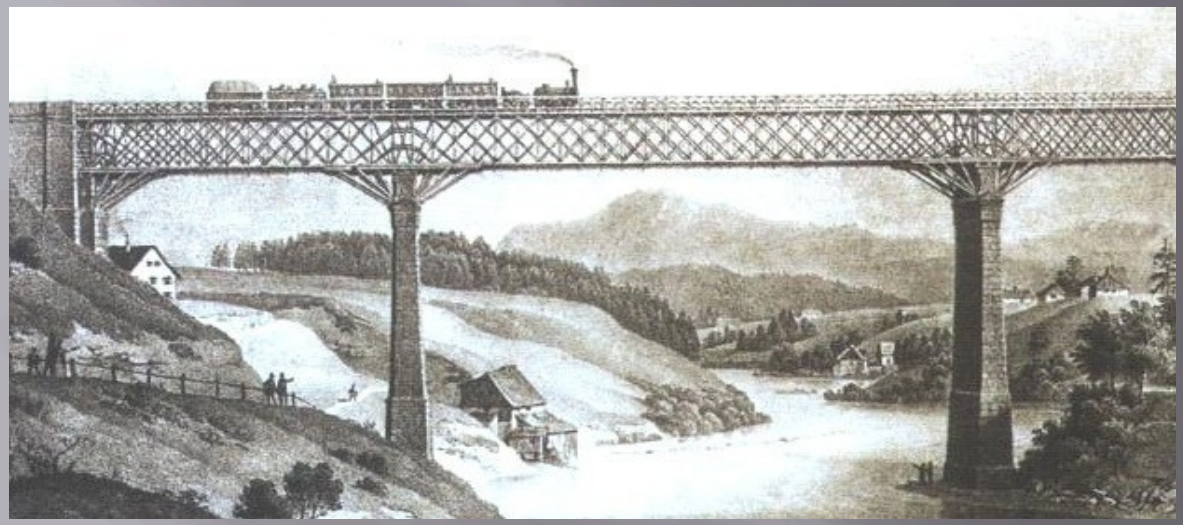
ZWEI ZEICHNUNGSTAFELN.

WIEN.

KAULFUSS WITWE, PRANDEL & COMPAGNIE.

1845.

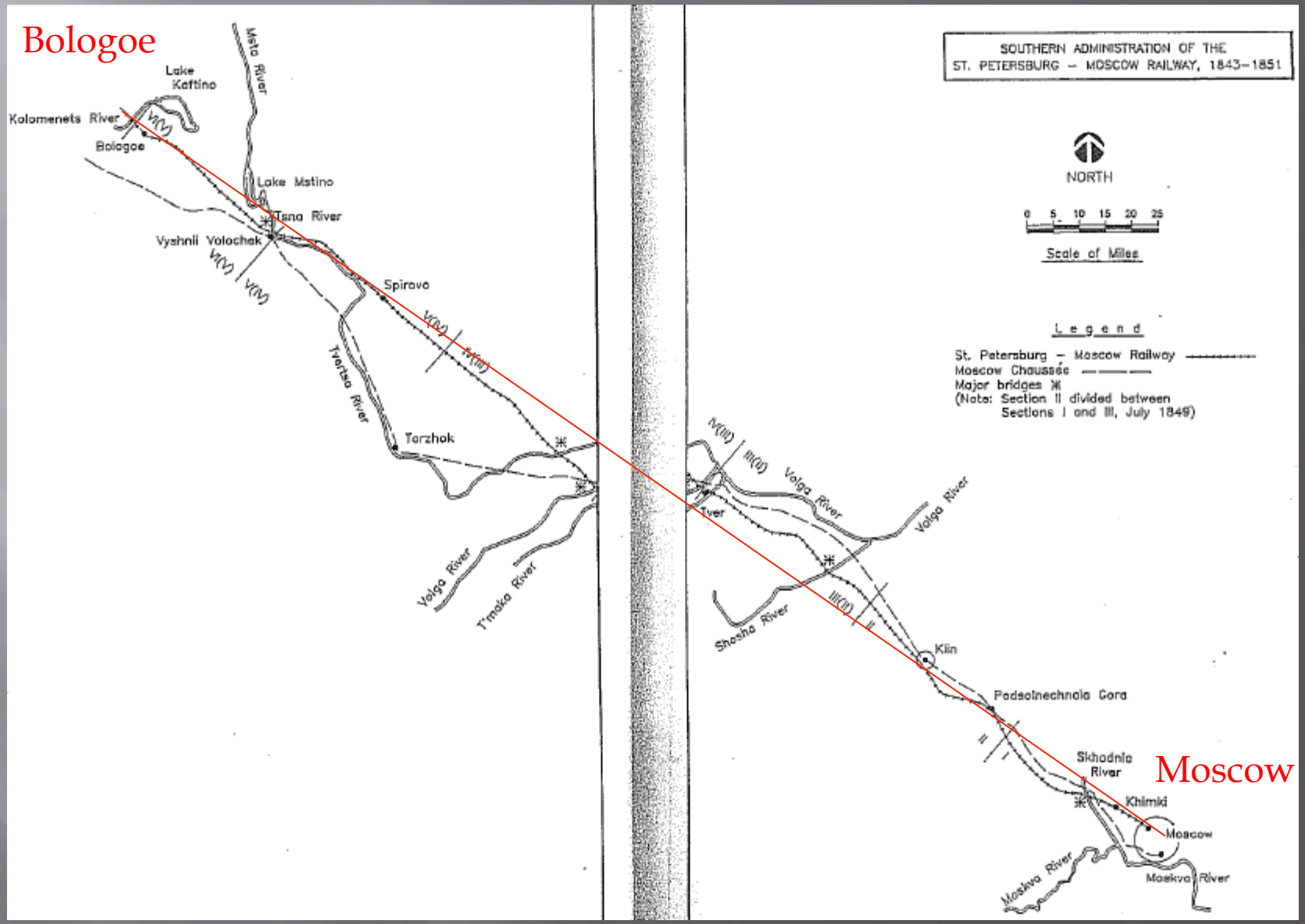
Ghega visited America in 1842. The Connecticut River Bridge is described on p11-17



Howe bridge, Kempten, Germany c1856

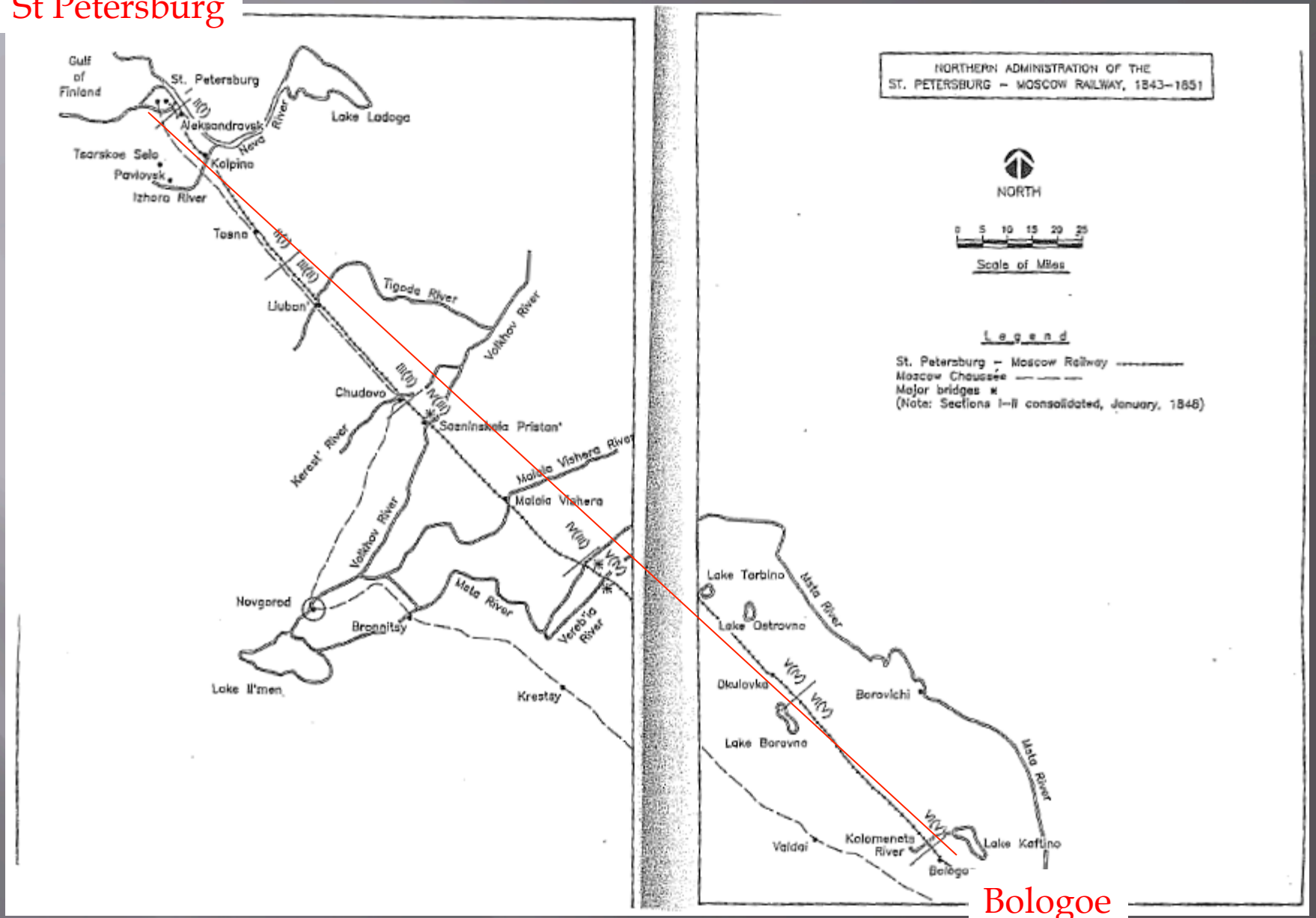
Organizational structure of Nikolayev Railway

Chronology: Nikolayev Railroad, 1841-1855, Southern Administration



Chronology: Nikolayev Railroad, 1841-1855, Northern Administration

St Petersburg



Bologoe

Chronology: Nikolayev Railroad, Russia,1841-1855, Organizational Structure

Main Administration of Transport and Public Buildings - Count P. Kleinmichel

Department of Railways – K. Fischer

Temporary Technical Commission – Whistler, Melnikov, Kraft, Fischer et al

Nikolaev Railway Project

<u>Northern Division</u> - Col. P. Melnikov

Districts – Military transport engineers

Contractors

Workers – Indentured serfs and free men

<u>Southern Division</u> – Col. N. Kraft

Districts – Military transport engineers

Contractors

Workers – Indentured serfs and free men

Gendarmerie – Prince Beloselsky-Belozersky

Alexandrovsky shop – Harrison, Wynans, and Eastwick

G. W. Whistler and the Nikolayev Railway

Locomotives and rolling stock
Rails
Alignment
Gauge
Embankments and cuttings
Bridges and culverts

(Haywood 1998)

- **Locomotives and rolling stock (for Nikolayev Railway)**

Ross Wynans (and his sons Thomas Wynans and William Wynans) of Baltimore and Joseph Harrison and Andrew Eastwick of Philadelphia were invited to Russia.

On October 5, 1843 Whistler, Harrison and T. Wynans completed "Specifications for locomotive engines and car trucks for the St Petersburg and Moscow Railway."

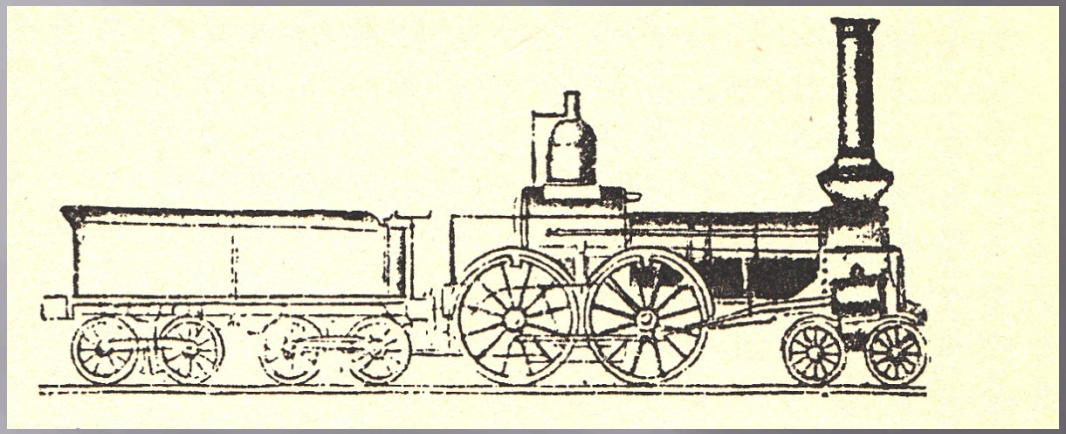
The Russian government awarded a contract to Harrison and Wynans on December 9, 1843 for delivery by the end of 1848 of:

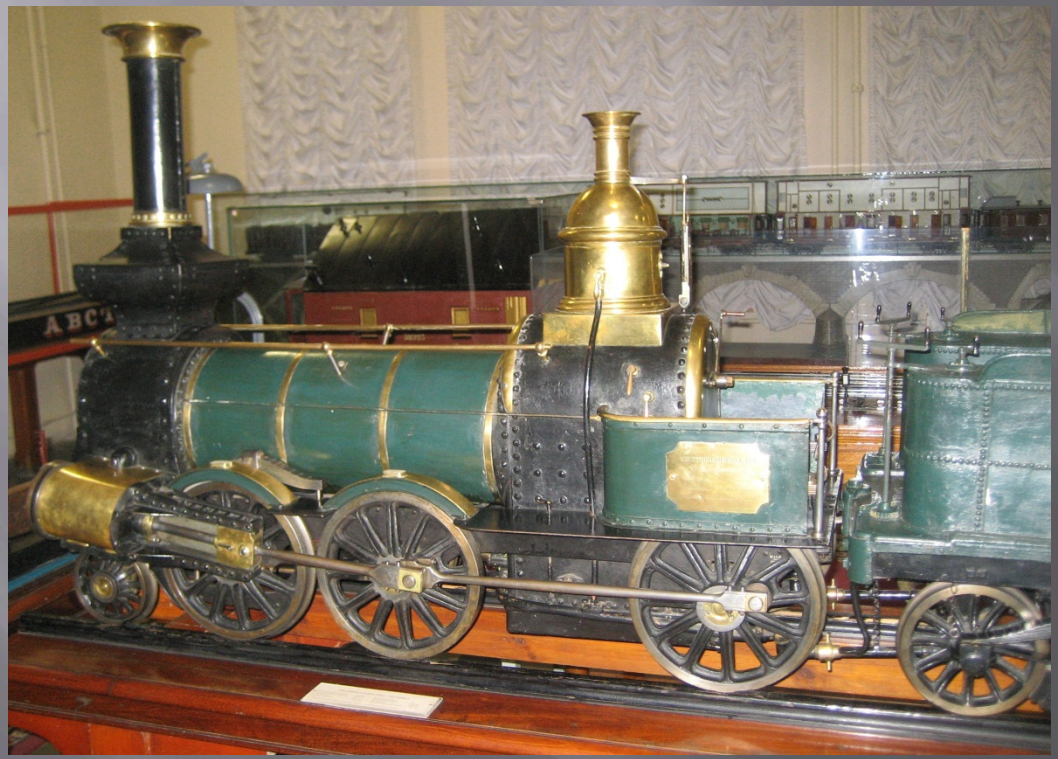
- **120 freight and 42 passenger locomotives**
- **5300 car tucks**

The Alexandrovsky shop (former foundry)

- **By 1846 staffed by 1613 Russians, 164 Swedes, 121 Germans, 17 Englishmen, and 5 Americans**

Chronology: Nikolayev Railroad, Russia,1841-1855, Whistler's Contribution





First Locomotives by Wynans, Russian State Museum of Transportation,1845

Chronology: Nikolayev Railroad, Russia,1841-1855, Whistler's Contribution

- **Rails**

In a report of September 9, 1842 Whistler recommended the use of "Vignoles" - flat bottomed rails of a weight of 60 lbs/ft, supported by crossties at 3ft on center

In 1843 and 1844 the Russian government signed contracts with Sir John Guest and Company of Merthyr Tydfil of South Wales for 80,000 metric tons of rails.

- **Alignment**

Preliminary surveys completed by April 1842. Detailed surveys began in June 1842. Whistler assisted until the final alignment was determined by April 1843.

- **Total length of approximately 402.5 miles**
- **Maximum elevation 635 ft at the Valdai Hills**
- **Swamps and wetlands for approximately 103 miles**
- **Maximum gradient 1/128 for a ten-mile length**
- **Northern Division – 192.5 miles**
- **Southern Division – 210 miles**

Chronology: Nikolayev Railroad, Russia,1841-1855, Whistler's Contribution

- **Gauge**

"Report of George W. Whistler to His Excellency the Count Kleinmichel on the Gauge of Russian Railways," September 9, 1842 (Manuscript Division, New York Public Library)

Whistler advocated for a 5ft gauge, which was accepted by the Tsar on February 14, 1843. This gauge remains in use for all major Russian railways

- **Embankments and cuttings**
  - **Right-of-way 162.5 feet**
  - **Volume of earth fill/removal ≈127,000,000 yd^3**
  - **Embankments designed by P. Melnikov**
    - **Top surface 31 feet wide**
    - **Slopes of 1:2**
    - **Level width of 1.5 ft**
    - **Drainage ditches 6 feet wide on both sides**
  - **Foundations in wetlands and swamps**
    - **Decided against pile foundations**
    - **Filled in with soil**
    - **Built on wooden platforms**
    - **Drainage ditches on both sides**

Chronology: Nikolayev Railroad, Russia,1841-1855, Whistler's Contribution

- **Bridges and culverts**
  - **Approximately 250 bridges and culverts**
  - **60 Howe bridges, including eight major multi-span bridges**

Chronology: Nikolayev Railroad, Russia,1841-1855, Construction Conditions

Mechanization - Practically none

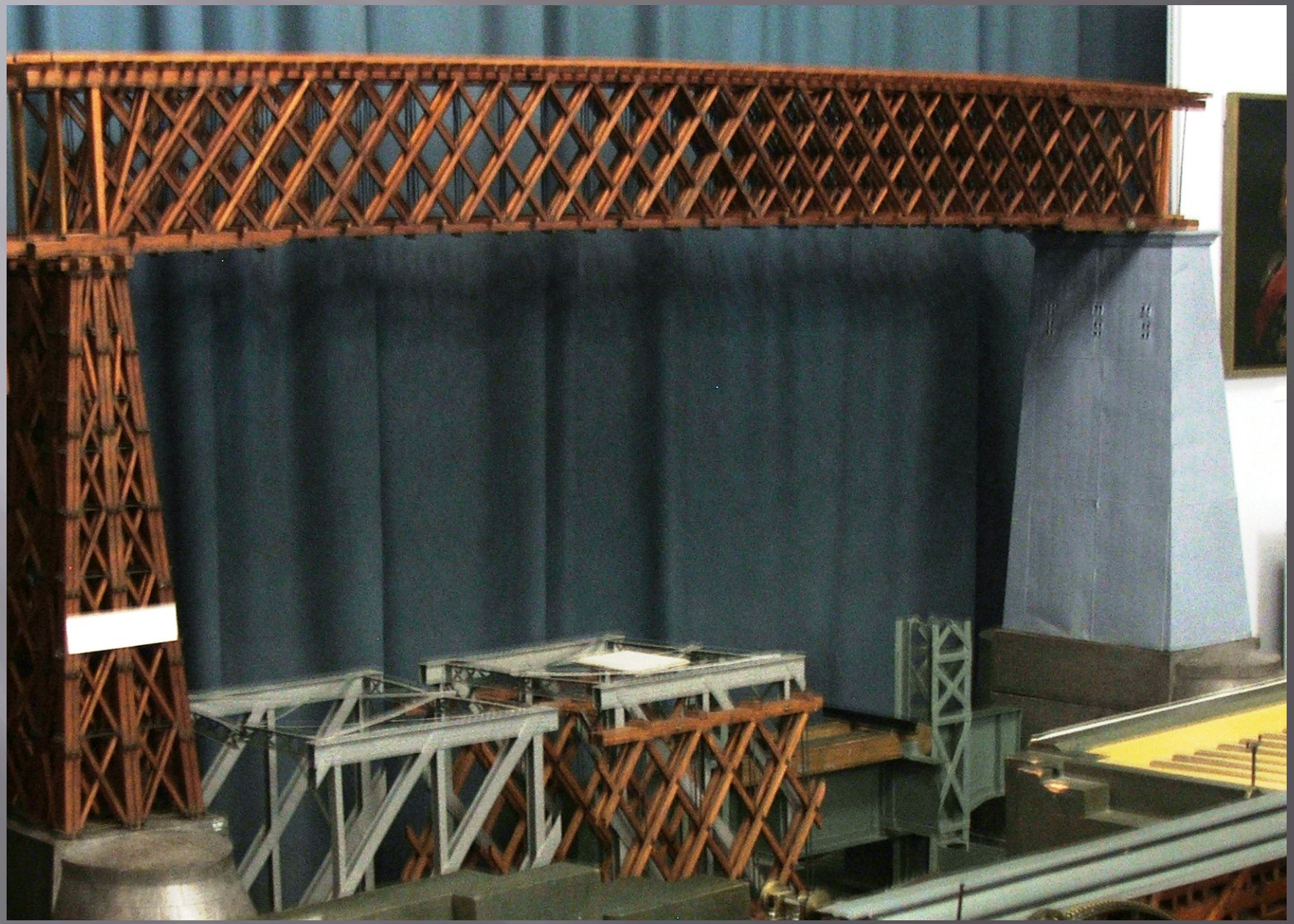
- Workforce ≈ 30,000 to 60,000 per season

Financing – By state; inconsistent because of government crises

Serf/worker conditions

- **"And on the sides [of the rail line], all Russian bones How many of them! Vanya, do you know?" (from *The Railroad* by N. Nekrasov, 1864)**
- **"Workers on similar projects in other countries at the time worked under conditions that were equally bad or even worse" (Haywood 1998)**
- **Health – Malnutrition, dysentery, influenza, typhoid, scurvy, and cholera**
- **Order – Public floggings by the *gendarmerie***
  Delegations to the Tsar
  Extensive "desertions"
- **Cheating/non-payment of wages**

Msta River Bridge – Nine spans of 189 feet

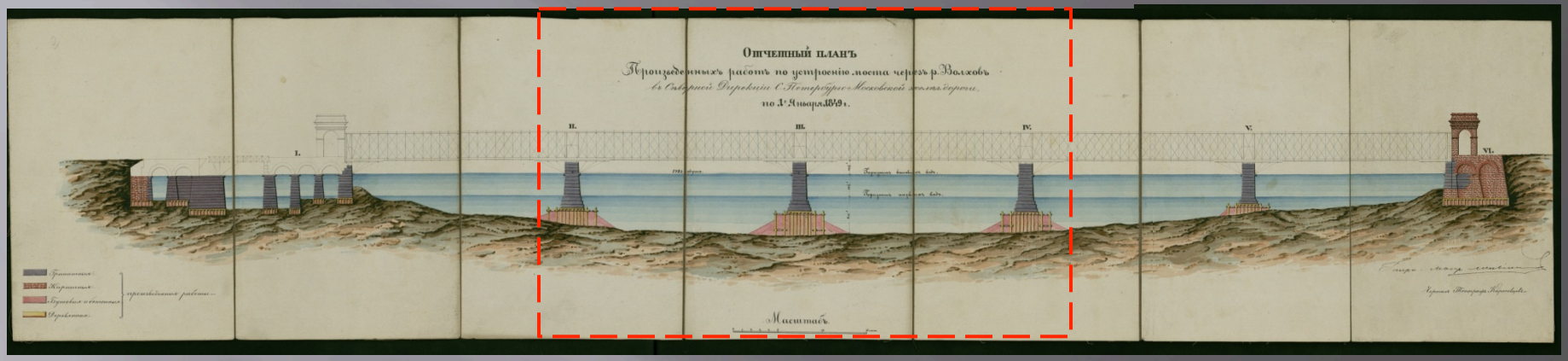


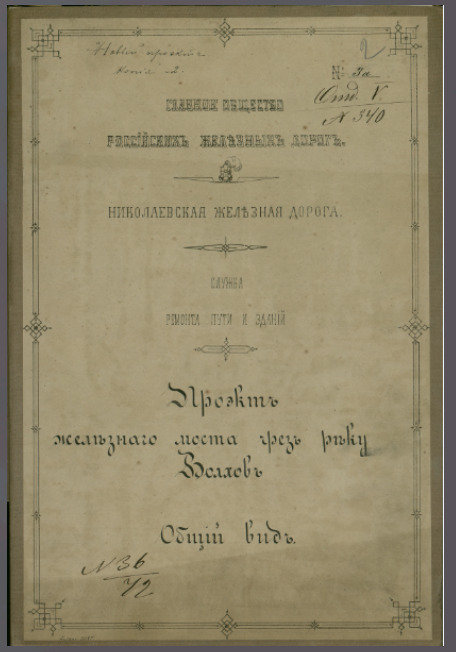
One span of Msta Bridge – St Petersburg Transportation Museum

Chronology: Nikolayev Railroad, Russia,1841-1855, Largest Bridges

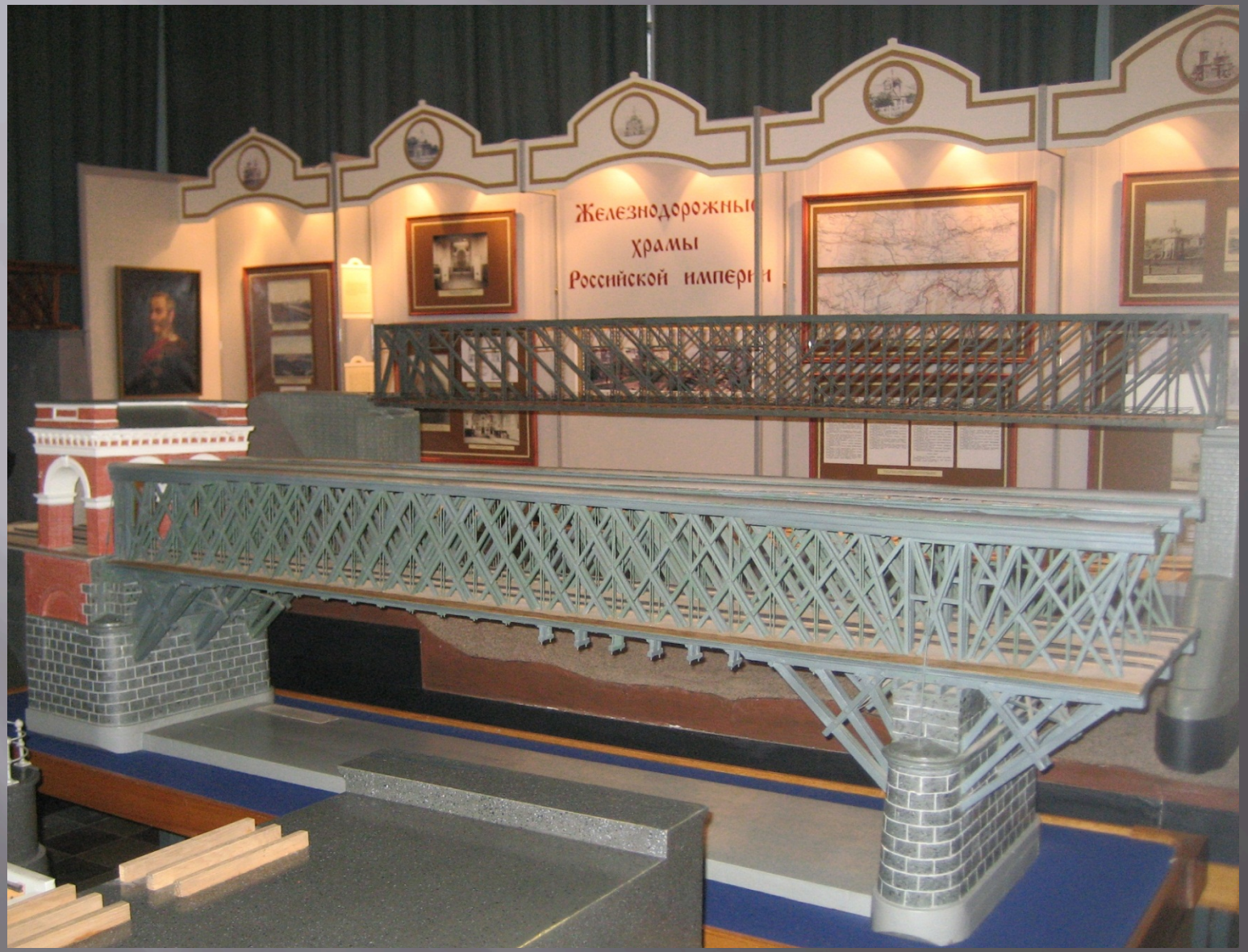
Tverca River Bridge – 196 ft spans

Chronology: Nikolayev Railroad, Russia,1841-1855, Largest Bridges

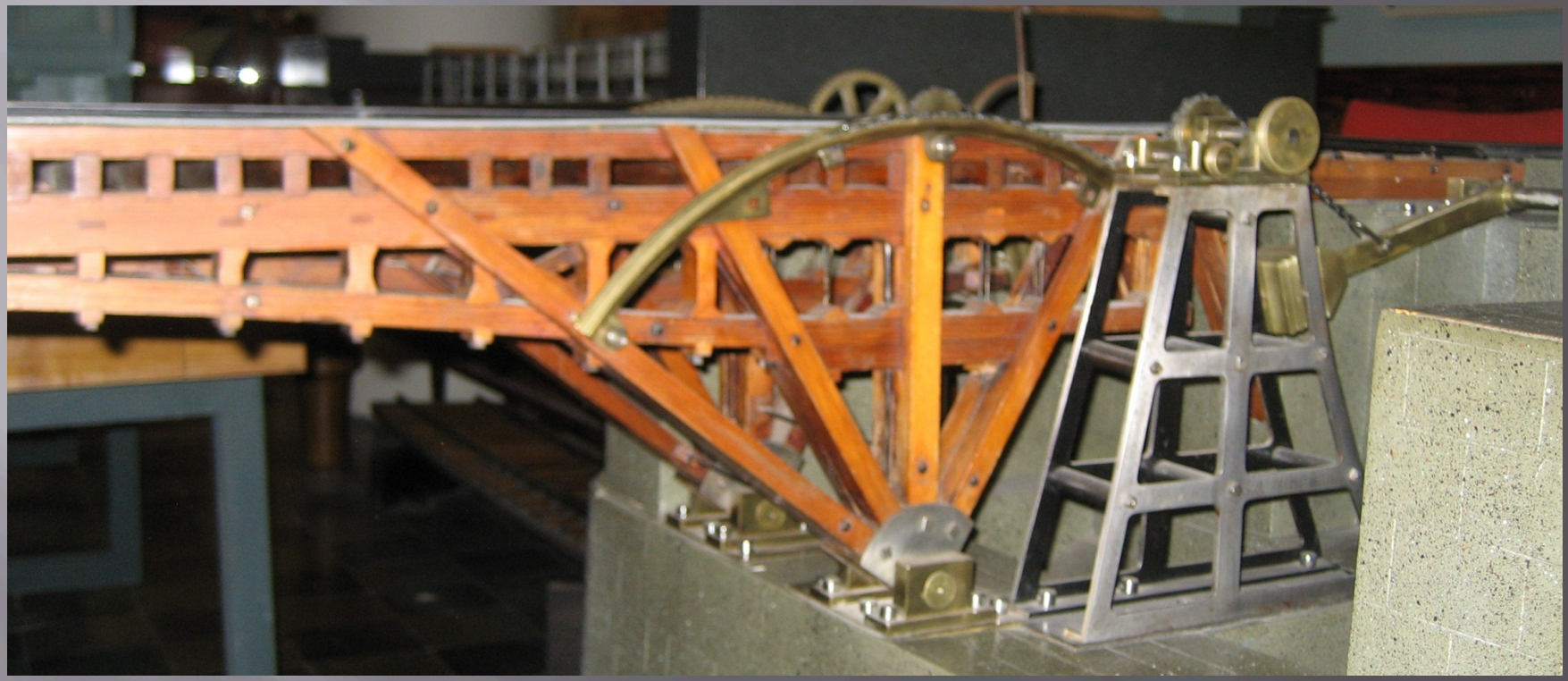




Volkhov River Bridge, 1849,
Russian State Historical Archives, Saint Petersburg

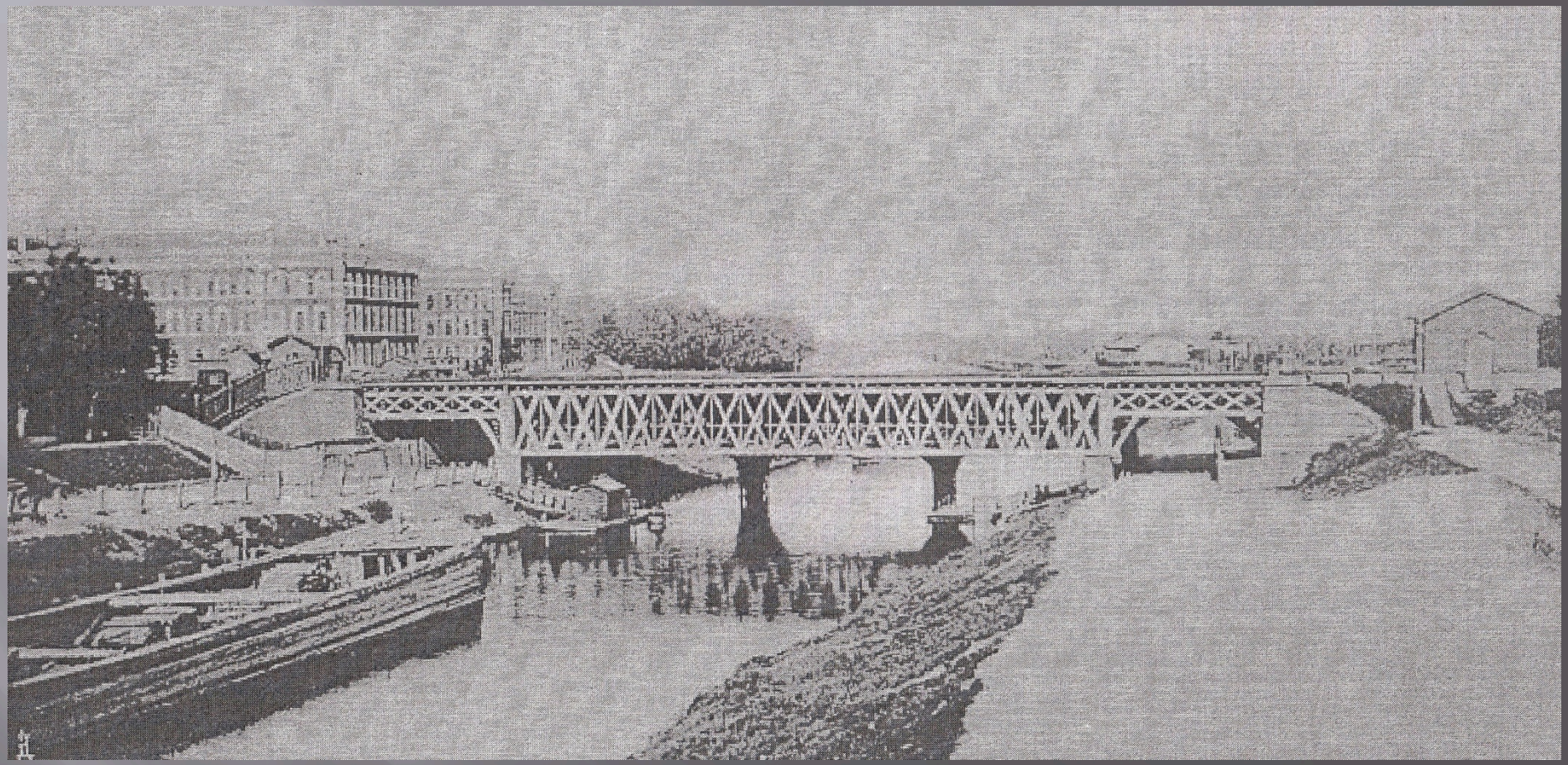


One span of the Volkhov Bridge – St. Petersburg Transportation Museum



Volkhov bascule span – St. Petersburg Transportation Museum

Chronology: Nikolayev Railroad, Russia,1841-1855, Largest Bridges



Obvodnoi Canal Bridge

Chronology: Nikolayev Railroad, Russia,1841-1855, Largest Bridges

Verebia Bridge – Nine 168 ft spans

Weather protection of top deck, Verebja Bridge

Chronology: Nikolayev Railroad, Russia,1841-1855, Juravsky Contribution

The largest bridges in Russia built from 1841 to 1856 utilizing Howe Type System									
River	Number of spans	Length (feet)	Span (feet)	Height Above water (ft)	Type	Notes	Photo Available	Replace ment	Builder
Msta	9	1802.6	188.9	122.1	Deck		Yes	1880	Krutikov C.F
Verebja	9	1606.7	167.9	163.1	Deck	Grade 0.78%	Yes	1881	Juravskij D.I.
Volkhov	5+1	925.2	167.9	35.1	Through	Bascule Span	Original drawing	1874 1888	Grave V.I.
Shodnja	4	805.2	187.3	93.2	Deck			1864	Benislavski j M.A.
Volga	3	637.8	195.8	48.9	Through	Inclined	Yes	1887	Antonov N.I.
Tverca	3	626.5	195.8	56.1	Through	Inclined	Yes	1875	Kolman A.K.
Sosha	2	377.9	180.8	35.1	Through	Inclined		1873	Vorob'ev E.G.
Cna	2	308.1		35.1	Through	Inclined		1877	Glazenap P.A.
Obvodnuj canal	3				Deck	1 large, 2 small spans	Yes	1869	G.W. Whistler (?)

Chronology: Nikolayev Railroad, Russia,1841-1855, Juravsky Contribution

Dmitry I. Jouravsky

1842 honors graduate of the St. Petersburg Institute for Transport Engineers

Performed structural analyses and tests on physical models of Howe trusses from 1843 to 1848

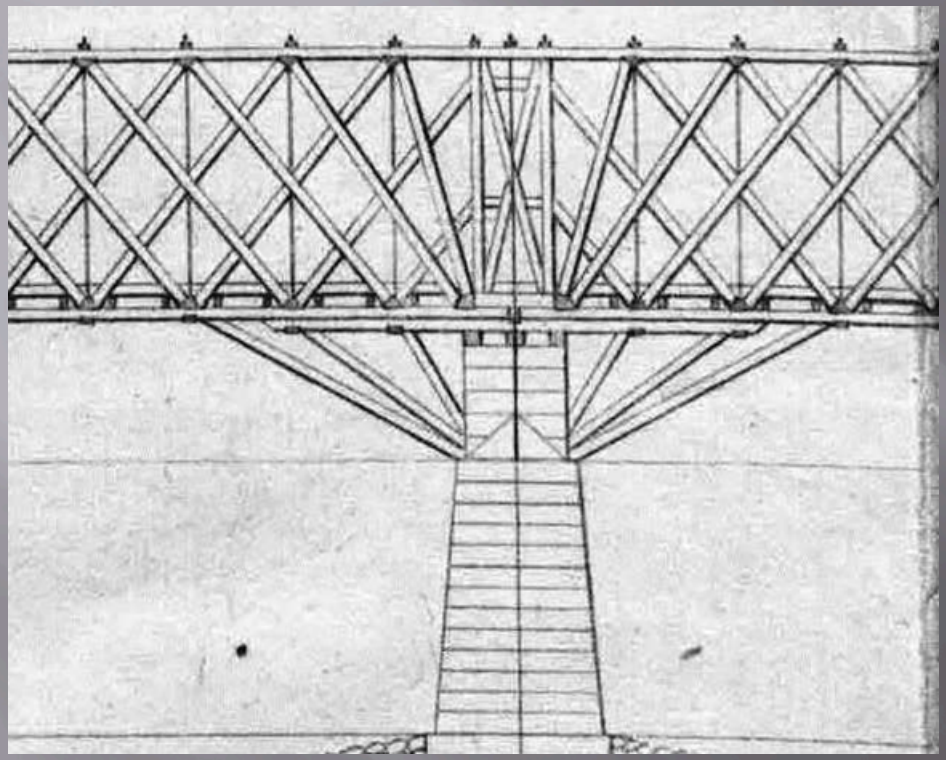
Published two books "About Bridges of the Howe System" in 1855 and 1856

(Timoshenko 1950, 1953; Rakcheev 1984)

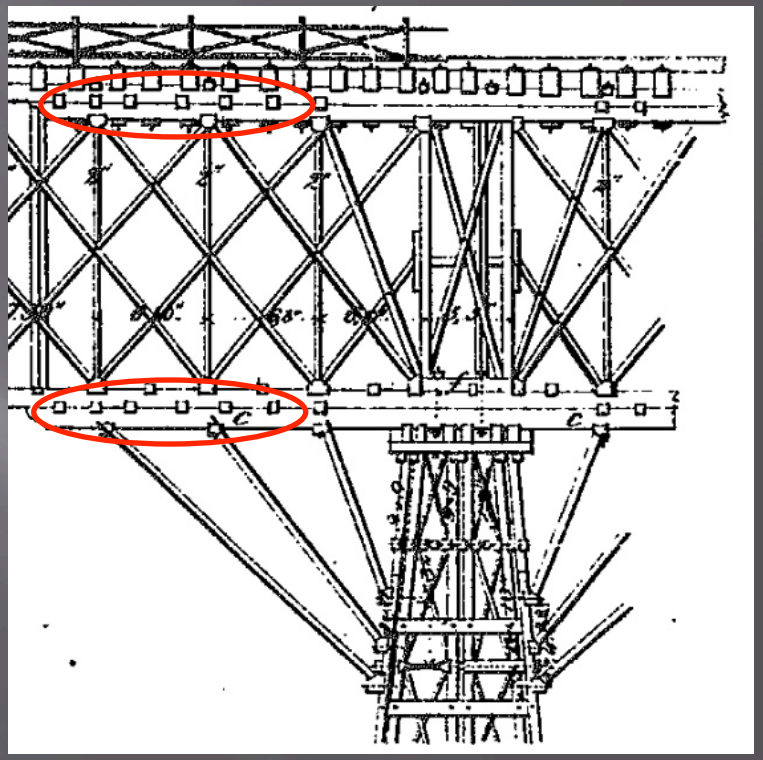
Juravsky's work:

- **Developed structural analysis of simple span Howe's Trusses (defined statically determinate models)**
- **Performed structural analysis of multi-span bridges on the example of Verebja bridge (defined statically indeterminate models)**
- **Executed studies of the effect of posttension in Howe trusses**
- **Developed the theory of shear forces and shear stresses in solid and build up beams**

Chronology: Nikolayev Railroad, Russia,1841-1855, Juravsky Contribution



Connecticut River Bridge



Verebja Bridge

Chronology: Nikolayev Railroad, Russia,1841-1855, Juravsky Contribution

In his work "About Bridges of the Howe System" (1855) Jouravsky provided the following measures for rehabilitation and maintenance:

1. **Protect chords from direct water contact**
2. **Provide visual observation of the bridge at least one time a month**
3. **Replacement of bearings or diagonals must be performed immediately (all replacements may be done without stopping traffic)**
4. **All small bolts have to be tightened**
5. **All cracks in the wood have to be patched, and all parts of the bridge have to be painted**
6. **Vertical rods are never to be tightened to the state that the steel pads between heads or nuts of the rod and chord will damage the wood itself**
7. **Rails and bed have to be in good shape; bad rails will produce additional vibration and risk damaging the bridge**

Performance

The post-tensioned wood Howe bridges served well for 25 to 35 years

Fire on three spans of the Msta River Bridge in 1869

Slowdowns on the Verebia Bridge because of its slope, 1/128

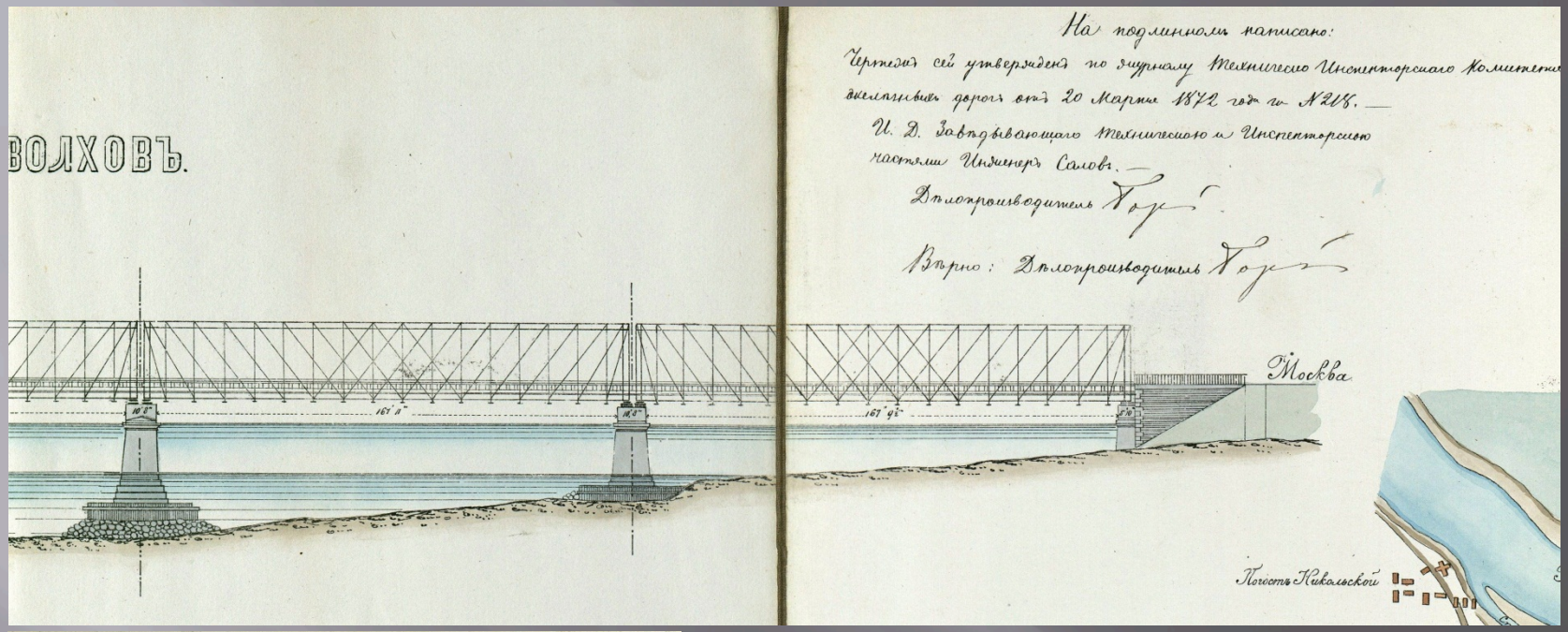
Chronology: Nikolayev Railroad, Russia,1841-1855, Howe Bridges Replacement

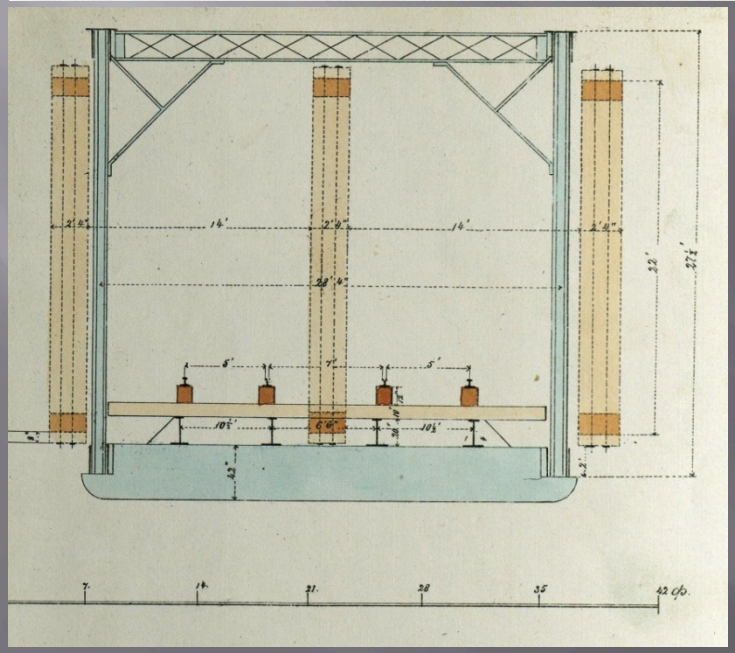
Shodnya River Bridge replaced with embankment

Chronology: Nikolayev Railroad, Russia,1841-1855, Howe Bridges Replacement

Replacement steel (or iron) bridges - Double or triple intersection Pratt trusses on simple spans

Chronology: Nikolayev Railroad, Russia,1841-1855, Howe Bridges Replacement





Volkhov replacement Pratt truss Russian State Historical Archives, 2013

Chronology: Nikolayev Railroad, Russia,1841-1855, Howe Bridges Replacement

Saint Petersburg Transportation Museum, 2013

In March 1847 Whistler was awarded the "Order of St. Anne of the Second Degree" by Tsar Nicholas

Whistler was stricken with cholera in November 1848 and died in St. Petersburg on April 7, 1849