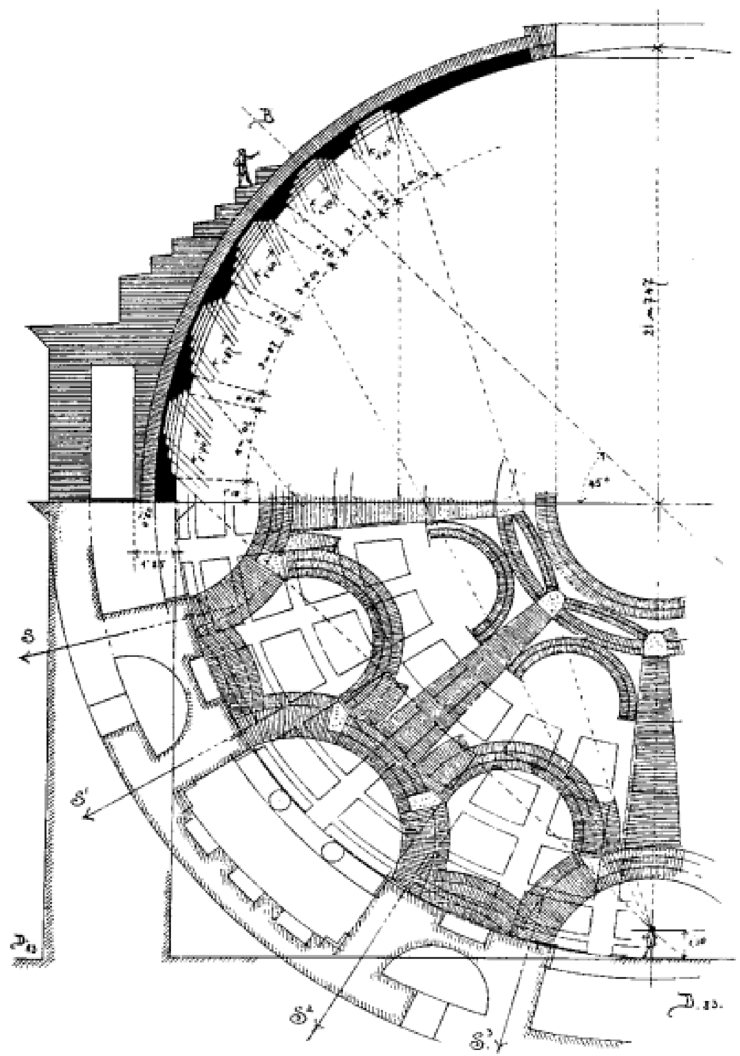
Developments in Concrete Construction

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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Composite Structures

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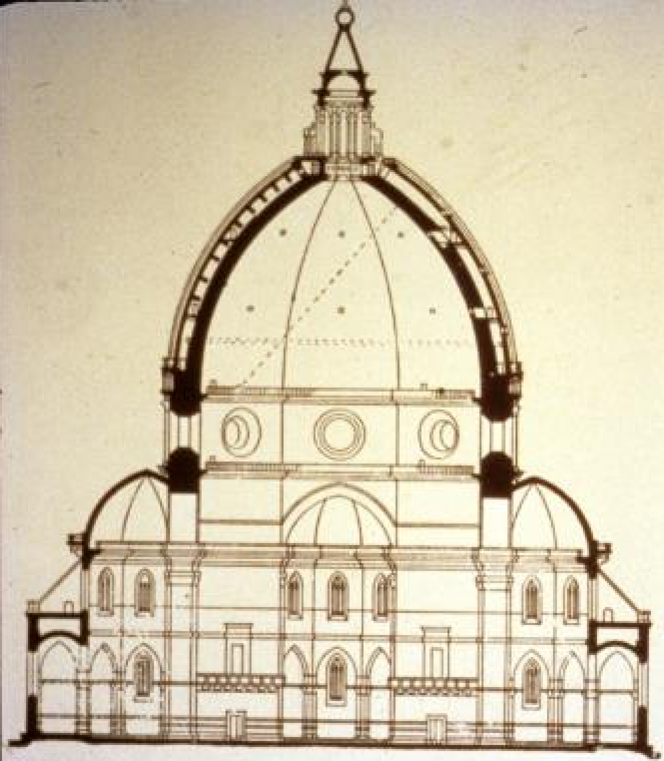
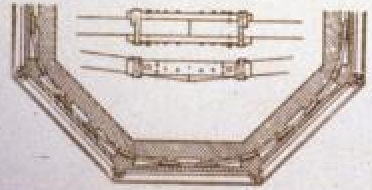
Use multiple materials each to their own structural advantage

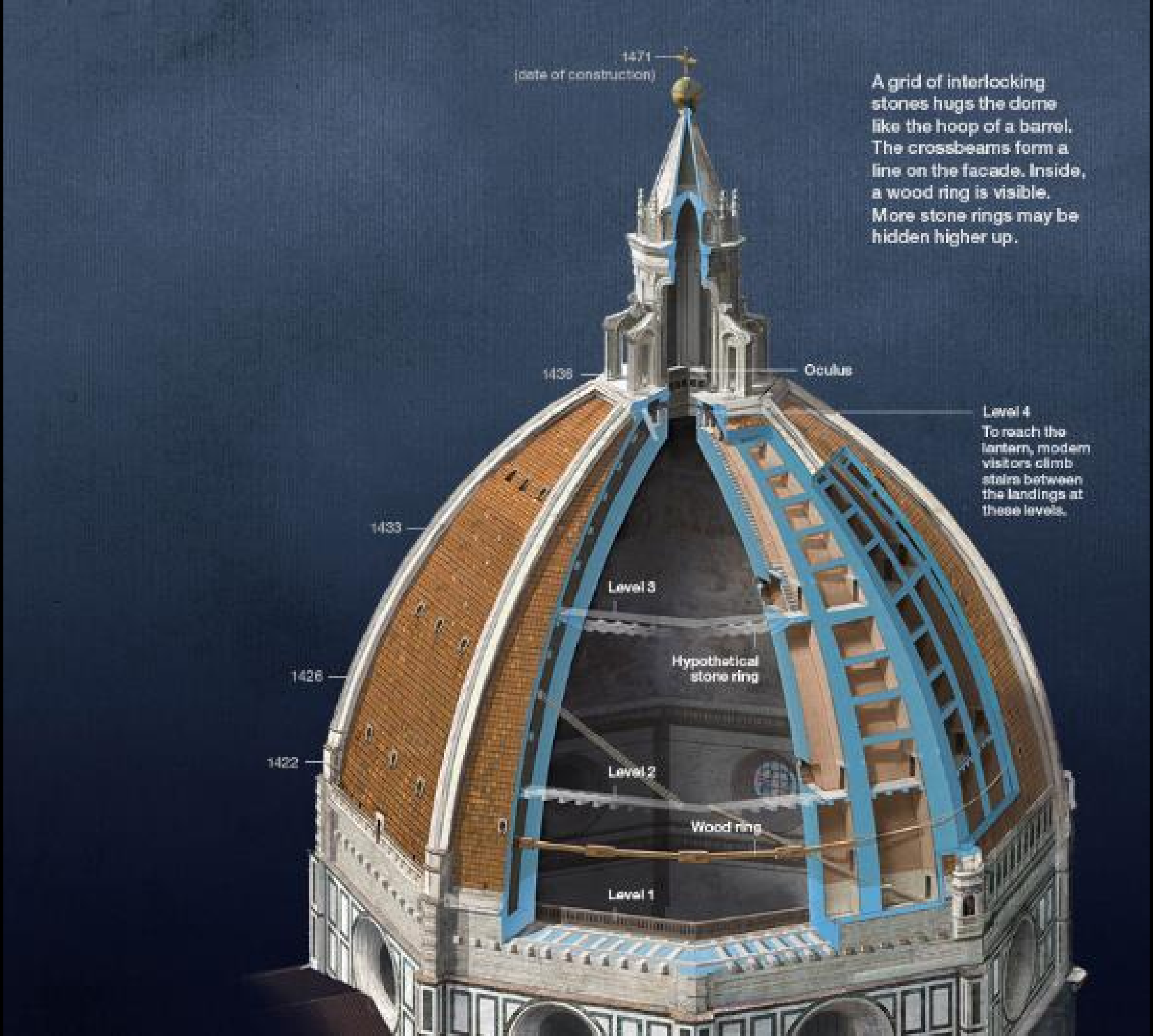


Section through the Florence Cathedral dome.



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

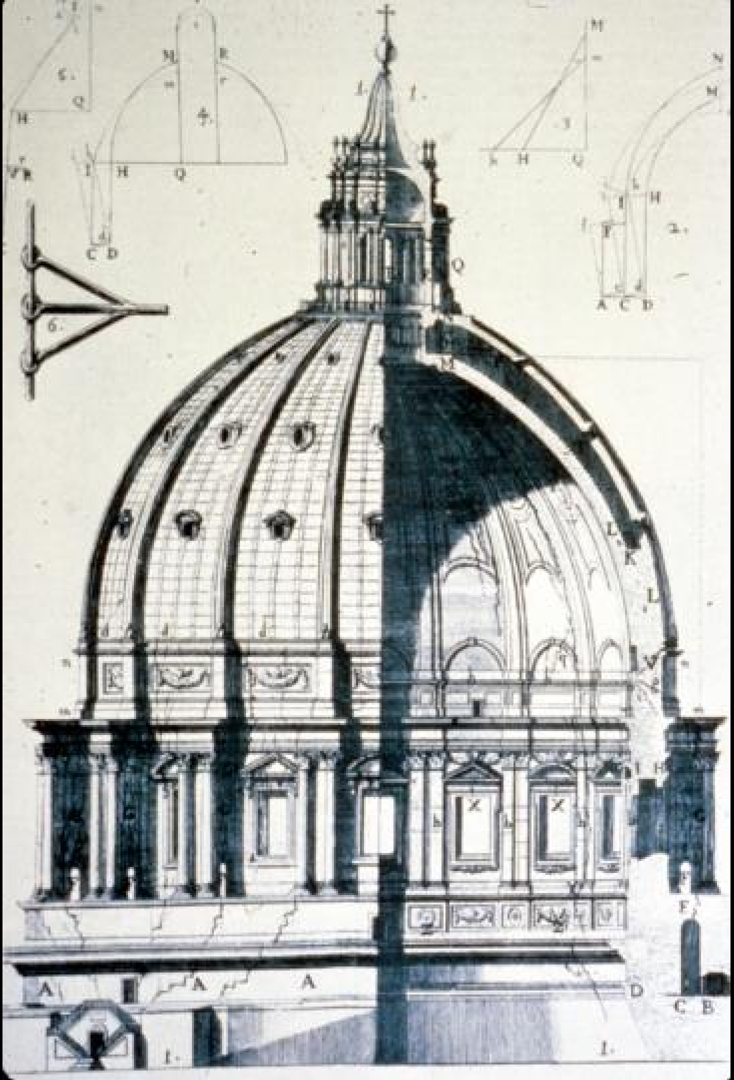
Santa Maria del
Fiore
Florence, Italy
Filippo Brunelleschi
1436


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.
1436
Oculus
Level 4
To reach the lantern, modern visitors climb stairs between the landings at these levels.
1433
Level 3
Hypothetical stone ring
1426
1422
Level 2
Wood ring
Level 1

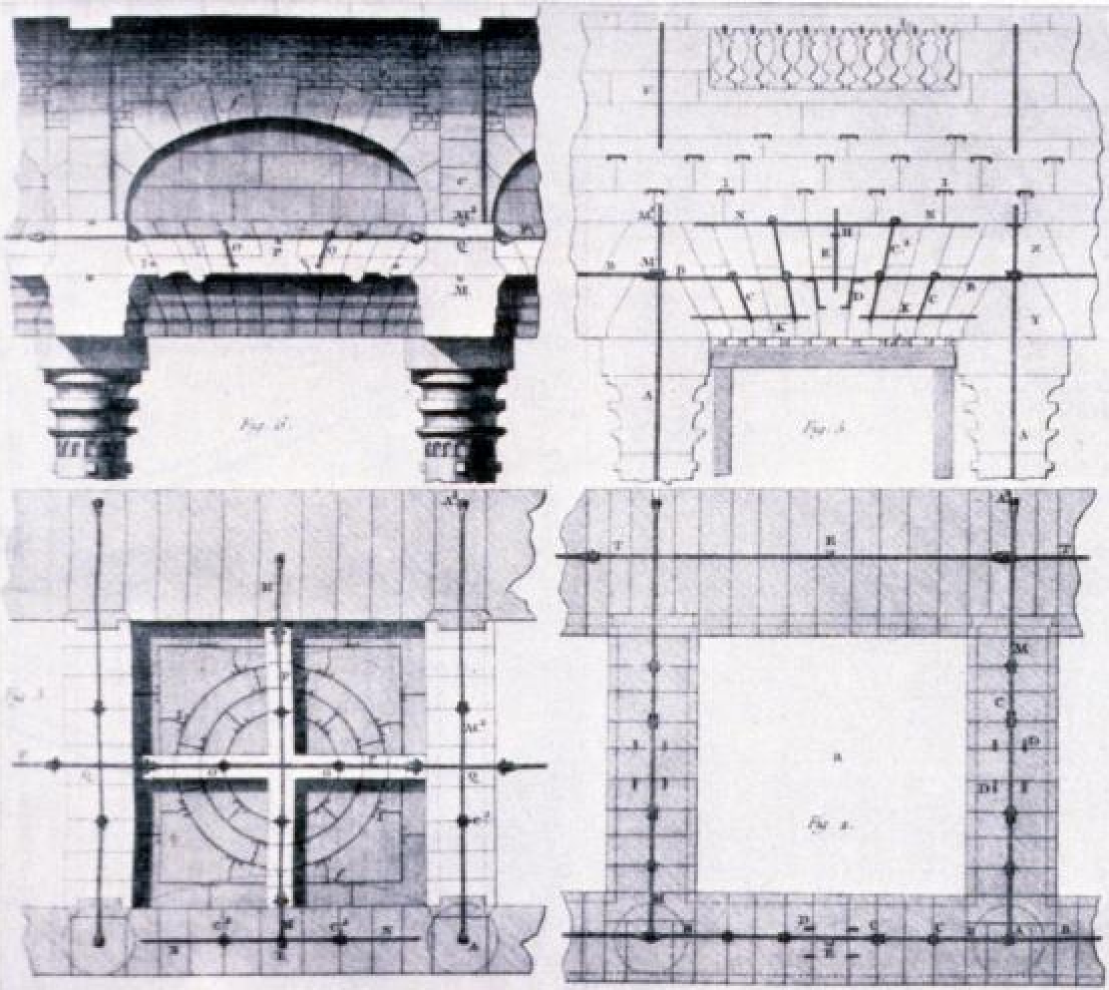
Basilica of St. Peter
Vatican, Italy
Various architects
1506-1626


REGNI CAELORVM TV ES PETRVS ET SVPER


S·PETRI GLORIAE SIXTVS·PP·V·A·M·D·X·C·PONTIF·V

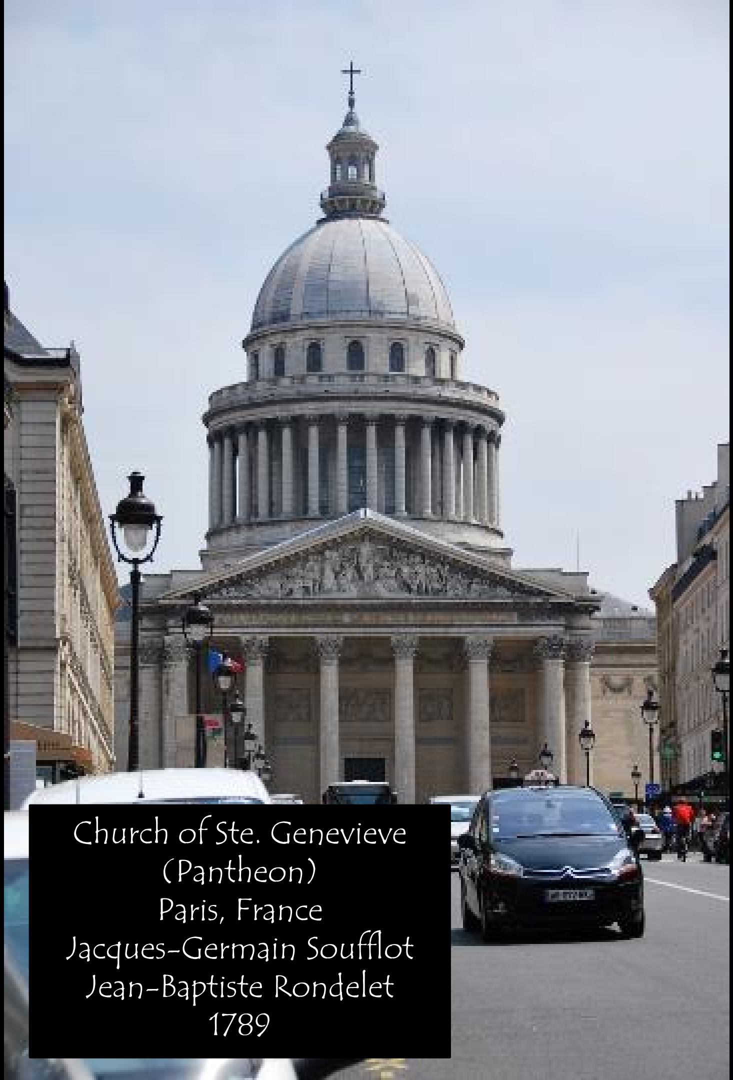


Place de la Concorde
Anges-Jacques Gabriel
Paris, France
1755

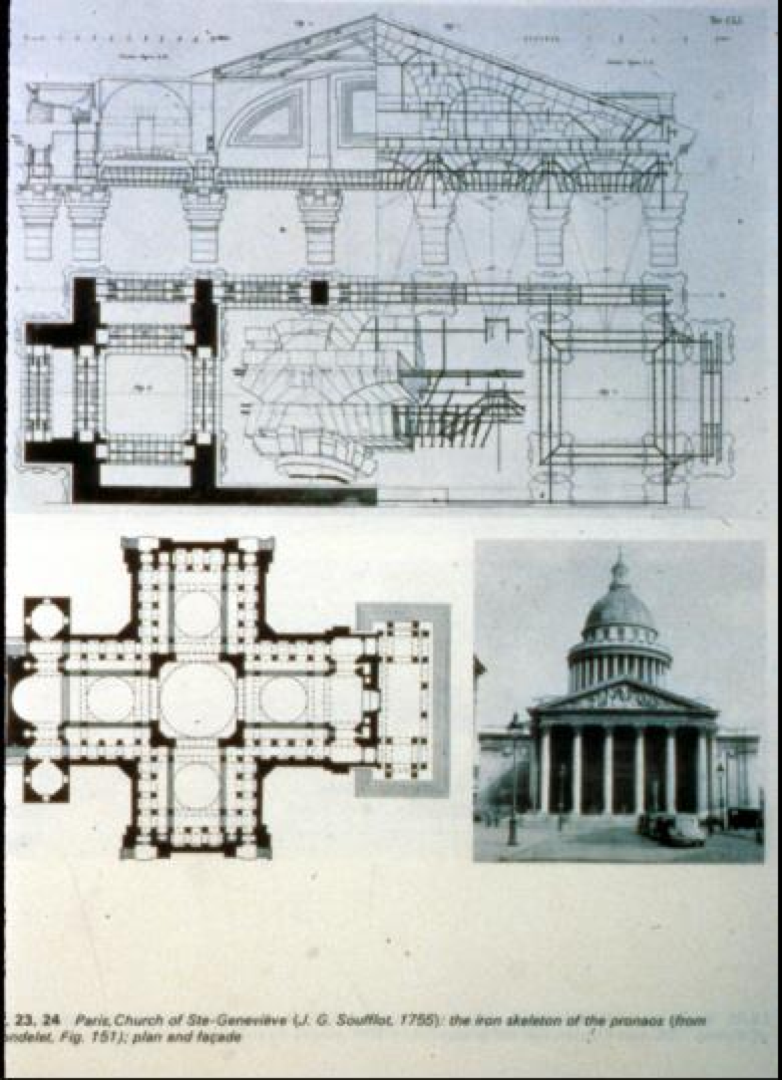


Echelle de ——— 4 ——— 8 Toises

Construction des Platebandes de la Place de Louis XV. à Paris.



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



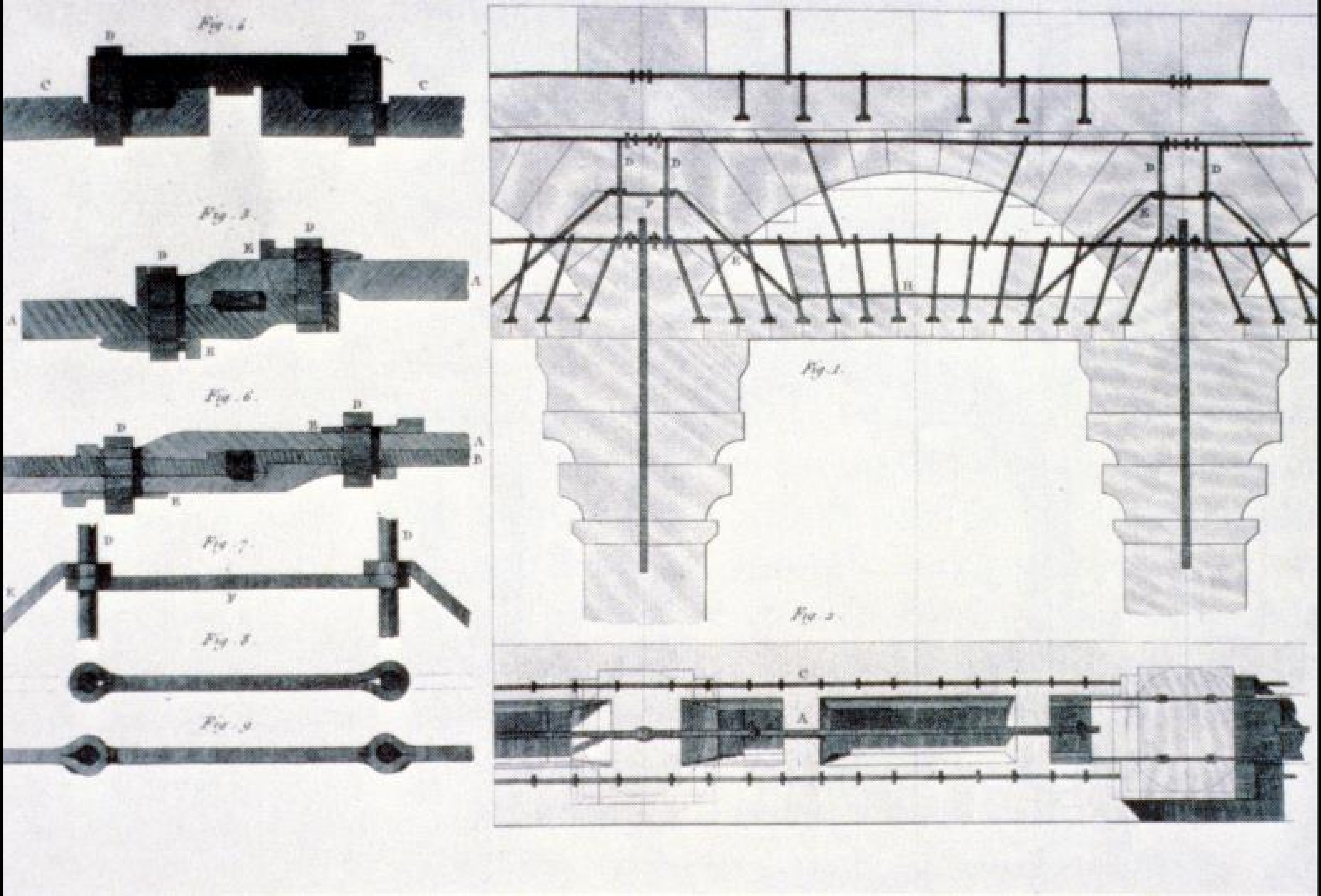


Fig. 4
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Fig. 5
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Fig. 6
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Fig. 7
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Fig. 8
Fig. 9
Fig. 1
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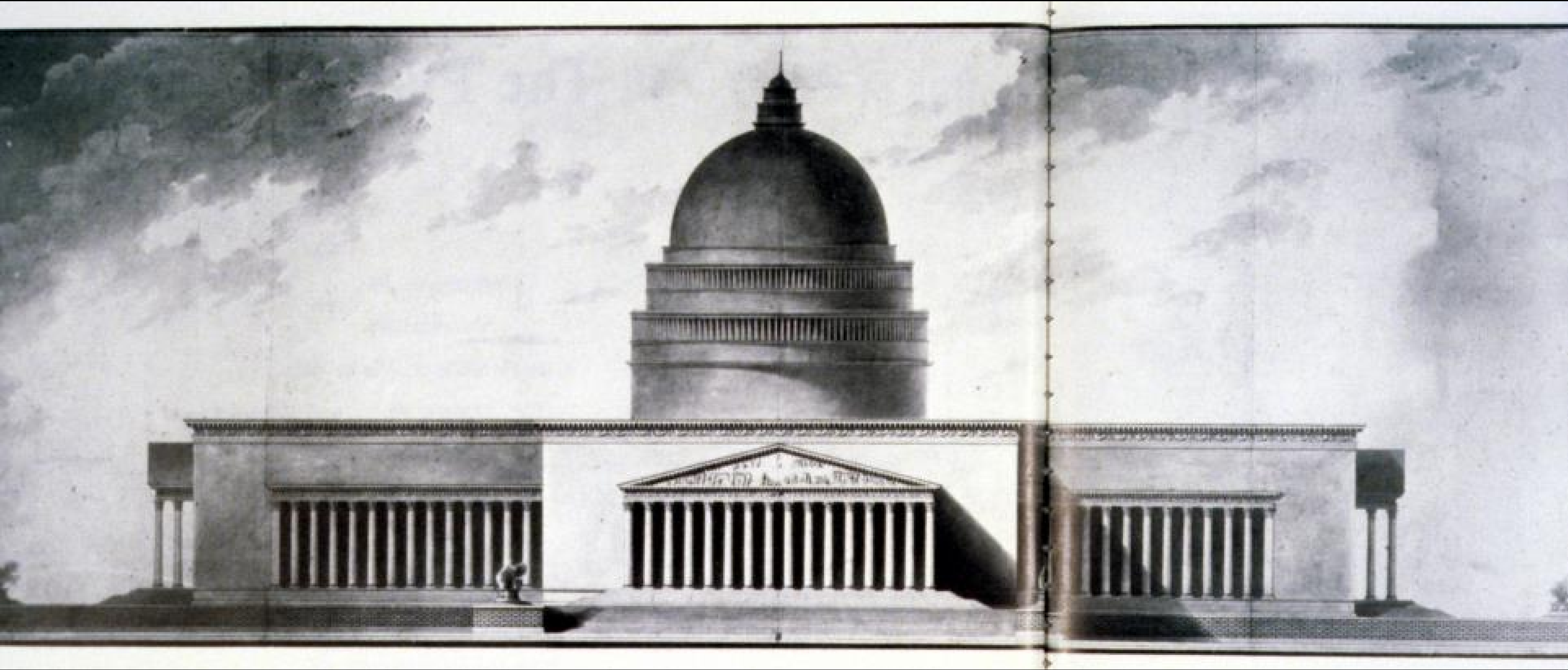
Fig. 2
C
A

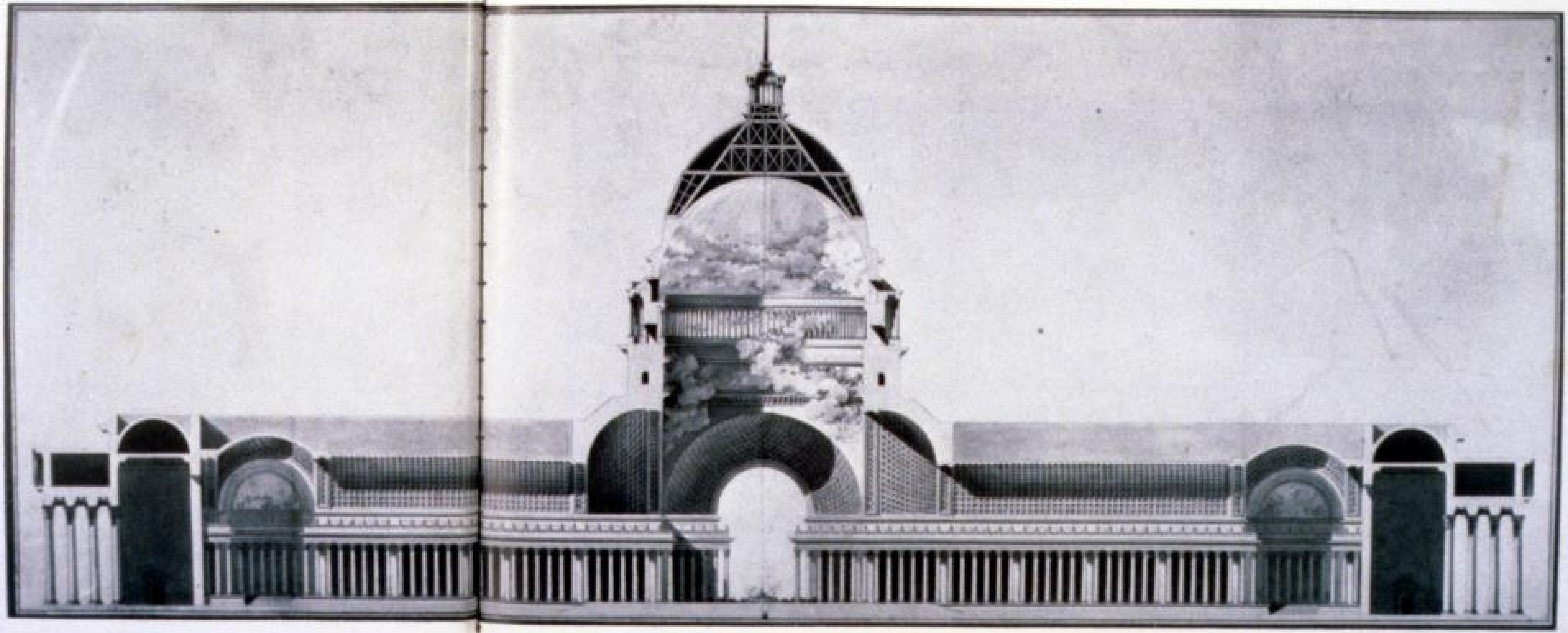
Visionary Architecture

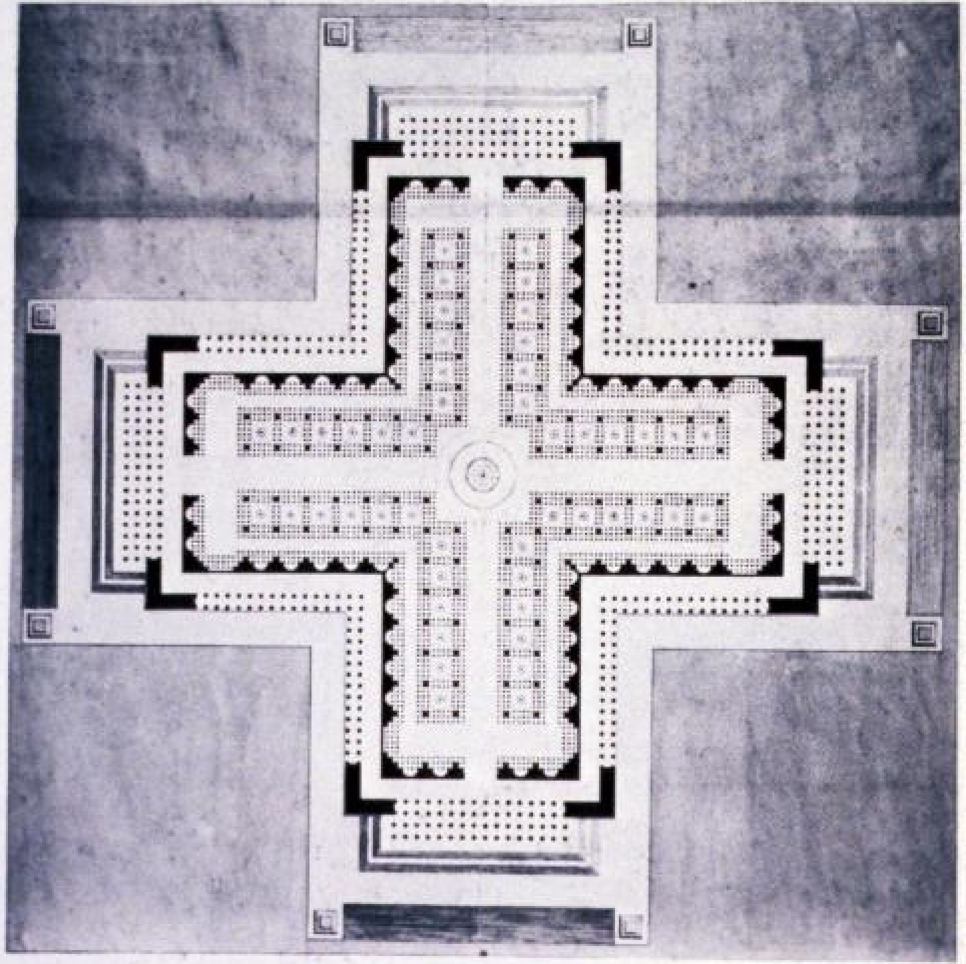
Etienne-Louis Boullee

French Visionary Architect

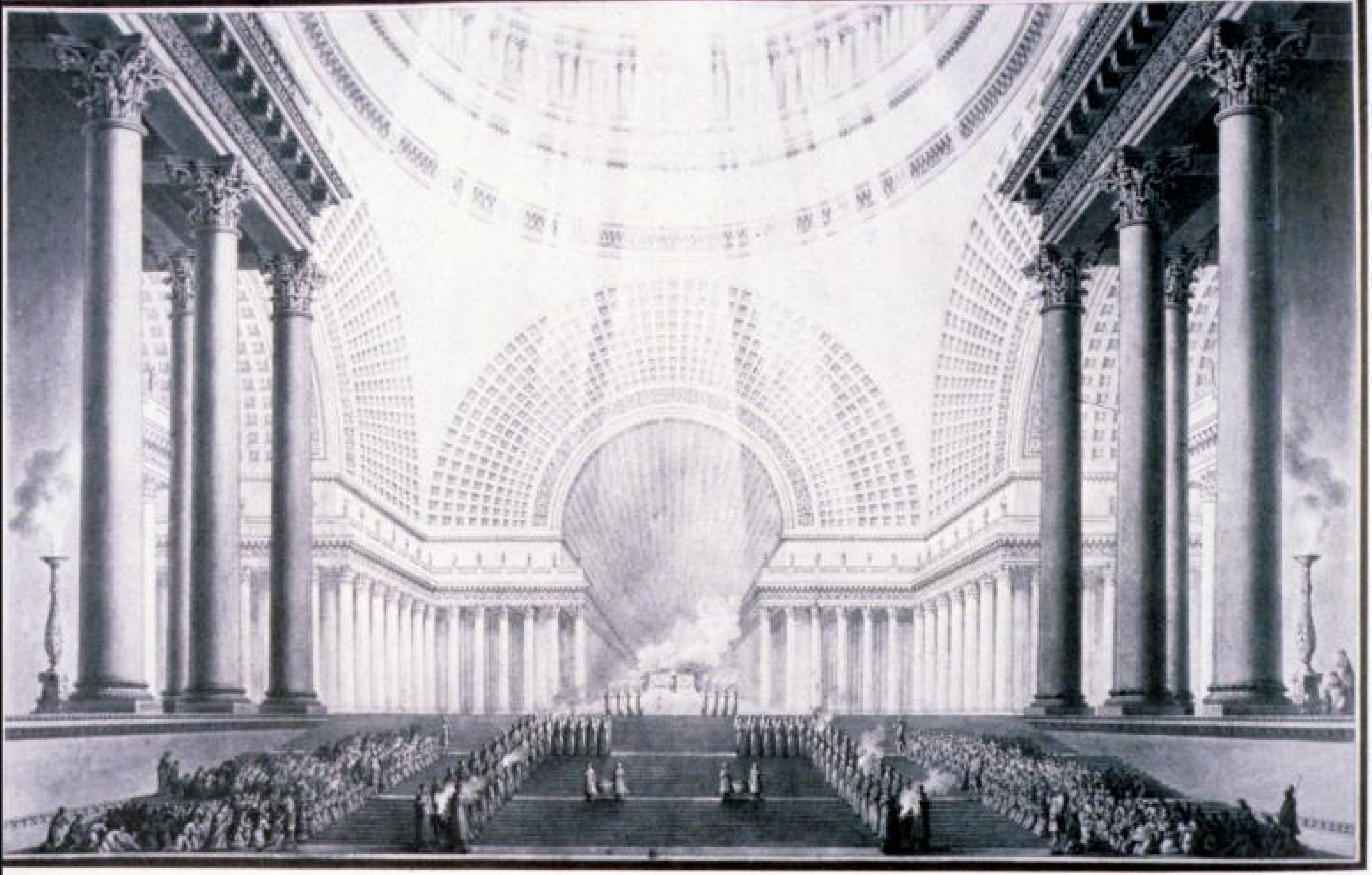
1728 to 1799





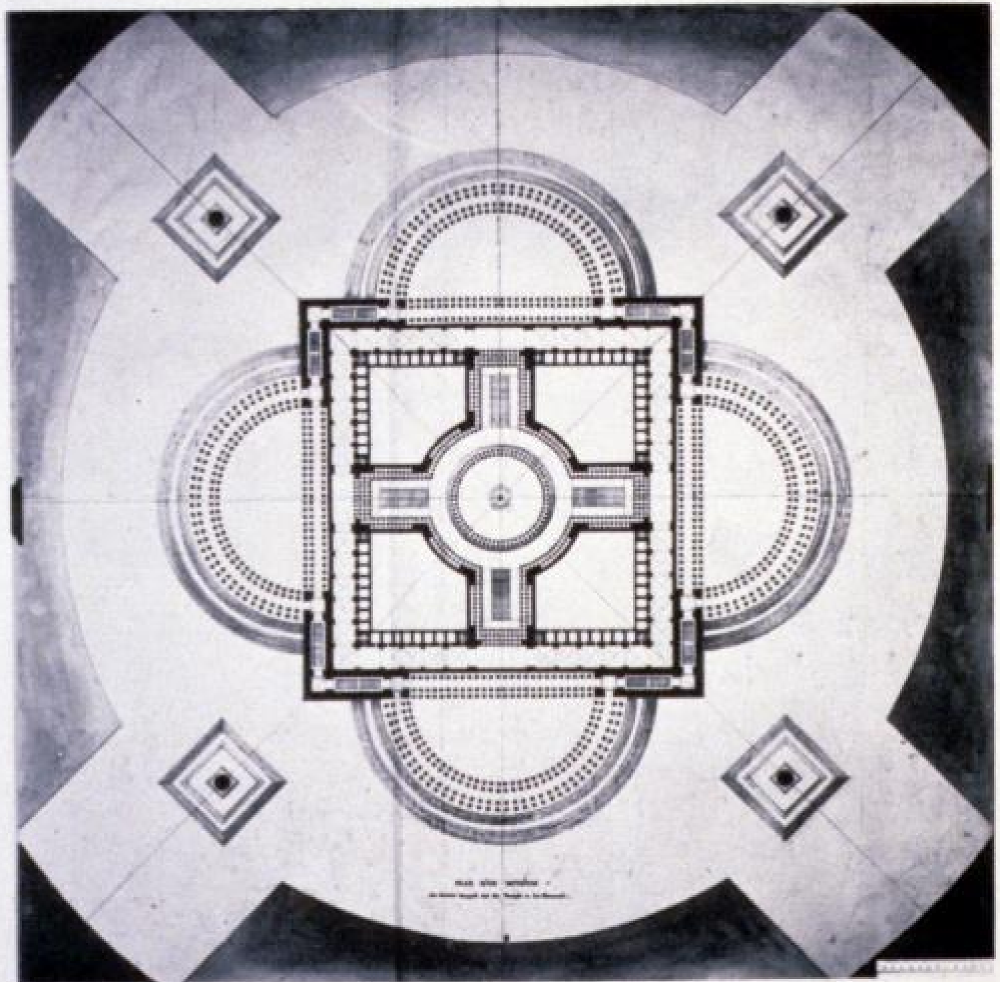


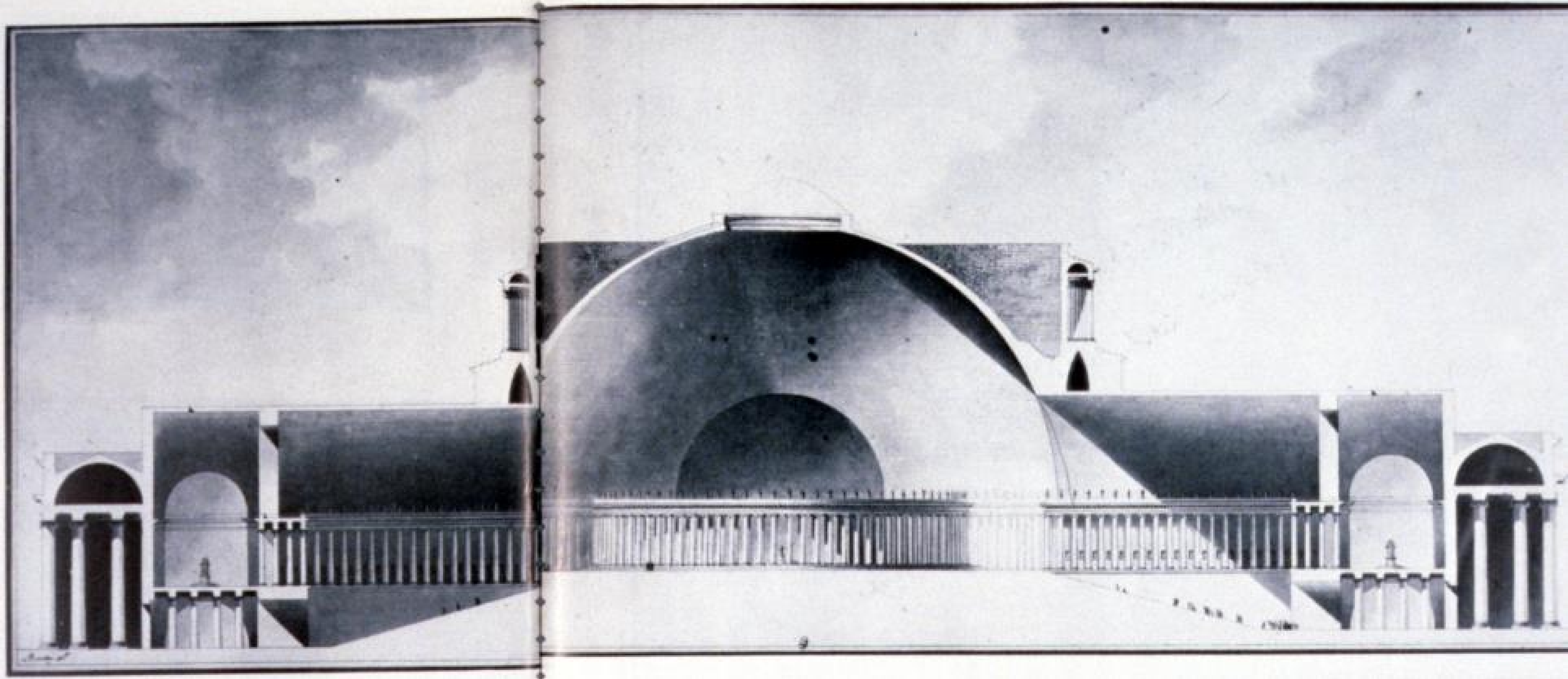
Metropole, ground plan (HA 56, no. 2)

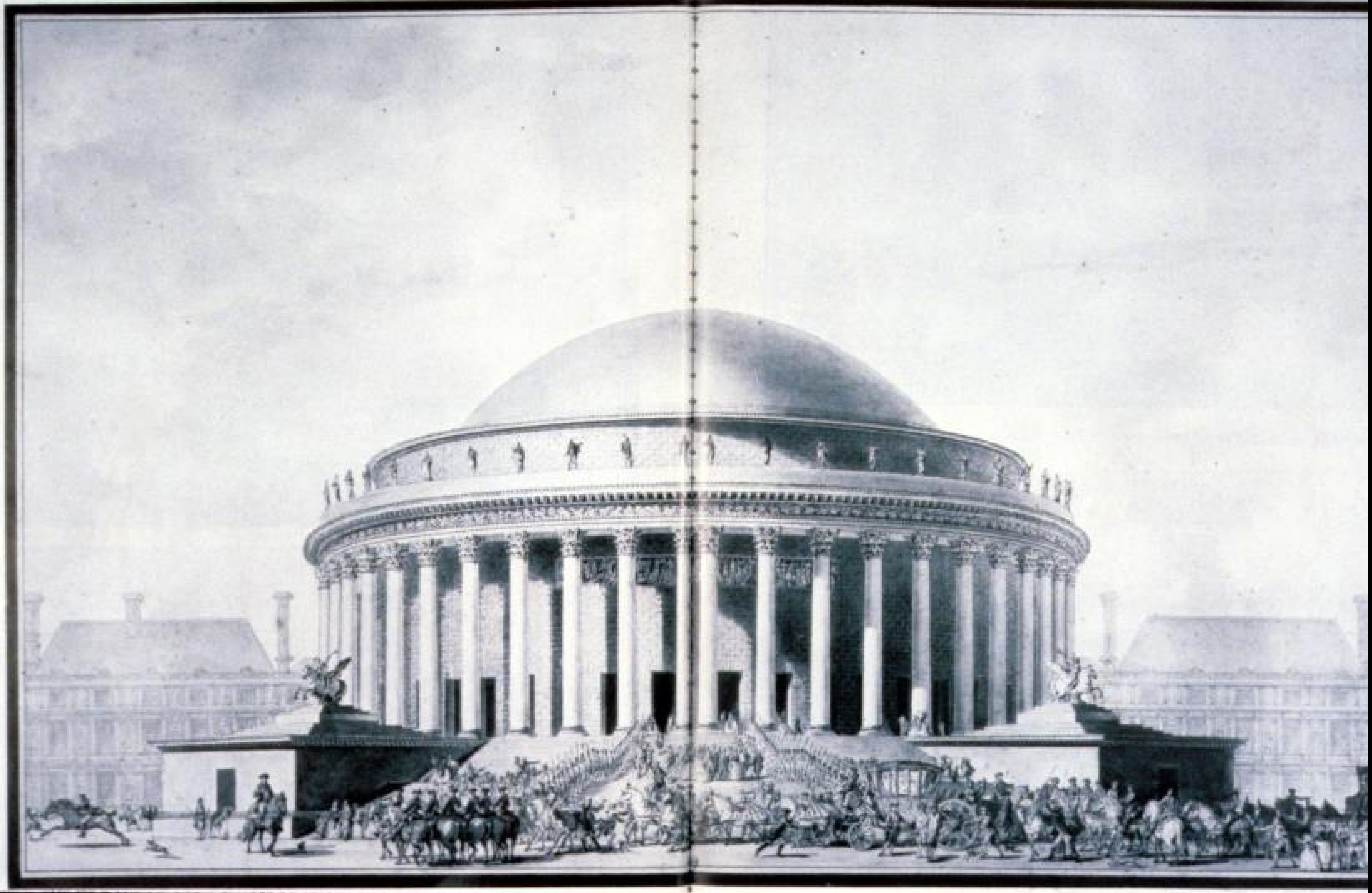


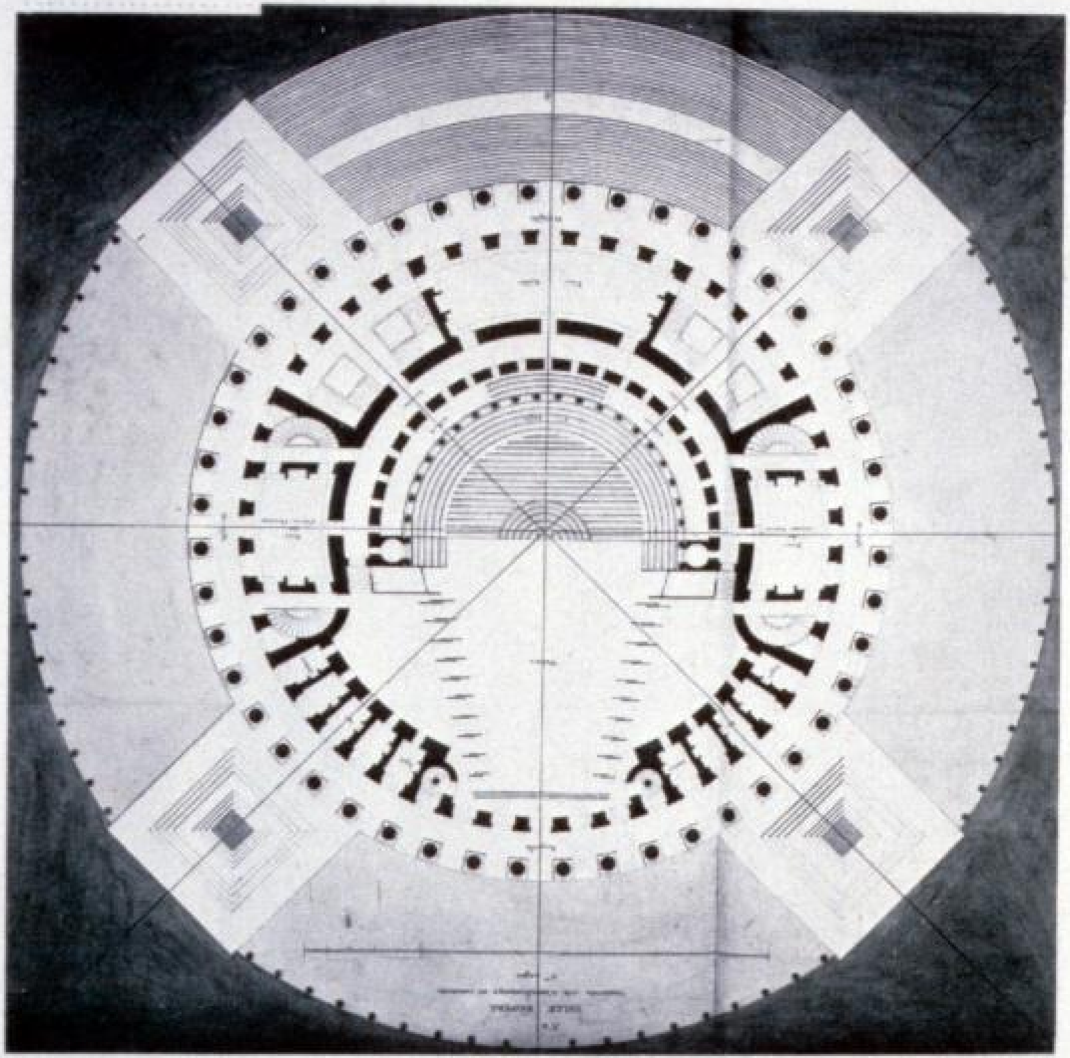
Metropole, interior view at Corpus Christi (HA 56, no. 8)

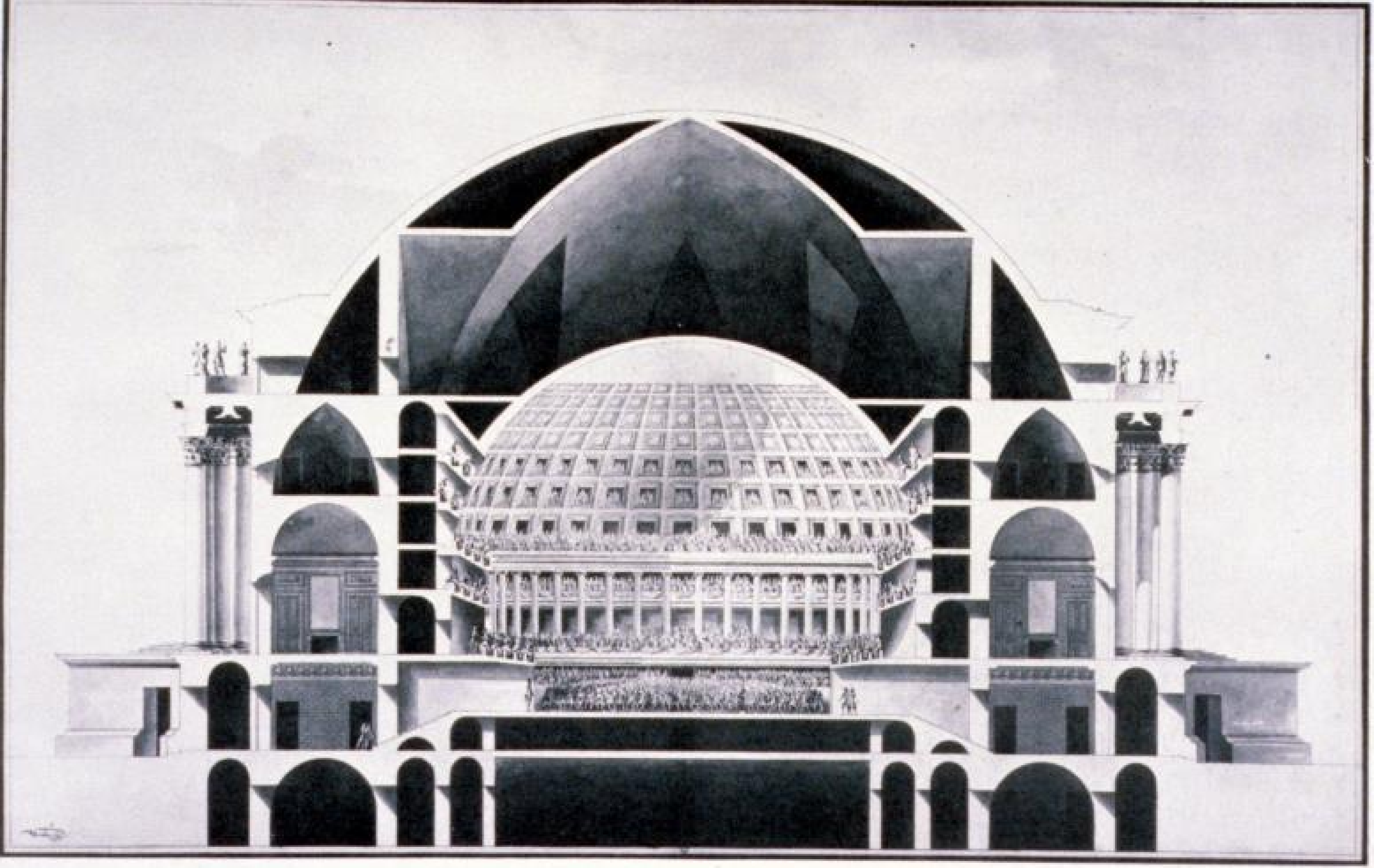
Museum, ground plan (HA 56, no. 26)



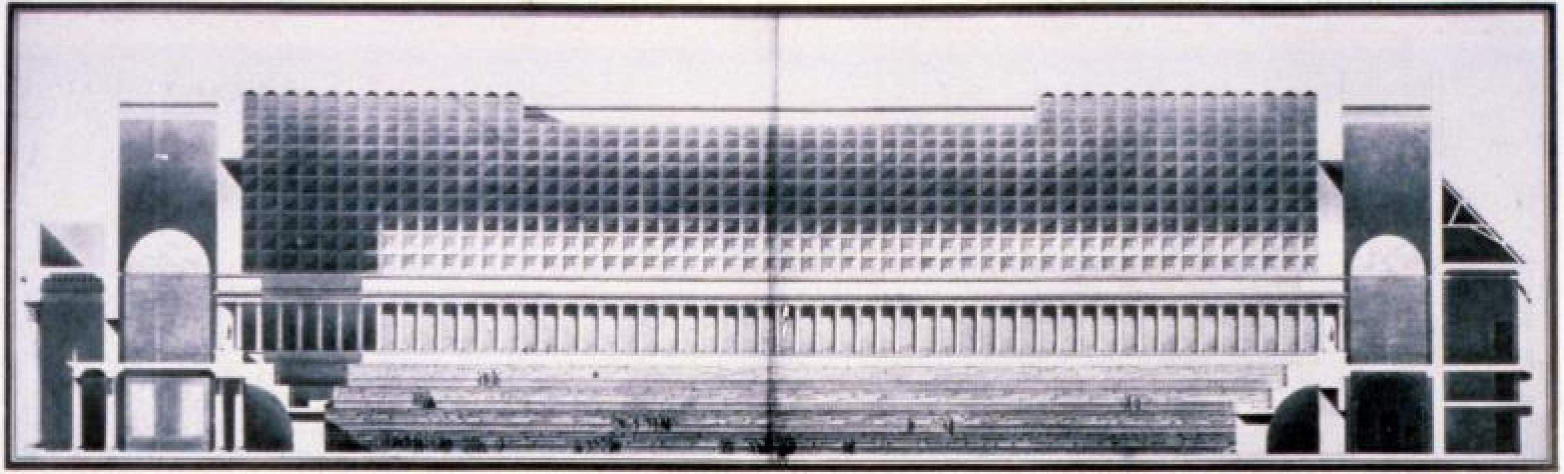


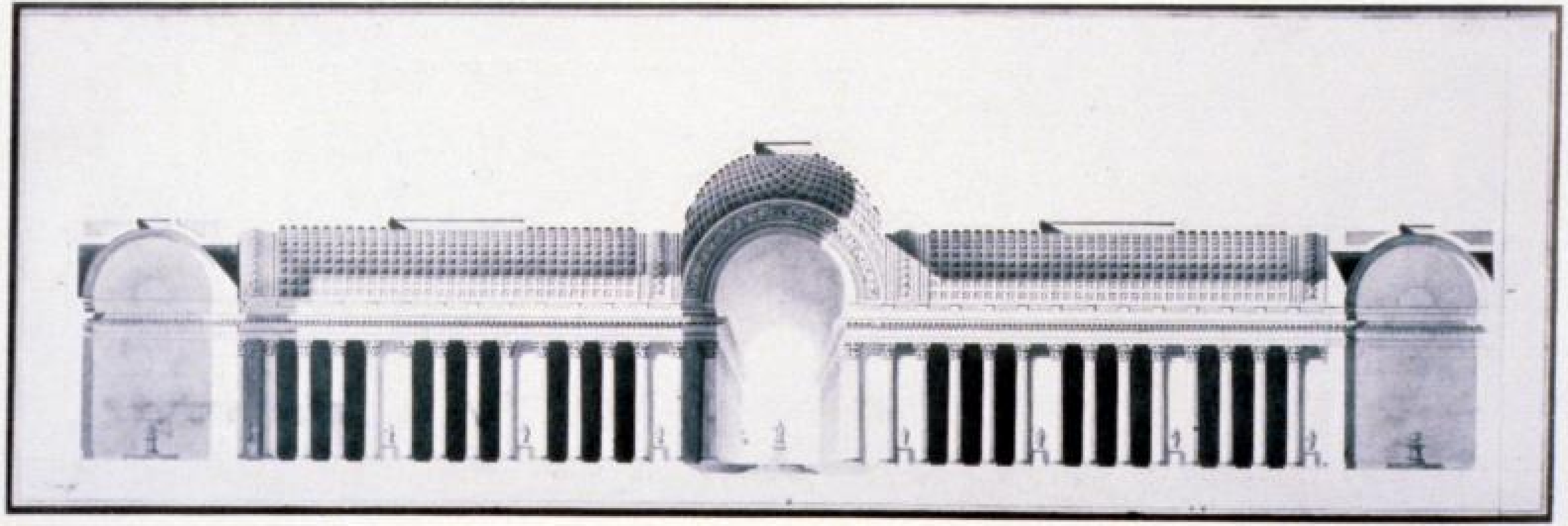




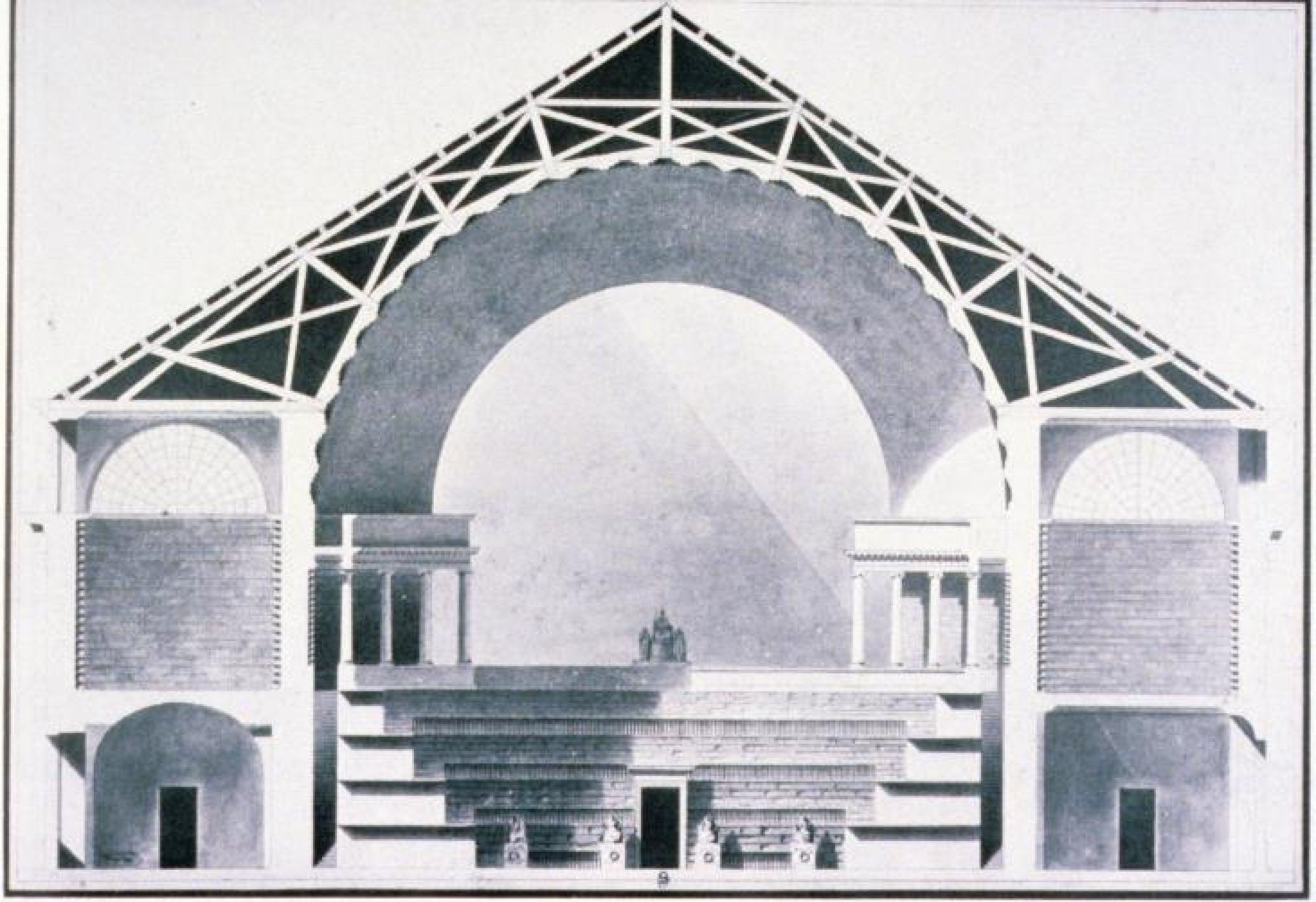


Above: Opera, section facing the auditorium (HA 55, no. 10) *Below:* Opera, section facing the stage (HA 55, no. 11)

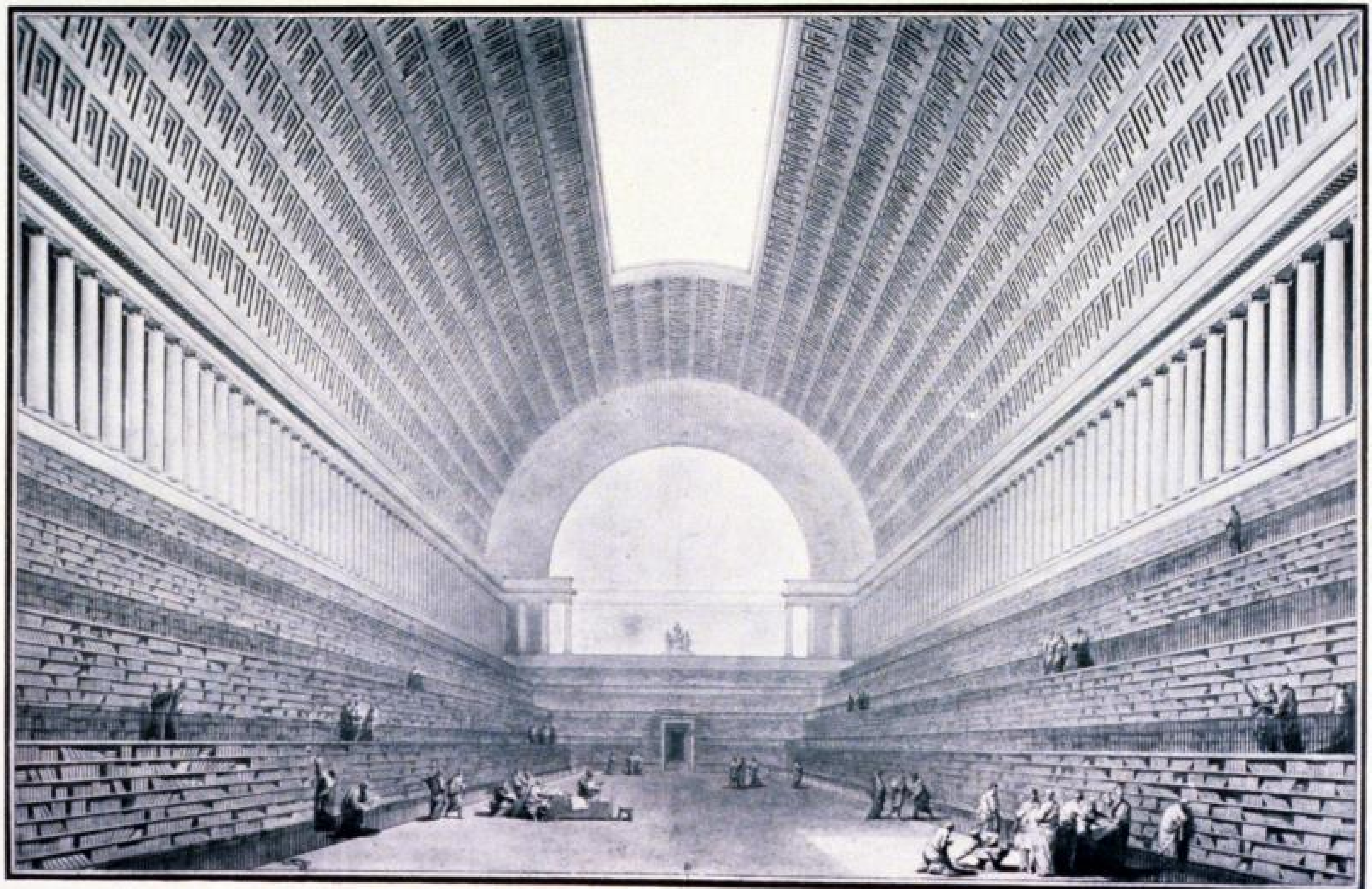


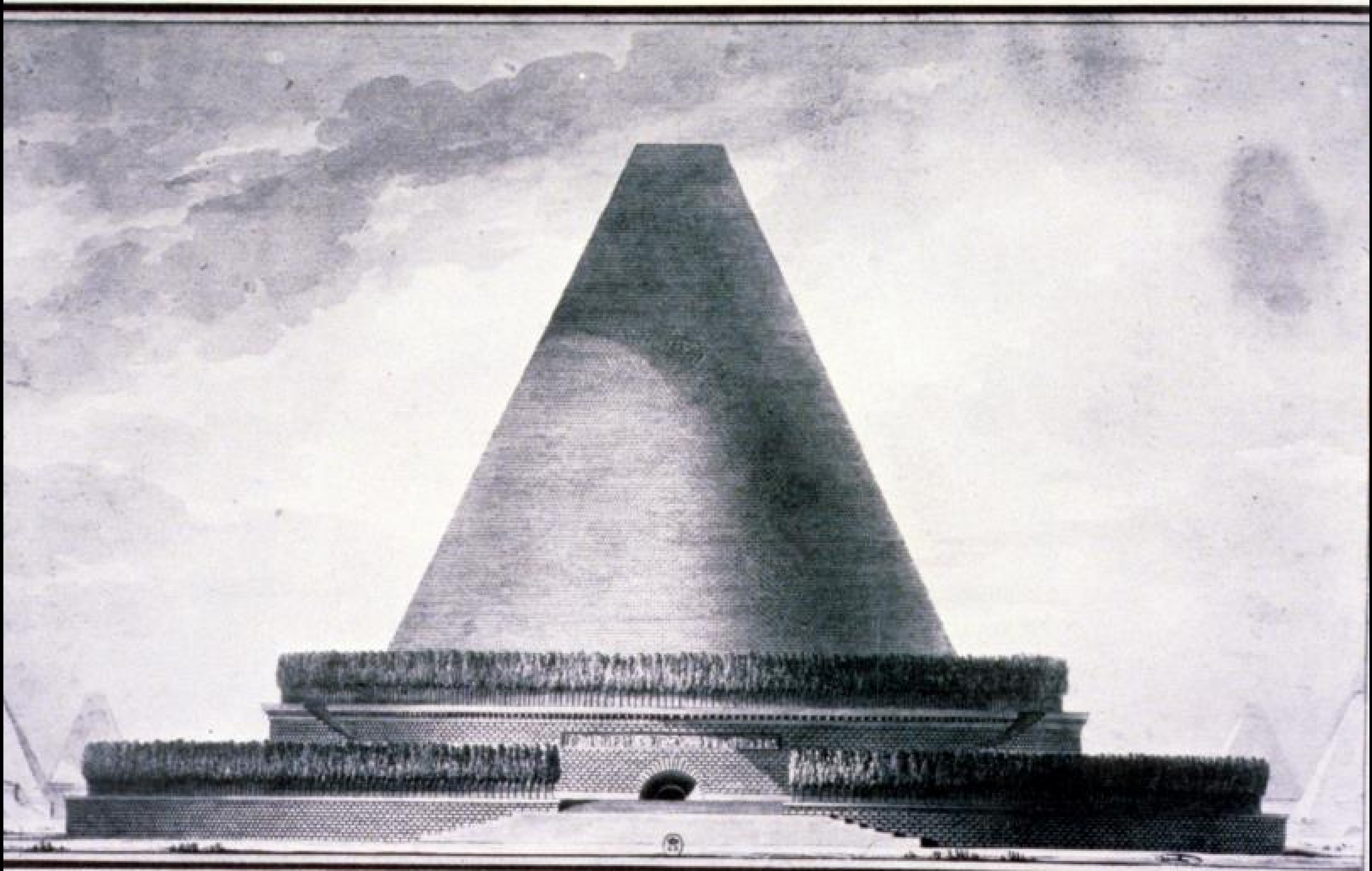


School of Athens
Rafael

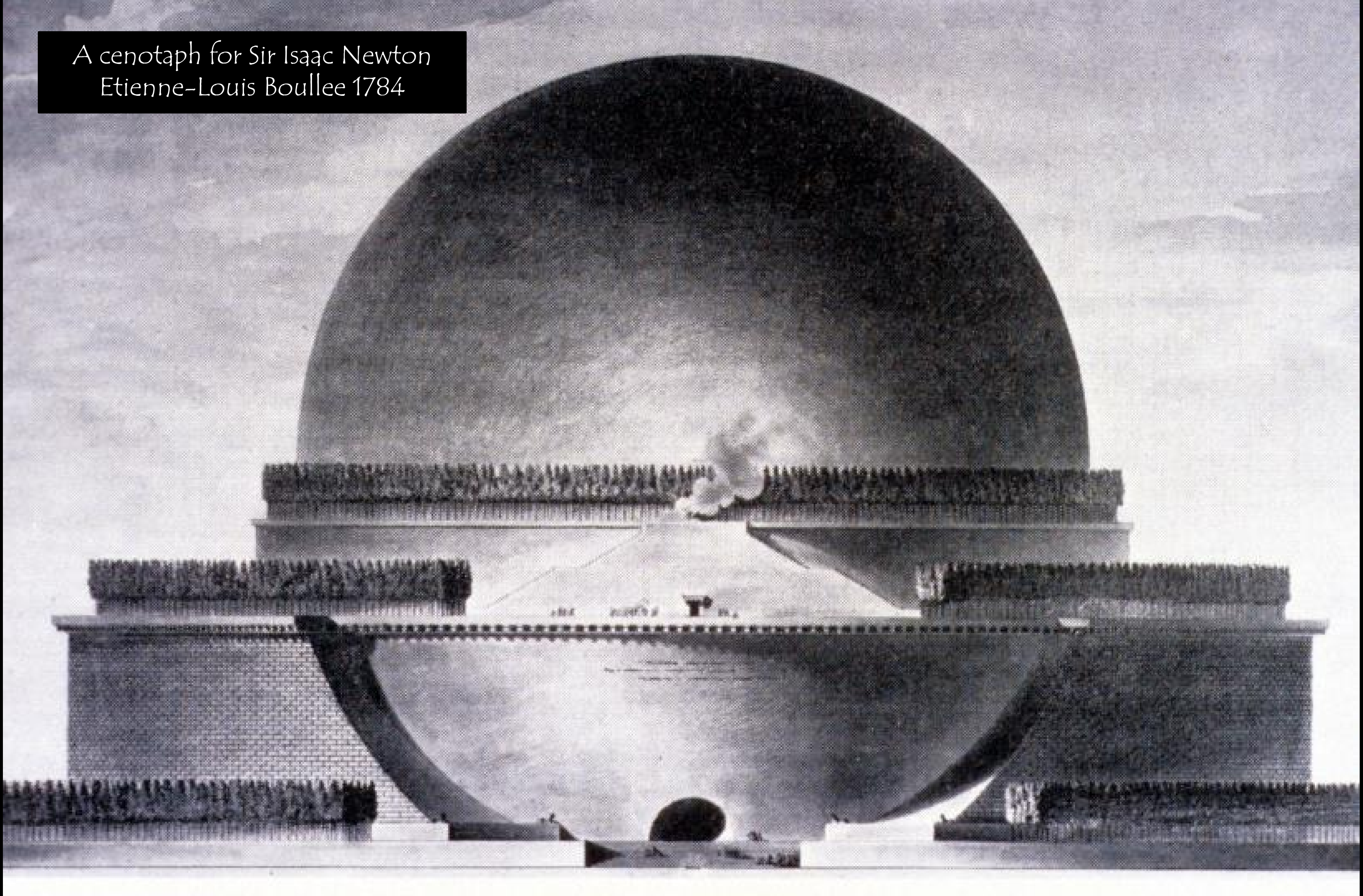


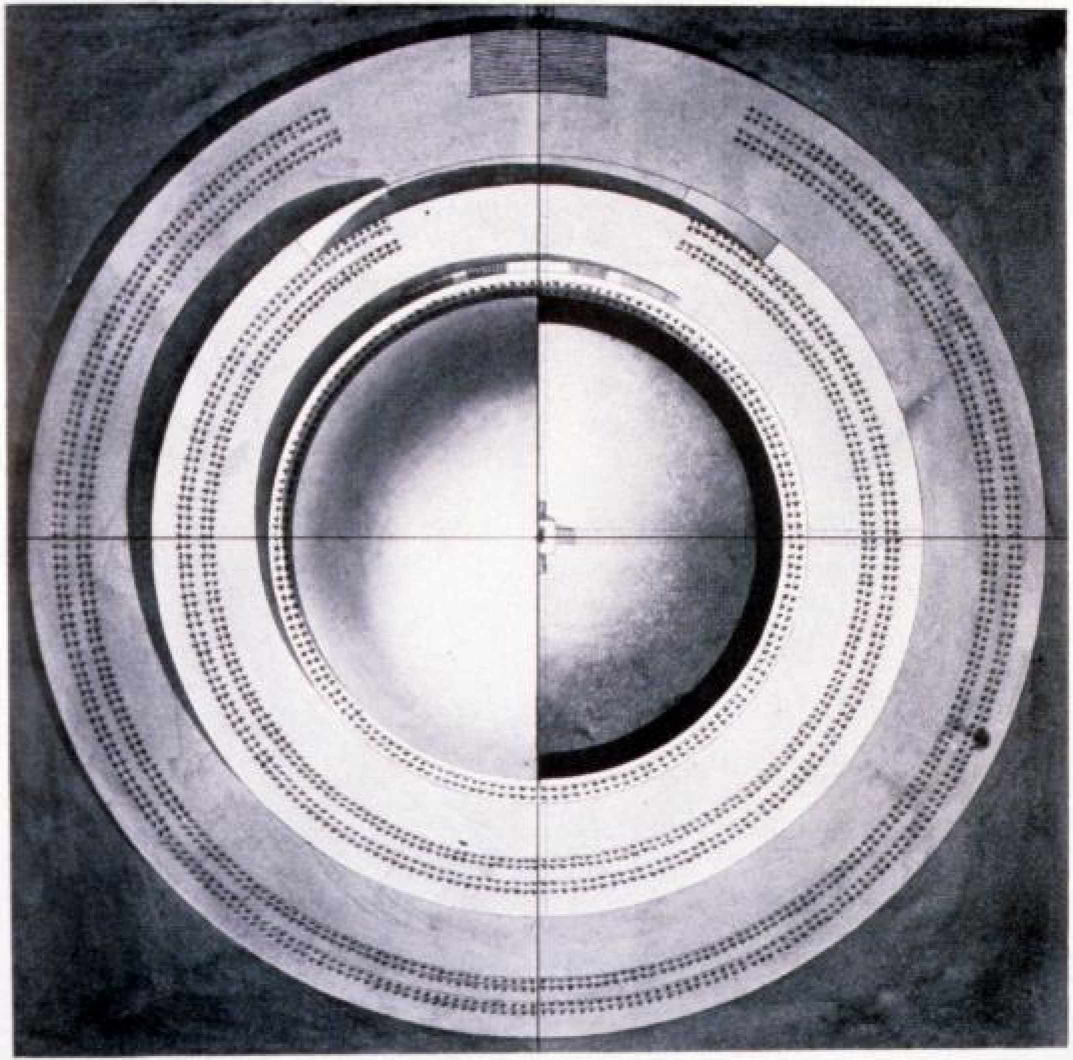
Bibliothèque Nationale, latitudinal section (HA 56, no. 42)



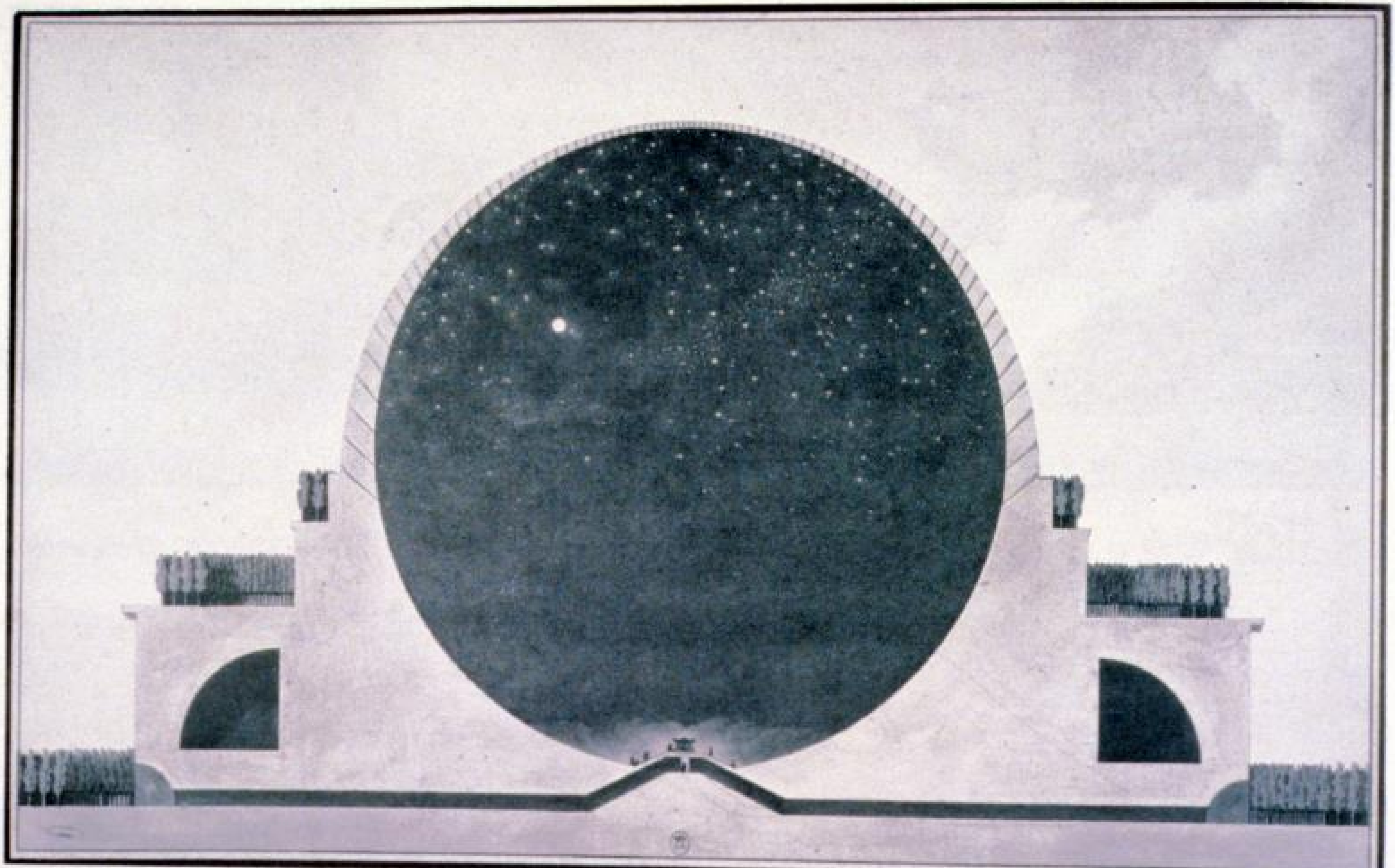


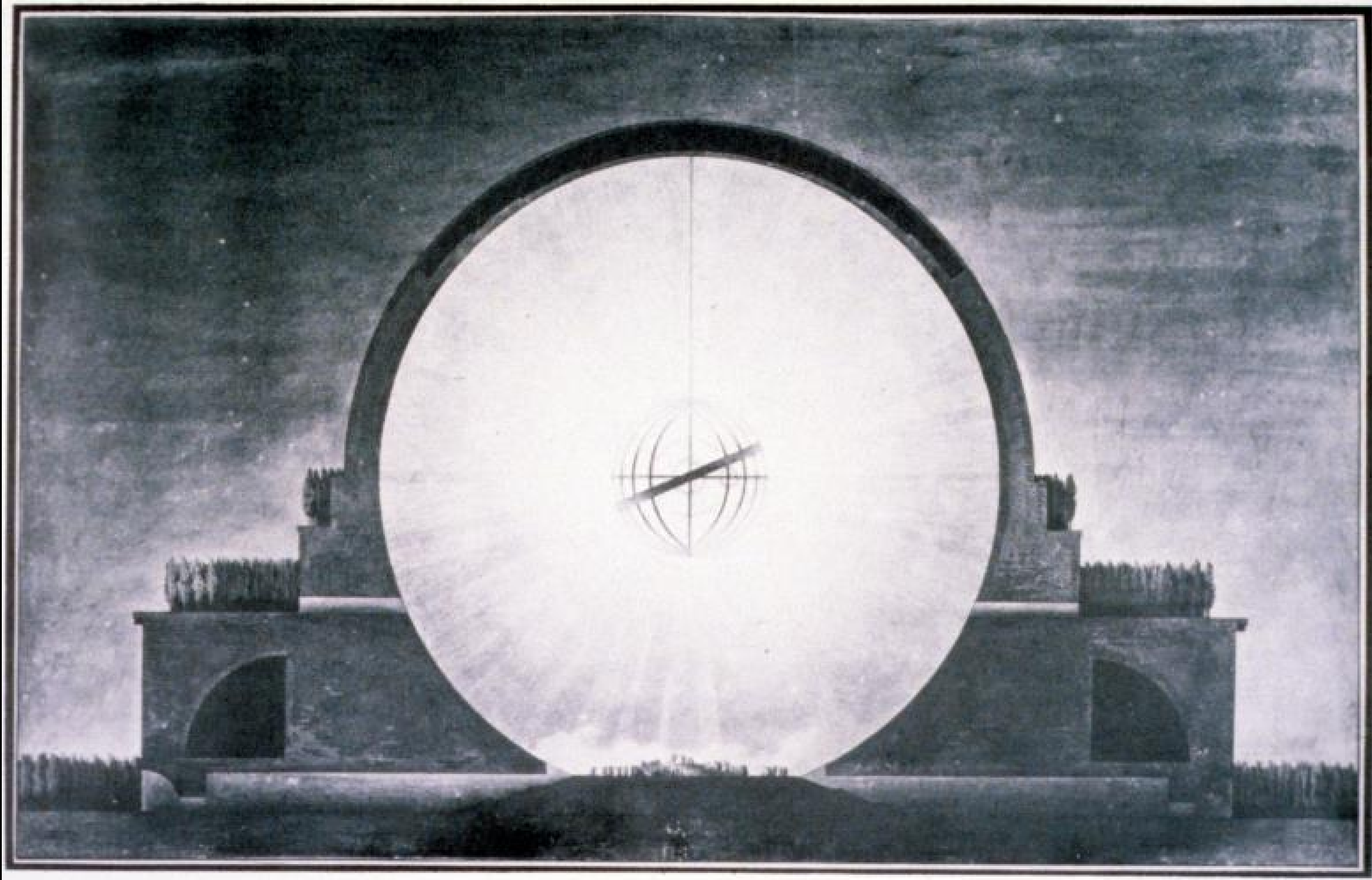
A cenotaph for Sir Isaac Newton
Etienne-Louis Boullee 1784





CENOTAPH FOR NEWTON

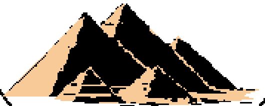




CONCRETE HISTORICAL TIMELINE

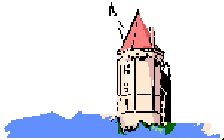
3000 B.C.- PRESENT

3000 B.C.
Egyptians used mud mixed with straw to bind bricks. They used gypsum and lime mortars in the pyramids.

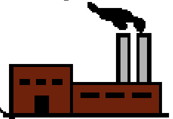


300 BC- 476 AD
Applian Way, Roman baths, the Colosseum and Pantheon used Pozzalana cement. Animal fat, milk and blood were used as admixtures.

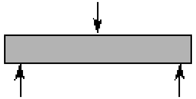
1793
John Smeaton used hydraulic lime to rebuild Eddystone Lighthouse in Cornwall, England



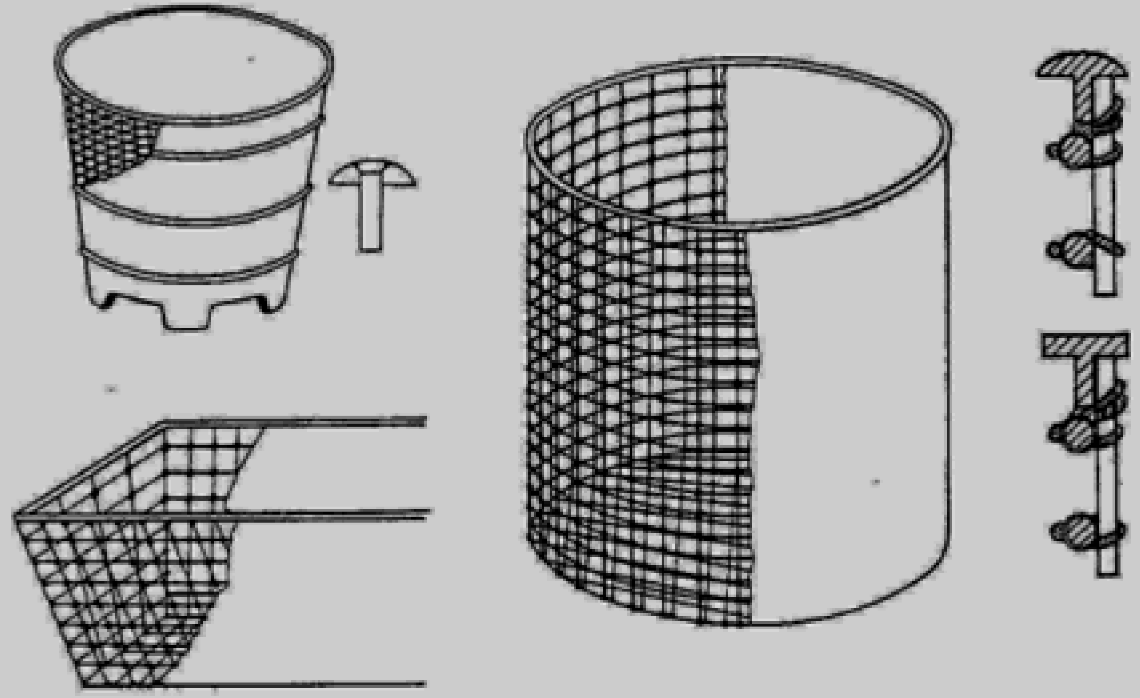
1824
Joseph Aspdin of England invented portland cement by burning ground chalk with finely divided clay in a lime kiln until carbon dioxide is driven off. The product was then ground.



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.



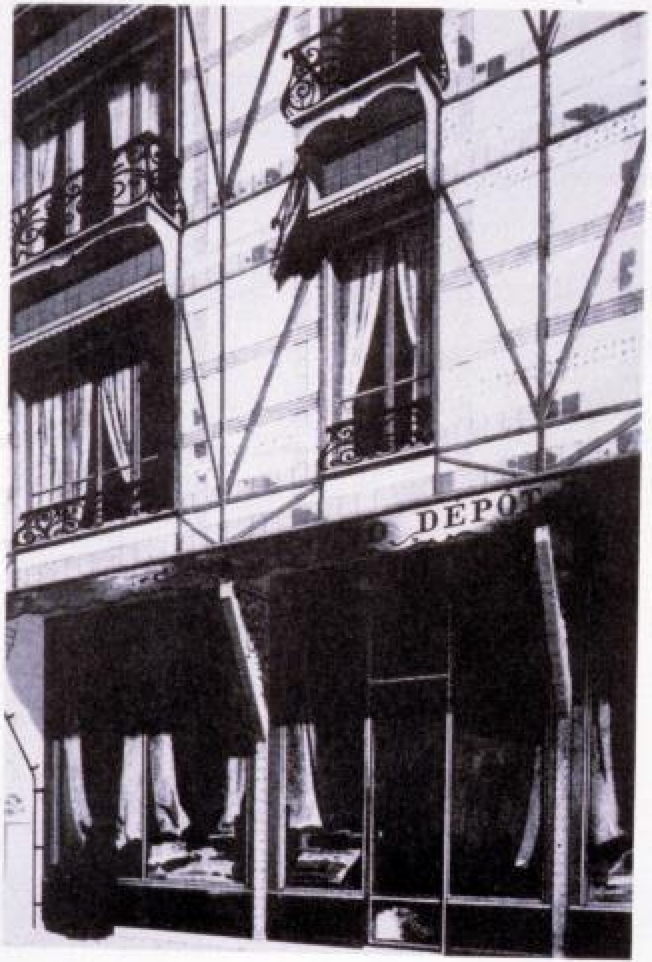


Plate 64. Eugène Viollet-le-Duc. Unpretentious shop and apartment building, 1863 (Viollet-le-Duc, *Atlas*, p. 36)

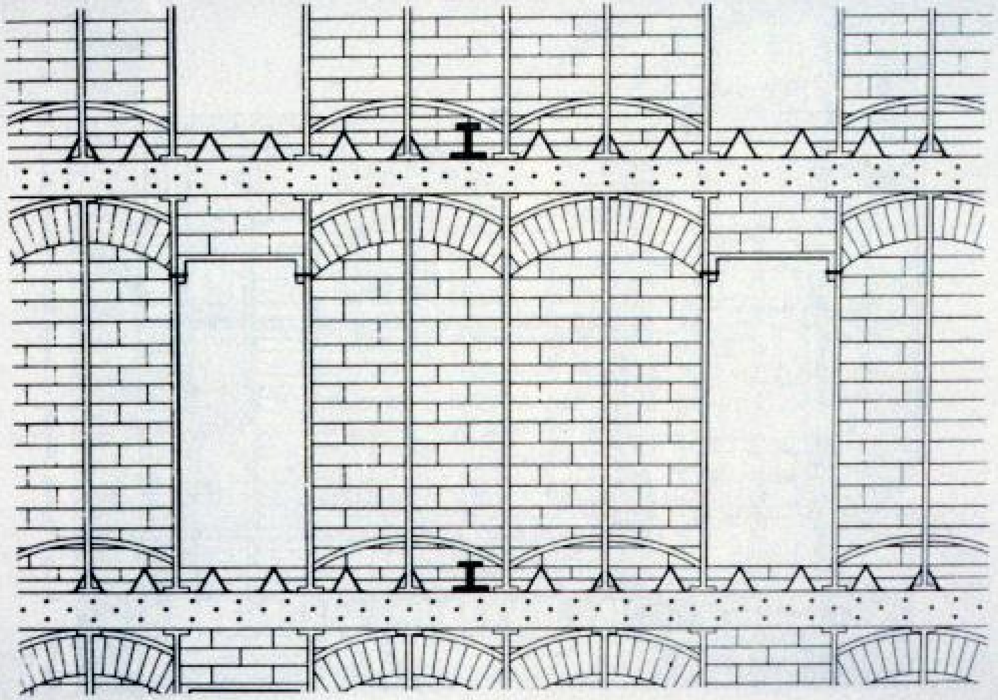


Plate 61. Charles Eck, *Pan de Fer* system, 1868 (Eck, 1868, pl.60)

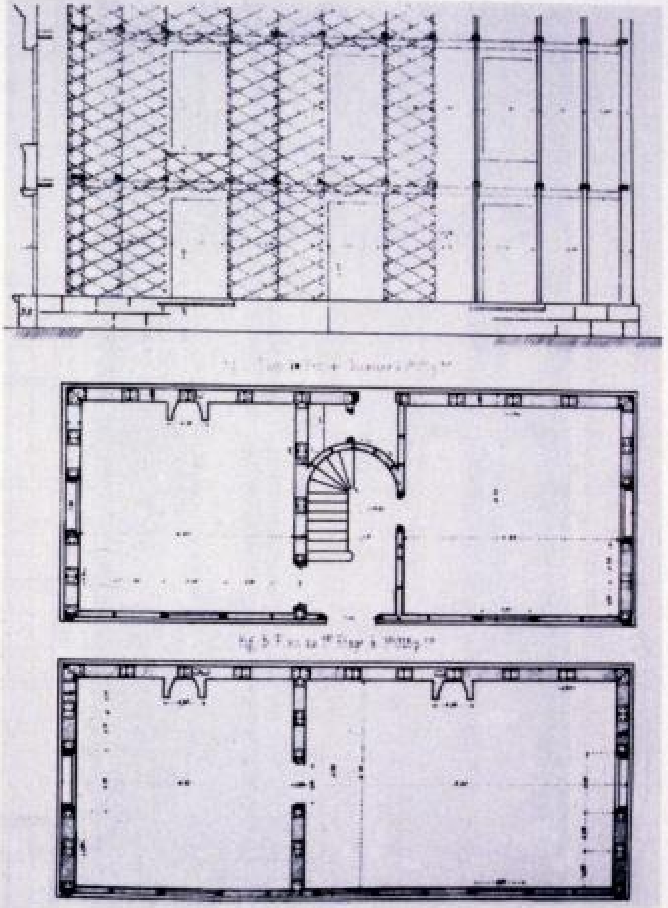
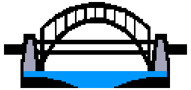


Plate 59. Lacroix system of framing with iron and cement or concrete (*Nouvelle annales de la construction*, X, January, 1864, pl. 7)

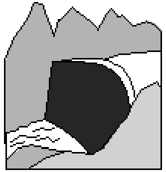
1886
First rotary kiln was introduced in England, which allowed for continuous production of cement.

1889
First concrete reinforced bridge was built.

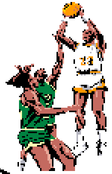


1891
First concrete street in the USA was placed in Bellefontaine, Ohio by George Bartholomew

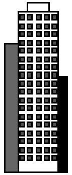
1936
First major concrete dams, the Hoover Dam and Grand Cooley Dam, were built.

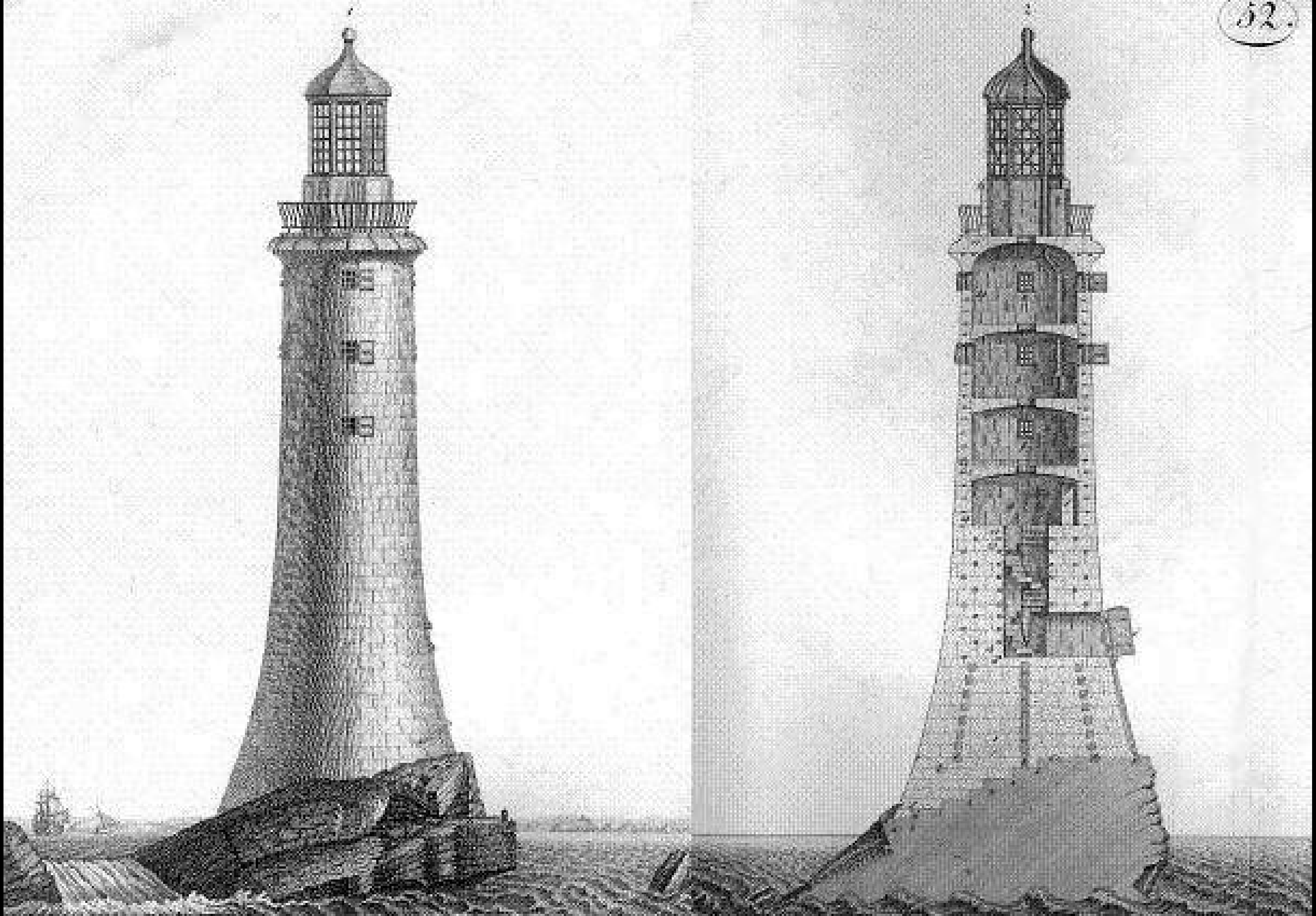


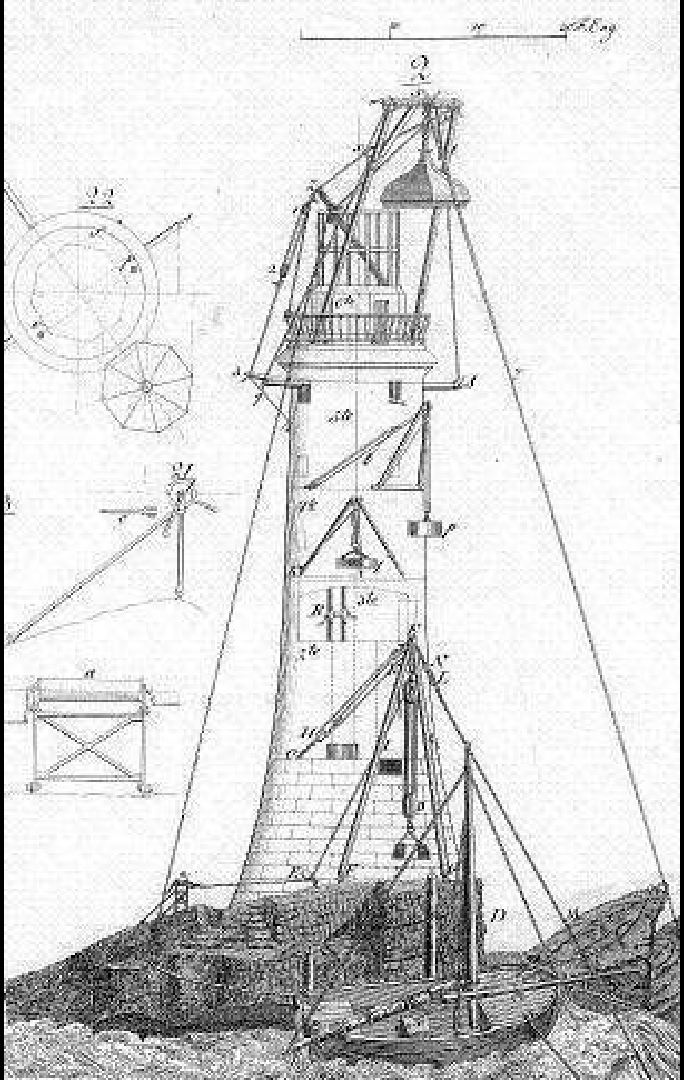
1967
First concrete dome sport structure constructed at the University of Illinois, Assembly Hall.



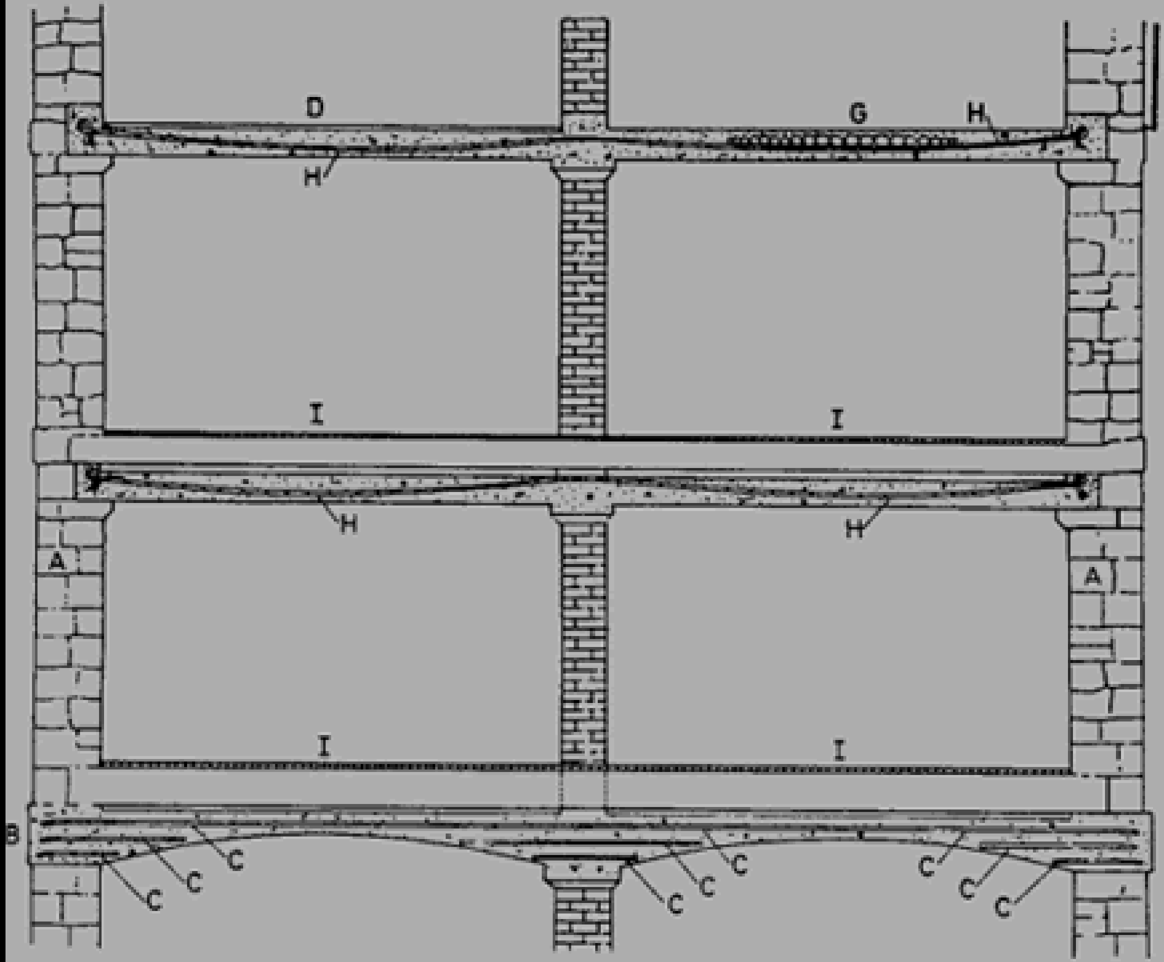
1992
Tallest reinforced building (946 ft) constructed in Chicago, IL







Concrete as STRUCTURE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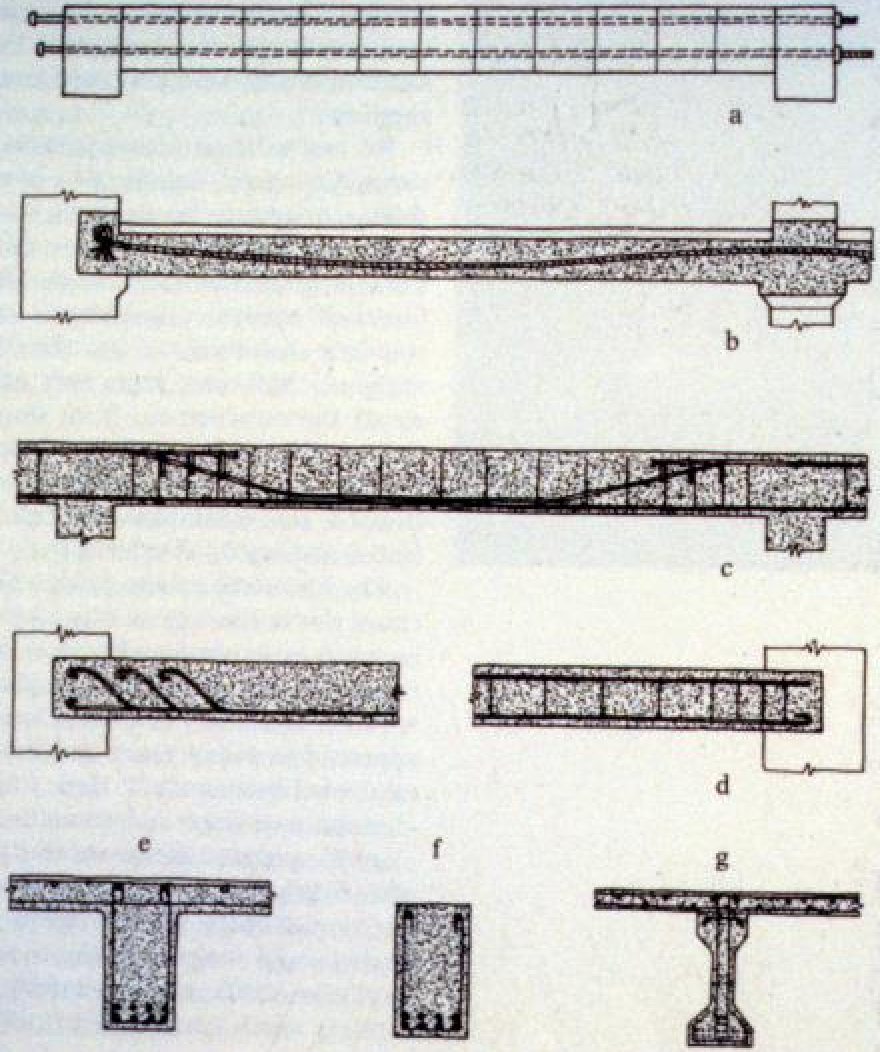
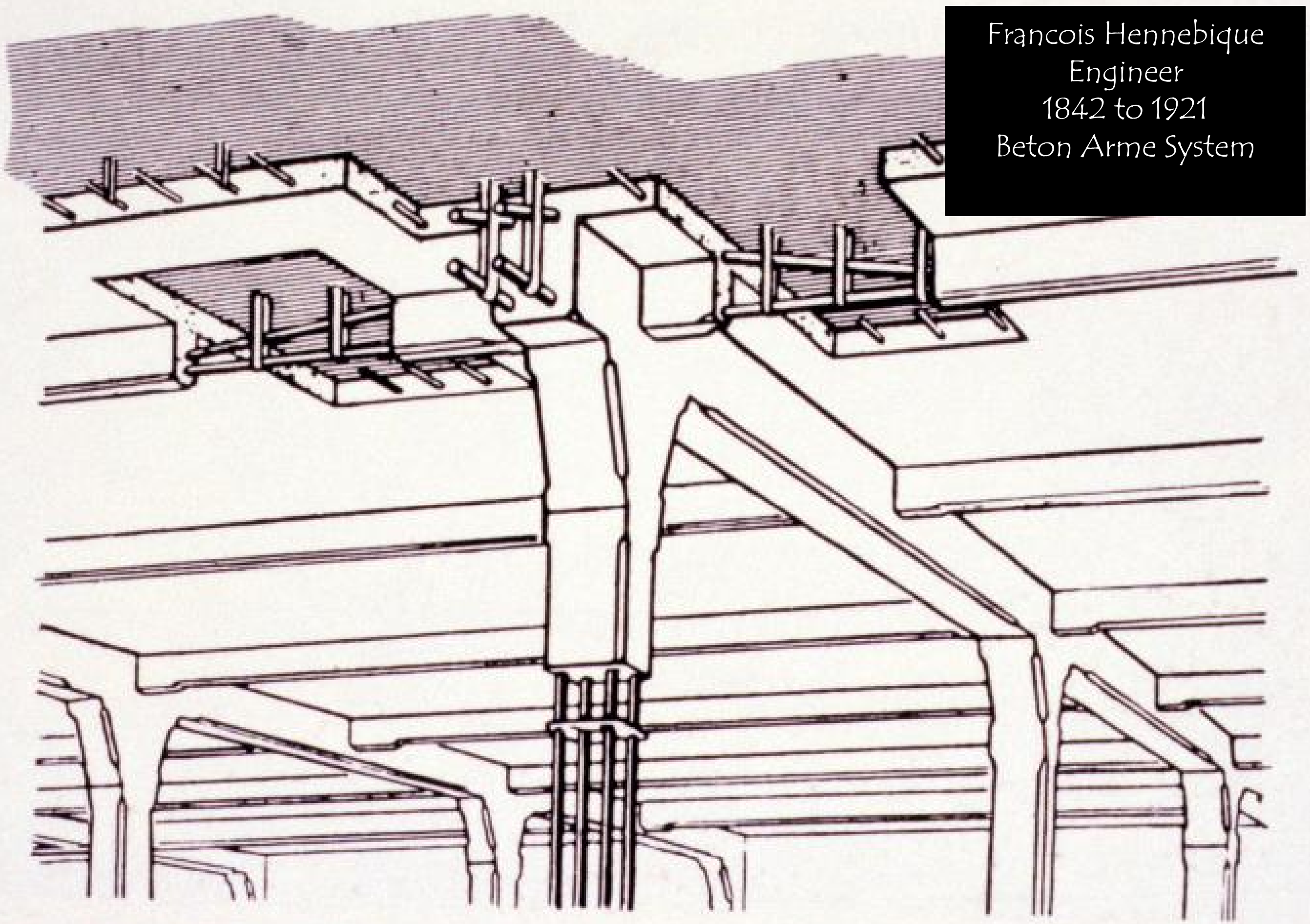
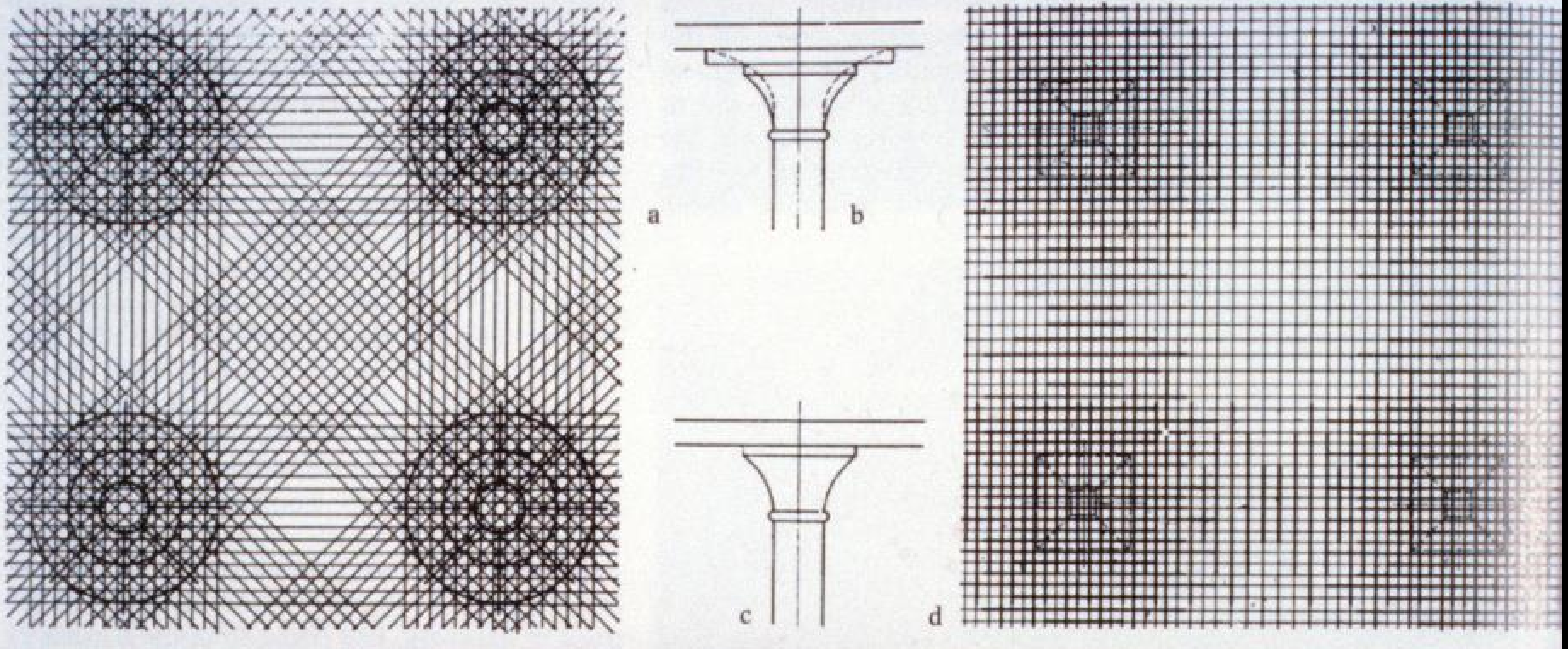


8.10 Reinforced-masonry, reinforced-concrete, and prestressed-concrete beams: [a] Pope, 1811; [b] Wilkinson, 1854 patent; [c] Hennebique, 1897 patent; [d, e, f] modern reinforced-concrete; [g] modern prestressed-concrete.

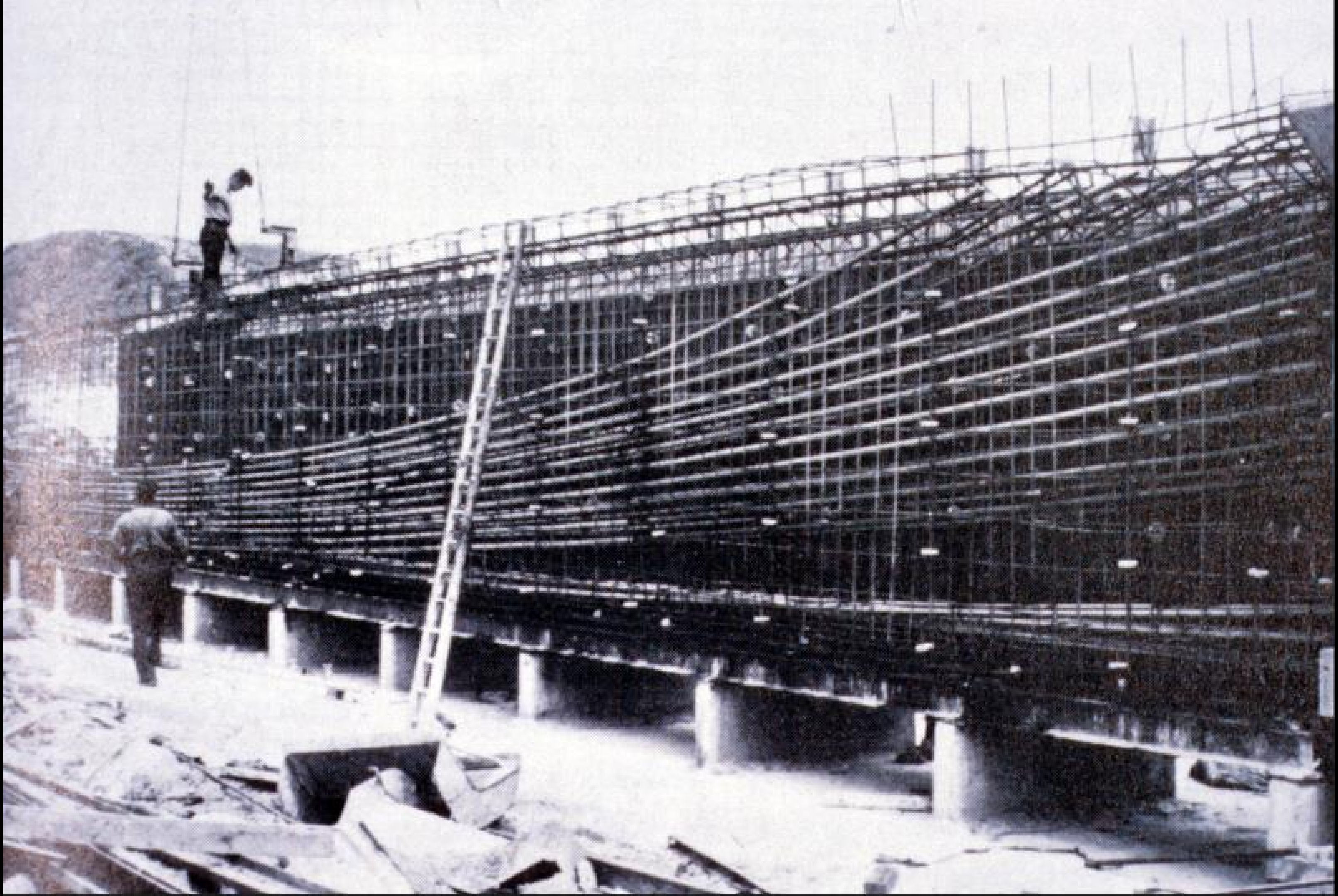
Francois Hennebique
Engineer
1842 to 1921
Beton Arme System

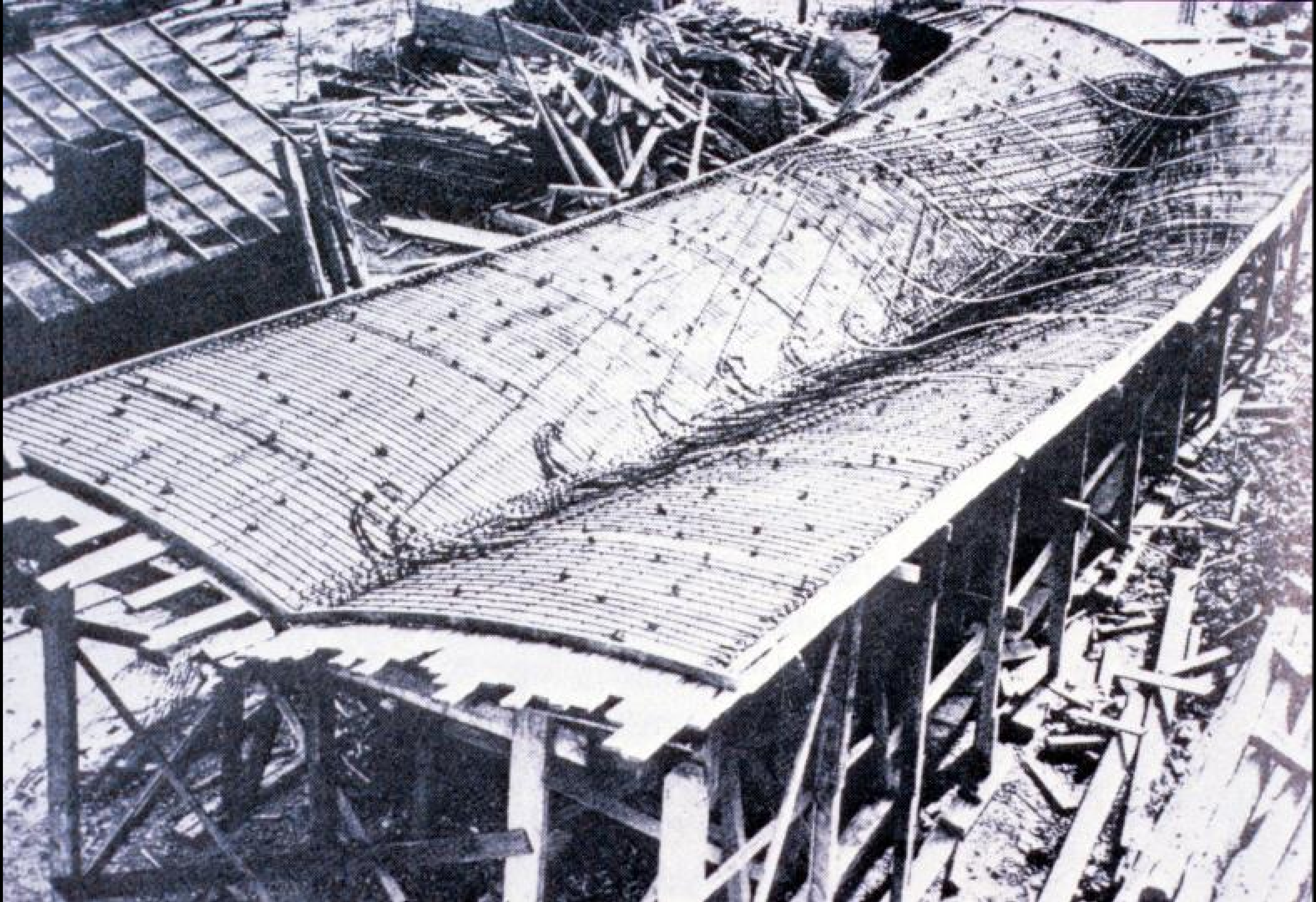


16 *Hennebique, patent reinforced concrete frame construction, 1892.*



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





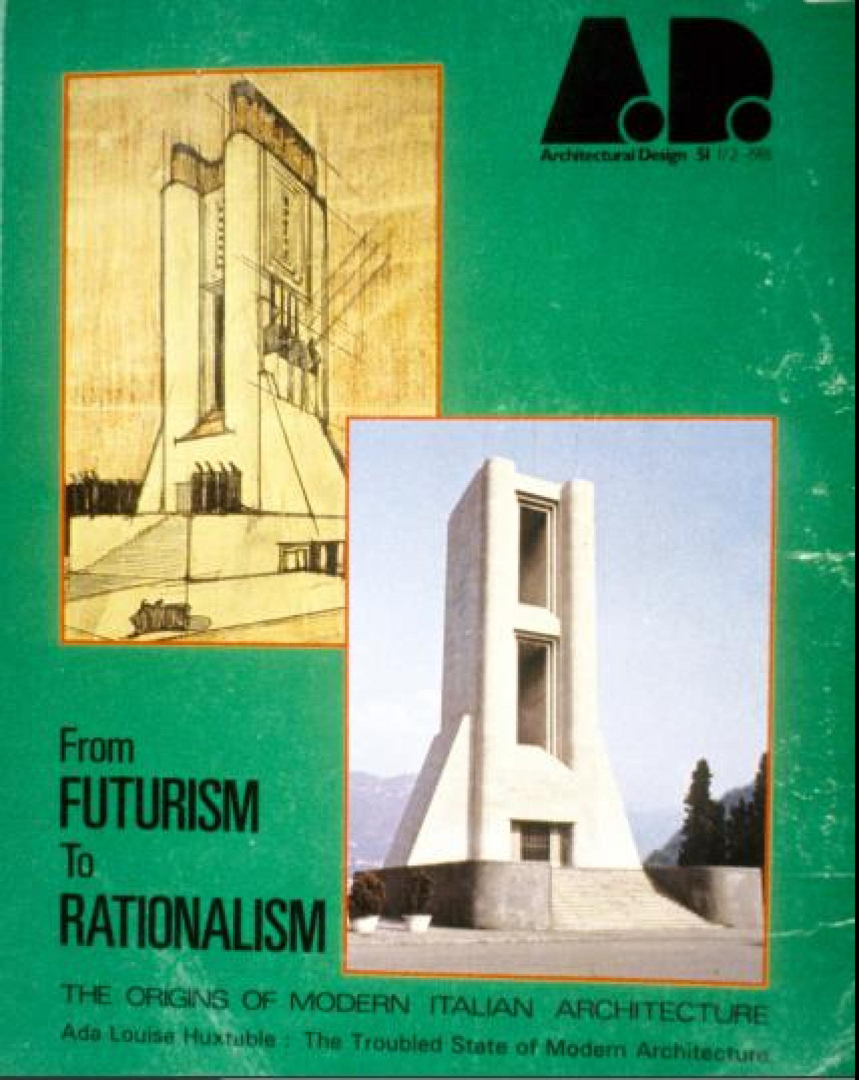
Hoover Dam
Nevada/Arizona Border
1931 tO 1936



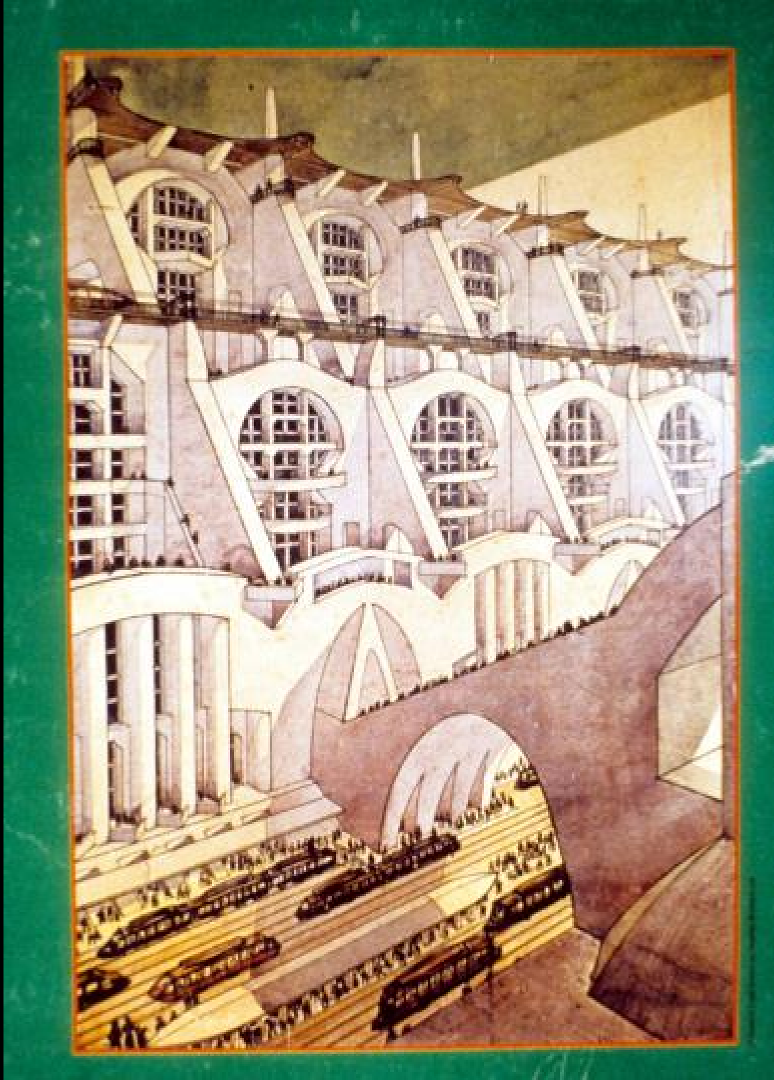
Grand Coulee Dam
Washington State
1933 to 1942

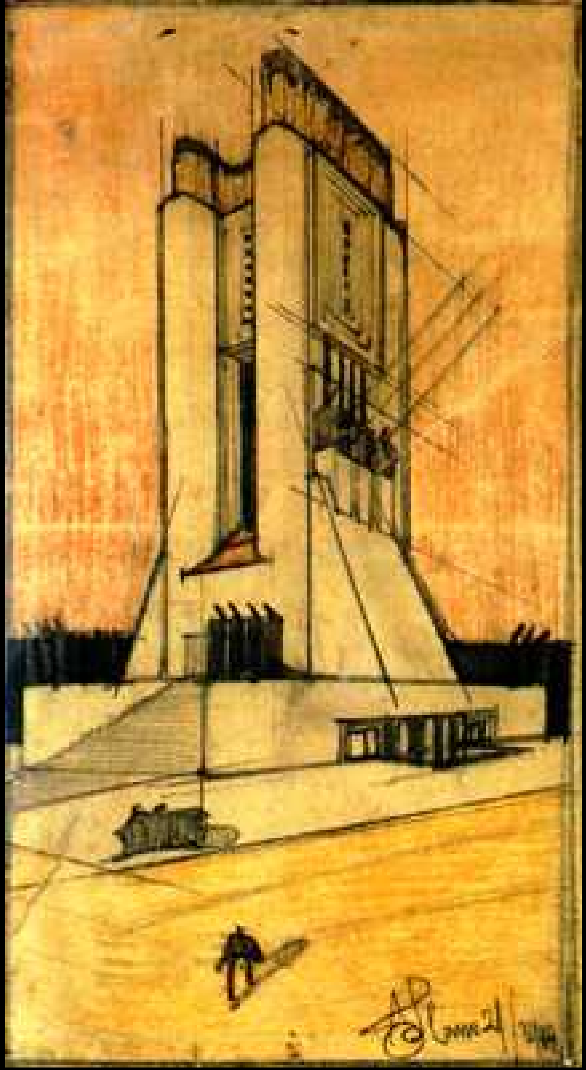
Concrete as STYLE

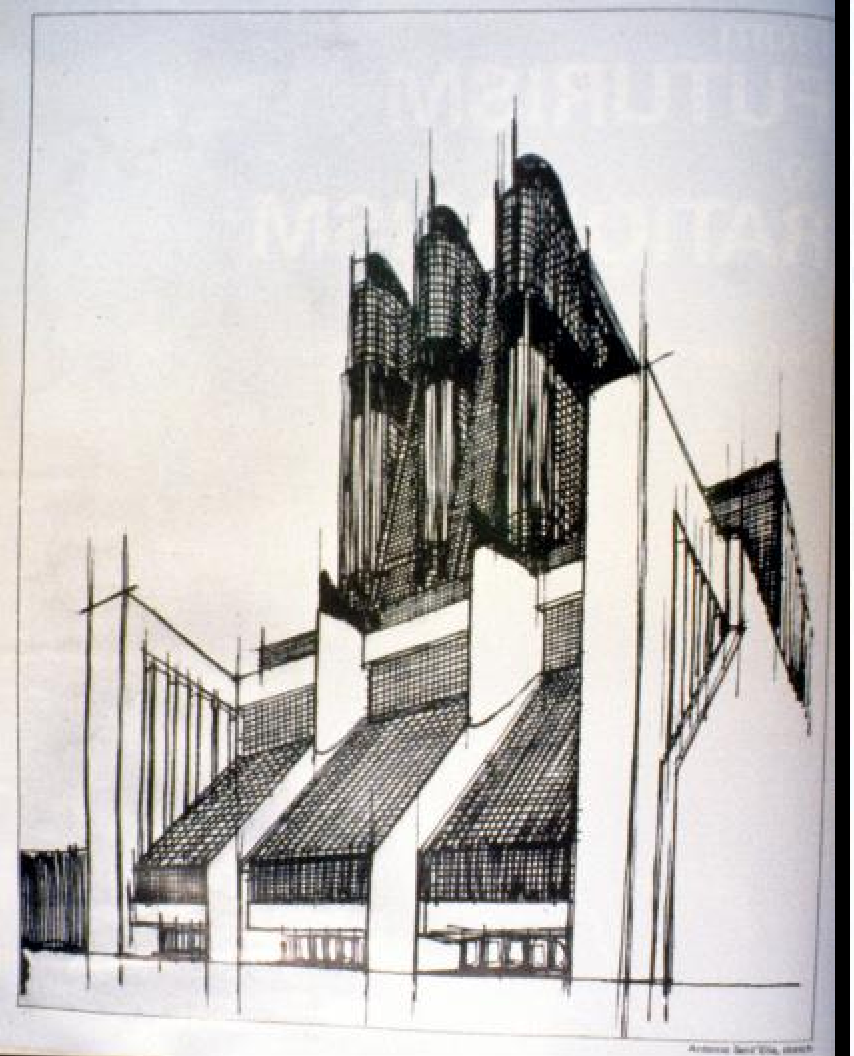
Futurism
and the beginnings of
The Modern Movement

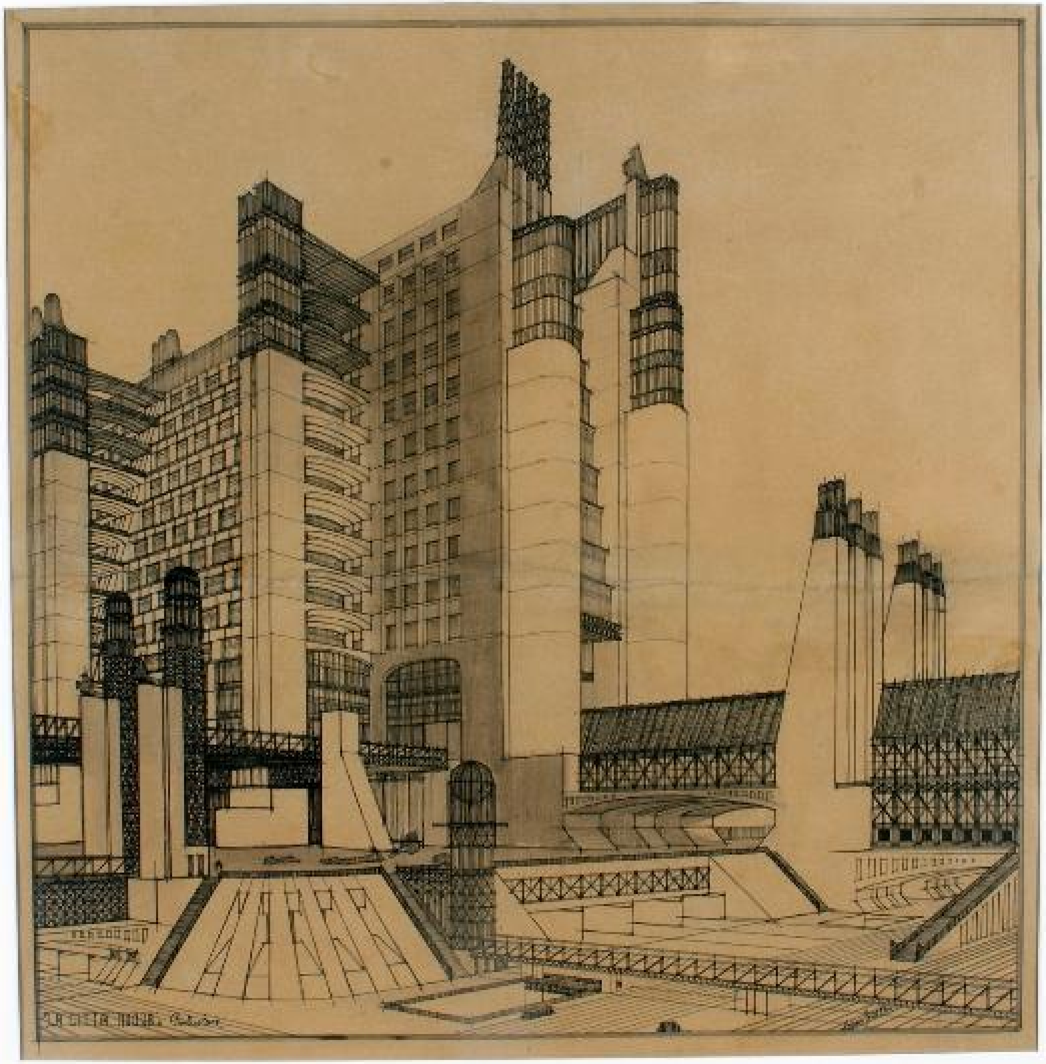


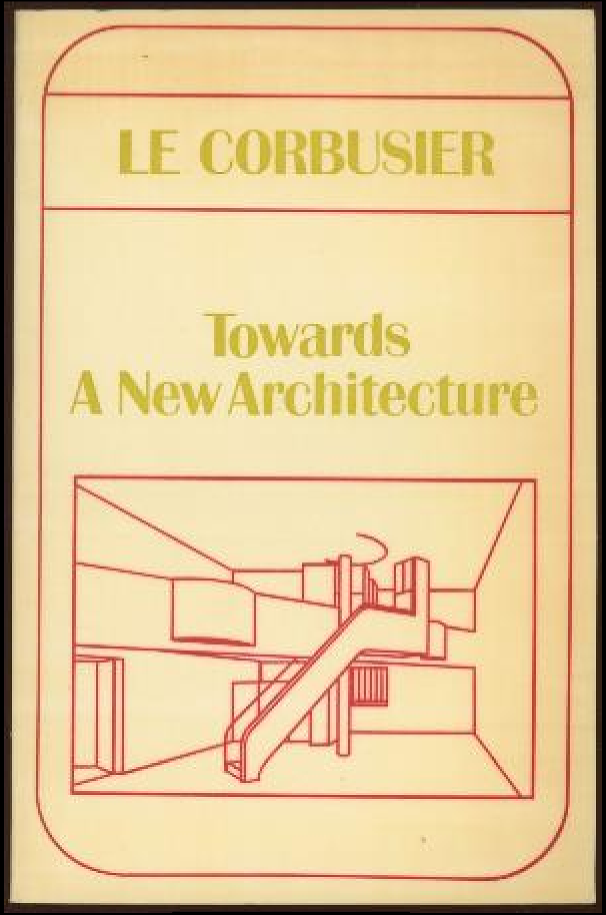
Antonio Sant'Elia
Italian Futurist
Architect
1888 to 1916



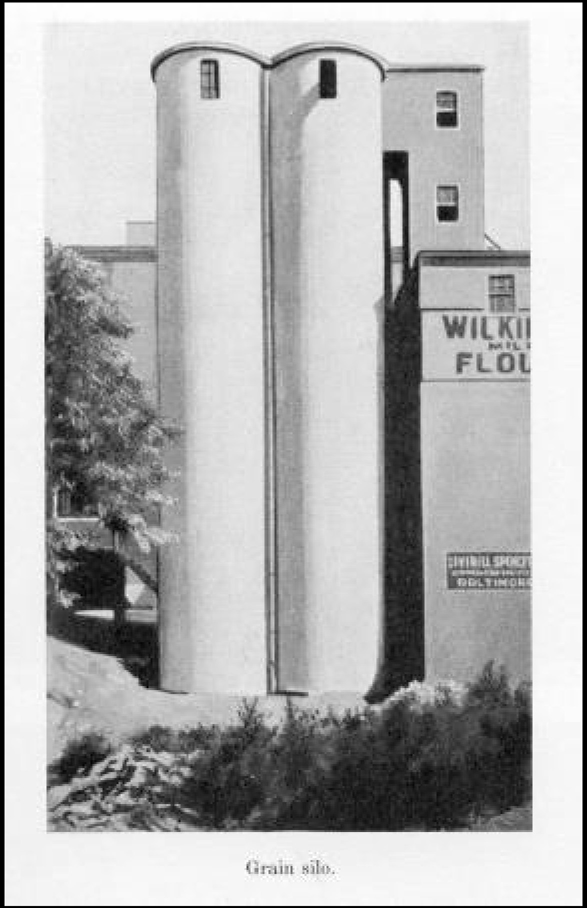


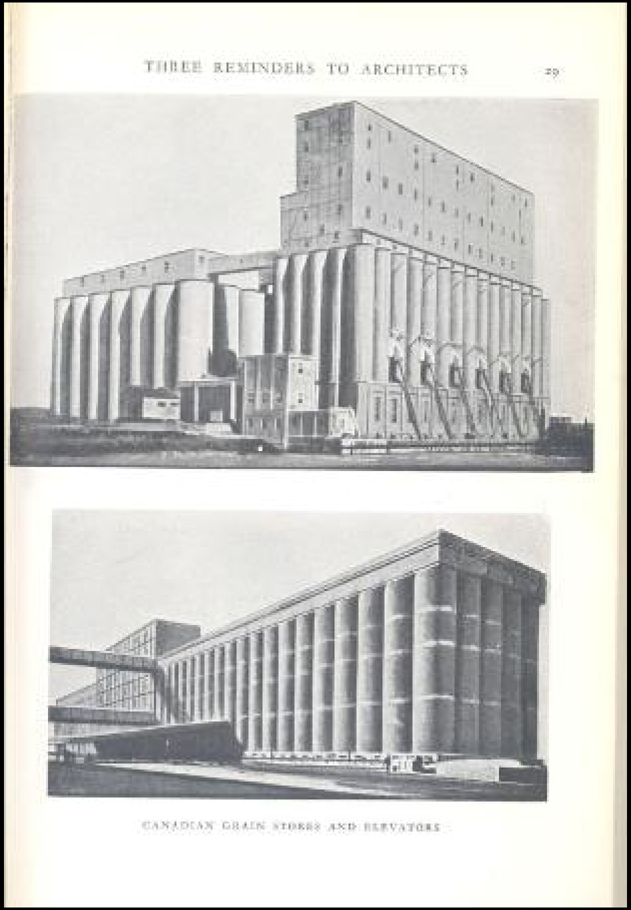





LE CORBUSIER
Towards
A New Architecture

1923

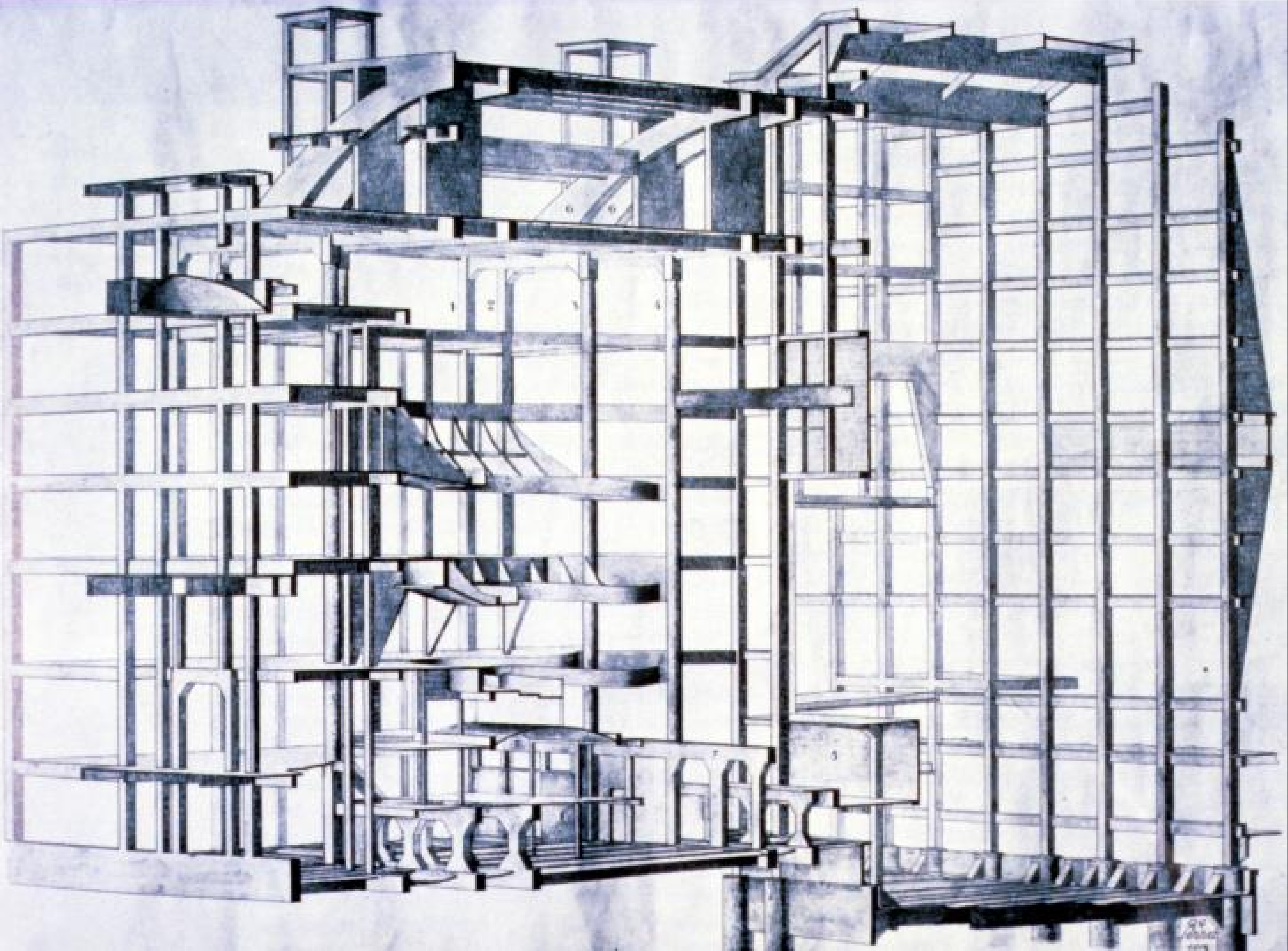

Grain silo.


THREE REMINDERS TO ARCHITECTS 29
CANADIAN GRAIN STORES AND ELEVATORS

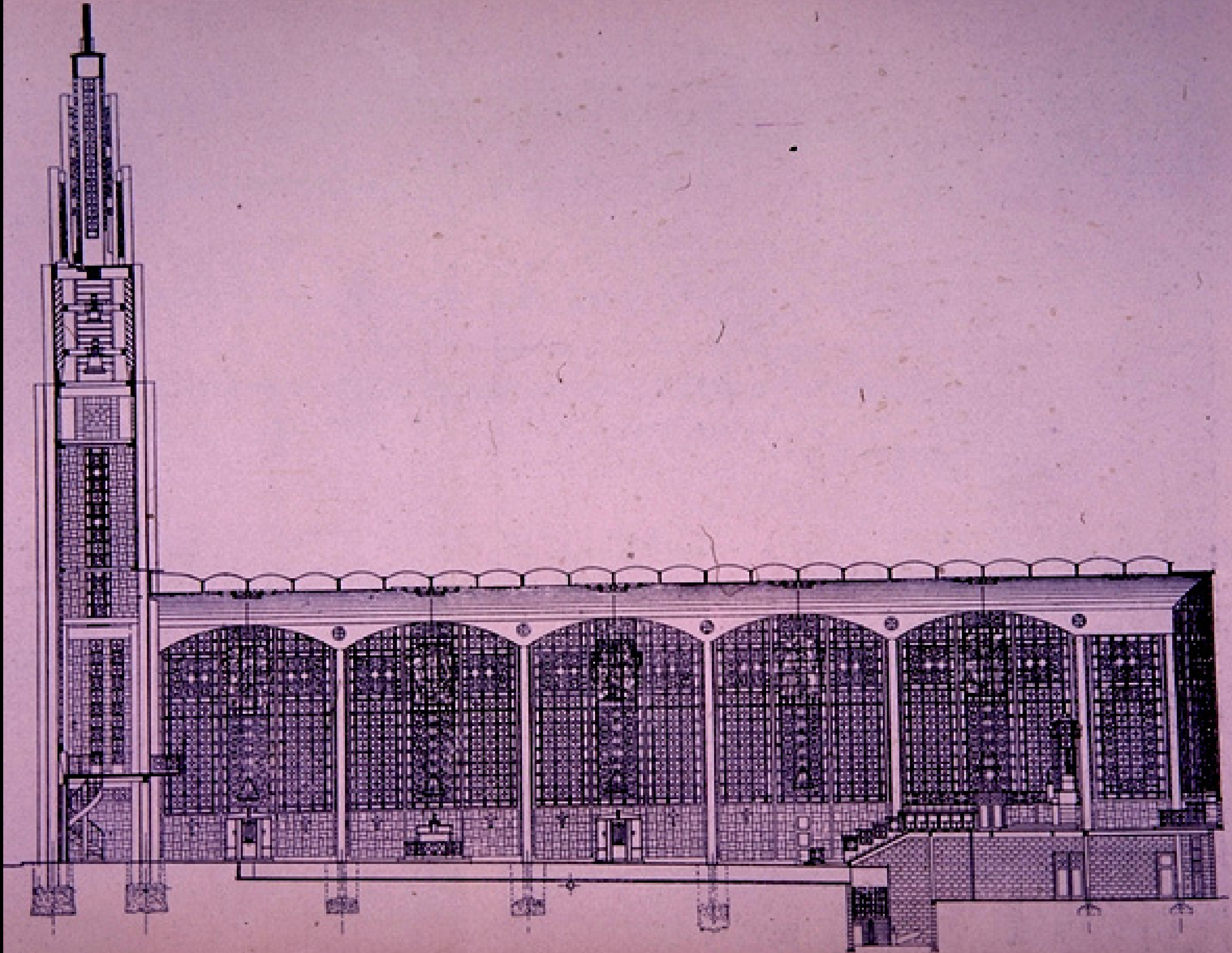
The North American Silo
Storage System

The Monolithic Frame

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



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

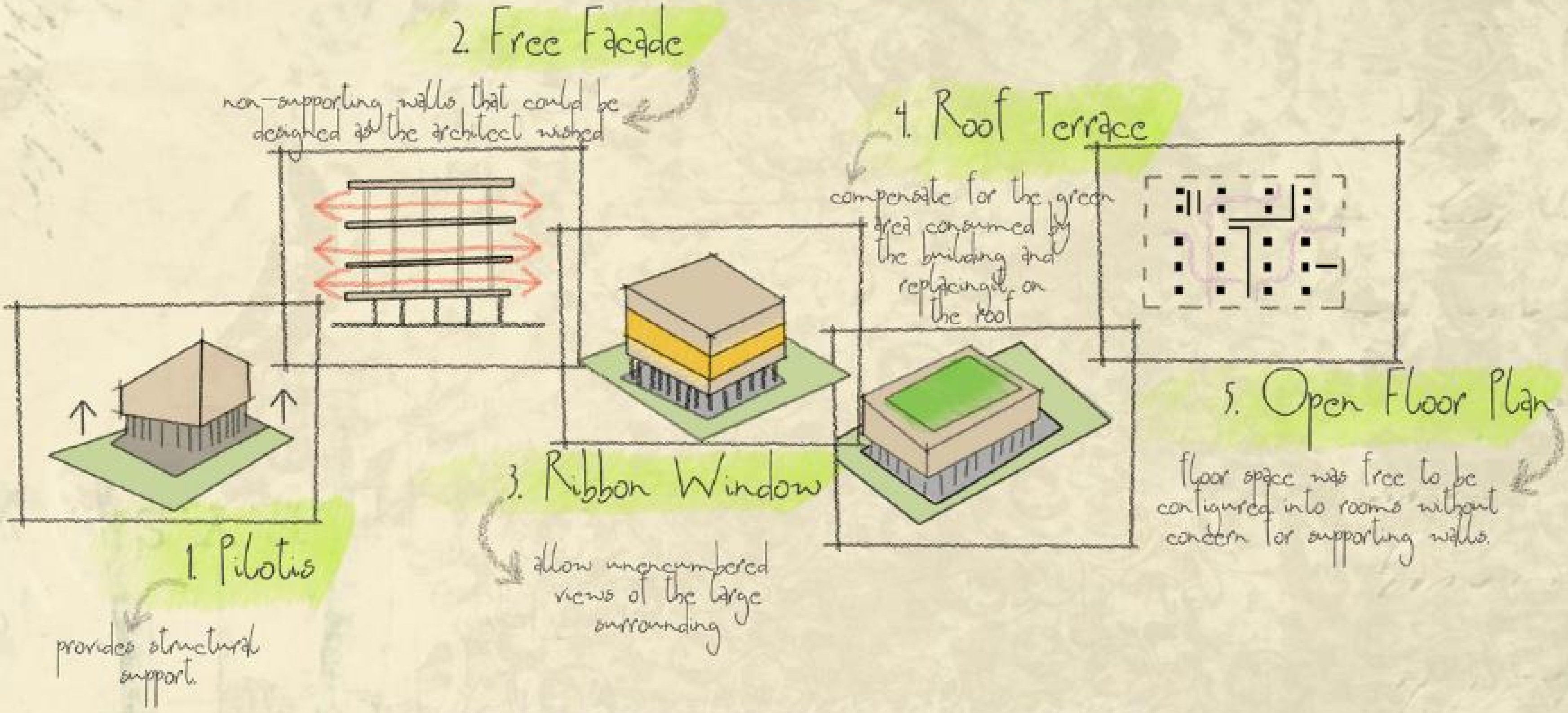


Long Span
~
Bridges

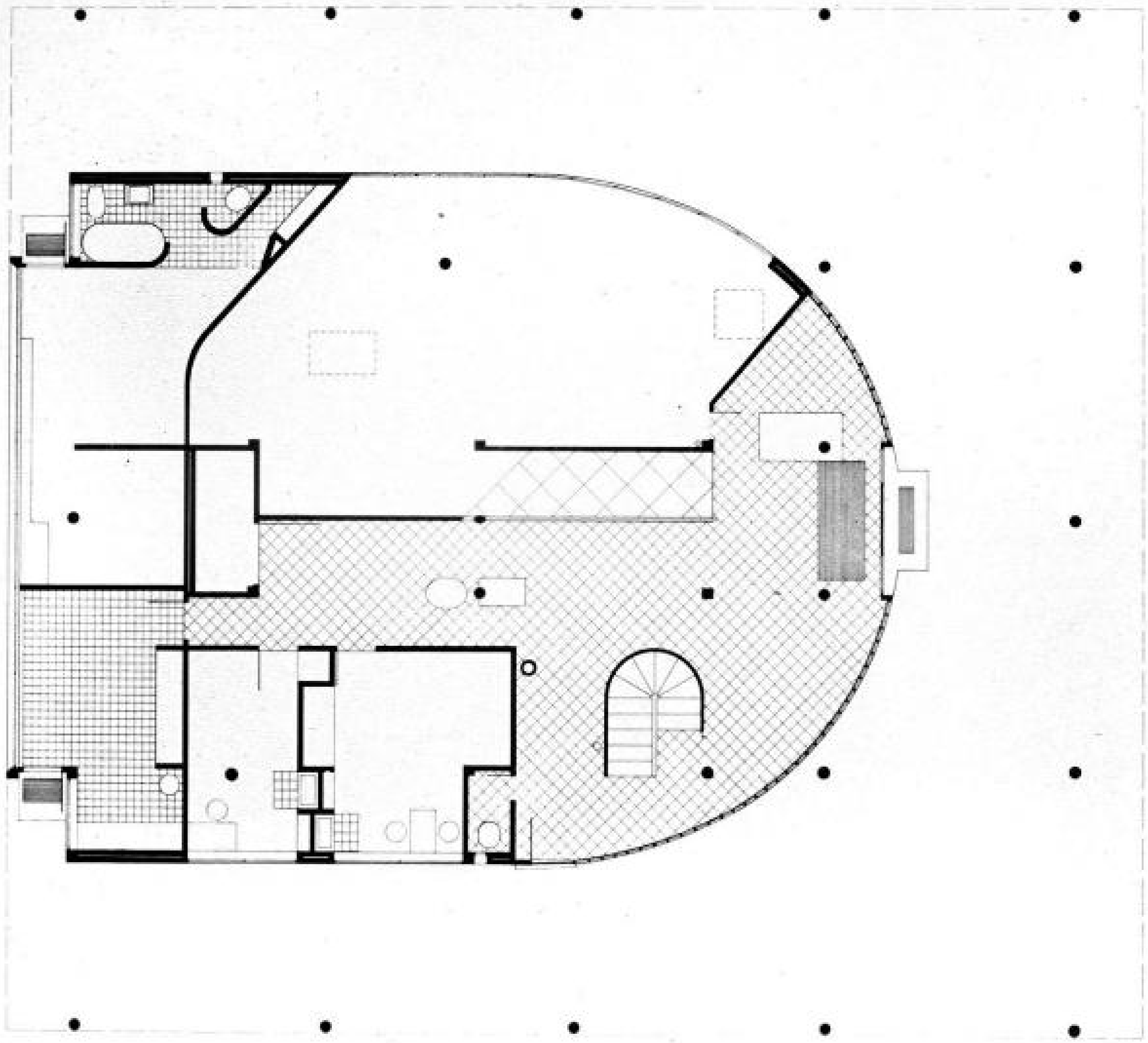
Salginatobel Bridge
Schiers, Switzerland
Robert Maillart
1930


Le Corbusier
Swiss/French Architect
1887 to 1965

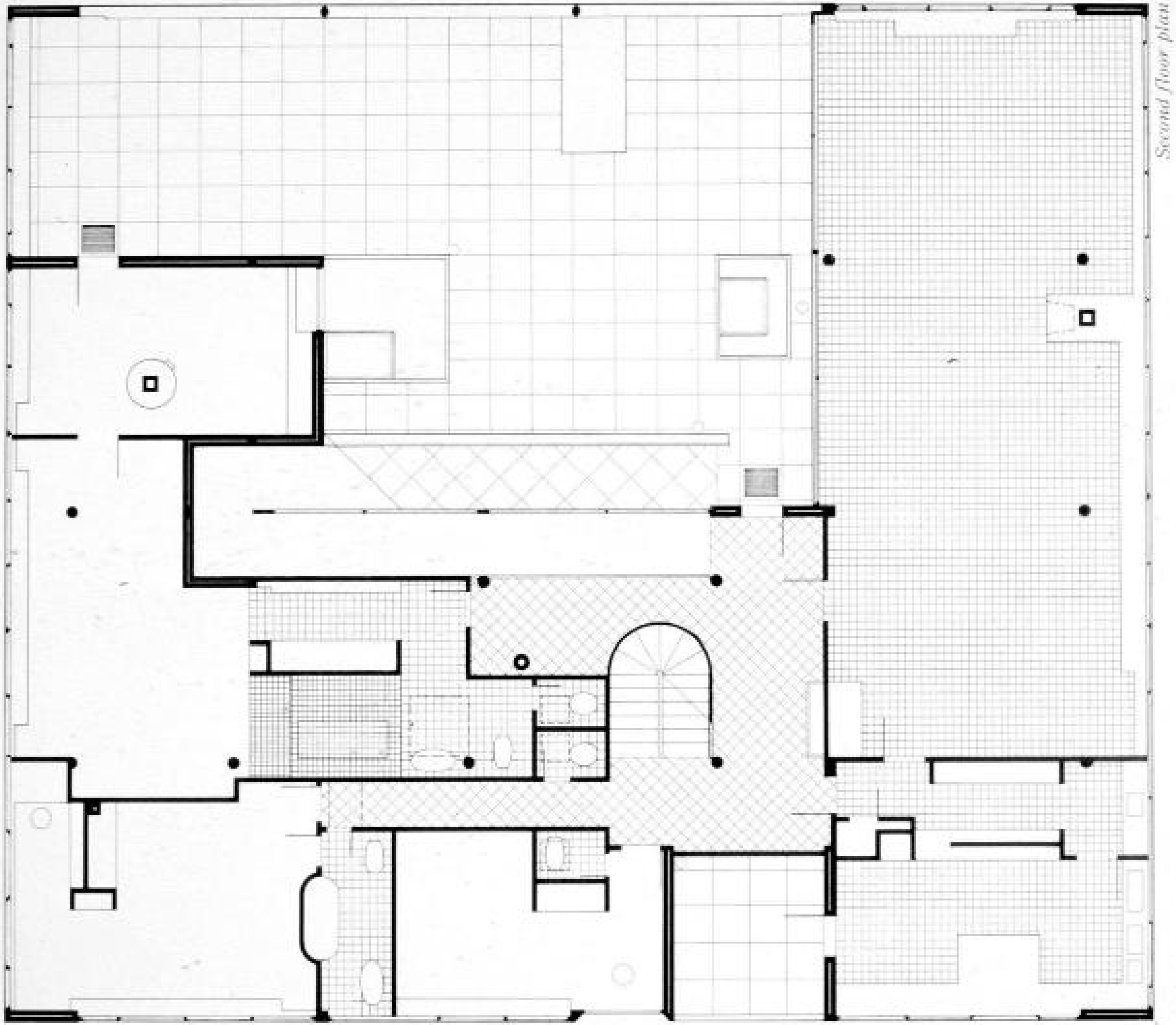
Le Corbusier's 5 points of Architecture



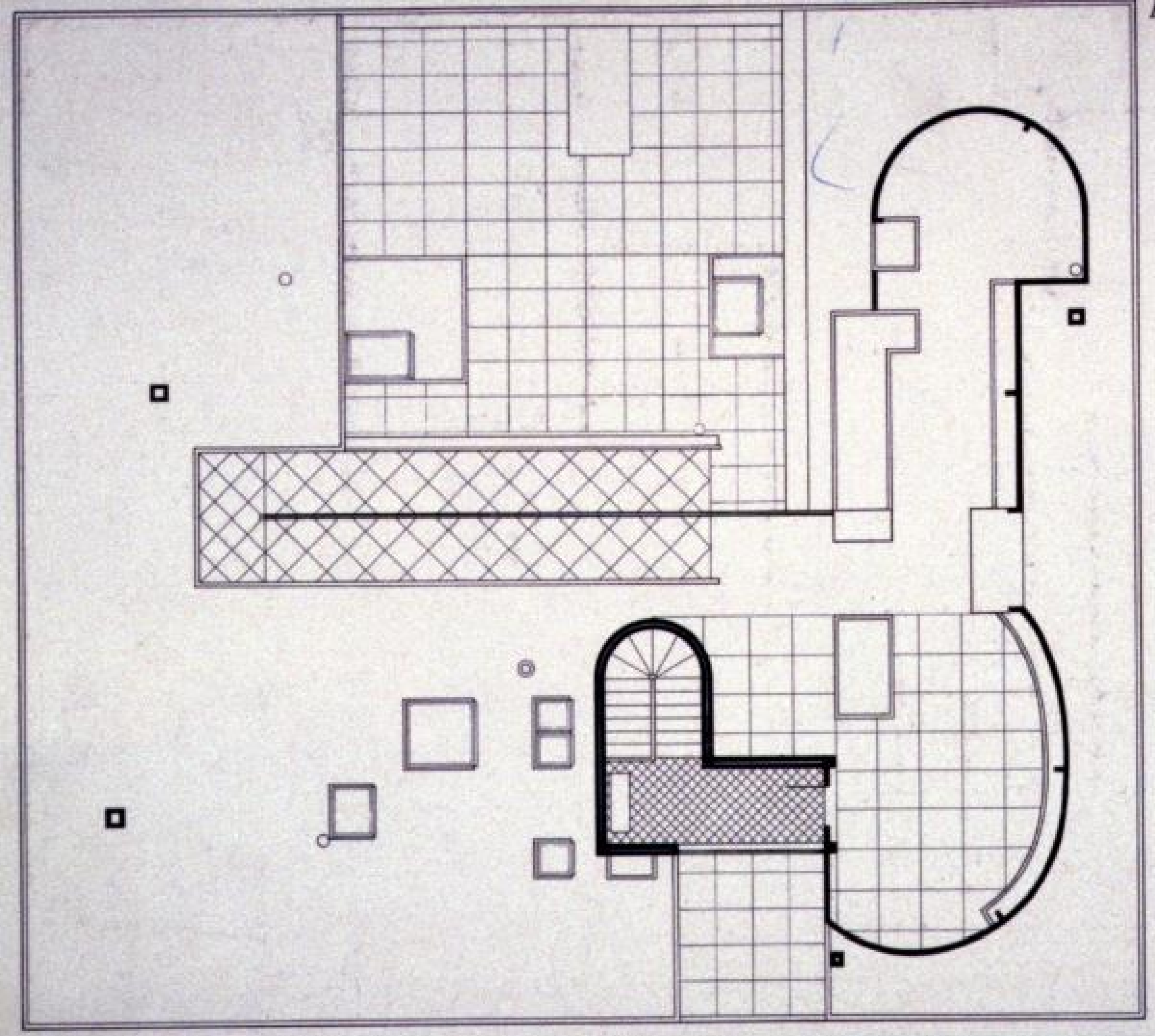
Villa Savoye
Poissy, France
Le Corbusier
1923 to 1925



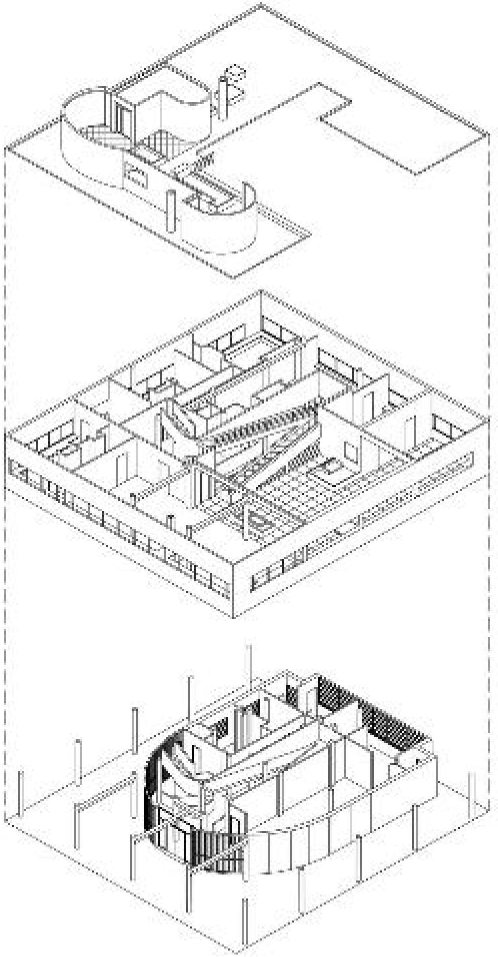
First floor plan

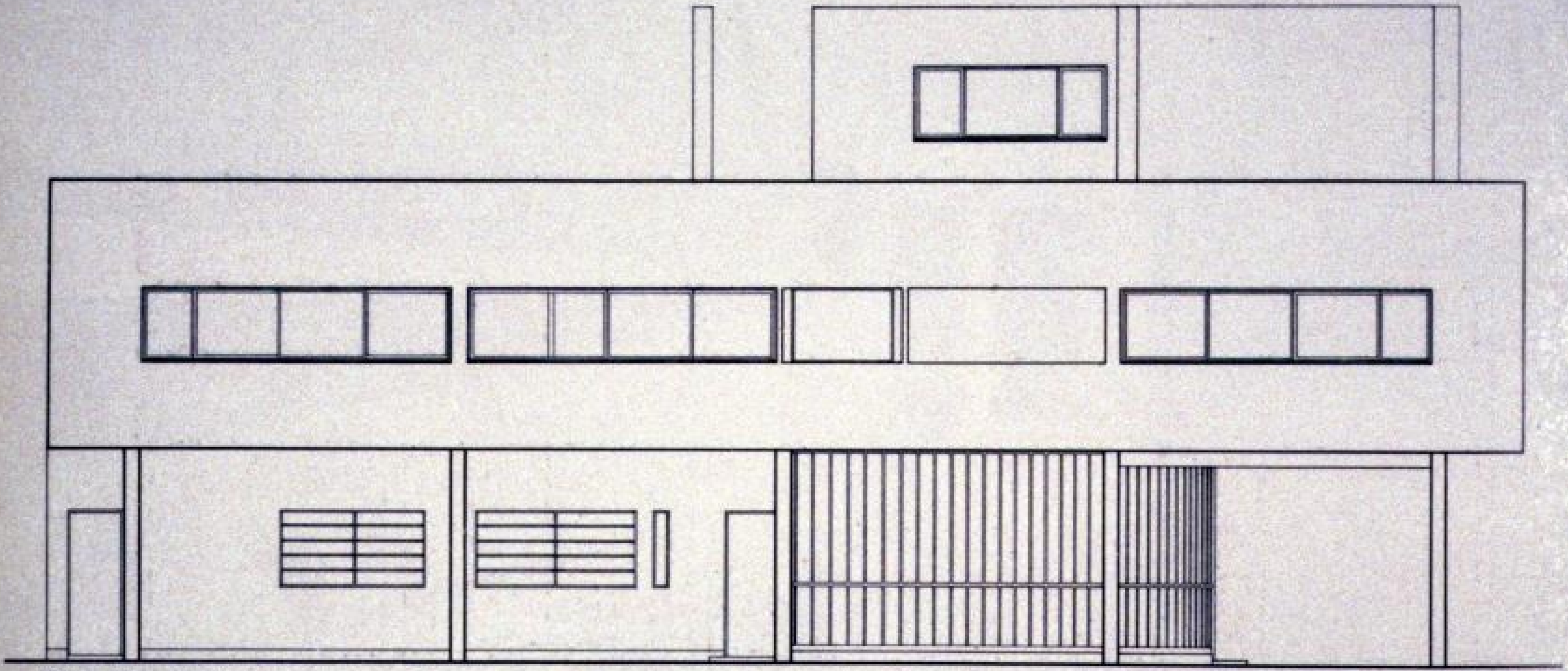


Second floor plan

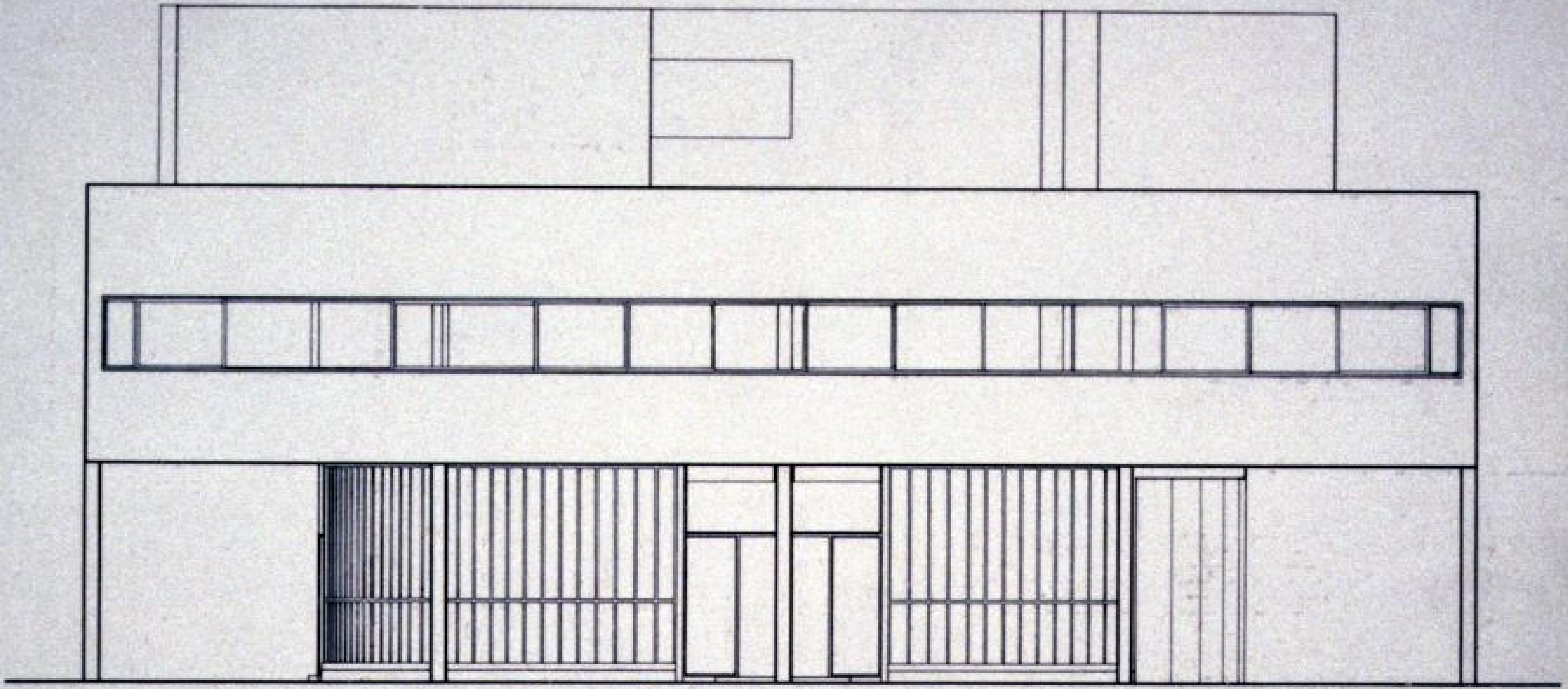


Roof plan



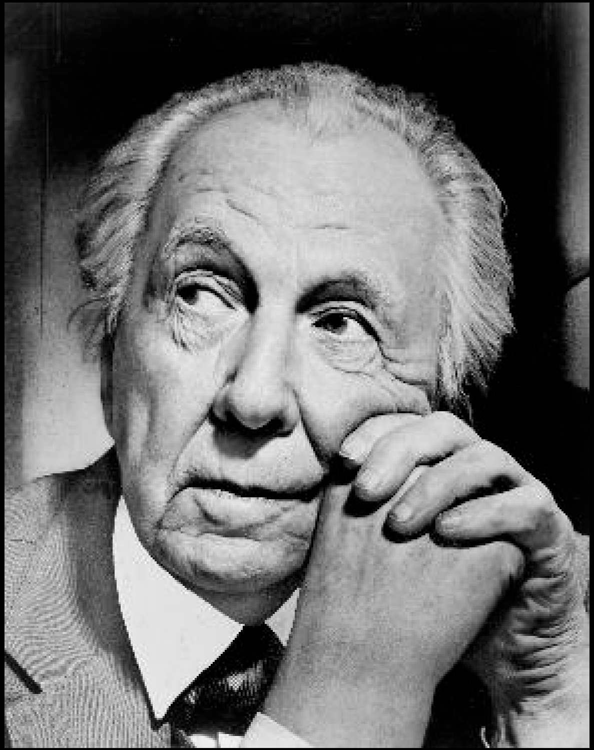


Elevation west



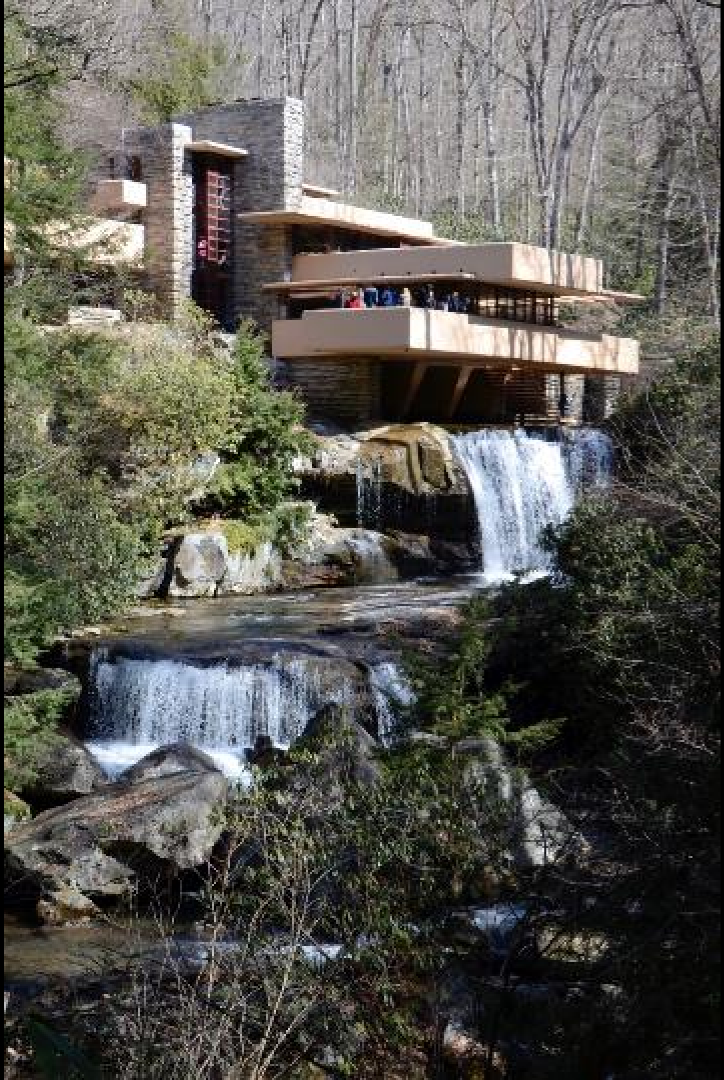
Elevation south



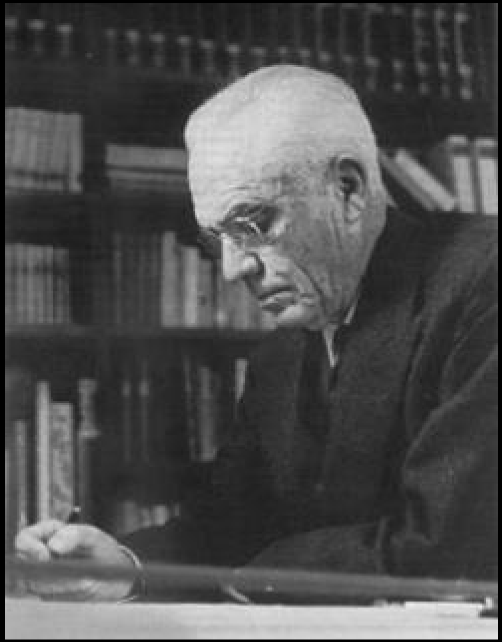



Frank Lloyd Wright
American Architect
1867 to 1959

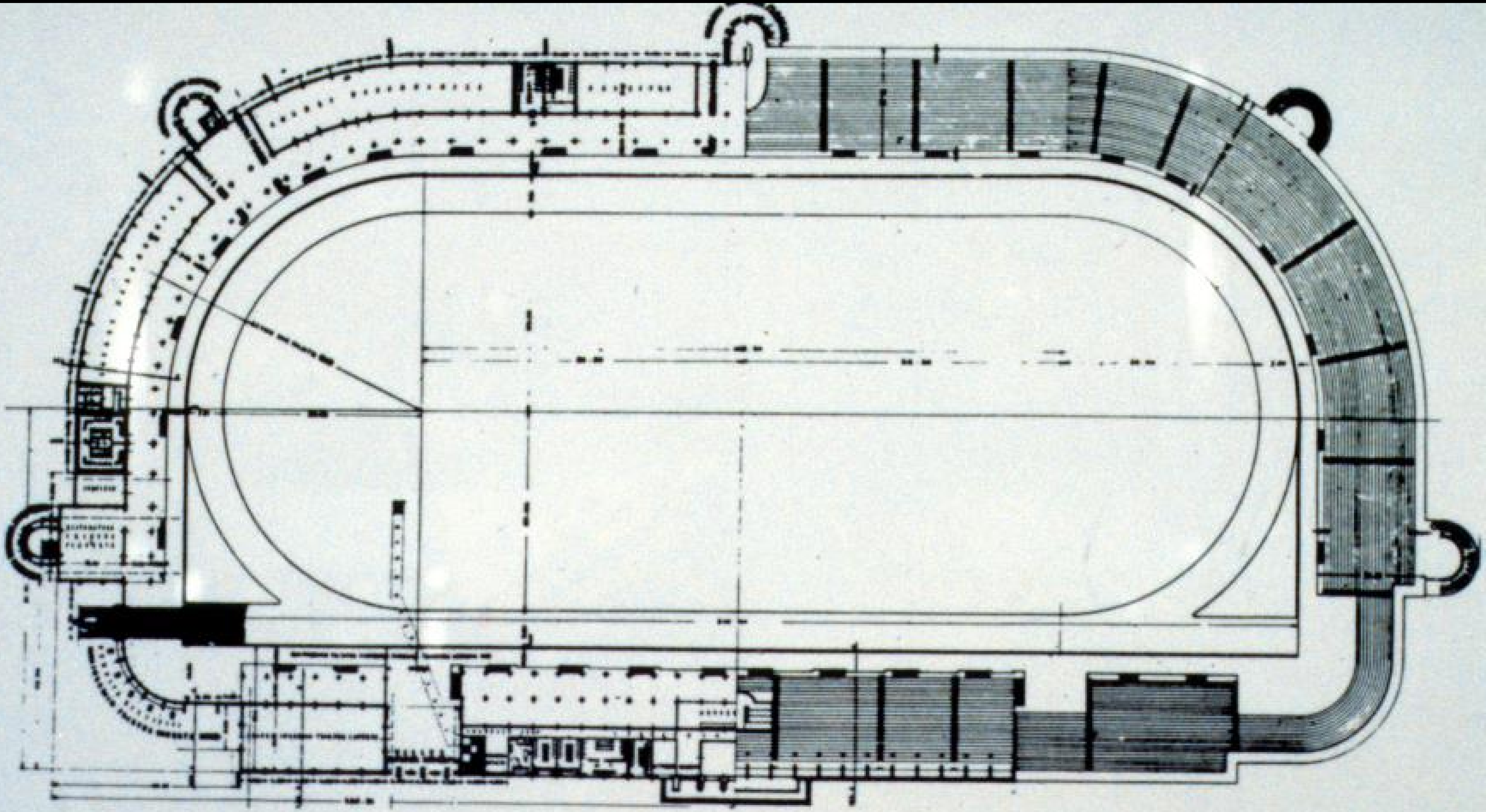
Falling Water
Mill Run, Pennsylvania
Frank Lloyd Wright
1939

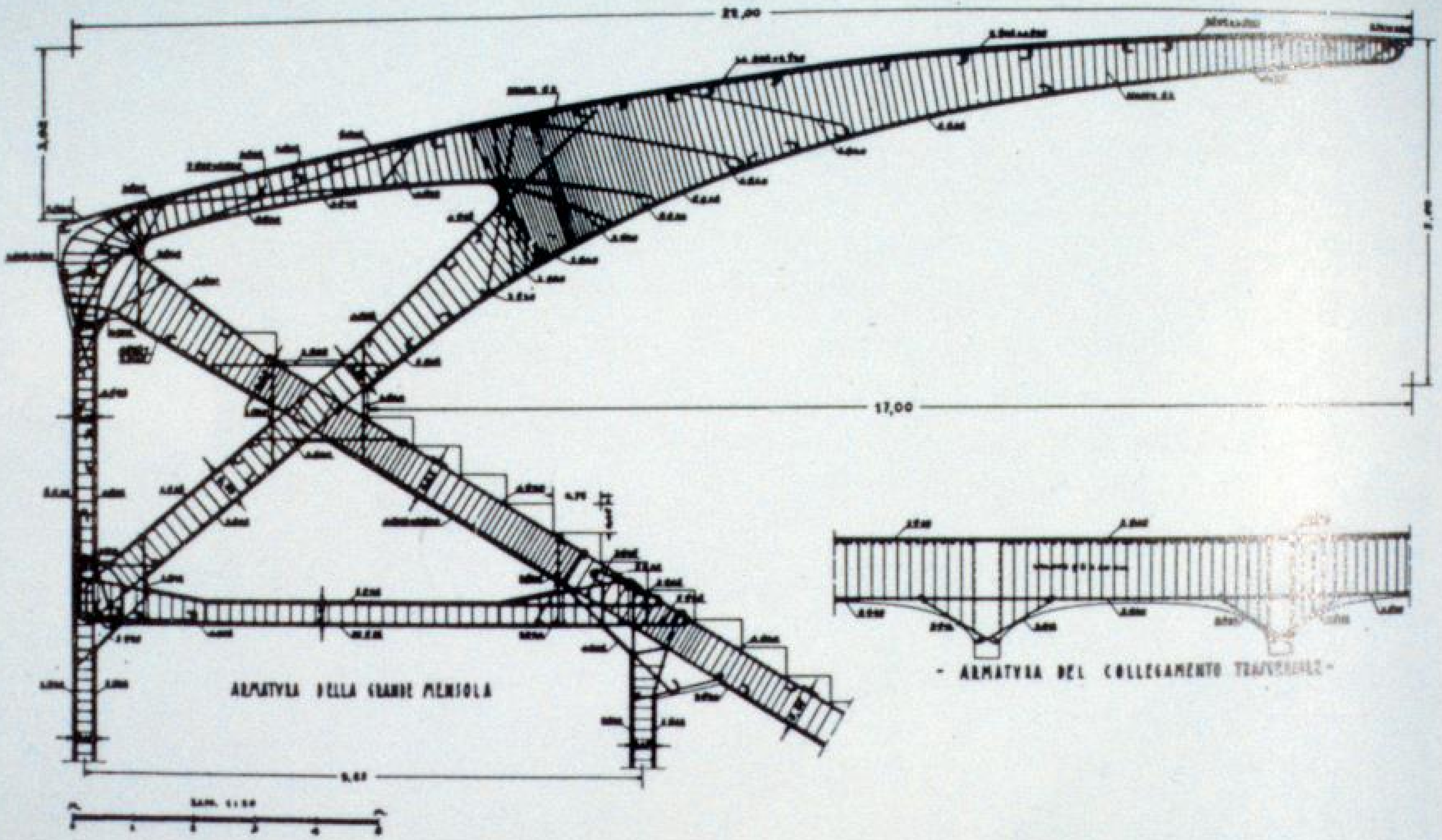


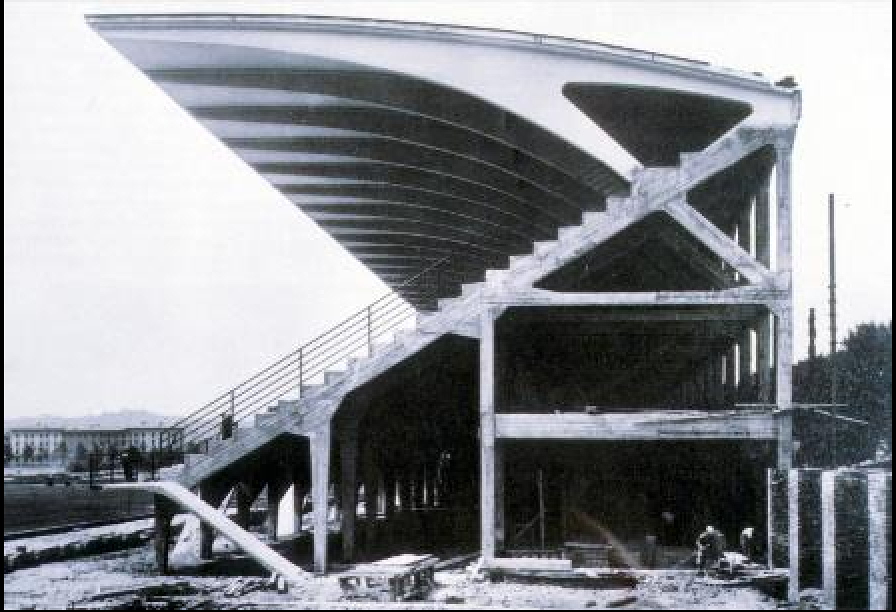
Cantilevers

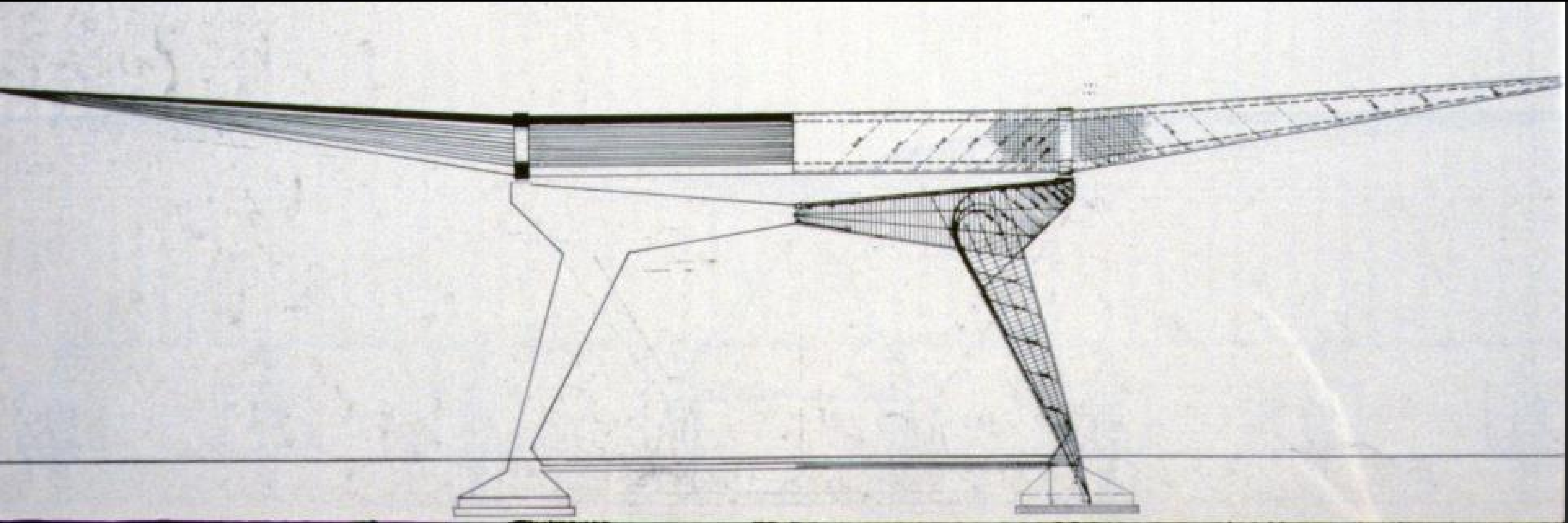


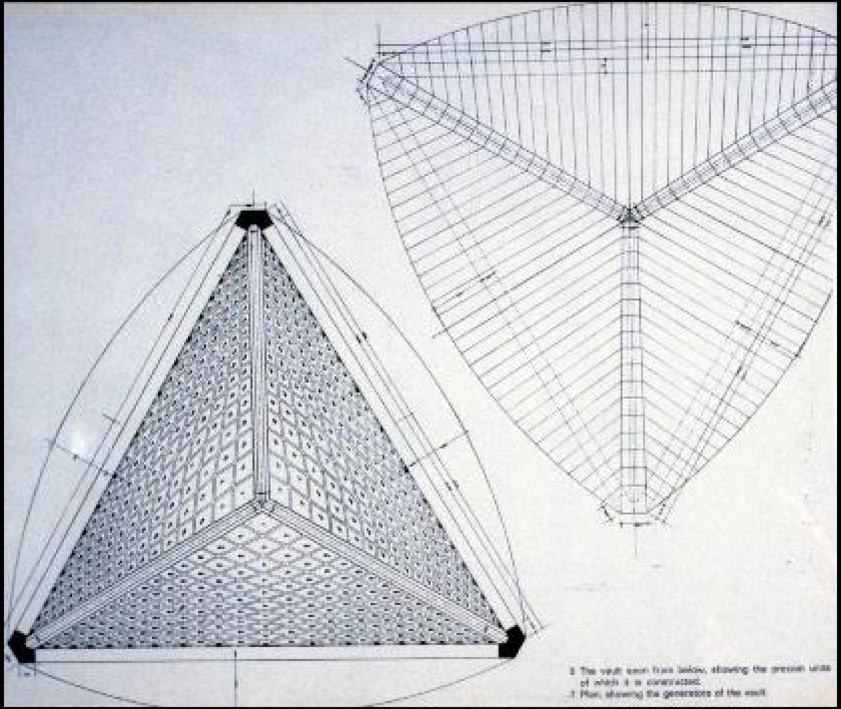
Pier Luigi Nervi
Italian Engineer
1891 to 1979

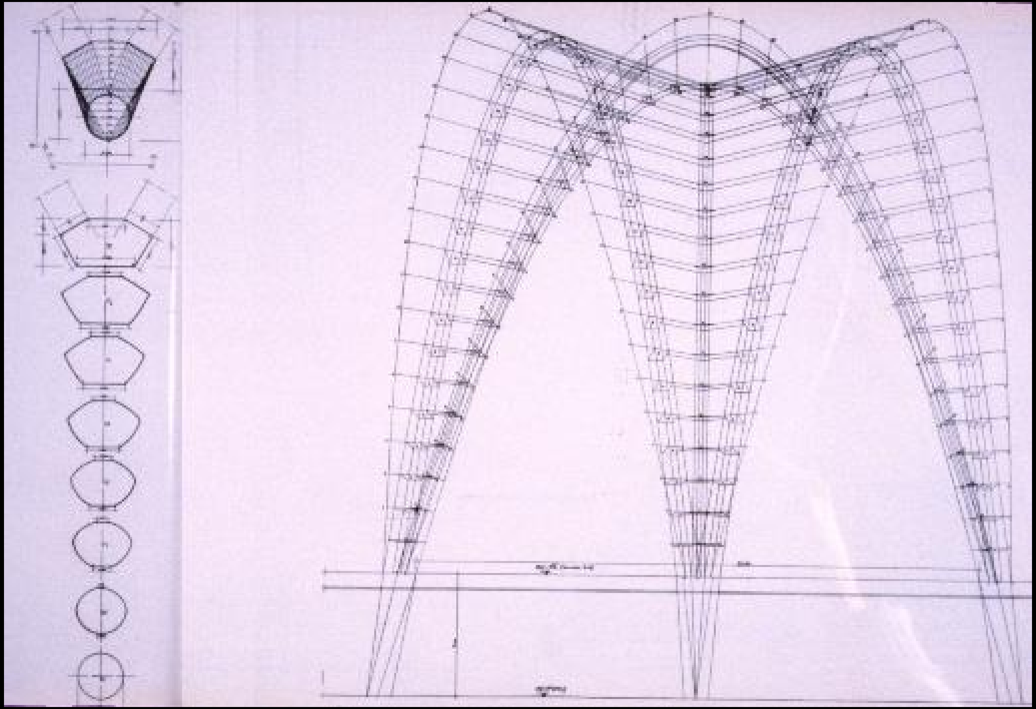


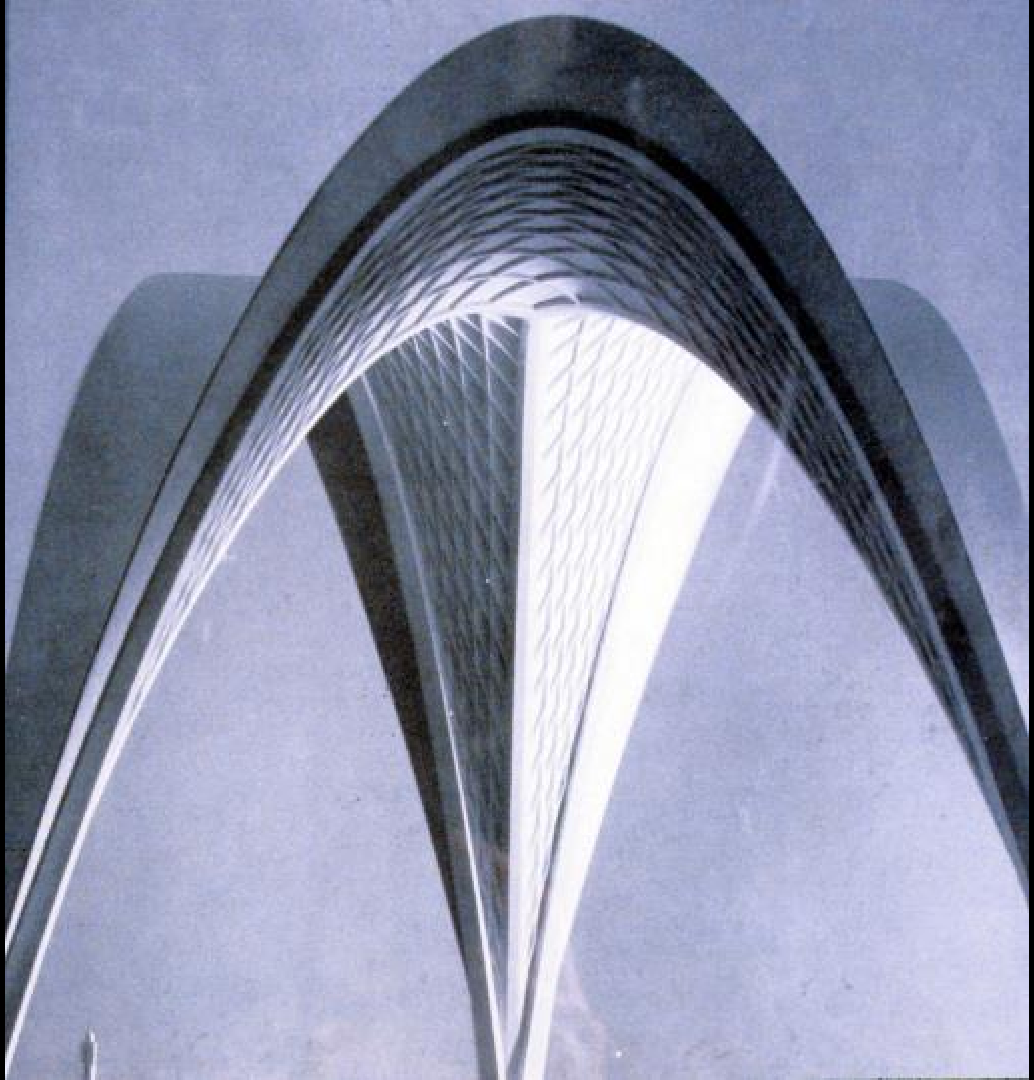

17,00
ARMATURA DELLA GRANDE MENSOLA
ARMATURA DEL COLLEGAMENTO

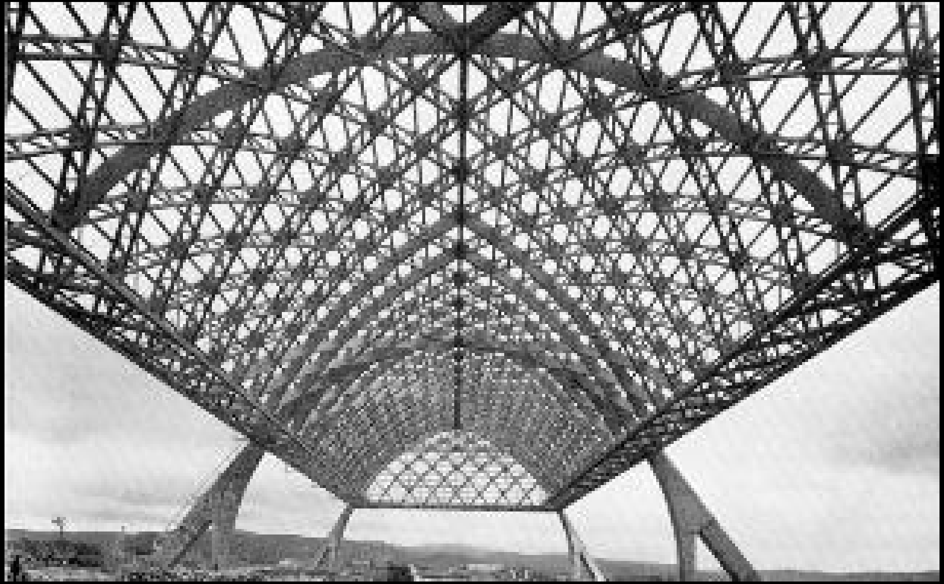


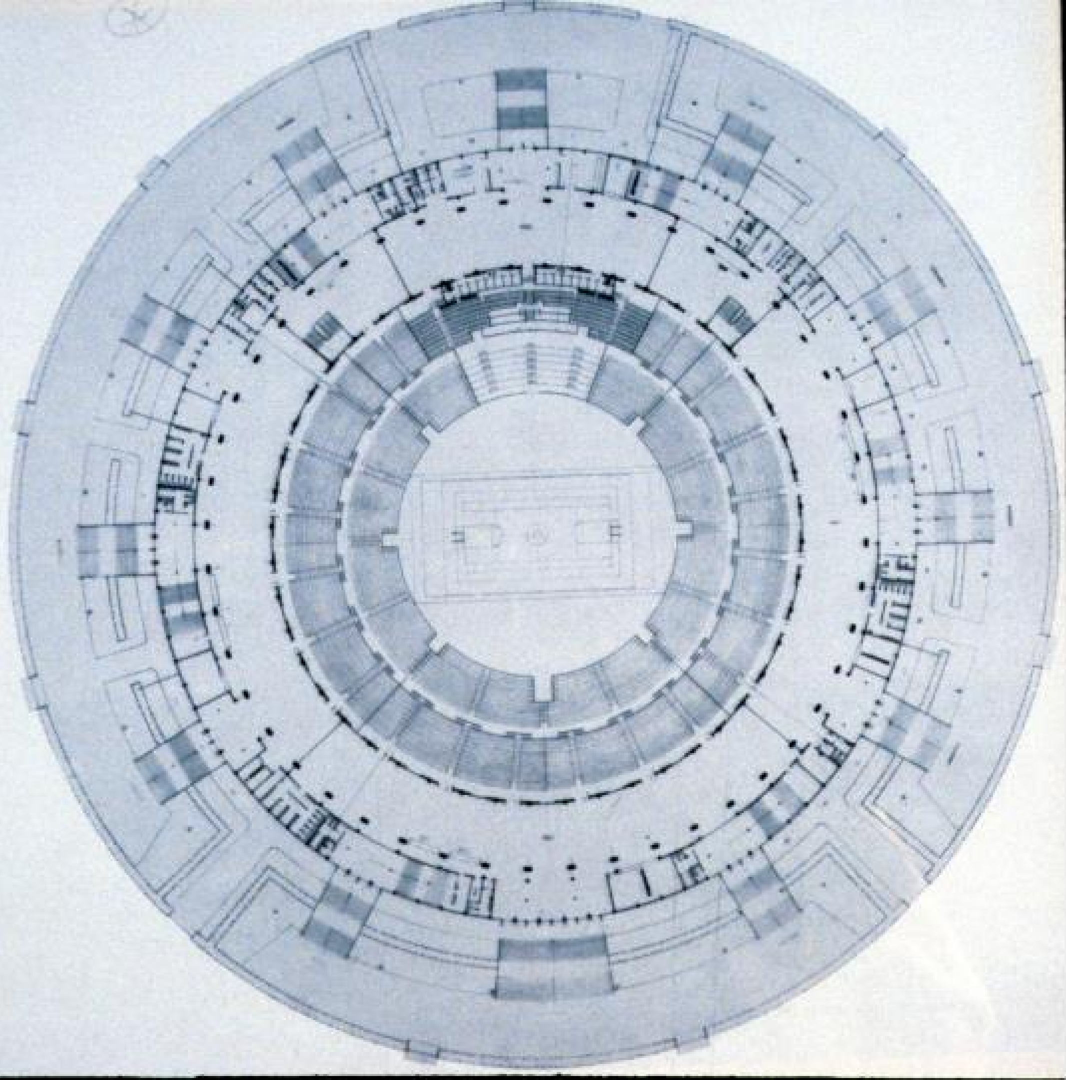

8 The vault seen from below, showing the precast units of which it is constructed.
7 Plan, showing the generators of the vault

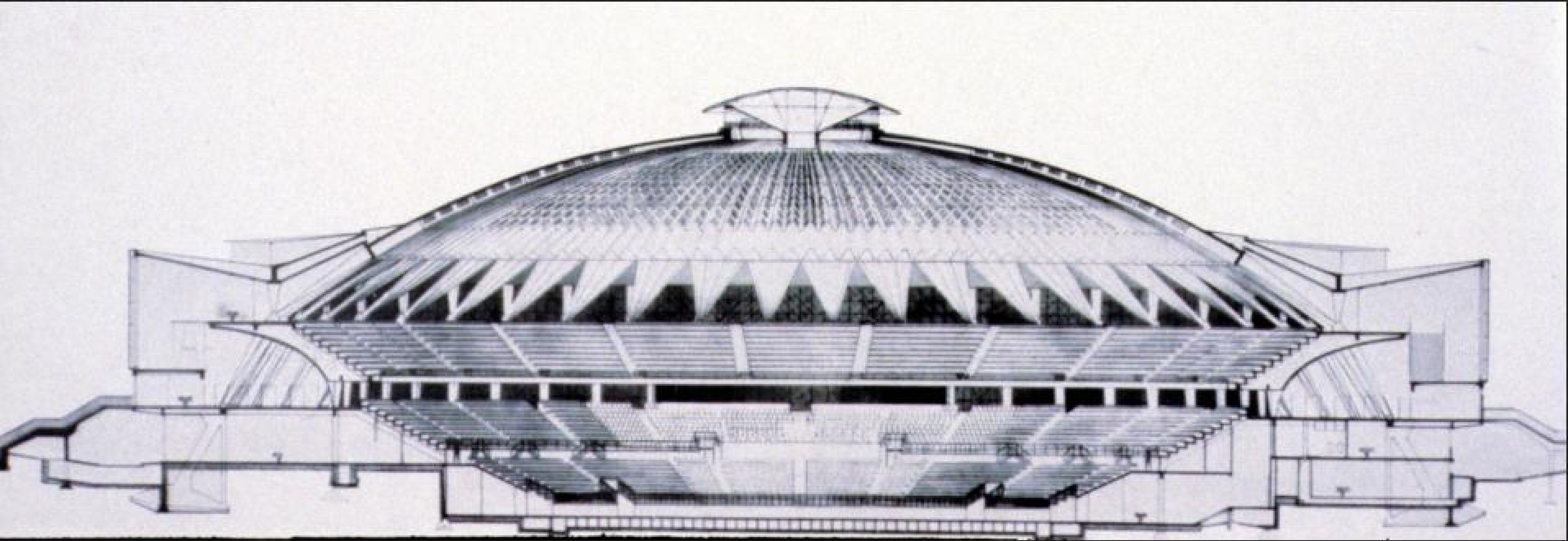


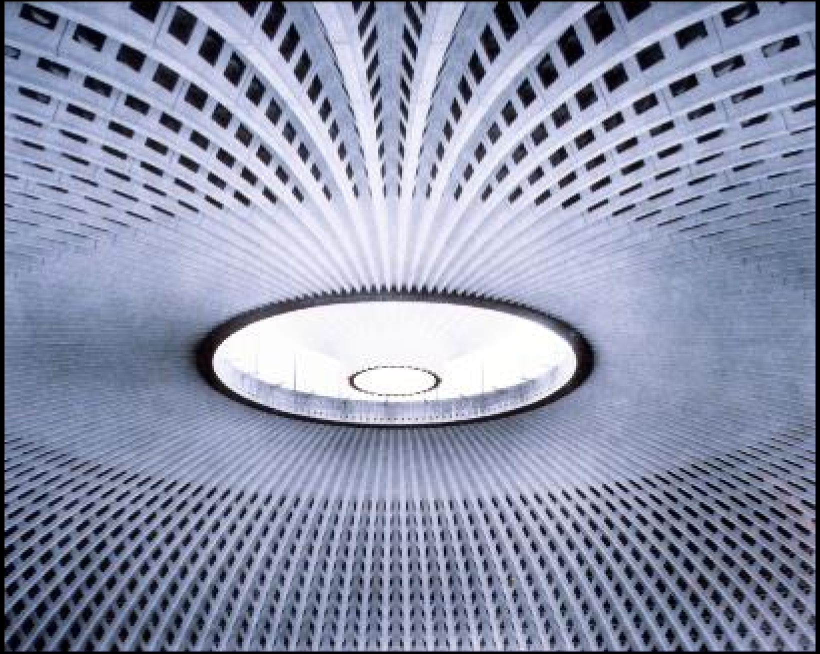


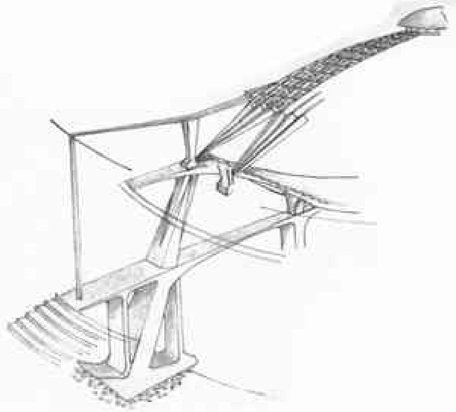


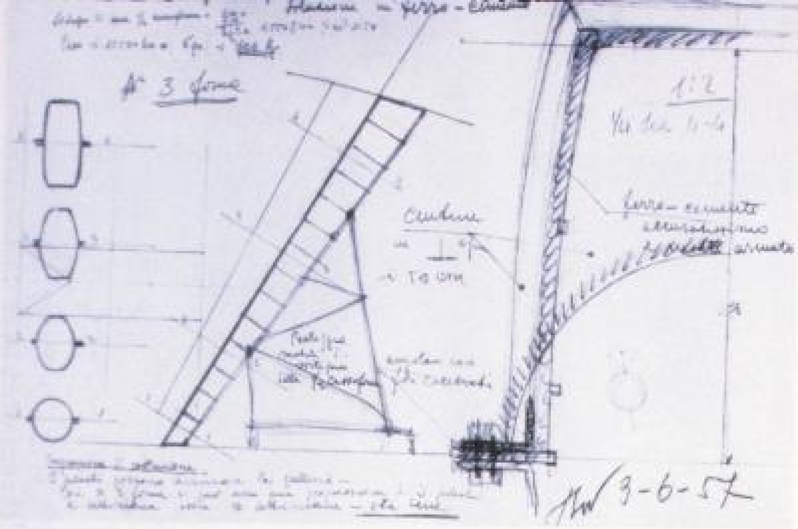
PalaLottomatica
(Palazzo dello Sport)
Rome, Italy
1960
Pier Luigi Nervi Engineer
Marcello Piacentini Architect





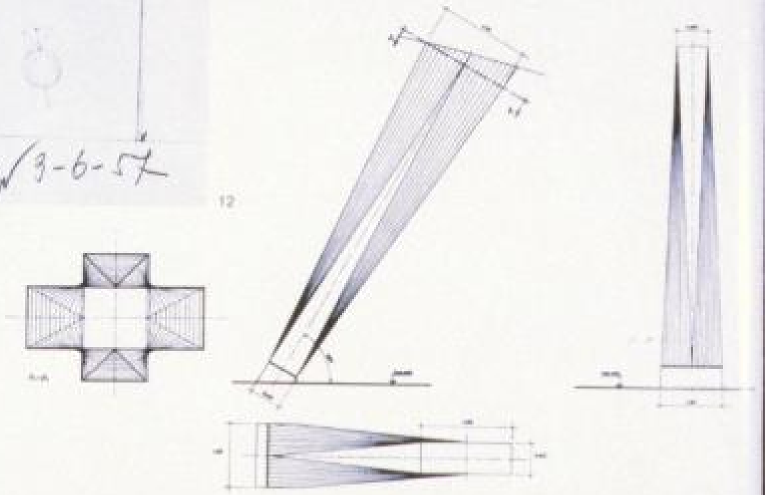







12

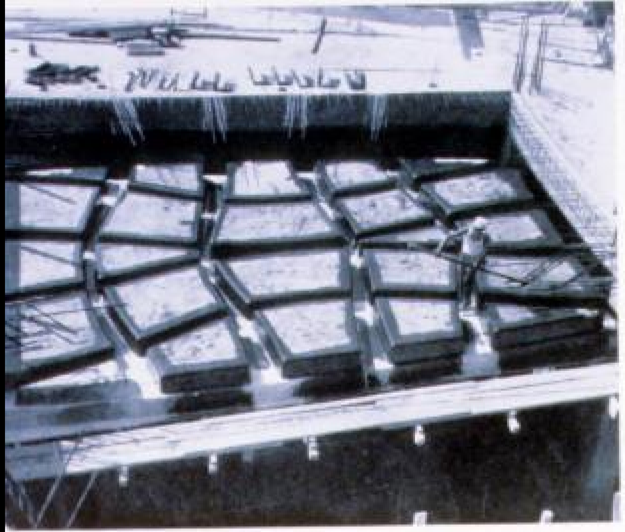
13

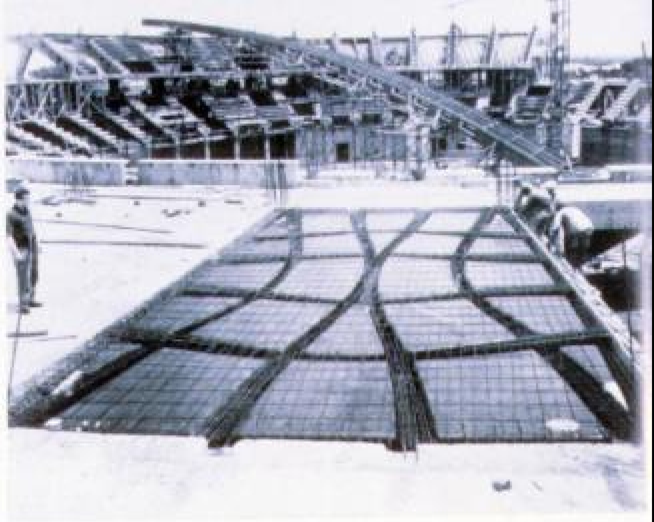


15

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.



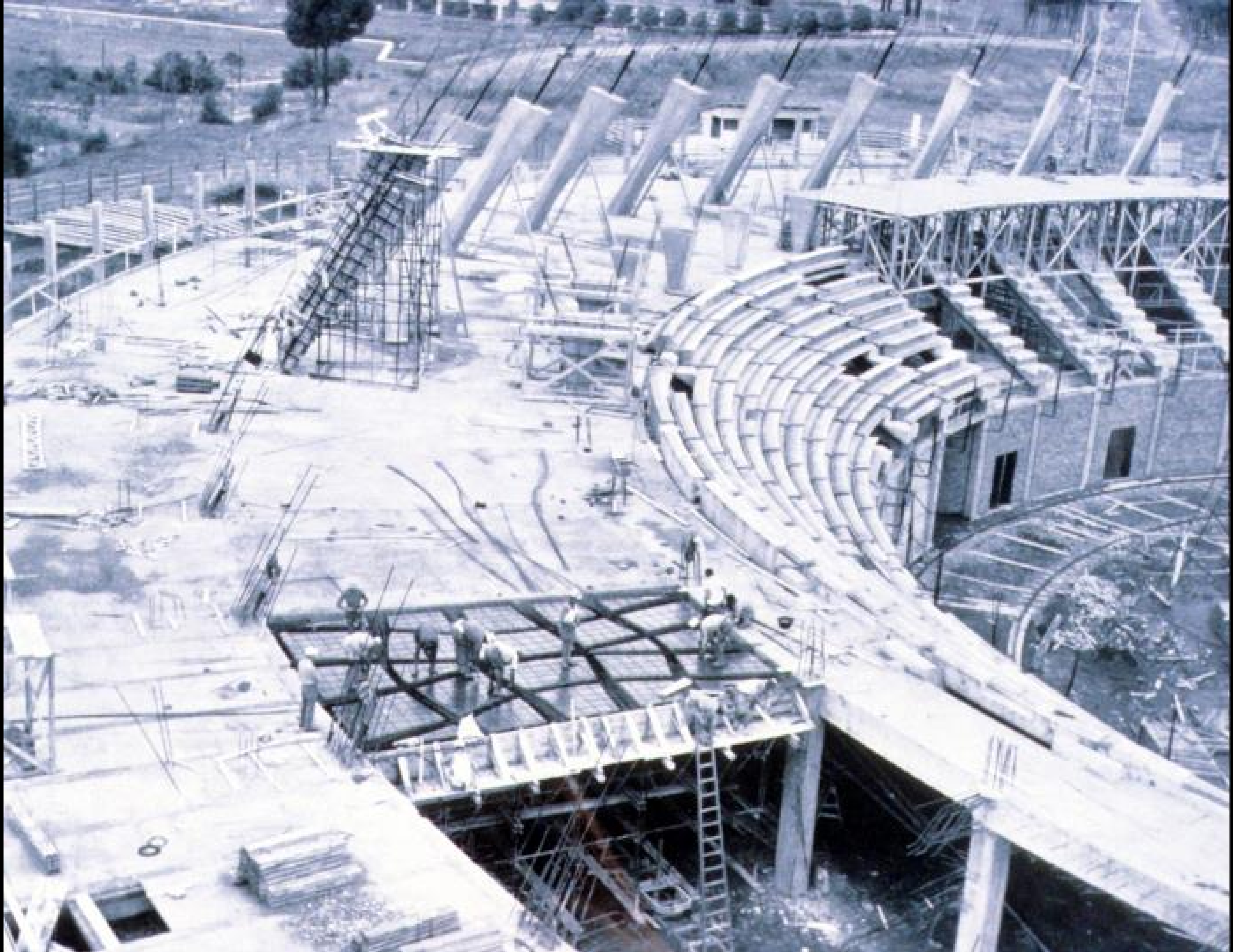


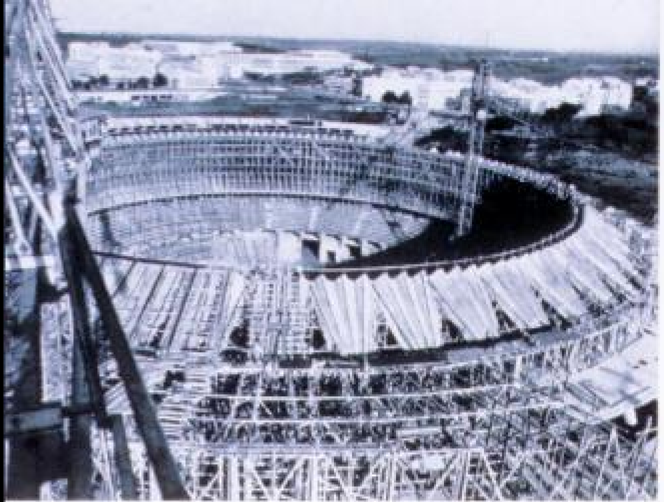
...able "ferro-cemento" forms used for casting the gallery floor, in ...h the ribs follow the lines of the principal stresses (P. L. Nervi ...tem)

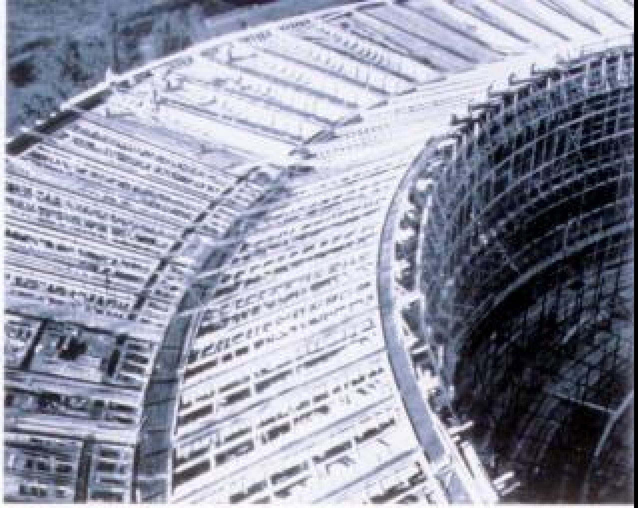
...mework ready for concreting.

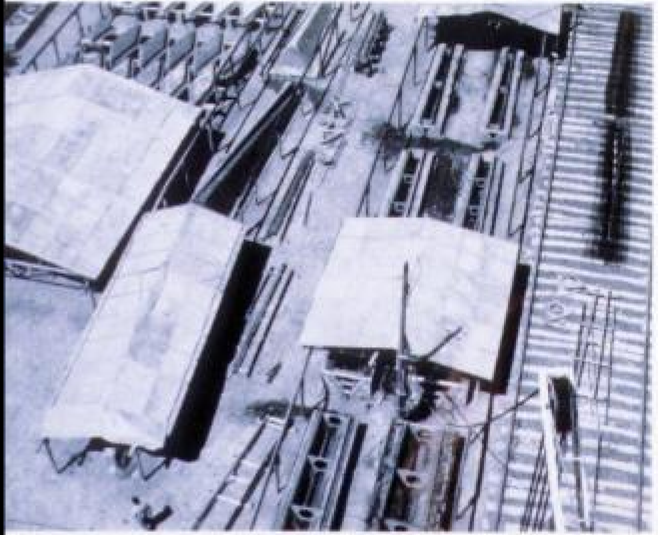
... finished floor, from below.

... hall under construction, showing the three sections of timber form-...k 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.


LOTTOMATICA

Palazzetto dello Sport
Rome, Italy
Pier Luigi Nervi
1960


Tribuna Flaminio
settore F1 / F


Ingresso Atleti

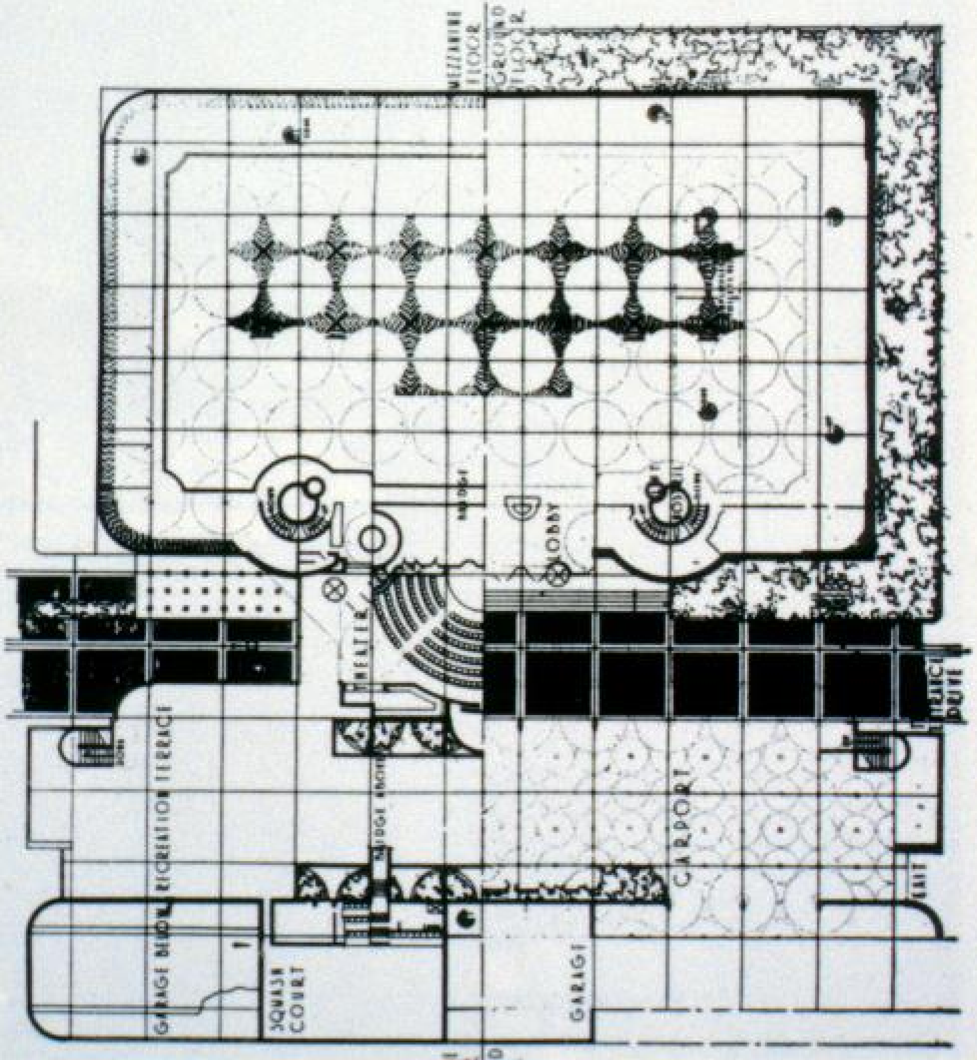

Air One
Lavoro

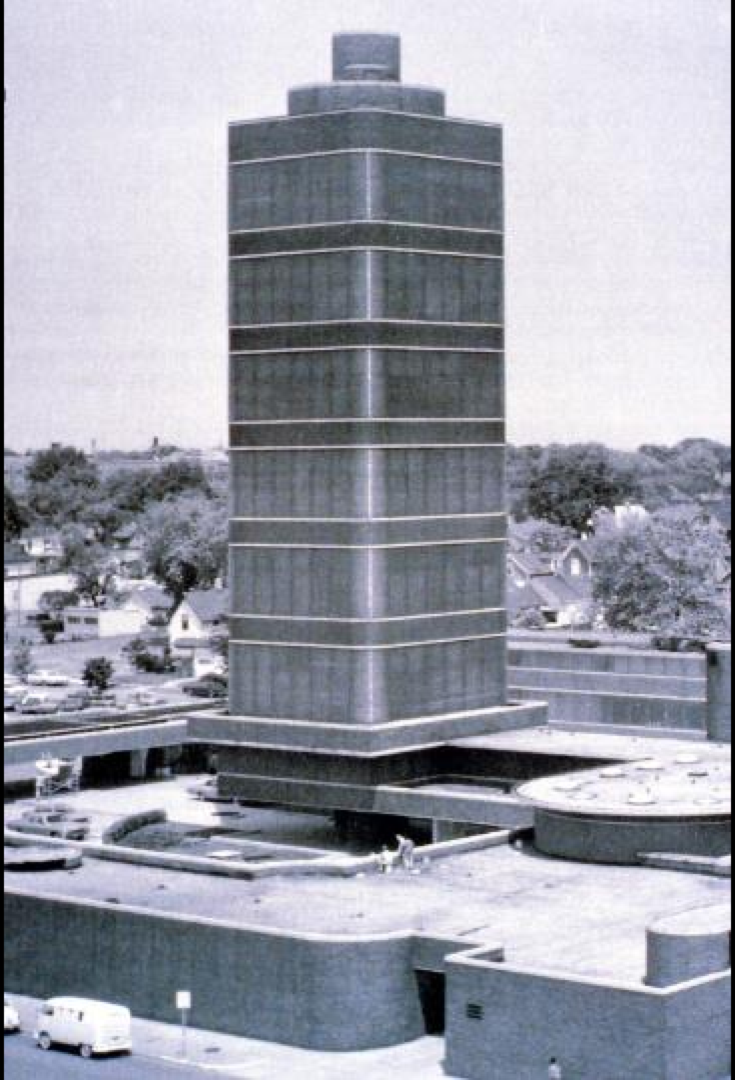

GRUPPO
LOTTOMATICA
giochi e servizi

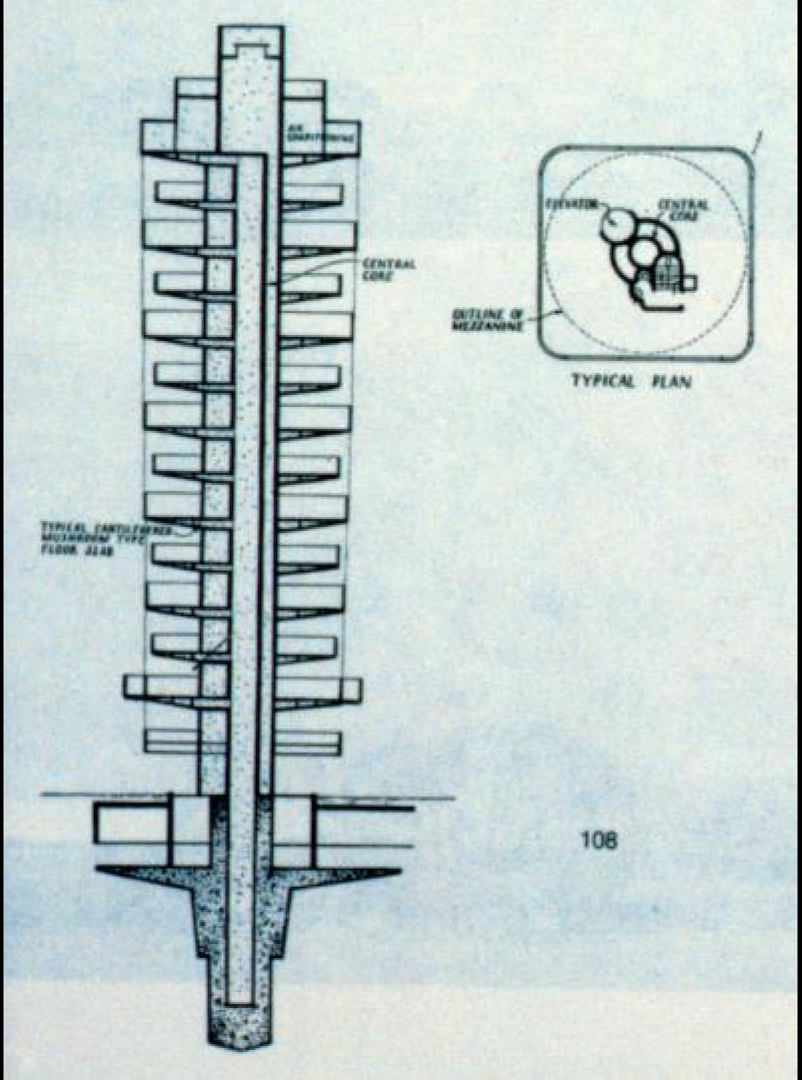
Developments in Concrete Construction

Part 2: Curves, Cantilevers and Brutalism

Johnson Wax Headquarters
Racine, Wisconsin
Frank Lloyd Wright 1939


MEZZANINE FLOOR
GROUND FLOOR
LOBBY
THEATER
CARPORT
GARAGE BELOW RECREATION TERRACE
SQUASH COURT
GARAGE




CENTRAL CORE
CENTRAL CORE
TYPICAL PLAN
108


www.GreatBuildings.com


www.GreatBuildings.com

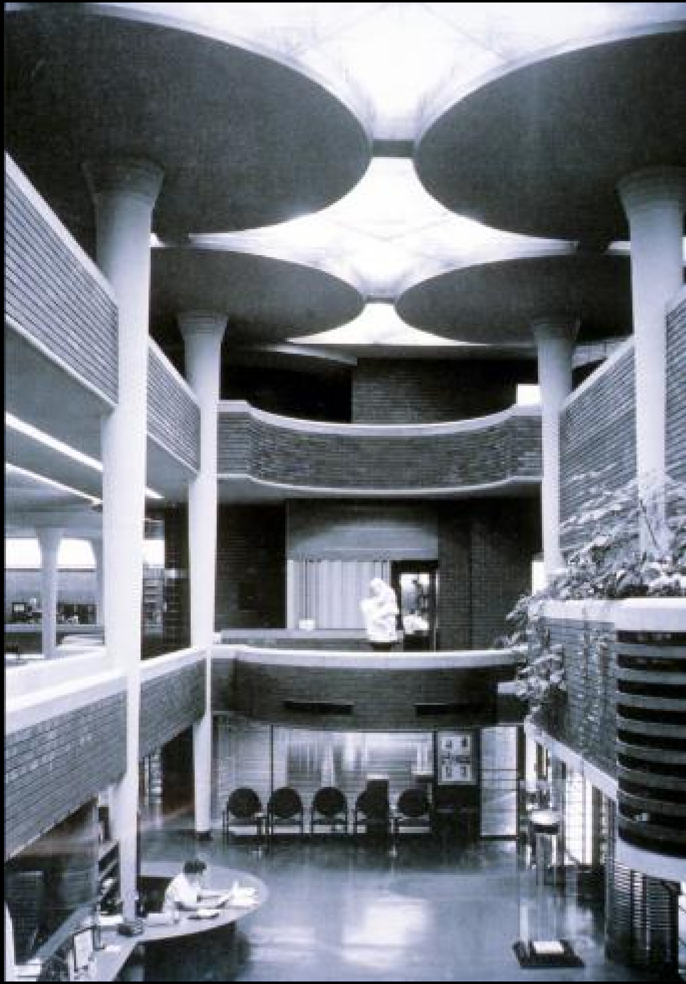



FIGURE 7.17 Model of Marina Towers in Chicago. Architects and engineers: Bertrand Goldberg and Associates. Consulting Engineers: Severud-Elstad-Krueger Associates. Foundation Consultants: Moran, Mueser and Rutledge and R. B. Peck. Sponsors: Building Service Employees International Union.

Marina Towers
Chicago, Illinois
Goldberg & Associates
1968

FIGURE 7.18 Marina Towers in Chicago during construction.

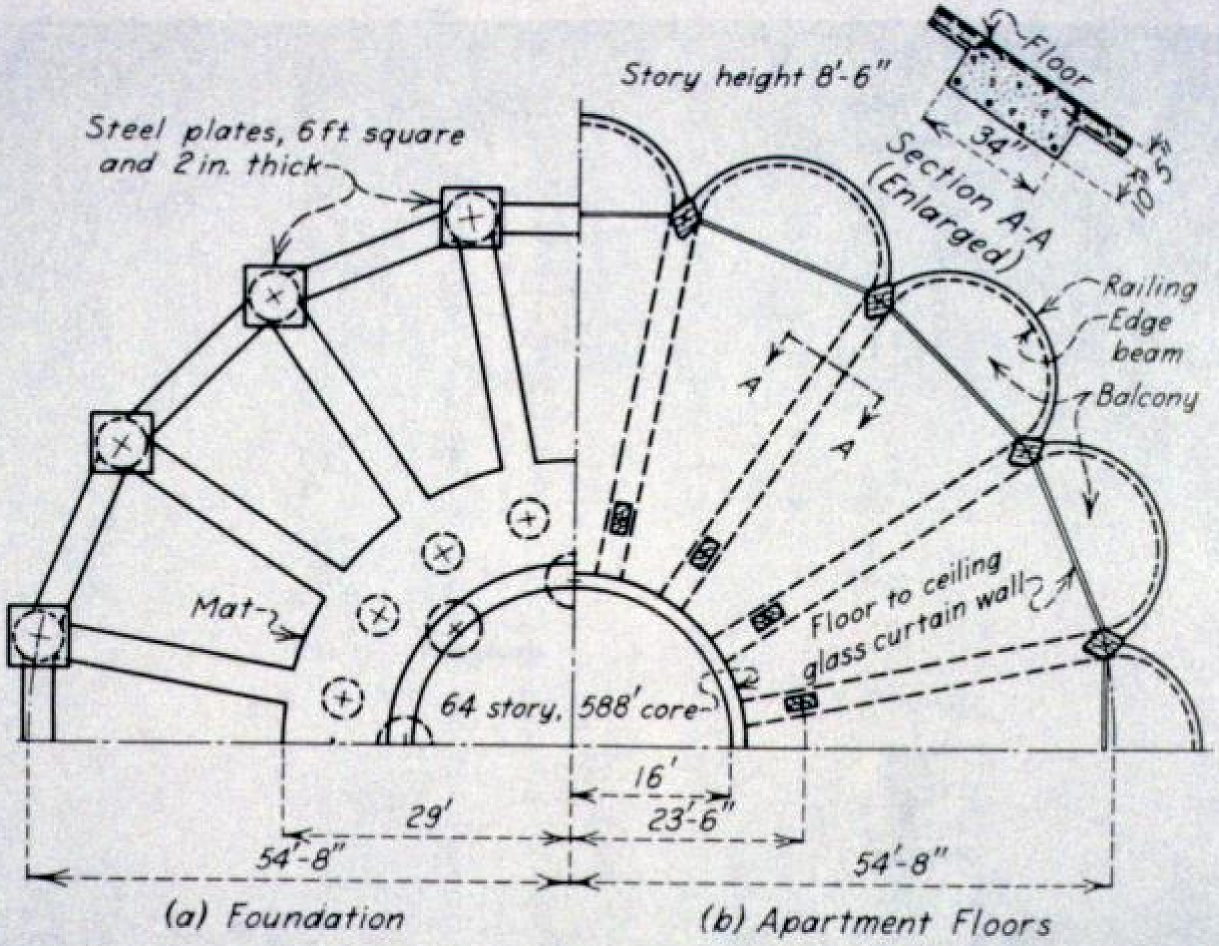
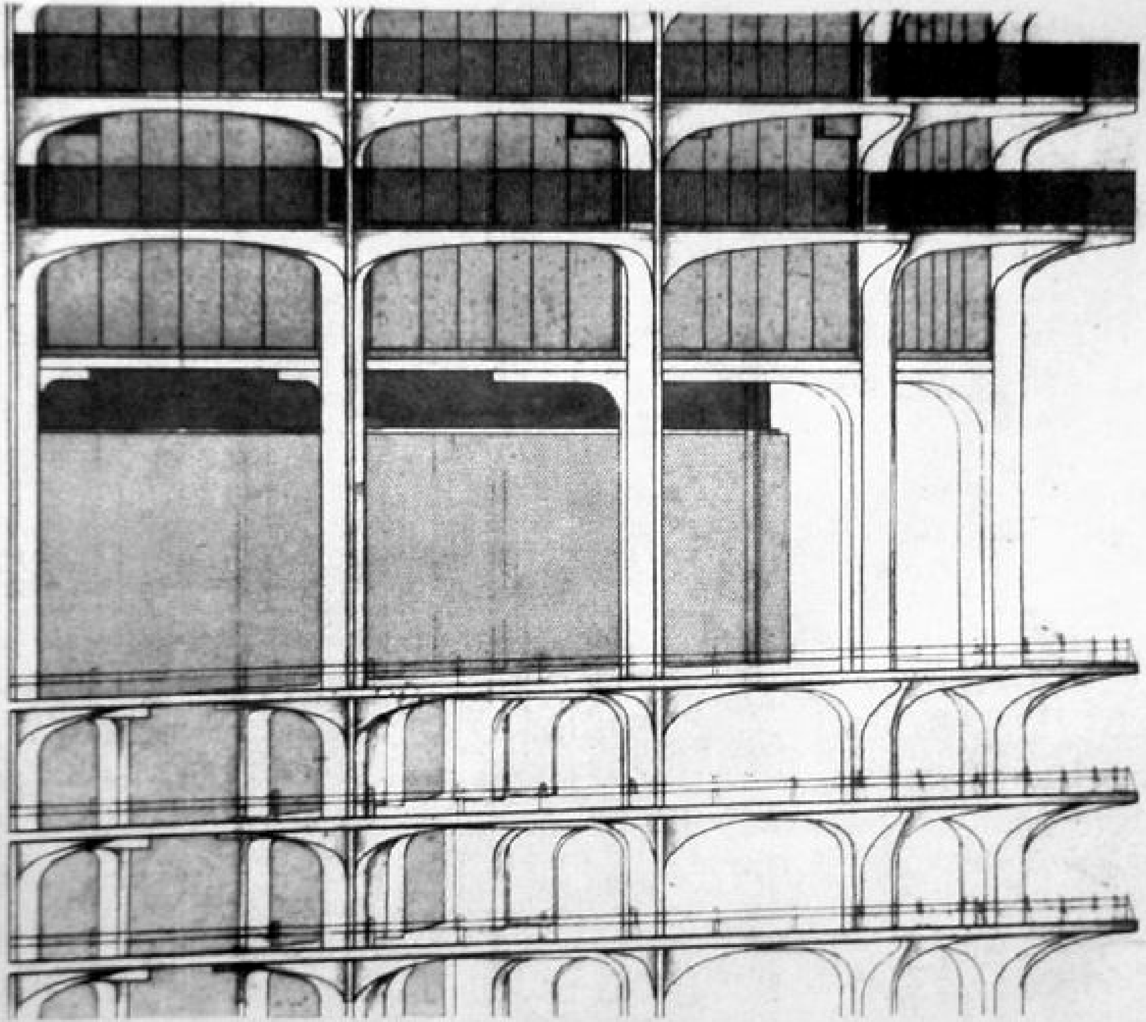
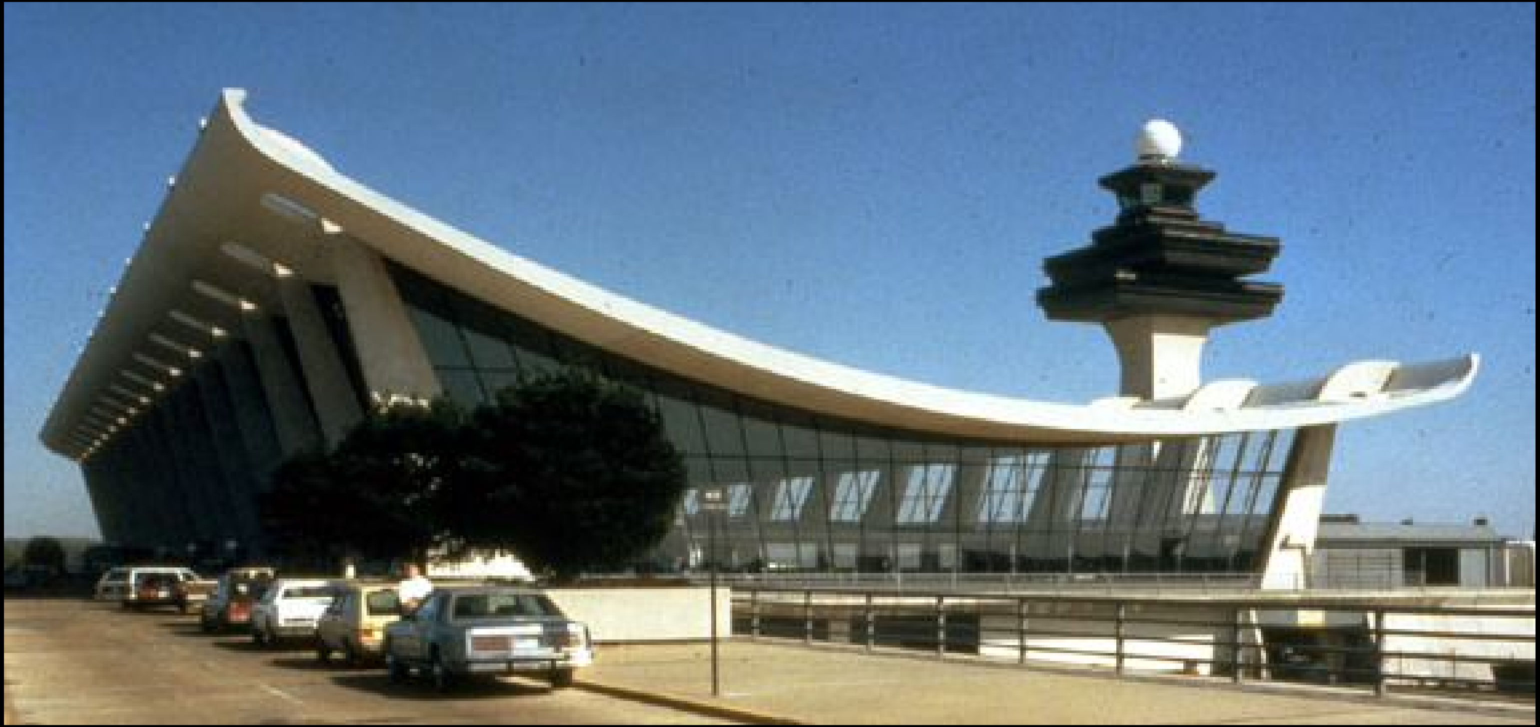


FIGURE 7.19 Partial plans of Marina Towers.

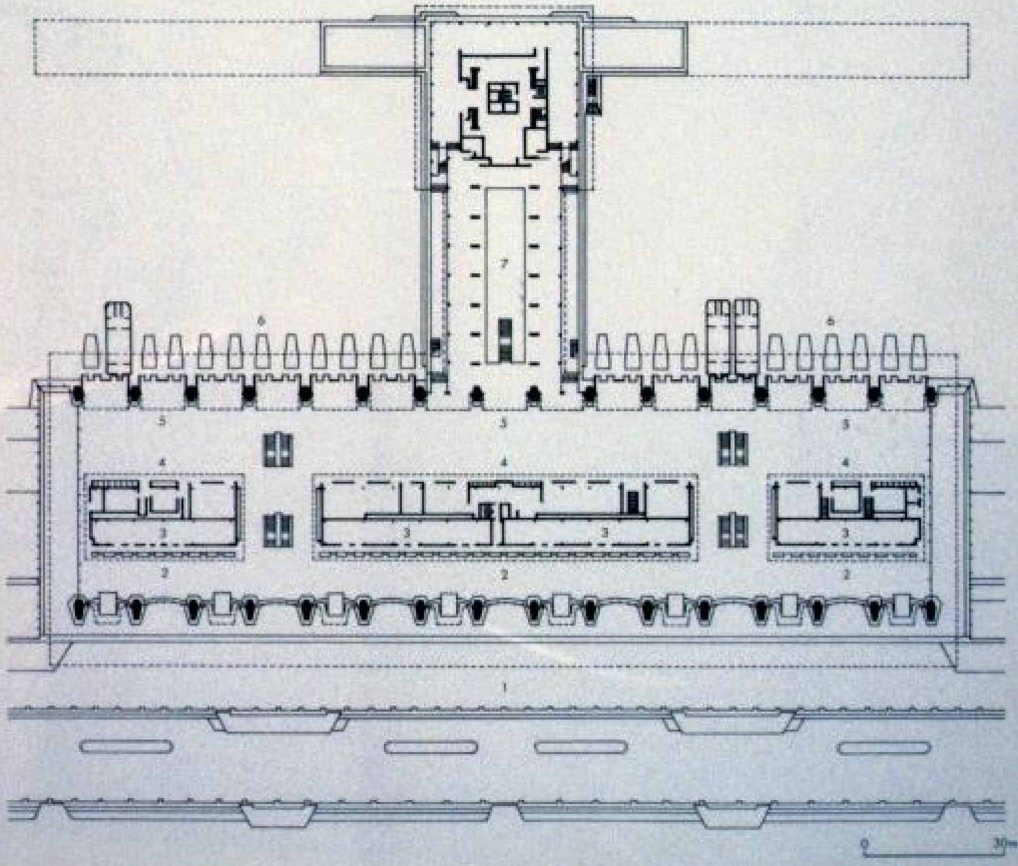


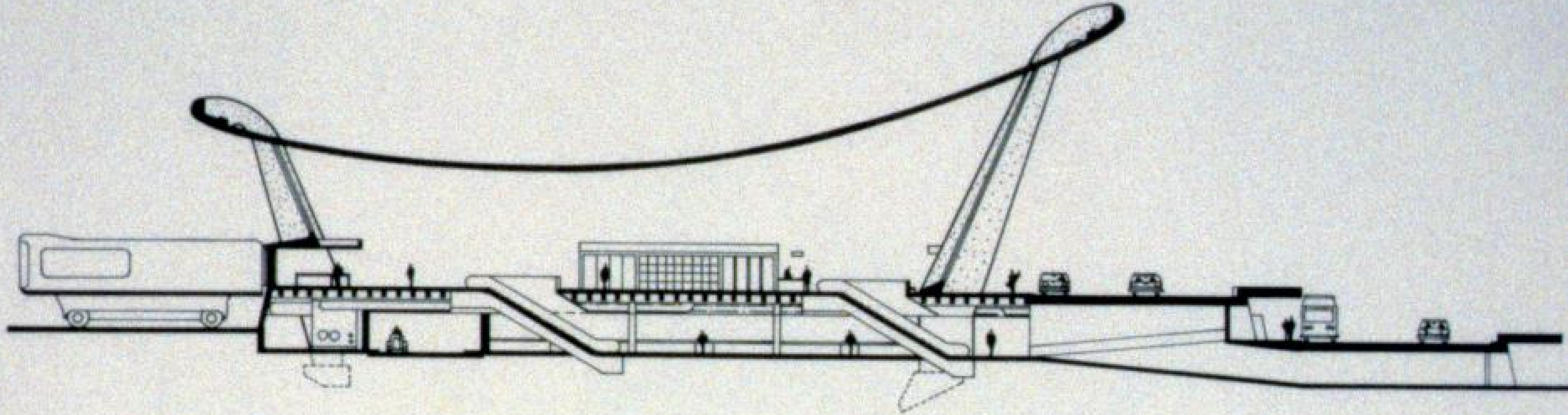

PUBLIC PARKING
MORNING SPECIAL
$9 75
MONDAY-FRIDAY
OPEN 24 HOURS
7 Days a Week
On State Street


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



Plan
1 Enplaning road
2 Ticketing
3 Offices
4 Concessions
5 Waiting area
6 Transporter docks
7 Concourse





Section






GAR-BRO

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


CURRENCY EXCHANGE

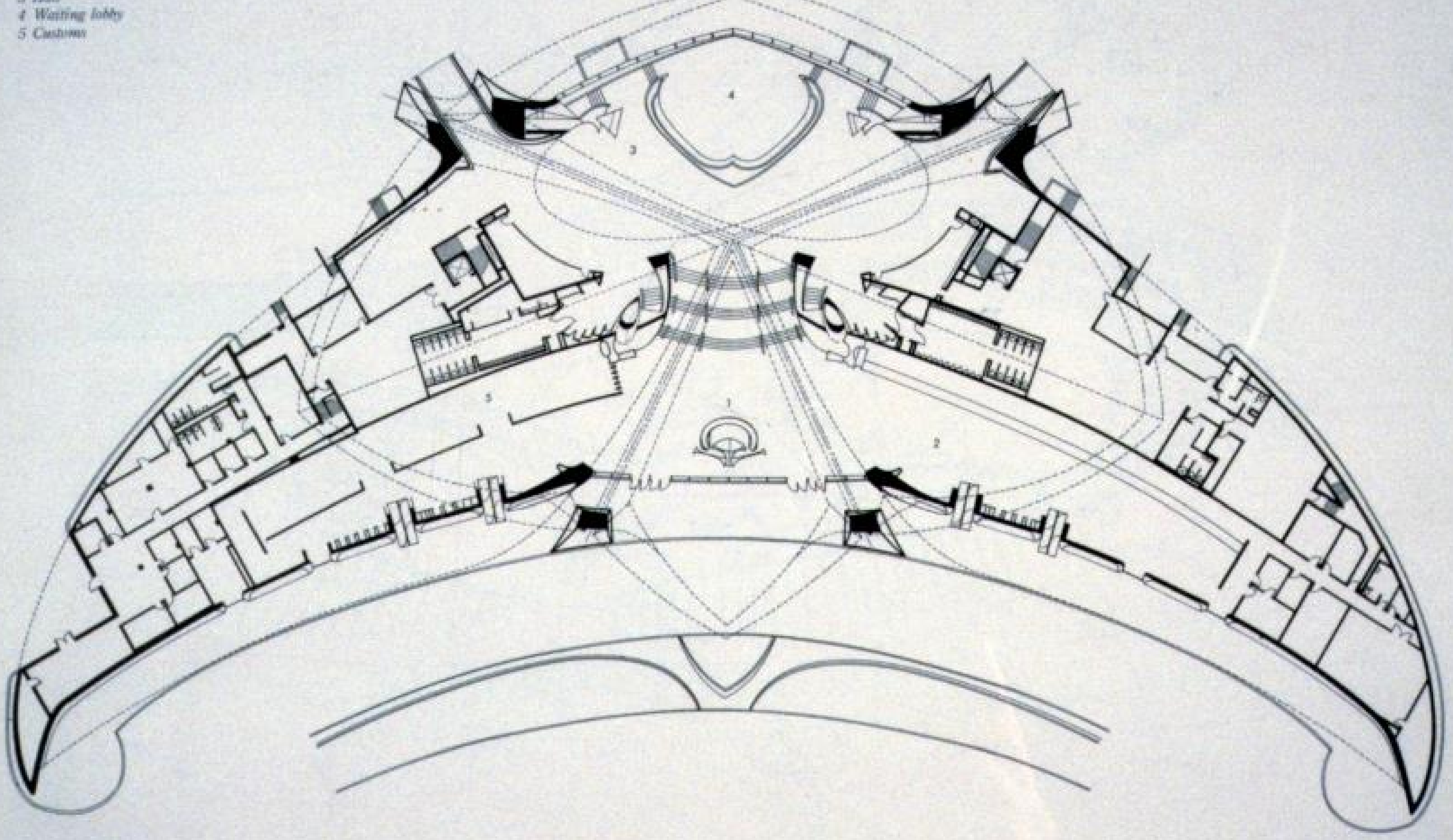

UNITED
UNITED
5

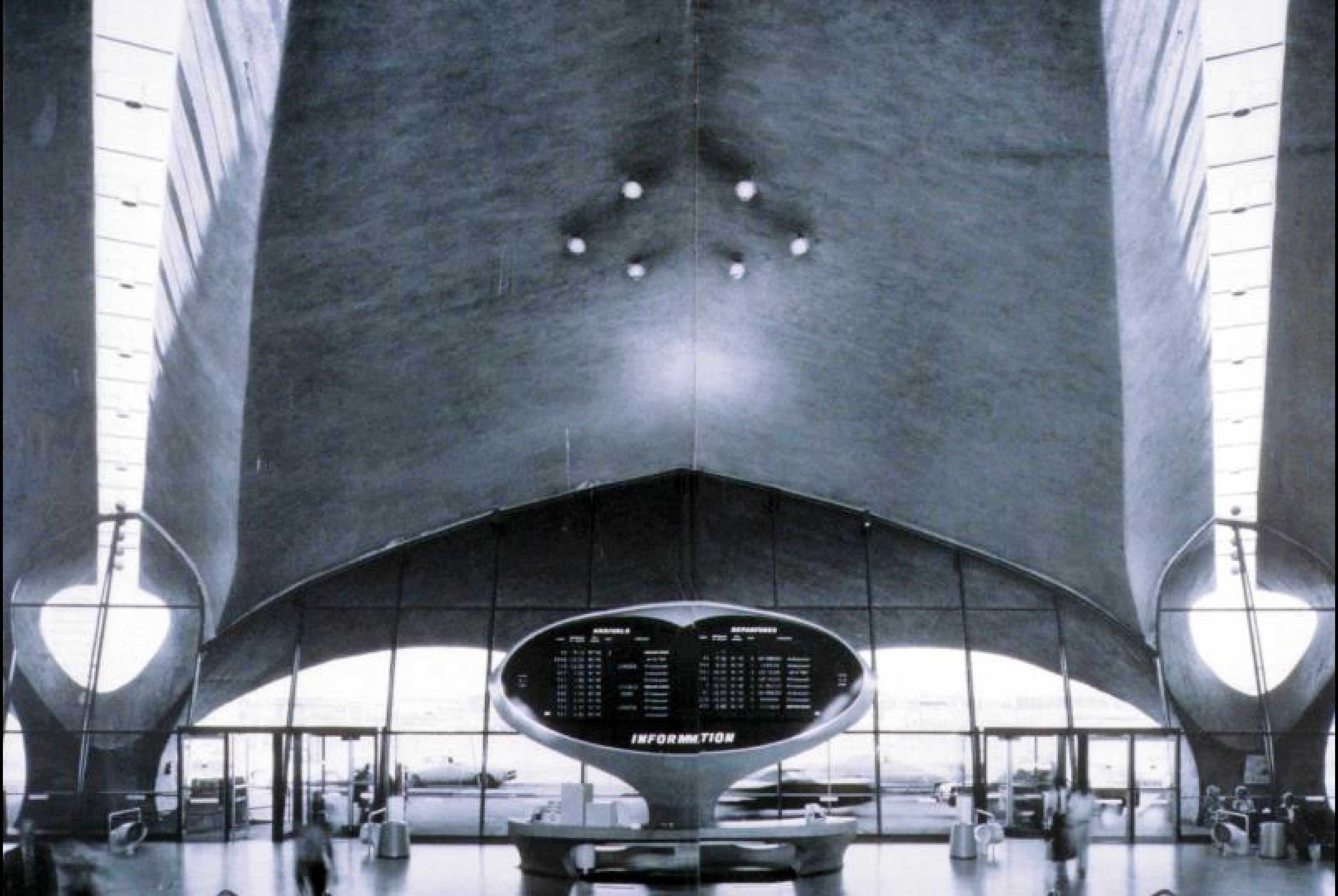

UNITED

TWA Flight Center
New York City, USA
Eero Saarinen
1962

Plan

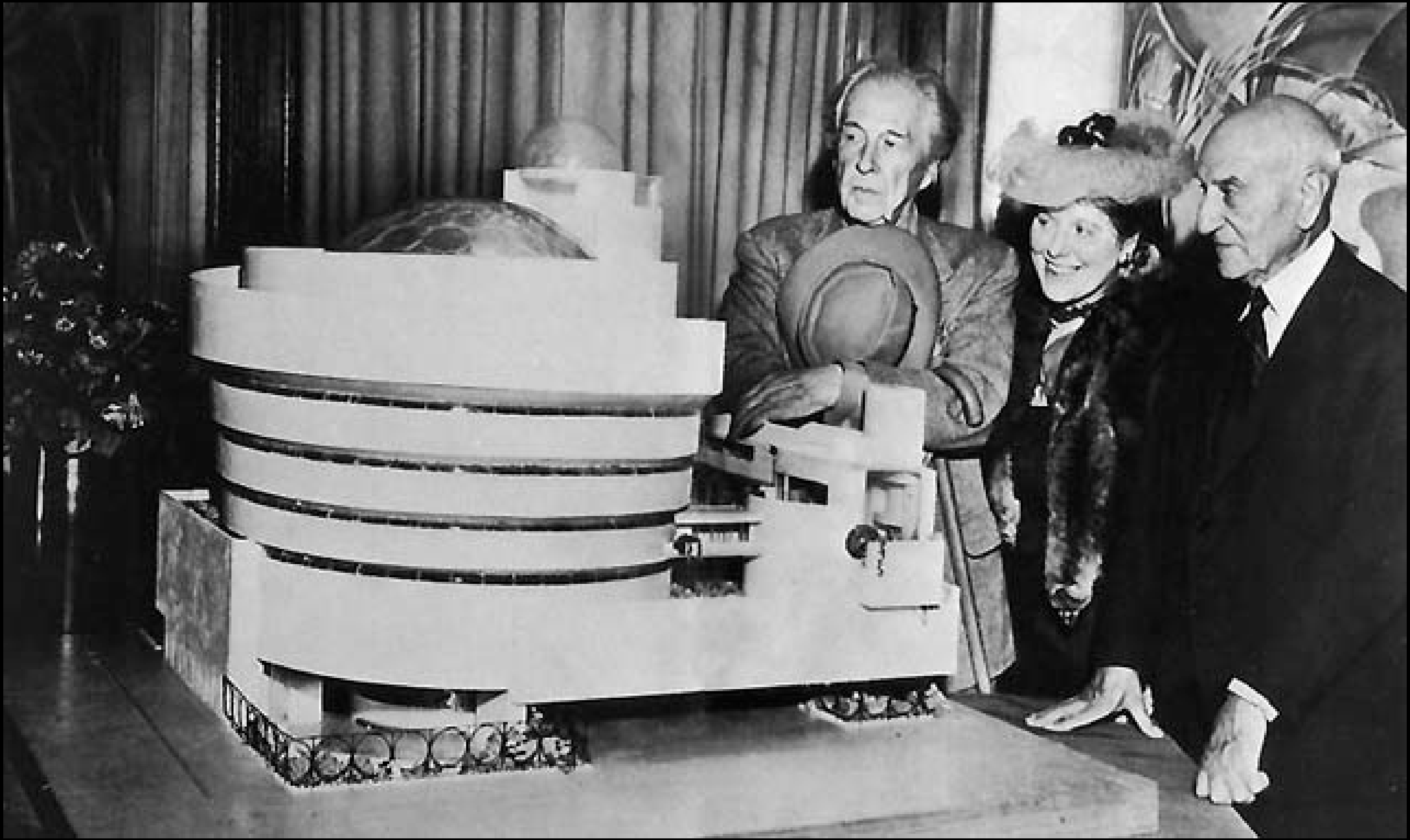
1 Information counter
2 Ticketing lobby
3 Hall
4 Waiting lobby
5 Customs



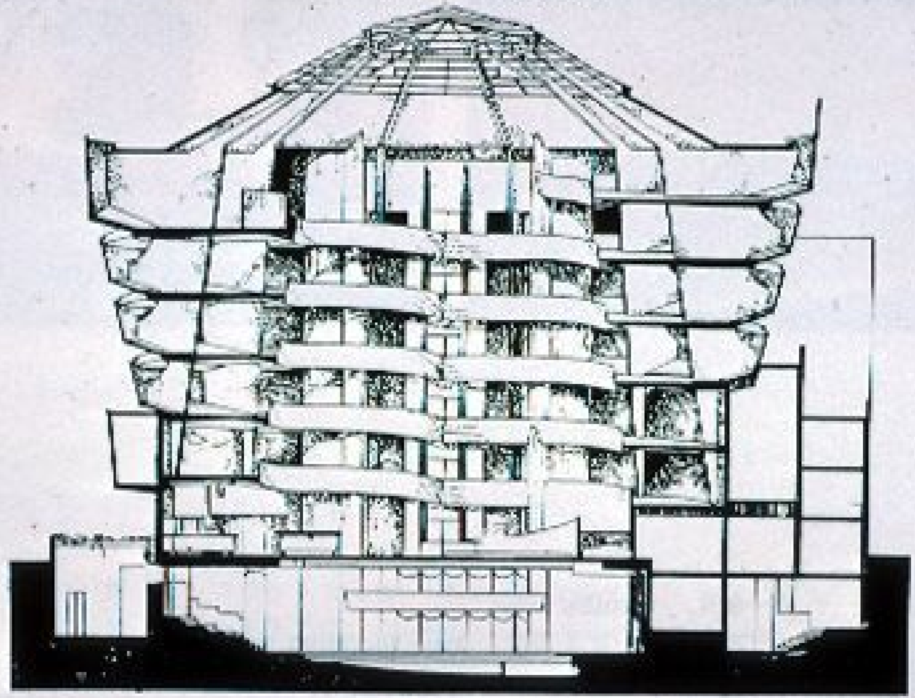

INFORMATION

Curves and Plastic Forms

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



5—断面図.　Section.



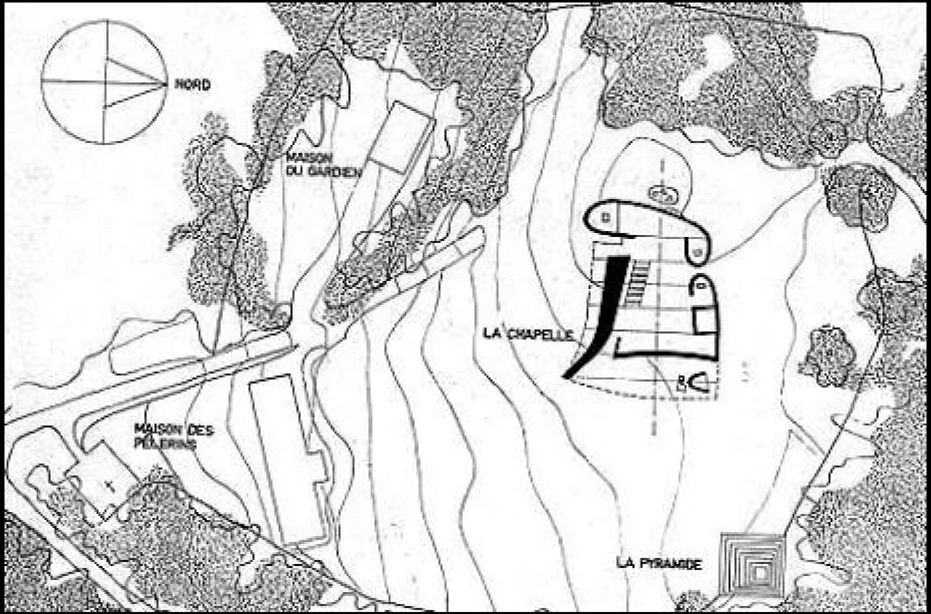


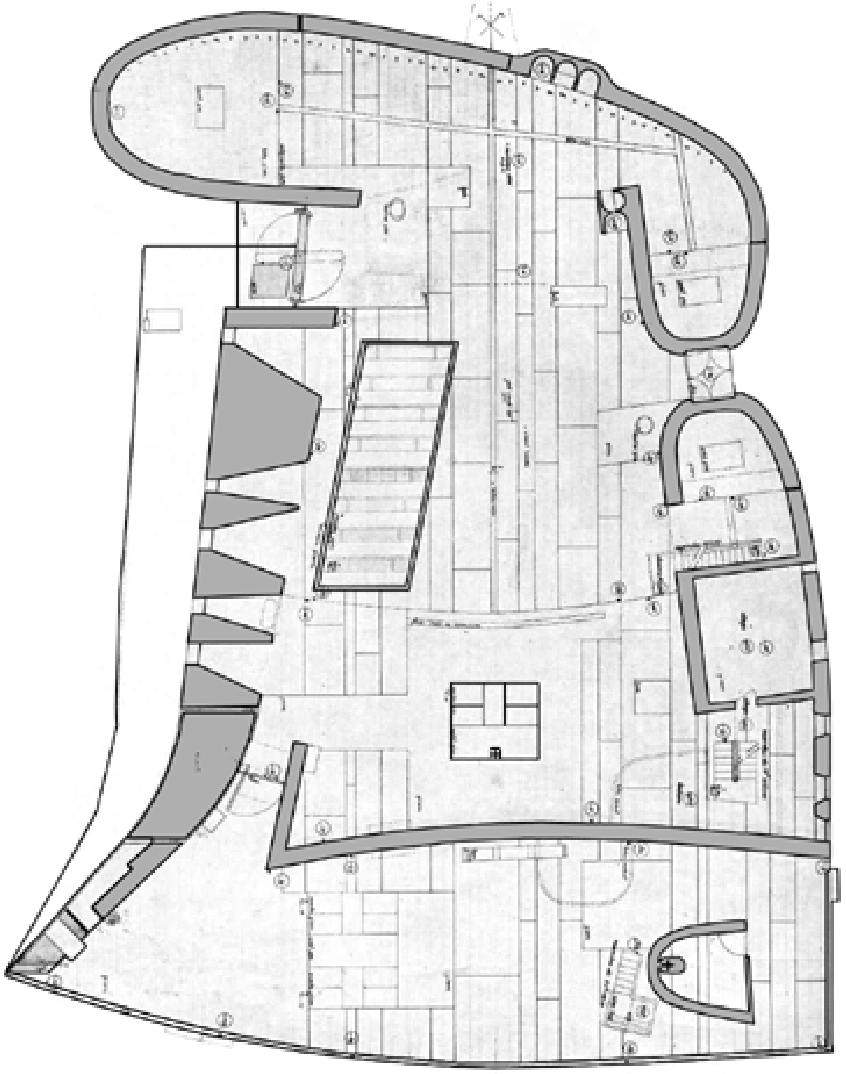
GUGGENHEIM



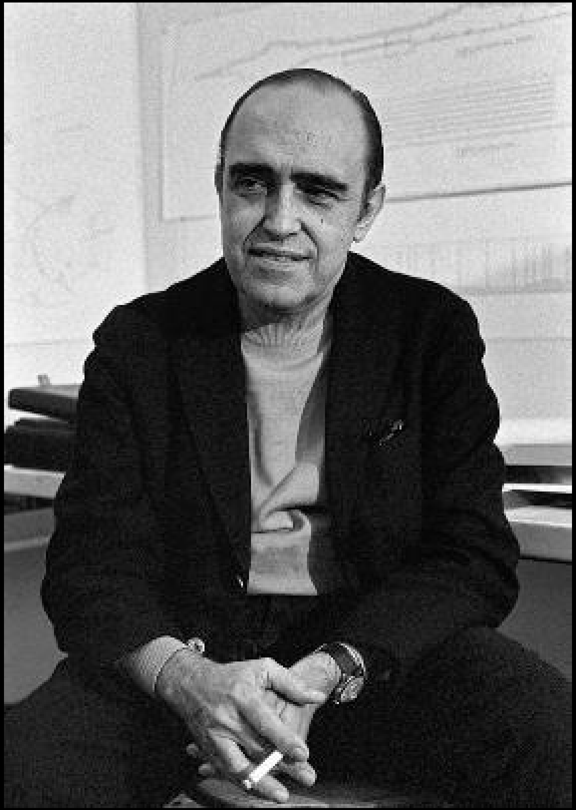


Chapelle Notre-Dame-du-
Haut de Ronchamp
Ronchamp, France
Le Corbusier
1955

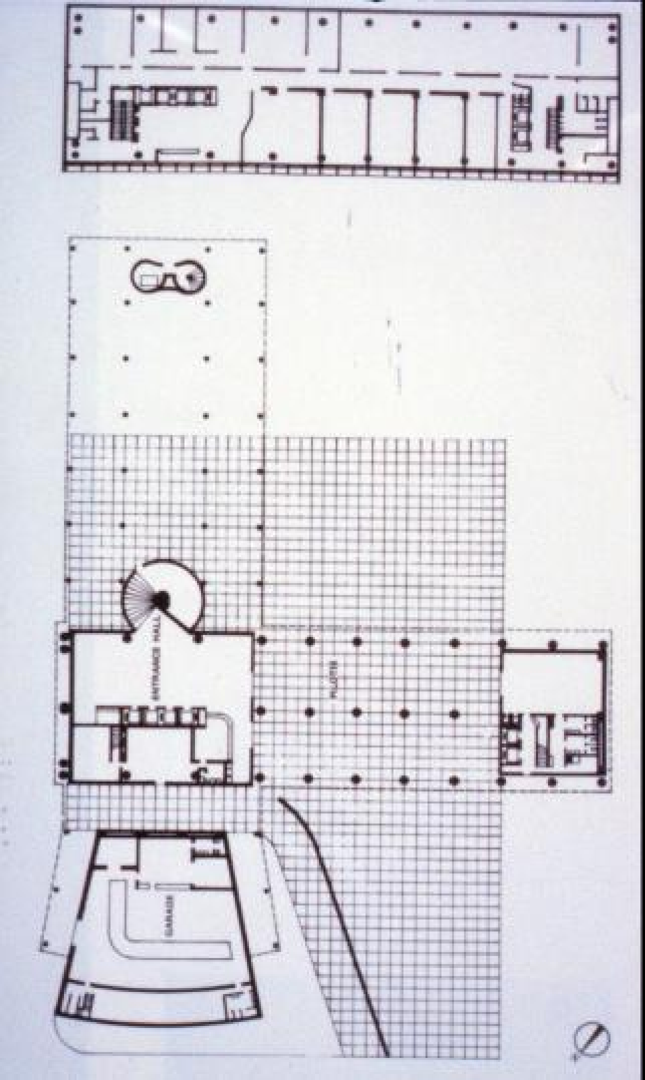

NORD
MAISON
DU GARDIEN
LA CHAPELLE
MAISON DES
PELERINS
LA PYRAMIDE







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



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

Cathedral of Brasilia
Brasilia, Brazil
Oscar Neimeier
1970


National Congress Building
Brasilia, Brazil
Oscar Neimeier
1960

Niterói Contemporary Art Museum
Niterói, Brazil
Oscar Neimeier
1996


Museu Oscar Neimeier
Curitiba, Brazil
Oscar Neimeier
2002

Auditório Ibirapuera
São Paulo, Brazil
Oscar Neimeier
2005

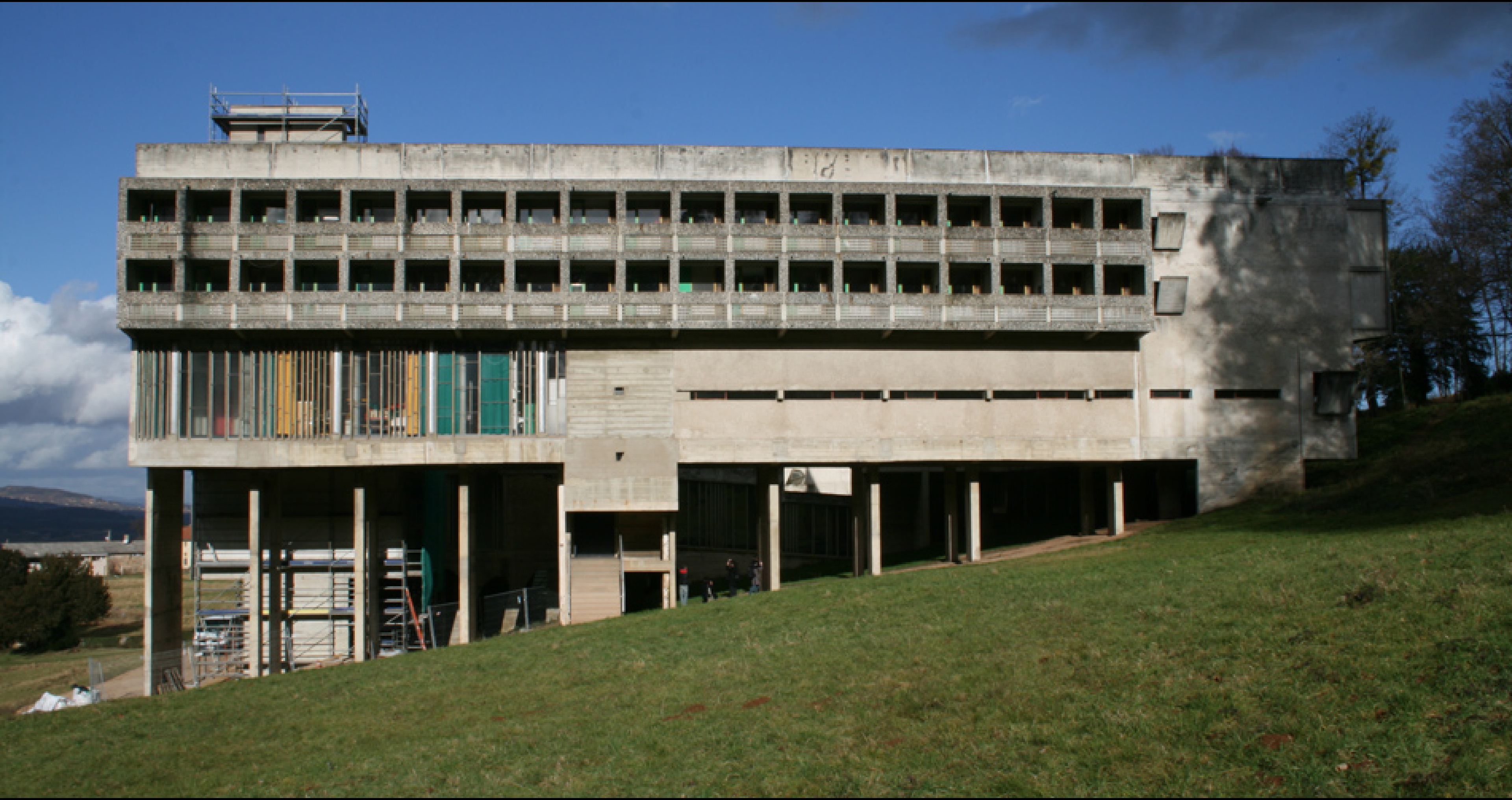
Brutalism

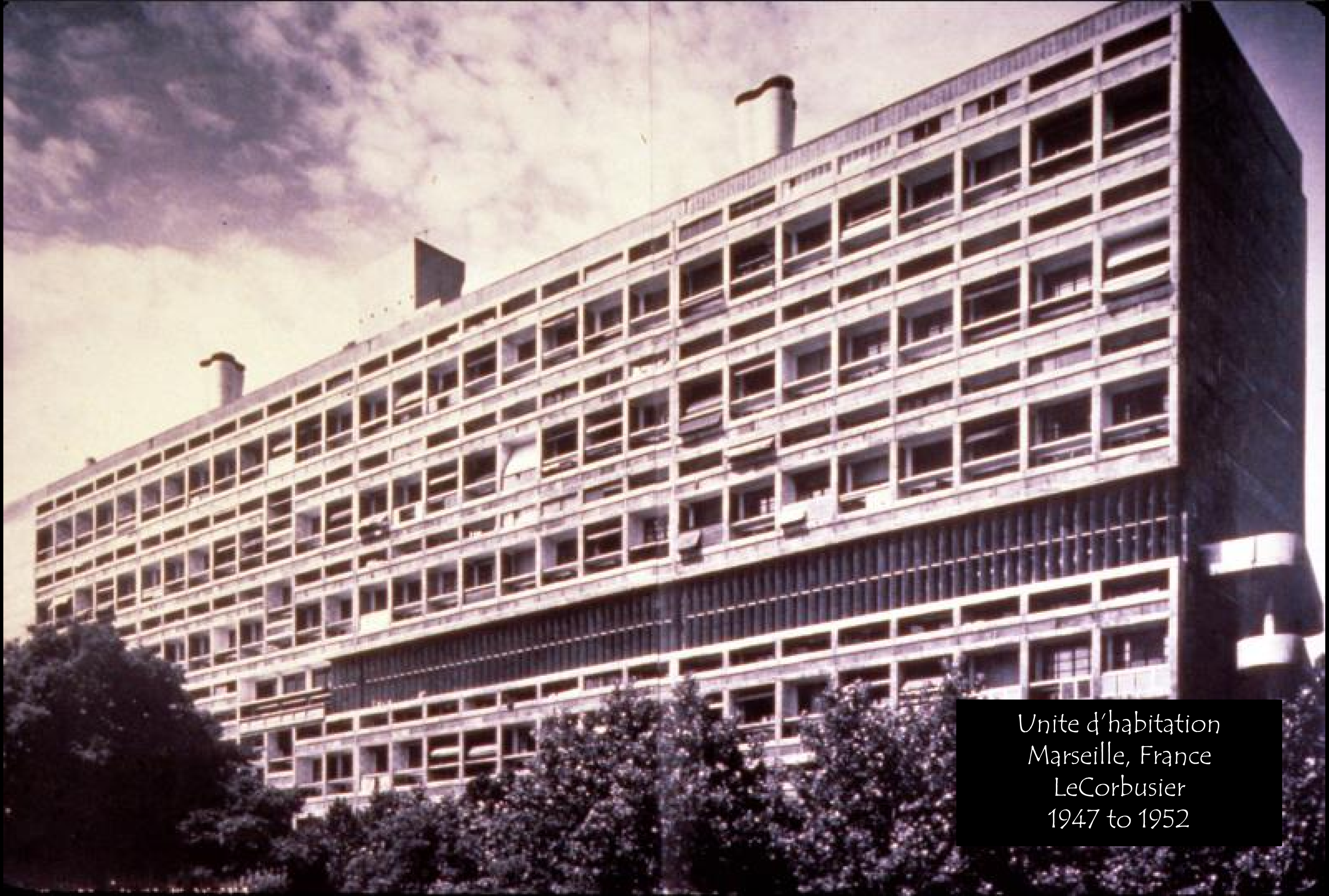
Maisons Jaoul
Neuilly-sur-Seine
Le Corbusier
1955





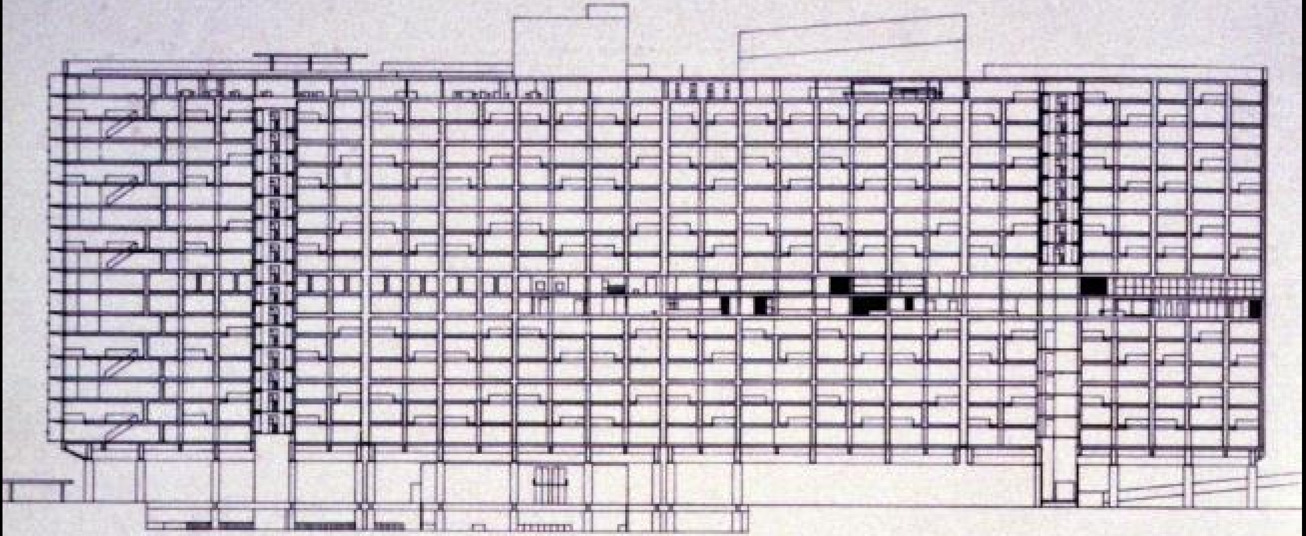
Sainte-Marie de La Tourette
Convent
Eveux, France
Le Corbusier
1960



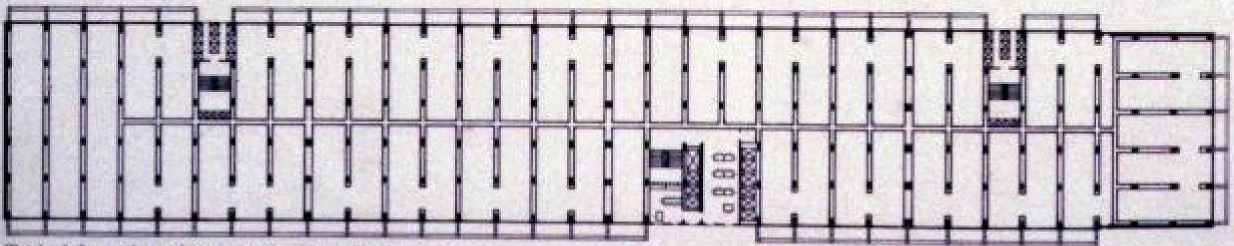



Unite d'habitation
Marseille, France
LeCorbusier
1947 to 1952

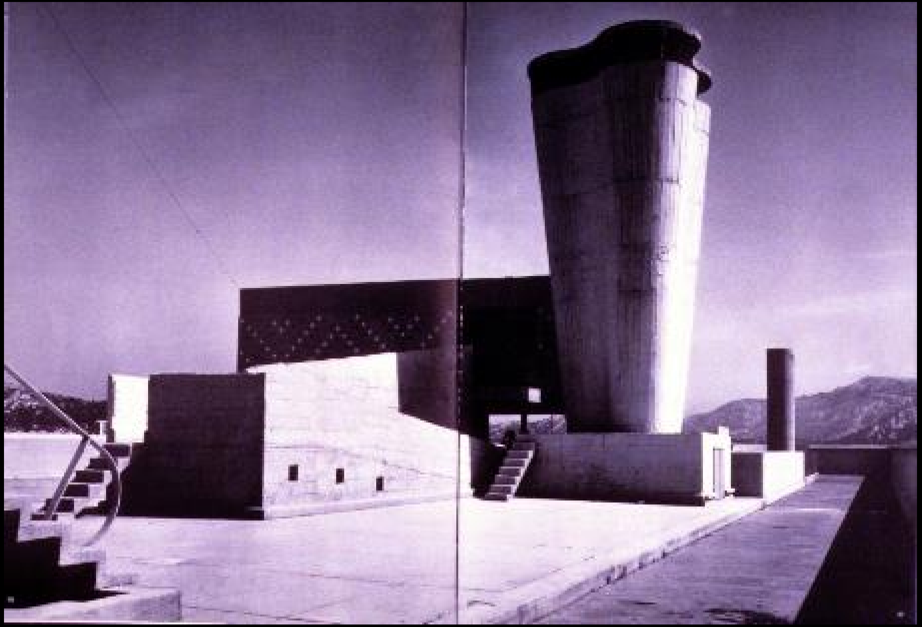
L'Unité d'habitation in Marseille



Long section looking west.



Typical floor plan of apartments, lower level.



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

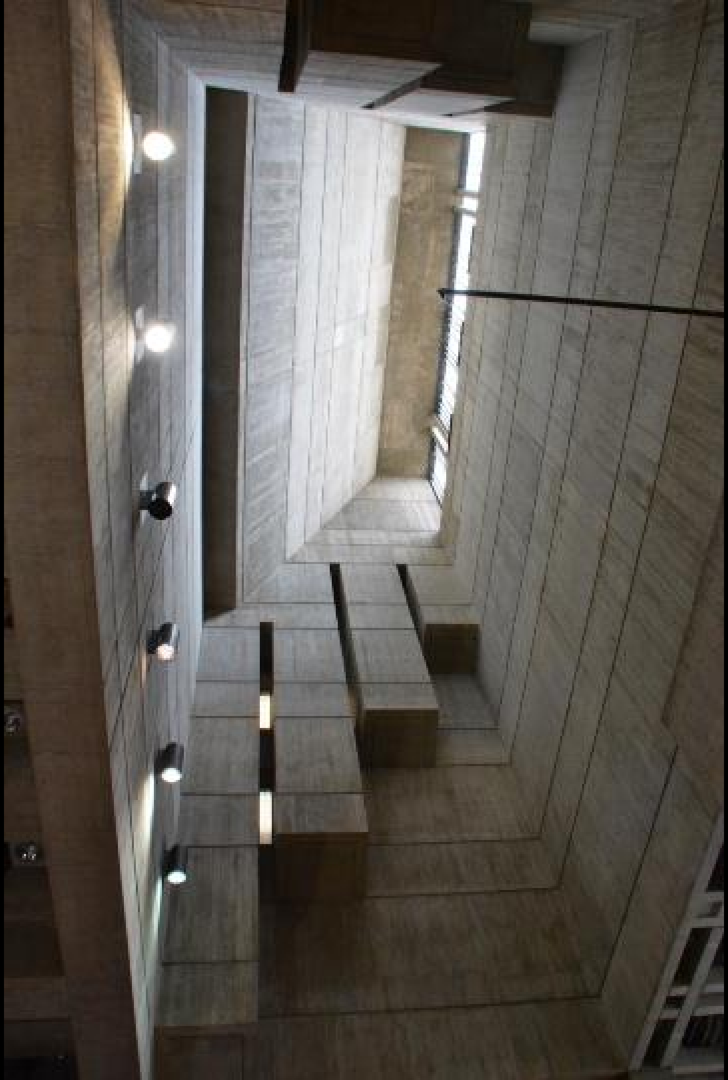


Reservierte
Parkplätze
45


SOLEIL
ESPACE
MERCURE

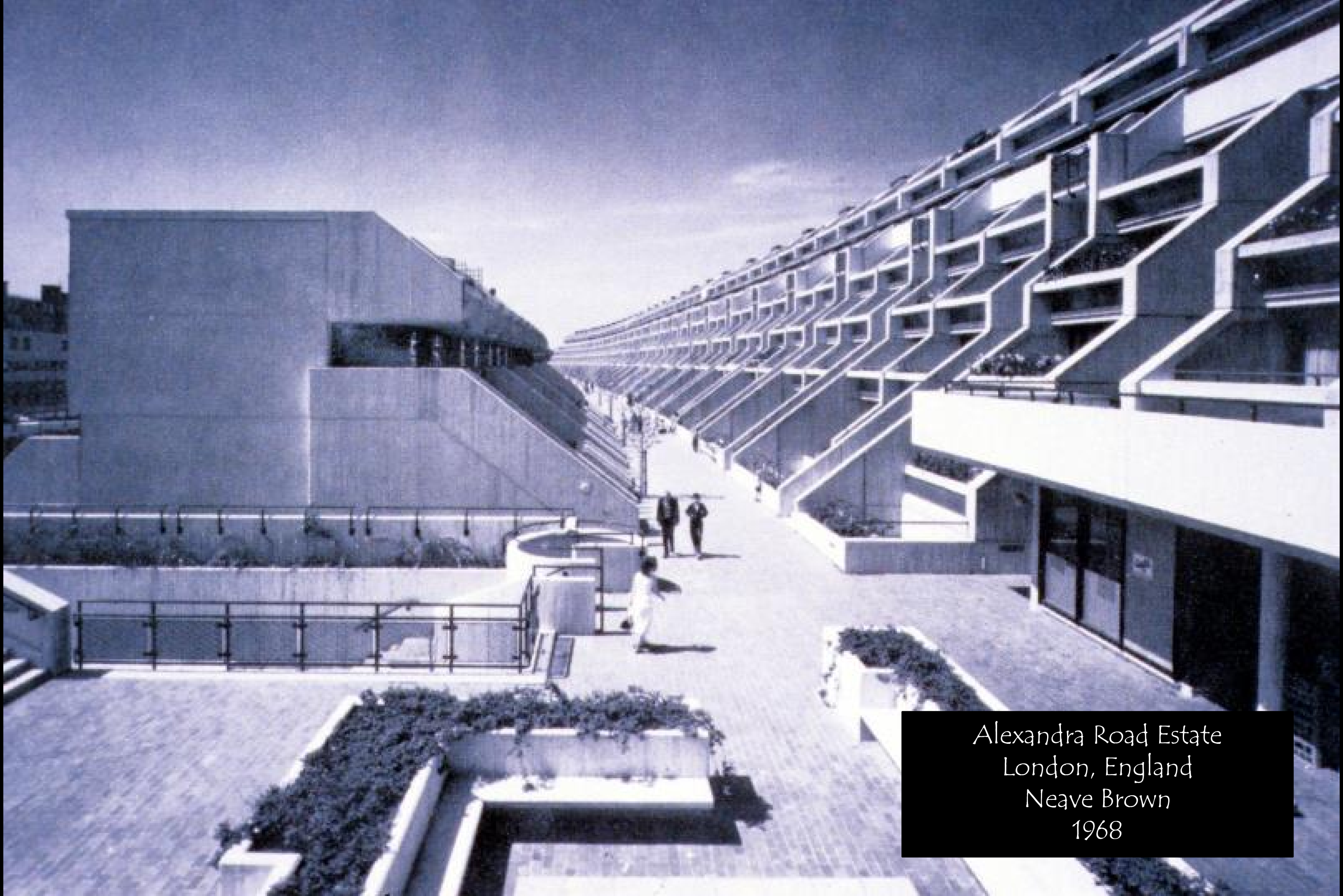
Carpenter Center for the Visual Arts
Harvard University, Massachusetts
Le Corbusier and
Guillermo Jullian de la Fuente
1962

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

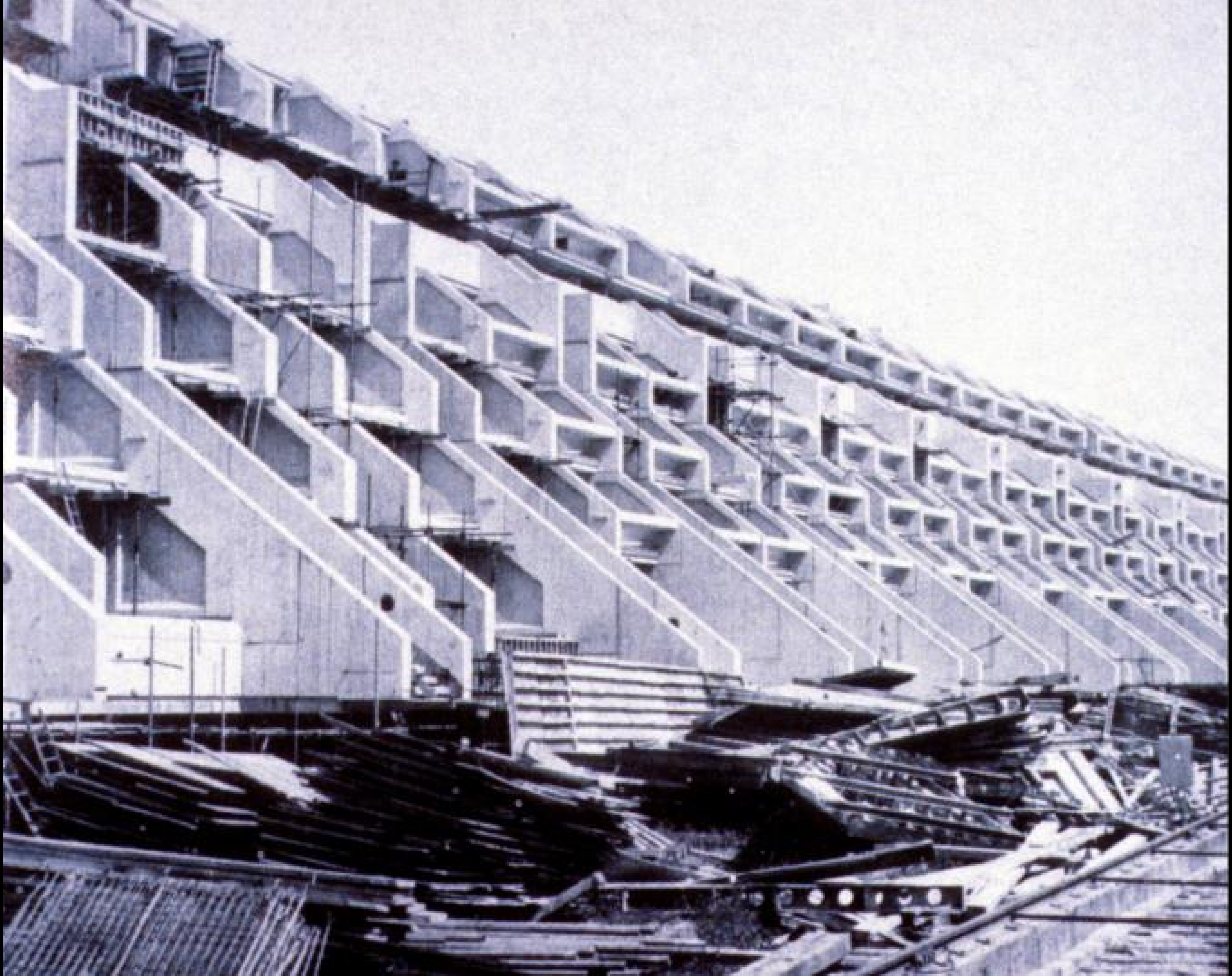




Math and Computer Building
University of Waterloo

Atelier 5
Swiss Architectural Firm



Alexandra Road Estate
London, England
Neave Brown
1968






Brunswick Centre
London, England
Patrick Hodgkinson
1967 to 1972


BRUNSWICK


theBRUNSWICK
SHOP, EAT, LIVE BLOOMSBURY


Trellick Tower
London, England
Erno Goldfinger
1972

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



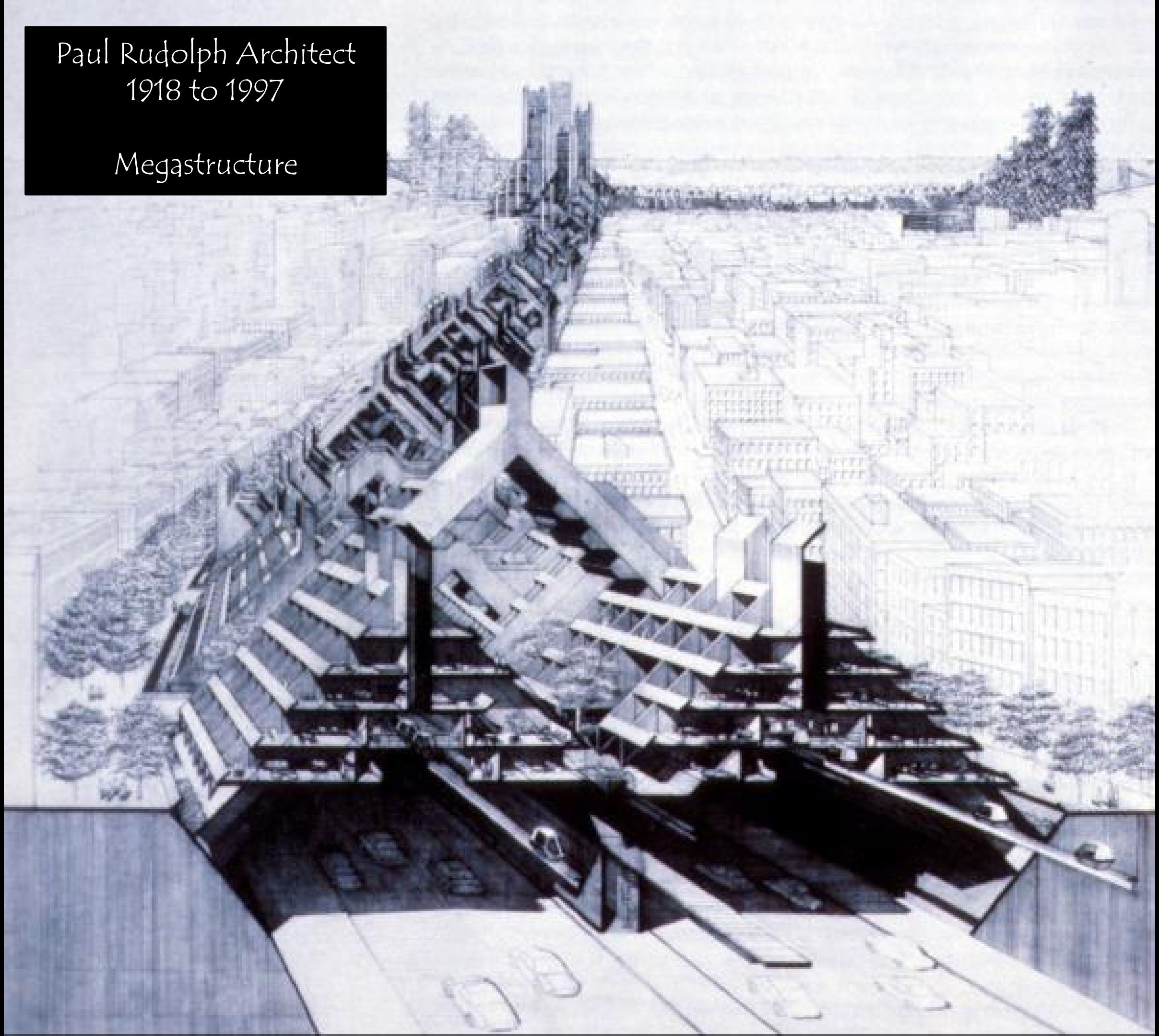
Wharfside
Point Nort


"A Clockwork Orange"
Film by
Stanley Kubrick

Thameshead Estate
London, England

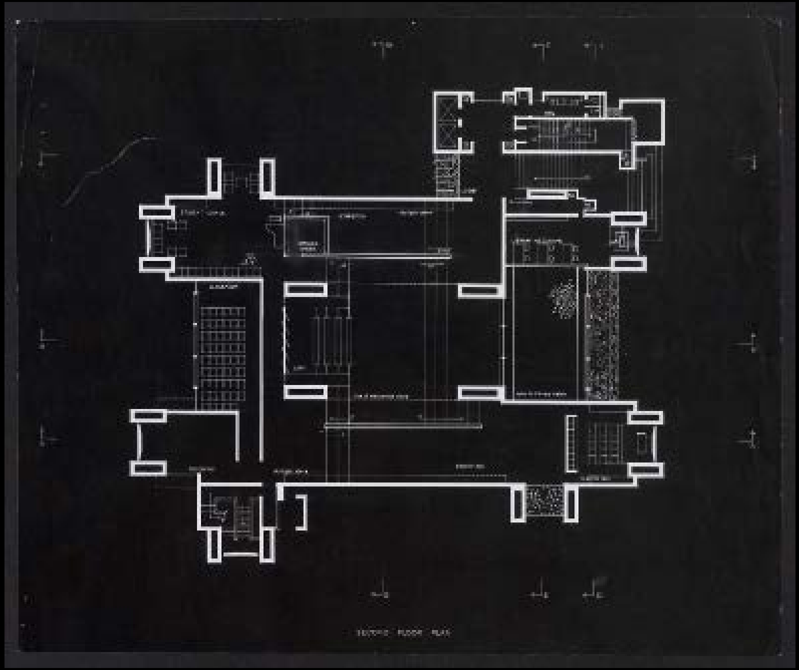
Paul Rudolph Architect
1918 to 1997

Megastructure

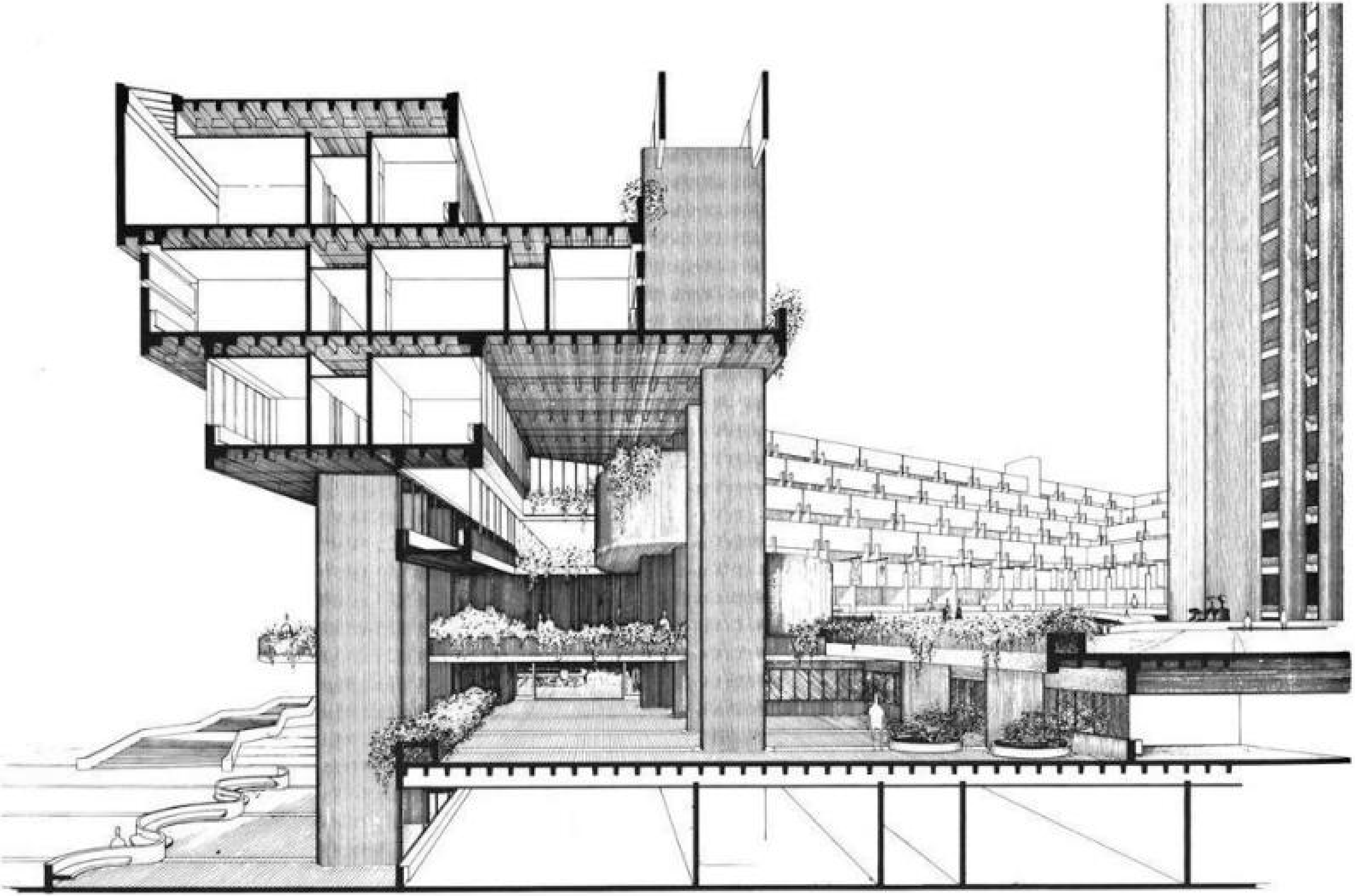


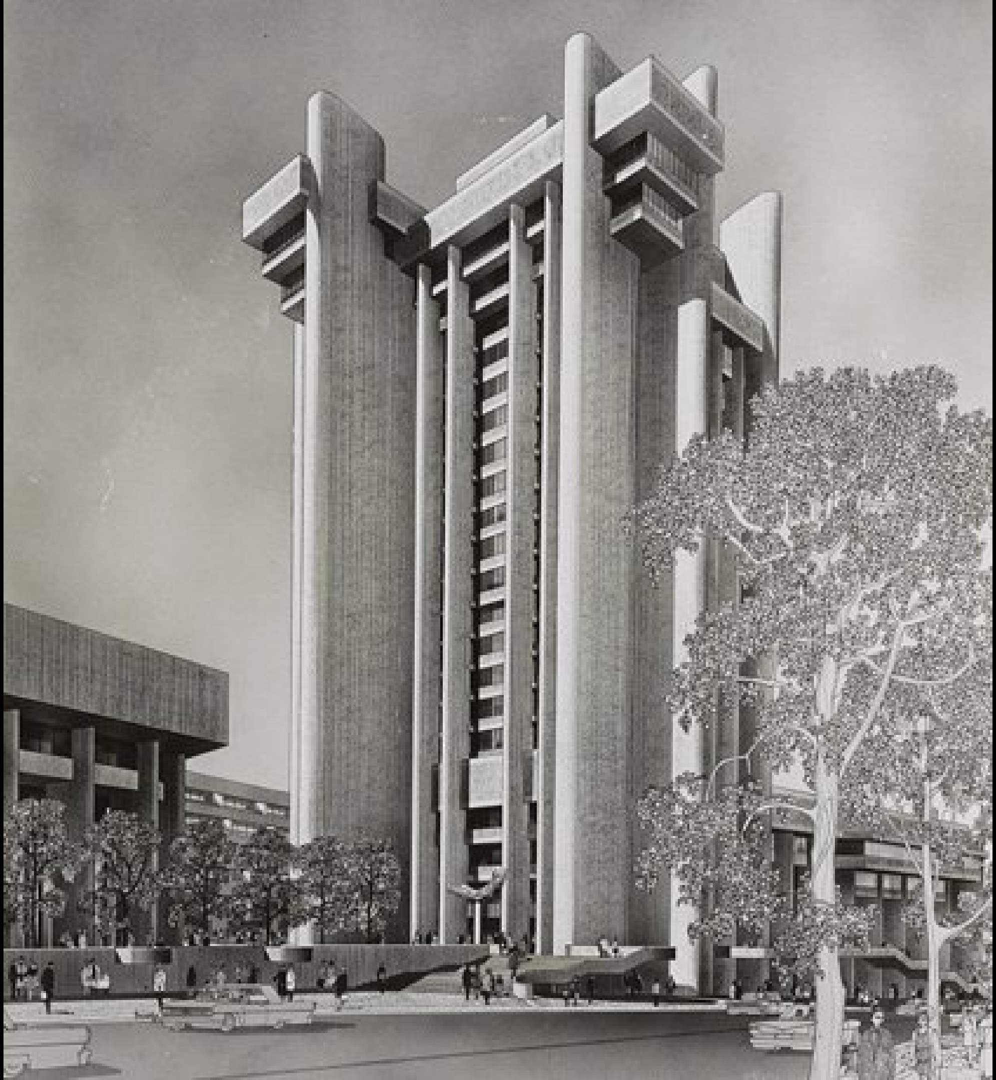
Yale Art and Architecture Building
New Haven, CN
Paul Rudolph
1963

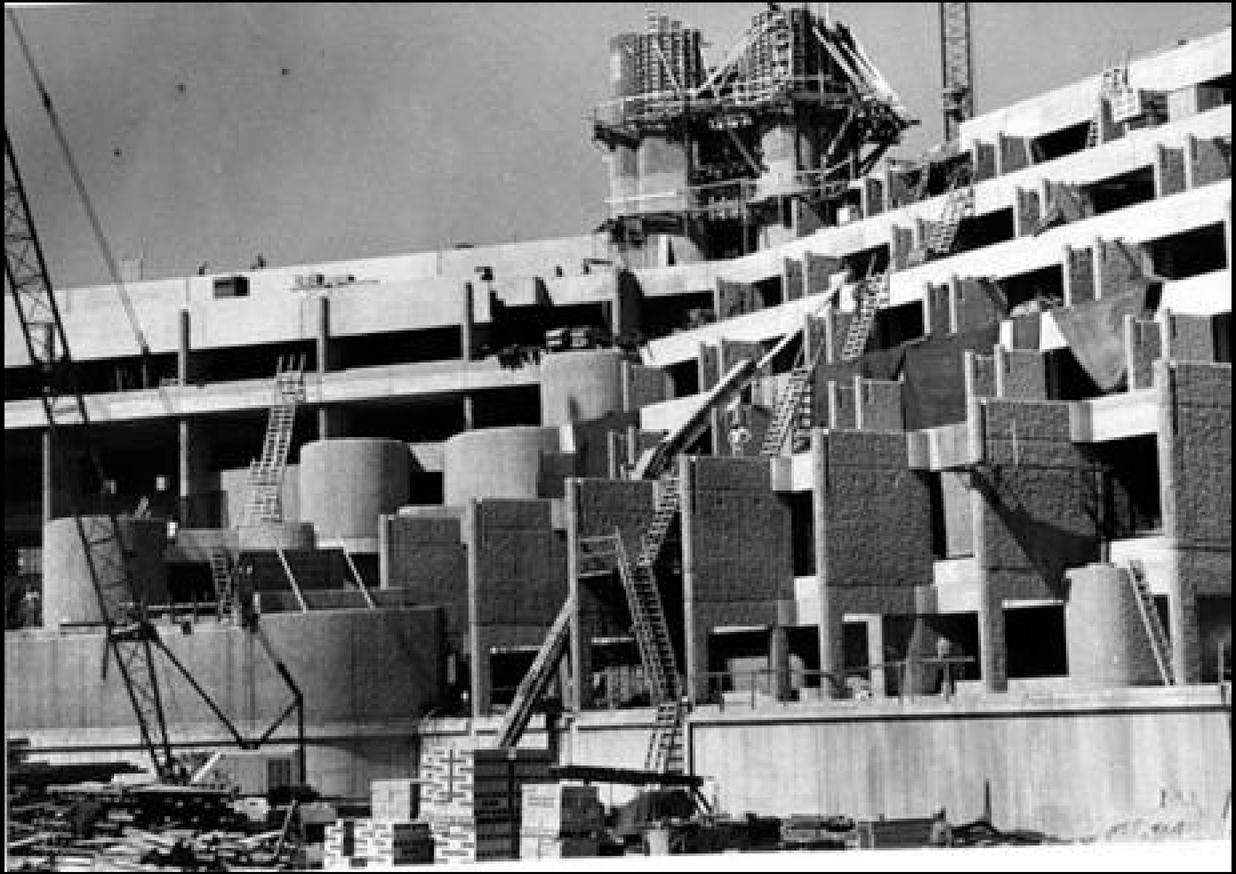
NEW HAVEN — It's hard to think of a building that has suffered through more indignities than the Yale School of Art and Architecture. On the day of its dedication in 1963, the architectural historian Nikolaus Pevsner condemned the oppressive monumentality of its concrete forms. Two years later the school's 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.



Erich Lindemann Mental Health Center
Boston, Massachusetts
Paul Rudolph
1971





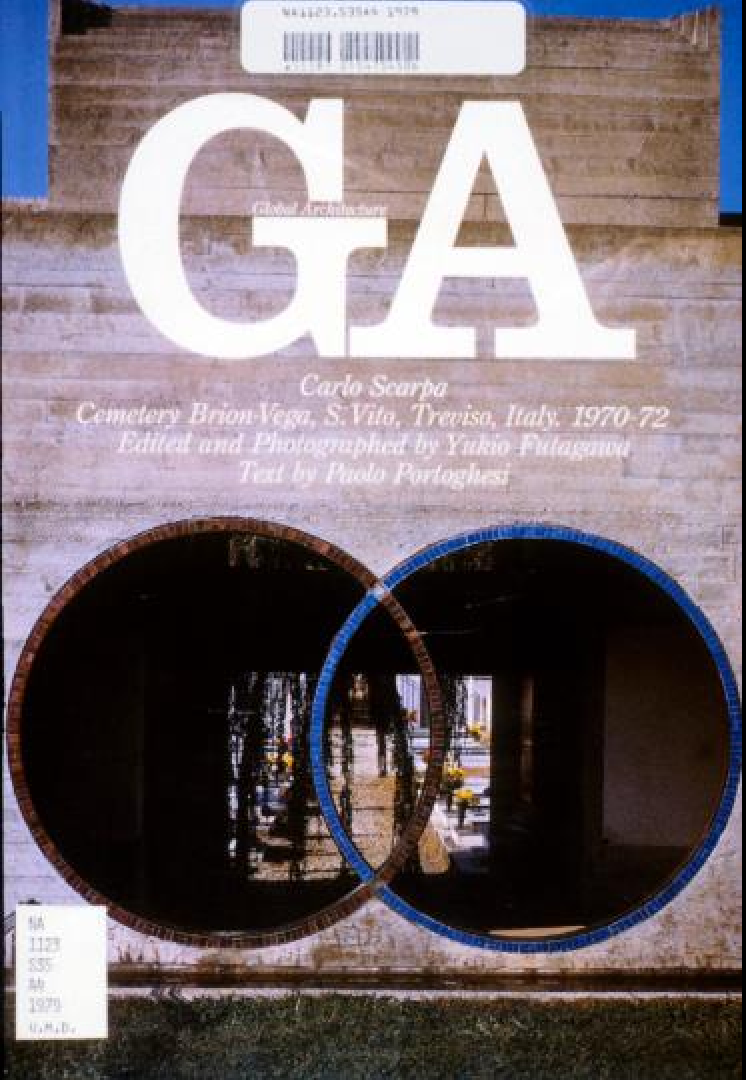


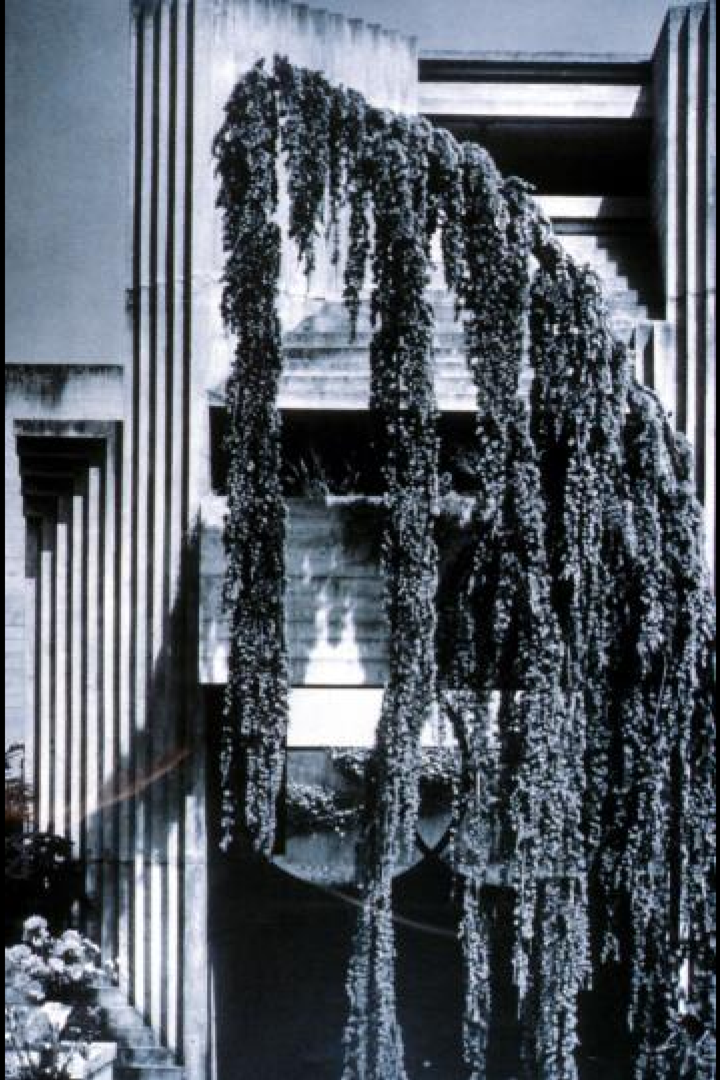
Place Bonaventure
Montreal, Quebec
Arcop
1967



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

University of Guelph
Guelph, Ontario
Circa 1970s





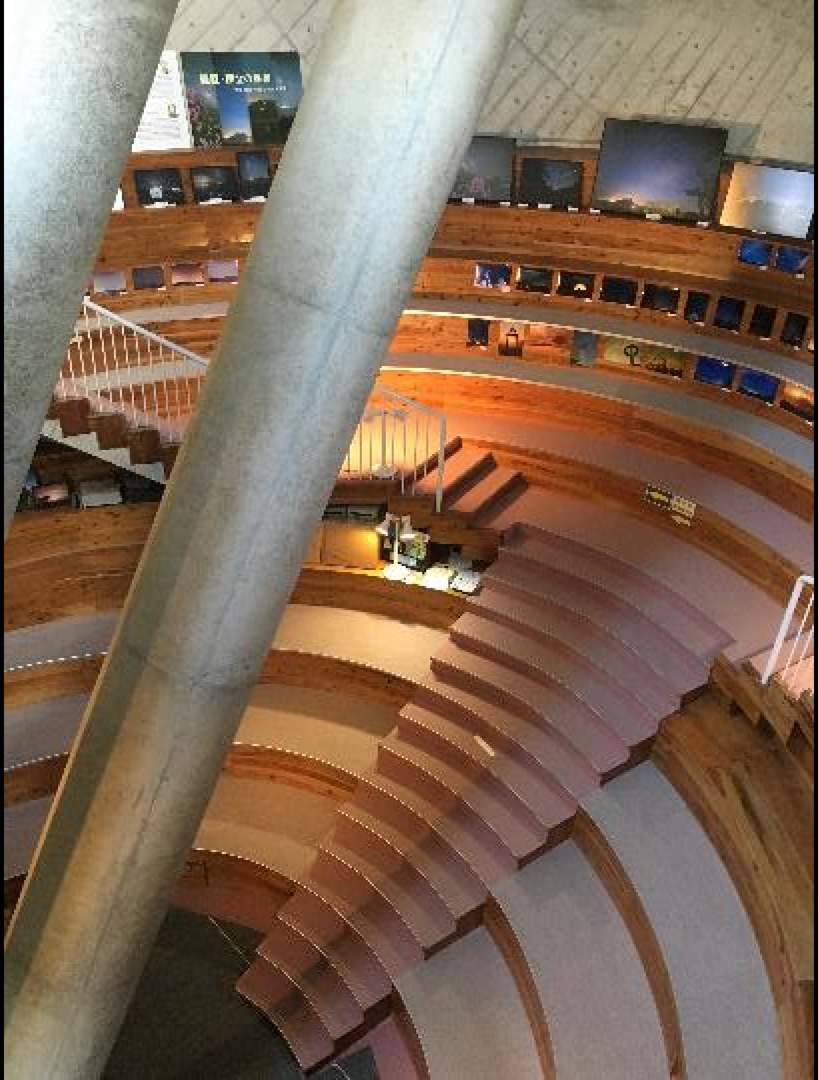
The Brion Cemetary
Treviso, Italy
Carlo Scarpa
1968


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
Kagoshima, Japan
Tadao Ando
1994

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

Tama Art University Library
Tokyo, Japan
Toyo Ito
2012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文化力

Expo '98 Portuguese National Pavilion
Alvaro Siza Vieira

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

Best of 2019

Concrete: the most destructive material on Earth

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