ARCHITECTURE

THE JOY OF BRIDGE BUILDING

Wednesday March 10, 2021

Morten Lund

BRIDGES ARE COMPLEX DESIGN:
PRIMARELY STRUCTURAL, WITH LANDSCAPE,
PRODUCT, URBAN...

RECOGNISE THE REQUIREMENTS: ALIGNMENT, CLEARANCE, LOAD, CONSTRUCTION, OPERATION...

DESIGN WITH FORCES IN SPACE !

IDENTIFY THE LOAD,
CHOOSE THE MATERIAL,
UNDERSTAND THE FOUNDATION

SPREAD THE FORCES EVENLY
ALL OVER THE MATERIAL BY
GIVING SHAPE TO THE BRIDGE

AIMING AT SUSTAINABILITY: POSSIBLY MAXIMUM SPAN WITH MINIMUM VOLUME OF MATERIAL

BENDING
COMPRESSION
TENSION

AVOID BENDING TO CARRY LOAD
bend a stick across your knee
and it will easily break

COMPRESSION TAKES MORE LOAD
push the stick harder along
and it will first buckle and then break

BUT TENSION IS MOST EFFICIENT
pull the stick along,
and it is almost impossible to break

BEAM BRIDGES
WORK IN BENDING
TYPICAL SPANS: < 200 METERS
SIMPLE SUPPORTS

ØRESUND BRIDGE, DENMARK-SWEDEN

ARCH BRIDGES
WORK IN COMPRESSION
TYPICAL SPANS: < 500 METERS
MORE COMPLICATED SUPPORTS

FREMONT BRIDGE, PORTLAND, OREGON

SUSPENSION BRIDGES
WORK IN TENSION
TYPICAL SPANS: < 2000 METERS
VERY DEMANDING SUPPORTS

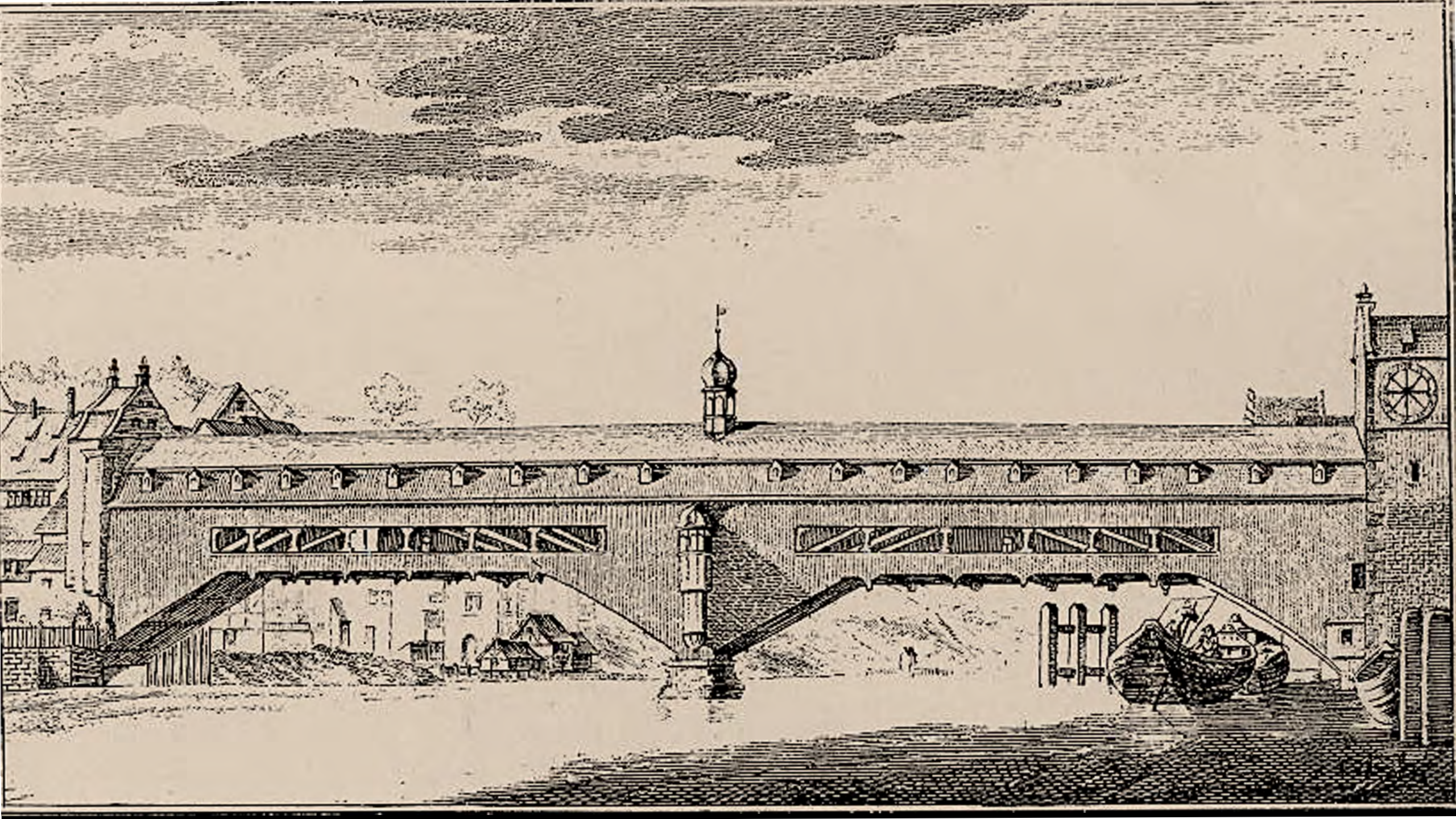
GREAT BELT BRIDGE, DENMARK

WOODEN BRIDGES

A wooden bridge
can be a cheap alternative
to arched stone bridges,
however, they come with a shorter life span.
Stone bridges are more durable,
they are traditionally constructed
on a scaffolding structure of wood,
yet another bridge that are disposed after use.

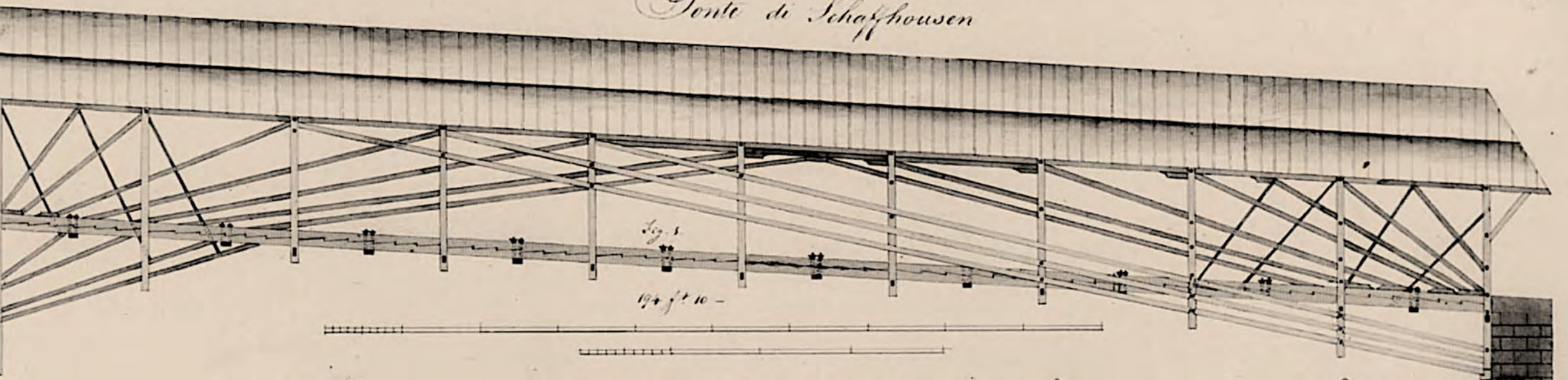
RHEINBRÜCKE SCHAFFHAUSEN
2 x 60m span
1758-99

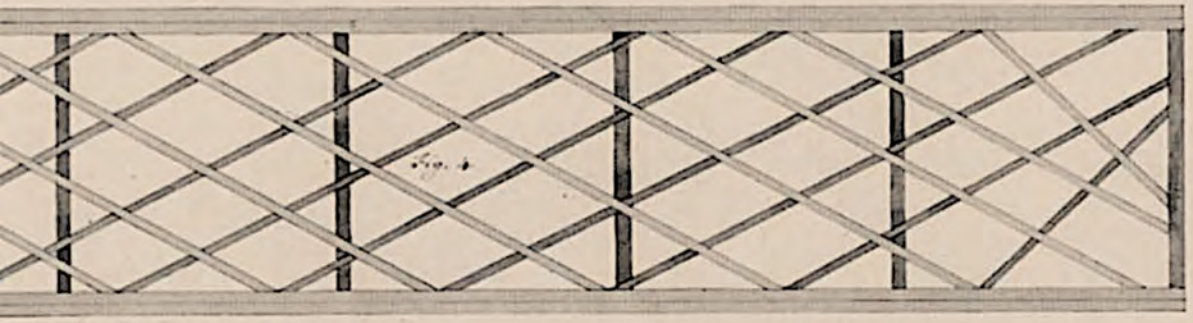
Hans Ulrich Grubenmann
1709-83

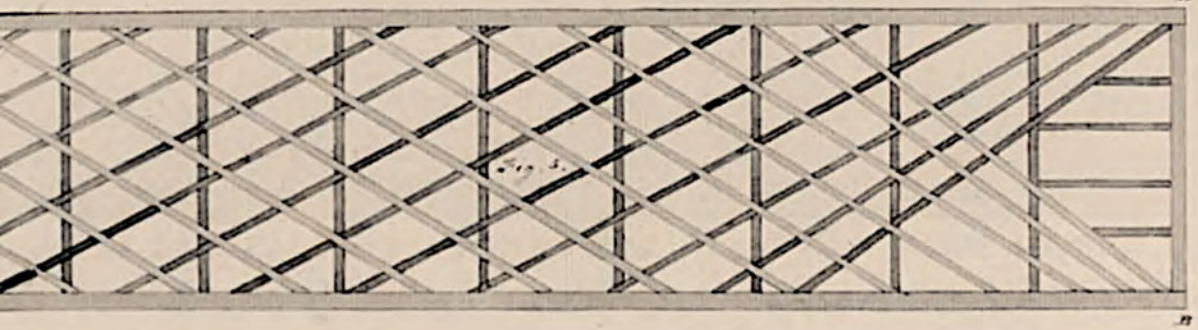


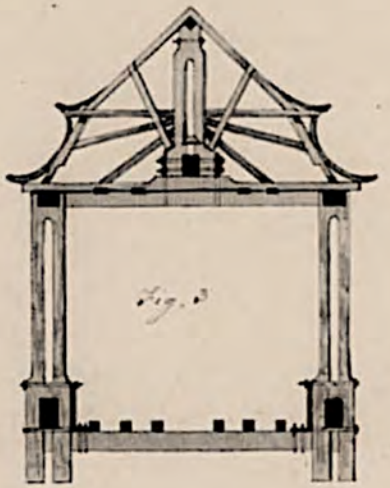
John Soane’s Museum, Lincoln Inn Field

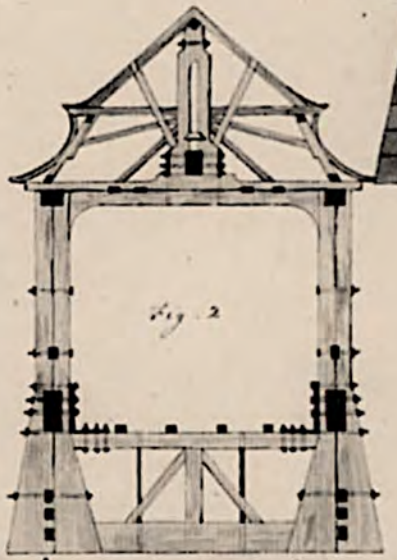
Ponte di Schaffhousen

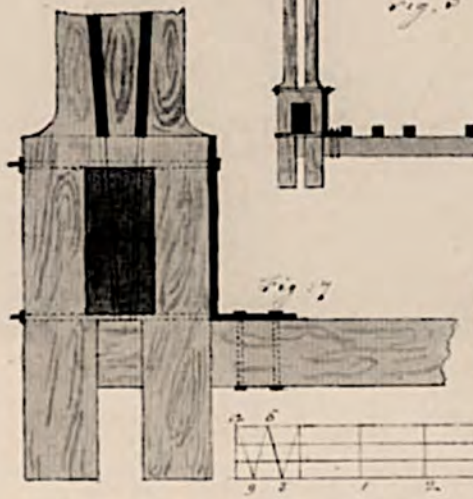


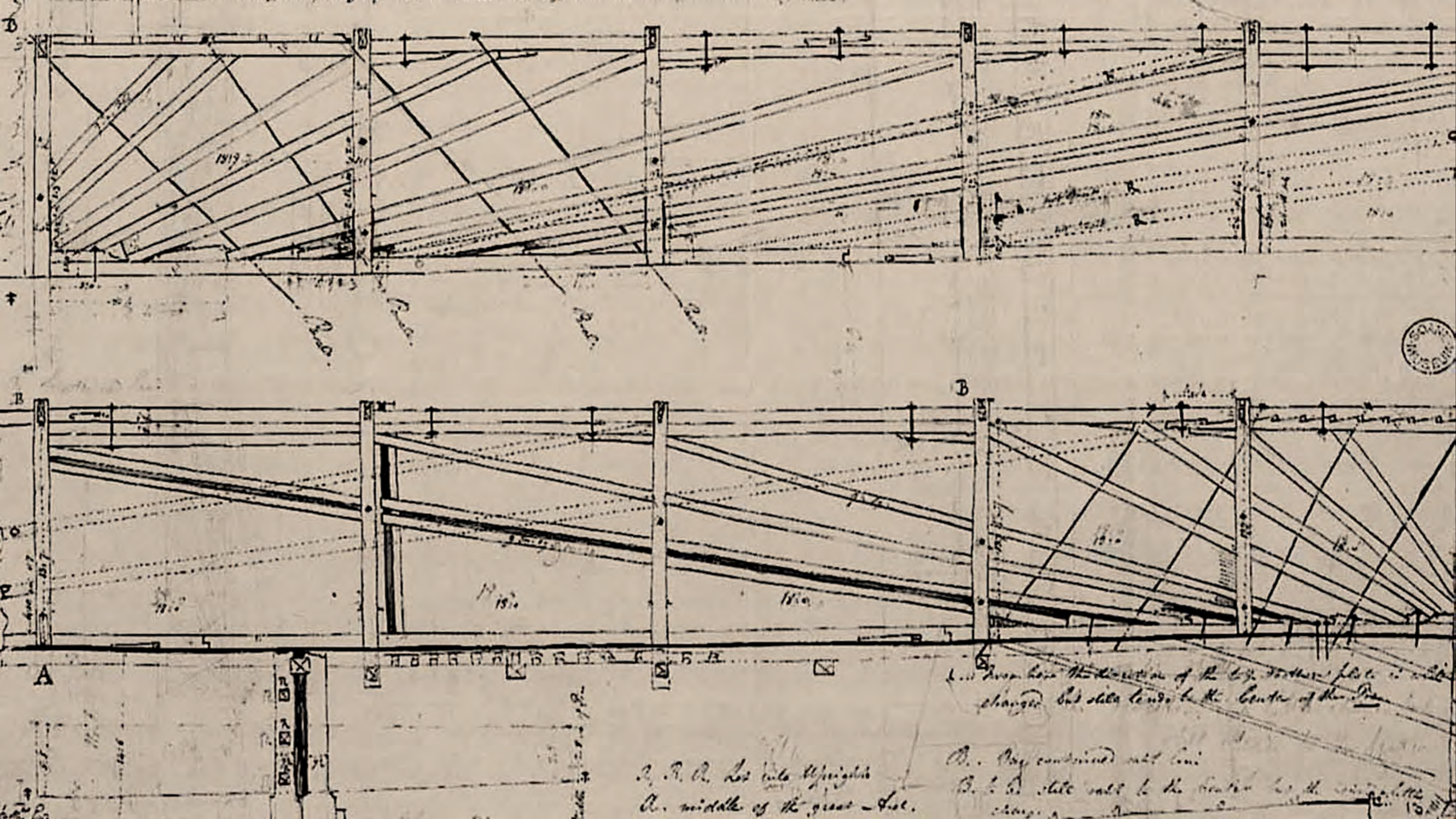


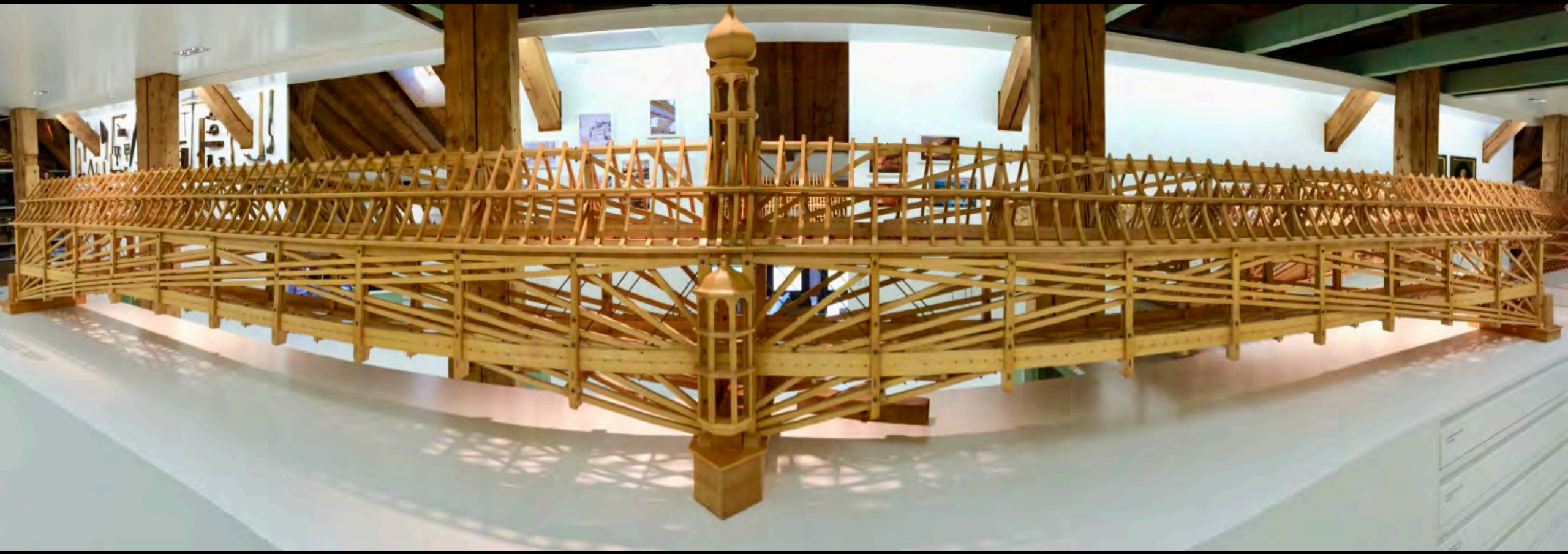









B
B
1819
A
A. middle of the great



Grubenmann Museum, Teufen, Switzerland

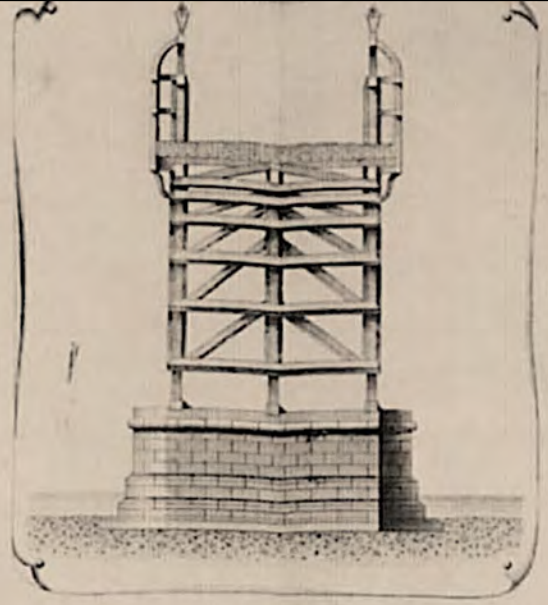
One span proposal for Schaffhausen Bridge

OLD WALTON BRIDGE
39m main span
1749, London, England
paintings by Canaletto
1754-55

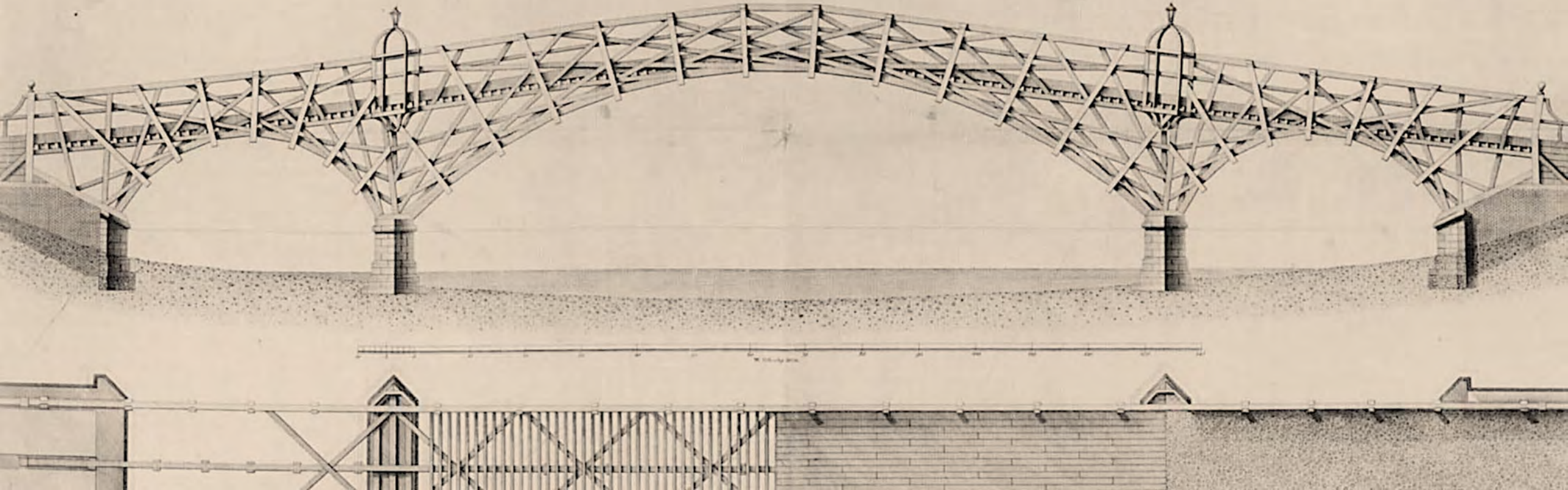
William Etheridge
1708-76

Canaletto, 1755, The Yale Center for British Art

A PLAN of the BRIDGE
from WALTON upon THAMES in SURRY.-



To the Oppolite Shore in the PARISH
of SHEPPERTON, in MIDDLESEX.



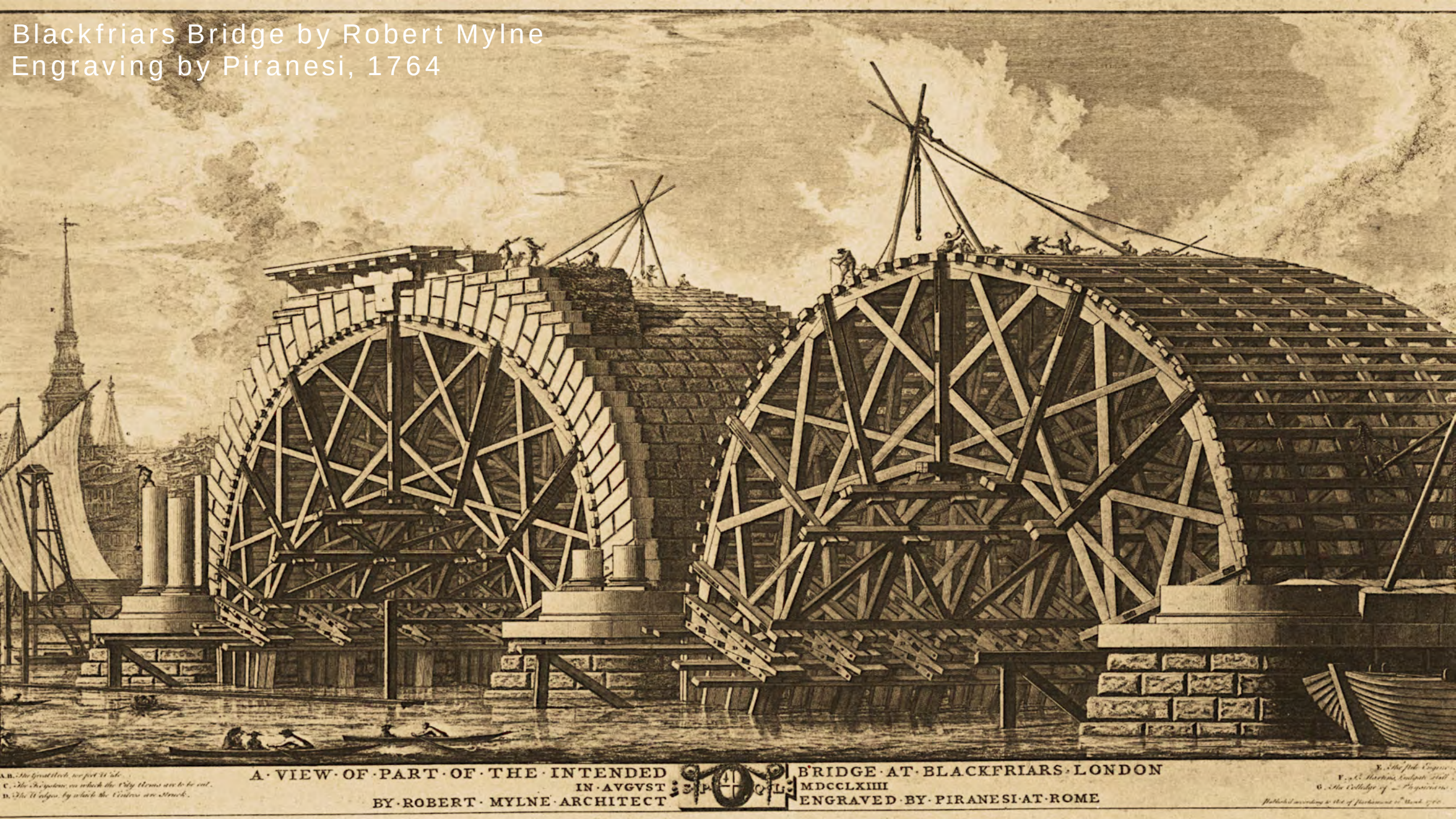
Dulwich Picture Gallery by John Soane


Canaletto, 1754, The Dulwih Picture Gallery


606
Old Walton Bridge
Canaletto

Mathematical Bridge,
Queens College, Cambridge

Blackfriars Bridge by Robert Mylne
Engraving by Piranesi, 1764



MORE WOODEN BRIDGES

A living bridge of vines
become stronger as it grows,
a centipede bridge of bamboo
made to be dismantled each year
before the rainy season
and rebuilt thereafter.

LIVING ROOT BRIDGES
aerial roots of rubber fig trees
about 20m span
Meghalaya
India

KAMPONG CHAM BAMBOO BRIDGE
across the Mekong River
a lot of 1m spans, about 1000m in total
rebuilt each year
Kampong Cham
Cambodia

MINIMAL STRUCTURES

MITCHELL STRUCTURES
are minimal structures ..

.. that achieve maximum stiffness
with minimum volume of material
in a filigree design that follows
the pattern of the inner force field.

ANTHONY G M MICHELL
1870 –1959
MELBOURNE

The Limits of Economy of Material in Frame-structures 1904

examples of Michell’s minimal structures:

SIMPLY SUPPORTED BEAM STRUCTURE WITH A POINT LOAD

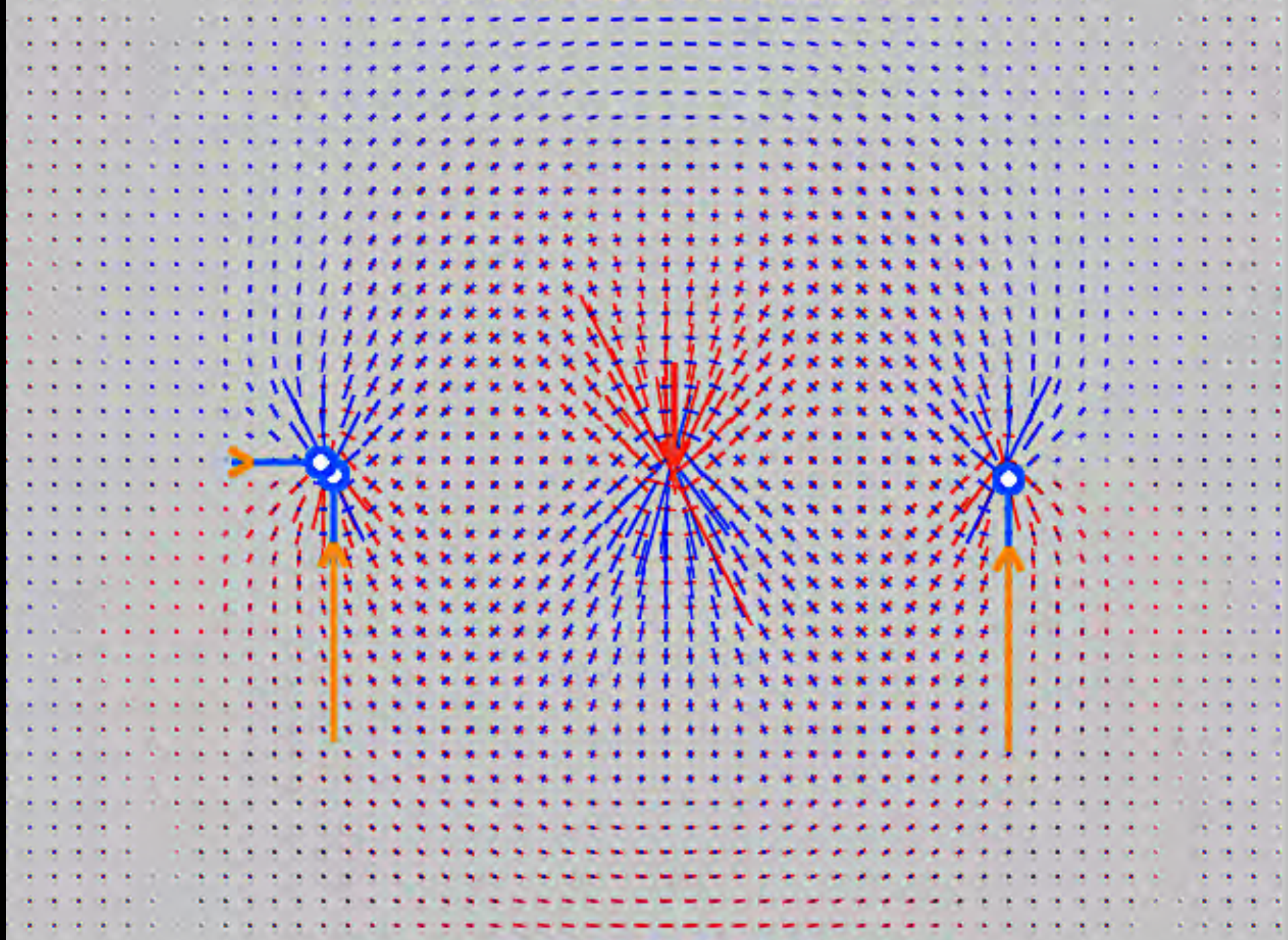
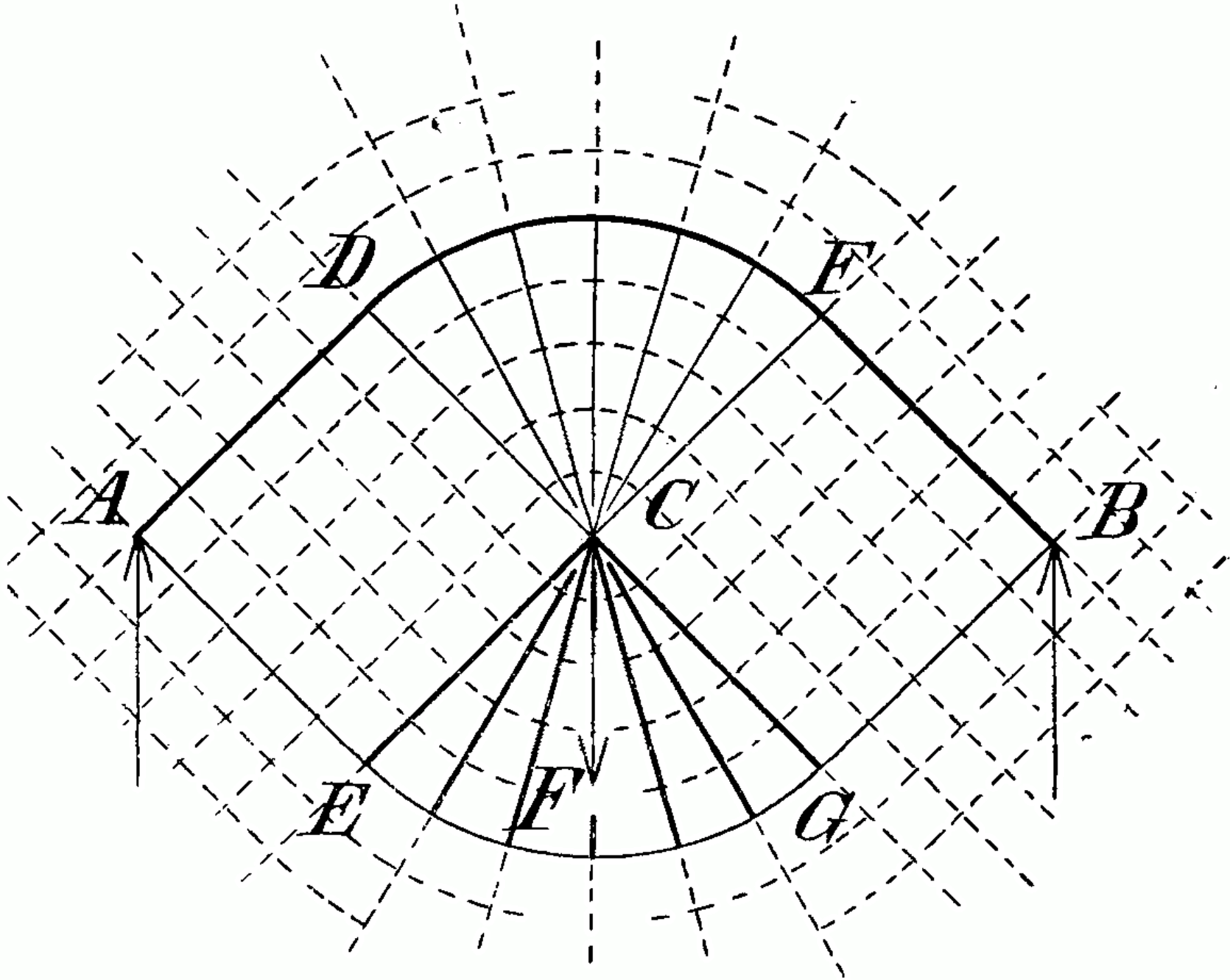


Fig. 2.



SEMICIRCULAR COMPRESSION ARCH WITH A POINT LOAD

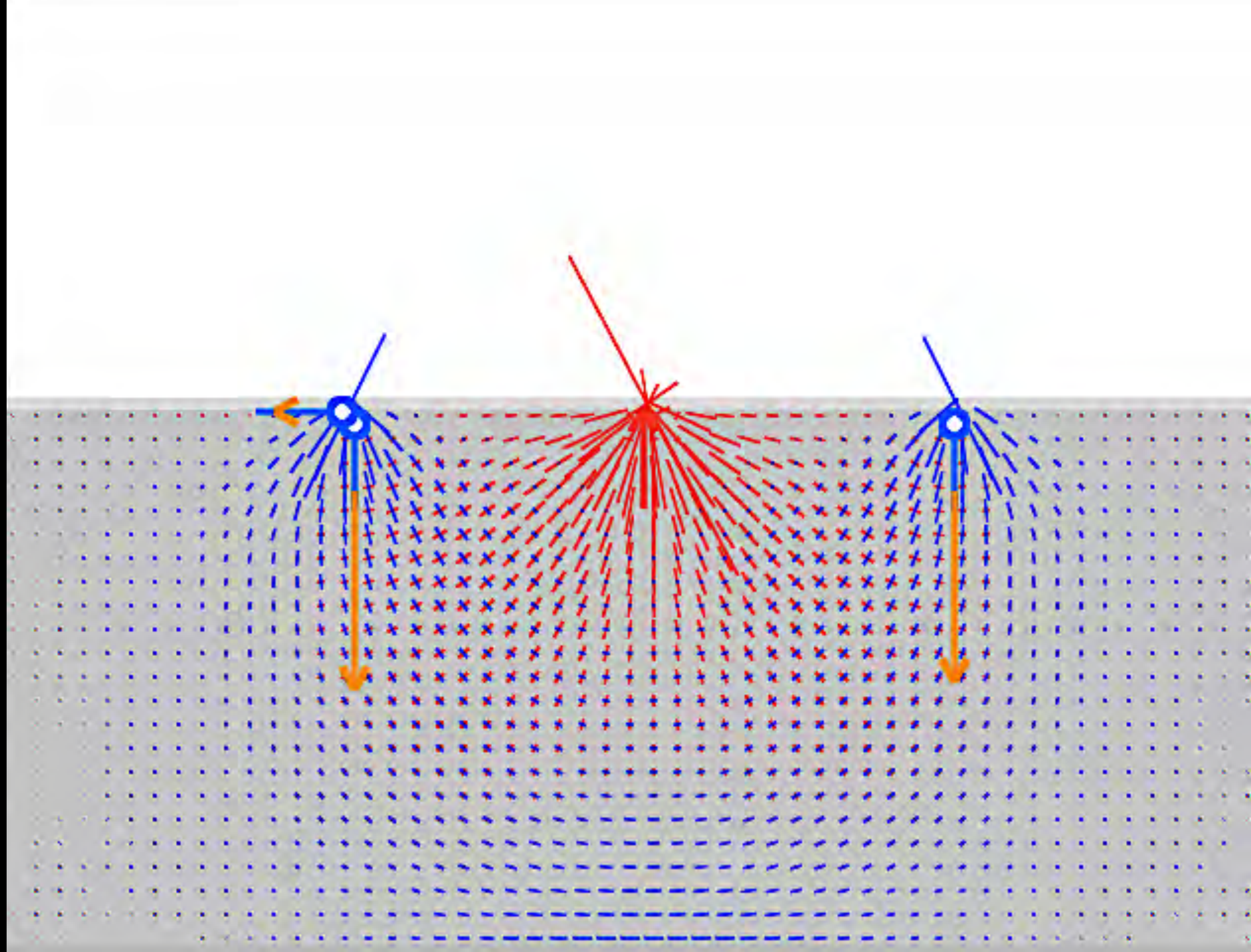
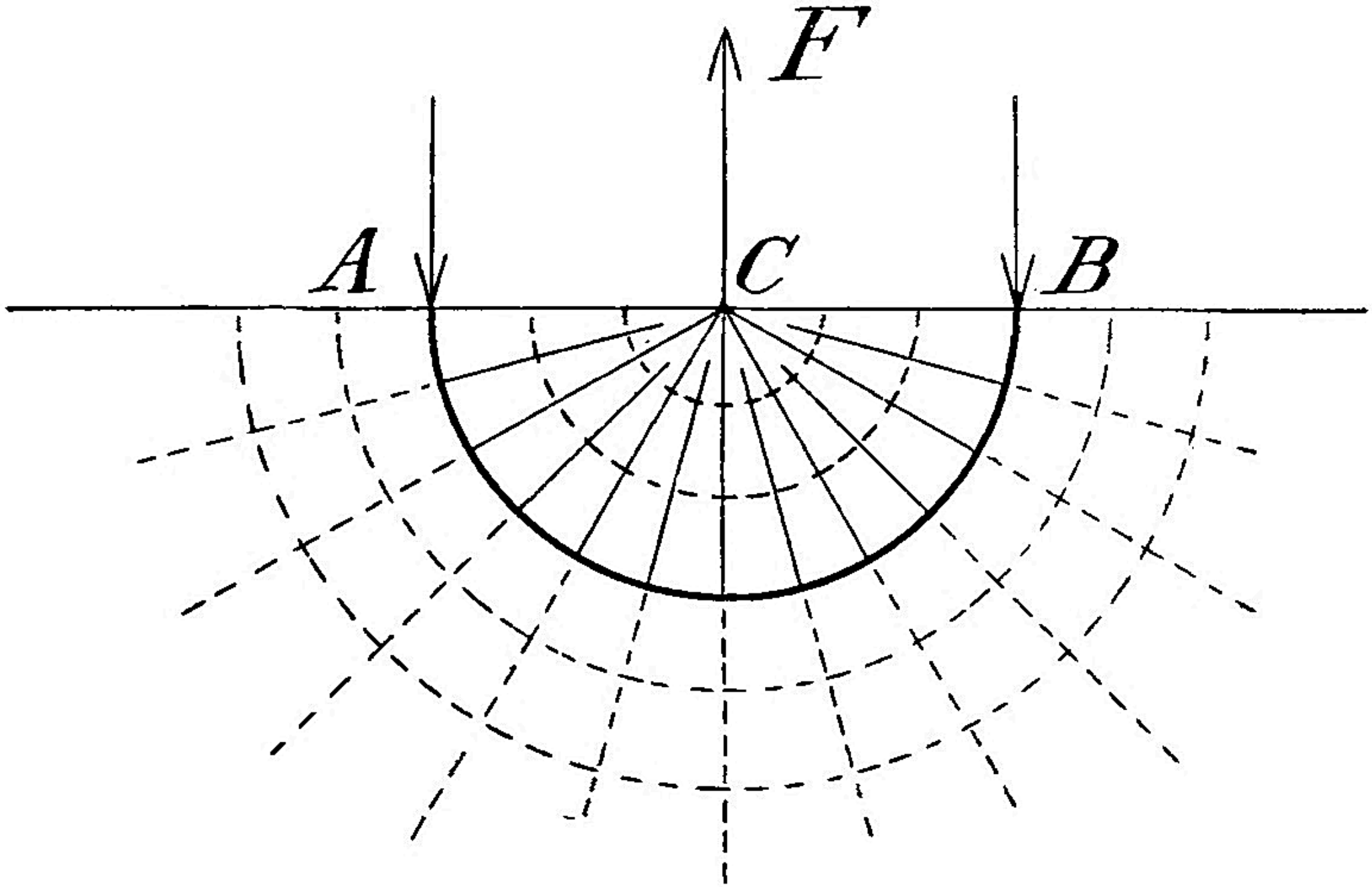


Fig. 3.



SEGMENTAL COMPRESSION ARCH WITH A POINT LOAD

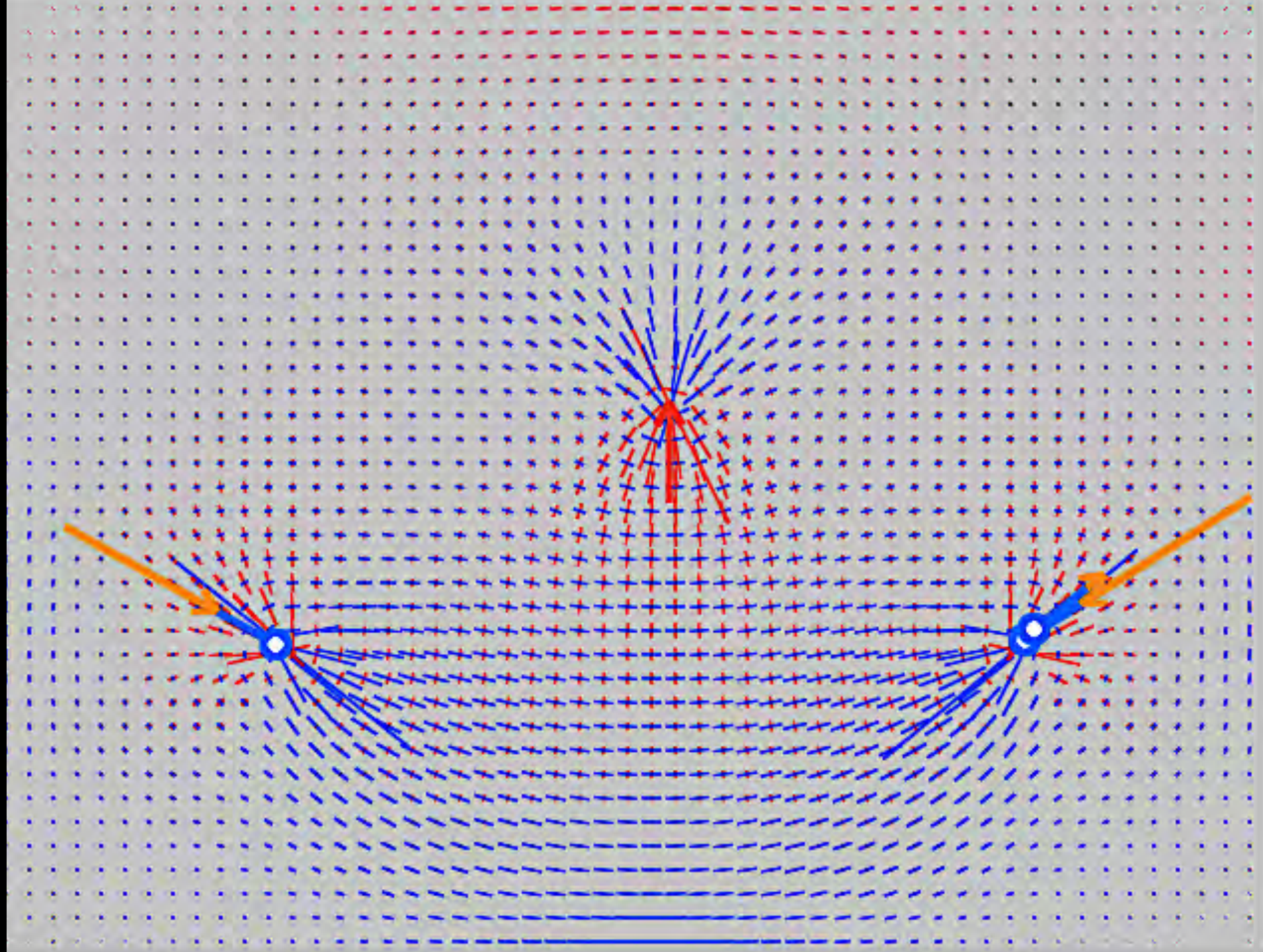
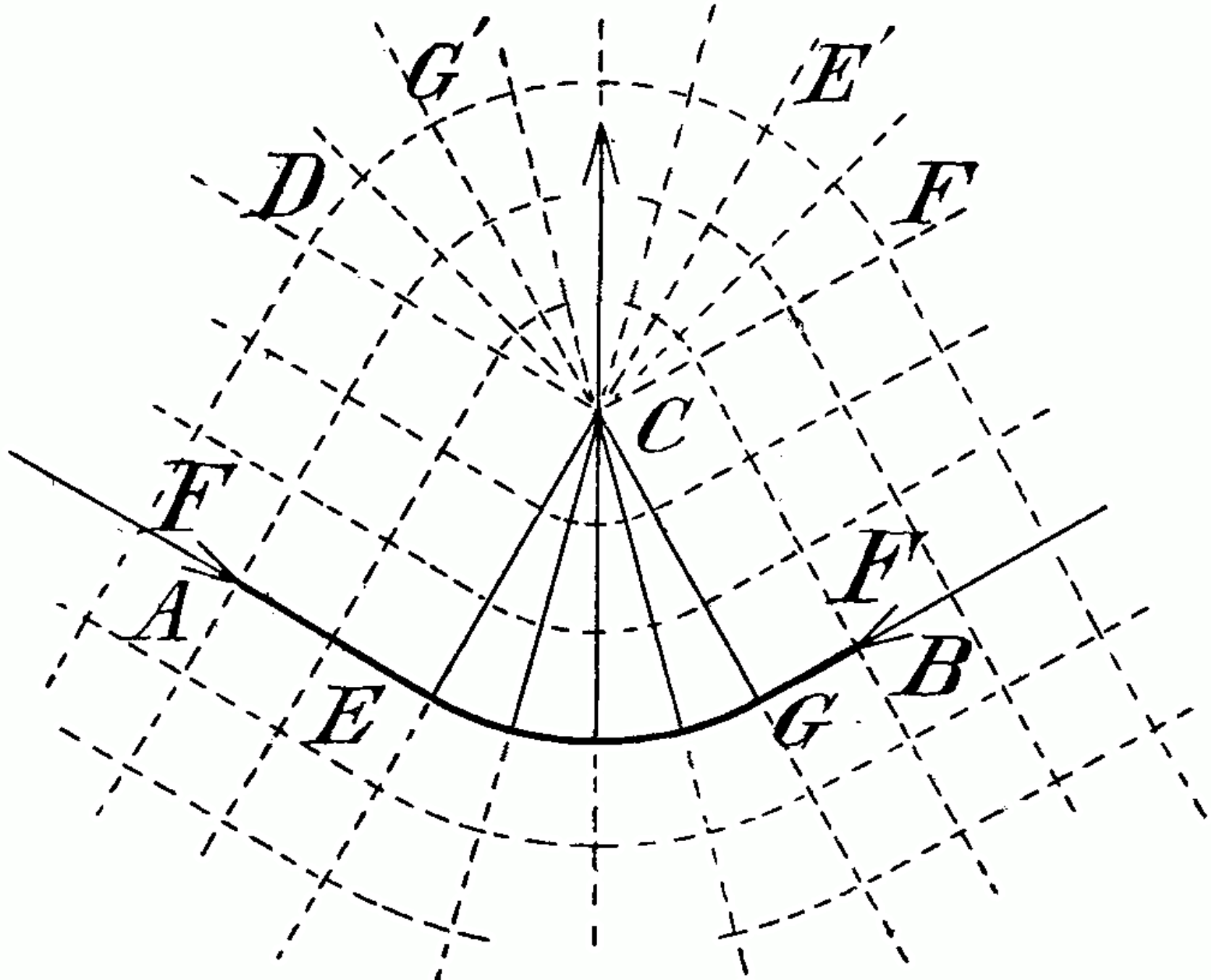


Fig. 4.



CANTILEVER BEAM WITH A POINT LOAD

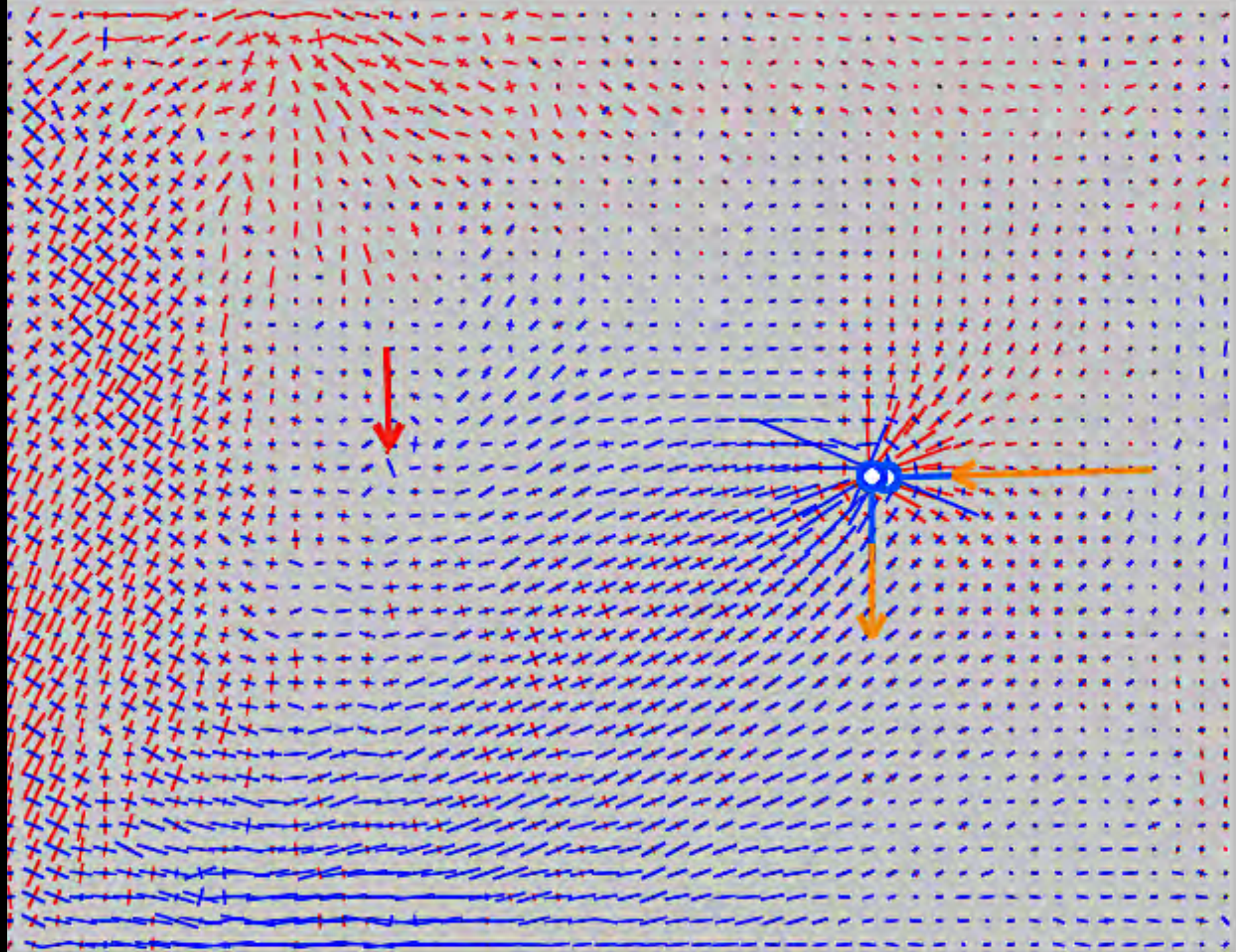
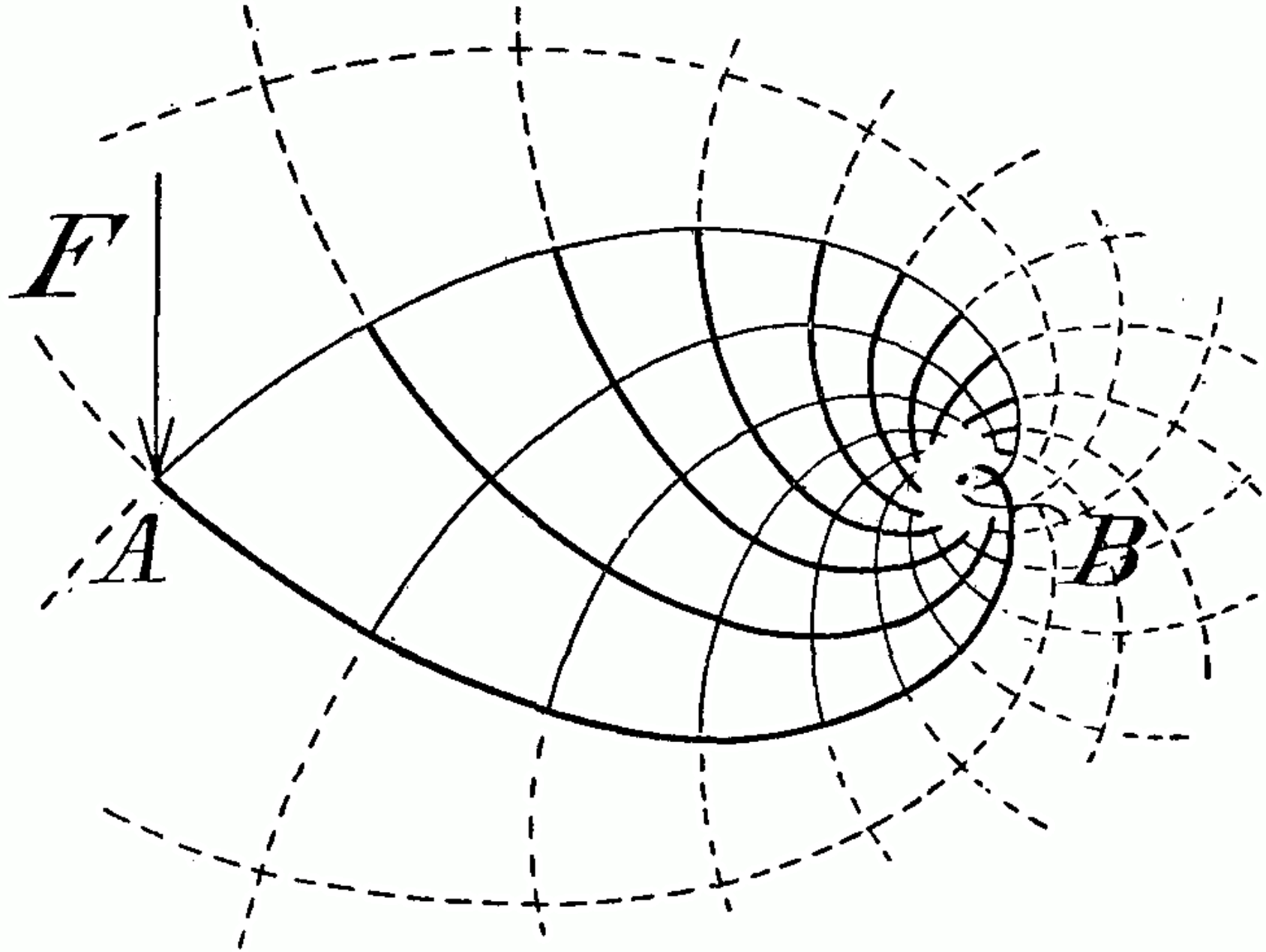


Fig. 1.



JAMES CLERK MAXWELL
1831-79
EDINBURG

Photoelasticity
1855

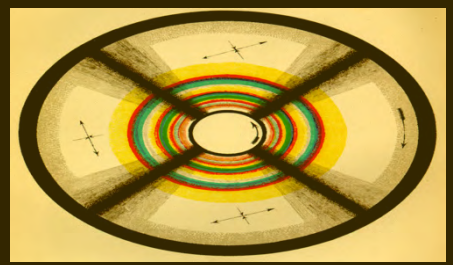
LIGHT SOURCE

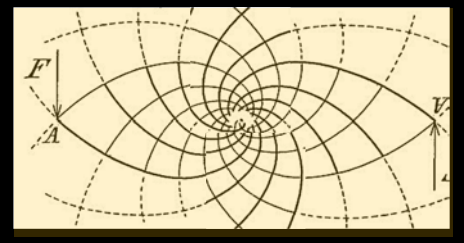
POLARISING FILTER

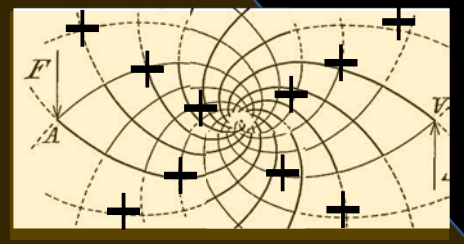
TRANSPARENT MATERIAL
IN TORQUE

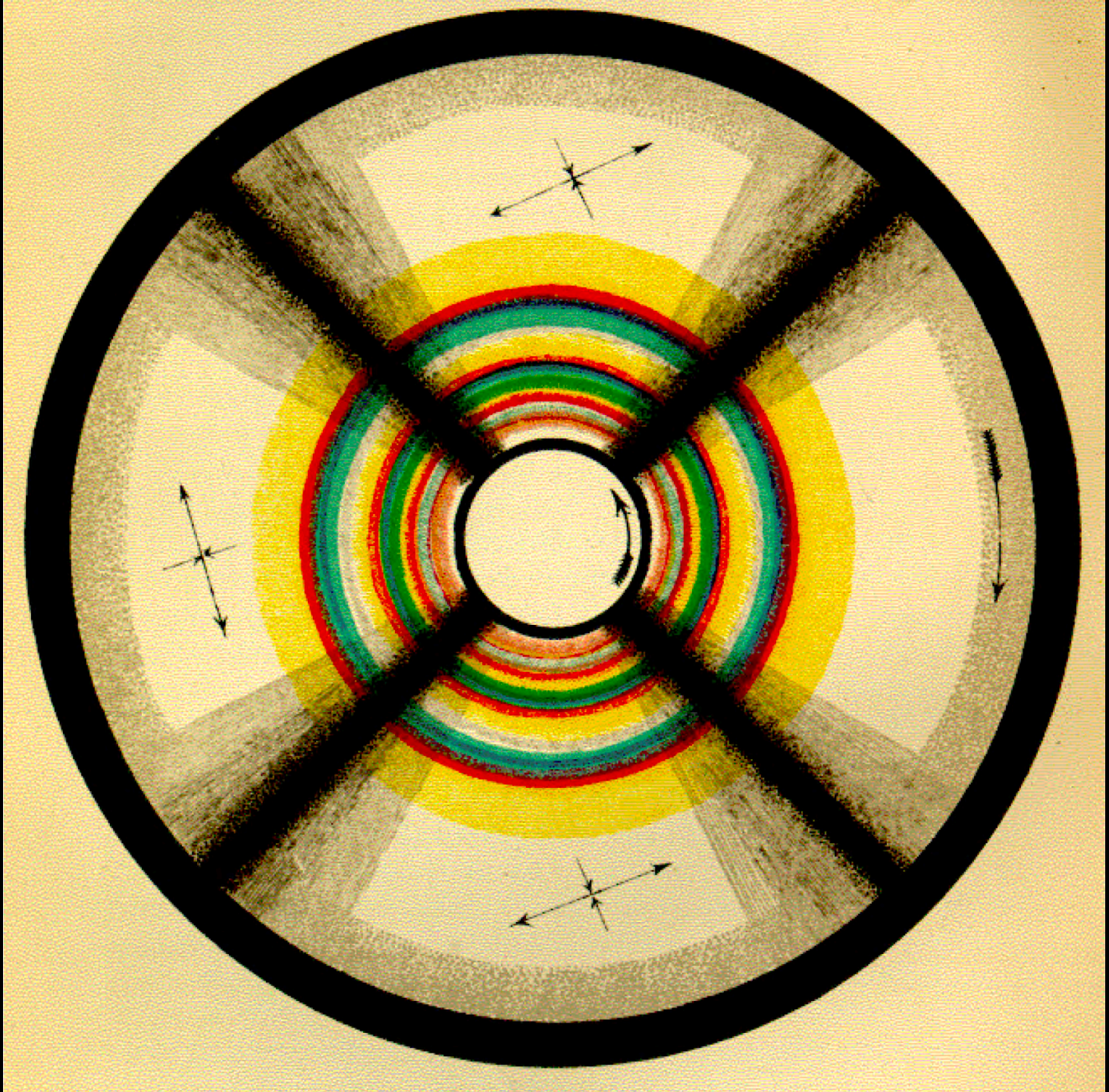
POLARISING FILTER

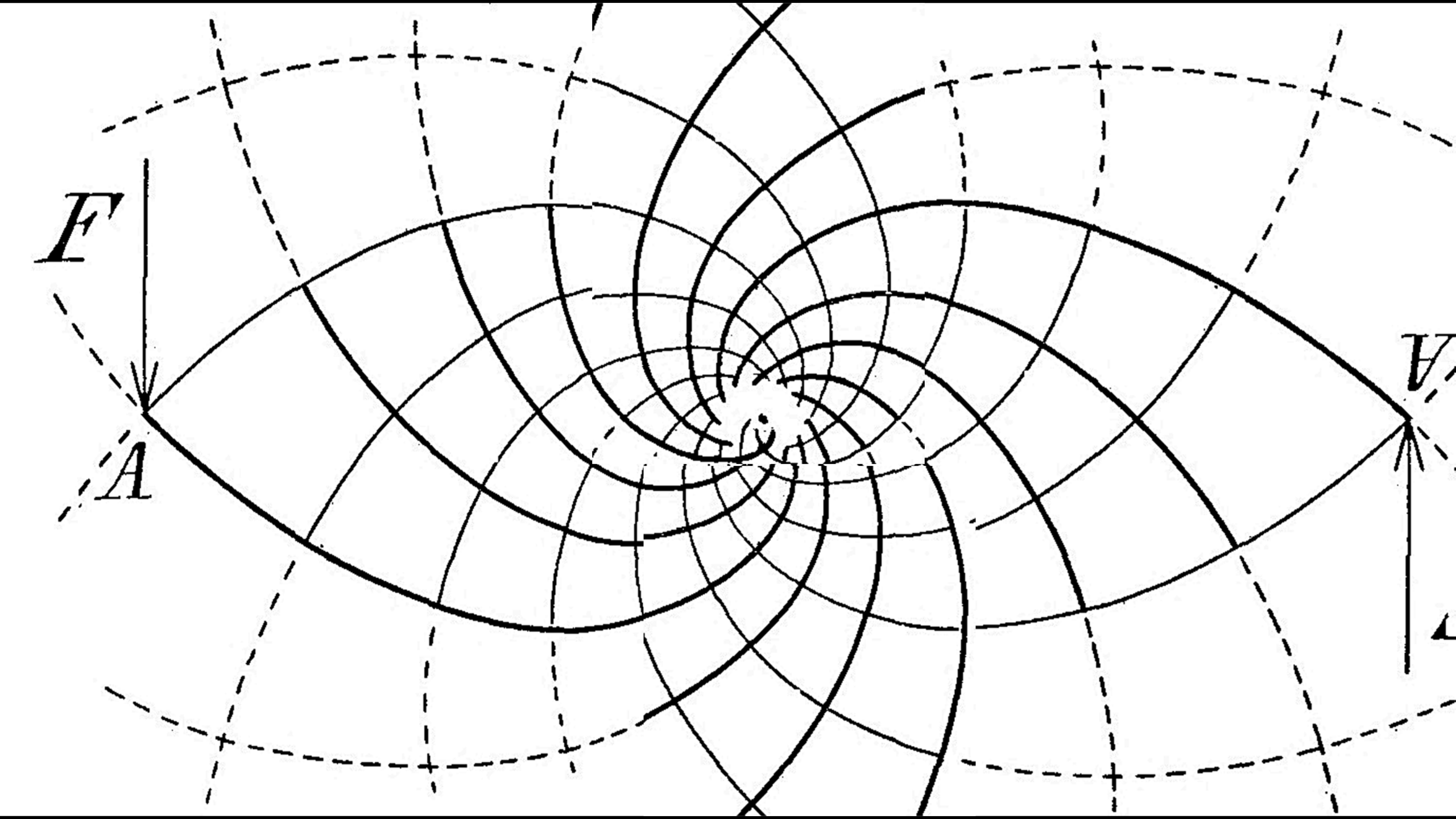
IMAGE OF FORCE FIELD







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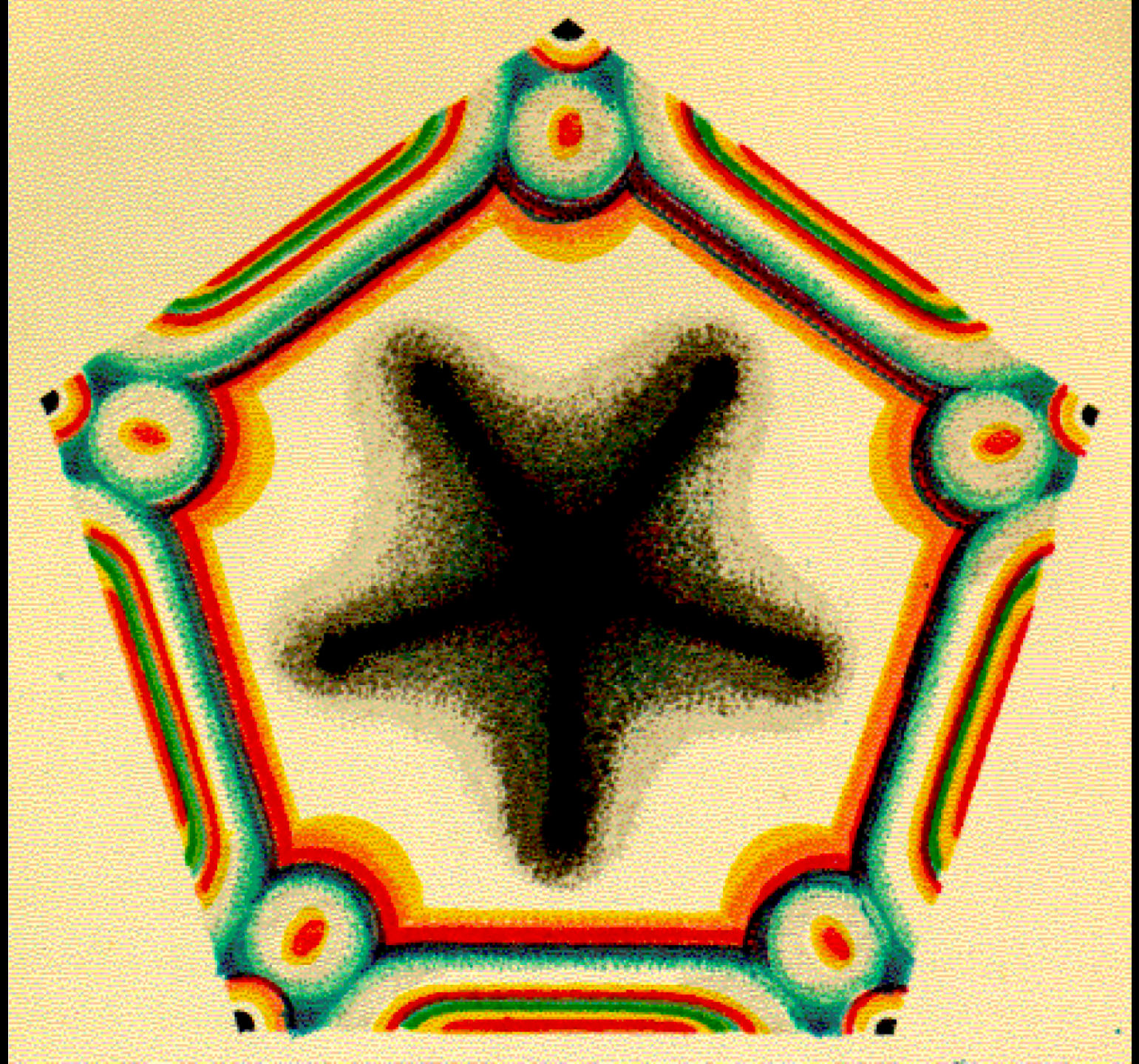
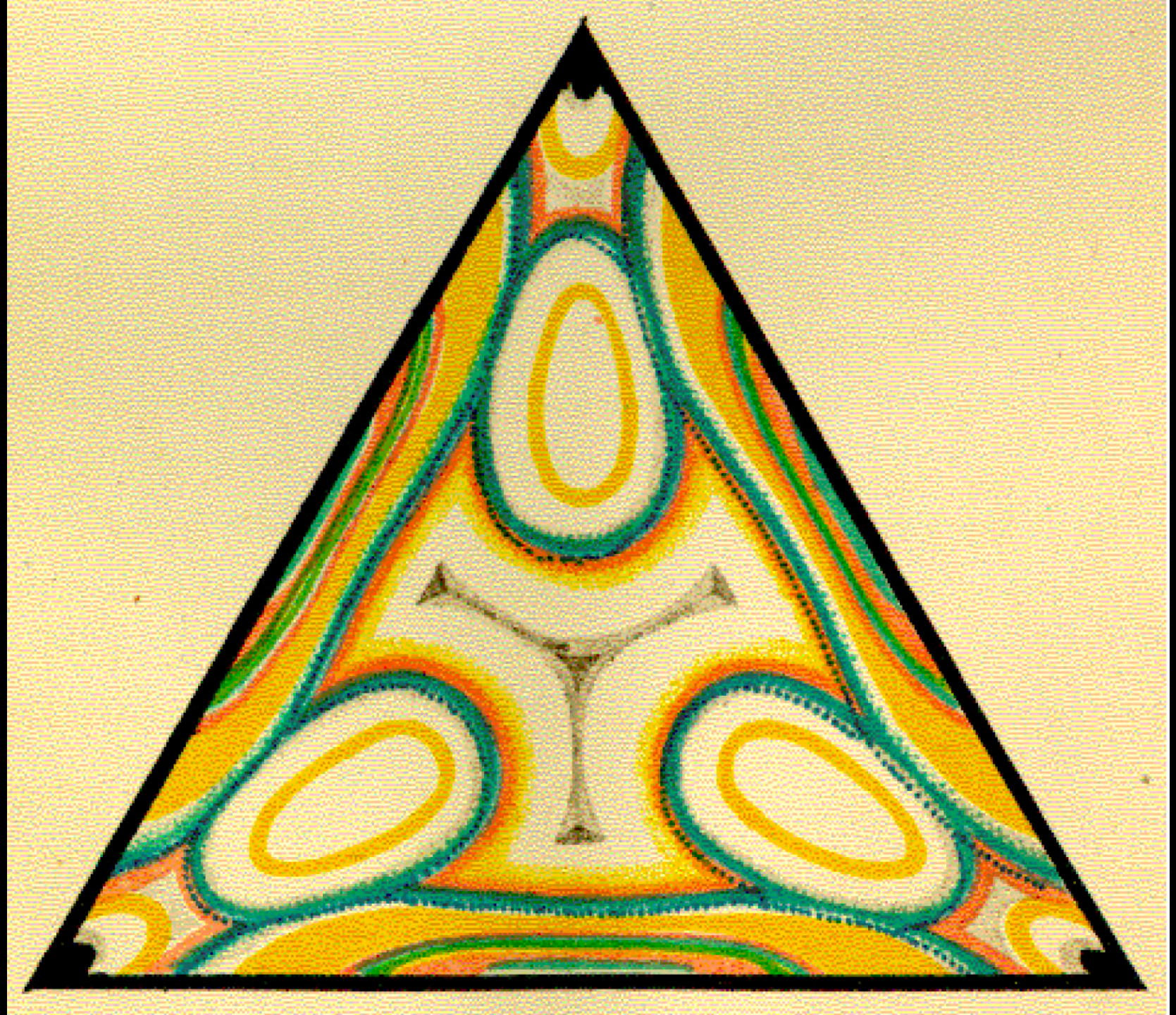
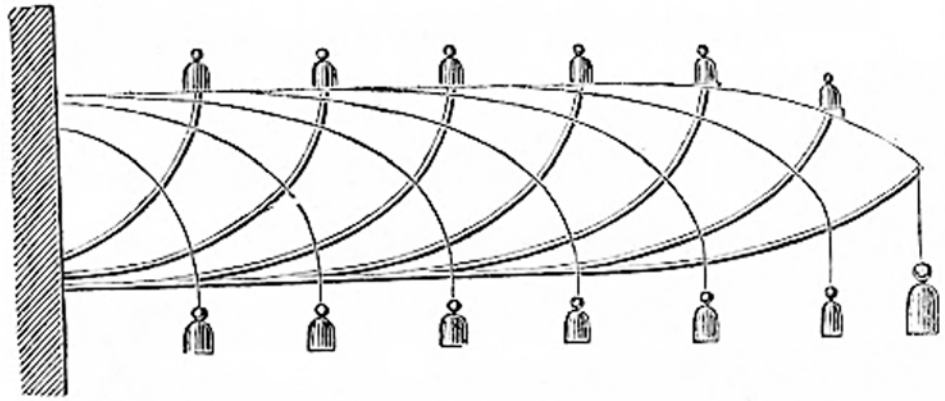




KARL CULMANN
1821-81
Zurich

Die graphische statik
1866

Fig. 107.



KRÆFTEPLAN EINES HALBPARABELTRÆGERS.

Spannweite = 50 m

Eigengewicht = 3,0 t pro Meter, Zufällige Last = 1,8 t pro Meter.

Fig. 4.

Fig. 1. (1 : 250)

Fig. 2.

Für Eigengewicht 1 mm = 1 t. Für volle Belastung 1 mm = 1,6 t

Fig. 3.

Verlag von Meyer u. Zeller in Zürich.

Lithogr. Anstalt von Wurster Randegger u. Cº in Winterthur.

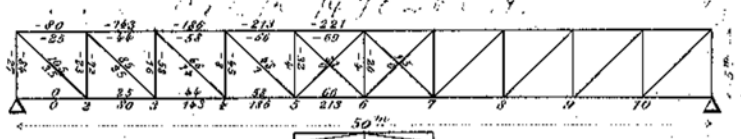
Culmann-Ritter, graphische Statik.

KRÆFTEPLAN EINES FACHWERKES MIT PARALLELEN STRECKBÄUMEN.

Spannweite - 50 m.

Eigengewicht - t pro Meter. Zufällige Last - 2 Bahnzüge.

Fig. 1.
1:500.



Kräftemaafsstab für Fig. 5 u. 6. $1^{m}/_{m} = 1\,t$

Kräftemaafsstab für Fig. 2. $1^{m}/_{m} = 5\,t$

Fig. 2.

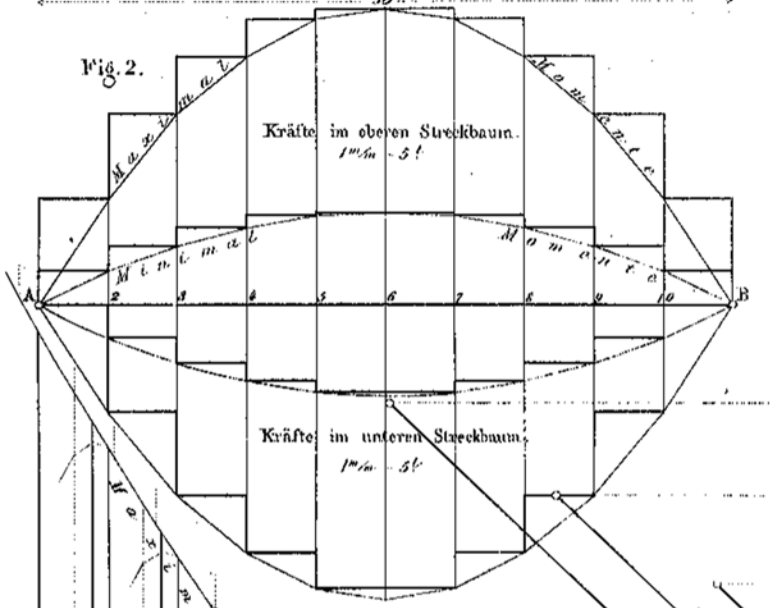


Fig. 6.
Kräfte in den Vertikalen.
$1^{m}/_{m} = 1\,t$

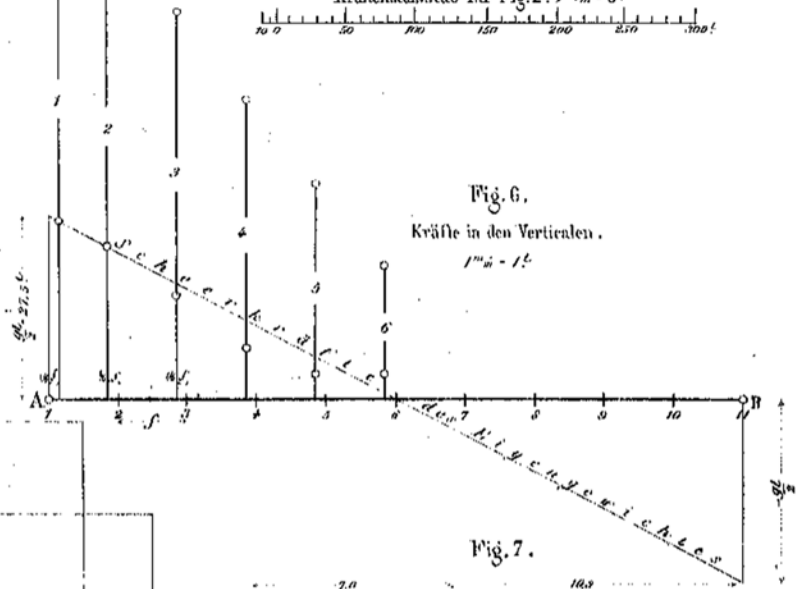


Fig. 7.

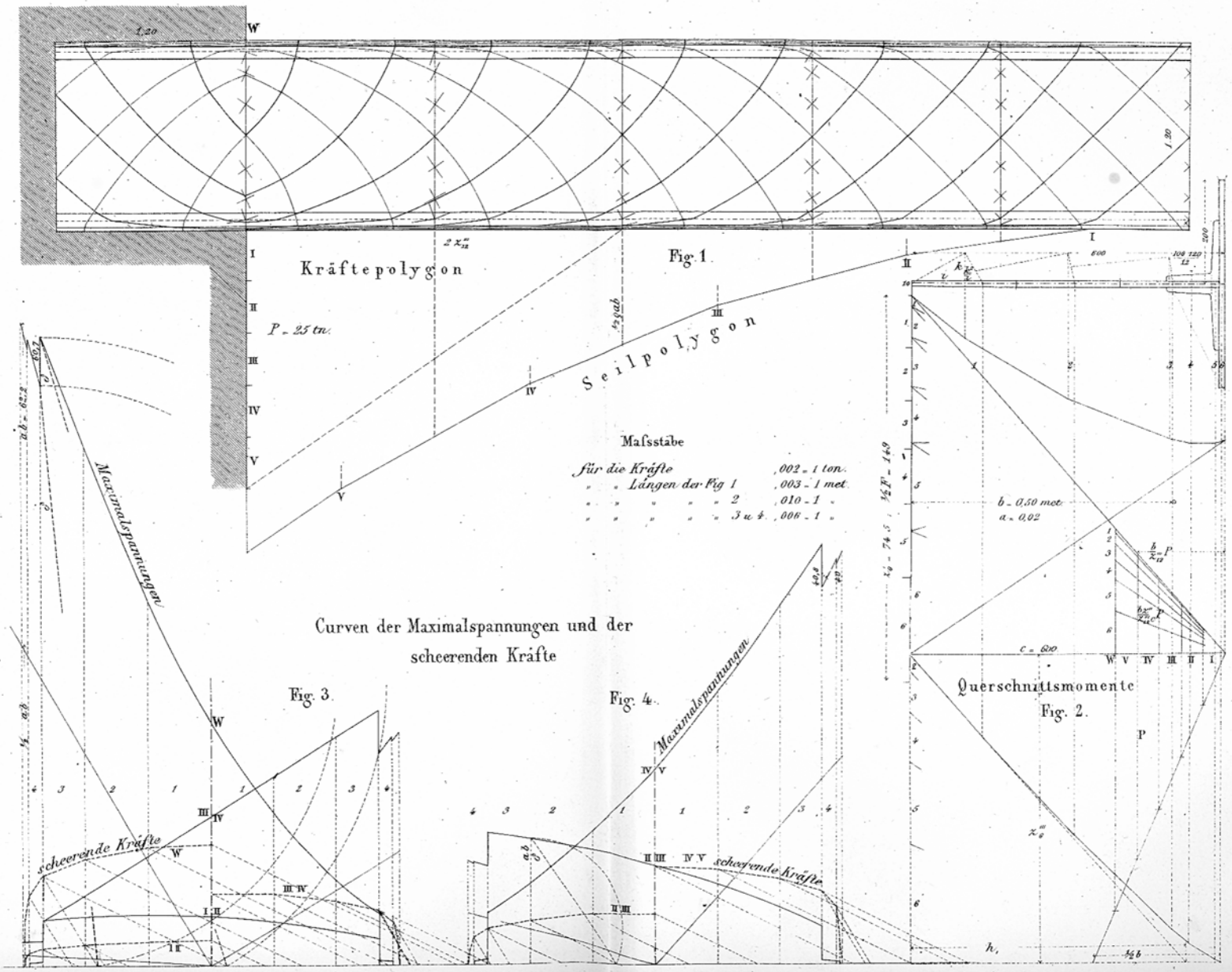
Fig. 3. $1^{m}/_{m} = 1\,t$

Fig. 4.

Fig. 5.
Kräfte in den Diagonalen.
$1^{m}/_{m} = 1\,t$

KRÆFTEPLAN EINES BLECHBALKENS

Ansicht, Kräfte-und Seilpolygon



Verlag v. Meyer u. Zeller in Zürich.

Culmann graphische Statik.

Lithogr. Anstalt von Wurster, Randegger & Cie in Winterthur

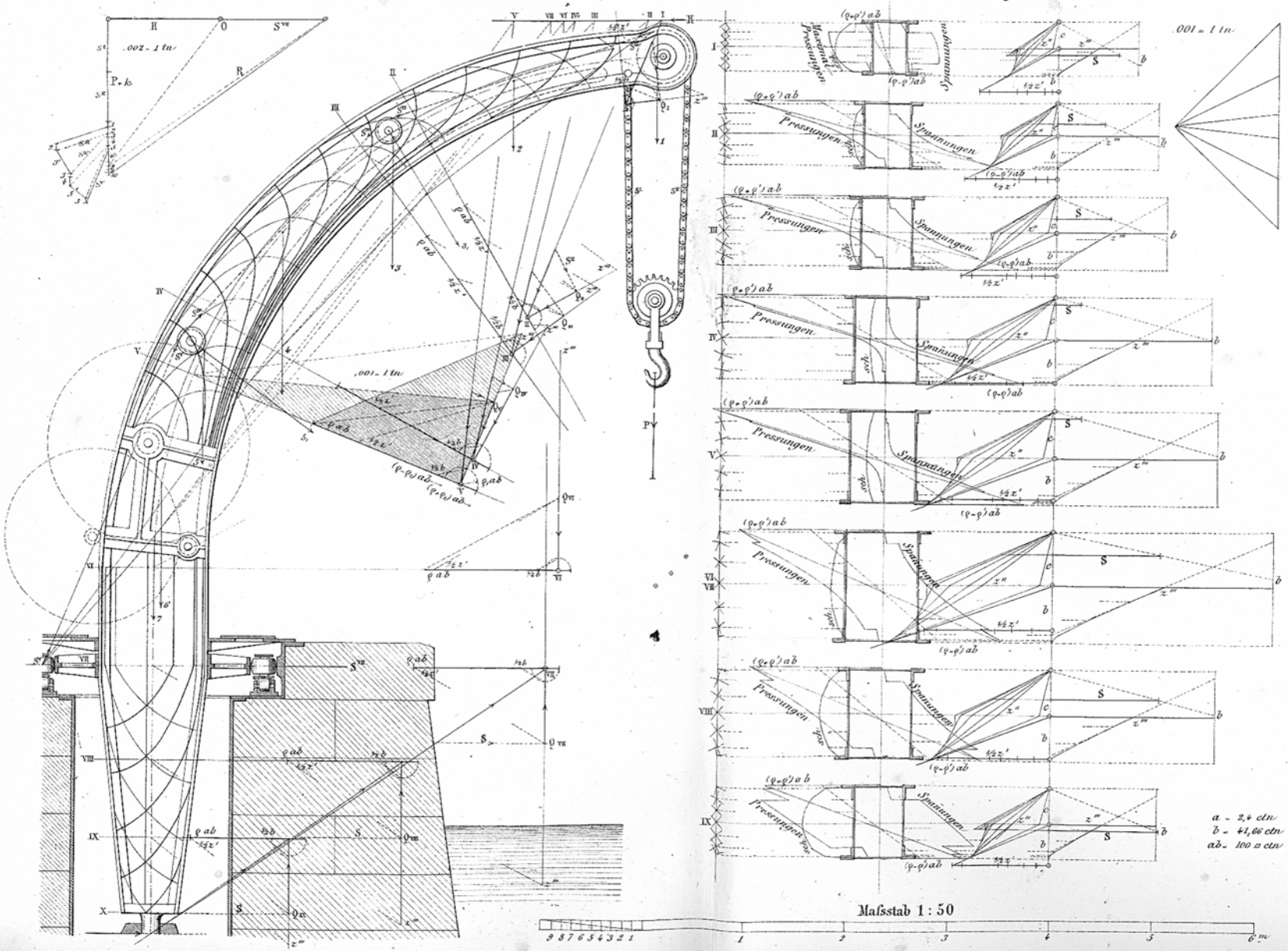
BLECHKRAHN

Kräftepolygon
Fig. 2.

Krahn und Seilpolygon
Fig. 1.

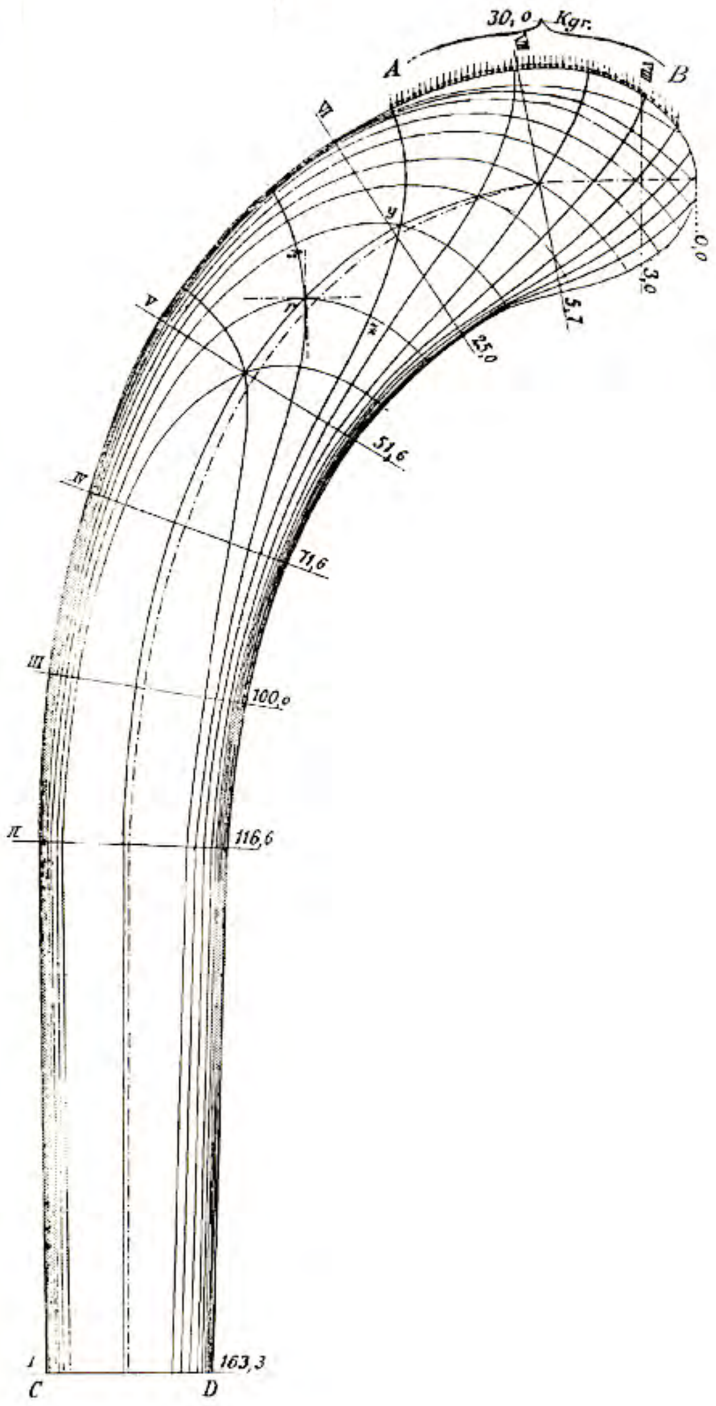
Querschnittsmomente
Fig. 3.

Fig. 4.



Verlag v. Meyer u. Zeller in Zürich.

Lith. Anstalt von Wurster, Randegger & Cº in Winterthur.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116,6
163,3
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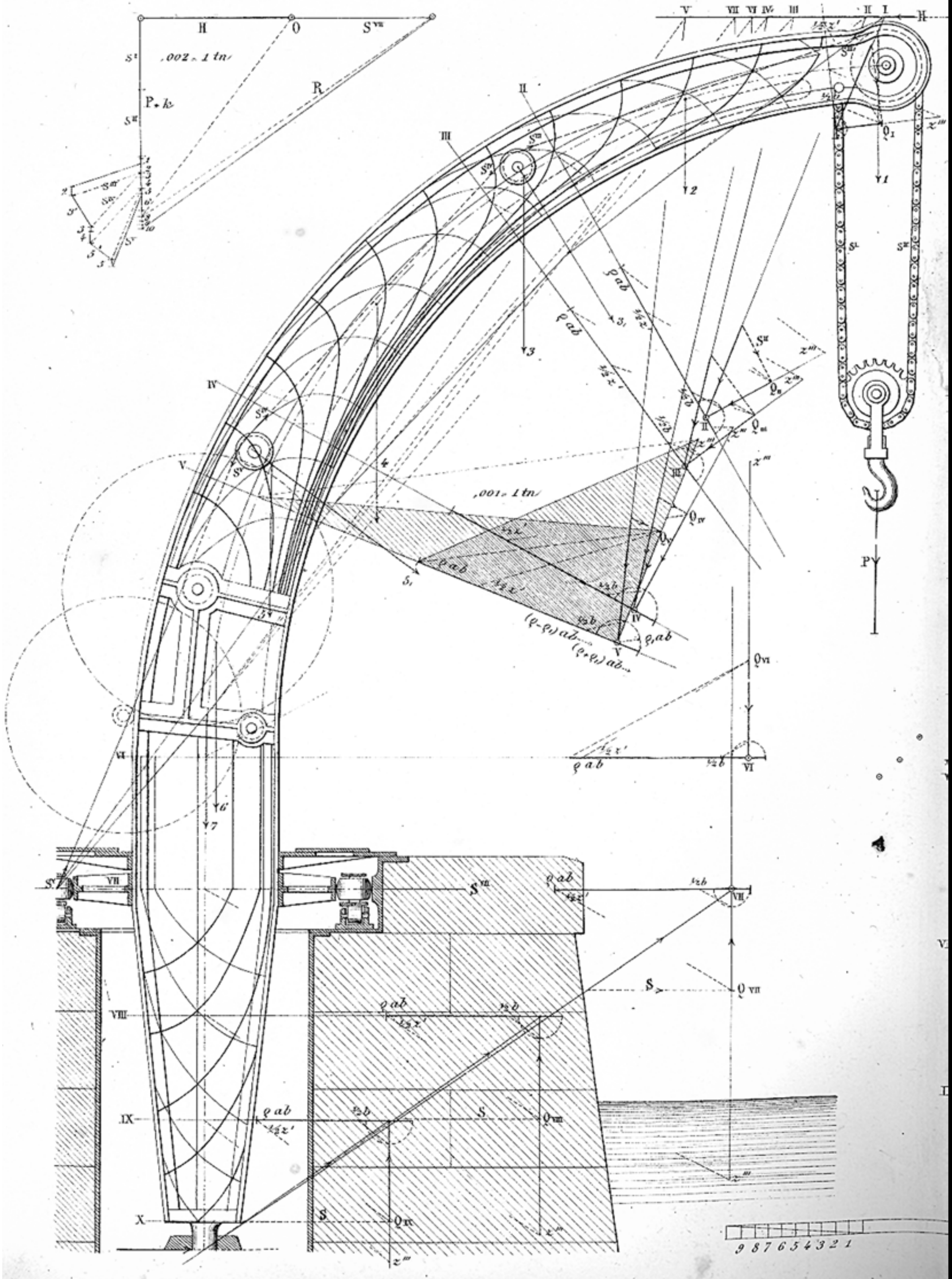
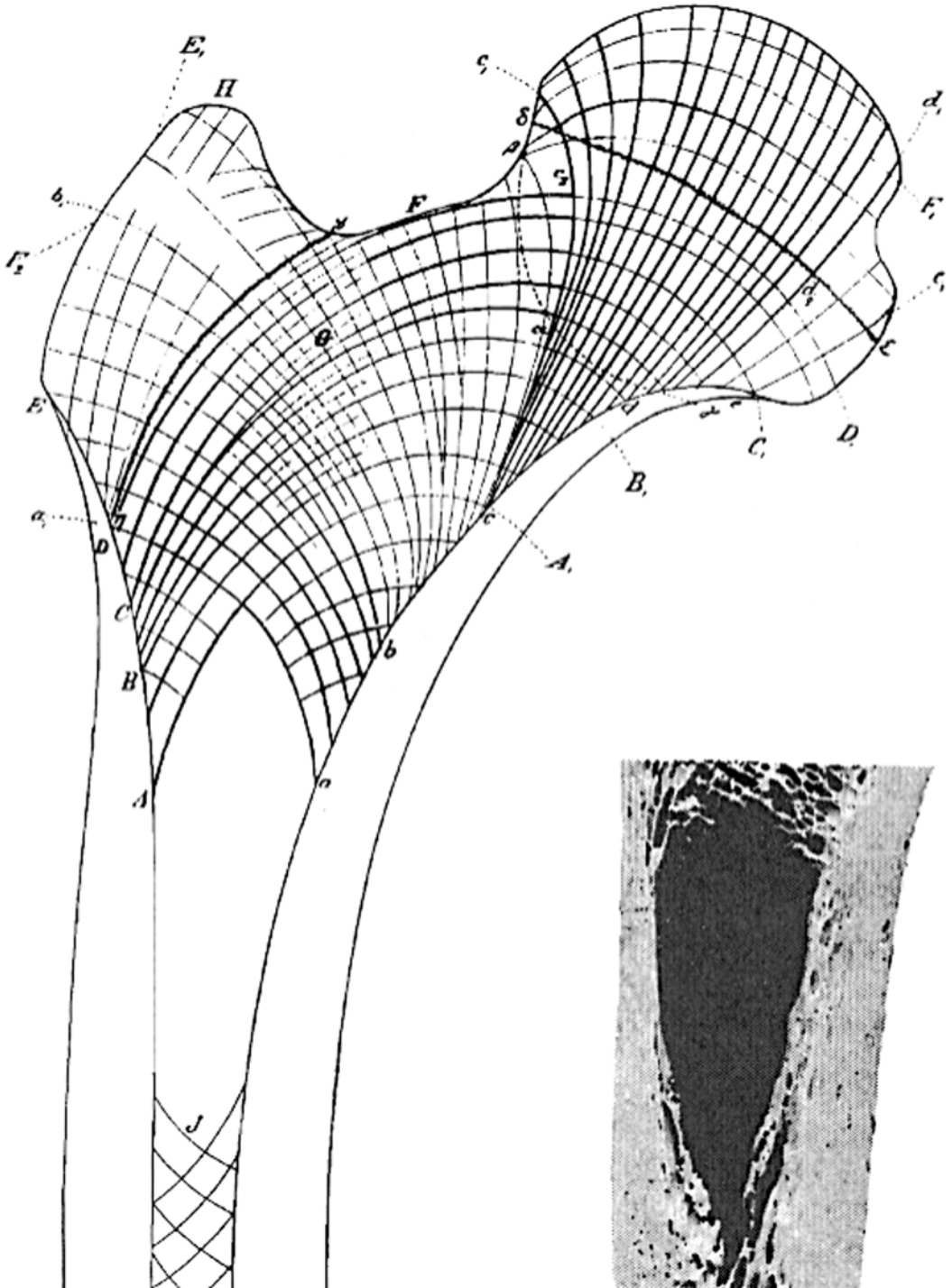

.002 = 1 tn
.001 = 1 tn
9 8 7 6 5 4 3 2 1

JULIUS WOLFF
1836-1902
Berlin

Über die Innere Architektur der Knochen 1870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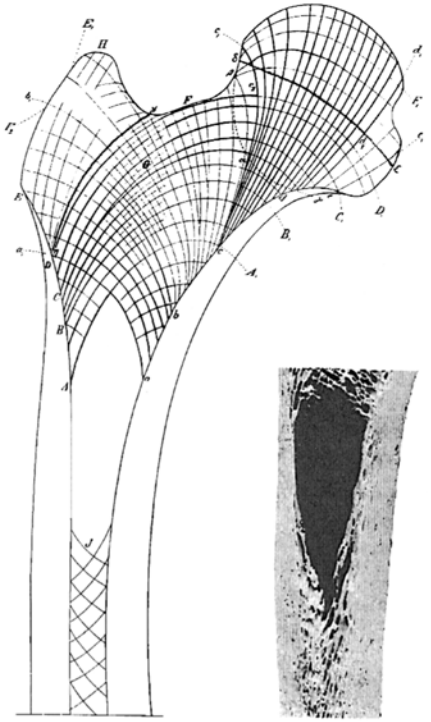

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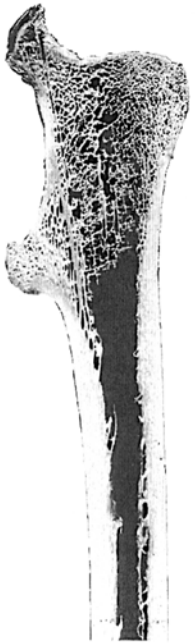

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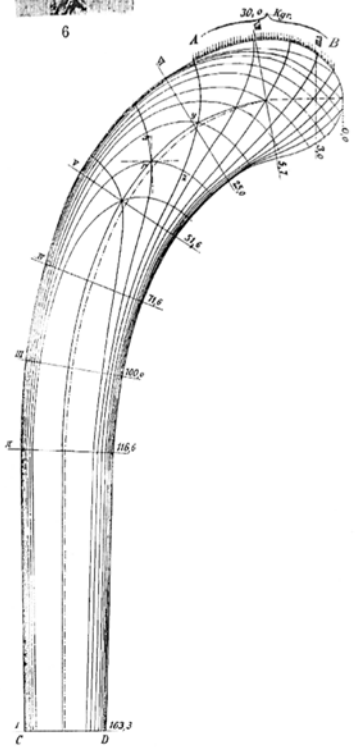

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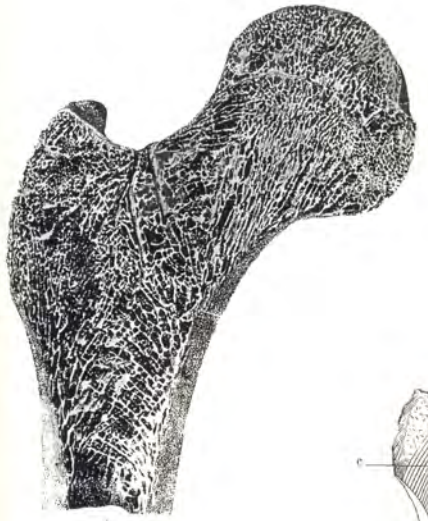

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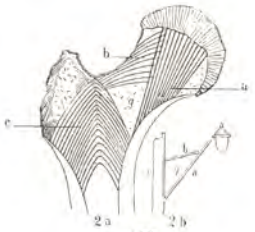
1832



2a 2b
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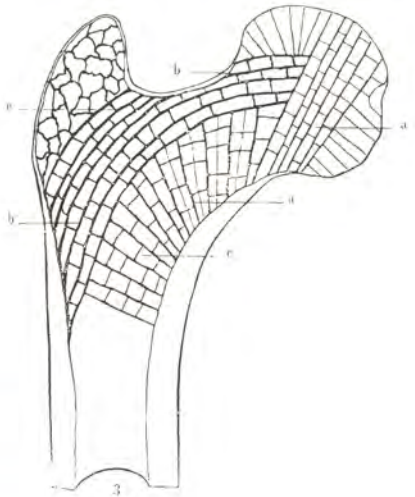

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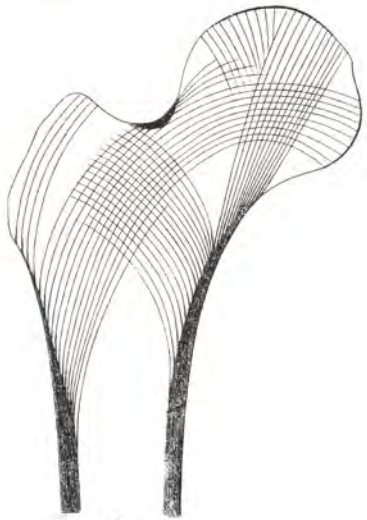
1851



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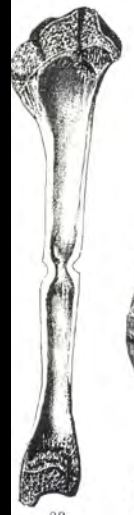

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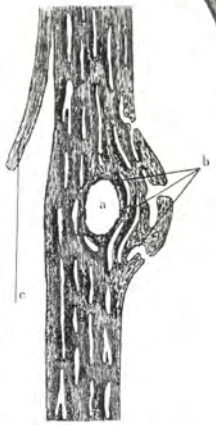

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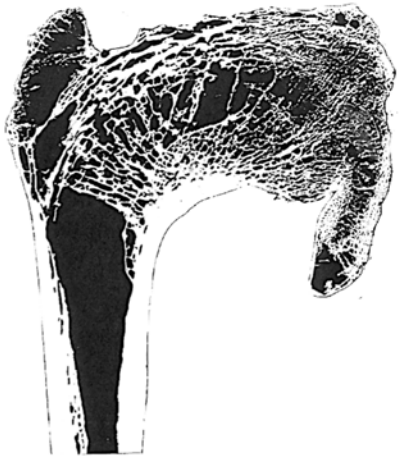

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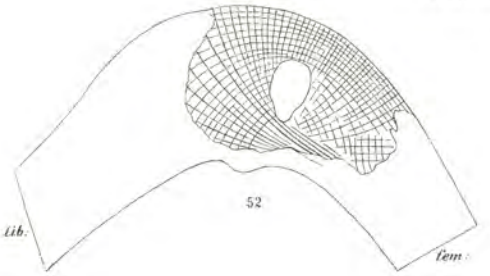

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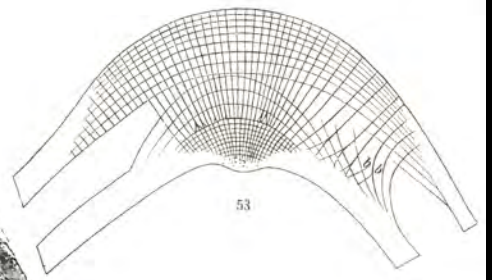

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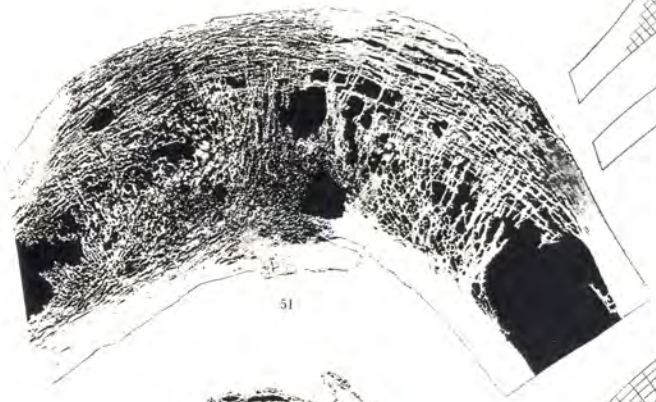

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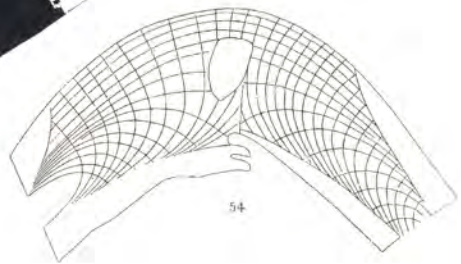

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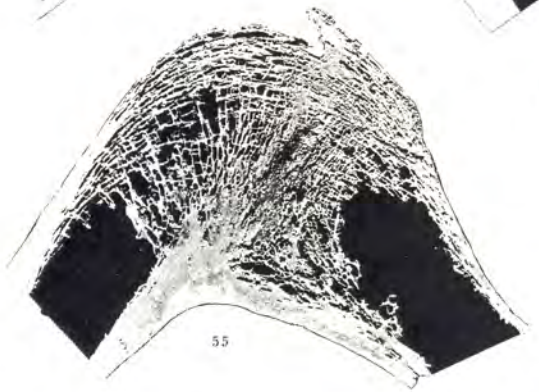

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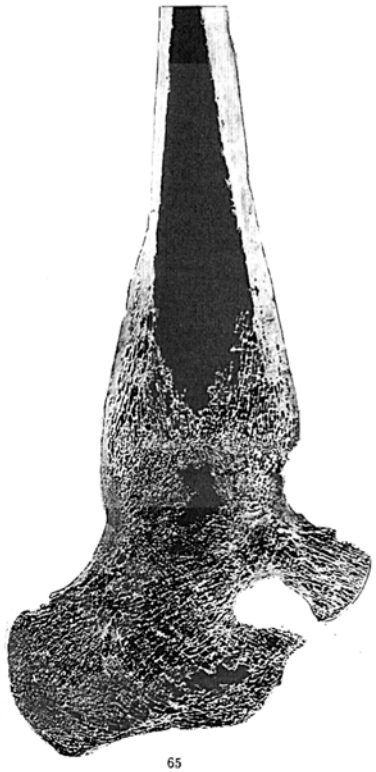

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62

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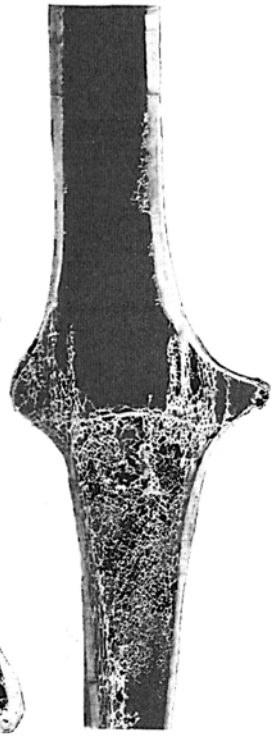

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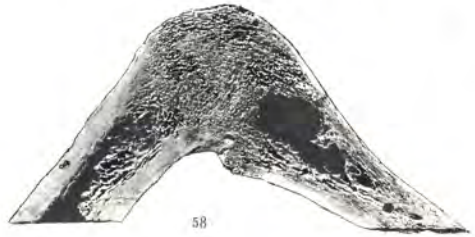


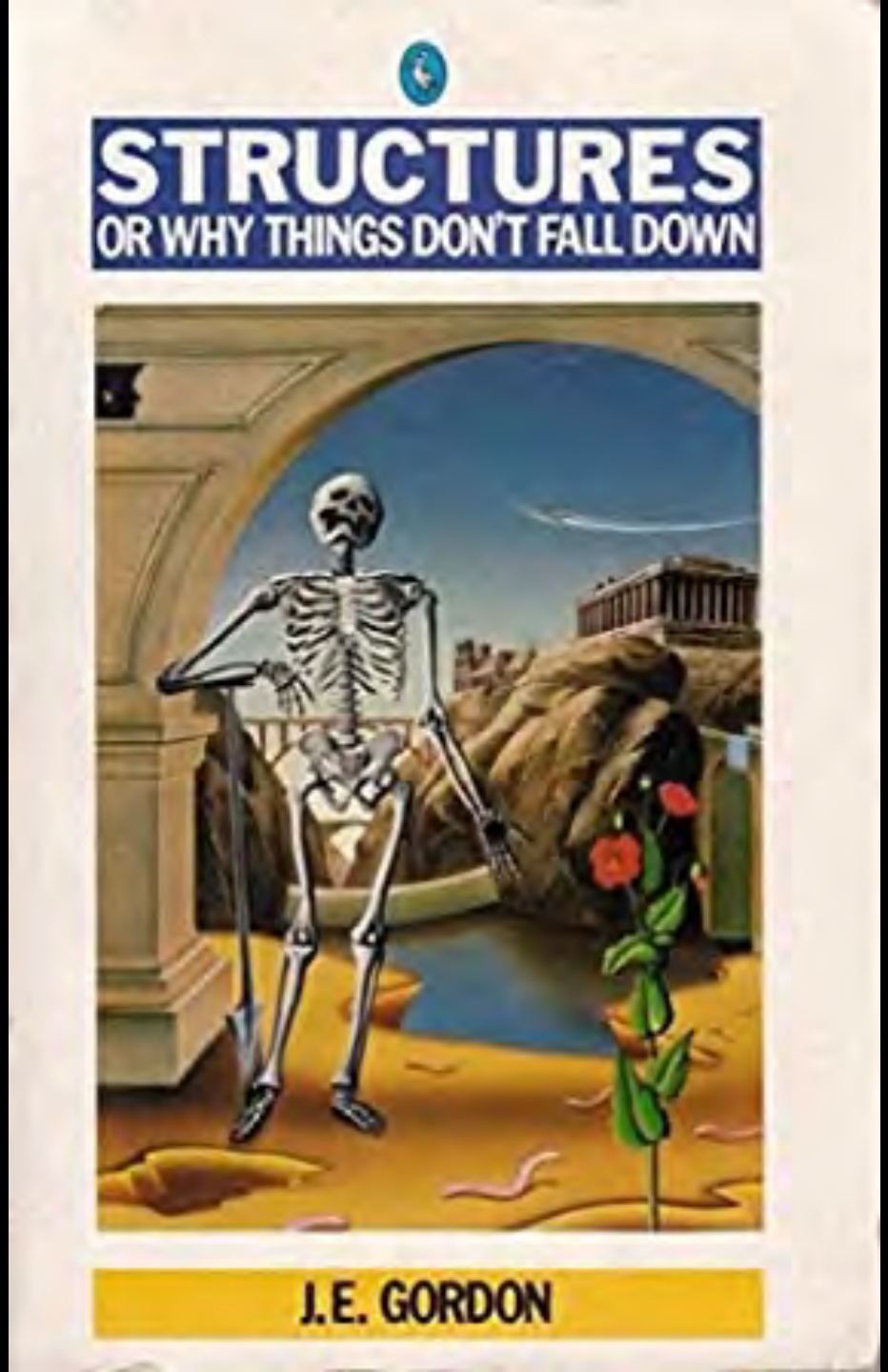
58

56

57

JAMES EDWARD GORDON
1913-2098

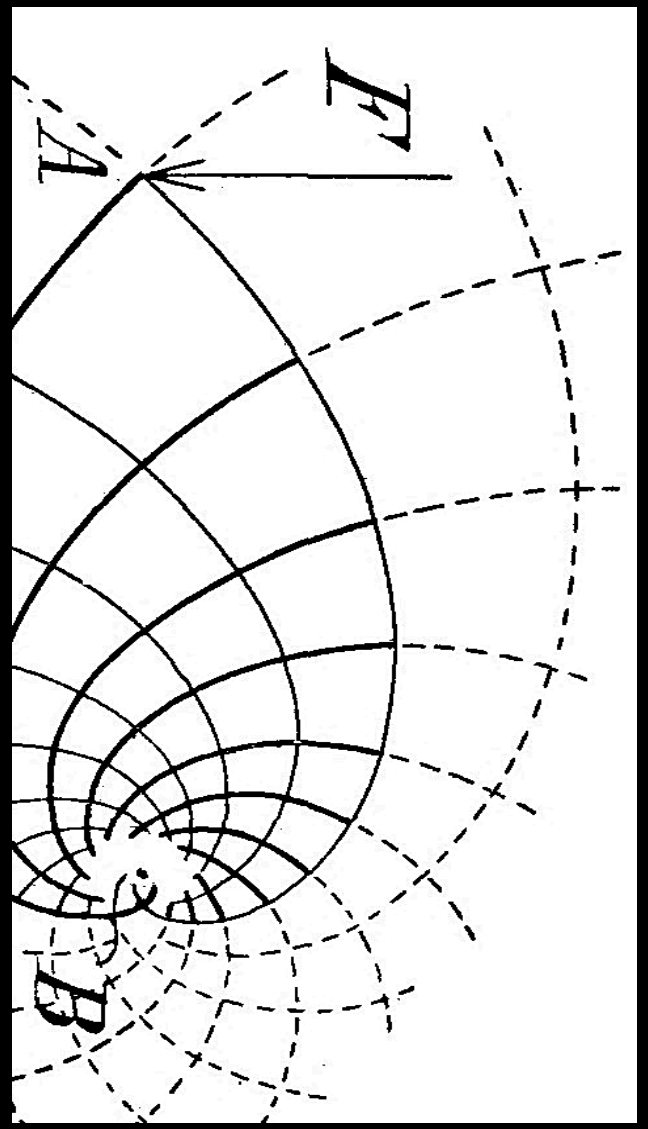
STRUCTURES
OR WHY THINGS DON’T FALL DOWN
1978

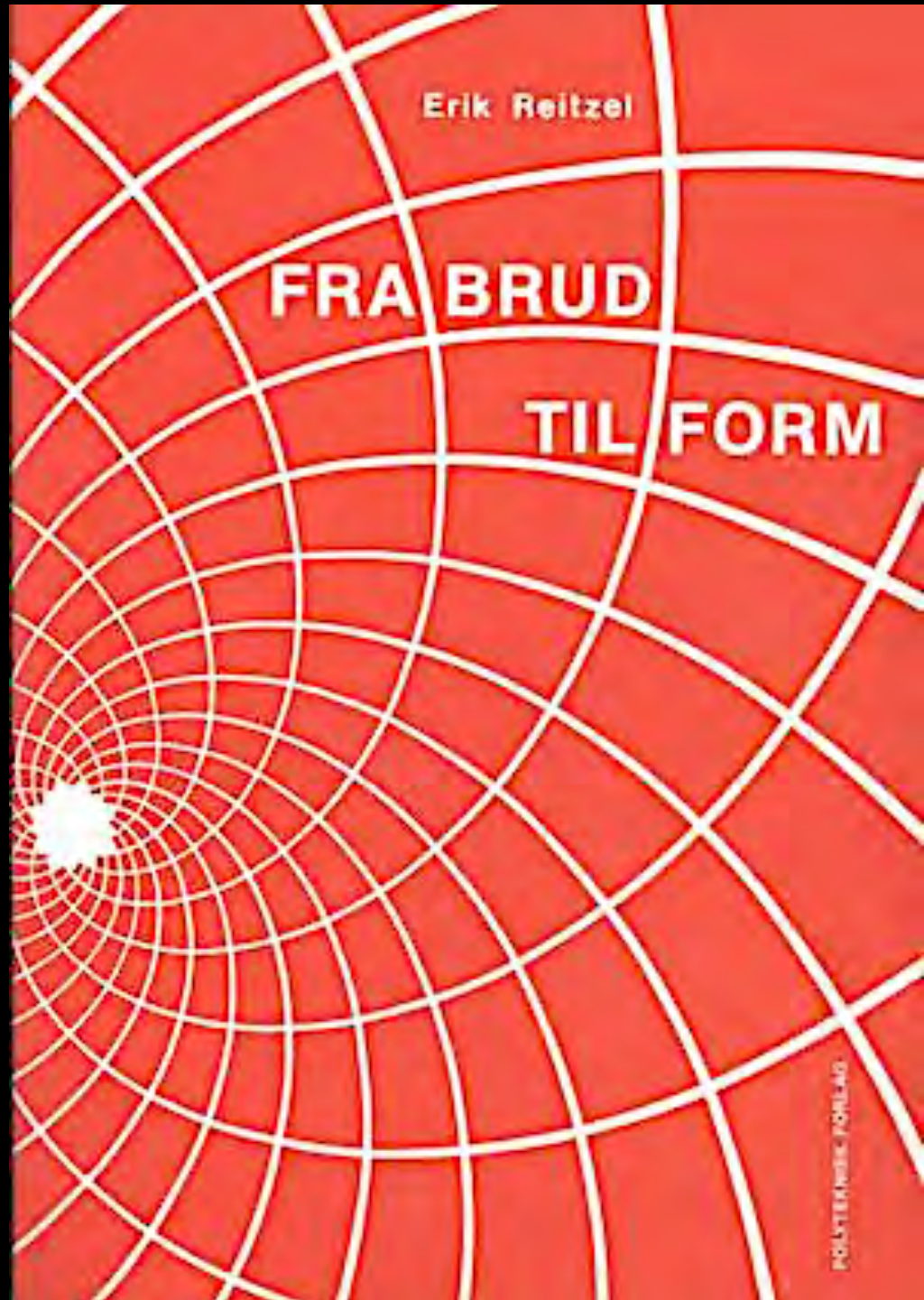


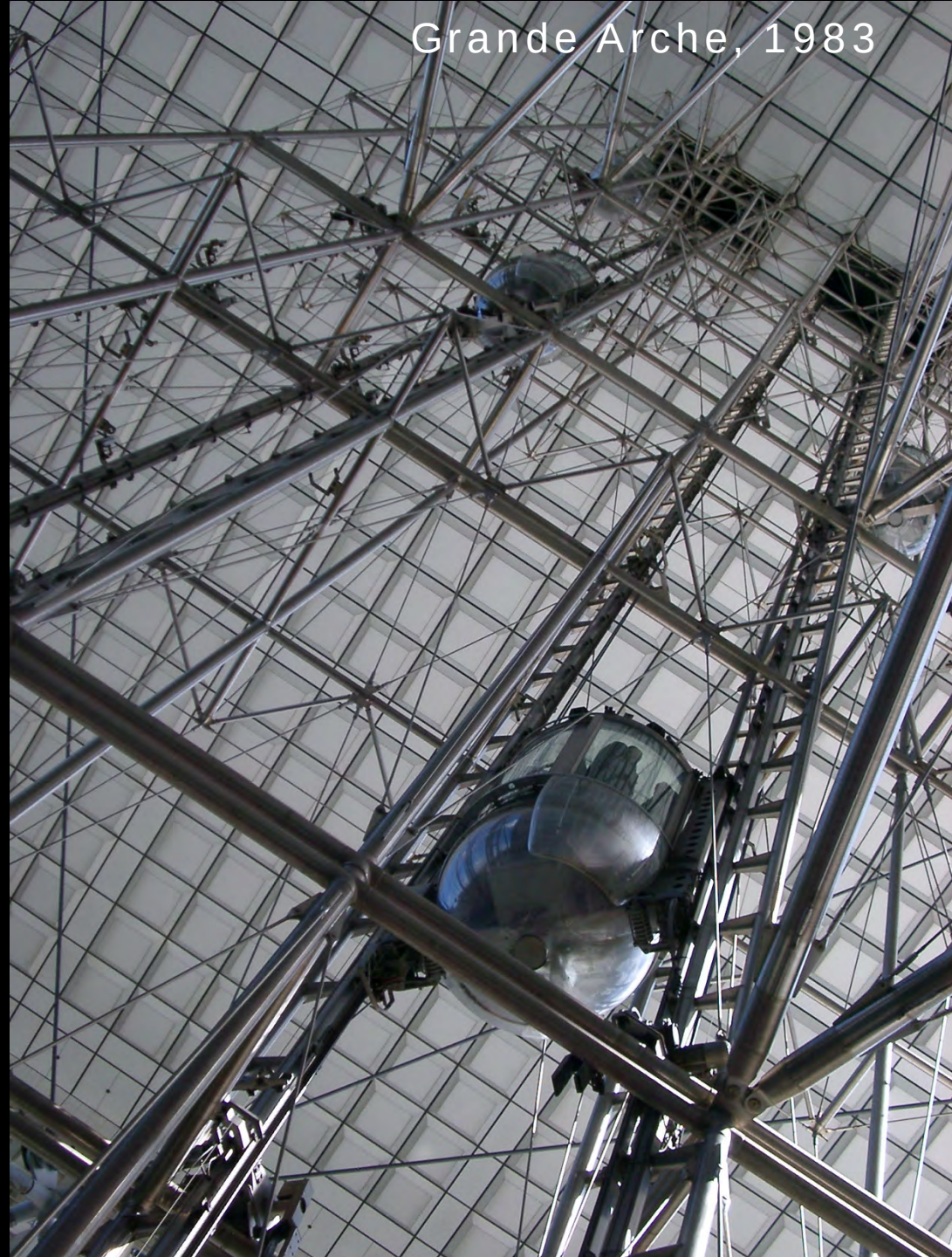
DH-98 Mosquito, 1940

ERIK REITZEL
1941-2012

Fra Brud til Form, 1979



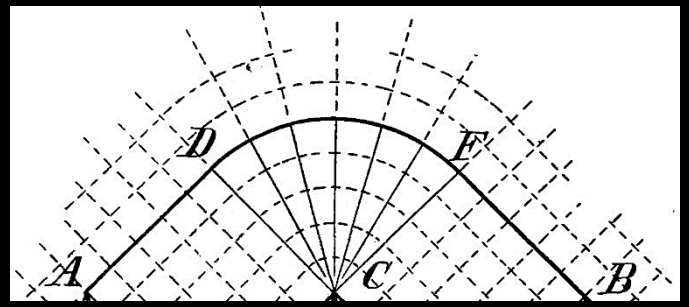




Grande Arche, 1983

BILL BAKER
1953

EXCHANGE HOUSE, 1990

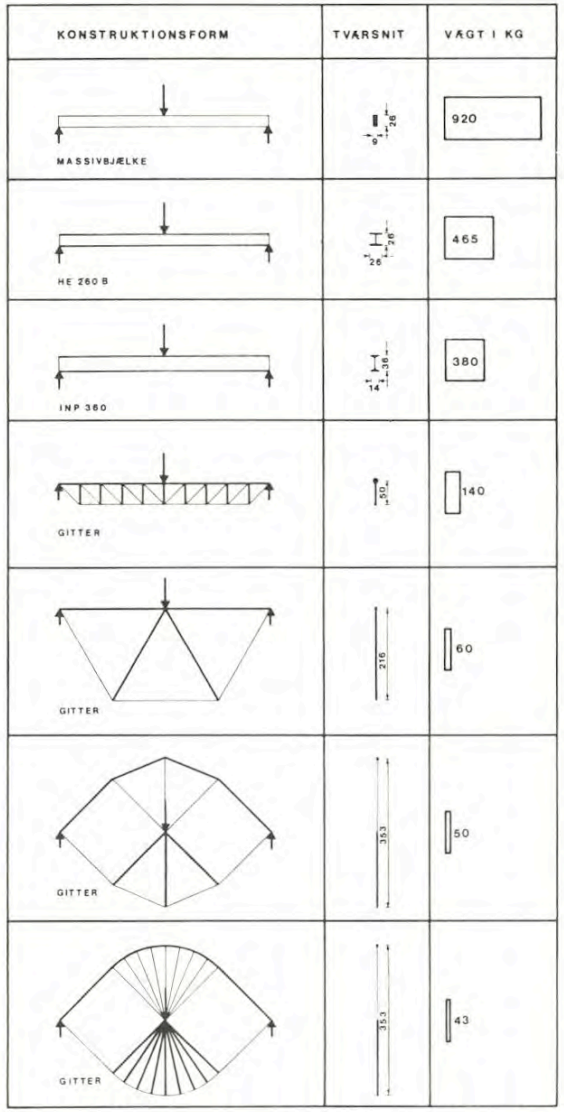



Burj Khalifa, 2010

Applications of minimal structures on design of beams in bending, simply supported with a pont load. The material is assumed to be steel and the volume varies from 920 kg with a massive square cross section to 43 kg for a minimal Mitchell design.

THEORETICAL VOLUME OF STRUCTURAL MATERIAL (STEEL) FOR DIFFERENT PROFILES OF A BEAM WITH A 5 METER SPAN.

BUCKLING IN COMPRESSION MEMBERS ARE DISREGARDED IN THE EXAMPLES.



Figur 3.07
Fiktiv skitsering af forskellige bjælkeformer med tilhørende nødvendigt materialeforbrug (i kg). Bjælkerne, som her er i stål, har alle samme spændvidde på 5 m og en belastning på 100 KN på midten.

Eksemplerne er teoretiske, og der regnes med, at trykstængerne er fasthold mod udbøjning.

920 kg

455 kg

380 kg

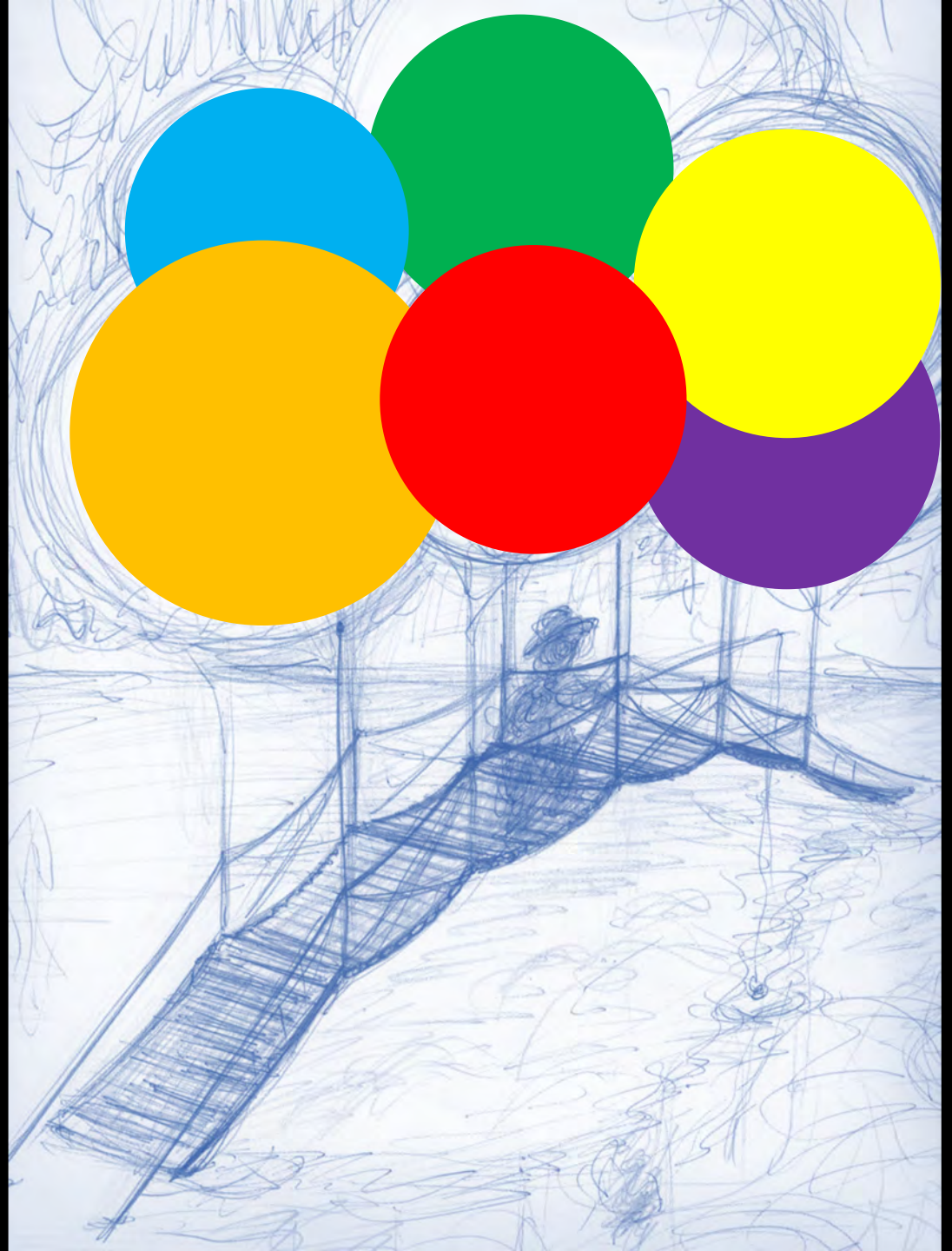
140 kg

60 kg

50 kg

43 kg

break ...

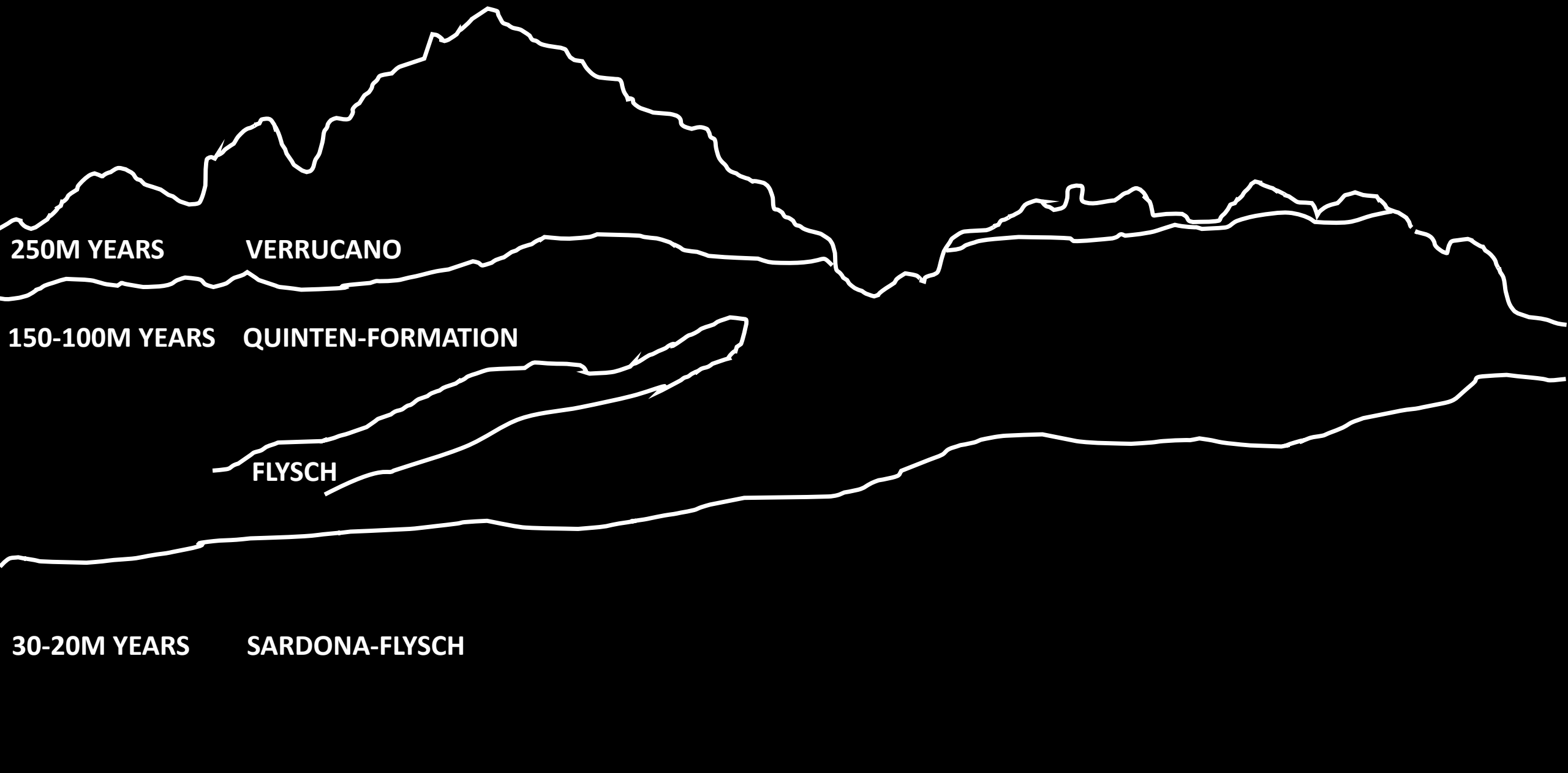


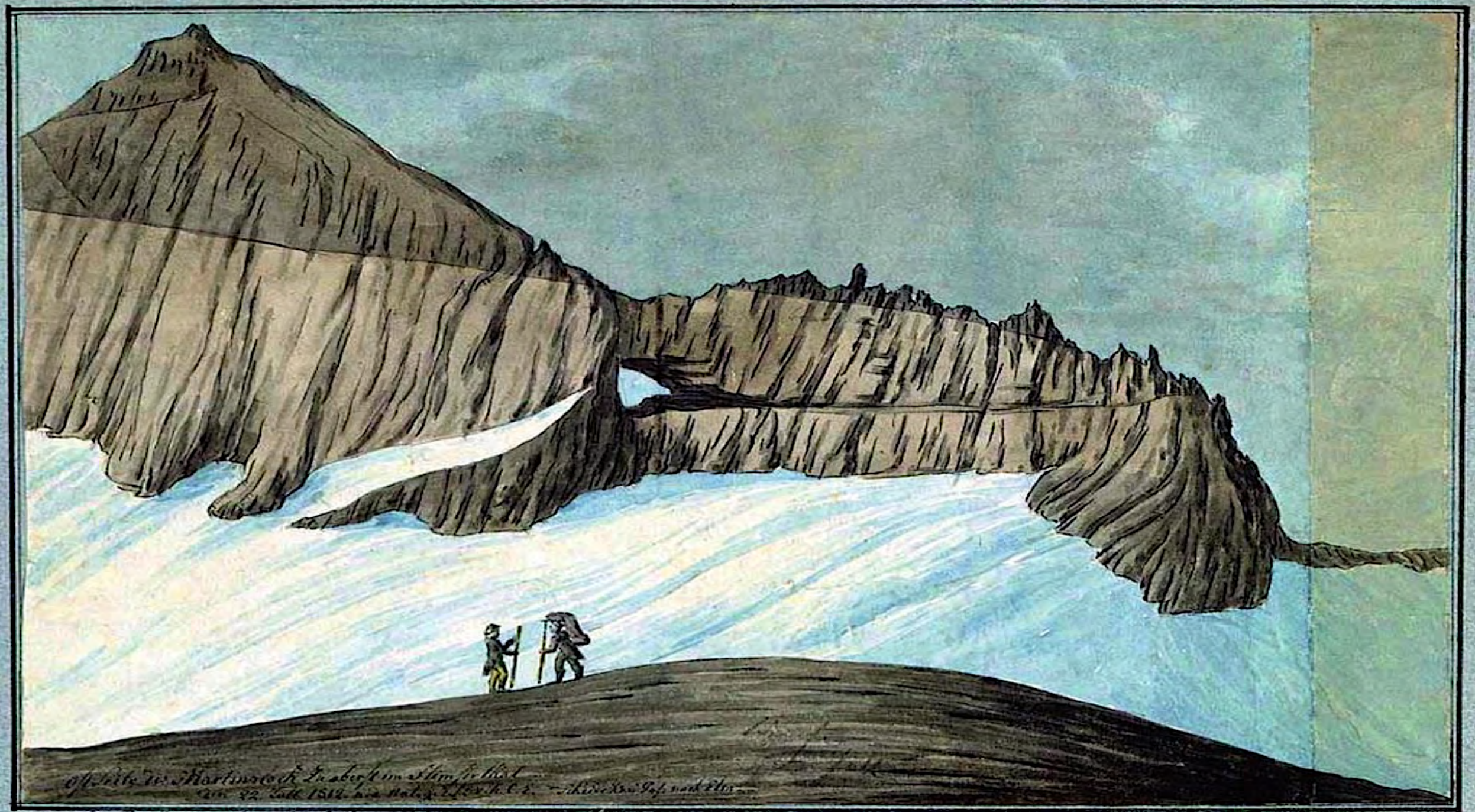
Olivier Grossetête

BRIDGES AS ENGINEERING ART

Three bridges by Jürg Conzett
in Switzerland
each with a strong concept.
Conzett plays with the forces
and tells a story
with a keen eye on the context.

WASSERFALL BRIDGE
about 12m SPAN
2014


250M YEARS
VERRUCANO
150-100M YEARS
QUINTEN-FORMATION
FLYSCH
30-20M YEARS
SARDONA-FLYSCH



An der Scheidecke des Martinsochs, ostseite derselben zuoberst im Flimserthal in Bünden ~~ Pass nach Elm. Den 22 Juli 1812 n. d. Nat. gezeichnet v. C. Escher

SURANSUNS BRIDGE
40 m SPAN
1999

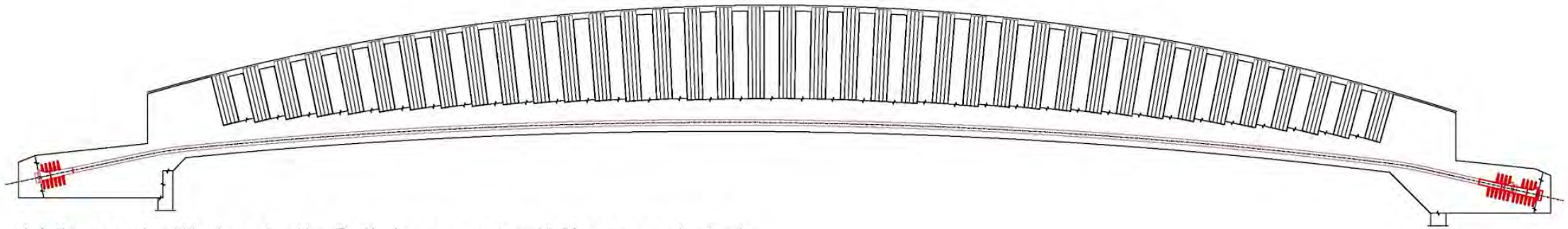
DORF BRIDGE
about 20m SPAN
2009

Jürg CONZETT
1956

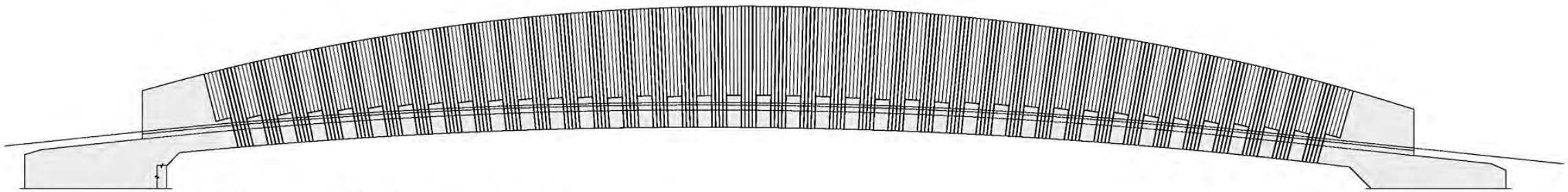
PHOTOGRAPHED BY
HÉLÈNE BINET


TOI TOI
CAT

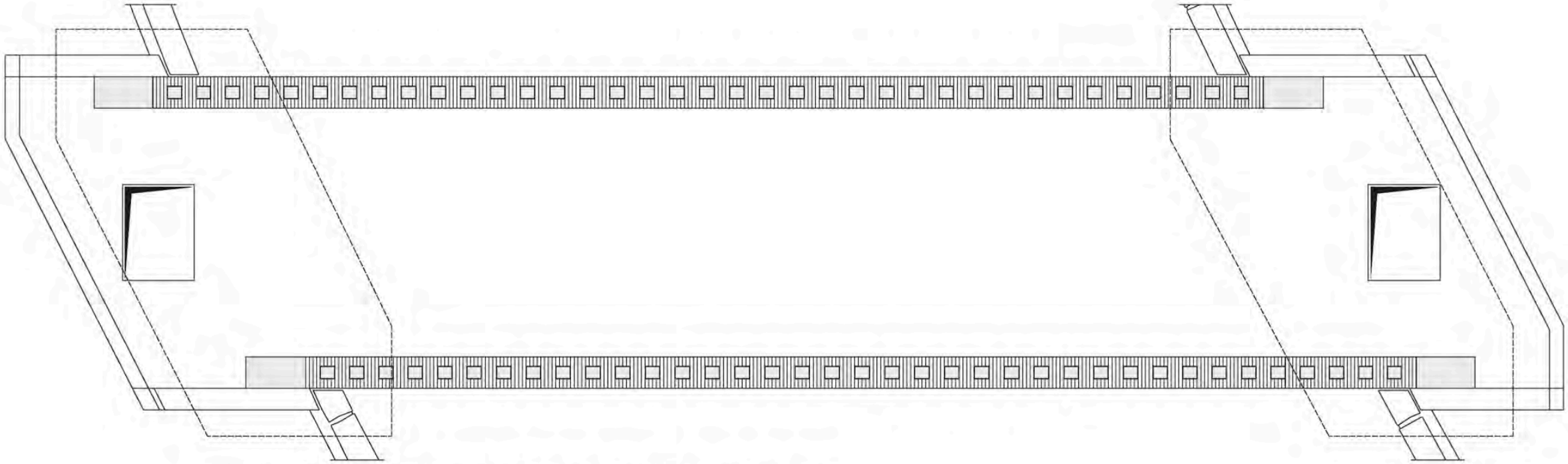

Zerfreila
P
ZONE



^Längsschnitt durch die Brückenwand mit Vorspannkabel.



^Ansicht der Brücke ohne Hochwasserschutzmauern.



^Aufsicht: Die Seitenwände sind parallel verschoben.

0 1 5 m


ZONE
Zerfreila

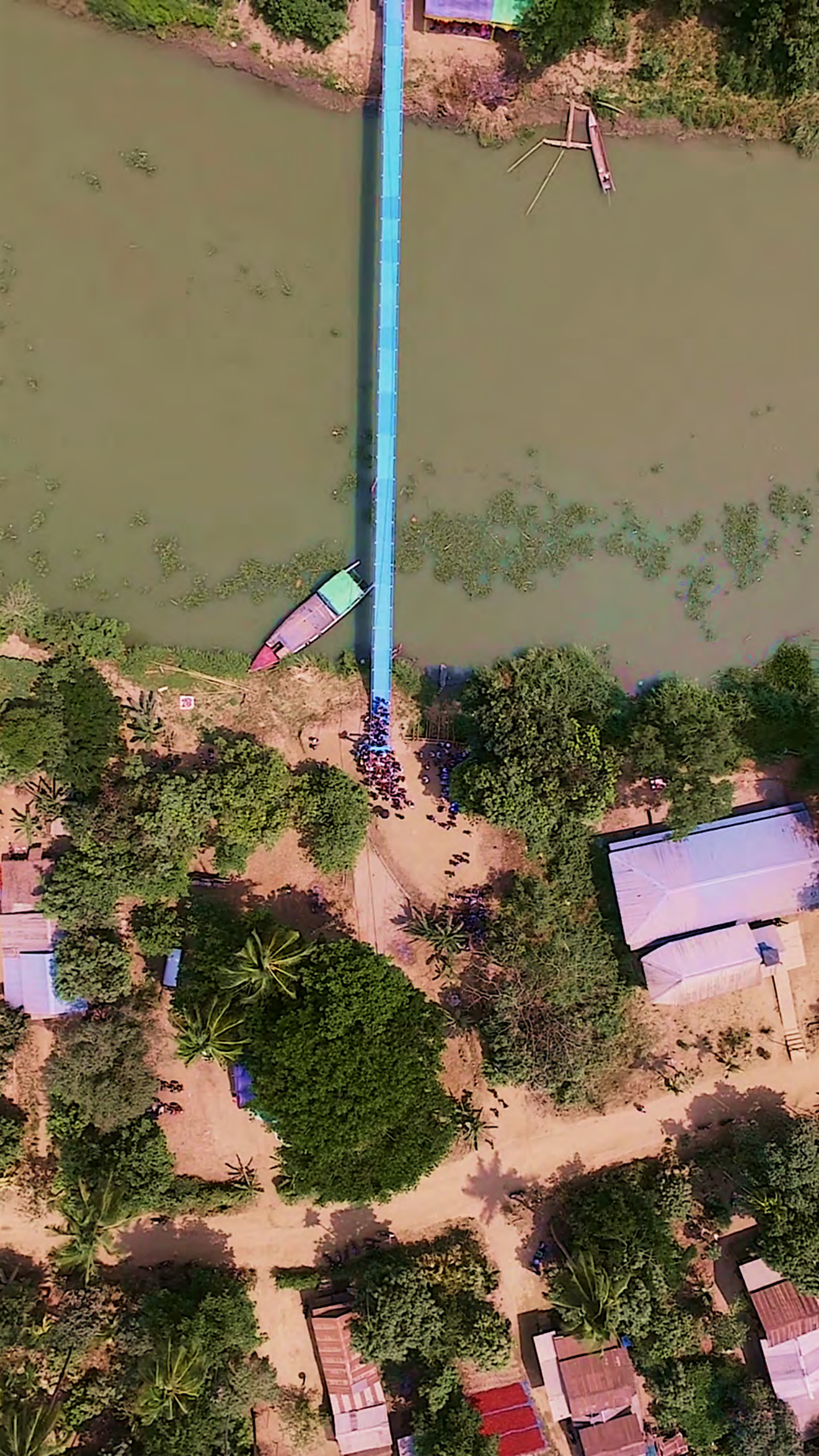
BRIDGES = EMPOWERMENT

The Swiss Toni Rüttimann
helps people in poor areas
of South Asia and South America
to build bridges themselves.
Materials are provided for free:
used cables from ski lifts
and pipes from the oil industry.

PUENTE DEL RÍO AGUARICO
Ecuador
264m span
1999

Toni Rüttiman
1967

PAY PIN TAUNG BRIDGE
Myanmar
about 100m span
2018

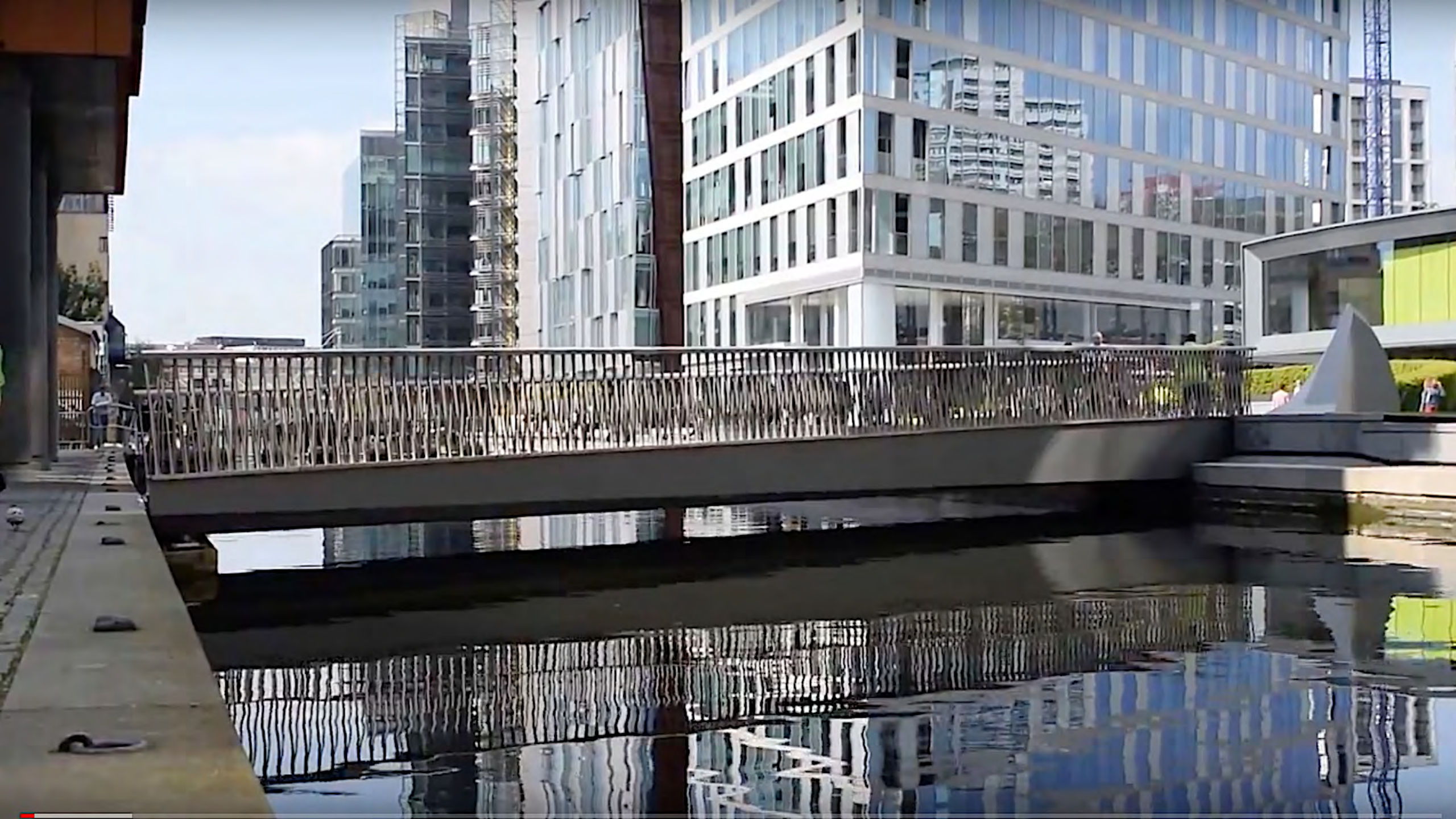


OPENING BRIDGES IN LONDON

Bridges can be made to open
and the mechanical movement
can be choreographed
into playful gestures
that gives the place
a particular identity.

FAN BRIDGE
20m span
2014
PADDINGTON

Knight Architects



ROLLING BRIDGE
12 m span
2004
PADDINGTON

Thomas Hetherwick
1970

JIADING BRIDGE PROJECT
2010
SHANGHAI, CHINA

Thomas Hetherwick

FLOATING BRIDGES

Floating bridges
are usually temporary.
They are fast to build,
yet demanding in operation.
They can be used
for festivals.

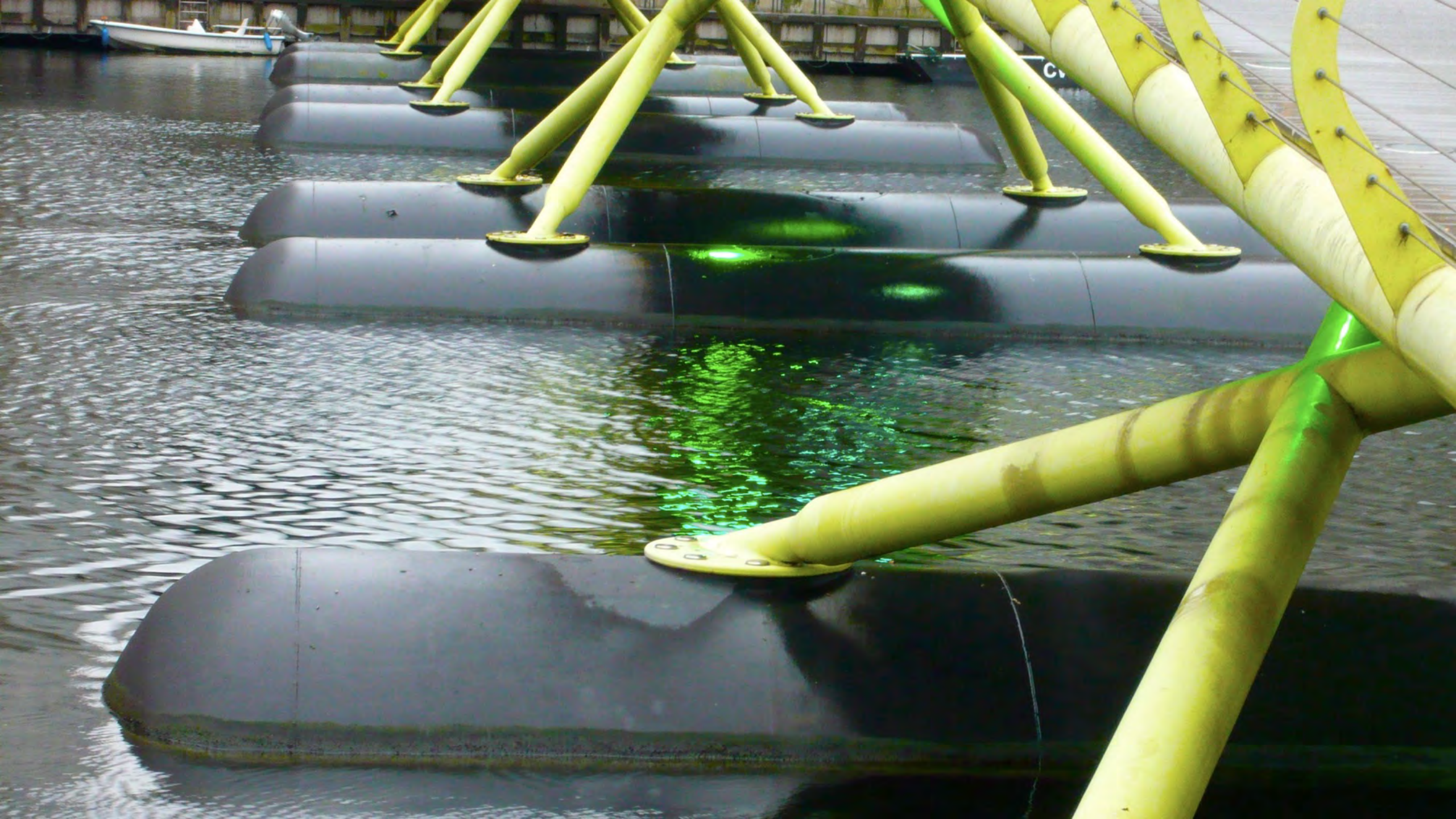
KUMBH MELA FESTIVAL
2001
ALLAHABAD

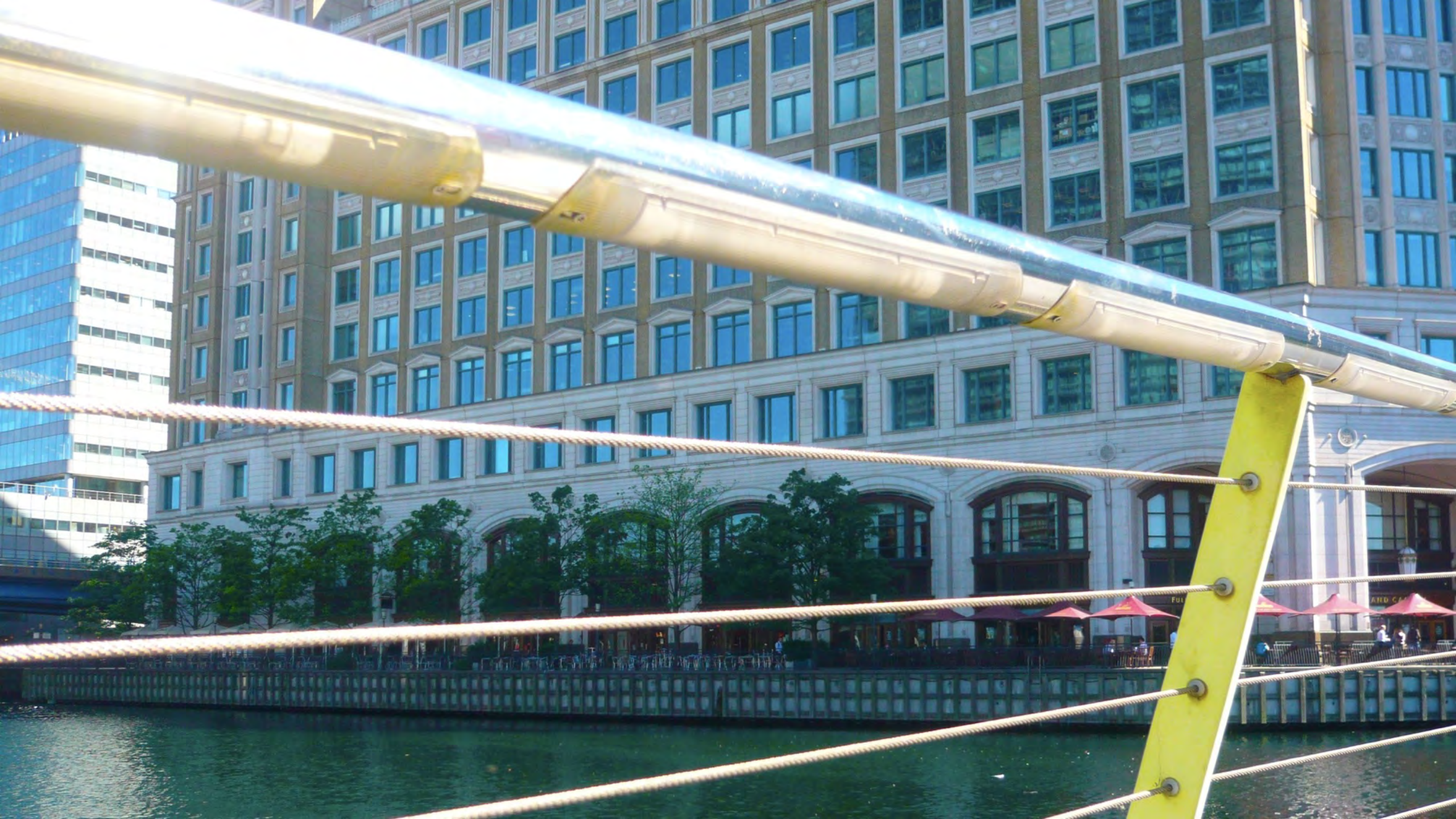
PONTE VOTIVO DEL REDENTORE
ANNUALLY FIESTA IN AUGUST
VENICE


EXIT

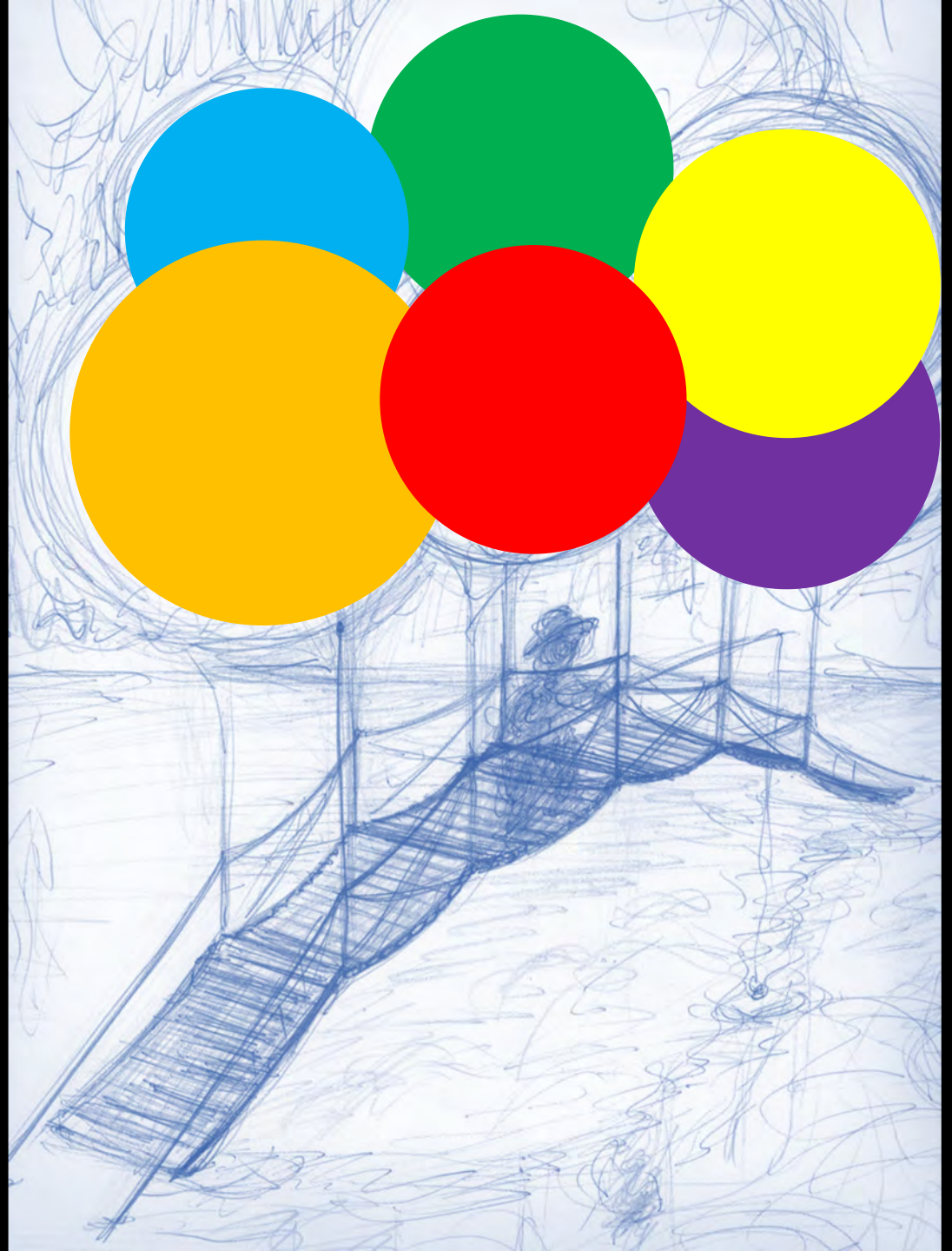
WEST INDIA QUAY BRIDGE
1996

Future Systems
Jan Kaplický
1937-2009





thank you



Olivier Grossetête