

# Freyssinet, Finsterwalder and Fallingwater

## Origins and Solutions in Prestressed Concrete

### Lecture themes

Freyssinet's story and the origins of prestressed concrete (PC)

Aside: how does construction elegance map into structural art?

Finsterwalder's advancements in PC bridges

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

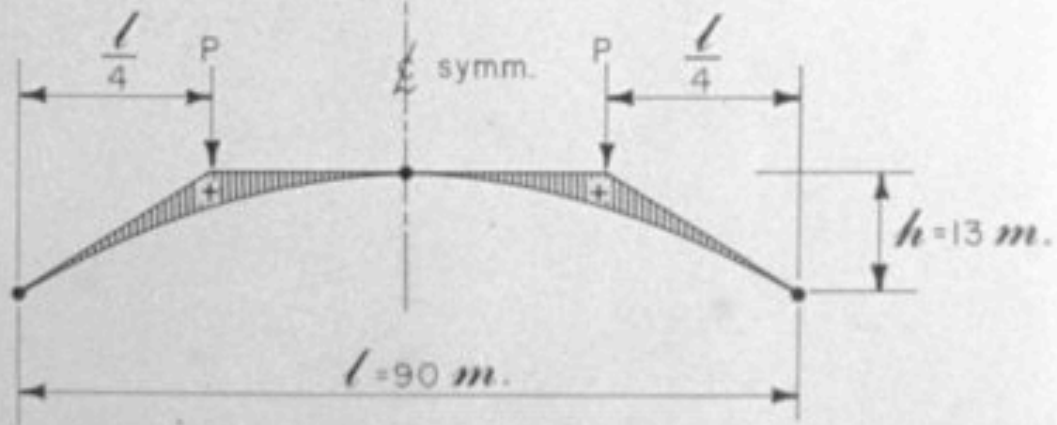




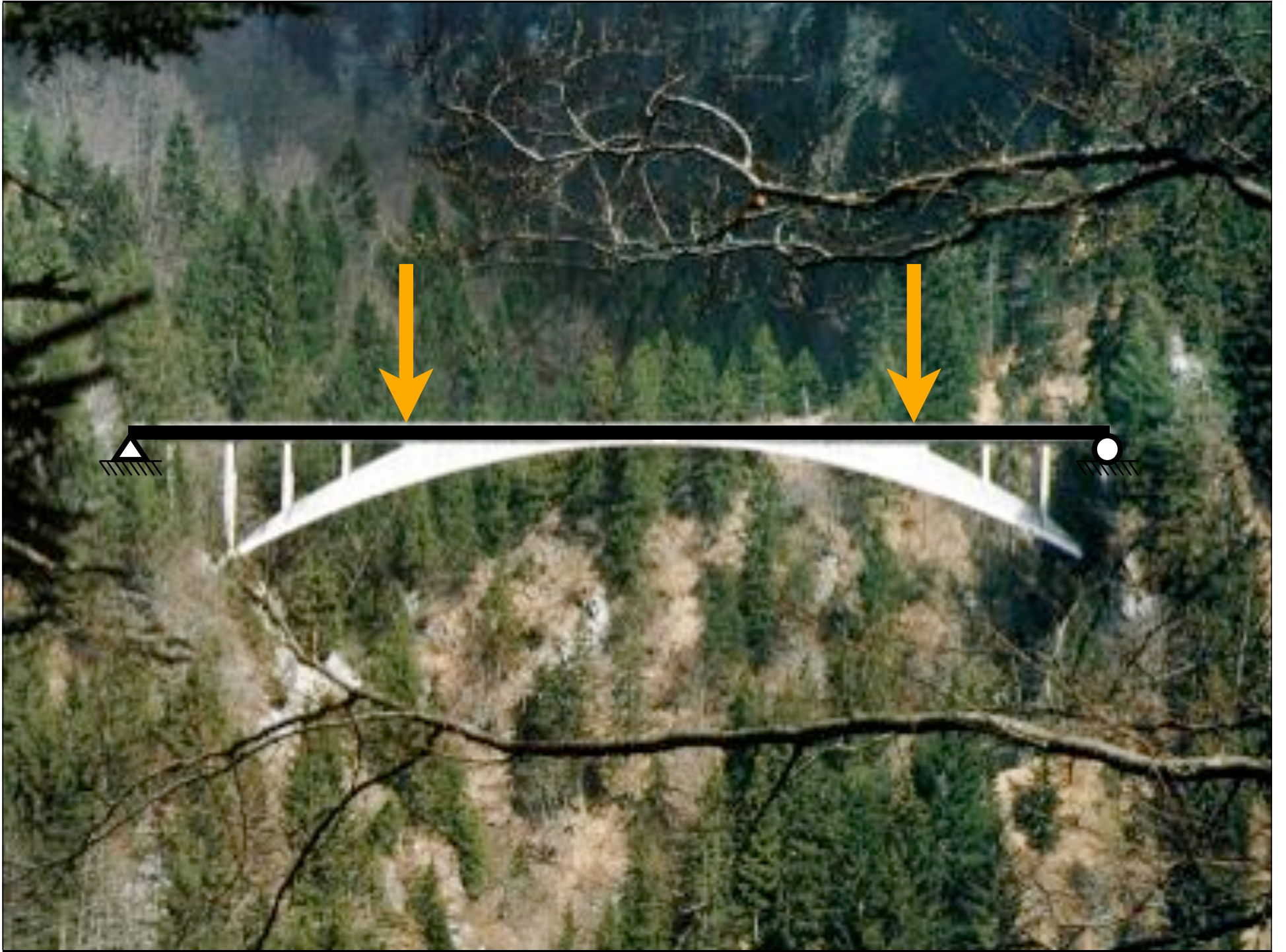
SIMPLE-BEAM MOMENT ( $H = 0$ )



HORIZONTAL-THRUST MOMENT ( $P = 0$ )



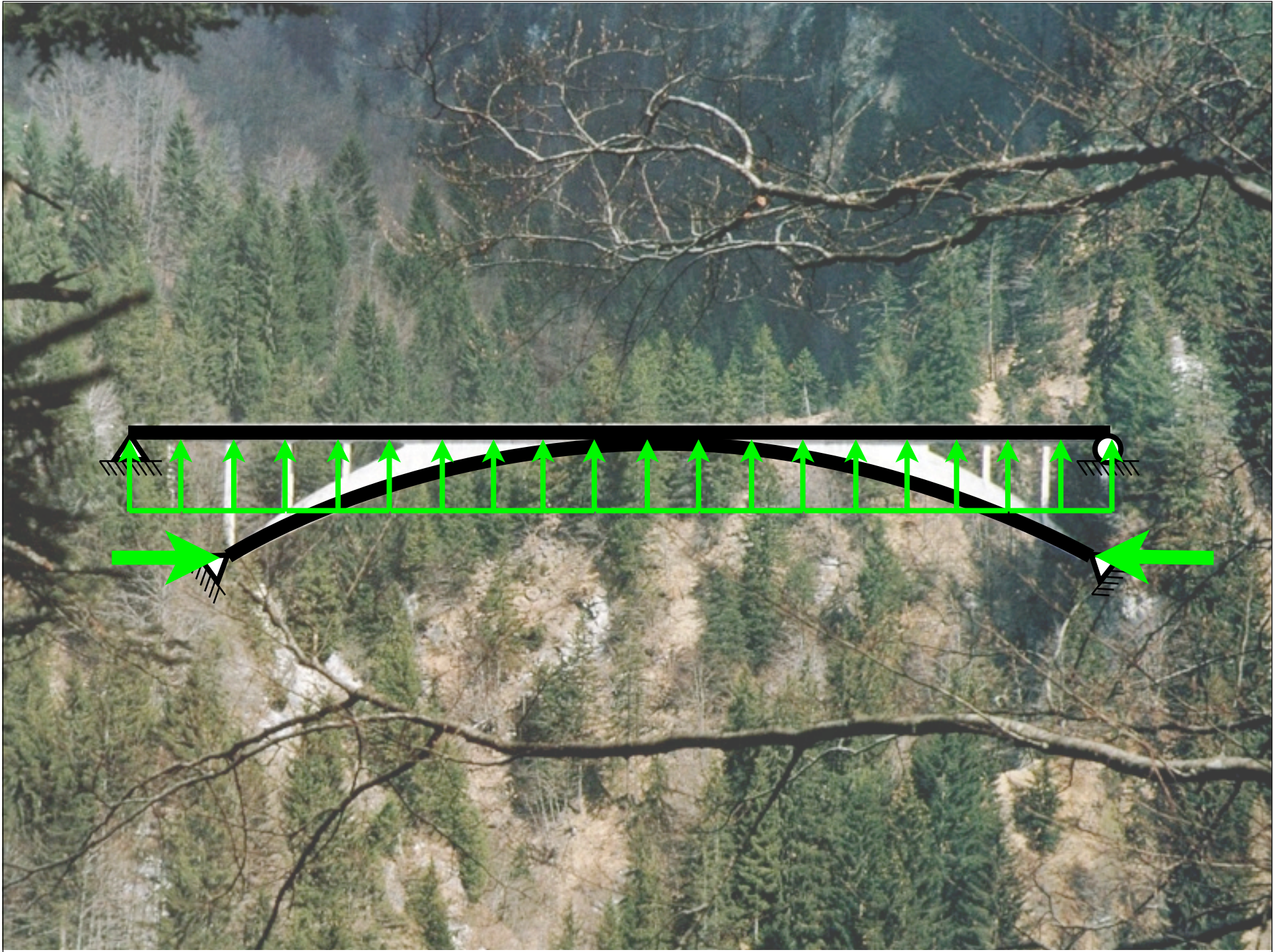
FINAL MOMENT DIAGRAM ( $H = \frac{Pl}{4h}$ )

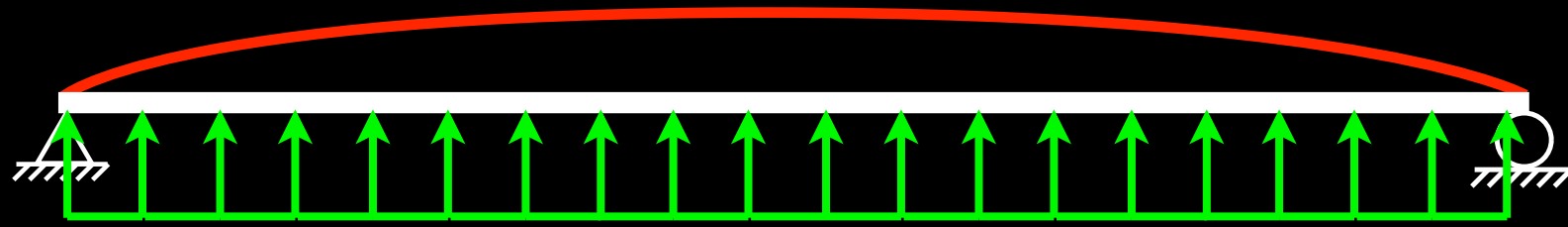




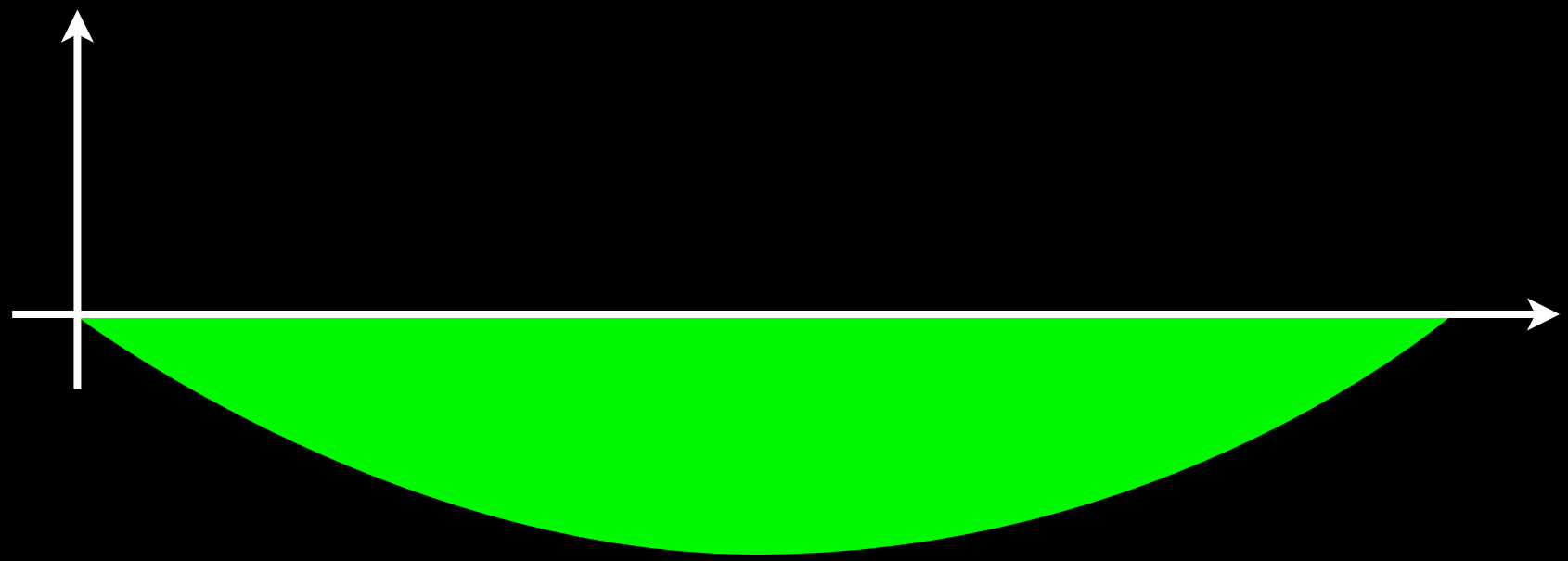
moment

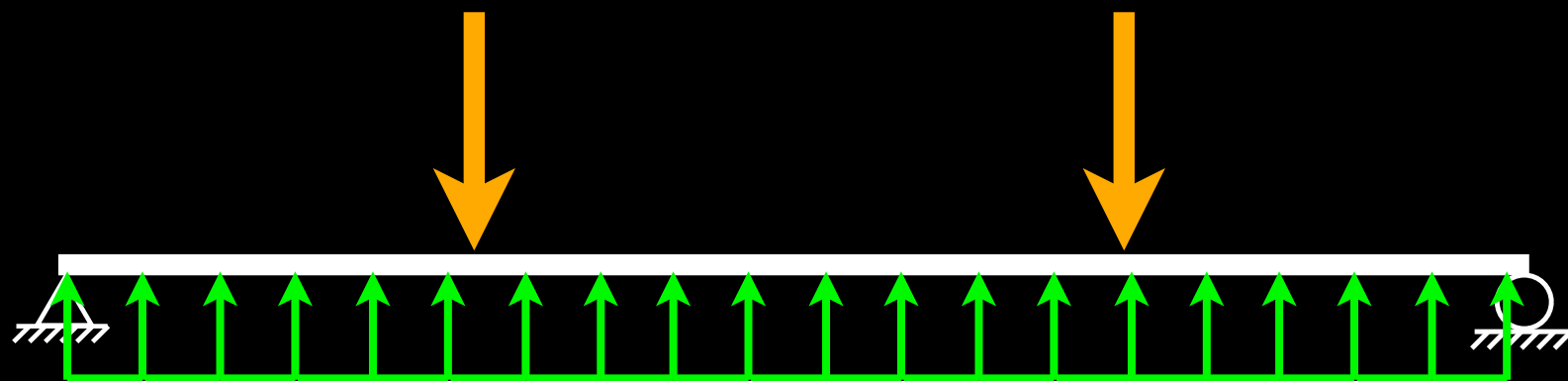




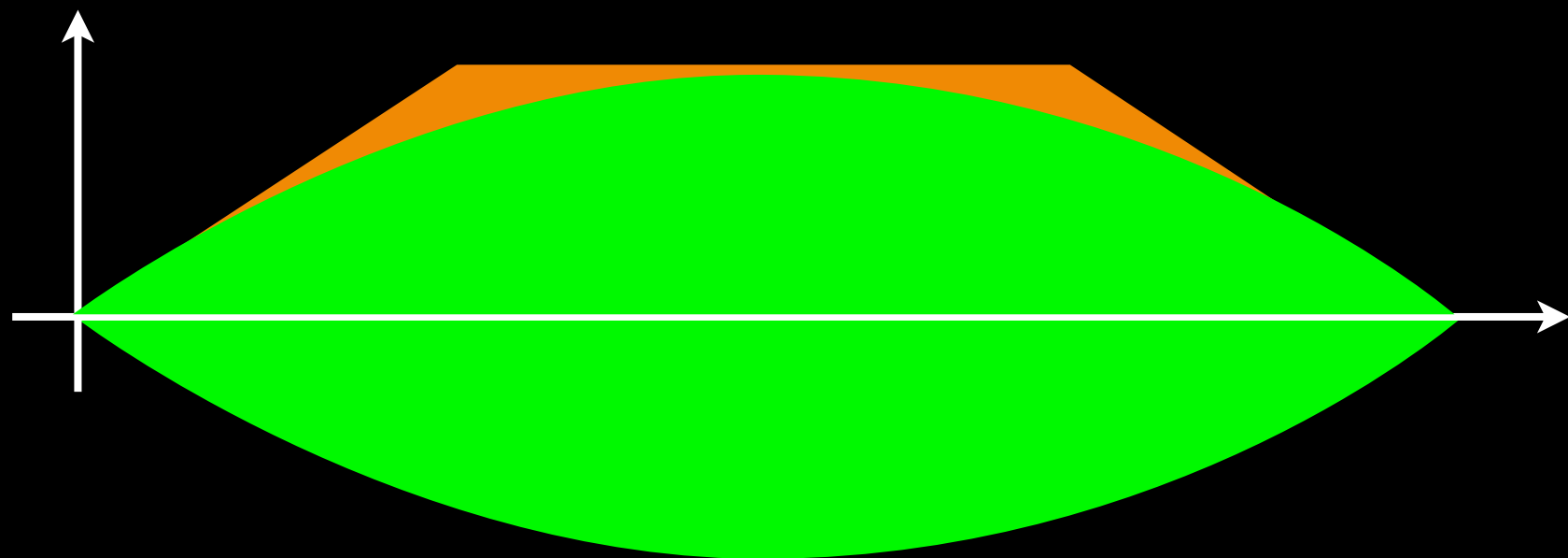


moment

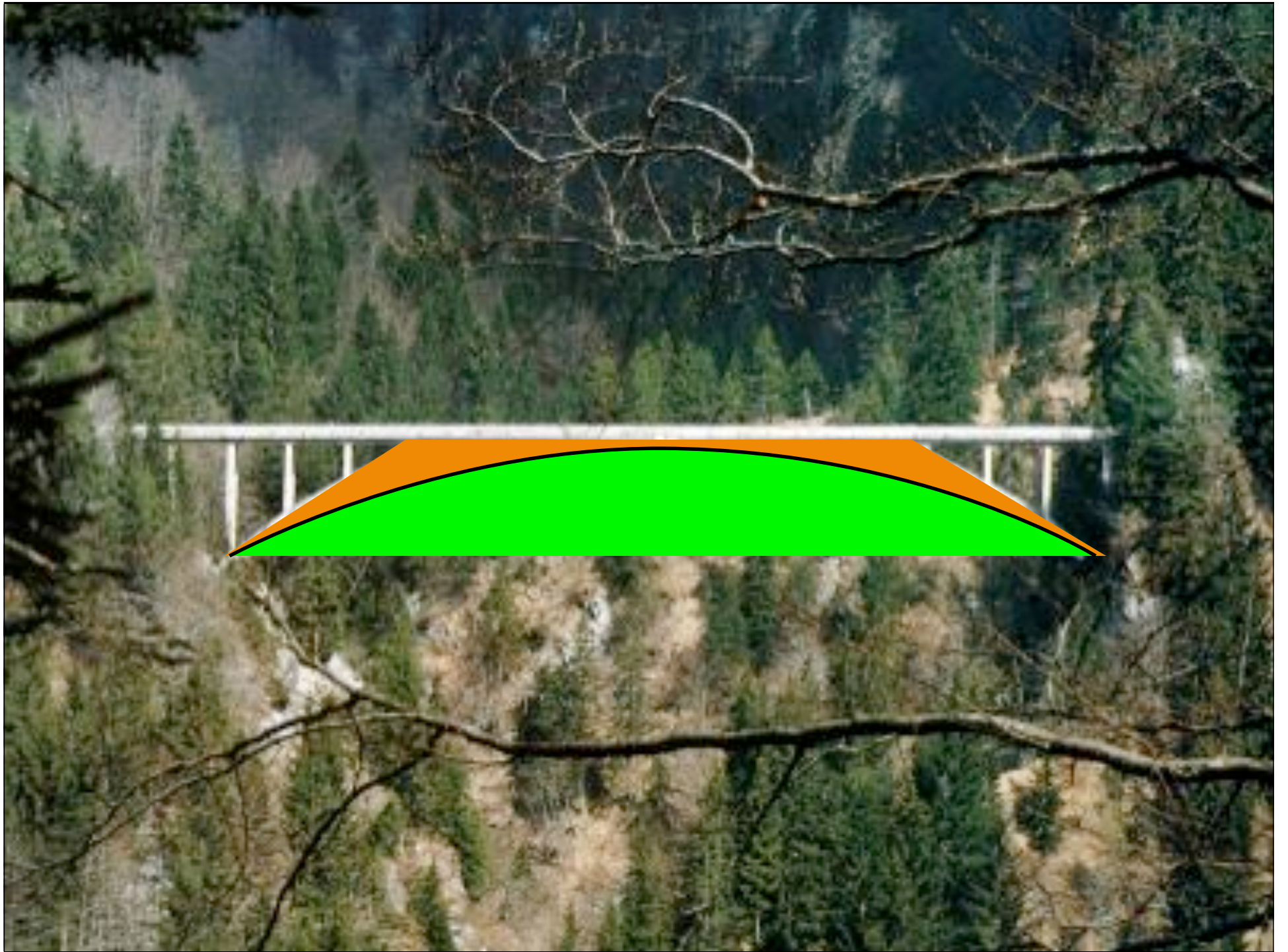




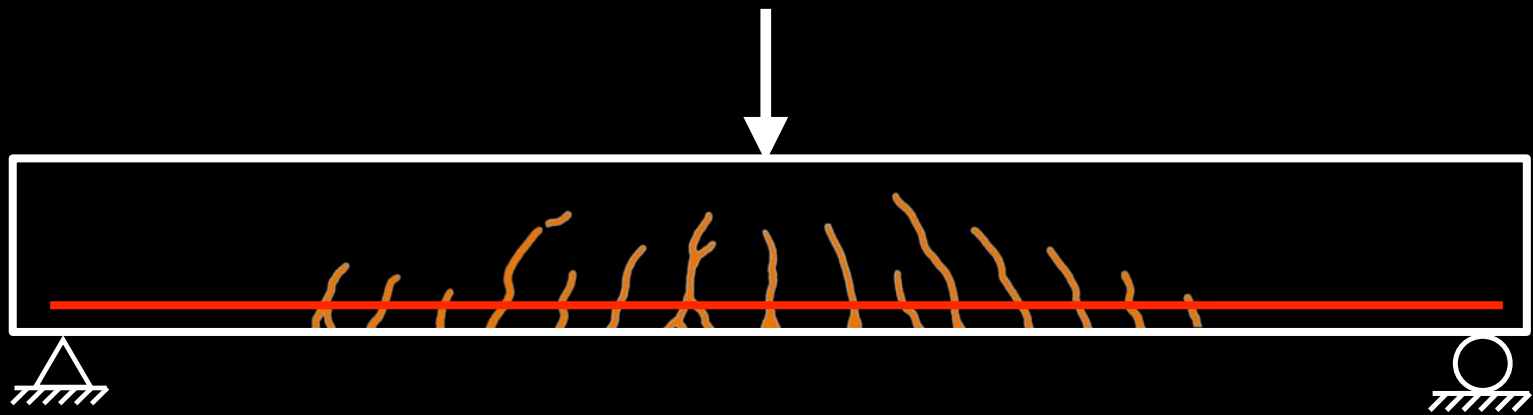
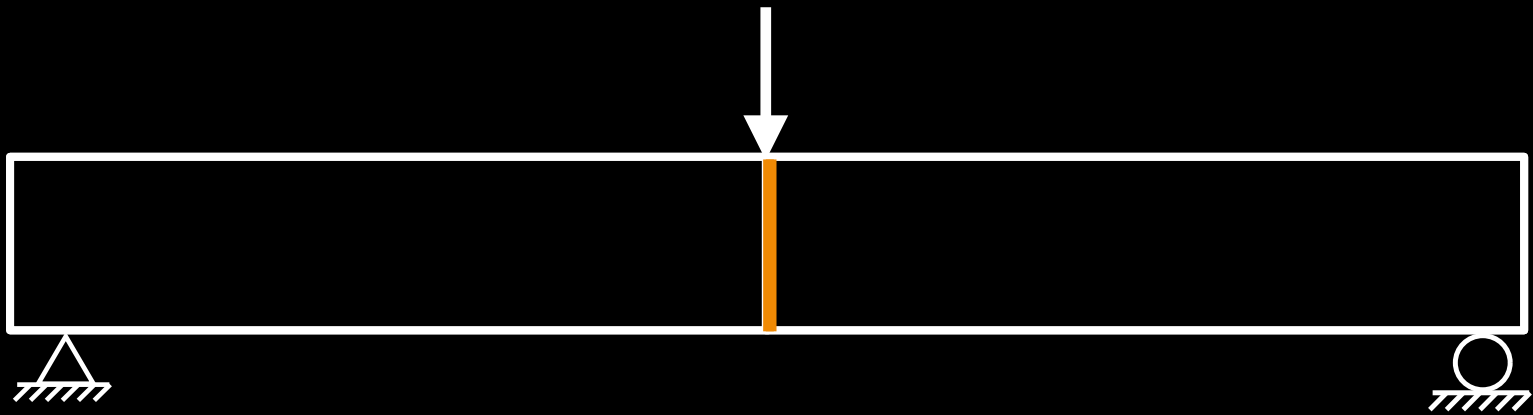
moment













Le Veudre

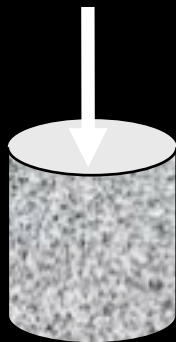


Freyssinet  
1879-1962



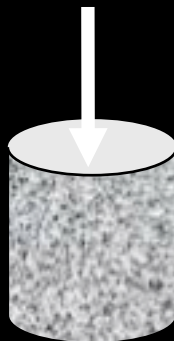
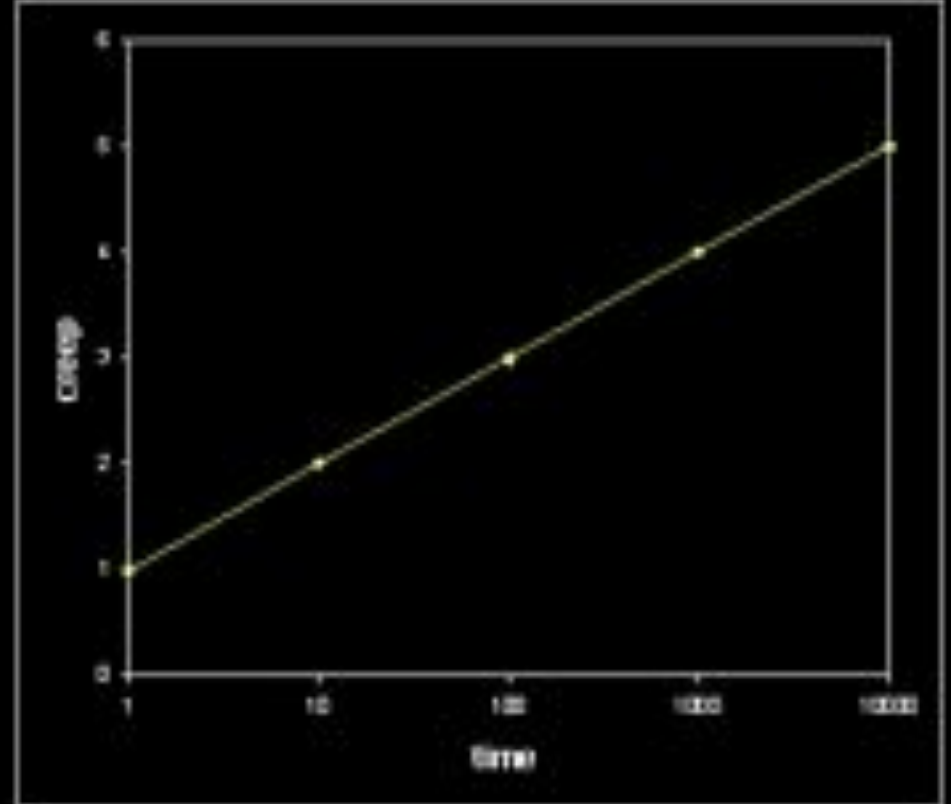
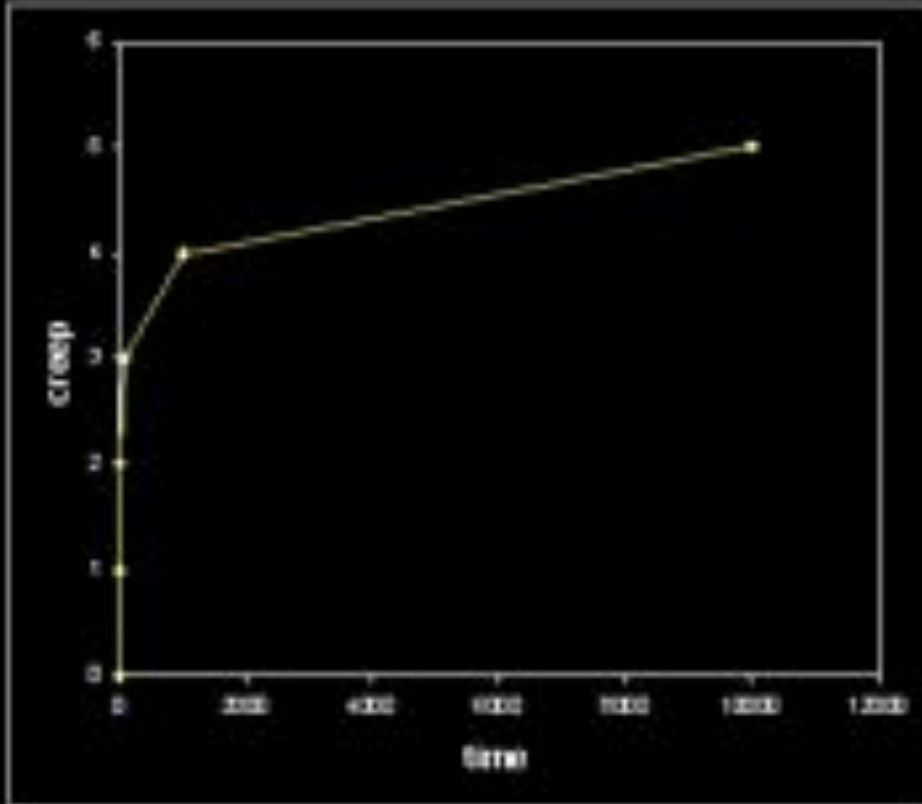
“an official letter put me in charge of supervising...the execution of these bridges whose designer I was, for which I was to be the contractor and the plans of which had never been submitted for anyone’s approval...[My superior granted] me unlimited credit out of his funds but without giving me a single 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  
Veudre commission



apply load and hold  
what happens?





apply load and hold  
what happens?



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

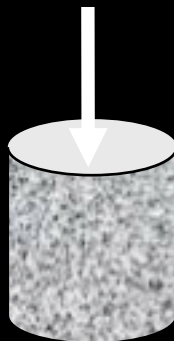
Mårten Larson<sup>1</sup> and Jan-Erik Jonasson<sup>2</sup>

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?

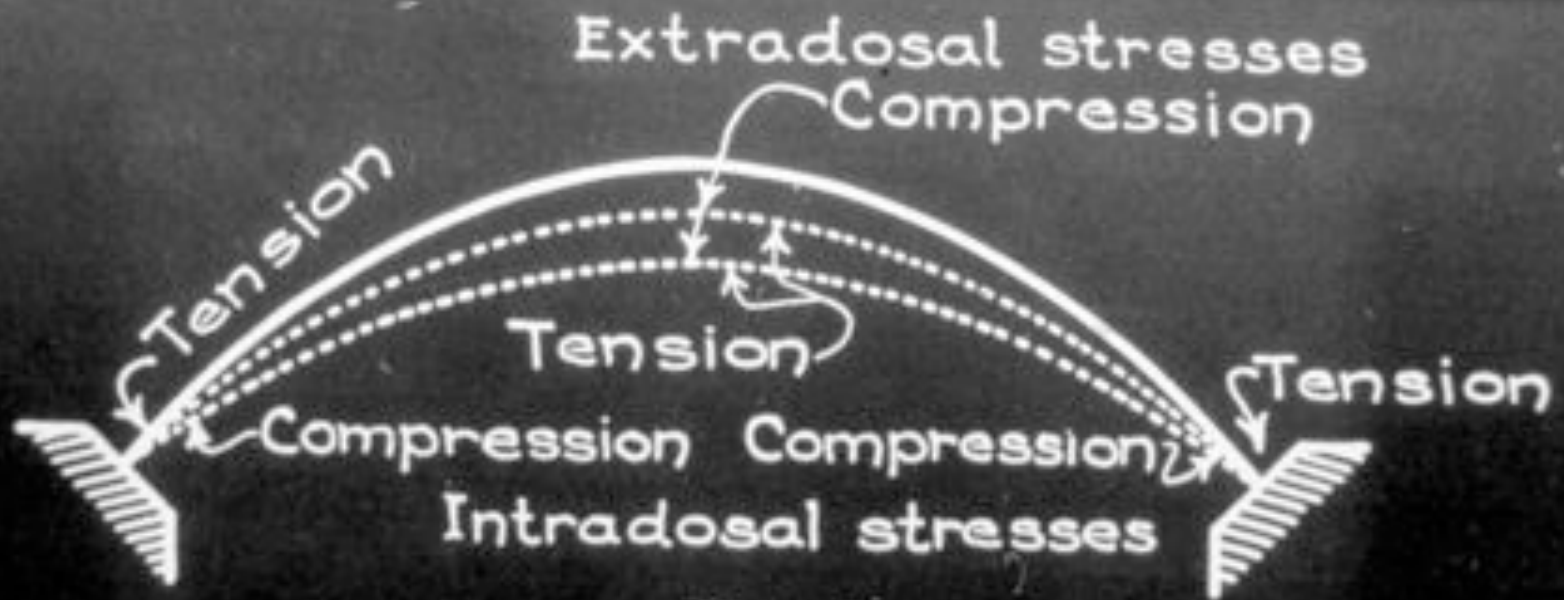
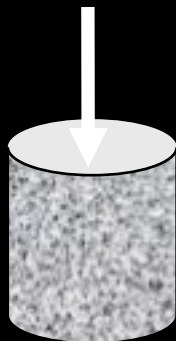
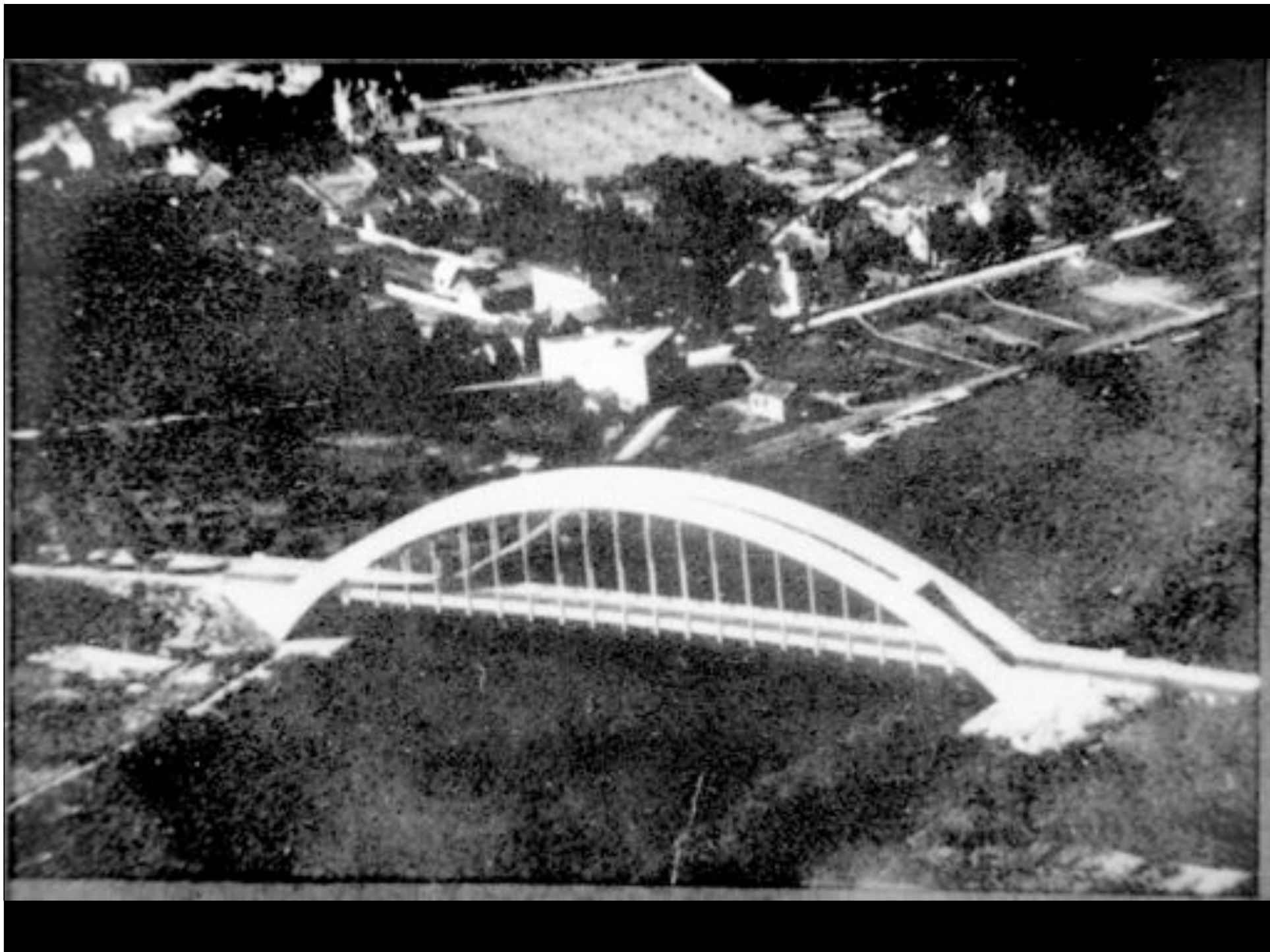


FIG. 7.



apply load and hold  
what happens?





St Pierre du Vauvray



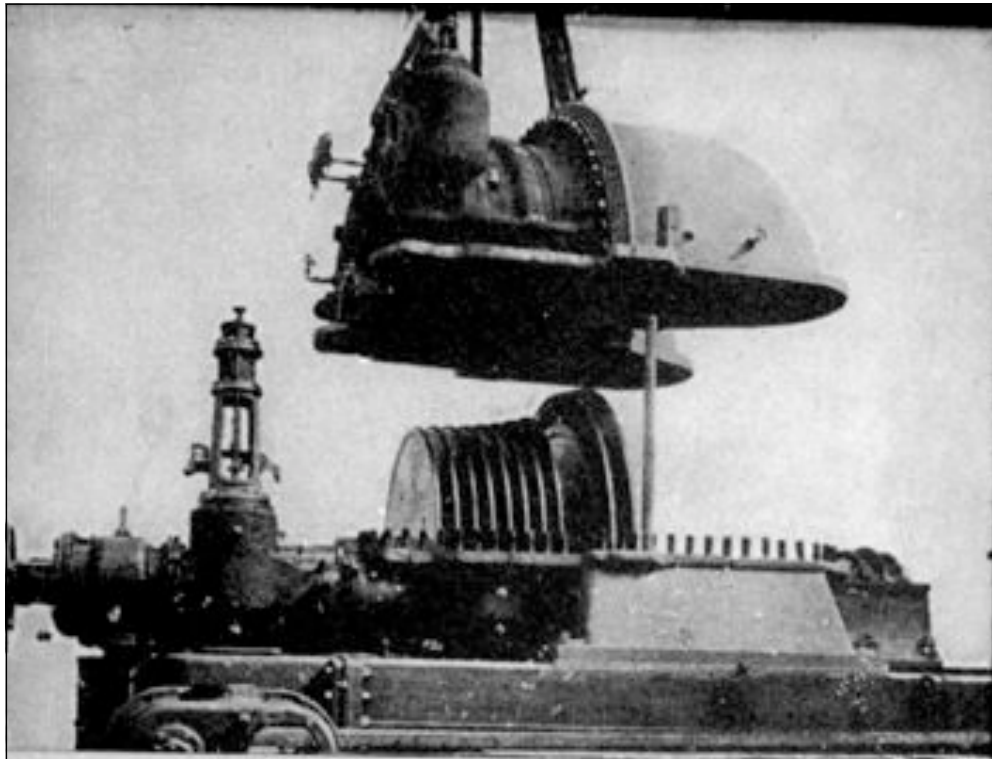


[www.structurae.de](http://www.structurae.de)

Saint-Pierre-du-Vauvray Bridge.

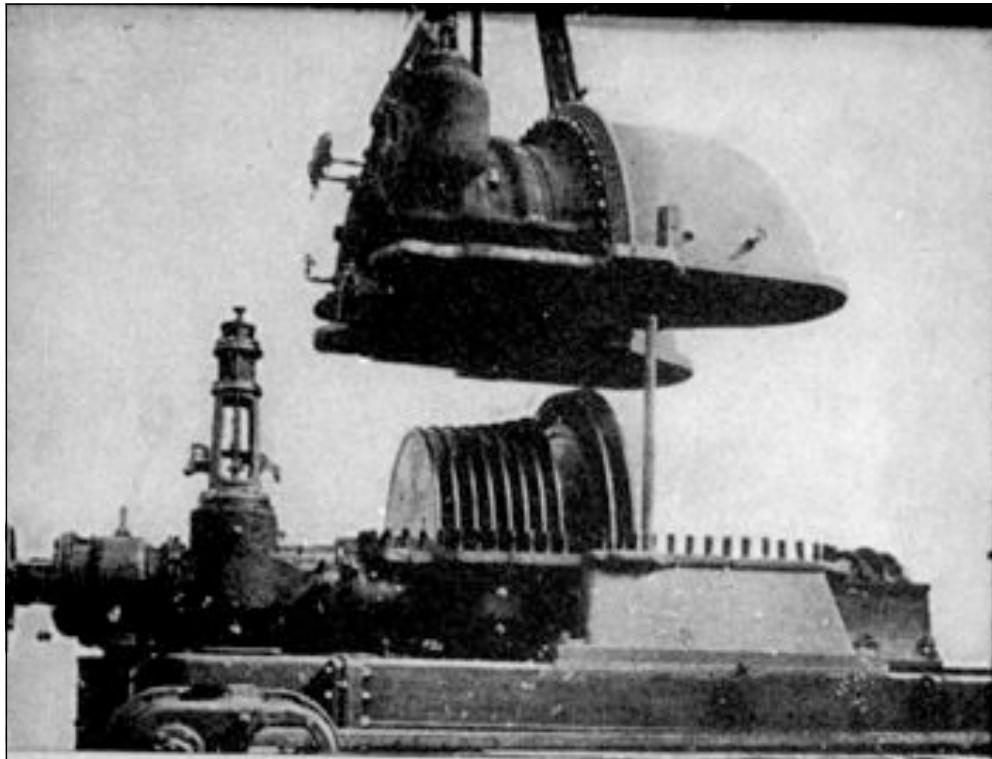
Photo by Jacques Mossot





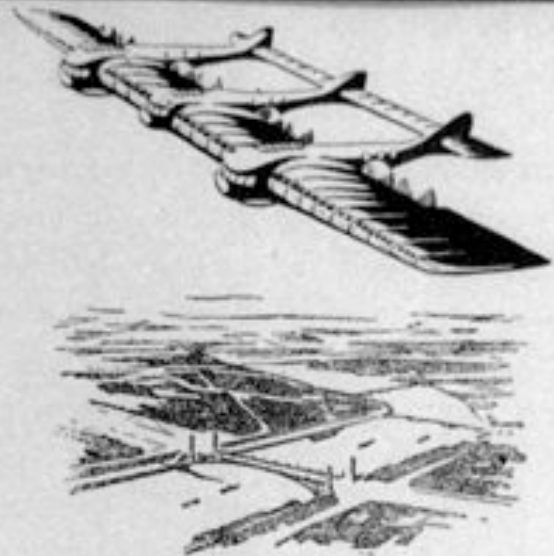
40,000 KILOWATT TURBINE FOR ELECTRICITY

ARCHITECTURE  
OR  
REVOLUTION



40,000 KILOWATT TURBINE FOR ELECTRICITY

ARCHITECTURE  
OR  
REVOLUTION



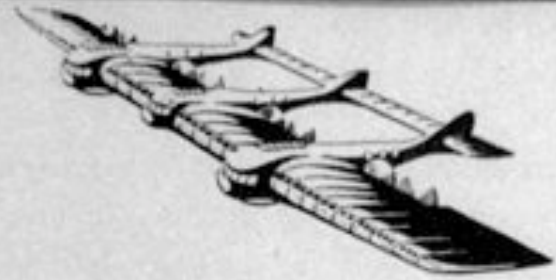
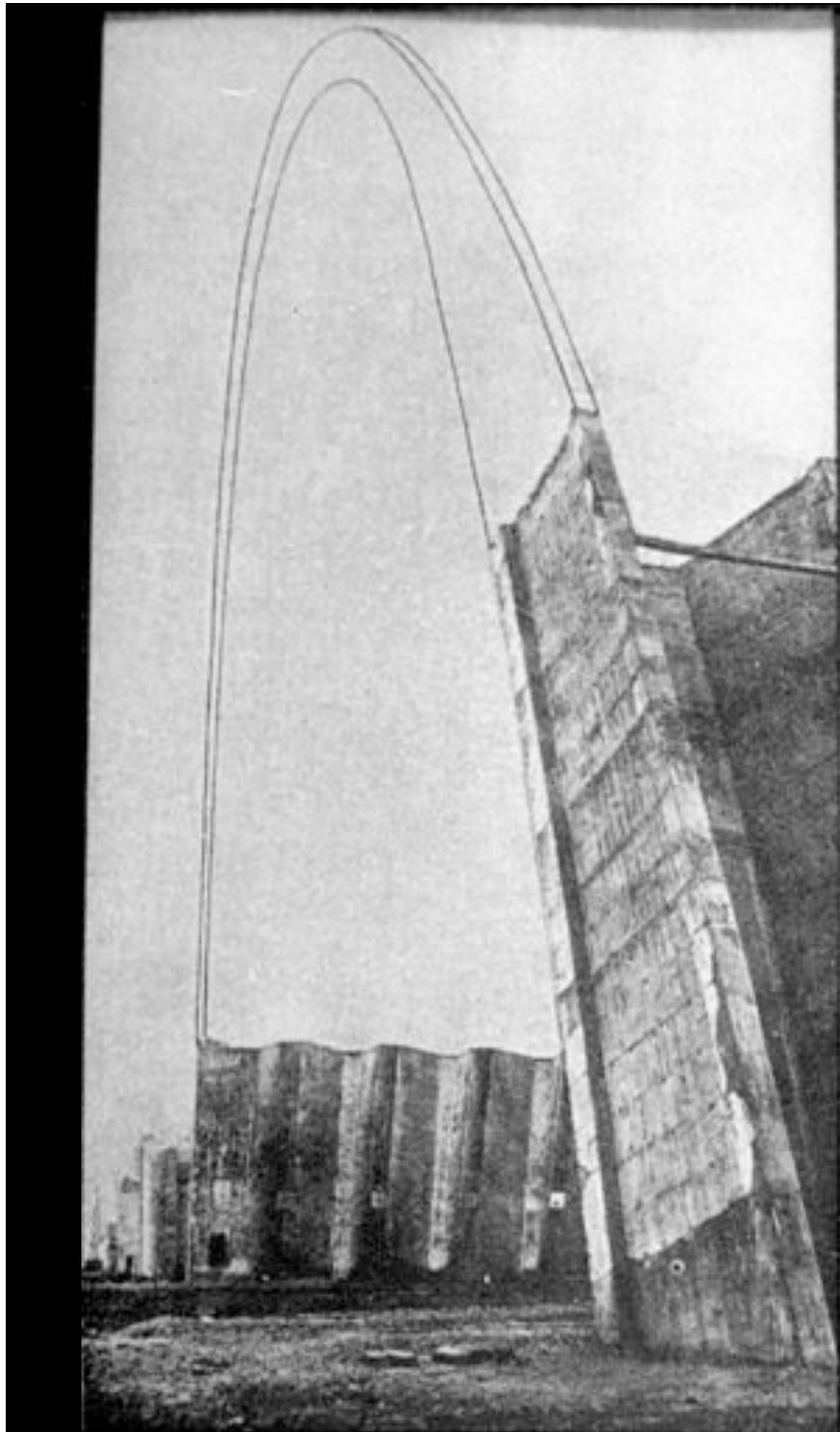
A FORECAST: THE AIRPLANE OF TO-MORROW

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 book provide a telling proof of this. Such tools are capable of



A FACTORY (PREYSSINRY & LIMOUSIN)





A FORECAST: THE AIRPLANE OF TO-MORROW

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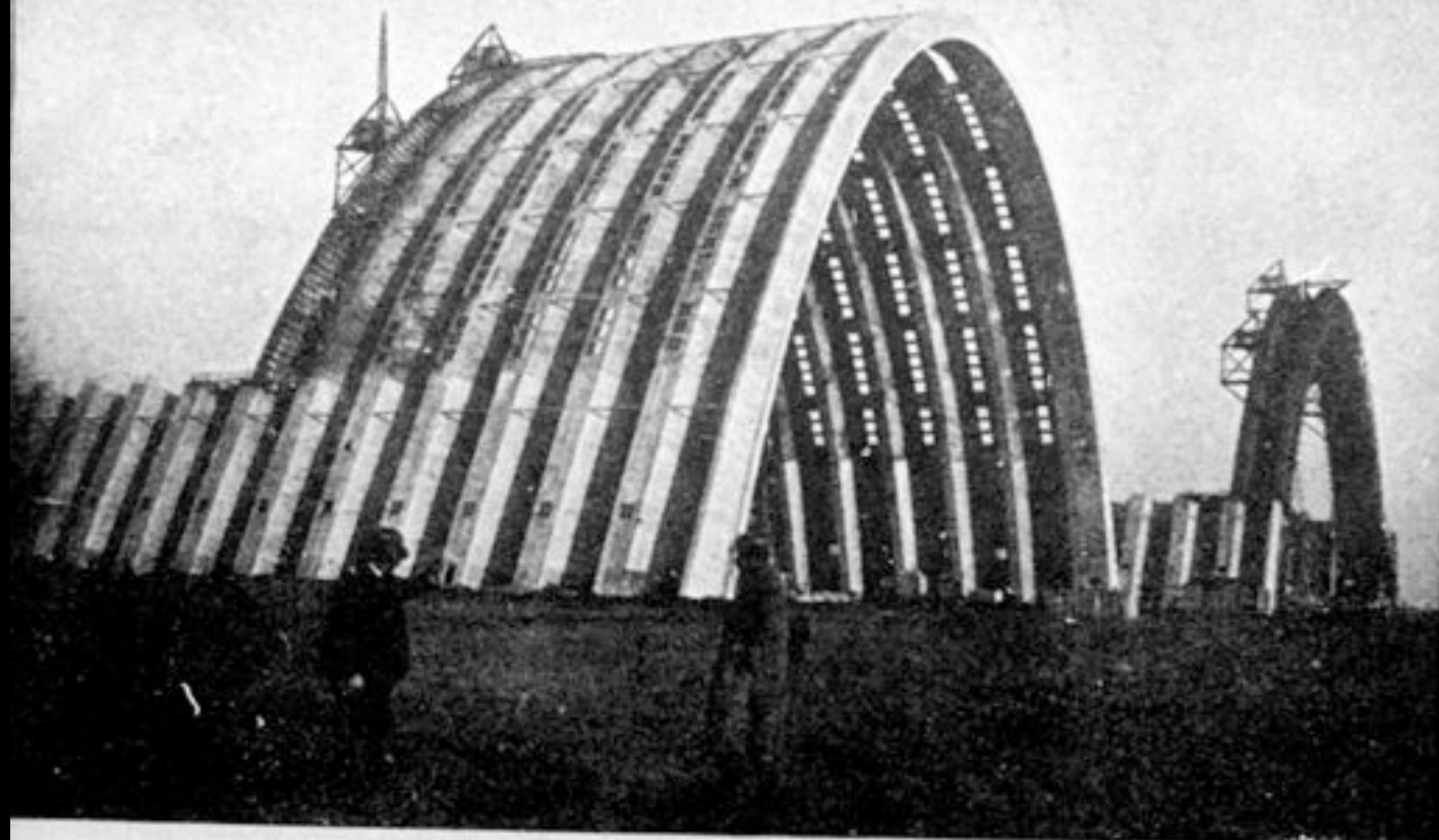
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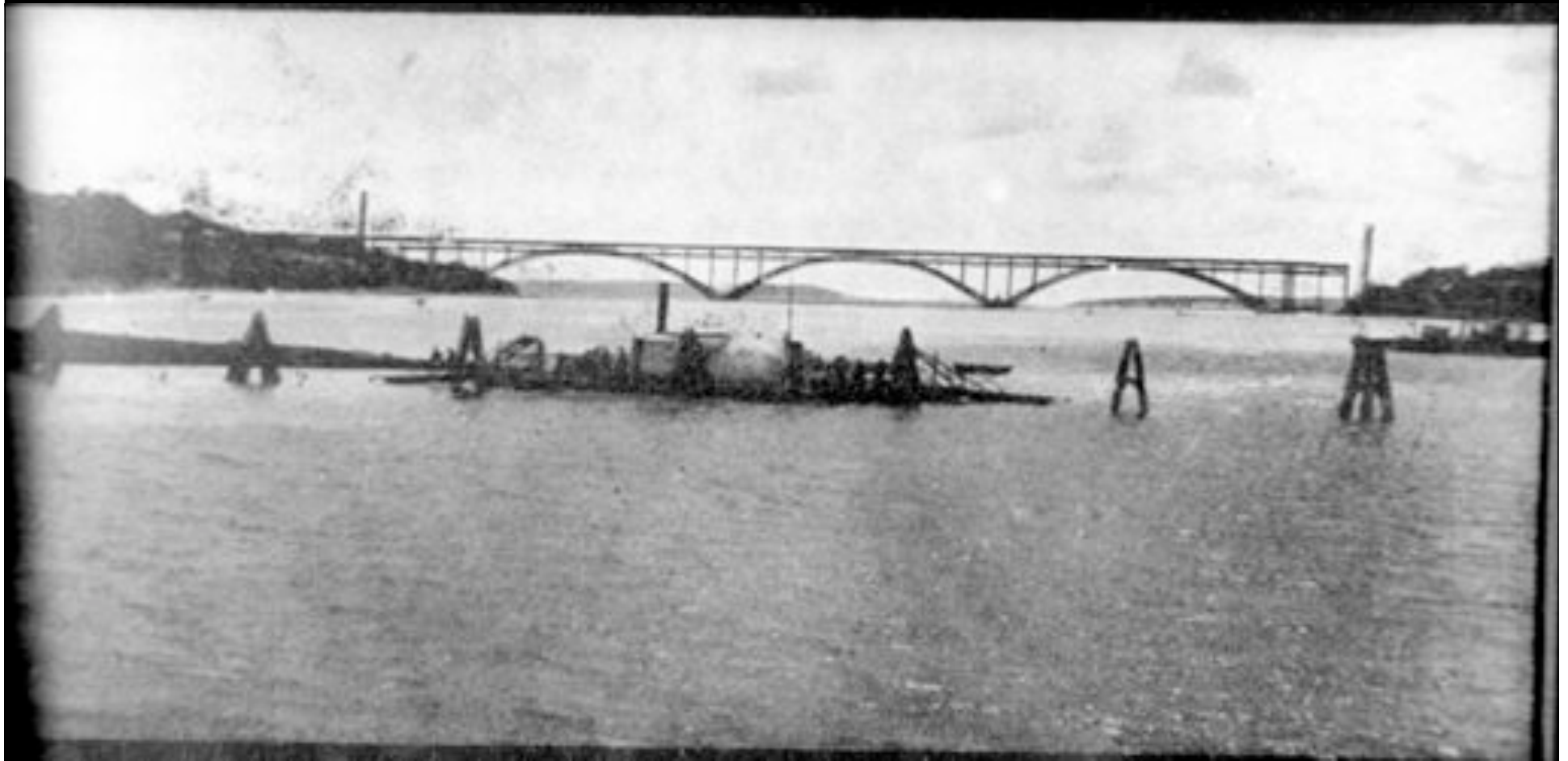


A FACTORY (PREYSSINRY & LIMOUSIN)

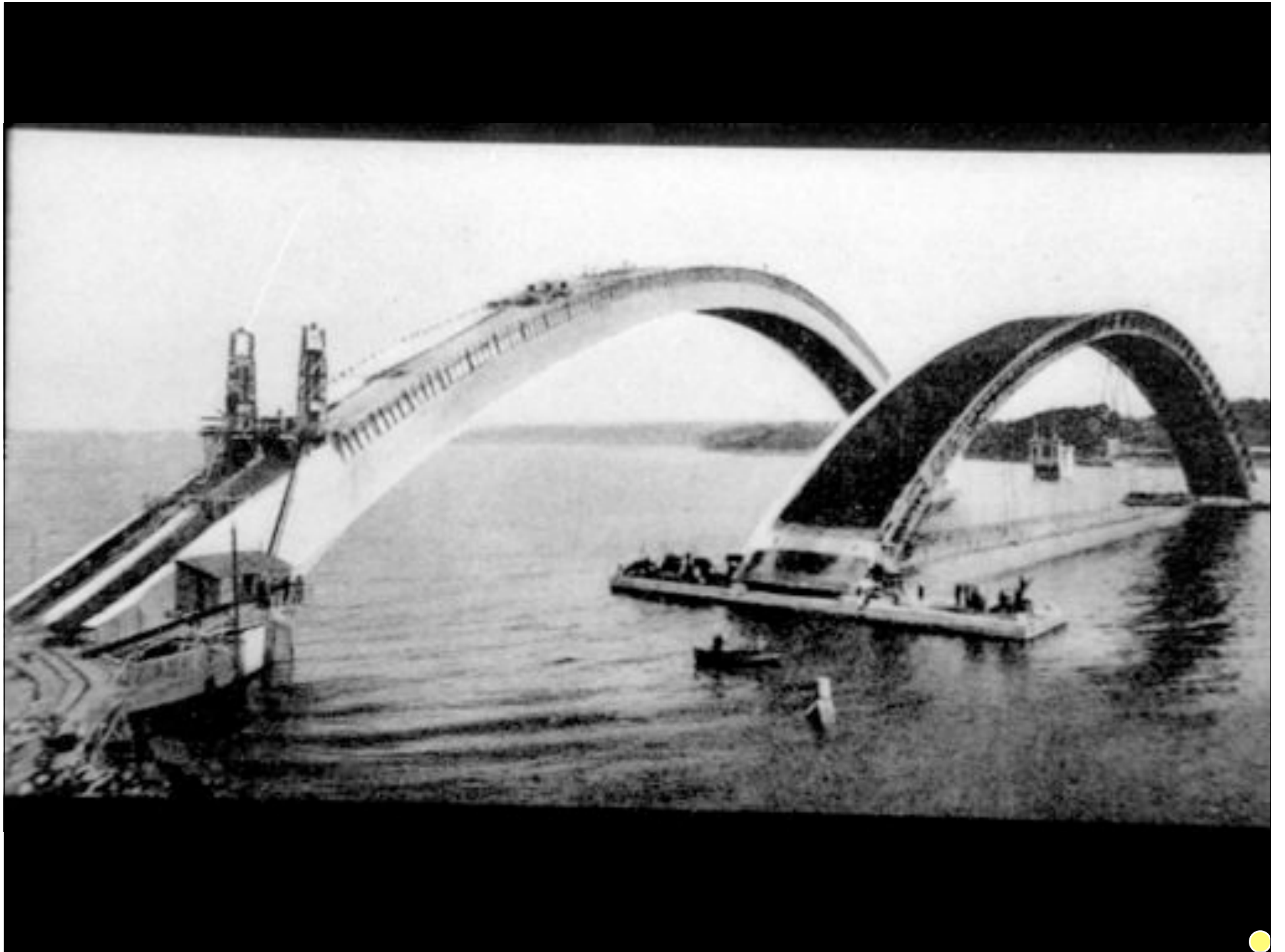


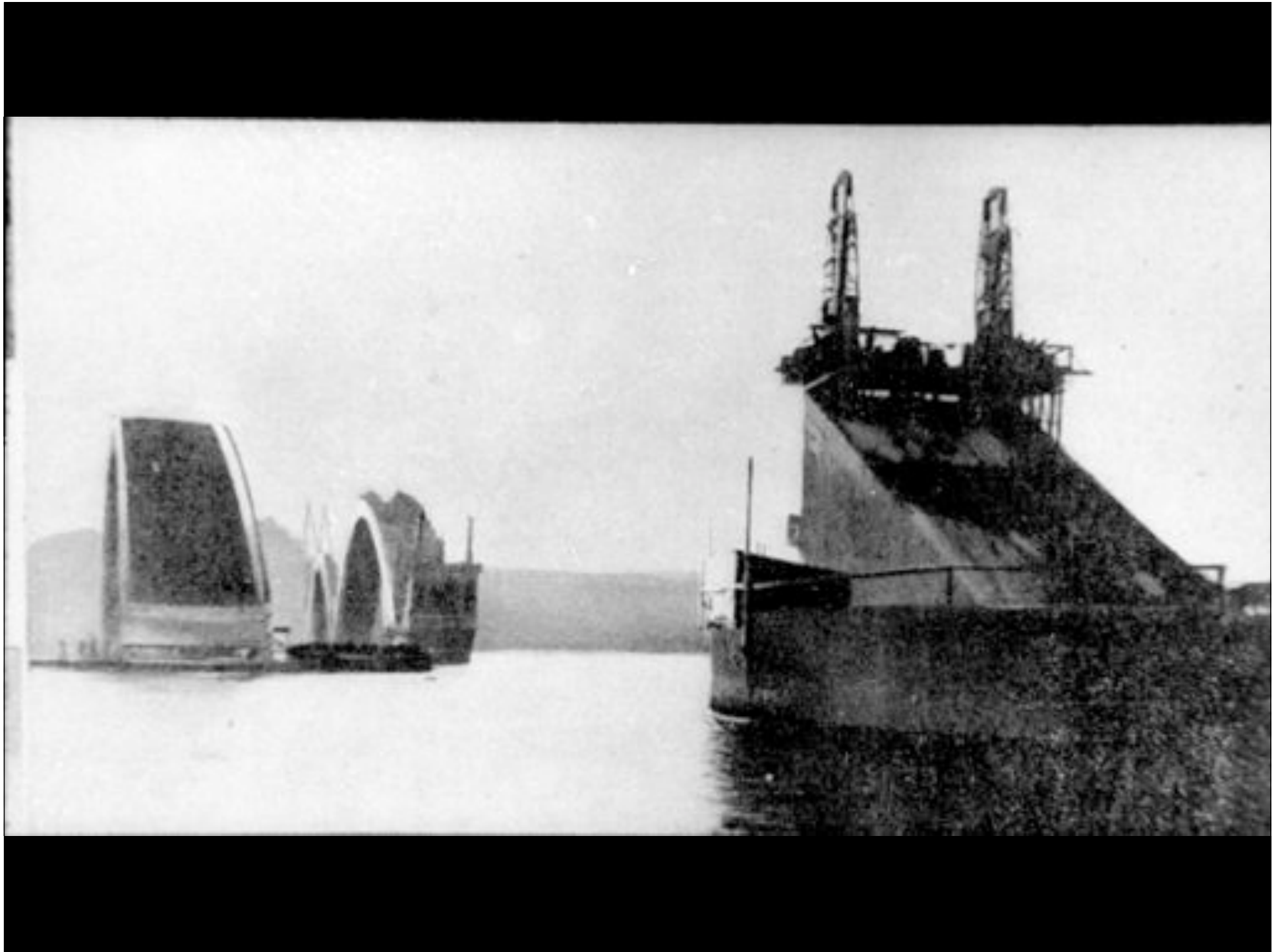
A HANGAR (FREYSSINET & LIMOUSIN)

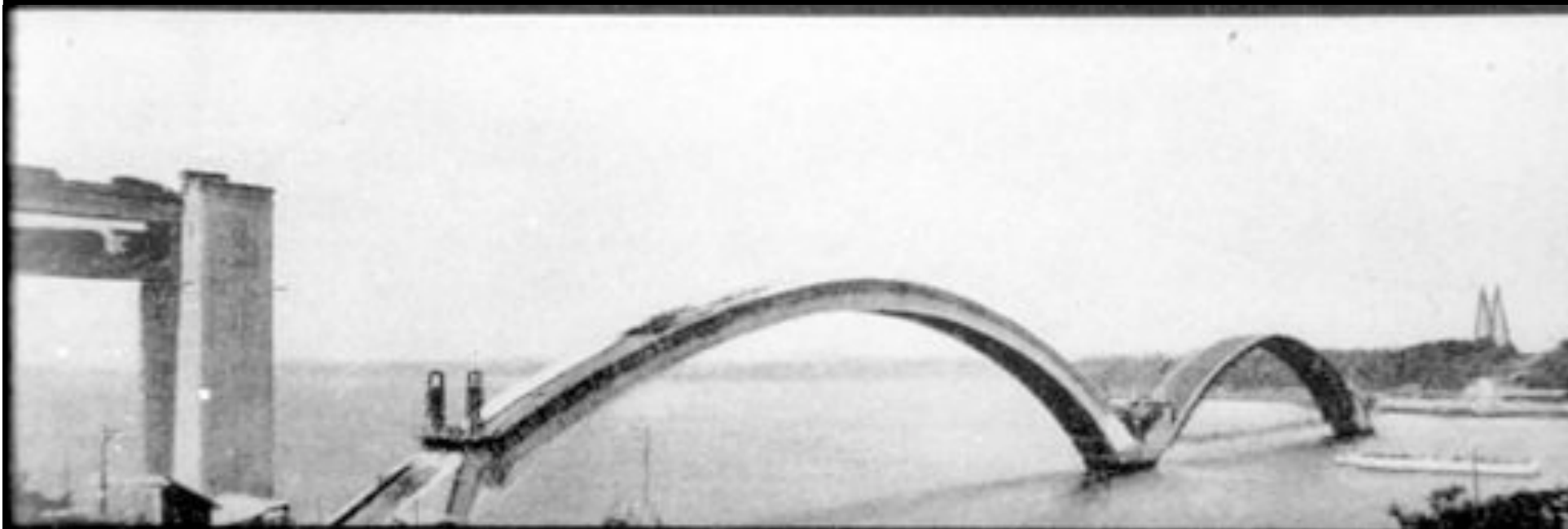
*Width 250 feet, height 150 feet, length over 900 feet. The Nave of Notre Dame is 40 feet wide and about 107 feet in height.*

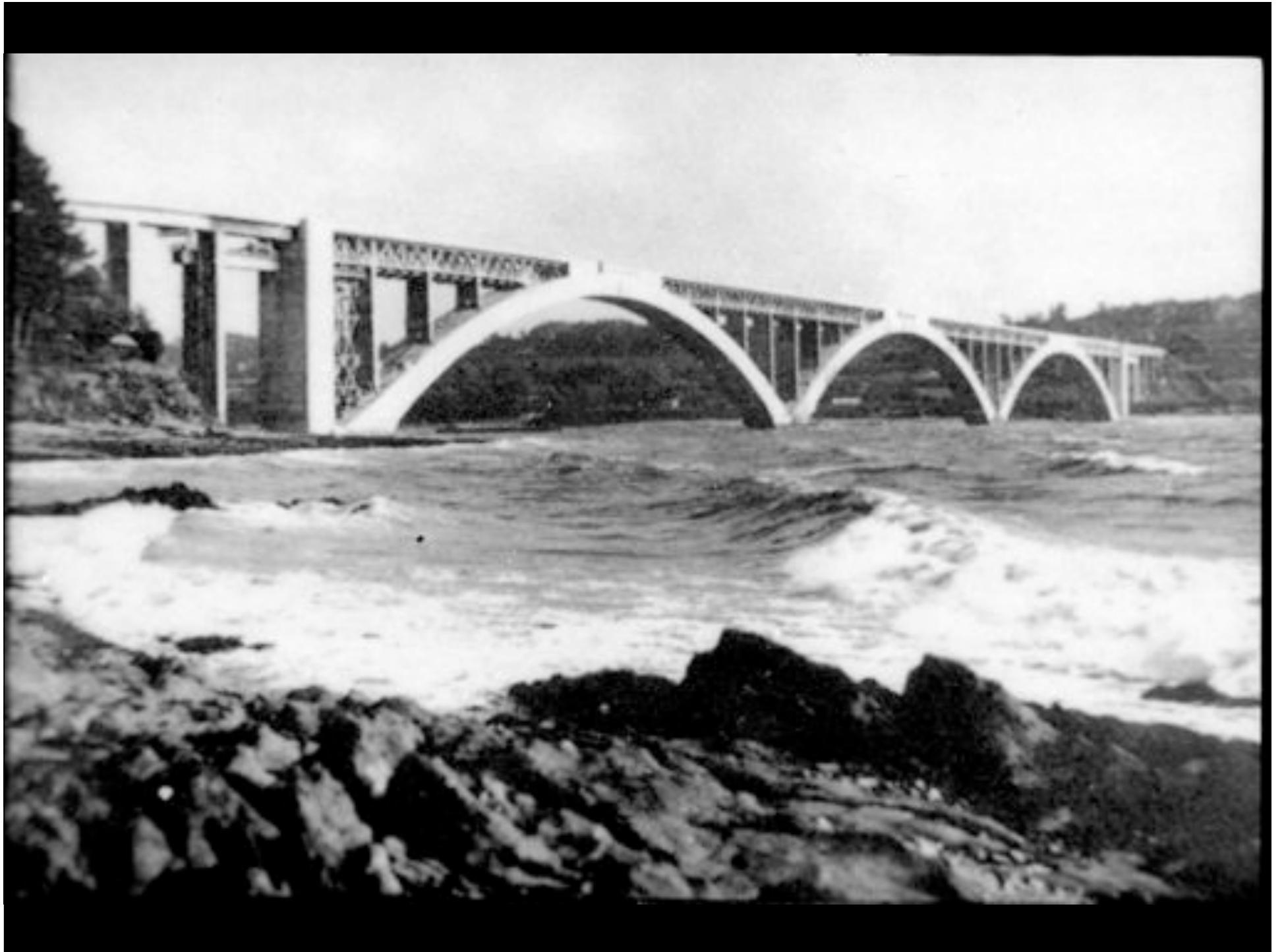


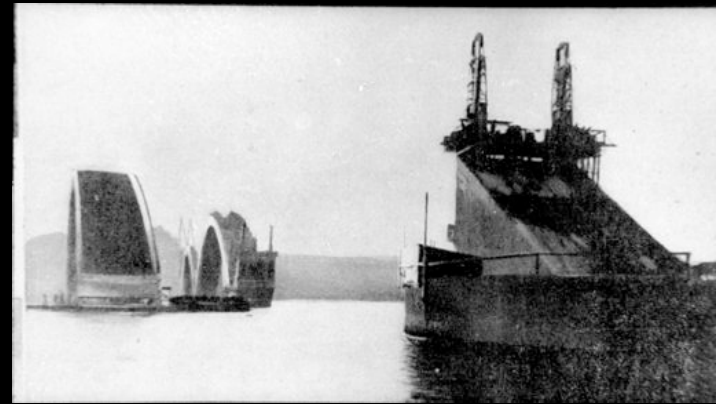
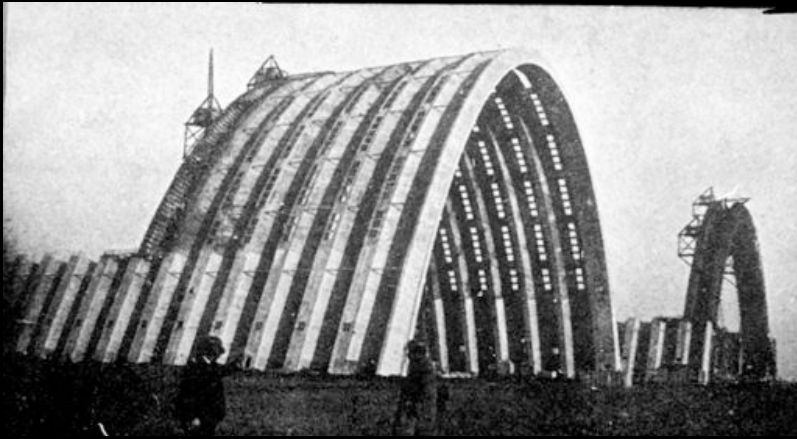
Plougastel (1930)





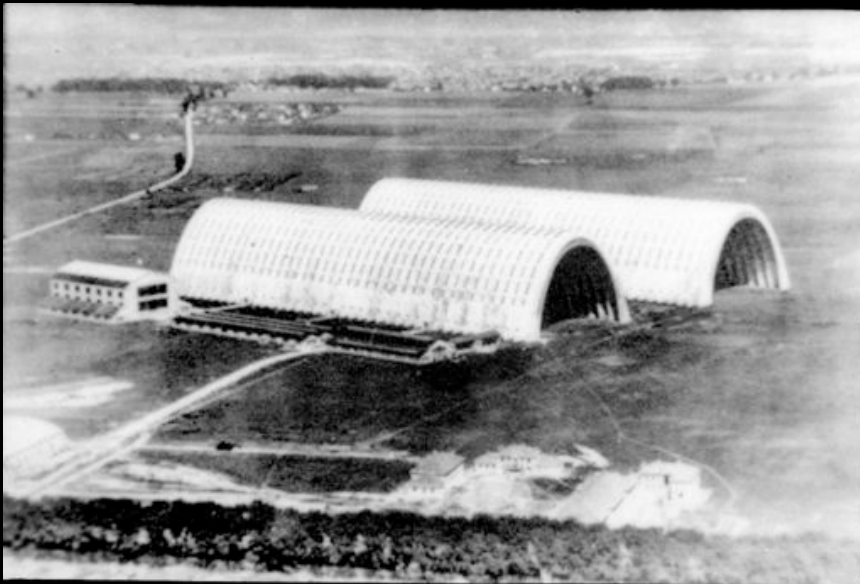




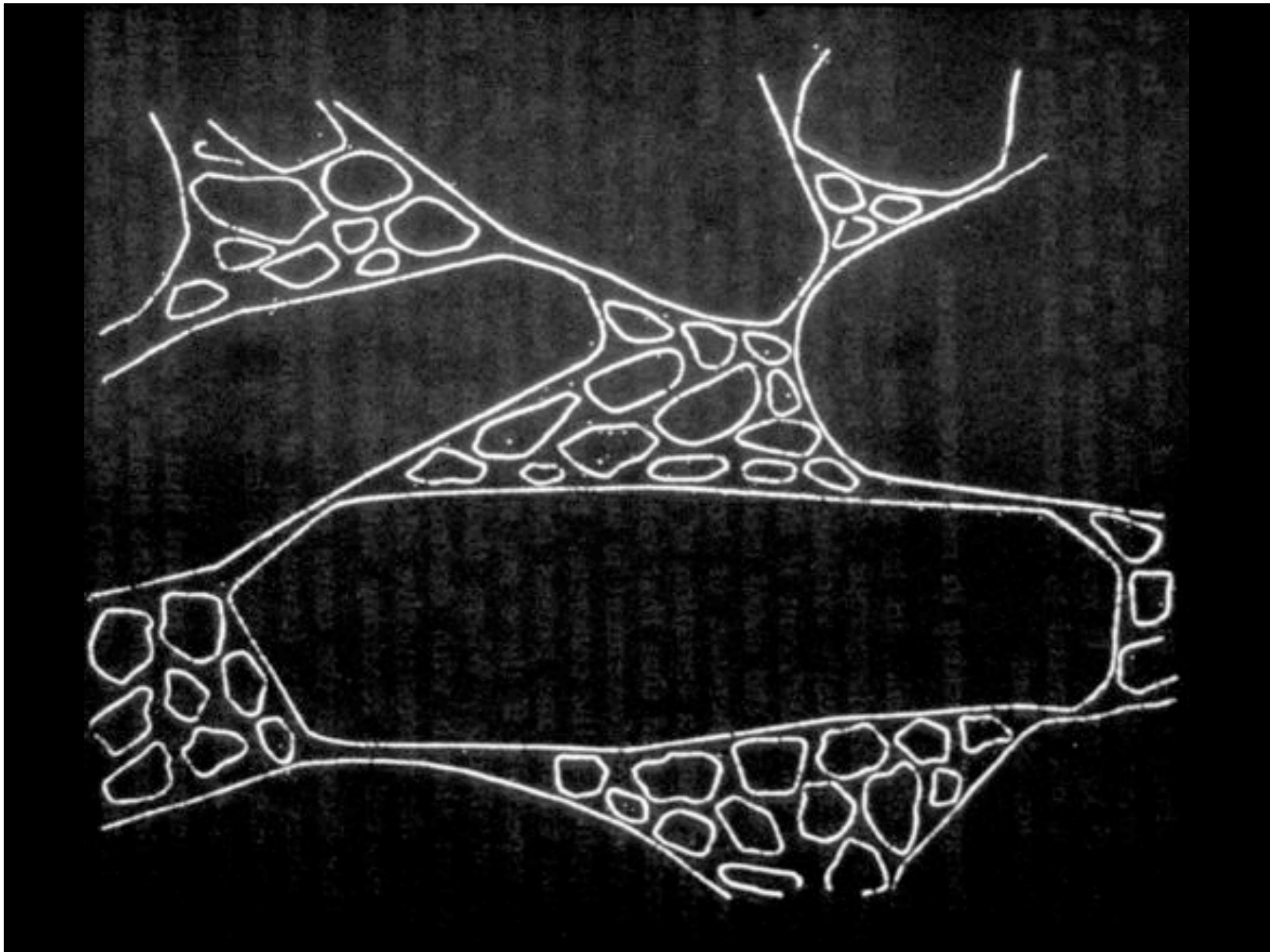


Q: Does elegance in construction matter?

Q: How *does* construction fit into the concept of structural art?

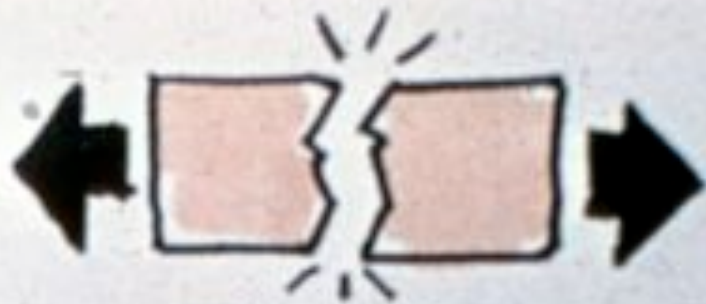




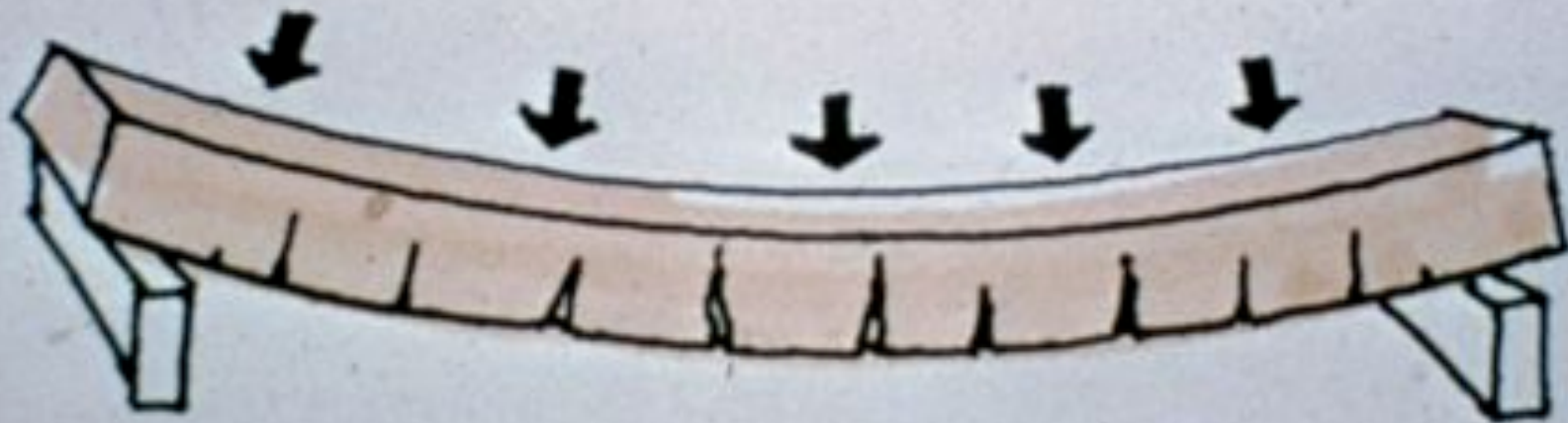




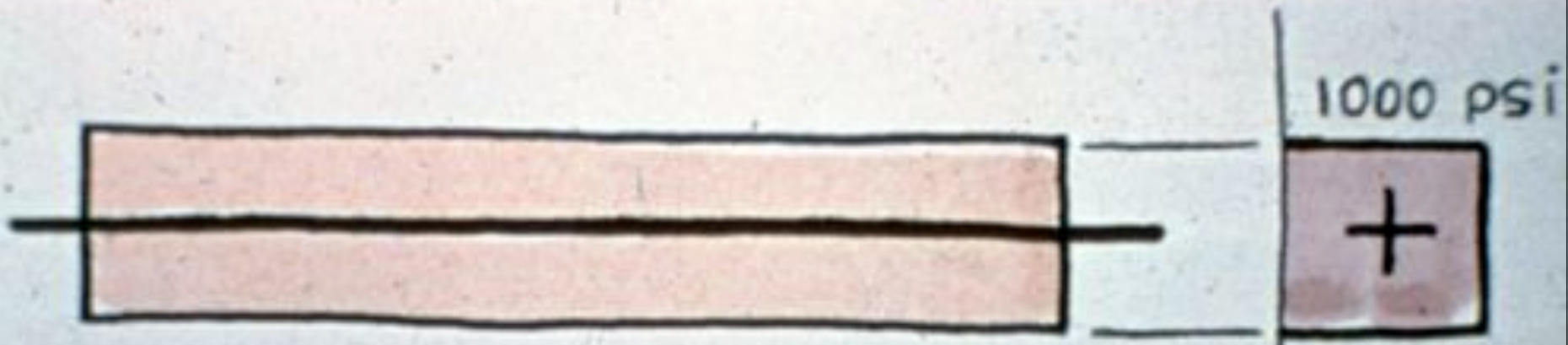
COMPRESSION

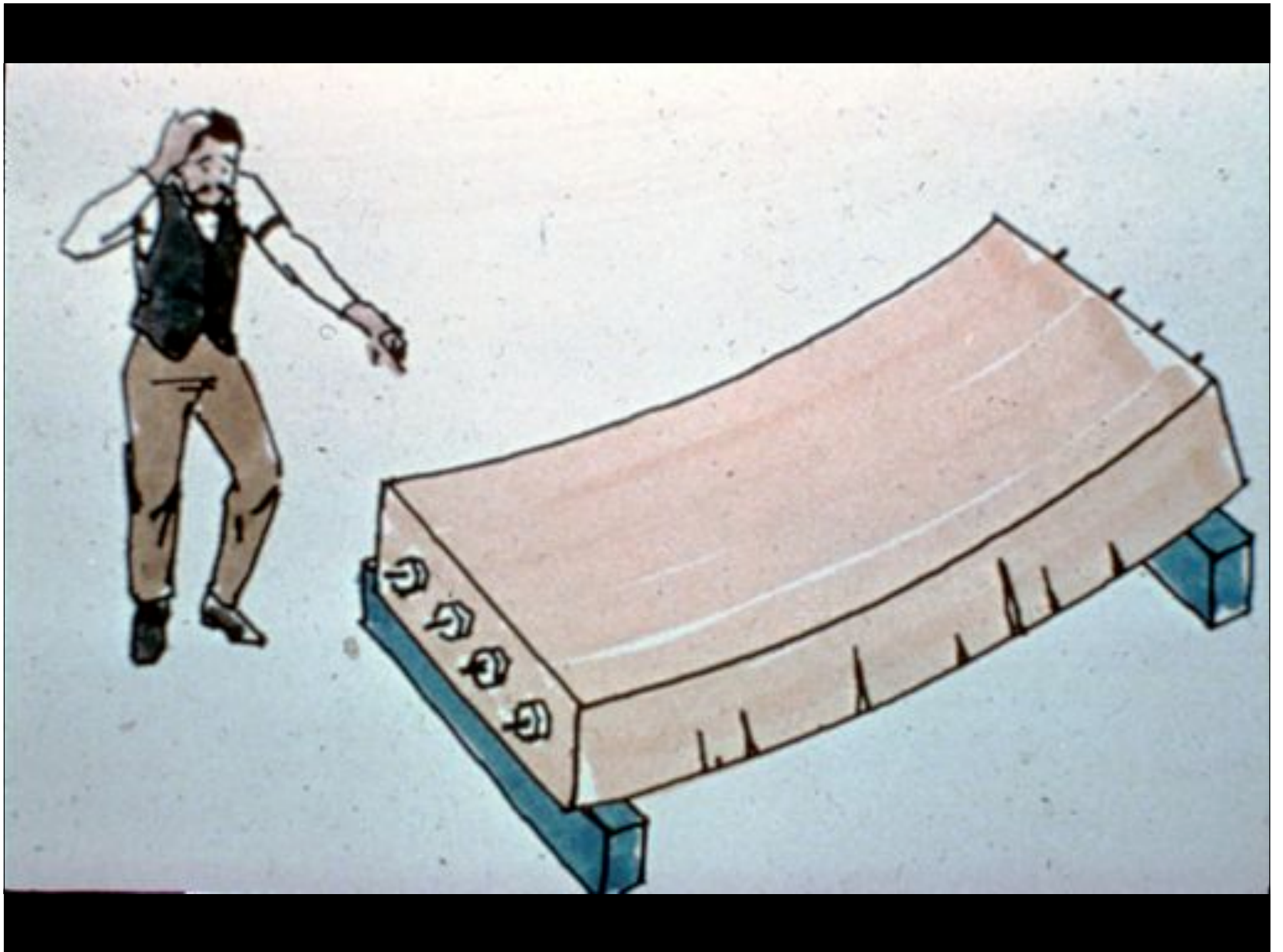


TENSION

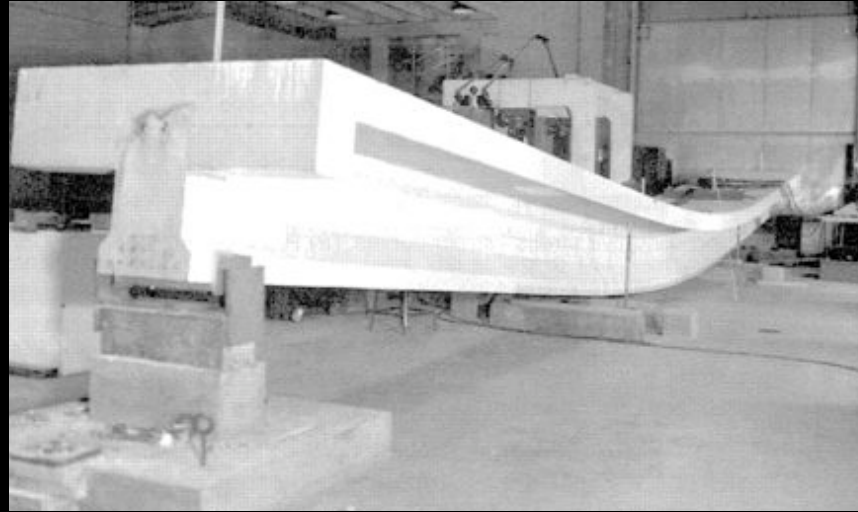


REINFORCED CONCRETE BEAM





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)

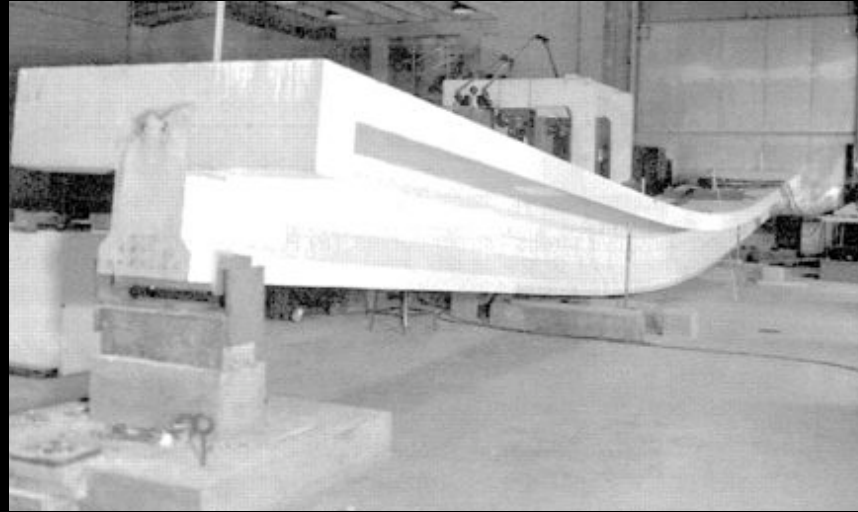
Relaxation       3,800 psi (26 MPa)

**Total**

fill in total here!

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

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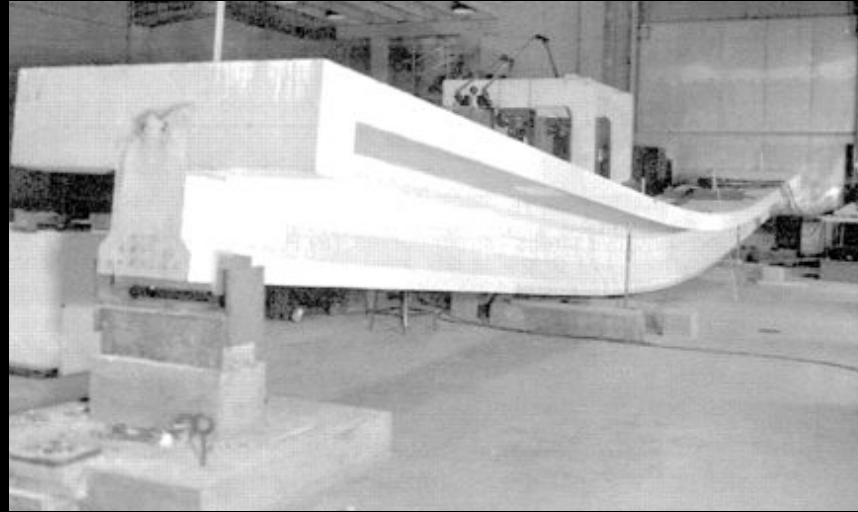
**Total            40,100 psi (276 MPa)**

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

% loss??

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

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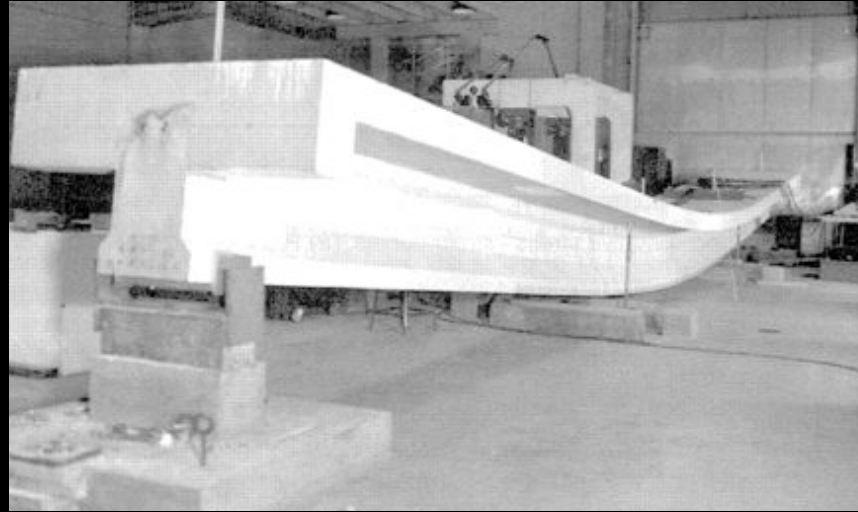
**Total            40,100 psi (276 MPa)**

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

$$40,100/50,000 = 0.8 \rightarrow 80\%$$

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

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Shrinkage       12,100 psi (83 MPa)

Relaxation       3,800 psi (26 MPa)

**Total            40,100 psi (276 MPa)**

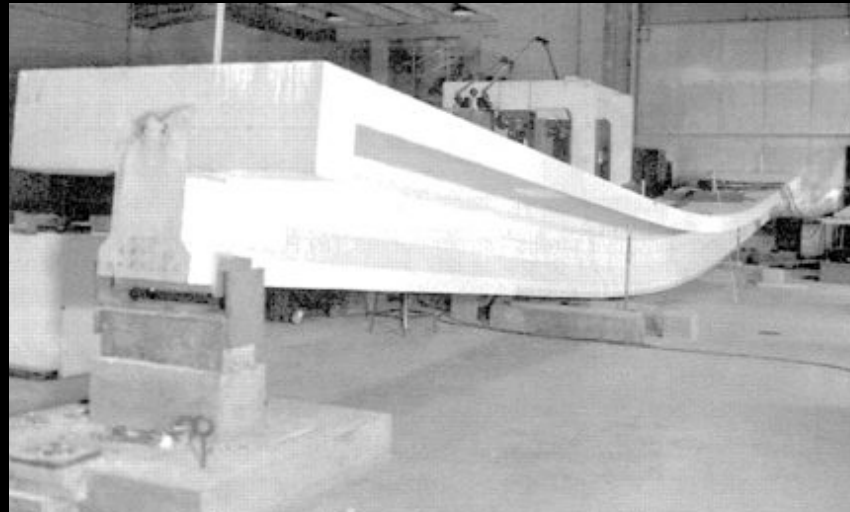
If I use steel strands, thank you Roebbing, I have 250,000 psi steel, now?

% loss??

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



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



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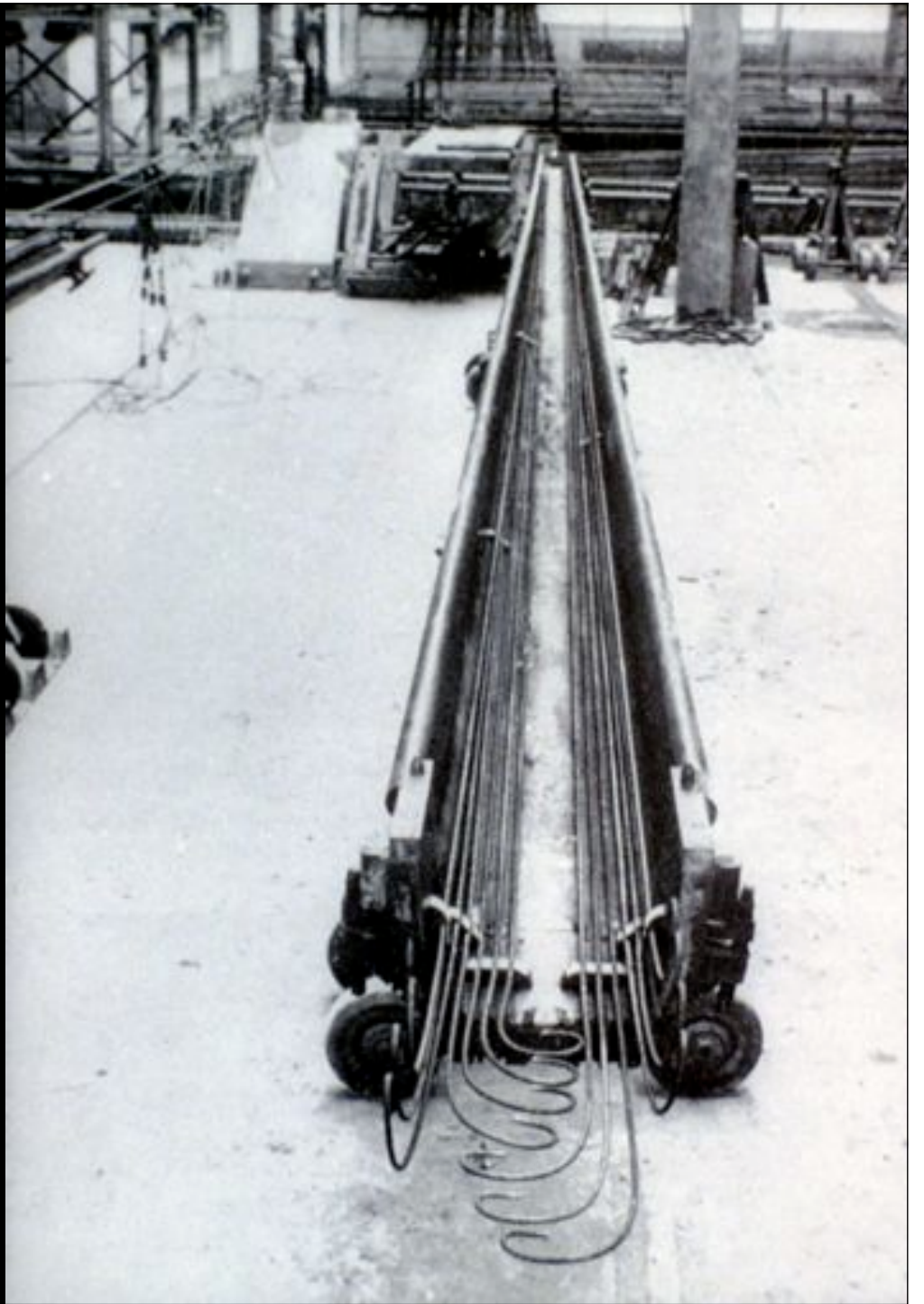
**Total            40,100 psi (276 MPa)**

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

$$40,100/250,000 = 0.16 \rightarrow 16\%$$

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







Luzancy Br. (1946)



[www.structurae.de](http://www.structurae.de)  
Pont de Luzancy.  
Photo by Jacques Mossot



[www.structurae.de](http://www.structurae.de)

Pont Saint-Michel, Toulouse.

Photo by Jacques Mossot



Similar to DC's 2006  
Woodrow Wilson Bridge?





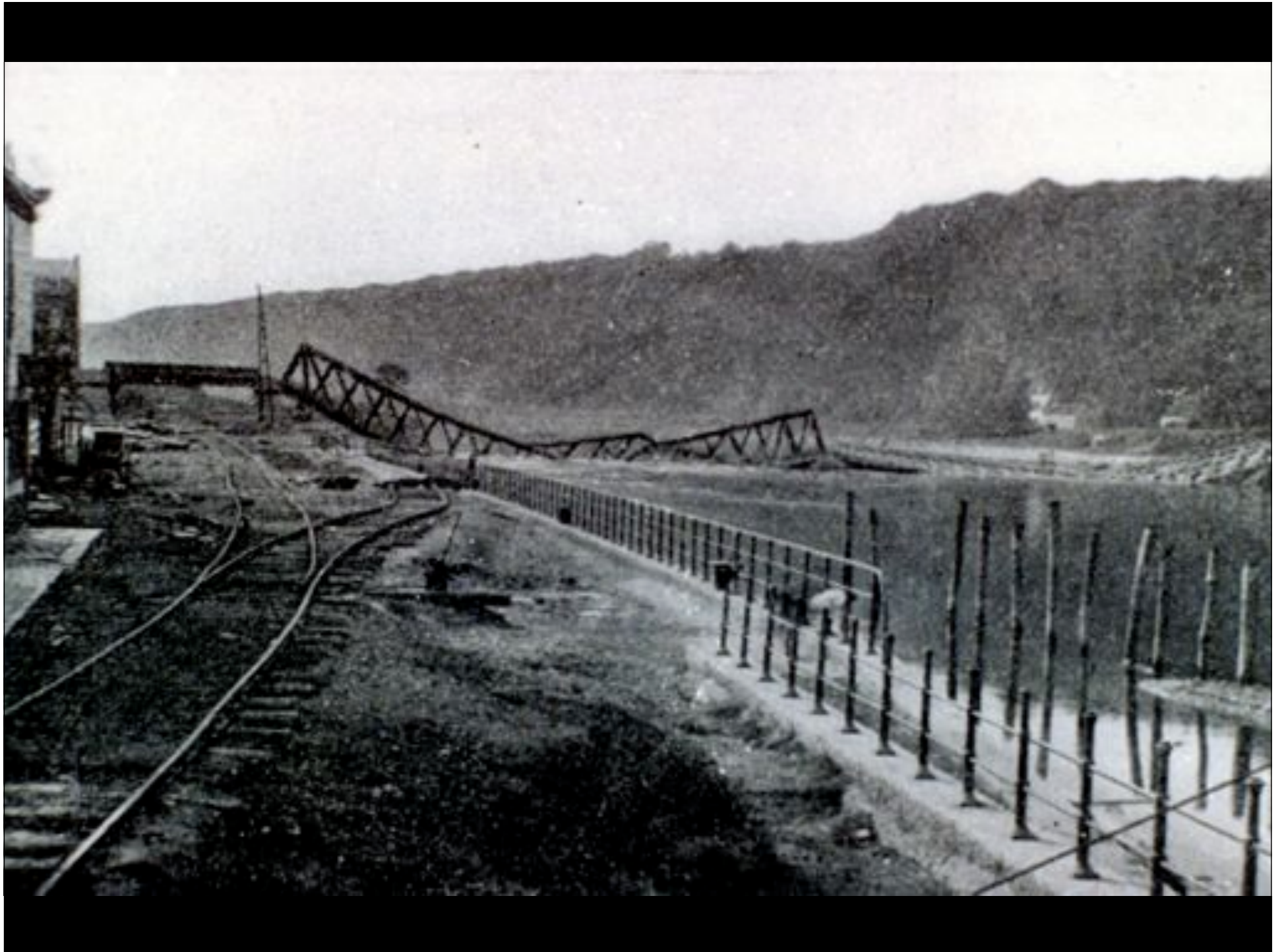




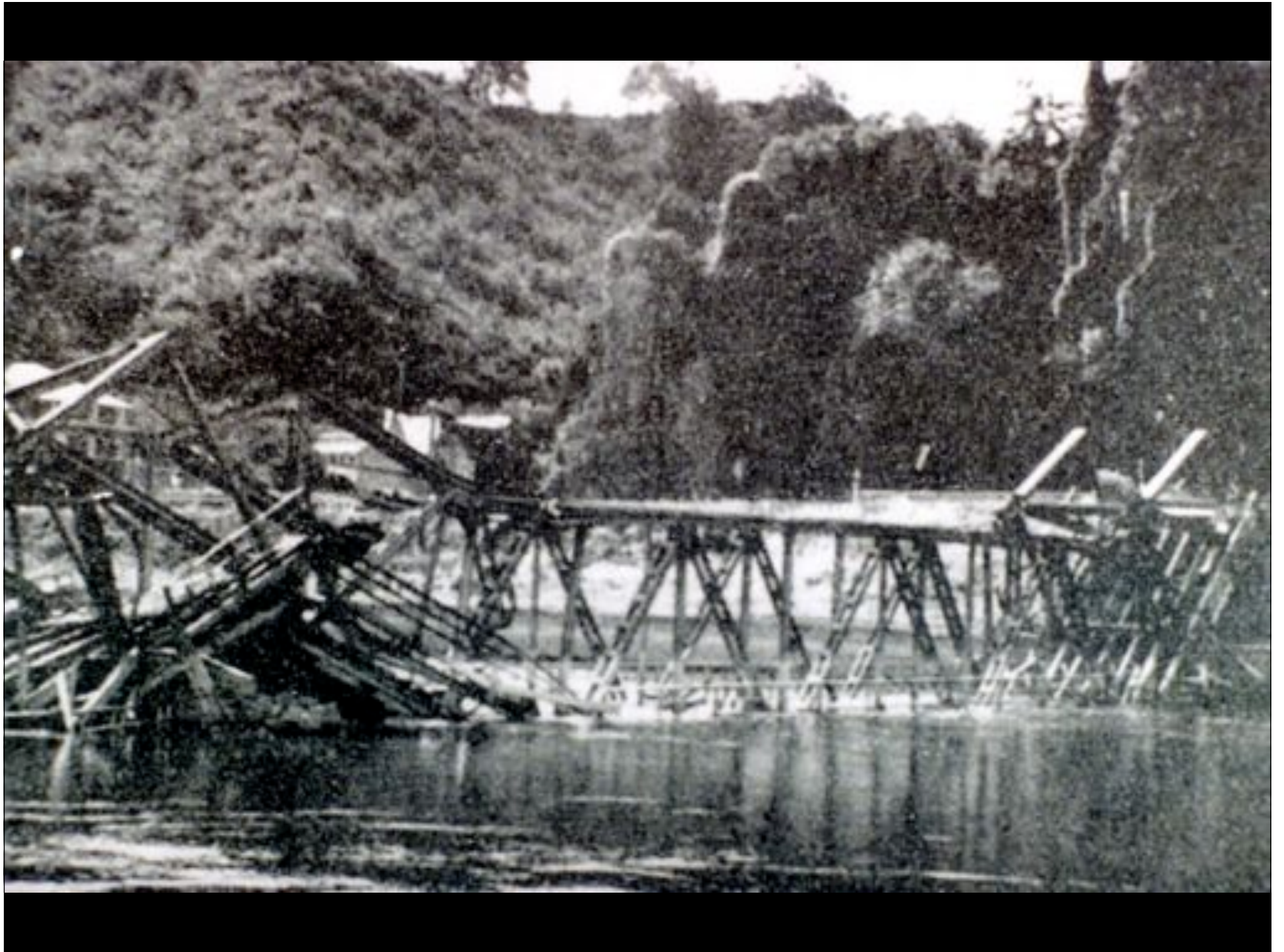
Gustave Magnel











№3с.



№4



№5.



№6.



ELEVATION - VUE D'AMONT

BOITE DE SOLAIE  
PLANCHE C



COUPE LONGITUDINALE



PLAN

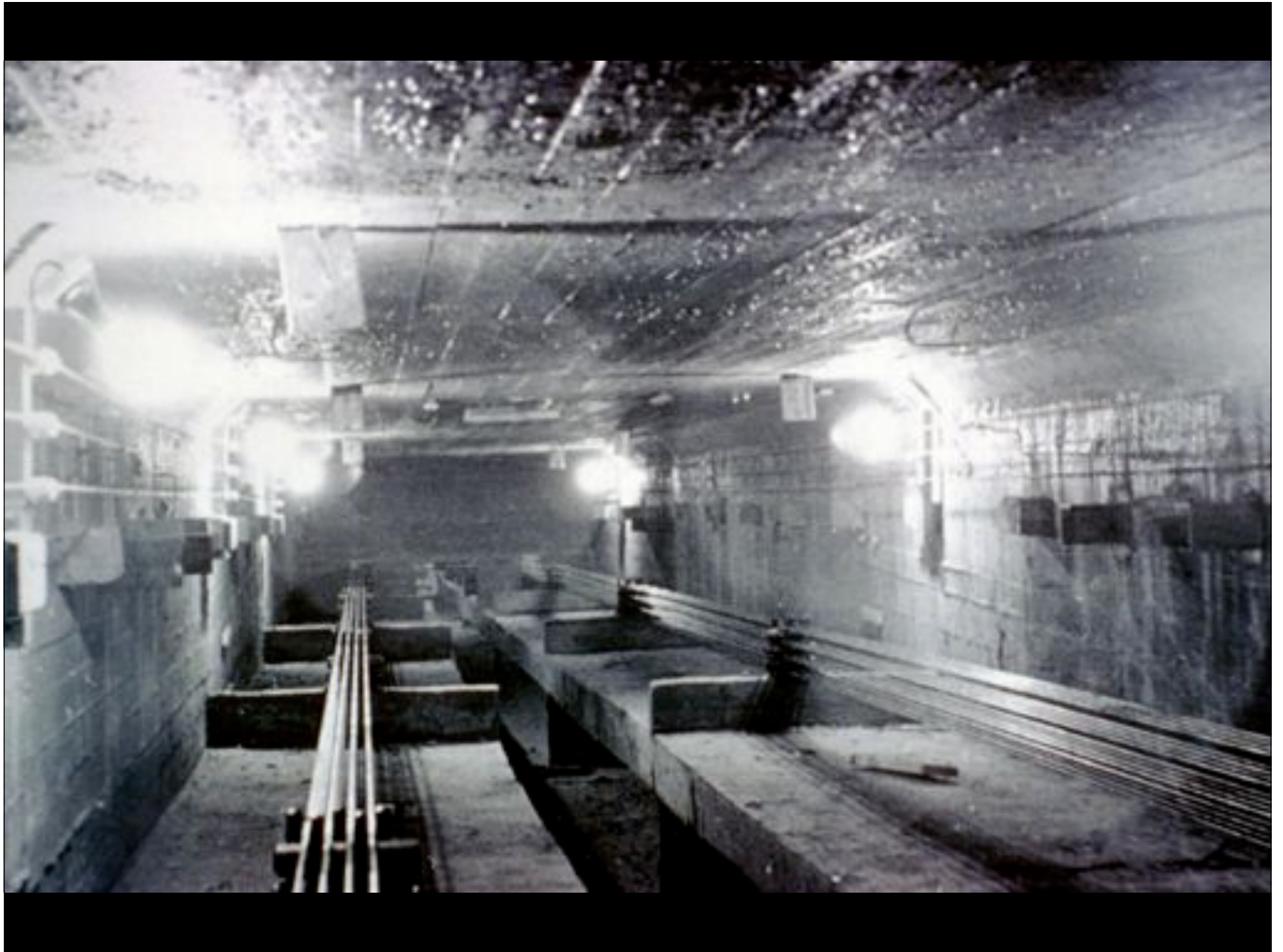


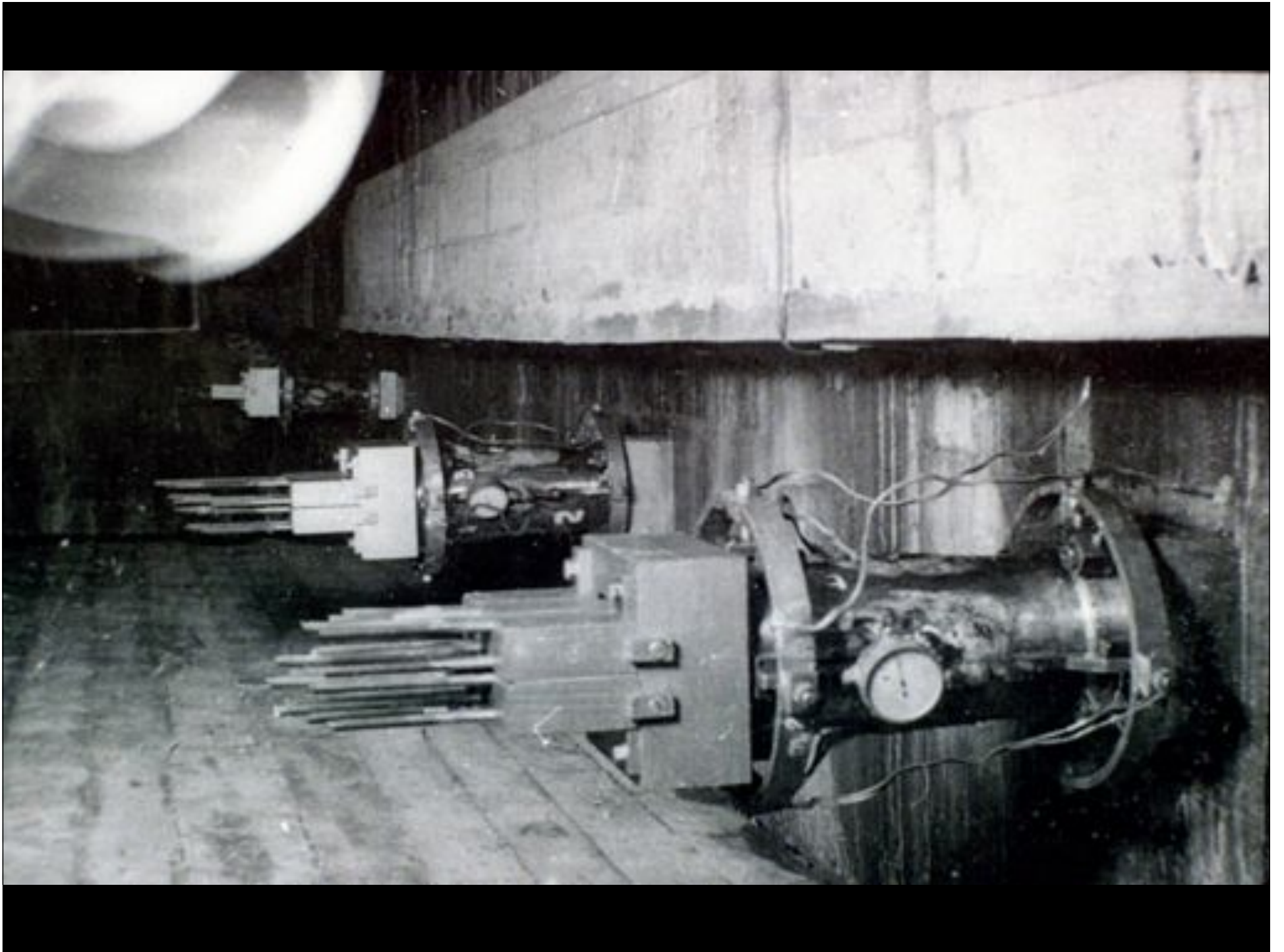




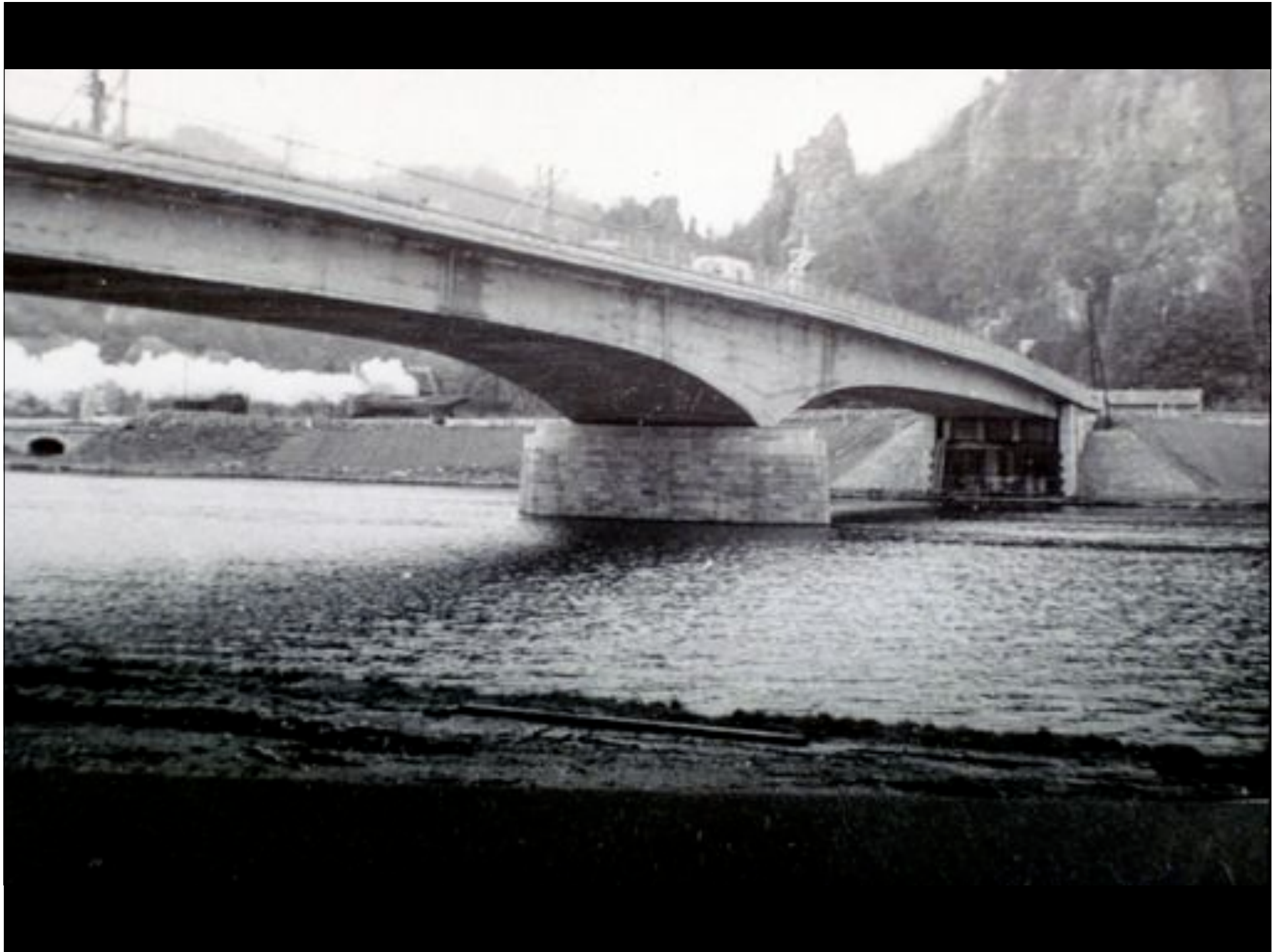
Sclayn

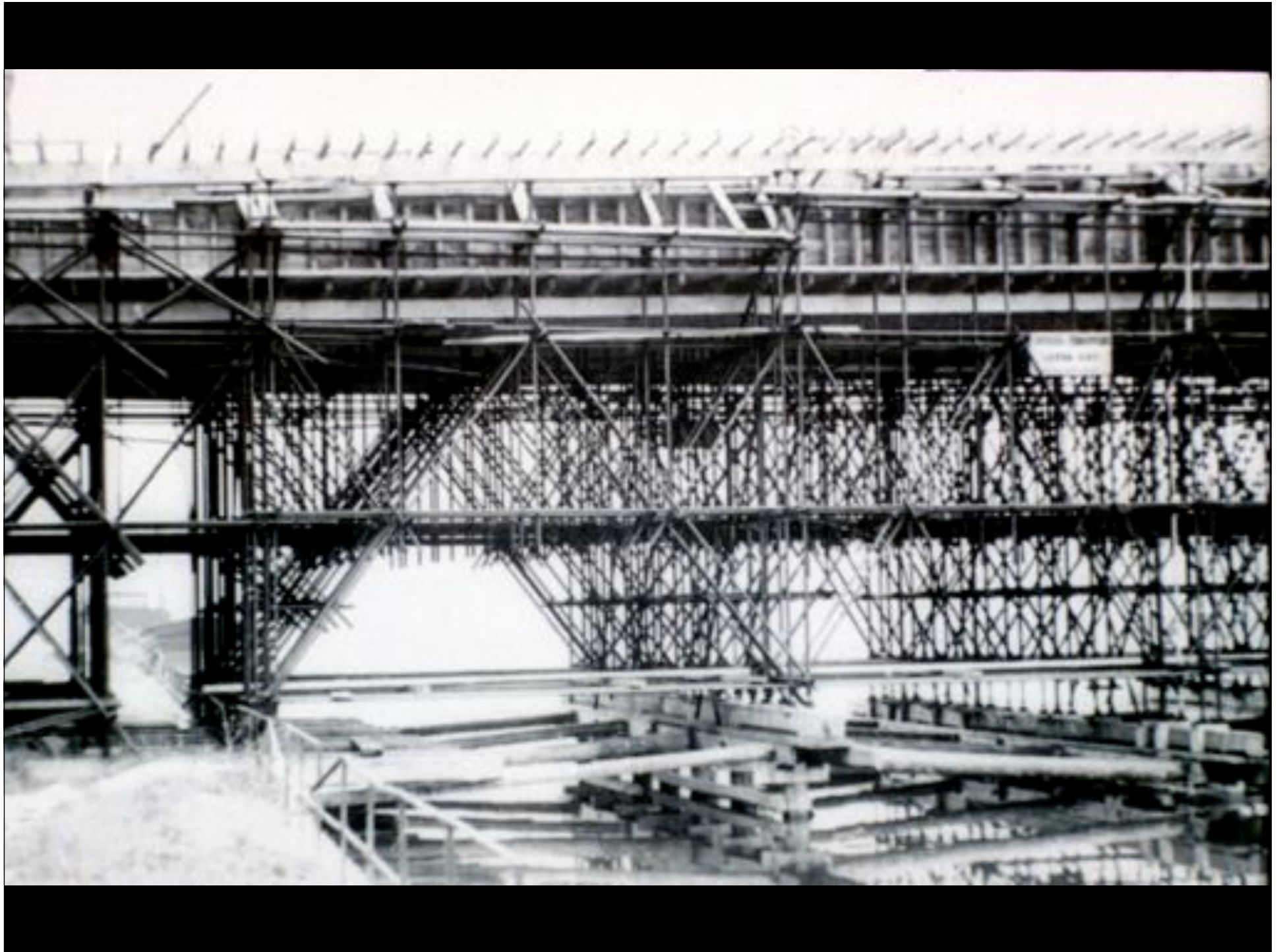


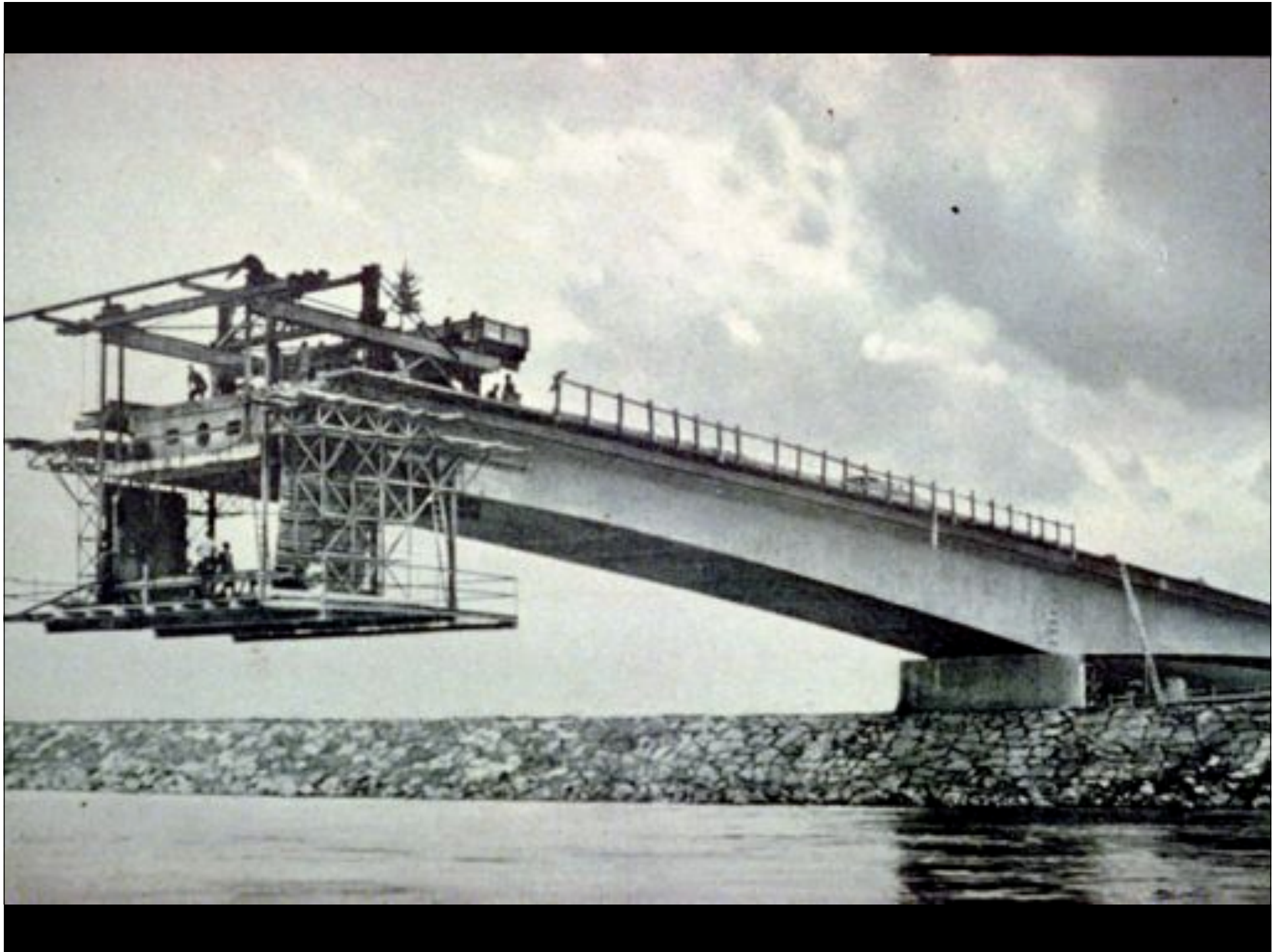




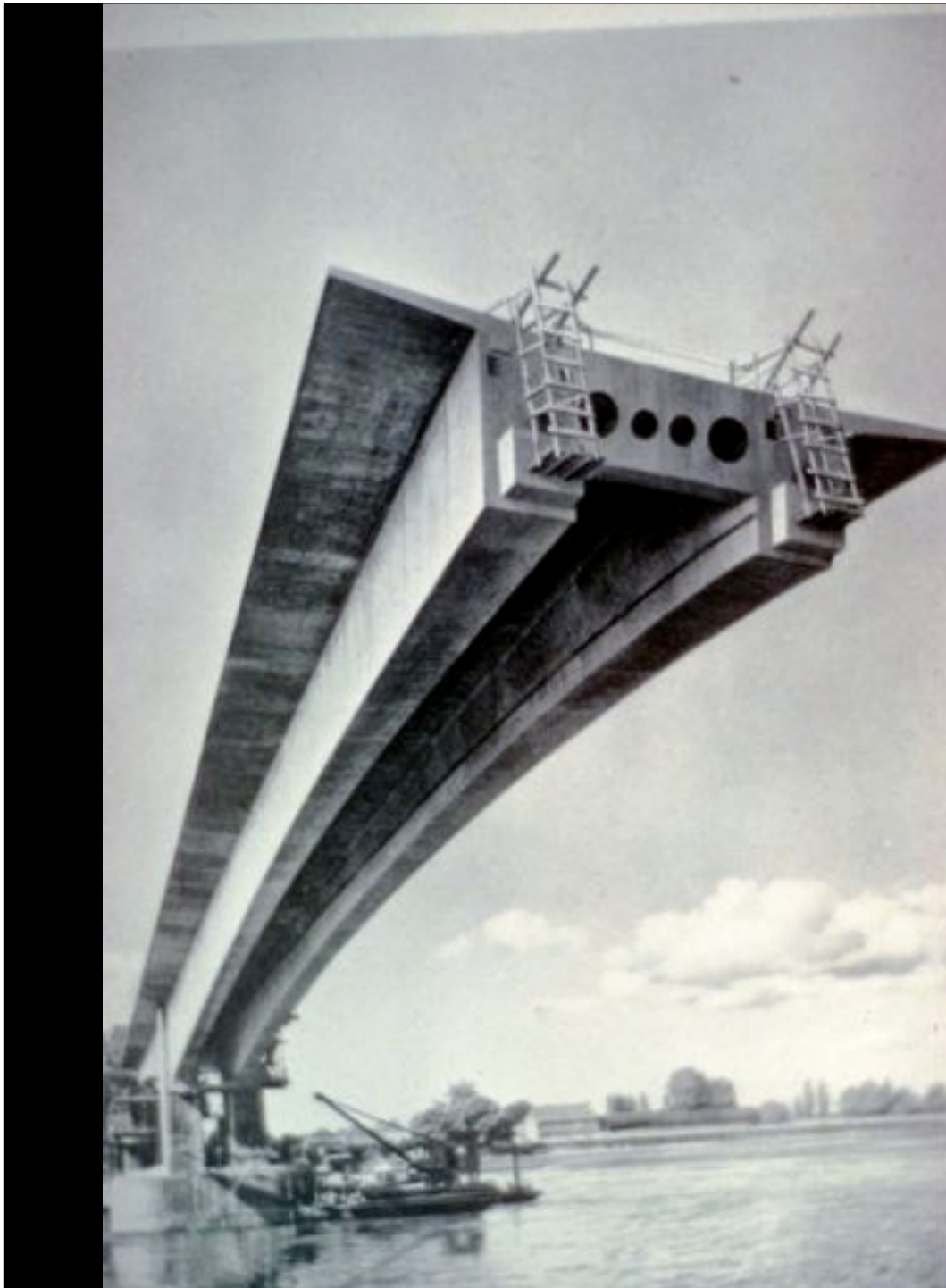






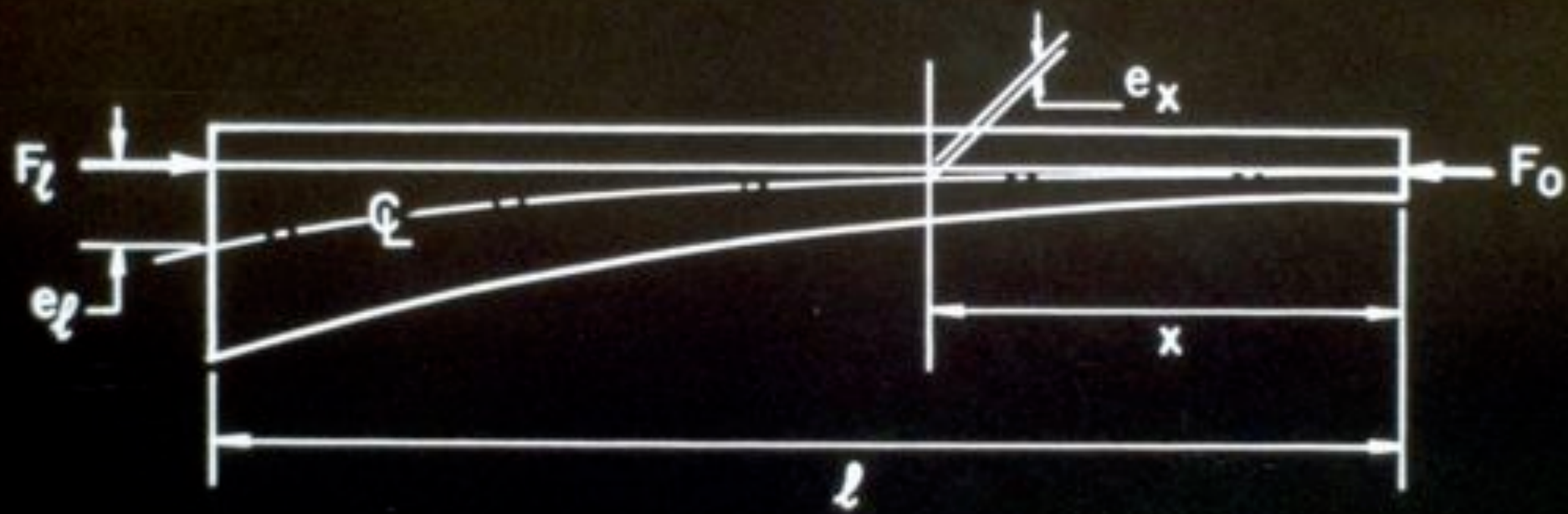




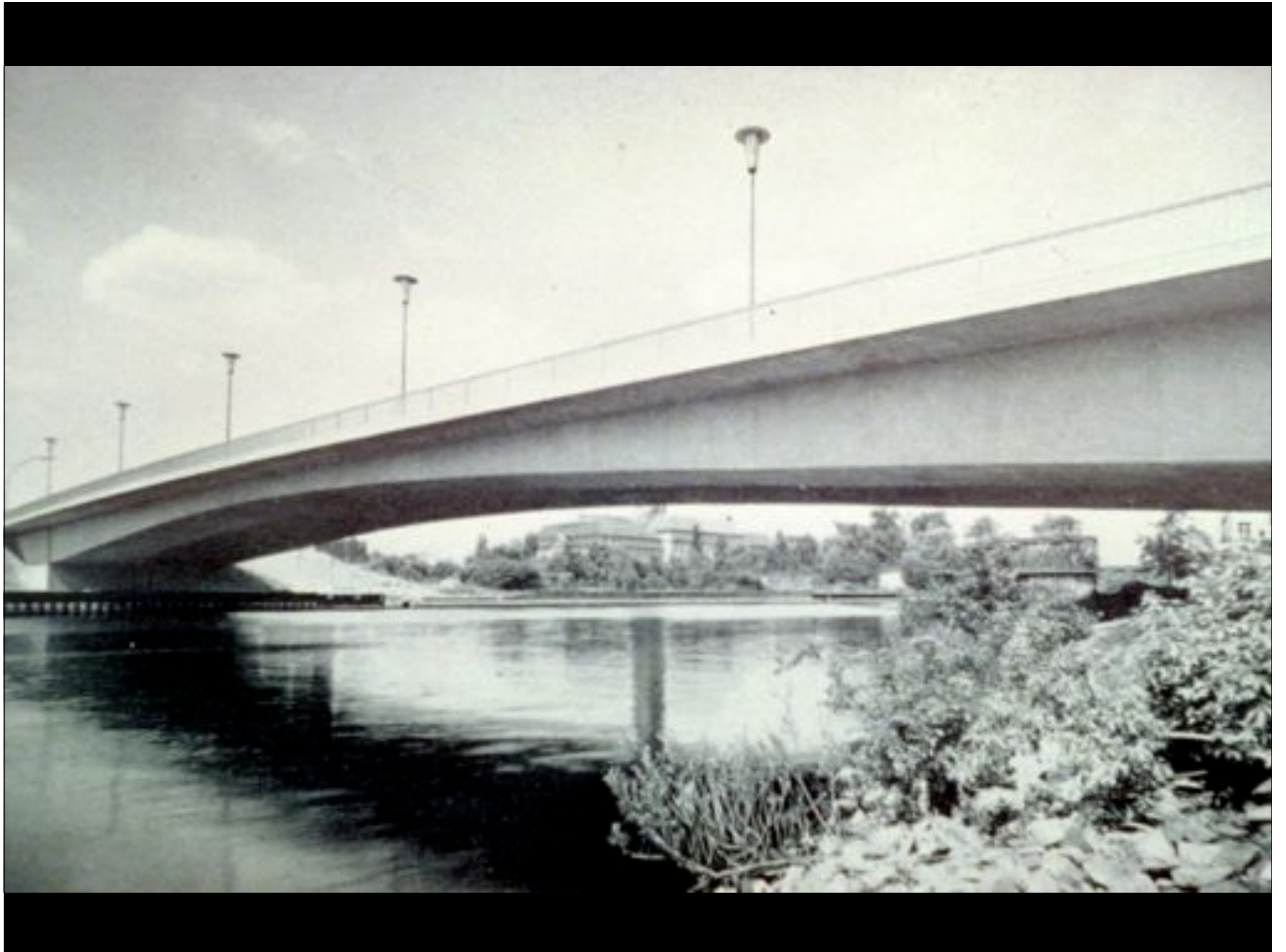


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Ulrich Finsterwalder



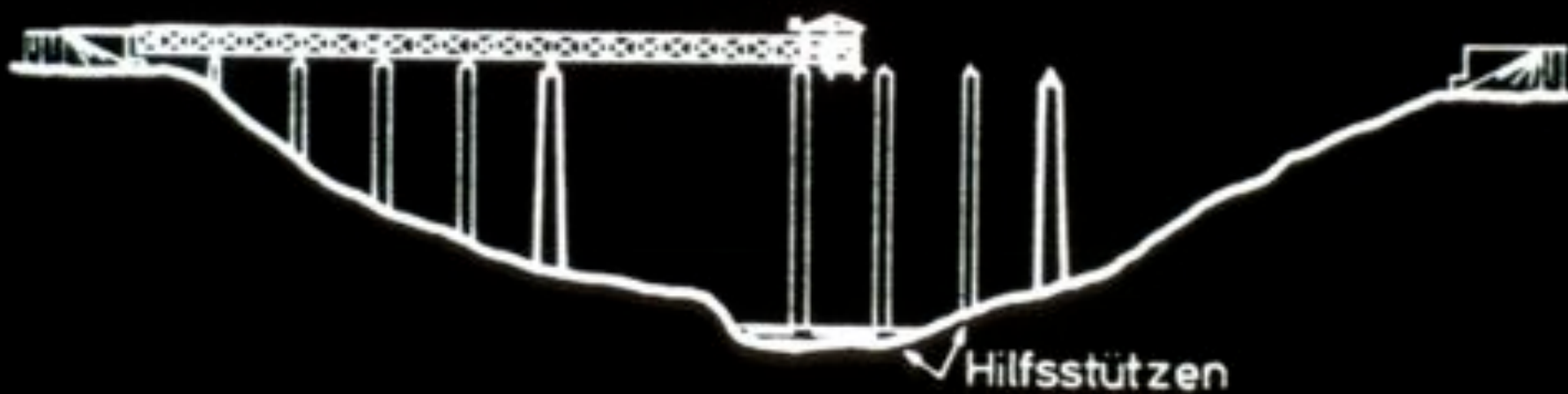






Mangfall

































# Power of prestressing:

effectiveness  
of prestress

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

beam size

material  
strength













[www.structurae.de](http://www.structurae.de)

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?

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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)

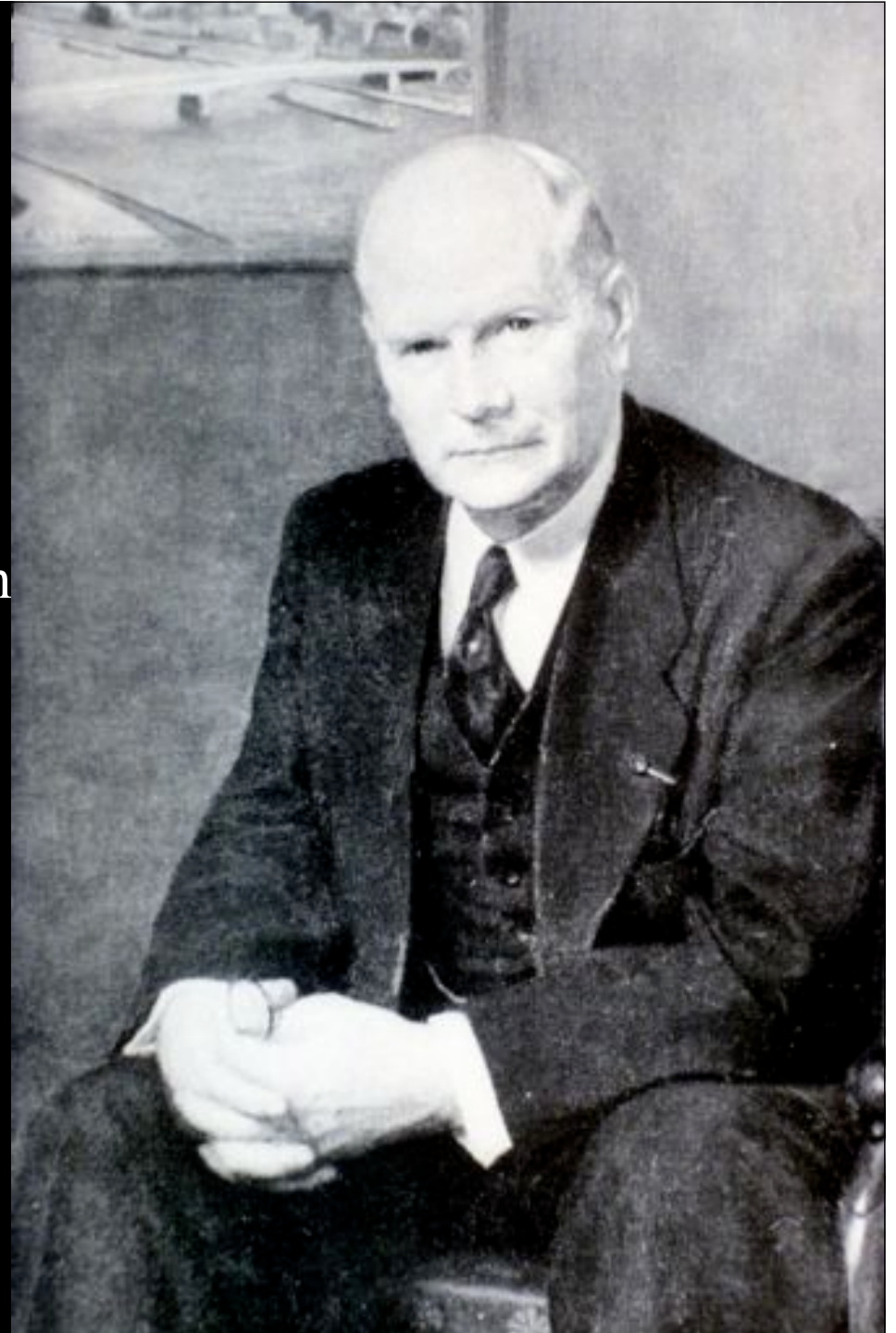




FIG. 4

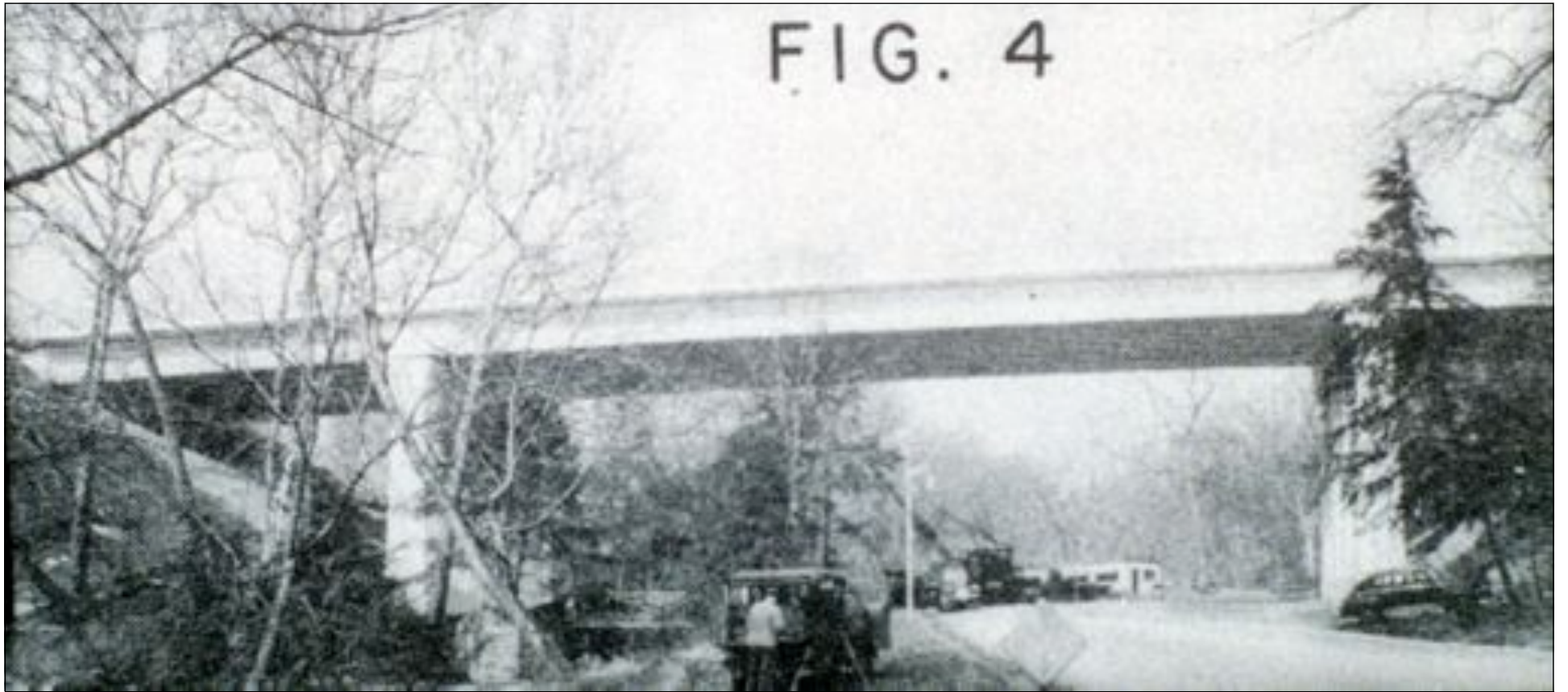
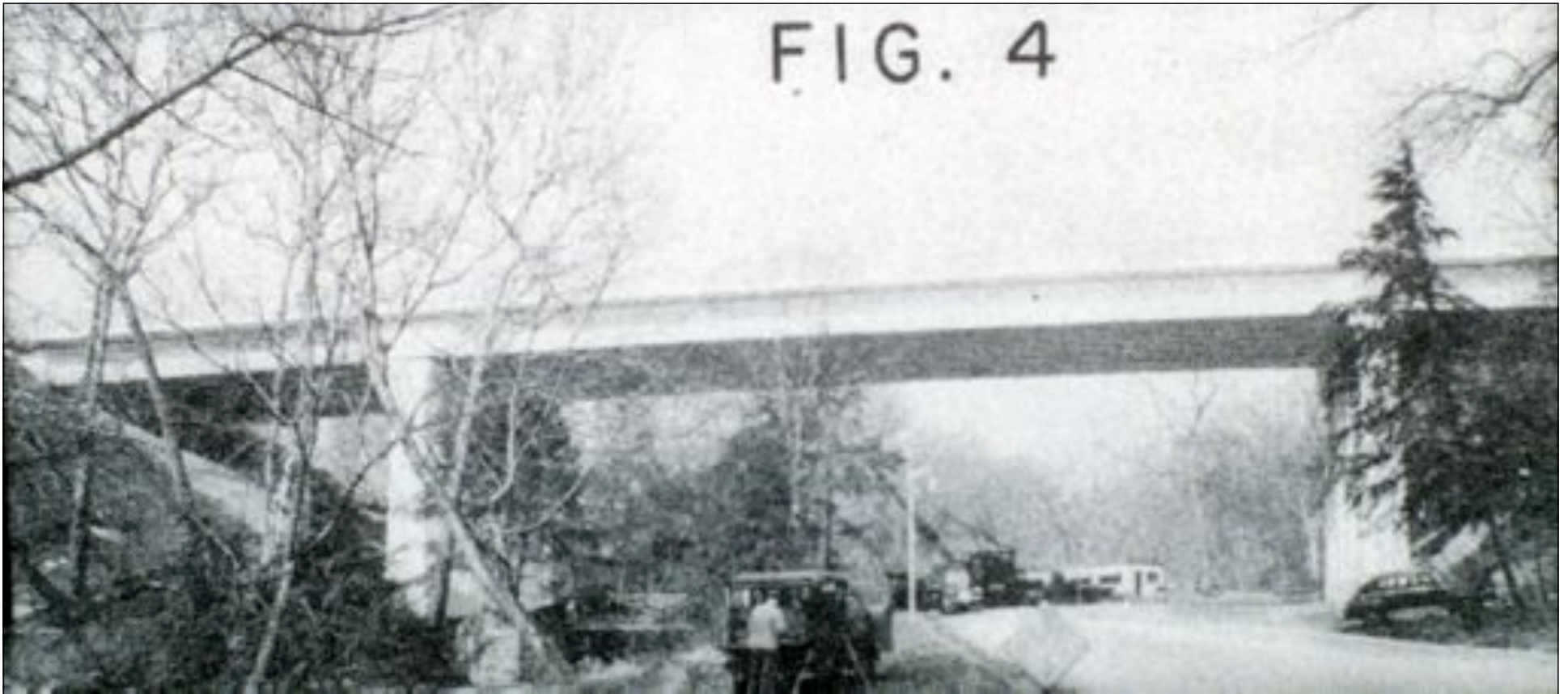


FIG. 4



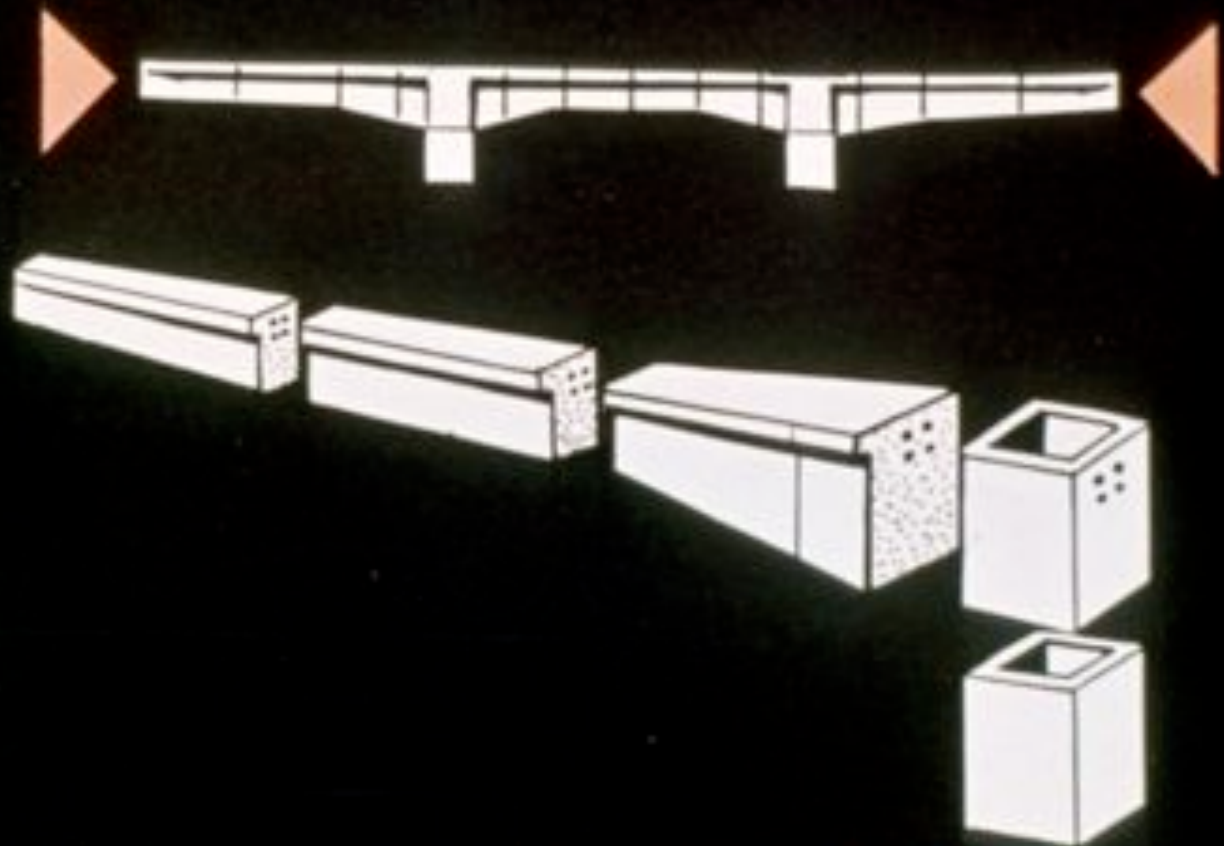
shape the pre-stressing tendon instead of shaping the beam...











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 skimmed 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



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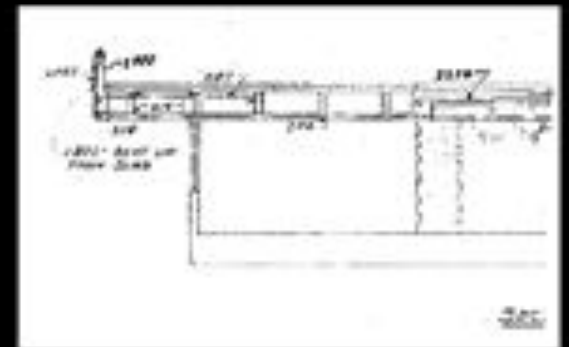


Site Survey



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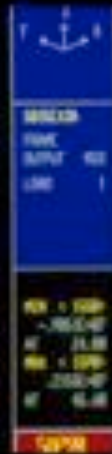
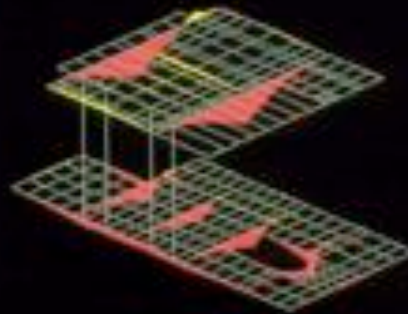
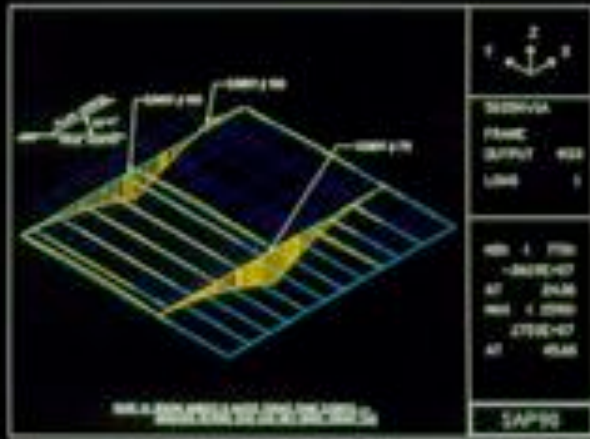
–New York Times



ROBERT SILMAN ASSOCIATES  
STRUCTURAL ENGINEERS  
WASHINGTON DC • NEW YORK

Historic Document Review



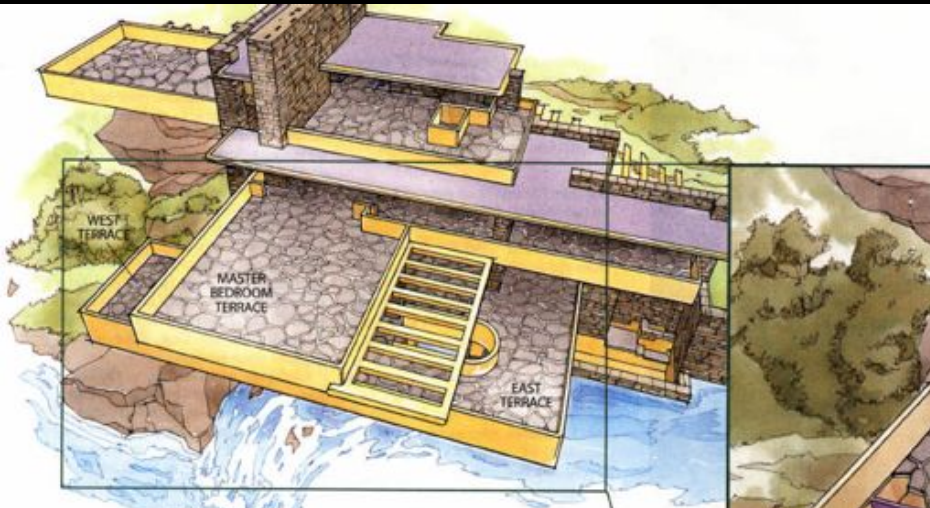


## Multi-Faceted Investigation – Preservation Approach

### Structural Analysis



### Temporary Shoring / Stabilization

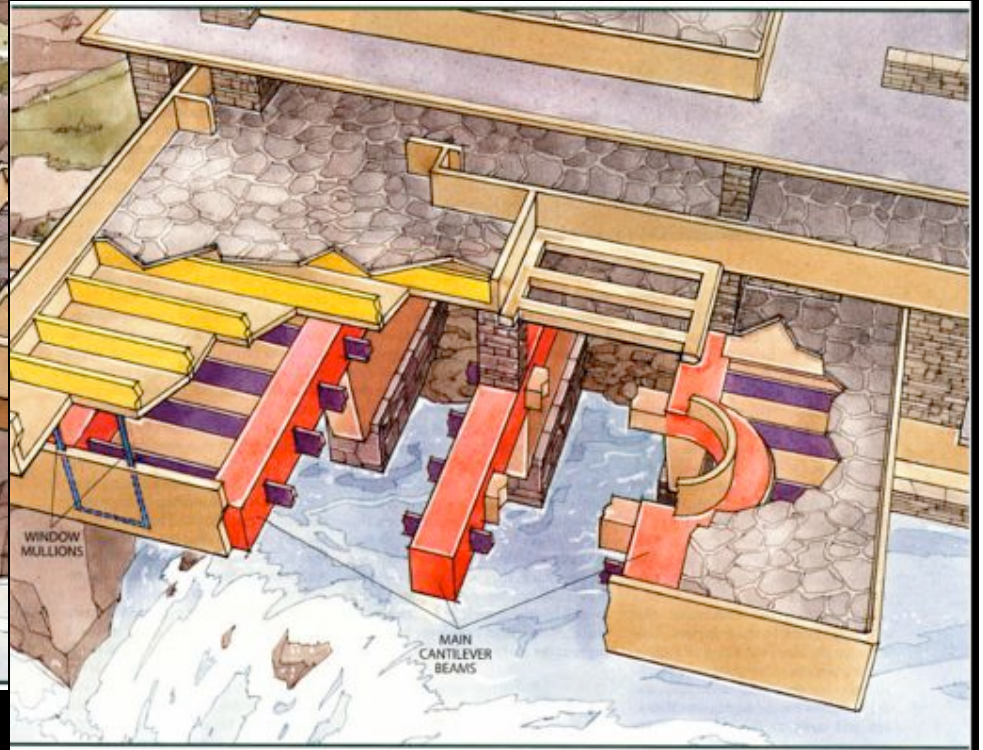


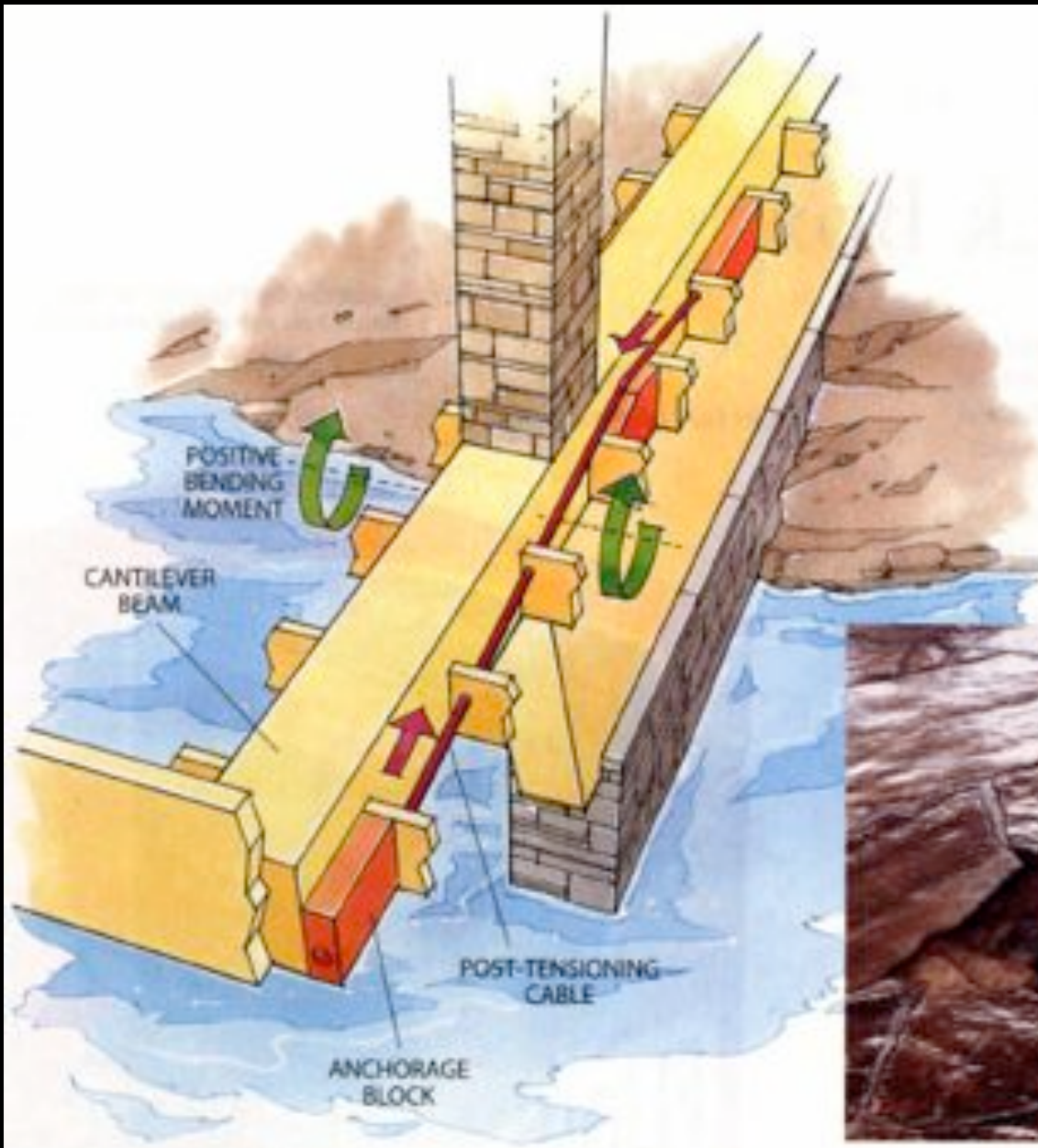
ed his design. Once again he forced Kaufmann, Sr., to choose between him and Merzger-Richardson. Kaufmann, Sr., decided to go ahead with the house as originally planned.

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.

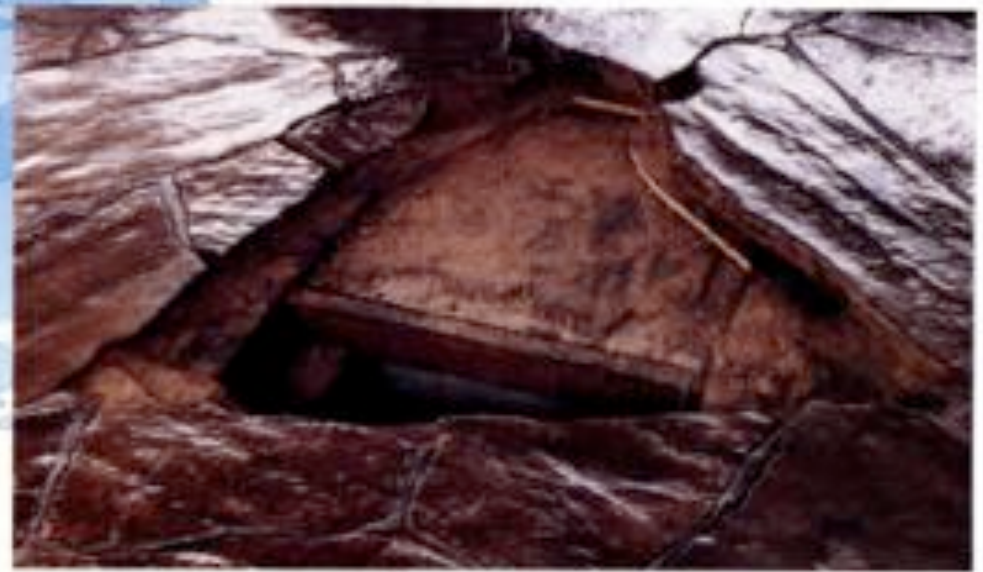
low, because the two floors are structurally interdependent.

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

