


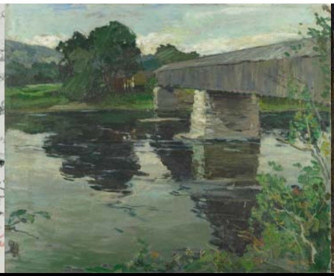

Covered Bridges as Structural Art

Integrating Covered Bridges into the Civil Engineering Curriculum

Rachel H. Sangree
Johns Hopkins University
Baltimore, MD

HISTORIC AMERICAN ENGINEERNING RECORD

PINE GROVE BRIDGE

HAER No. PA-586

LOCATION: Ashville Road and Forge Road, spanning Octoraro Creek between Pine Grove, Little Britain Township, Lancaster County and Oxford vicinity, Lower Oxford Township, Chester County, Pennsylvania UTM: 18.410558.4405367, Kirkwood, PA Quad.

STRUCTURAL TYPE: Wooden covered bridge, two span Burr arch-truss

DATE OF CONSTRUCTION: 1884

BUILDER: Capt. Elias McMellan, Lancaster, PA

PRESENT OWNER: State of Pennsylvania

PREVIOUS USE: Vehicular bridge

PRESENT USE: Vehicular bridge

SIGNIFICANCE: The Pine Grove Bridge was built in 1884 after a destructive flood carried away in 1846 bridge at this site. The county hired Capt. Elias McMellen, a well-respected and prolific Lancaster bridge builder to rebuild it. McMellen constructed over thirty-five bridges in the region. The bridge is a typical example of the vernacular Burr arch-truss, the most common design for covered bridges in this area. The bridge is still open to vehicular traffic.

HISTORIAN: Researched by Lola Bennett and Sarah Maria Rose Dangelas. Written by Sarah Maria Rose Dangelas, 2003

PROJECT INFORMATION: The National Covered Bridges Recording Project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. HAER is part of the Historic American Buildings Survey/Historic American Engineering Record, a

[redacted]

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PROJECT INFORMATION: Historic The National

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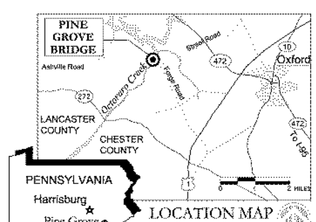
Pine Grove Bridge

Spanning Octoraro Creek

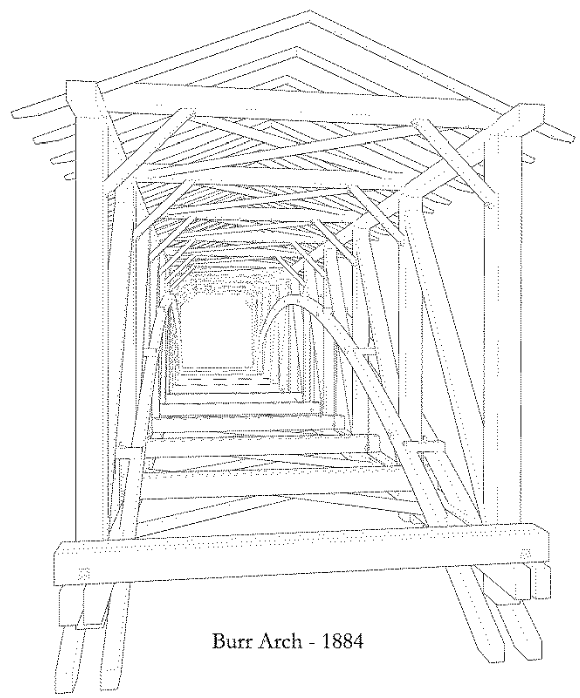
Pine Grove, Pennsylvania

The Pine Grove Bridge and the story of its erection are instructive illustrations of both the product and process of covered bridge-building at its peak in southeastern Pennsylvania. The current bridge was built in 1884, on the site of at least two previous bridges, one dating from 1816 and another from 1846. After a destructive flood carried away the 1846 bridge and dozens of others along the river, the county hurried to replace it, as this was a well-traveled crossing. They awarded the contract to Captain Elias McMellen, a well-respected Lancaster bridge builder and Civil War veteran responsible for constructing at least thirty-five known bridges in the region. To follow the history of this bridge is to glimpse into local politics and industry, the process of bridge construction, and the preservation ethics of residents in this area through time.

Likewise, a look at the bridge itself allows us to see the vernacular Burr arch-truss in its typical incarnation. The Burr arch was the most common design used for covered bridges in this area. Its strength and endurance are evidenced at Pine Grove in the continued use of this bridge over a century after its construction. The engineering analysis that accompanies this HAER report offers further illustration as to the structural behavior and efficiency of the Pine Grove Bridge.



LOCATION MAP
UTM Coordinates:
18 410558 4405367



Burr Arch - 1884

The National Covered Bridges Recording Project - Phase I was undertaken during the summer of 2002 and is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. HAER is administered by the Historic American Buildings Survey/Historic American Engineering Record (E. Blaine Cliver, Chief), a division of the National Park Service, U.S. Department of the Interior. The Federal Highway Administration funded the project. The Chester Water Authority (Pat Sabler, Chief Engineer) provided assistance at Pine Grove Bridge.

The field work, measured drawings, historical report, and photography were completed under the direction of Eric DeLony, Chief of HAER, Christopher Marston, Project Leader, and Richard O'Connor, HAER Senior Historian. The field team consisted of Field Supervisor Naomi Hernandez (Pratt Institute), Architects Kimberly Clauer (U. of Wisconsin- Milwaukee), Vuong Dang (U. of Arkansas), William Dickinson (U. of Pennsylvania), Dave Groff (U. of Maryland), and Charu Chaudhry (ICOMOS-India); Engineers Francesca da Porto (ICOMOS-Italy) and Dylan Lamar (U. of Arkansas); Historians Joseph Conwill (Rangeley, ME), Lola Bennett (Stow, MA), and Sarah Dangelas (U. of Maryland). Dr. Dario Gasparini, P.E. (Case Western Reserve U.), and Dr. Ben Schafer (Johns Hopkins U.), served as engineering consultants. Large-format photography was produced by Jet Lowe.

DELINEATED BY: VUONG DANG, DAVE GROFF, 2002

NATIONAL COVERED BRIDGES RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

PINE GROVE BRIDGE - 1884
SPANNING OCTORARO CREEK AT ASHVILLE & FORGE ROADS
PINE GROVE | LANCASTER COUNTY | PENNSYLVANIA

SHEET 1 OF 7

HISTORIC AMERICAN ENGINEERING RECORD PA-586

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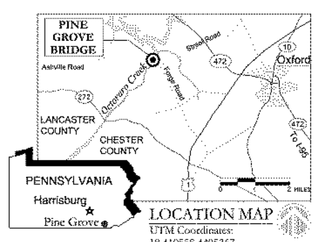

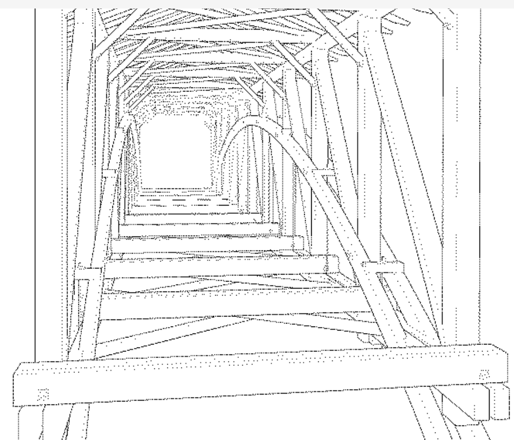

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Note the significant tensile forces calculated in the diagonals just to the right of the loading that decrease toward mid-span. Since the diagonal/post connection is designed for bearing in compression only, tensile loads in the diagonals are not possible and must be disregarded. This condition was not anticipated, and the model was not designed to handle "compression-only" joints. It is, however, only a theoretical case in that it does not include the dominant dead load. This may not be a problem when considering the total dead-plus-live-load condition, however. As long as the *net* forces in the diagonal members are compressive, the model will remain useful.

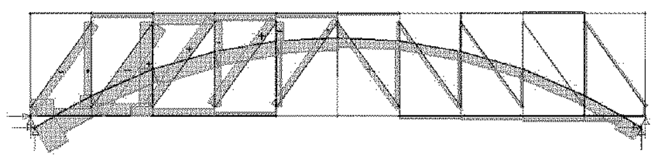


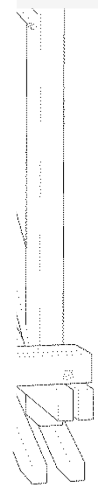
Figure 32. Axial Forces in Arch-Truss due to Quarter Point Live Load.

Table 17. Maximum Values of Arch-Truss due to Quarter Point Live Load.

Arch Max Compressive Stress (psi)	-98	Ends
Truss Max Compressive Stress (psi)	-67	Diagonal, panel D, left
Max Tensile Stress (psi)	122	Post 4, above diagonal, left
Max Deflection (in)	-0.06	Post 4, left

DEAD LOAD PLUS QUARTER-POINT LIVE LOAD

The forces shown in Figure 33 are the linear combination of the quarter-point live load and dead load results, with the dead load reaction dominating. This loading produces the greatest stresses of any case considered (Table 18). The largest stress, -489 psi, occurs at the left end of the arch, but this is well below current maximum design values. The force at this location is also 375 percent greater than the largest force in the truss, which again speaks for the arch's structural dominance. The greatest shear stress also occurs under this loading case, but it, too, is safely below allowable limits.



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Burr Arch - 1884

PINE GROVE BRIDGE - 1884
LANCASTER COUNTY
DELINEATED BY: VUONG DANG, DAVE GROFF, 2002
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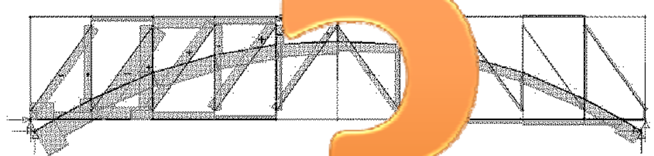

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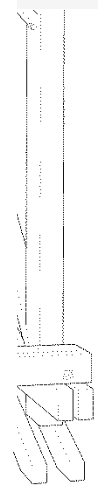

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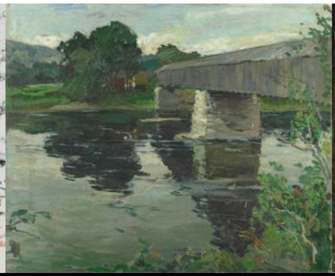
Burr Arch - 1884

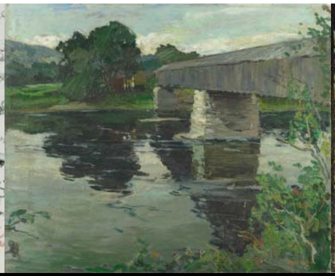
PINE GROVE BRIDGE - 1884
LANCASTER COUNTY
DELINEATED BY: VUONG DANG, DAVE GROFF, 2002
PINE GROVE


Back to the Future
Historical structures draw engineering students into design aesthetics.

Covered Bridges as Structural Art

Integrating Covered Bridges into the Civil Engineering Curriculum

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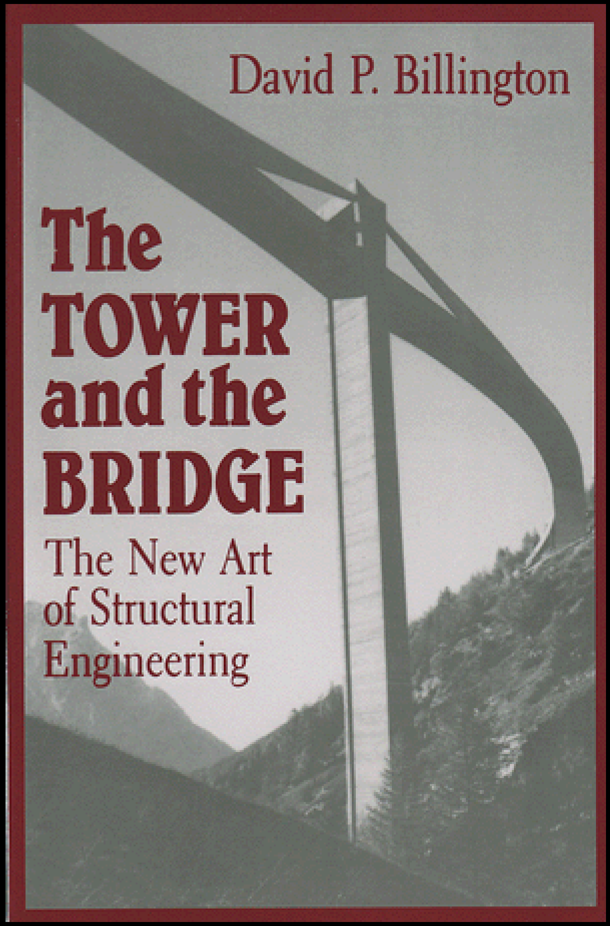
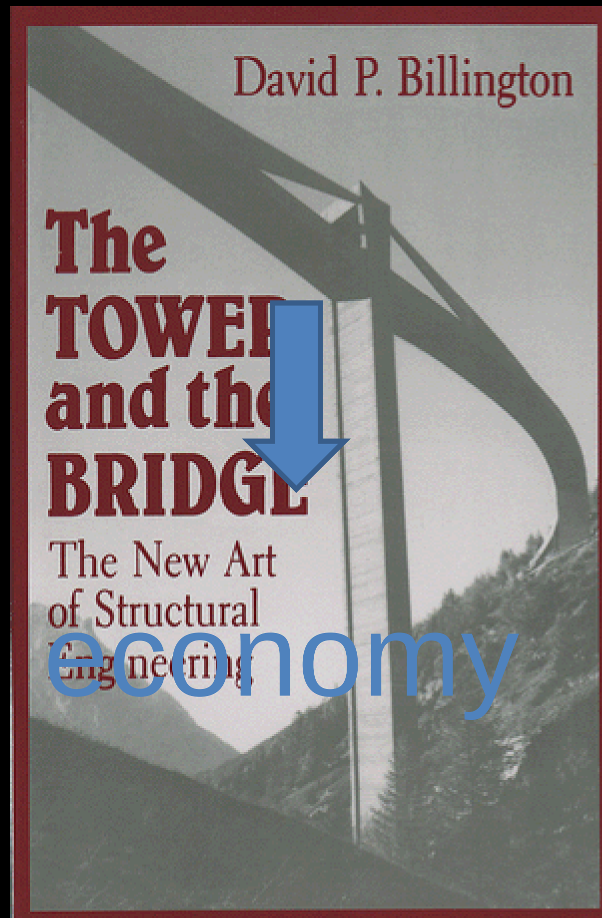
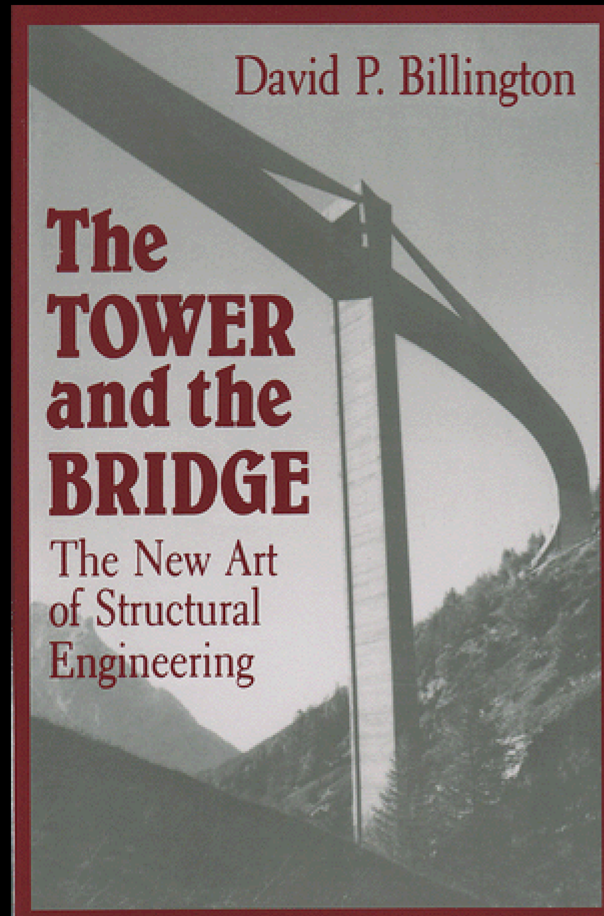

David P. Billington
The TOWER and the BRIDGE
The New Art of Structural Engineering



efficiency economy elegance

3 Dimensions of Structural Art:

scientific social symbolic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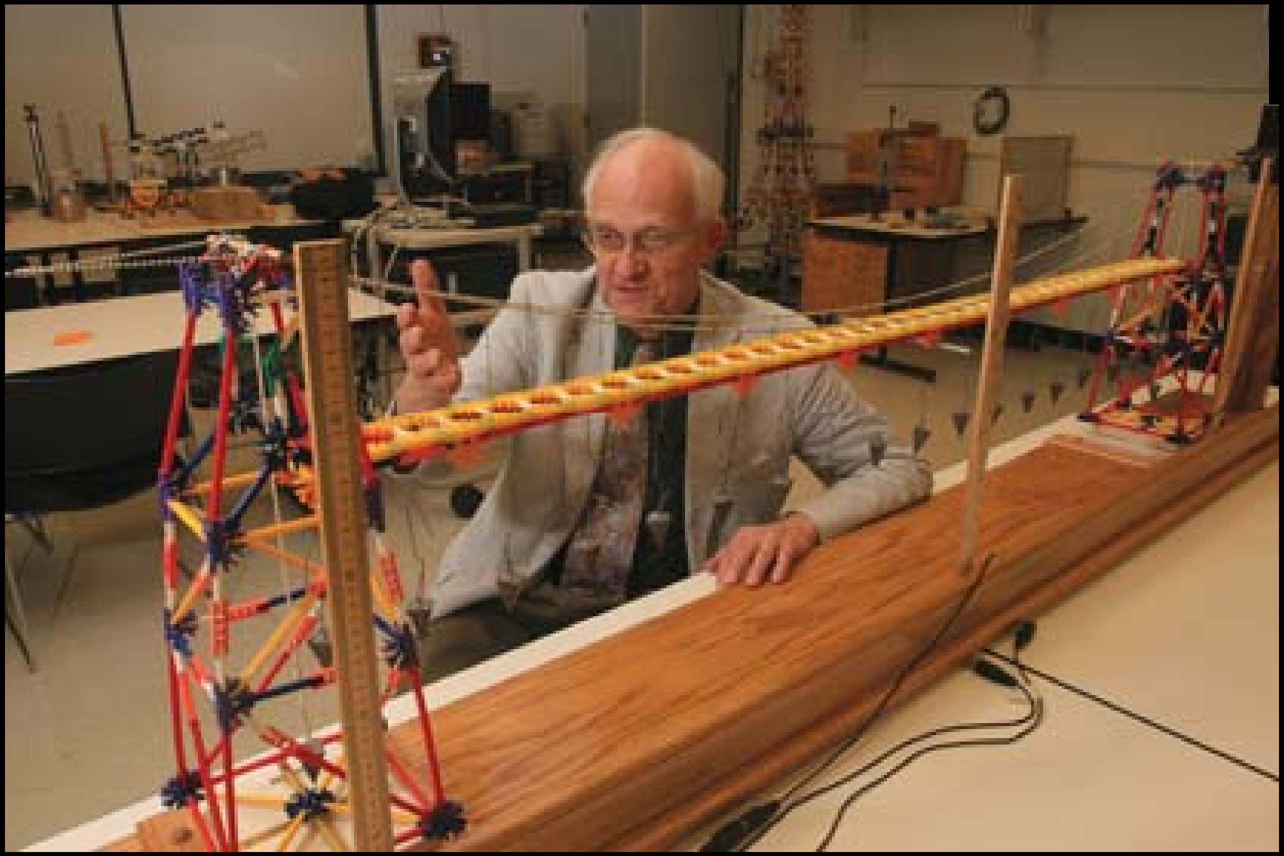

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EN.560.141
Perspectives on the Evolution of Structures

Why do buildings and bridges look the way they do today? Students will be provided the tools to answer this question for themselves through a study of the history of the design of buildings and bridges throughout the world from both engineering and architectural/ aesthetic perspectives.

- The Washington Monument and the Eiffel Tower
- The Eiffel Tower and the St. Louis Gateway Arch
- Telford, Brunel, and British Metal Forms
- Eads, Eiffel, and the Forth Bridge
- John Roebling and the Brooklyn Bridge
- History and Aesthetics in Suspension Bridges
- Covered Bridges

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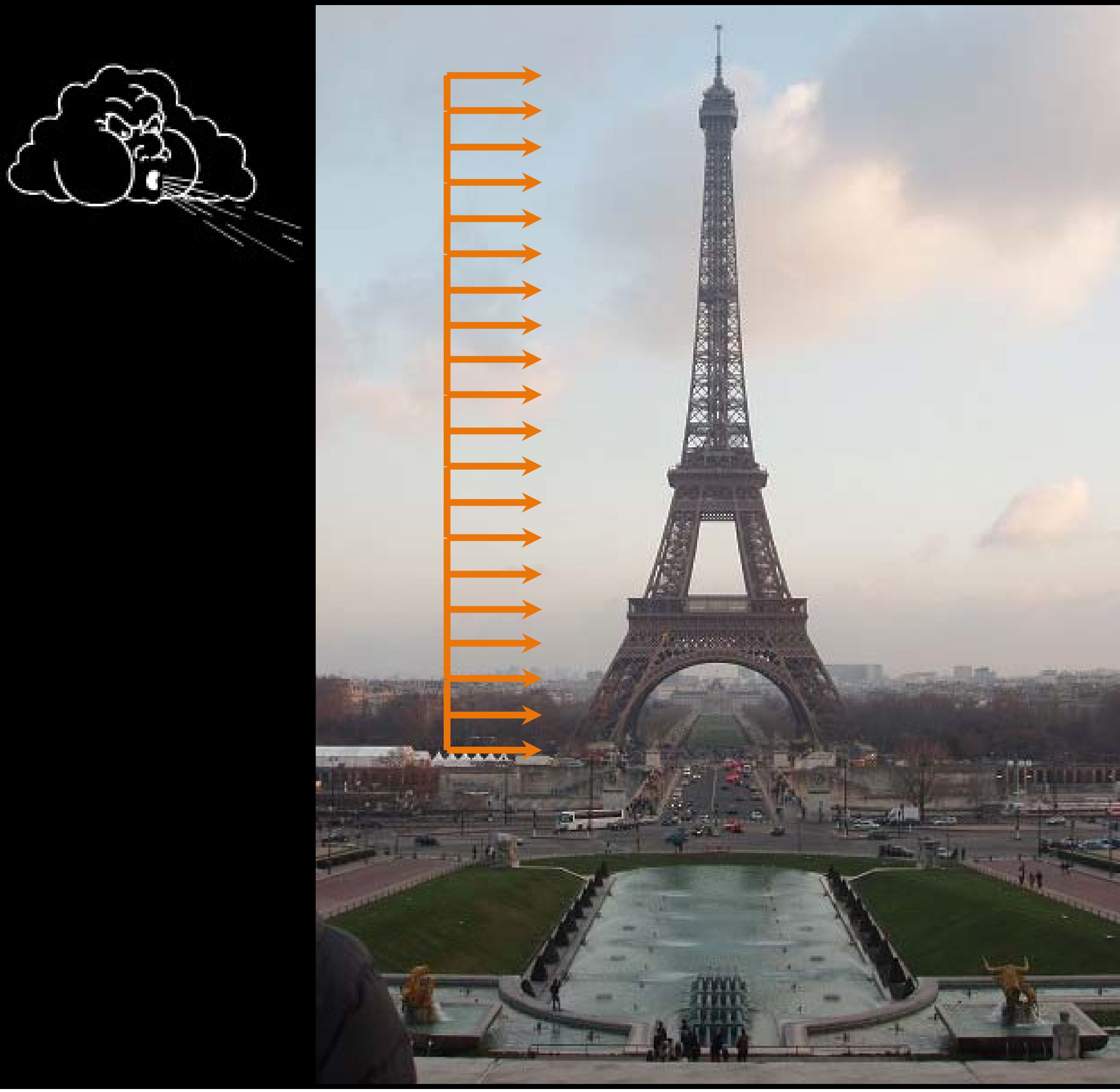
- Chicago and the Skyscraper
- New York and the Skyscraper
- Robert Maillart and the Origins of R/C
- Freyssinet, Finsterwalder, and the Origins of P/S Concrete
- Cable-Stayed Bridges
- Roof Vaults and National Styles
- The Swiss Tradition of Bridge Design
- New Bridge Forms: Maillart and Menn
- New Building Forms: Maillart and Isler
- Baltimore Structures
- Green Buildings from Fathy to Yeang
- High, Wide, and Far: Structural Engineering Today

scientific social symbolic

"The … scientific criterion … essentially comes down to *making structures with a minimum of materials* and yet with enough resistance to loads and environment so that they will last."

scientific social symbolic



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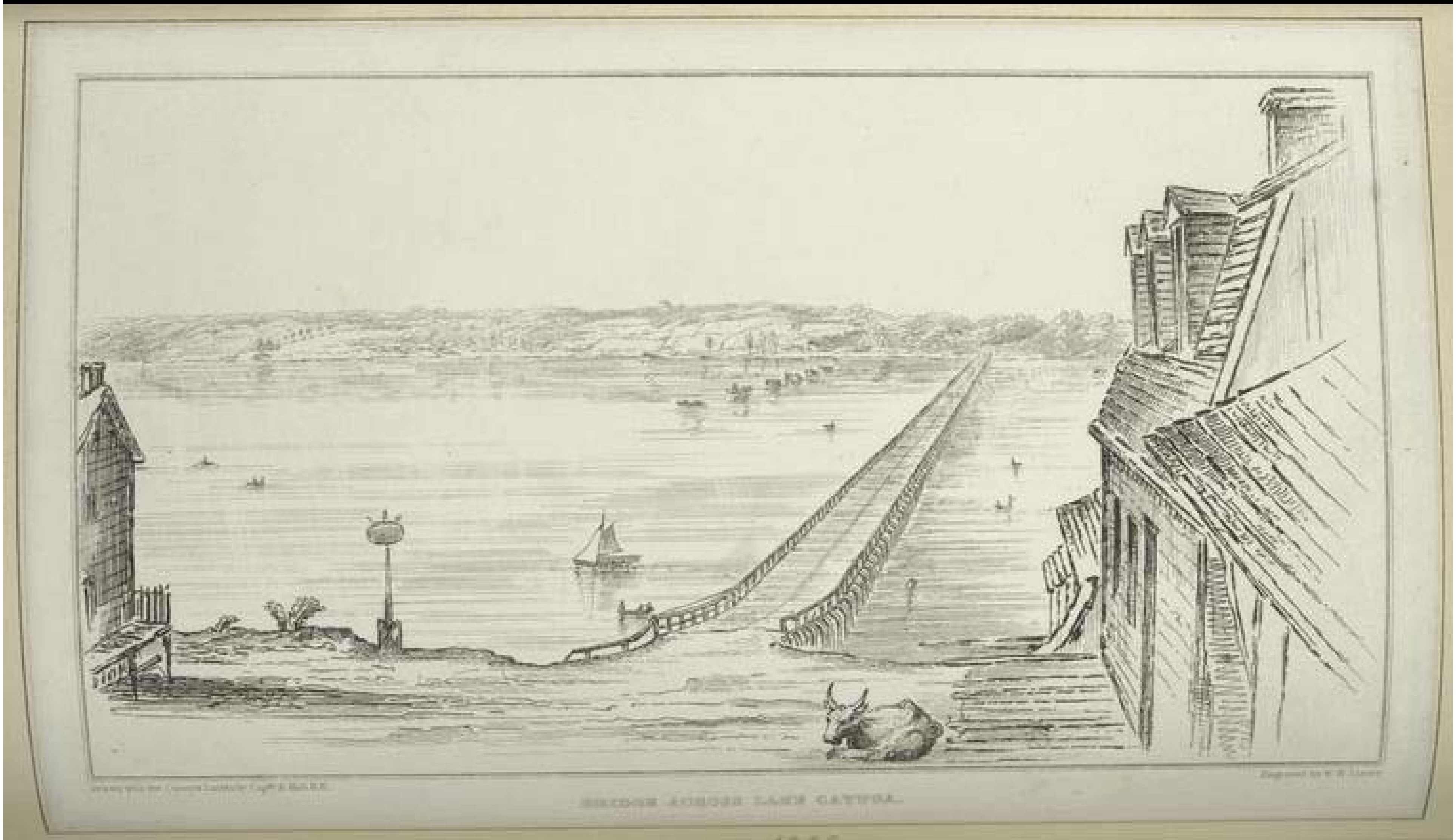

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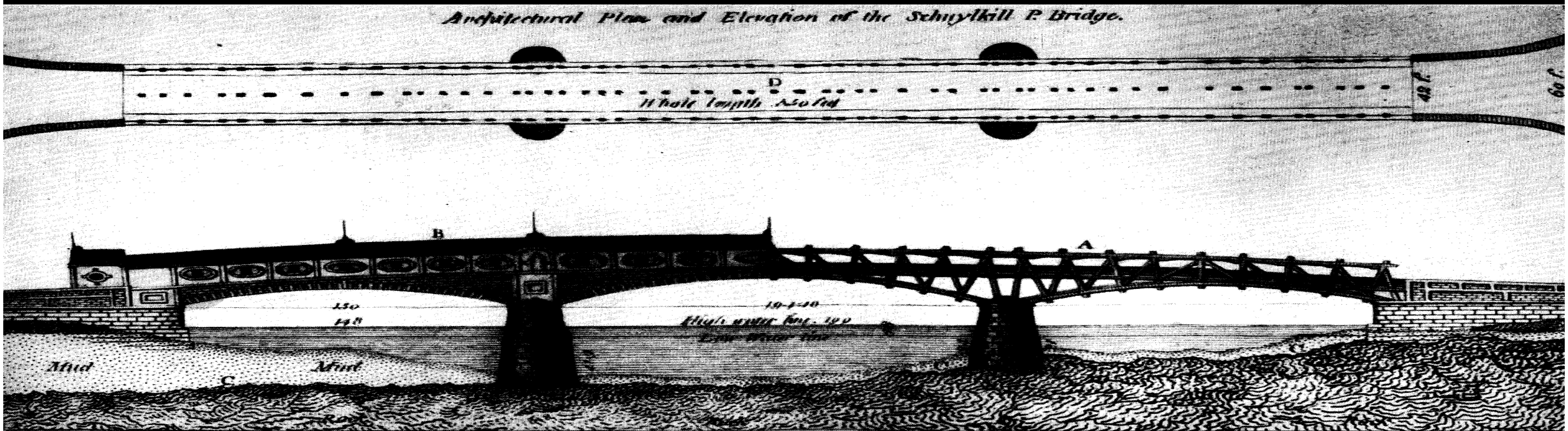
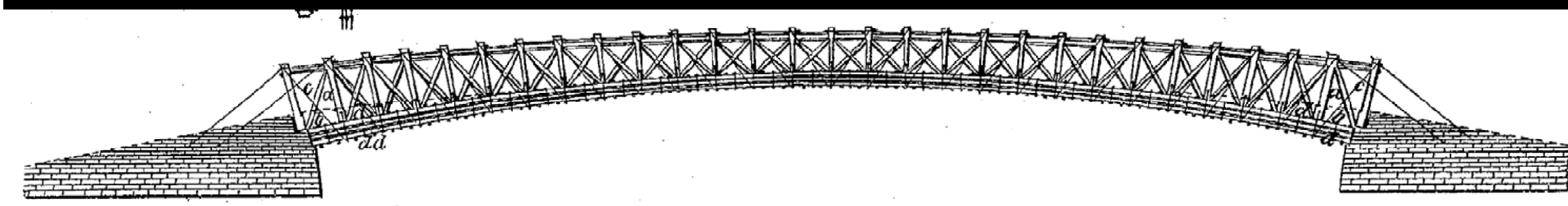
Efficiency: constructing a long-span bridge with a minimum number of piers in the waterway



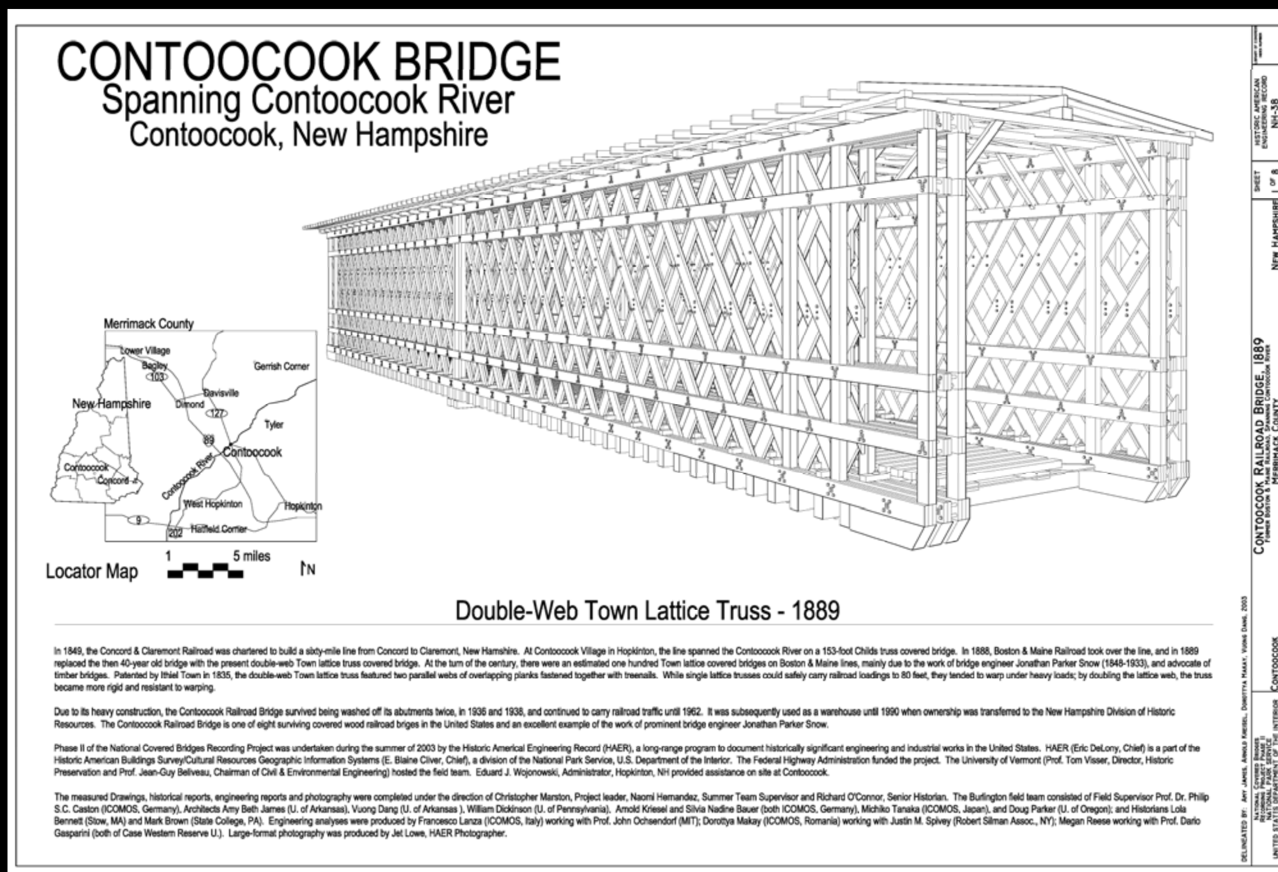


scientific social symbolic

Efficiency: constructing a long-span bridge truss with a simple arch - truss system

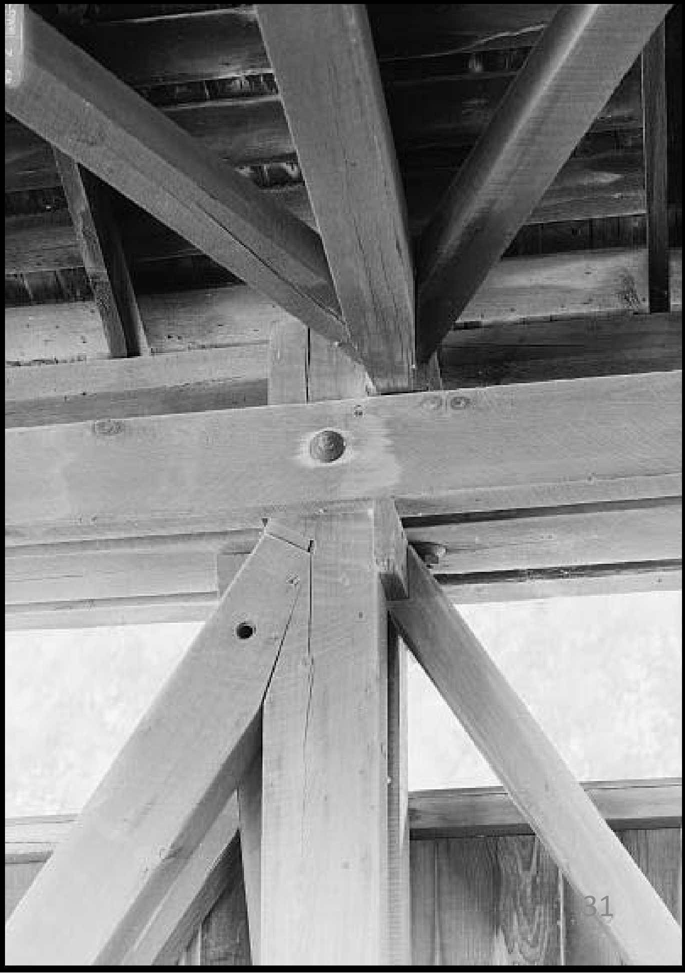
scientific social symbolic

Efficiency: Constructing a long-span bridge truss without traditional wooden joinery and arches



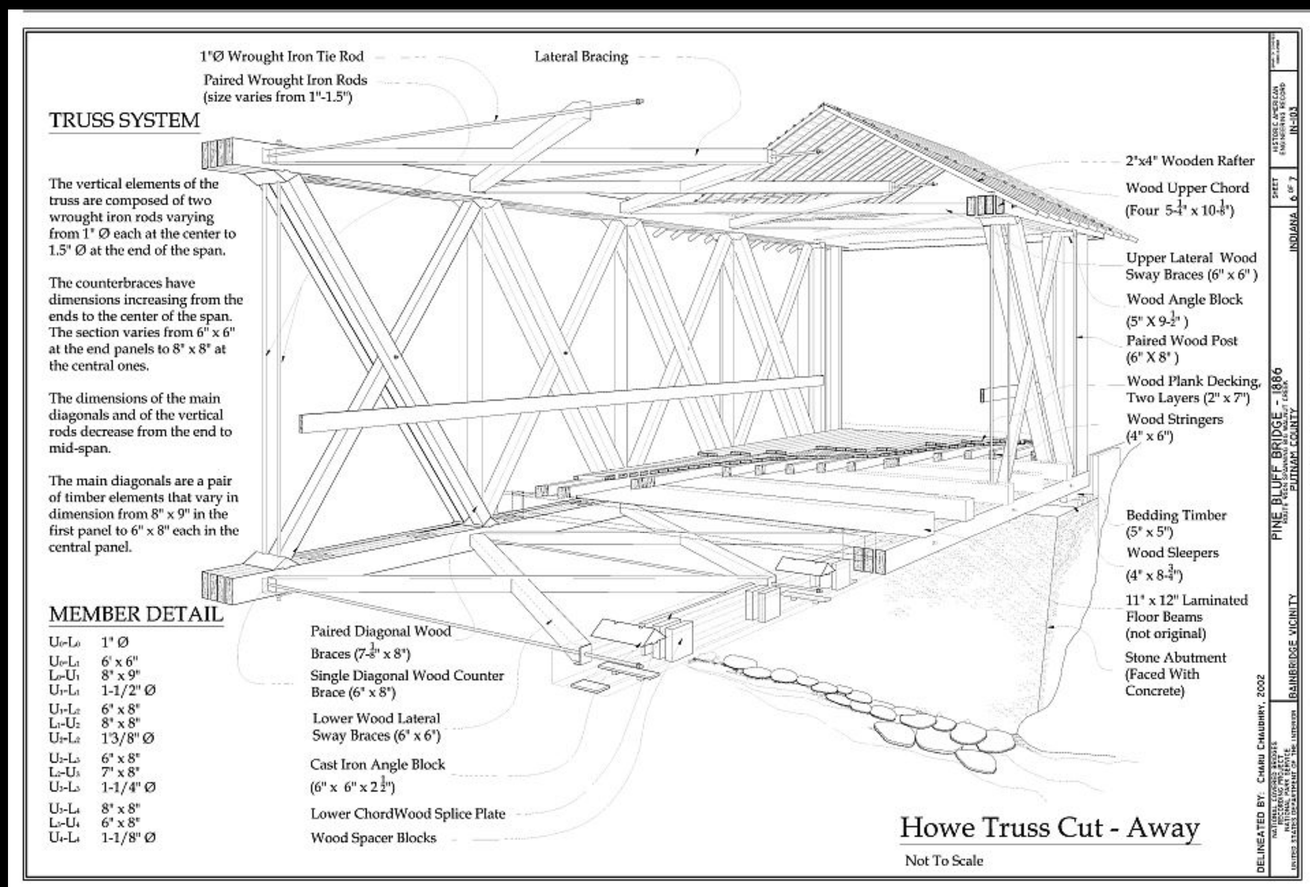
scientific social symbolic

Efficiency: Constructing a long-span bridge truss with effective counterbraces (to provide stiffness without an arch)



scientific social symbolic

Efficiency: Constructing a long-span bridge truss with a simplified method of prestressing the counterbraces



scientific social symbolic

"The second, or social criterion, comprises mainly *analyses of costs* as *compared to the usefulness* of the forms by society."

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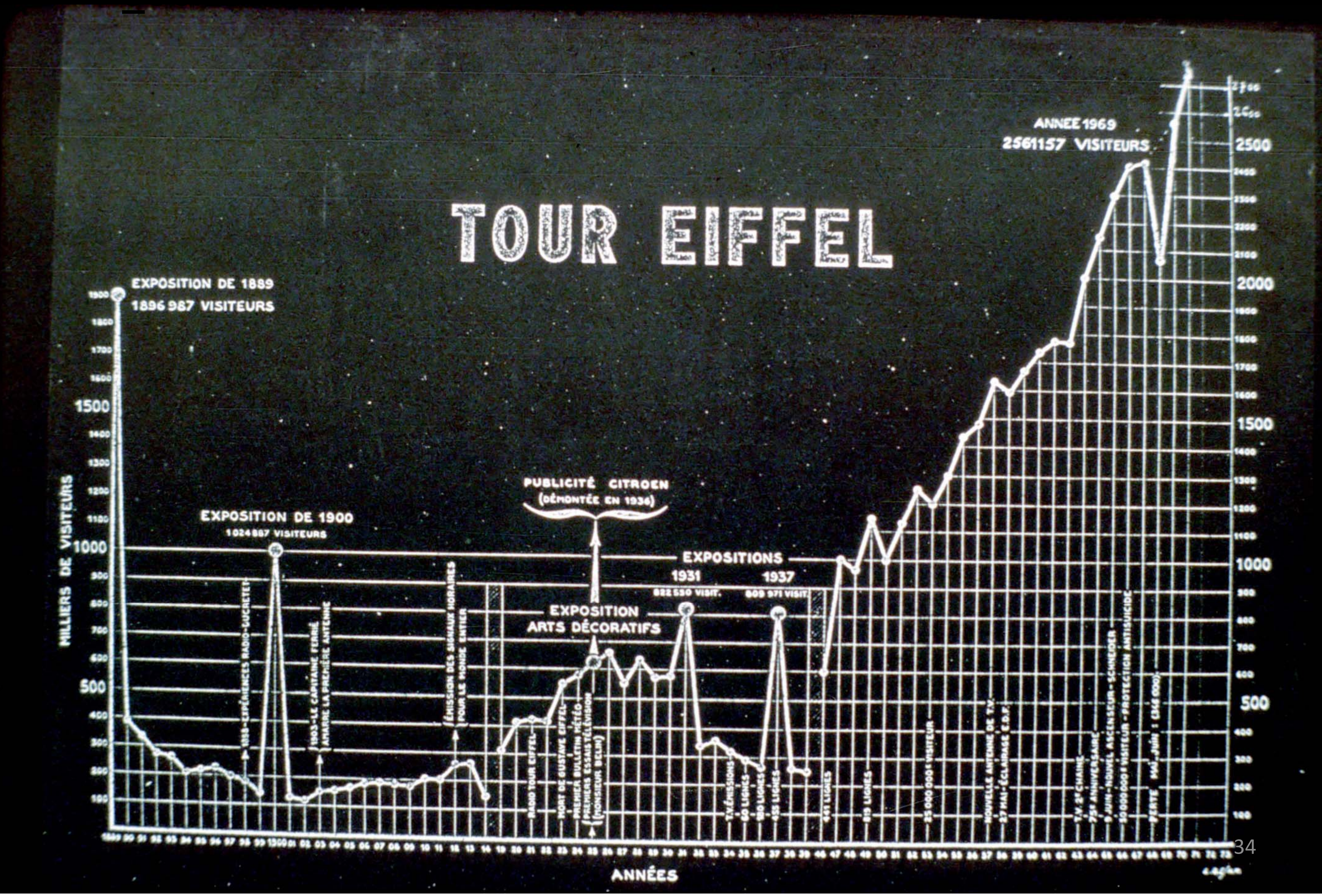
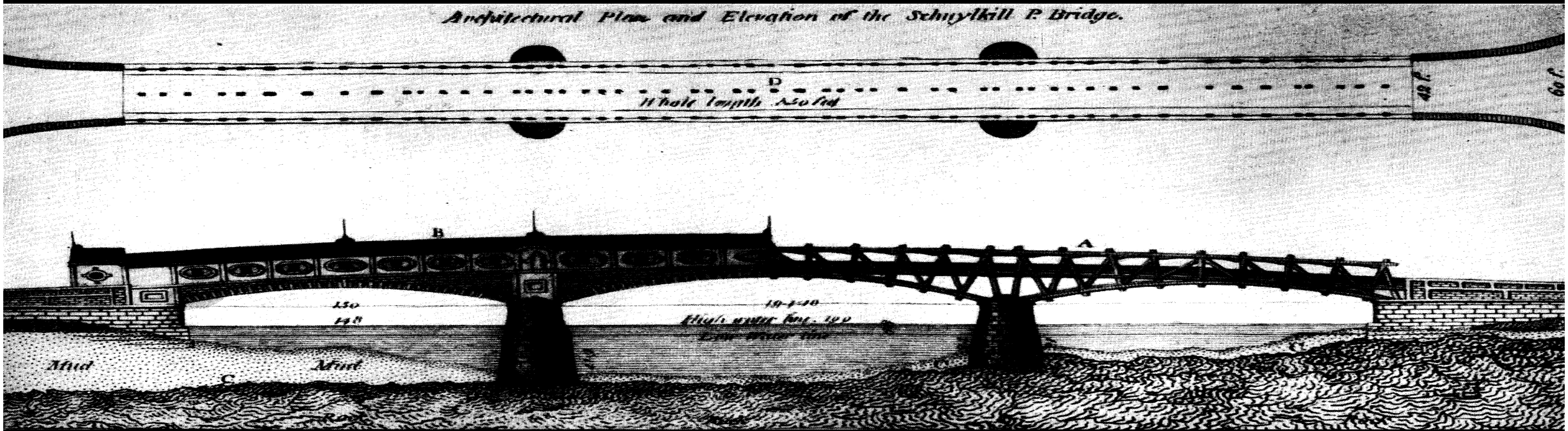
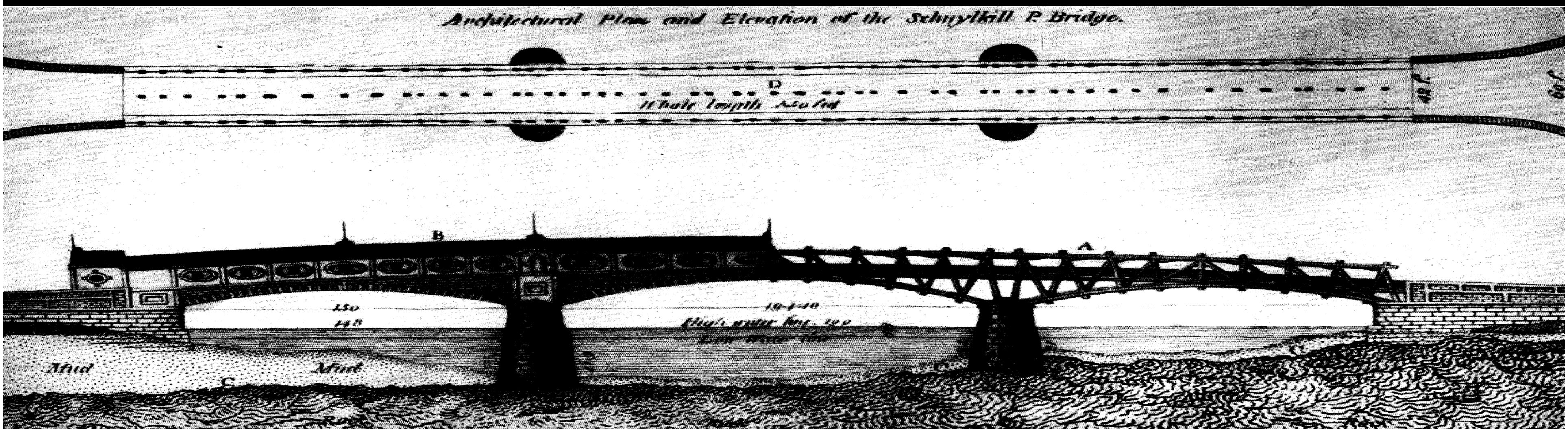


scientific **social** symbolic



Permanent Bridge (1806)
Timothy Palmer

scientific social symbolic



"And it is sincerely my opinion, that the Schuylkill bridge will last 30 and perhaps 40 years, if well covered. You will excuse me in saying that I think it would be sporting with property, to suffer that beautiful piece of architecture . . . which has been built at so great expense and danger, to fall into ruins in 10 or 12 years!"

-A Statistical Account of the Schuylkill Permanent Bridge,1806

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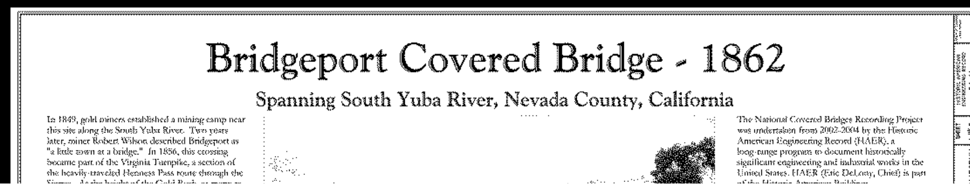
Addendum to
BRIDGEPORT COVERED BRIDGE
HAER No. CA-41
(Page 4)



Within a year of the discovery of gold at Sutter's Mill at Coloma in 1848, the population of California tripled. The urgent demand for roads and bridges was initially met by the establishment of privately financed ferries, turnpikes and toll bridges. In 1850, John T. Little of Castine, Maine, built California's first covered bridge at Salmon Falls. By 1860, there were at least one hundred toll bridges in the gold mining region of California. The majority of these were timber truss bridges and, presumably, many of them were covered. Over time, however, the covered bridges were replaced with new structures, or lost to floods, fires, vandalism, neglect or decay. By 1938 there were still thirty covered bridges in California.[2] That number dropped to 17 by 1954.[3] Today there are 9 historic covered bridges in California:[4]

WG #05-12-05	Zane's Ranch	Humboldt County, CA	1937	Queenpost truss	WPA

[2] S. Griswold Morley, *The Covered Bridges of California* (Berkeley: University of California Press, 1938), p.1.
[3] Richard Sanders Allen, "Covered Bridges in California," *Connecticut River Valley Covered Bridge Society Bulletin* 2 (June 1955): 5.
[4] California also has several non-authentic or non-historic covered bridges that have appeared in recently published lists, including: Aptos Creek Bridge (1974); Jacoby Creek (1969); Castleberry (1984); Roaring Camp (1969) and Brookwood (1969).
[5] See HAER No. CA-314, Knights Ferry Bridge and HABS No. CA-158, Knight's Ferry Covered Bridge
[6] See HAER No. CA-313, Powder Works Bridge.
[7] See HAER No. CA-106, Wawona Covered Bridge.
[8] See HAER No. CA-312, Honey Run Bridge.

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Covered Wood Railroad Bridges

Some of the earliest railroad bridges were timber structures because wood was abundant, cheap, and easy to work with. In 1830, Lewis Wernwag built the first wood railroad bridge in the

chords are connected vertically by paired posts, varying in dimension from 6"x6" at midspan to

Presumably hundreds of covered railroad bridges were built in the nineteenth century. In 1841, one English traveler noted, "The timber bridges of America are justly celebrated for their magnitude and strength. By their means the railways of America have spread widely and extended rapidly."[1] By the late nineteenth century, most railroad bridges were being built of iron or steel.[2] In 1957, there were only twenty-nine surviving timber truss railroad bridges in the country. Today there are eight. The Sulphite Railroad Bridge is the only surviving deck truss covered bridge in the United States.

center, to 3"x8" (laid flat) at the eaves to form the slight pitch of the roof. Sheet metal roofing is fastened to these timbers. Railroad ties, tapered on the underside, support the tracks just above the roof.

Historic photos indicate that this bridge once had vertical board siding. Vandals burned the siding off in 1981, leaving only the charred trusses and roof intact. Because of its unusual deck truss configuration, this bridge is locally referred to as the "Upside-down Covered Bridge."

overed Wood Railroad Bridges

Some of the earliest railroad bridges were timber structures because wood was abundant, cheap, and easy to work with. In 1830, Lewis Wernwag built the first wood railroad bridge in the

more than $200,000. We know of no other case in which so much money has been spent for so little purpose on a railroad project."[6] However, the local paper industry made good use of the line, transporting large quantities of sulphur to the mills until the 1920s. In 1895, the Franklin &

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[1] Richard Sanders Allen, *Covered Bridges of the Northeast* (Brattleboro: Stephen Greene Press, 1957), p.94.
[2] Nevertheless, the process of replacing bridges was a gradual one. In 1889, railroad engineer Theodore Cooper stated that among the 1,600 miles of railroad bridges in existence, only 380 miles were iron. Theodore Cooper, "American Railroad Bridges," *Transactions of the American Society of Civil Engineers* 21 (July 1889).
[3] The Pemigewasset and Winnipesaukee Rivers form the Merrimack River. According to Alonzo J. Fogg's 1874 *Statistics and Gazetteer of New Hampshire*, the Winnipesaukee River "has a rapid descent of about 232 feet, and furnishes some of the best and most permanent water power in New Hampshire," p.590.
[4] D. Hamilton Hurd, *History of Merrimack and Belknap Counties, New Hampshire* (Philadelphia: J.W. Lewis & Co., 1885), p.325.
[5] Alonzo J. Fogg, *The Statistics and Gazetteer of New Hampshire* (Concord: D.L. Guernsey, 1874), p.162.
[6] *Forty-Seventh Annual Report of the Railroad Commissioners of the State of New Hampshire, 1891.*

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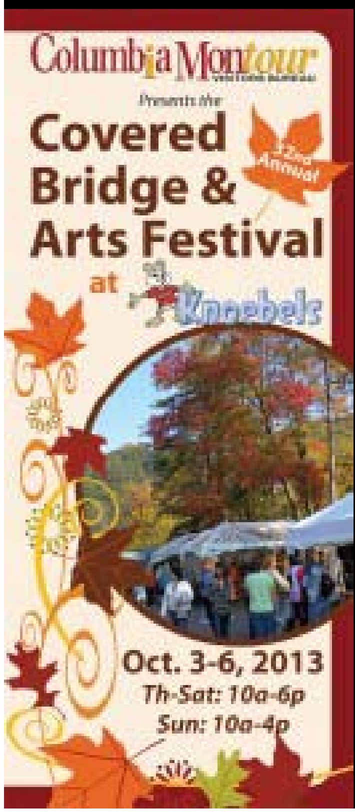

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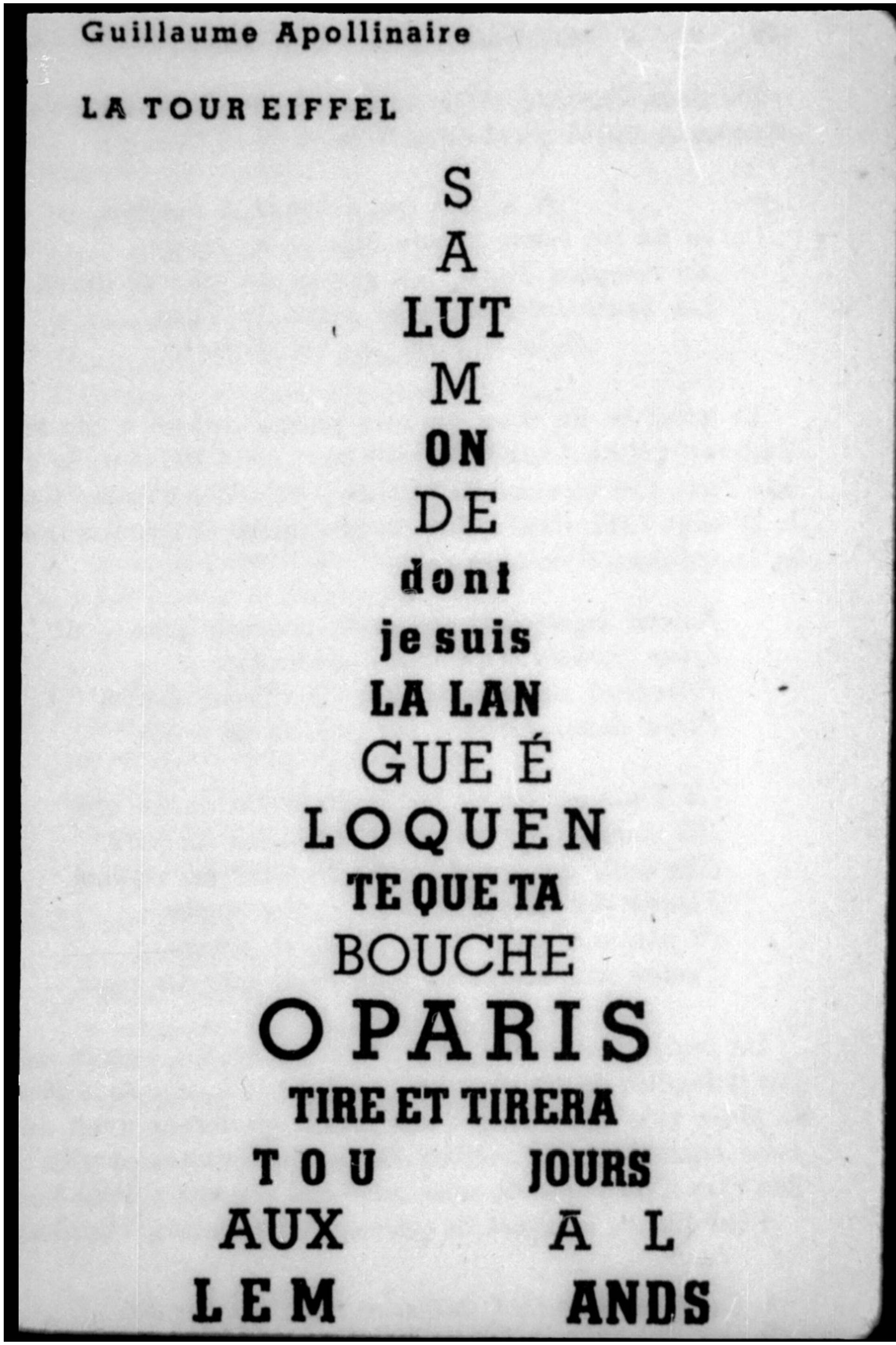
"…the third criterion, the symbolic, consists of *studies in appearance*, along with a consideration of how elegance can be achieved within the constraints set by the scientific and social criteria."



Guillaume Apollinaire

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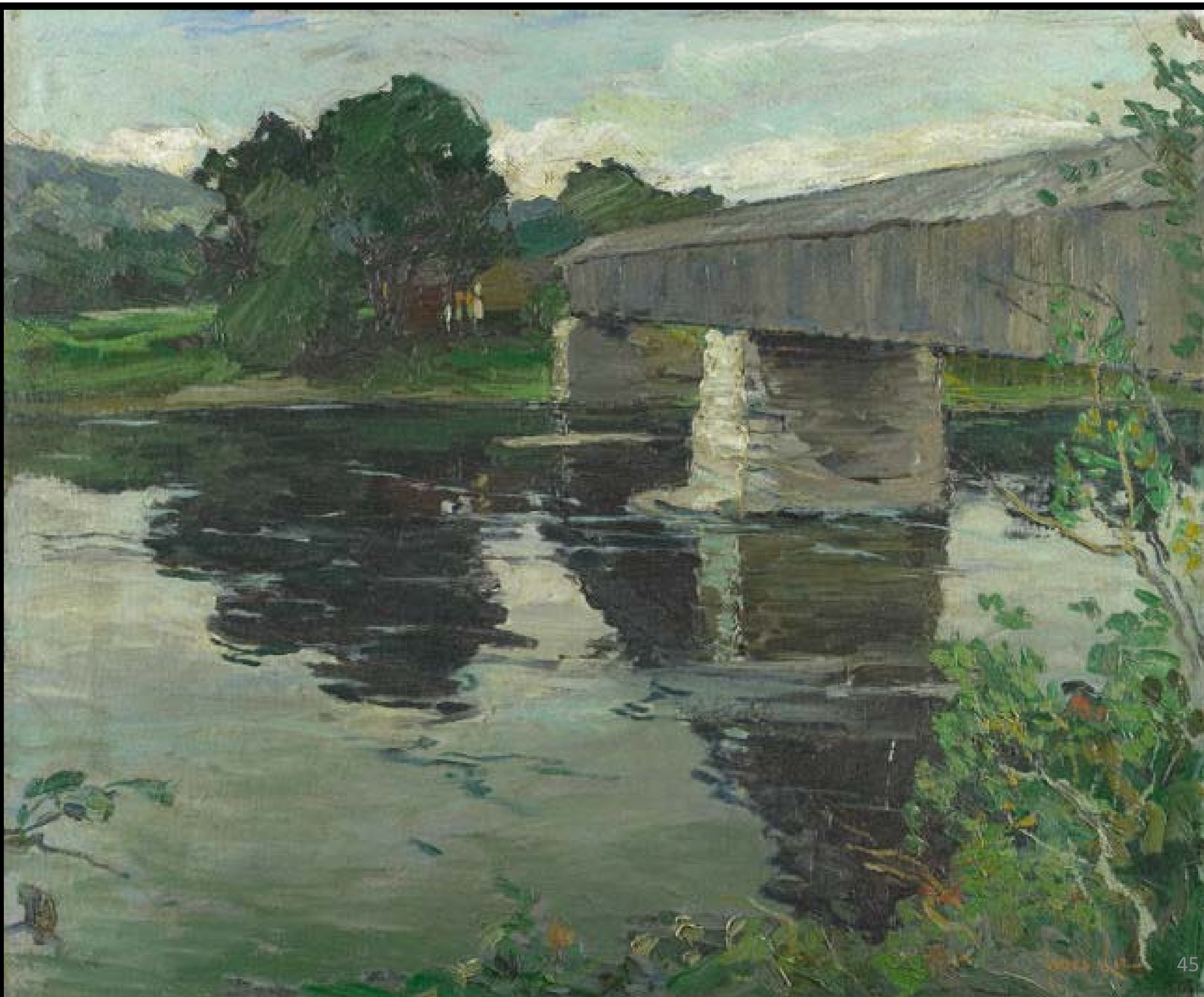
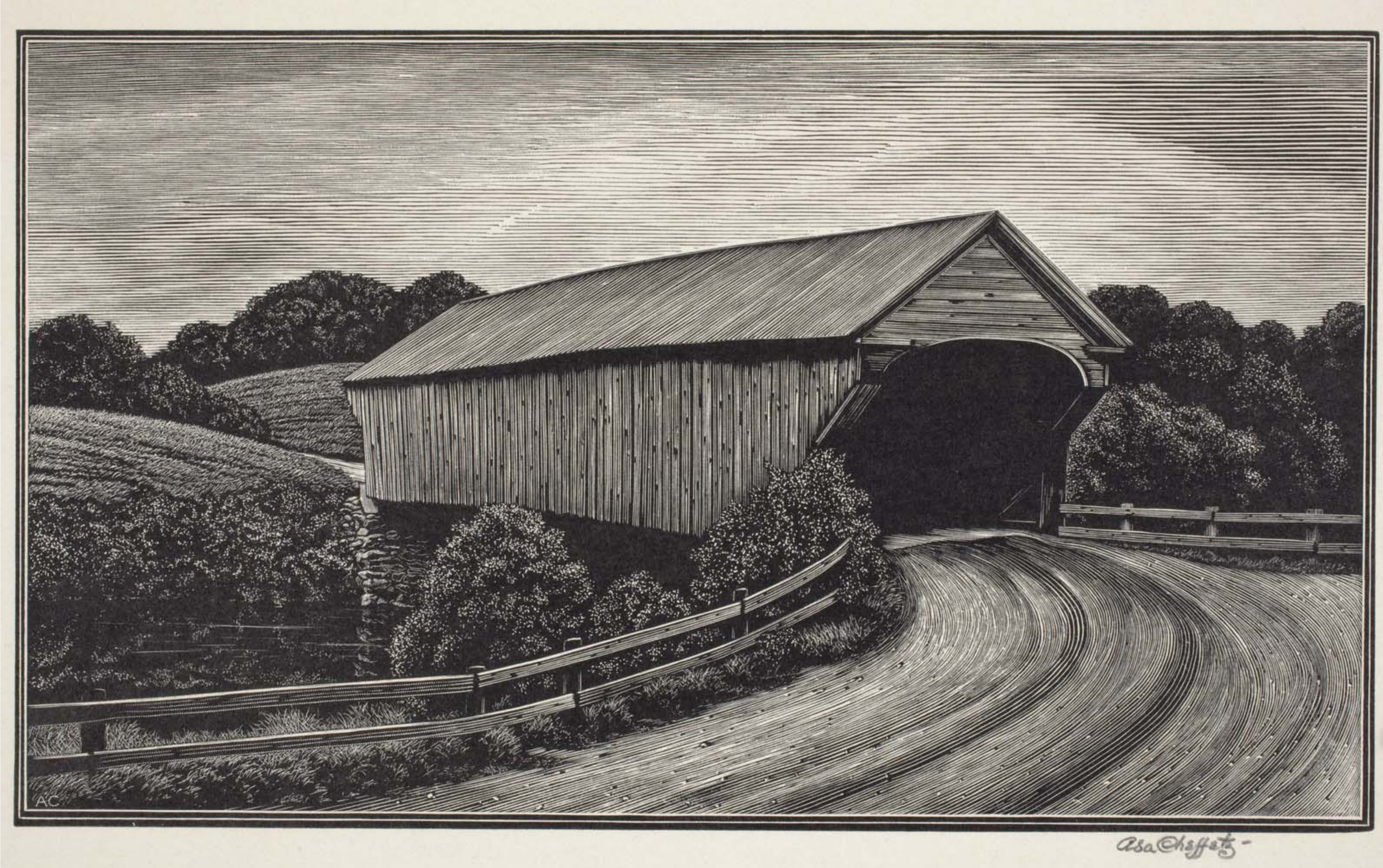



Lancaster County


AC
Asa Cheffetz


COVERED BRIDGE
20/25
CHANNING S.SMITH

Acknowledgements

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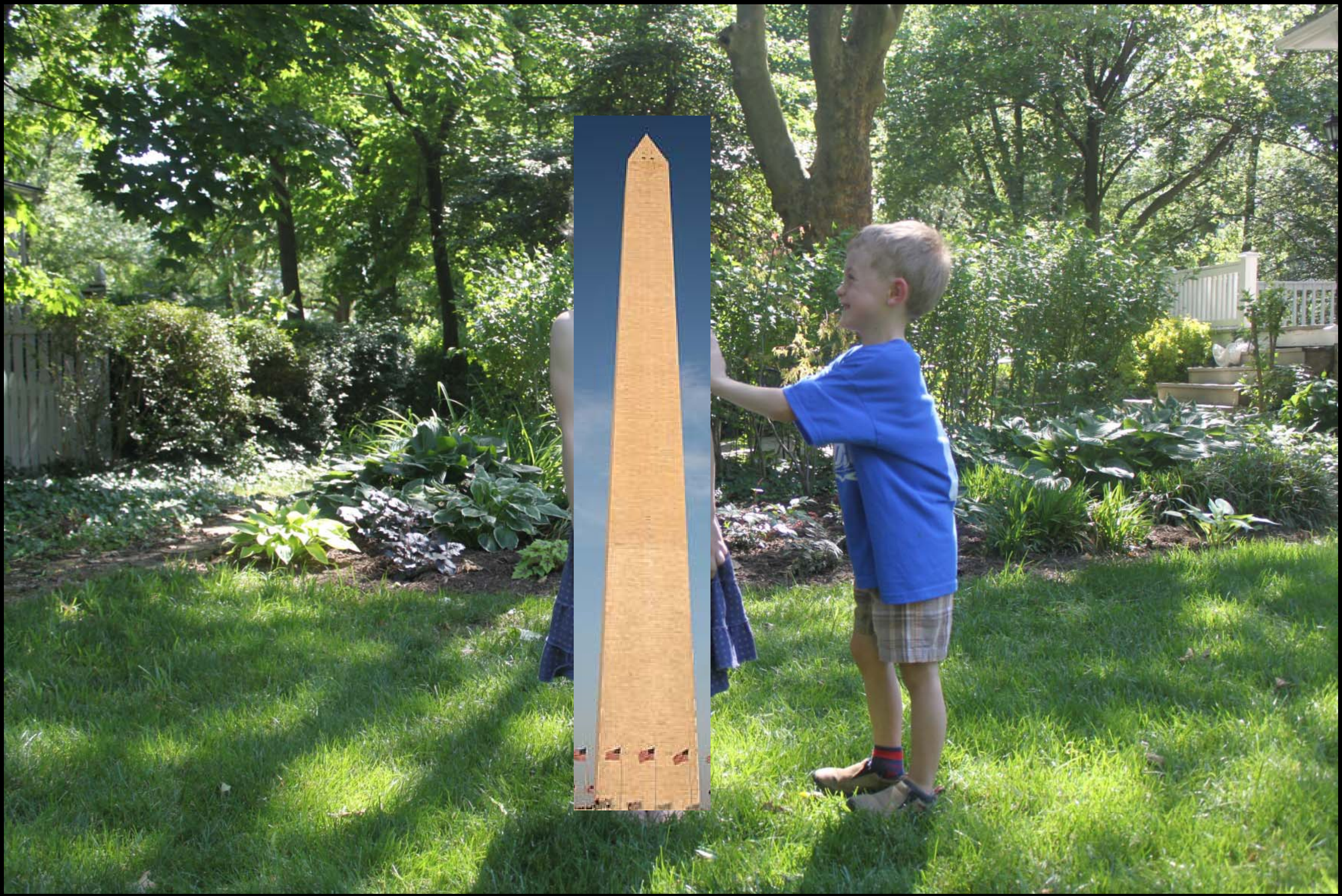

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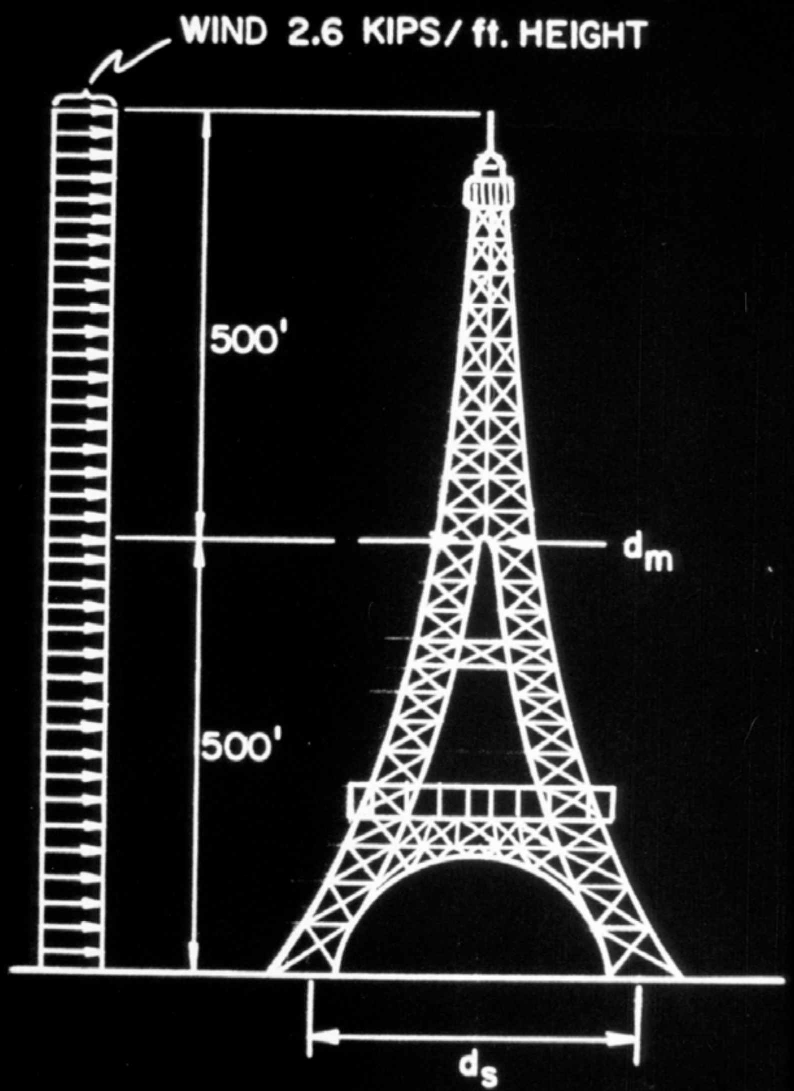

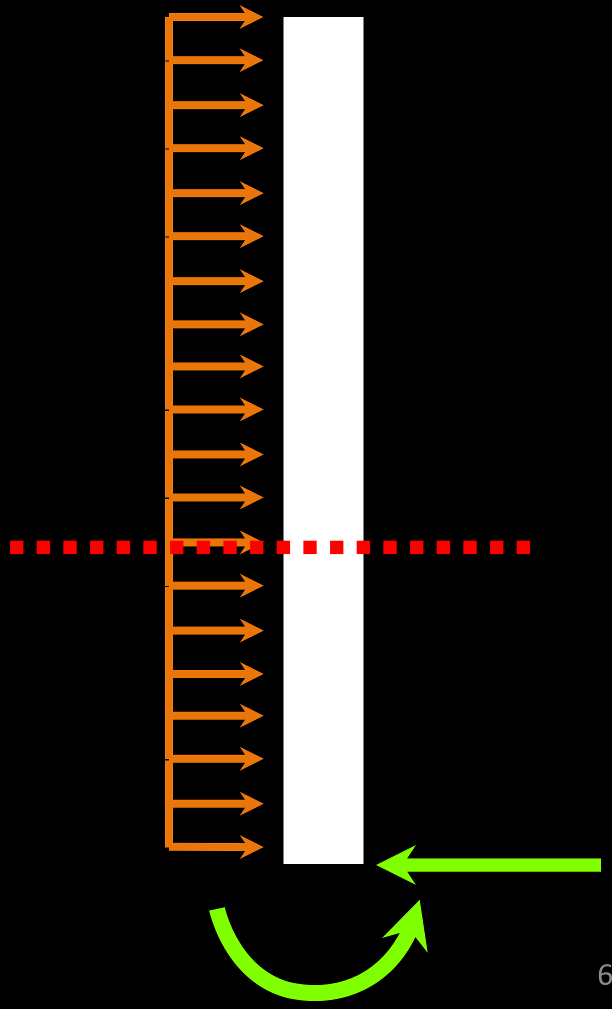

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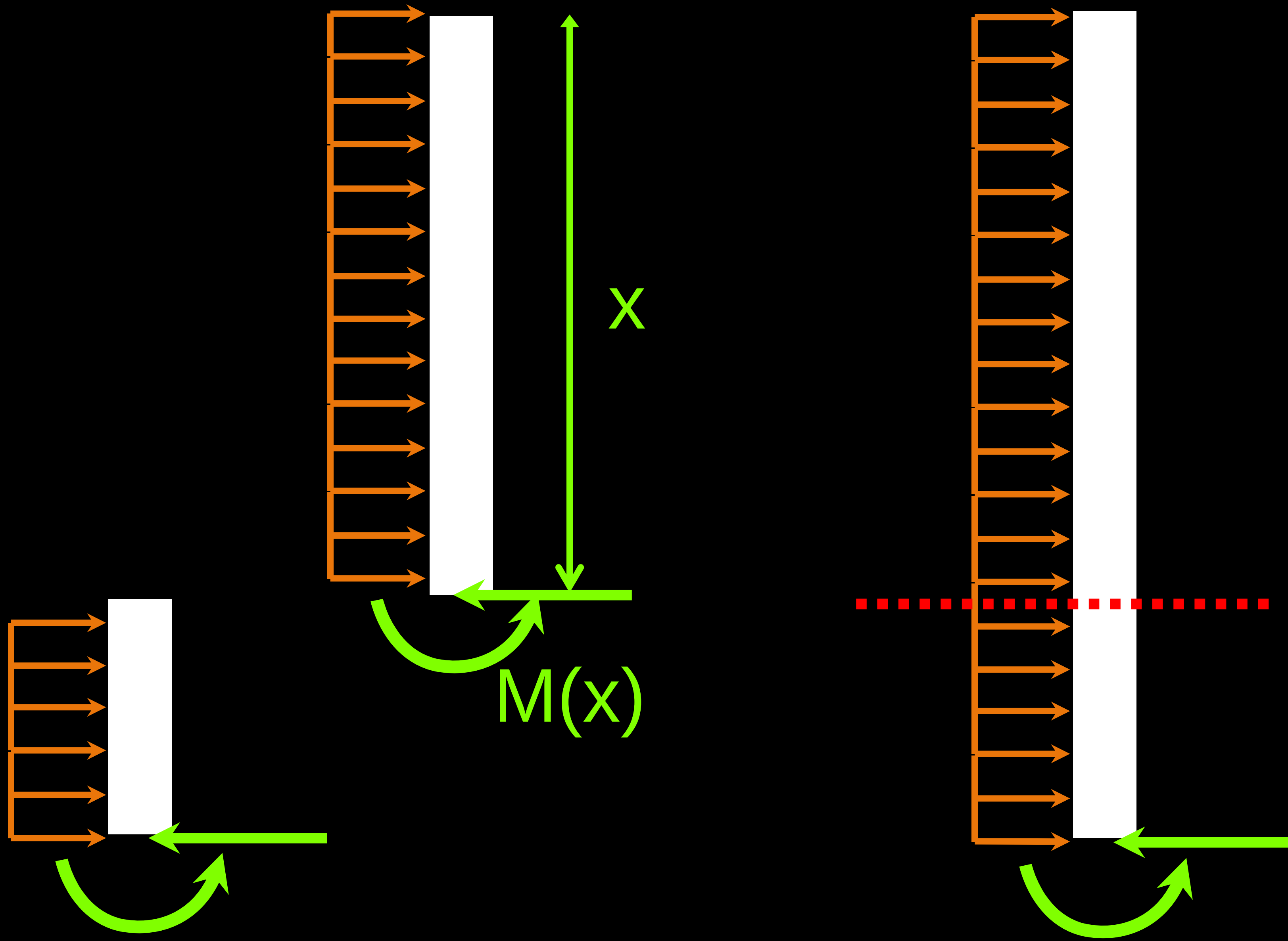

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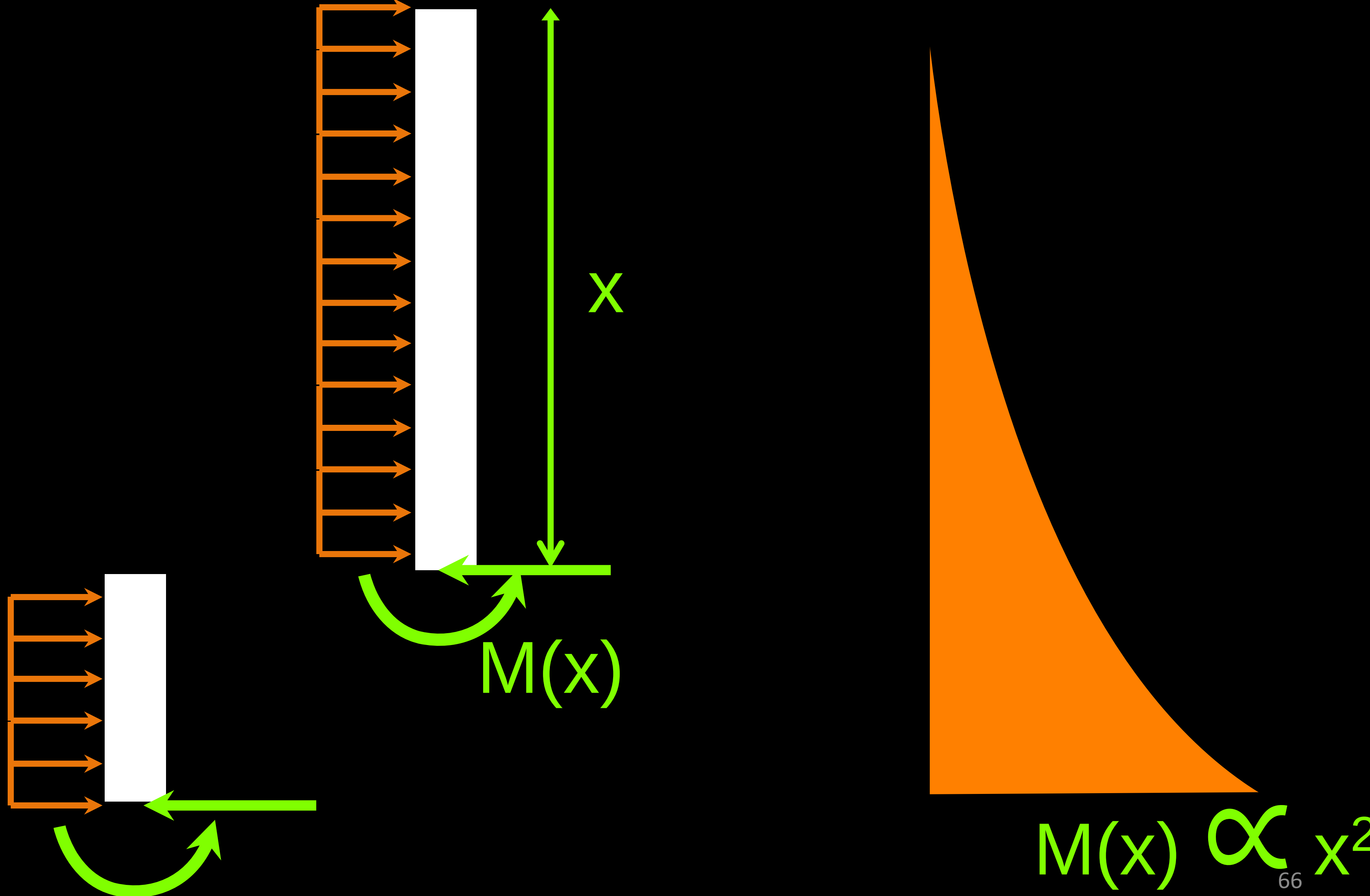

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