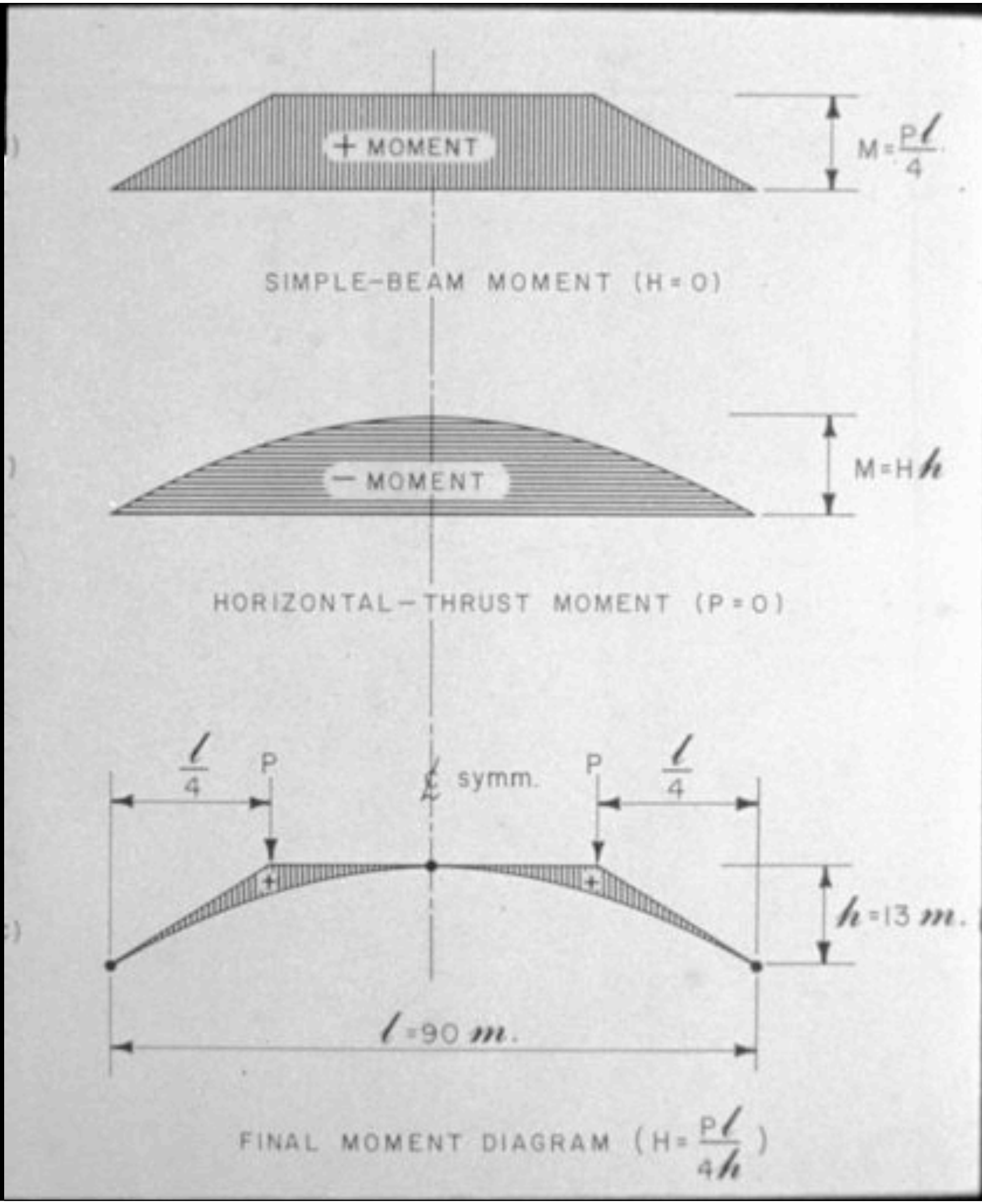
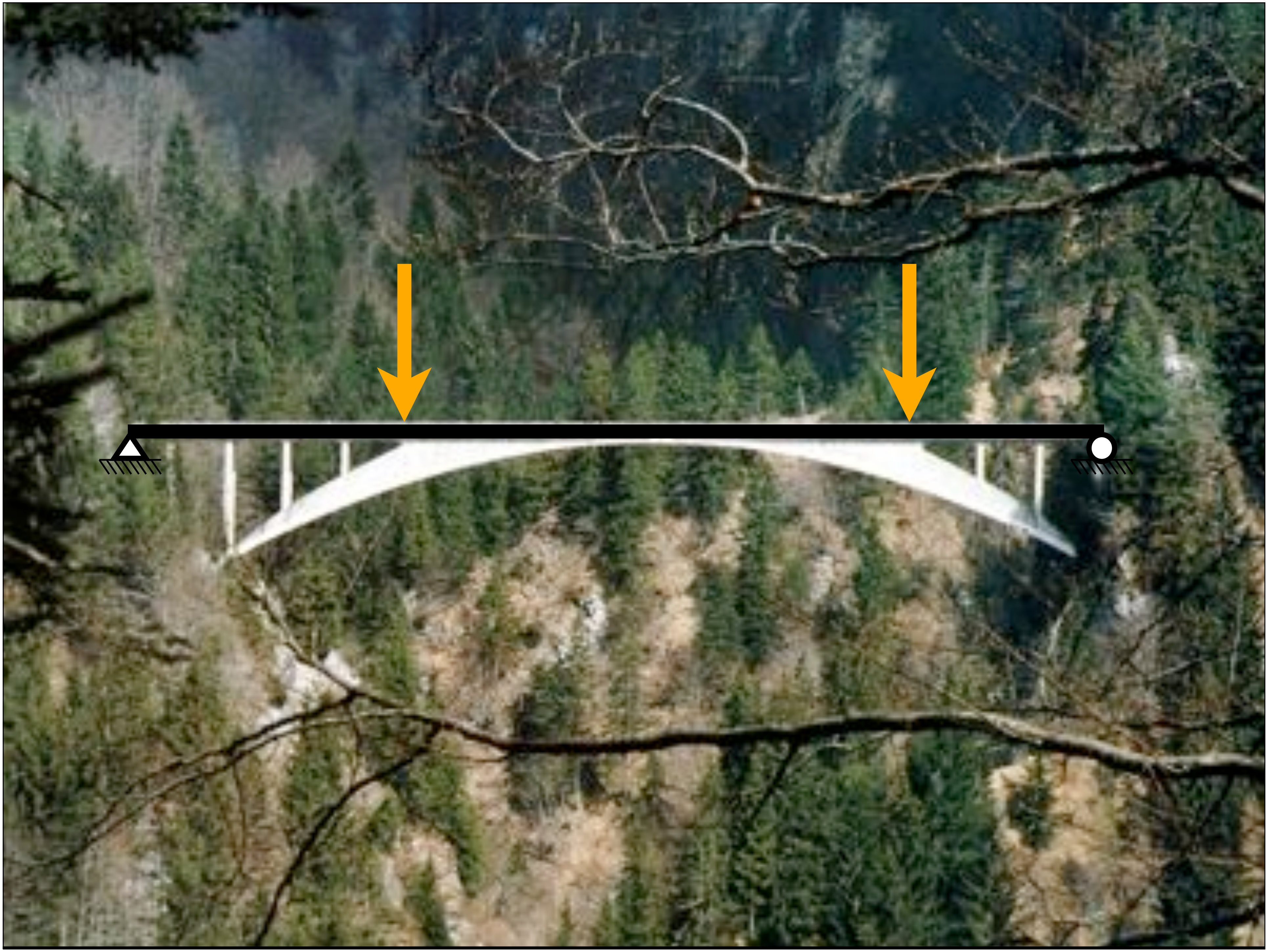
Freyssinet, Finsterwalder and Fallingwater

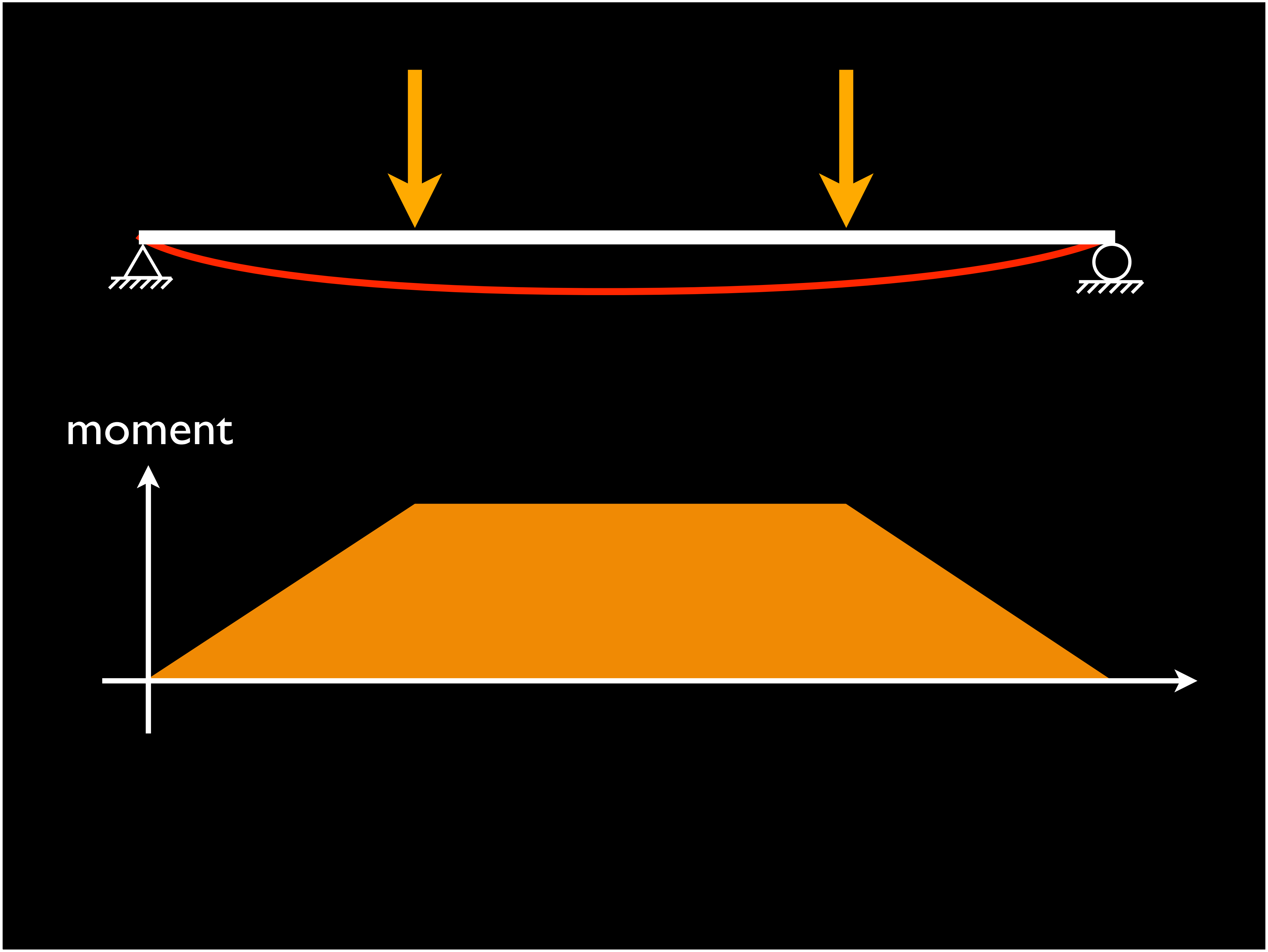
Origins and Solutions in Prestressed Concrete

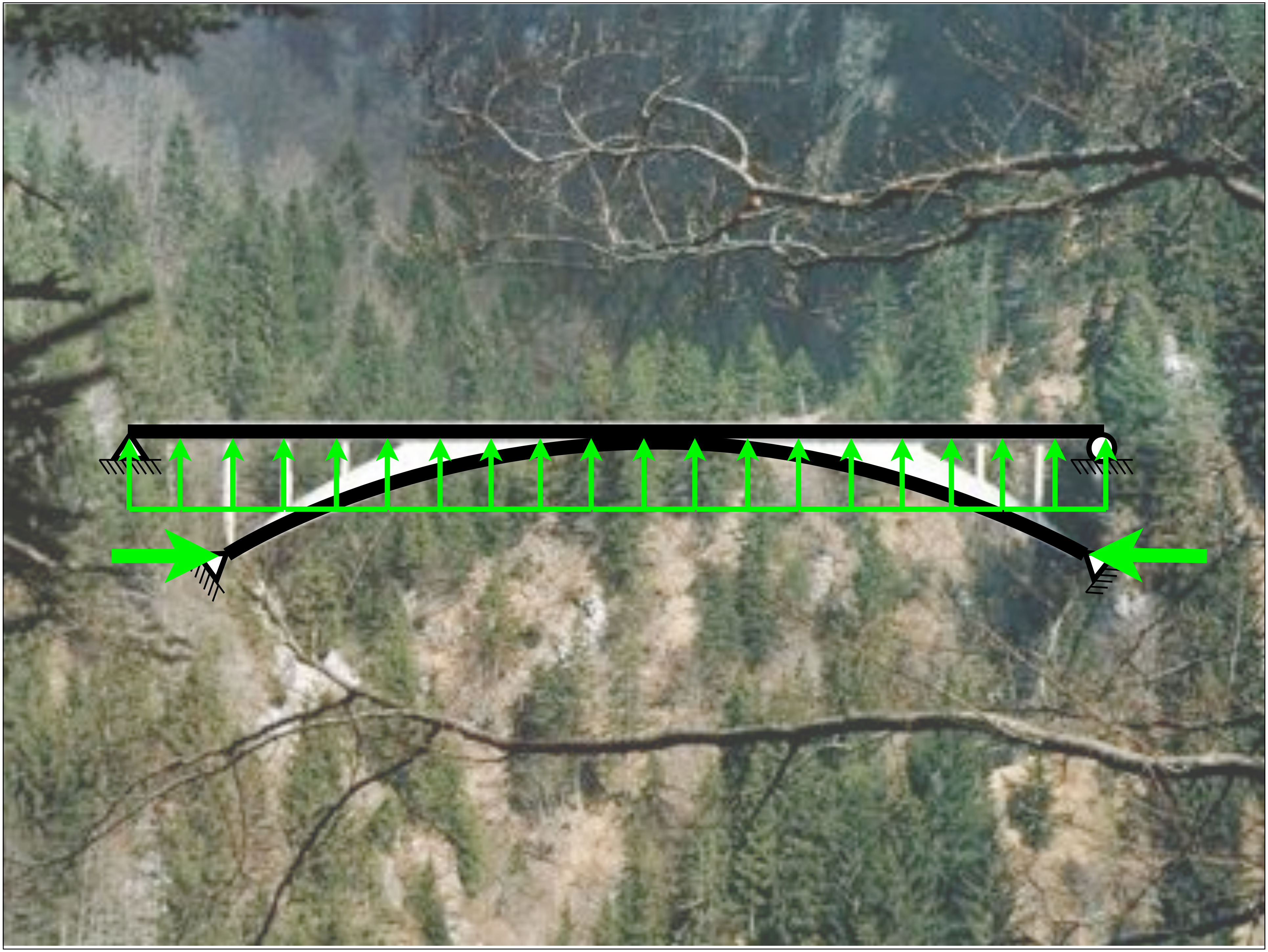
<u>Lecture themes</u>

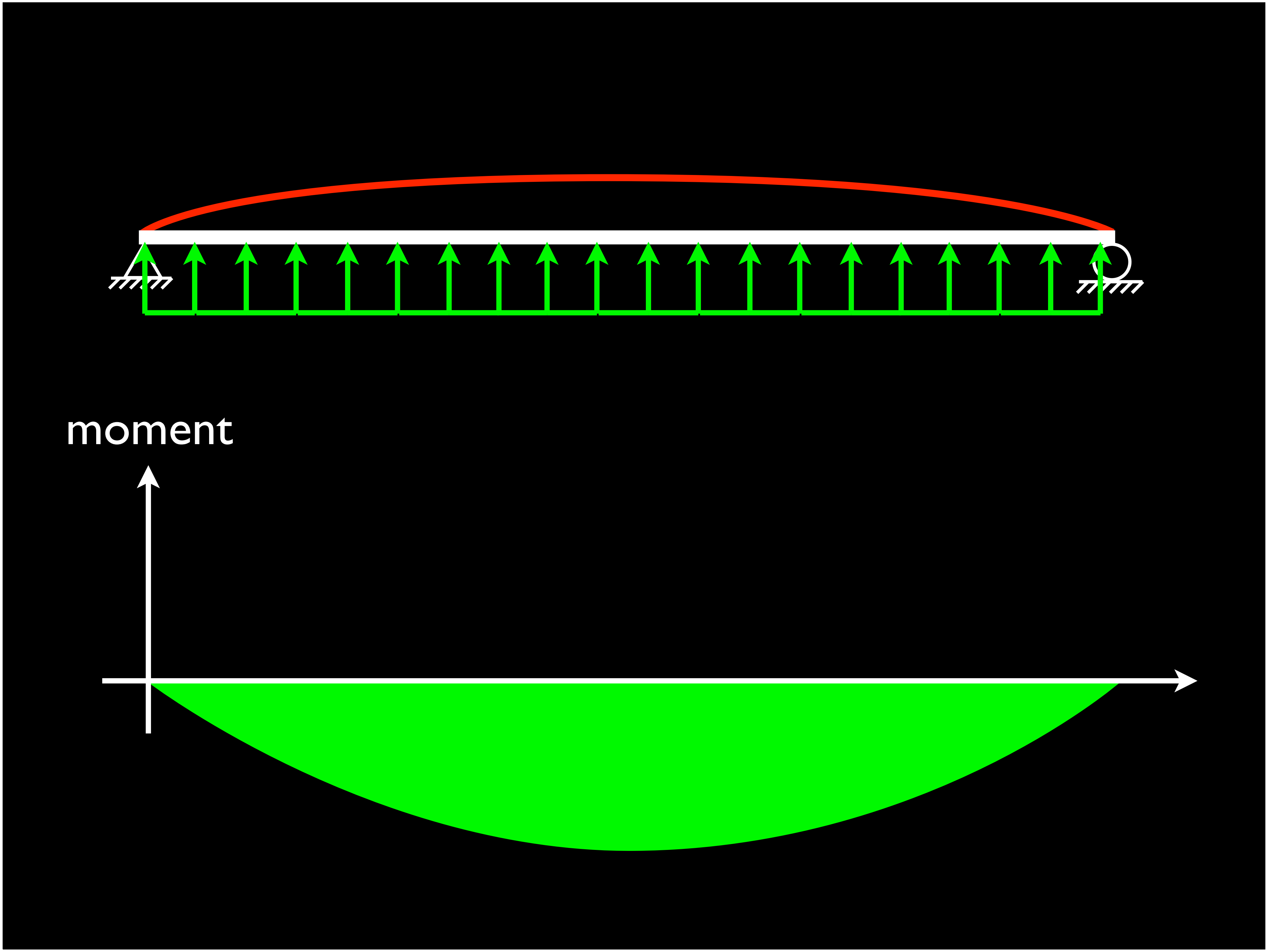
Freyssinet's story and the origins of prestressed concrete (PC)
  Aside: how does construction elegance map into structural art?
Finsterwalder's advancements in PC briddges
  Aside: Magnel's ground breaking work popularizing PC
Precast PC and America's Walnut Lane Bridge
  Aside: Challenges with expressing form in PC
Fallingwater, historic preservation enabled through PC


+ MOMENT
M = Pl/4
SIMPLE-BEAM MOMENT (H = 0)
− MOMENT
M = Hh
HORIZONTAL-THRUST MOMENT (P = 0)
l/4
P
℄ symm.
P
l/4
+
+
h = 13 m.
l = 90 m.
FINAL MOMENT DIAGRAM (H = Pl/4h)




moment

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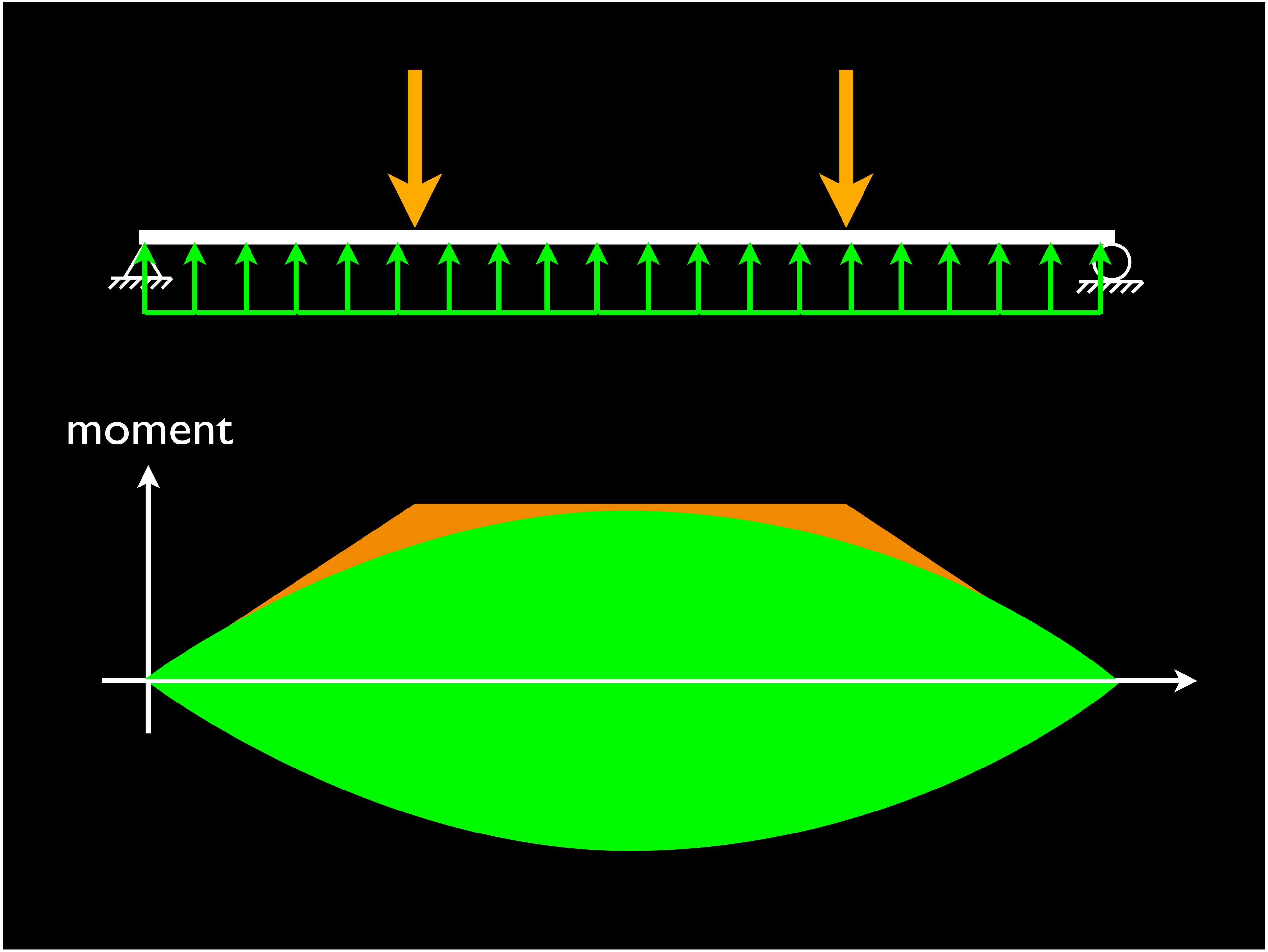
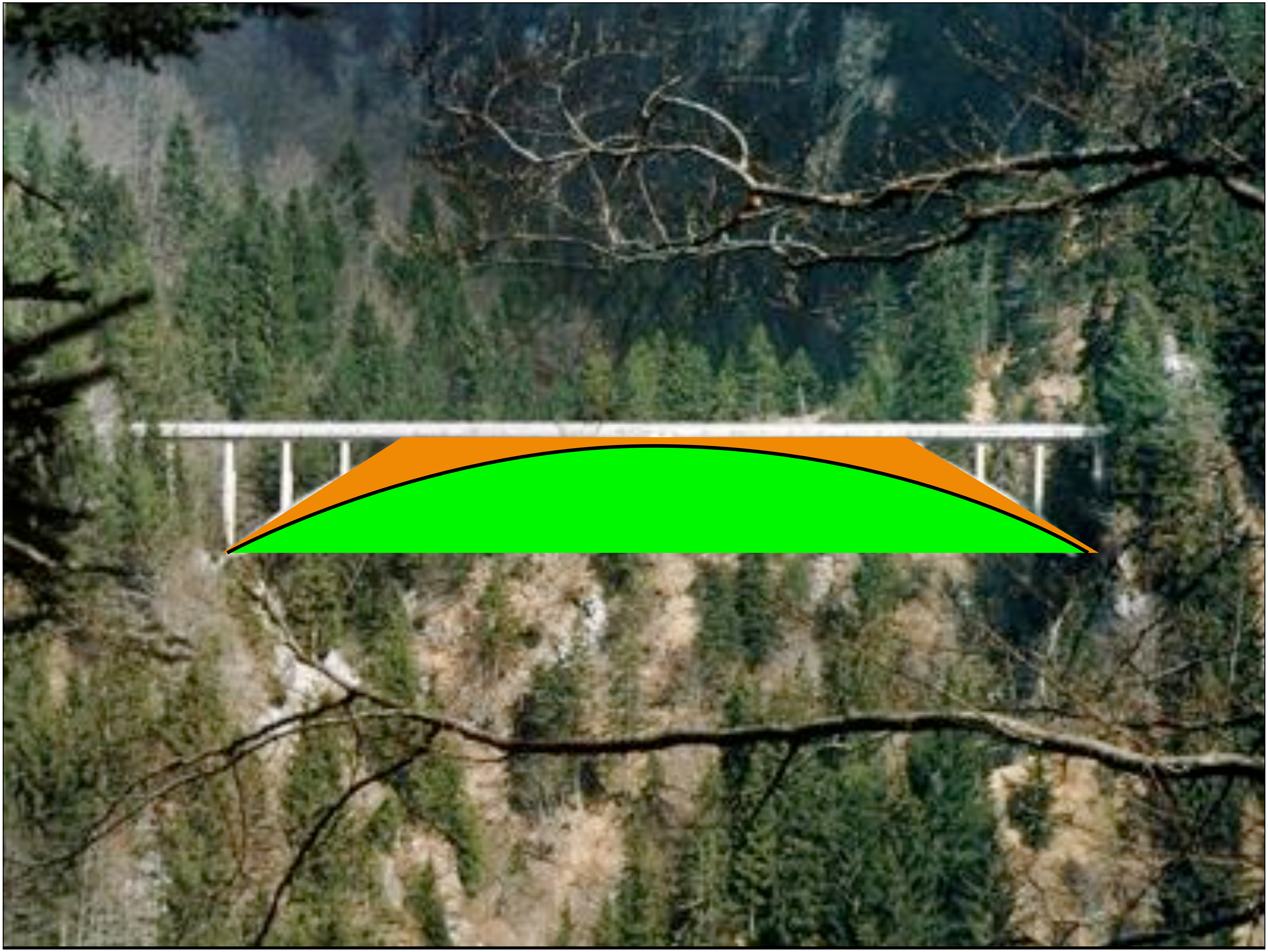
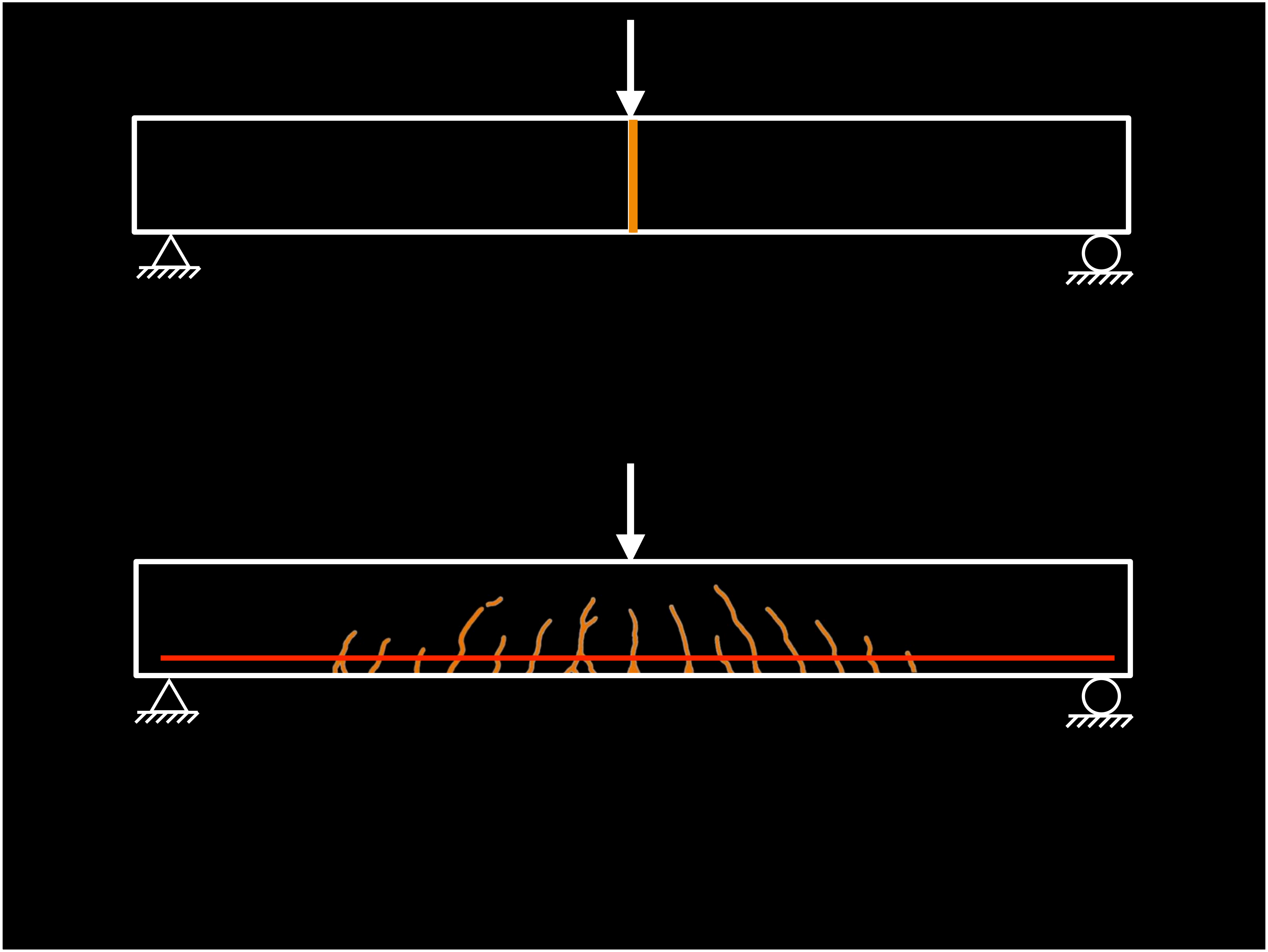

moment



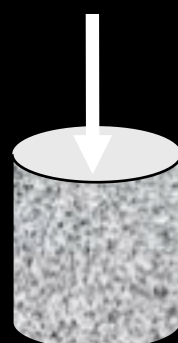


Le Veurdre

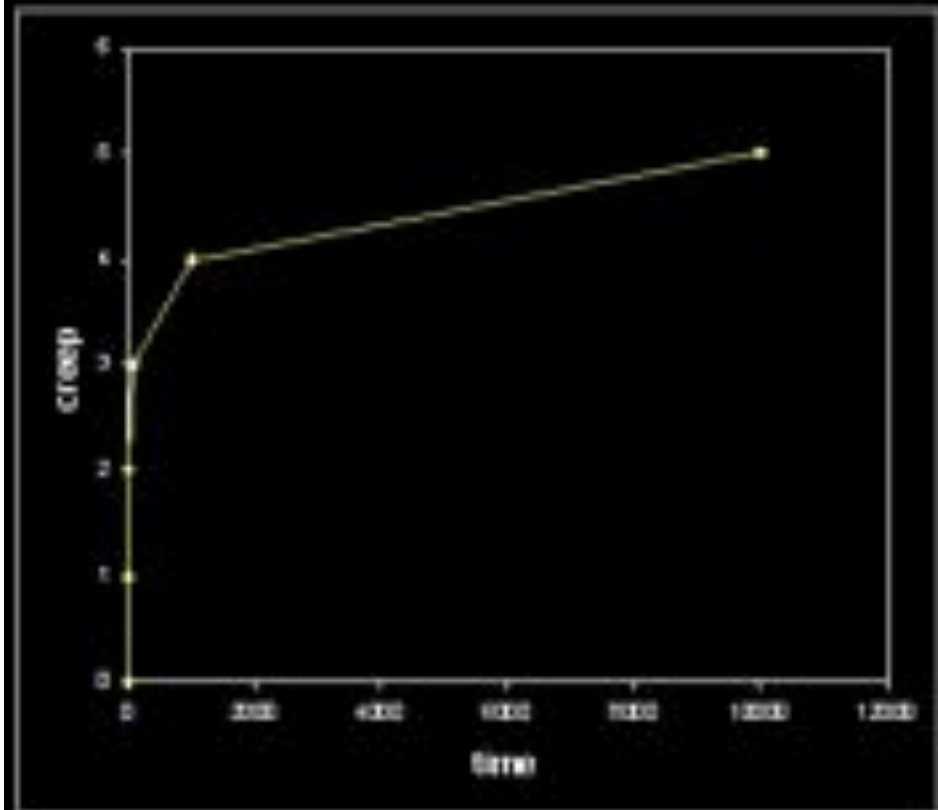
Freyssinet
1879-1962

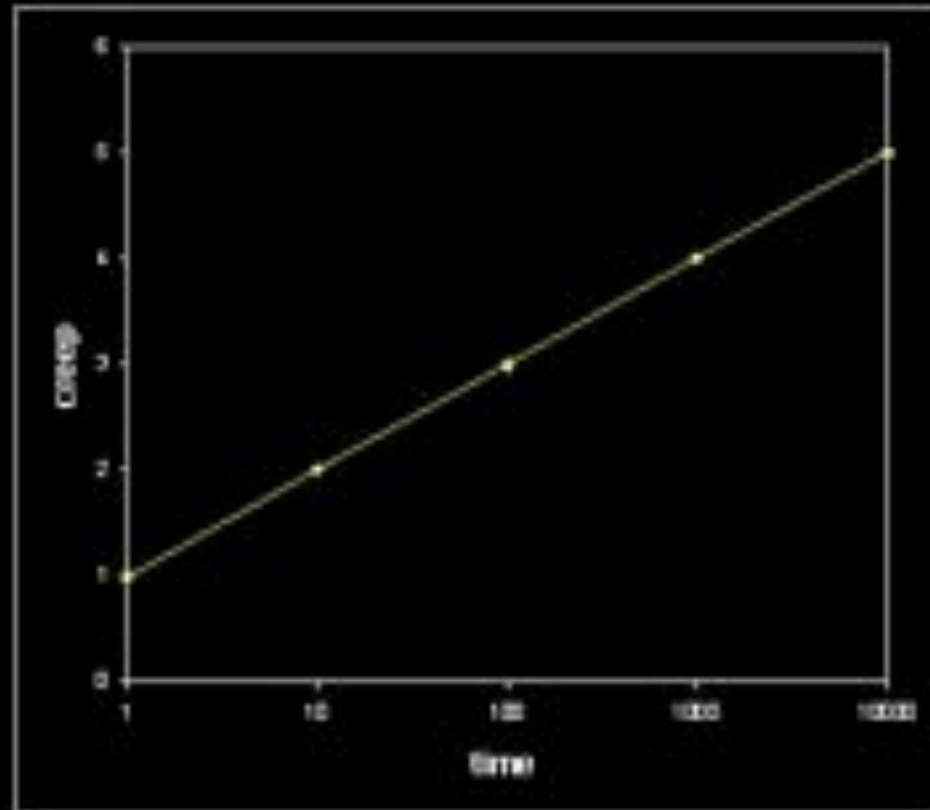
"an official letter put me in charge of supervising…the execution of these bridges whose designer I was, for which I was to be the contractor and the plans of which had never been submitted for anyone's approval…[My superior granted] me unlimited credit out of his funds but without giving me a single man, tool, or piece of advice. Never was a builder given such freedom, I was absolute master receiving orders and advice from no one."

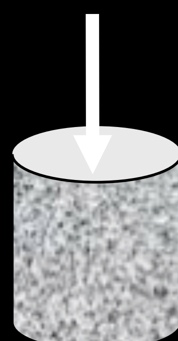
Freyssinet's recollection of the Le Veurdre commission



apply load and hold
what happens?







apply load and hold
what happens?

Journal of Advanced Concrete Technology Vol. 1, No. 2, 188-200, July 2003 / Copyright © 2003 Japan Concrete Institute

Linear Logarithmic Model for Concrete Creep
II. Prediction Formulas for Description of Creep Behaviour

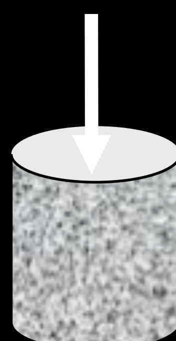
Mårten Larson[1] and Jan-Erik Jonasson[2]

Received 30 November 2002, accepted 10 April 2003

Abstract

A reliable modelling of the young concrete creep behaviour is of great importance for consistent thermal crack risk estimations that shall contribute to assure a desired service lifetime and function of a structure.

All-embracing creep tests aimed for thermal stress analyses are often very time consuming and thereby also costly to perform. Therefore thermal stress calculations in everyday engineering practice are often performed with standard sets of creep data involving no or very limited laboratory testing, which increases the error of the crack risk predictions and consequently also affect the design safety margins. The need for formulations that based on limited test data can make



apply load and hold
what happens?

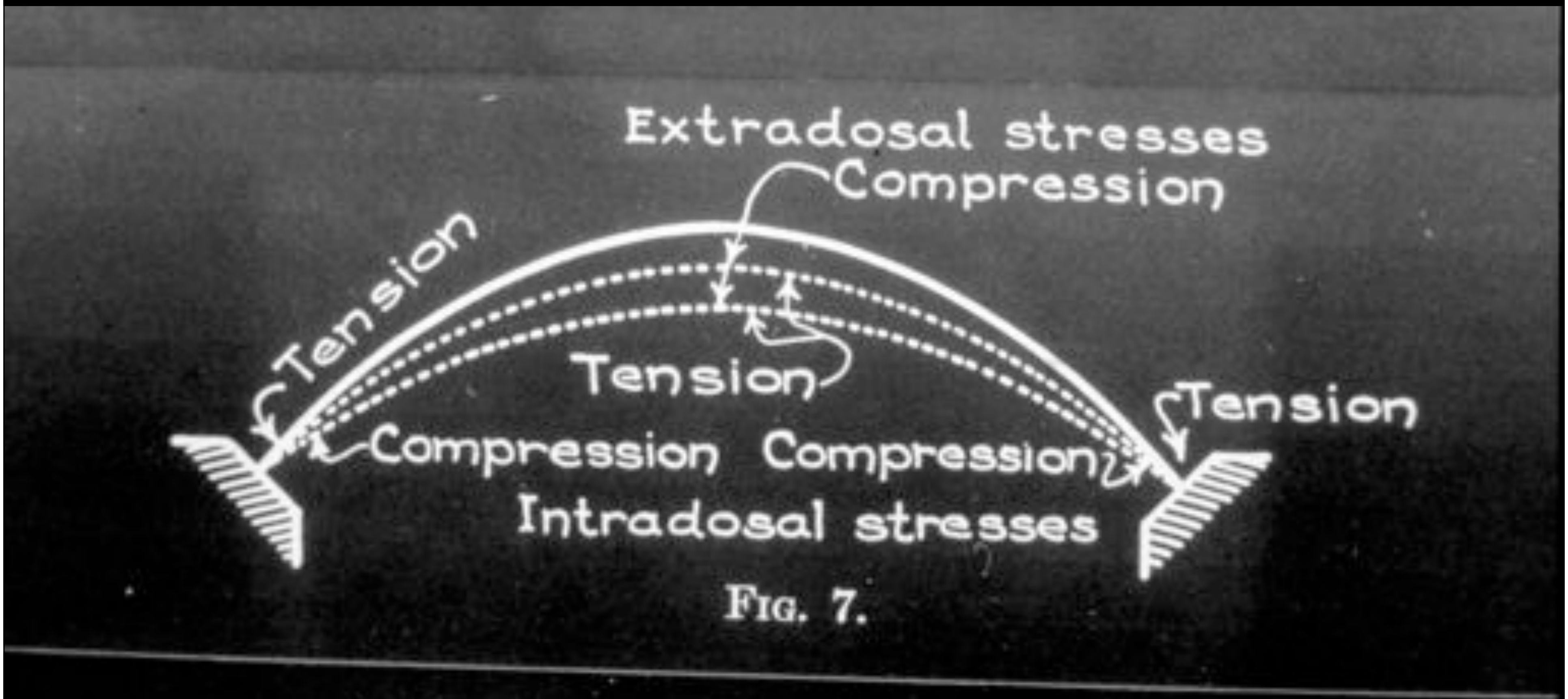
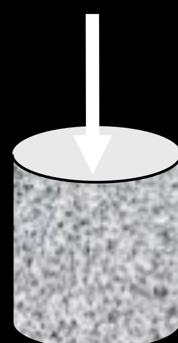
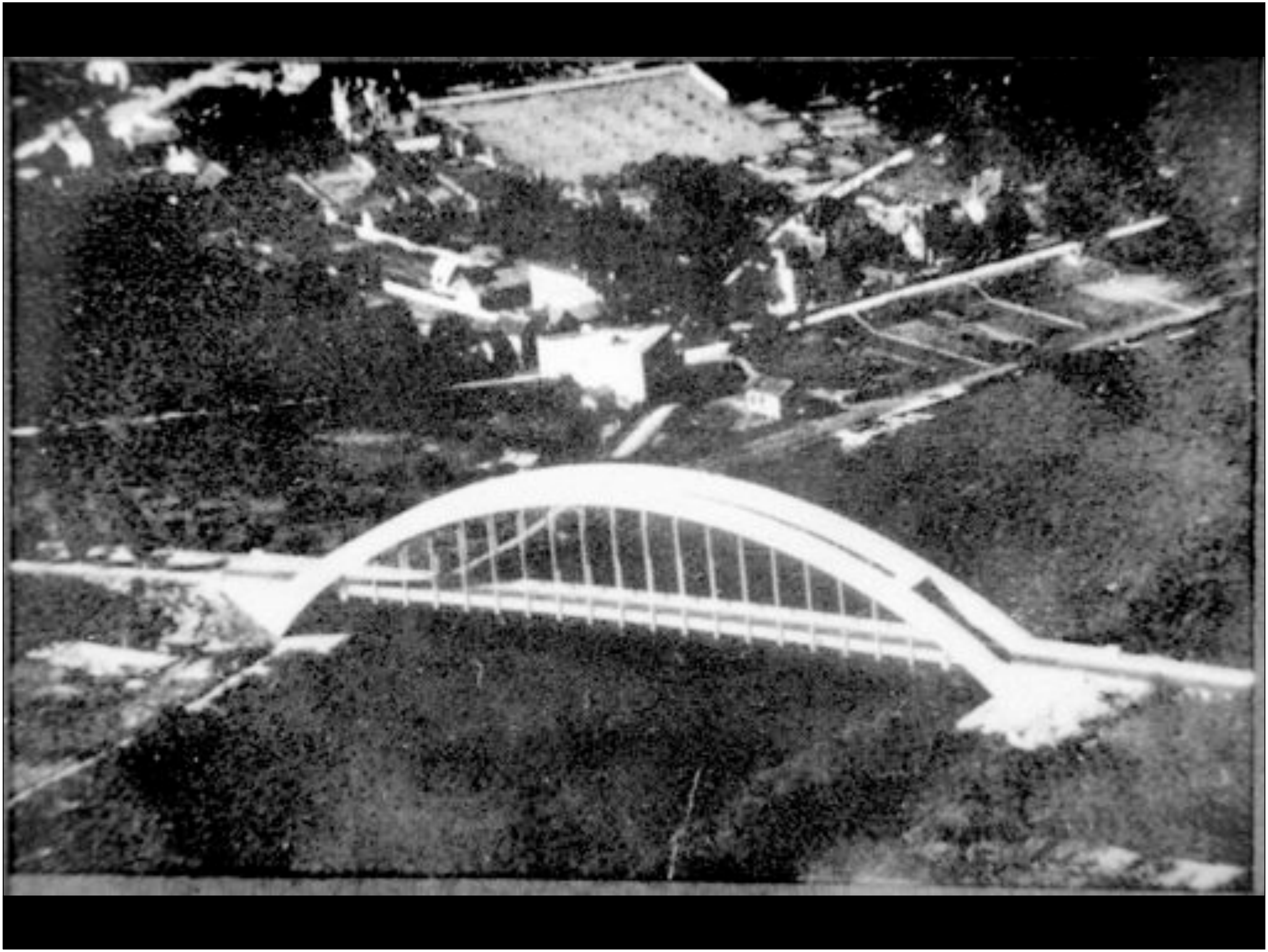


FIG. 7.



apply load and hold
what happens?

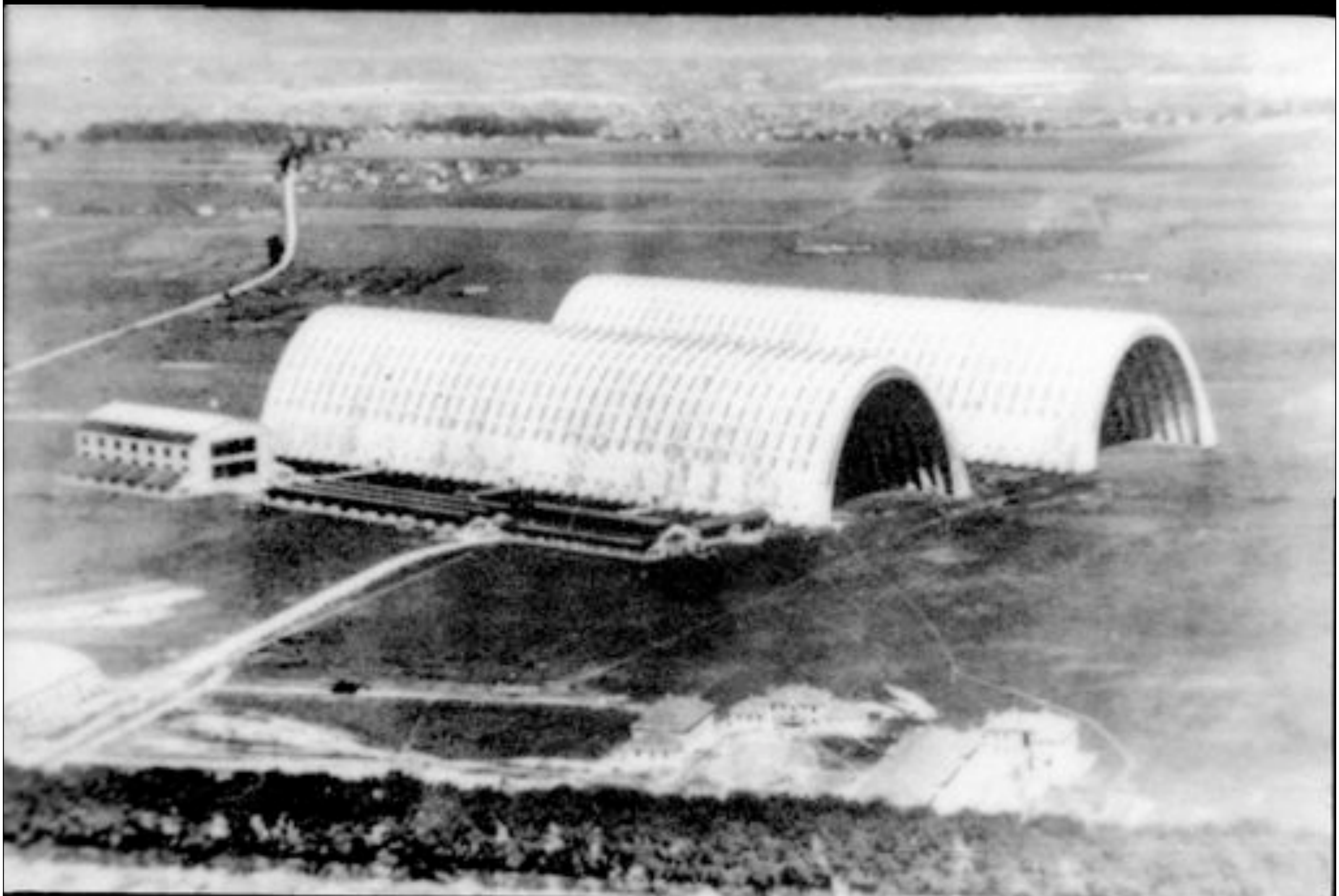


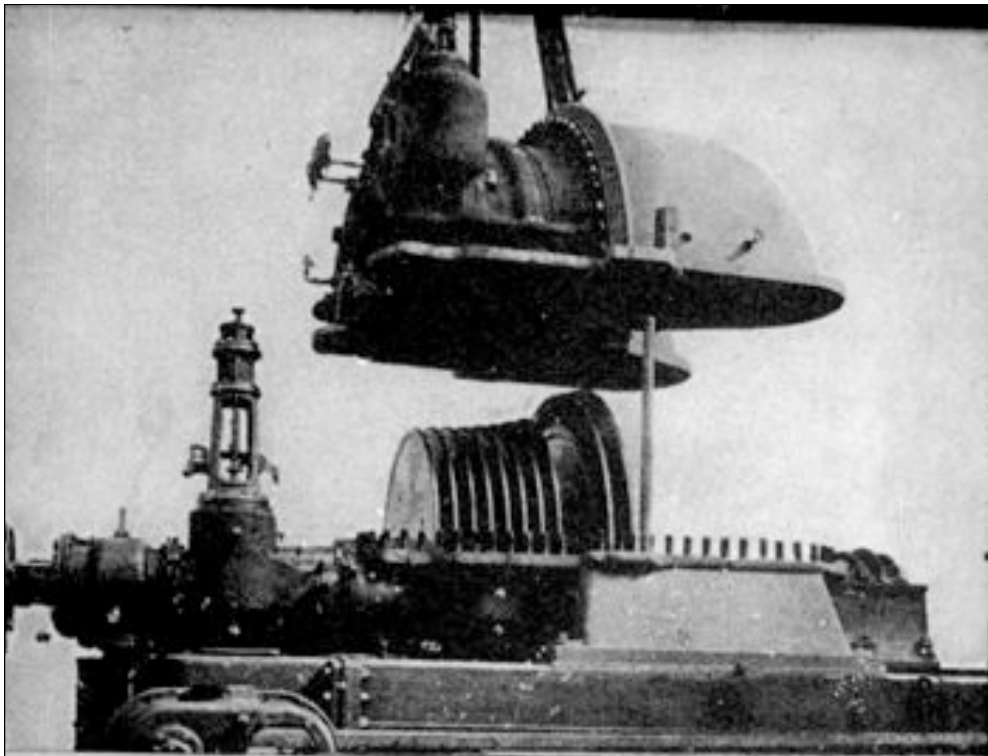
St Pierre du Vauvray

www.structurae.de

Saint-Pierre-du-Vauvray Bridge.

Photo by Jacques Mossot



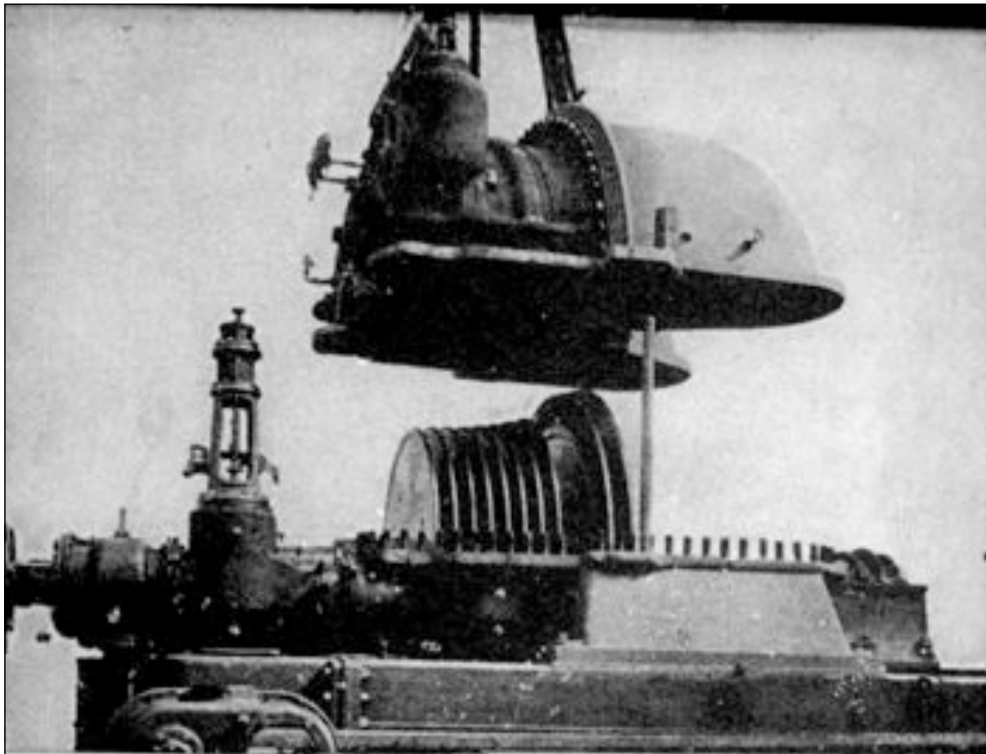


40,000 KILOWATT TURBINE FOR ELECTRICITY

ARCHITECTURE

OR

REVOLUTION

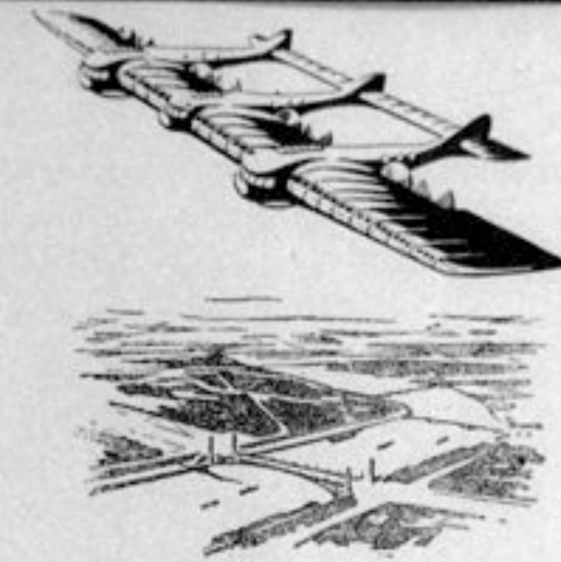


40,000 KILOWATT TURBINE FOR ELECTRICITY

ARCHITECTURE

OR

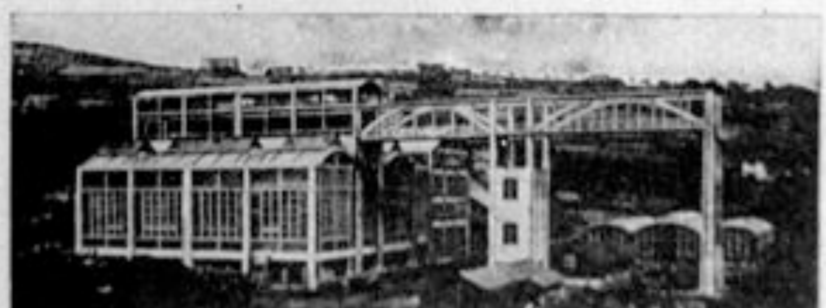
REVOLUTION



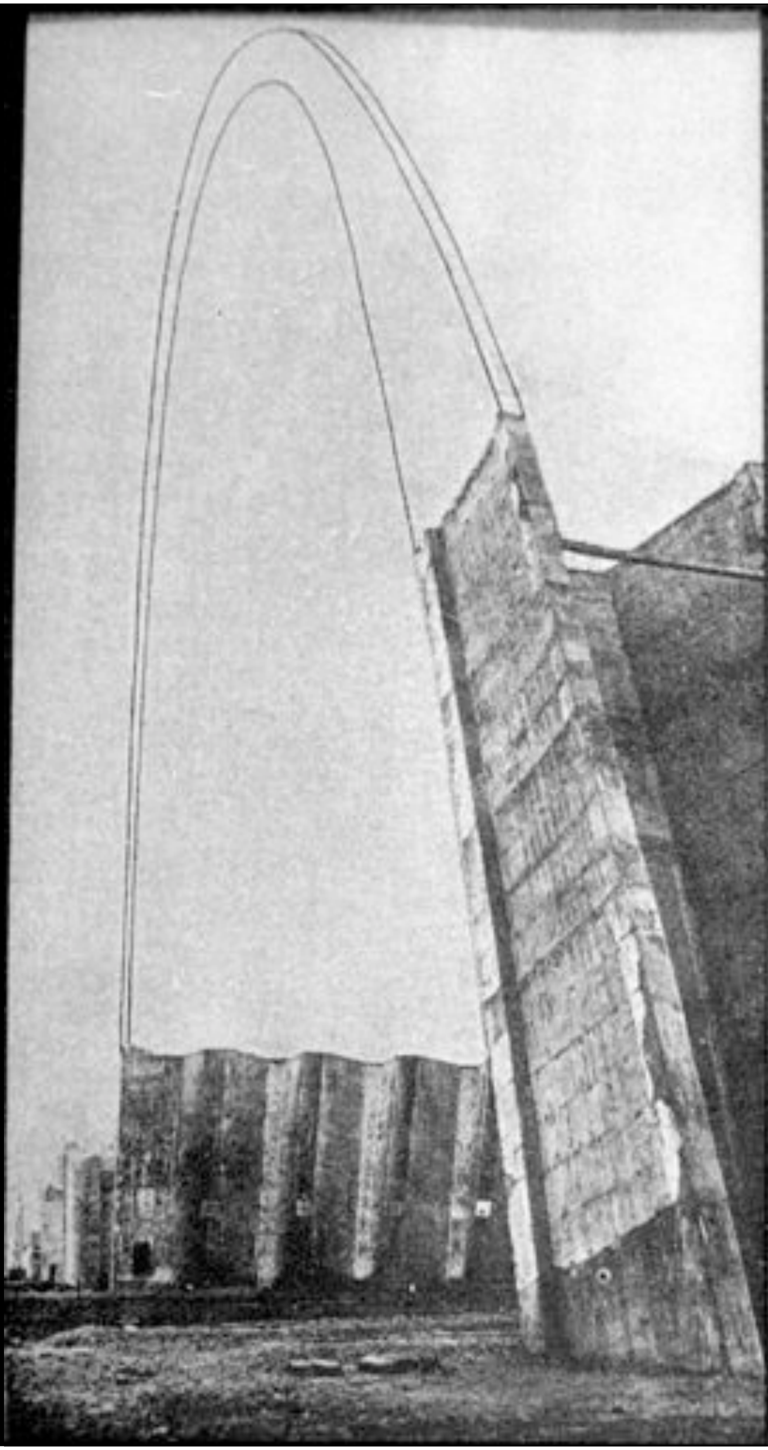
A FORECAST: THE AIRPLANE OF TO-MORROW

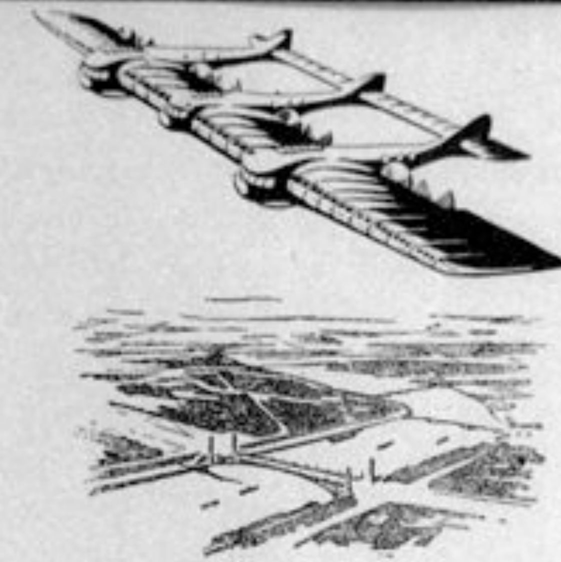
Industry has created its tools.
Business has modified its habits and customs.
Construction has found new means.
Architecture finds itself confronted with new laws.

Industry has created new tools: the illustrations in this ook provide a telling proof of this. Such tools are capable of



A FACTORY (FREYSSINET & LIMOUSIN)





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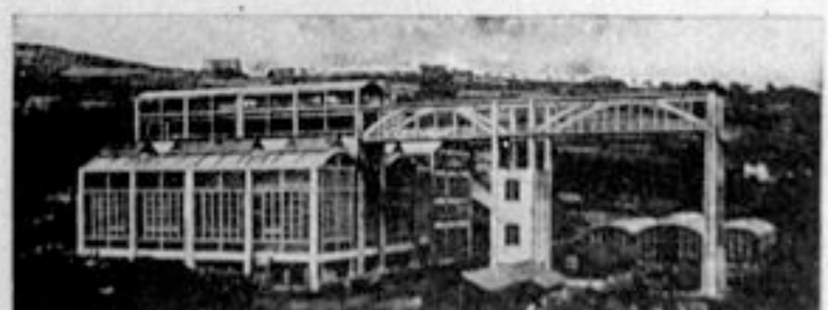
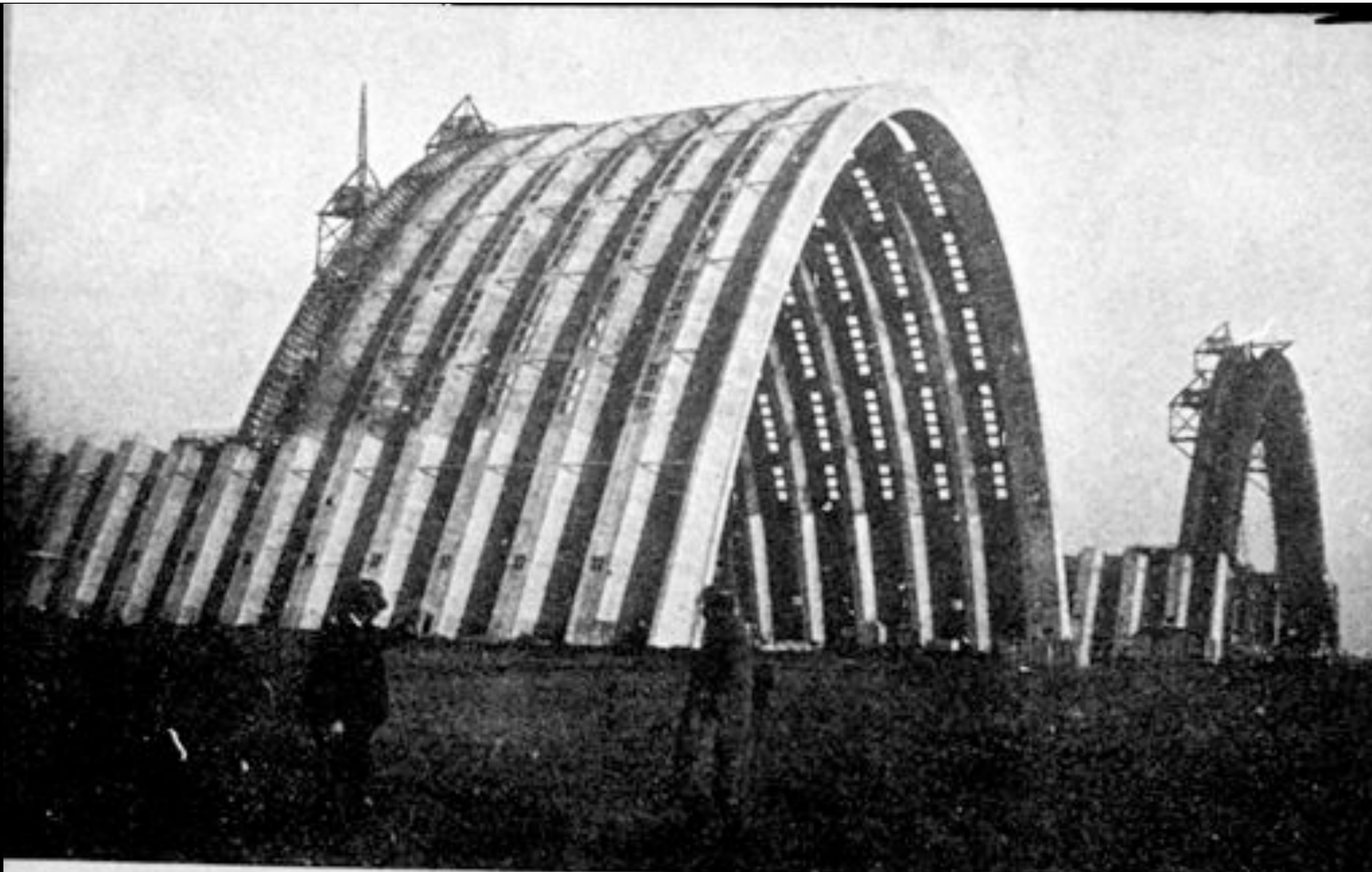
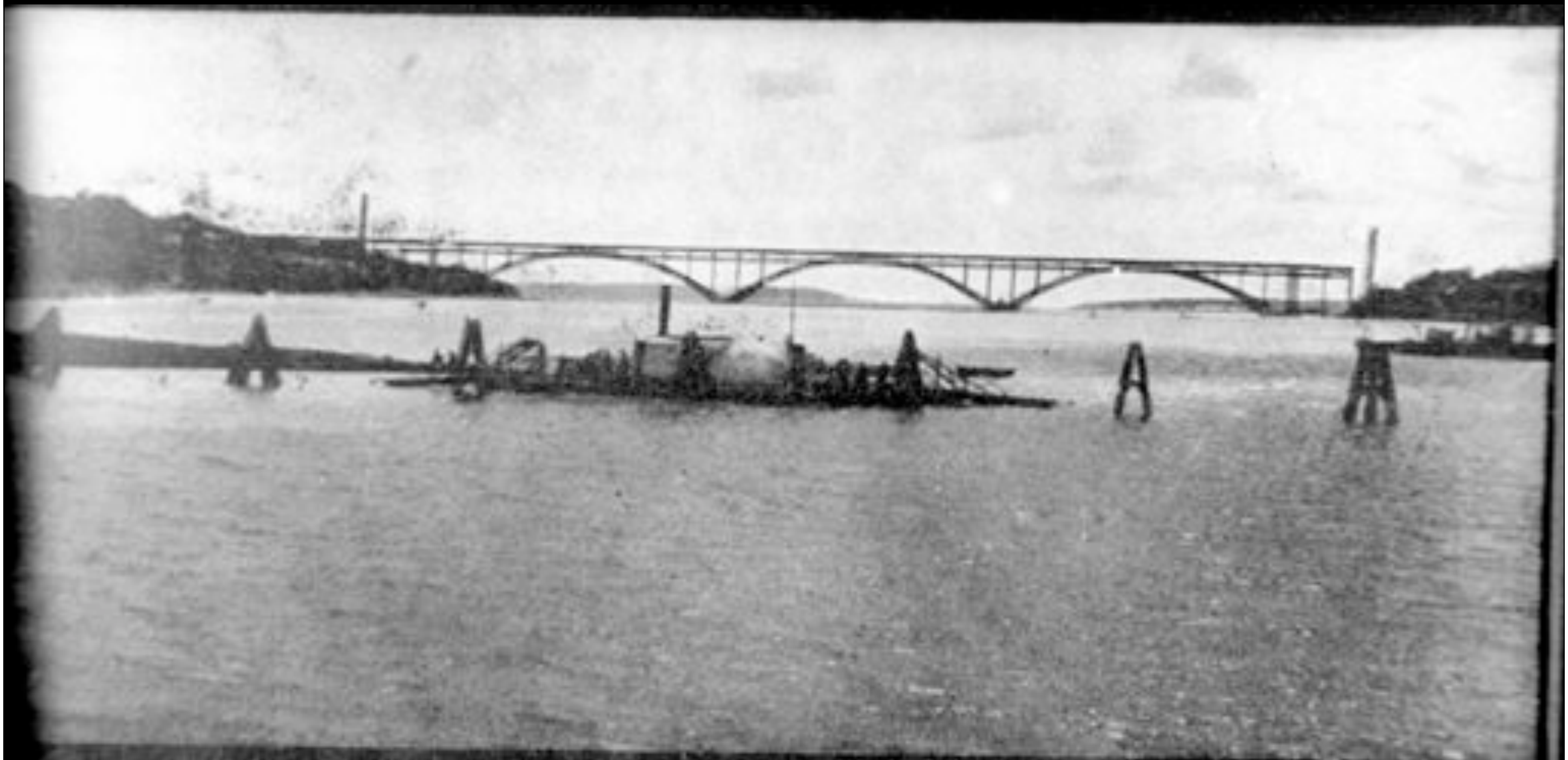


A FACTORY (FREYSSINET & LIMOUSIN)

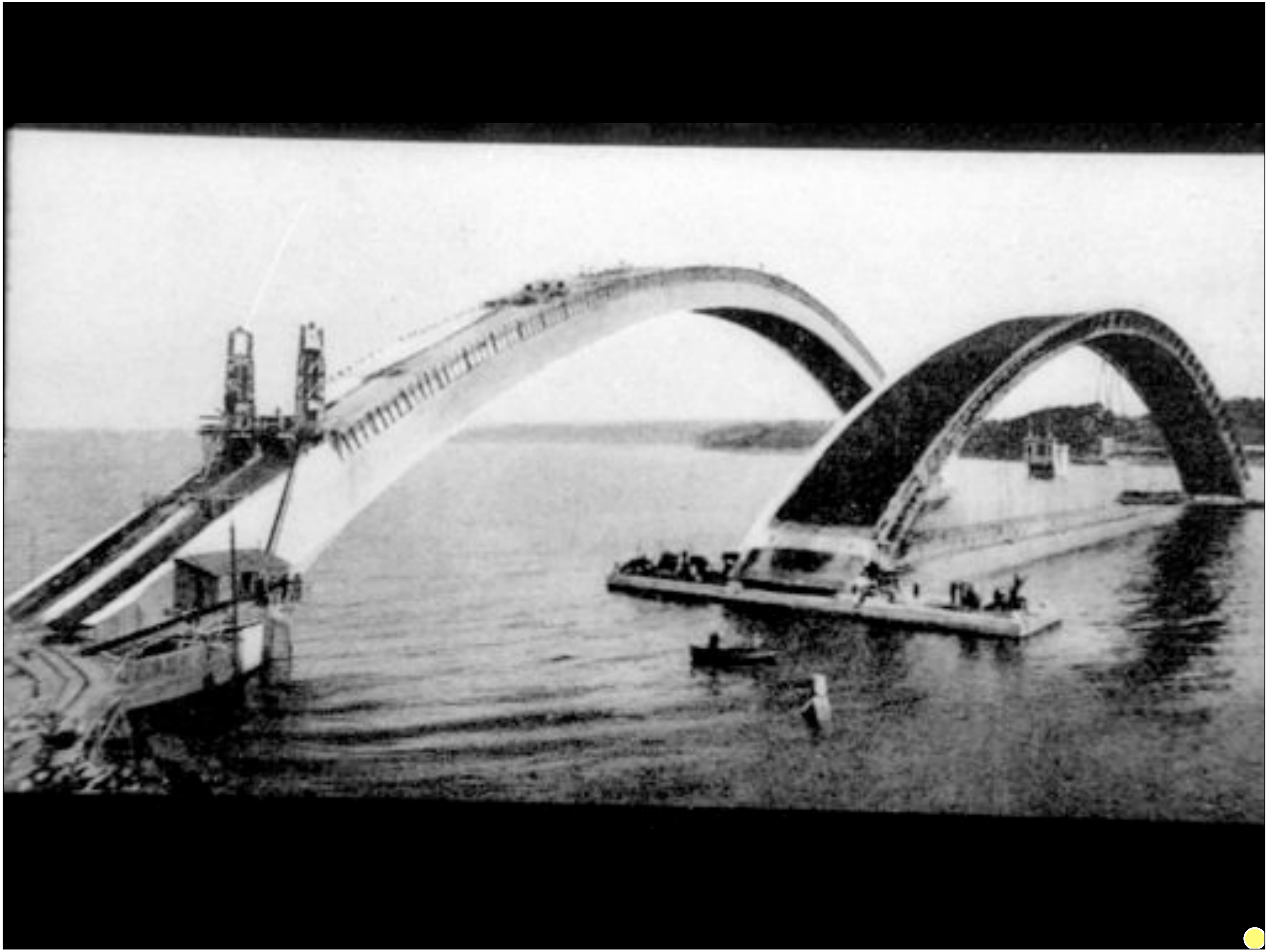


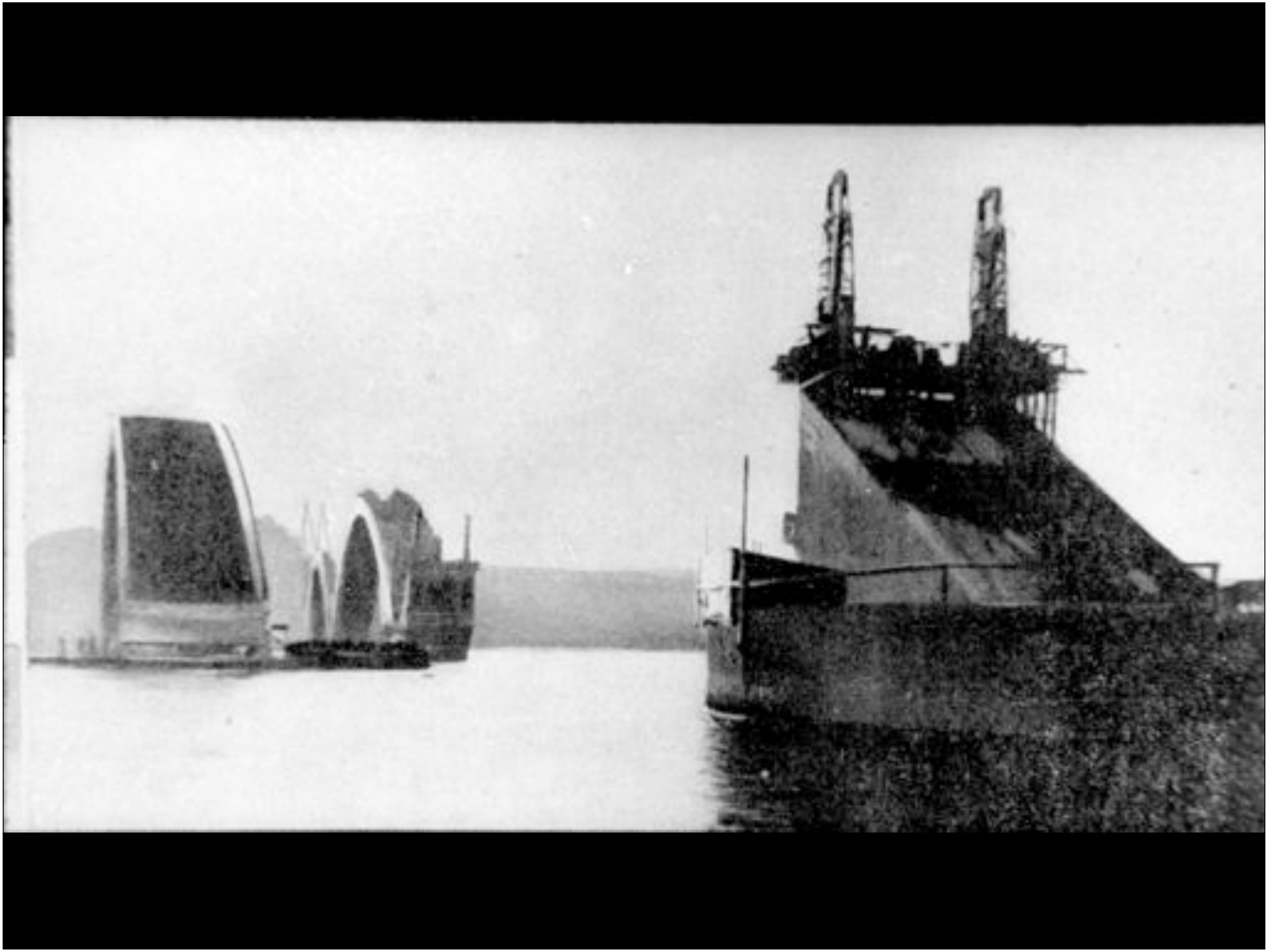
A HANGAR (FREYSSINET & LIMOUSIN)

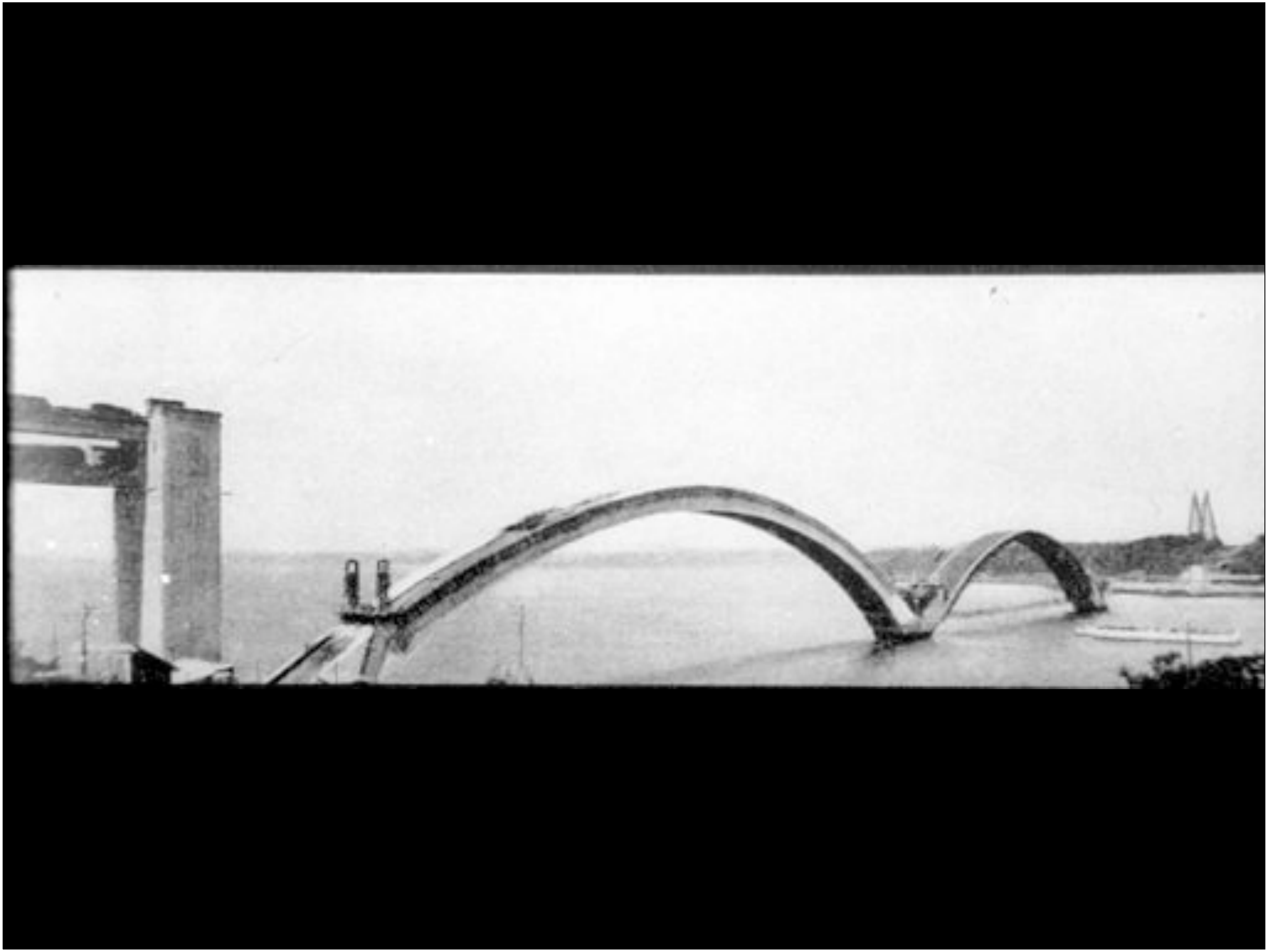
Width 250 feet, height 150 feet, length over 900 feet. The Nave of Notre Dame is 40 feet wide and about 107 feet in height.

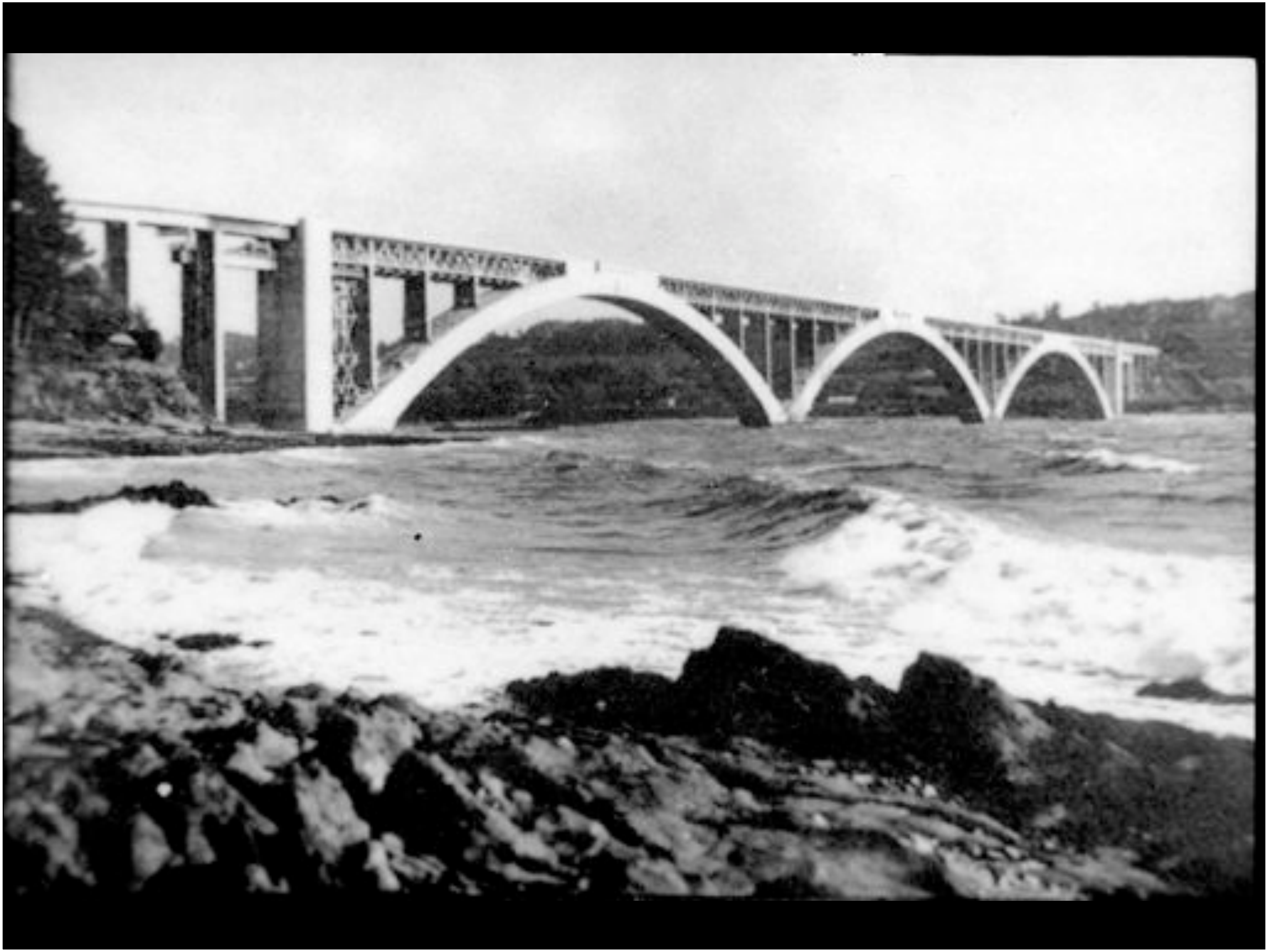


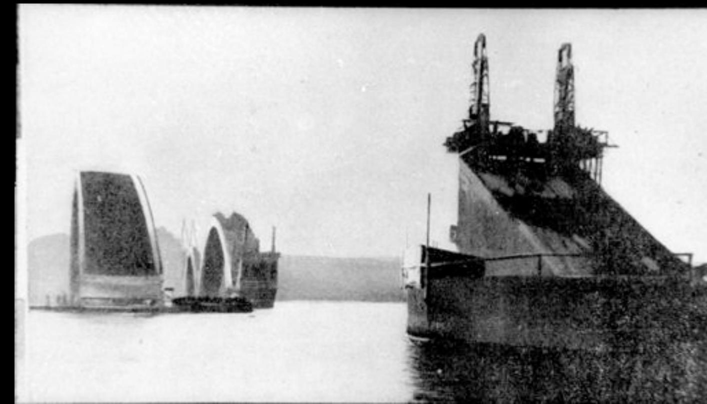
Plougastel (1930)



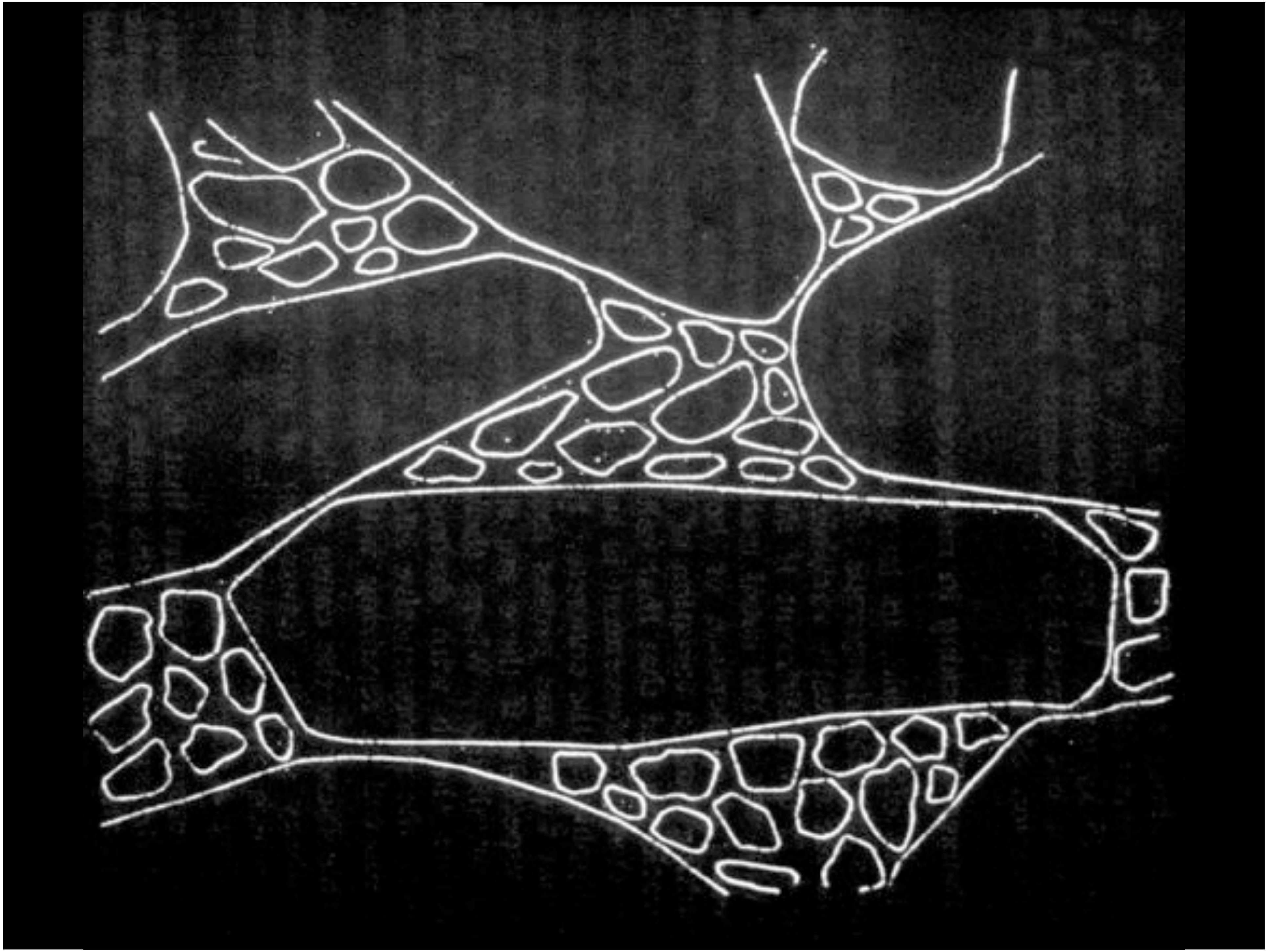


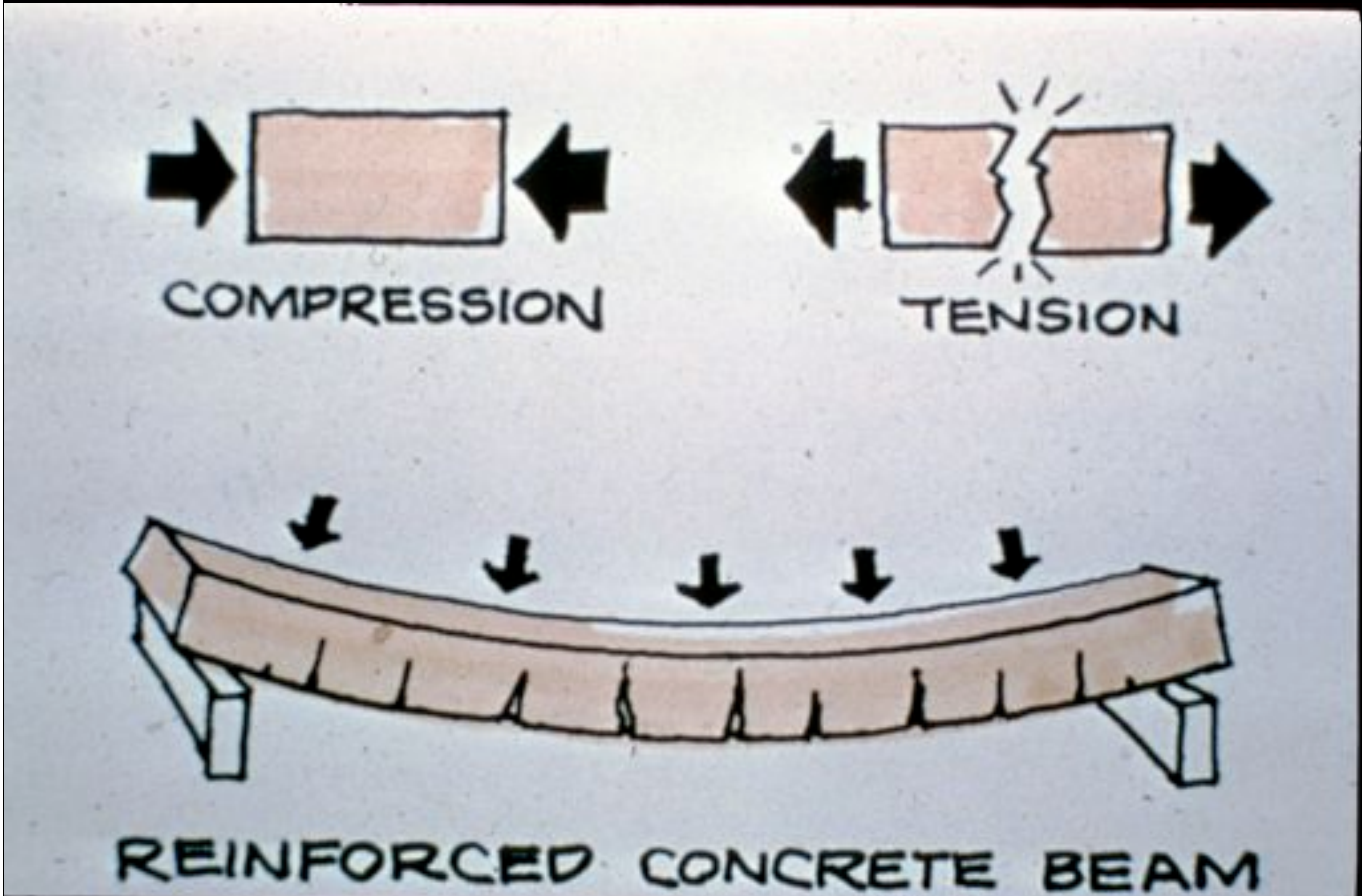


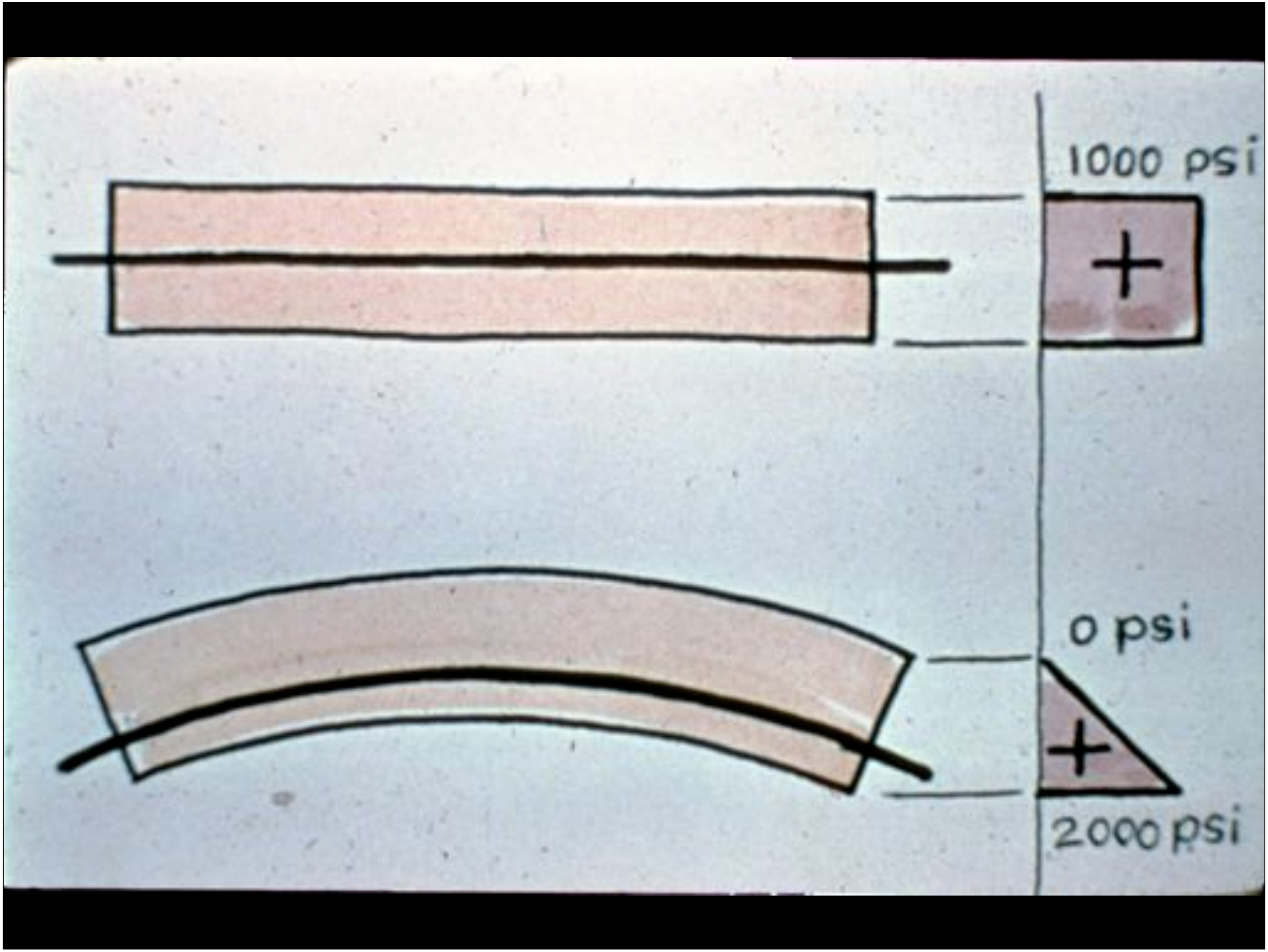


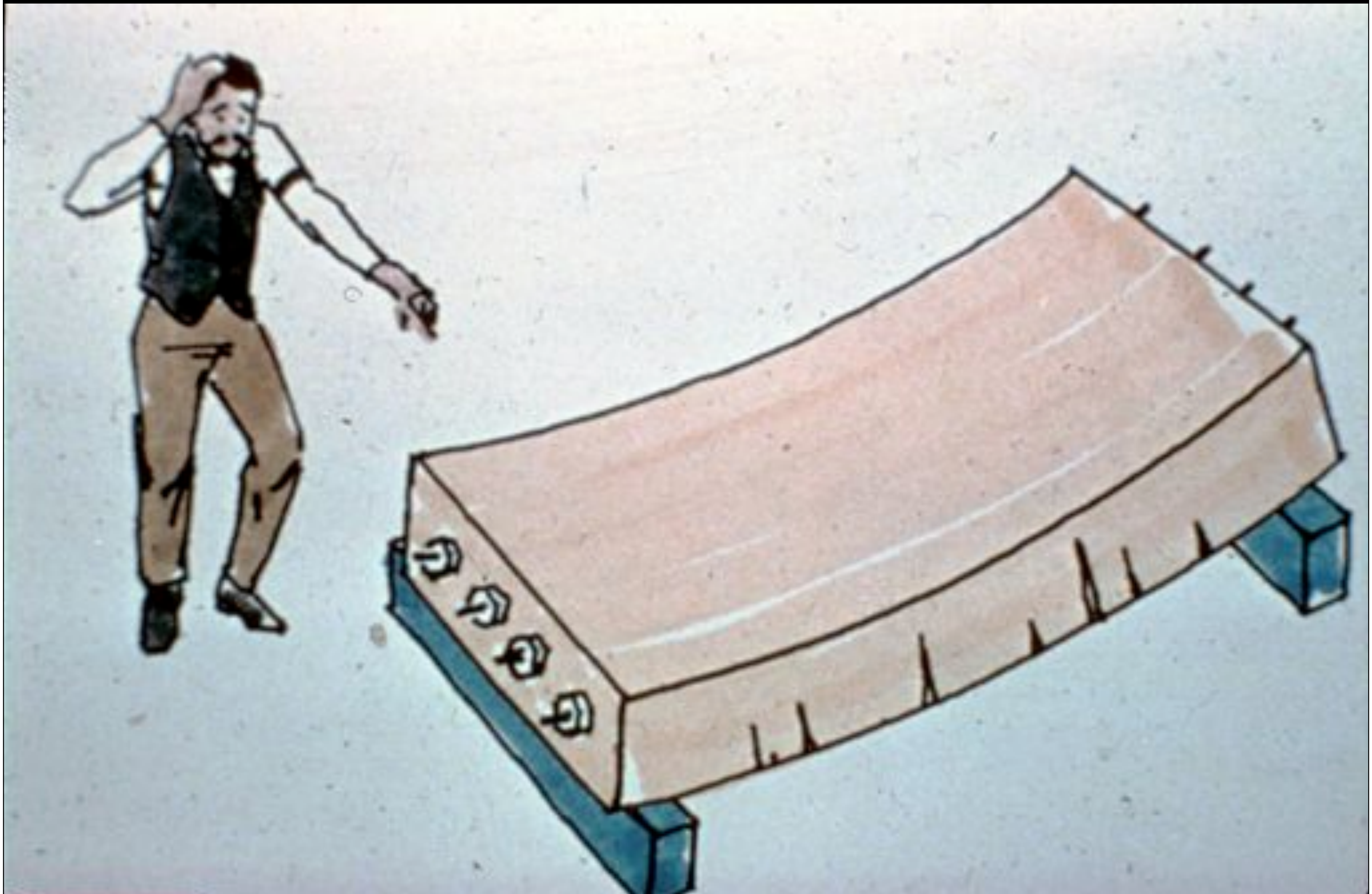


Q: Does elegance in construction matter?
Q: How *does* construction fit into the concept of structural art?

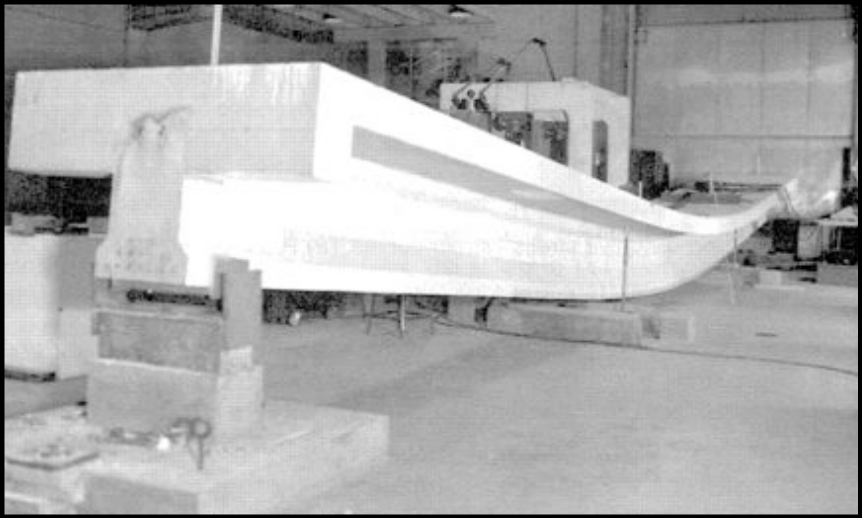



COMPRESSION
TENSION
REINFORCED CONCRETE BEAM


1000 psi
+
0 psi
+
2000 psi



Consider a single pre-stressed concrete T-beam as shown under load test to the right

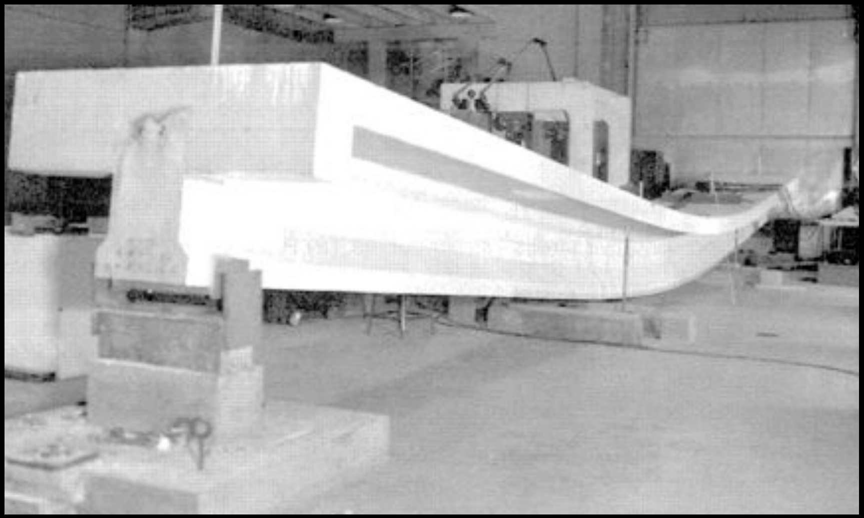


Loss of stress in the pre-stressing steel

Friction	6,800 psi (47 MPa)
Creep	17,400 psi (120 MPa)
Shrinkage	12,100 psi (83 MPa)
Relaxation	3,800 psi (26 MPa)
Total	fill in total here!

*numerical values inspired from Nilson, Design of Presstressed Concrete, Ch. 6

Consider a single pre-stressed concrete T-beam as shown under load test to the right



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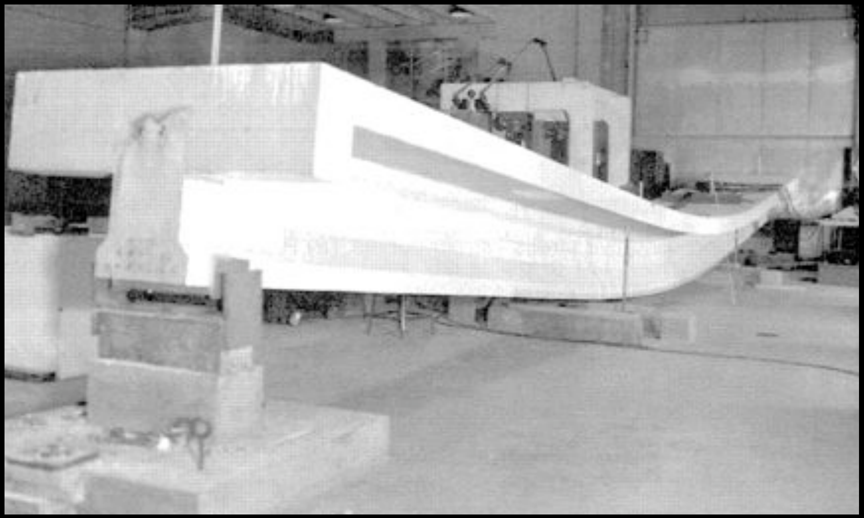
Relaxation	3,800 psi (26 MPa)
Total	40,100 psi (276 MPa)

If I use standard 50,000 psi steel what is the loss in effectiveness?

% loss??

*numerical values inspired from Nilson, Design of Presstressed Concrete, Ch. 6

Consider a single pre-stressed concrete T-beam as shown under load test to the right



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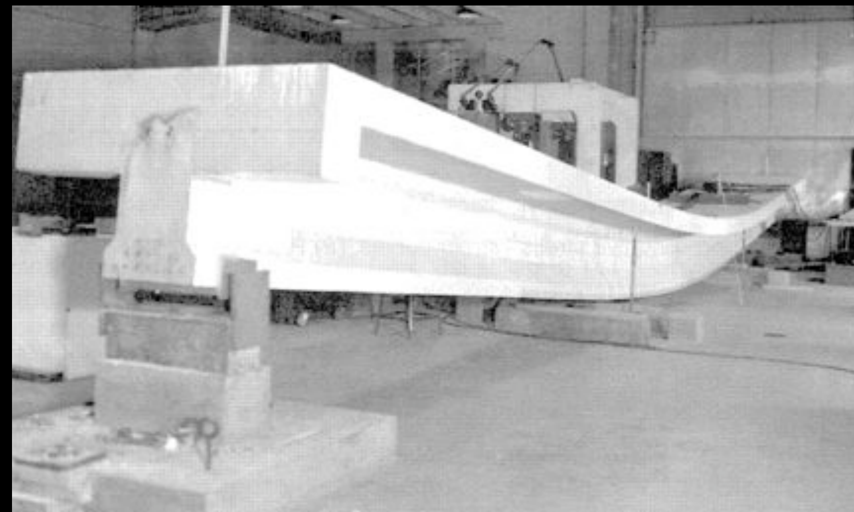
Relaxation	3,800 psi (26 MPa)
Total	40,100 psi (276 MPa)

If I use standard 50,000 psi steel what is the loss in effectiveness?

40,100/50,000= 0.8 → 80%

*numerical values inspired from Nilson, Design of Presstressed Concrete, Ch. 6

Consider a single pre-stressed concrete T-beam as shown under load test to the right



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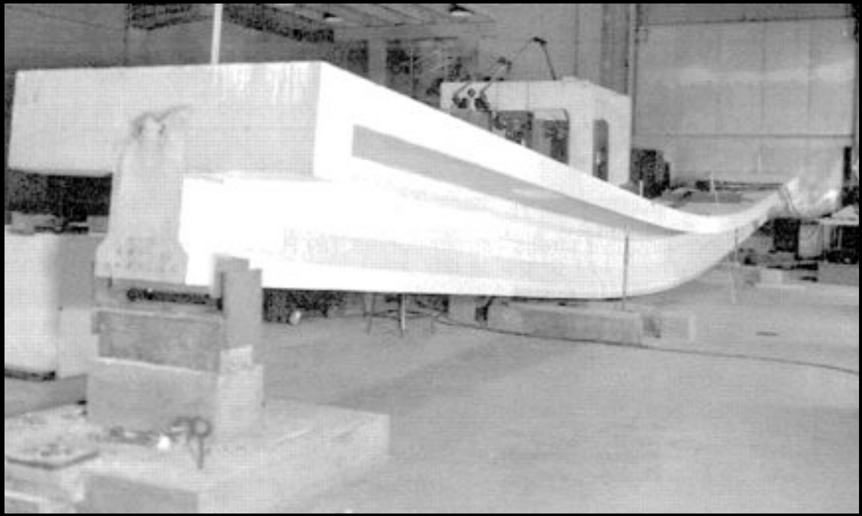
If I use steel strands, thank you Roebling, I have 250,000 psi steel, now?

% loss??

*numerical values inspired from Nilson, Design of Presstressed Concrete, Ch. 6

Consider a single pre-stressed concrete T-beam as shown under load test to the right



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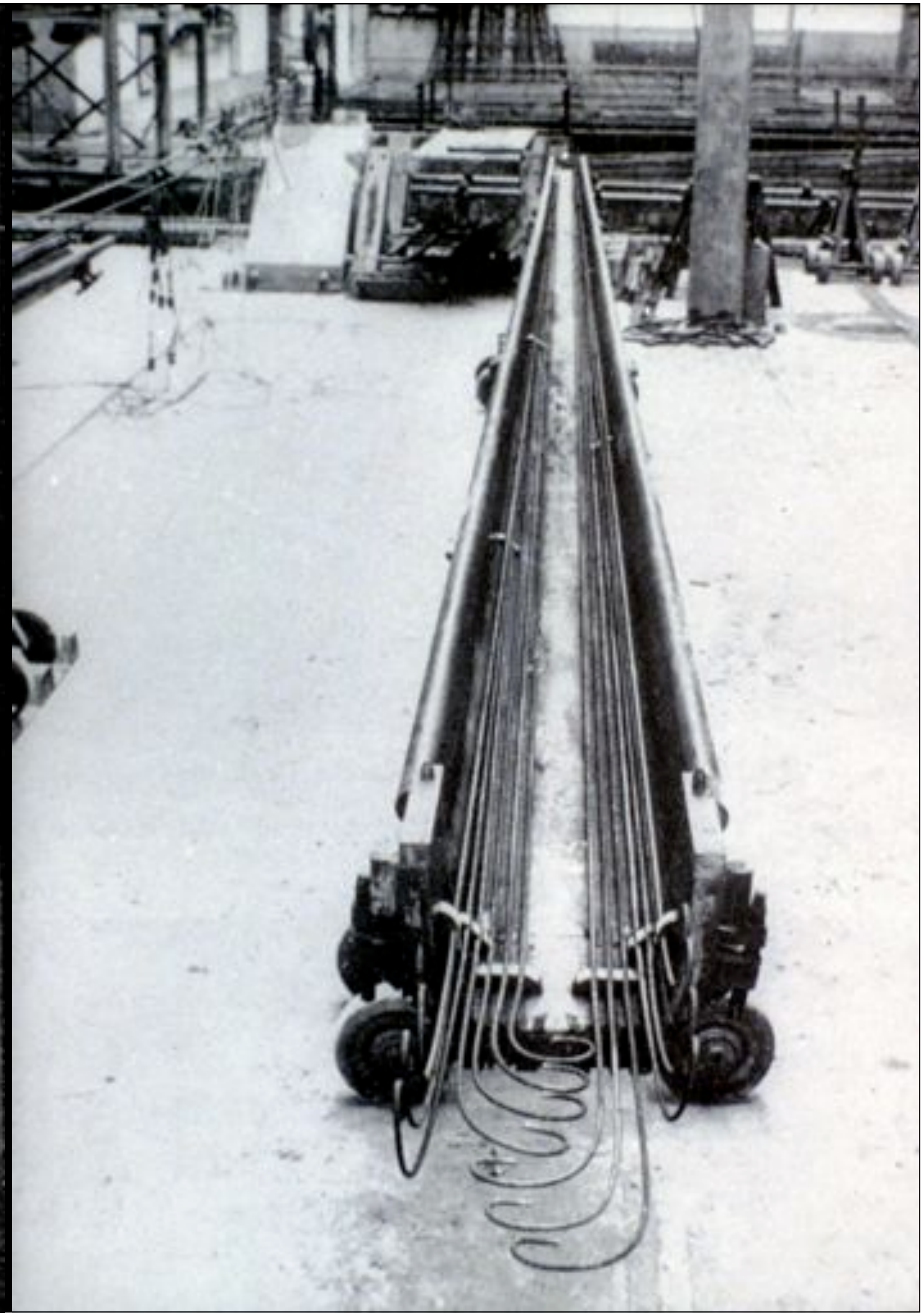
Creep	17,400 psi (120 MPa)
Shrinkage	12,100 psi (83 MPa)
Relaxation	3,800 psi (26 MPa)
Total	40,100 psi (276 MPa)

If I use steel strands, thank you Roebling, I have 250,000 psi steel, now?

40,100/250,000= 0.16 → 16%

*numerical values inspired from Nilson, Design of Presstressed Concrete, Ch. 6

Luzancy Br. (1946)

www.structurae.de

Pont de Luzancy.

Photo by Jacques Mossot

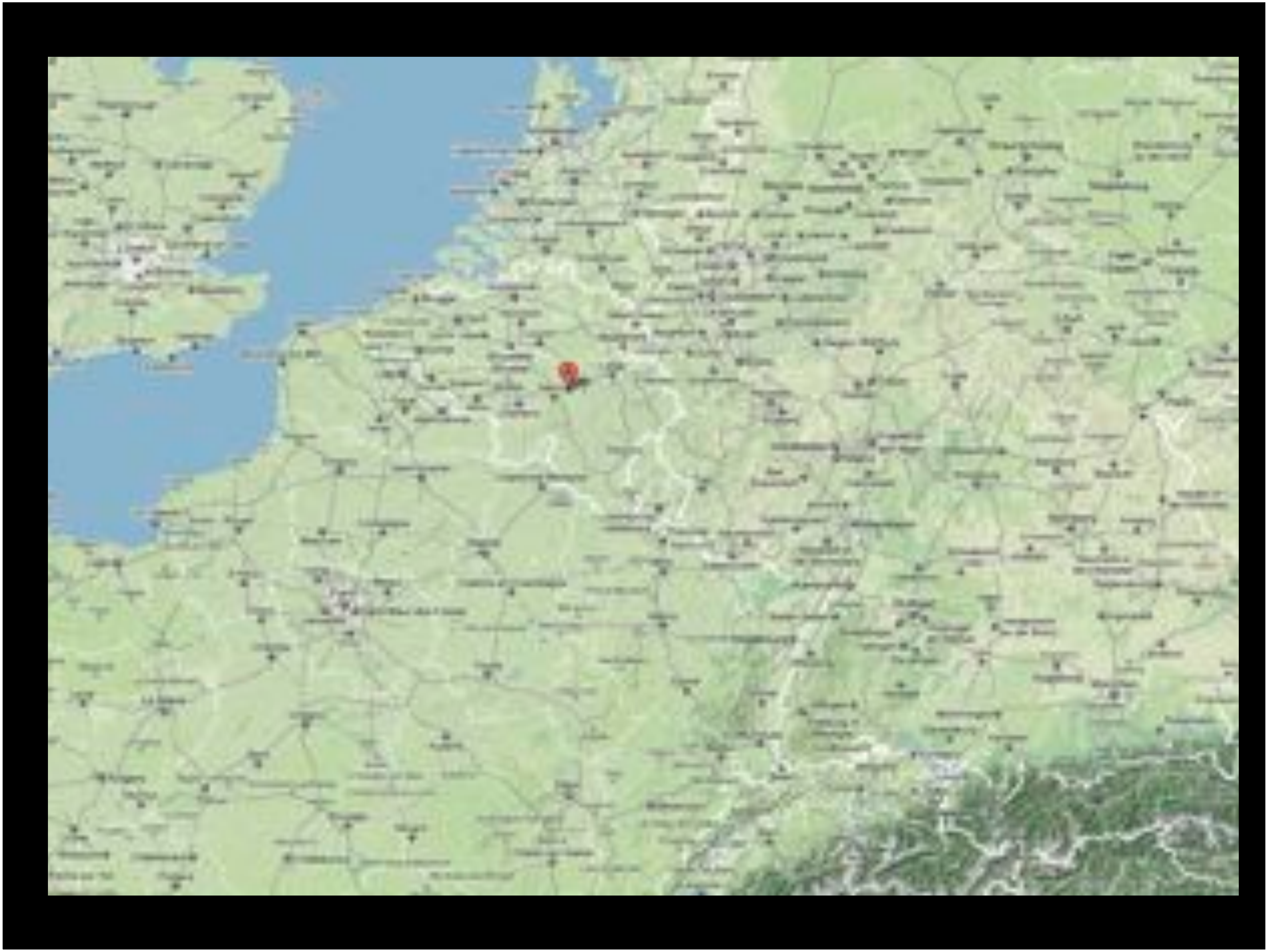
www.structurae.de

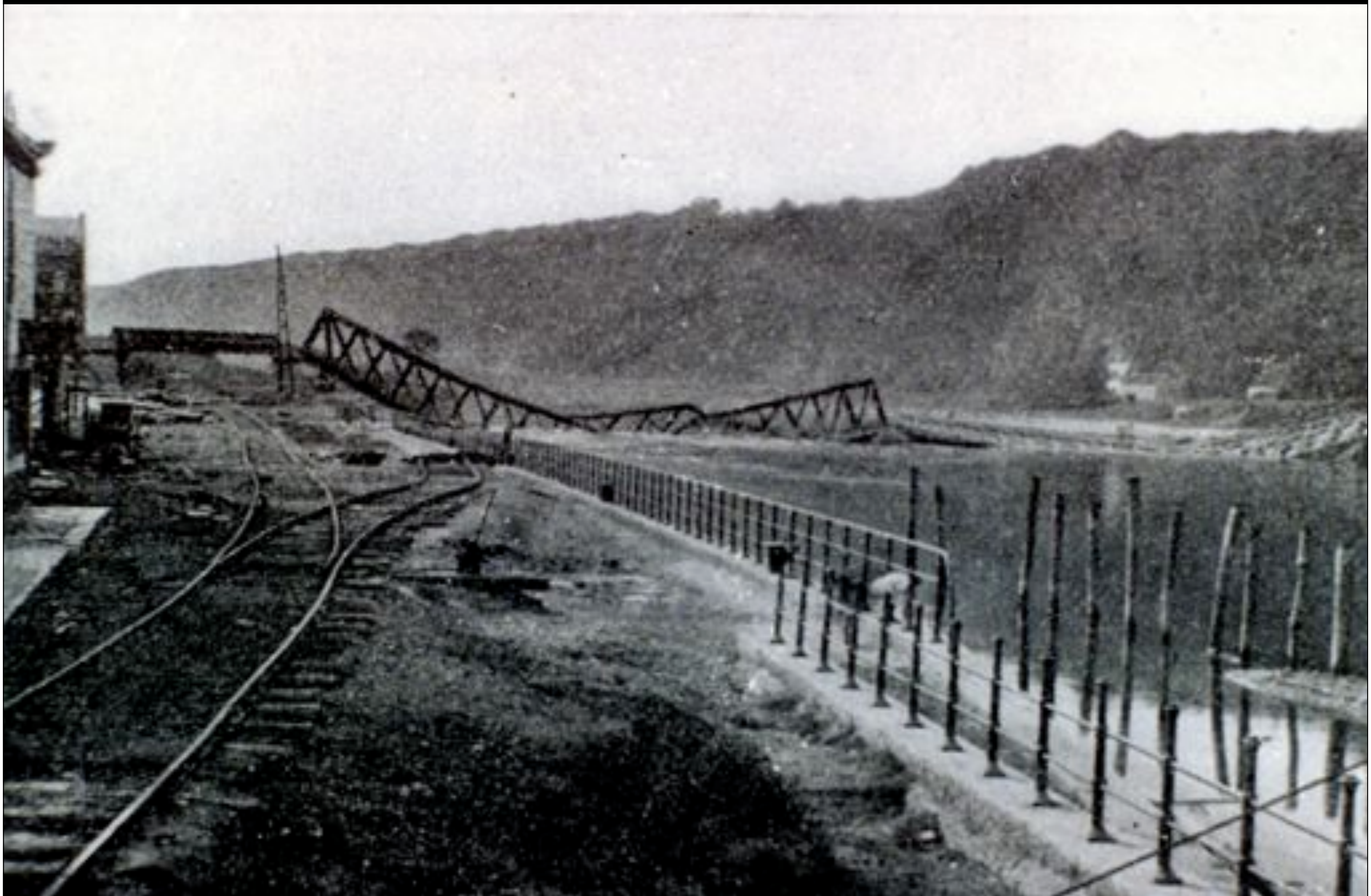
Pont Saint-Michel, Toulouse.

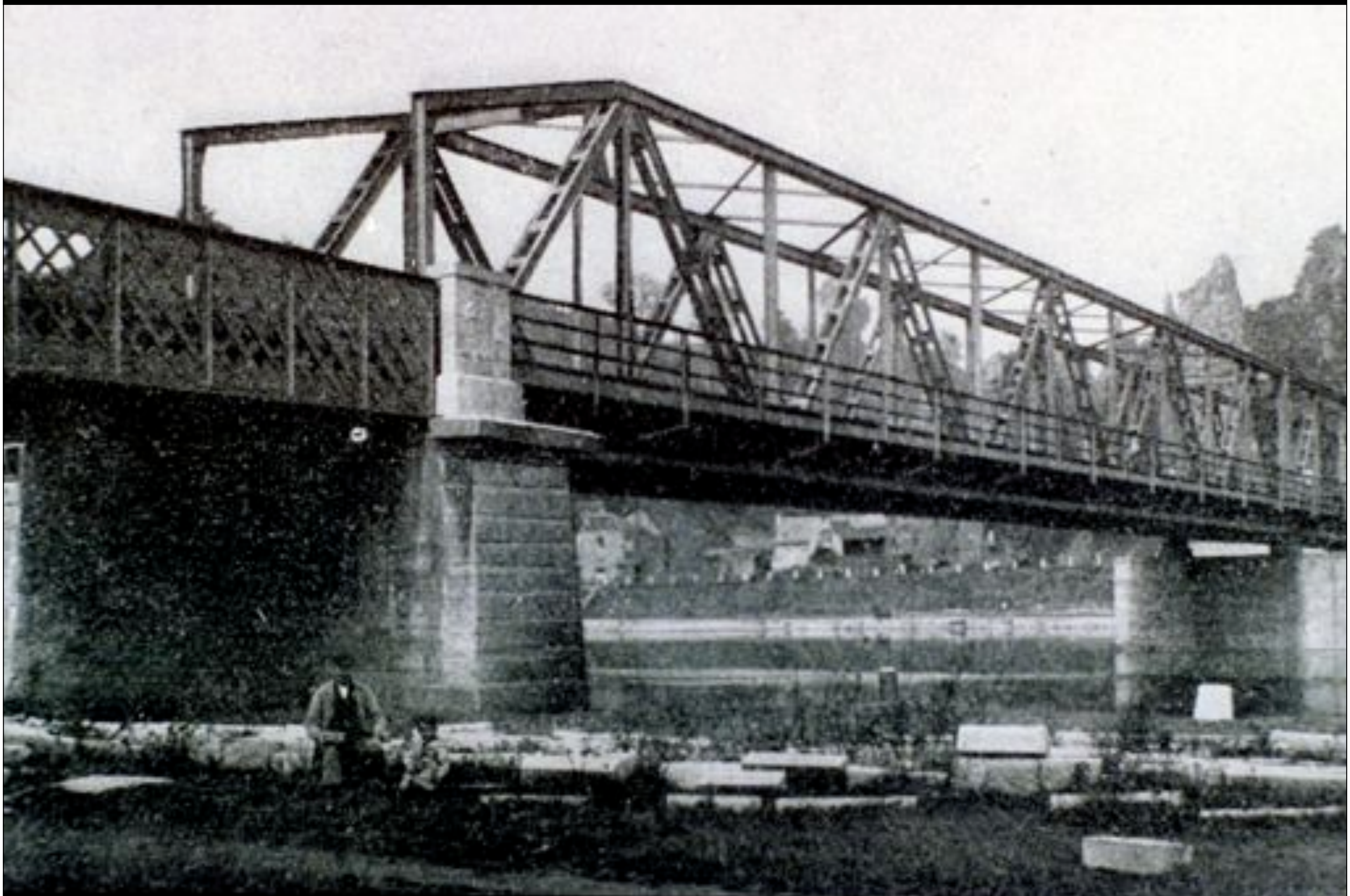
Photo by Jacques Mossot

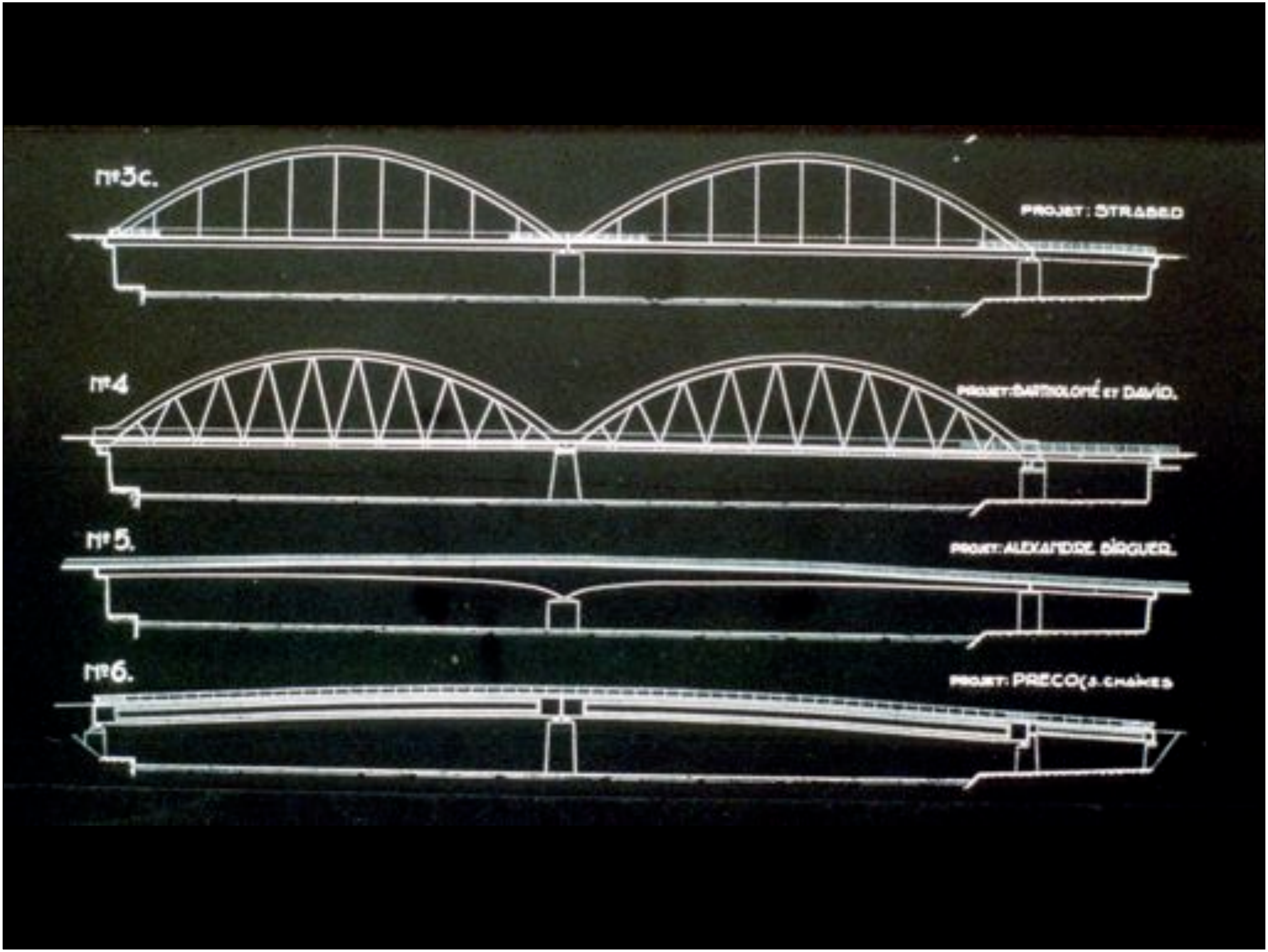
Similar to DC's 2006
Woodrow Wilson Bridge?

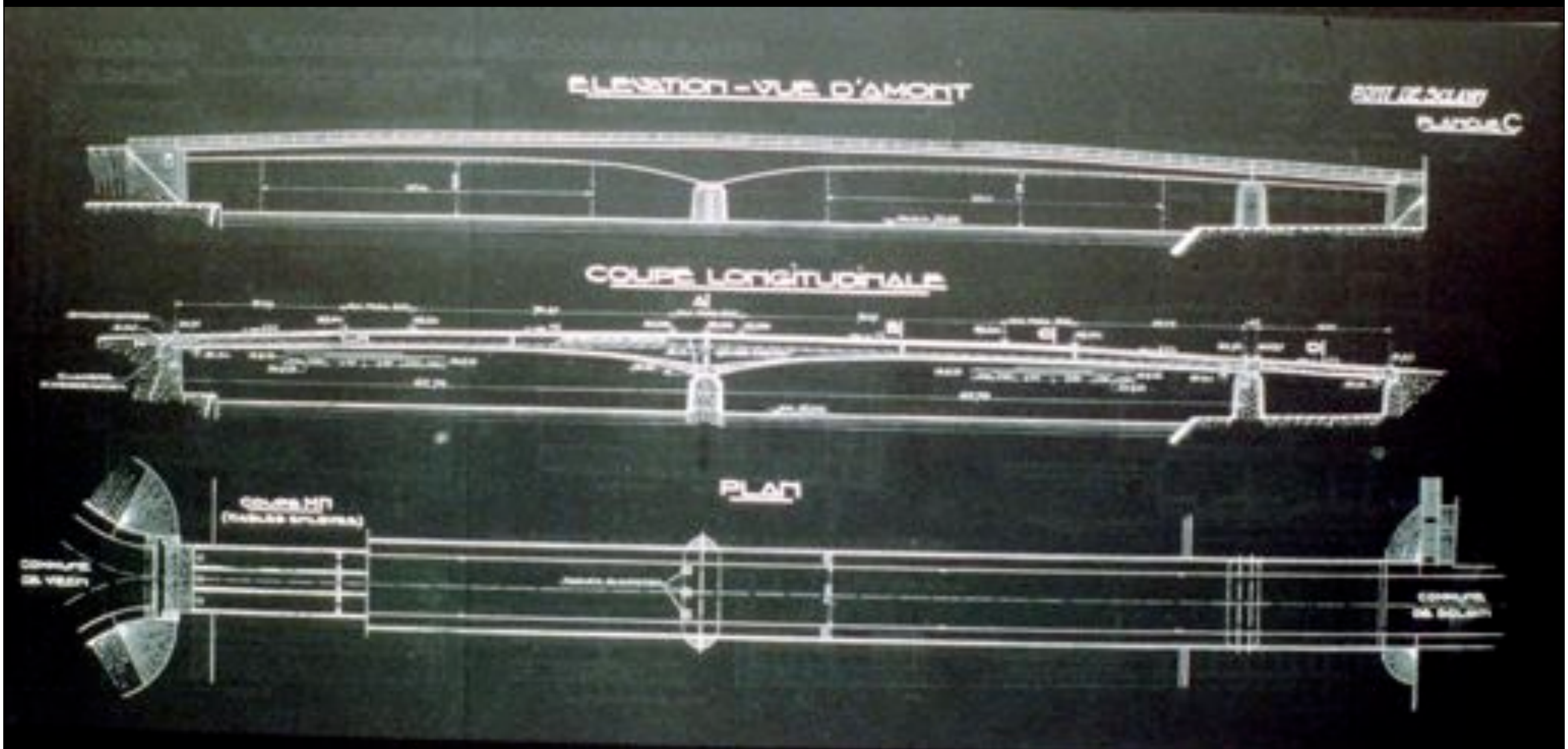
Gustave Magnel



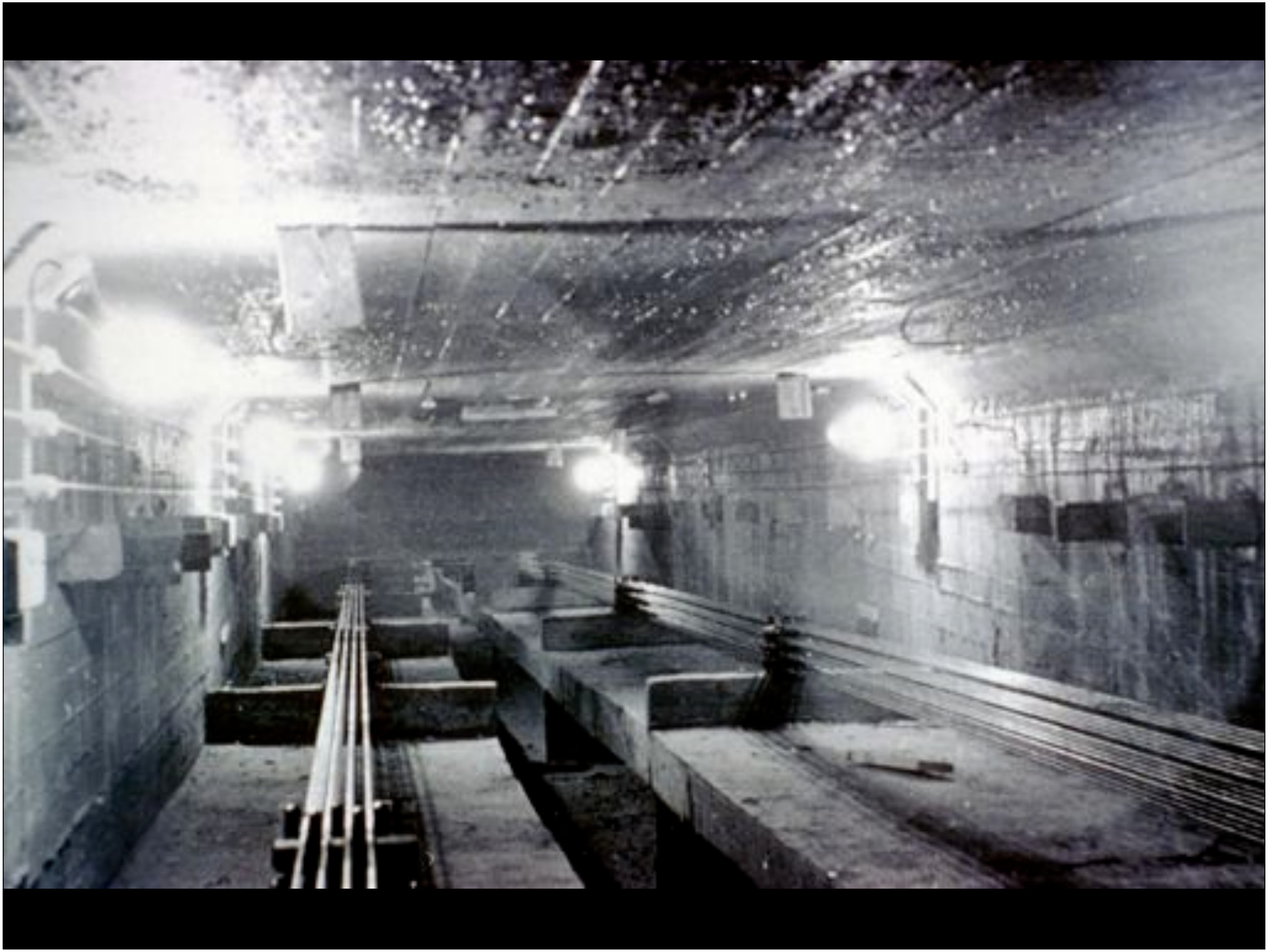


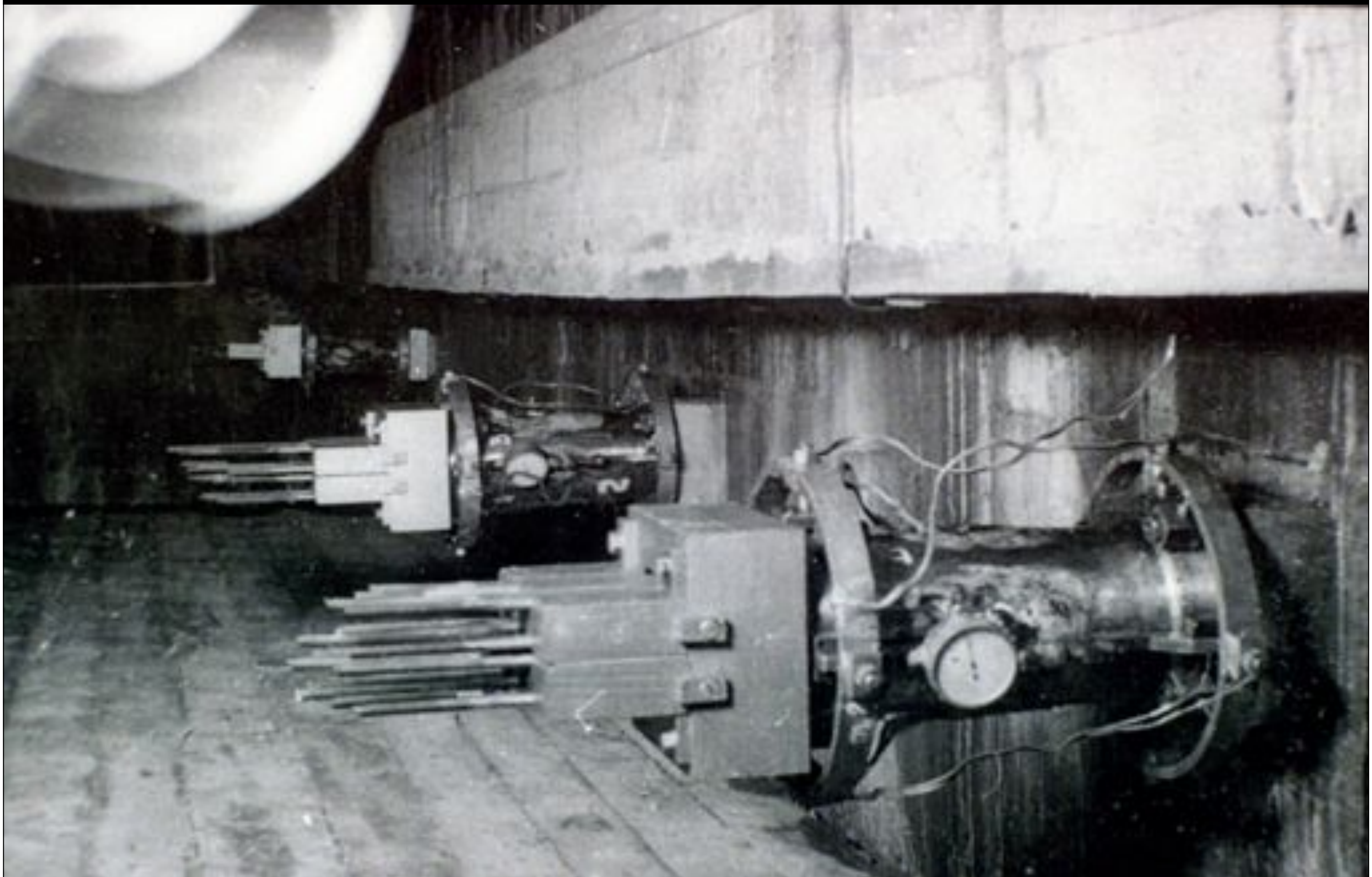


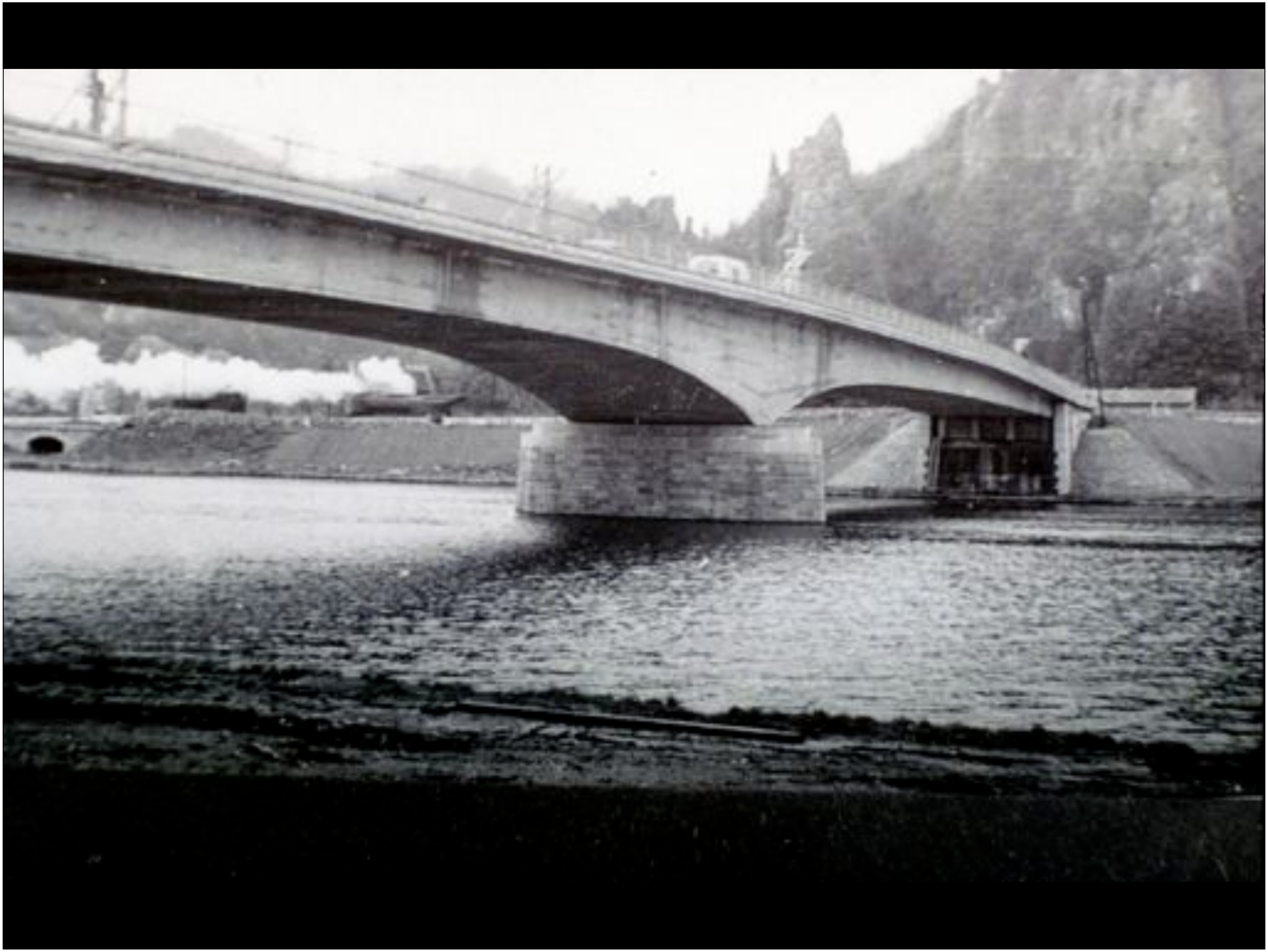

N°3c.
PROJET : STRABED
N°4
PROJET: BARTHOLONÉ ET DAVID.
N°5.
PROJET: ALEXANDRE BIRGUER.
N°6.
PROJET: PRECO(3 CHAÎNES

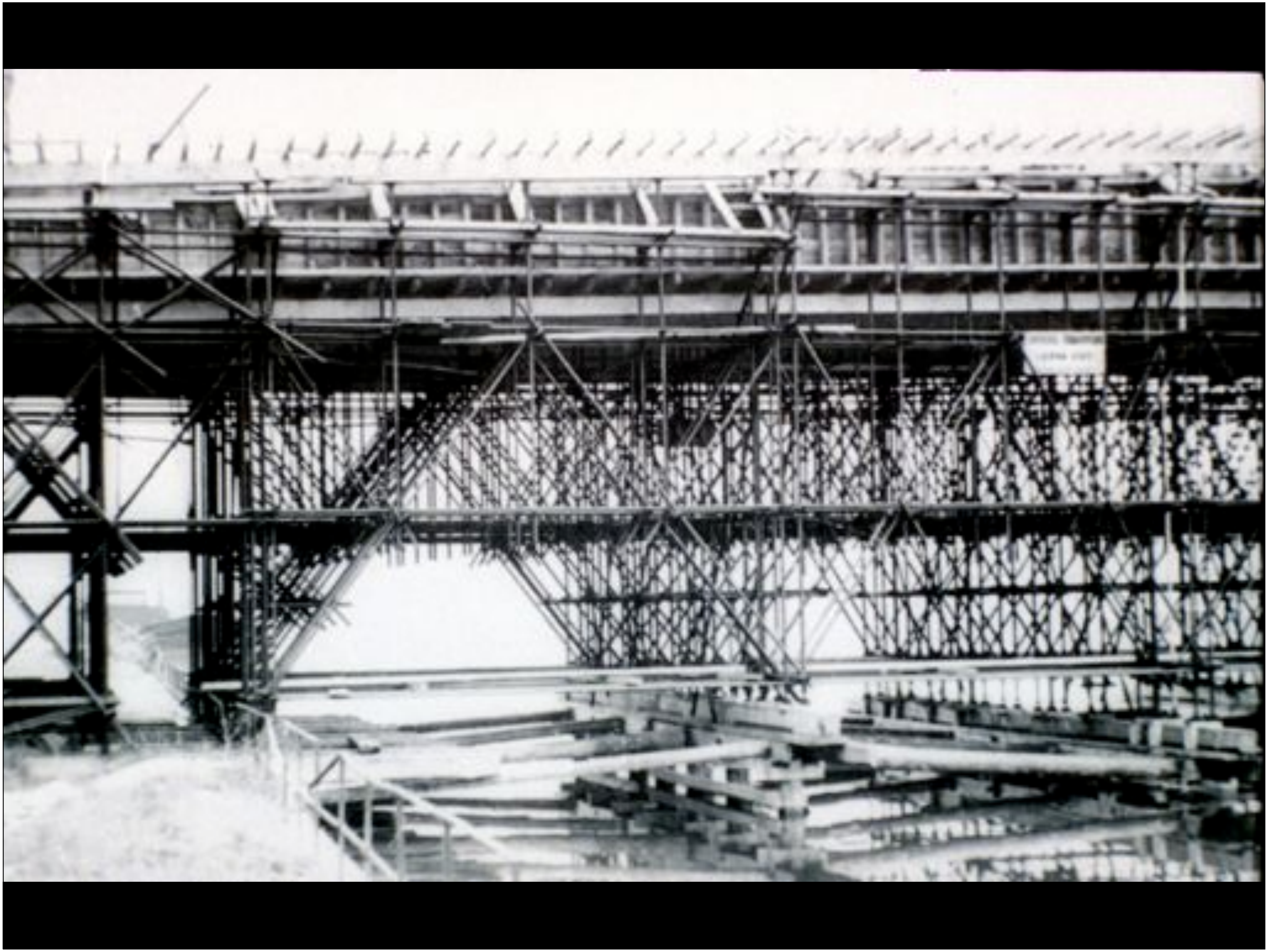

ELEVATION - VUE D'AMONT
PLANCHE C
COUPE LONGITUDINALE
PLAN

Sclayn

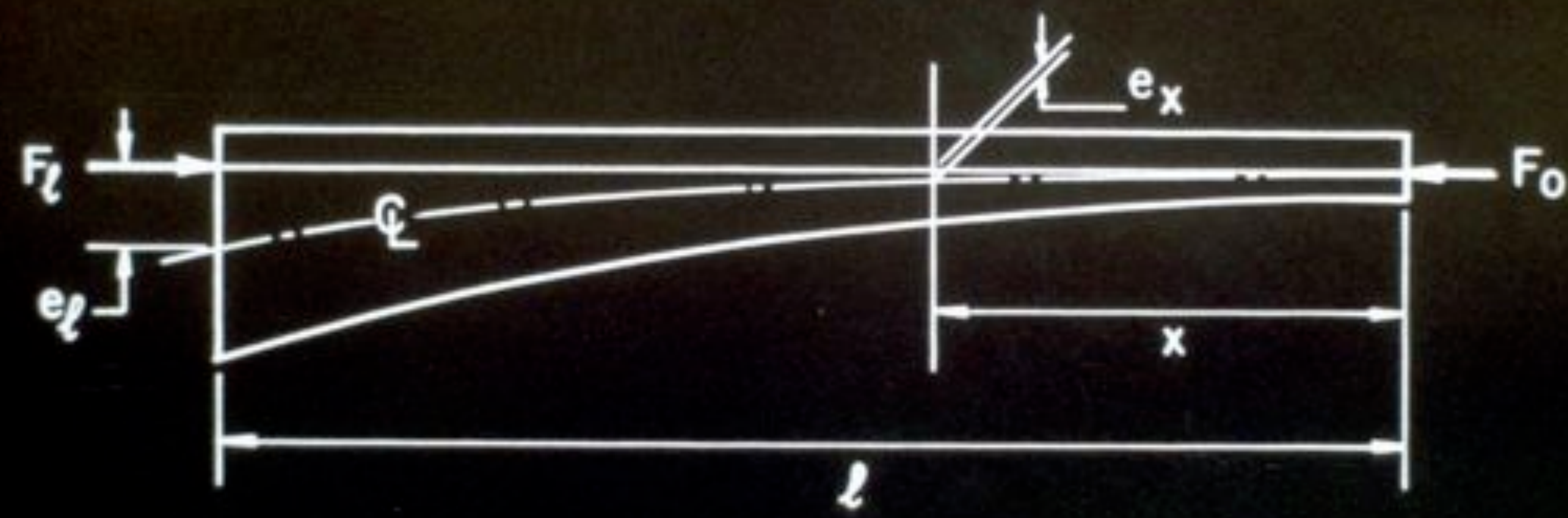




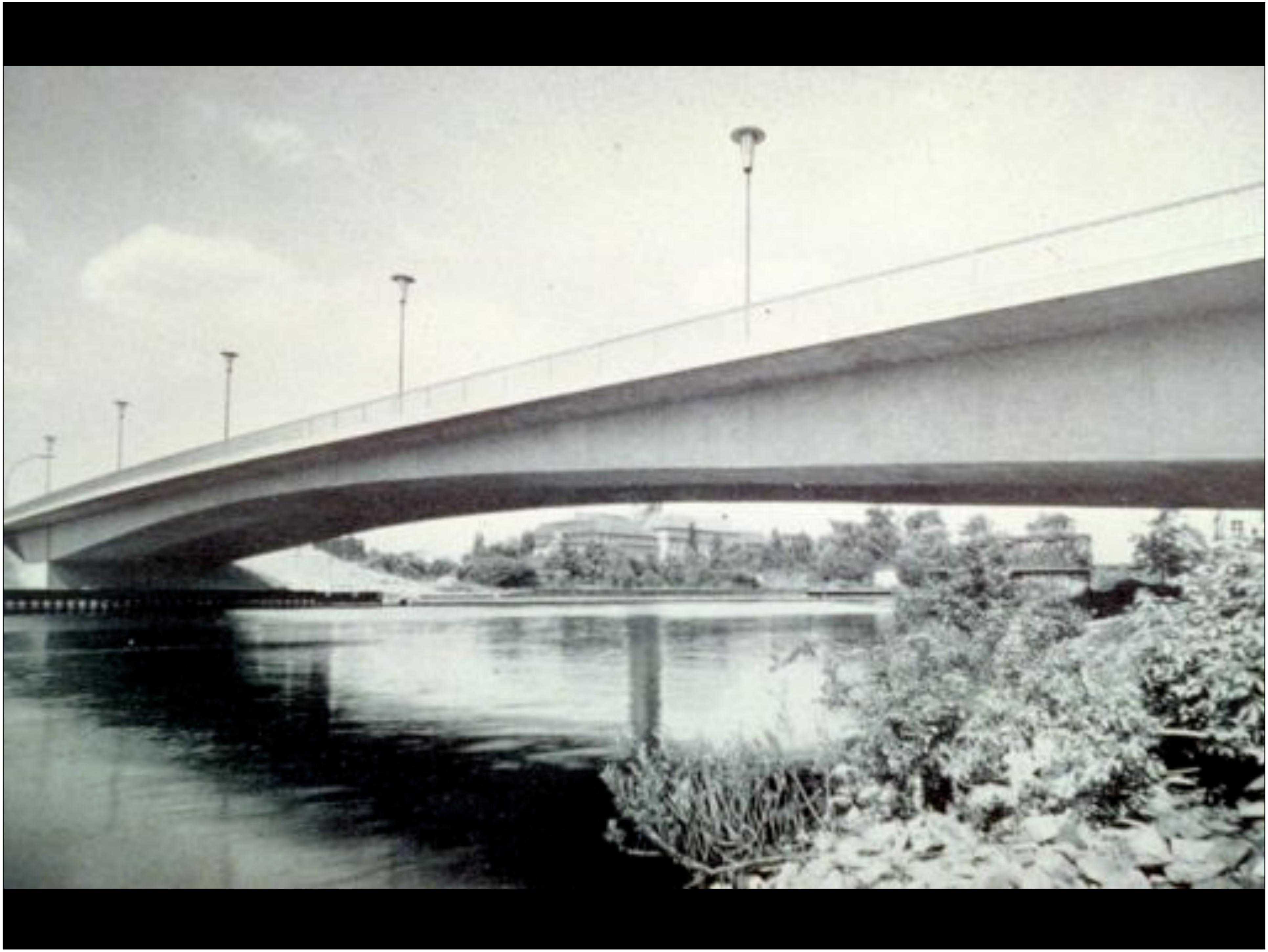




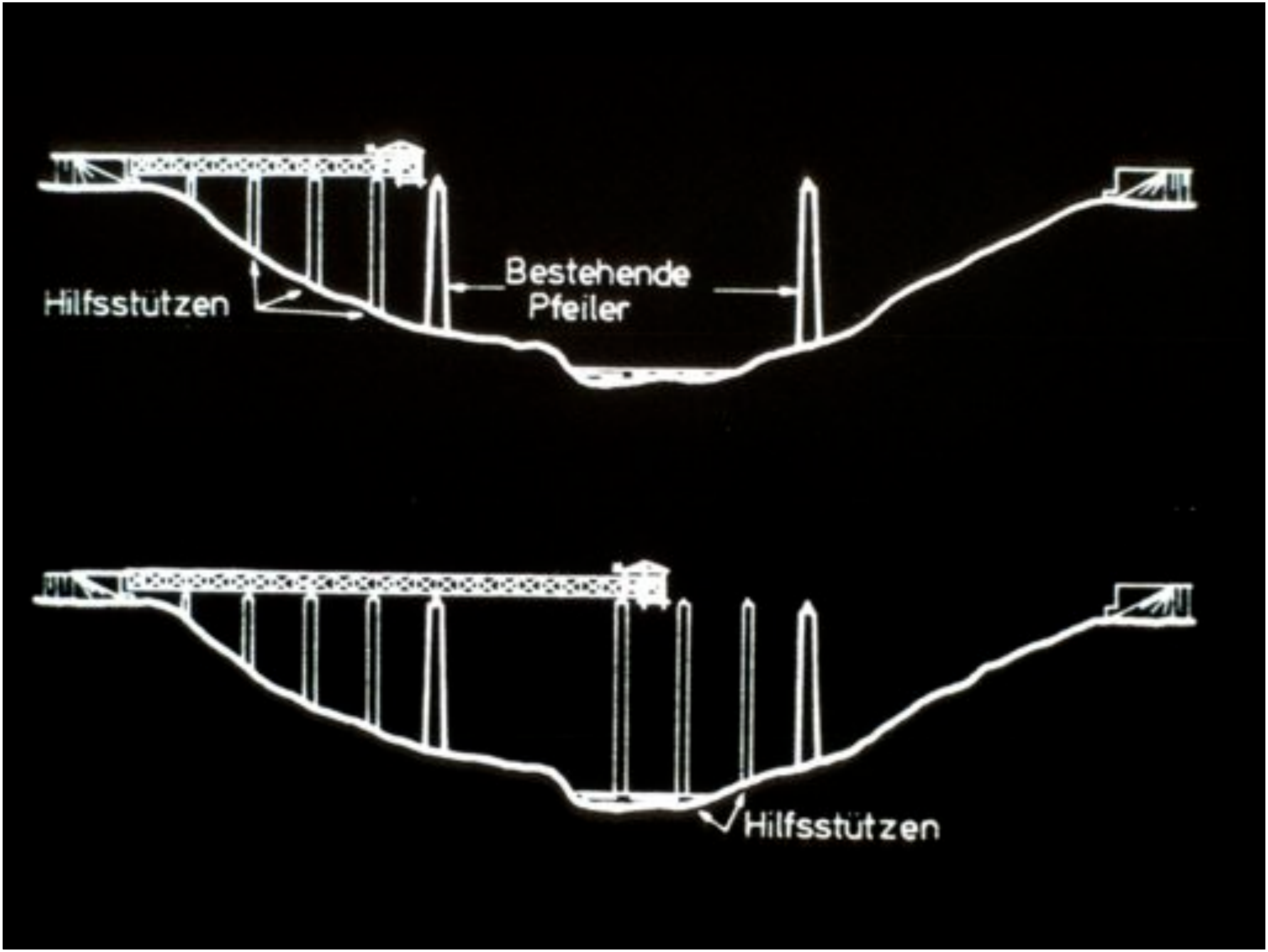
Ulrich Finsterwalder



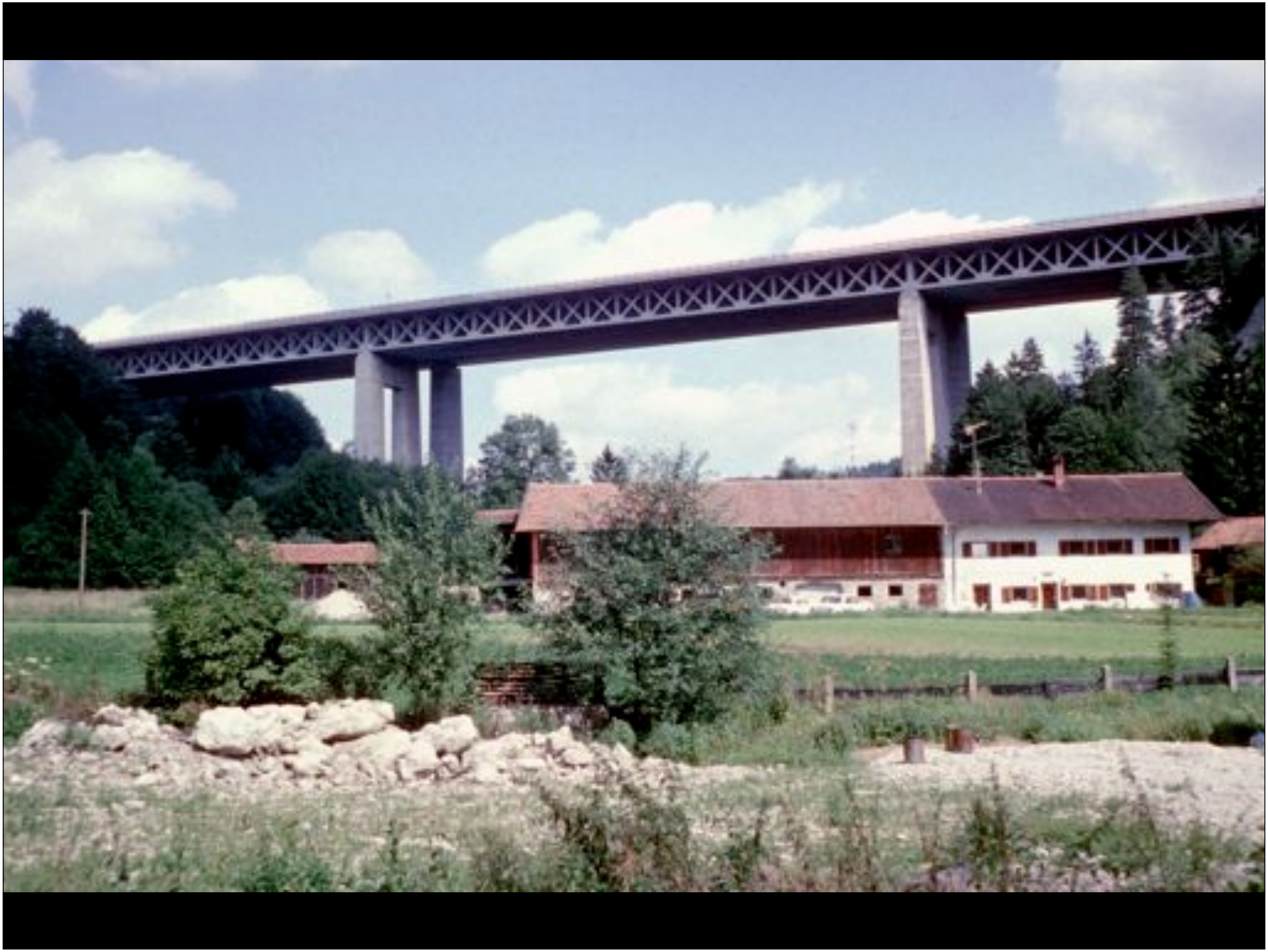
F_ℓ
e_x
F_0
℄
e_ℓ
x
ℓ



Mangfall



Bestehende
Pfeiler
Hilfsstützen
Hilfsstützen



Power of prestressing:

$$Z_b = \frac{M_{TL} - \alpha M_D}{\sigma_b}$$

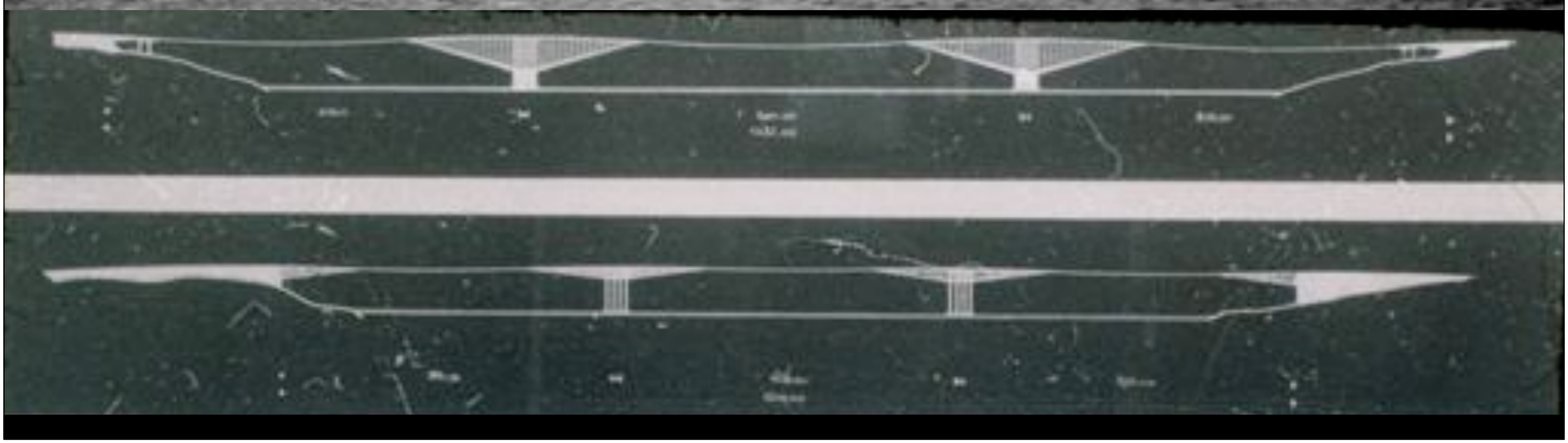
live

dead

effectiveness of prestress

beam size

material strength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Maldonado Bridge

Date taken: 8 March 2003

Photo by Jose Bellido de Luna

Pre-stressing is an enabling technology.

Does it always enable innovation in structures that leads to structural art?

Pre-stressing is an enabling technology.

Does it always enable innovation in structures that leads to structural art?

Let us learn the story of how pre-stressed concrete came to America. (and what aspects of pre-stressing became popular the world over)

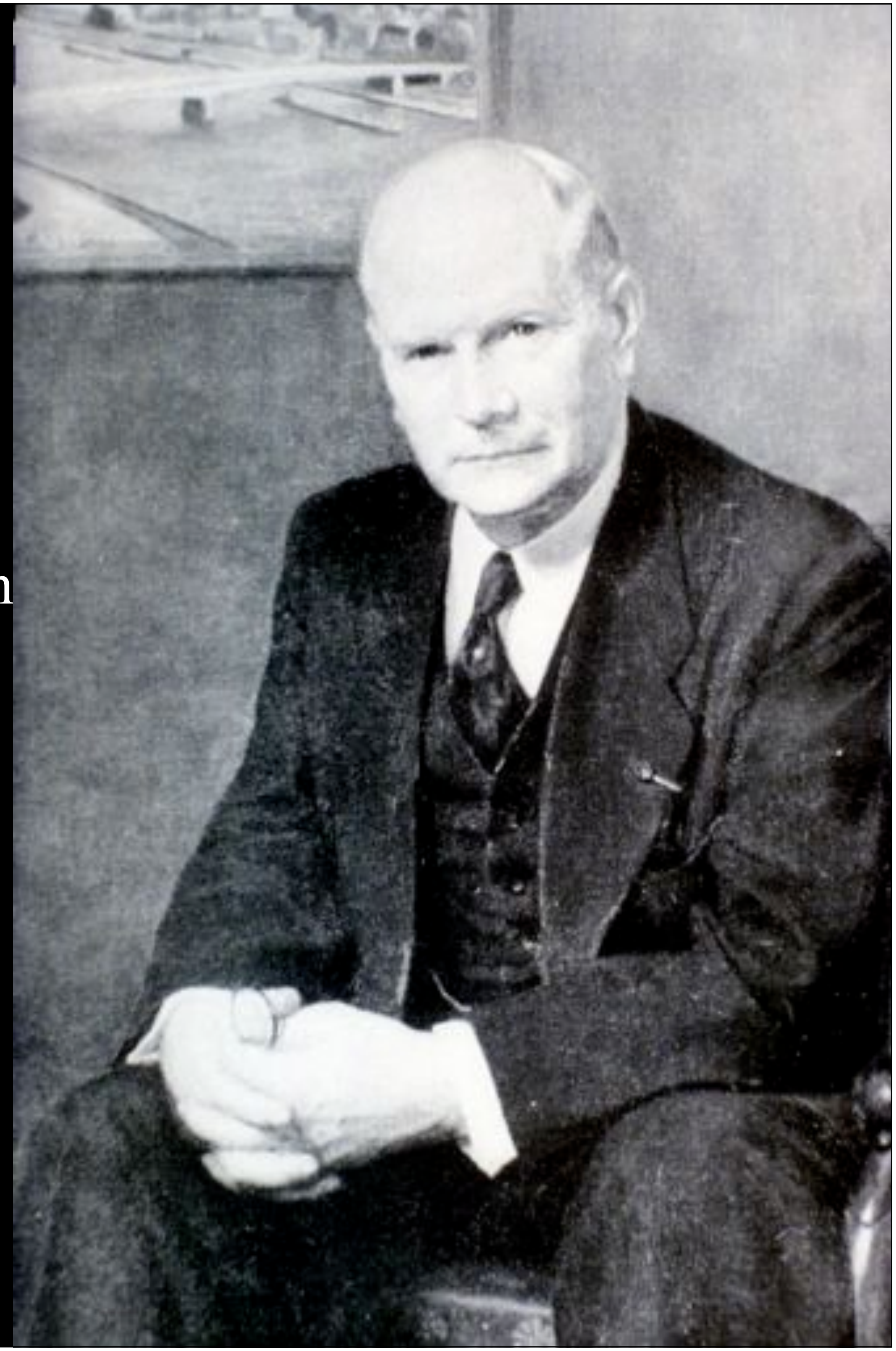


FIG. 1

[redacted]

FIG. 2

[redacted]

FIG. 4

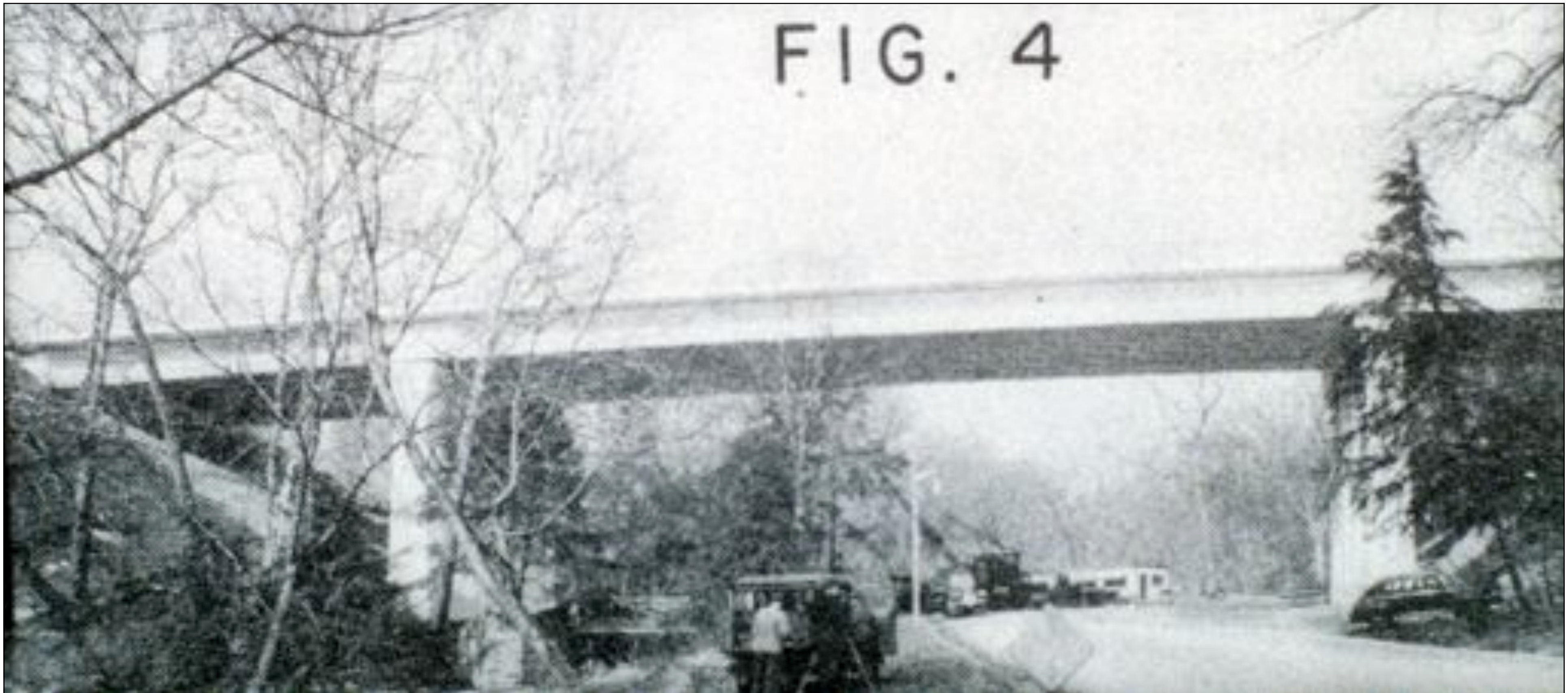
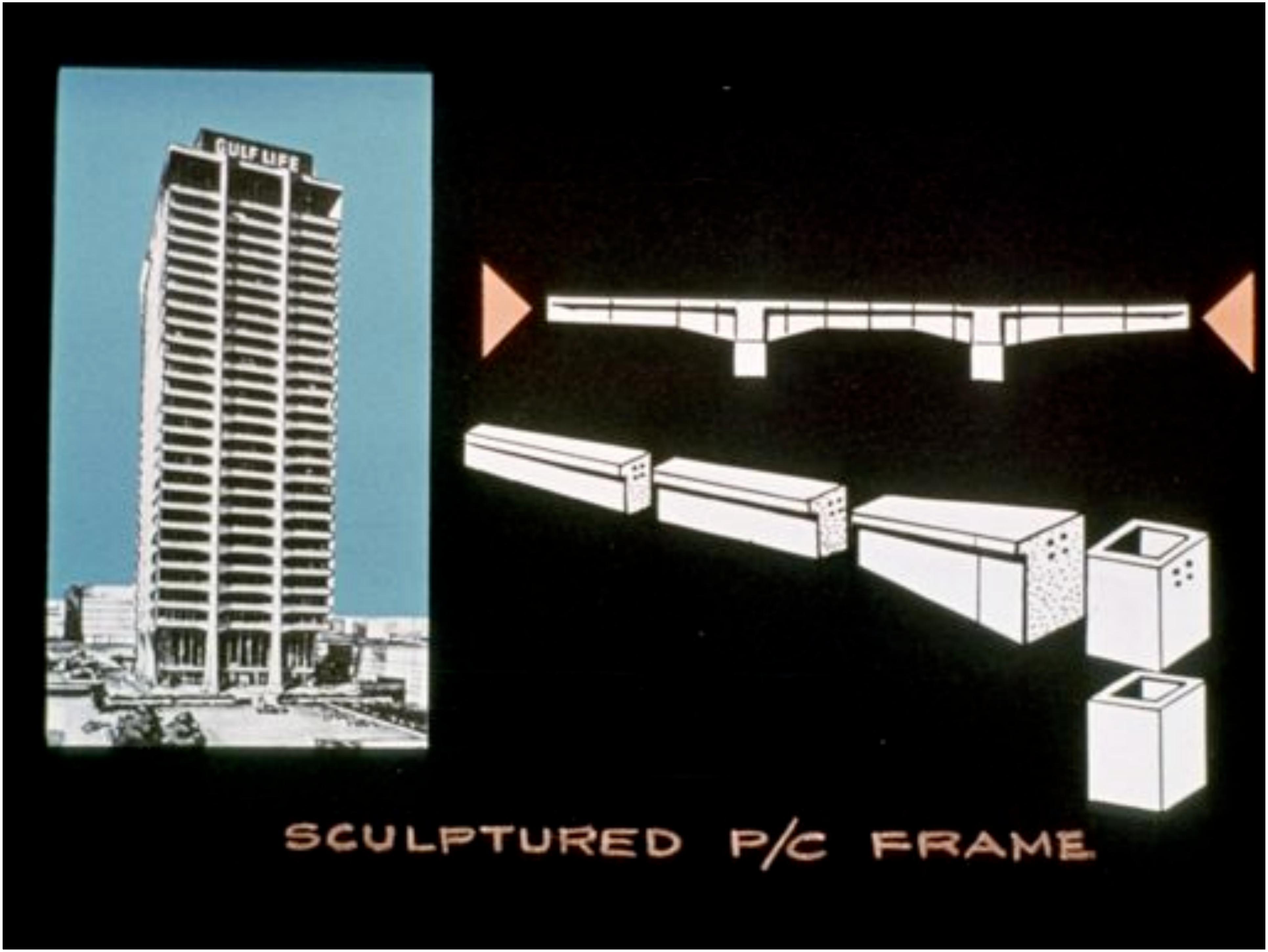


FIG. 4

shape the pre-stressing tendon instead of shaping the beam...


GULF LIFE
SCULPTURED P/C FRAME

Pre-stressing is an enabling technology.

Does it always enable innovation in structures that leads to structural art?

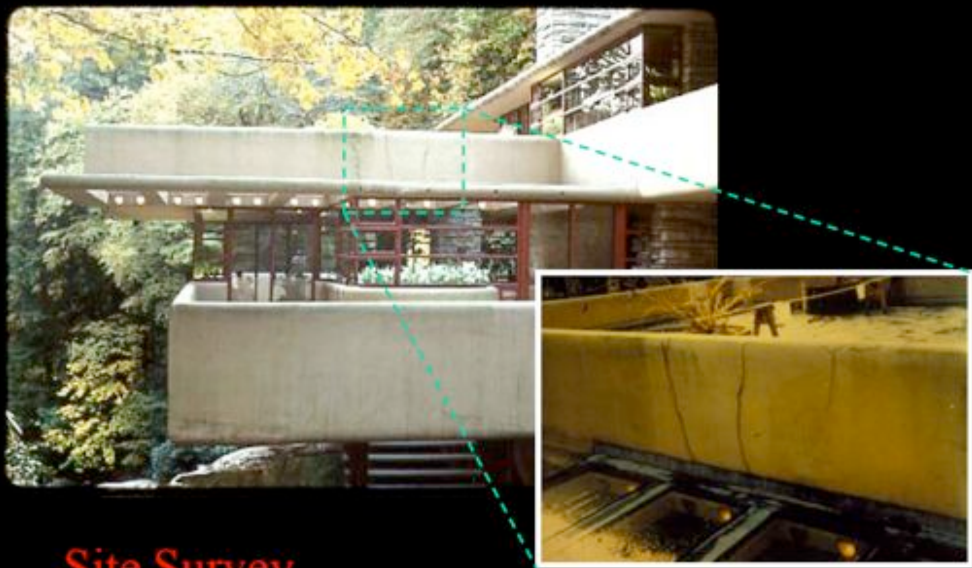
Discuss..

Pre-stressing is an enabling technology.

Does it always enable innovation in structures that leads to structural art?

What are other potentials of such technology?

"It is every homeowner's nightmare. The architect got into a fight with the engineer over whether the design skimped on structural materials. The engineer wanted to make the floors stronger, but the architect said extra steel would make them unsupportably heavy. Now, both are dead, and it turns out that the engineer was right."
–New York Times



Site Survey

"It is every homeowner's nightmare. The architect got into a fight with the engineer over whether the design skimped on structural materials. The engineer wanted to make the floors stronger, but the architect said extra steel would make them unsupportably heavy. Now, both are dead, and it turns out that the engineer was right."
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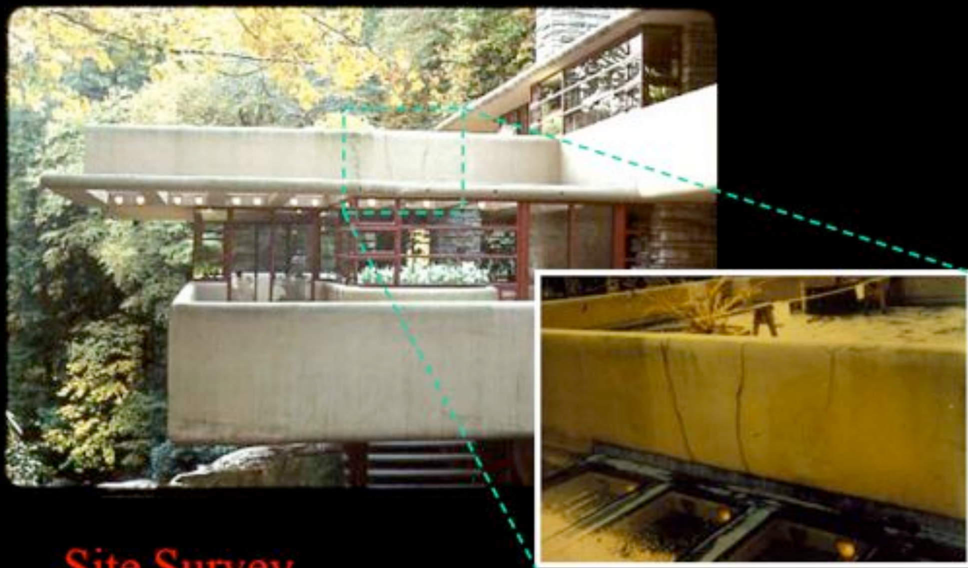

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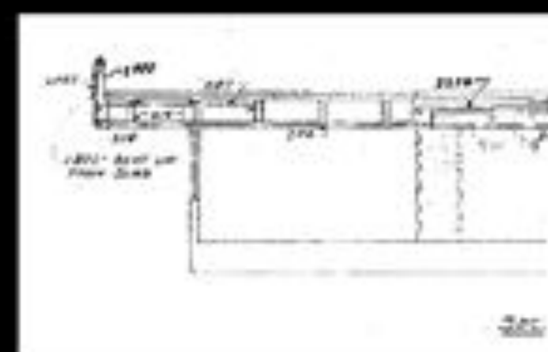
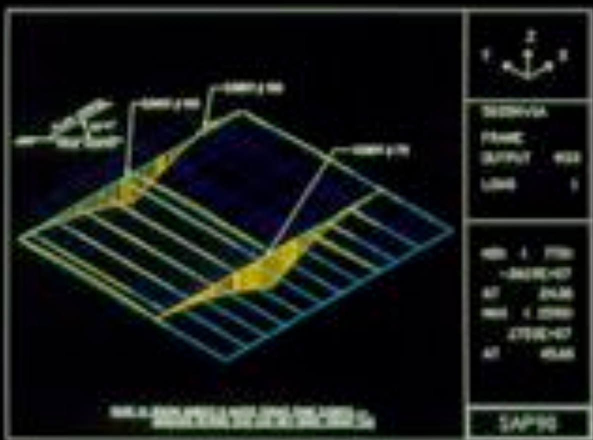
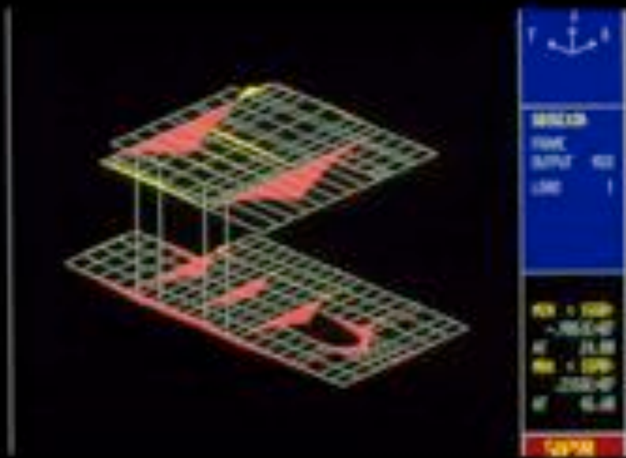


Historic Document Review

ROBERT SILMAN ASSOCIATES
STRUCTURAL ENGINEERS
WASHINGTON DC • NEW YORK

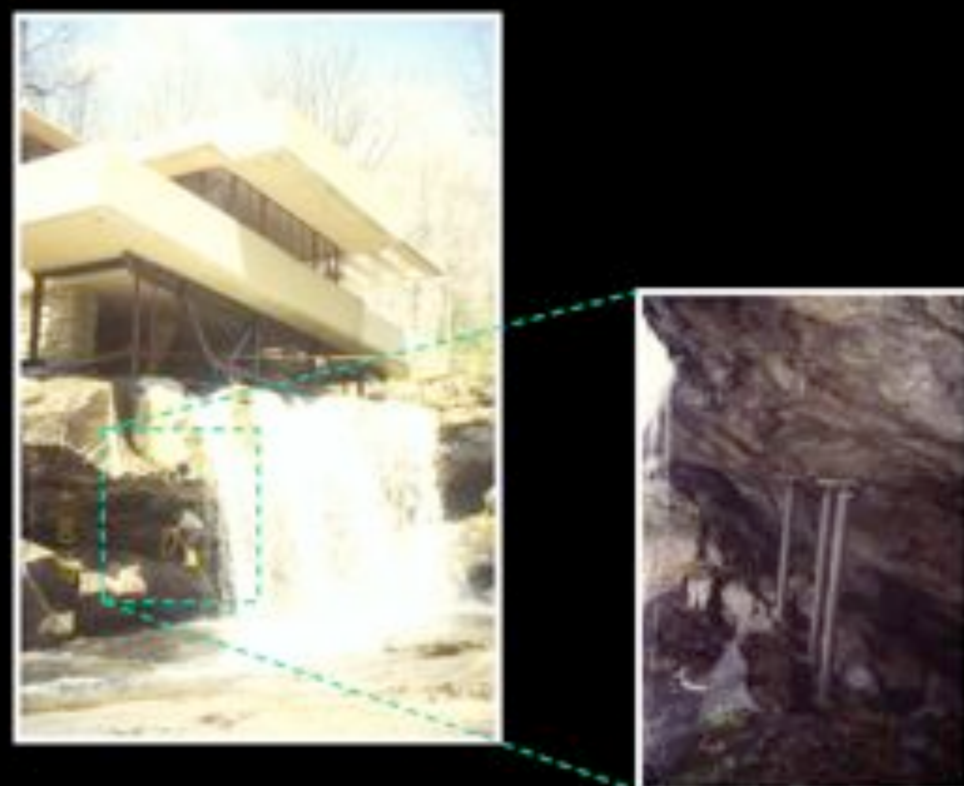


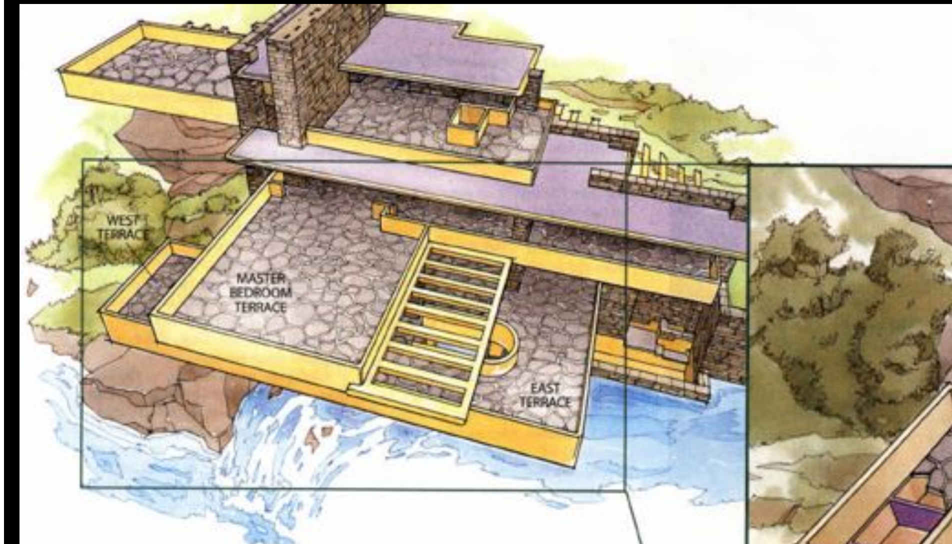


Multi-Faceted Investigation – Preservation Approach

Structural Analysis

Temporary Shoring / Stabilization



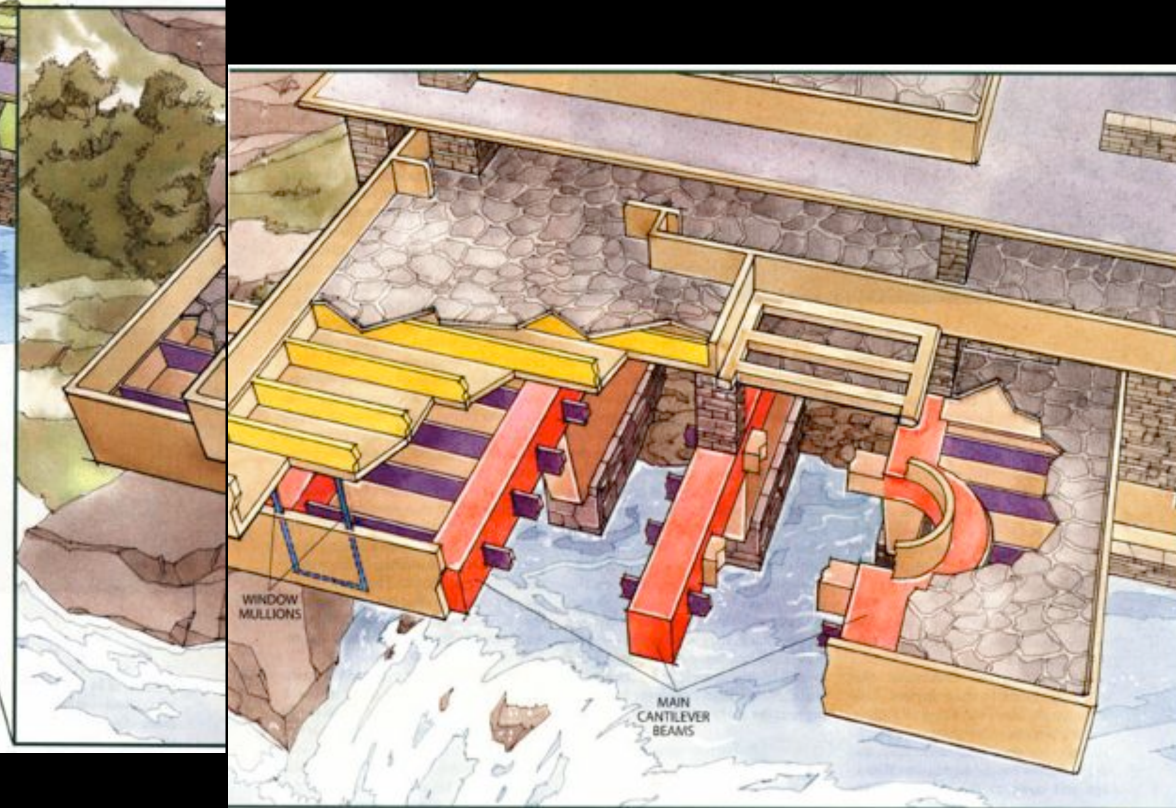


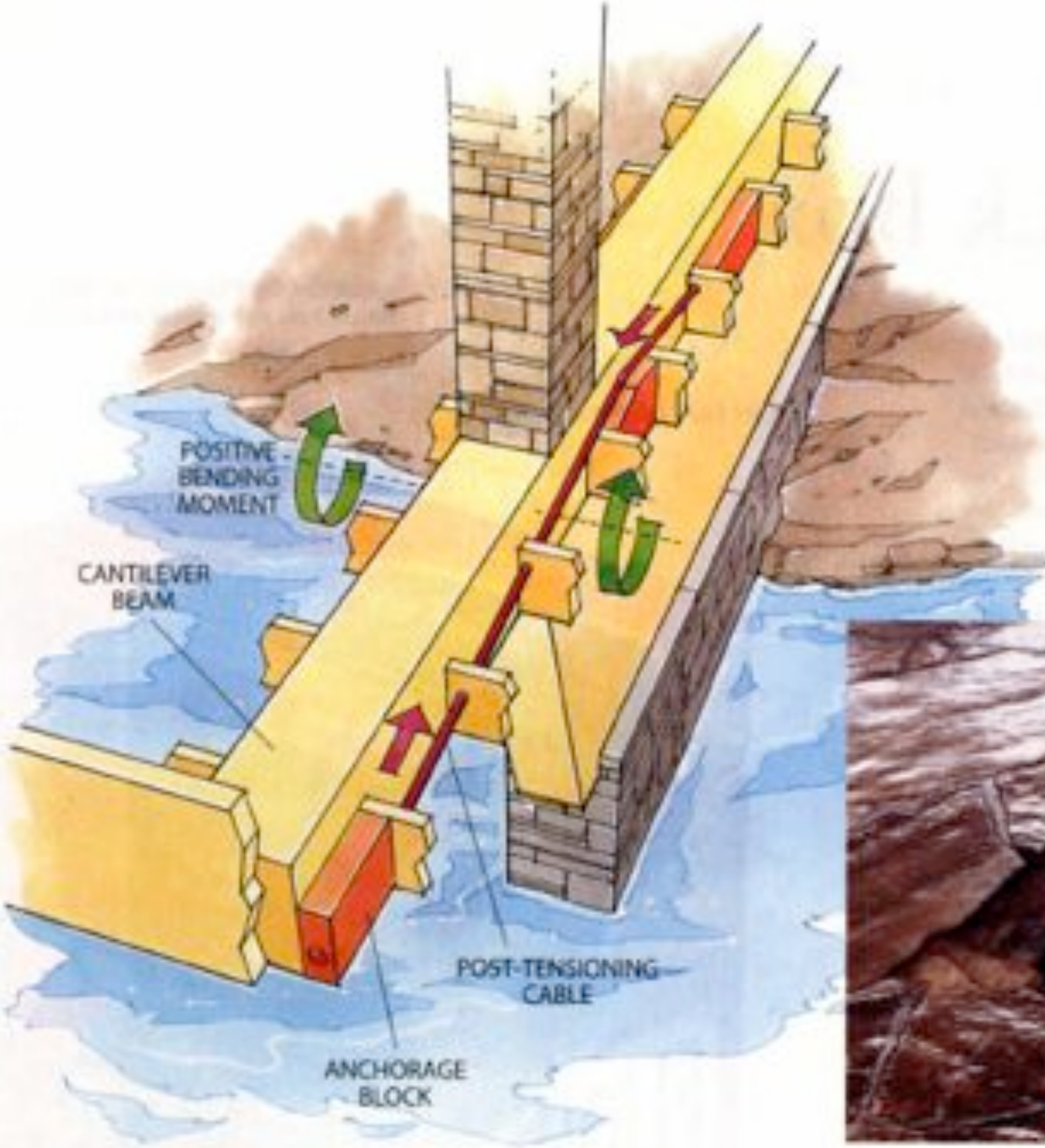
ed his design. Once again he forced Kaufmann, Sr., to choose between him and Metzger-Richardson. Kaufmann, Sr., decided to go ahead with the house as originally planned.

Still, the house's owner remained concerned about the tilting of the terraces, so he commissioned a surveyor to measure the deflections on a regular basis by recording the elevations of the tops of the parapet walls. This was done from 1941 until 1955, when Kaufmann, Sr., died. In 1963 Kaufmann, jr., presented the house to the Western Pennsylvania Conservancy. Between 1955 and the time our firm was retained in 1995, only one or two random measurements of the terraces' deflections were recorded.

low, because the two floors are structurally interdependent.

Our first question was, "Have the deflections stopped, or are they still growing?" Using an instrument called a water level, we took height readings at more than 30 locations and attempted to relate them to the survey readings done earlier. Our measurements showed that the edge of the west terrace had sagged by as much as 146 millimeters and the edge of the east terrace by as much as 184 millimeters. The deflection of the south end of the master bedroom terrace was about 114 millimeters. We then installed electronic monitors to measure very small movements of the terraces and changes in the width of the cracks in the terrace's parapets.





PLANNED REPAIRS involve relieving the stresses in the cantilever beams through the creative use of post-tensioning. Steel cables will be rigged on both sides of each beam, anchored in concrete blocks attached to the beam's ends (*left*). The cables will then be tightened from the outside using a hydraulic jack. The tension in the cables will exert a positive bending moment on the beam, counteracting the negative moment caused by cantilever action. A section of one cantilever beam beneath the living room floor (*below*) has already been exposed to allow engineers to inspect it.

Construction / Renovation

Finished Work

- Sustainability of Resources
- Sustainability of Culture