


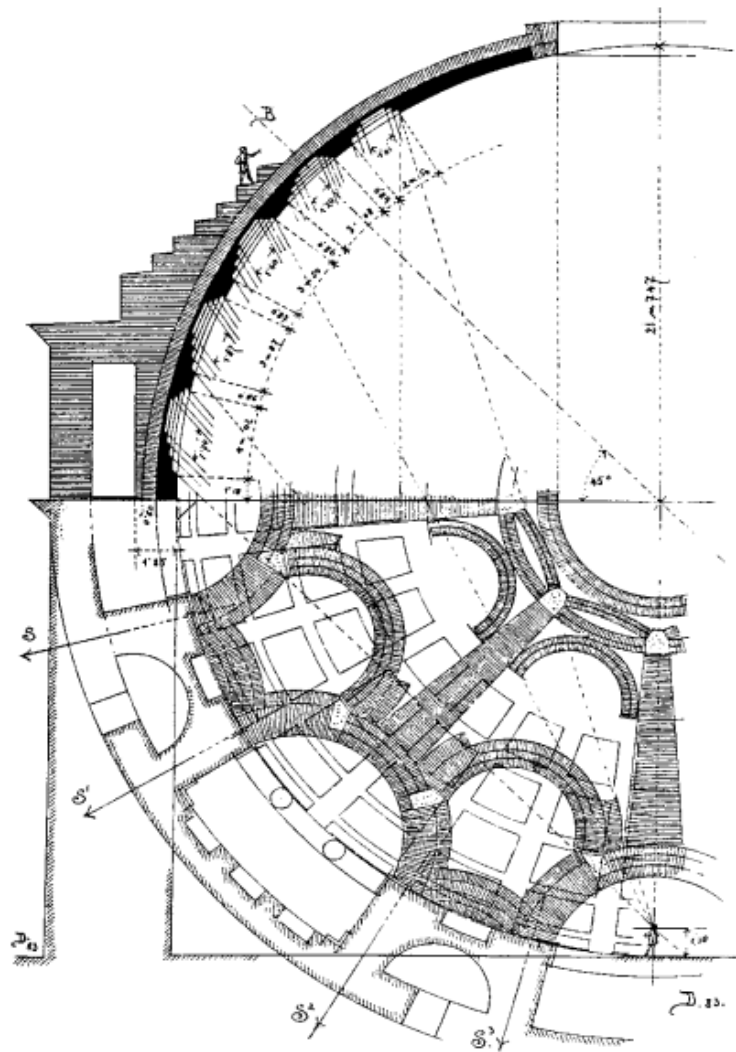
Developments in Concrete Construction

Part 1: Origins and Early Development



Stone relied on its form to put it into compression, which is the only force that stone can resist.

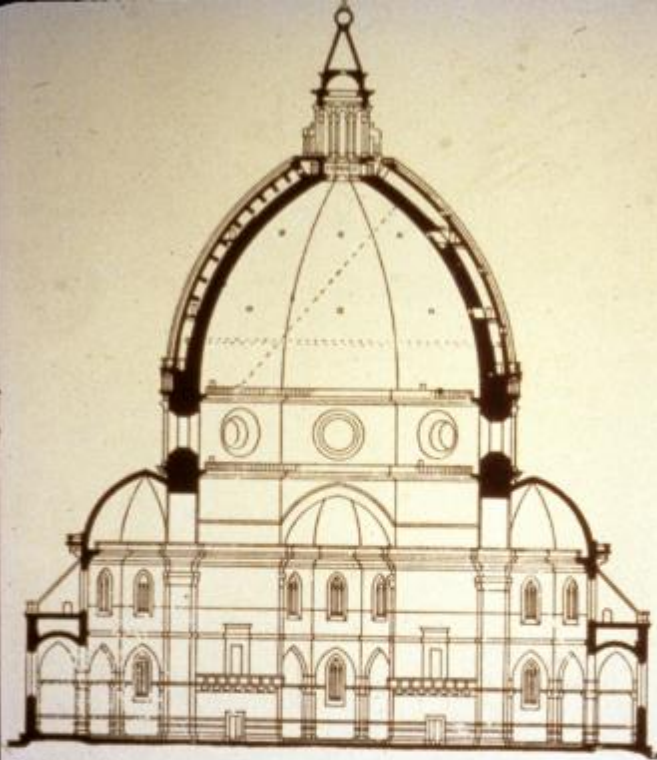
The Pantheon
Rome, Italy
113-125 CD



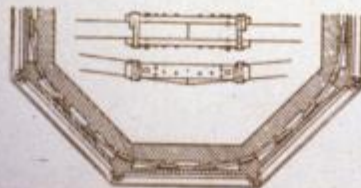
Composite Structures

~

Use multiple materials each to their
own structural advantage



Section through the Florence Cathedral dome.

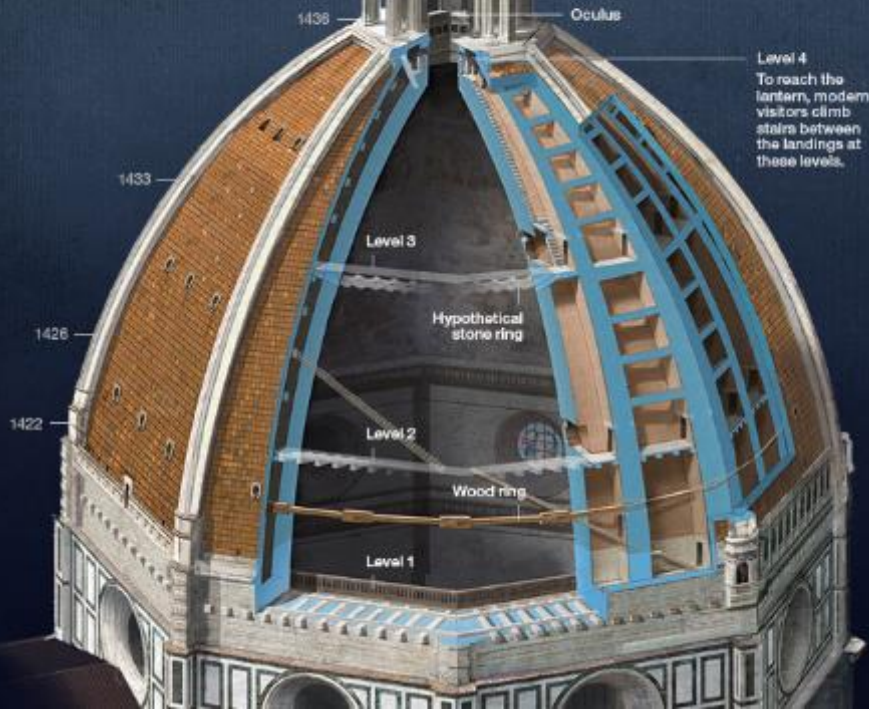


Half plan of the dome and detail showing the iron chain.

Santa Maria del
Fiore
Florence, Italy
Filippo Brunelleschi
1436

1471
(date of construction)

A grid of interlocking stones hugs the dome like the hoop of a barrel. The crossbeams form a line on the facade. Inside, a wood ring is visible. More stone rings may be hidden higher up.

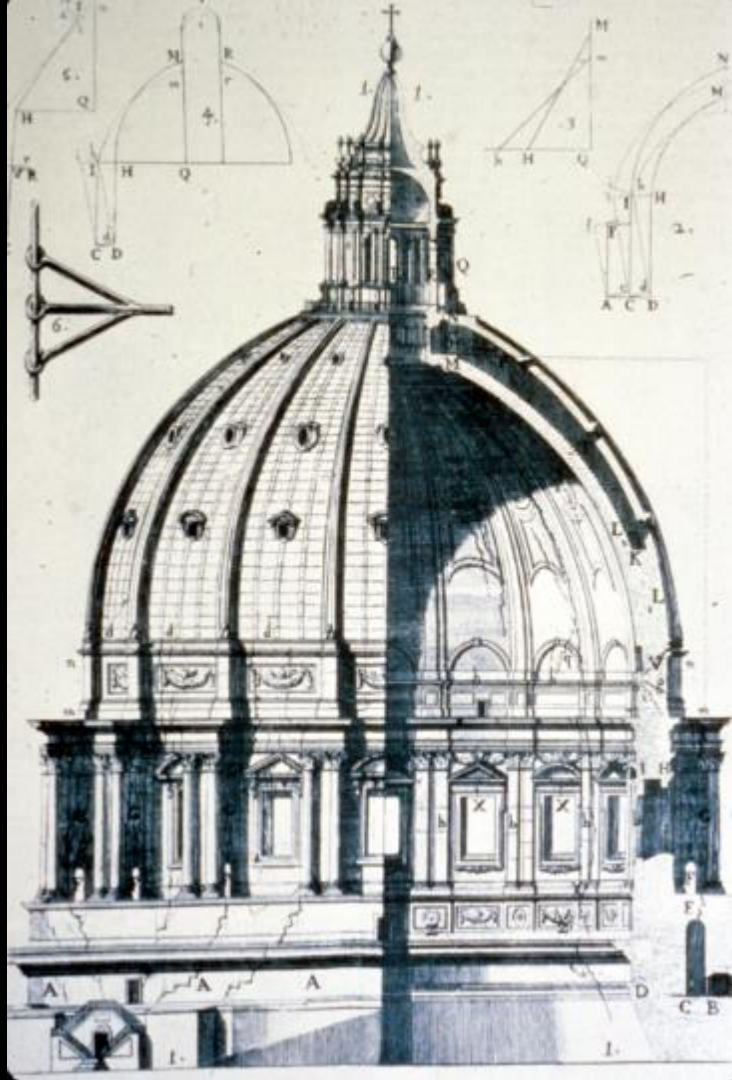




Basilica of St. Peter
Vatican, Italy
Various architects
1506-1626











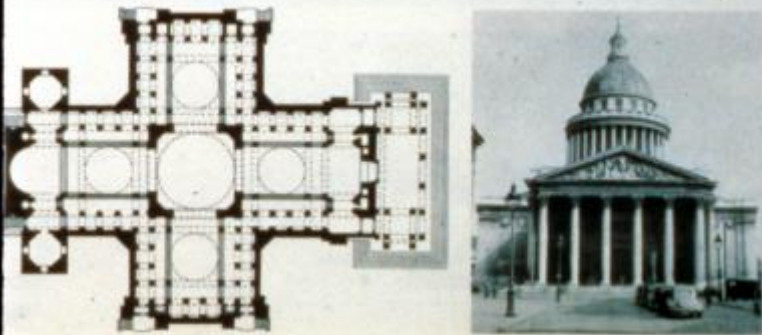
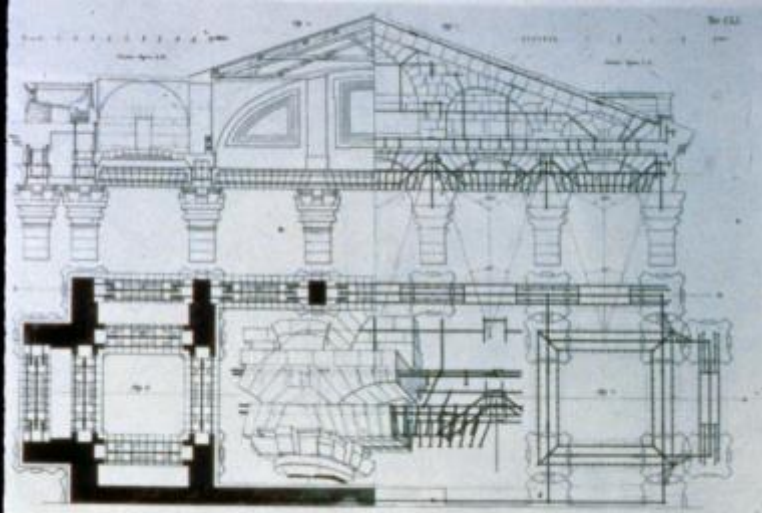




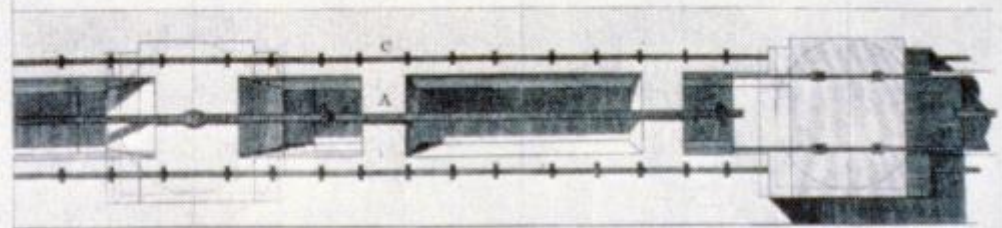
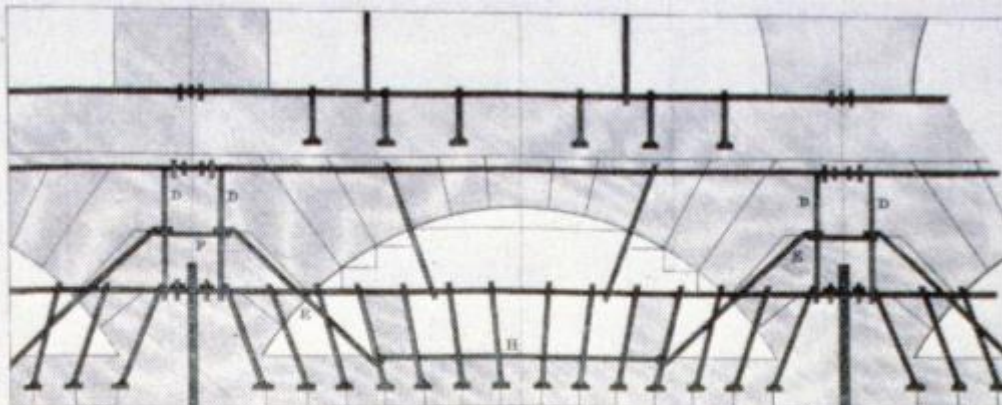
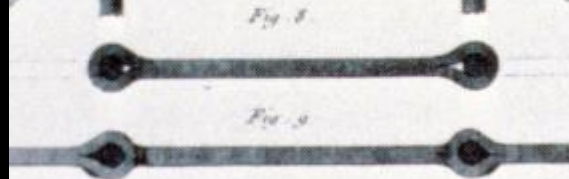
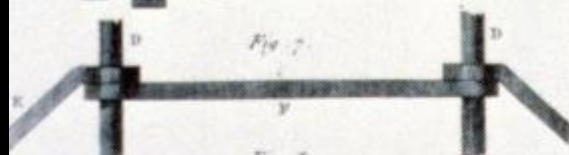
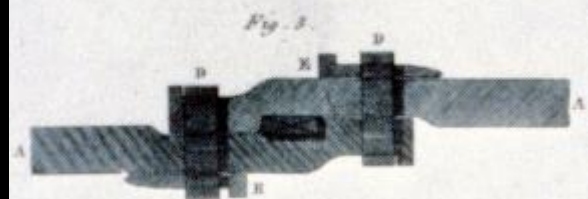
Place de la Concorde
Anges-Jacques Gabriel
Paris, France
1755



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

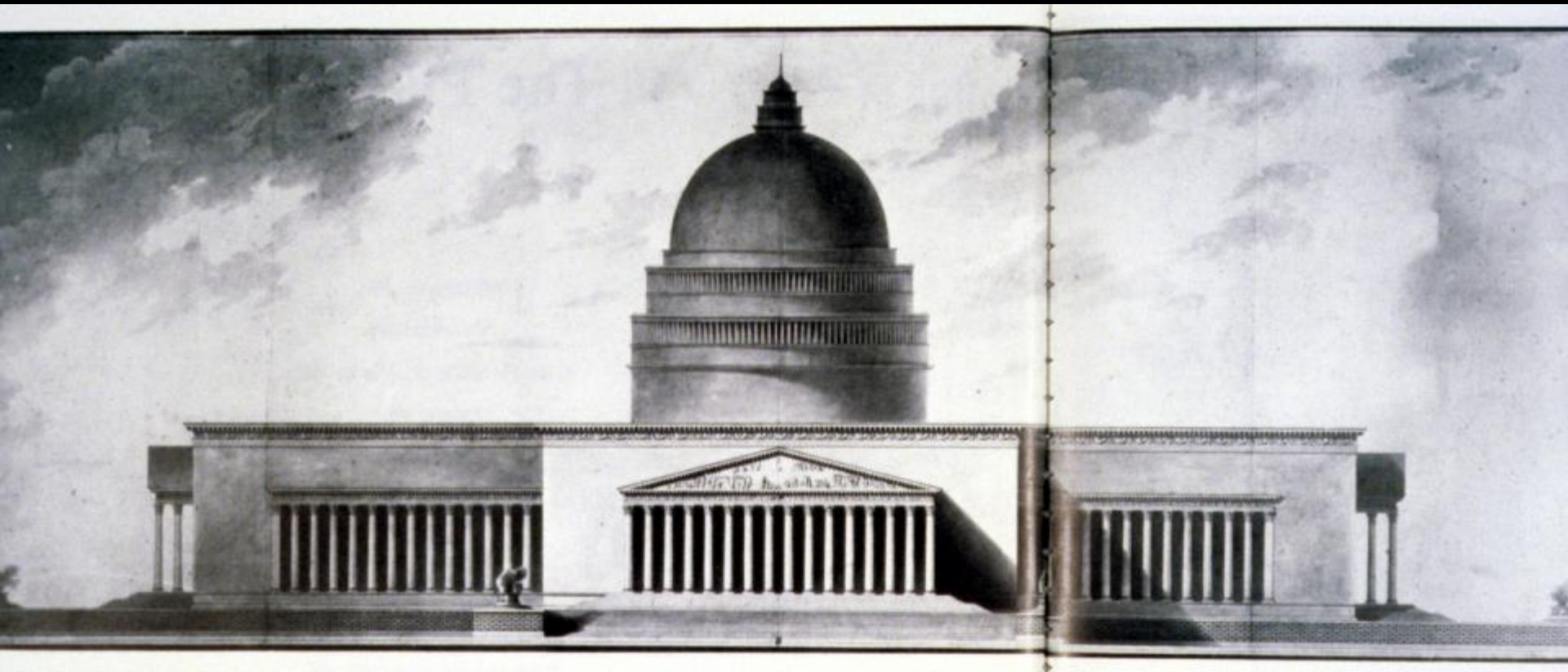


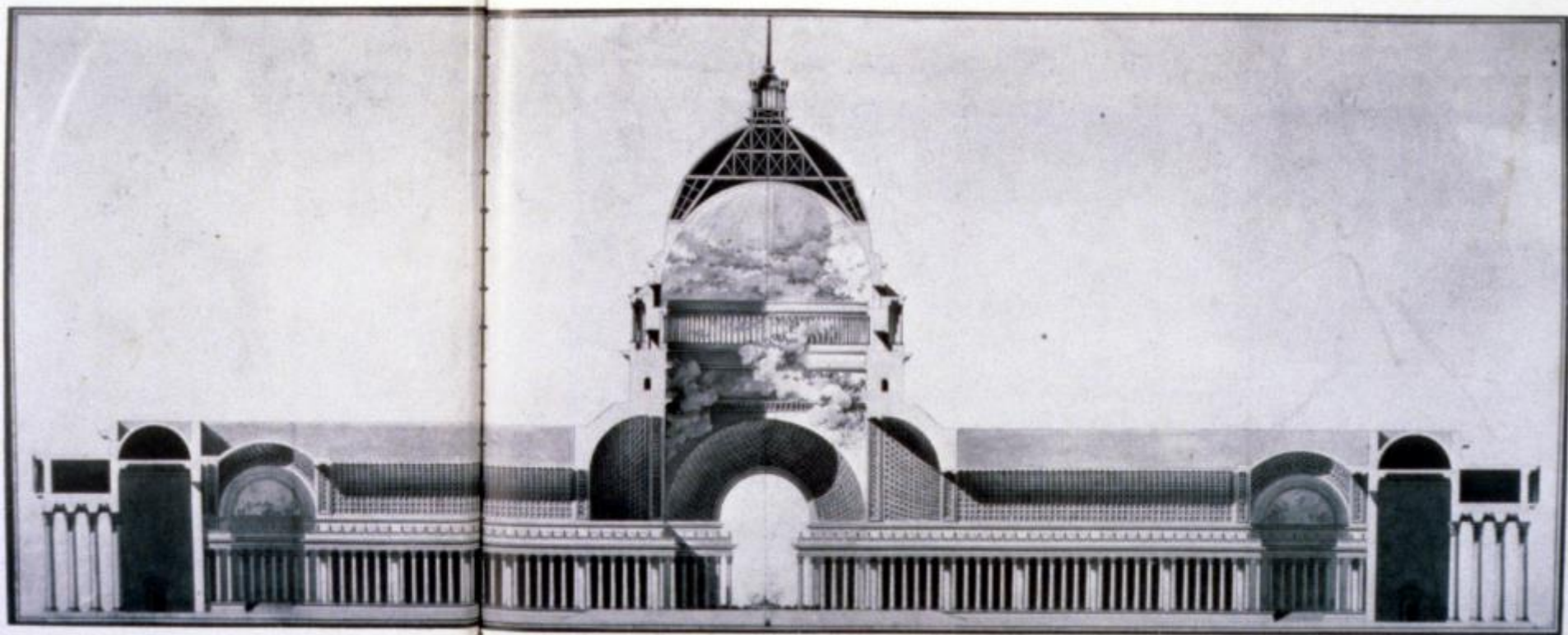
23, 24 Paris, Church of St. Genevieve (J. G. Soufflot, 1755): the iron skeleton of the pronaos (from Rondelet, Fig. 151); plan and facade

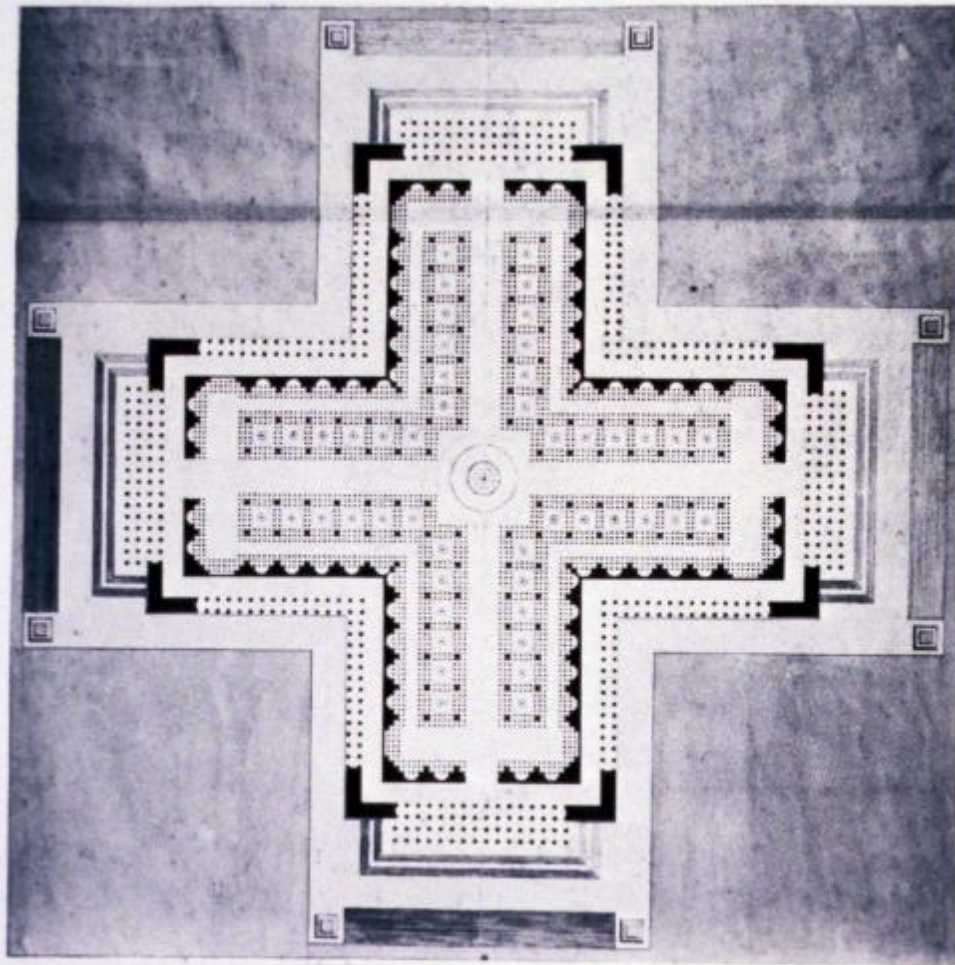


Visionary Architecture

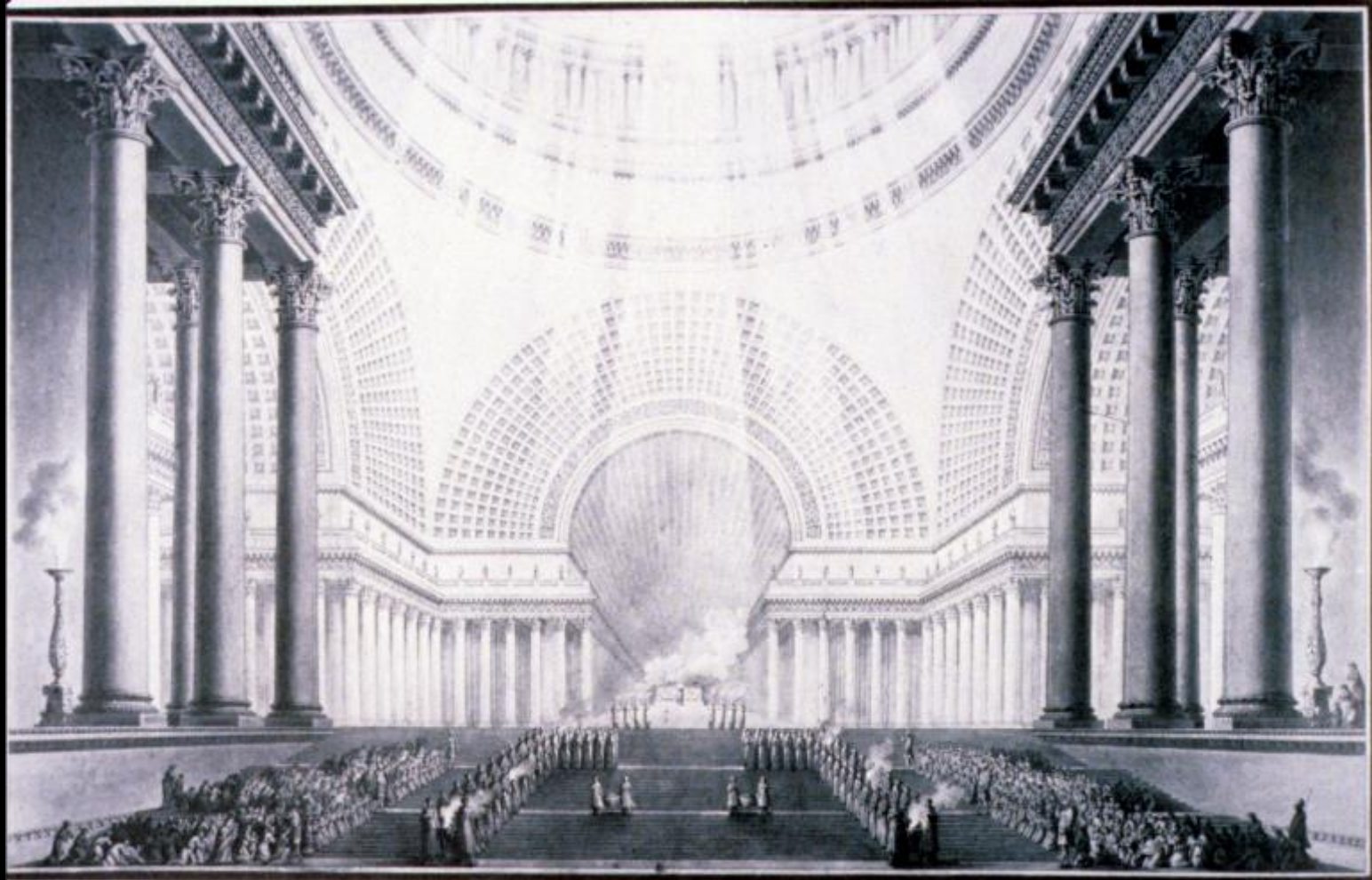
Etienne-Louis Boullée
French Visionary Architect
1728 to 1799





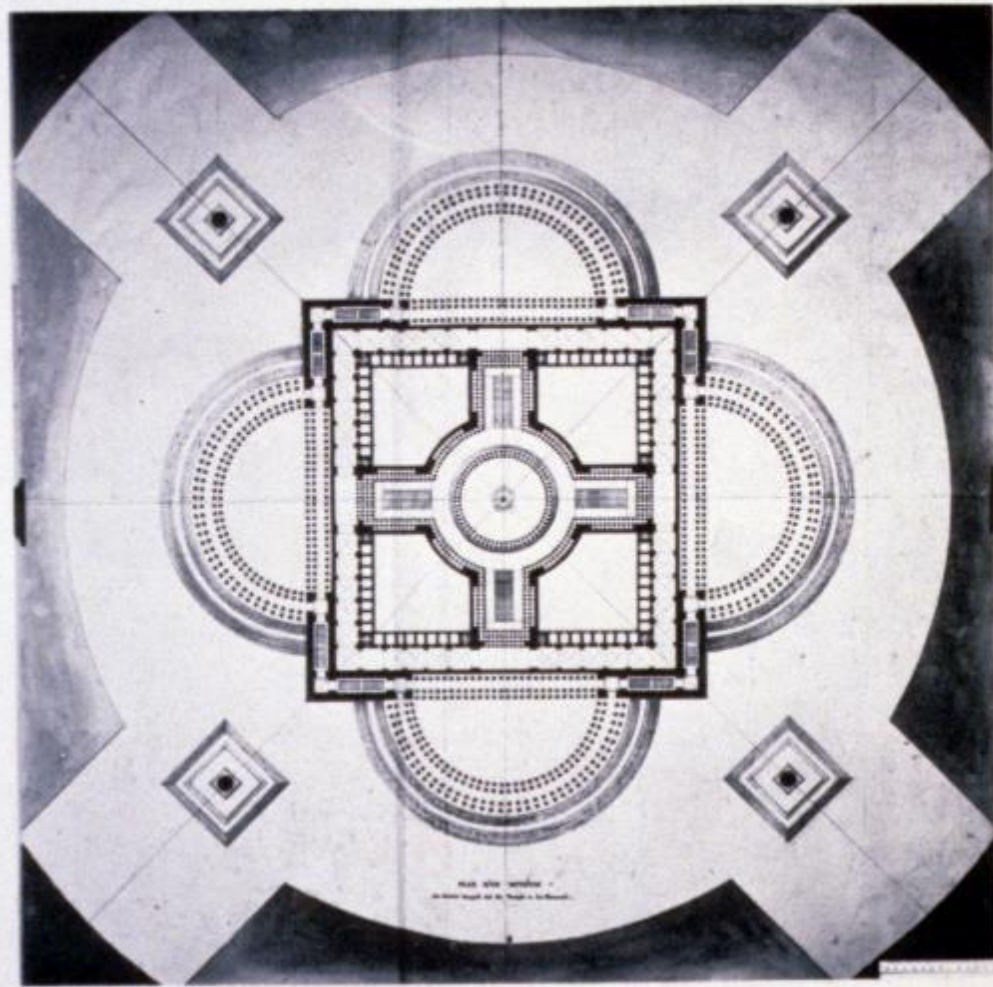


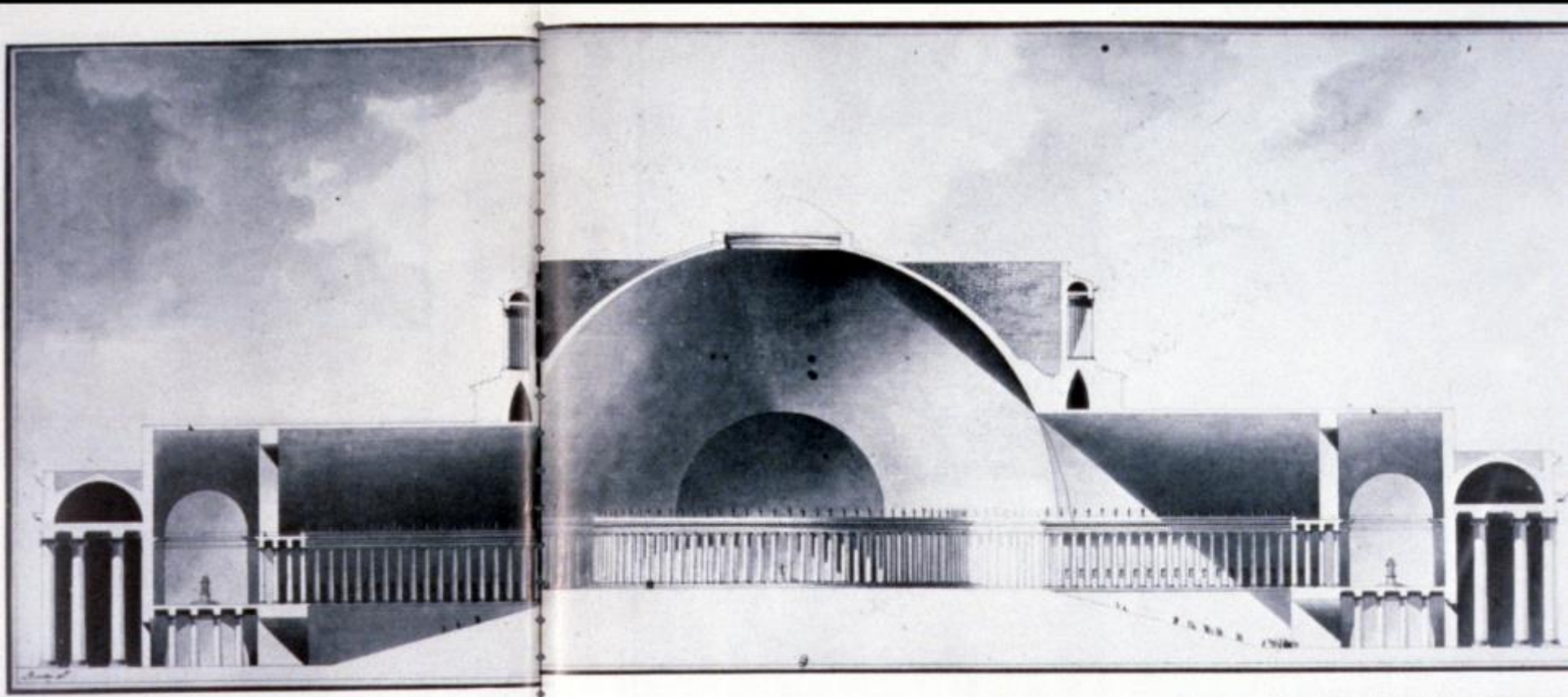
Metropole, ground plan (HA 56, no. 2)

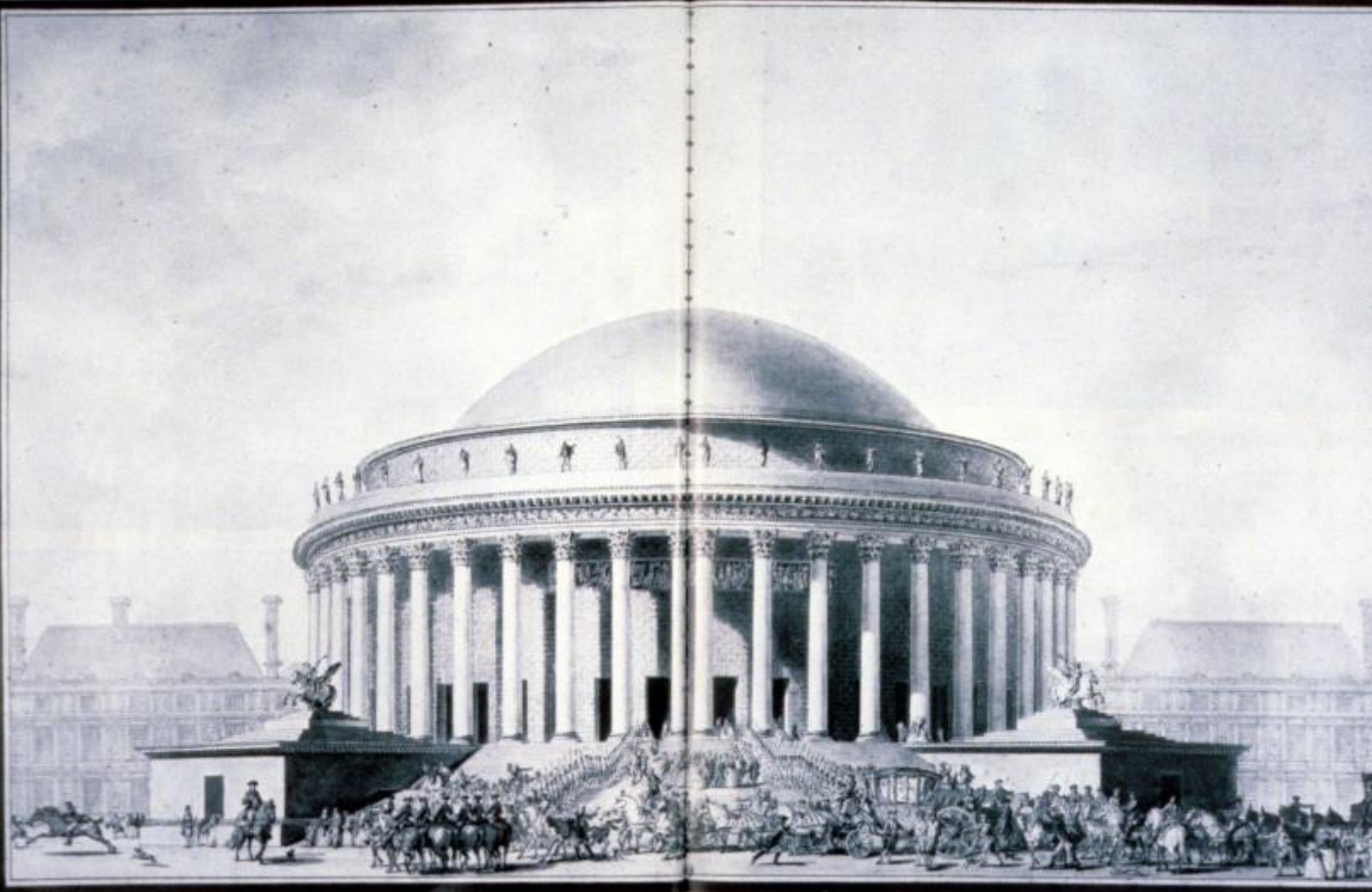


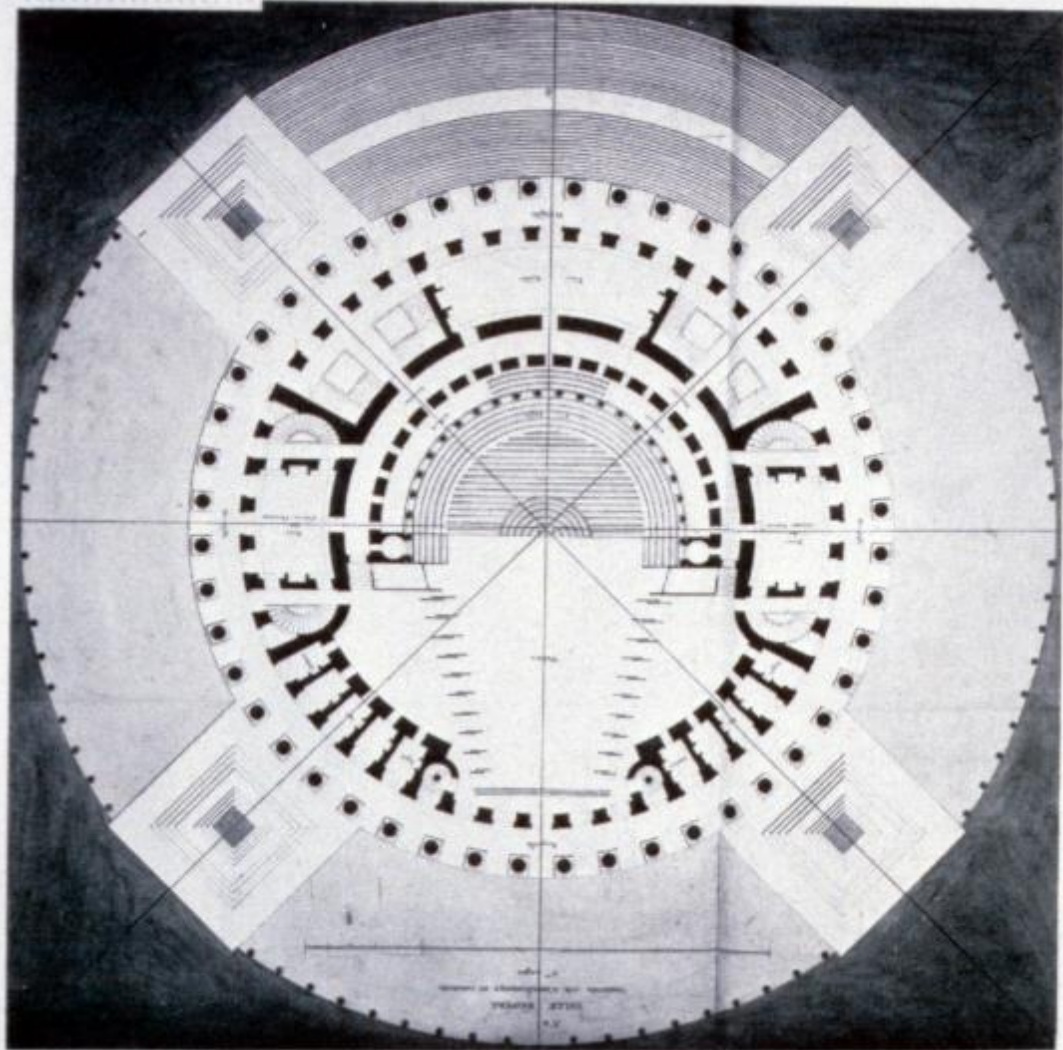
Metropole, interior view at Corpus Christi (HA 56, no. 8)

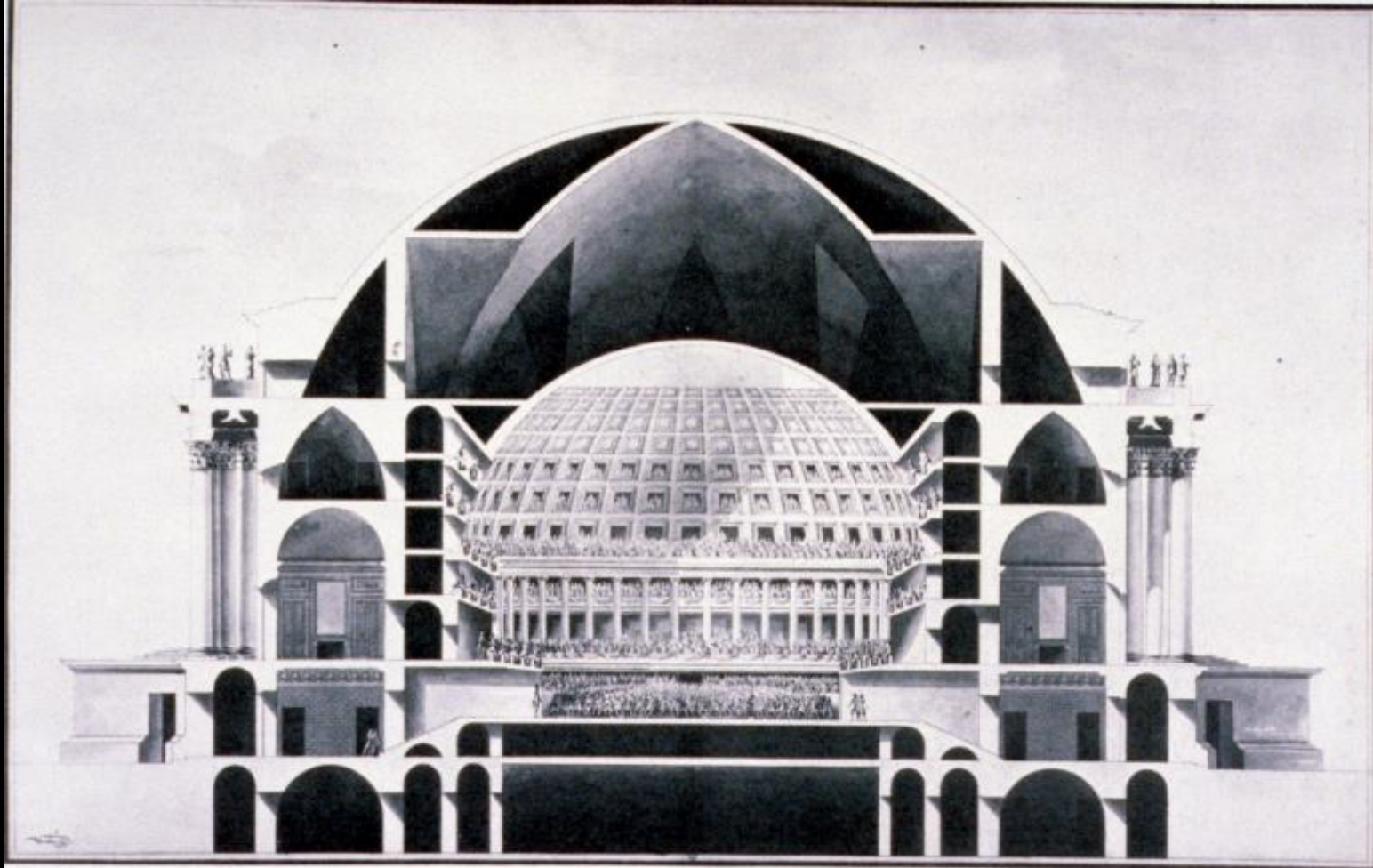
Museum, ground plan (HA 56, no. 26)



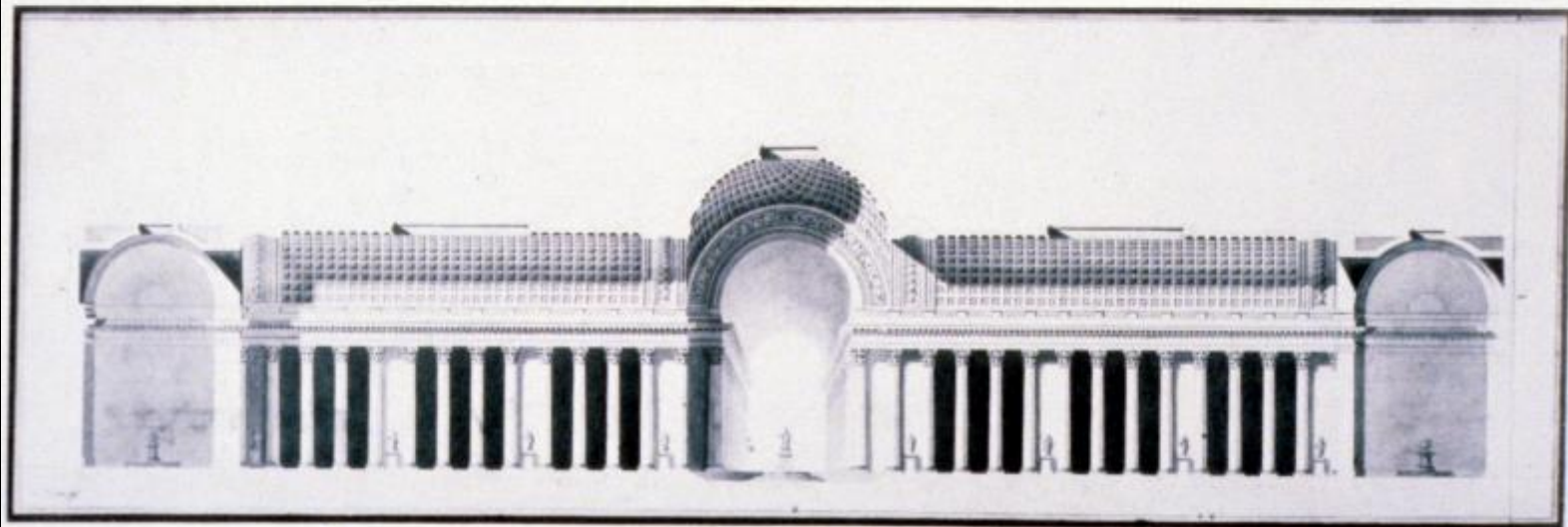
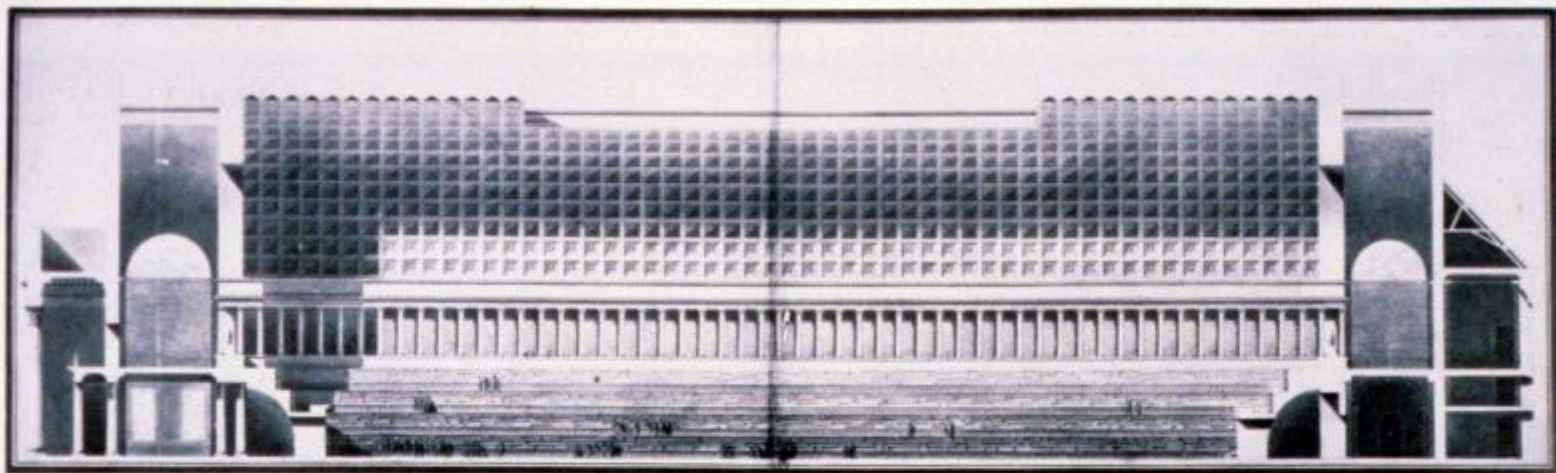






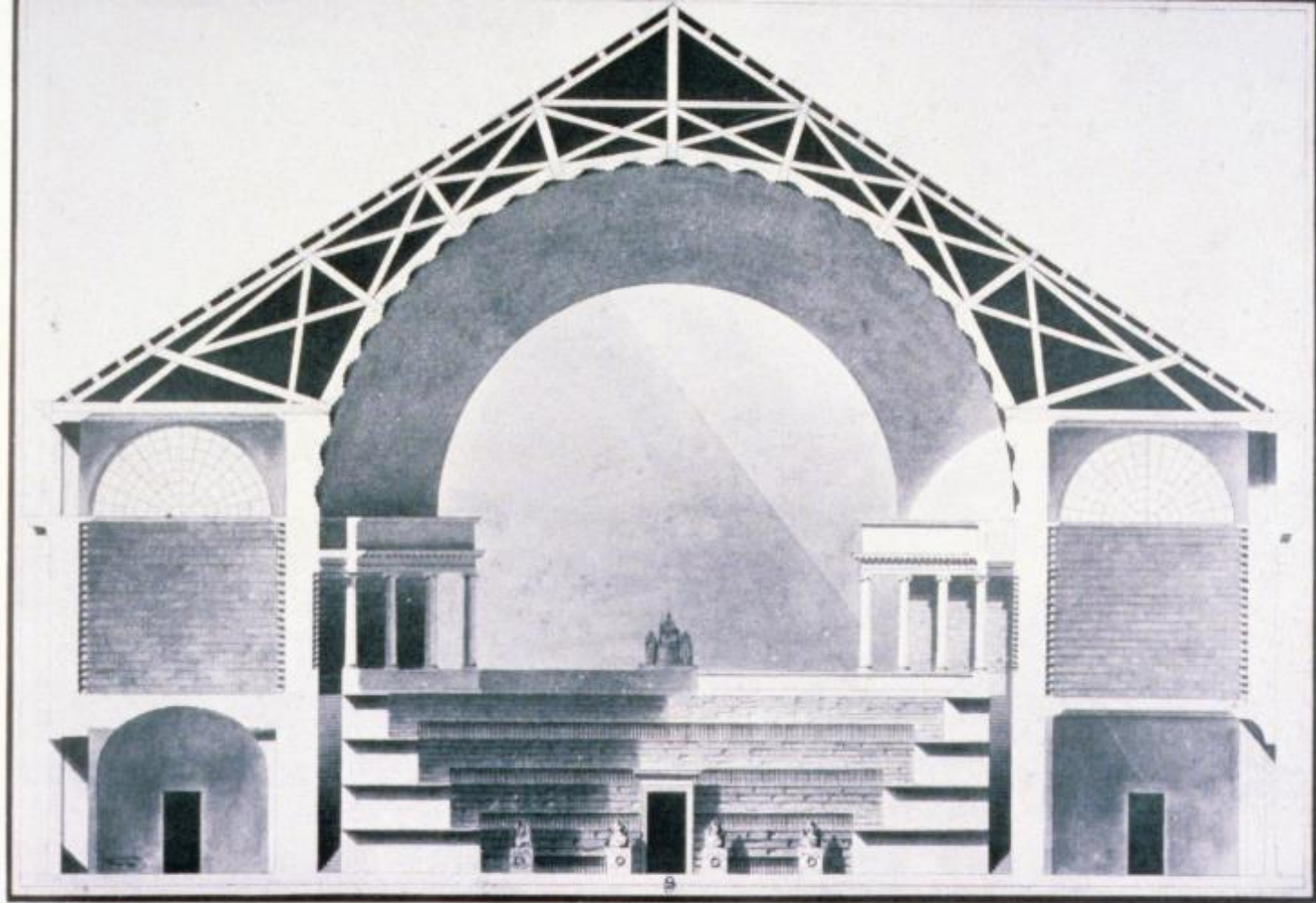


Above: Opera, section facing the auditorium (HA 55, no. 10) Below: Opera, section facing the stage (HA 55, no. 11)

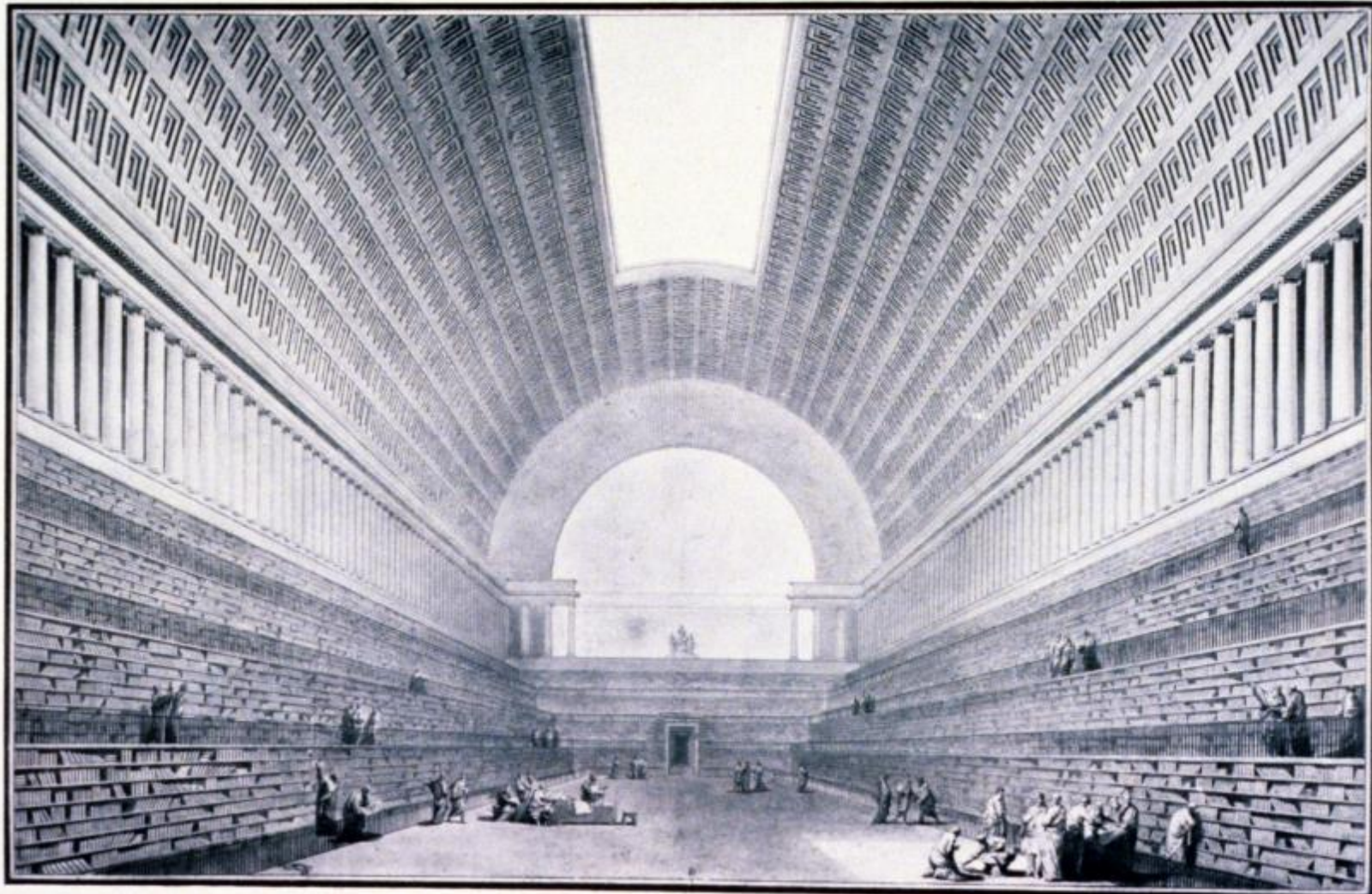


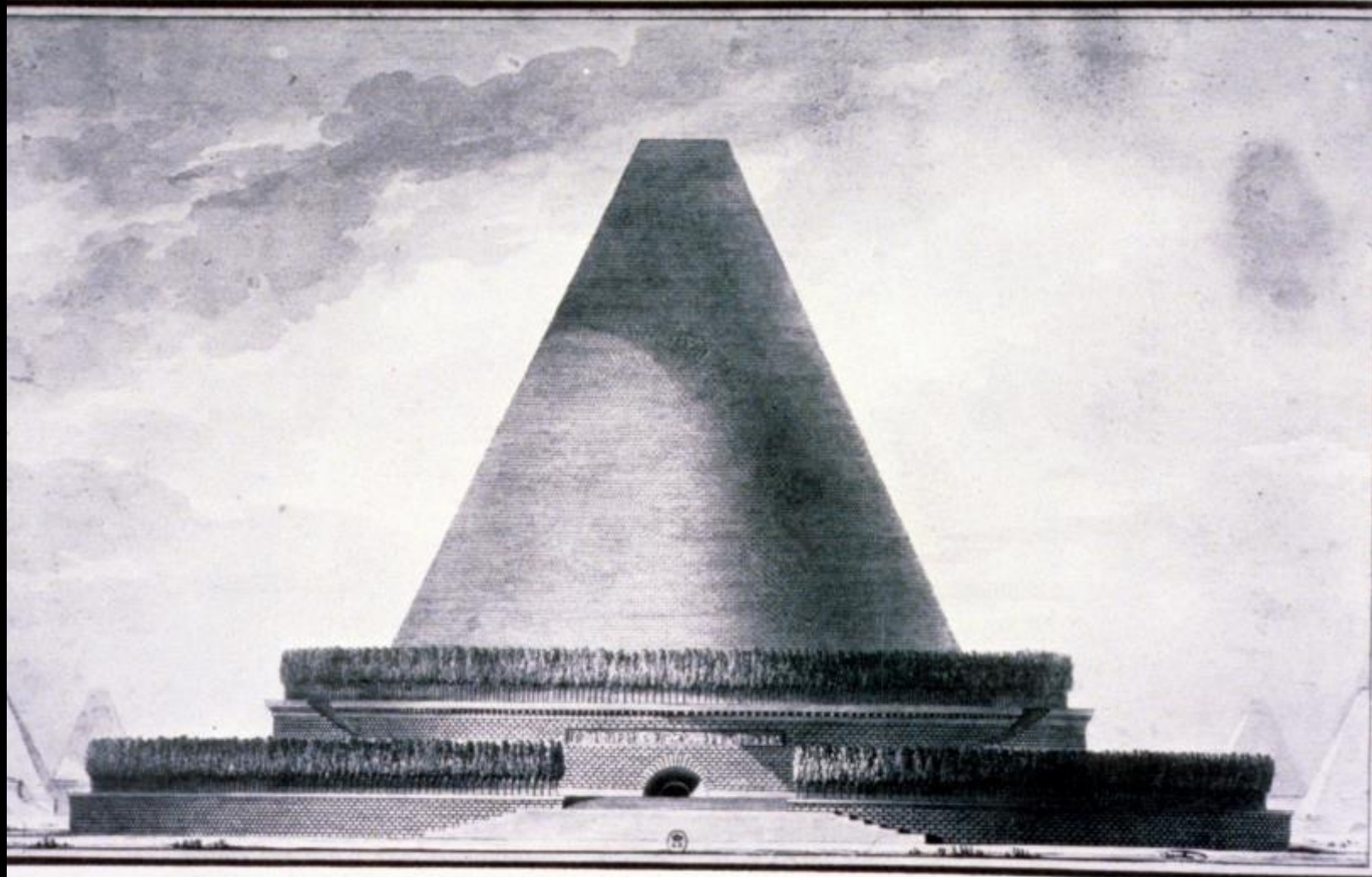


School of Athens
Rafael



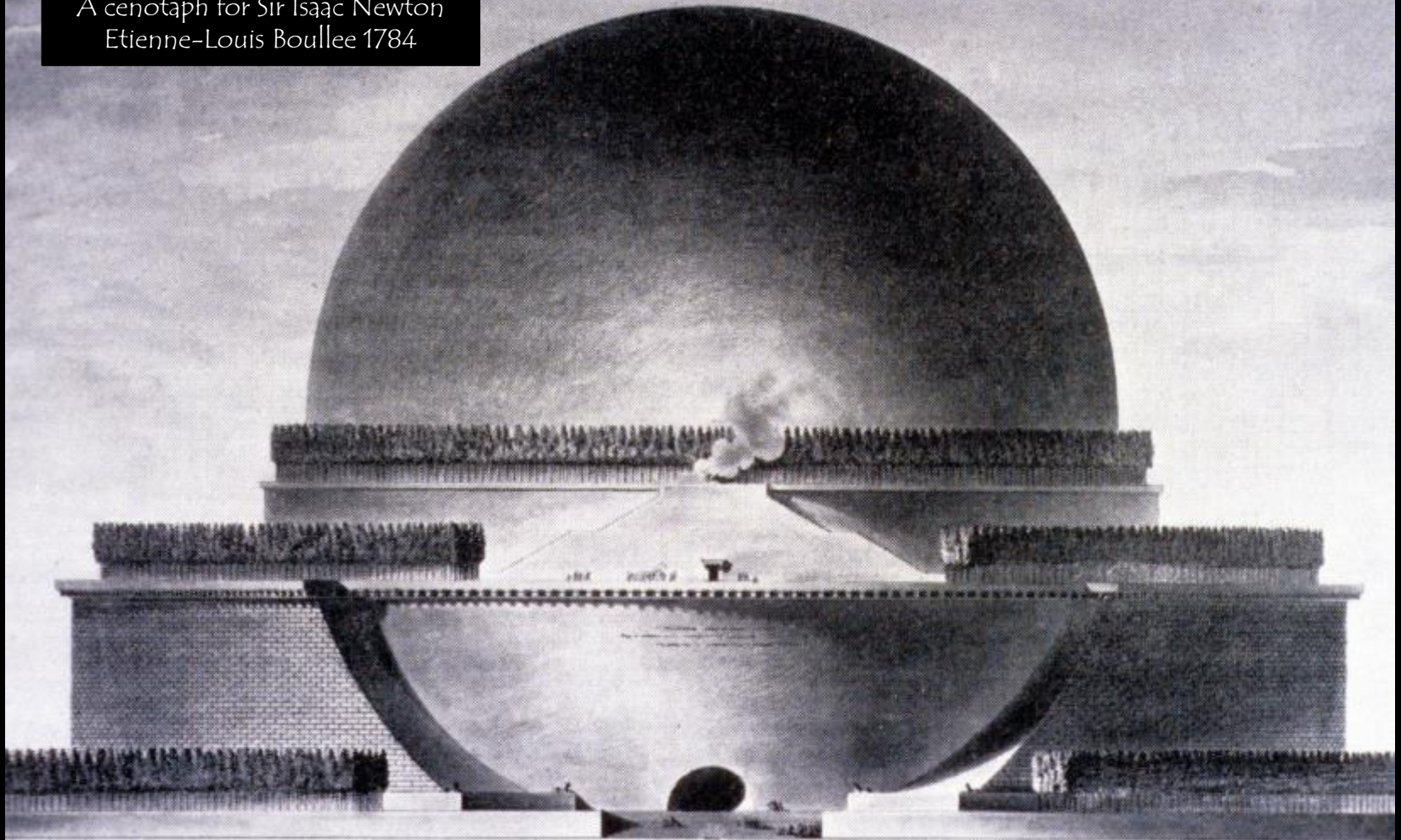
Bibliothèque Nationale, latitudinal section (HA 56, no. 42)

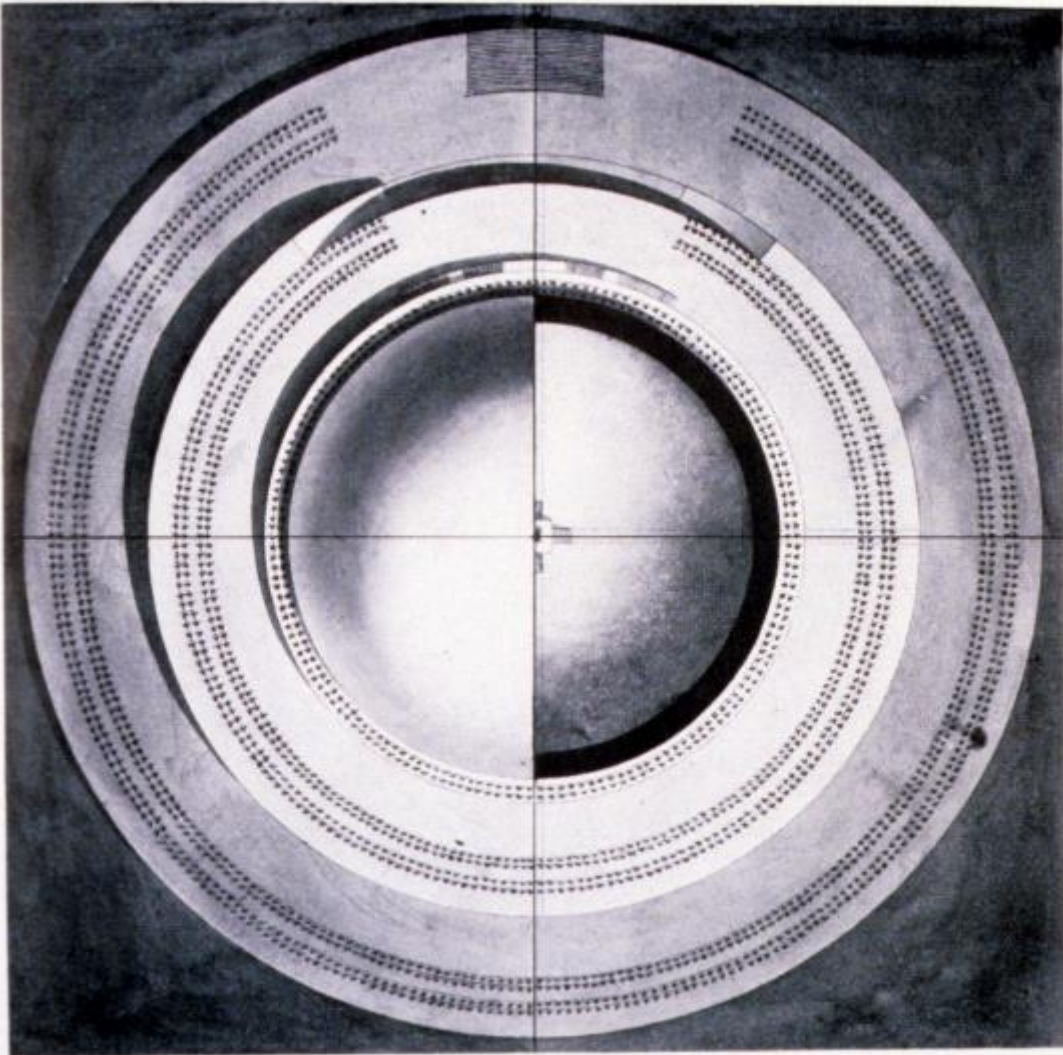




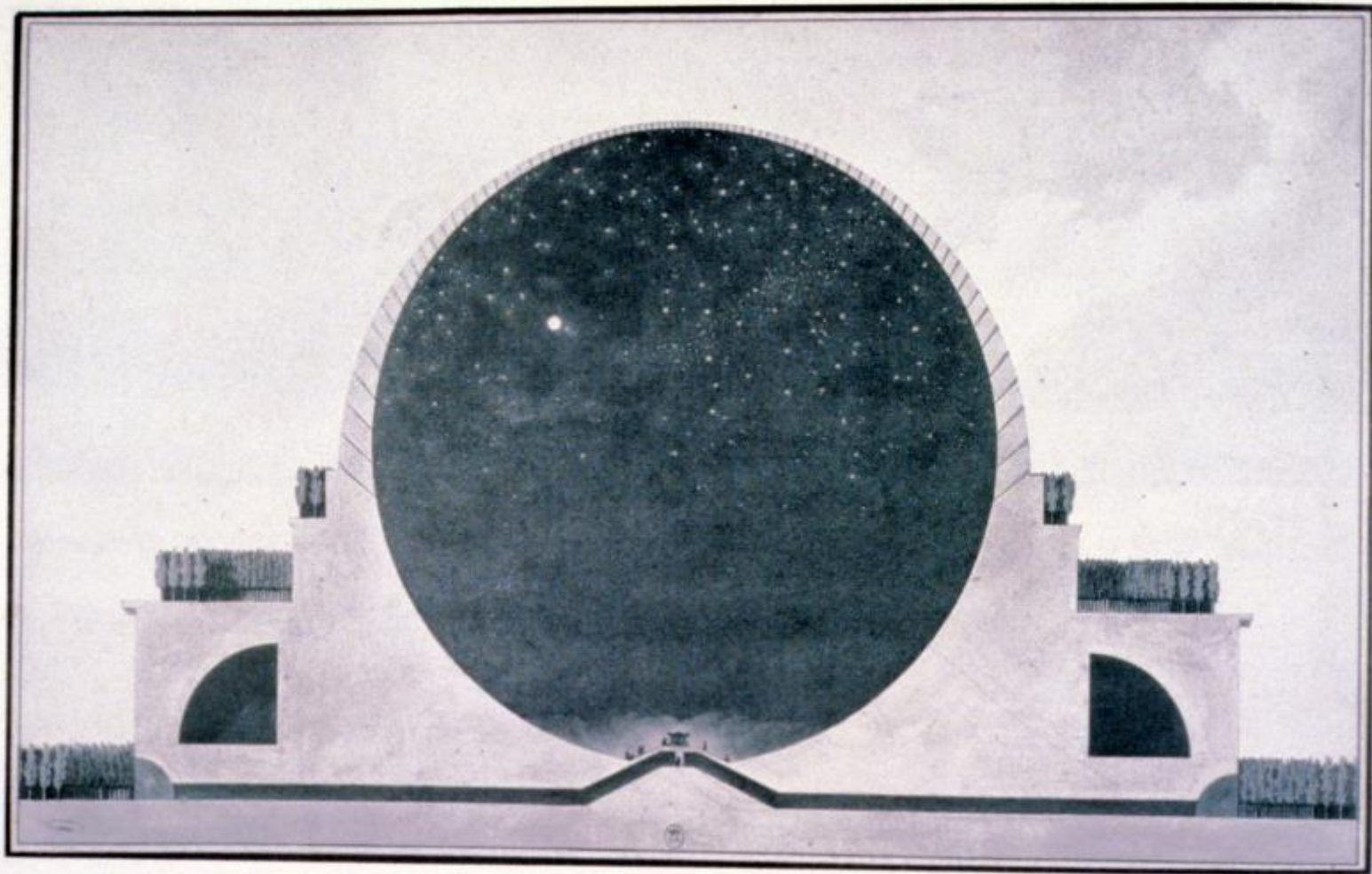


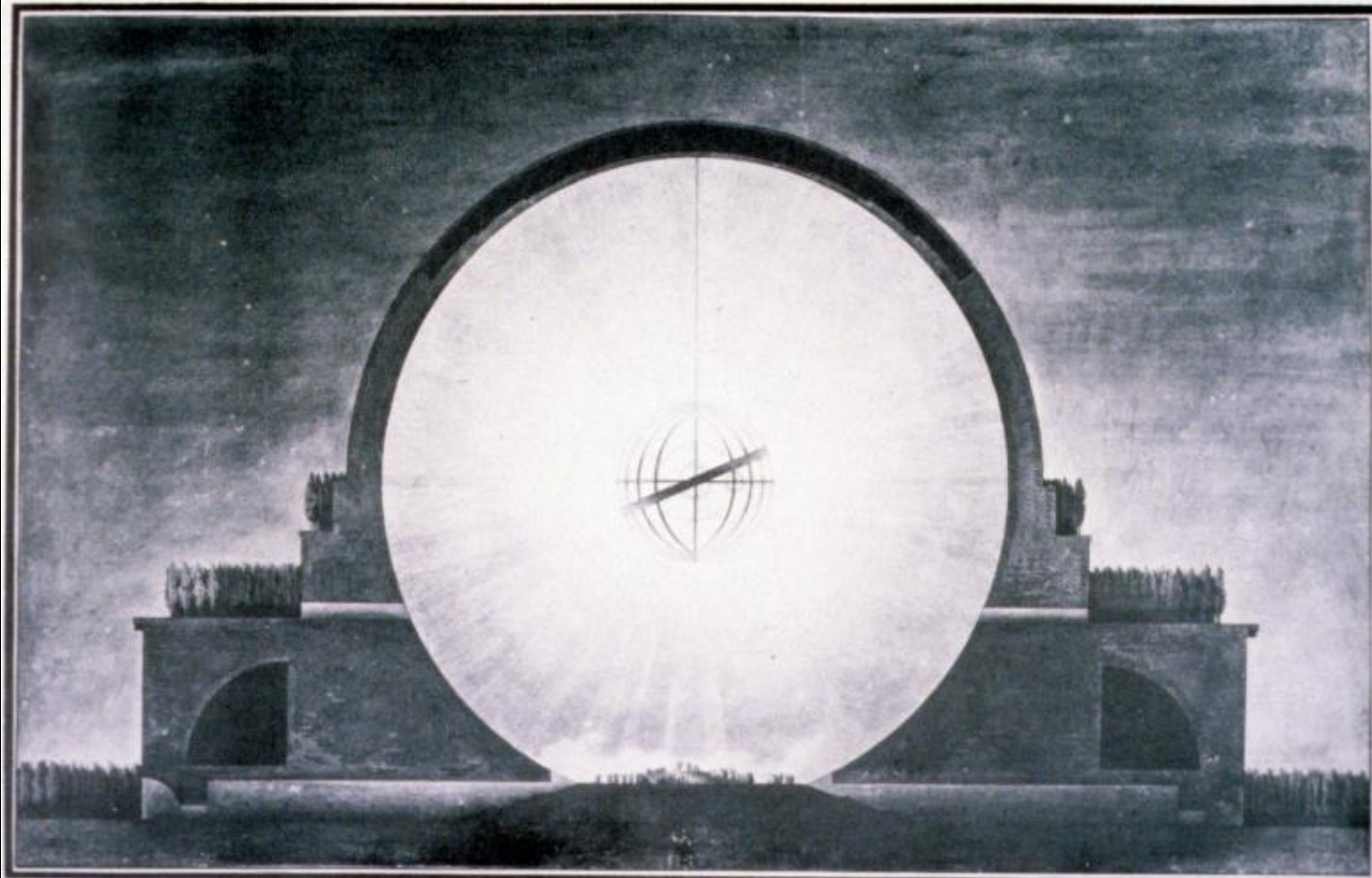
A cenotaph for Sir Isaac Newton
Etienne-Louis Boullée 1784





CENOTAPH FOR NEWTON





3000 B.C.

Egyptians used mud mixed with straw to bind bricks. They used gypsum and lime mortars in the pyramids.



300 BC- 476 AD

Applian Way, Roman baths, the Colosseum and Pantheon used Pozzallana cement. Animal fat, milk and blood were used as admixtures.



CONCRETE HISTORICAL TIMELINE

1793

John Smeaton used hydraulic lime to rebuild Eddystone Lighthouse in Cornwall, England



1824

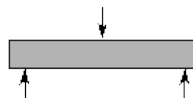
Joseph Aspdin of England invented portland cement by burning ground chalk with finely divided clay in a lime kiln until carbon dioxide is driven off. The product was then ground.



3000 B.C.- PRESENT

1836

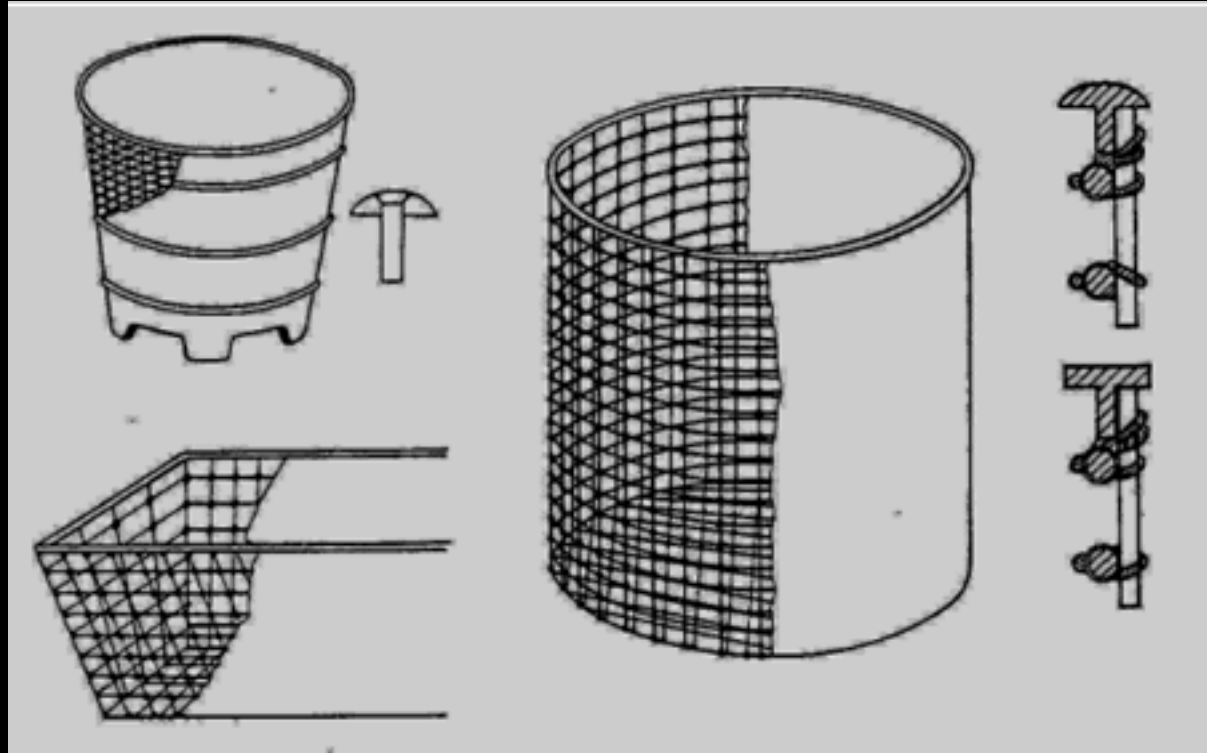
The first systematic test of tensile and compressive strength took place in Germany



1867

Joseph Monier of France reinforced flower pots with wire ushering in the idea of iron reinforcing bars.





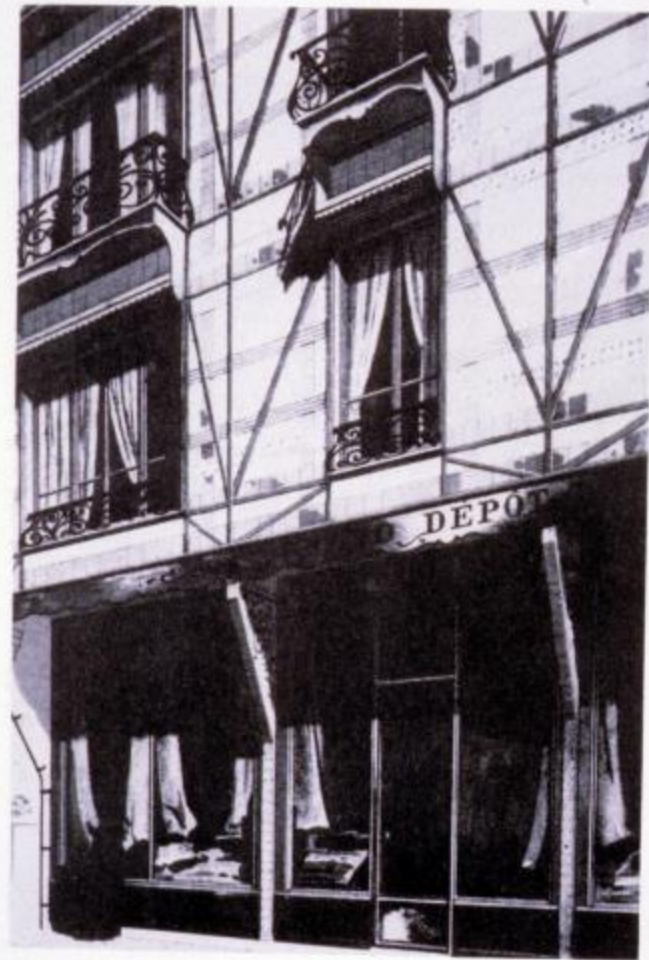


Plate 64. Eugène Viollet-le-Duc. Unpretentious shop and apartment building, 1863 (Viollet-le-Duc, *Atlas*, p. 36)

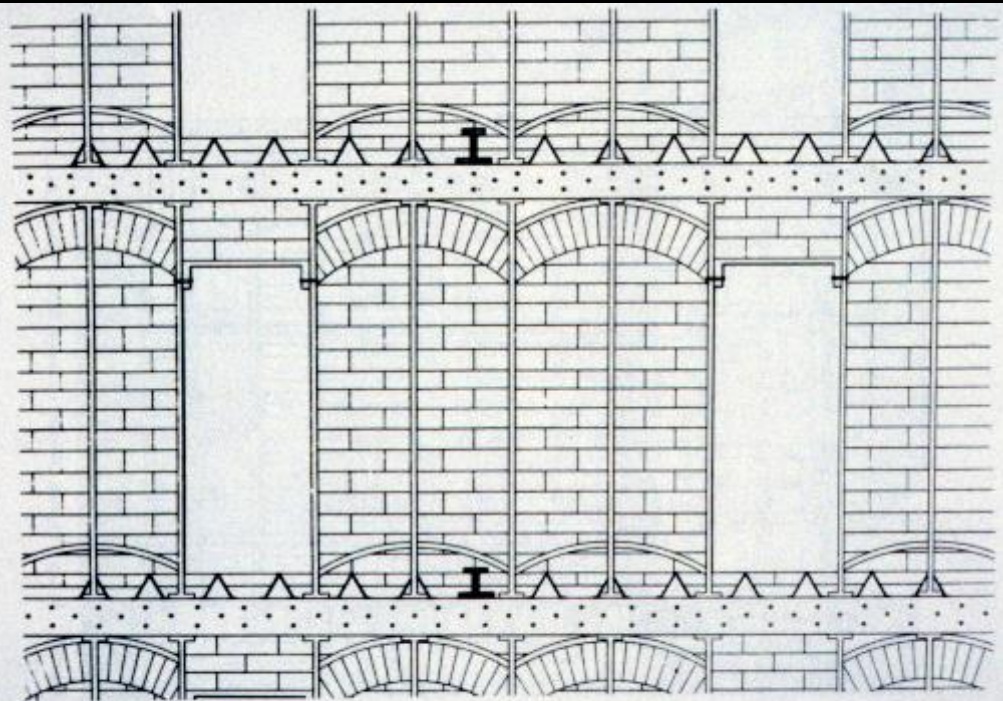


Plate 61. Charles Eck, *Pan de Fer* system, 1868 (Eck, 1868, pl. 60)

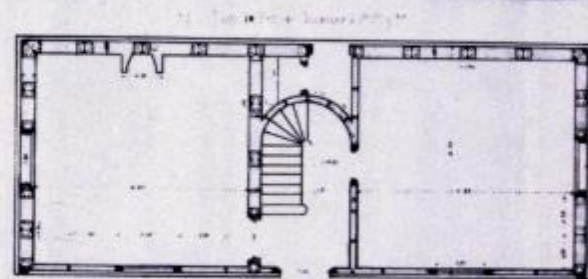
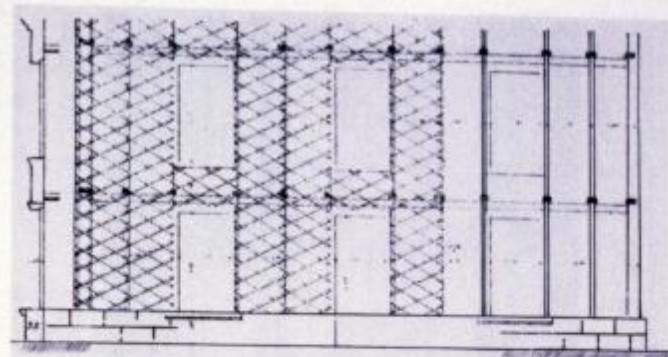


Fig. 57. Lacroix system of framing with iron and cement or concrete.

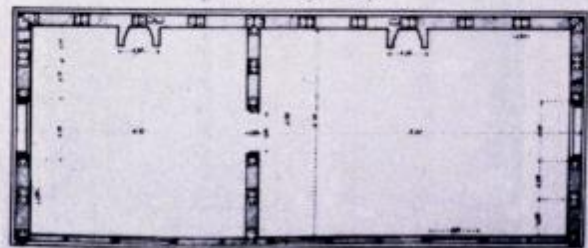


Plate 59. Lacroix system of framing with iron and cement or concrete (*Nouvelle annales de la construction*, X, January, 1864, pl. 7)

1886
First rotary kiln was introduced in England, which allowed for continuous production of cement.



1889
First concrete reinforced bridge was built.



1891
First concrete street in the USA was placed in Bellefontaine, Ohio by George Bartholomew



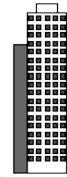
1936
First major concrete dams, the Hoover Dam and Grand Coulee Dam, were built.

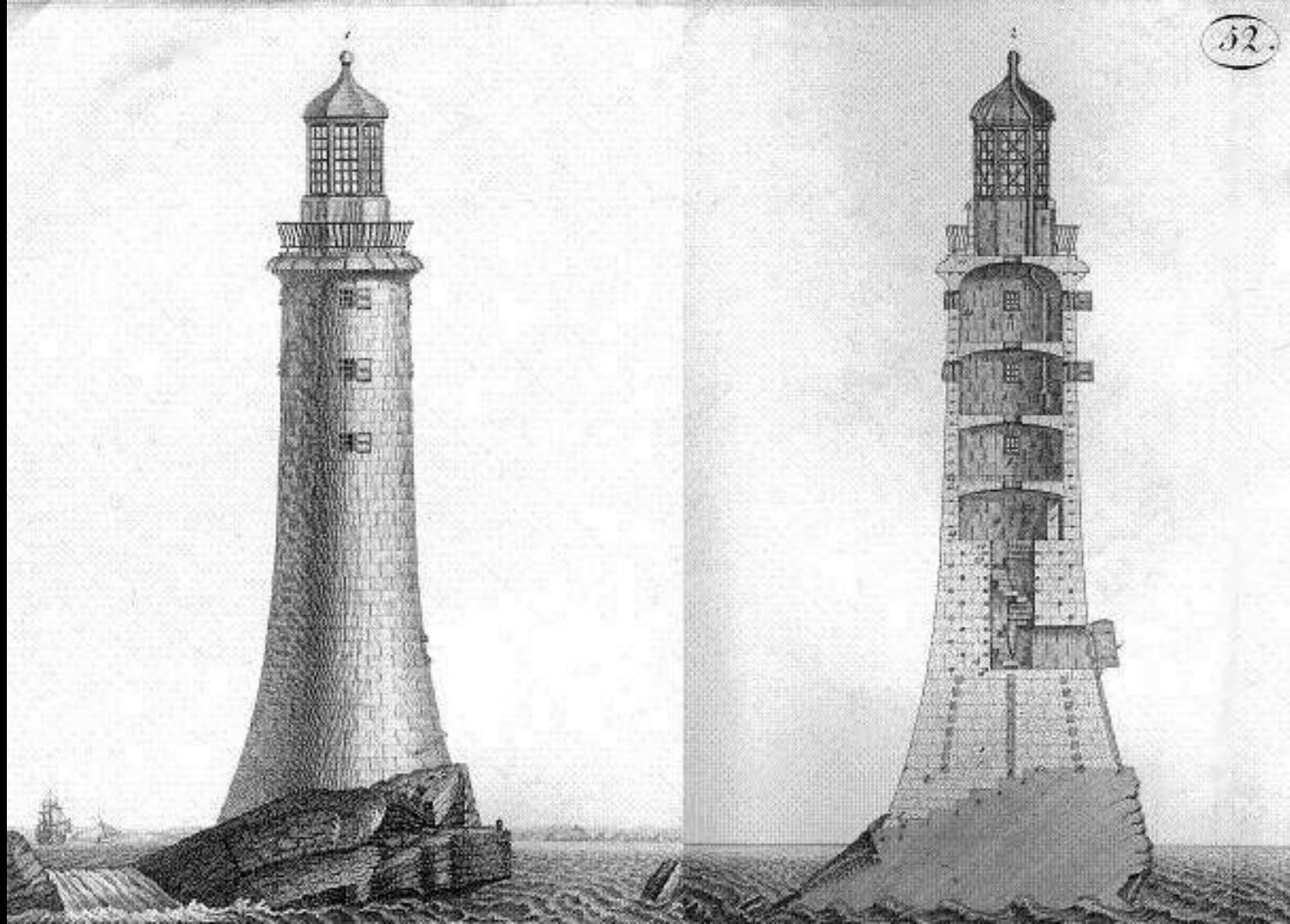


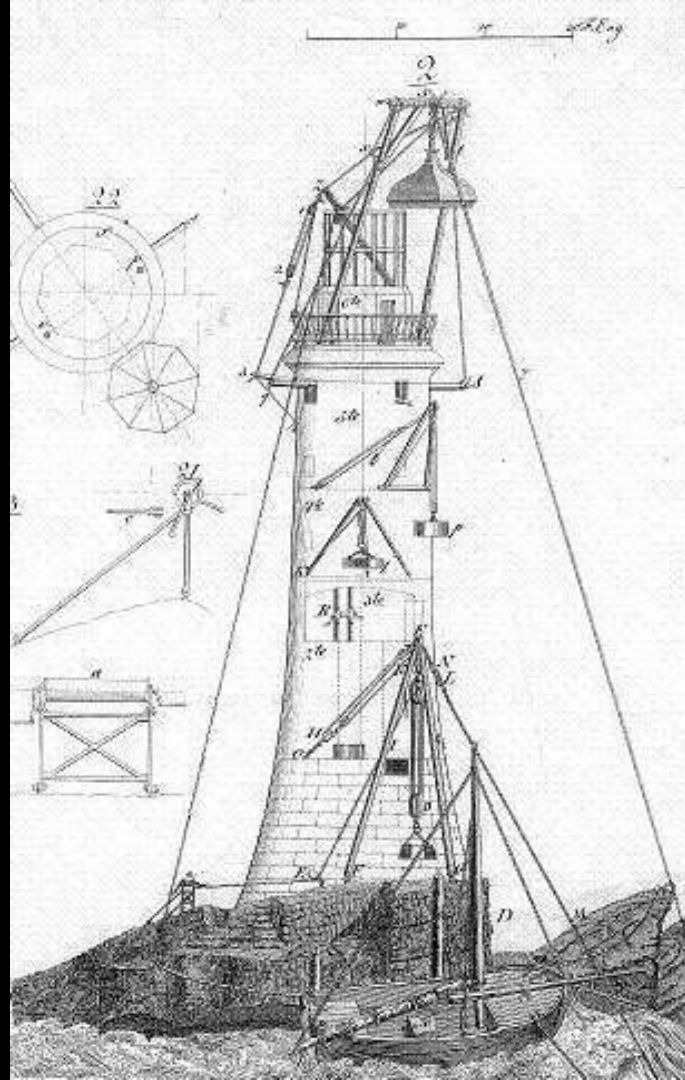
1967
First concrete dome sport structure constructed at the University of Illinois, Assembly Hall



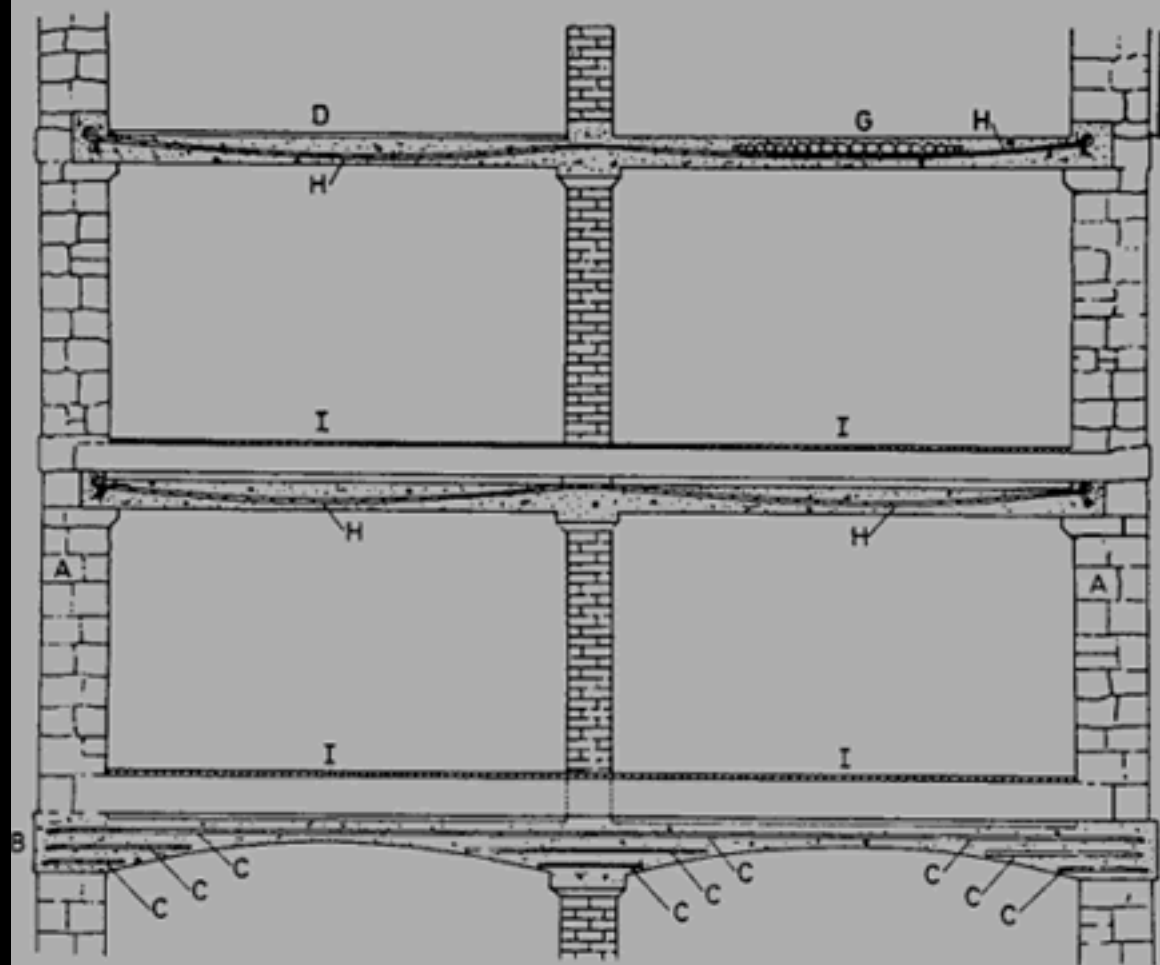
1992
Tallest reinforced building (946 ft) constructed in Chicago, IL

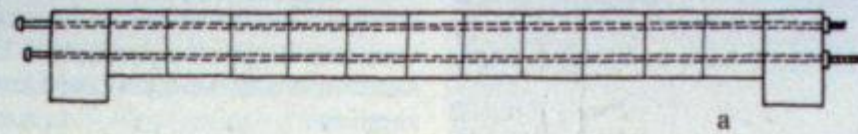




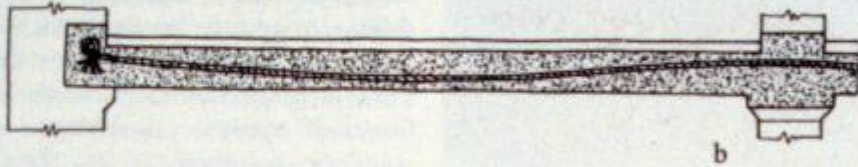


Concrete as STRUCTURE





a



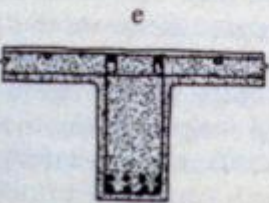
b



c



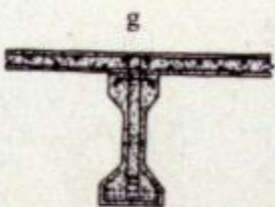
d



e



f

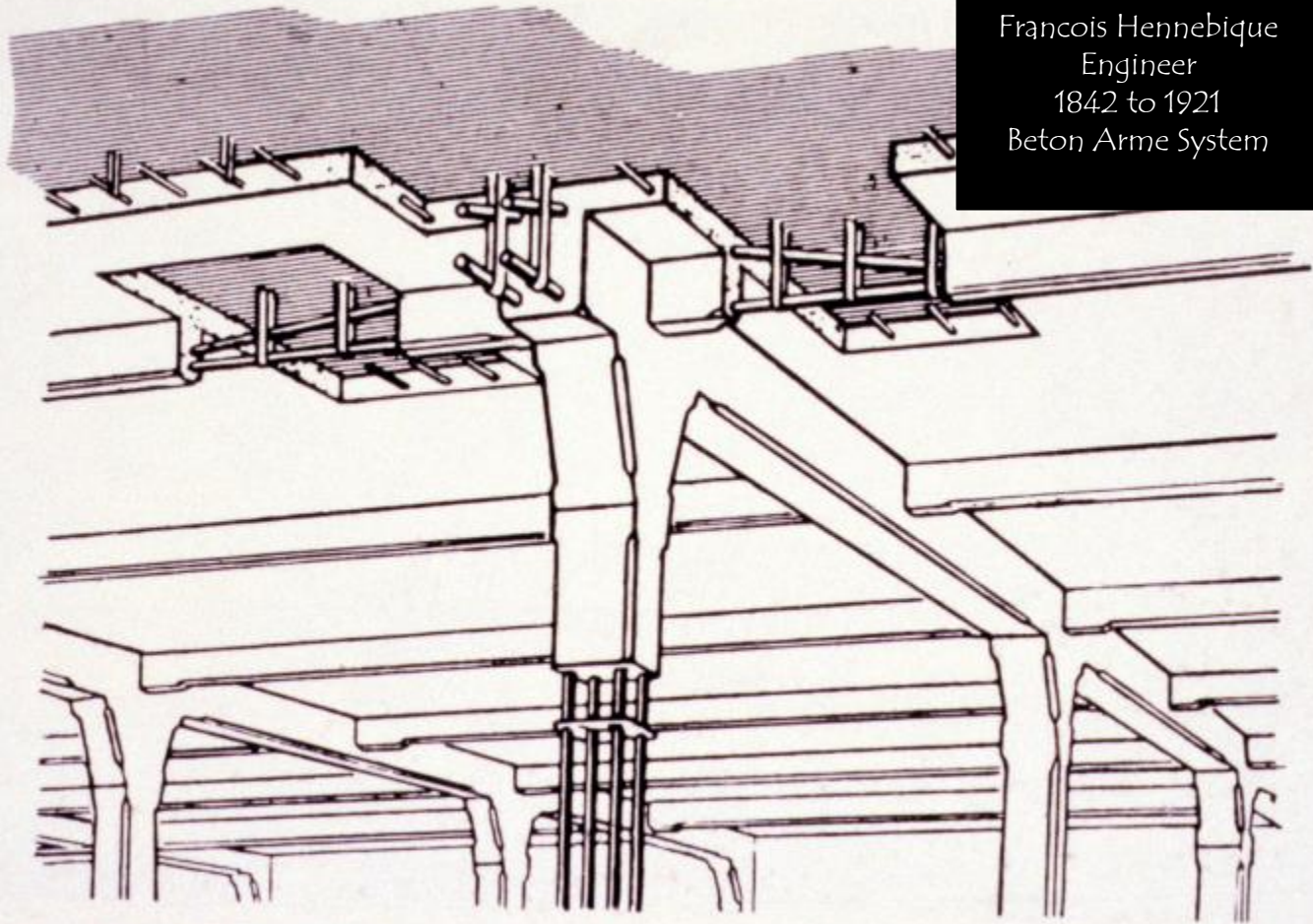


g

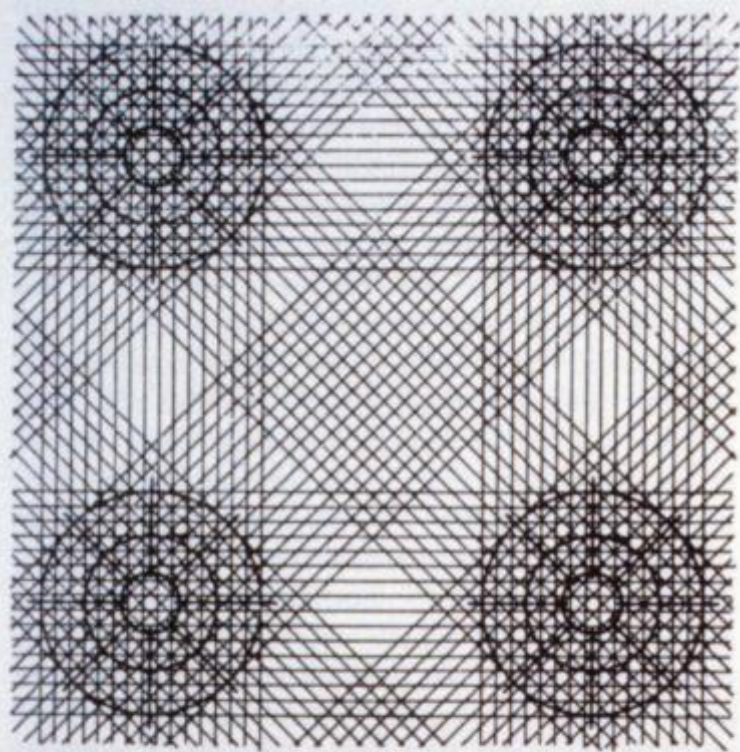
8.10 Reinforced-masonry, reinforced-concrete, and prestressed-concrete beams: [a] Pope, 1811; [b] Wilkinson, 1854 patent; [c] Hennebique, 1897 patent; [d, e, f] modern reinforced-concrete; [g] modern prestressed-concrete.



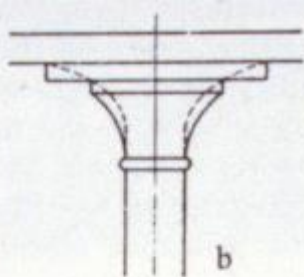
François Hennebique
Engineer
1842 to 1921
Béton Armé System



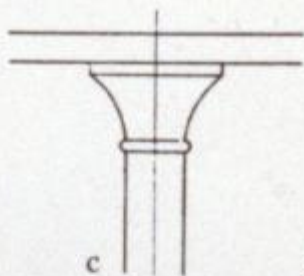
16 Hennebique, patent reinforced concrete frame construction, 1892.



a

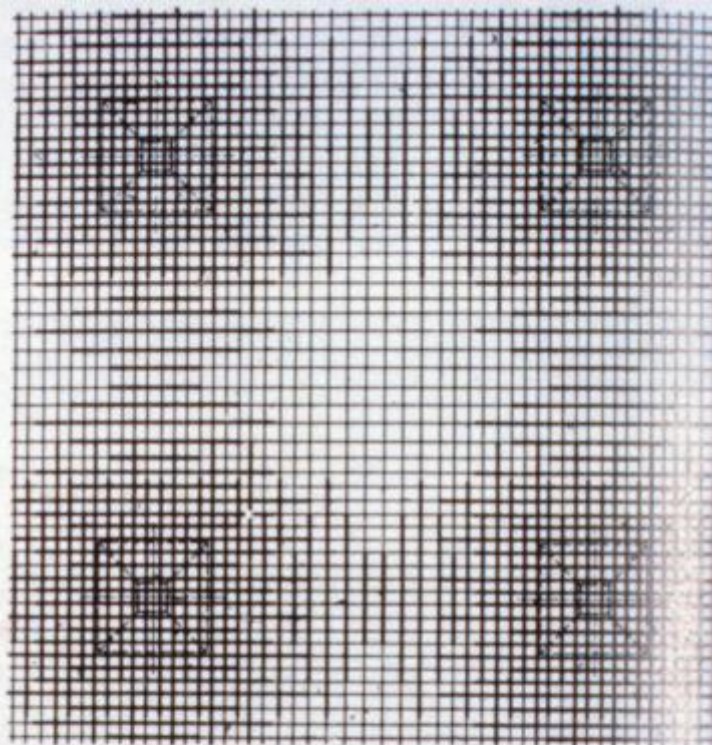


b

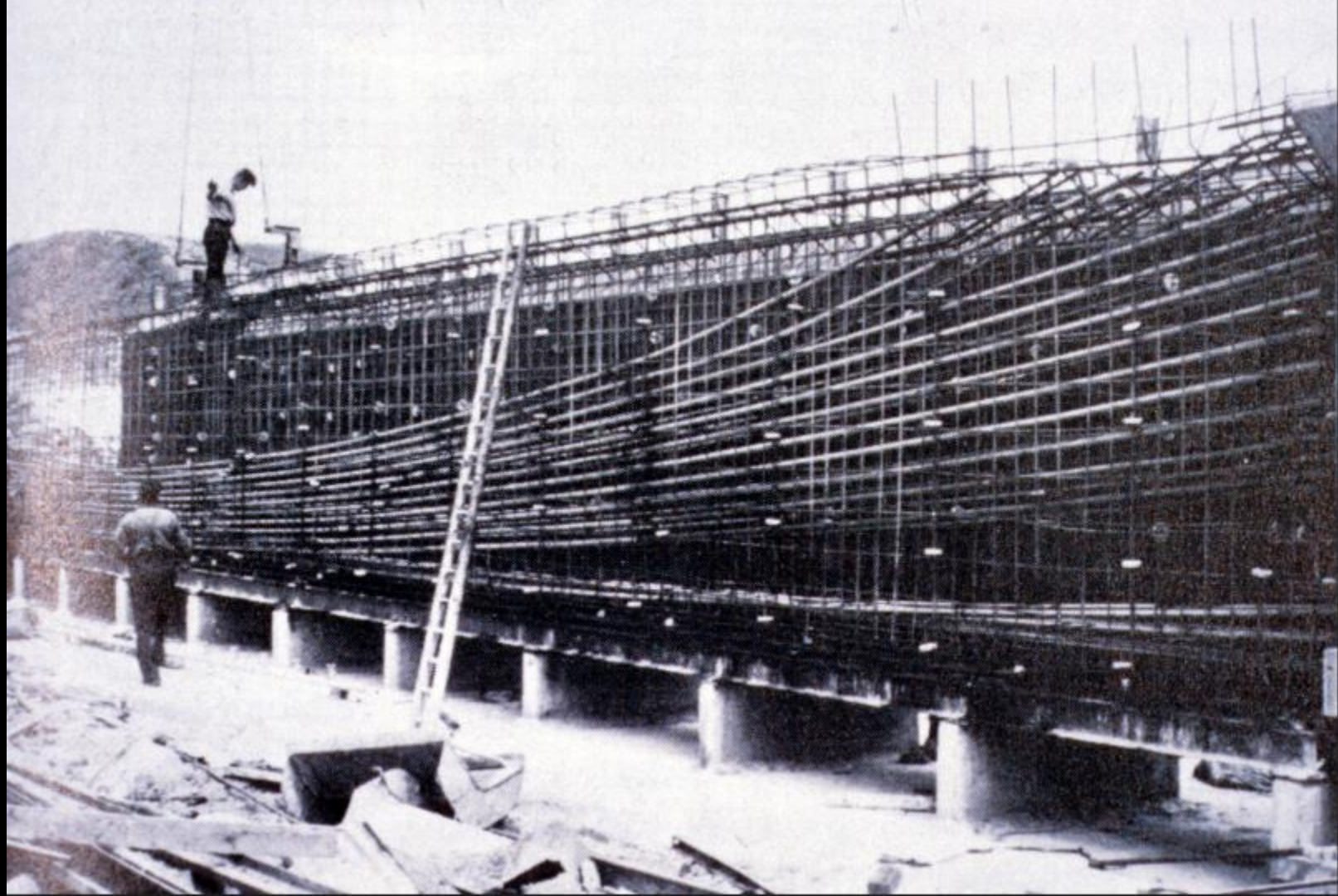


c

d

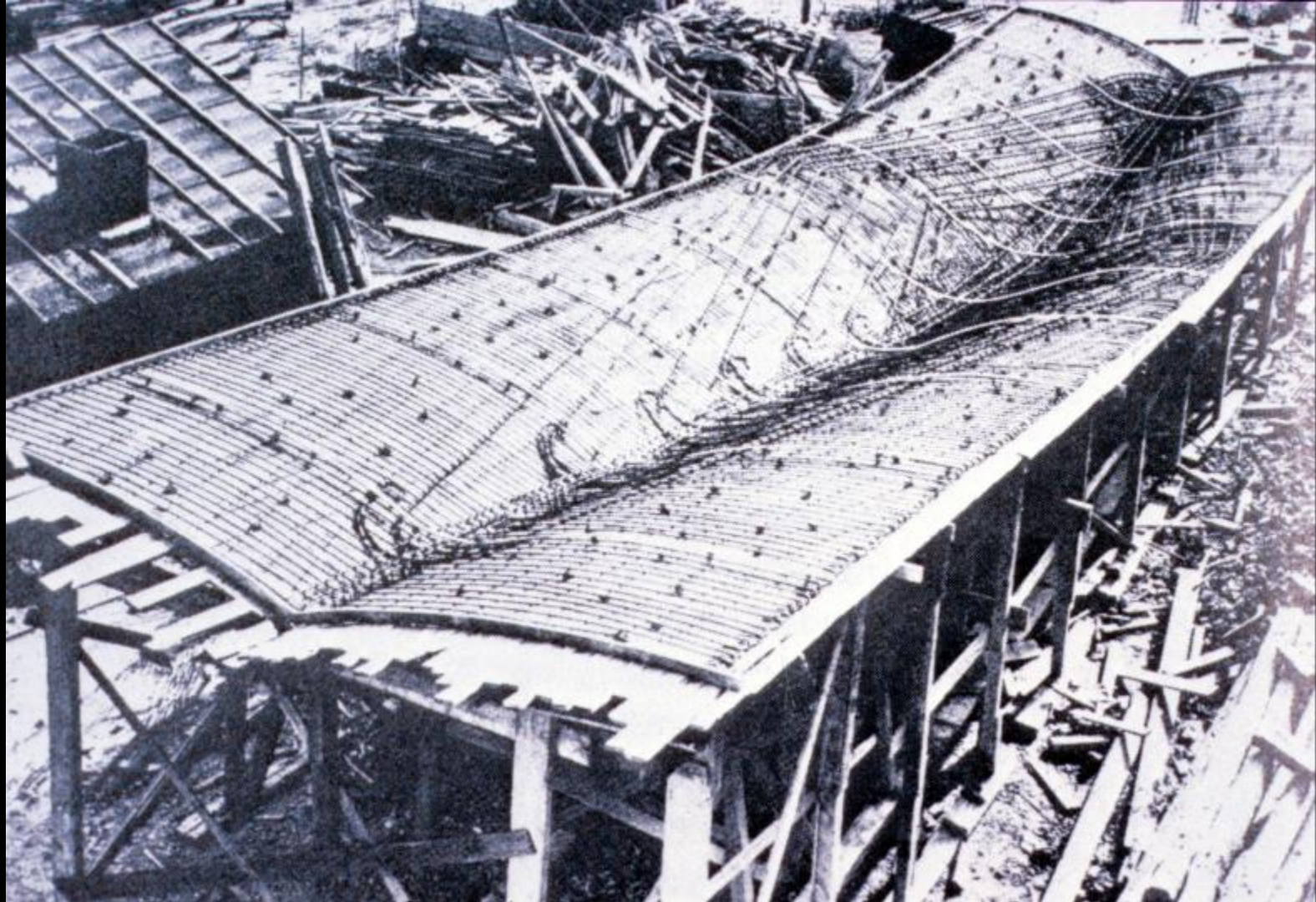


8.16 Early forms of reinforced-concrete flat slab: (a, b) Turne system; (c, d) Maillart system.











Hoover Dam
Nevada/Arizona Border
1931 to 1936









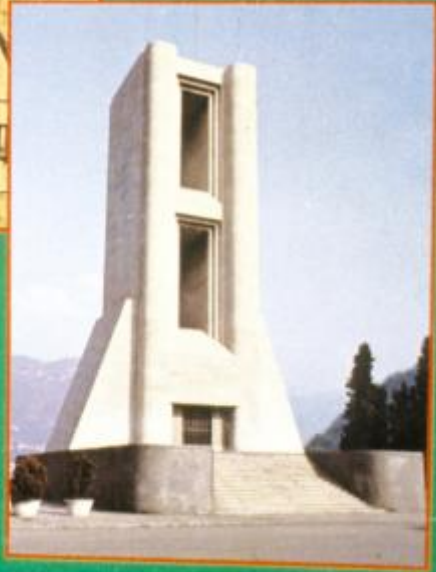


Grand Coulee Dam
Washington State
1933 to 1942



Concrete as STYLE

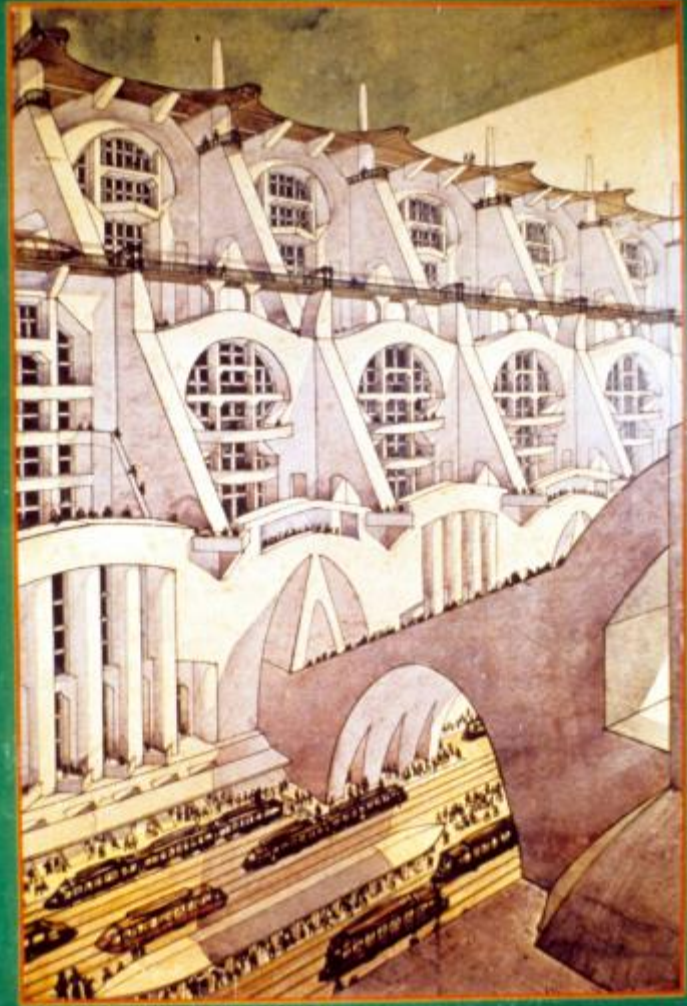
Futurism
and the beginnings of
The Modern Movement



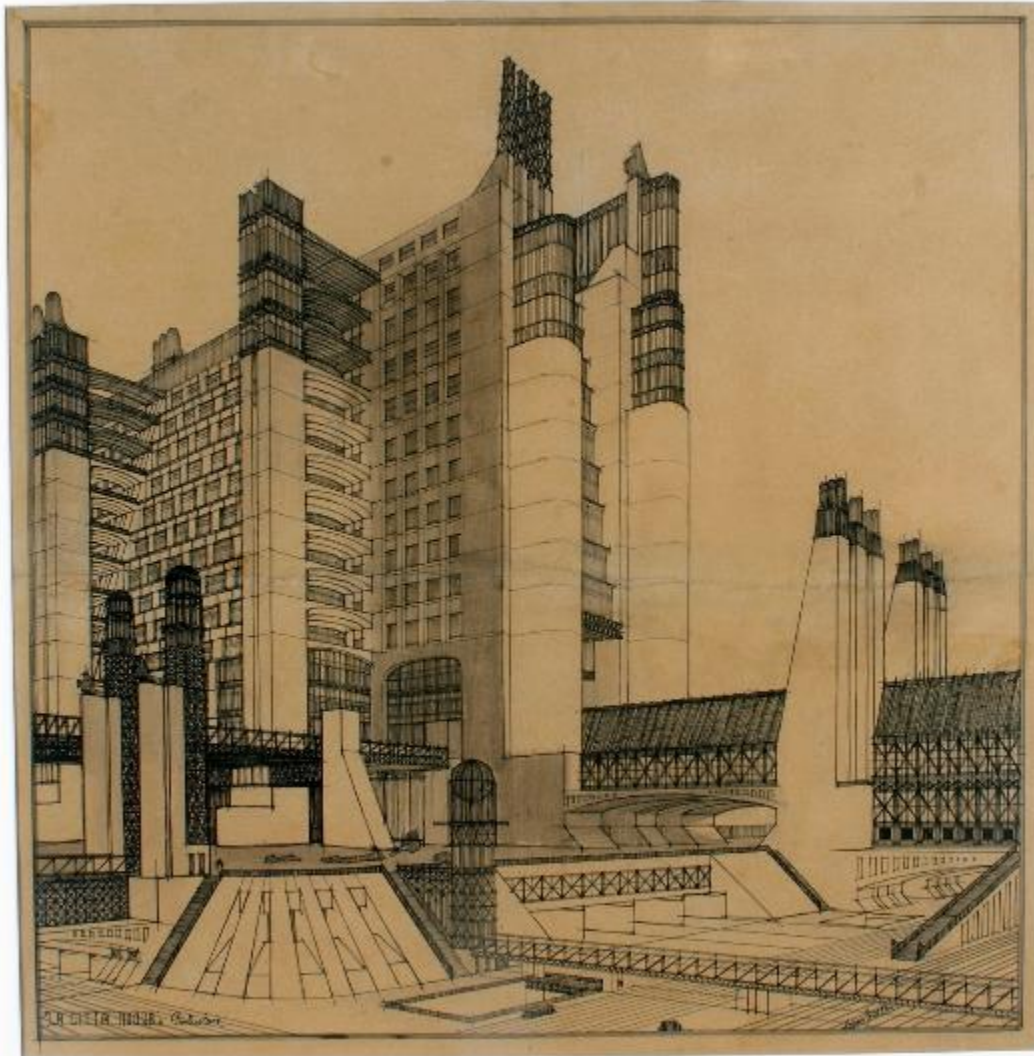
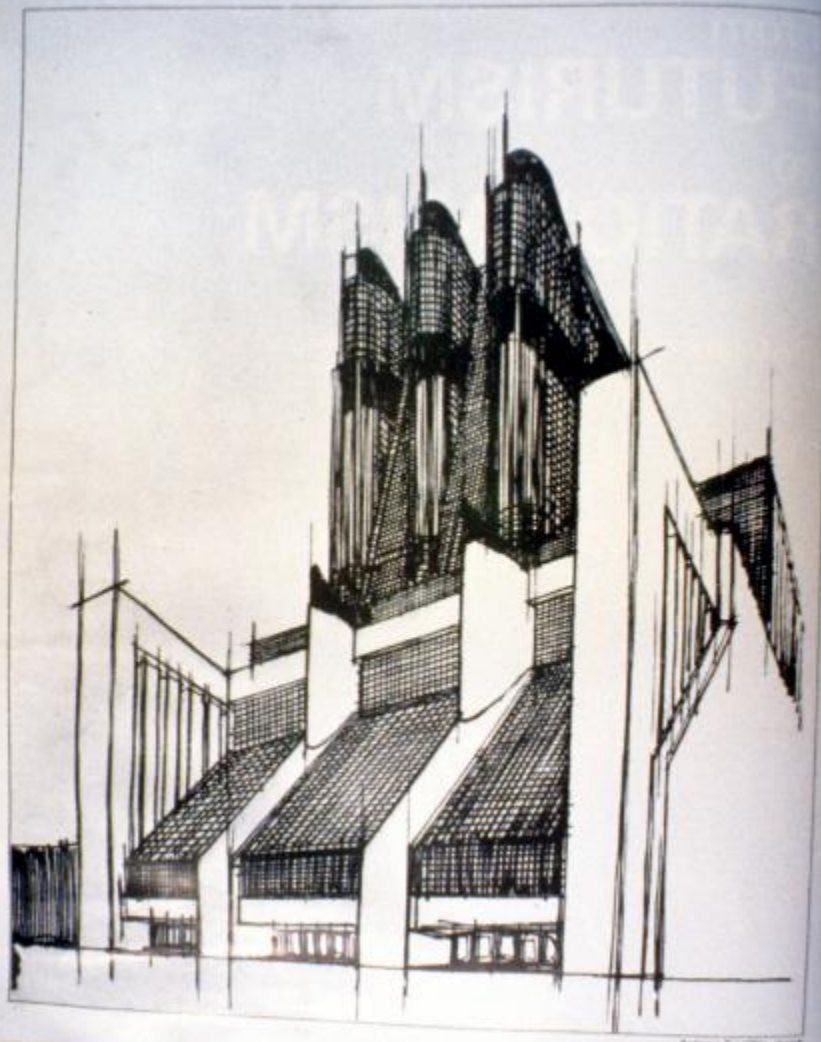
From
FUTURISM
To
RATIONALISM

THE ORIGINS OF MODERN ITALIAN ARCHITECTURE
Ada Louise Huxtable : The Troubled State of Modern Architecture

Antonio Sant'Elia
Italian Futurist
Architect
1888 to 1916







LE CORBUSIER

Towards
A New Architecture



1923



Grain silo.

THREE REMINDERS TO ARCHITECTS

29



CANADIAN GRAIN STORES AND ELEVATORS



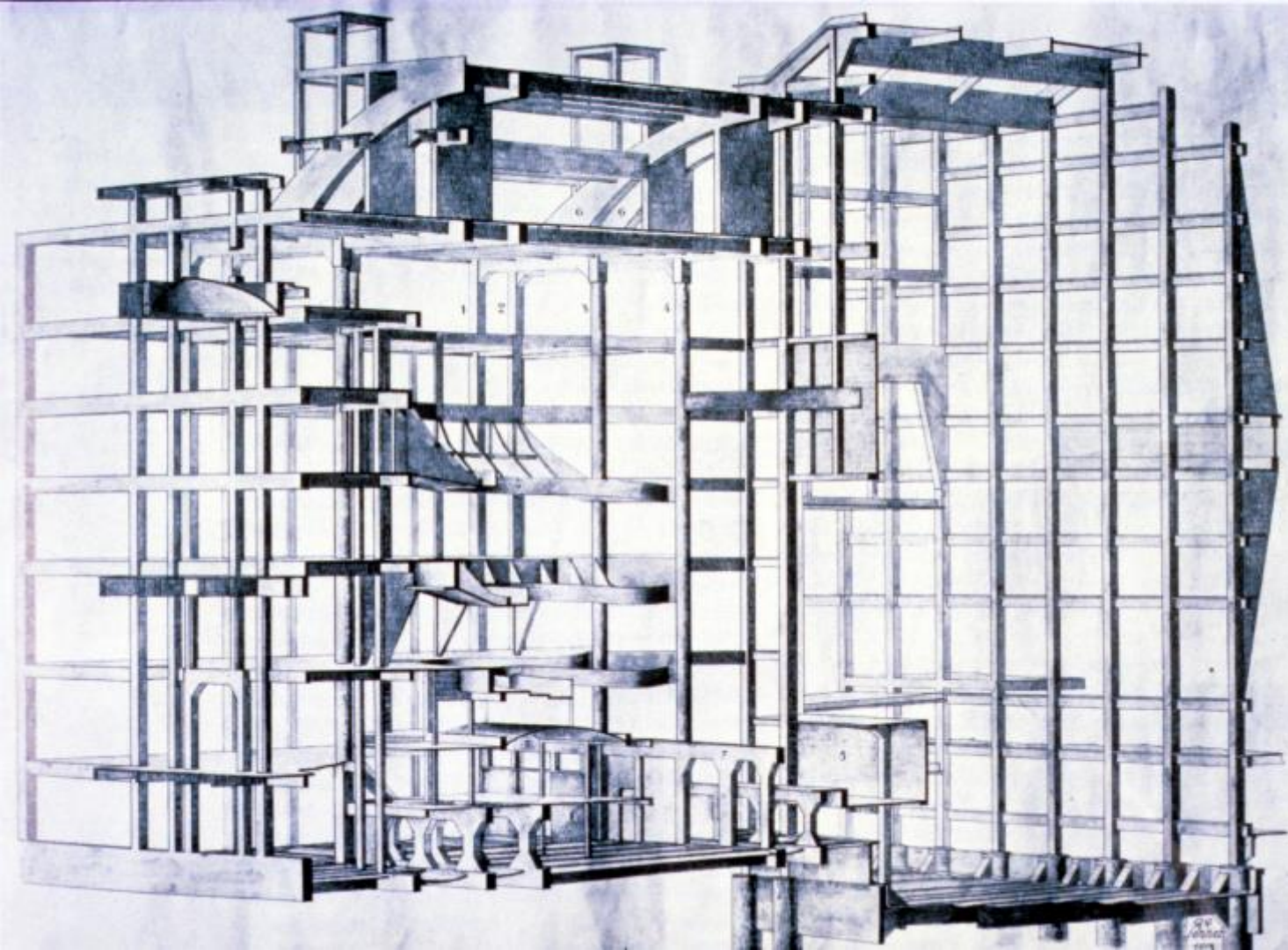
The North American Silo
Storage System



The Monolithic Frame



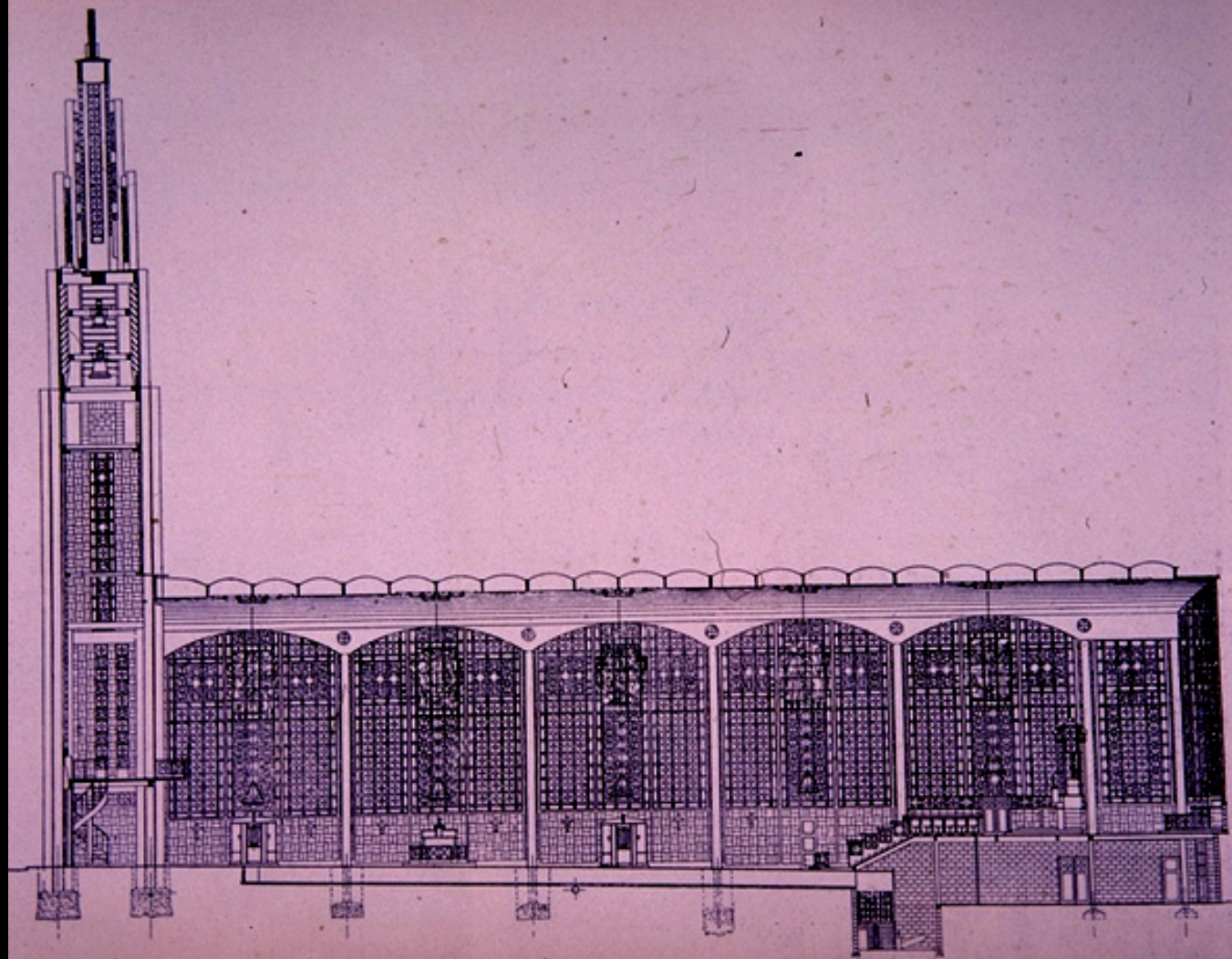
Theatre des Champs-Élysées
August Perret Architect
Paris, France
1911-1913







L'église Notre-Dame de la
Consolation du Raincy
August Perret Architect
France
1922





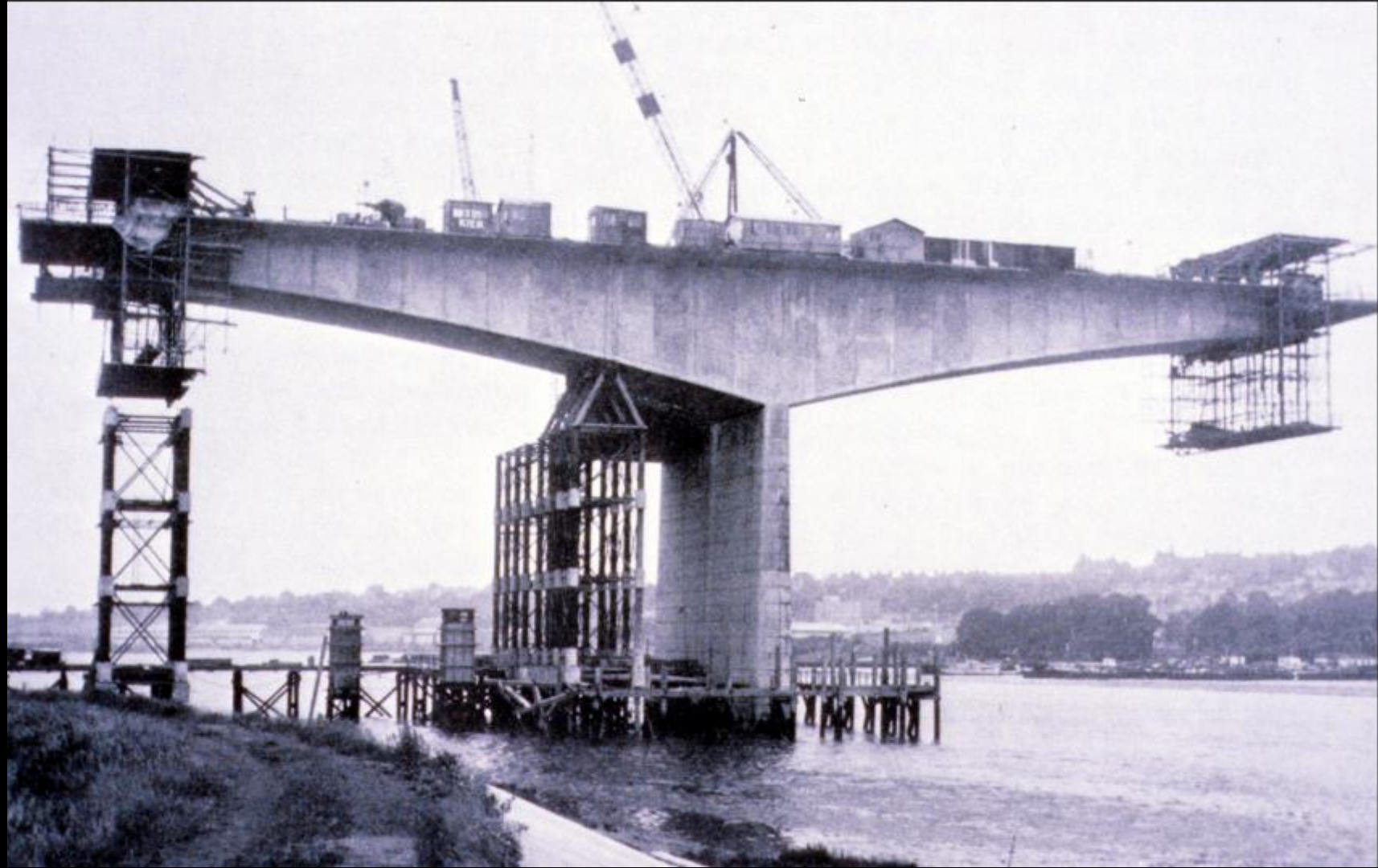


Long Span

~

Bridges







Salginatobel Bridge
Schiers, Switzerland
Robert Maillart
1930







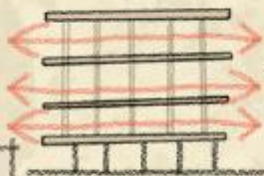


Le Corbusier
Swiss/French Architect
1887 to 1965

Le Corbusier's 5 points of Architecture

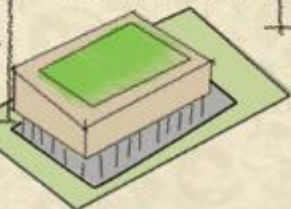
2. Free Facade

non-supporting walls that could be designed as the architect wished



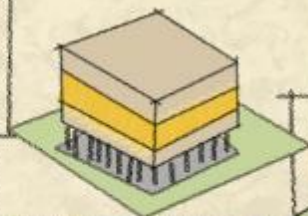
4. Roof Terrace

compensate for the green area consumed by the building and replacing it on the roof



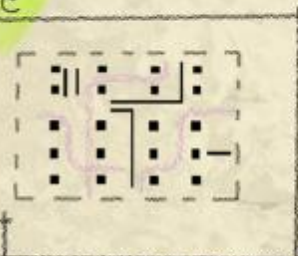
3. Ribbon Window

allow unobstructed views of the large surrounding



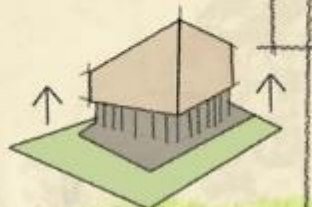
5. Open Floor Plan

floor space was free to be configured into rooms without concern for supporting walls.



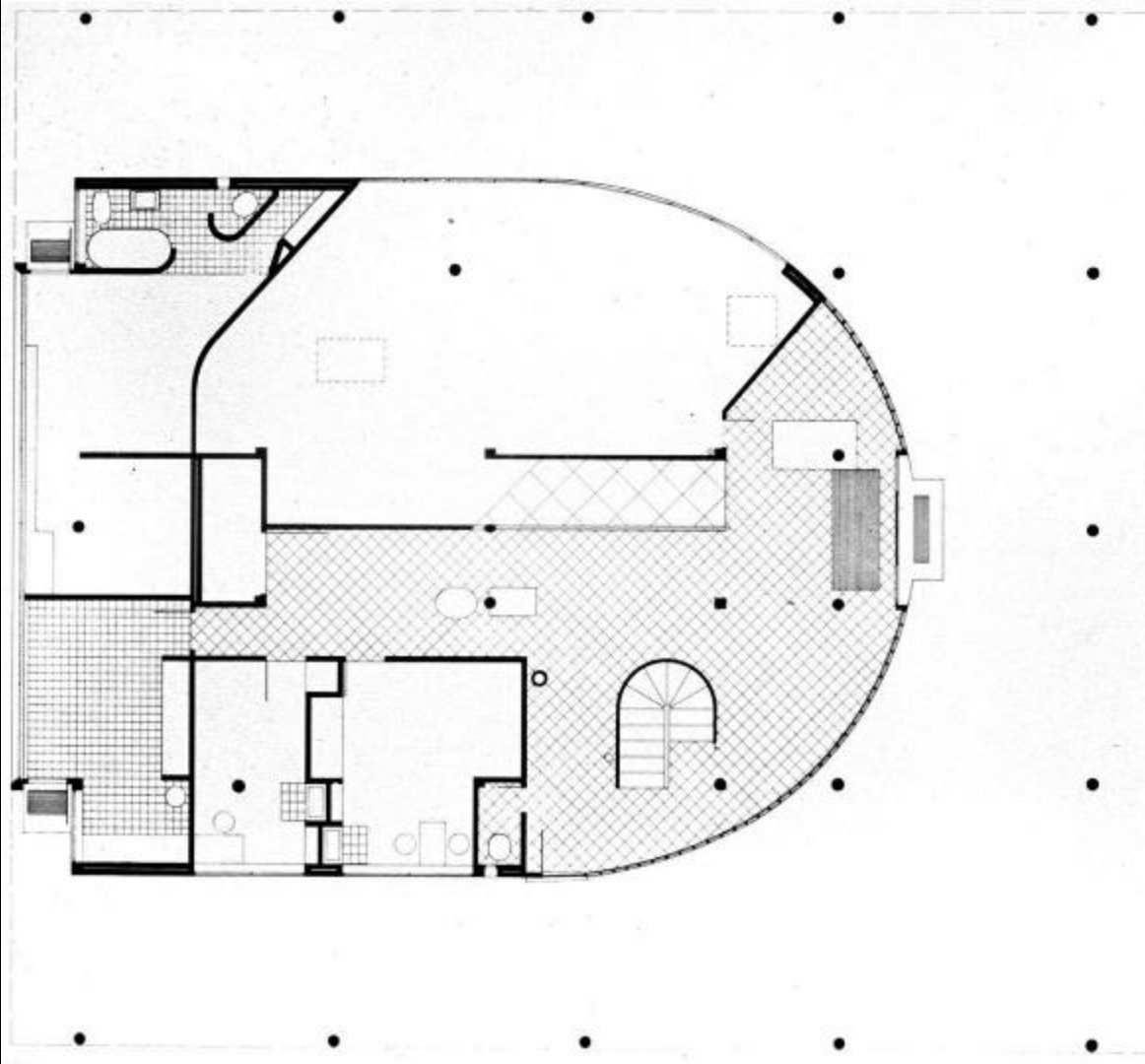
1. Pilotis

provides structural support.

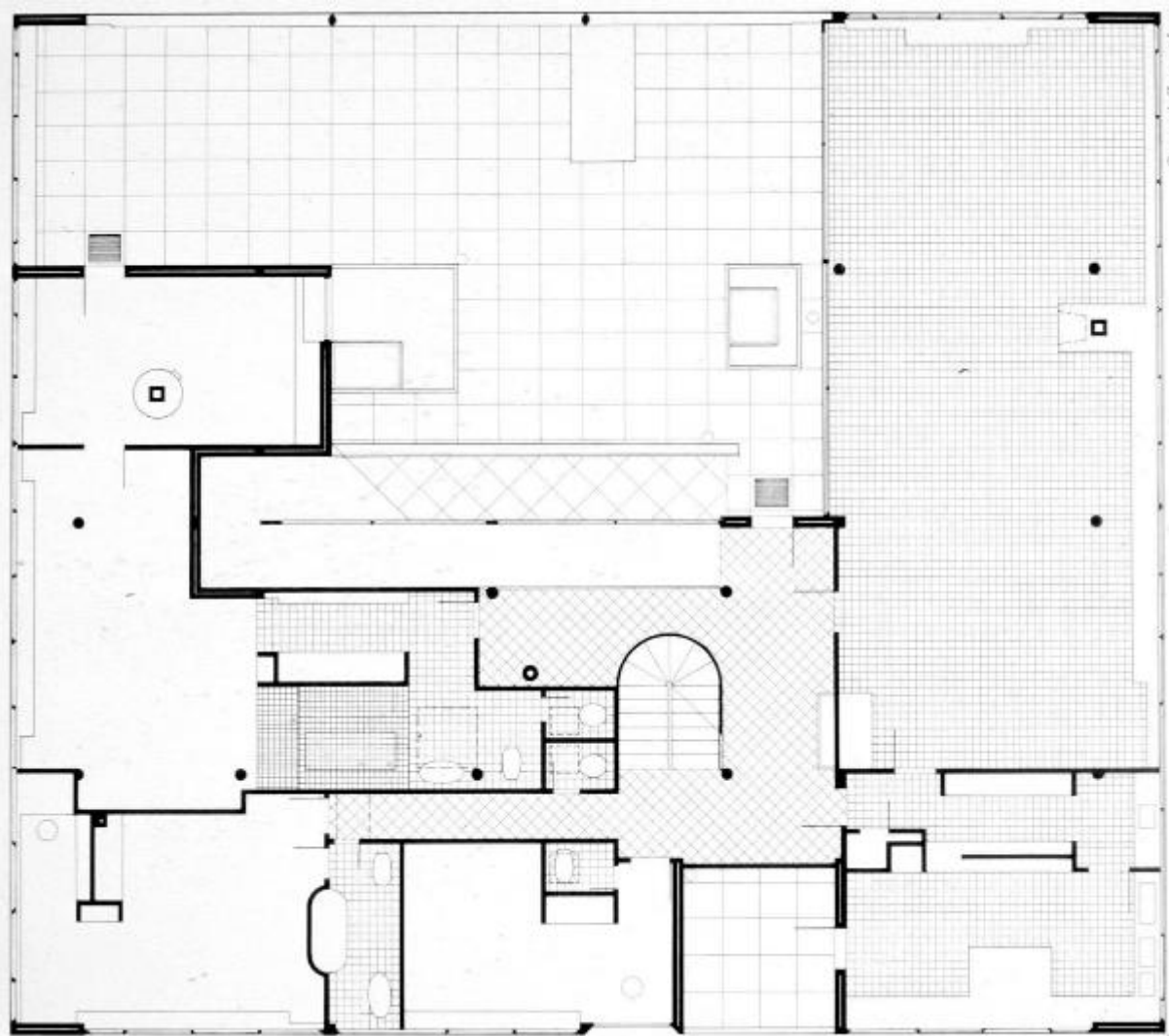




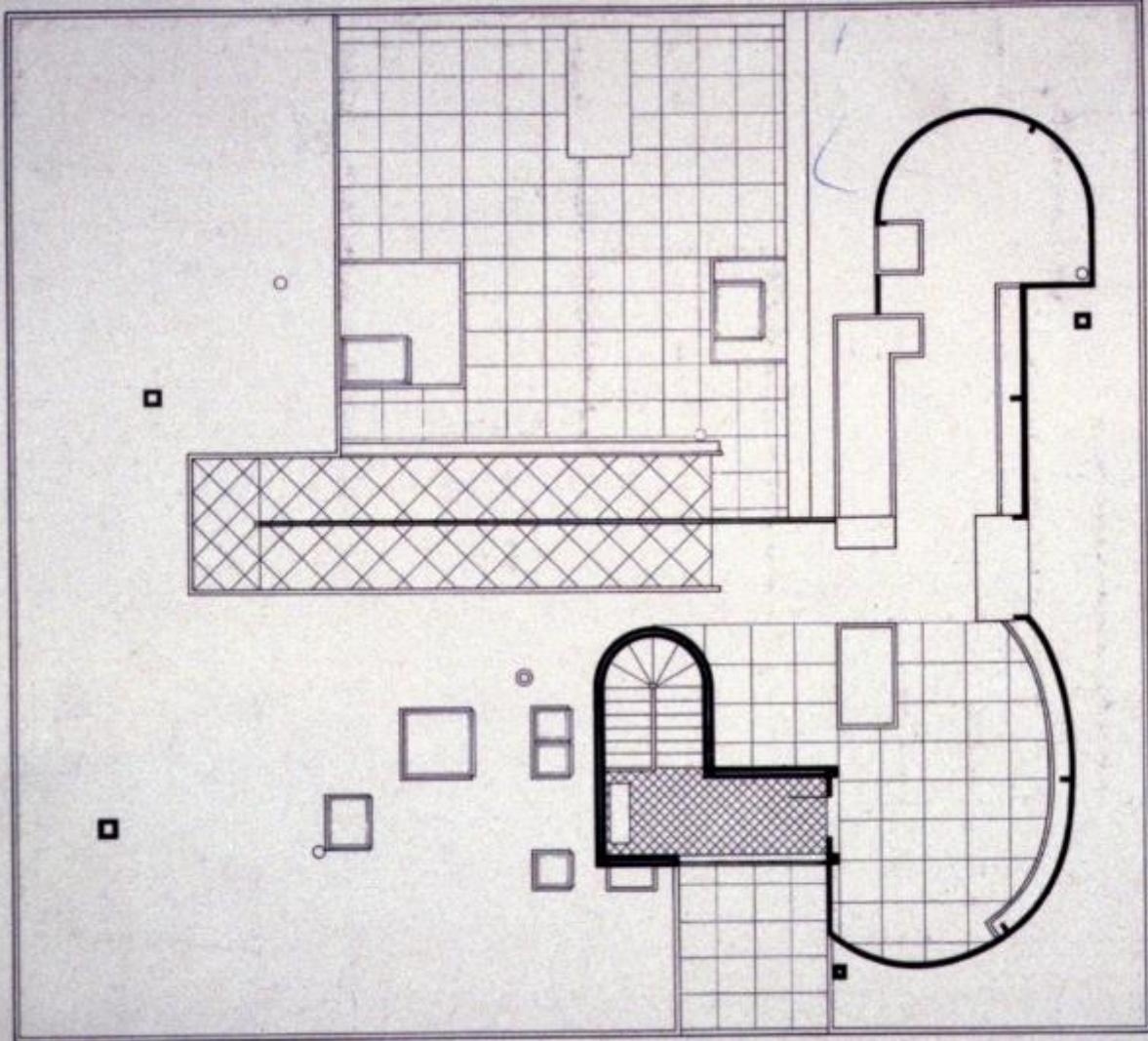
Villa Savoye
Poissy, France
Le Corbusier
1923 to 1925

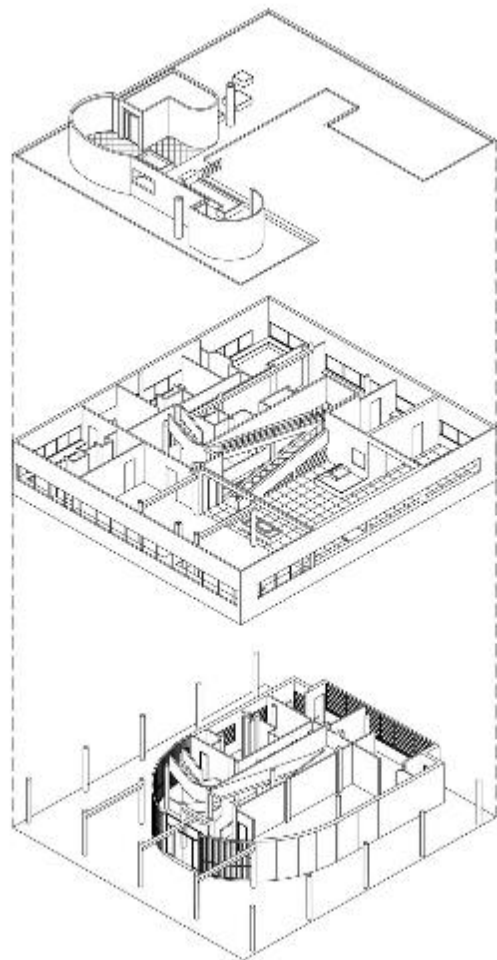


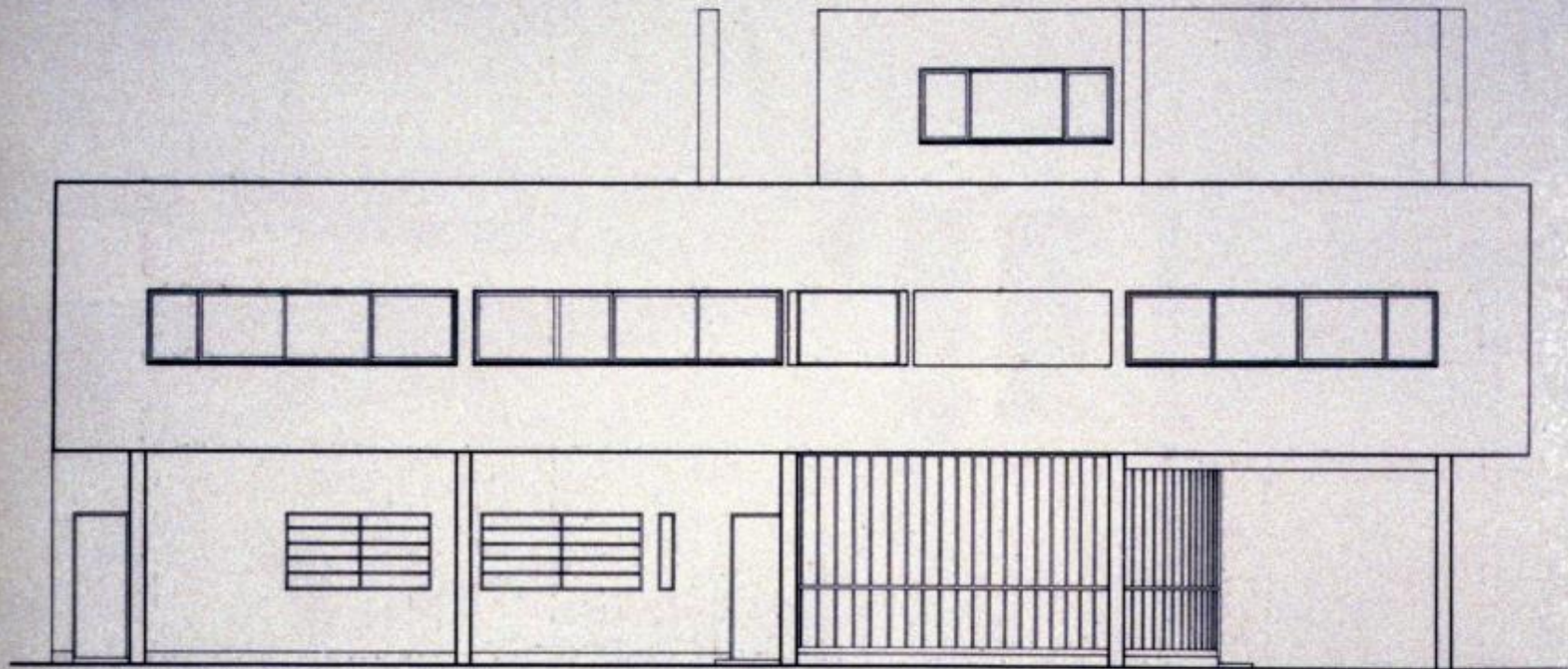
First floor plan



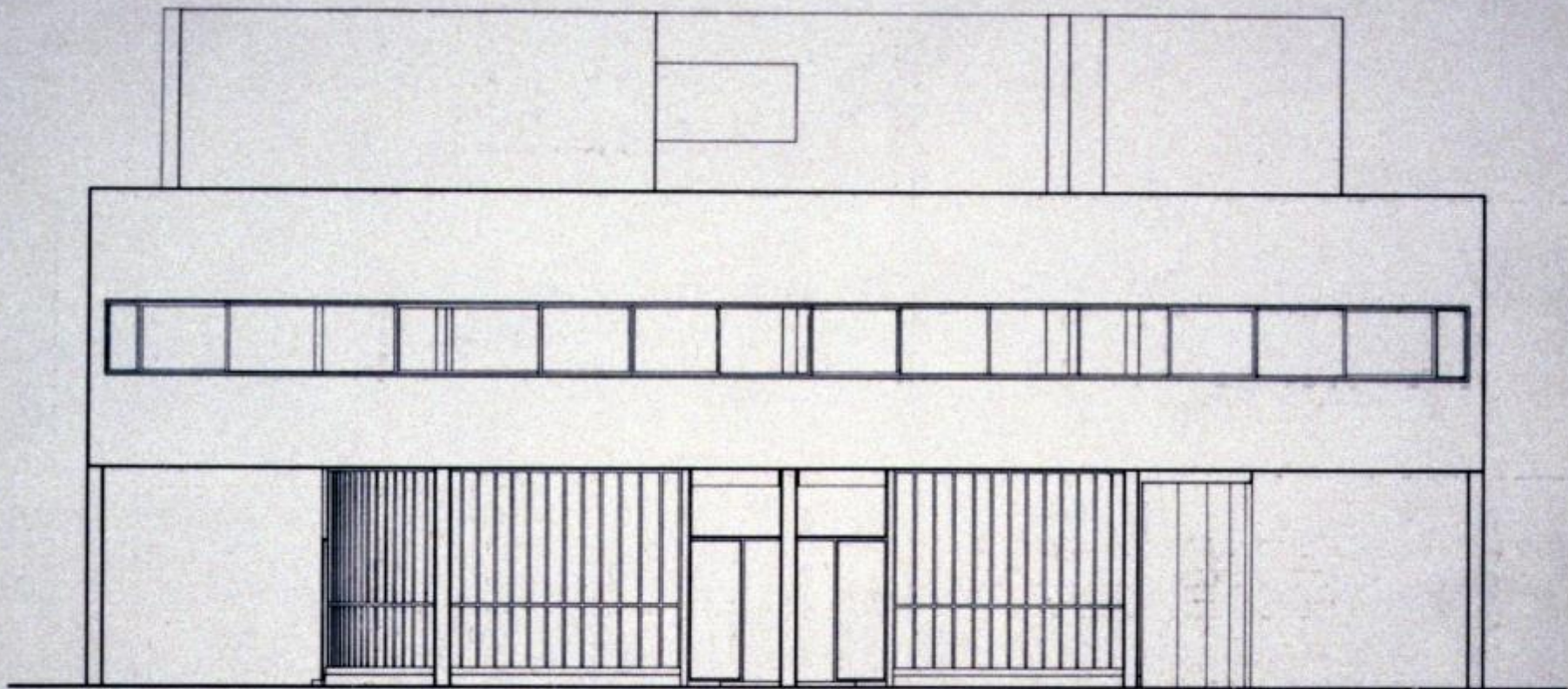
Second floor plan







Elevation west



Elevation south



















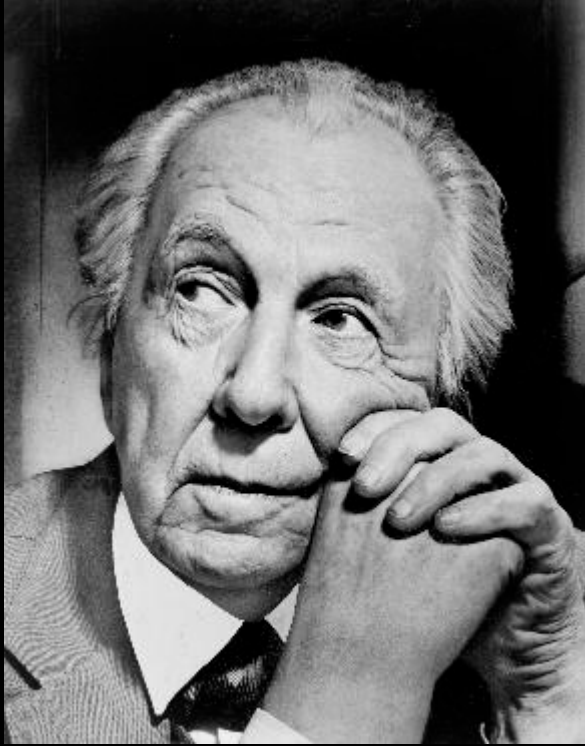












Frank Lloyd Wright
American Architect
1867 to 1959



Falling Water
Mill Run, Pennsylvania
Frank Lloyd Wright
1939











































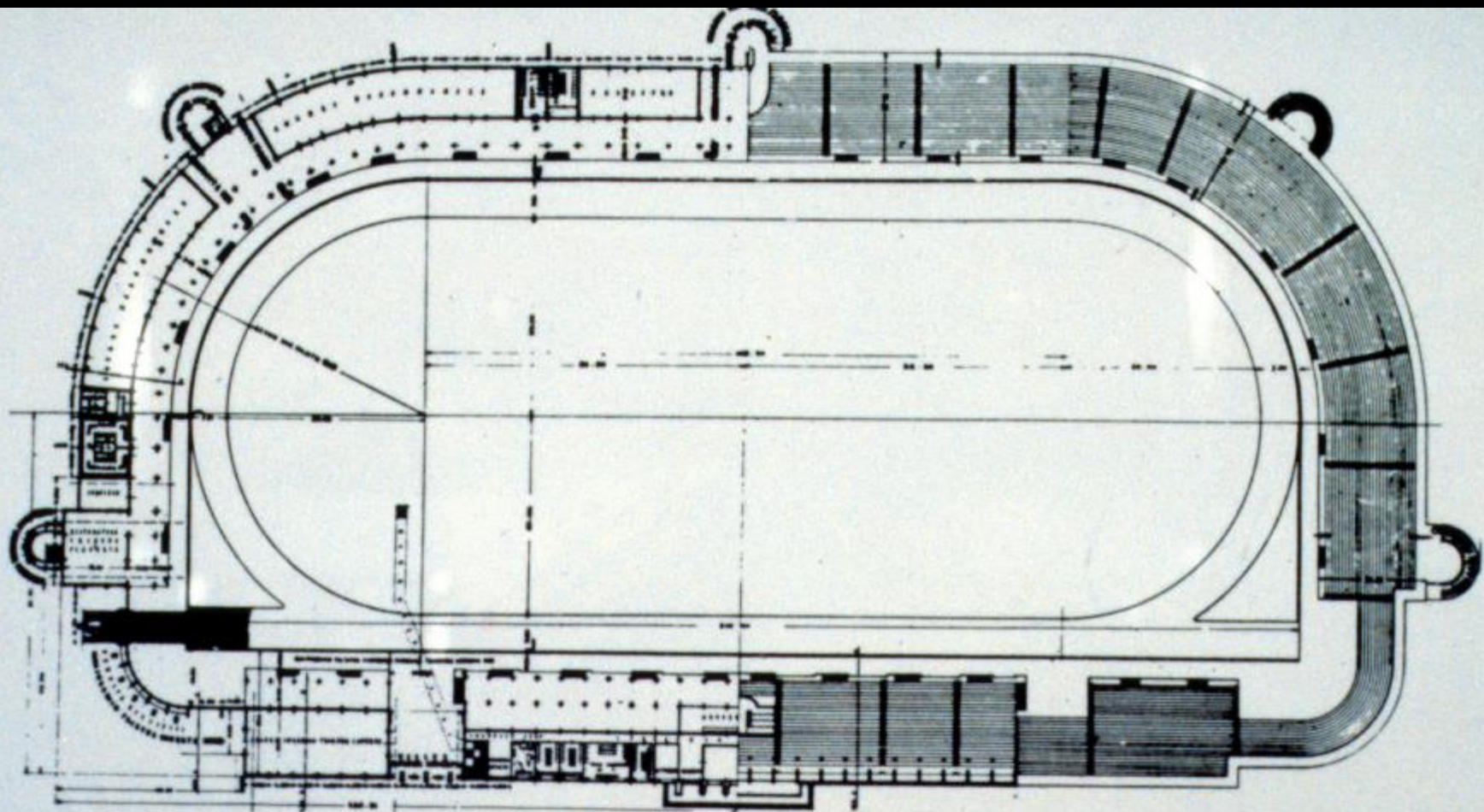


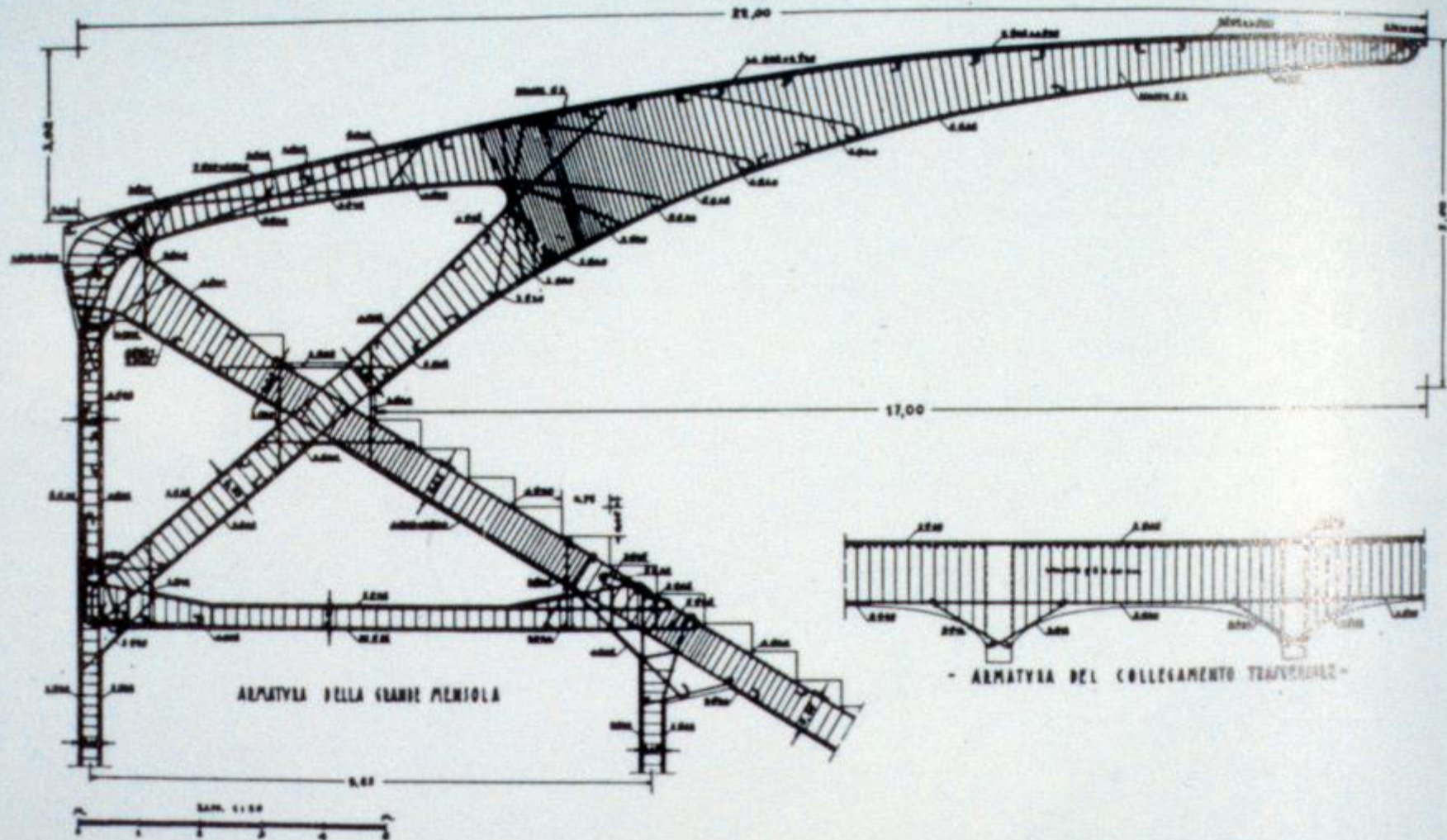


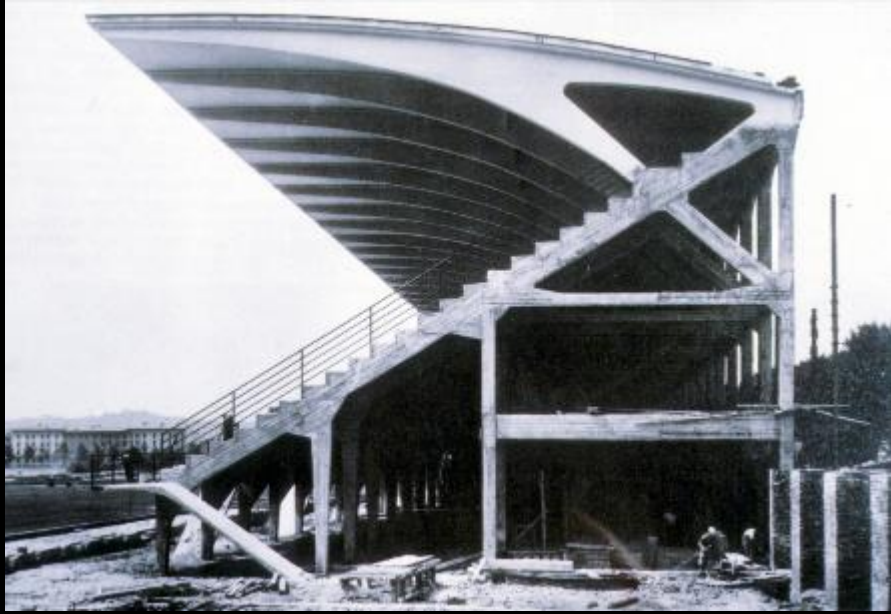
Cantilevers

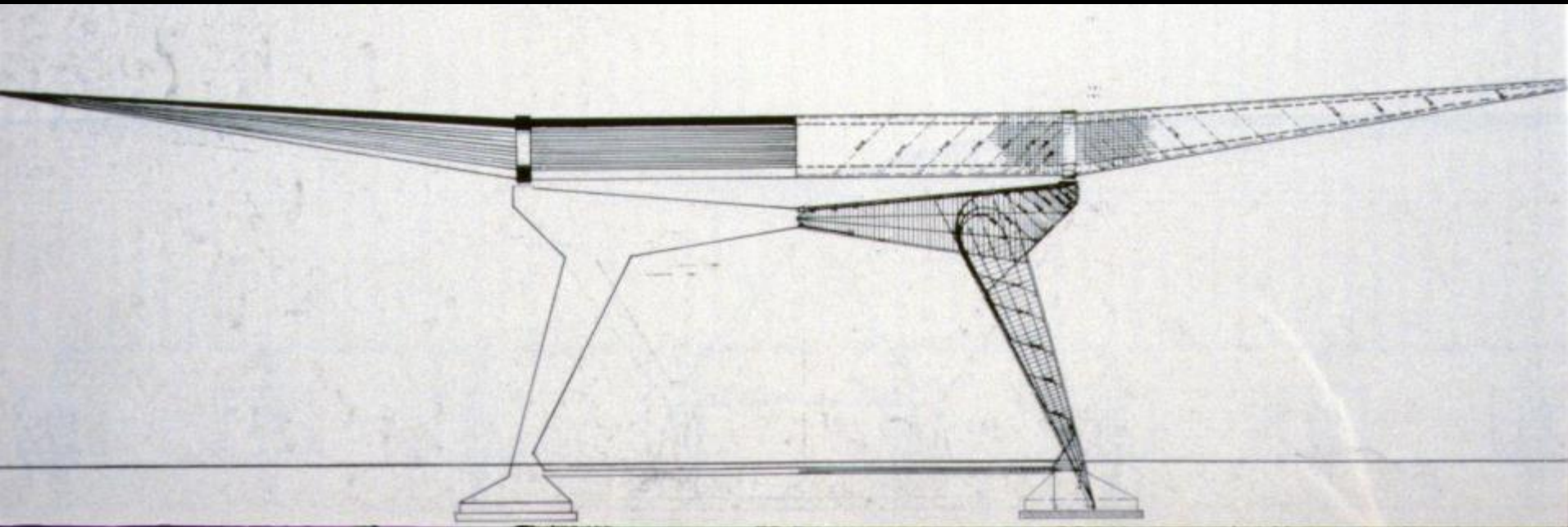


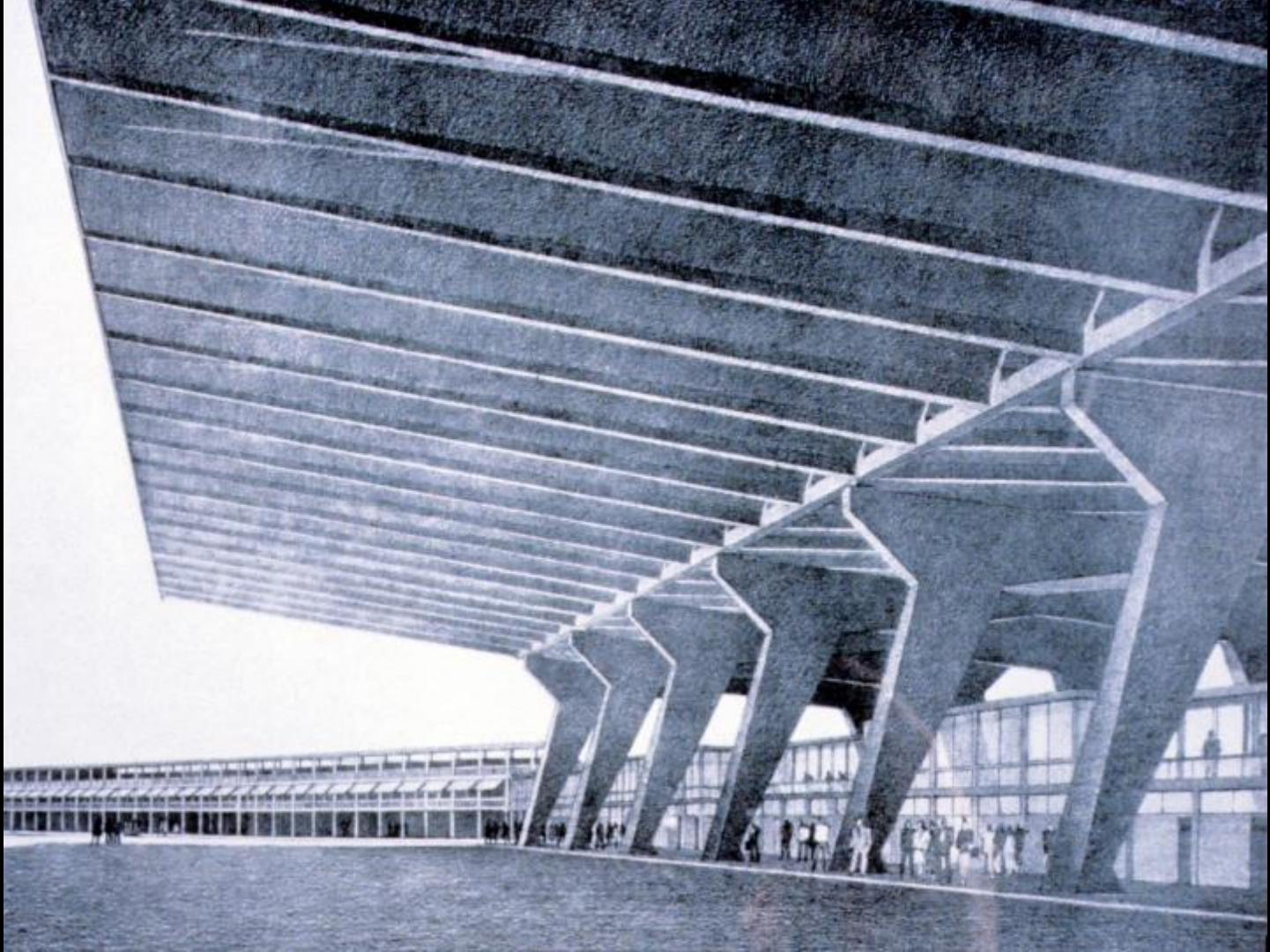
Pier Luigi Nervi
Italian Engineer
1891 to 1979

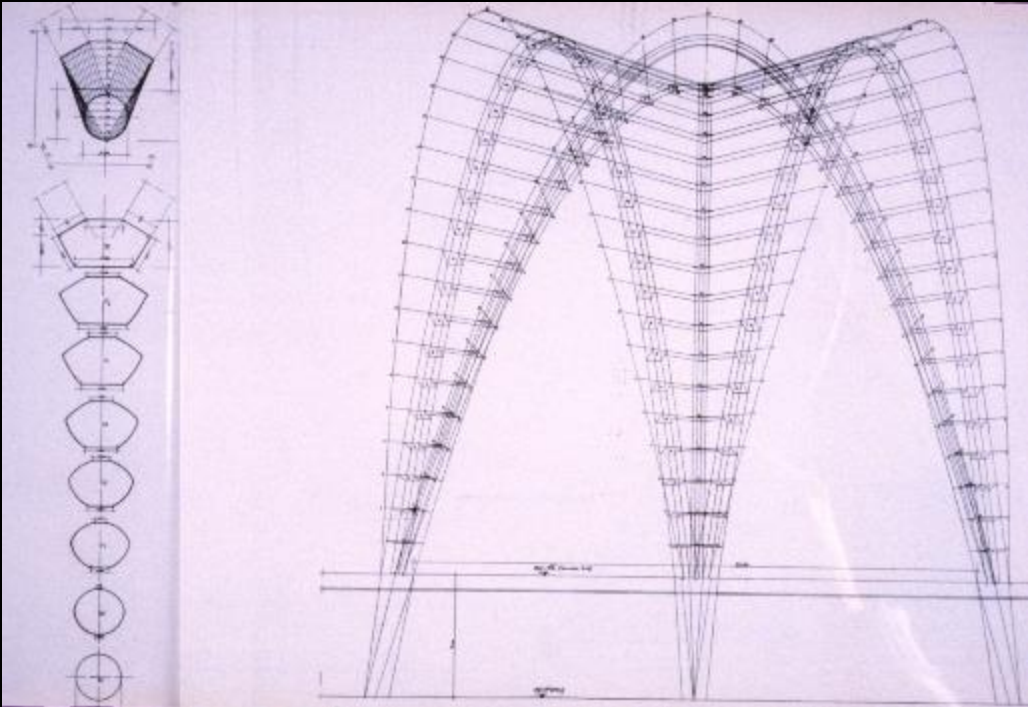
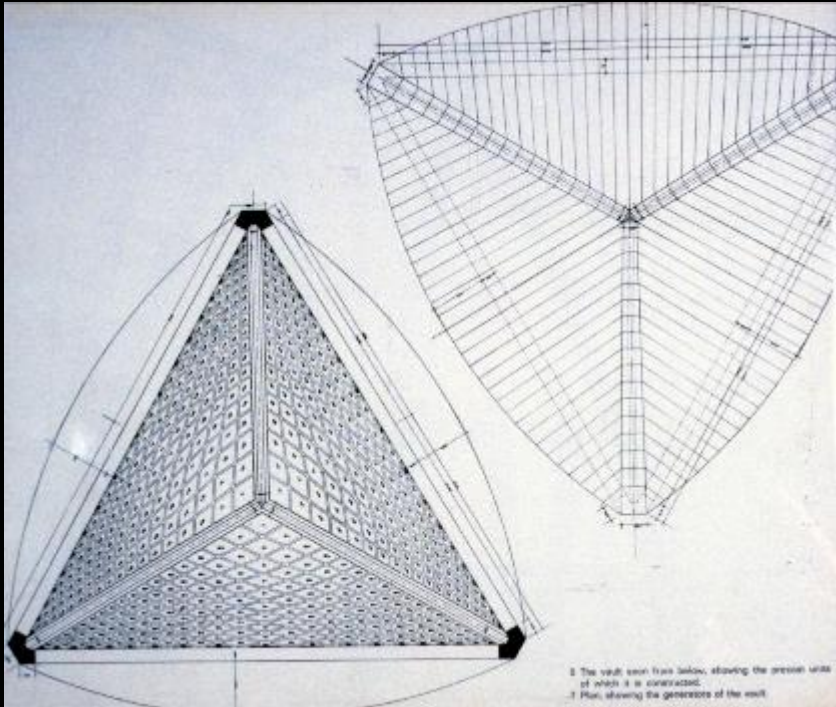


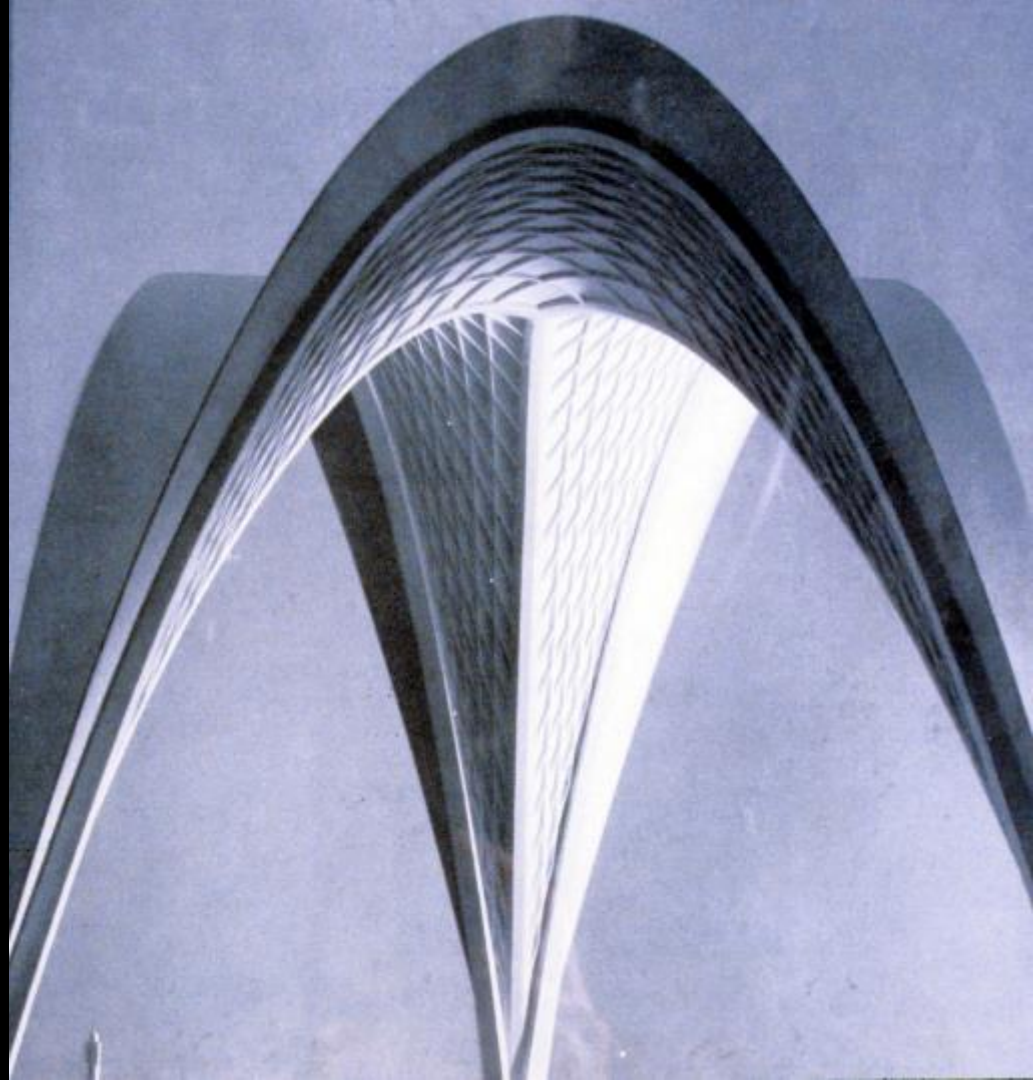










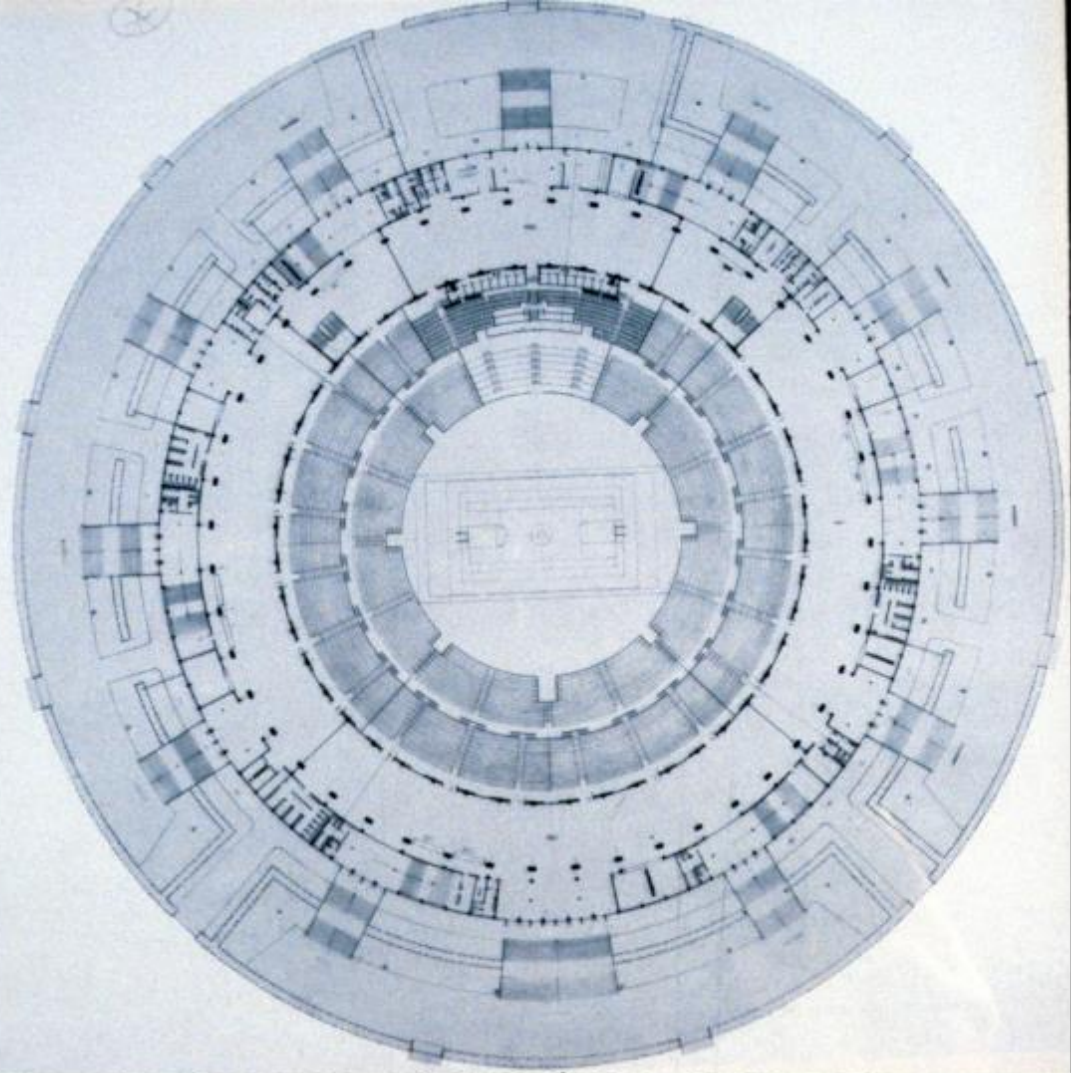


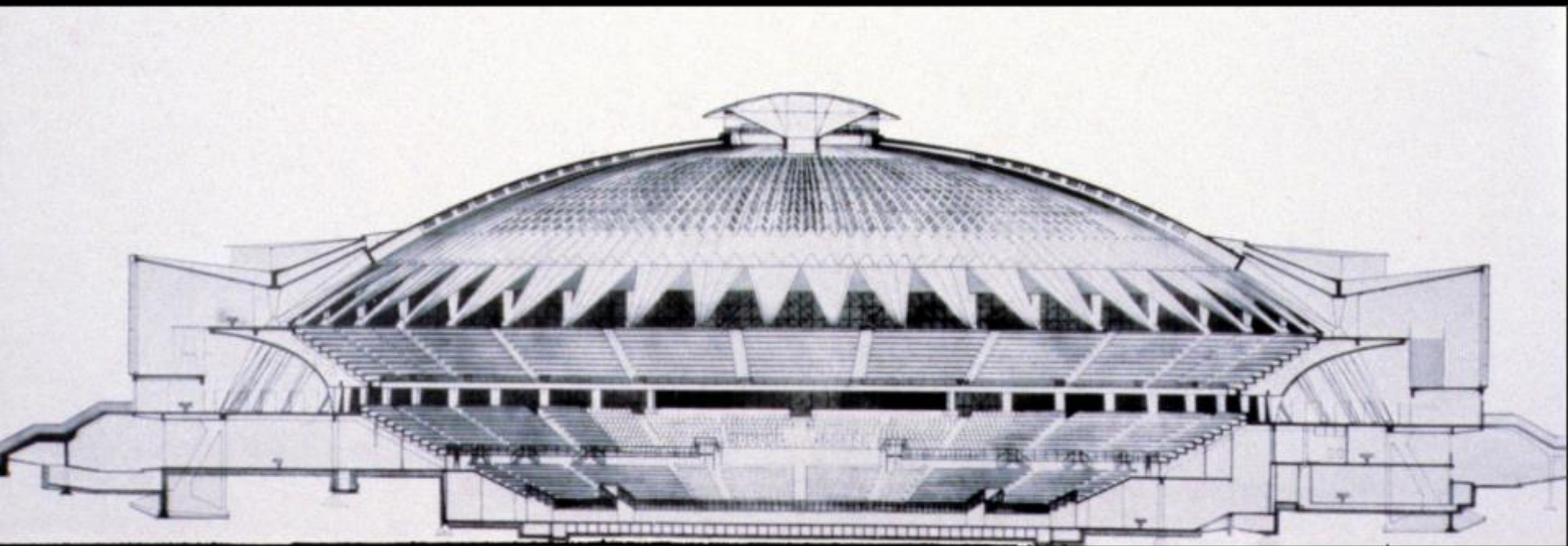




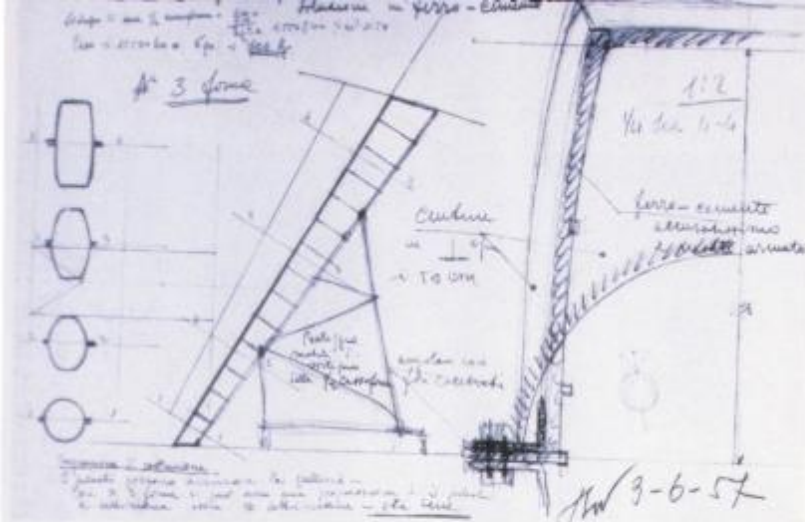
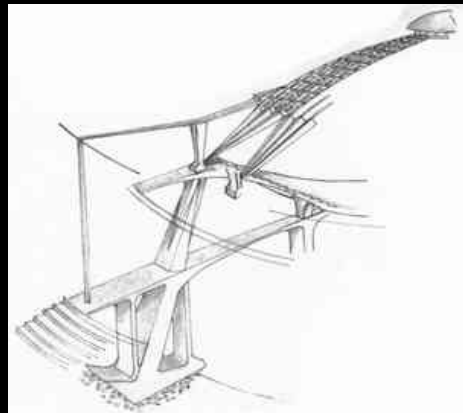
PalaLottomatica
(Palazzo dello Sport)
Rome, Italy
1960

Pier Luigi Nervi Engineer
Marcello Piacentini Architect

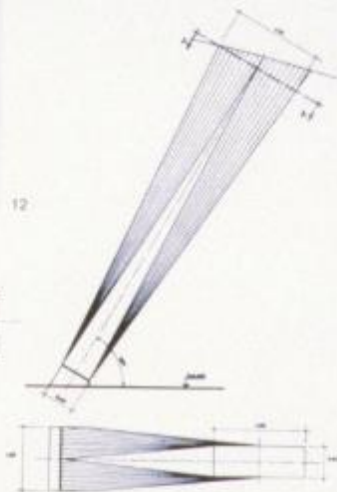








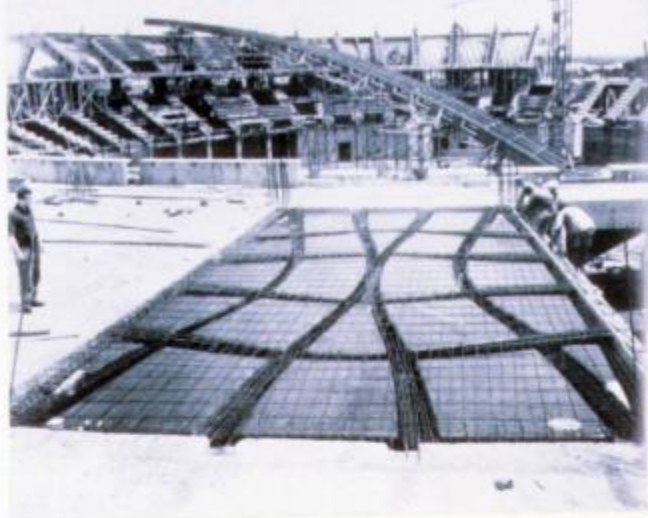
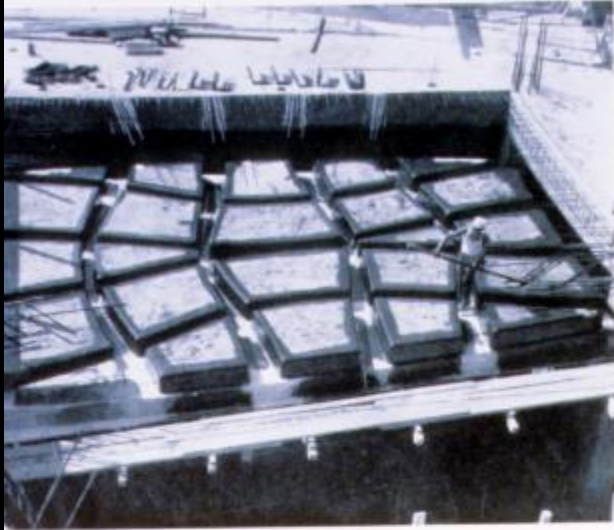
12



15

16

- 12 Studies for the formwork of the inclined columns (in "ferro-cemento")
 13 Construction of the moulds, in rendered brick, for casting the units forming the peripheral gallery.
 14 Placing the precast units roofing the peripheral gallery.
 15, 16 Timber formwork for the columns.
 17 Column details. The inclination exactly follows the resultants of the thrust of the dome and of the vertical reaction due to the upper bank of seats and the roof of the peripheral gallery.
 18 View of the gallery and the inclined columns.



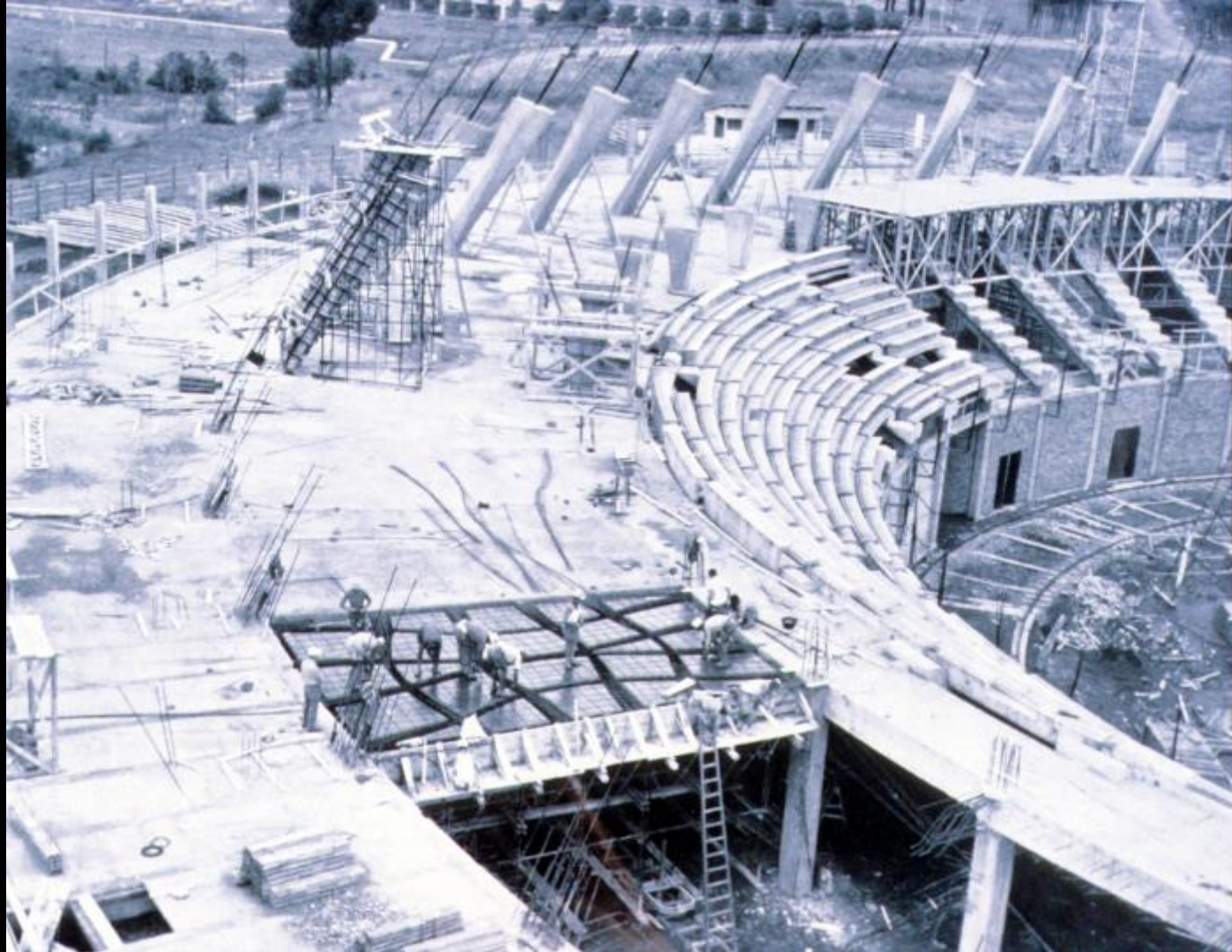
able "ferro-cemento" forms used for casting the gallery floor, in which the ribs follow the lines of the principal stresses (P. L. Nervi, 1928).

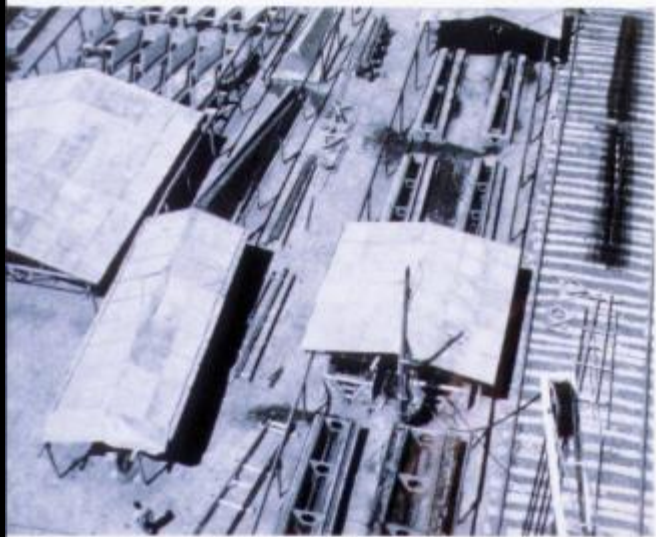
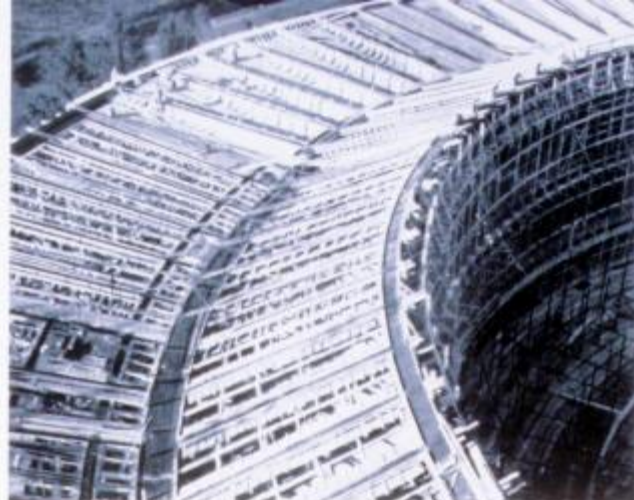
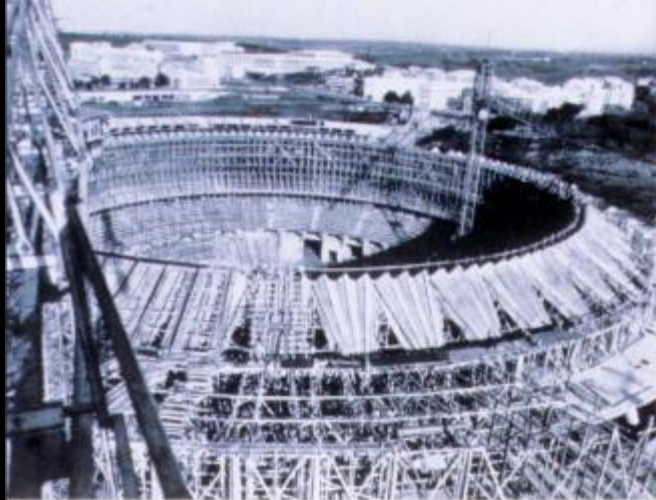
Reinforcement ready for concreting.

Finished floor, from below.

Reinforcement ready for concreting, showing the three sections of timber formwork reinforced with steel which were used for casting the 48 inclined







22 The prefabricated fan-shaped supports.
23 Timber formwork in position for casting the peripheral roof.
24 The casting yard.























Palazzetto dello Sport
Rome, Italy
Pier Luigi Nervi
1960






Tribuna Flaminio

settore F1 / F2




Ingresso Atleti











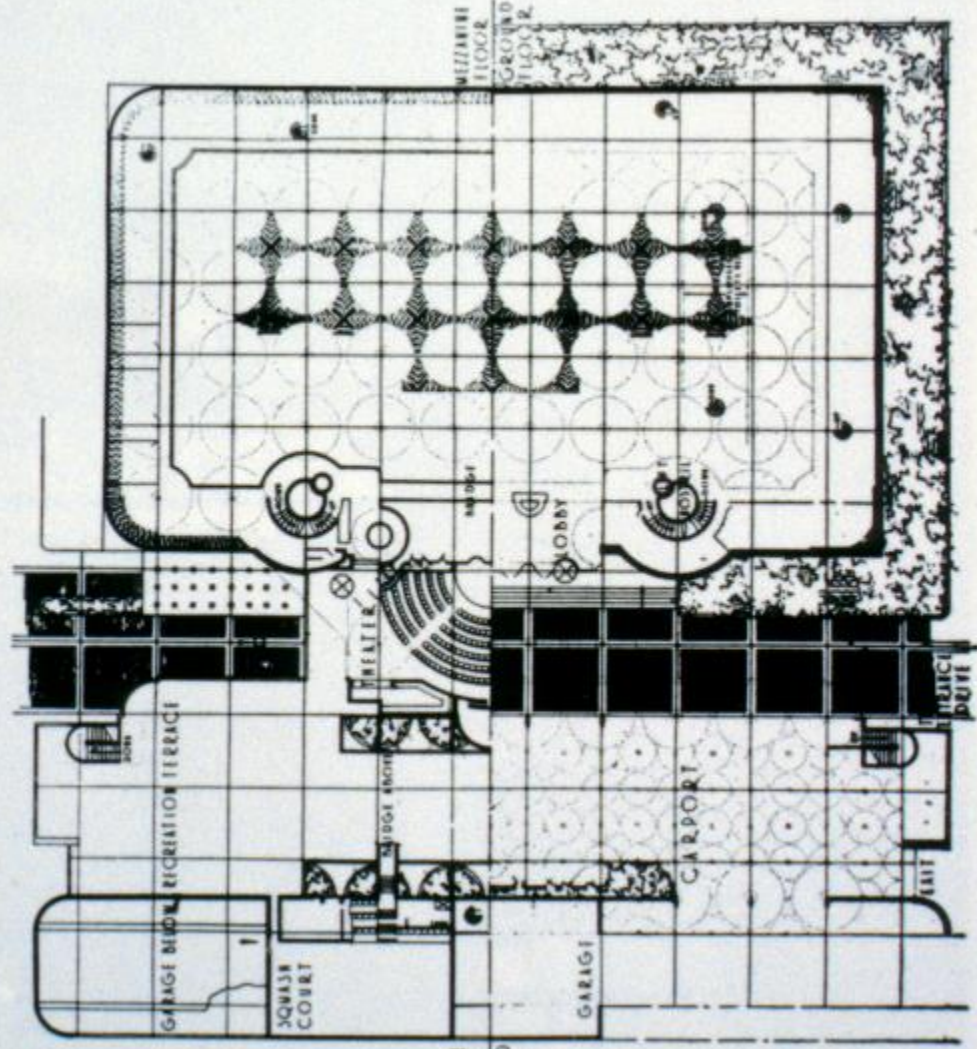
GRUPPO
LOTTOMATICA
giochi e servizi

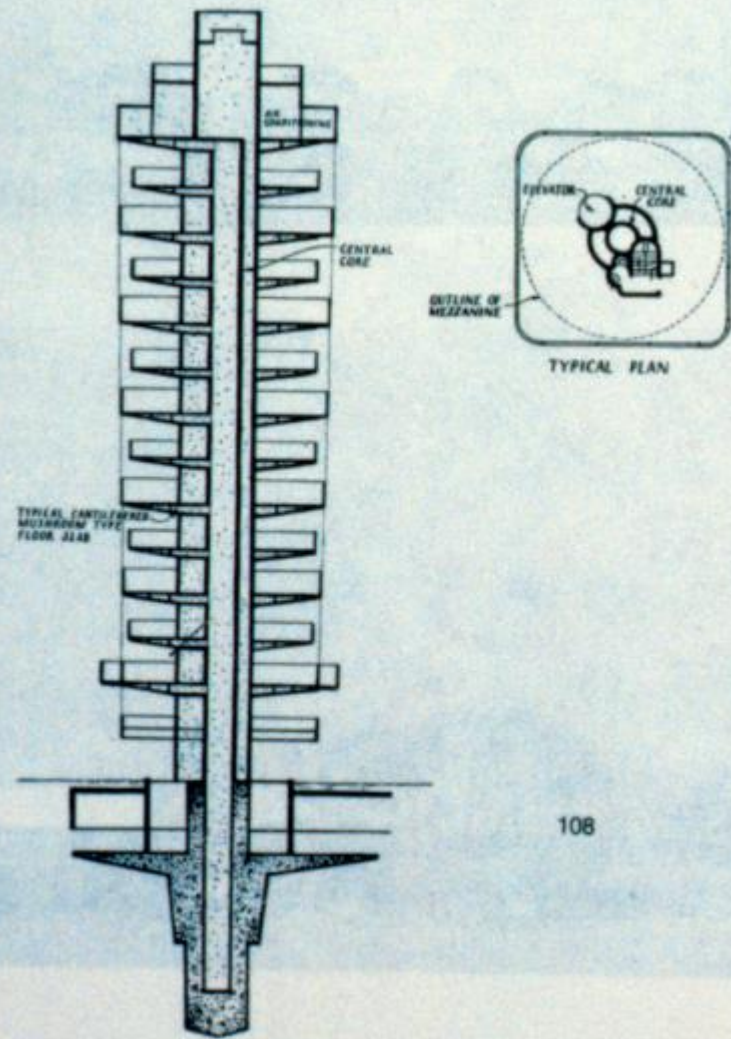
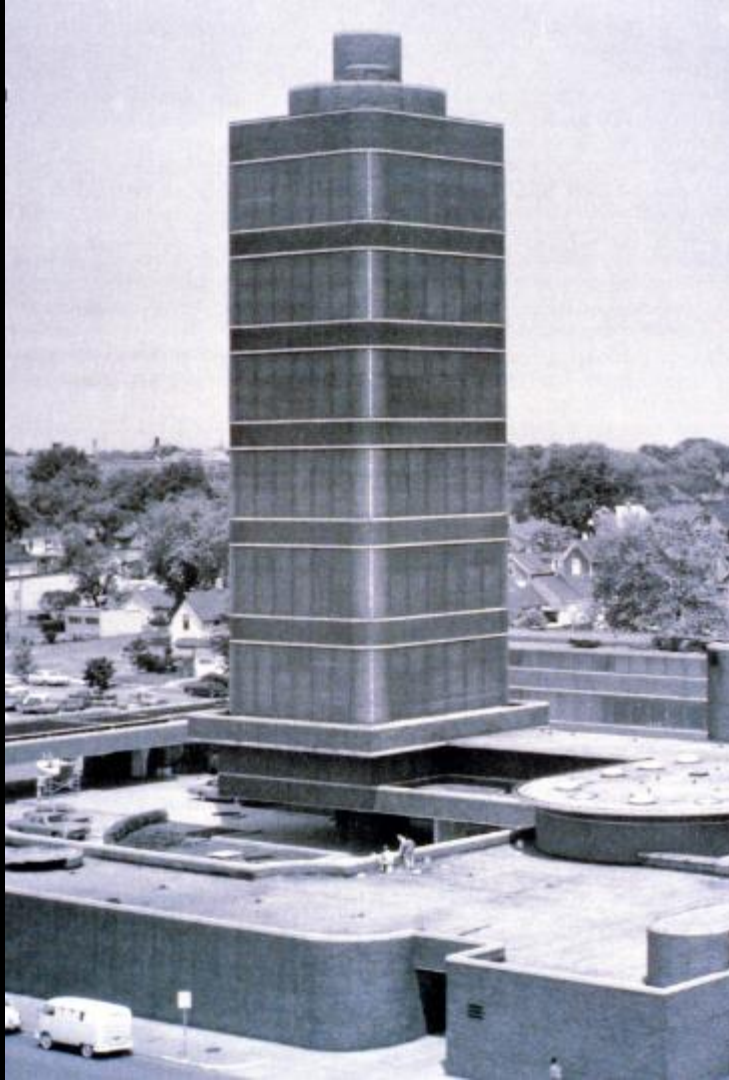
Developments in Concrete Construction

Part 2: Curves, Cantilevers and Brutalism



Johnson Wax Headquarters
Racine, Wisconsin
Frank Lloyd Wright 1939

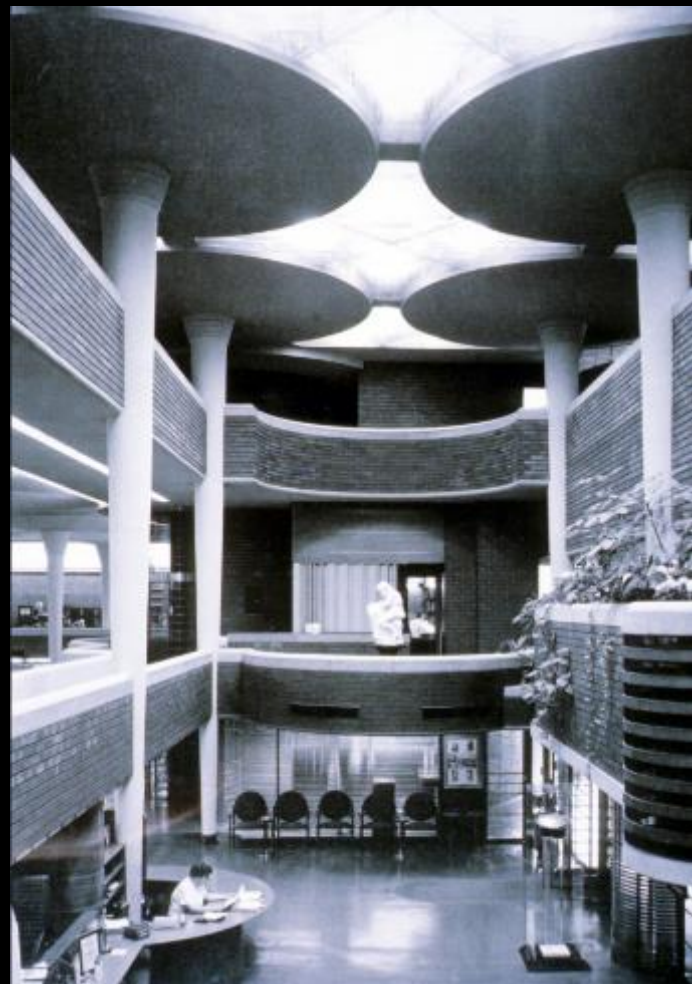














Marina Towers
Chicago, Illinois
Goldberg & Associates
1968



FIGURE 7.18 Marina Towers in Chicago during construction.

FIGURE 7.17 Model of Marina Towers in Chicago. Architects and engineers: Bertrand Goldberg and Associates. Consulting Engineers: Severud-Elstad-Krueger Associates. Foundation Consultants: Moran, Mueser and Rutledge and R. B. Peck. Sponsors: Building Service Employees International Union.

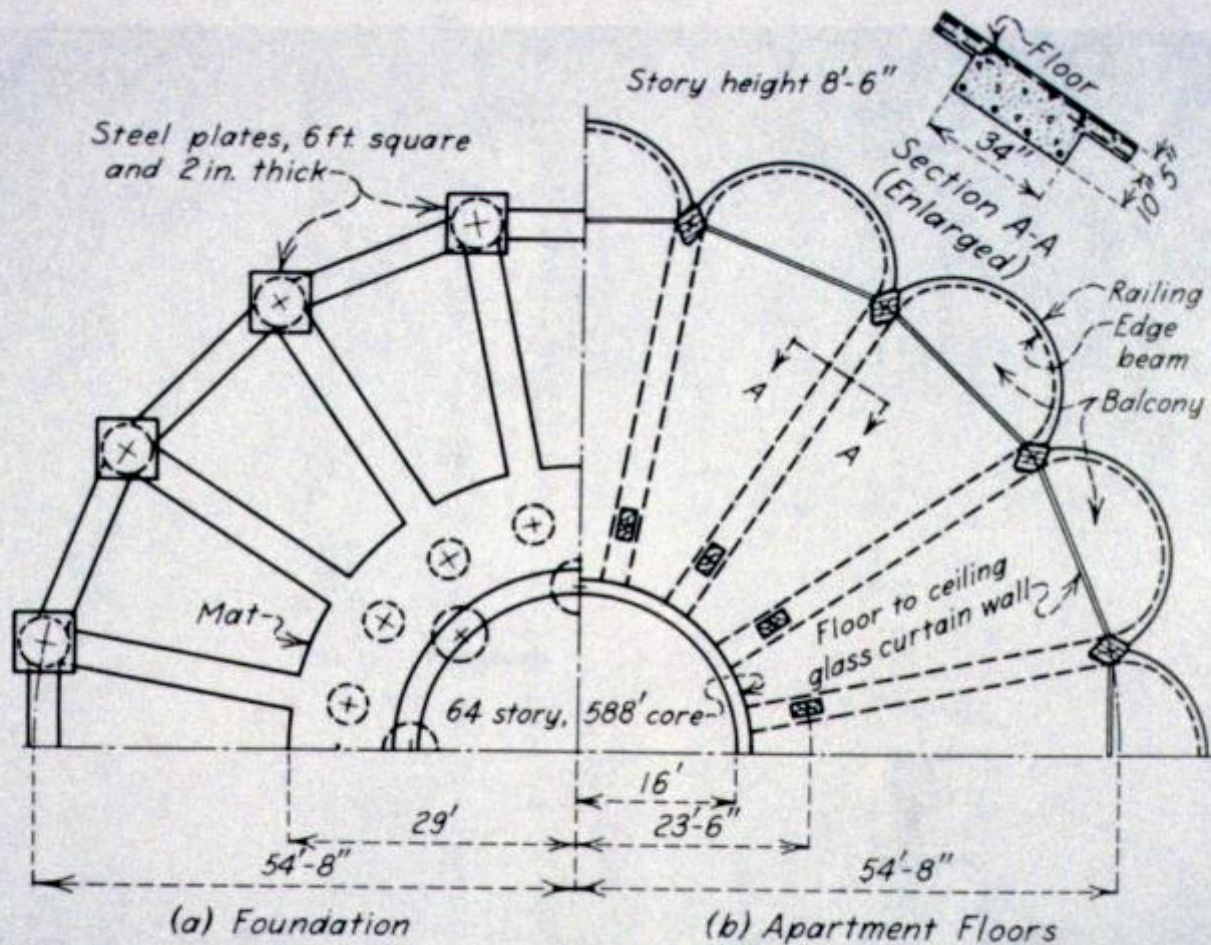
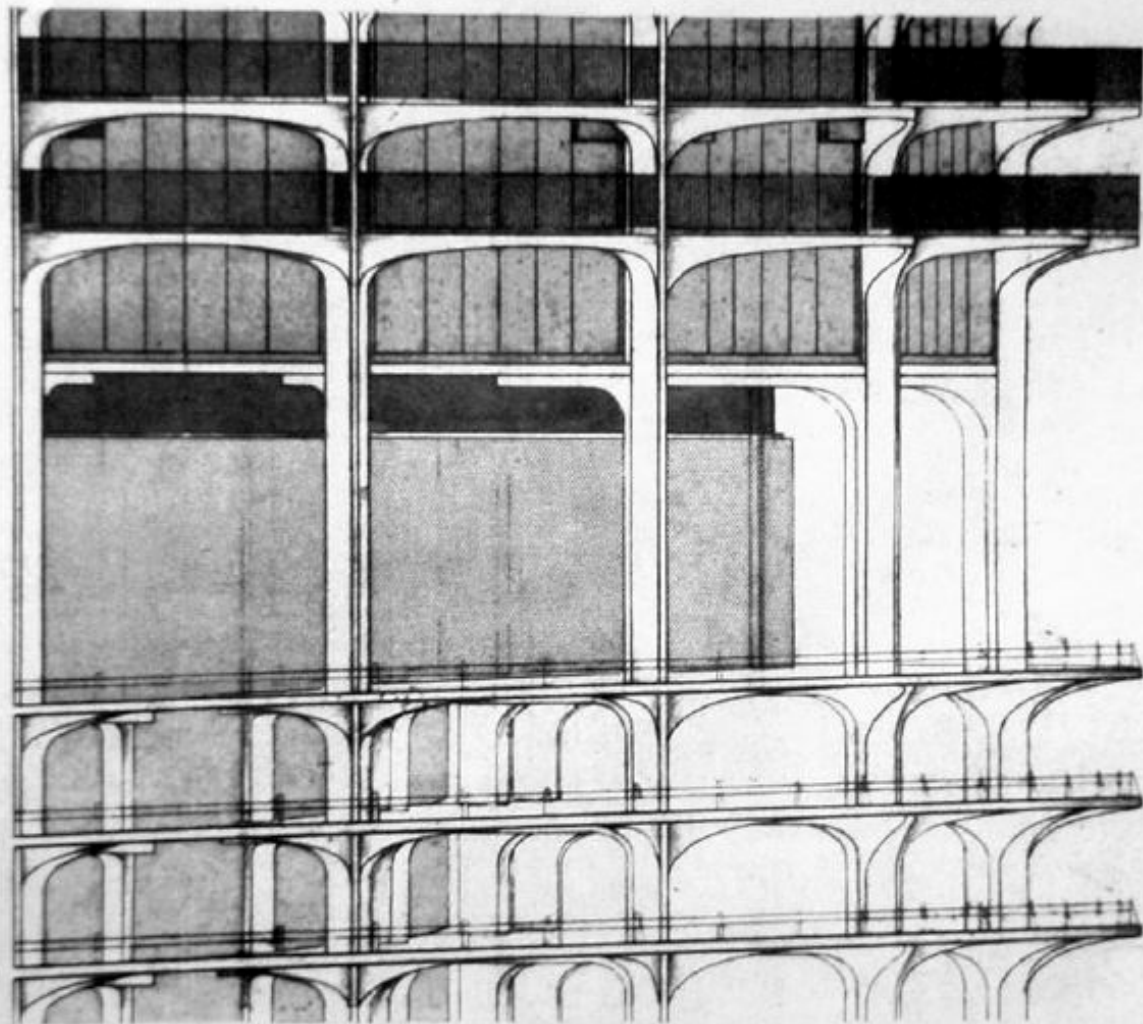


FIGURE 7.19 Partial plans of Marina Towers.









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MORNING SPECIAL

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PER HOUR

**MONDAY -
FRIDAY**

In by 10:00am - Out by 7:00pm

OPEN 24 HOURS
7 Days a Week

Enter On State Street

























NA
737
S28F87
1977
U.N.B.

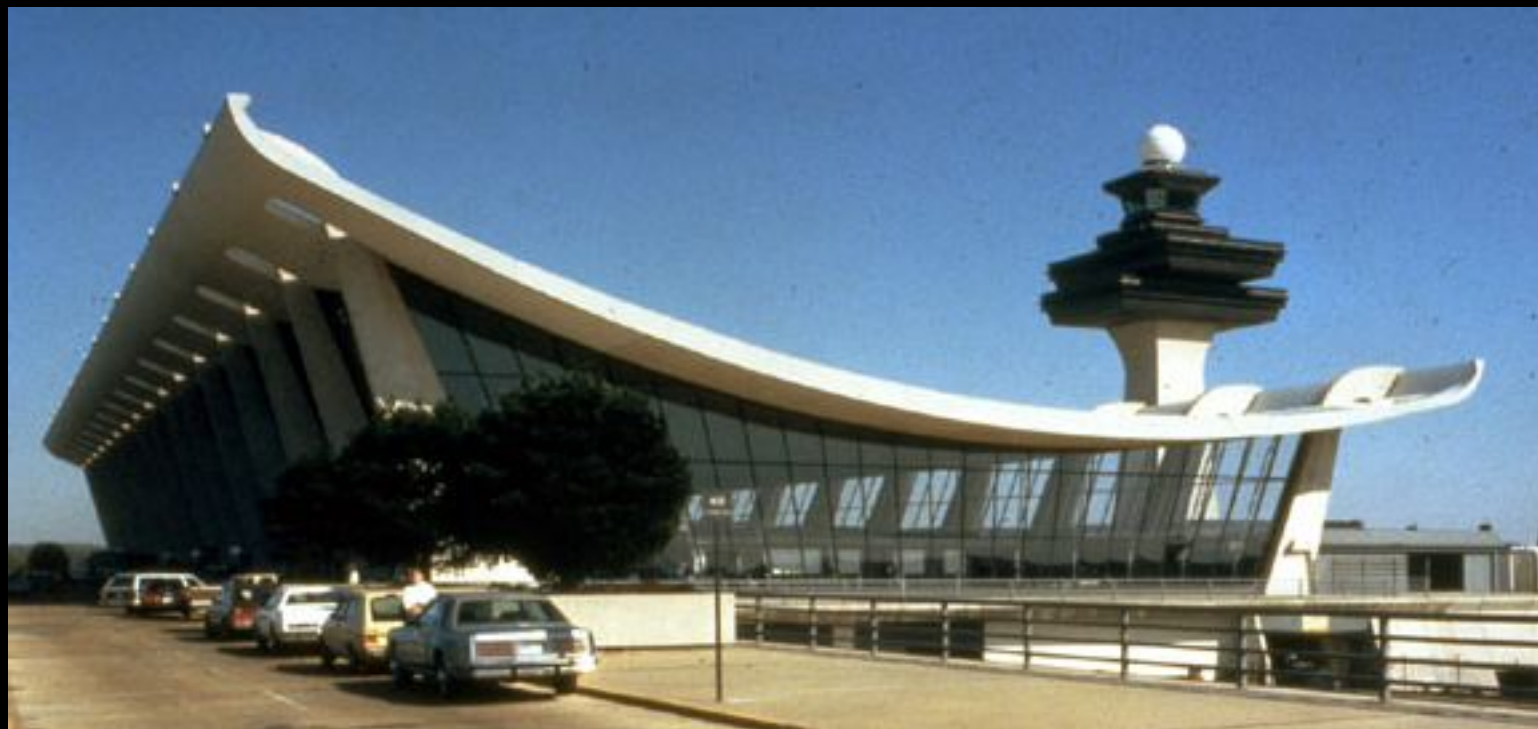


Washington Dulles International Airport
Washington, DC, USA
Eero Saarinen Architect
1962



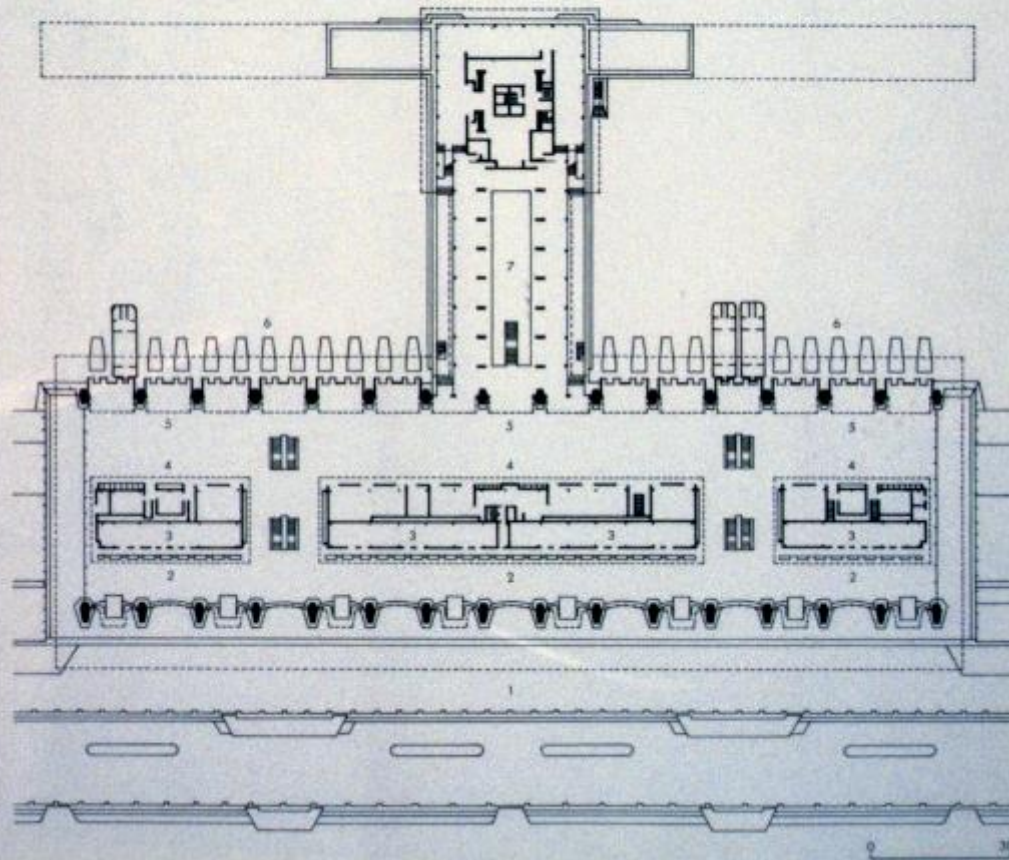
GTA
Global Architecture

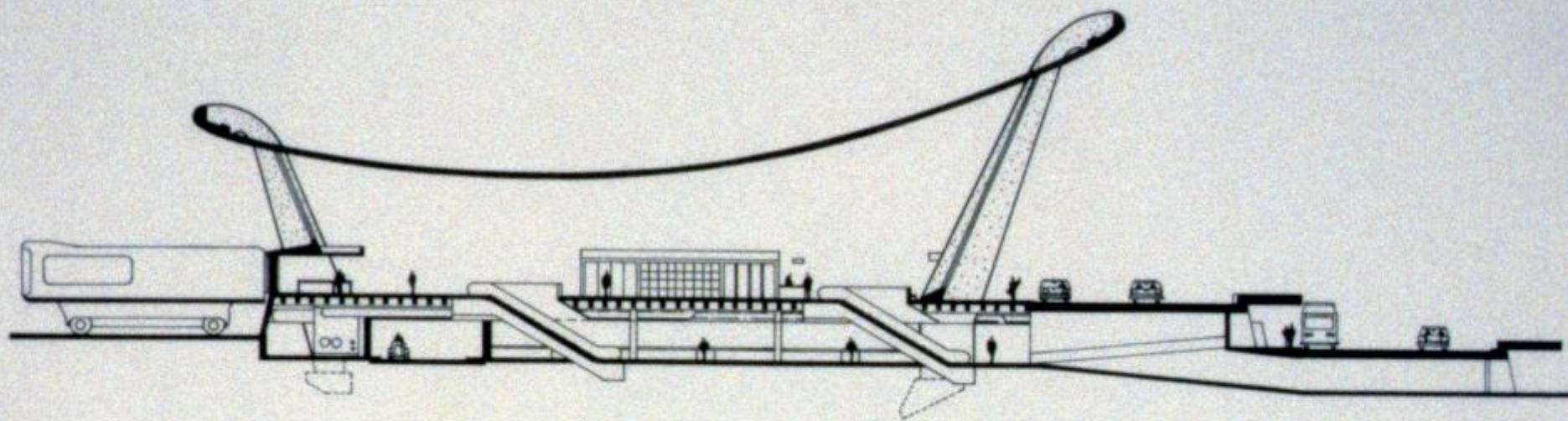
*Eero Saarinen
DWA Terminal Building,
Kennedy Airport, New York. 1956-62
Dulles International Airport (Washington, D.C.)
Chantilly, Virginia. 1958-62
Edited and Photographed by Yukio Futagawa
Text by Nobuo Hozumi*



Plan

- 1 Explaining road*
- 2 Ticketing*
- 3 Offices*
- 4 Concessions*
- 5 Waiting area*
- 6 Transporter docks*
- 7 Concourse*





Section











Another architectural pilgrimage:
How far will you go to visit a building?
How important are buildings to you?

















GE
CURRENCY EXCHANGE

Bank Cash Go

Orange	Green	Purple
1000	2000	5000

Bank Cash Go logo at the bottom.





UNITED

5

united.com
bag check

UNITED

UNITED

UNITED

UNITED

UNITED

UNITED STATES AIR FORCE
UNITED STATES AIR FORCE

UNITED STATES AIR FORCE
UNITED STATES AIR FORCE

UNITED STATES AIR FORCE
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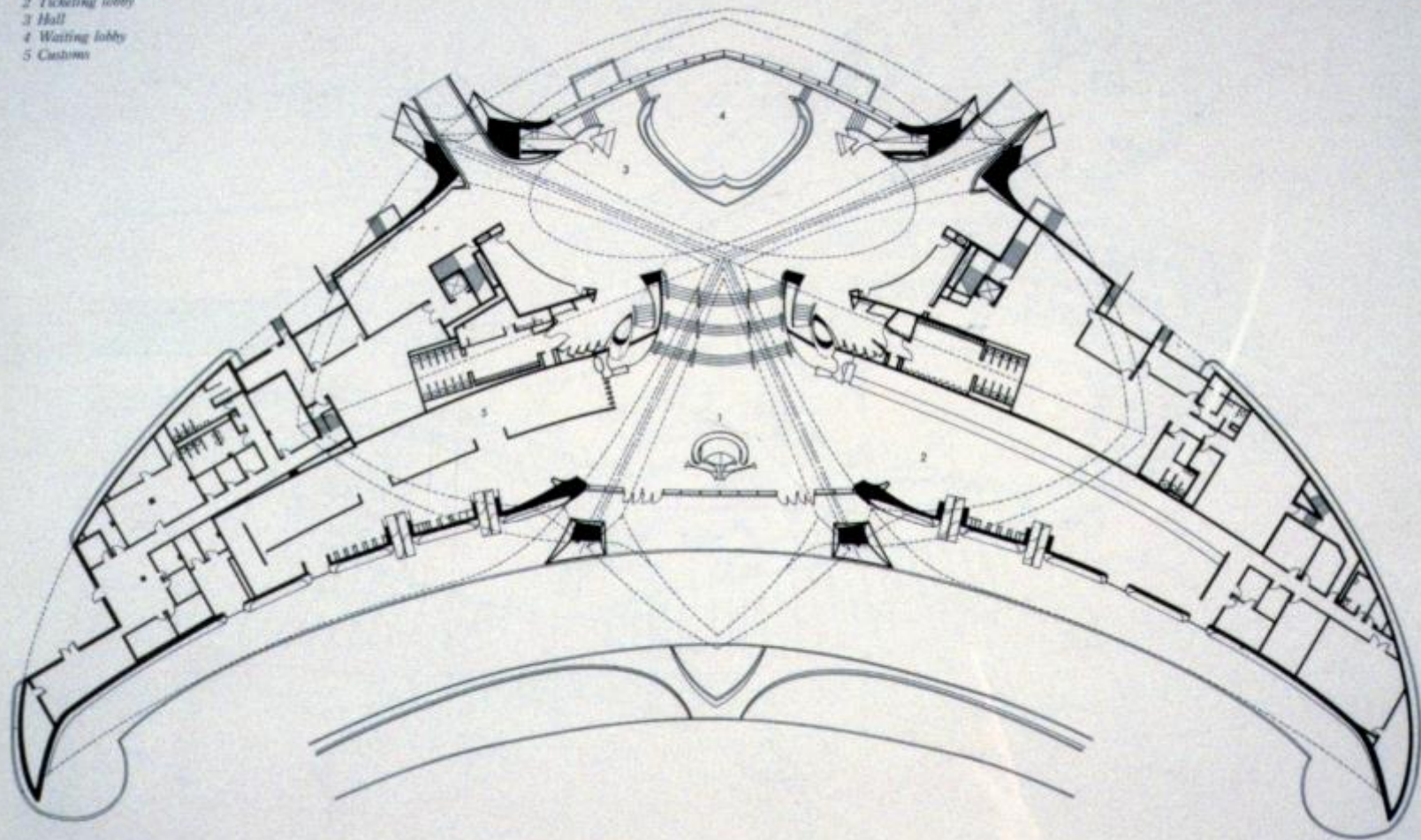
UNITED STATES AIR FORCE
UNITED STATES AIR FORCE



TWA Flight Center
New York City, USA
Eero Saarinen
1962

Plan

- 1 Information counter*
- 2 Ticketing lobby*
- 3 Hall*
- 4 Waiting lobby*
- 5 Customs*





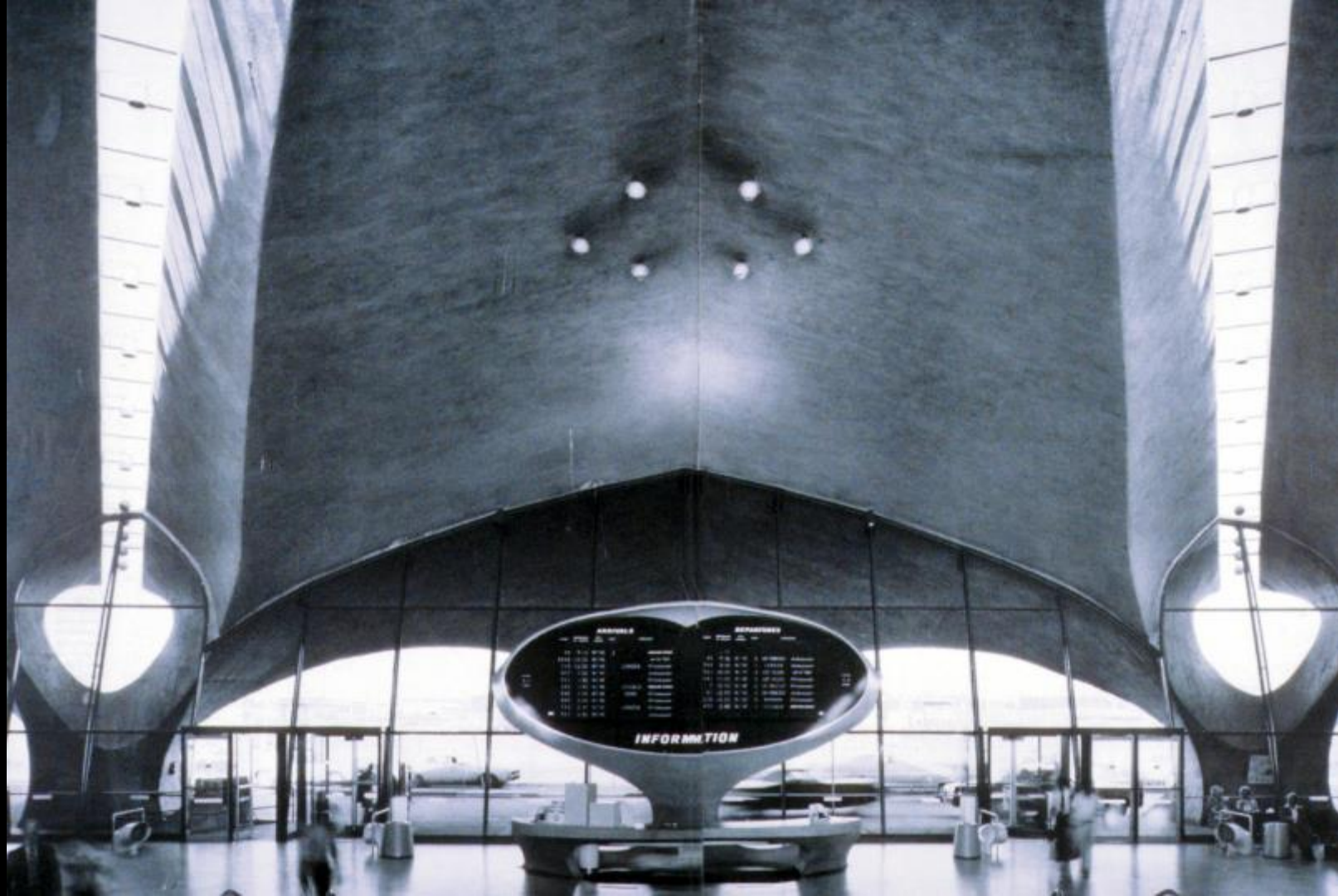


Bill Meyer photo









ARRIVALS

11:00
11:15
11:30
11:45
12:00
12:15
12:30
12:45

12:00
12:15
12:30
12:45
13:00
13:15
13:30
13:45

DEPARTURES

12:00
12:15
12:30
12:45
13:00
13:15
13:30
13:45

14:00
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15:45

INFORMATION

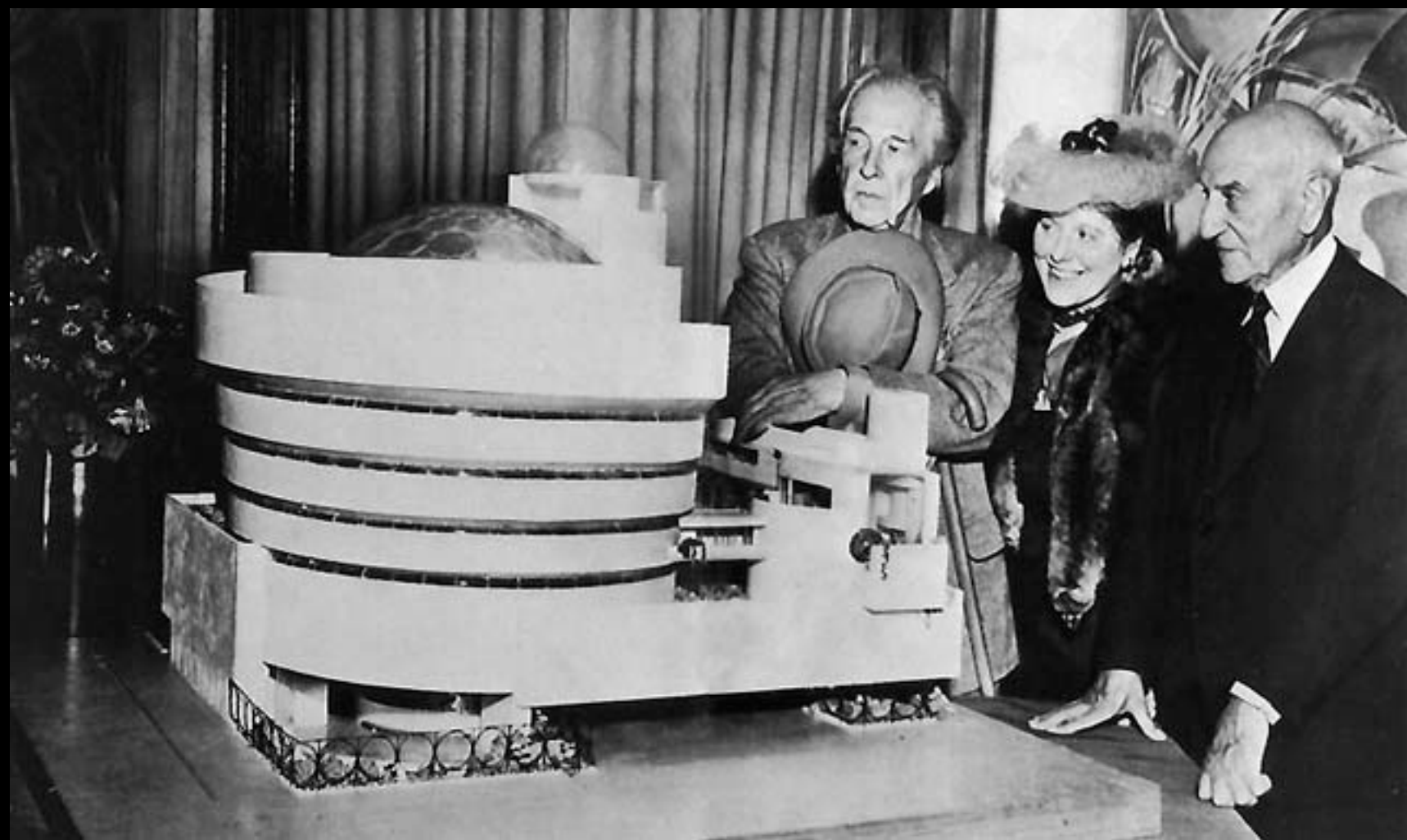




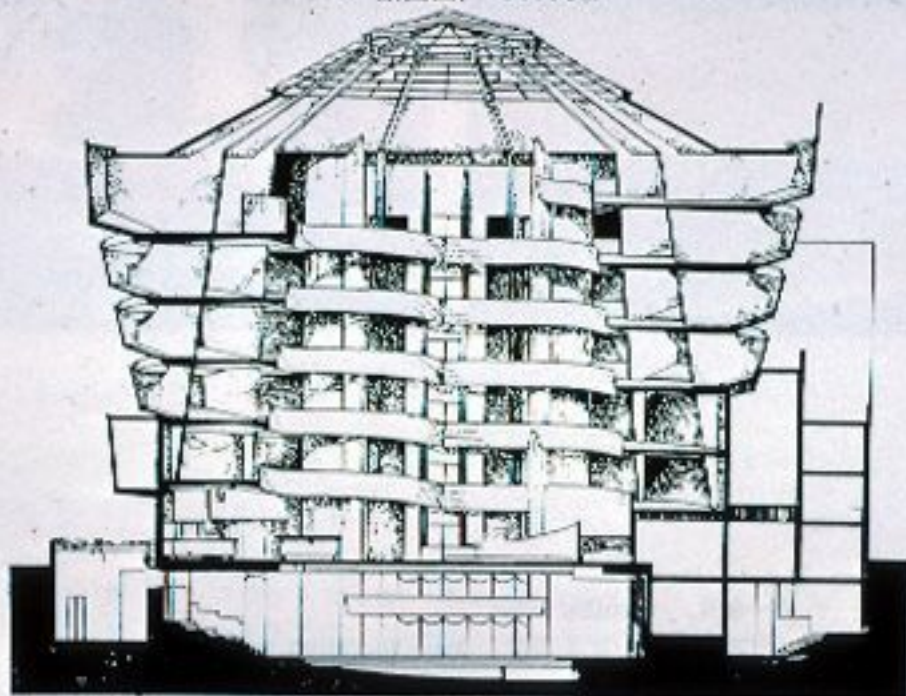
Curves and Plastic Forms



Solomon R. Guggenheim Museum
New York City, USA
Frank Lloyd Wright
1959



5- 塔圖, Section.





















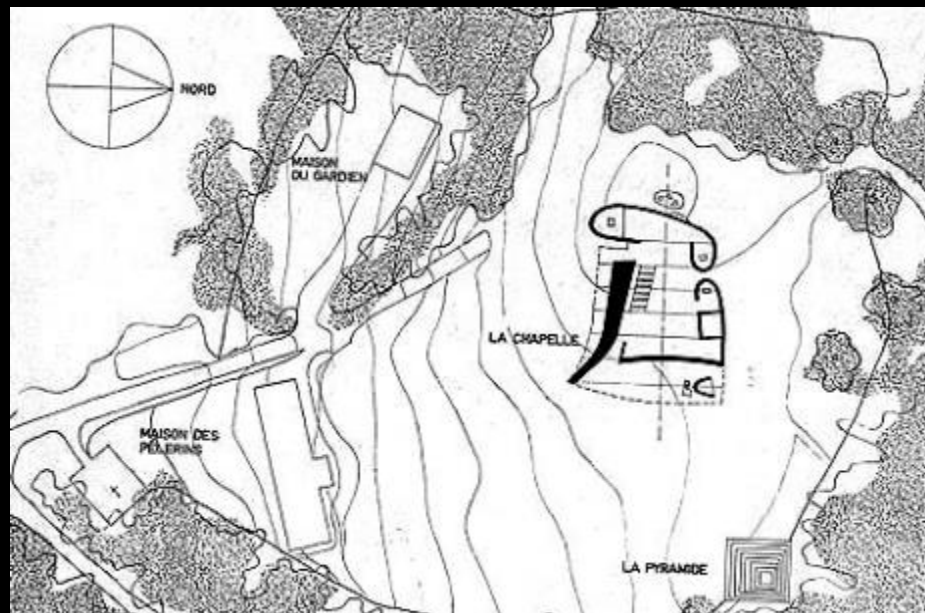


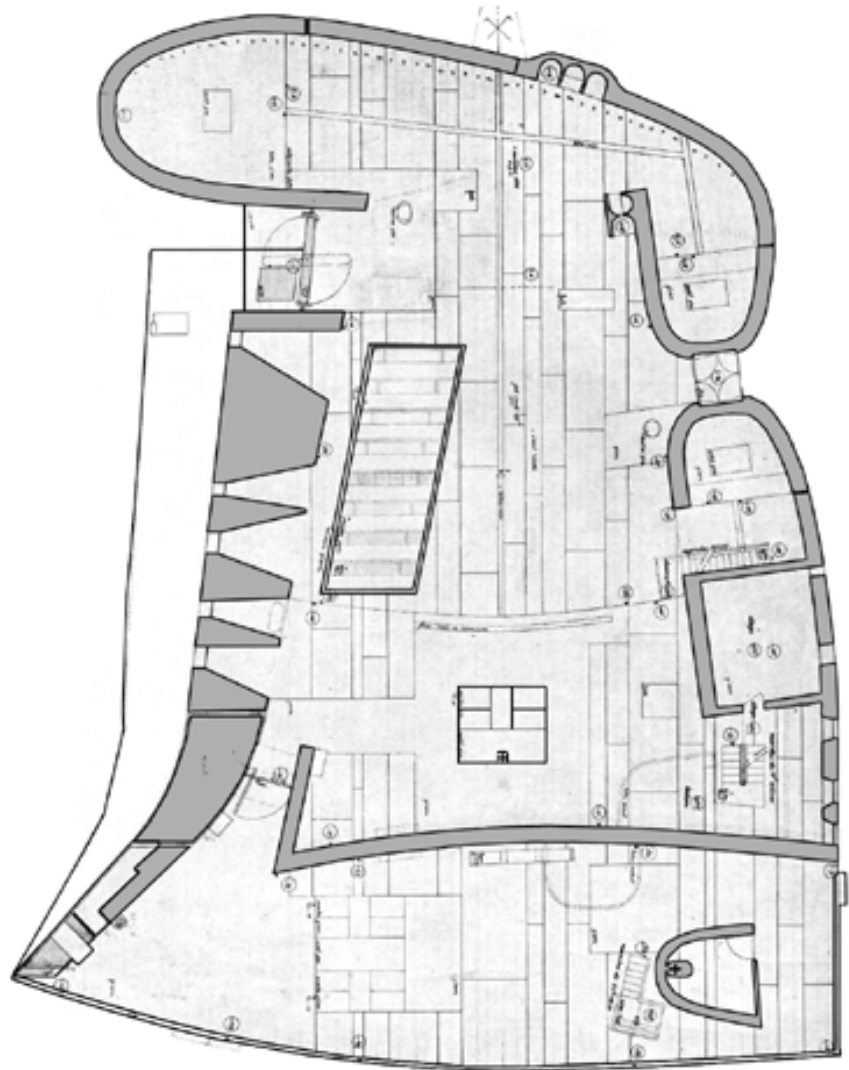






Chapelle Notre-Dame-du-
Haut de Ronchamp
Ronchamp, France
Le Corbusier
1955







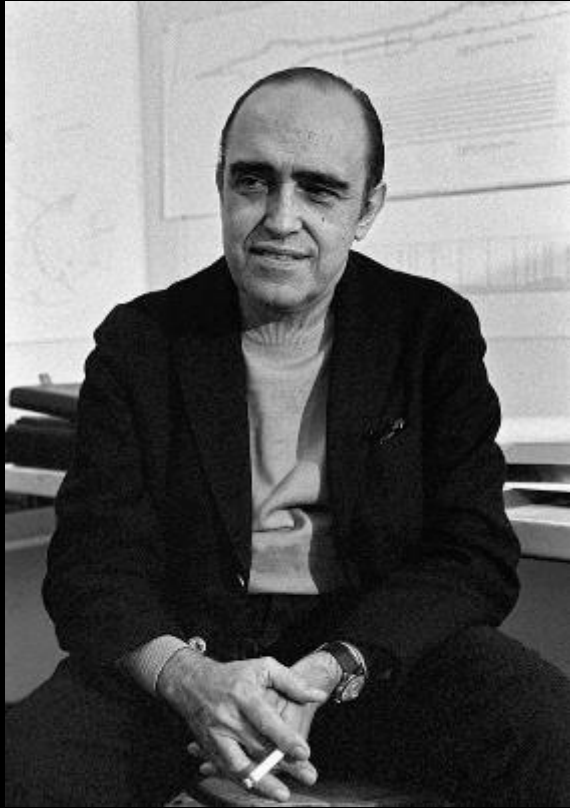




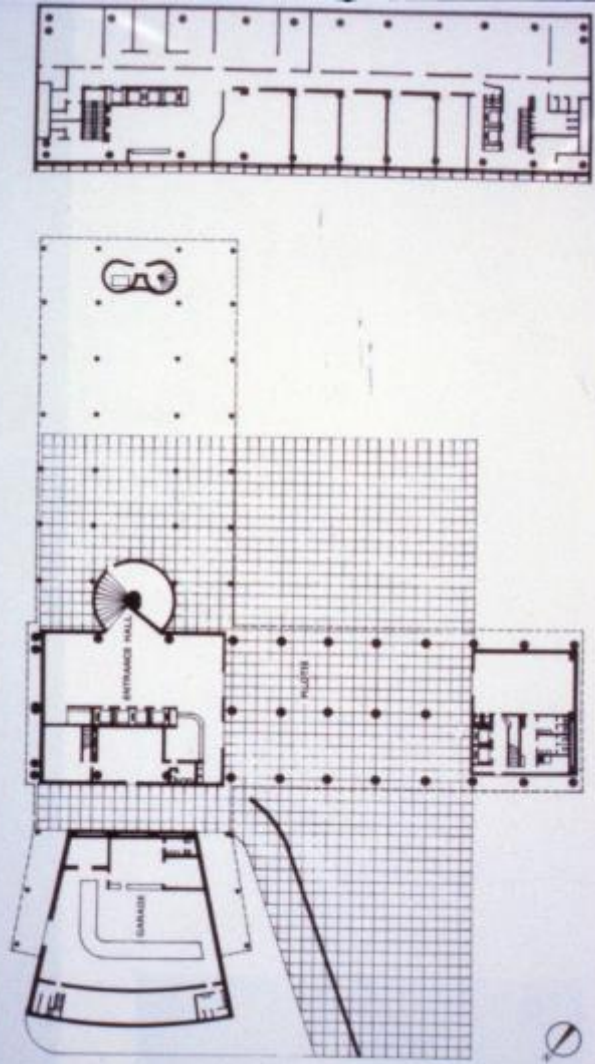








Oscar Niemeyer
Brazilian Architect
1907 to 2012
(104 years!)



Ministry of Education
and Health
Rio de Janeiro, Brazil
Oscar Neimeier
1943





Cathedral of Brasília
Brasília, Brazil
Oscar Neimeier
1970





National Congress Building
Brasília, Brazil
Oscar Neimeier
1960





Niterói Contemporary Art Museum
Niterói, Brazil
Oscar Neimeier
1996








Museu Oscar Neimeier
Curitiba, Brazil
Oscar Neimeier
2002





Auditorio Ibirapuera
São Paulo, Brazil
Oscar Neimeier
2005



Brutalism



Maisons Jaoul
Neuilly-sur-Seine
Le Corbusier
1955







Sainte-Marie de La Tourette
Convent
Eveux, France
Le Corbusier
1960

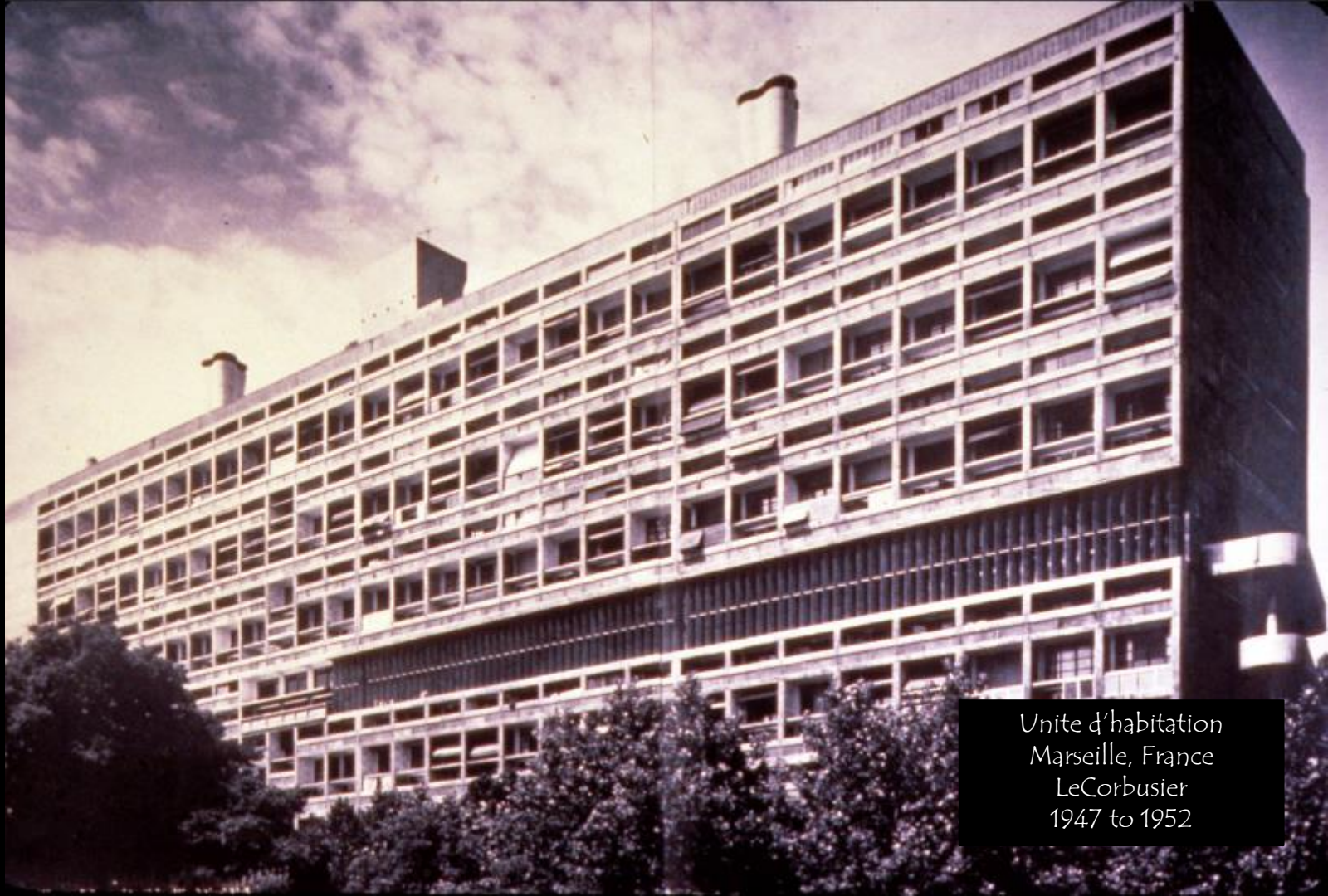




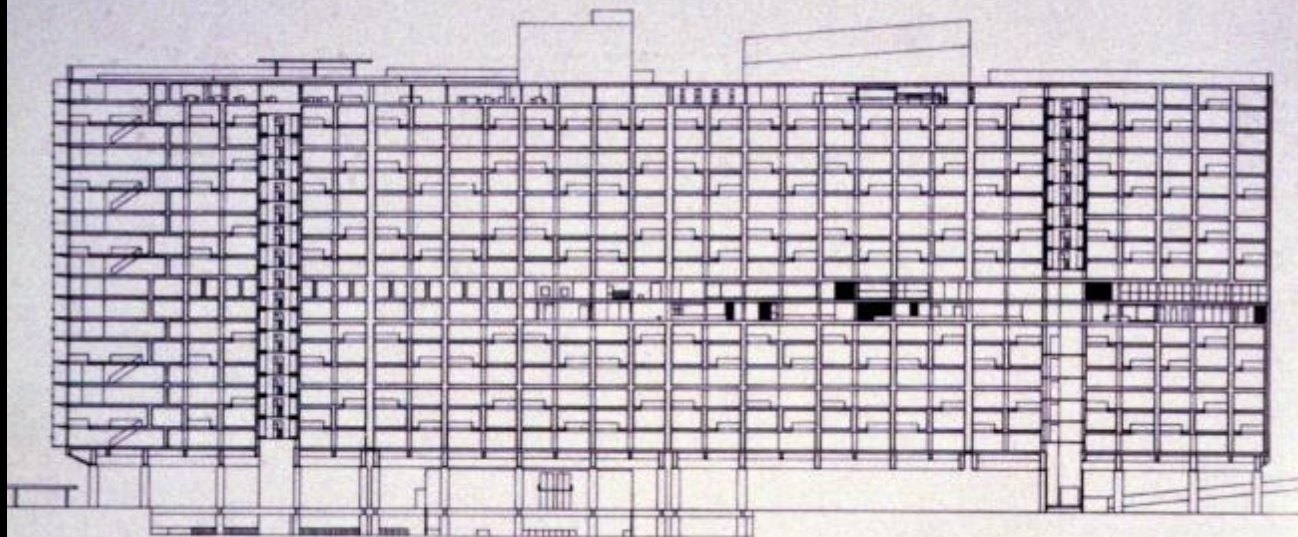




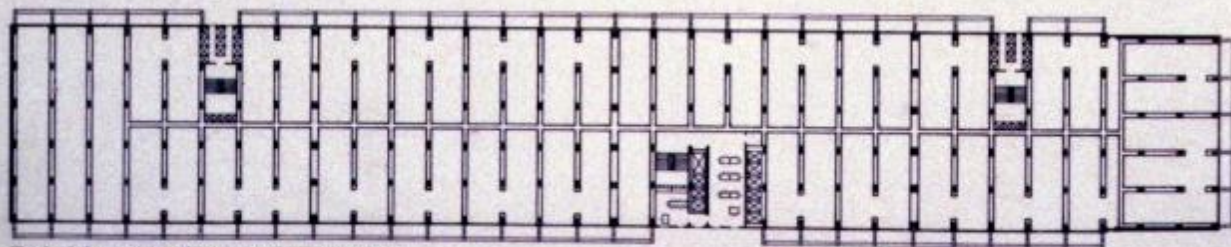




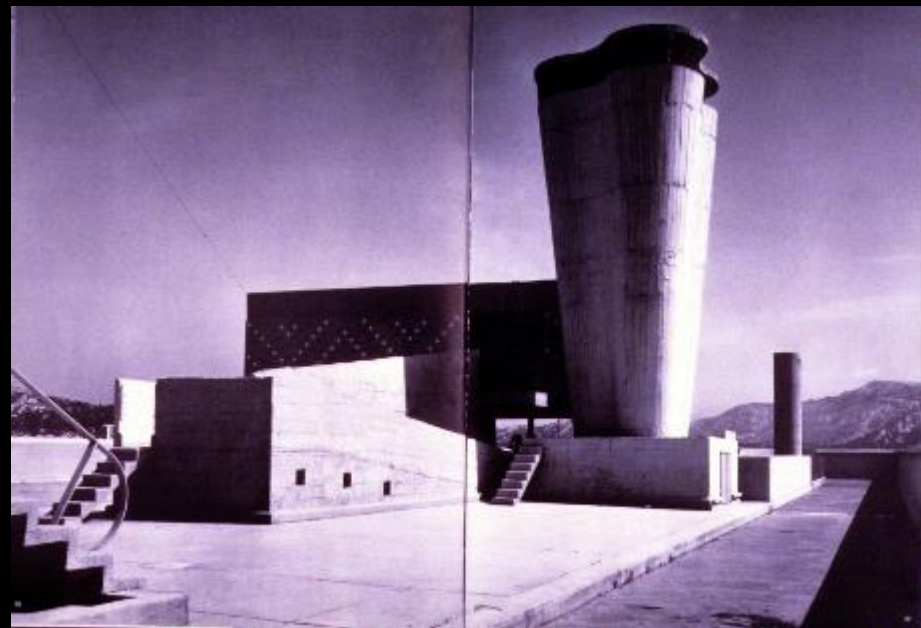
Unité d'habitation
Marseille, France
LeCorbusier
1947 to 1952



Long section looking west.



Typical floor plan of apartments, lower level.





Unite d'habitation of Berlin
Berlin, Germany
Le Corbusier
1958











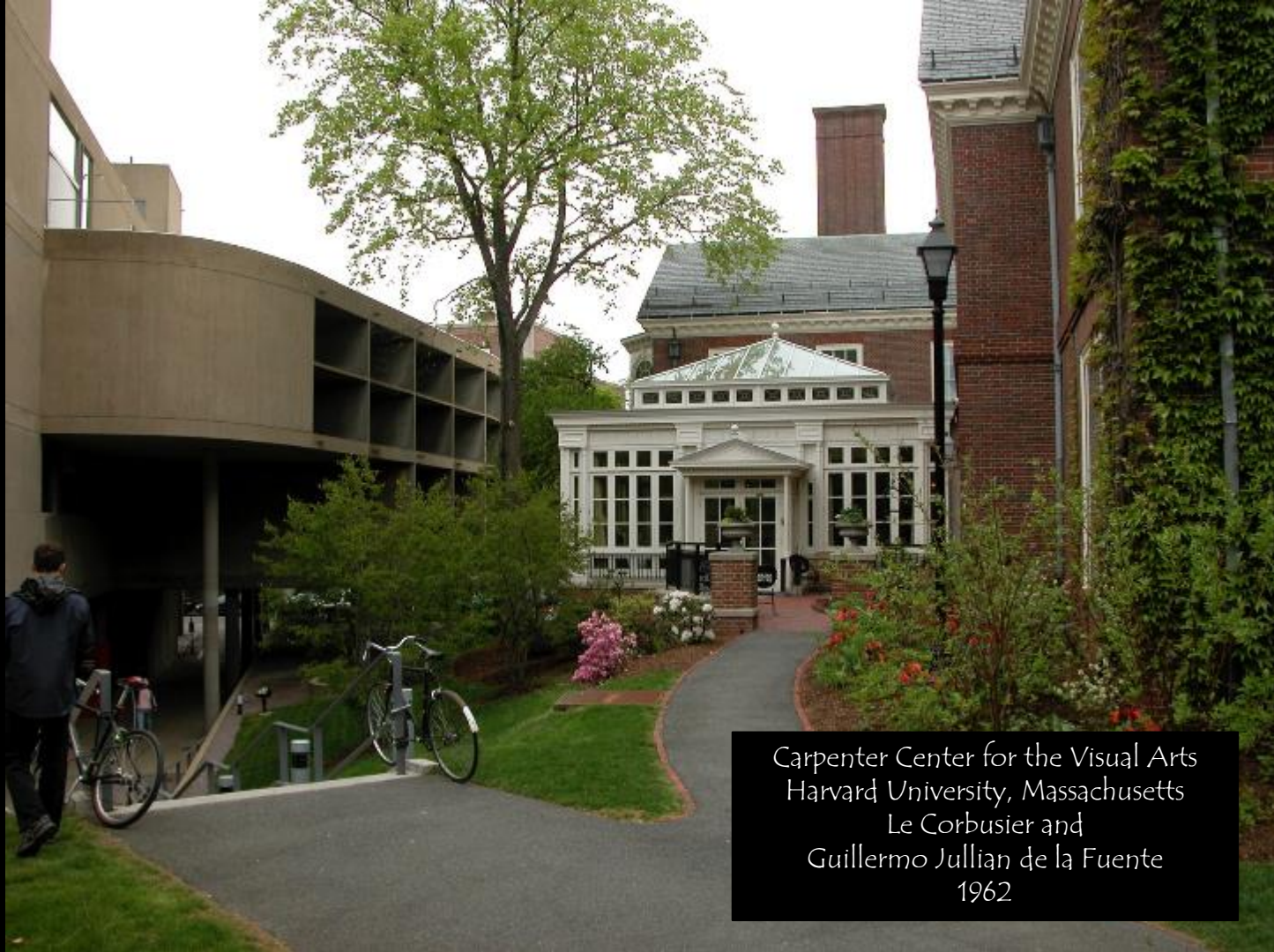












Carpenter Center for the Visual Arts
Harvard University, Massachusetts
Le Corbusier and
Guillermo Jullian de la Fuente
1962















Boston City Hall Plaza
Boston, Massachusetts
Kallmann McKinnell & Knowles
1962







1916



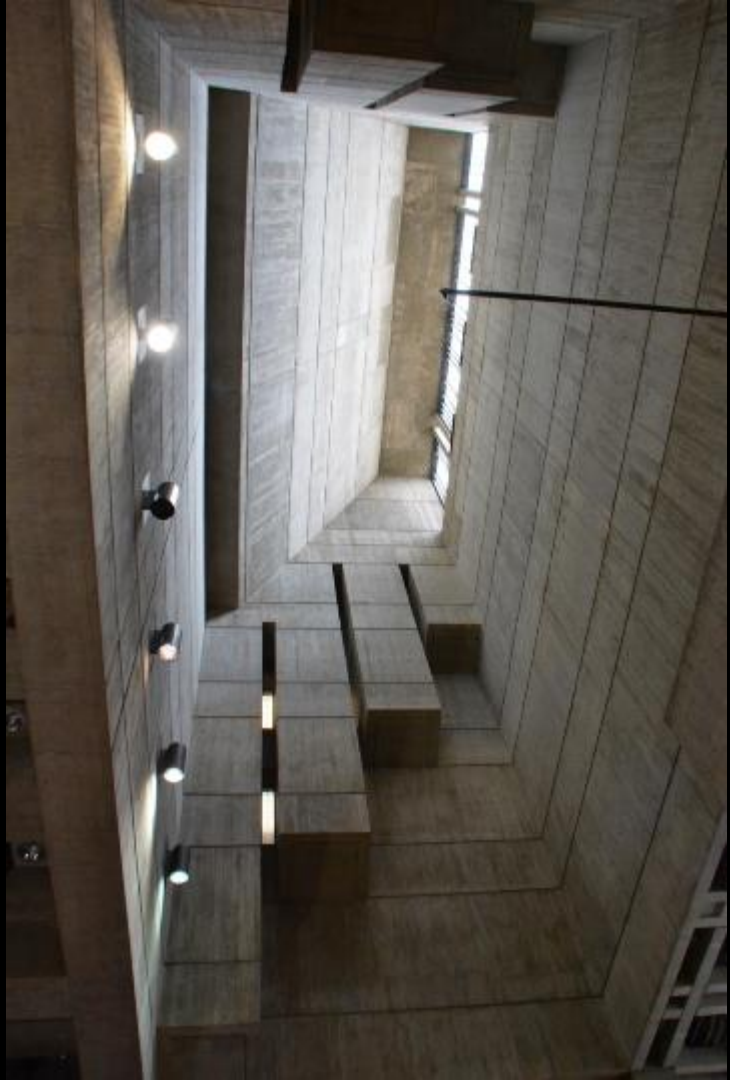














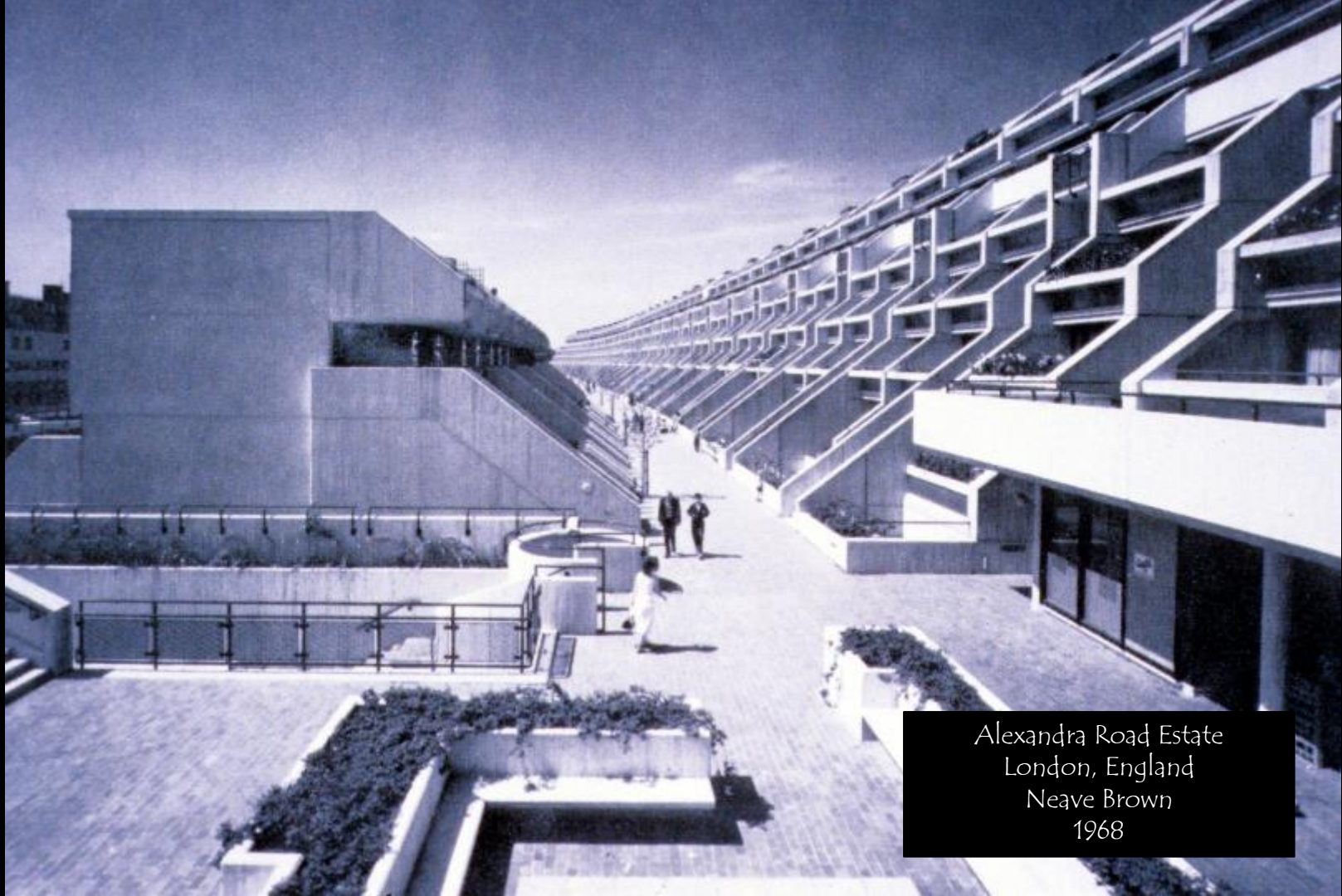
Math and Computer Building
University of Waterloo



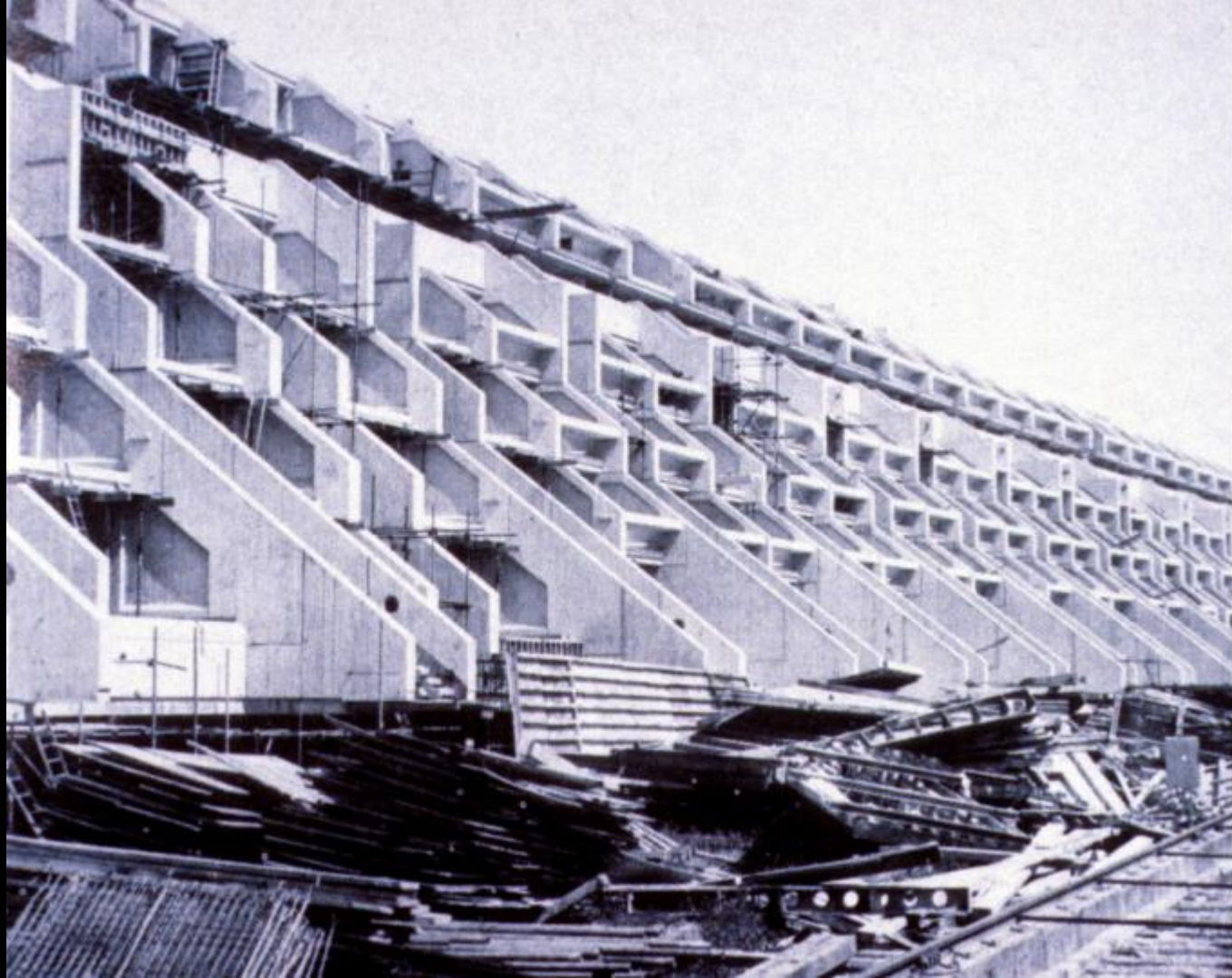
Atelier 5
Swiss Architectural Firm







Alexandra Road Estate
London, England
Neave Brown
1968









Brunswick Centre
London, England
Patrick Hodgkinson
1967 to 1972



BRUNSWICK













Trellick Tower
London, England
Erno Goldfinger
1972

























Robinhood Gardens
London, England
Peter and Alison Smithson
1972
(demolition 2017-2019)











Healy Wharf (via subway)
Swanwich (via foot tunnel)



 Wharfside
Point North





"A Clockwork Orange"
Film by
Stanley Kubrick

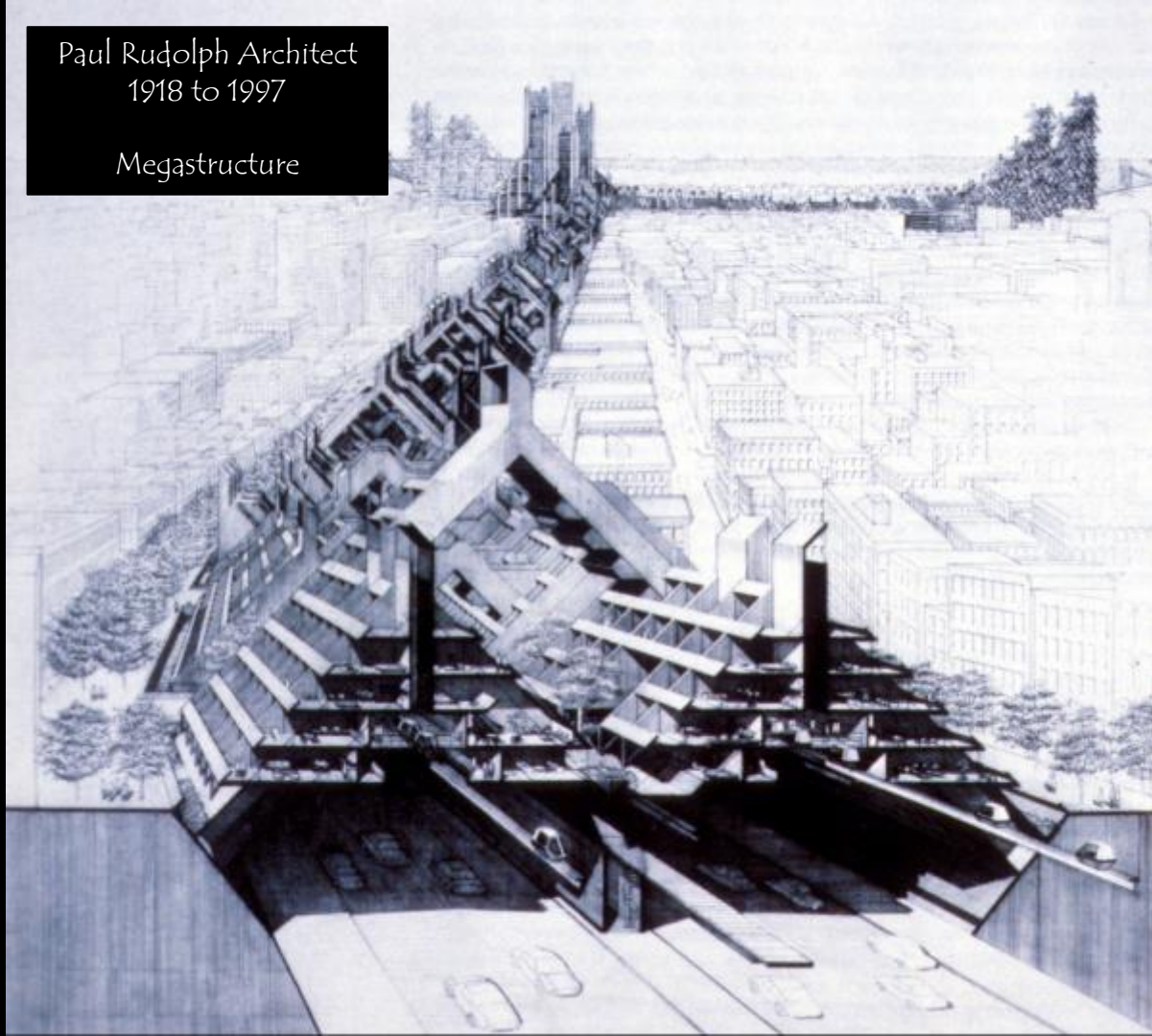


Thameshead Estate
London, England



Paul Rudolph Architect
1918 to 1997

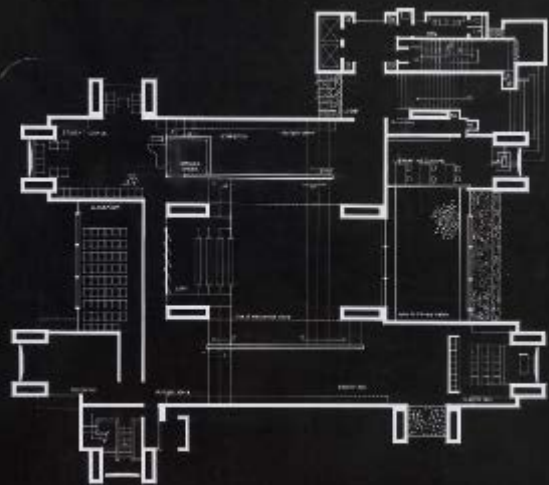
Megastructure



Yale Art and Architecture Building
New Haven, CN
Paul Rudolph
1963



NEW HAVEN It's hard to think of a building that has suffered through more indignities than the Yale School of Art and Architecture. On the day of its dedication in 1963, the architectural historian Nikolaus Pevsner condemned the oppressive monumentality of its concrete forms. Two years later the school's dean brutally cut up many of the interiors, which he claimed were dysfunctional. A few years after that a fire gutted what was left. By then the reputation of the building's architect, Paul Rudolph, was in ruins.

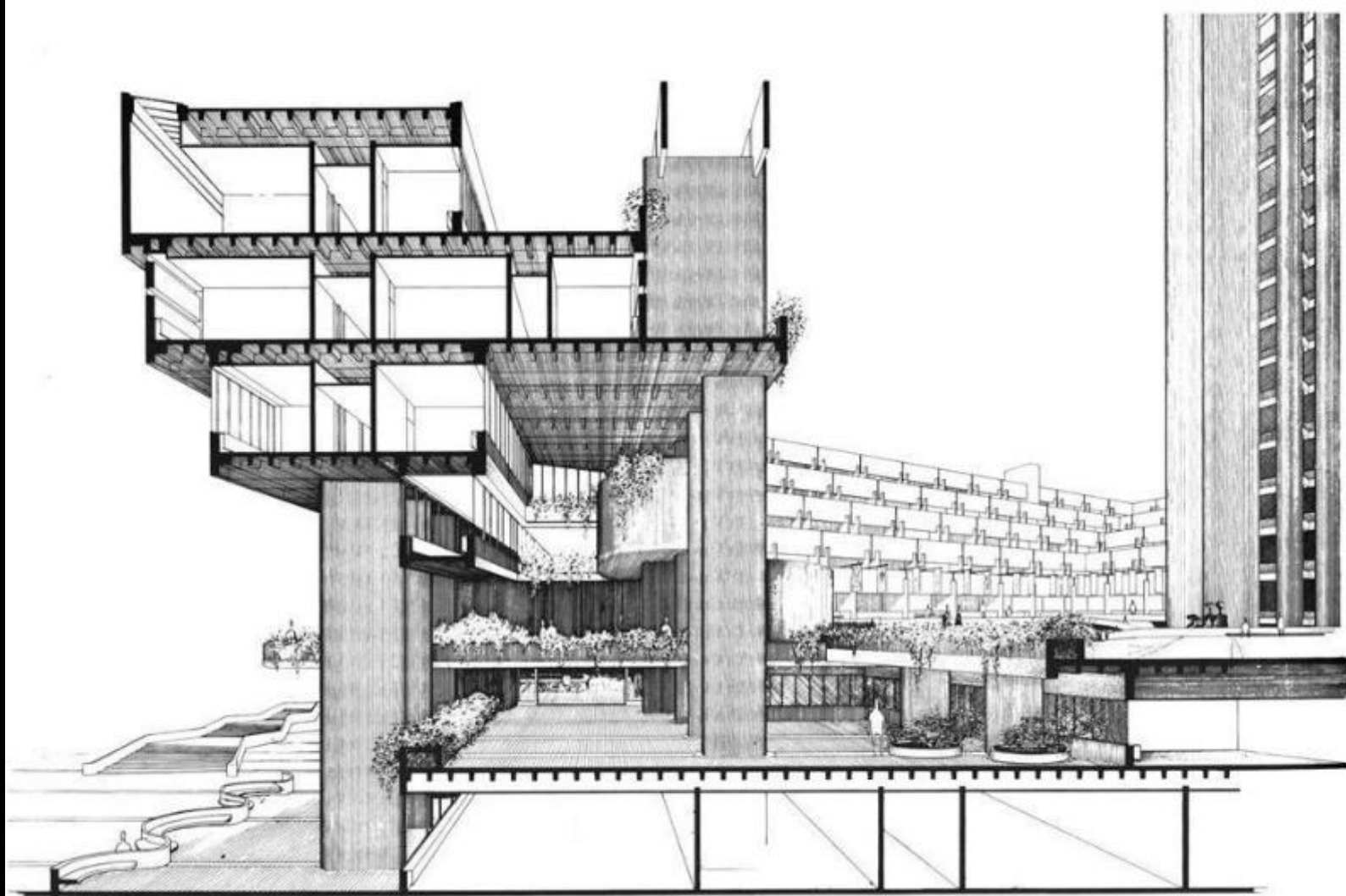


10TH FLOOR PLAN

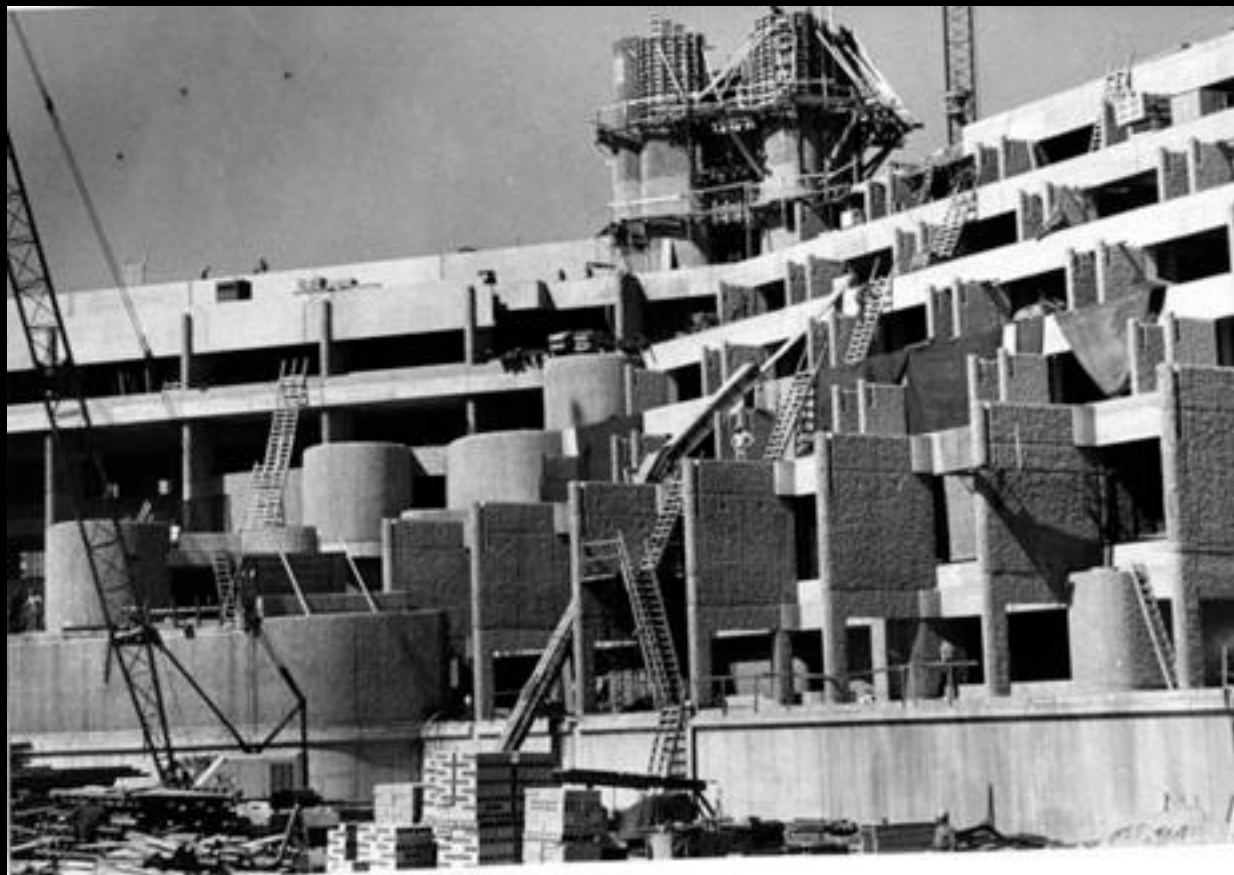


Erich Lindemann Mental Health Center
Boston, Massachusetts
Paul Rudolph
1971





















Place Bonaventure
Montreal, Quebec
Arcop
1967

Place
BONAVENTURE

McDonald's

Place de Bonaventure







A photograph of the Robarts Library at the University of Toronto, a prime example of Brutalist architecture. The building is a massive, multi-story concrete structure with a complex, geometric facade. It features several prominent vertical columns and large, rectangular openings that create a sense of depth and shadow. The building's design is characterized by its heavy, blocky forms and the use of raw concrete. In the foreground, a tree with autumn-colored leaves stands to the left of the building. To the right, a street scene is visible, including a bus stop shelter, a street lamp, and a traffic light. The sky is overcast, and the overall atmosphere is one of a typical urban setting.

Robarts Library University of Toronto
Toronto, Ontario
Mathers and Haldenby
1973









University of Guelph
Guelph, Ontario
Circa 1970s







941103-57544-5729



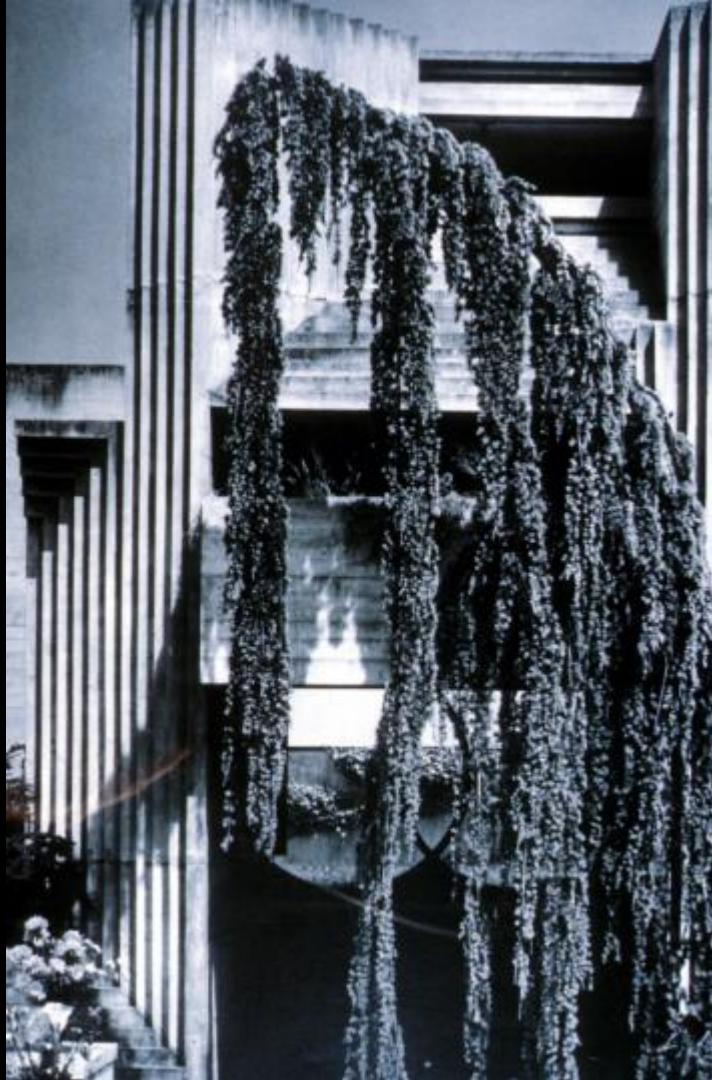
GA

Global Architecture

Carlo Scarpa
Cemetery Brion-Vega, S. Vito, Treviso, Italy. 1970-72
Edited and Photographed by Yukio Futagawa
Text by Paolo Portoghesi



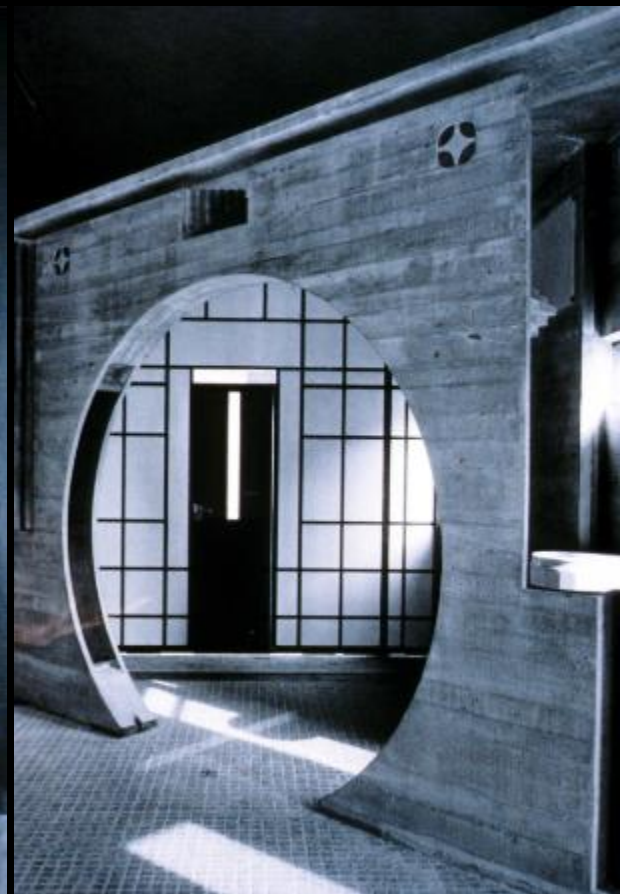
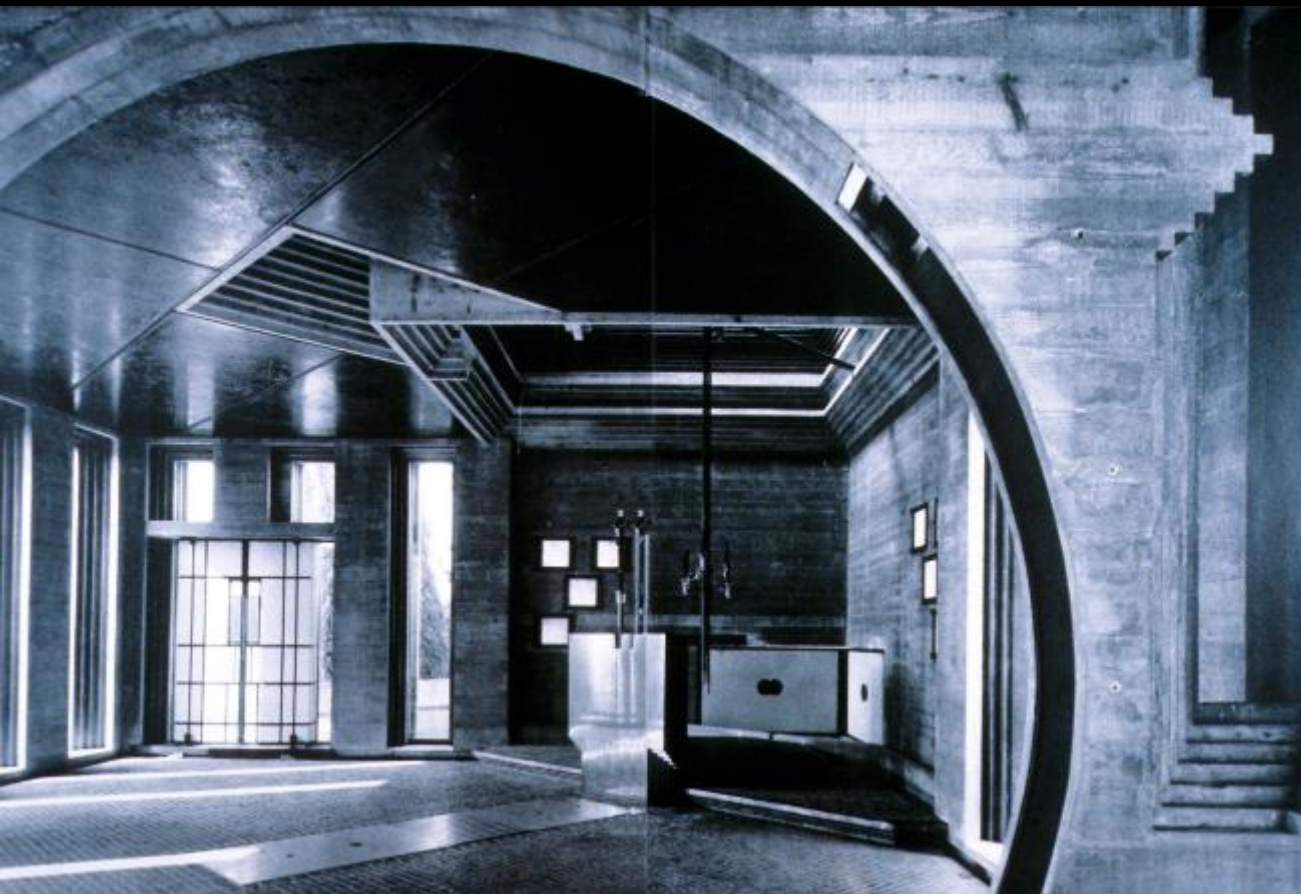
94
1123
535
94
1979
U.S.A.



The Brion Cemetery
Treviso, Italy
Carlo Scarpa
1968











Nichinan Cultural Centre (Bunka)
Nichinan, Japan
Kenzo Tange
1963







Oita Prefectural Library
Oita, Japan
Arata Isozaki
1966





New Prefectural Library
Oita, Japan
Arata Isozaki
1966





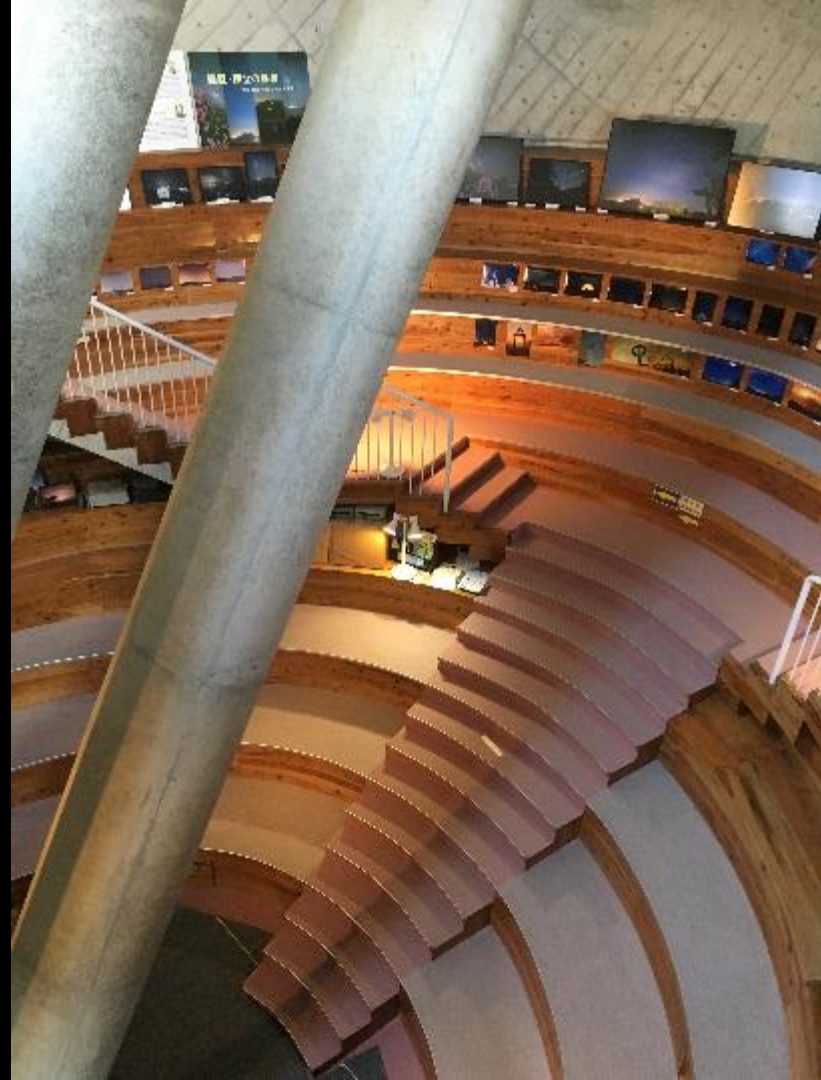


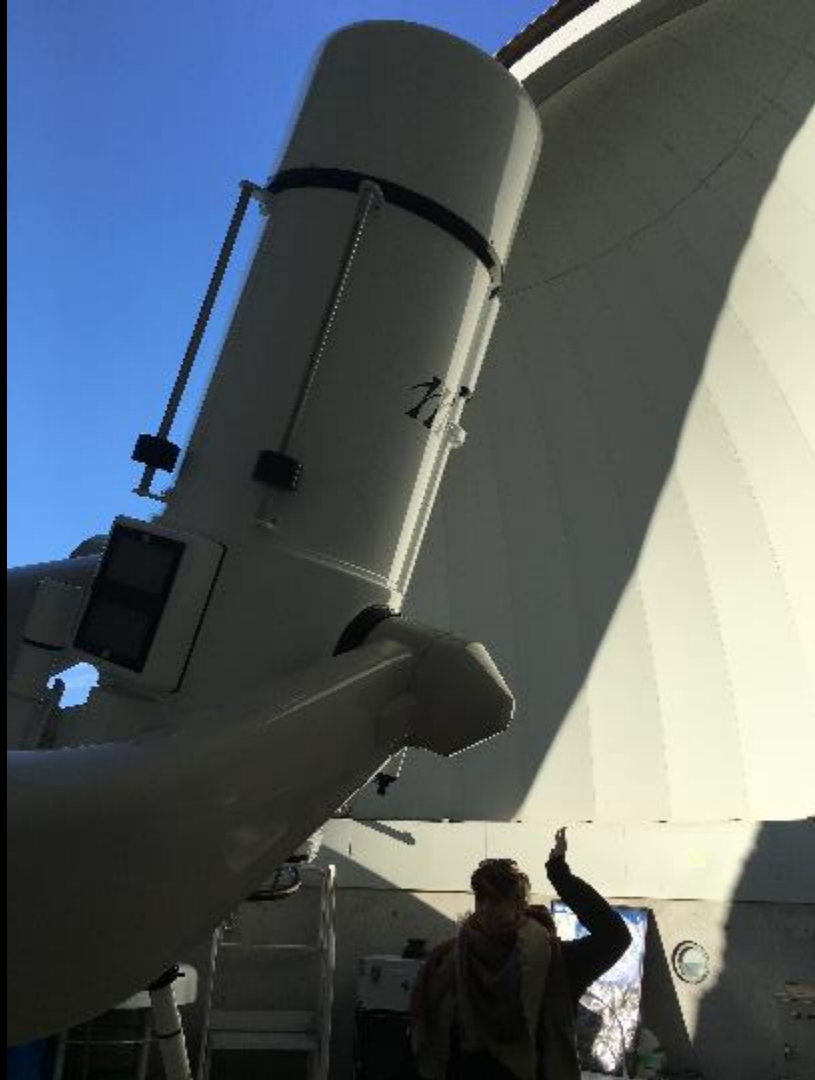


Kihoku Astronomical
Observatory
Kagoshima, Japan
Masaharu Takasaki
1995









INAMORI AUDITORIUM

Inamori Auditorium
Kagoshima, Japan
Tađao Ando
1994











St. Mary's Cathedral
Tokyo, Japan
Kenzo Tange
1964







A photograph of the Tama Art University Library, a modern building with a white facade and large arched glass windows. The building is surrounded by green trees and a paved walkway. The sky is clear and blue.

Tama Art University Library
Tokyo, Japan
Toyo Ito
2012



























Expo '98 Portuguese National Pavilion
Alvaro Siza Vieira















Best of 2019

Concrete: the most destructive material on Earth

▲ Limestone quarries and cement factories are often sources of air pollution. Photograph: Zoonar GmbH (Alamy)

After water, concrete is the most widely used substance on the planet. But its benefits mask enormous dangers to the planet, to human health - and to culture itself

- [A brief history of concrete: from 10,000BC to 3D printed houses](#)
- Editor's pick: best of 2019. We're bringing back some of our favorite stories of the past year. [Support the Guardian's journalism in 2020](#)

by [Jonathan Watts](#)

In the time it takes you to read this sentence, the global building industry will have poured more than 19,000 bathtubs of concrete. By the time you are halfway through this article, the volume would fill the Albert Hall and spill out into Hyde Park. In a day it would be almost the size of China's Three Gorges Dam. In a single year, there is enough to patio over every hill, dale, nook and cranny in England.

After water, concrete is the most widely used substance on Earth. If the cement industry were a country, it would be the third largest carbon dioxide emitter in the world with up to 2.8bn tonnes, surpassed only by [China](#) and

After water, concrete is the most widely used substance on Earth. If the cement industry were a country, it would be the third largest carbon dioxide emitter in the world with up to 2.8 billion tonnes, surpassed only by China and the USA