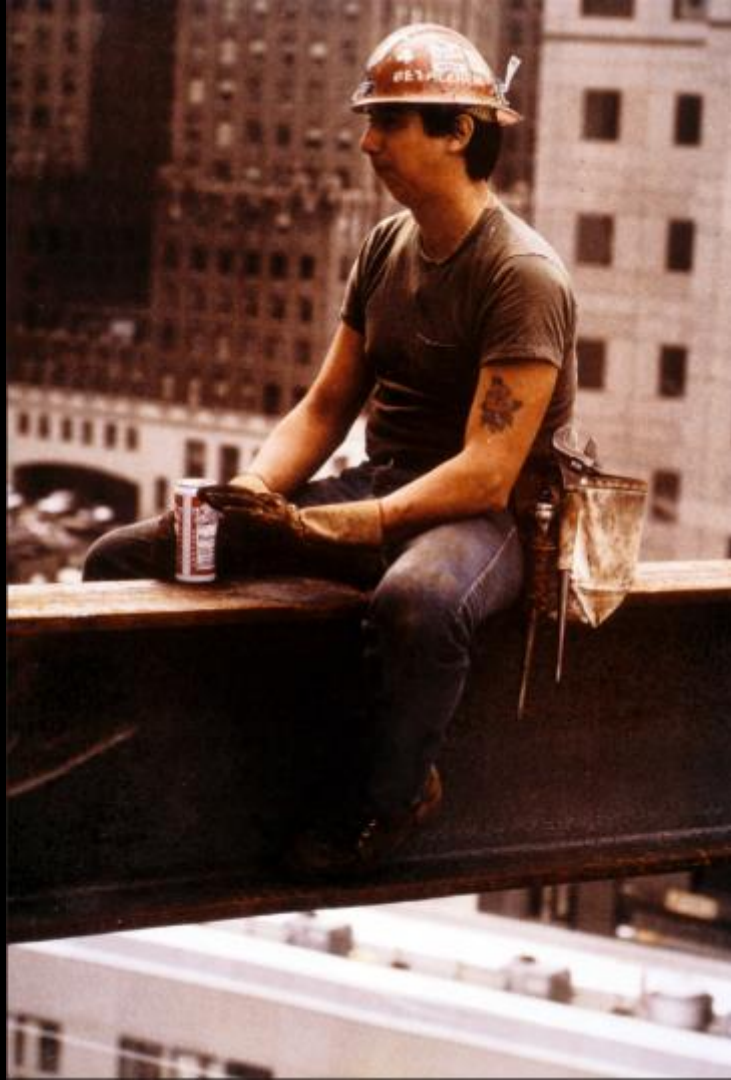


From Iron to Steel
~ technique to technology~

Part One: Material advances
and to the Invention and uses of Framing











Pig Iron

~noun

1. Iron tapped from a blast furnace and cast into pigs in preparation for conversion into steel, cast iron or wrought iron.
2. Iron in the chemical state in which it exists when tapped from the blast furnace without alloying or refinement

[Origin: 1655-65]

Wrought iron

~ noun

A form of iron, almost entirely free of carbon and having a fibrous structure including a uniformly distributed slag content that is readily forged and welded

Inherently better at resisting corrosion

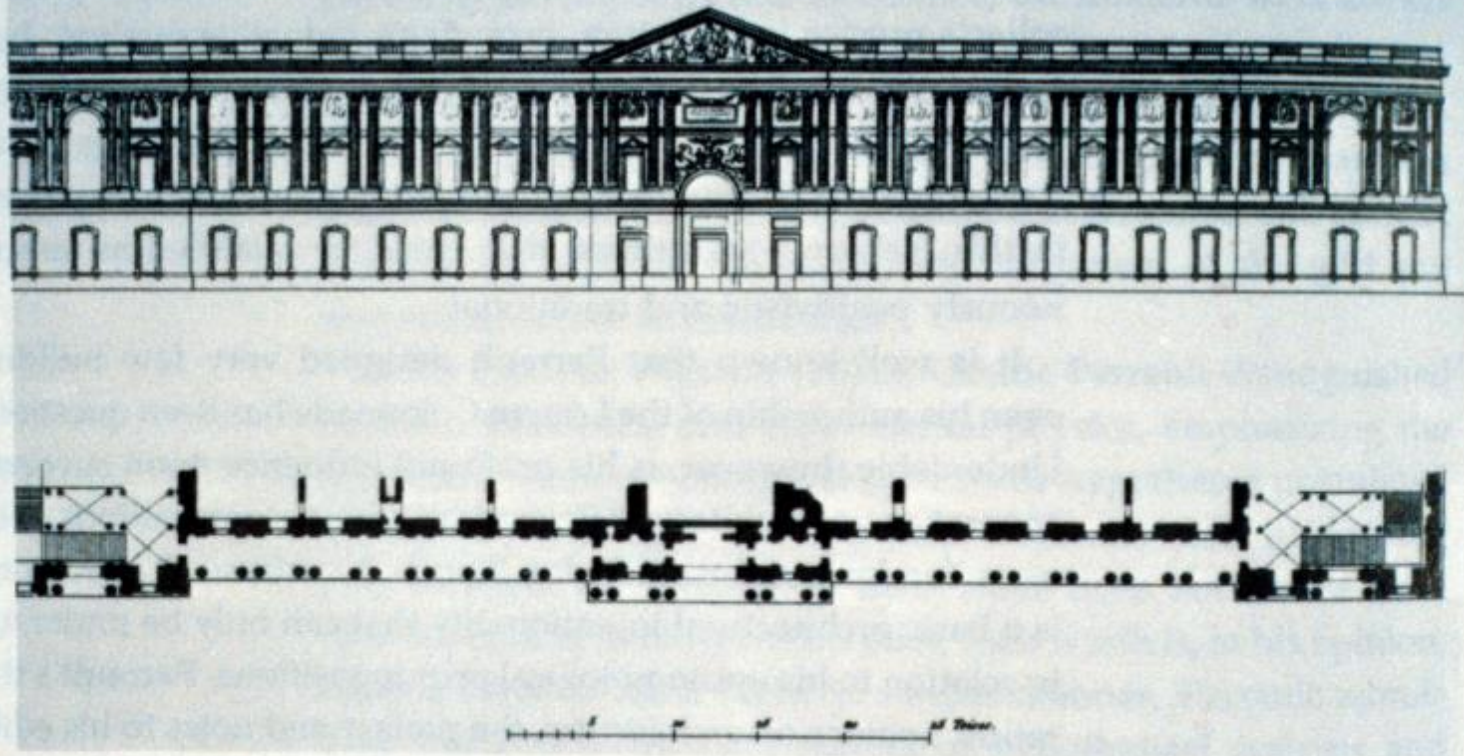
Cast iron

~noun

An alloy of iron containing so much carbon that it is brittle and so cannot be wrought but must be shaped by casting – meaning heating to a much higher temperature so it can liquefy



Claude Perrault
East Façade of the Louvre Museum
Paris, France
1680



Perrault's design for the eastern facade of the Louvre with its controversial paired columns, from Quatremère de Quincy's *Histoire de la Vie et des Ouvrages des Plus Célèbres Architectes* (1830).



Place de la Concorde
Ange-Jacques Gabriel
Paris, France
1755



The obelisk was
stolen from the
Temple at Luxor

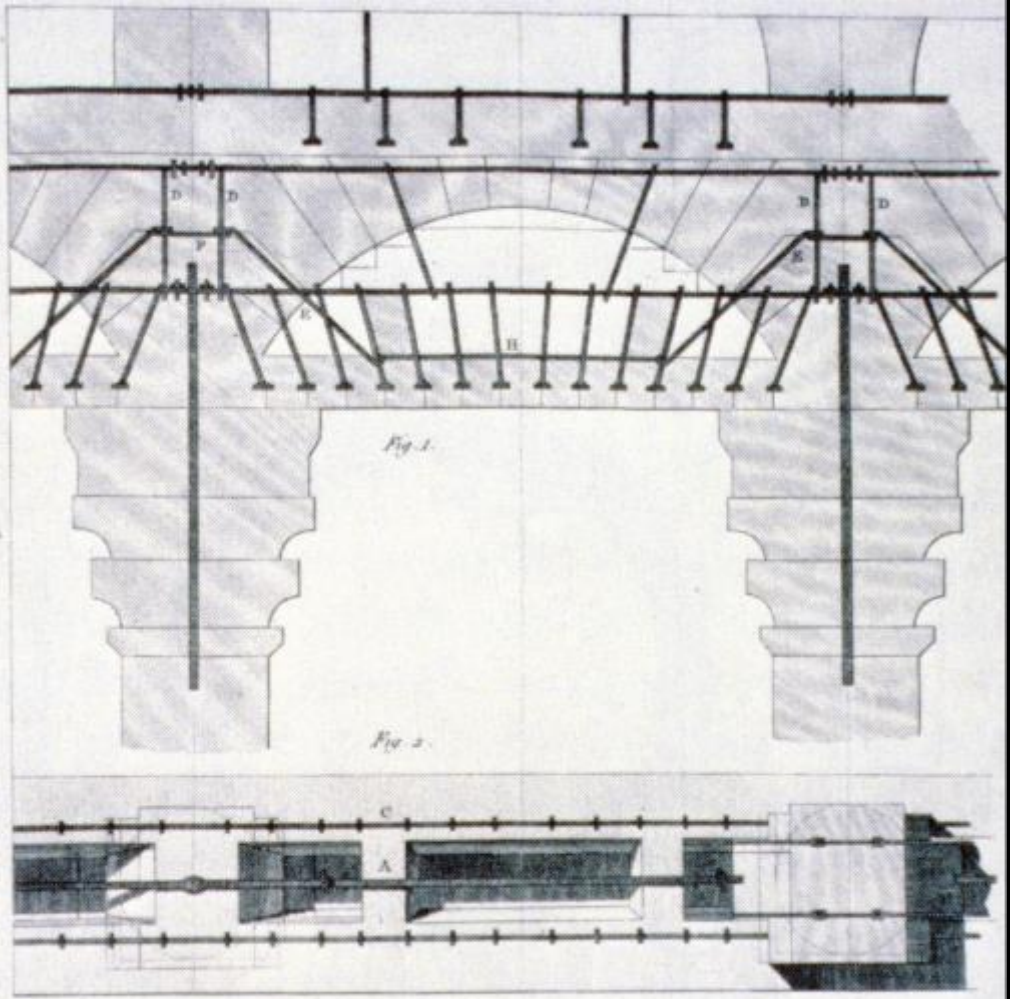
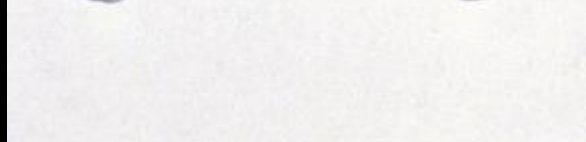
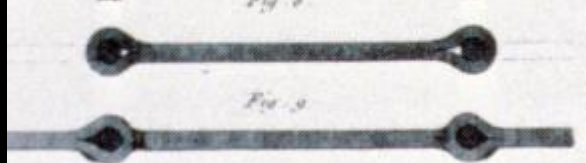
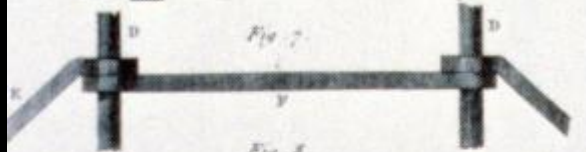
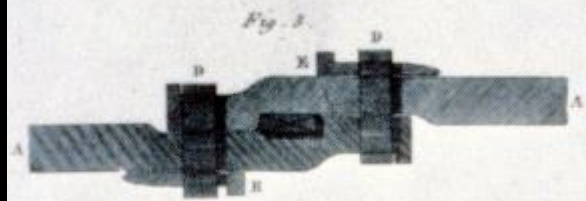






Church of Ste. Genevieve
(Pantheon)
Paris, France
Jacques-Germain Soufflot
Jean-Baptiste Rondelet
1789





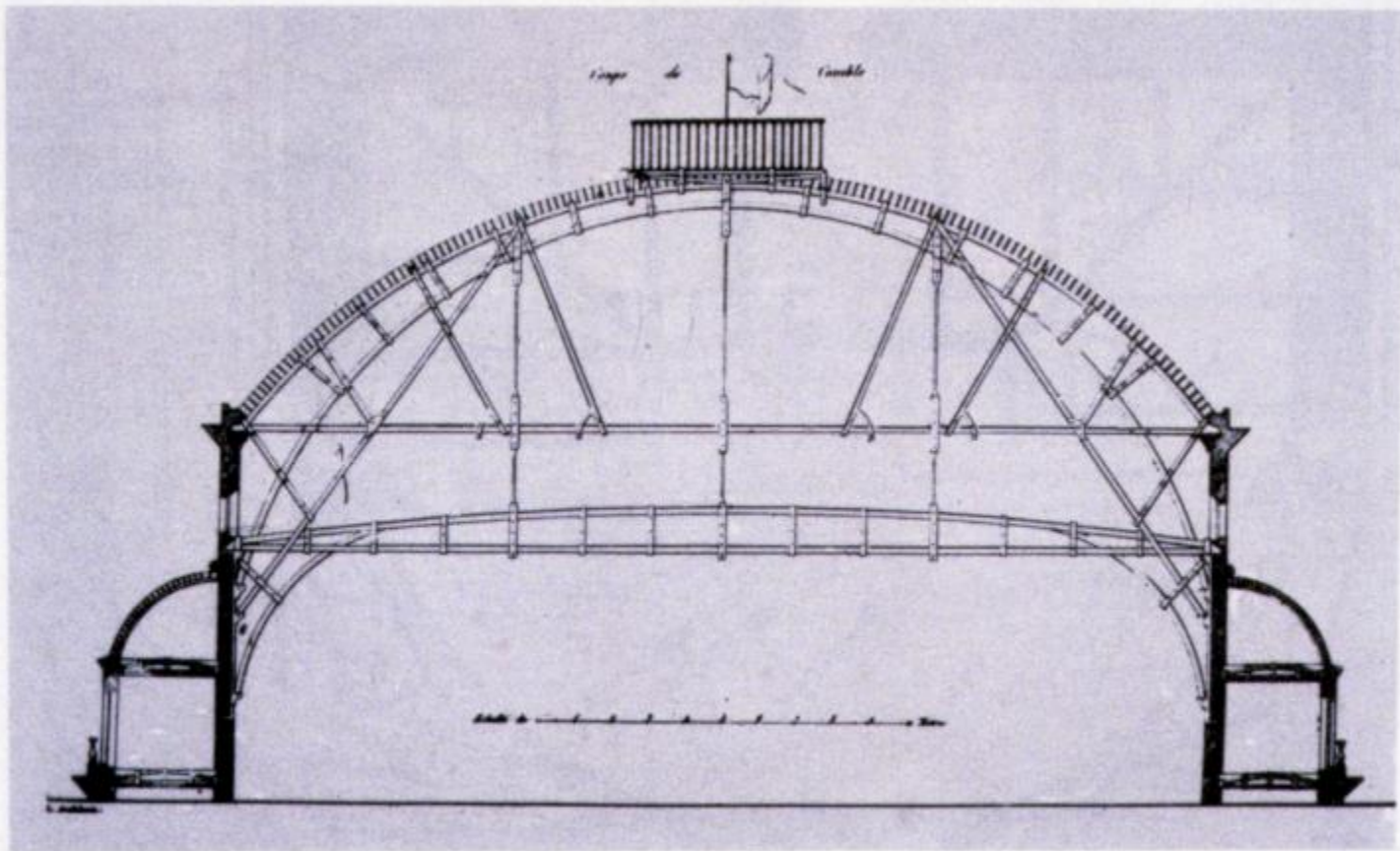
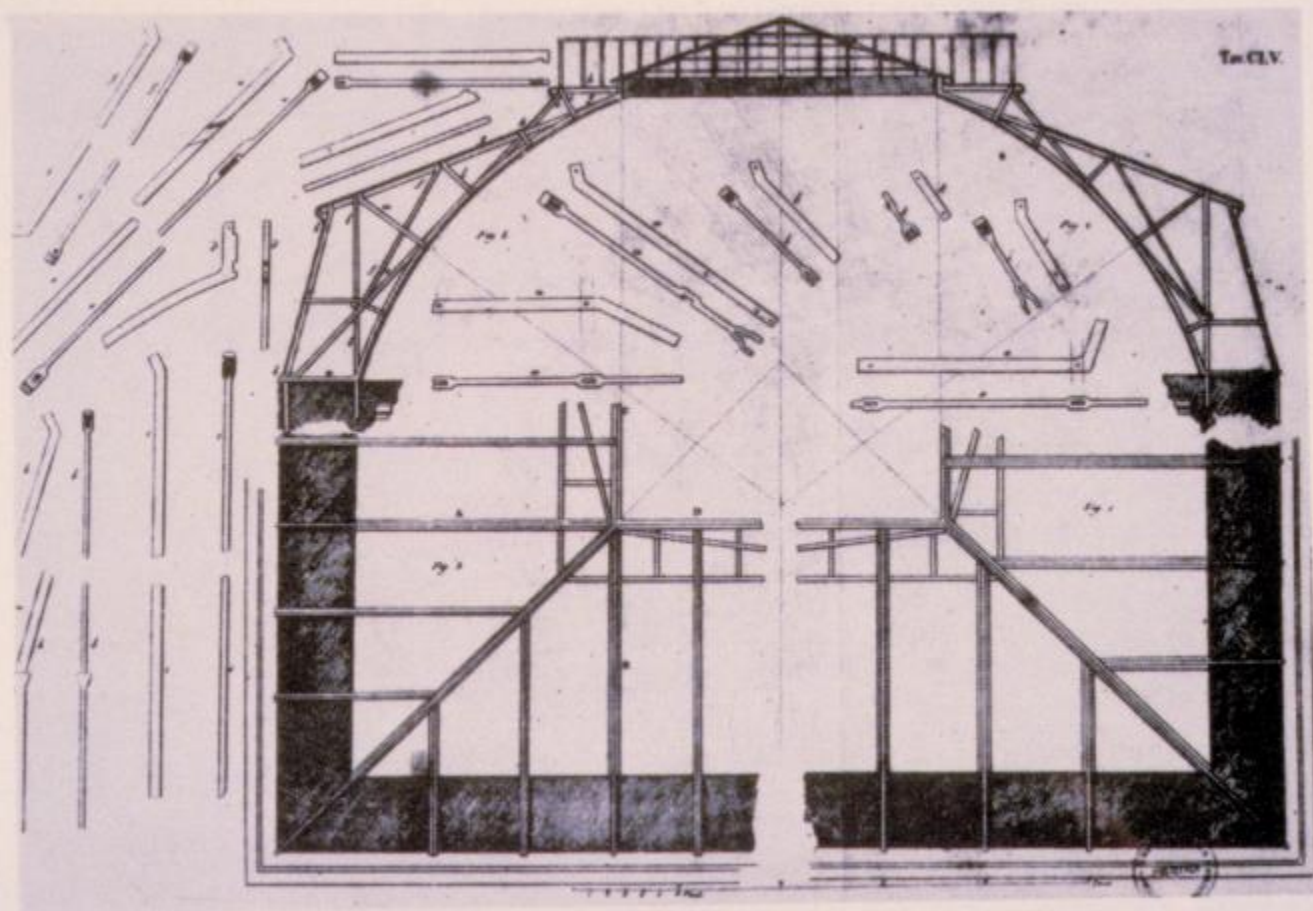


Plate 5. Victor Louis. Théâtre Français, Paris, 1786 (Rondelet, *L'Art de bâtir*, pl. 154)

Plate 6. Auguste Rénard. Iron roof over the Salon adjoining the Grande Galerie.
Louvre, Paris, 1789 (Rondelet, *L'Art de bâtir*, p. 155)



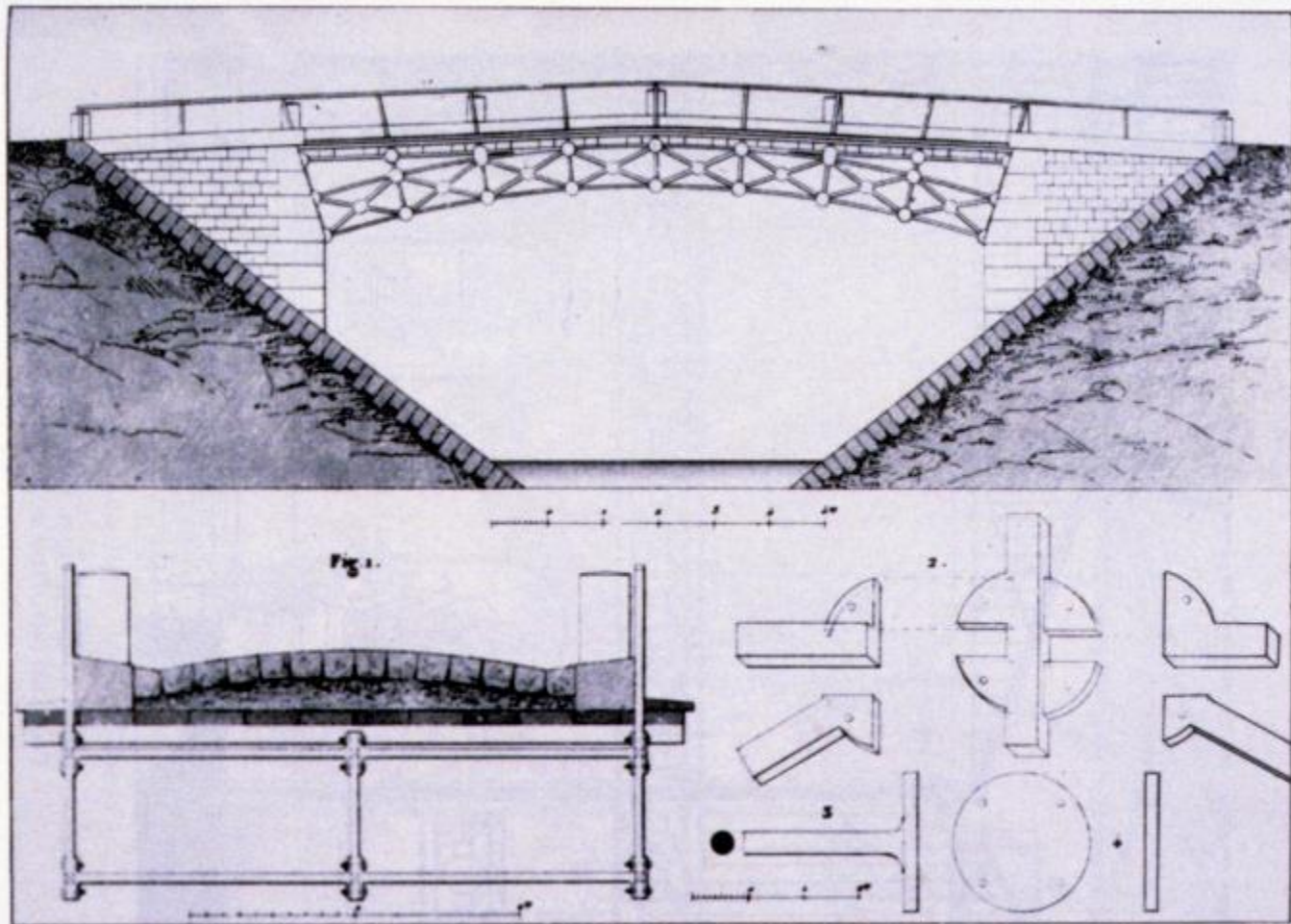


Plate 9. Louis Bruyère. Pont sur la Crou, near Saint-Denis, 1808 (Thiollet, 1832, p. 32)



Pont des Arts
Louis-Alexandre de Cessart and Jacques Dillon
Paris, France
1804
Original 9 arch bridge rebuilt
1984 with 7 arches





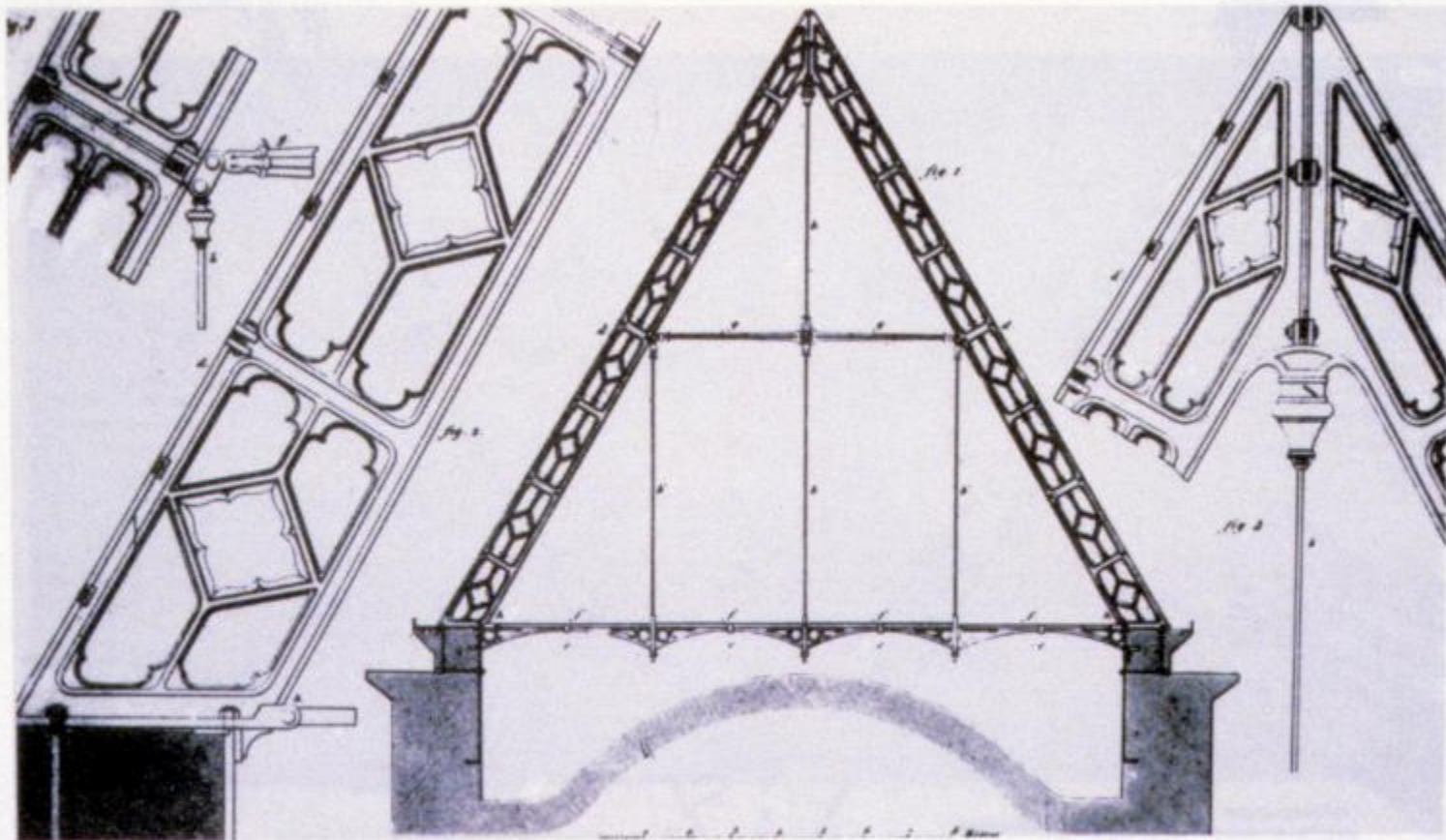
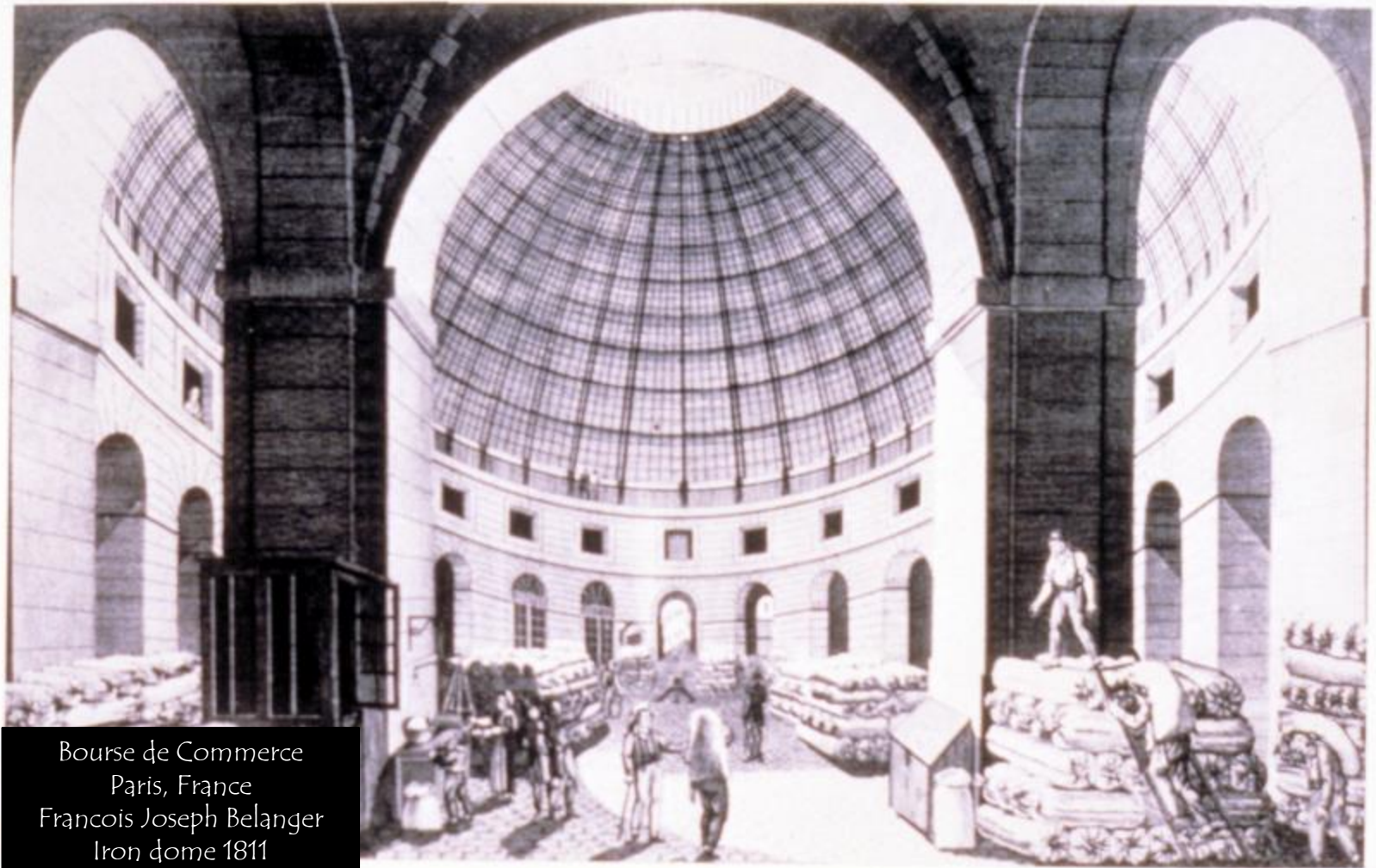


Plate 35. Leturc. Project for the roof of Chartres Cathedral, 1836 (Eck, *Traité de construction*, pl. 28)



Bourse de Commerce
Paris, France
François Joseph Belanger
Iron dome 1811



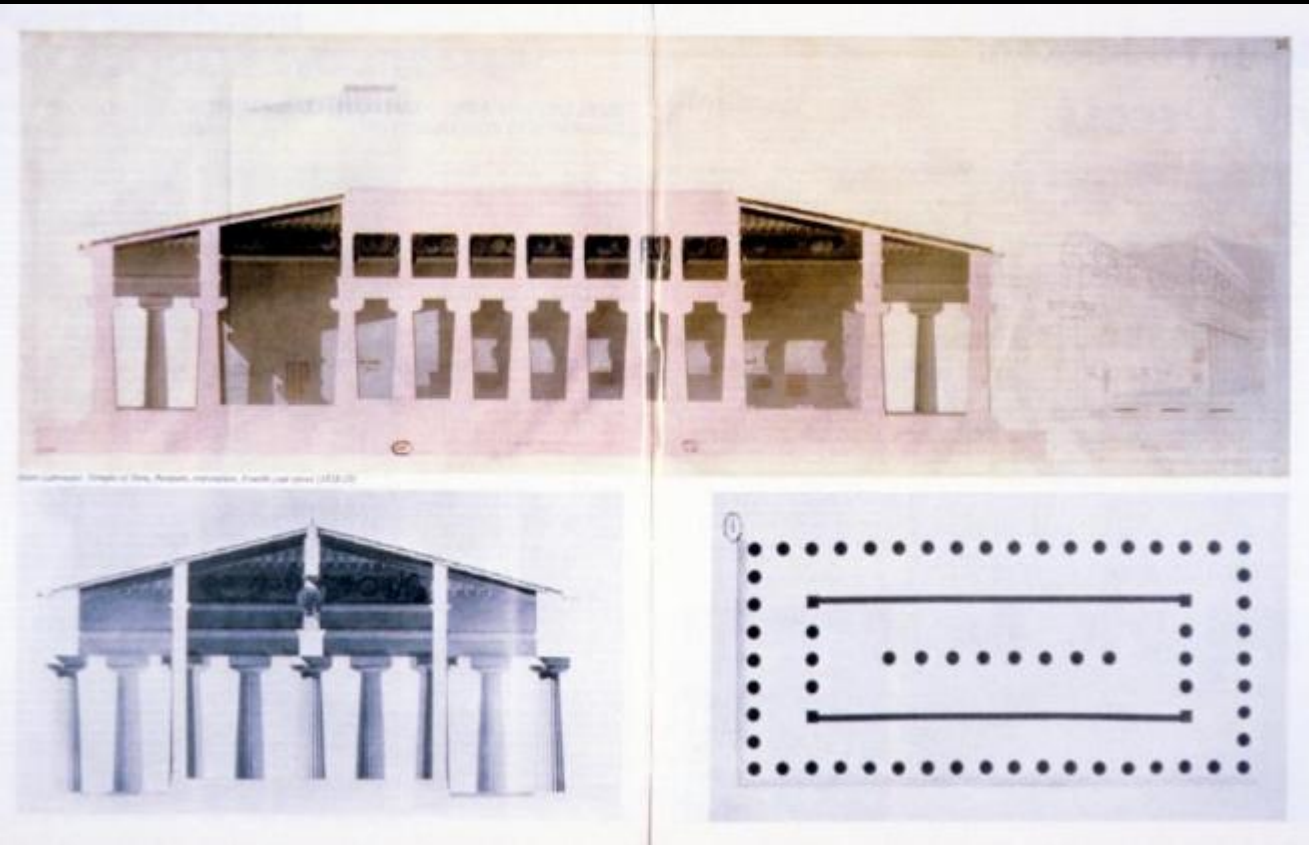


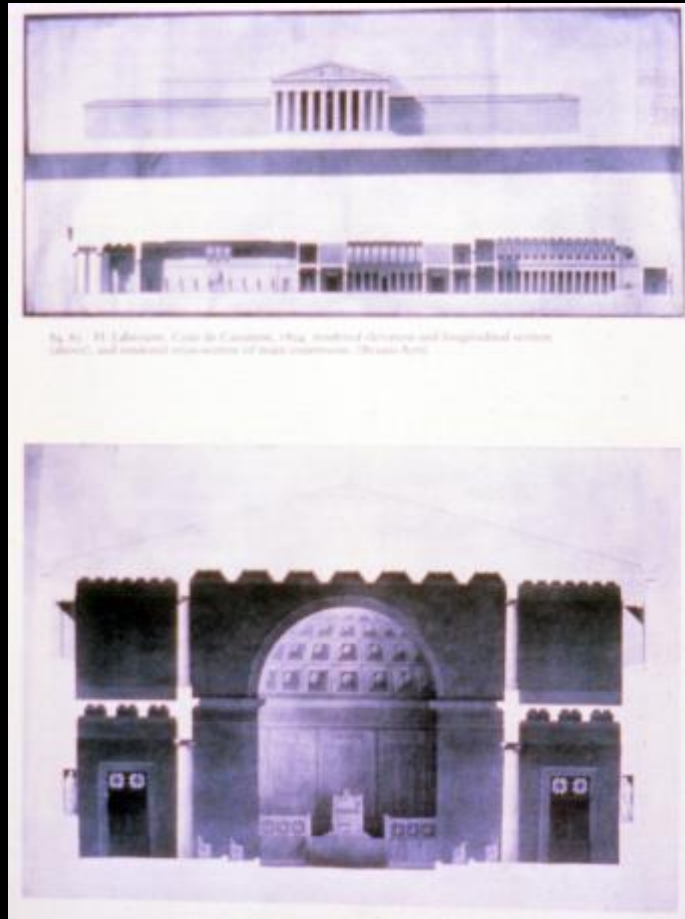
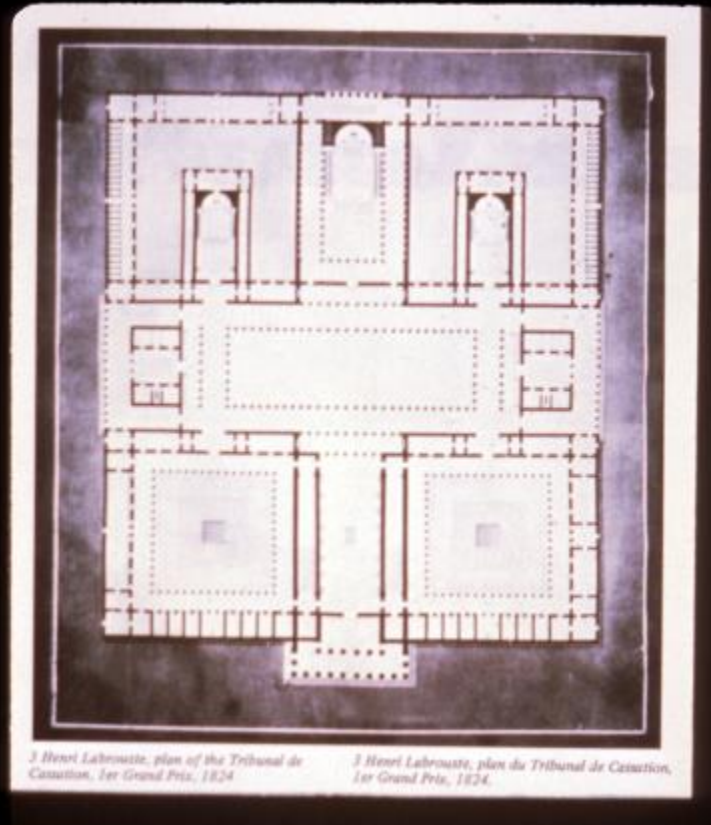




Renovation/Restoration
Tađao Anđo

Henri Labrouste
Ecole des Beaux Arts
1801 to 1895
Structural Rationalism

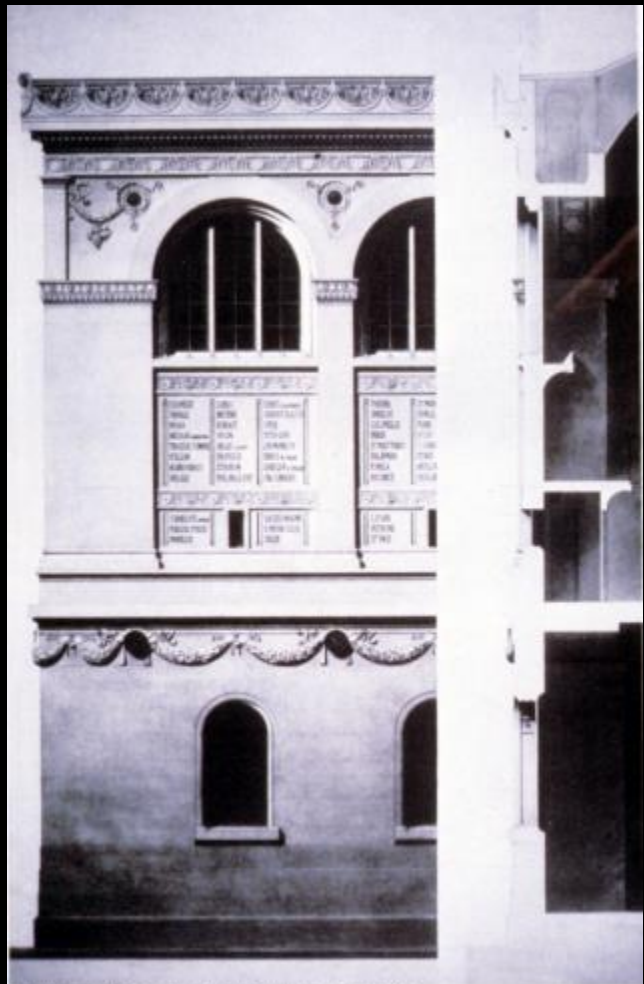
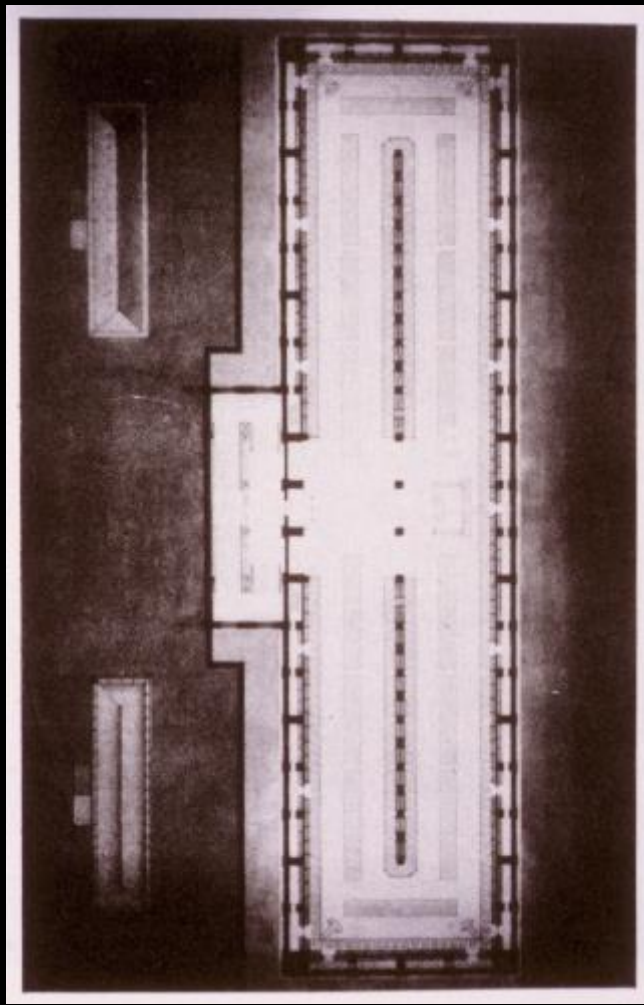
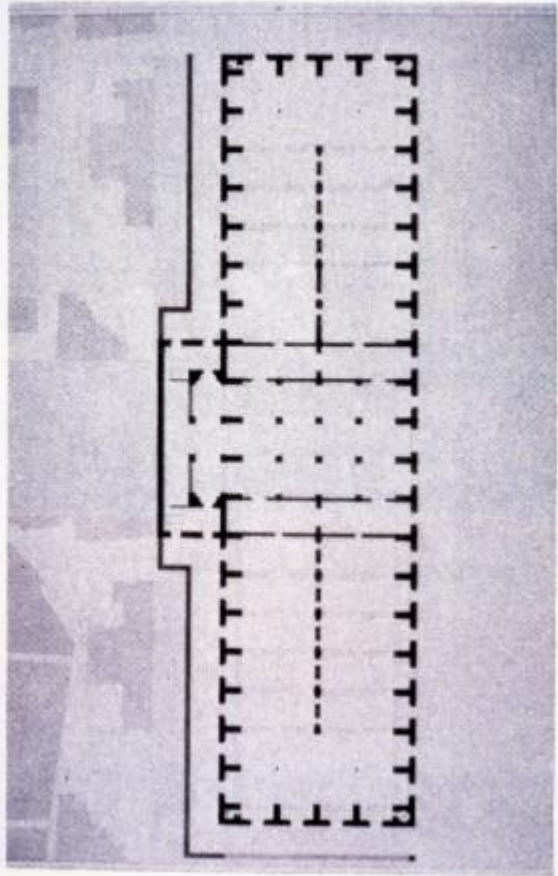






Bibliothèque Sainte-Geneviève
Paris, France
Henri Labrouste
1838-1851

Henri Labrouste's Bibliothèque Sainte-Geneviève, Paris, 1838-50



Bibliothèque Sainte-Geneviève d'Henri Labrouste à Paris (1838-50)

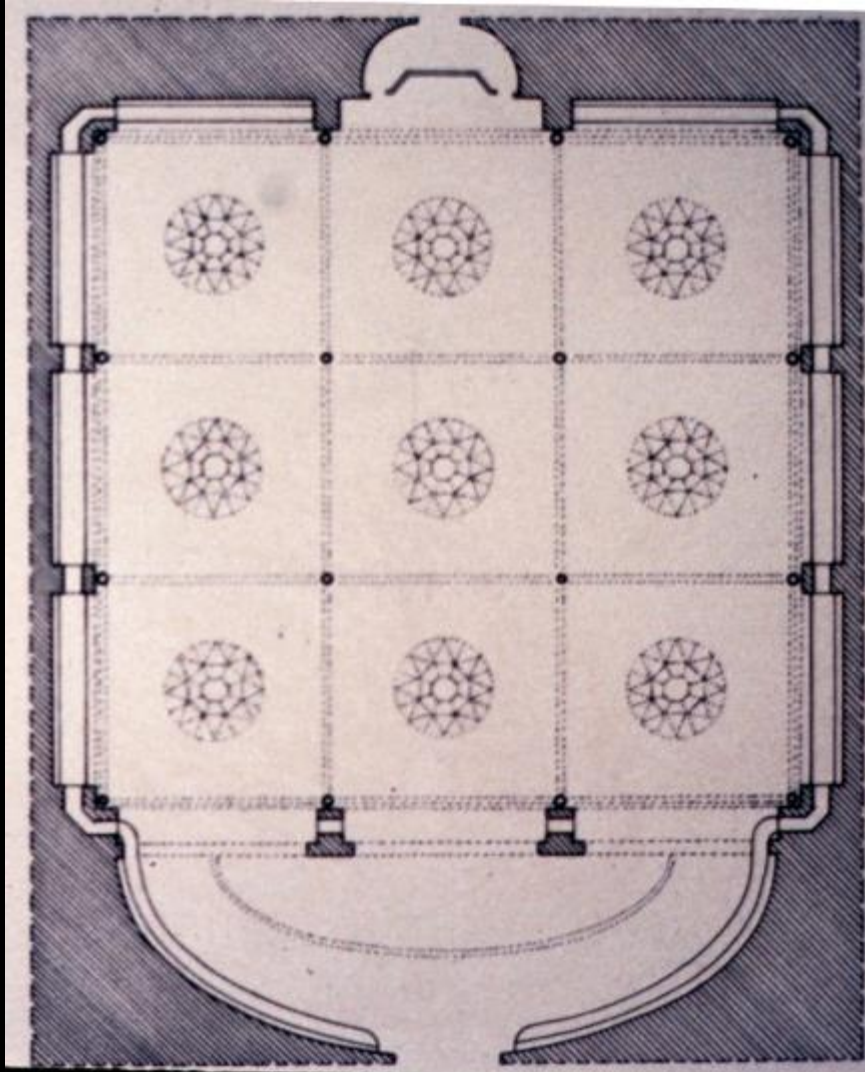






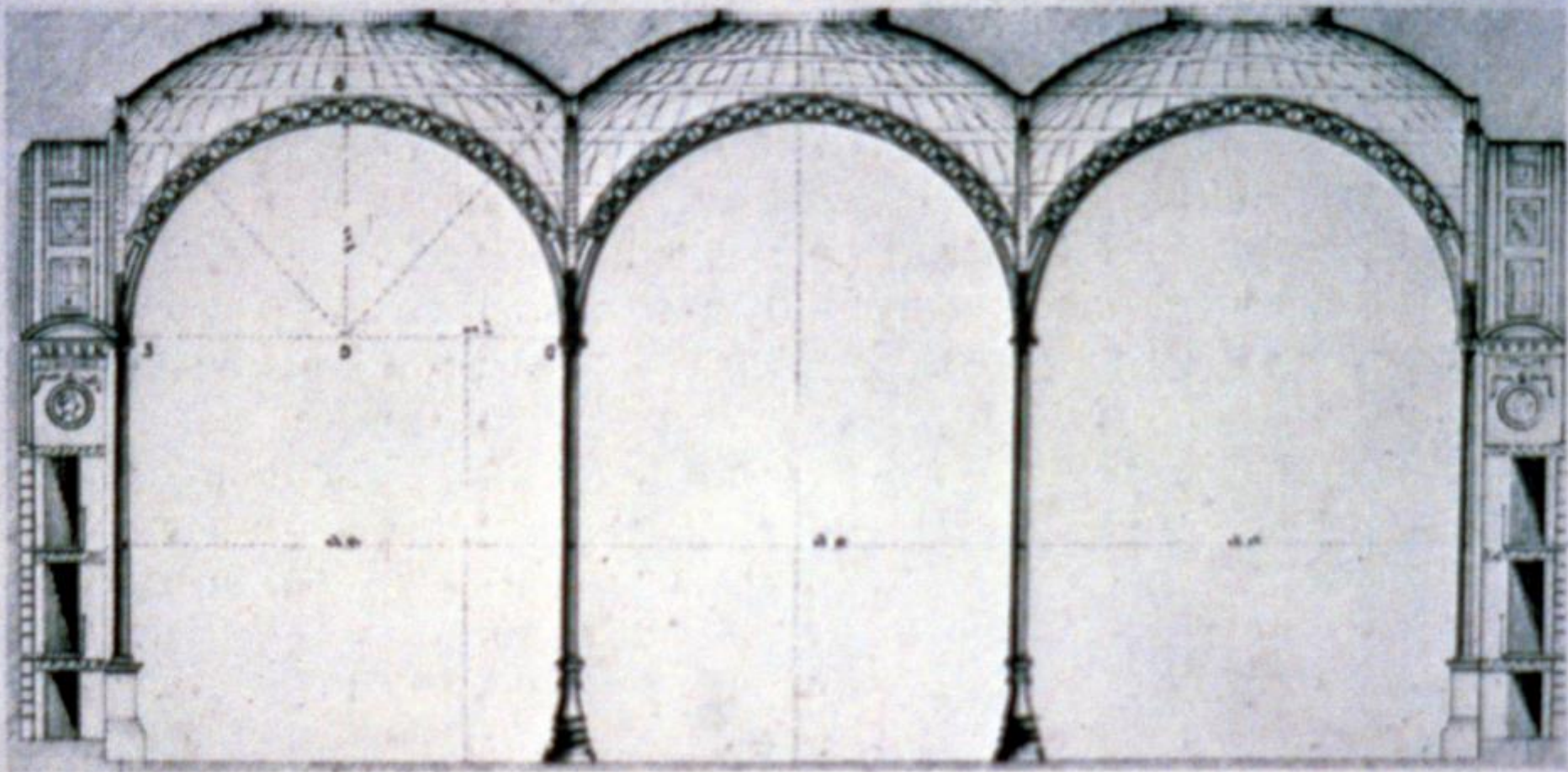






Bibliothèque Nationale de
France
Paris, France
Henri Labrouste
1862 to 1868

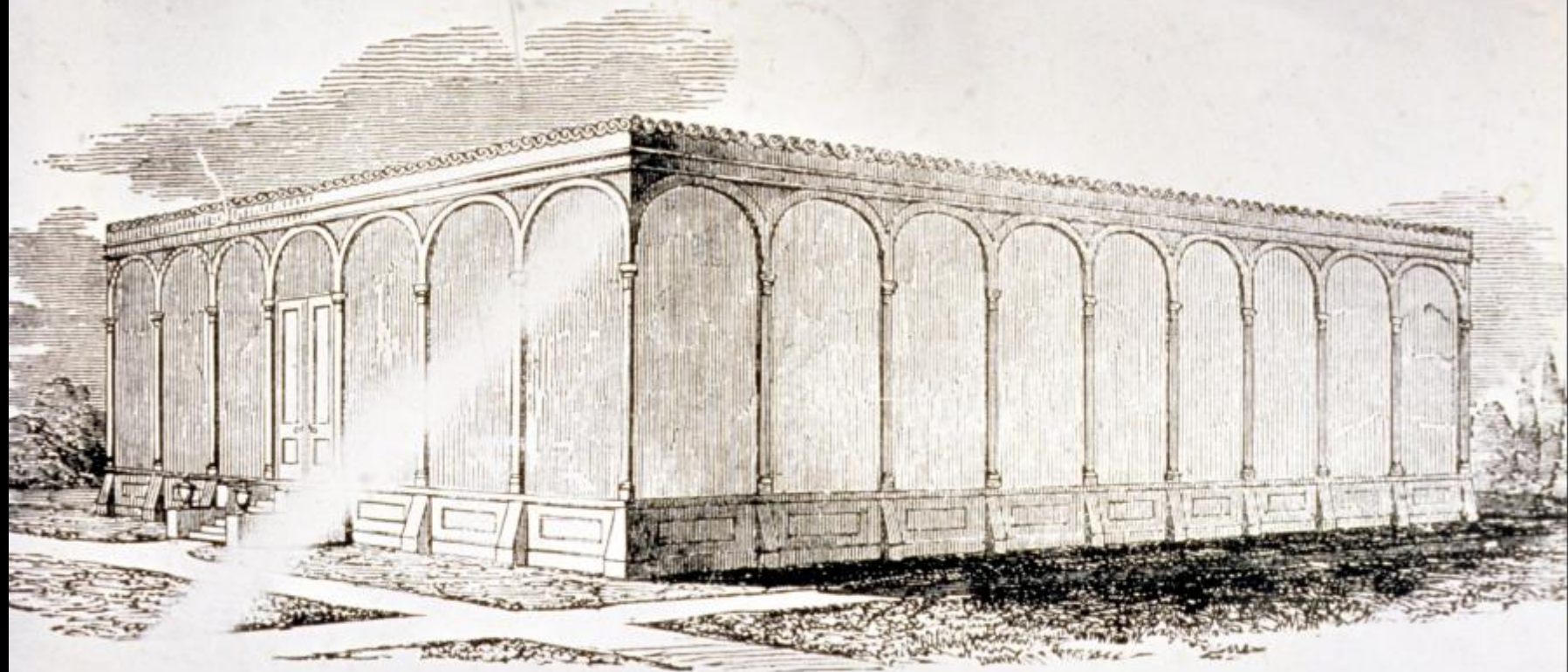






Invention usually requires
NEED

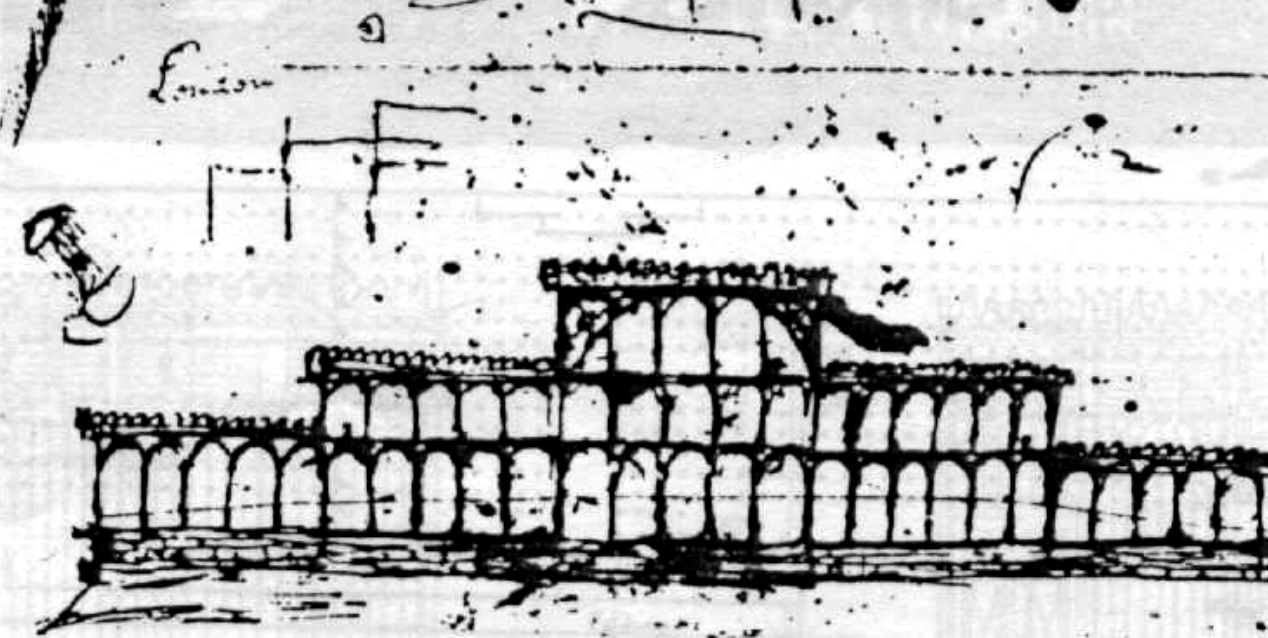
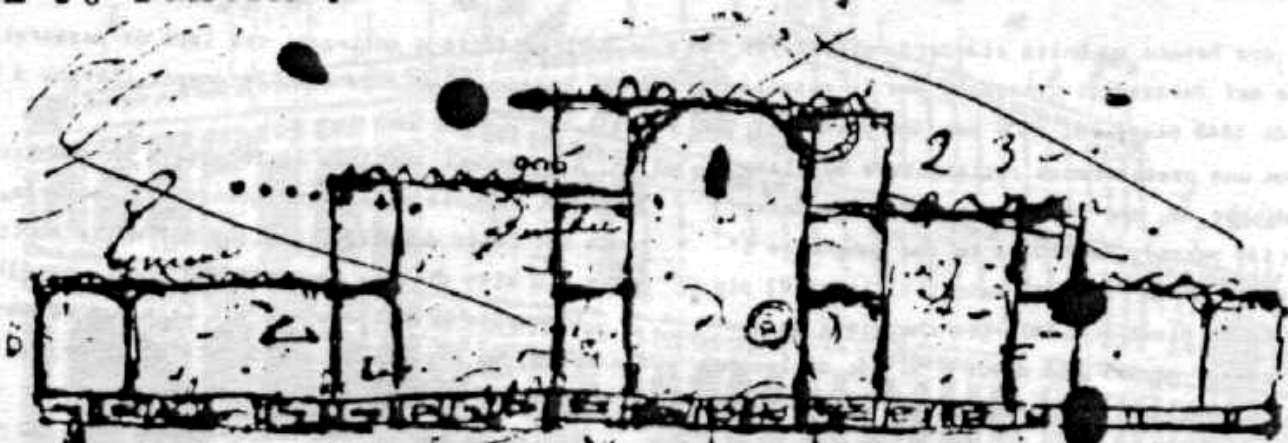
Sir Joseph Paxton
British Gardener
1803 - 1865

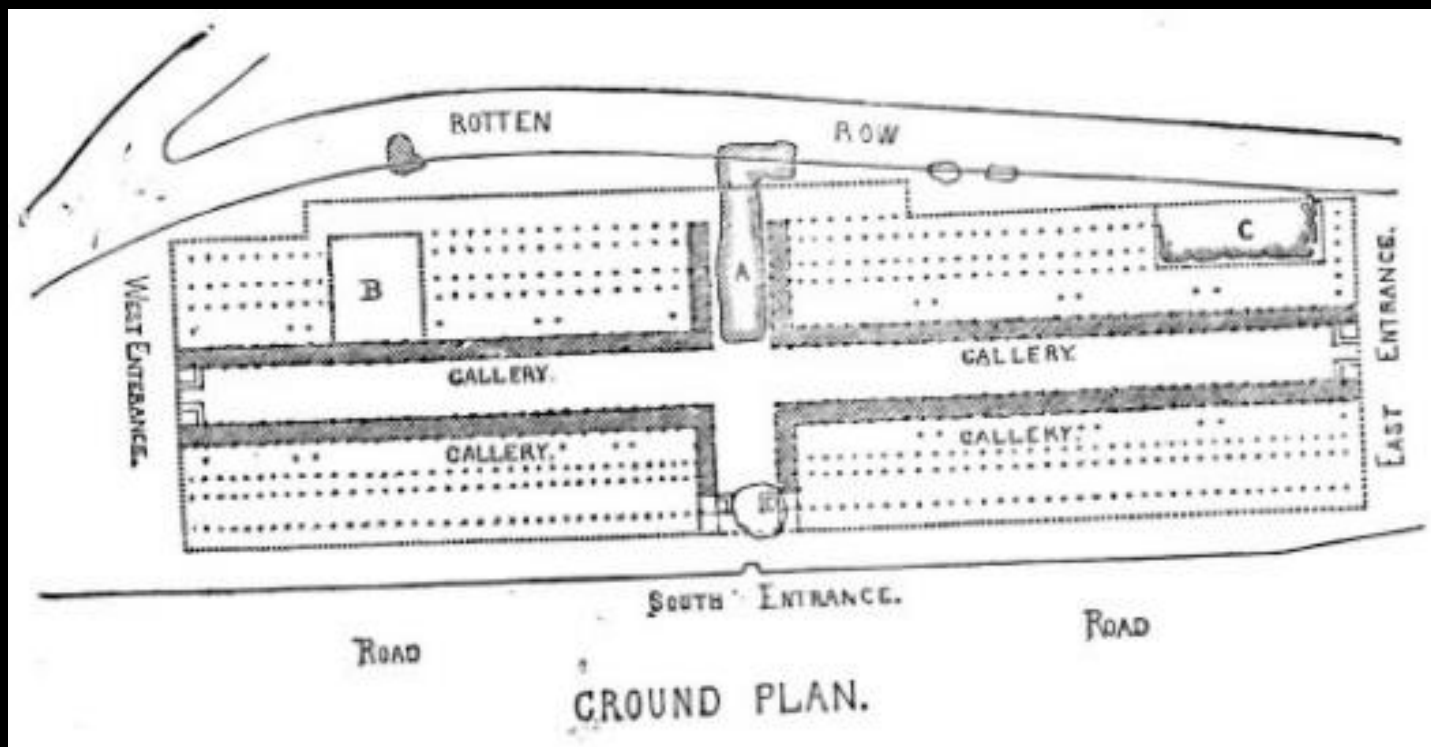


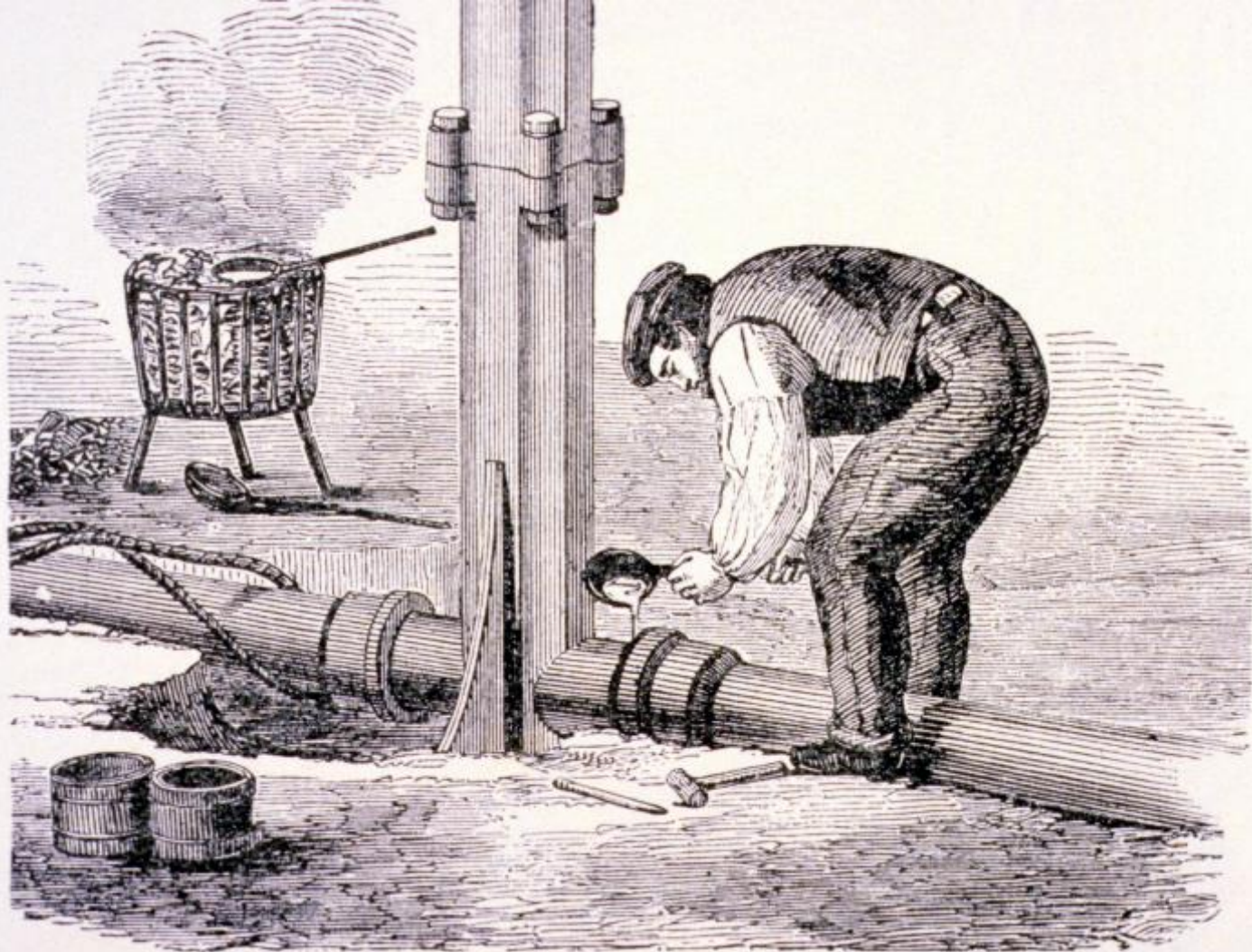
THE NEW VICTORIA REGIA HOUSE.—EXTERIOR.

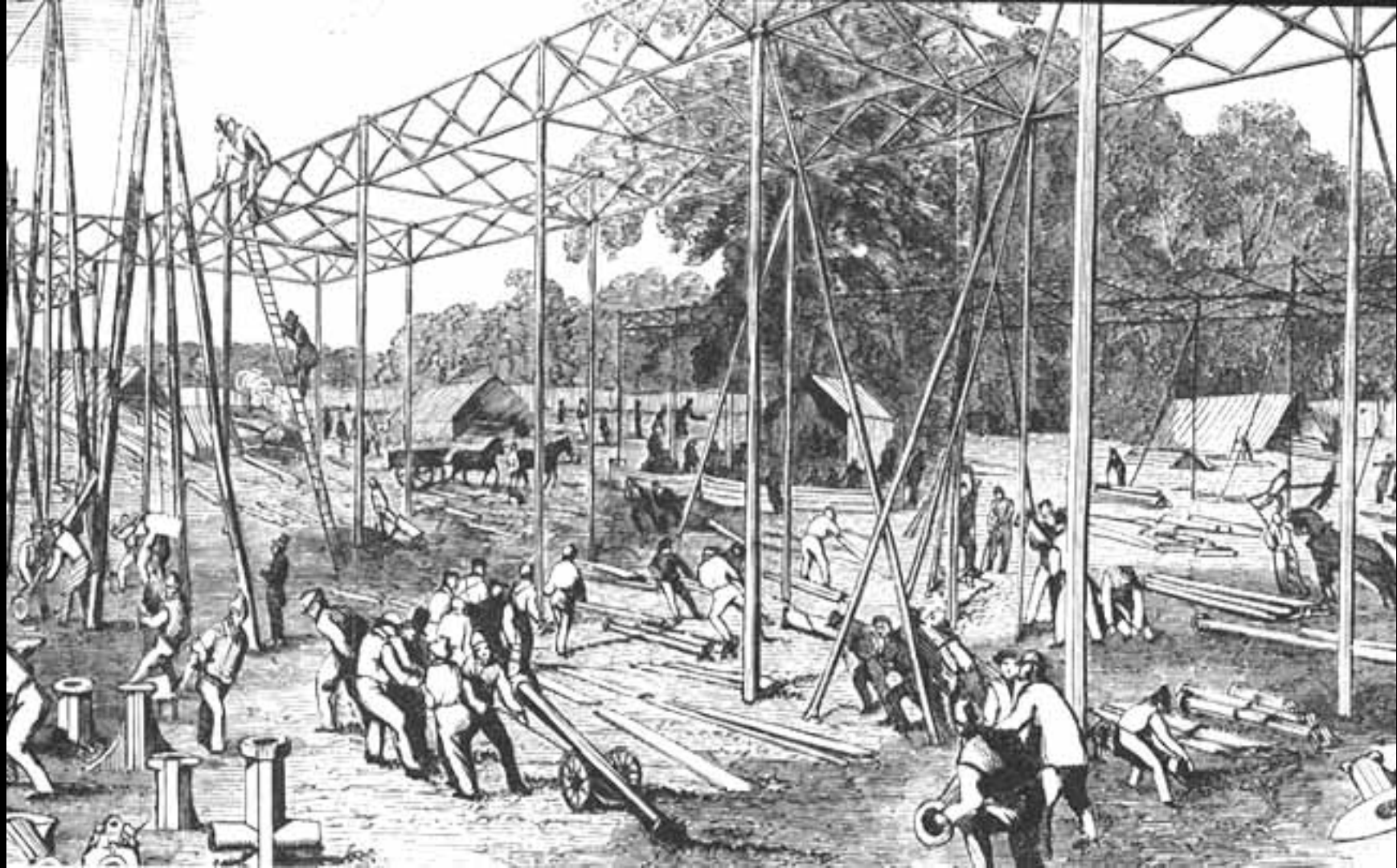


The Great Exhibition 1851
Hyde Park, London, England
Sir Joseph Paxton



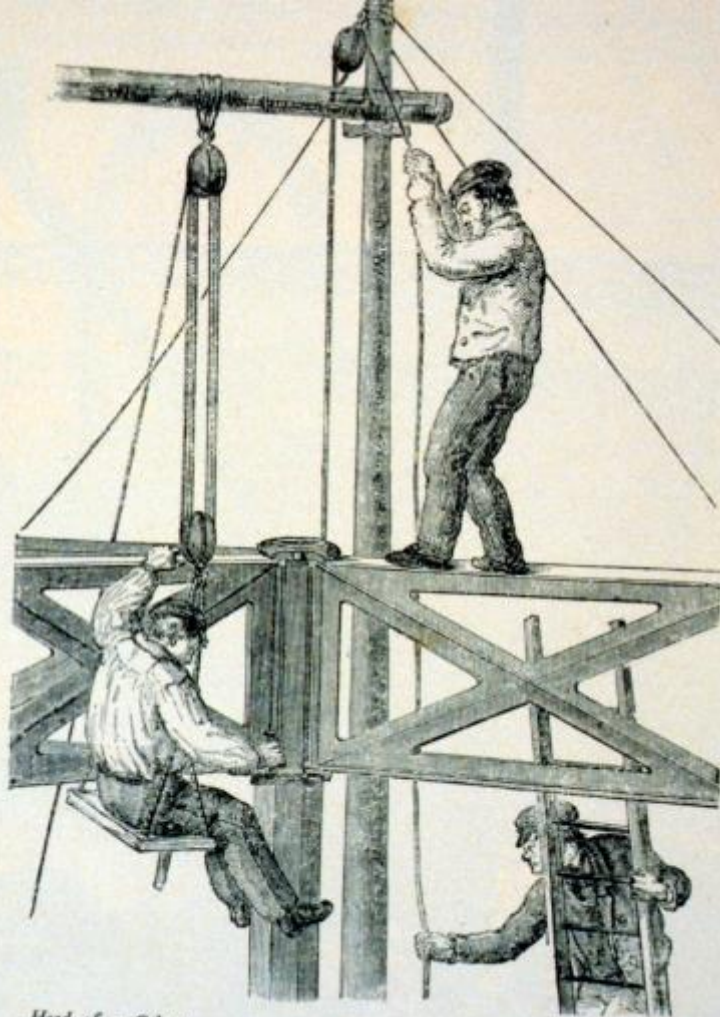




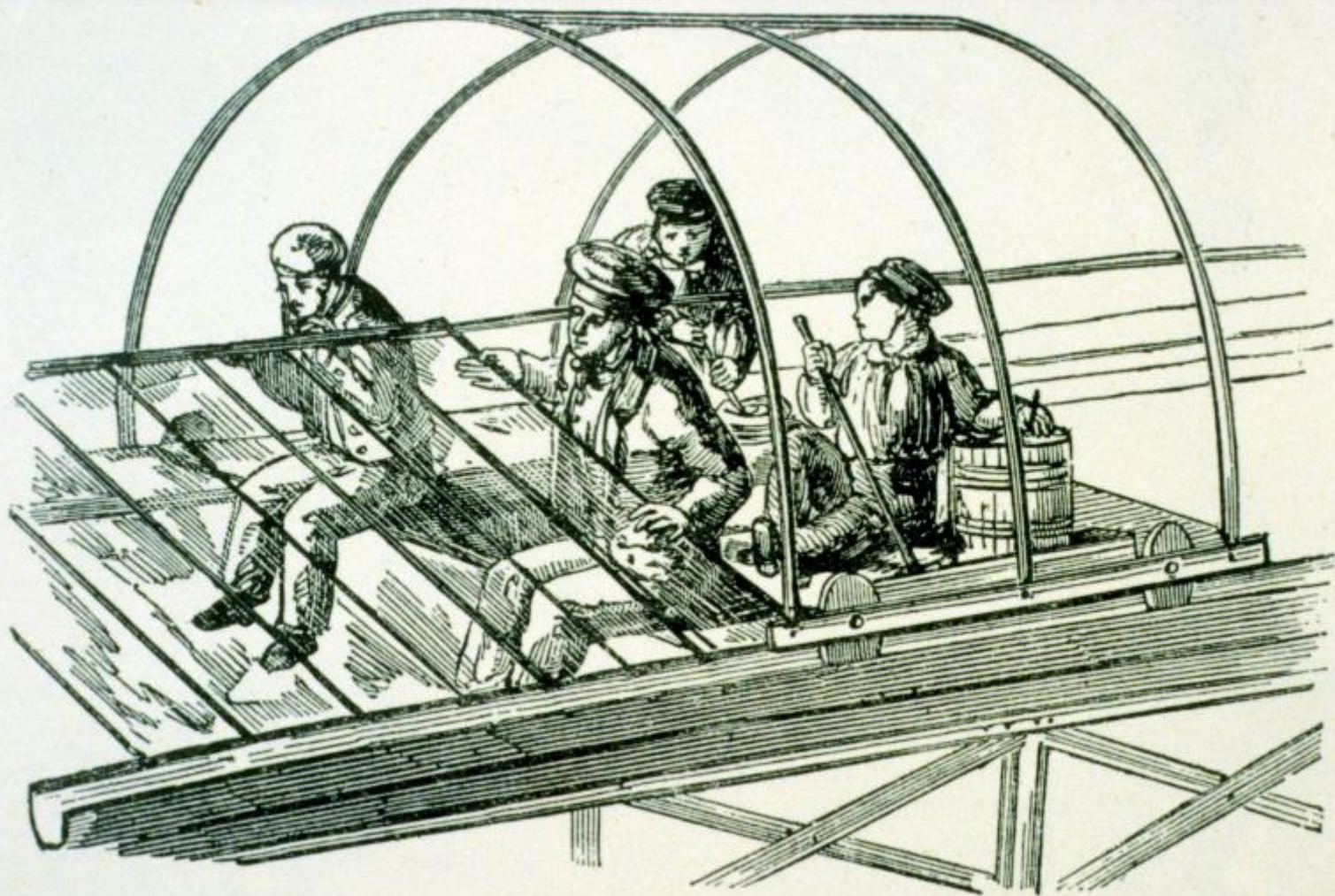








Head of a Column.



Glazing Waggon.



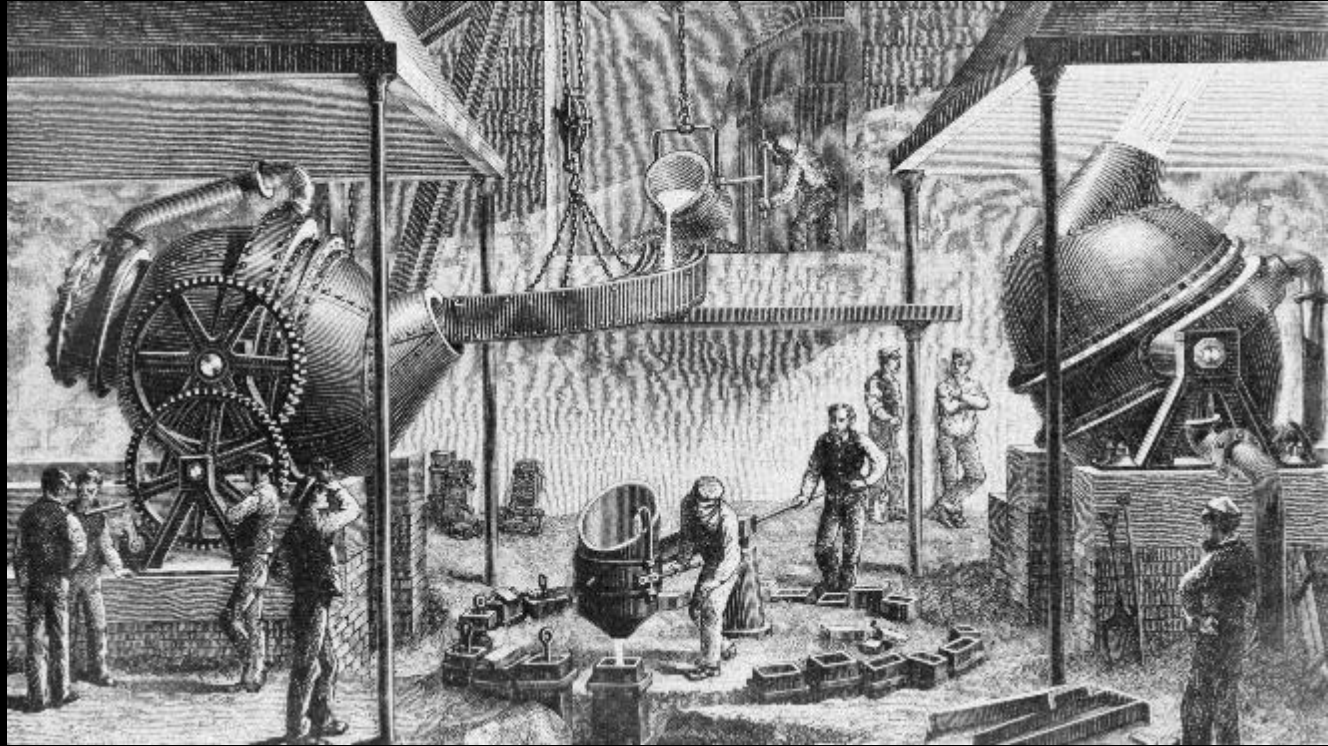


Bessemer Process

~noun *metallurgy*

A process of producing steel in which impurities are removed by forcing a blast of air/oxygen through molten iron

[Origin: 1855-60;
after Sir Henry
Bessemer]



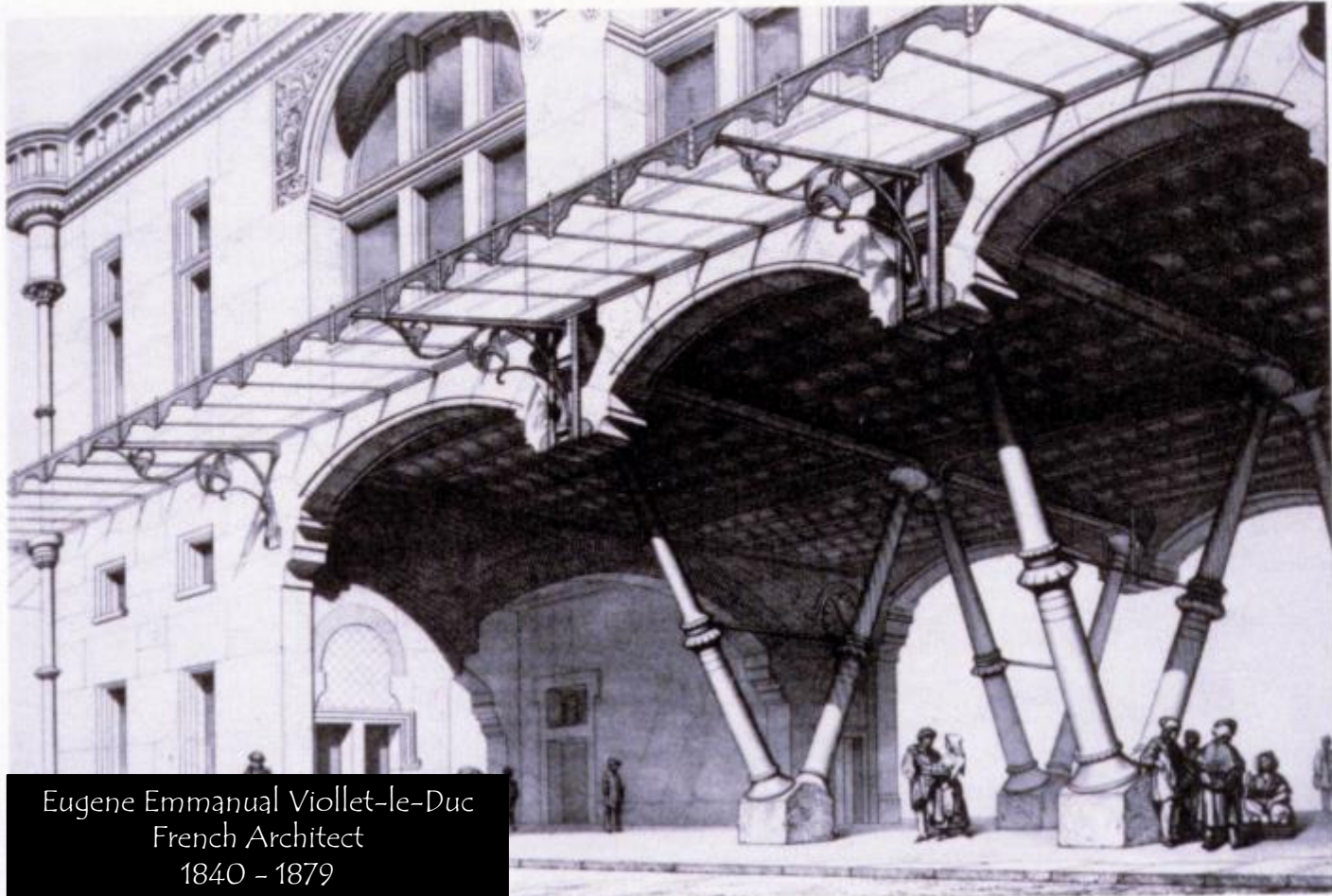
<https://dozr.com/blog/bessemer-process>



Paris Metro Entrances
Hector Guimard
1900 to 1913
Art Nouveau Style







Eugene Emmanuel Viollet-le-Duc
French Architect
1840 - 1879

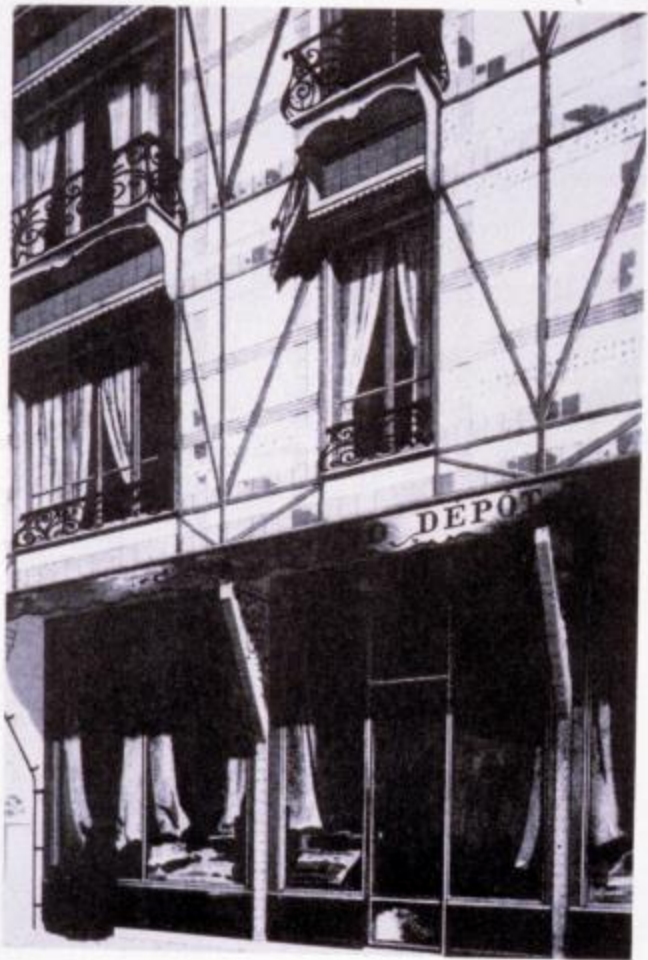


Plate 64. Eugène Viollet-le-Duc. Unpretentious shop and apartment building, 1863 (Viollet-le-Duc, *Atlas*, p. 36)

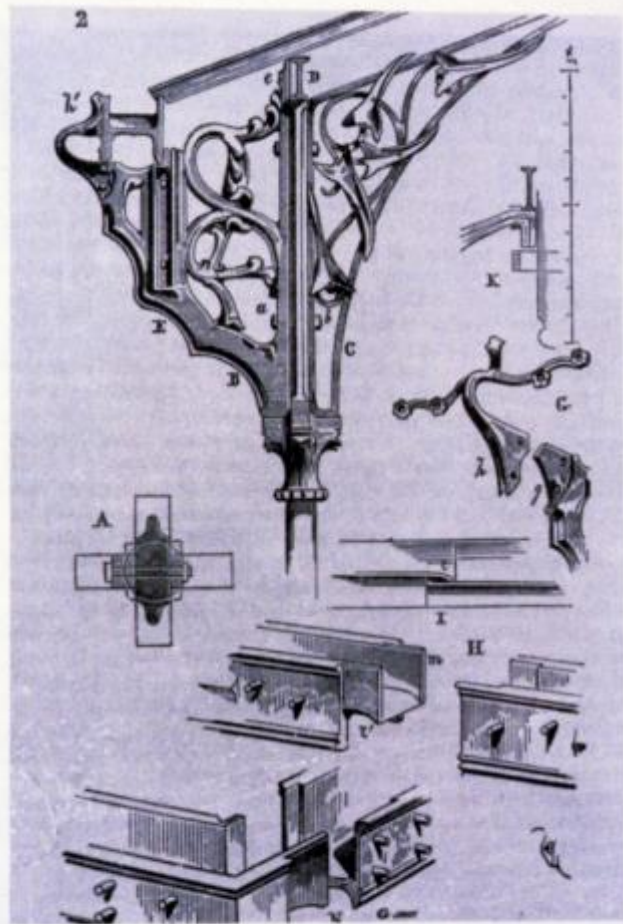


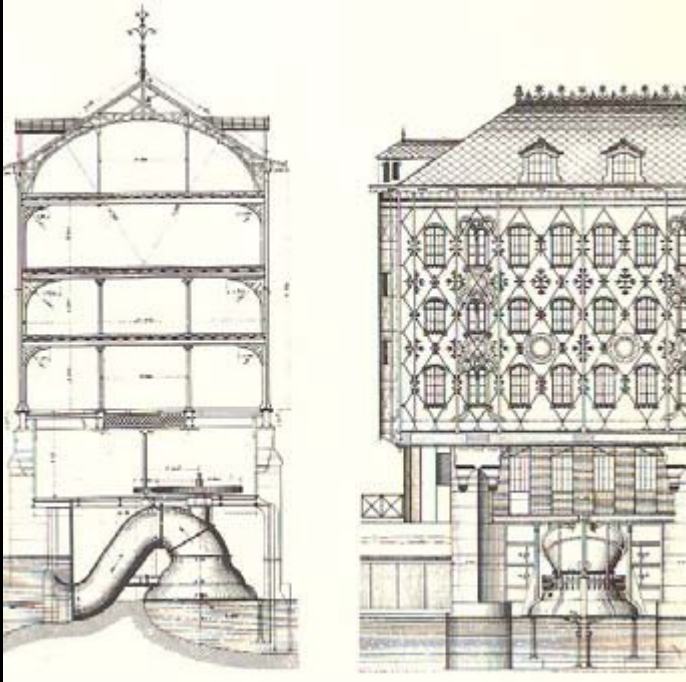
Plate 49. Eugène Viollet-le-Duc. Project for an Hotel de Ville (Viollet-le-Duc, *Lecture XIII*, p. 125)



Menier Chocolate Factory
Noisiel sur Marne, France
Jules Saulnier
1872

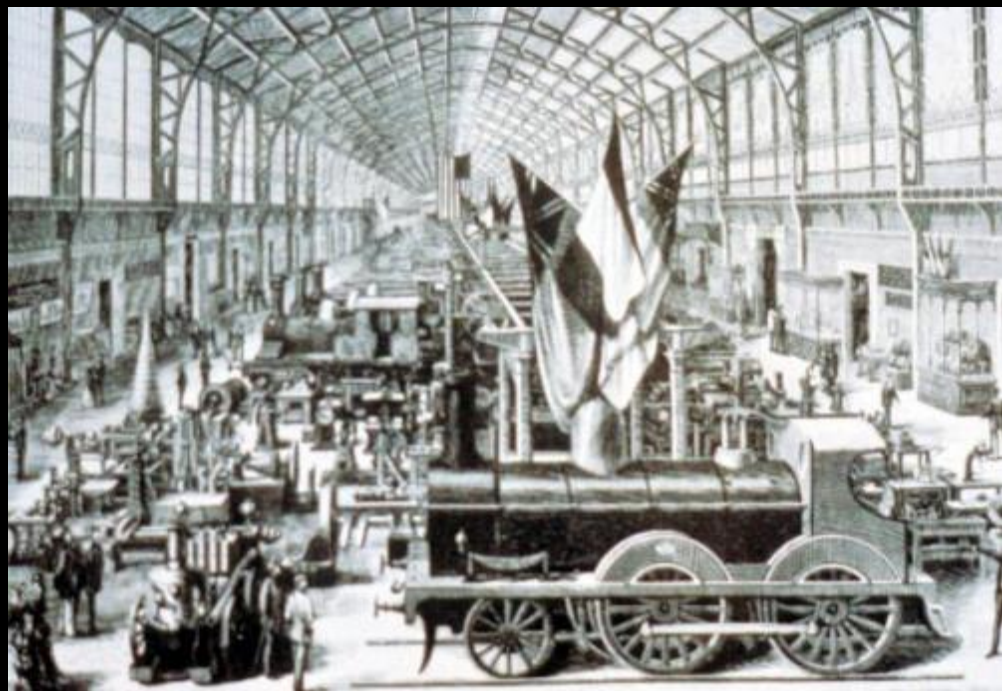


Looking for larger clear SPANS to accommodate industrial processes/machines

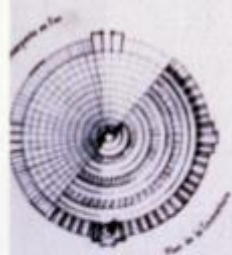


Exhibition Buildings





Plan Circulaire



Plan Elliptique

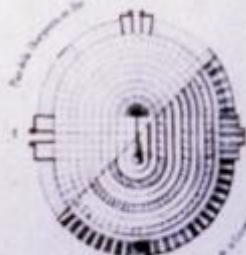


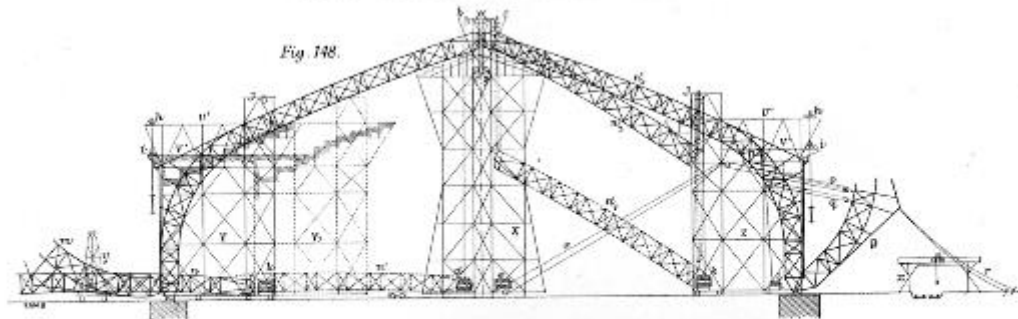
Plate 41. Paul Goussier. Project for the International Exhibition Building of 1867, published in 1865 (Goussier, pl. 1)

528. PARIS — Galerie des Machines C. L. C.



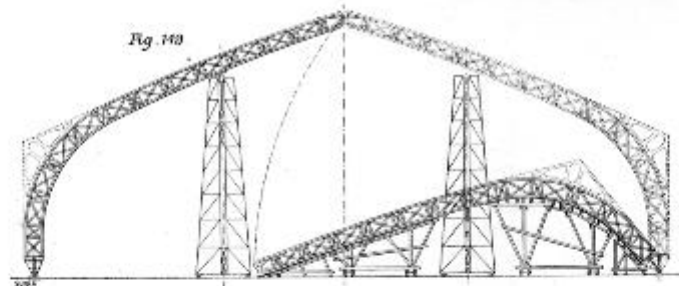
Galerie des Machines
Exposition Universale
Paris, France
Victor Contamin Engineer
1889

Fig. 148.



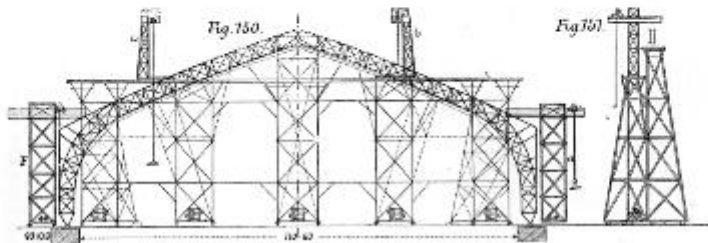
MODE OF ERECTING MACHINERY HALL ROOF; THE FIVES LILLE COMPANY. (See page 457.)

Fig. 149.



PROPOSED MODE OF ERECTING MACHINERY HALL ROOF. (See page 457.)

Fig. 150.



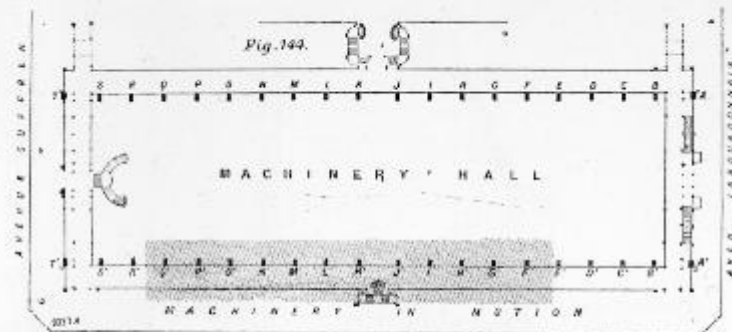
MODE OF ERECTING MACHINERY HALL ROOF; H. M. GAIL ET CIE. (See page 458.)

Fig. 151.



THE MACHINERY HALL.

Fig. 144.



PLAN SHOWING POSITION OF PIERS AND STAIRCASES. (See page 453.)



Fig. 145.

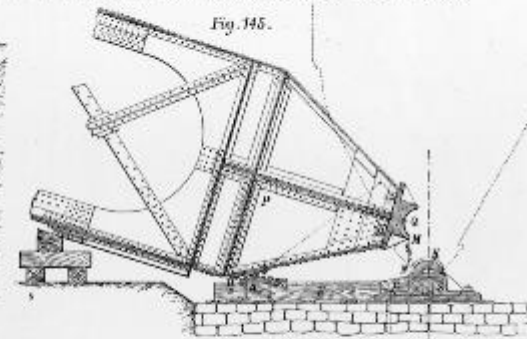
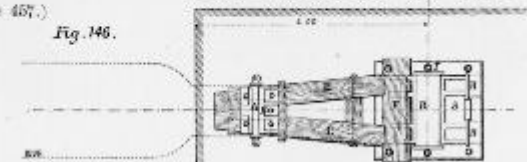
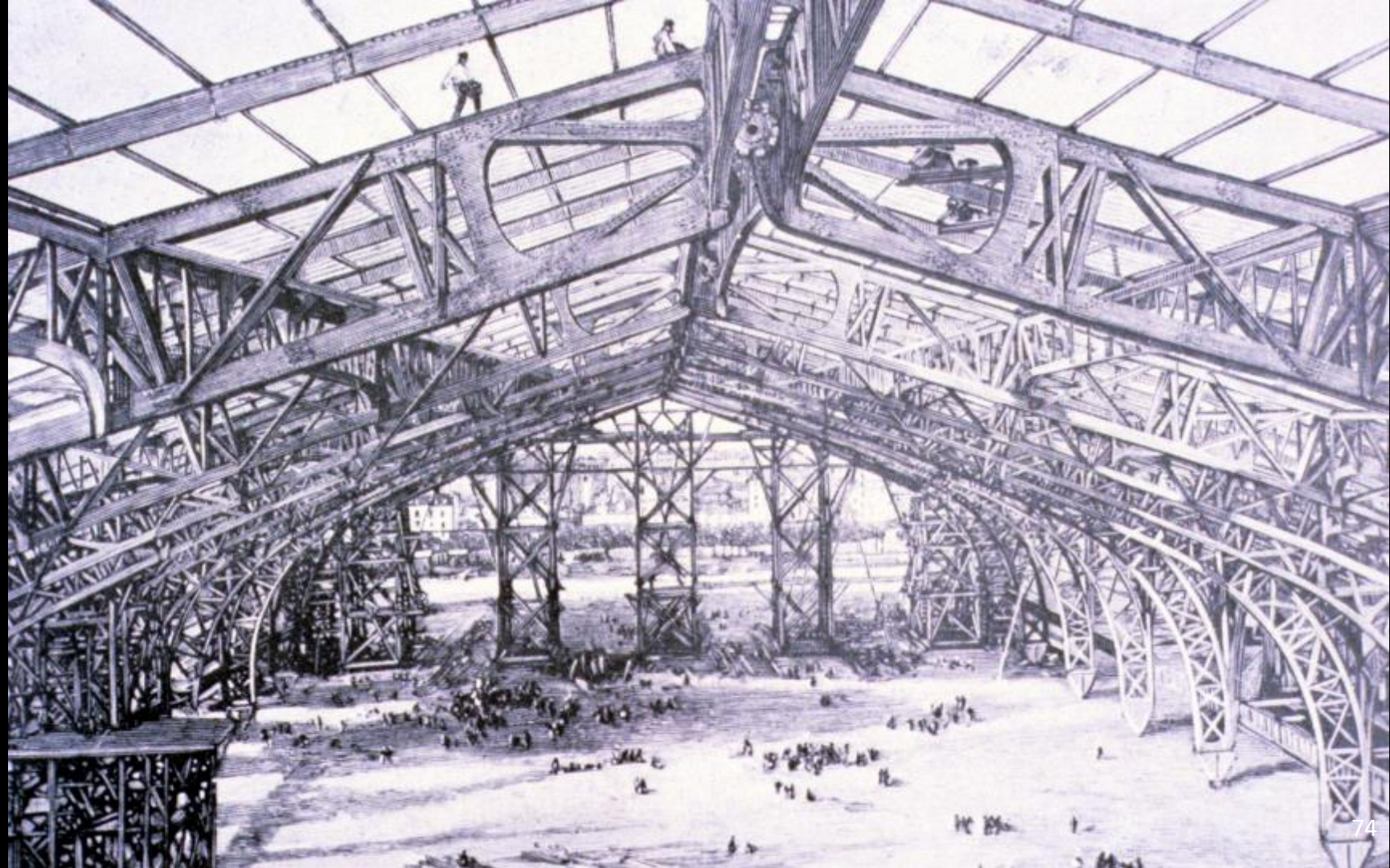


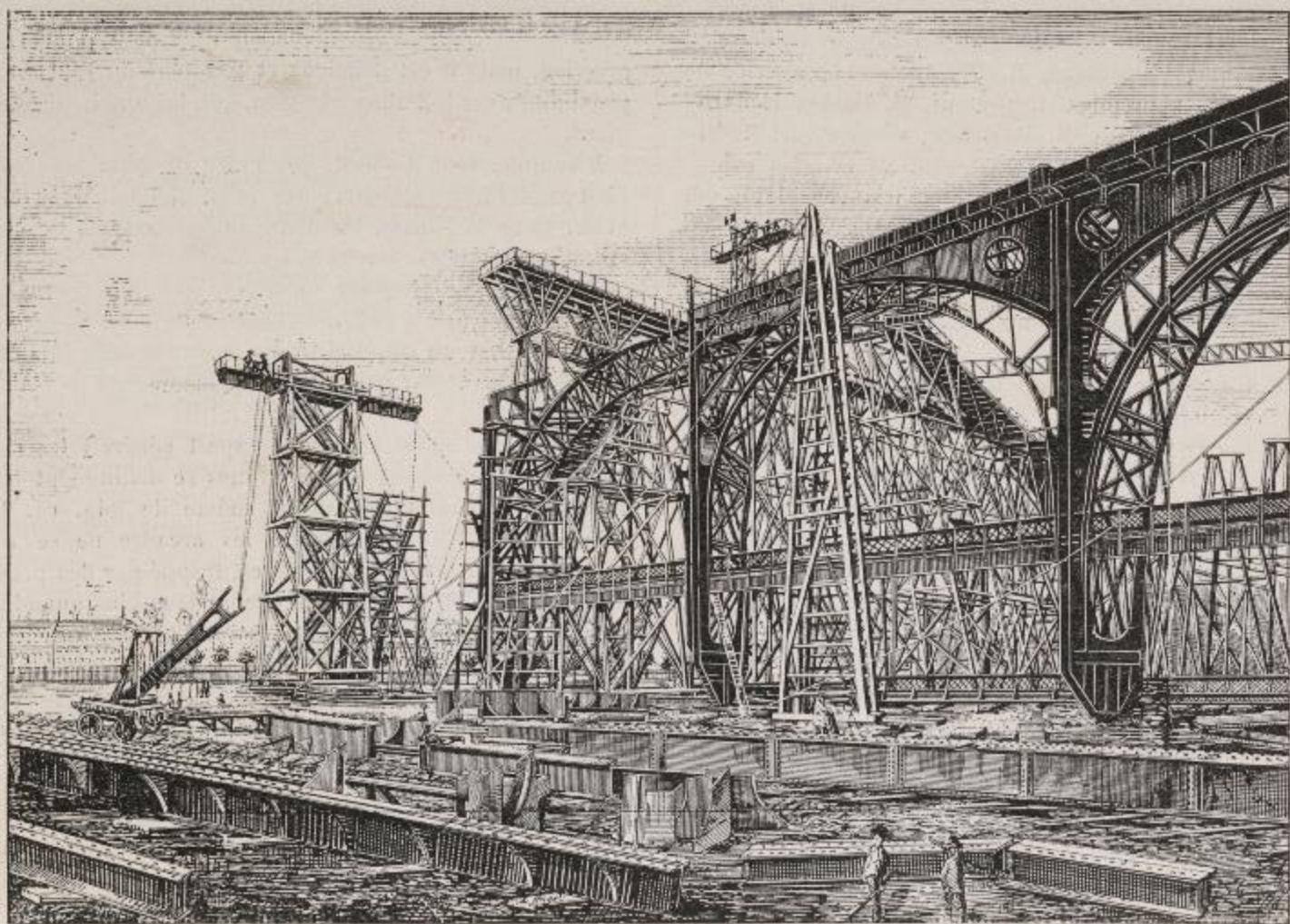
FIG. 147. (See page 457.)

Fig. 146.

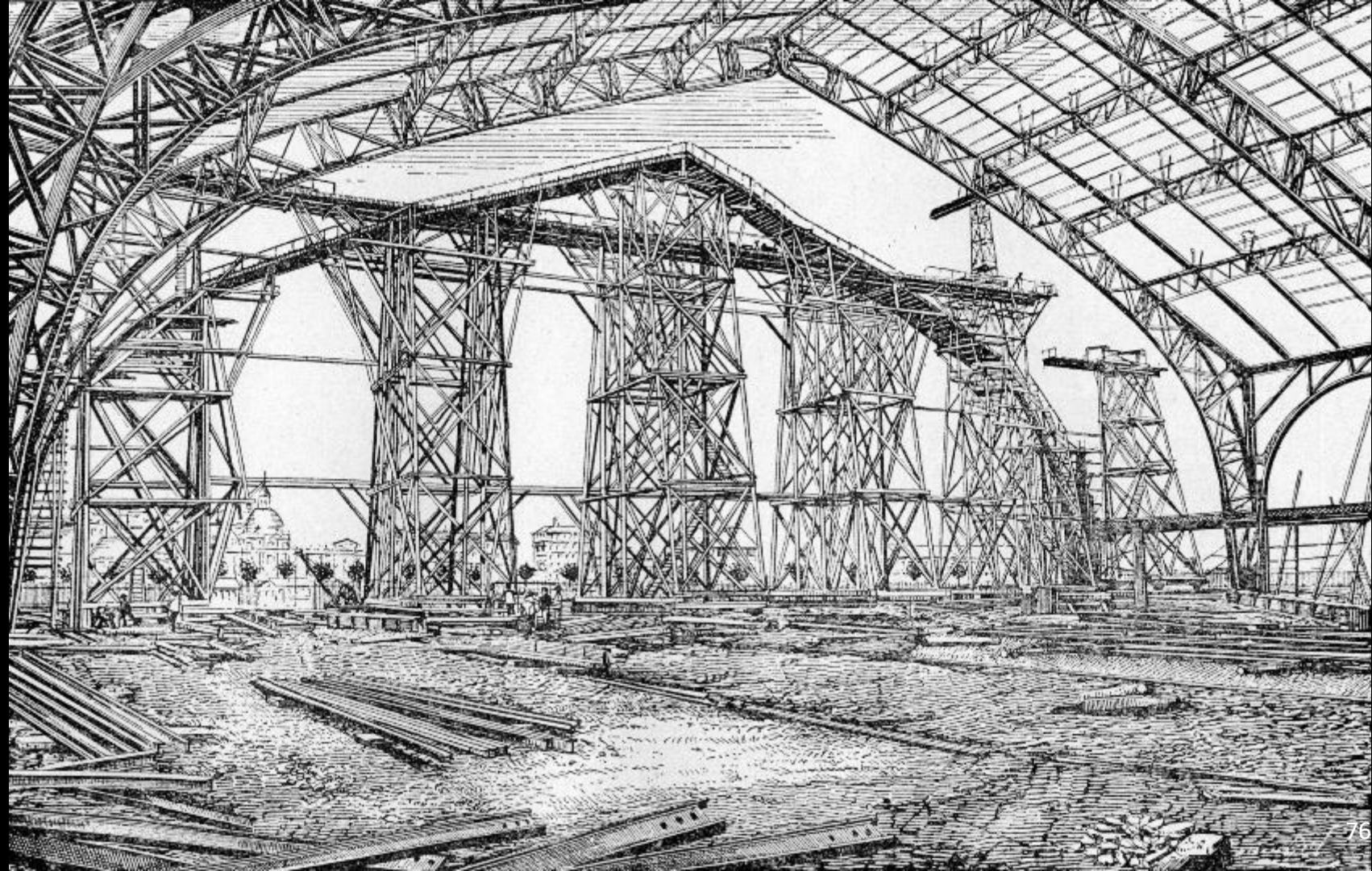


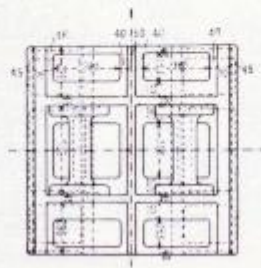
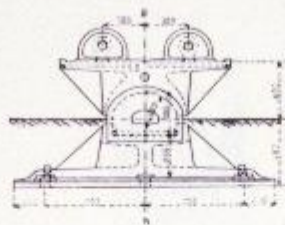
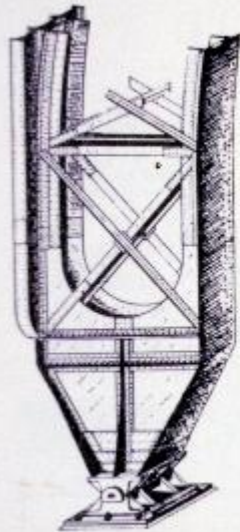
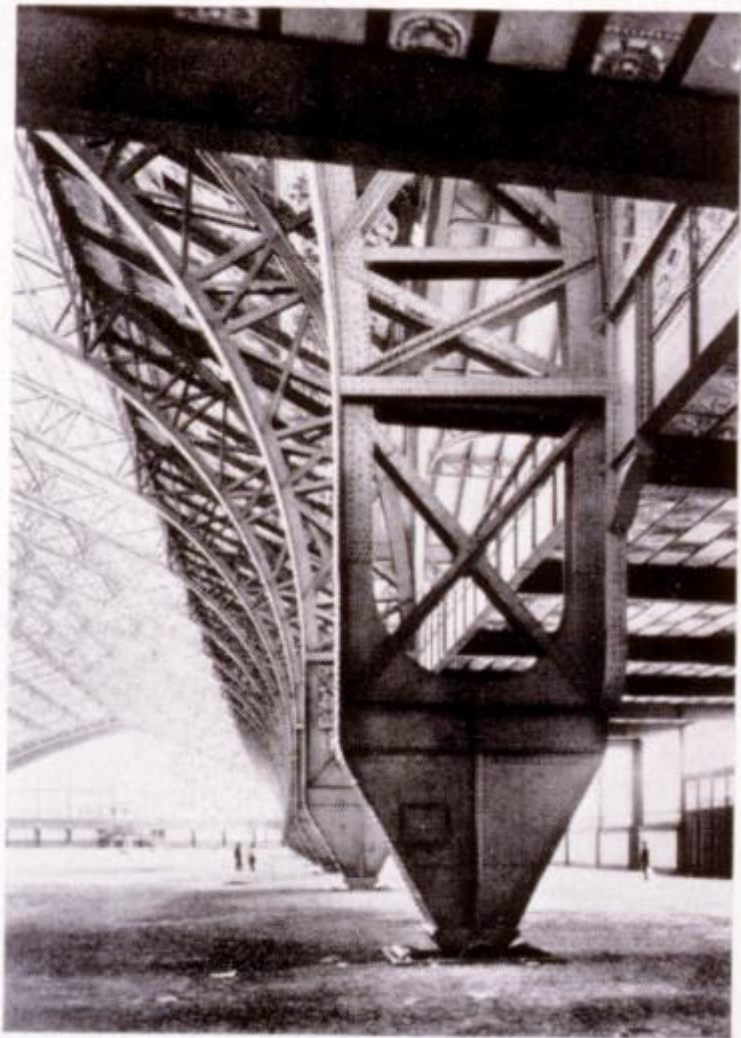
MODE OF ERECTING PRINCIPALS. (See page 458.)





Le montage des grandes fermes de la Galerie des Machines.





14 Contamin and Dutert,
Galerie des Machines, Paris, 1887-89.
Detail of the hinged supports.

706. - PARIS. - La Galerie des Machines (VII^e). - G. I.







Eiffel Tower
Great Exposition 1889
Paris, France
Gustav Eiffel
324m

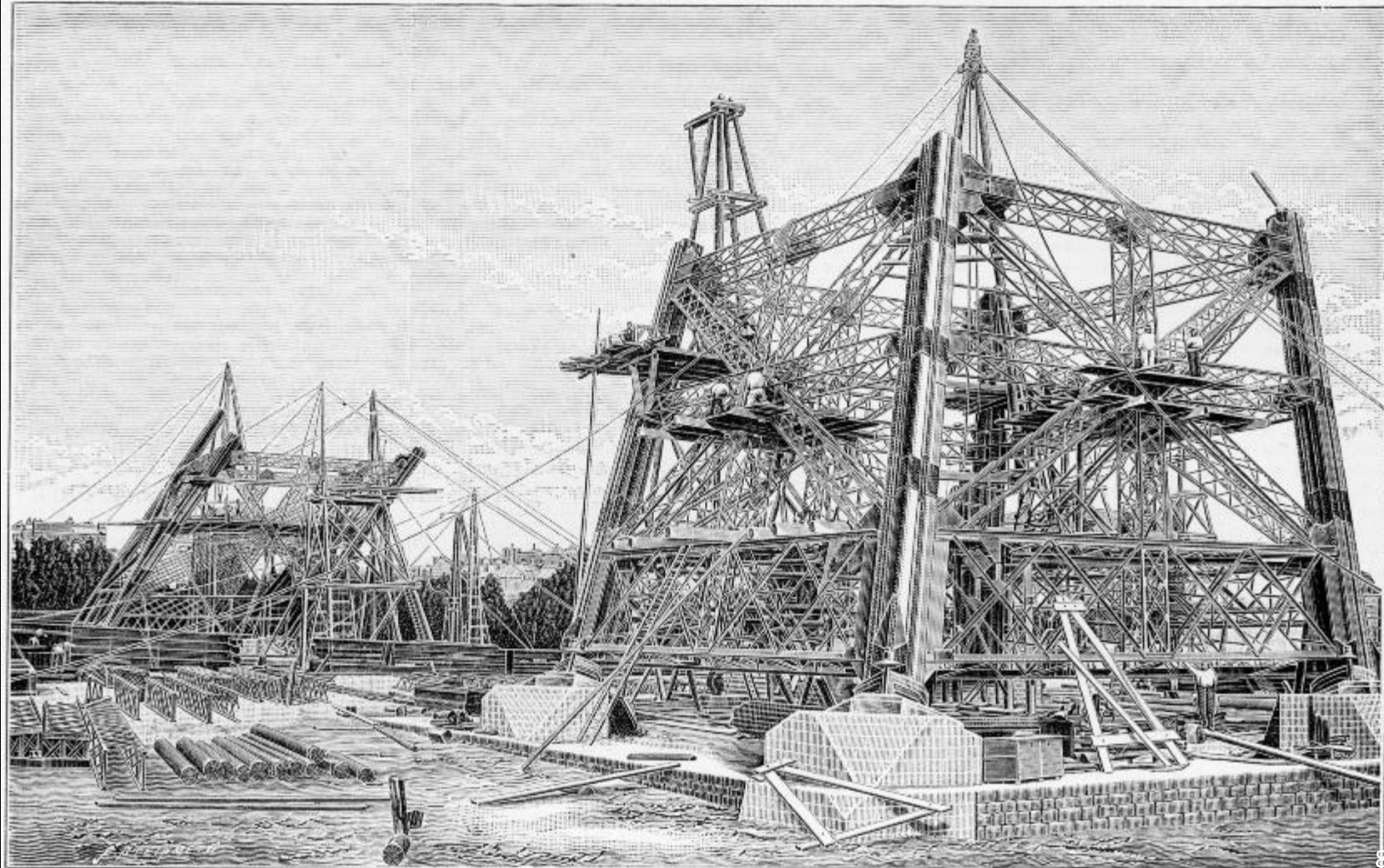


FIG. 37. THE EIFFEL TOWER, COLUMN NO. 4; SEPTEMBER, 1887.

















Grand Palais des Champs Elysees
Universal Exposition of 1900
Paris, France
1900







Train Stations and Railroads

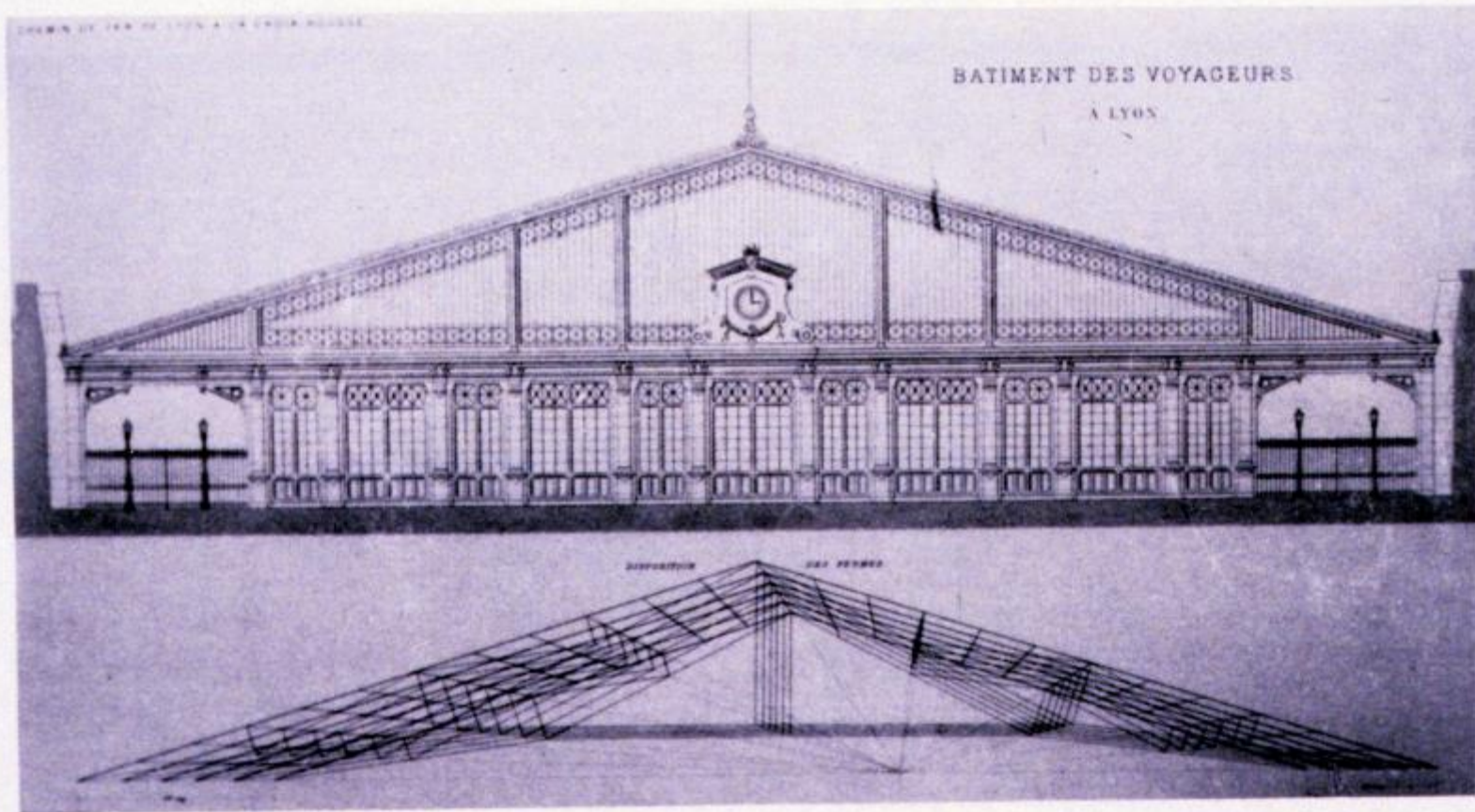


Plate 13. François Cendrier and A. Julien. Gare de Perrache, Lyon, 1855 (*Révue générale de l'architecture*, XVIII, pl. 17)



Paddington Station
London, England
Isambard Kingdom Brunel Engineer
1838









St. Pancras Station
London, England
William Henry Barlow Architect
1868





Kings Cross Station
London, England
George Turnbull and Lewis Cubitt
1852





Liverpool Street Station
London, England
1874



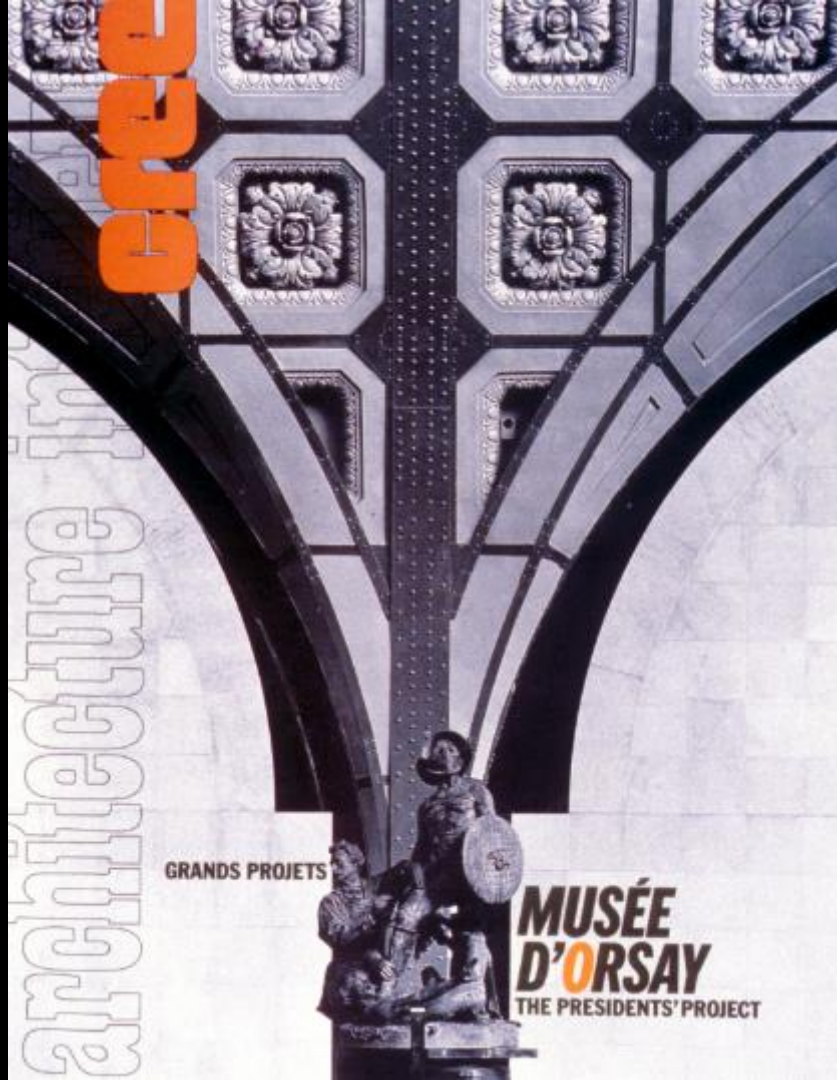






Gare d'Orsay
Victor Laloux, Lucien Magne and Emile Benard
Paris, France
1900
Renovated to Musee d'Orsay
Gae Aulenti Architect
1986





Orsay

architecture in

GRANDS PROJETS

**MUSÉE
D'ORSAY**
THE PRESIDENTS' PROJECT

















Steel/Iron and Glass

Atrium Roofs

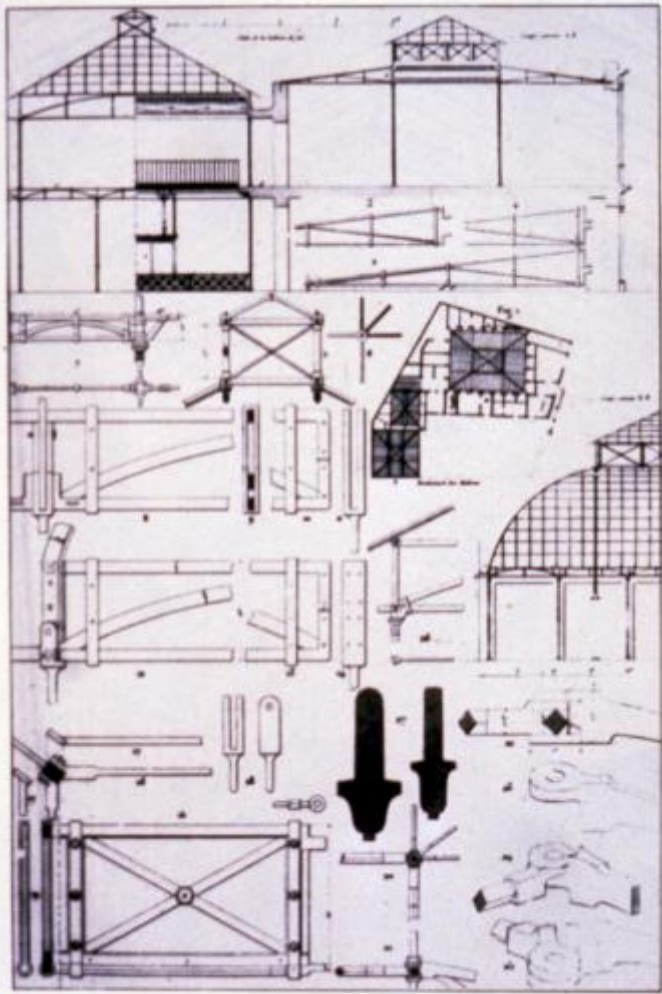
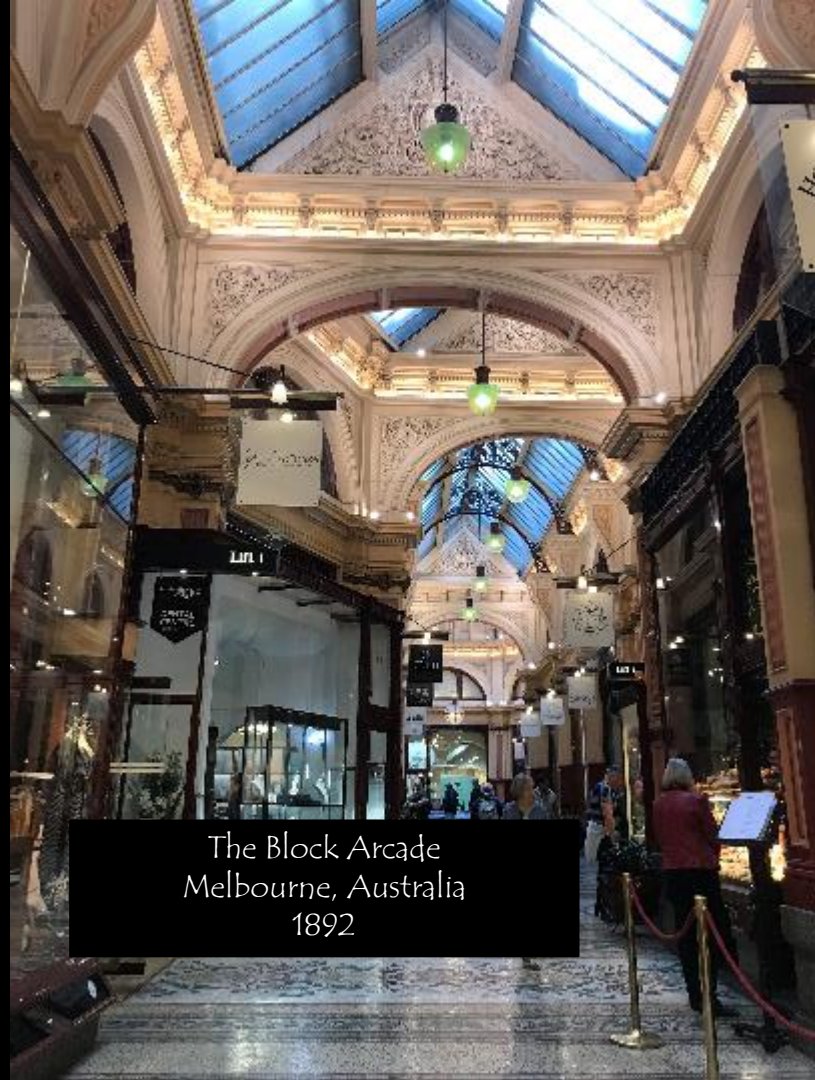


Plate 20. Tavernier. Galerie de Fer, Paris, 1829 (Thiollet, 1832, pl. 26)



Plate 19. Passage des Princes, Paris, 1860 (Frances H. Steiner)



The Block Arcade
Melbourne, Australia
1892







Galeries Lafayette
Paris, France
Georges Chedann Architect
Art Nouveau Style
1912

Glass by Tiffany













Gran Hotel Ciudad de
Mexico
Mexico City
Art Nouveau
1899

Glass by Tiffany














The image shows the exterior of The Rookery building in Chicago. The central focus is a large, ornate stone archway made of reddish-brown granite. The arch is filled with intricate carvings of floral and geometric patterns. Below the arch is a glass-enclosed entrance with wooden frames. To the left and right of the arch are windows with blue signage for 'BROTHERS' and 'usbank'. Two people are walking on the sidewalk in front of the building. A black text box in the bottom left corner contains the following information:

The Rookery
Chicago, Illinois, USA
Burnham and Root
1891
Glass Court
Frank Lloyd Wright
1905











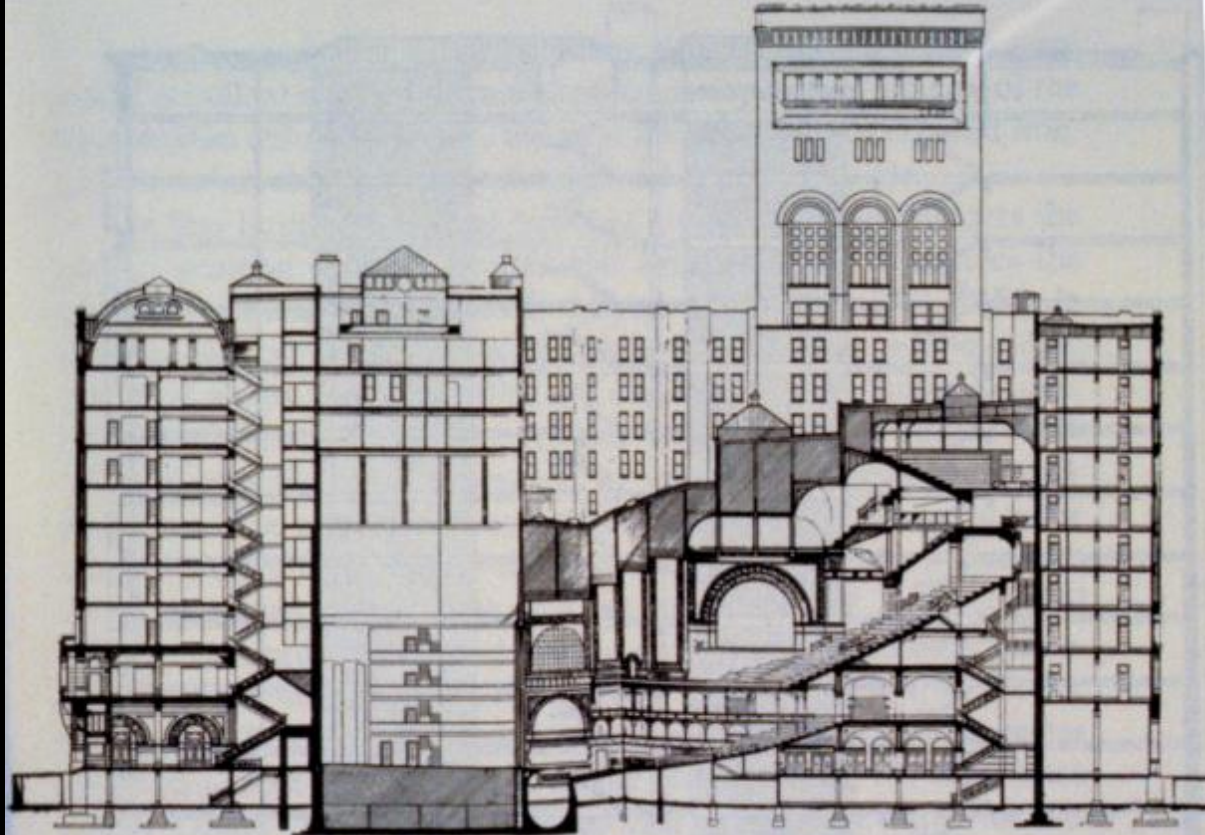
Steel Framing
–
Multi-storey buildings
to
Skyscrapers



Auditorium Building
Dankmar Adler & Louis Sullivan
Chicago, Illinois, USA
1889



40. Auditorium Building, Chicago, Ill., 1887-89. Adler and Sullivan, architects. Longitudinal section. The interior framework of the Auditorium embraced every structural technique in iron available at the time.





William Le Baron Jenney
Architect and Engineer
Father of the Skyscraper
1832 - 1907

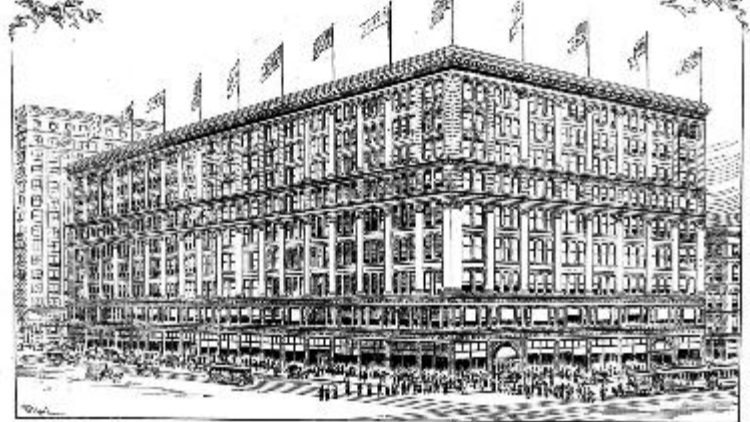
*The Fair, Department Store, Chicago
State and Adams Streets*



The Fair Store
Chicago, Illinois
William Le Baron Jenney
1874



THE FAIR



THE LARGEST AND GRANDEST STORE IN THE WORLD, NOW BEING RAPIDLY PUSHED TO COMPLETION,

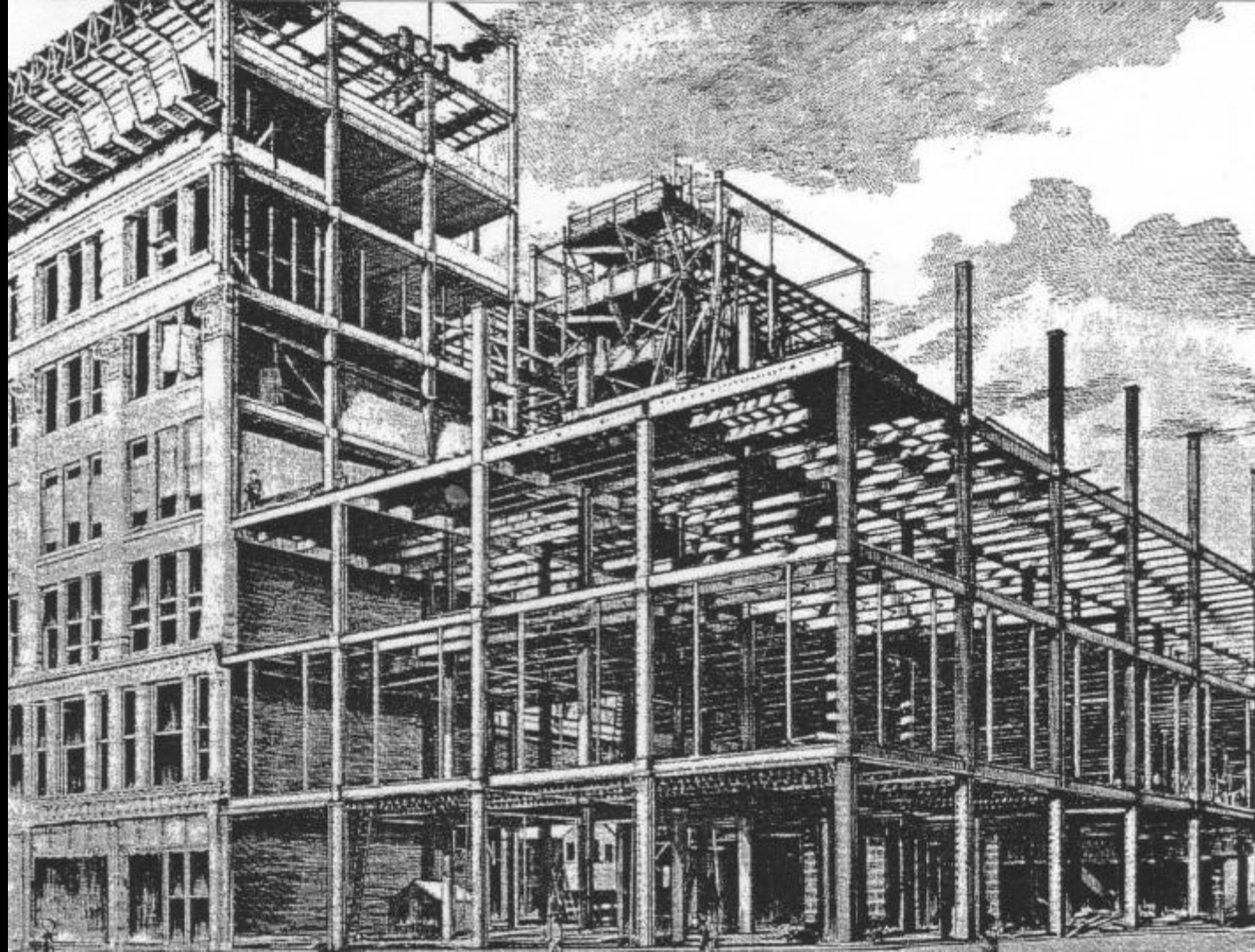
to occupy 10,366,750 CUBIC FEET—677,600 SQUARE FEET, OR OVER 1.5% ACRES OF SPACE—730 FEET FRONTAGE—a marvel of Chicago push, pluck, and enterprise—grown from an acorn to the mightiest oak—a success merited and won by always keeping faith with the people—selling goods cheaper—liberal methods—square, upright dealing—and truthful advertising. In 1875, with a capital of less than one thousand dollars, The Fair began business in the little 10x20 store, as shown in cut. It immediately grew in popular favor—because it sold goods cheaper than others—abundantly, constantly we forged ahead—winning to win the people's confidence—serving with might and main to sell more so we could sell cheaper. In five years an immense business had been established—which has now grown to such proportions as to compel the necessity of erecting the above magnificent structure—unrivalled anywhere on earth—a store which shall not only be the largest, but in every way the greatest, cheapest, most satisfactory trading place in the world. A CHICAGO PRODUCT—MADE GREAT BY THE THRIFTY MONEY-SAVING PEOPLE OF CHICAGO AND VICINITY—WHO KNOW THE VALUE OF A DOLLAR AND WHERE TO GET THE MOST FOR IT.

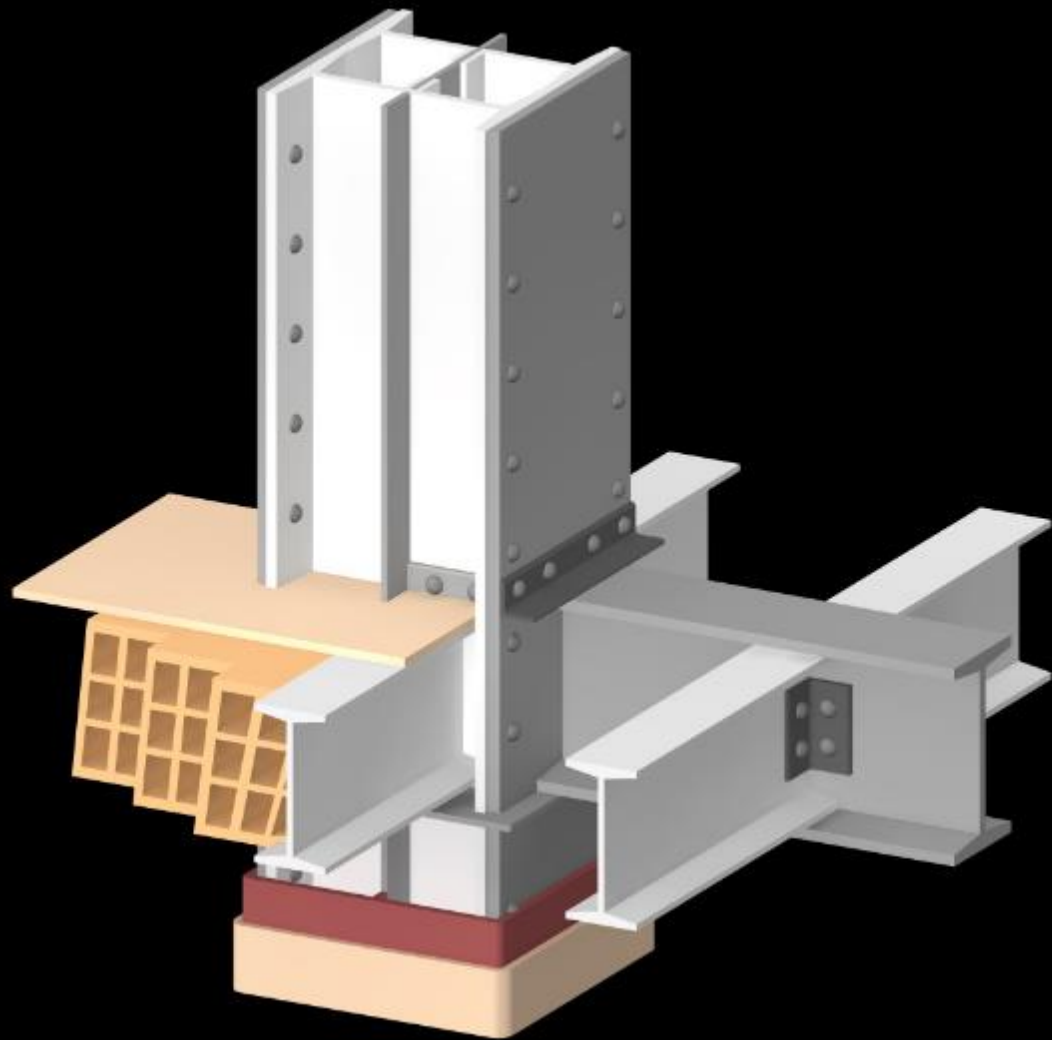


40 Bargains for Today that Explain Why The Fair Has Justly Become a Household Word for Economy.

Screen Doors Sash Doors 25c	Yards 10c	Boys' Suits 15c	Shirt Waists 15c	Boys' Suits \$1.00	Milkens 25c	Handkerchiefs 10c	Boys' 10c	Teapots 10c	Clones 10c
The Fair's 25c	Capit Saws 10c	Boys' Suits 15c	Boys' Suits \$3.75	Boys' Suits 15c	Boys' Suits \$1.00	Ladies' Suits \$5.99	Boys' 10c	Teapots 10c	Clones 10c
Skidder 15c	Boys' Suits 15c	Boys' Suits 15c	Boys' Suits \$1.00	Boys' Suits 15c	Ladies' Silk Hosiery 40c	Ladies' Suits \$4.99	Boys' 10c	Teapots 10c	Clones 10c
Synges 15c	Boys' Suits 15c	Boys' Suits 15c	Boys' Suits \$7.40	Boys' Suits 15c	Ladies' Hosiery 20c	Ladies' Suits 20c	Boys' 10c	Teapots 10c	Clones 10c

The department store was a new building type.







HOW IS This for High?

SIXTEEN STORIES,
MONADNOCK BUILDING.

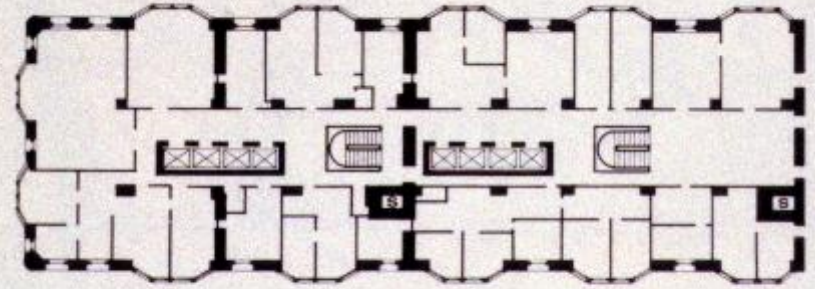
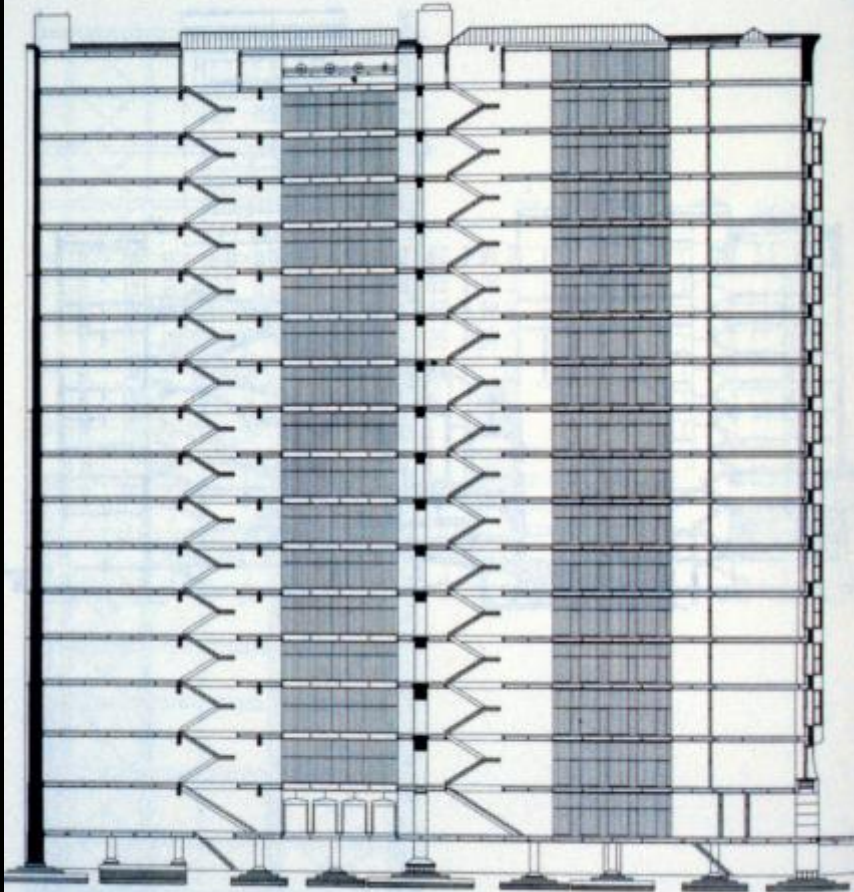
All the windows hung with the **Gardner Ribbon, Pulleys and Attachments**. Investigate, and you will use no other. Send for our new catalogue, containing half tone etchings of seventy-five of the finest buildings in the world, all using the Gardner materials: sent free if you mention the **SCIENTIFIC AMERICAN**.

GARDNER
Sash Balance Co.

First Nat'l Bank Bldg.,
CHICAGO, ILL.

Monadnock Building (north
half)
Chicago, Illinois
Burnham & Root
1891

41. Monadnock Building, Chicago, Ill., 1889-91. Burnham and Root, architects. Longitudinal section. The heavy masonry walls were already out of date in Chicago by the time John Wellborn Root designed this architectural landmark, but the interior iron frame of the Monadnock embodied the most advanced principles.



0 5 10 20

26 Root, Monadnock Block, Chicago, 1891. Typical floor plan.





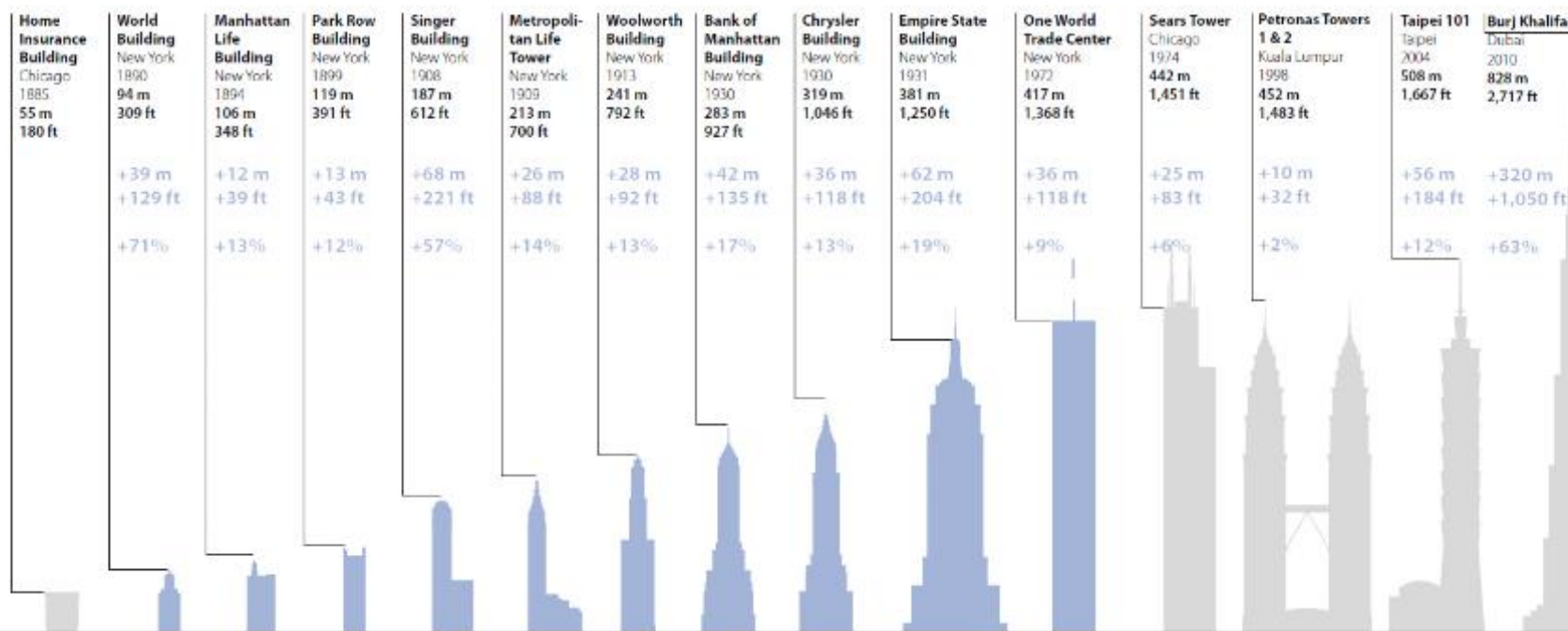




History of the "World's Tallest Building"

According to CTBUH Height Criteria: Height to Architectural Top

● NYC Buildings ● Non-NYC Buildings





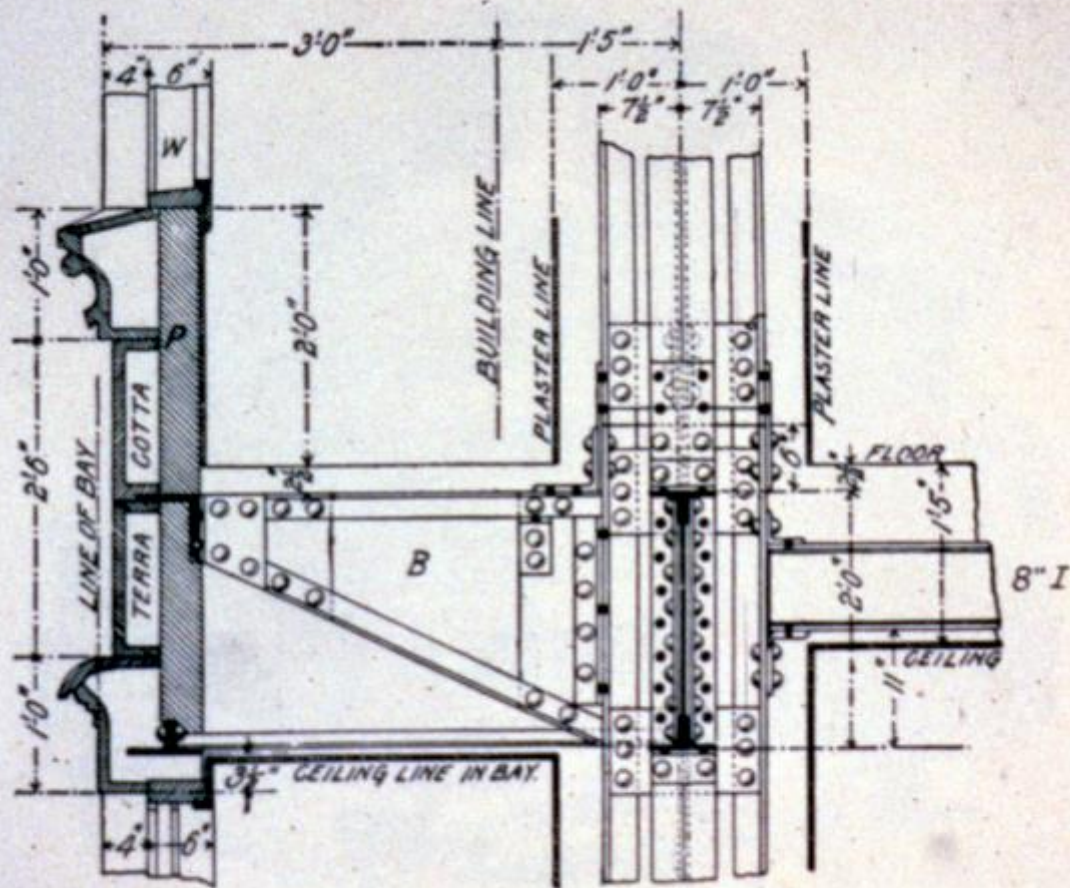
2 storey addition

Original 10 storey height

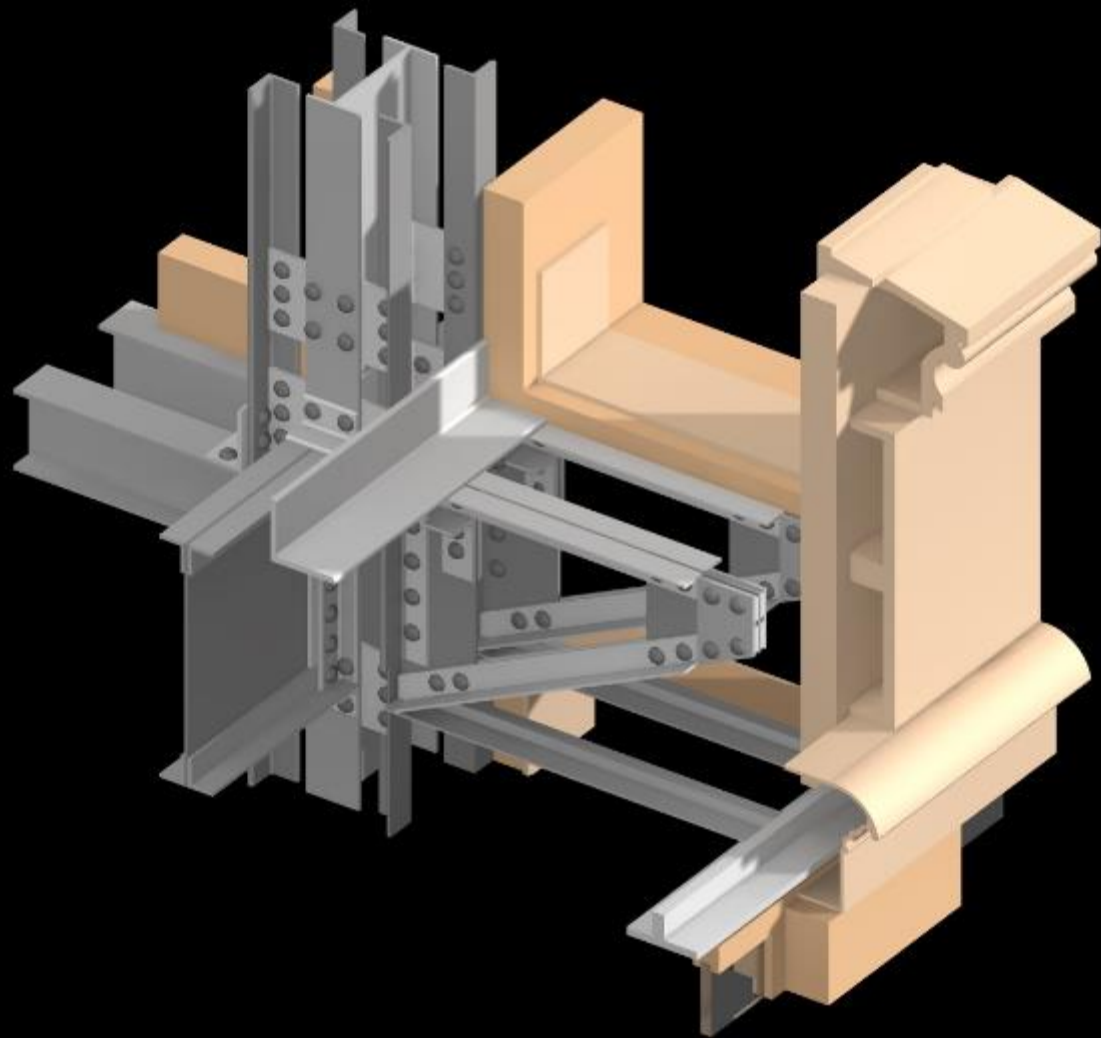
Home Insurance Building
Chicago, Illinois
William Le Baron Jenney
1885



Reliance Building
Chicago, Illinois
Burnham, Root & Atwood
1895
First real curtainwall skyscraper



27 Atwood and Burnham, Reliance Building,
Chicago, 1890/94-95. Cross section of window bay.

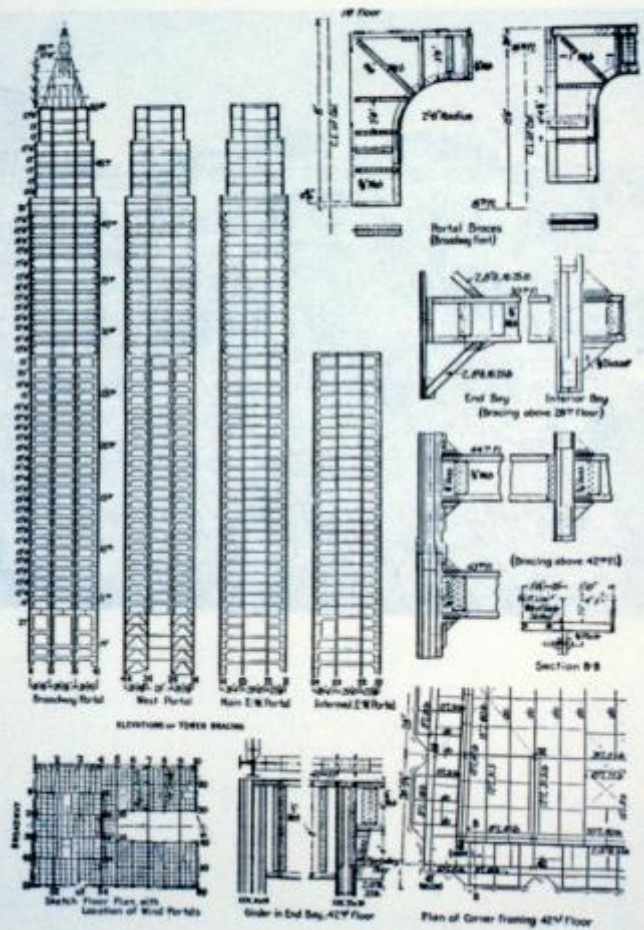








67. Woolworth Building, New York City, 1911-13. Cass Gilbert, architect; Gunvald Aus Co., engineers. Elevations and details of the steel frame. The Woolworth was the highest building in the world at the time of its construction and was supported on the most elaborately braced steel frame.

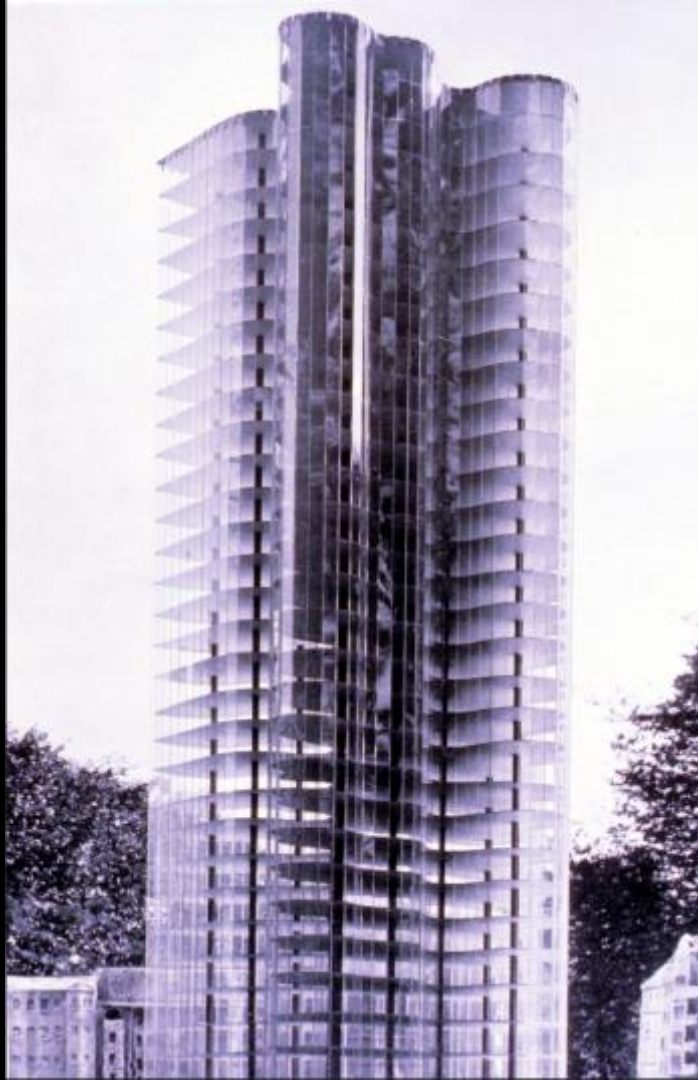


Woolworth Building
New York City, USA
1913

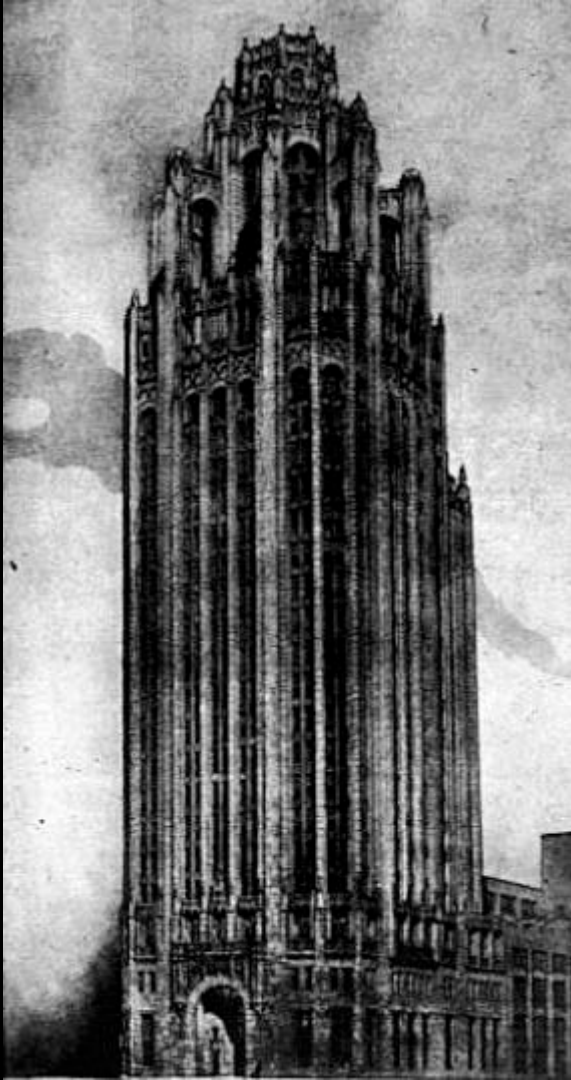


The role of the Competition in Inventing a New Typology

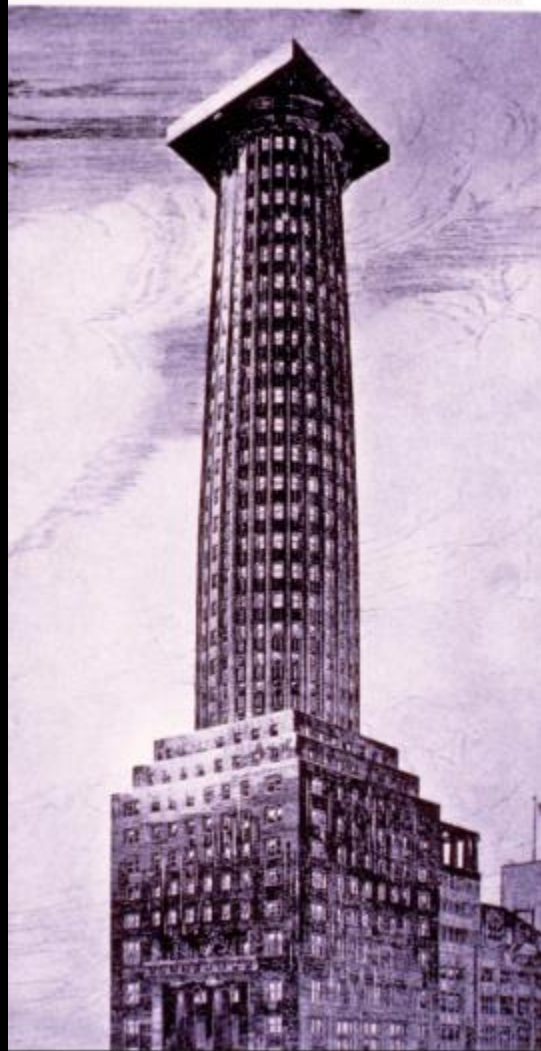
What is a Skyscraper??



Mies van der Rohe
Idea for a glass skyscraper for Berlin
1921

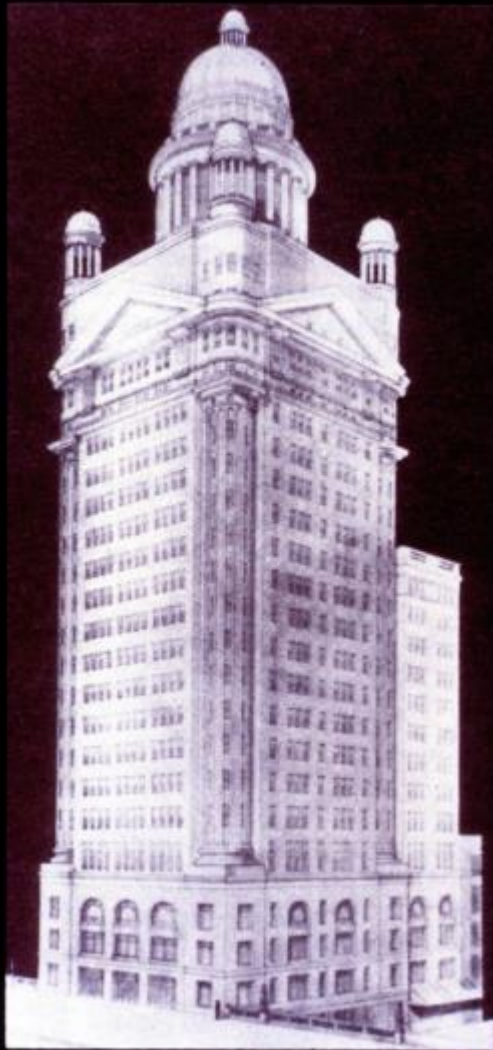


Winning Entry for the Chicago Tribune
Tower Competition 1923
John Mead Howells and Raymond Hood

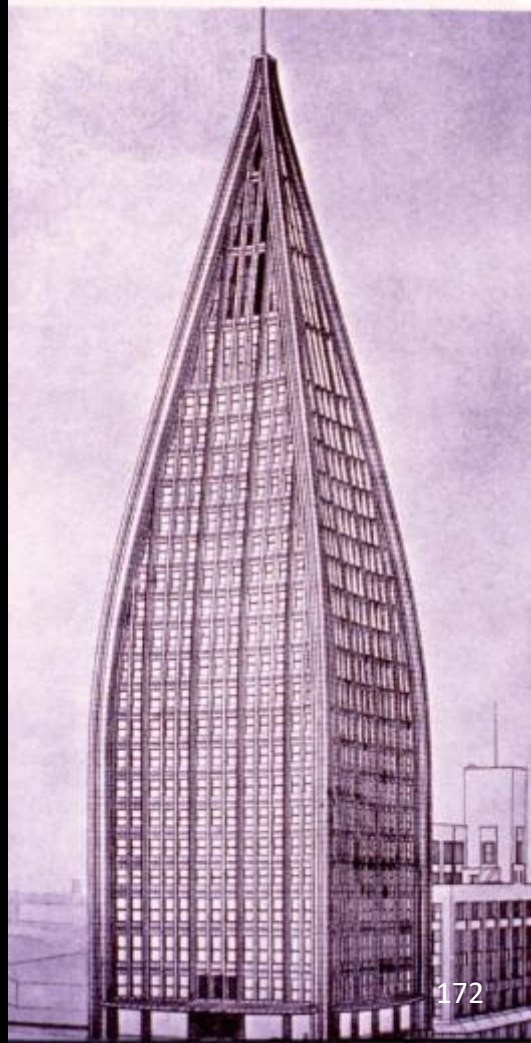


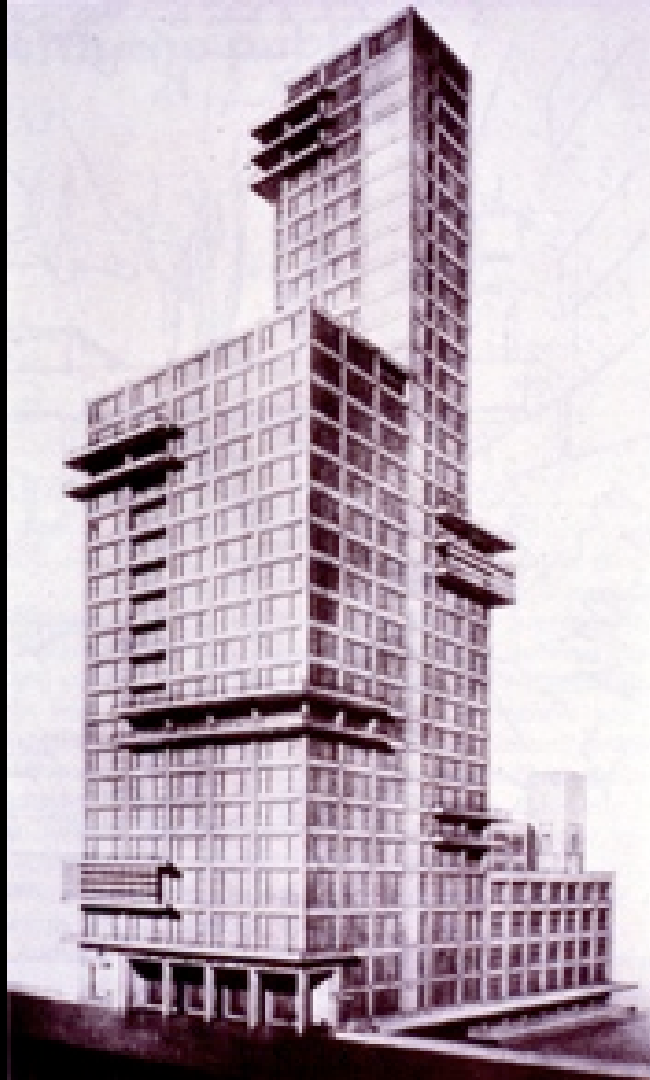


Eliel Saarinen. Perspective



Bruno Taut







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THE CHRYSLER BUILDING
William van Alen, Architect - Completed 1930

Chrysler Building
New York City
1930
319m

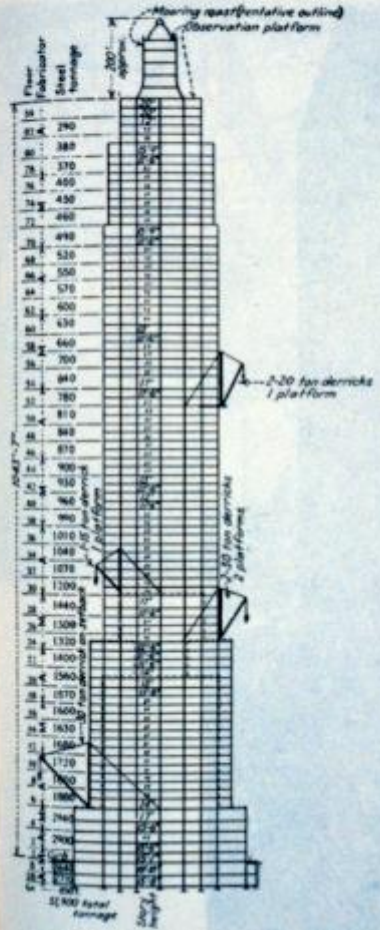
Art Deco Style







8. Empire State Building, New York City, 1929-31. Shreve, Lamb and Harmon, architects; H. G. Balcom, engineer. Elevation of the steel frame. The highest of all American skyscrapers until the World Trade Center is completed, the Empire State is carried on a traditional portal-braced steel frame.

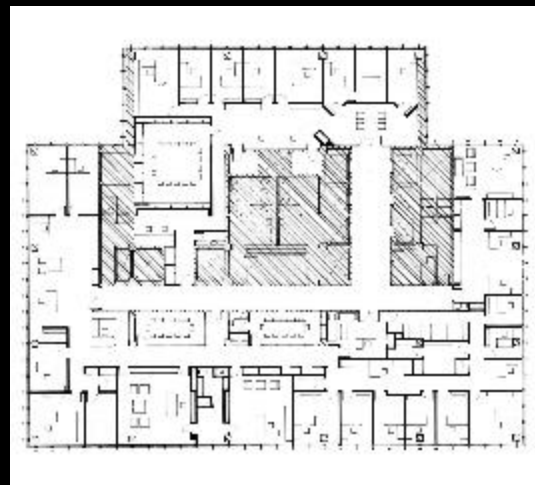
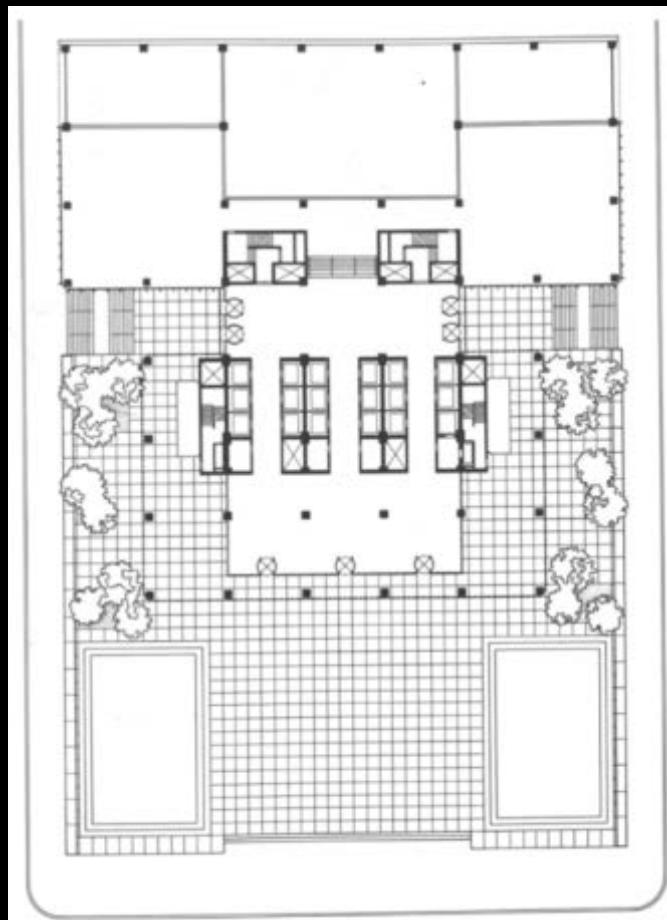


Empire State Building
New York City, USA
1931
381m



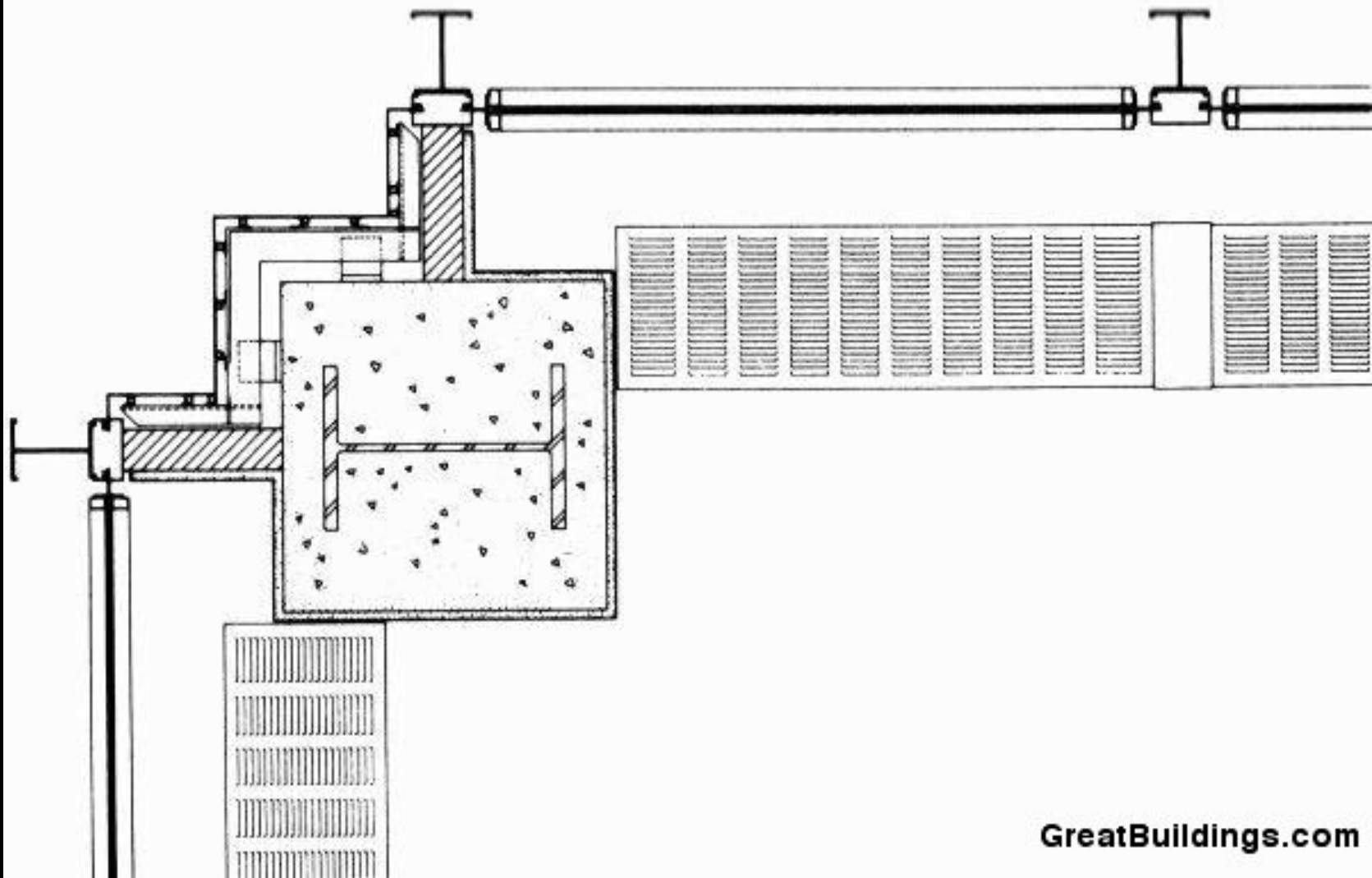


Seagram Building
New York City
Ludwig Mies van der Rohe
1958
157m











Lever House
New York City
Skidmore Owings and Merrill
1952
94m





New World Trade Tower
New York City
SOM
2014
546.2m



John Hancock Center
Chicago, Illinois
SOM and Fazlur Khan
1970
344m









Sears Tower (Willis)
Chicago, Illinois
SOM and Fazlur
Khan
1972
442m





The Shard
London, UK
Renzo Piano
2013
244m





Gateway Arch
St. Louis, Missouri
Eero Saarinen
1963
192m





From Iron to Steel
~ technique to technology~

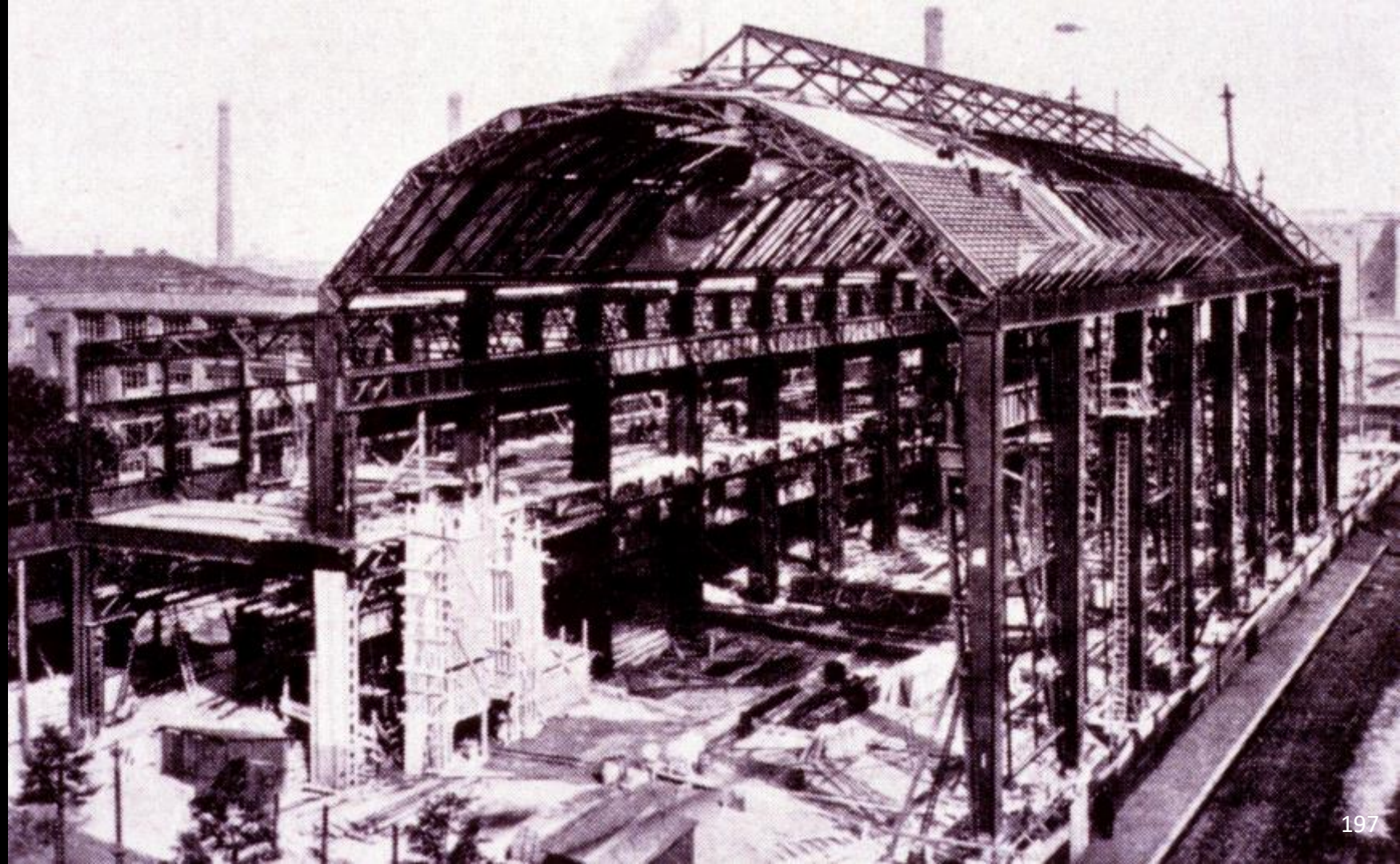
Low-rise framing



AEG Turbine Factory
Berlin, Germany
Peter Behrens Architect
1909



BRINENFABRIK

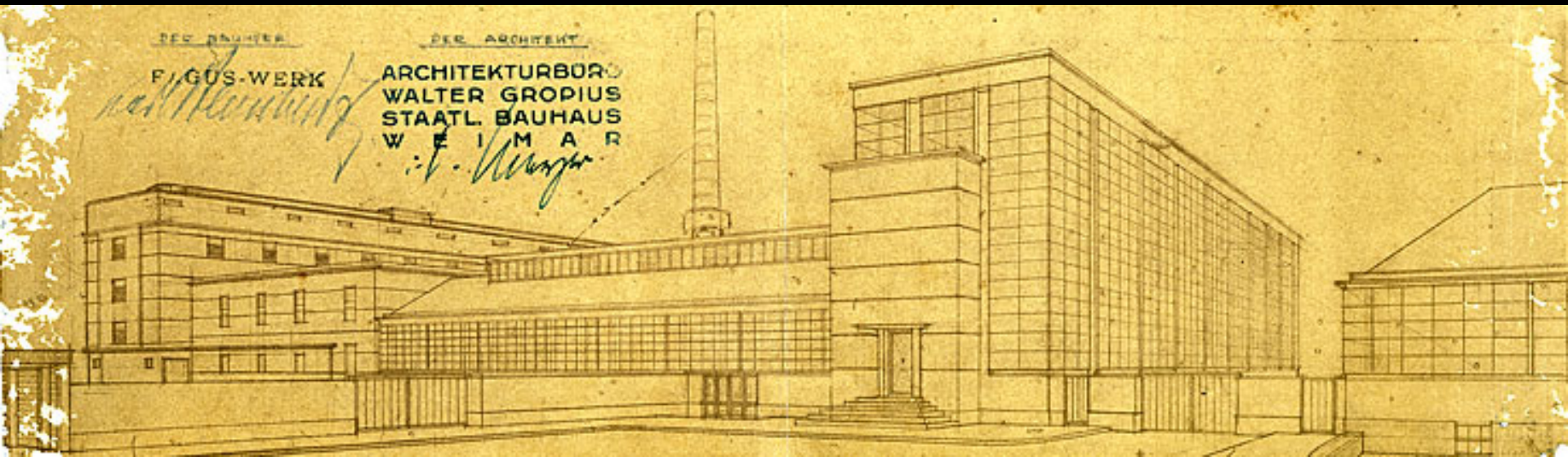




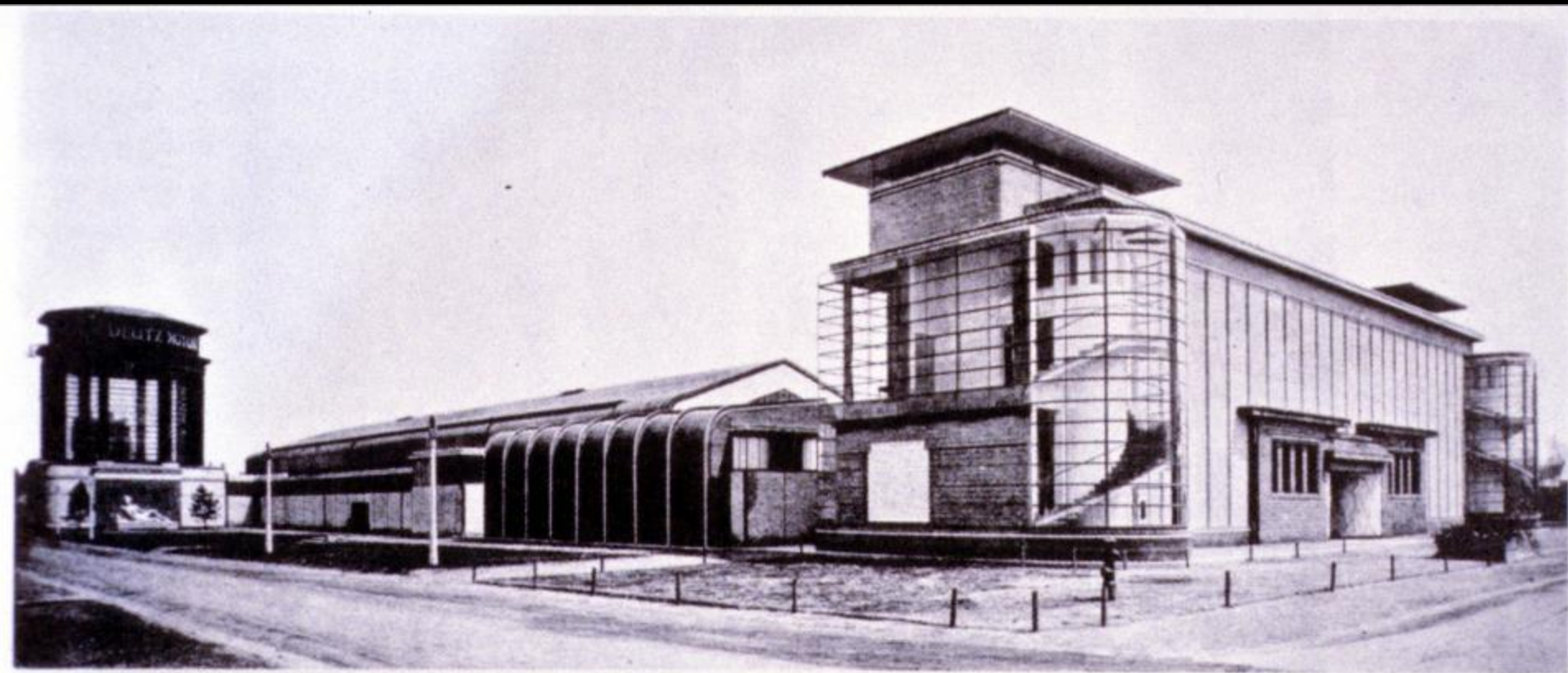




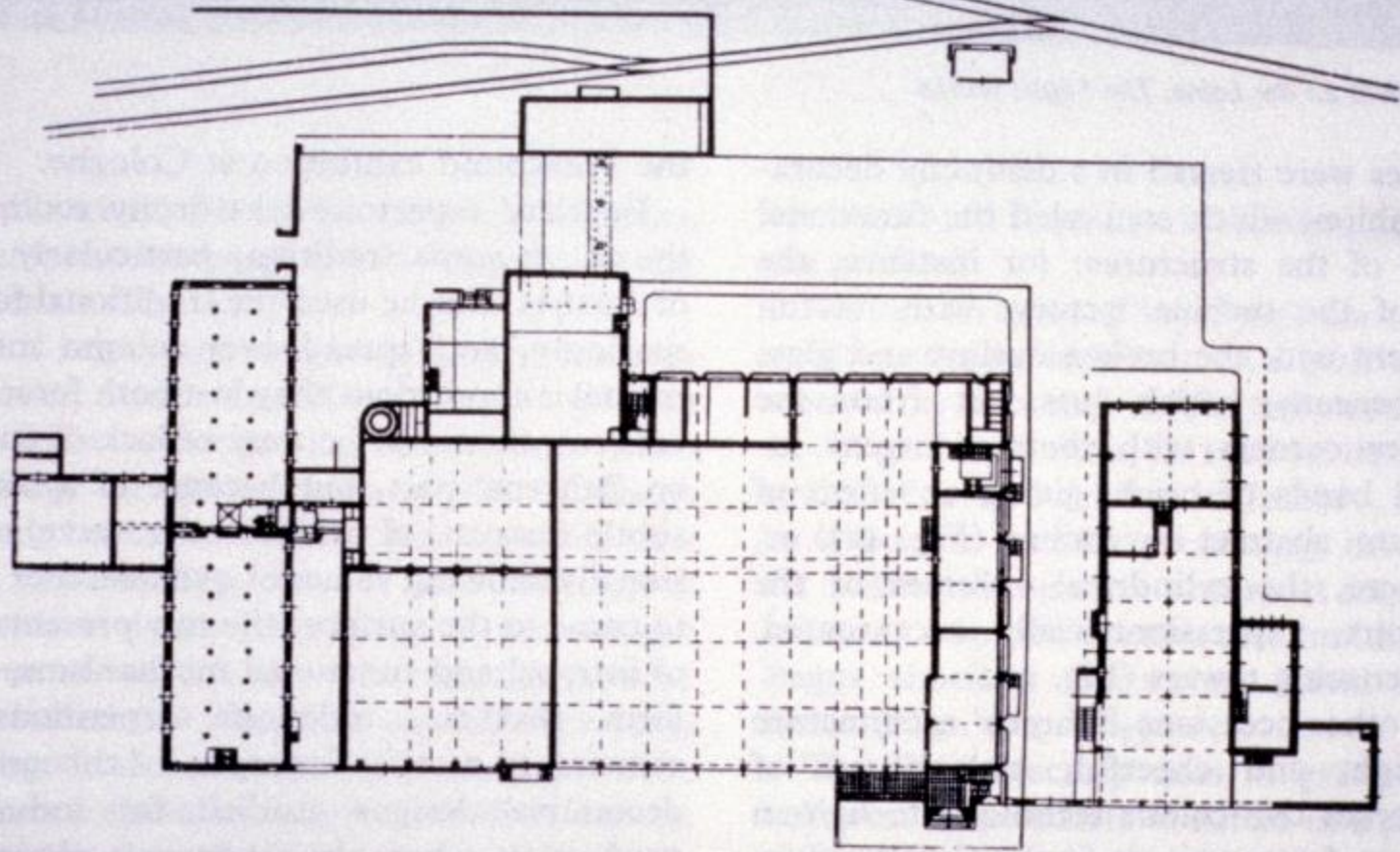




Fagus Factory
Alfeld, Germany
Adolph Meyer & Walter Gropius
1911



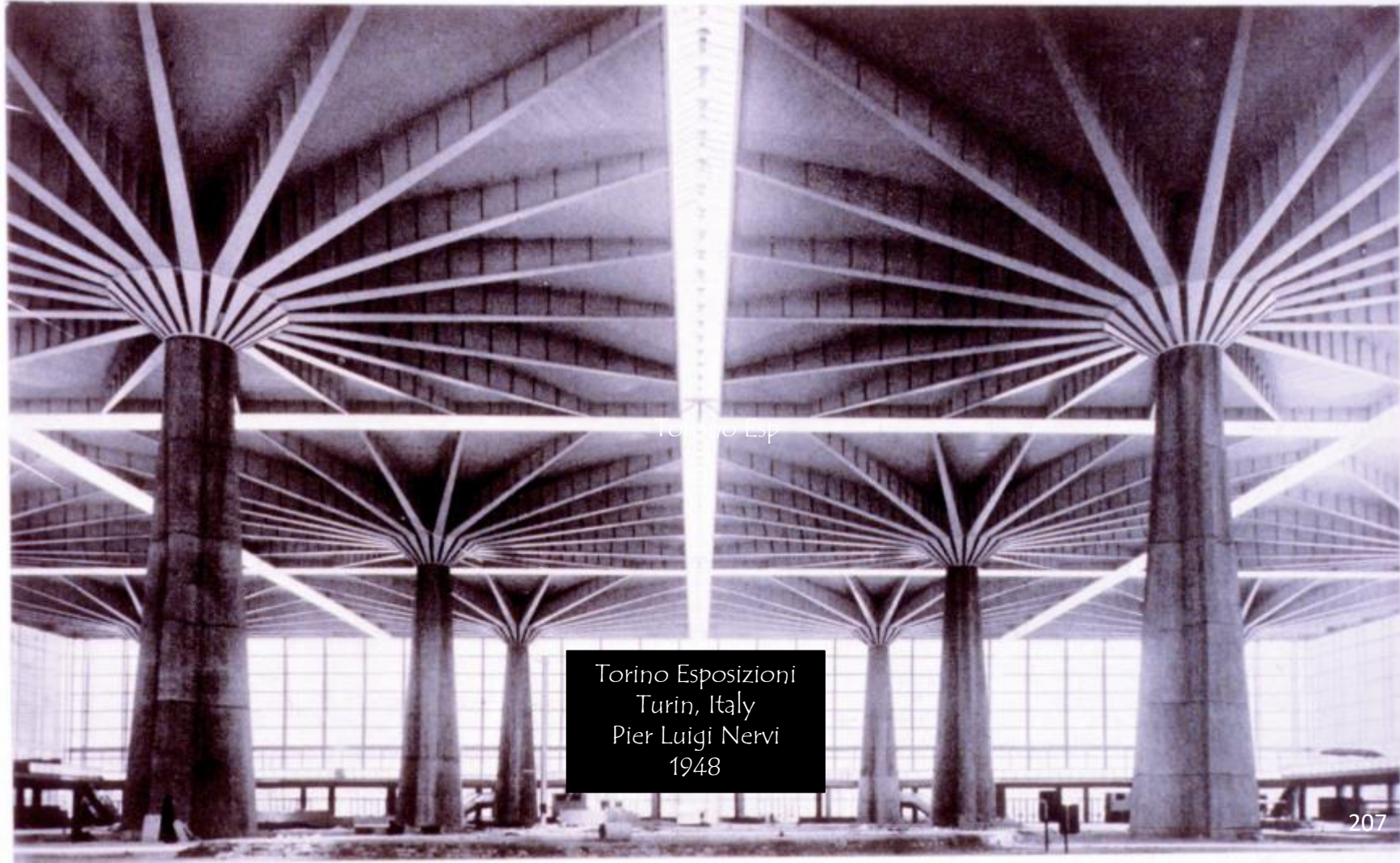
430, 431 *W. Gropius and A. Meyer, Detail of the Fagus works and the model factory at the exhibition of the Werkbund in Cologne, 1914 (from G. A. Platz, op. cit.)*



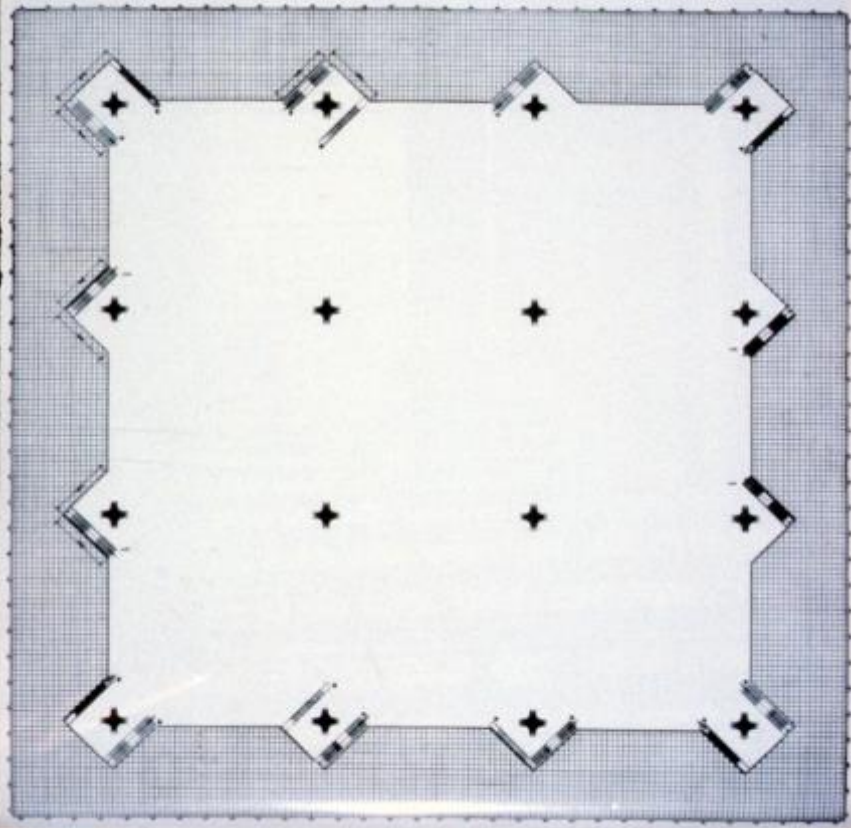
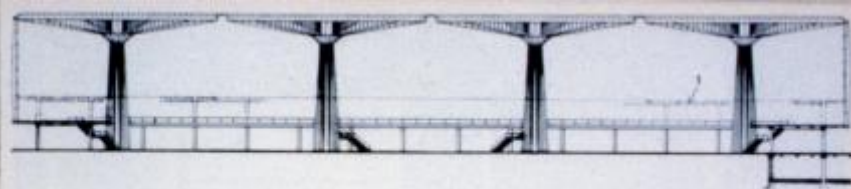
426, 427 Alfeld an der Leine, The Fagus works (W. Gropius and A. Meyer 1911)

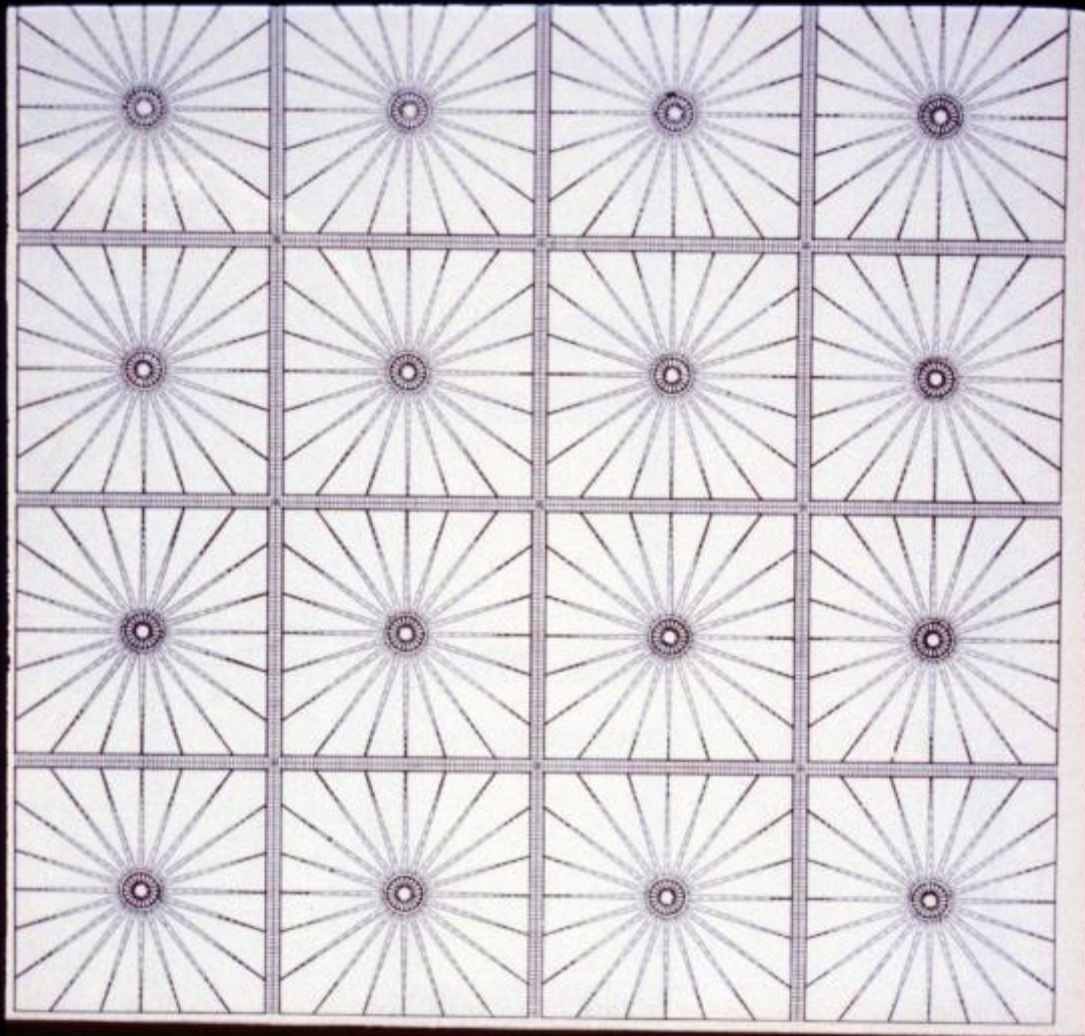






Torino Esp
Torino Esposizioni
Turin, Italy
Pier Luigi Nervi
1948





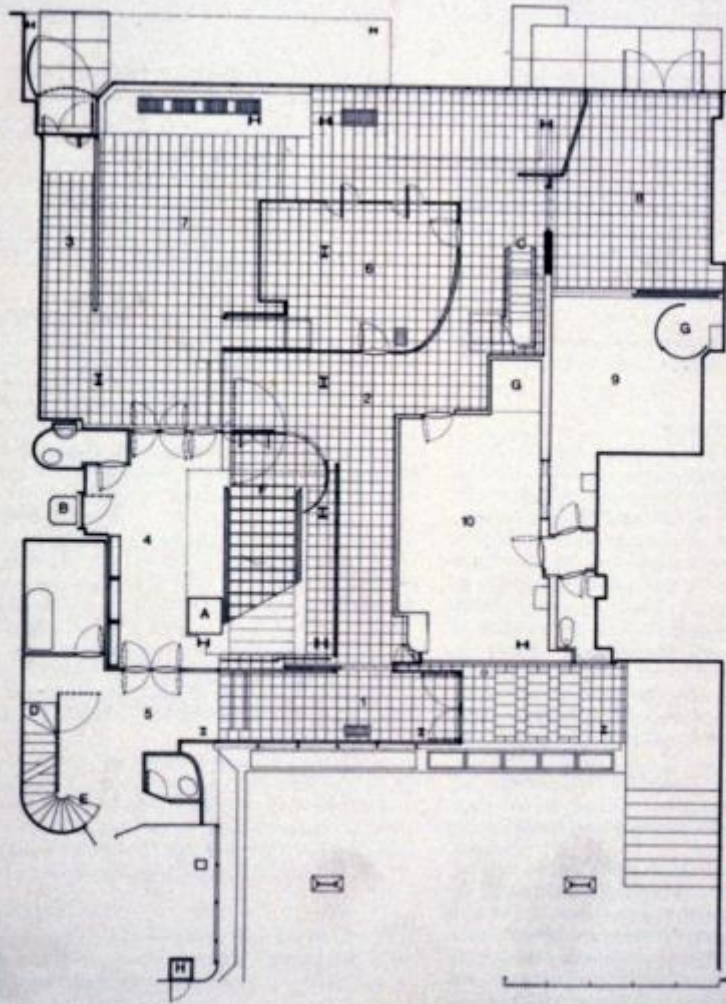




Residential Buildings



Maison de Verre
Paris, France
Pierre Chareau
1932



Ground floor plan











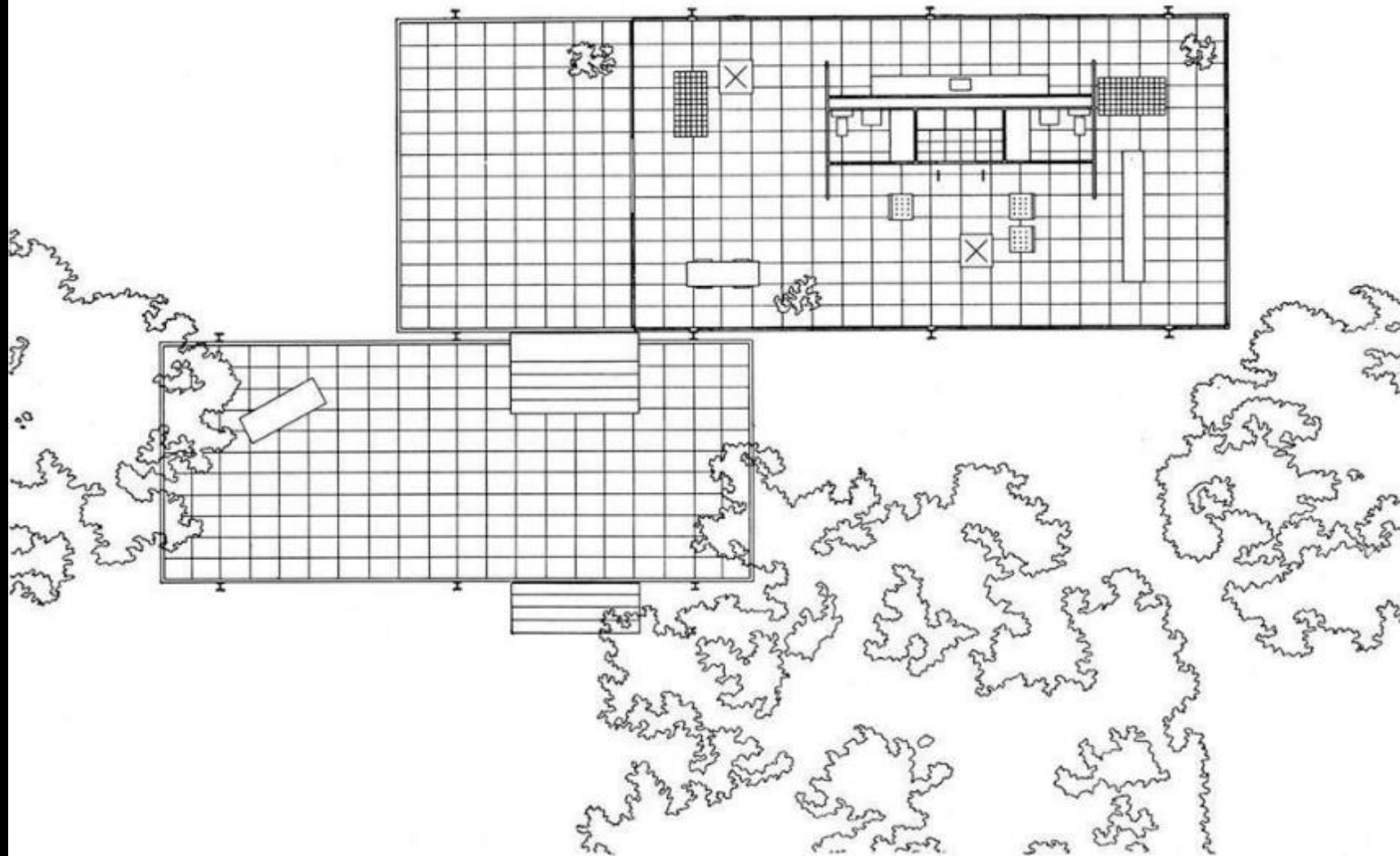
Farnsworth House
Ludwig Mies van der Rohe
Plano, Illinois
1951

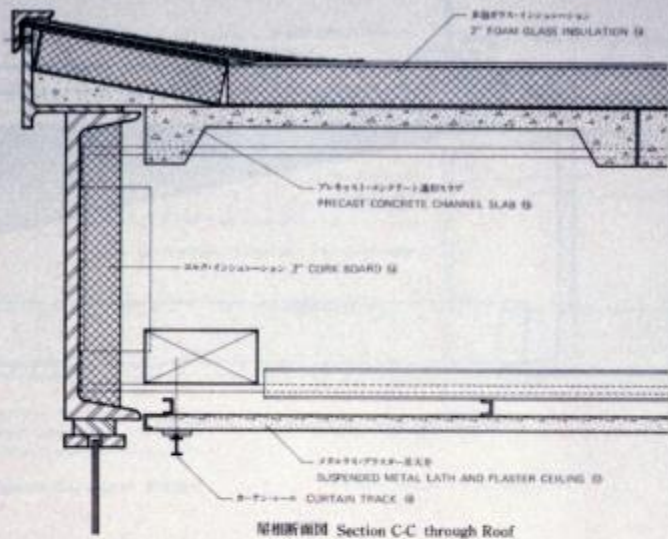




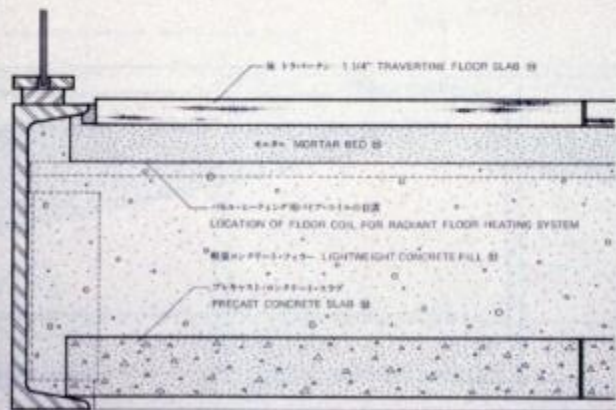




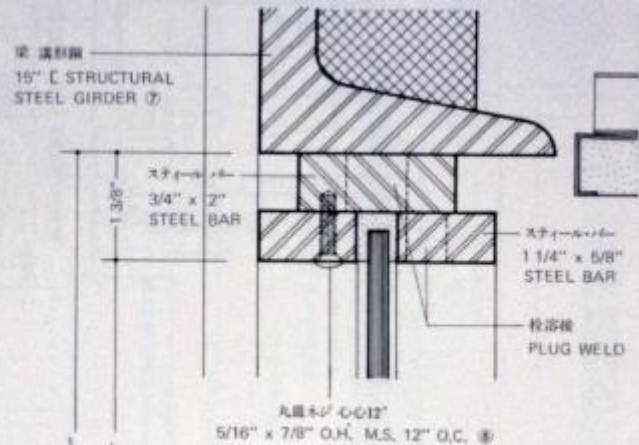




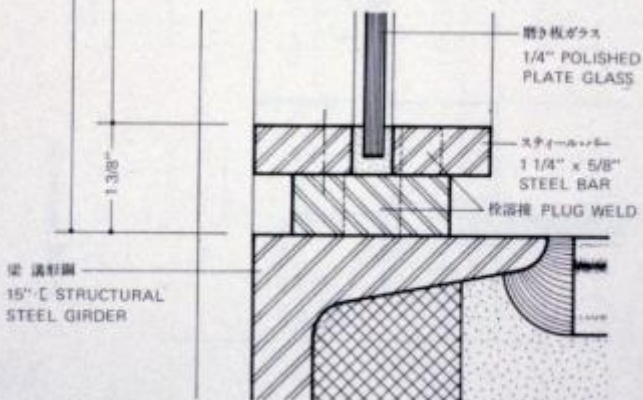
屋根断面図 Section C-C through Roof



床断面図 Section C-C through Floor



断面図 Section 109



断面図 Section 110







S. R. Crown Hall
Illinois Institute of Technology
Chicago, Illinois, USA
Ludwig Mies van der Rohe
1956





















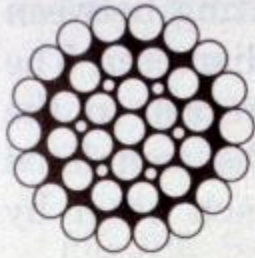


From Iron to Steel
~ technique to technology ~

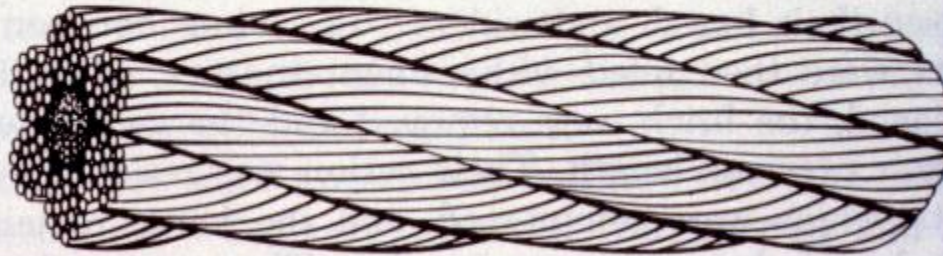
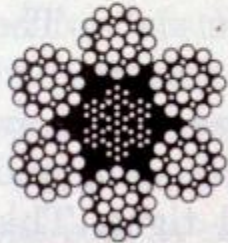
Tensile Structures

Iron and steel were able to resist
TENSION forces
Completely changing the range of
possibility in structural design

cables = steel "rope"



(a) Galvanized Bridge Strand



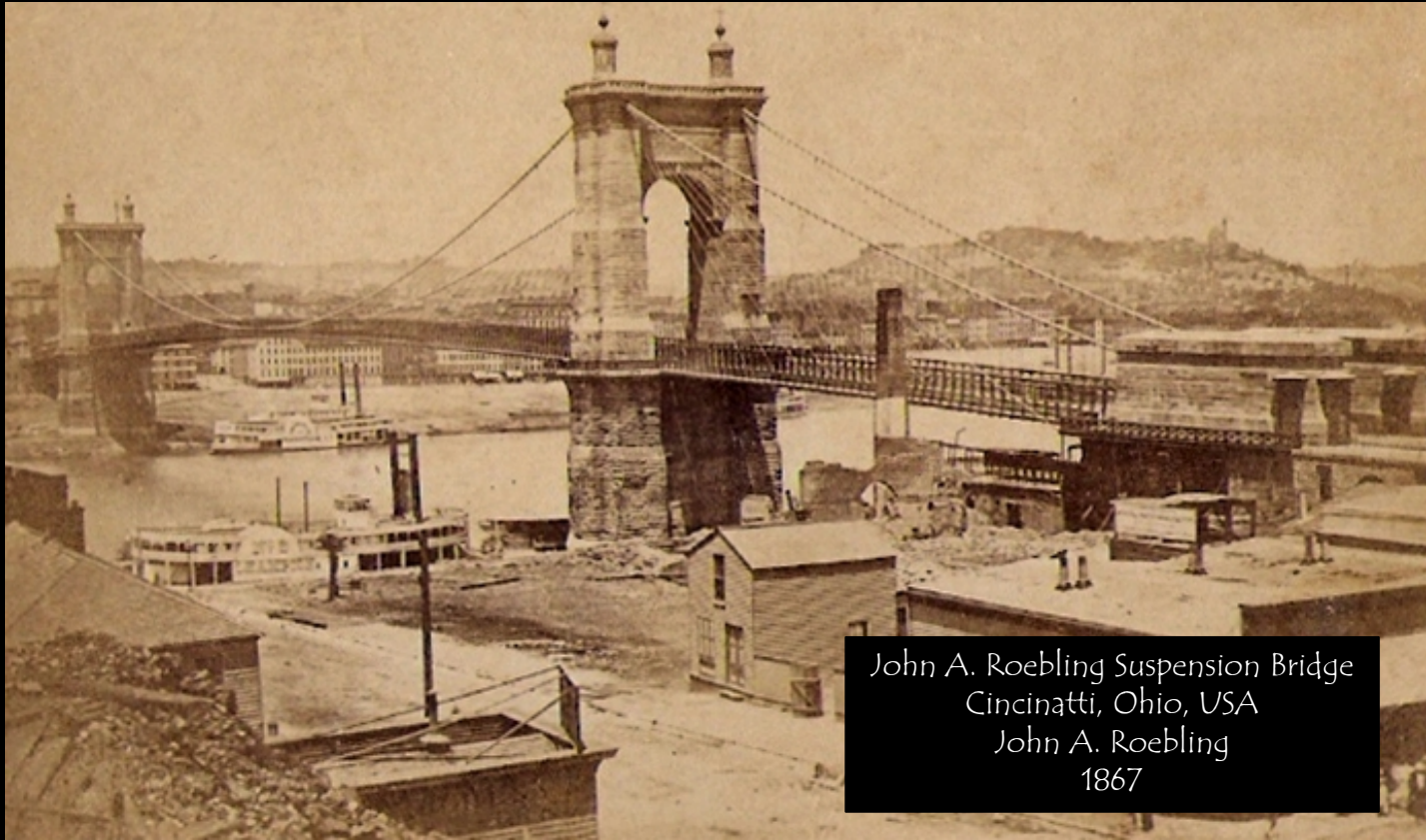
(b) Galvanized Bridge Rope

FIGURE 6.43 Wire strand and rope.

Bridges

New possibilities for greater spans between
abutments due to cables





John A. Roebling Suspension Bridge
Cincinnati, Ohio, USA
John A. Roebling
1867





John A. Roebling Bridge
1867

JOHN A. ROEBLING BRIDGE

JOHN A. ROEBLING (1806-1869), PIONEER CIVIL ENGINEER, WAS THE DESIGNER AND BUILDER OF THE COVINGTON-CINCINNATI SUSPENSION BRIDGE WHICH WAS COMPLETED IN 1866. IT SERVED AS THE PROTOTYPE FOR ROEBLING'S DESIGN OF THE BROOKLYN BRIDGE, WHICH WAS COMPLETED IN 1883 UNDER THE DIRECTION OF HIS SON, WASHINGTON A. ROEBLING, CHIEF ENGINEER. ON JUNE 27, 1983, THE COMMONWEALTH OF KENTUCKY OFFICIALLY RENAMED THE COVINGTON-CINCINNATI SUSPENSION BRIDGE IN HONOR OF THE DESIGNER AND BUILDER.

PRESENTED 1984 BY
AMERICAN SOCIETY OF CIVIL ENGINEERS















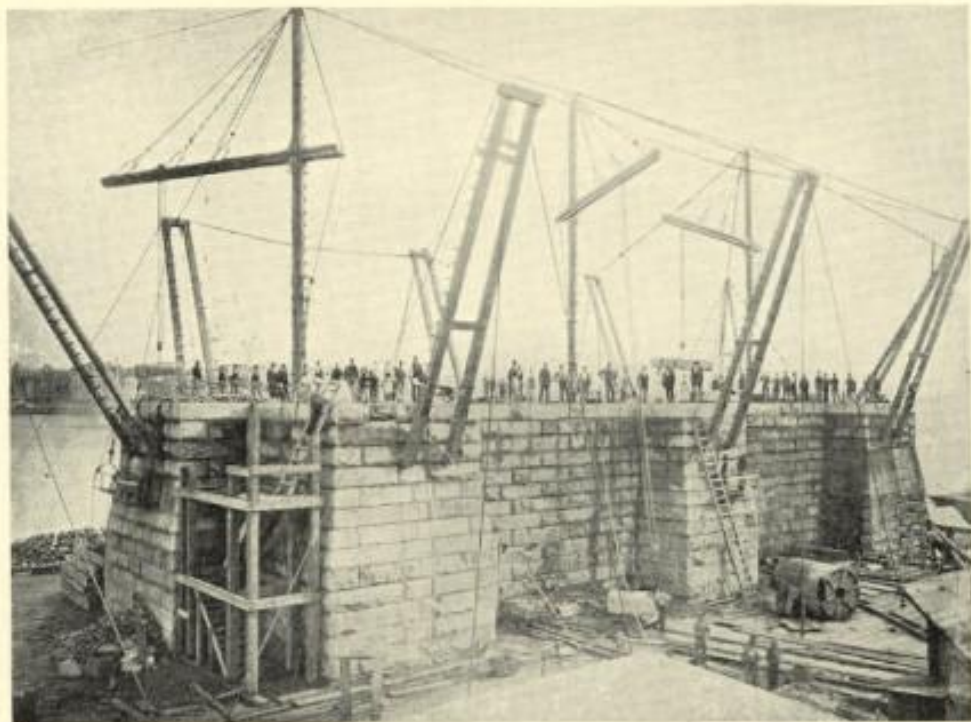








Brooklyn Bridge
New York City, USA
John A. Roebling
1893



New York Masonry Tower under construction. Tower completed July, 1876.

Brooklyn Anchorage—October, 1878.

The photograph shows how the cables are fastened to the Anchor Bars leading to the Anchor Plates under the masonry.



HENRY C. MURPHY, *Arch.* WM. DEMPSEY, *Foreman of Rigging* W. HILDENBRAND, *1st Draftsman*
 JOHN H. DEWENTICE, *Stress* WM. H. BAINE, *2nd Draft* E. F. FARRINGTON, *Master Carpenter*
 C. P. QUINTARD, *Chief* WM. VAN DER BOSCH, *Draftsman* CHARLES C. MARTIN, *3rd Draft*
 F. COLLINGWOOD, *4th Draft*
 GEO. W. MCNULTY, *5th Draft*



Brooklyn Bridge looking toward Manhattan—1933.



Brooklyn Bridge. Wire cables under construction. Last cable wire was run October 5, 1878.

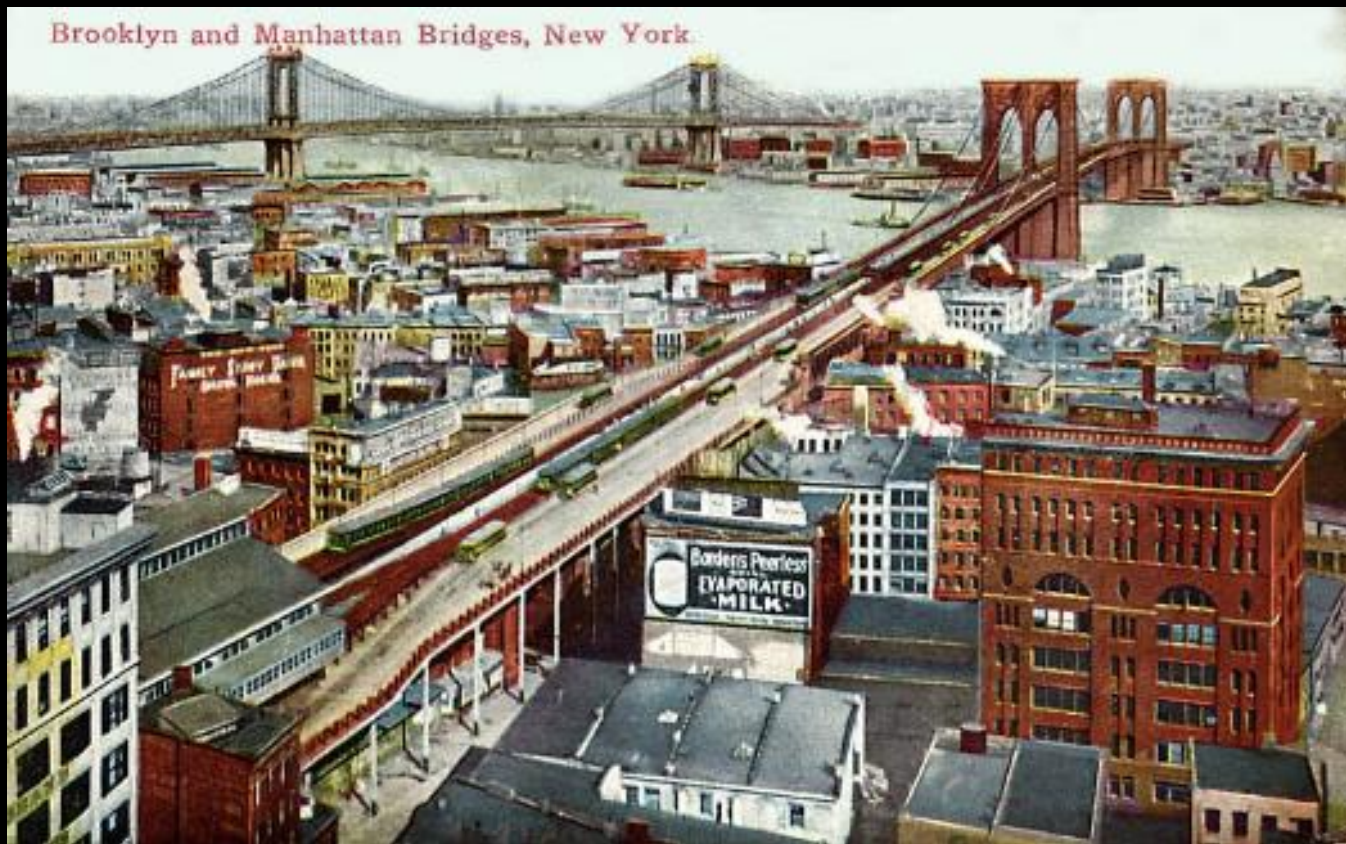


10781-86

EAST RIVER AND DOWNTOWN, NEW YORK. FROM BROOKLYN BRIDGE.

PHOTO, BROWN BROS., NEW YORK.

Brooklyn and Manhattan Bridges, New York.











Pedestrian Bridge
Dalian, China









Humber Bay Arch Bridge
Toronto, Ontario
Montgomery Sisam Architects
1994







London Millennium Footbridge
London, England
Sir Norman Foster and Partners
Arup Engineers
2000











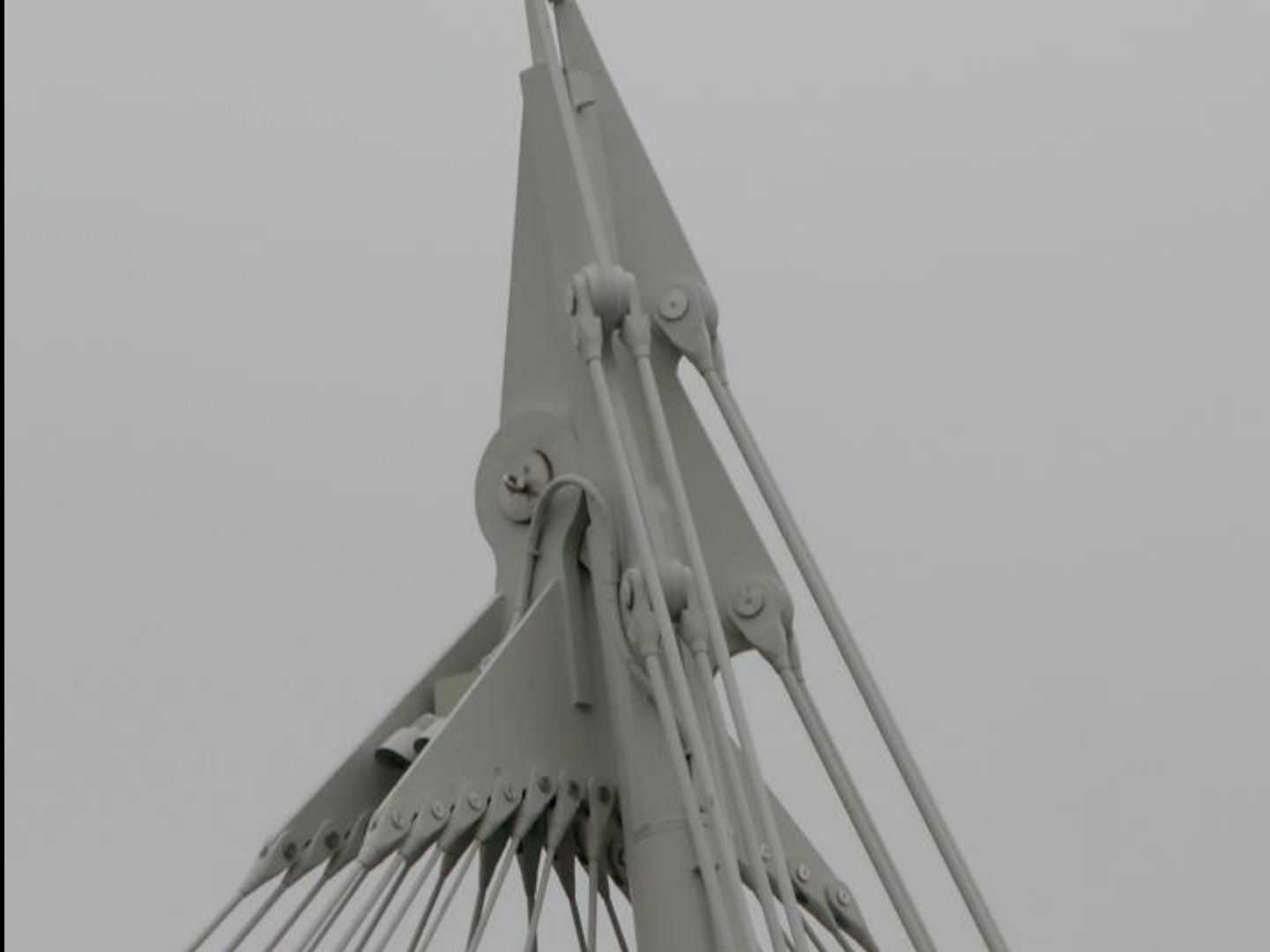




Golden Jubilee Bridge
London, England
Lifshutz Davidson Sandilands Architects
WSP Group Engineers
2000









Kurilpa Bridge
Brisbane, Australia
Cox Rayner Architects
Arup Engineers
Tensegrity cable stayed bridge
2009









Tensile structures

~

Taking advantage of what steel does BEST

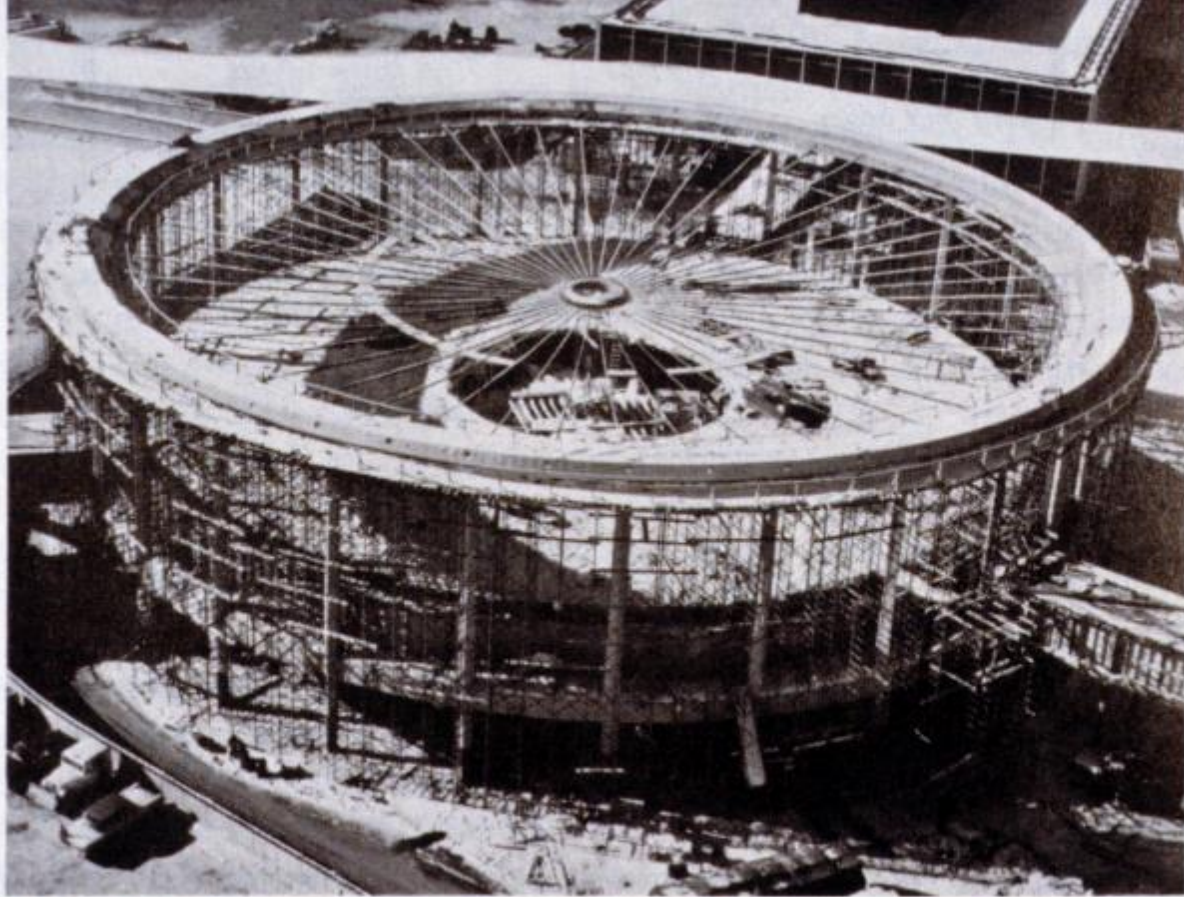
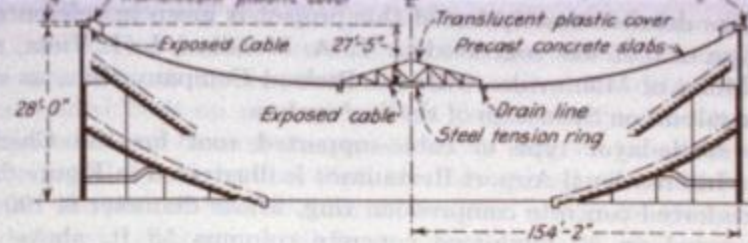


FIGURE 6.45 Single-layer, cable-supported roof. Chicago O'Hare International Airport Restaurant. Architects and Engineers: C. F. Murphy Associates. Roof Contractor: E. H. Marhoefer, Jr. Cables furnished by John A. Roebling's Sons Division, Colorado Fuel and Iron Corp.

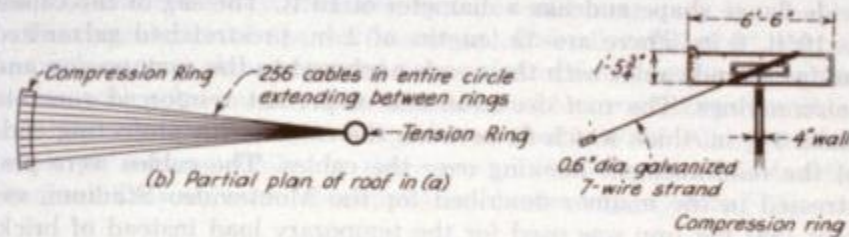




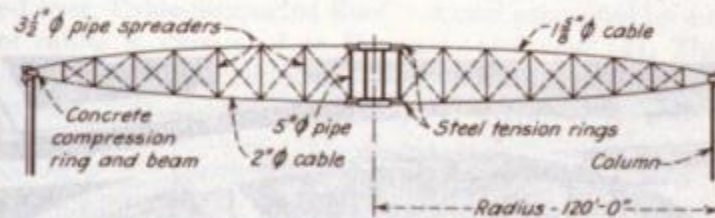




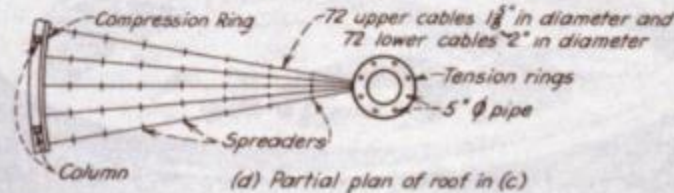
(a) Cross section of one-layer cable-supported roof



(b) Partial plan of roof in (a)



(c) Cross section of two-layer cable supported roof



(d) Partial plan of roof in (c)

FIGURE 6.44 Single-layer and double-layer cable-supported roofs.



Munich Olympic Stadium
Munich, Germany
Frei Otto & Guntar Benisch
1972










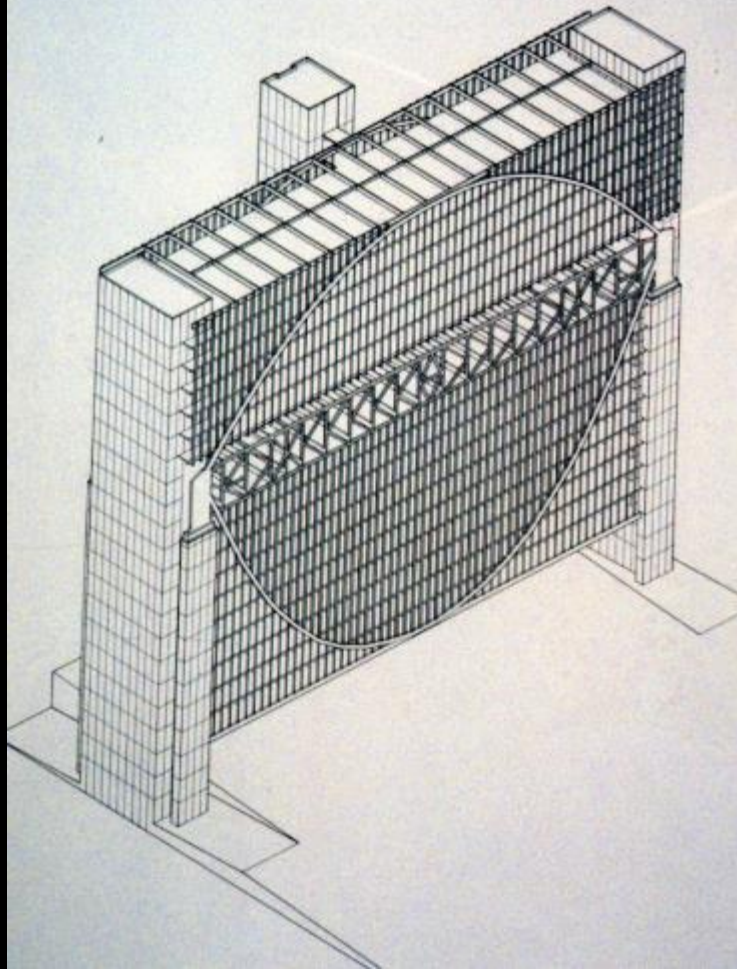


A person wearing a black shirt, dark pants, and a yellow safety harness is walking on a metal roof. The roof is covered in a grid of metal panels with visible rivets. A safety railing system consisting of vertical posts and horizontal cables is installed along the edge of the roof. The person is holding onto the railing with both hands. The background is a clear blue sky.

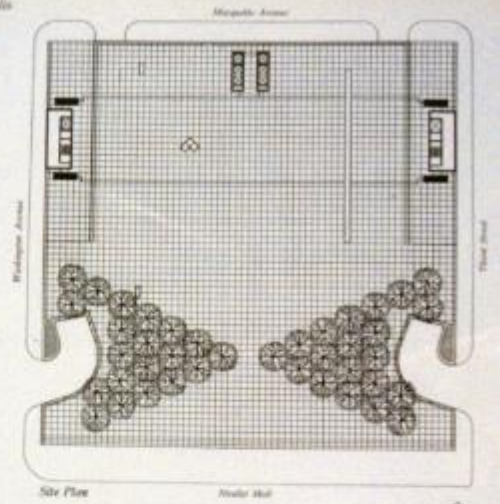
Walk on the roof?
Why not?



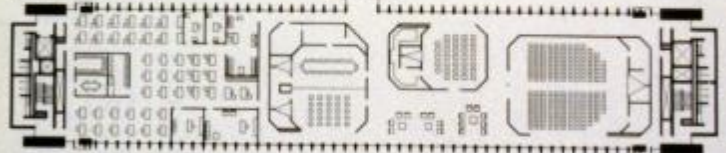
Marquette Plaza
(formerly Federal Reserve Bank)
Minneapolis, Minnesota, USA
Gunnar Birkerts
1973



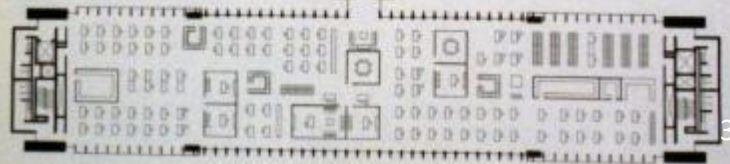
Federal Reserve Bank of Minneapolis

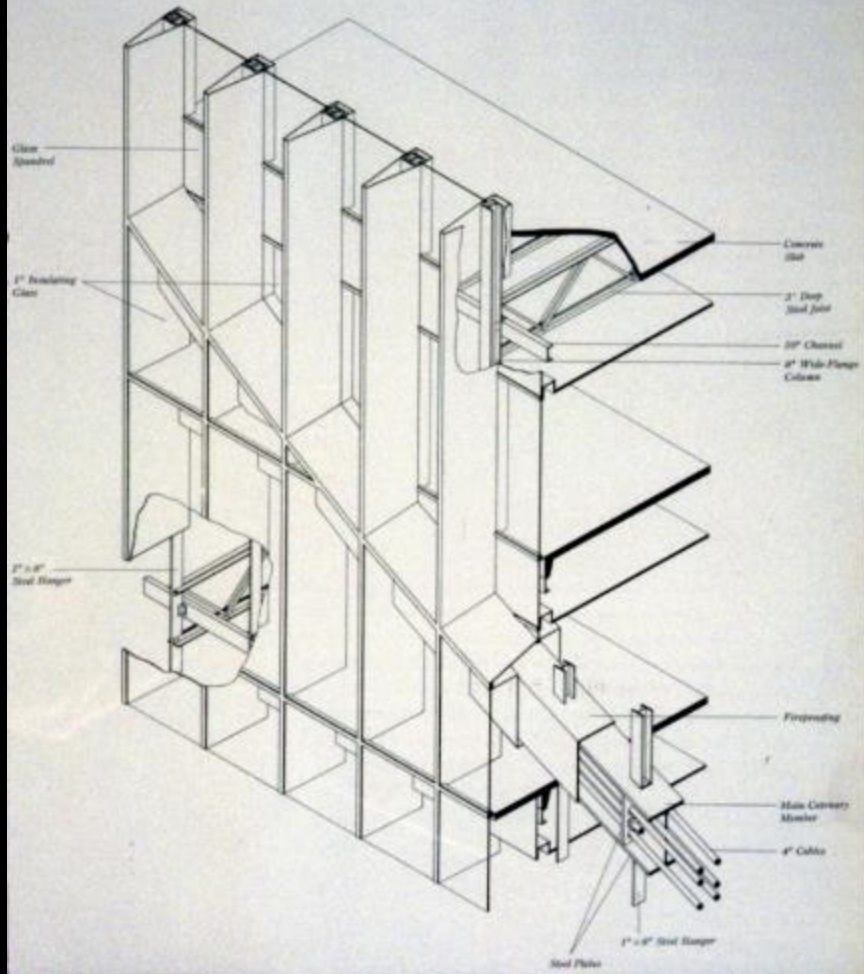


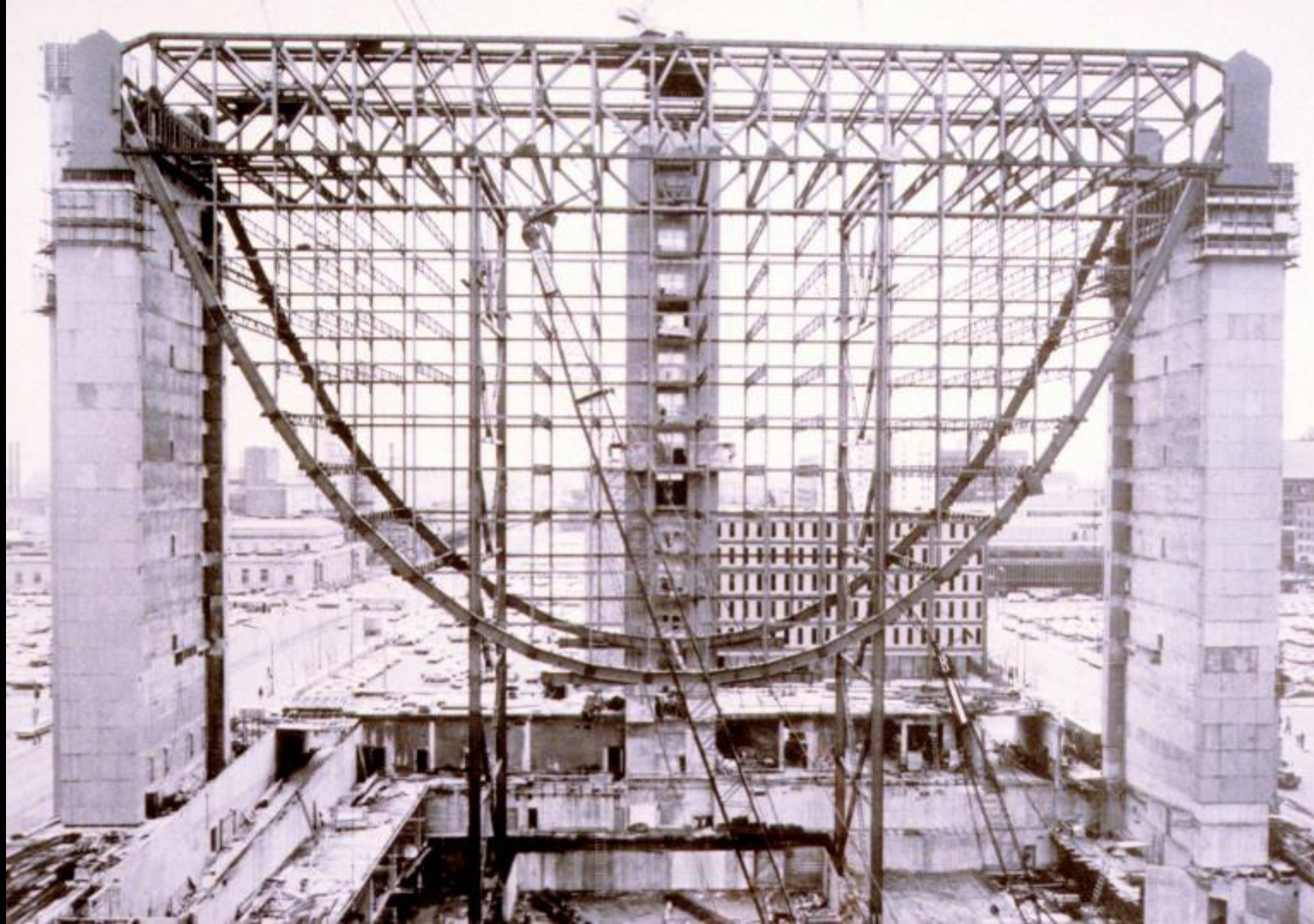
Conference Room Floor Plan

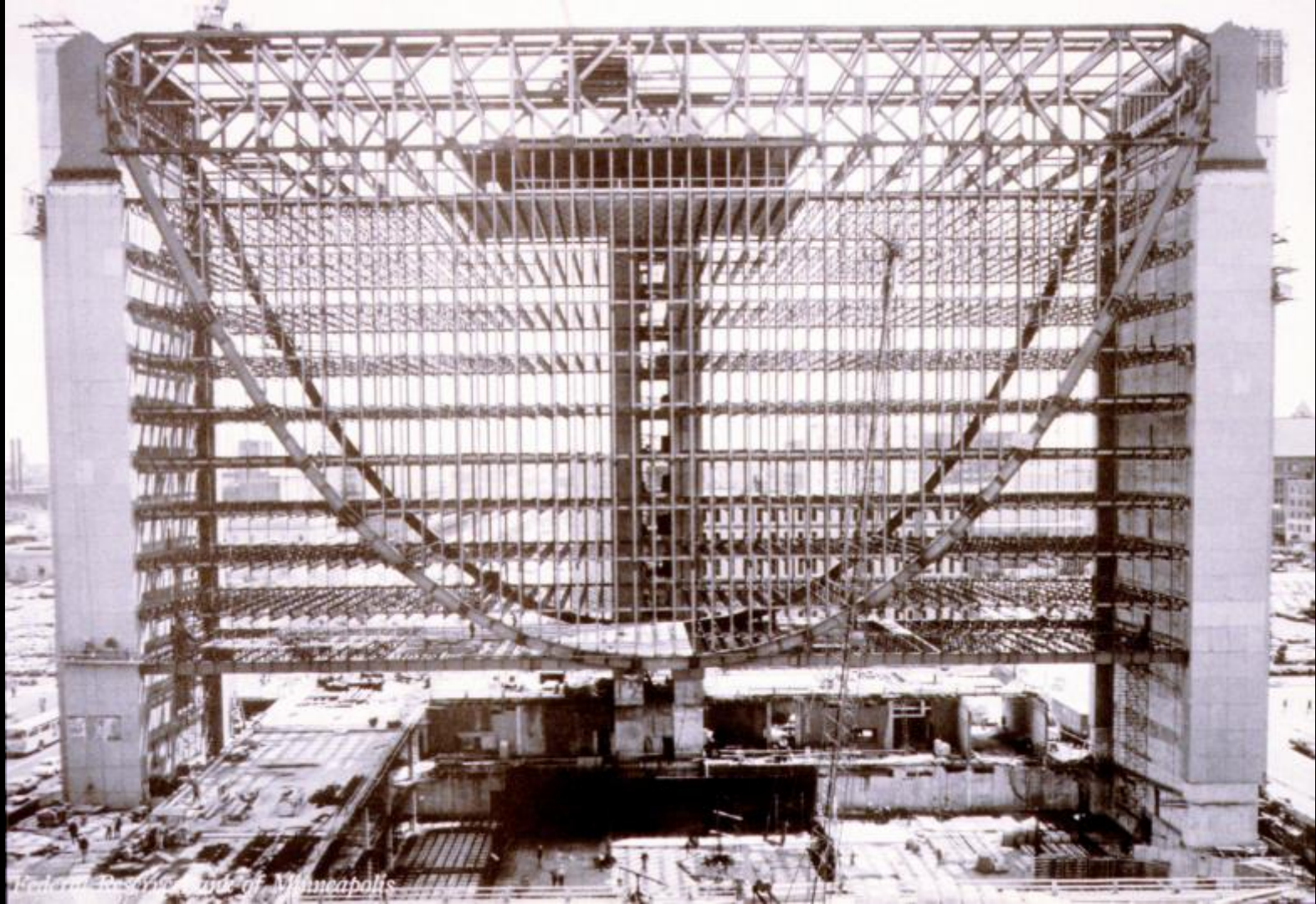


Typical Office Floor Plan









Federal Reserve Bank of Minneapolis









The Sony Centre
Berlin, Germany
Helmut Jahn
2000











Quadracci Pavilion
Milwaukee Art Museum
Milwaukee, Wisconsin
Santiago Calatrava
2001





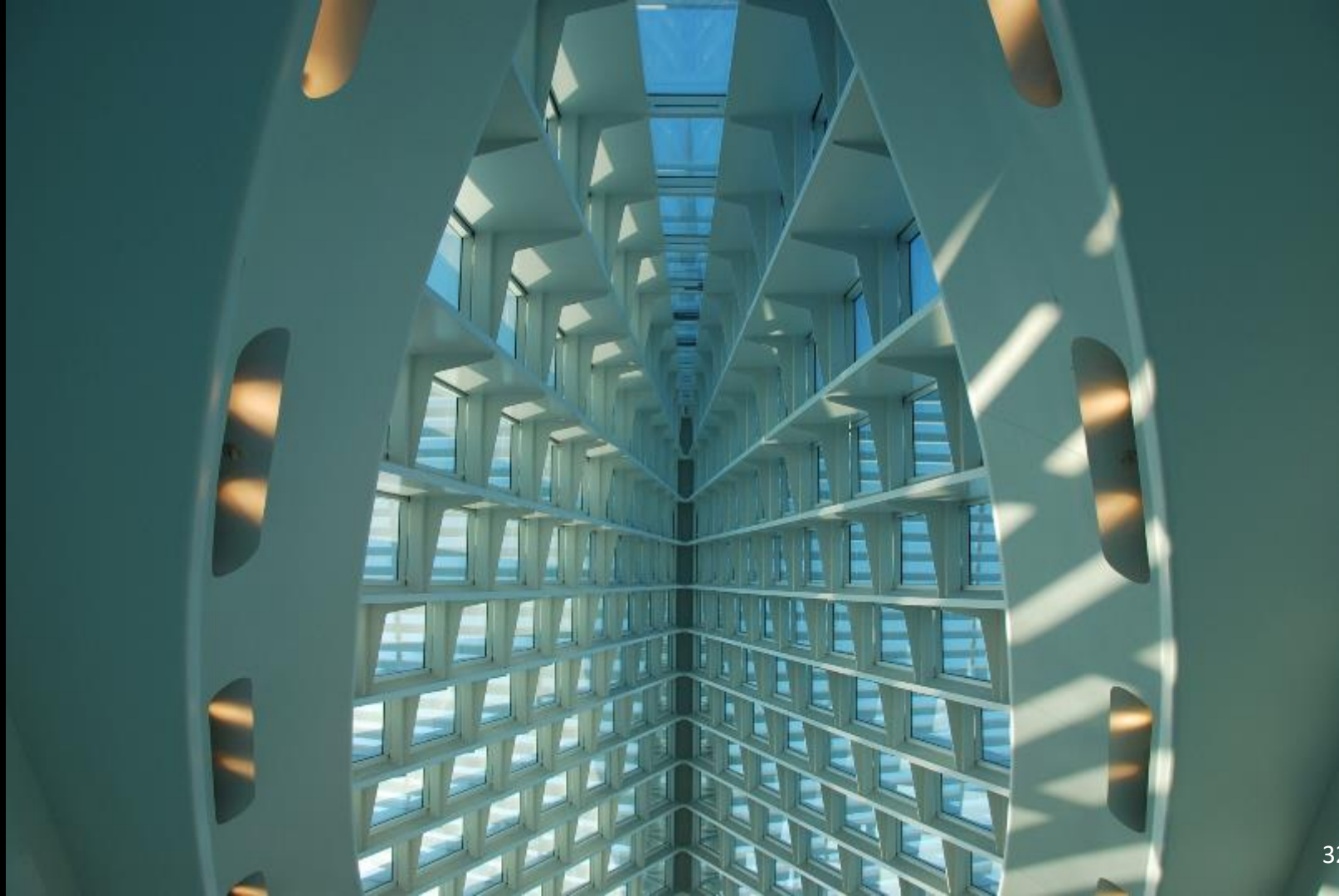


















You can remelt/recycle steel indefinitely
without losing any quality

The majority of the steel used today is from
recycled scrap

New more efficient furnaces are reducing the
CO₂ emissions from steel manufacturing