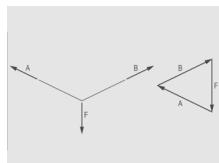


Structural Design I

Philippe Block · Joseph Schwartz

Structural design I+II



2. Equilibrium and graphic static



1. Introduction



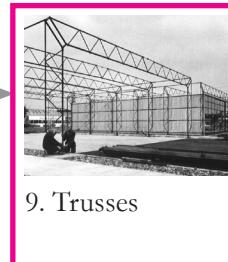
3.+4. Cables



5.+7. Arches

Structural design I

6.+8. Arch-cable-structures



6.+8. Arch-cable-structures



9. Trusses



10.+11. Beams and frames



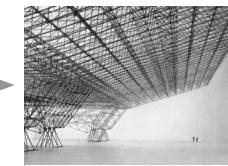
13. Cable-net and membrane structures



14.+15. Vaults, domes and shells



16. Spatial arch-cable-structures



17. Spacial trusses



16. Shear walls and plates

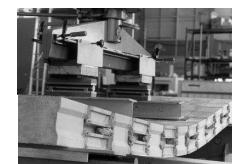


20. Columns



12. Materials and dimensioning

Structural design II



19. Bending

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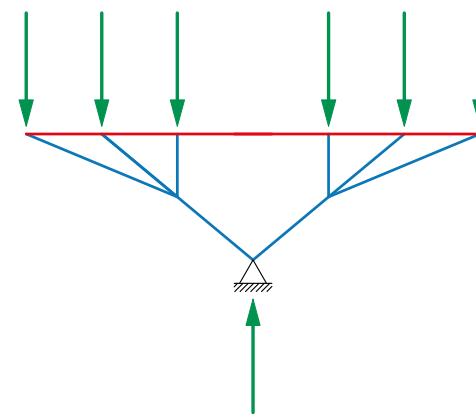
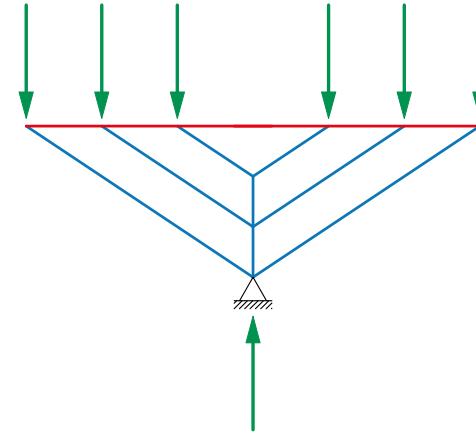
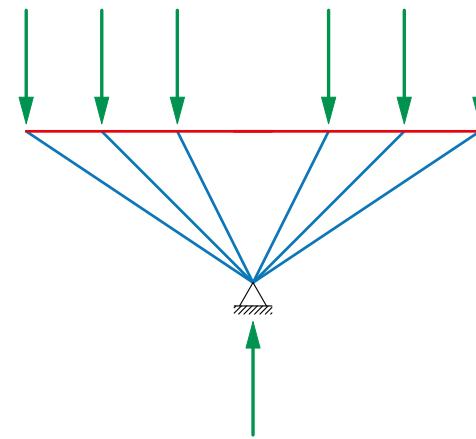
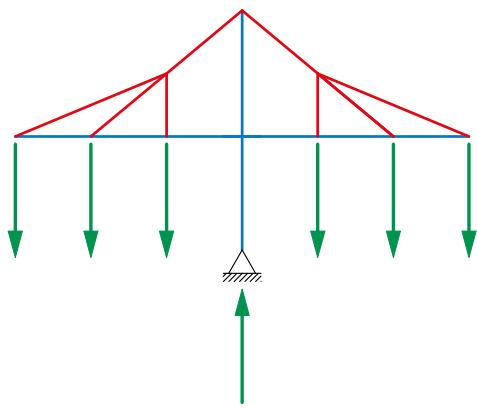
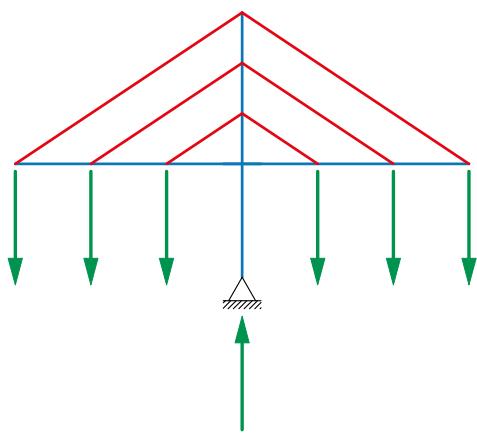
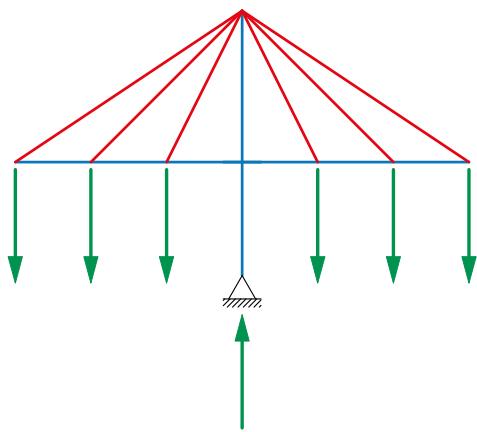
Statical determinacy of trusses

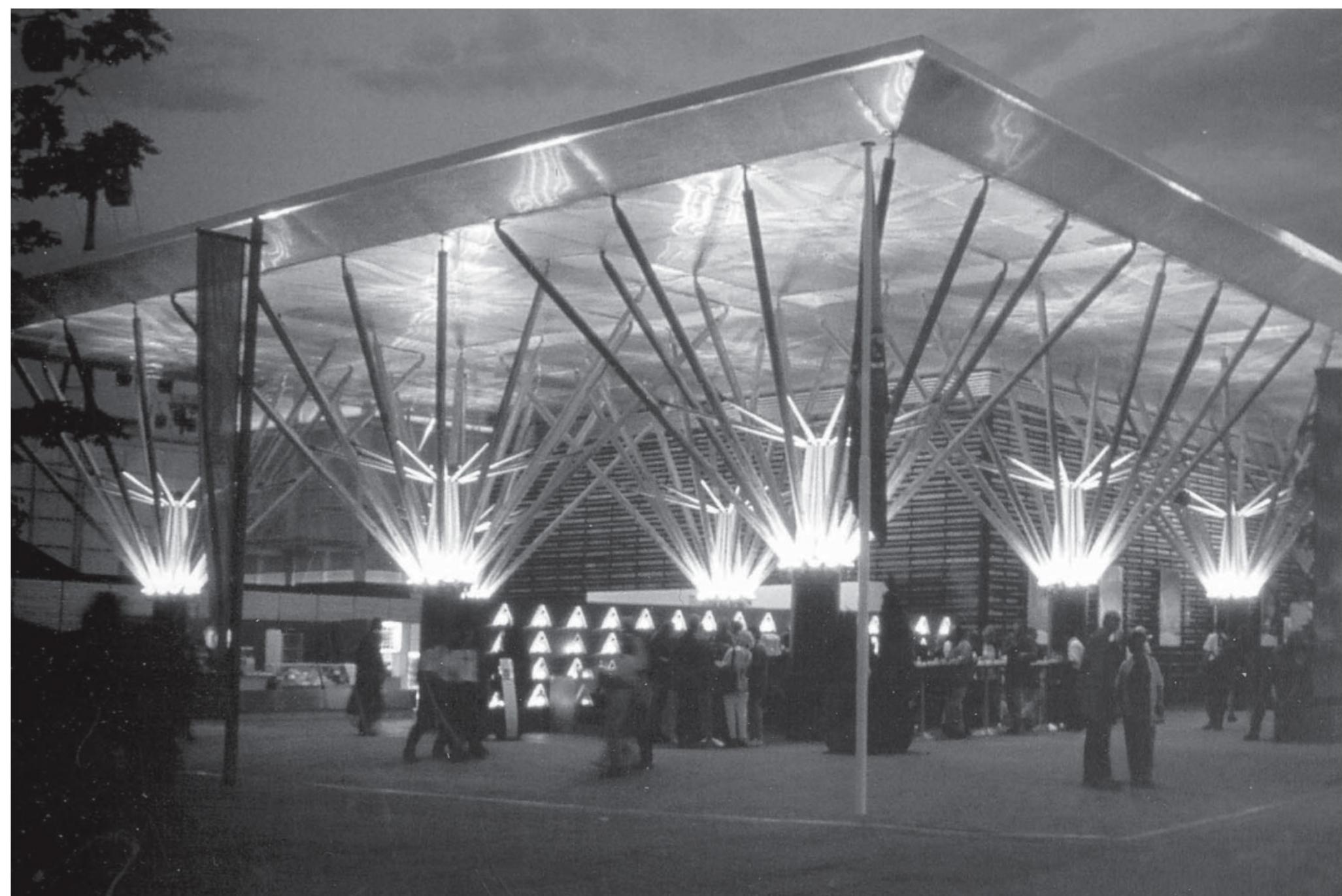
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Daniel Bonilla: Colombia Pavilion, Hannover Expo 2000



Christian Menn: Ganter Bridge, Brig, 1980



Robert Maillart: Simme River Bridge, Garstatt, 1940



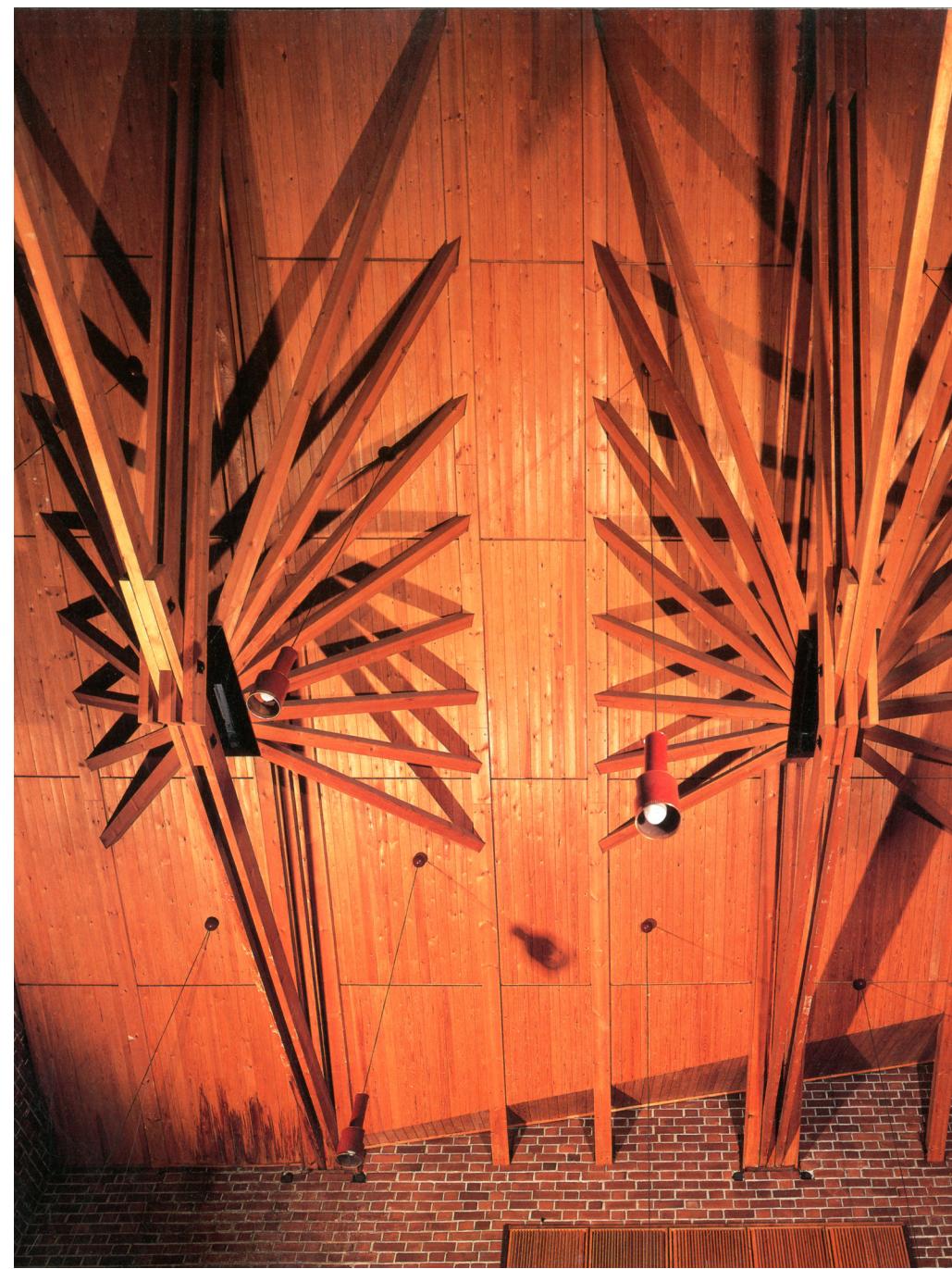
Jürg Conzett: Glenner Bridge, Peiden Bad, 2002



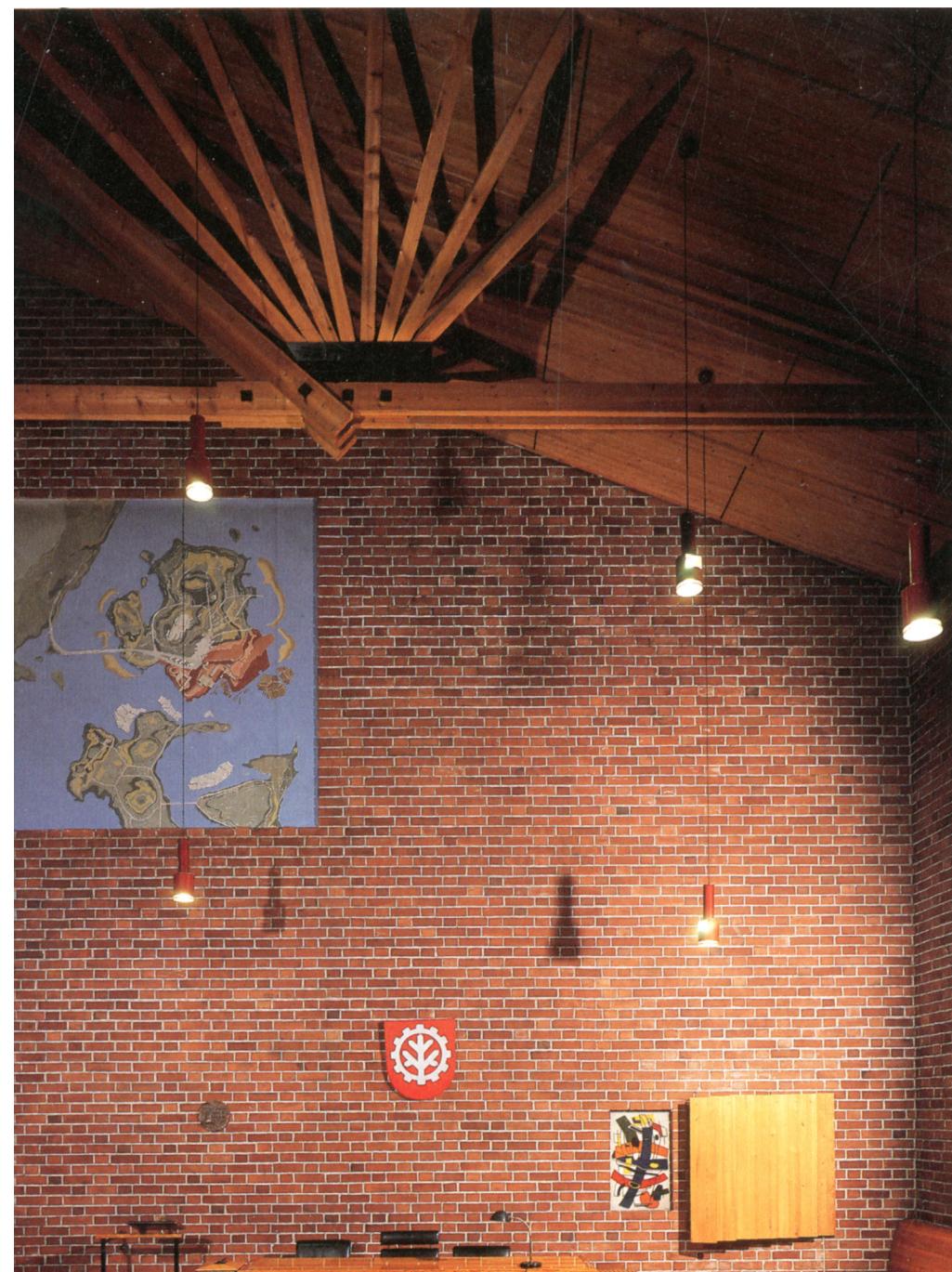
Jürg Conzett: Glenner Bridge, Peiden Bad, 2002



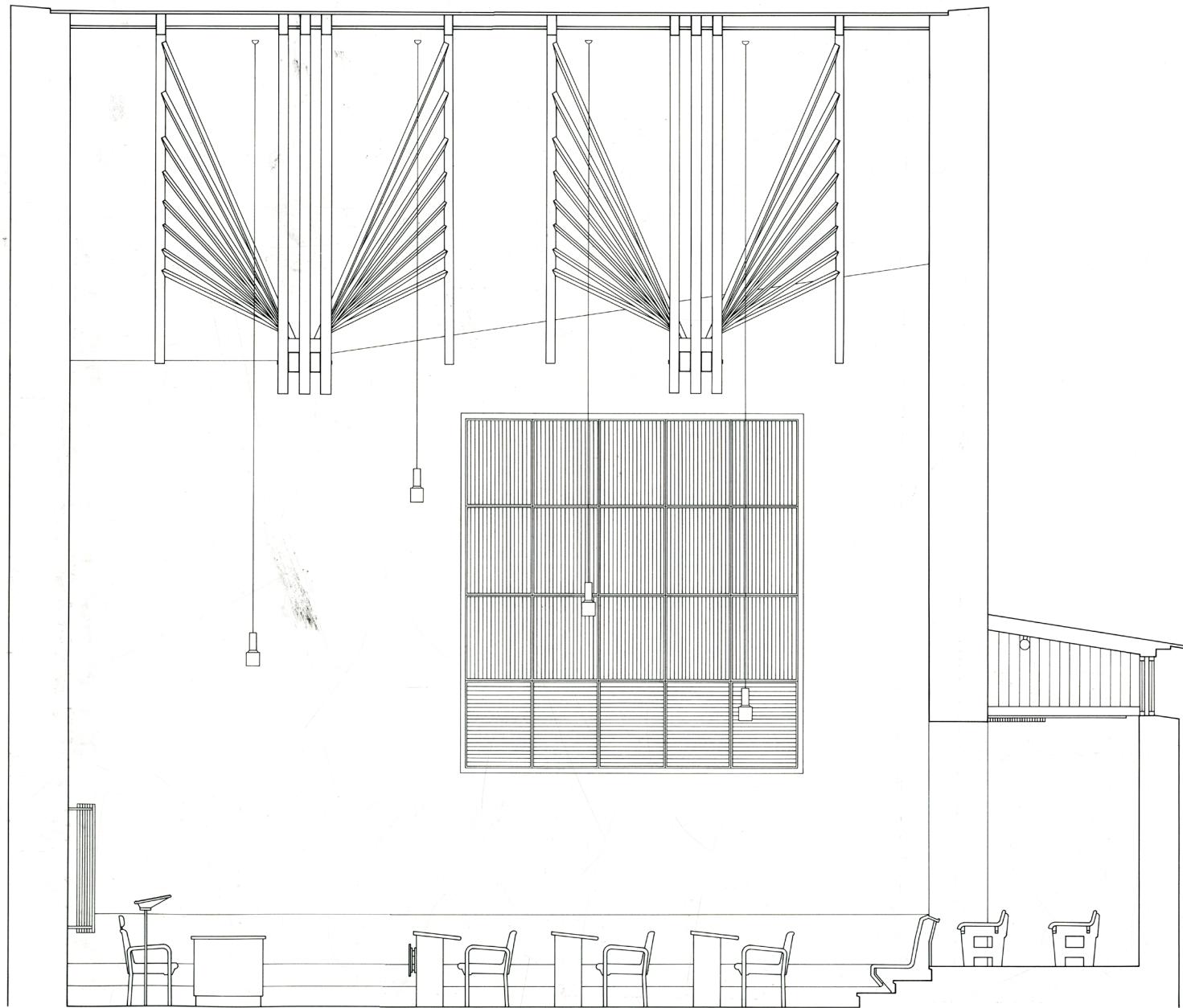
Jürg Conzett: Glenner Bridge, Peiden Bad, 2002



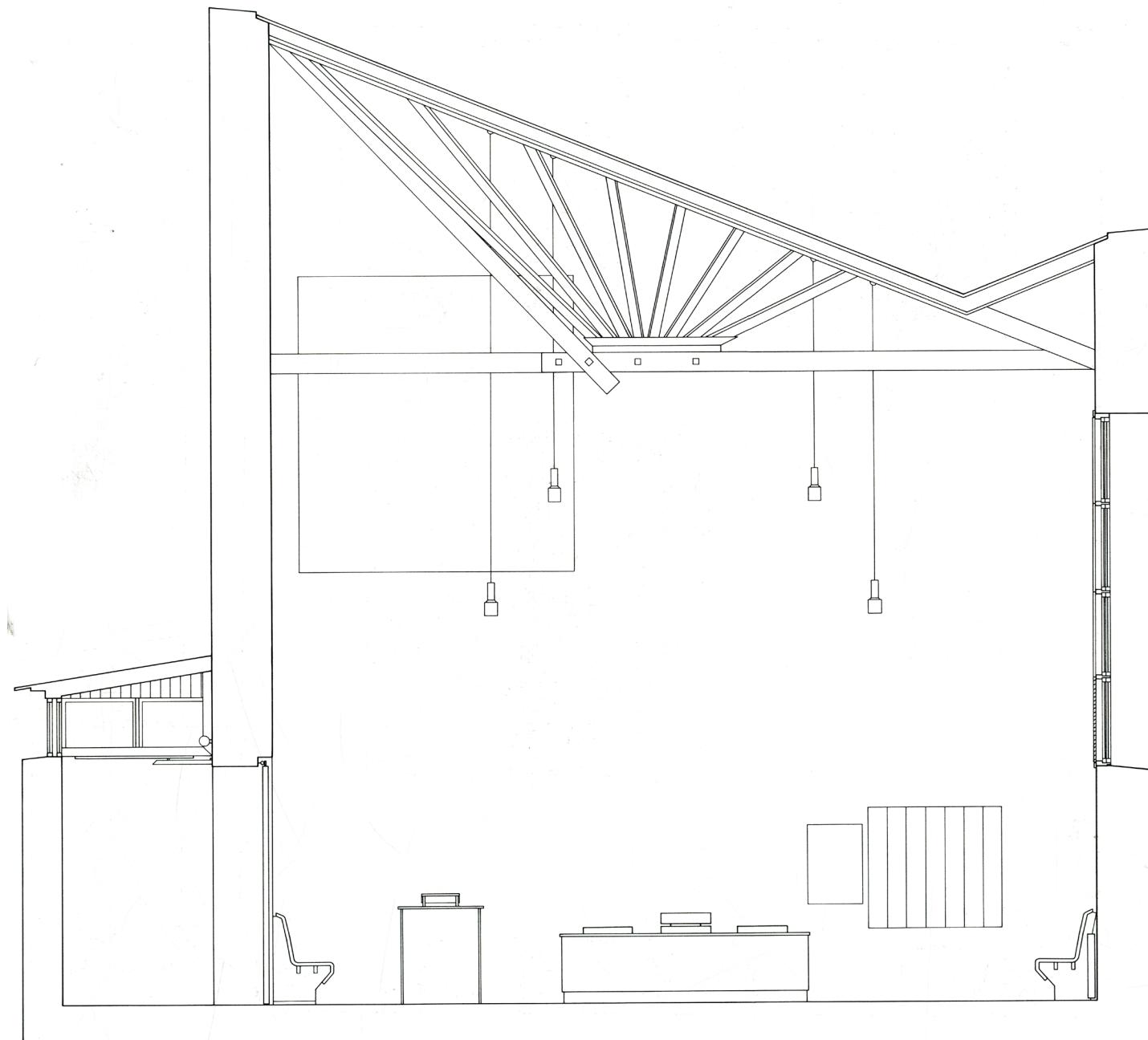
Alvar Aalto: Säynätsalo Town Hall, Finland, 1993



Alvar Aalto: Säynätsalo Town Hall, Finland, 1993



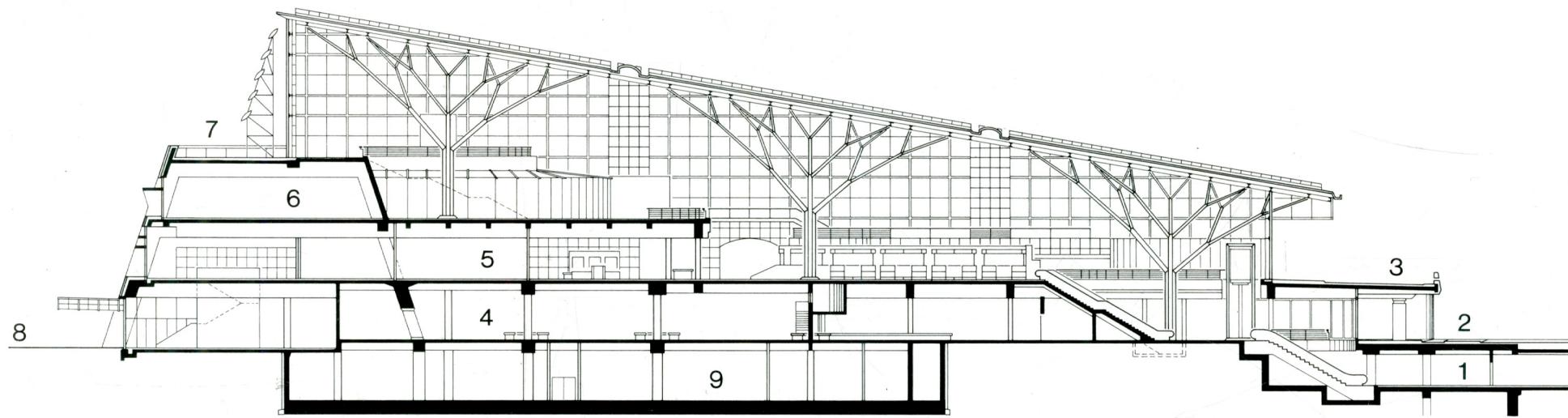
Alvar Aalto: Säynätsalo Town Hall, Finland, 1993

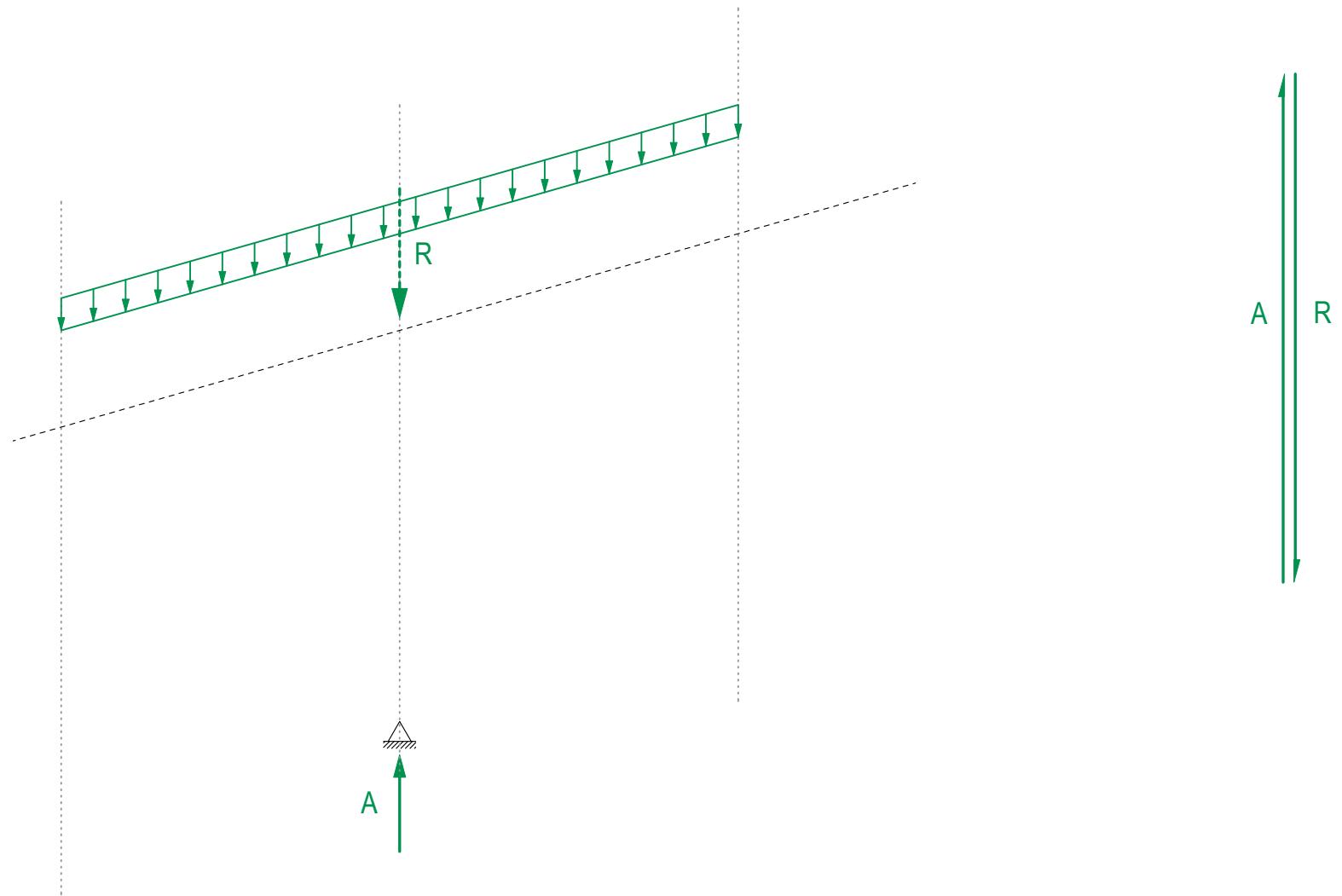


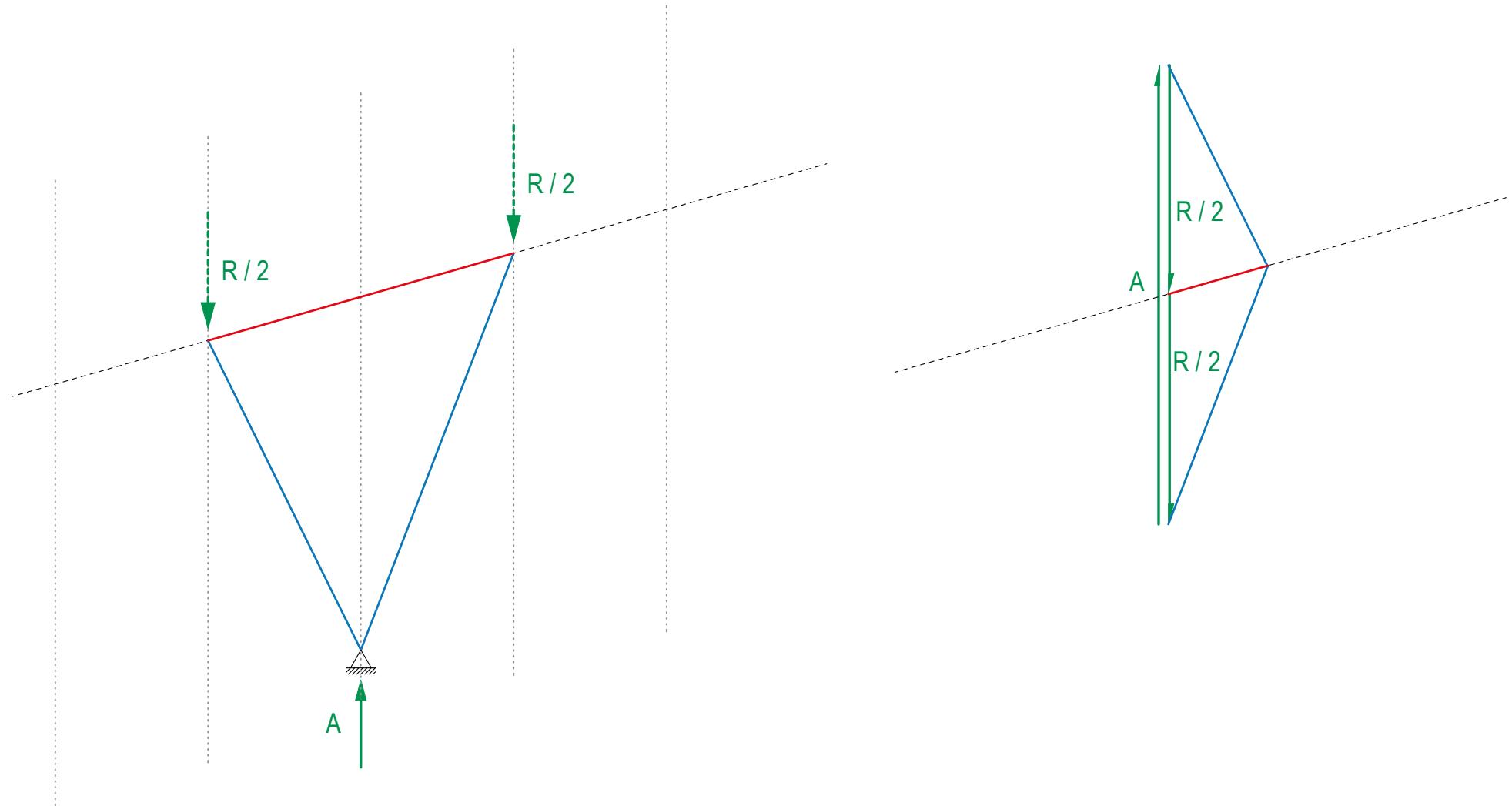
Alvar Aalto: Säynätsalo Town Hall, Finland, 1993

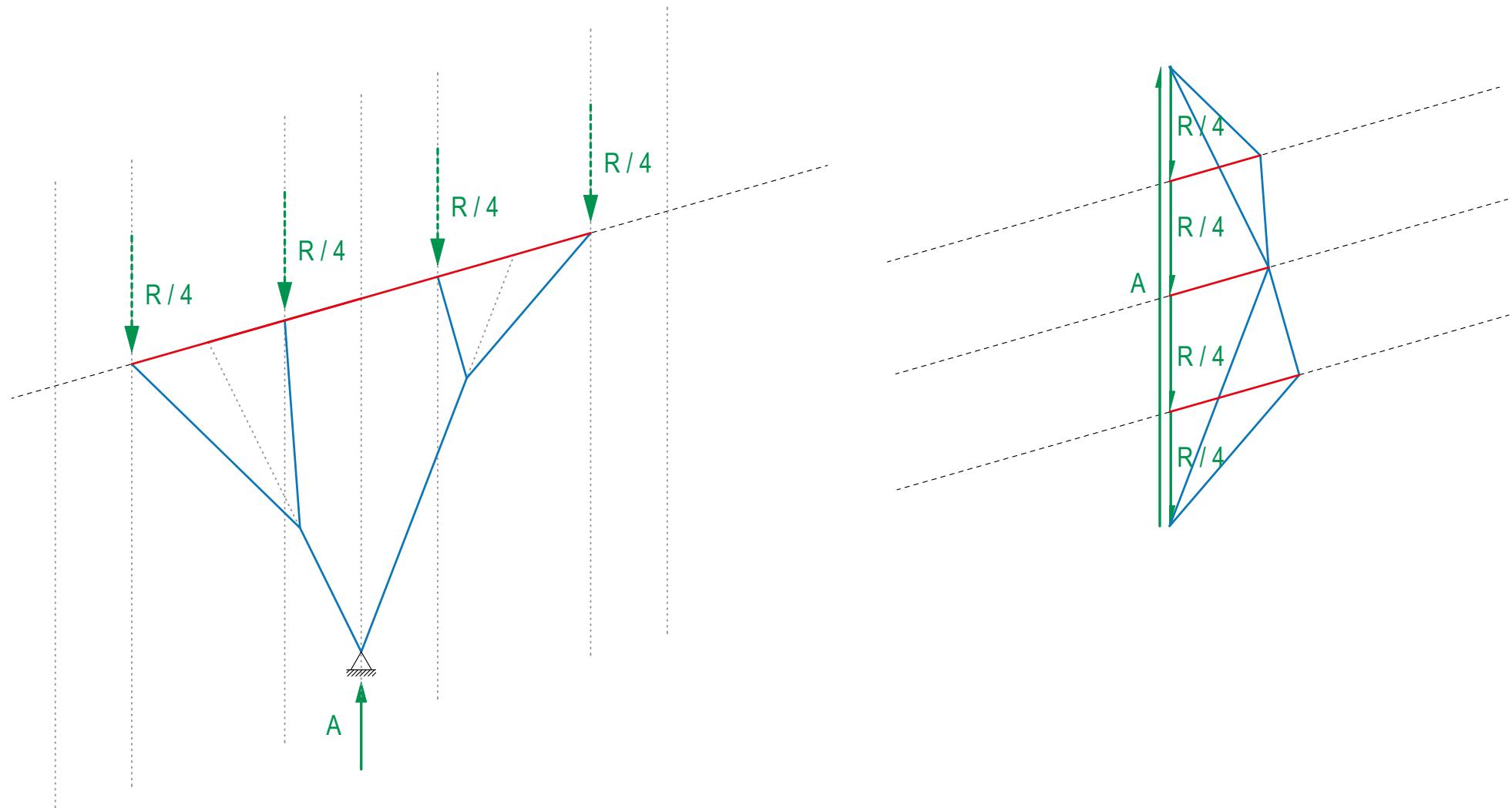


Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004





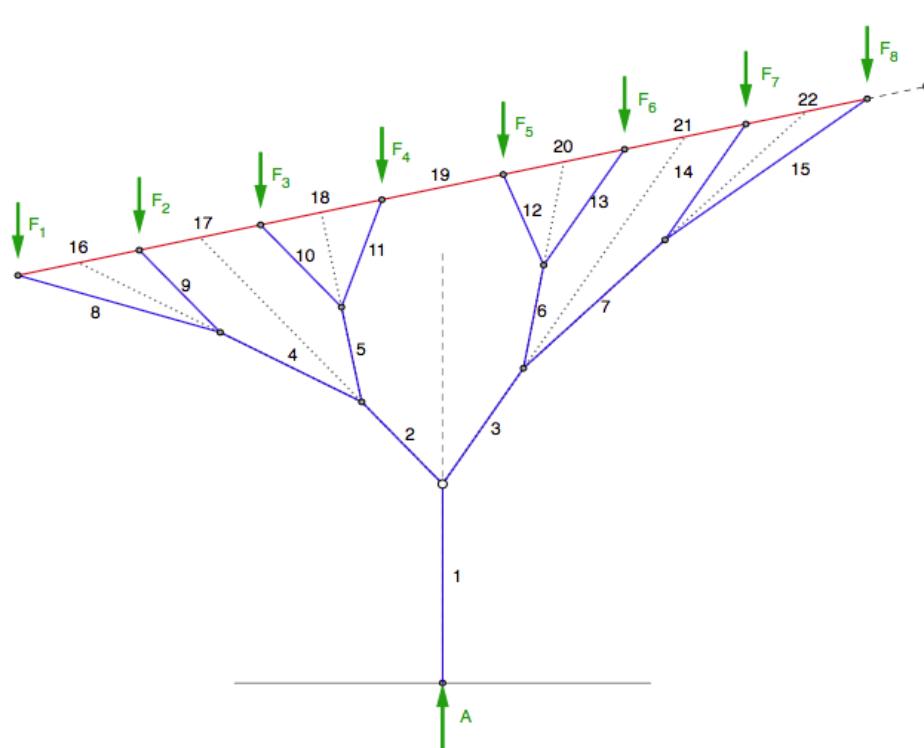




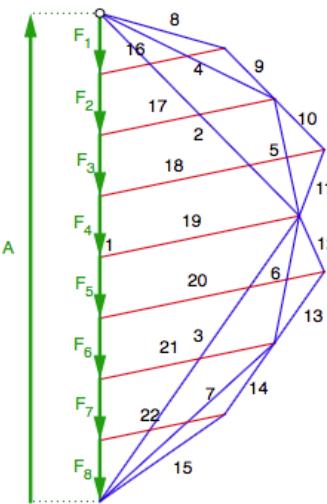
eQ

Tree structure

Form Diagram



Force Diagram



offsetLoads = 0

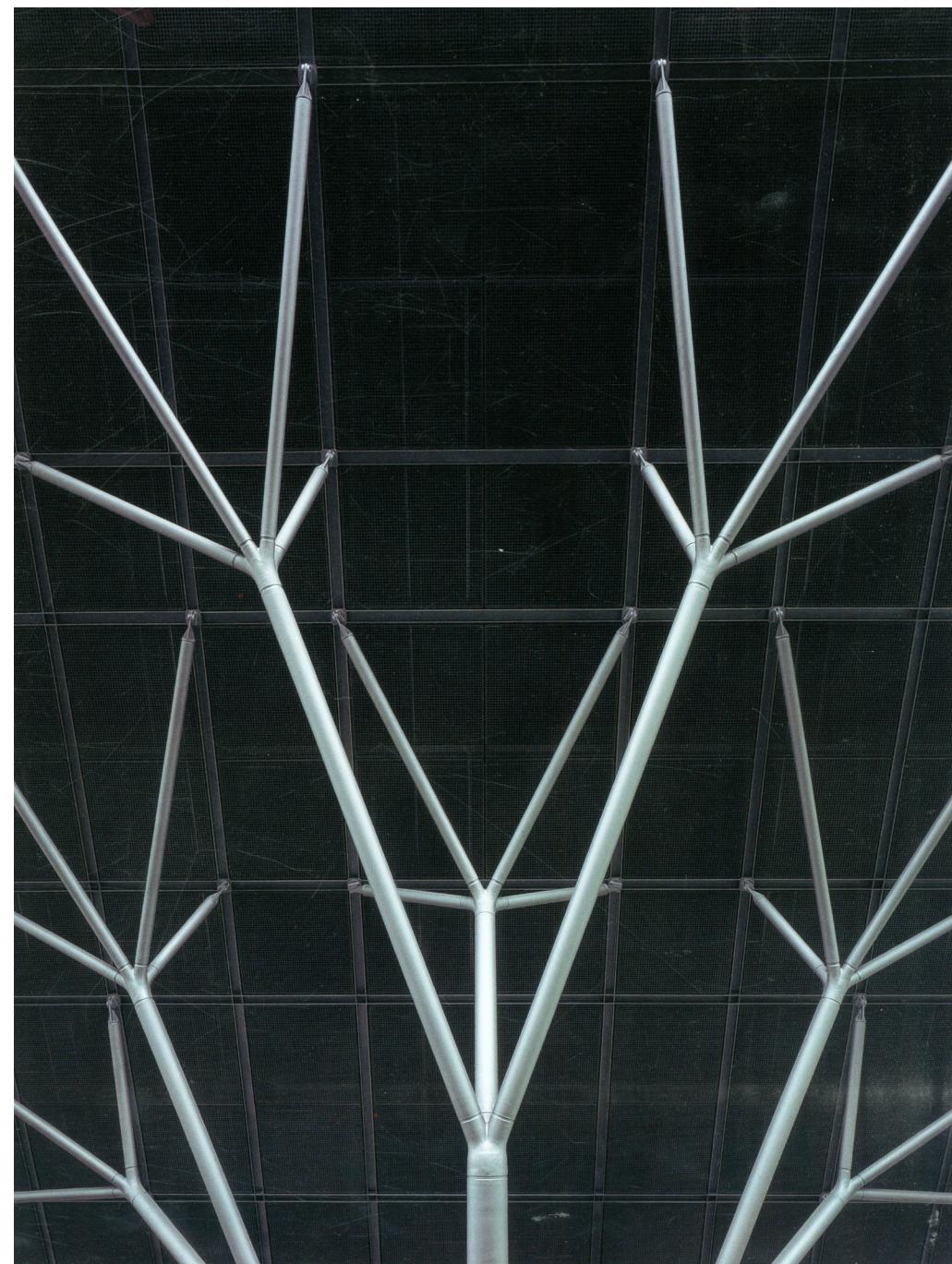


offsetReactionForces = 1

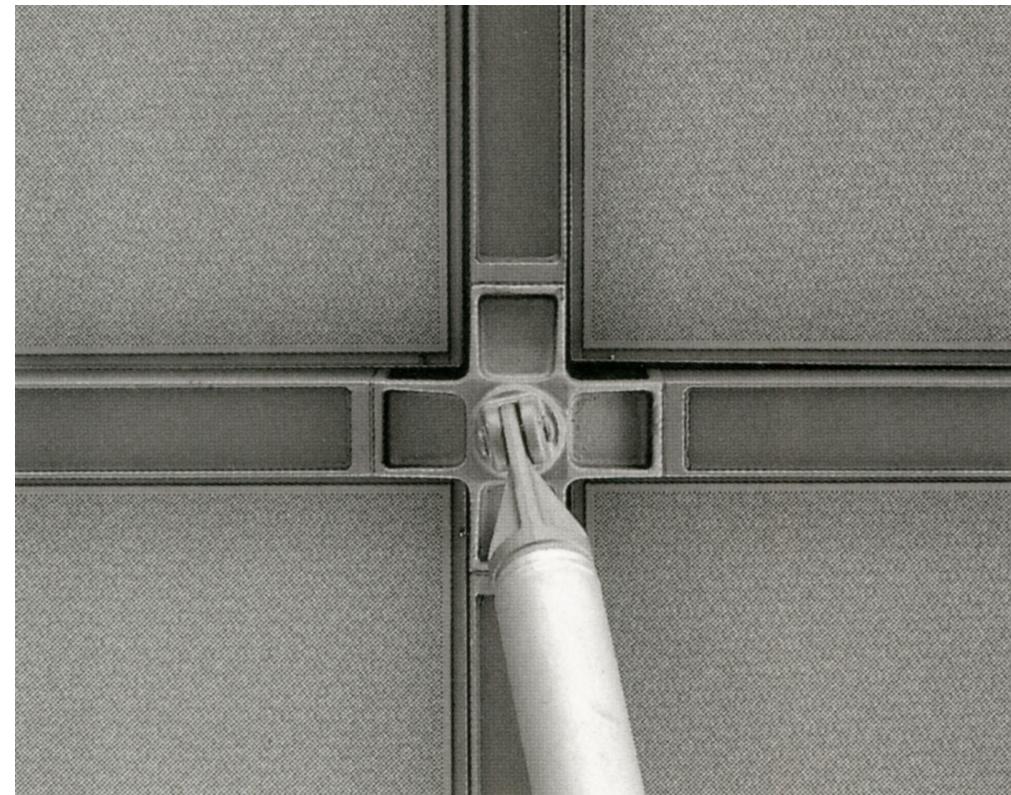




Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004



Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004



Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004

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Waclaw Zalewski, Jerzy Hryniwiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006



Waclaw Zalewski, Jerzy Hryniewiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006



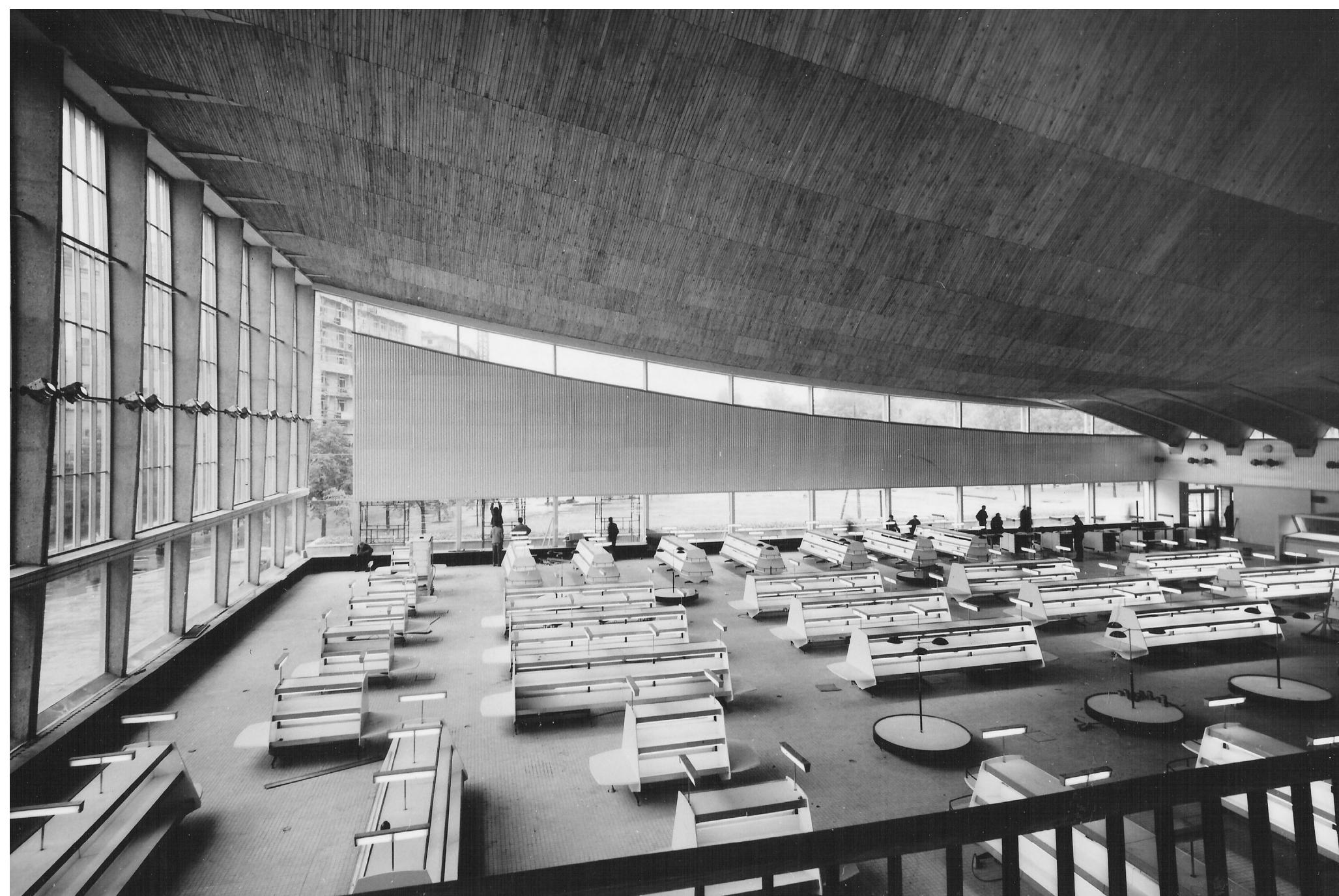
Waclaw Zalewski, Jerzy Hryniewiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006



Waclaw Zalewski, Jerzy Hryniewiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006



Waclaw Zalewski, Jerzy Hryniewiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006



Waclaw Zalewski, Jerzy Hryniewiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006



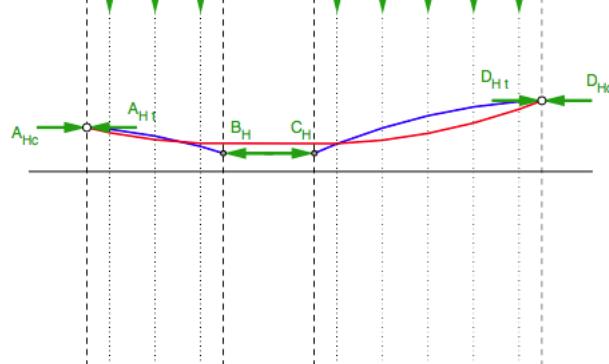
Waclaw Zalewski, Jerzy Hryniewiecki: Supersam supermarket, Warsaw, Poland, 1962, demolished 2006

eQ

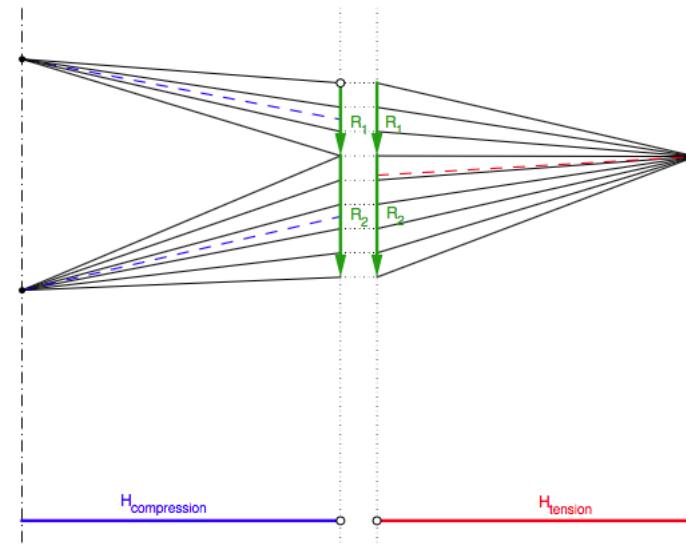
Supersam

mode = 0 [scales](#)[forces](#)[show/hide](#)

Form Diagram

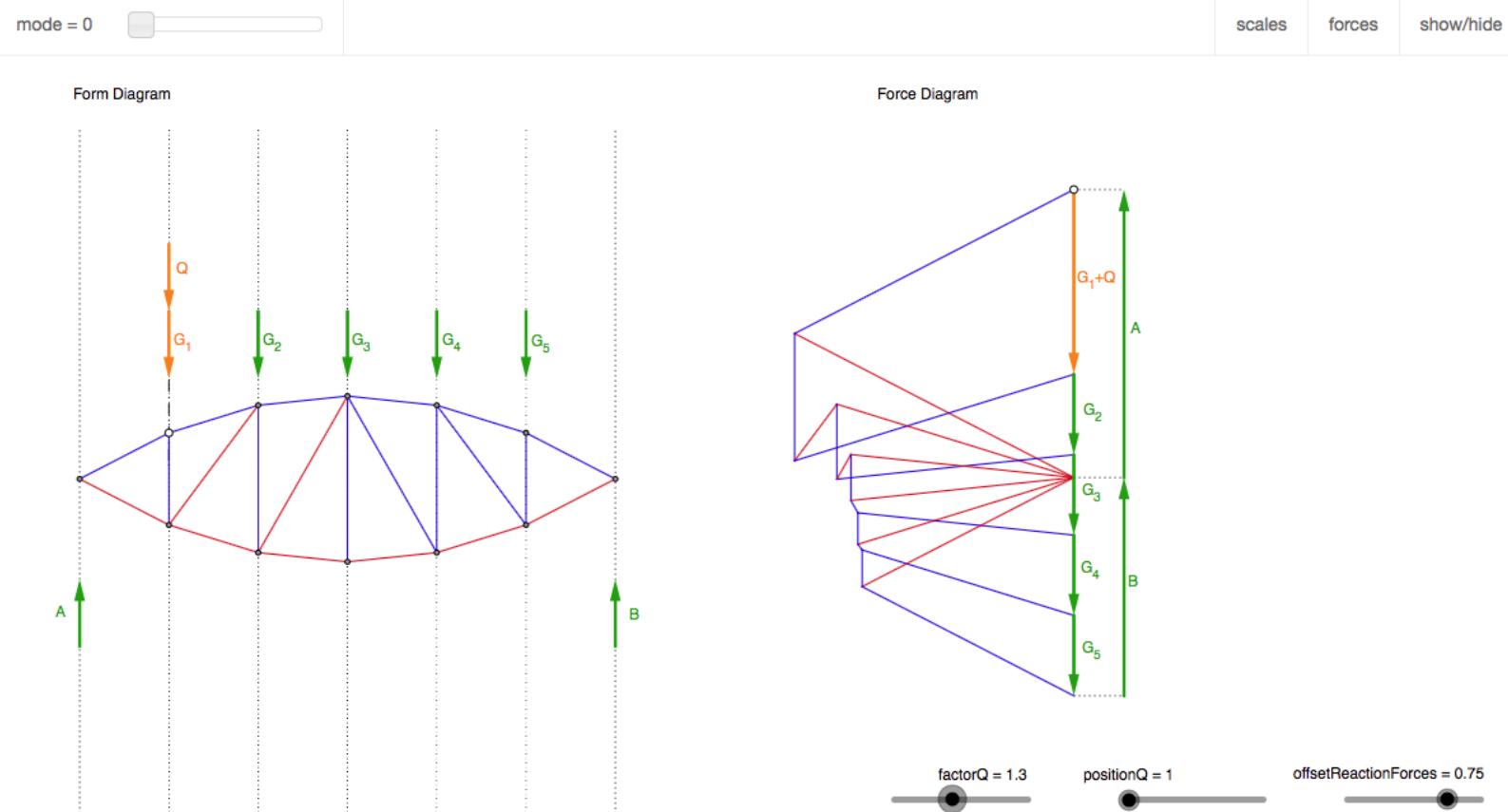


Force Diagram

factor_H = 0.8 offset = 0.6

eQ

Lenticular truss



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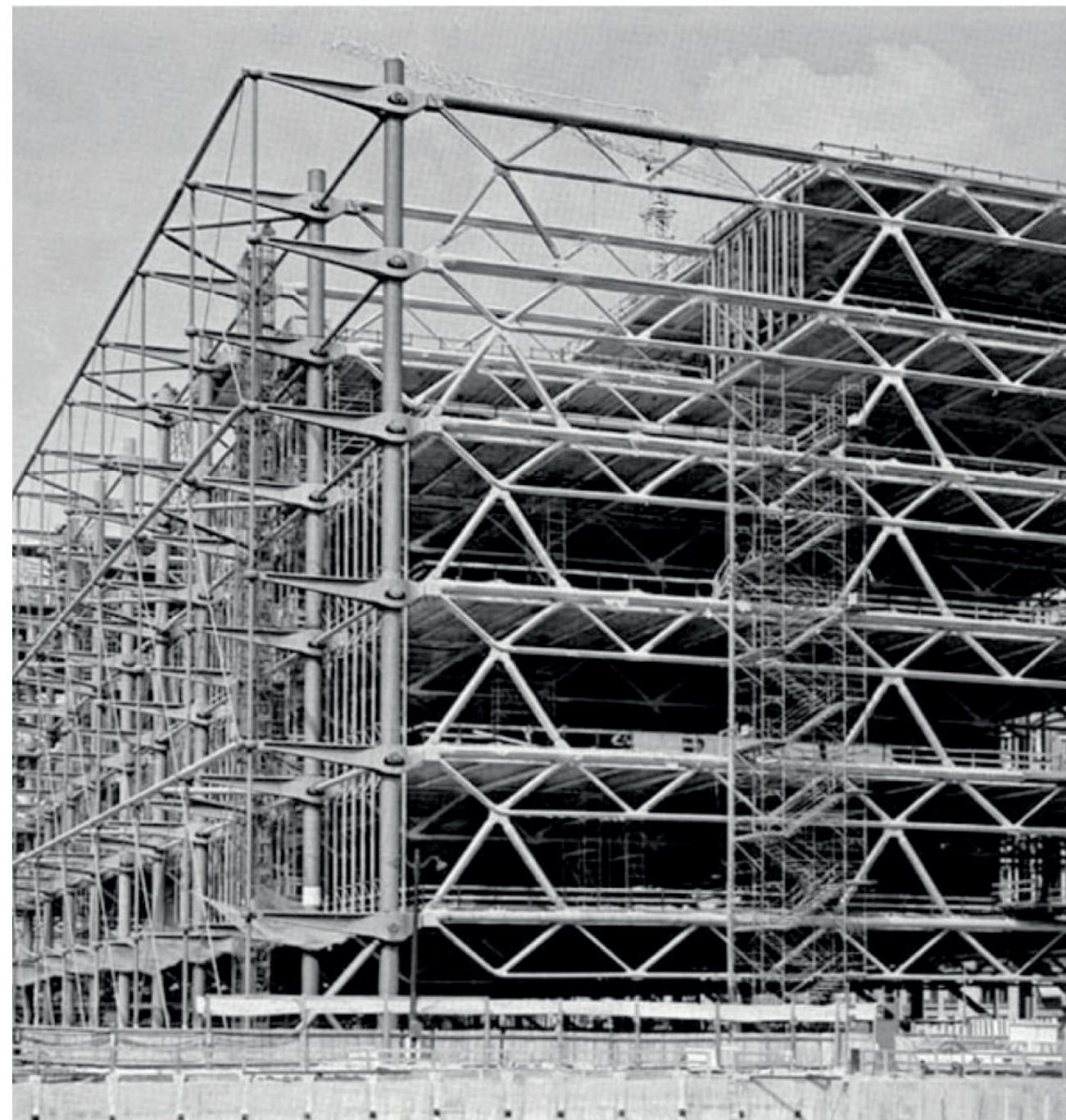
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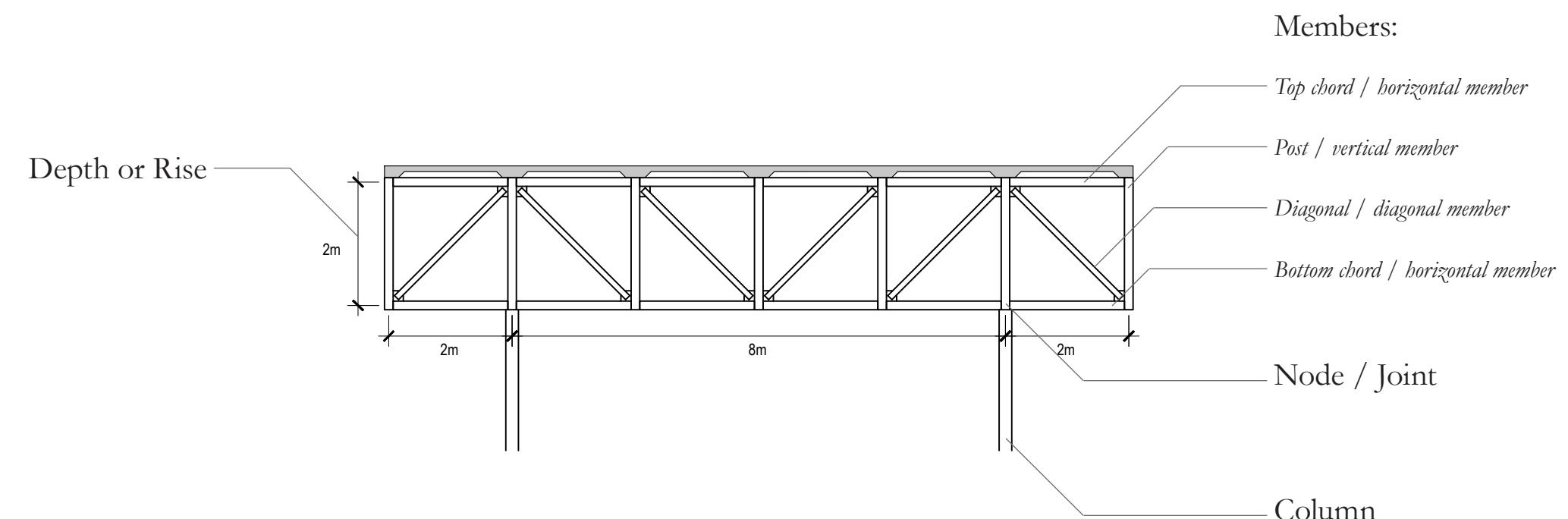
Analysis of trusses

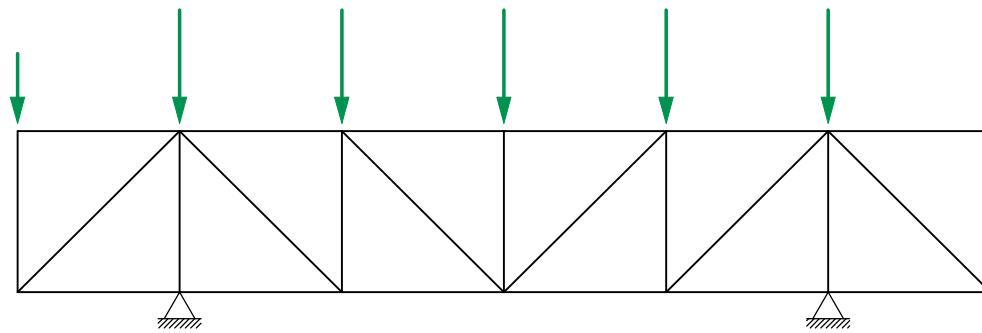
Case study: Lufthansa maintenance hall V

Construction of trusses



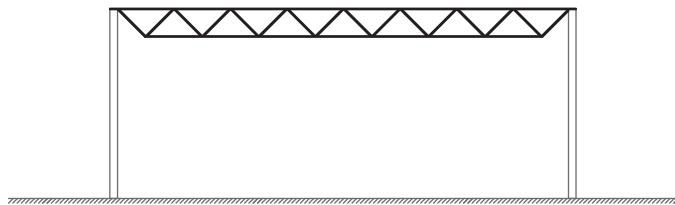
Renzo Piano, Richard Rogers, Peter Rice: Centre Pompidou, Paris, 1977



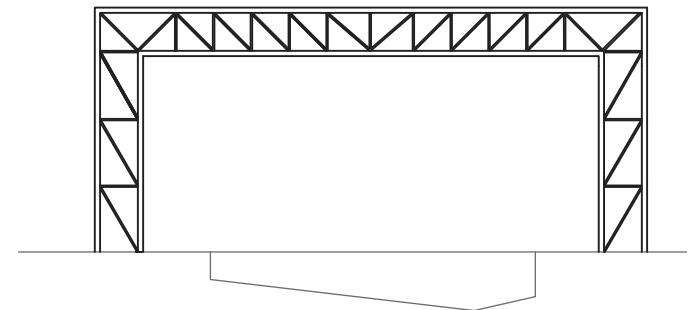


- All connections are pin joints
- All elements are straight
- Loads only apply on nodes
- Only axial forces occur
- Trusses consist out of stiff triangles

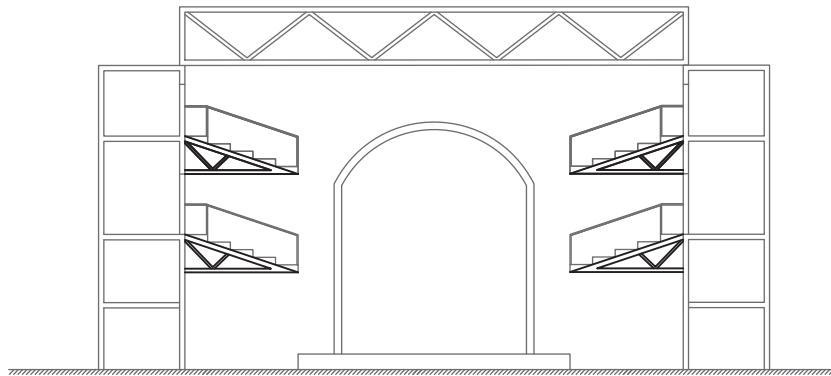
Trussed beam



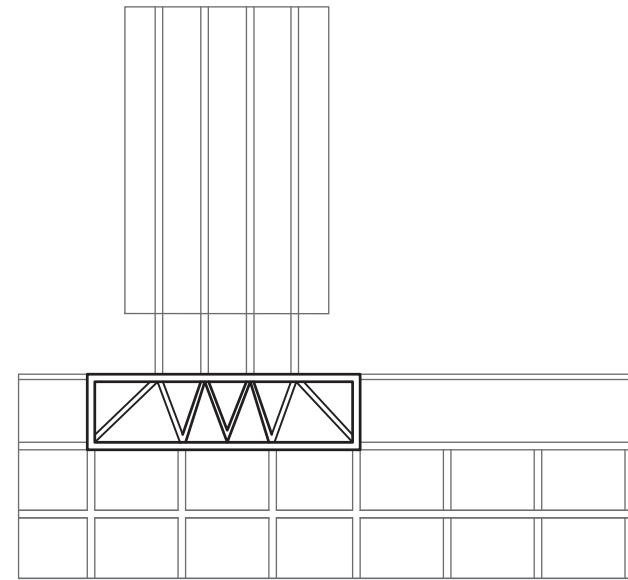
Trussed frame



Cantilever truss



Transfer truss



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$$S + A < 2 * K$$

The system is unstable/ a mechanism

$$S + A = 2 * K$$

The system is statically determinate

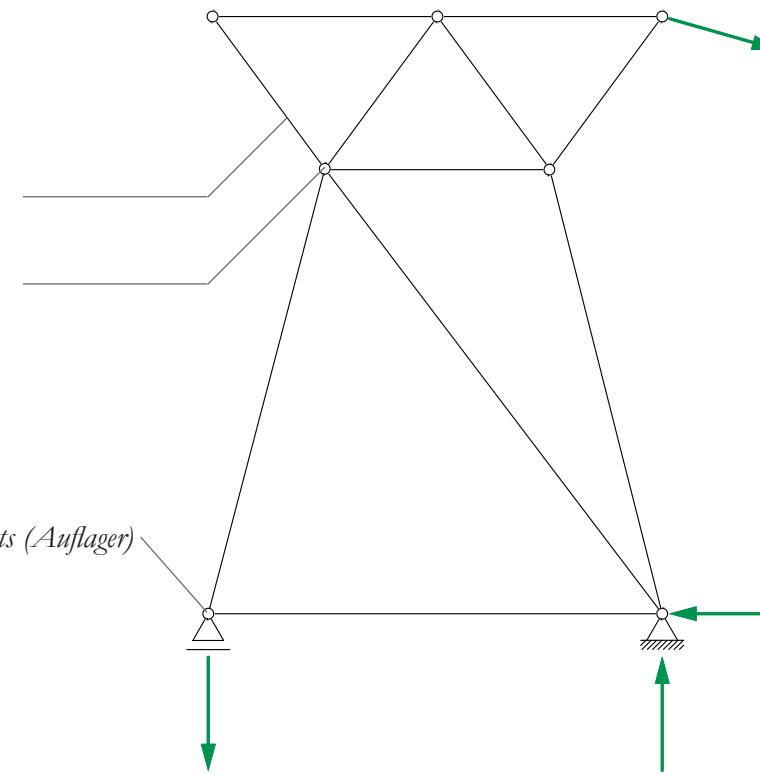
$$S + A > 2 * K$$

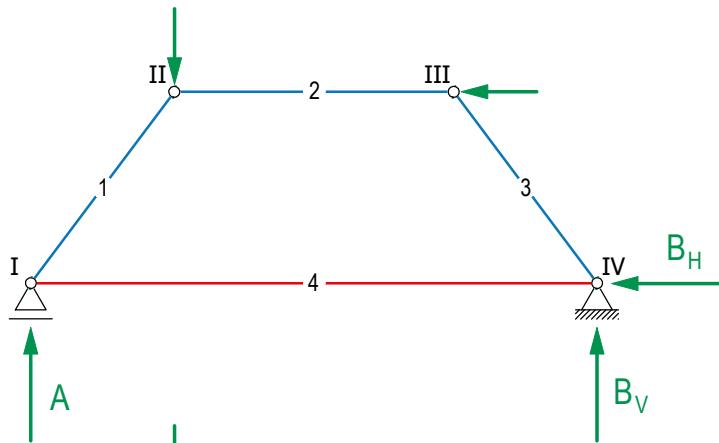
The system is statically indeterminate

$S = \text{Number of members (Stäbe)}$

$K = \text{Number of nodes (Knoten)}$

$A = \text{Number of support restraints (Auflager)}$





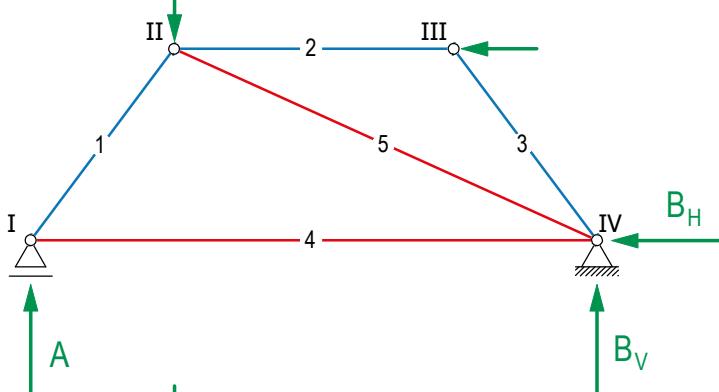
$$S = 4$$

$$A = 3$$

$$K = 4$$

$$S + A = 7 < 2 * K = 8$$

The system is unstable/ a mechanism.



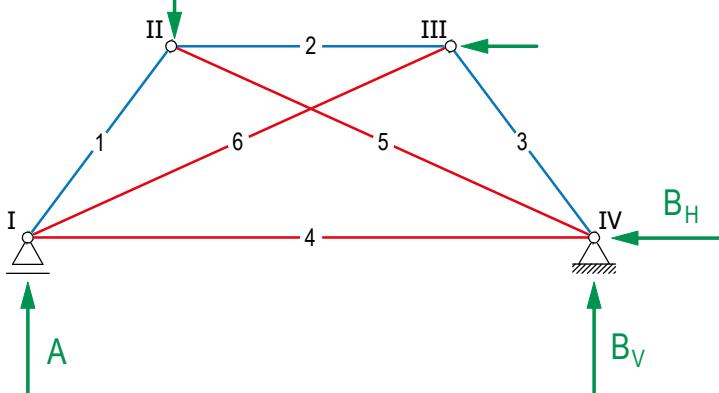
$$S = 5$$

$$A = 3$$

$$K = 4$$

$$S + A = 8 = 2 * K = 8$$

The system is statically determinate.



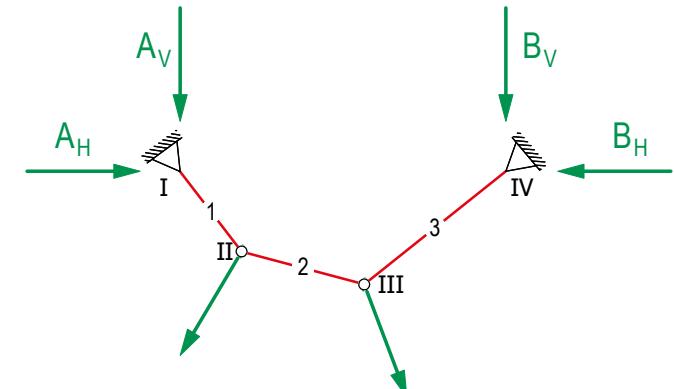
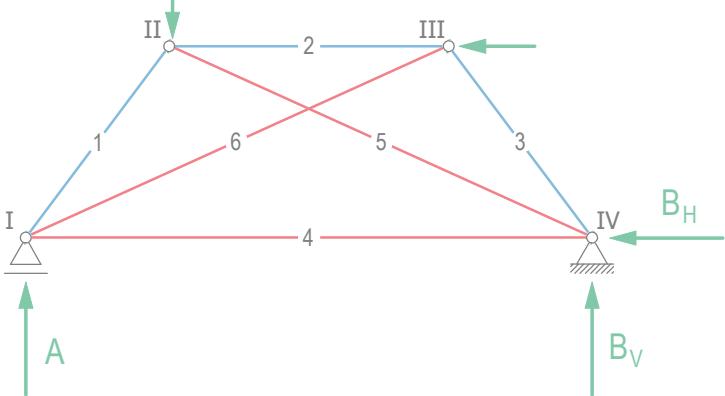
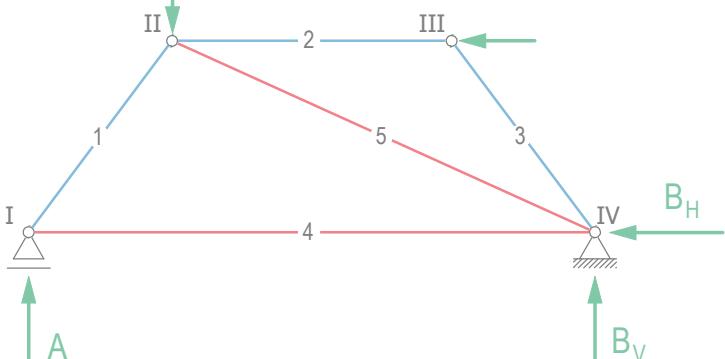
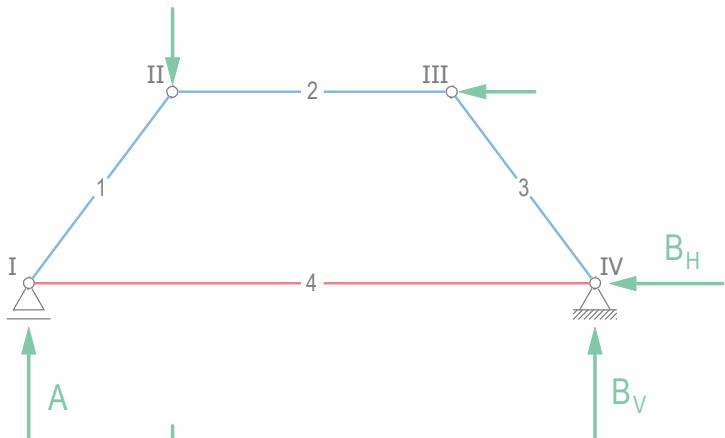
$$S = 6$$

$$A = 3$$

$$K = 4$$

$$S + A = 9 > 2 * K = 8$$

The system is statically indeterminate.



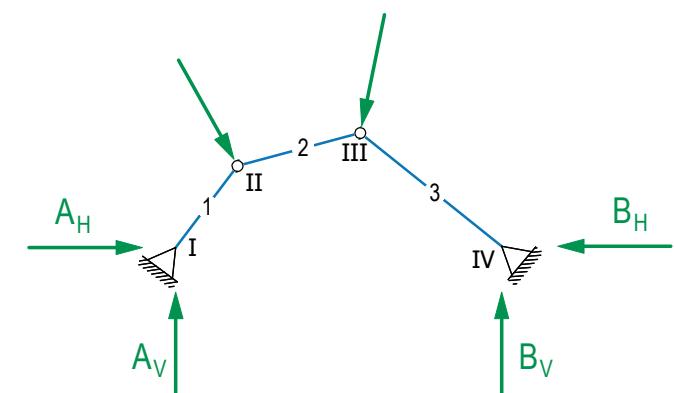
$$S = 3$$

$$A = 4$$

$$K = 4$$

$$S + A = 7 < 2 * K = 8$$

The system is unstable/ a mechanism.



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eQ

Single panel truss

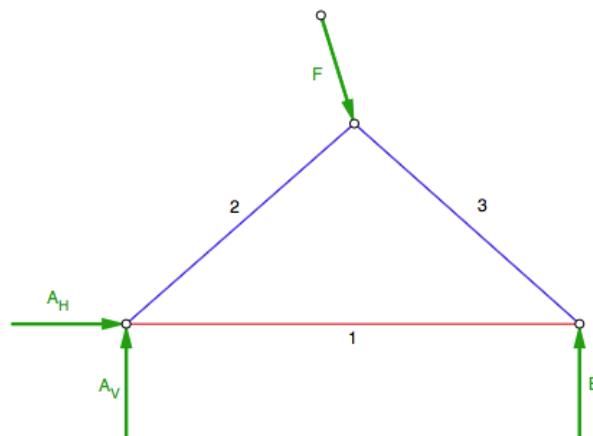
mode = 0



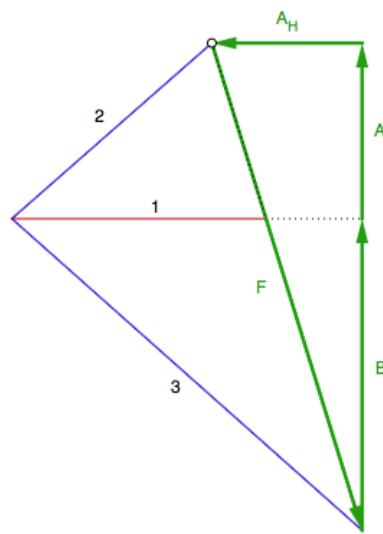
scales

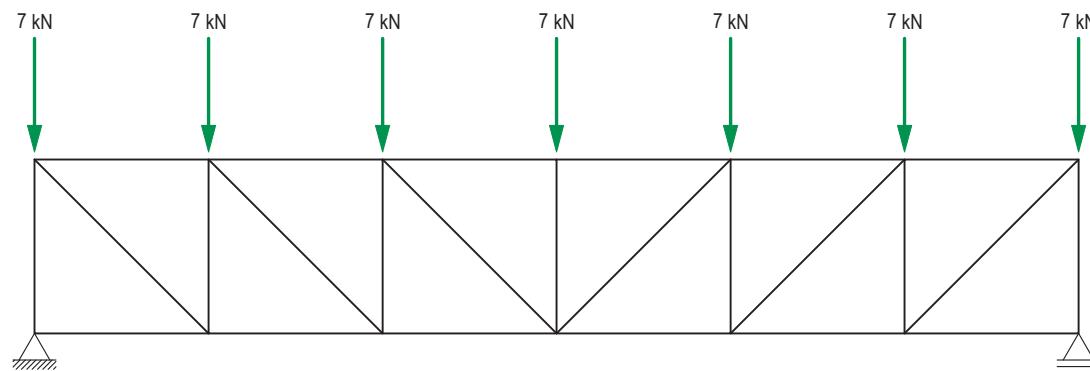
forces

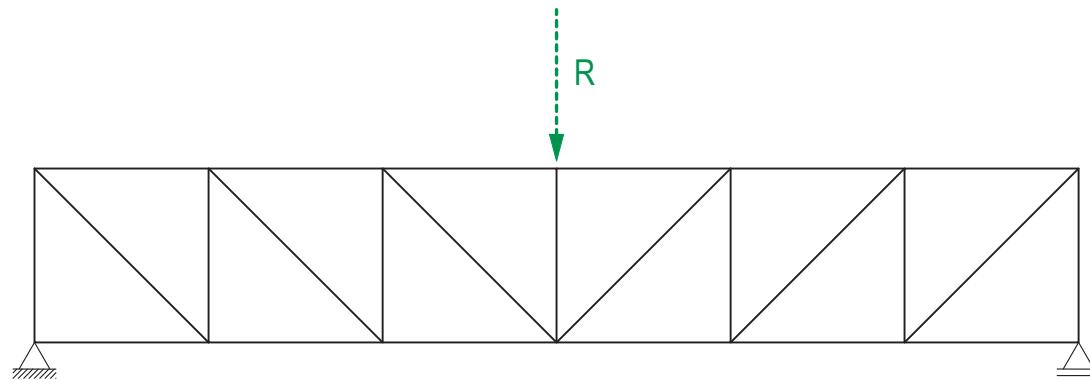
Form Diagram

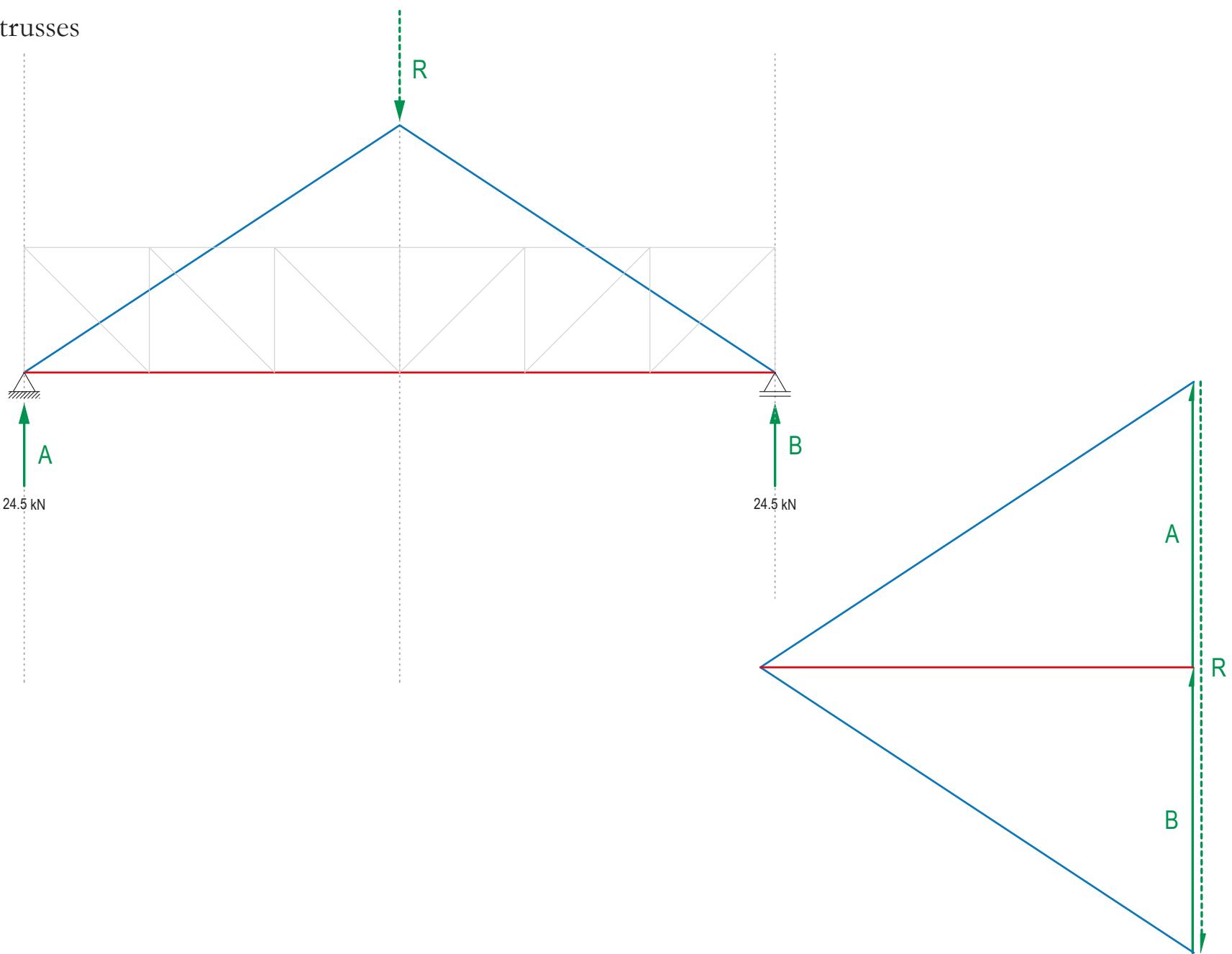


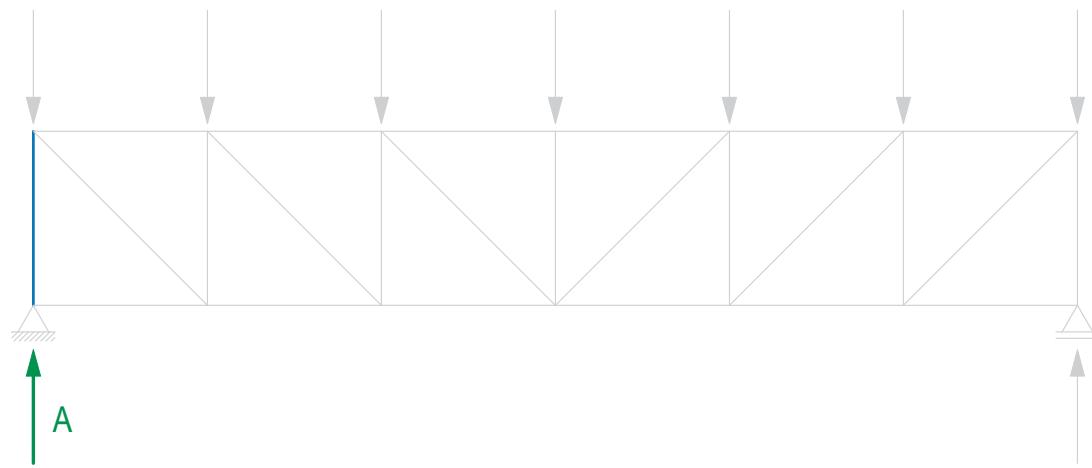
Force Diagram

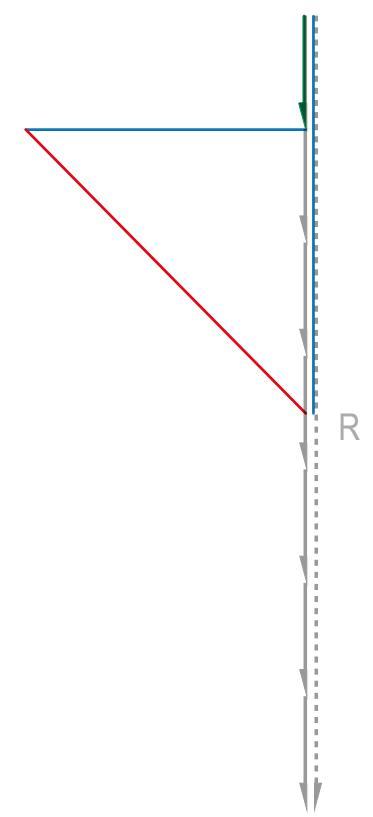
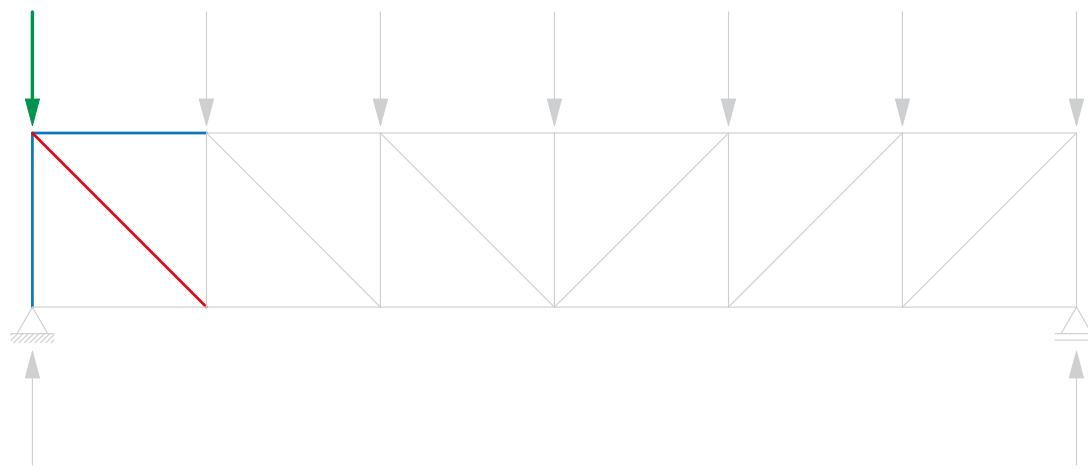


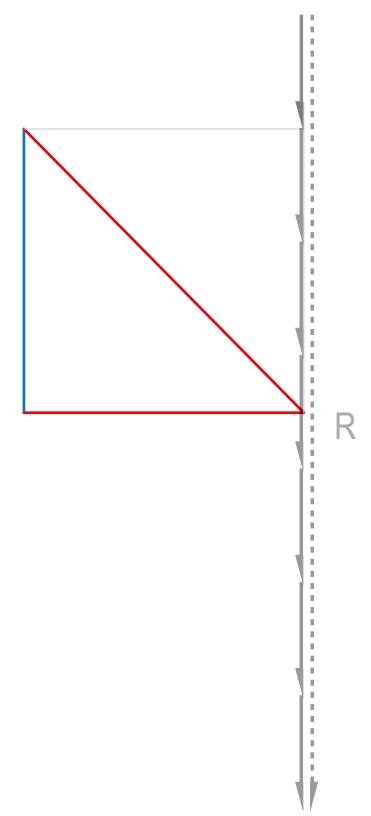
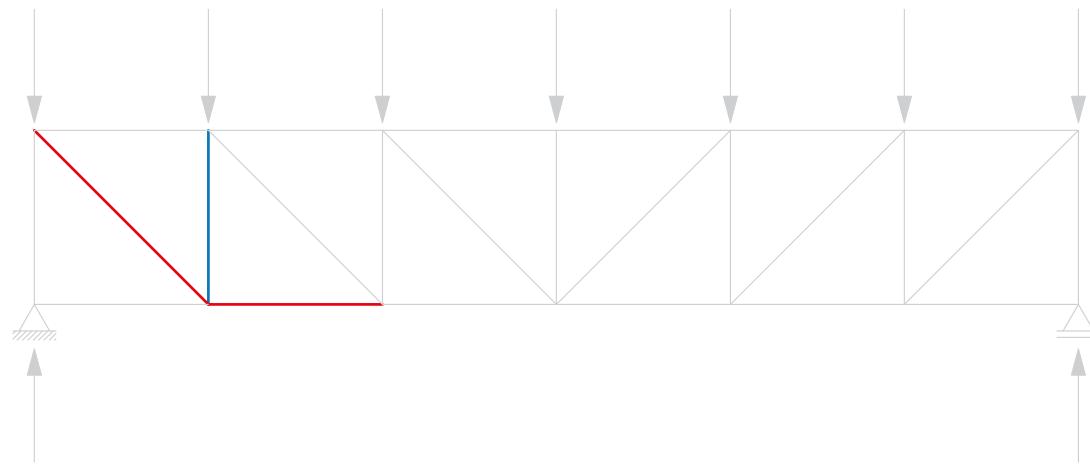


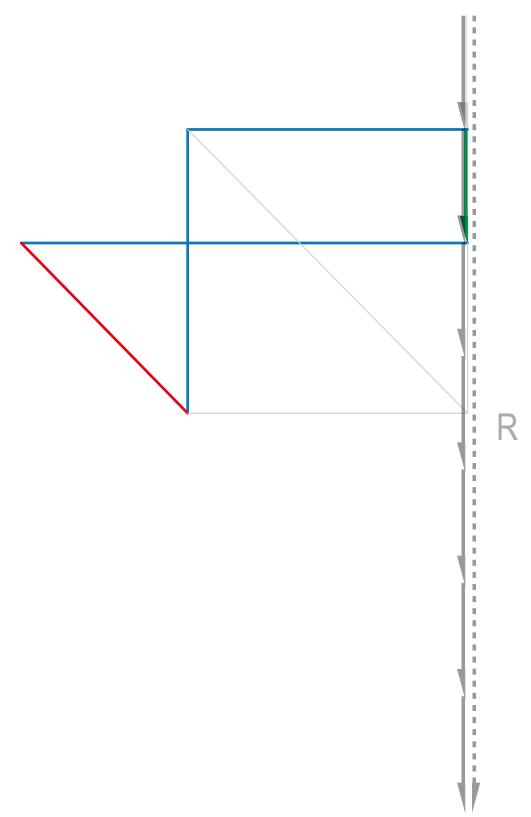
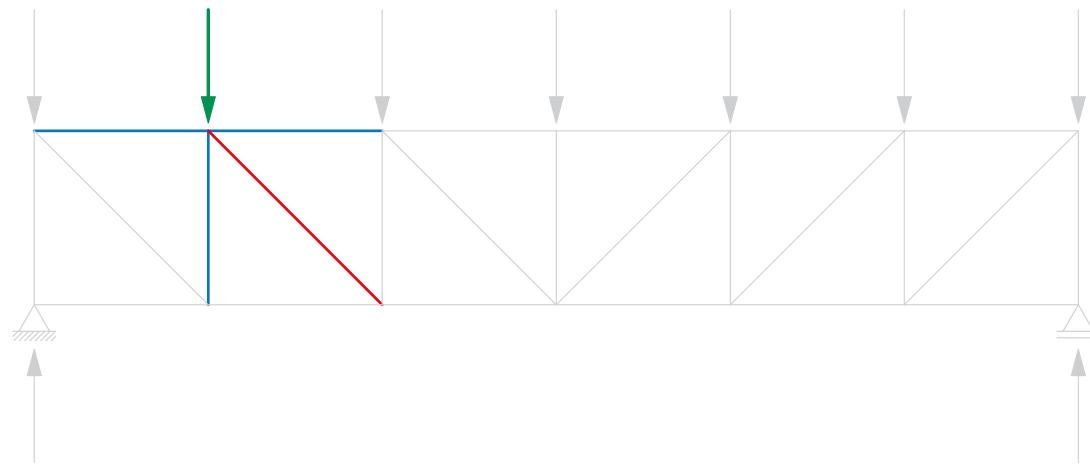


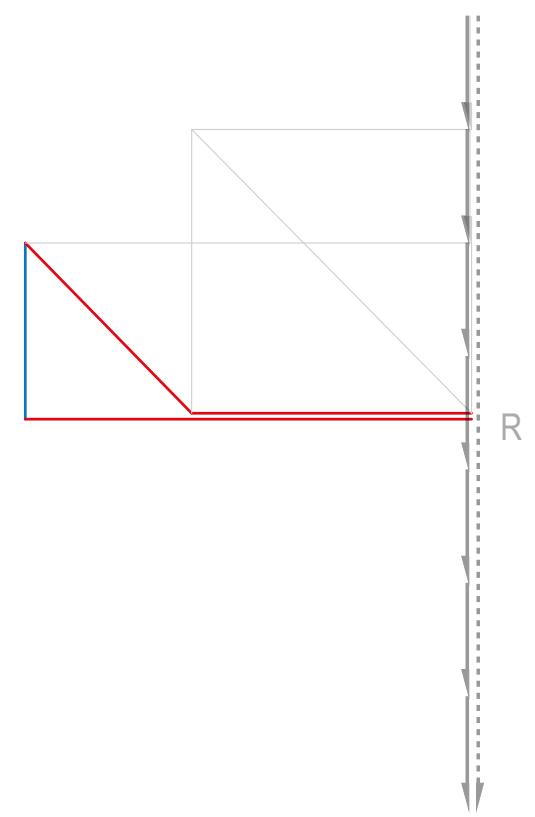
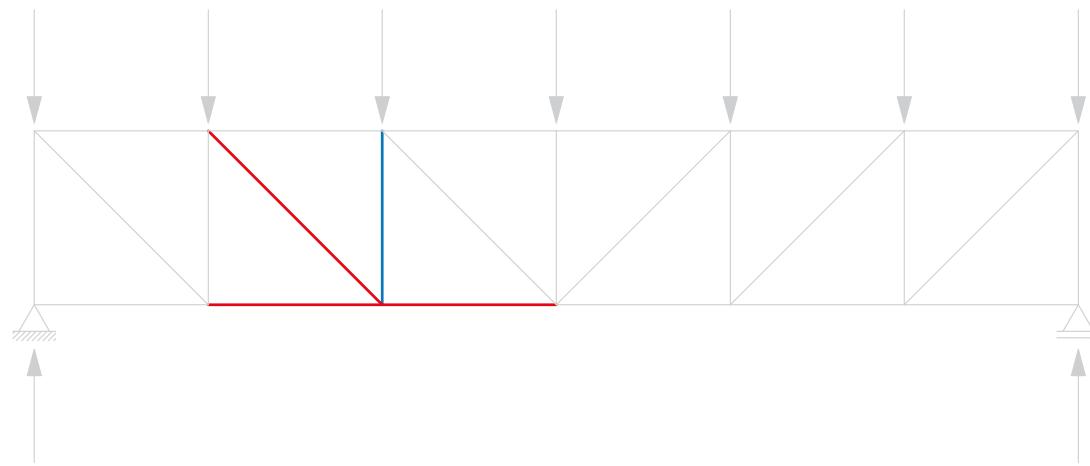


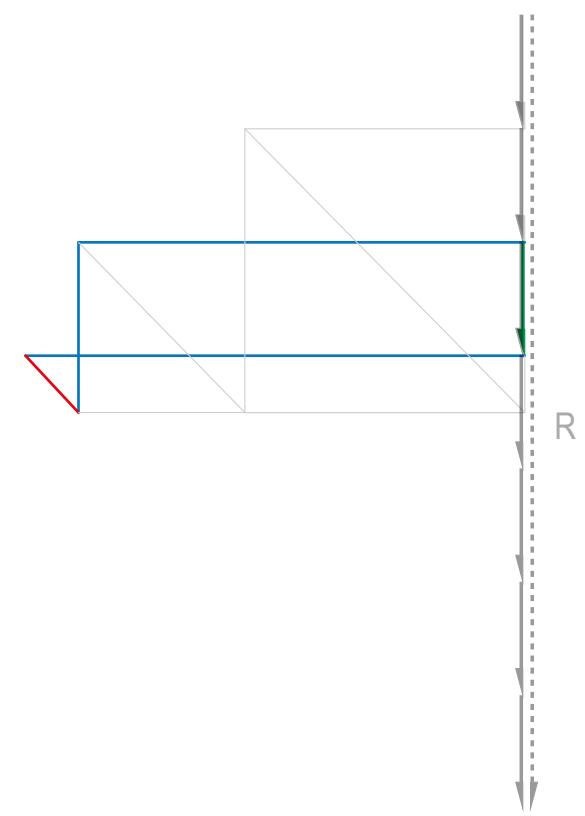
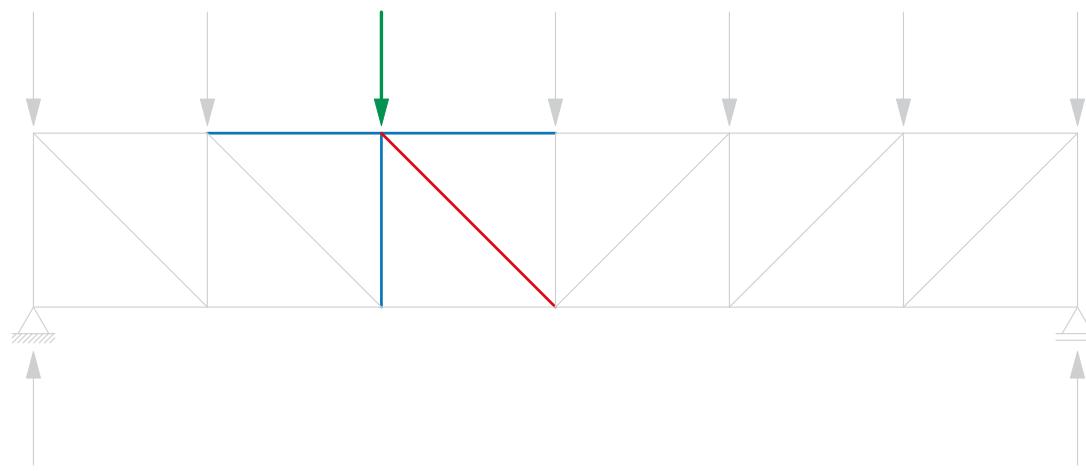


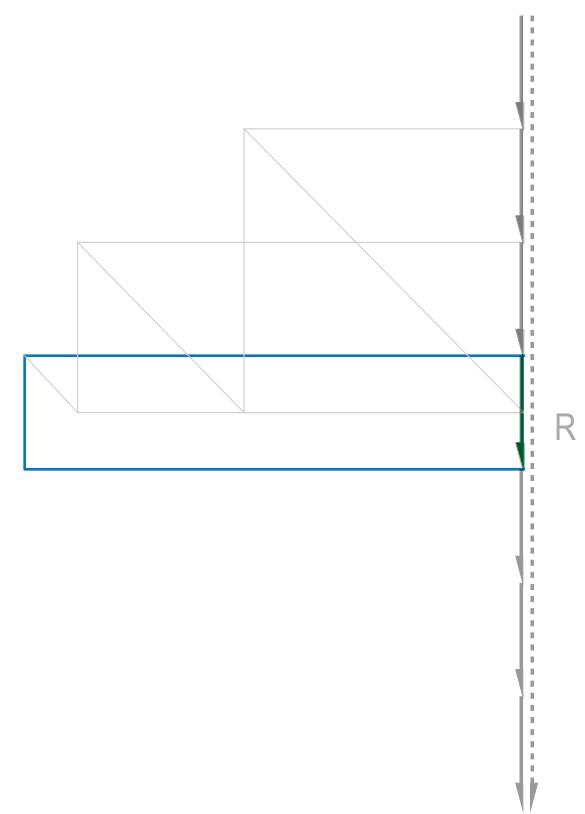
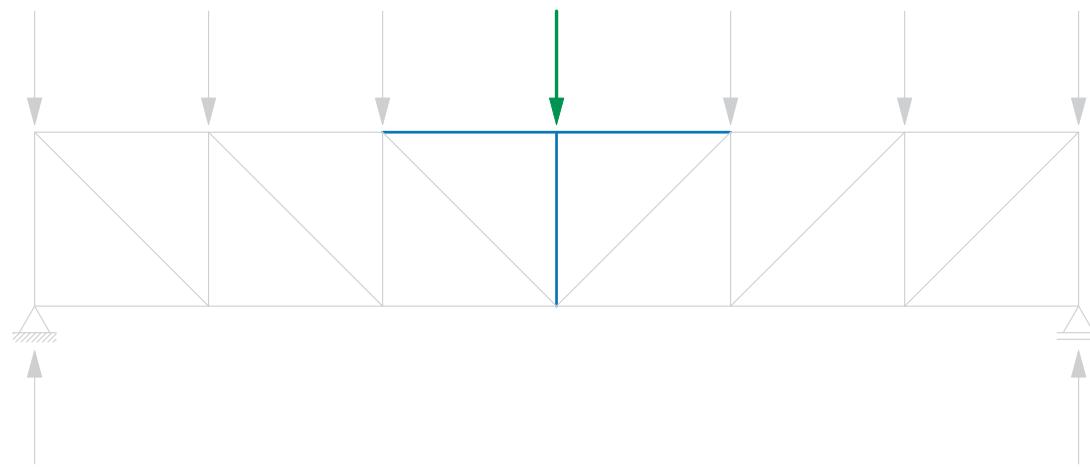


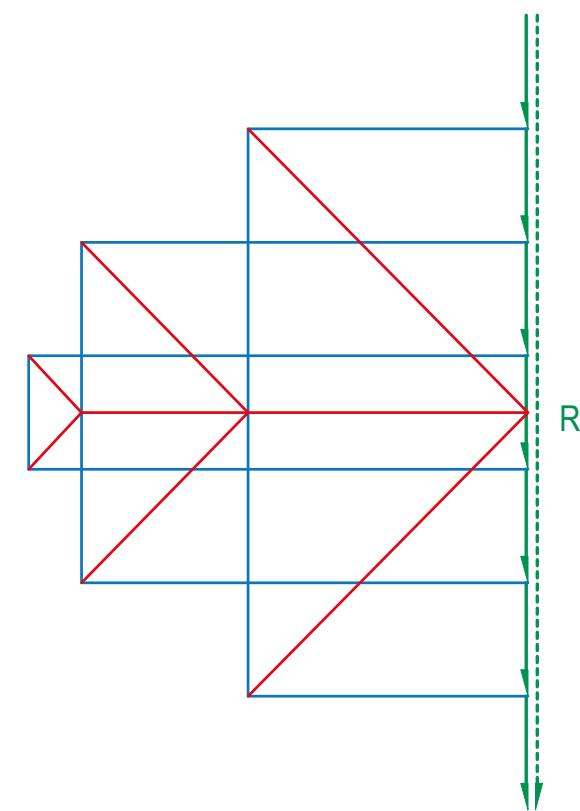
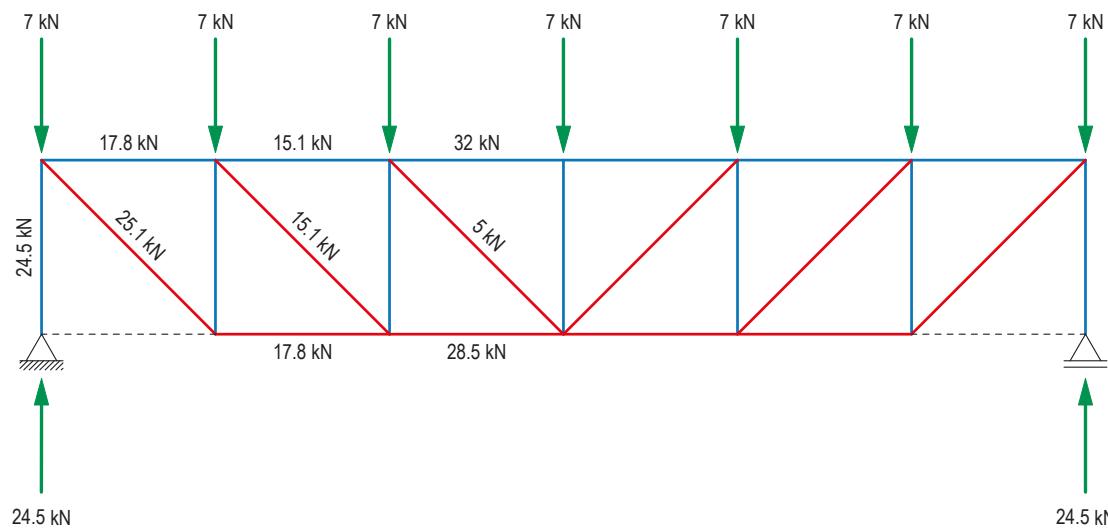


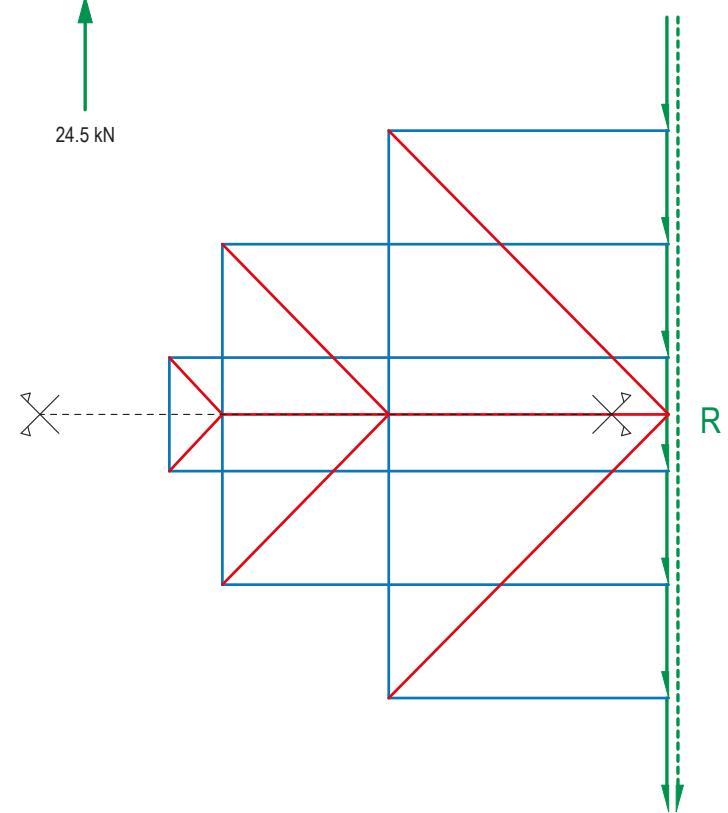
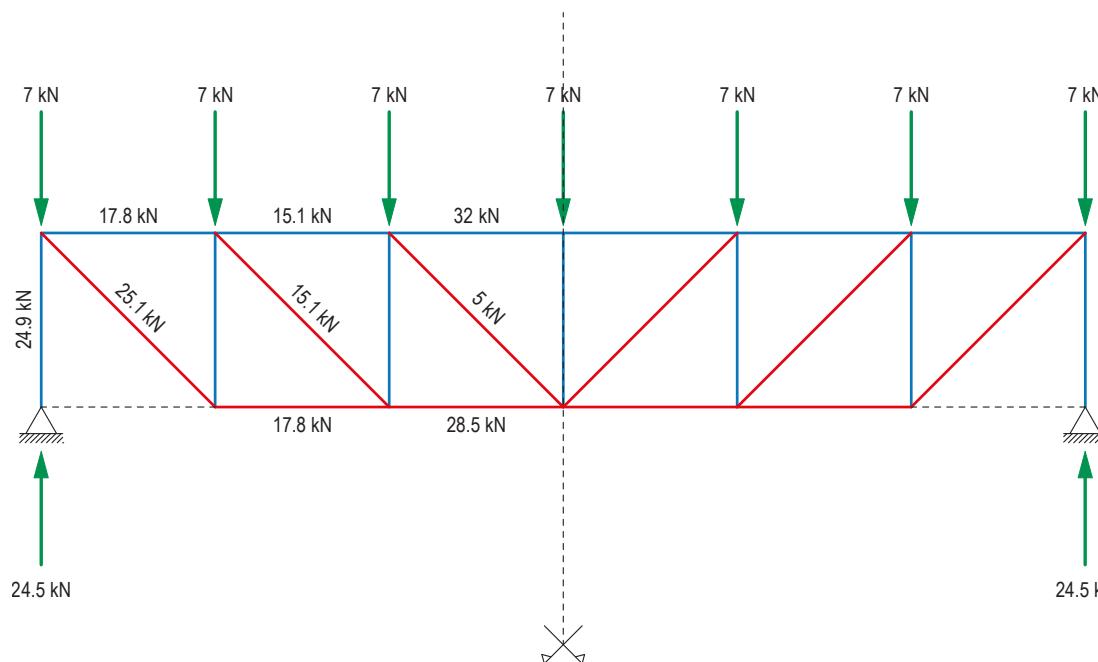


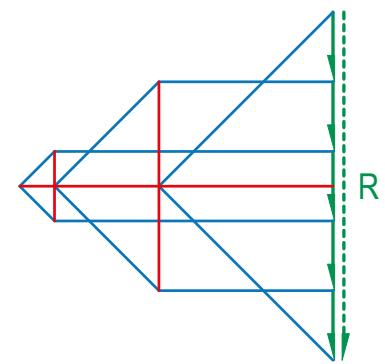
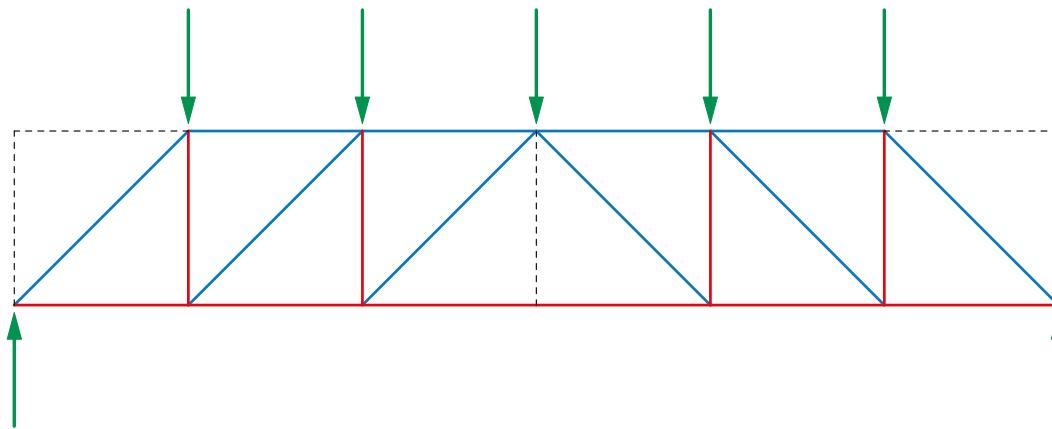
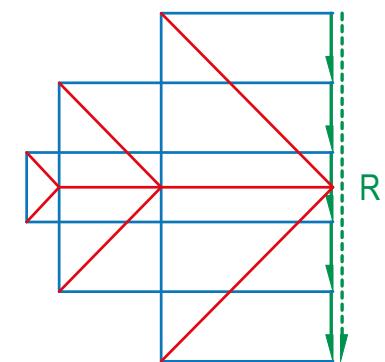
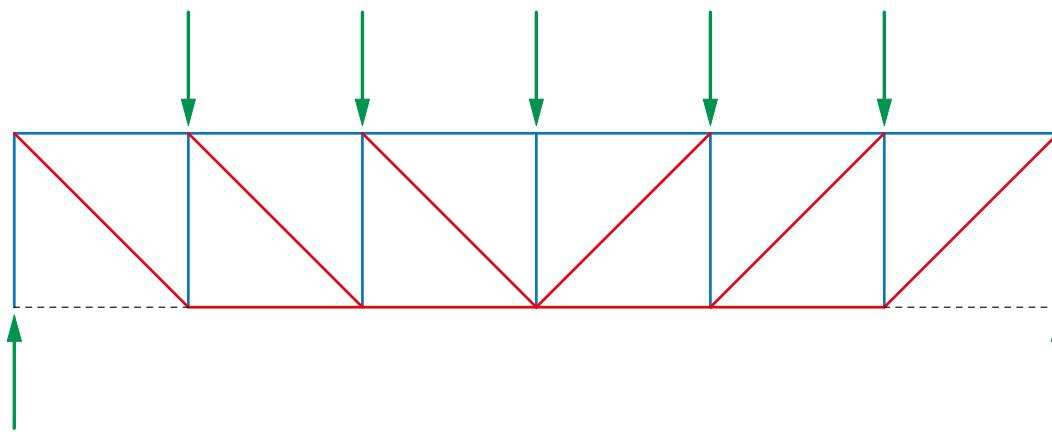


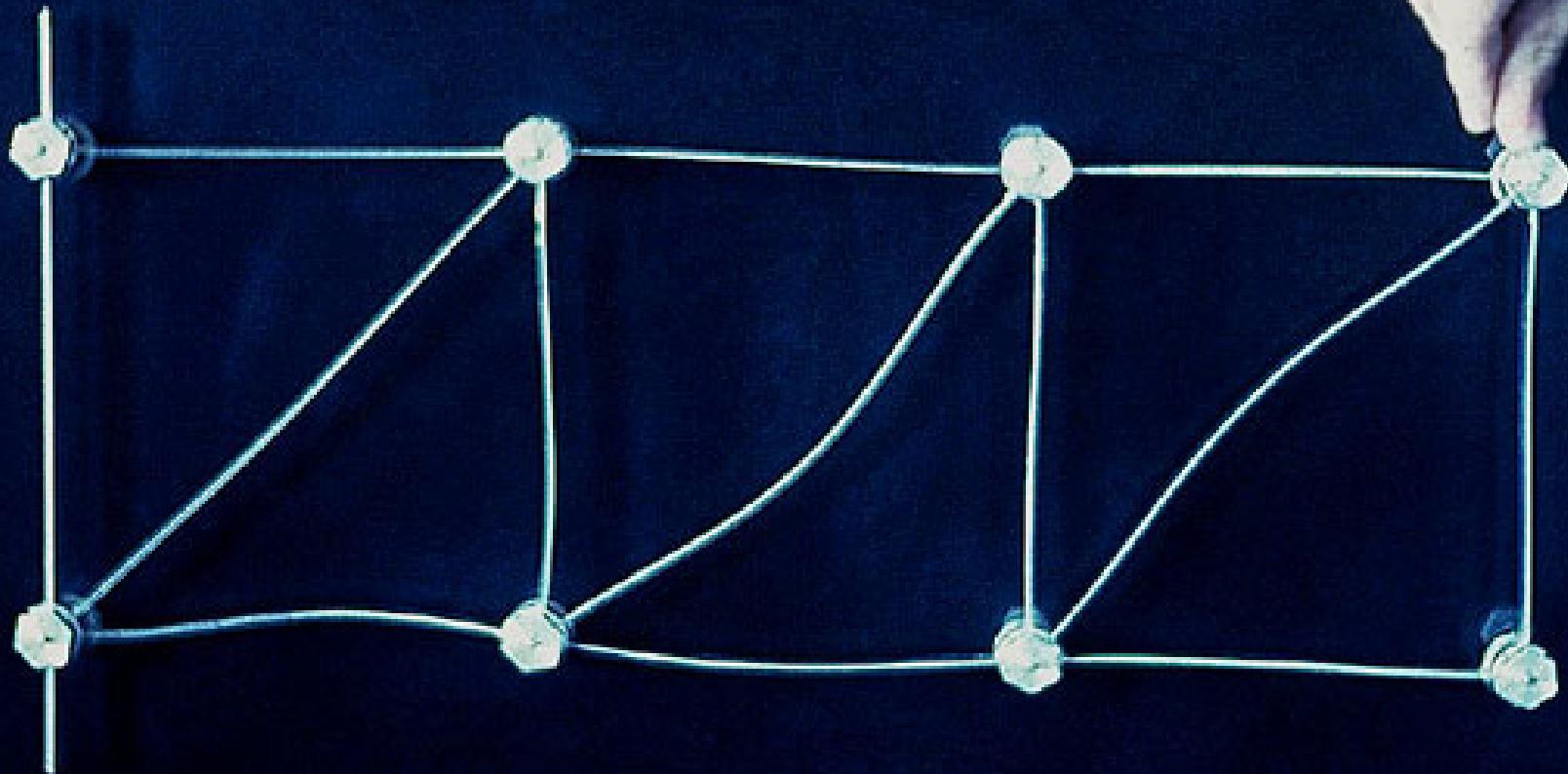


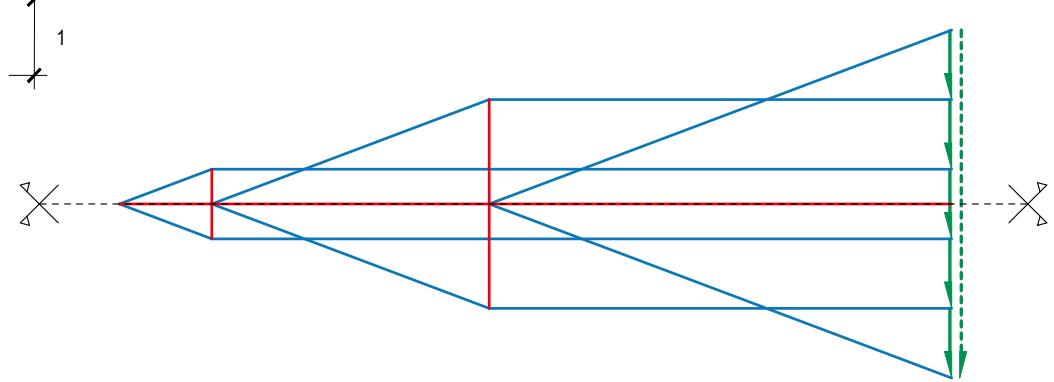
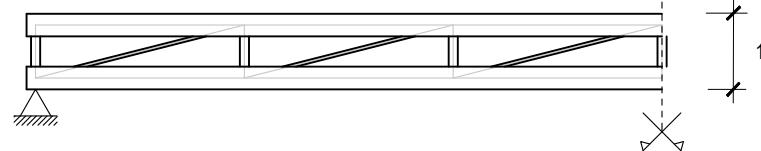
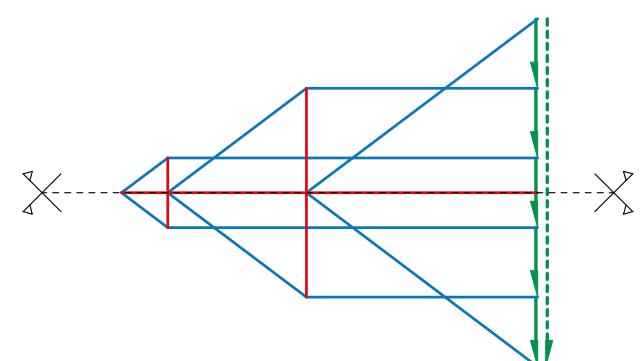
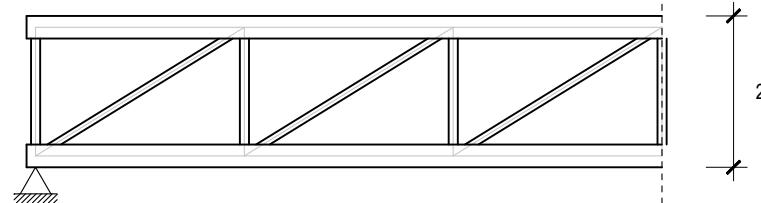
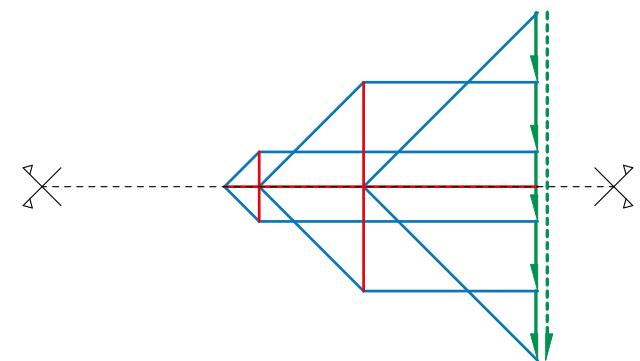
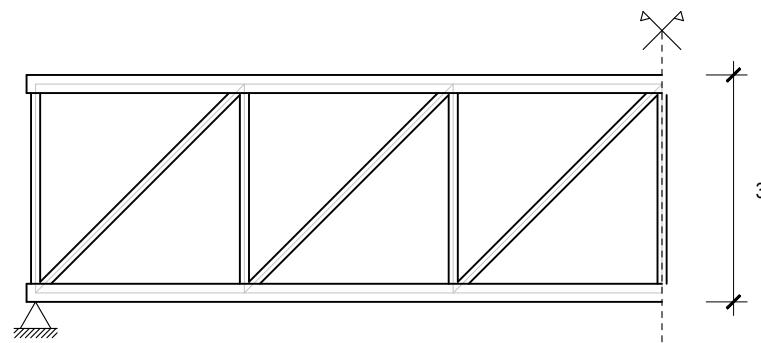












eQ

Pratt / Howe truss

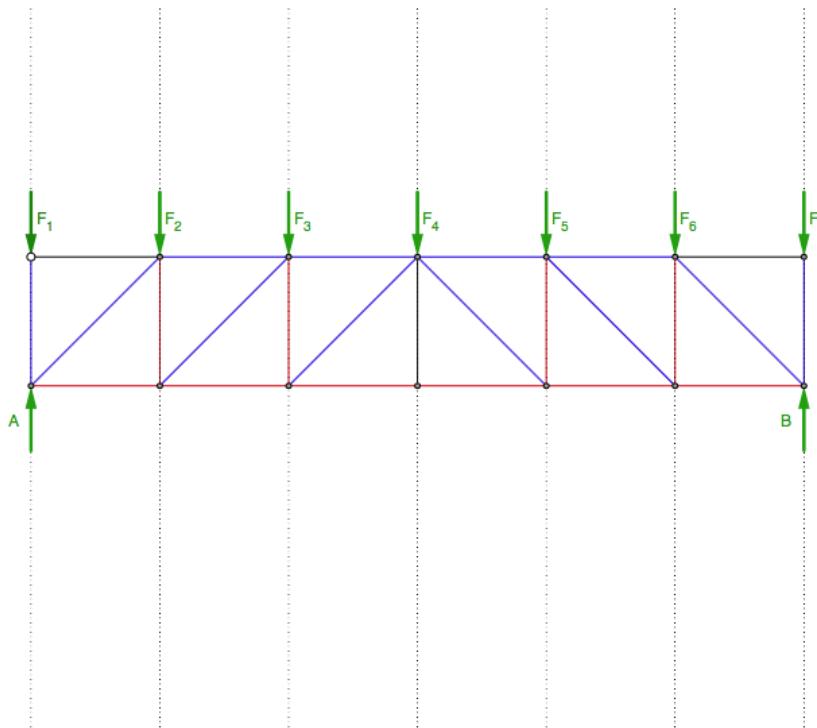
mode = 0

scales

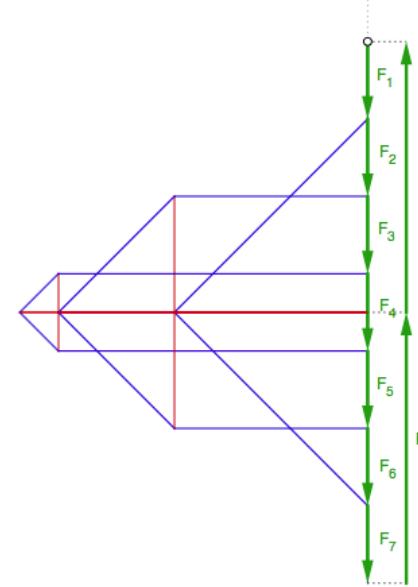
forces

show/hide

Form Diagram



Force Diagram



Howe / Pratt

offsetLoads = 0

offsetReactionForces = 0.6

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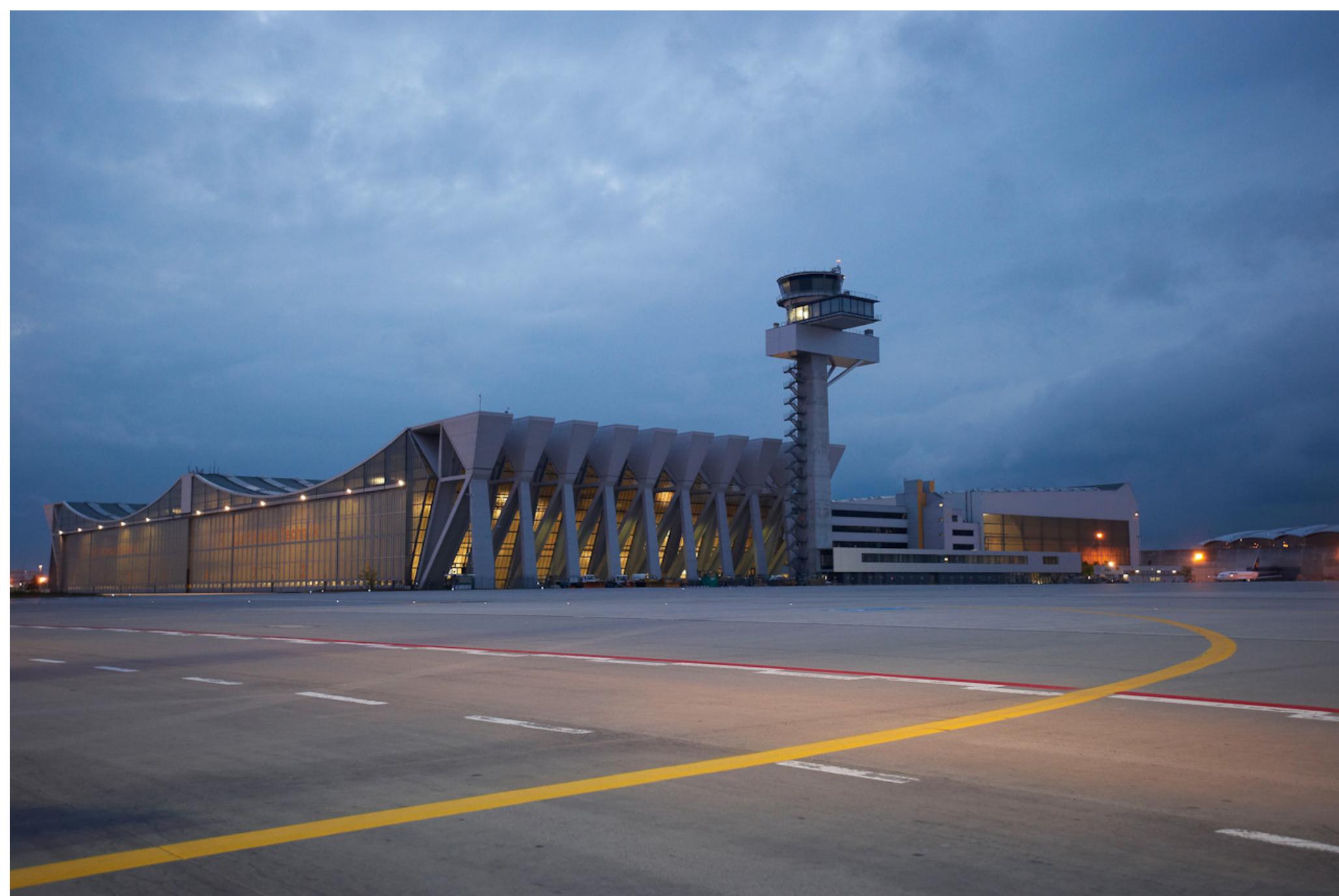
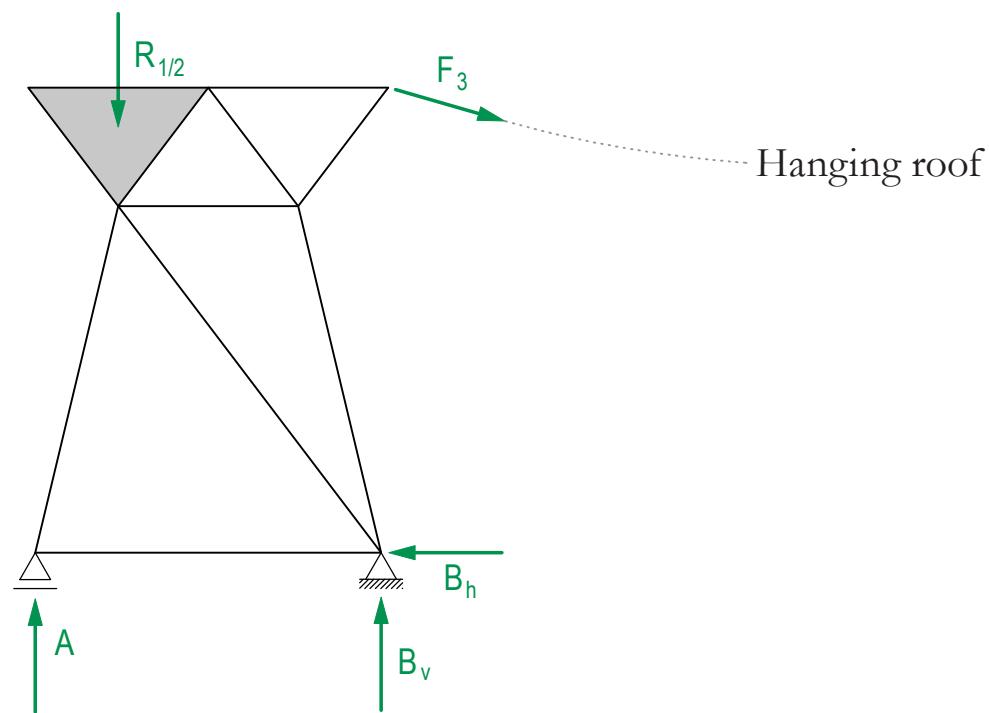
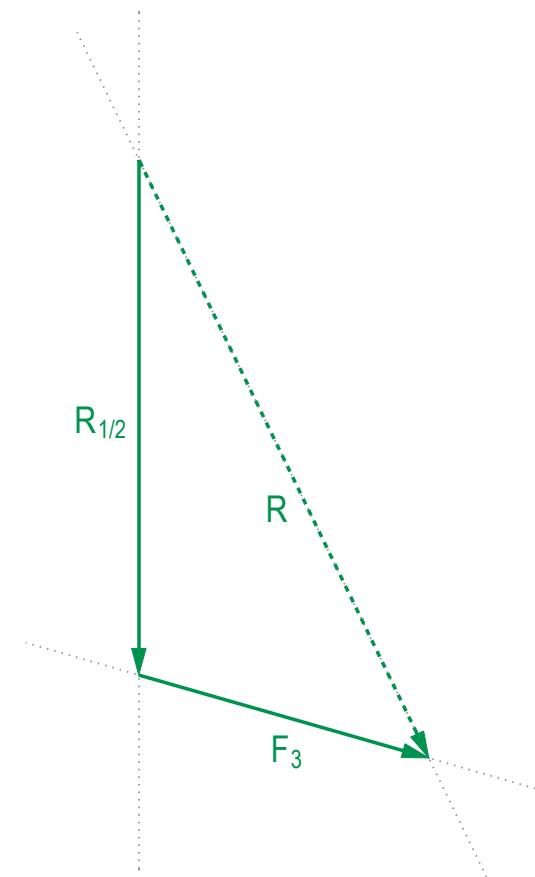
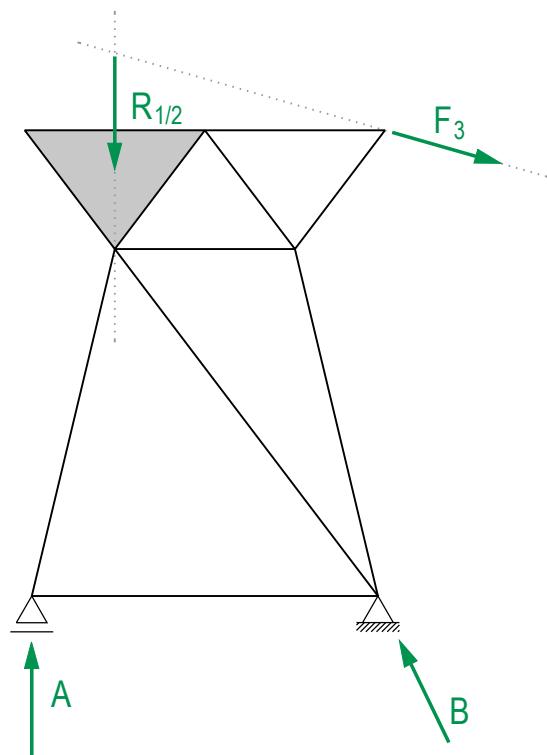
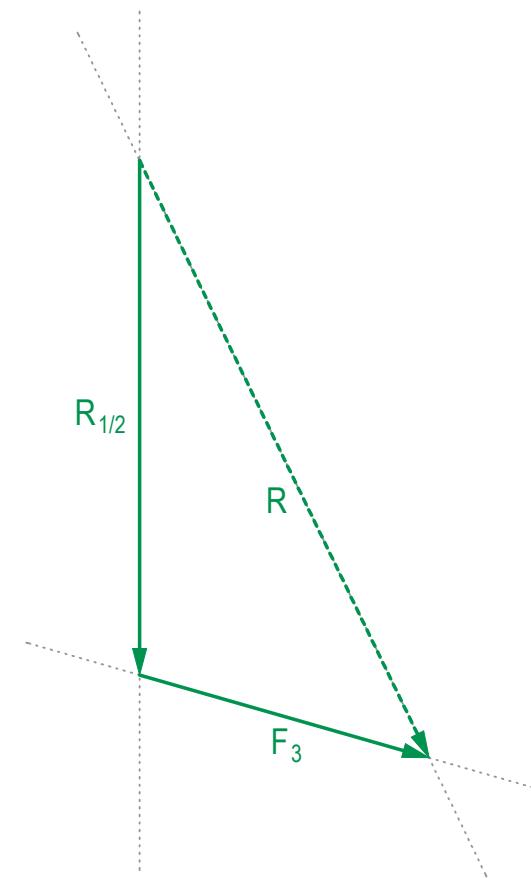
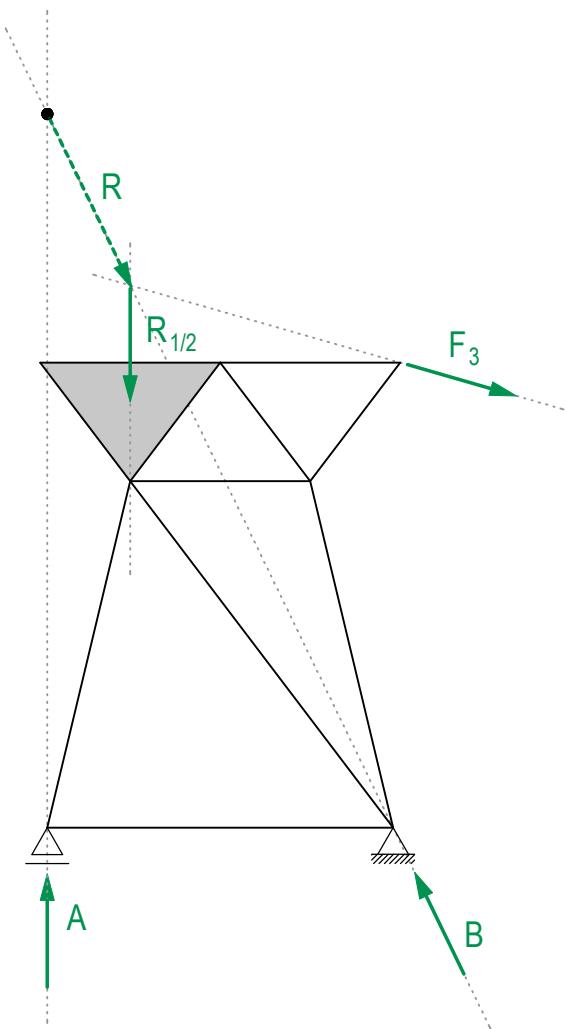
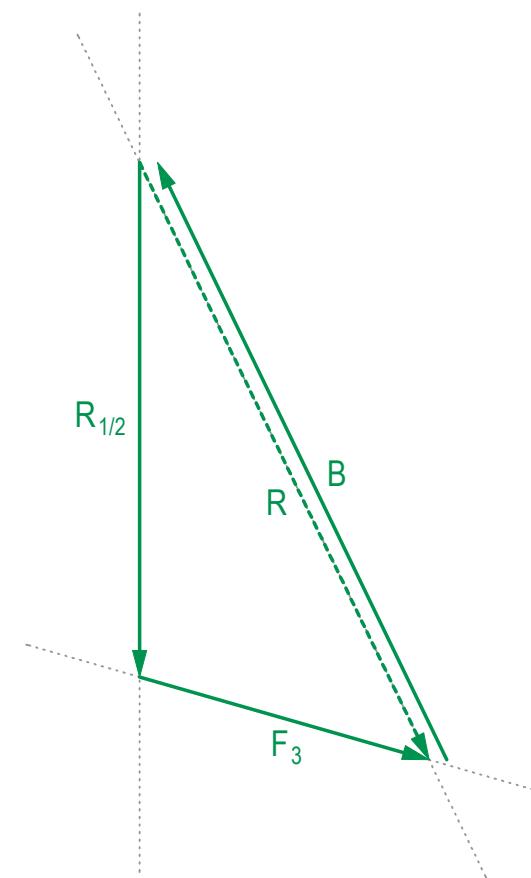
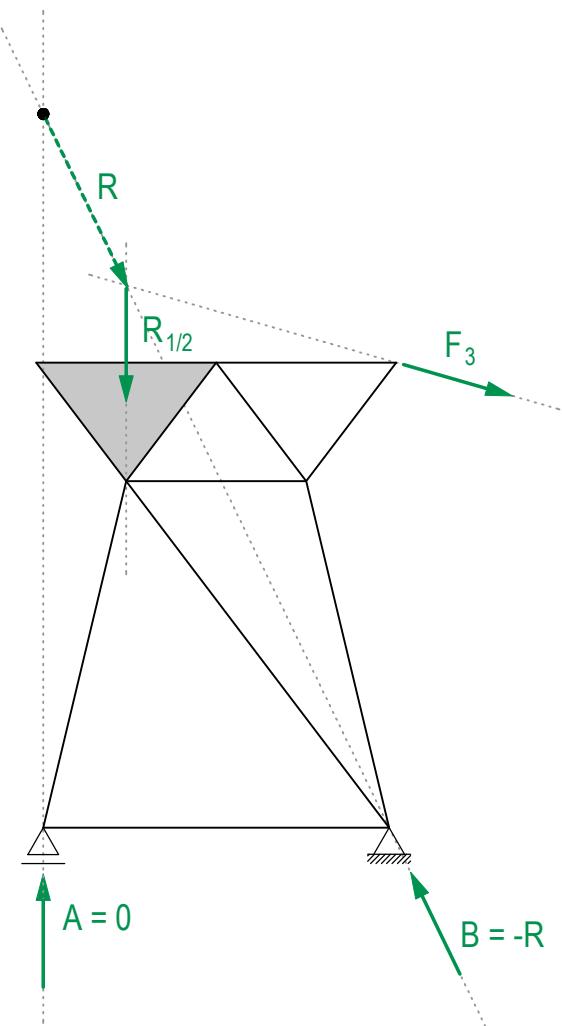


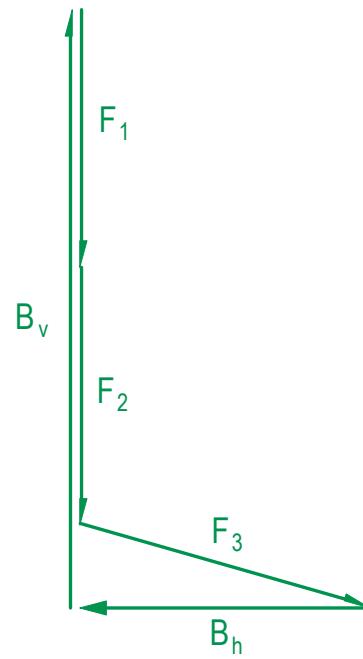
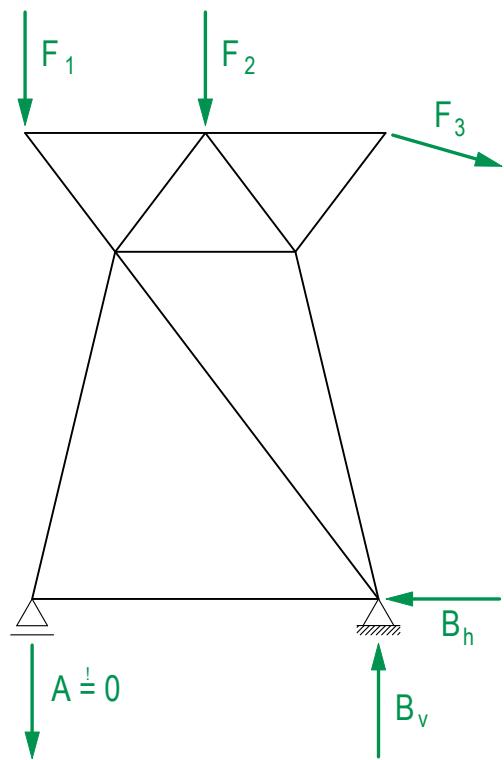
ABB Architects, Dyckerhoff & Widmann, Maintenance hall V, Frankfurt, 1972

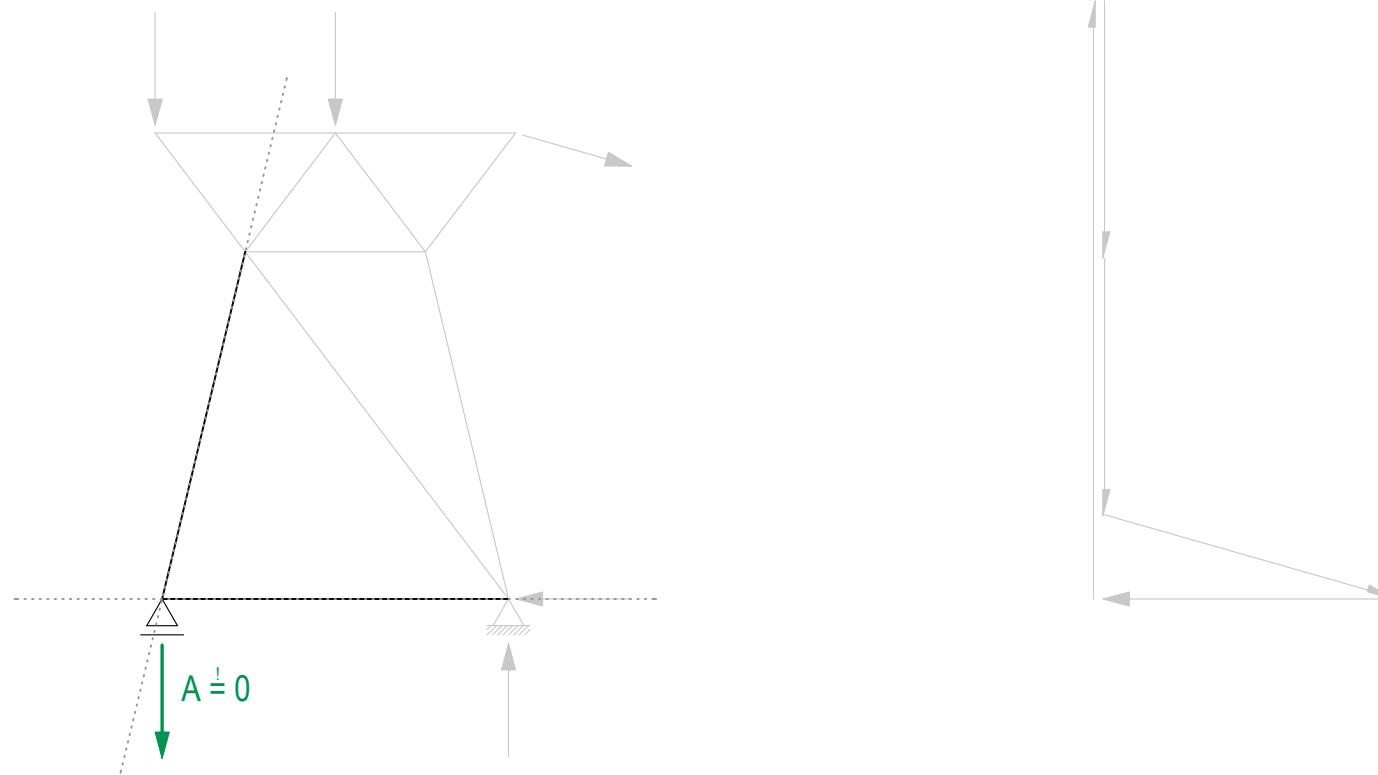


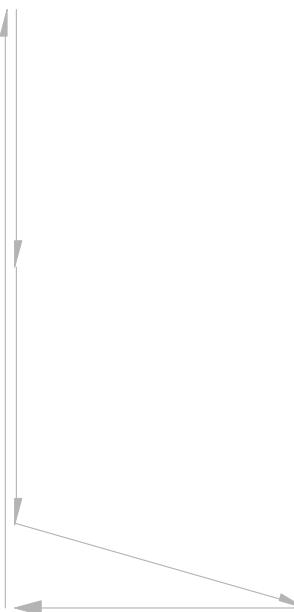
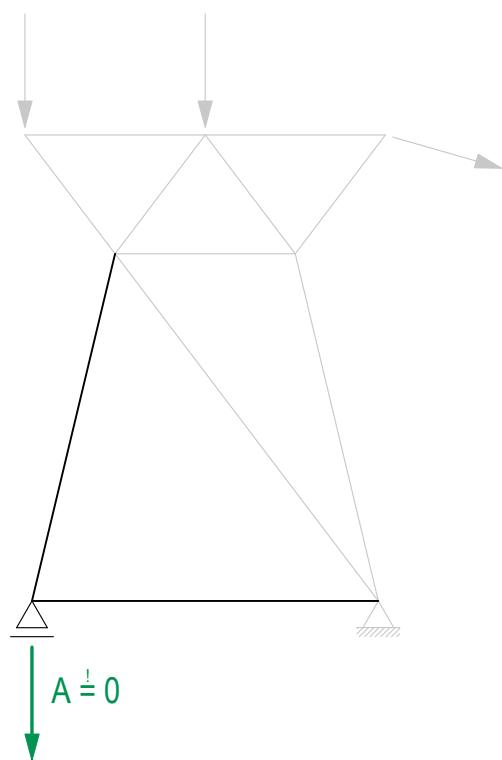


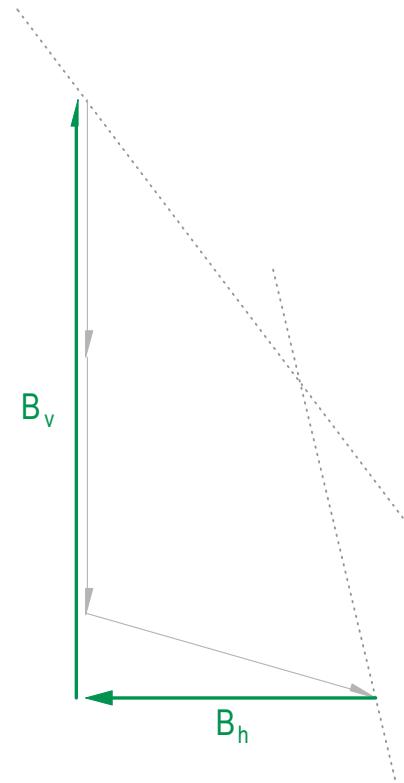
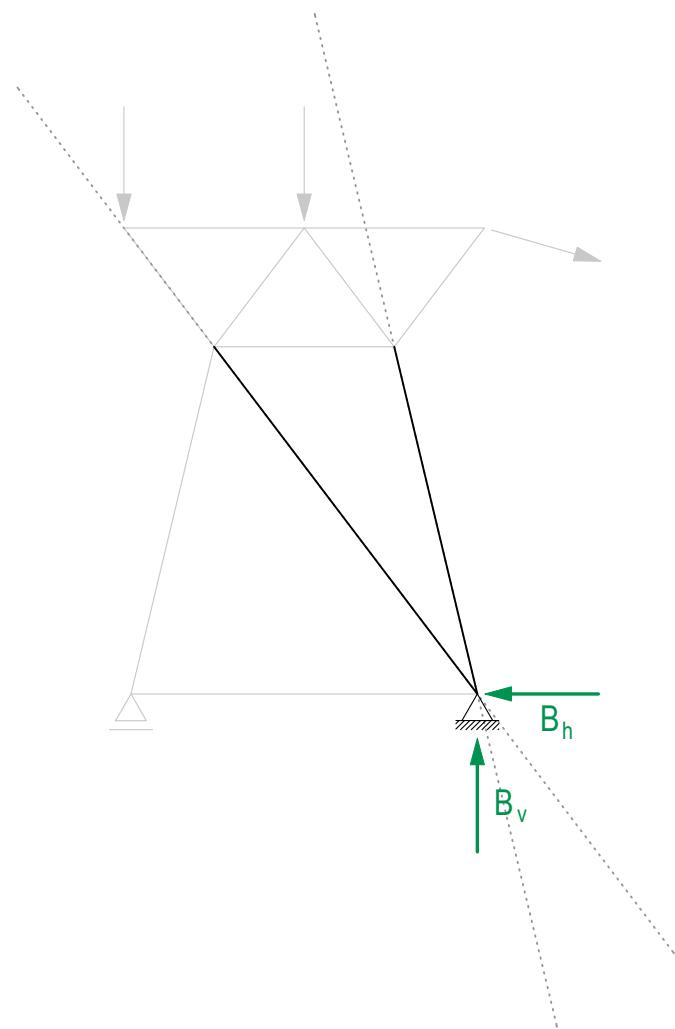


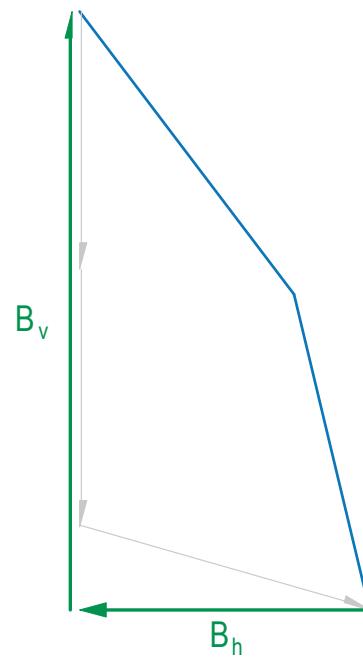
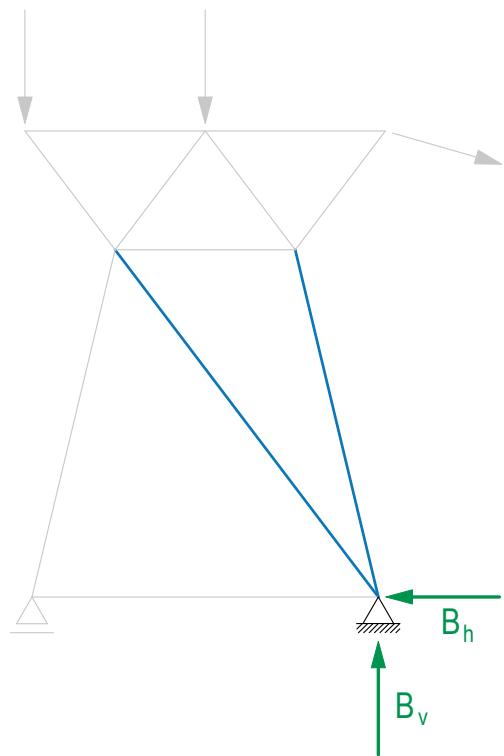


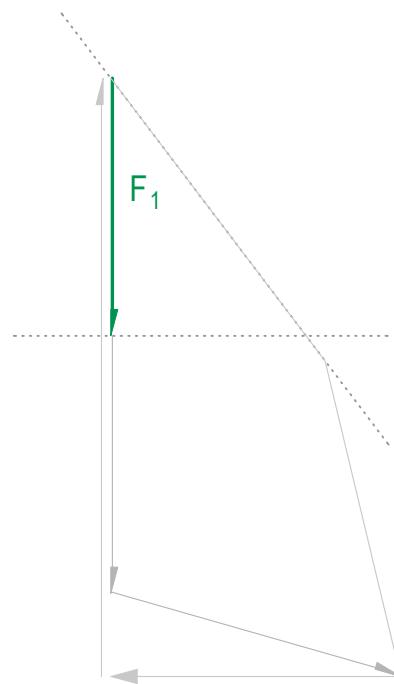
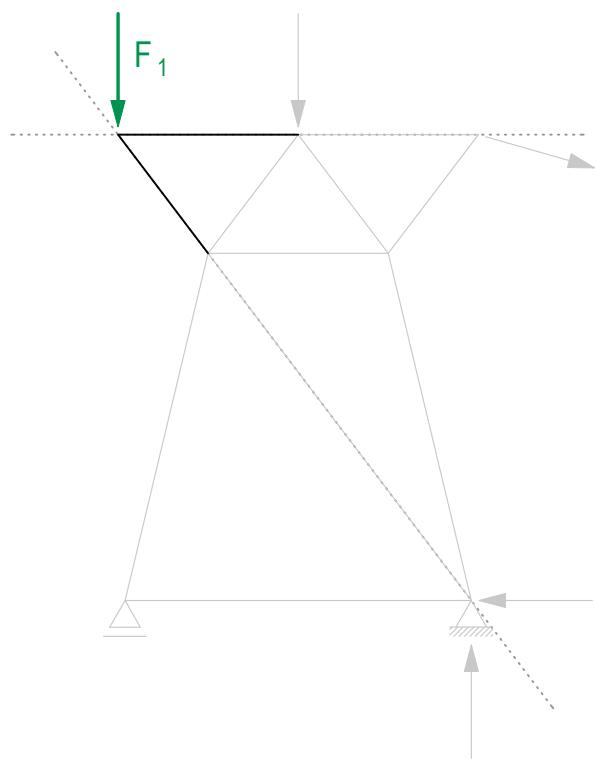


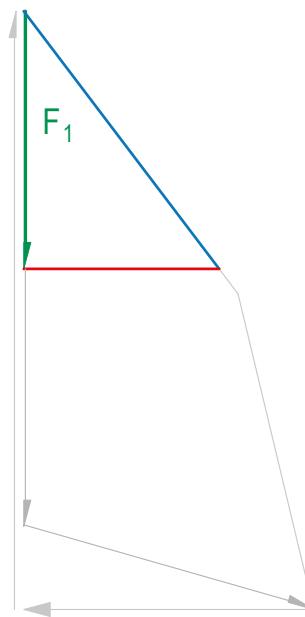
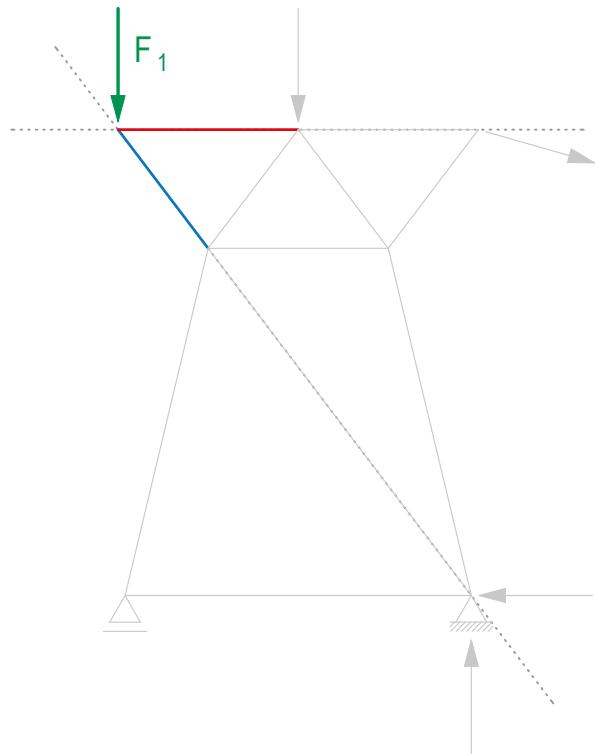


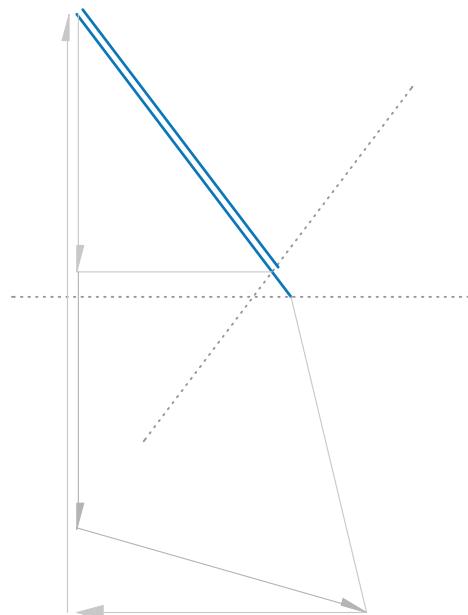
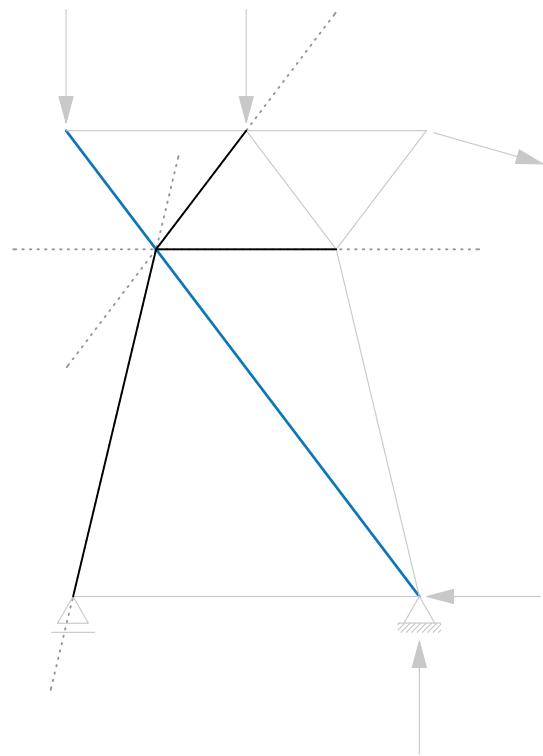


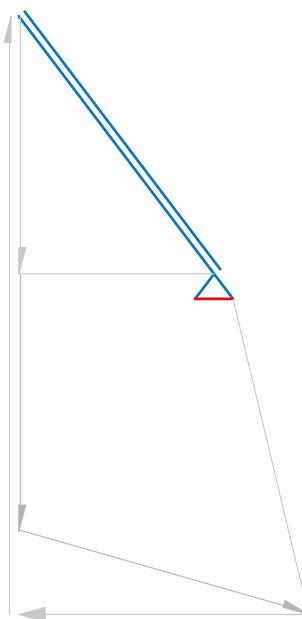
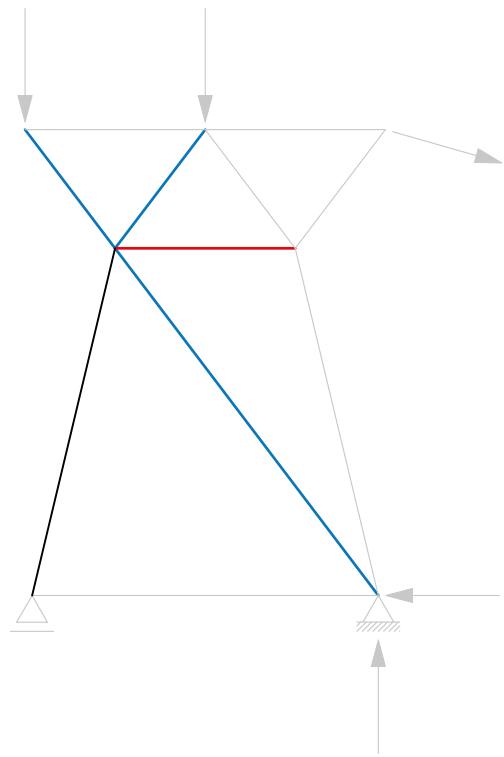


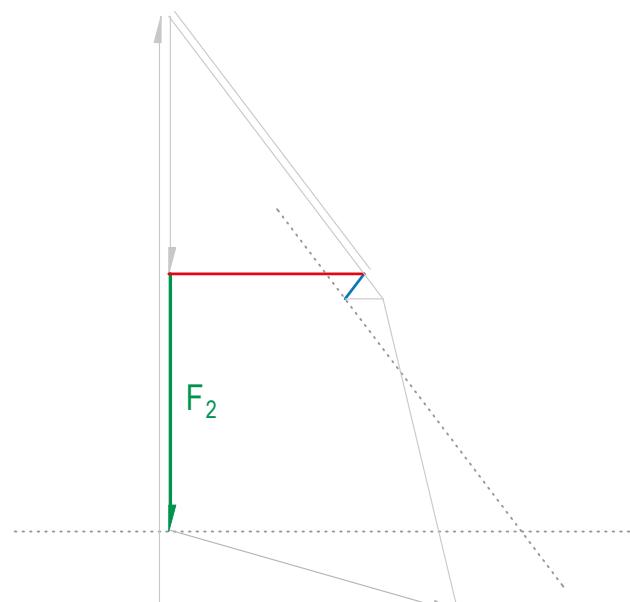
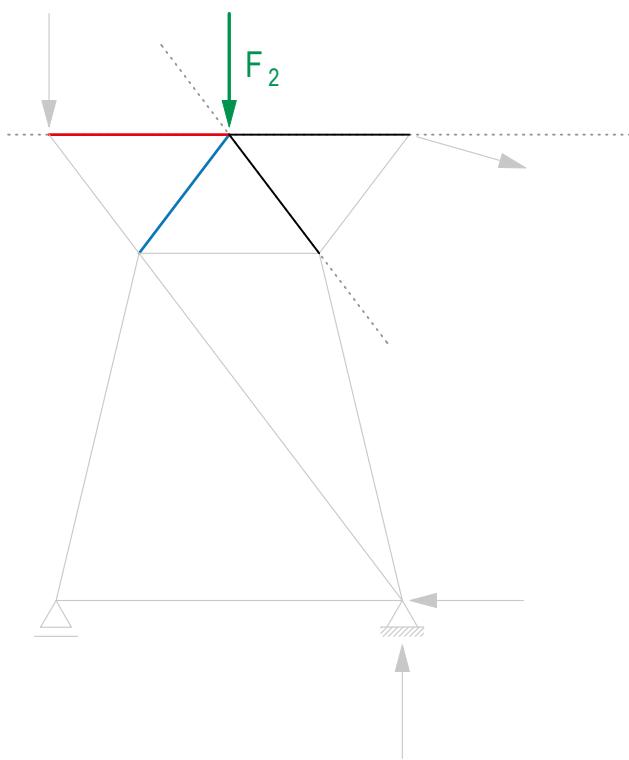


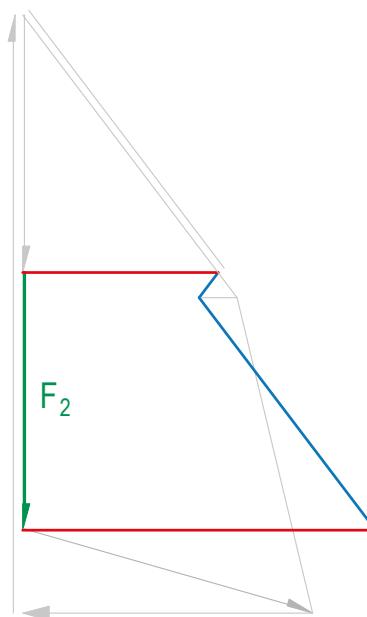
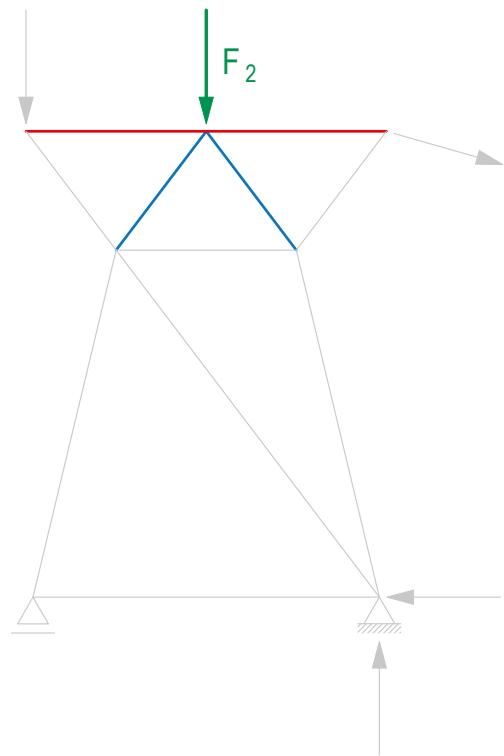


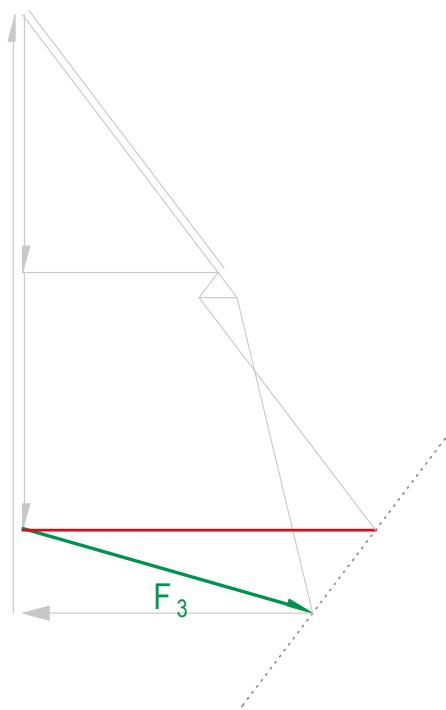
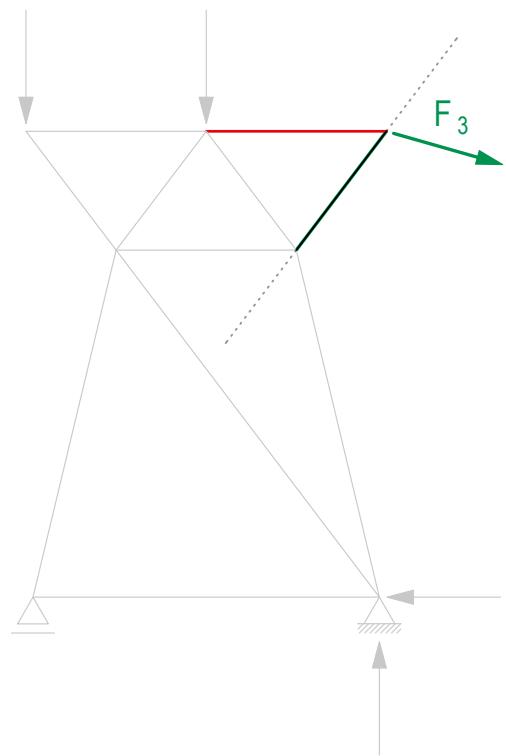


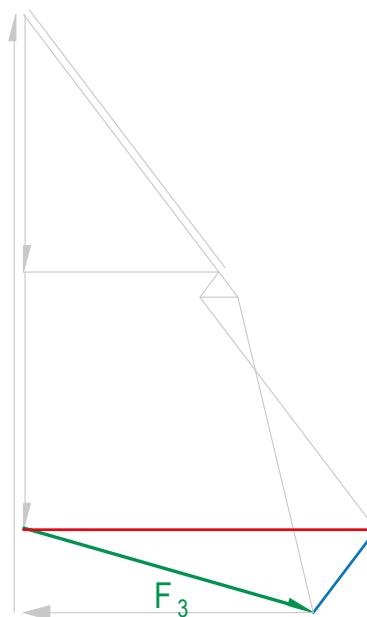
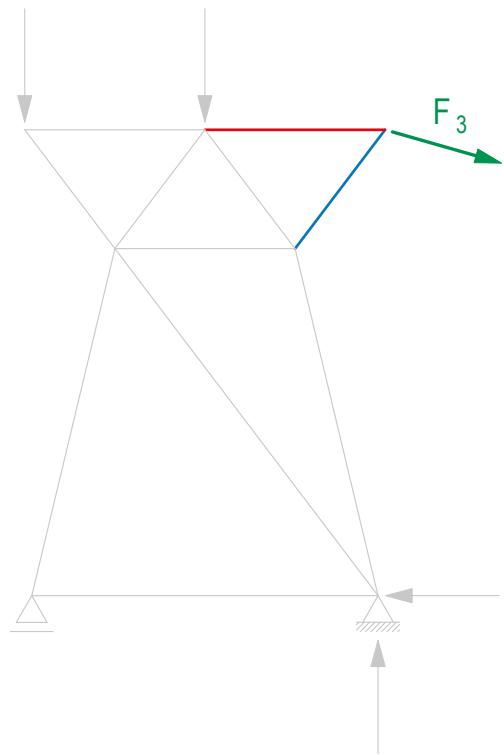


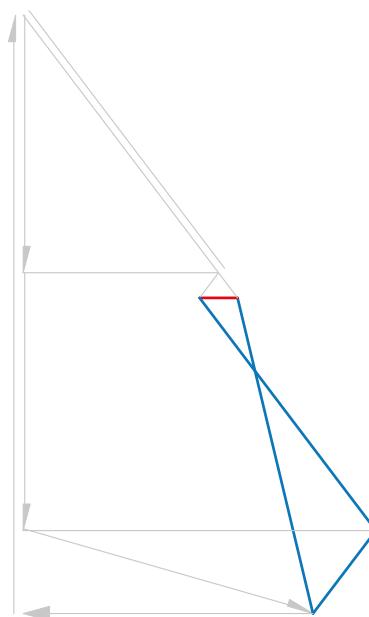
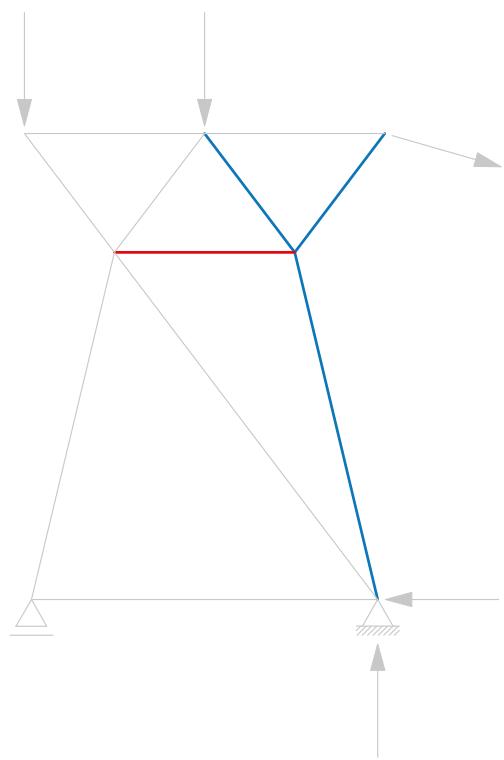


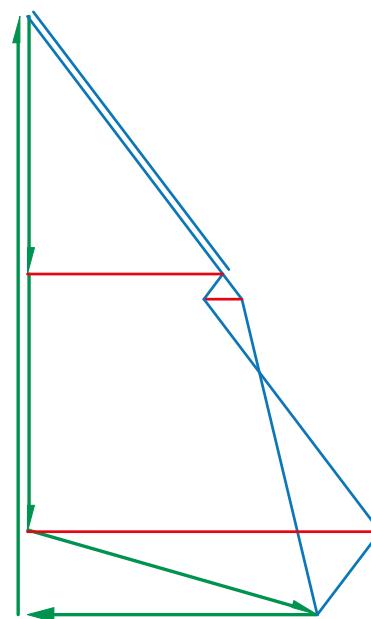
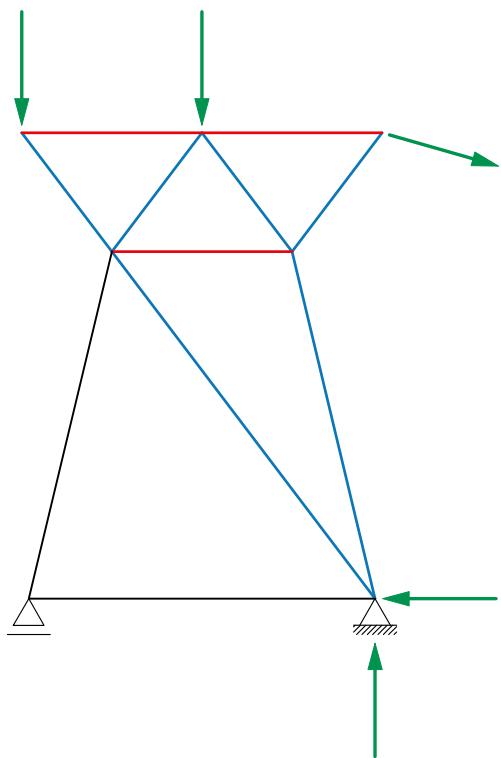


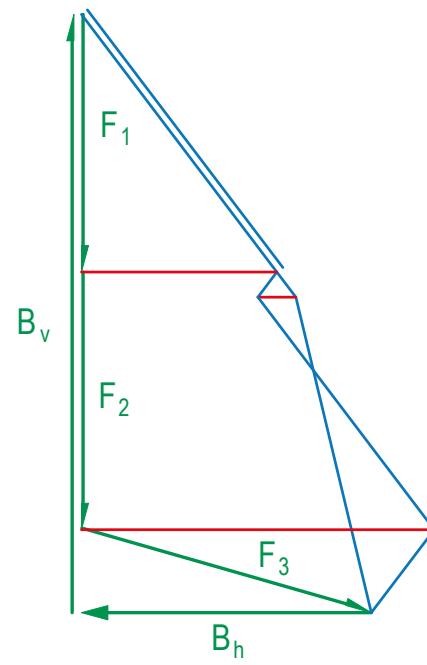
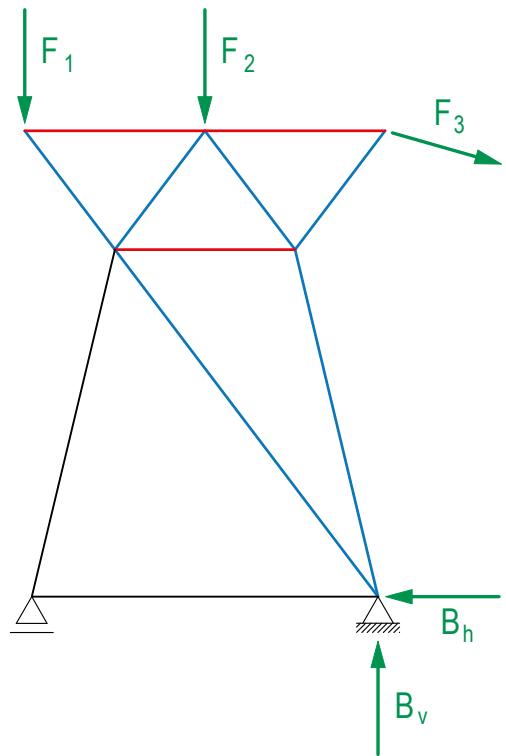


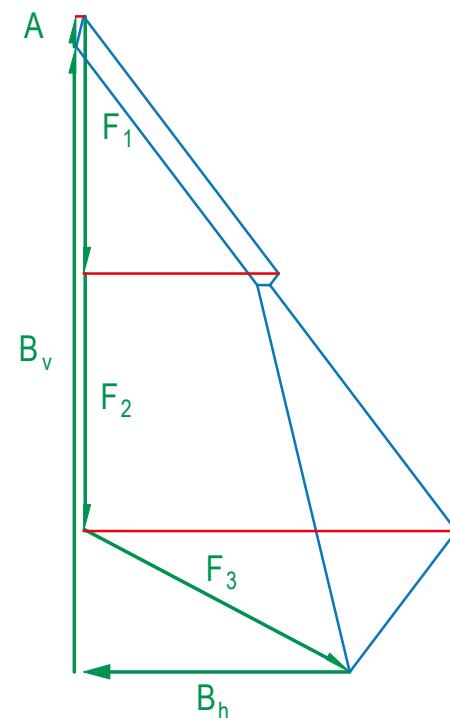
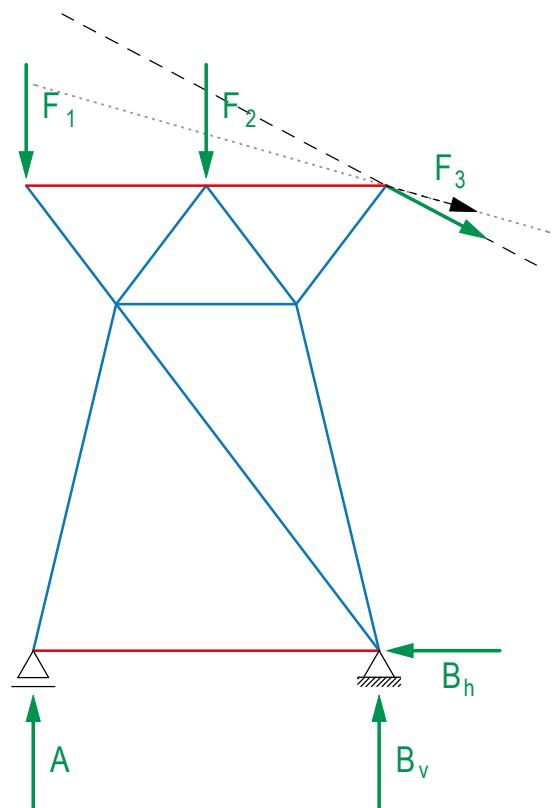










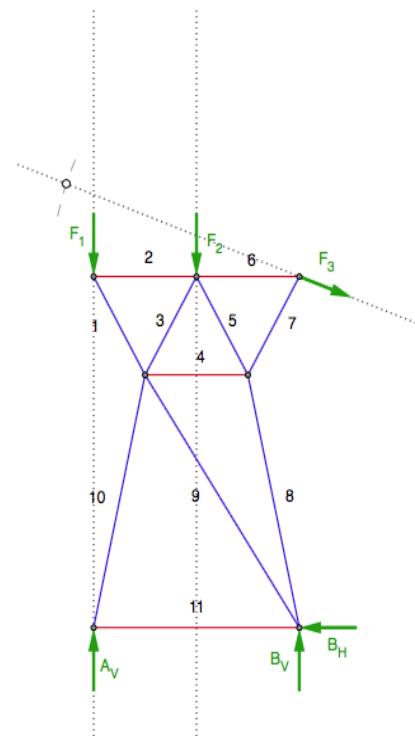
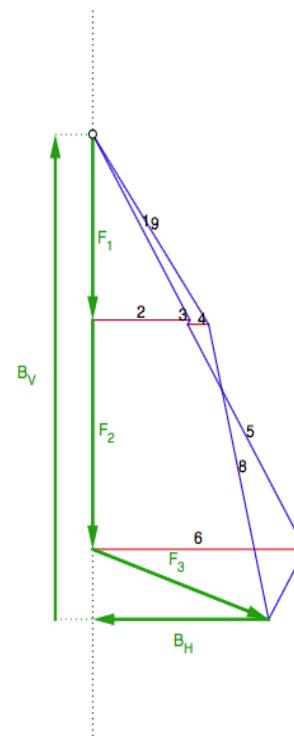


eQ

Lufthansa Hangar V

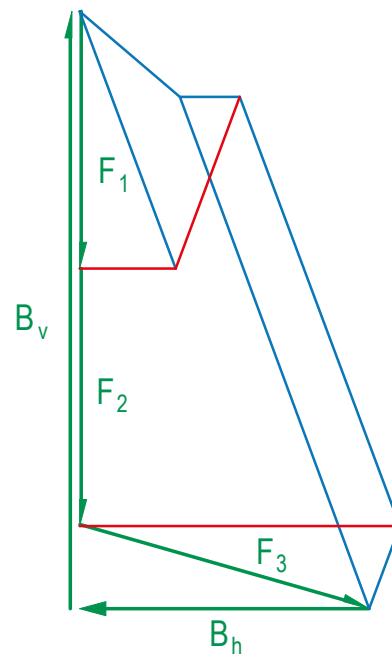
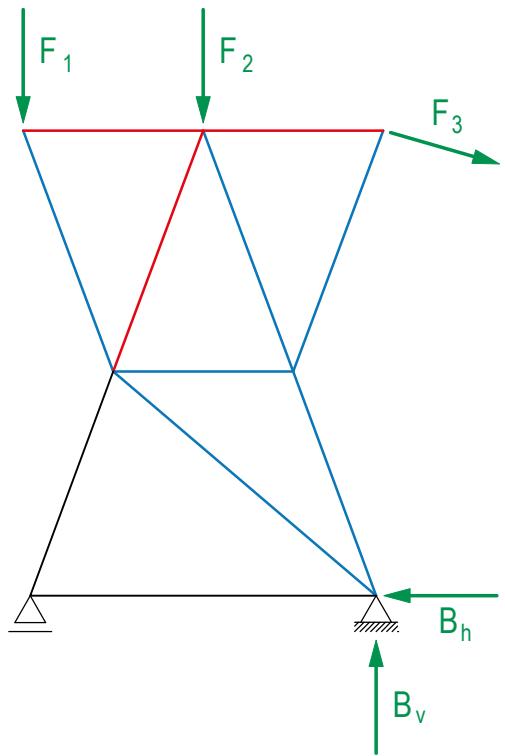
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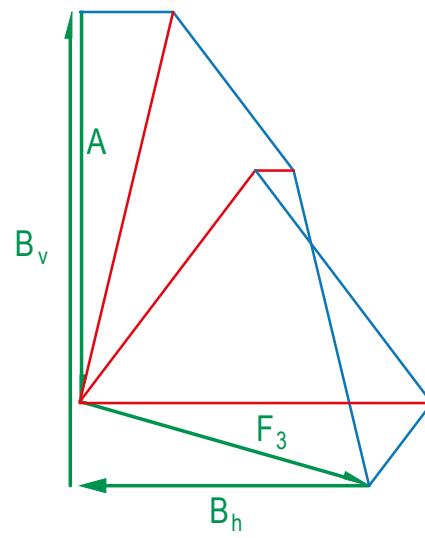
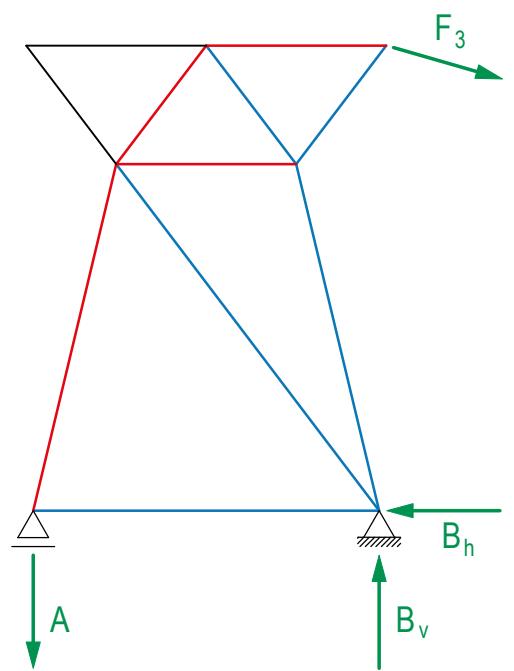
scales forces show/hide

Form Diagram
1 unit :: 1mForce Diagram
1 unit :: 50 kN

offsetReactionForces = 4

ChangeGeometryofTruss = 11





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Arch-cable structures: Tree structures

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Analysis of trusses

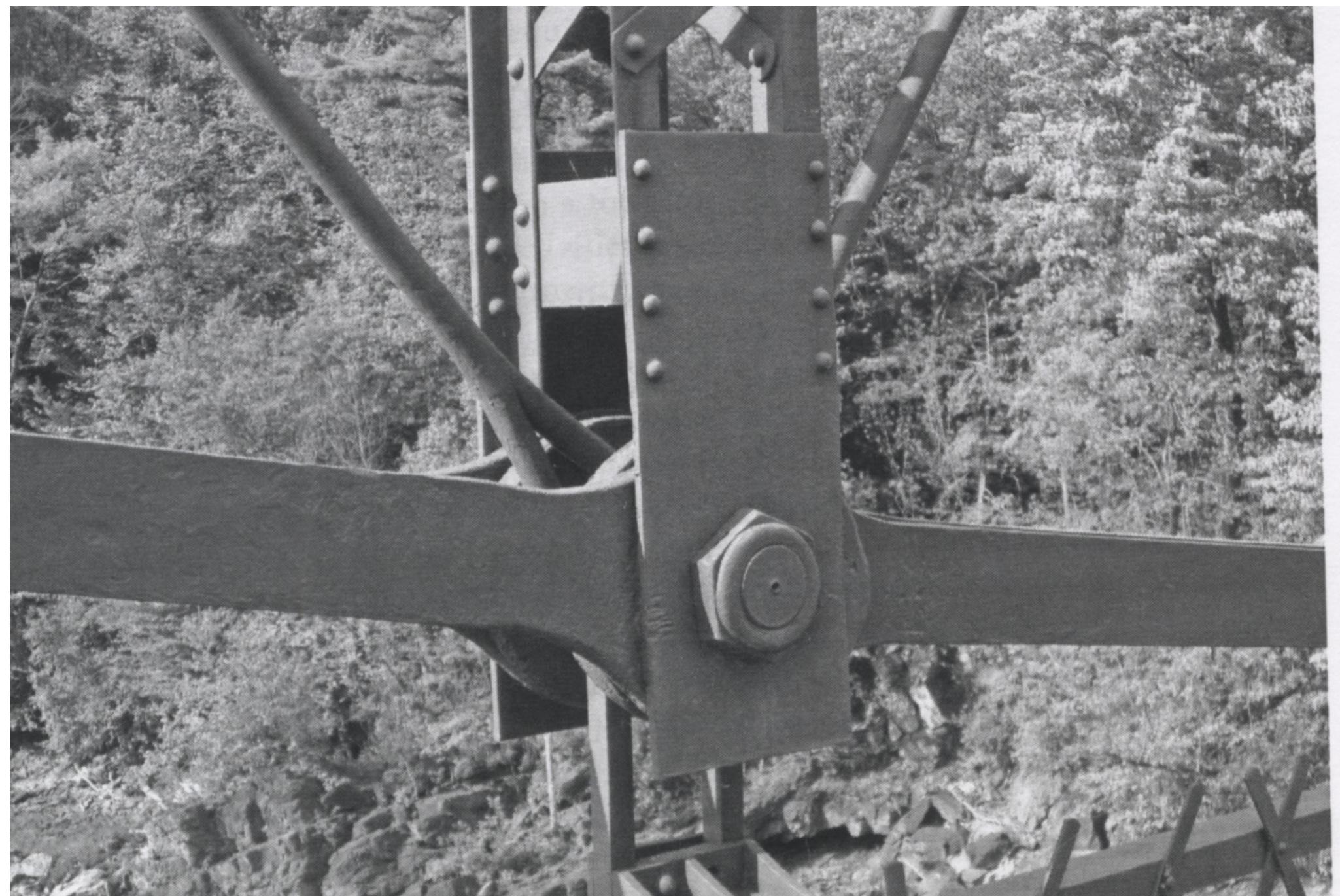
Case study: Lufthansa maintenance hall V

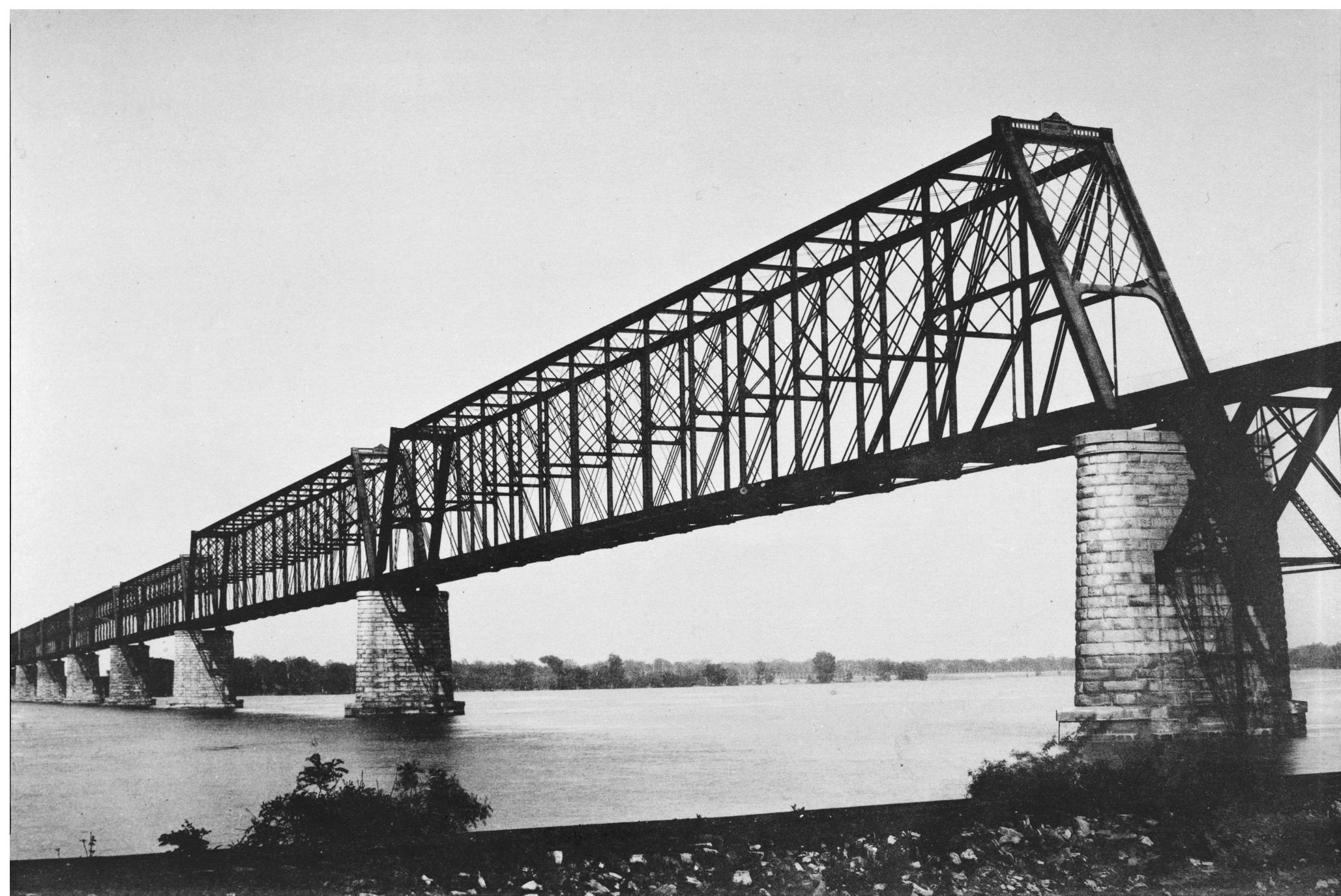
>> Construction of trusses



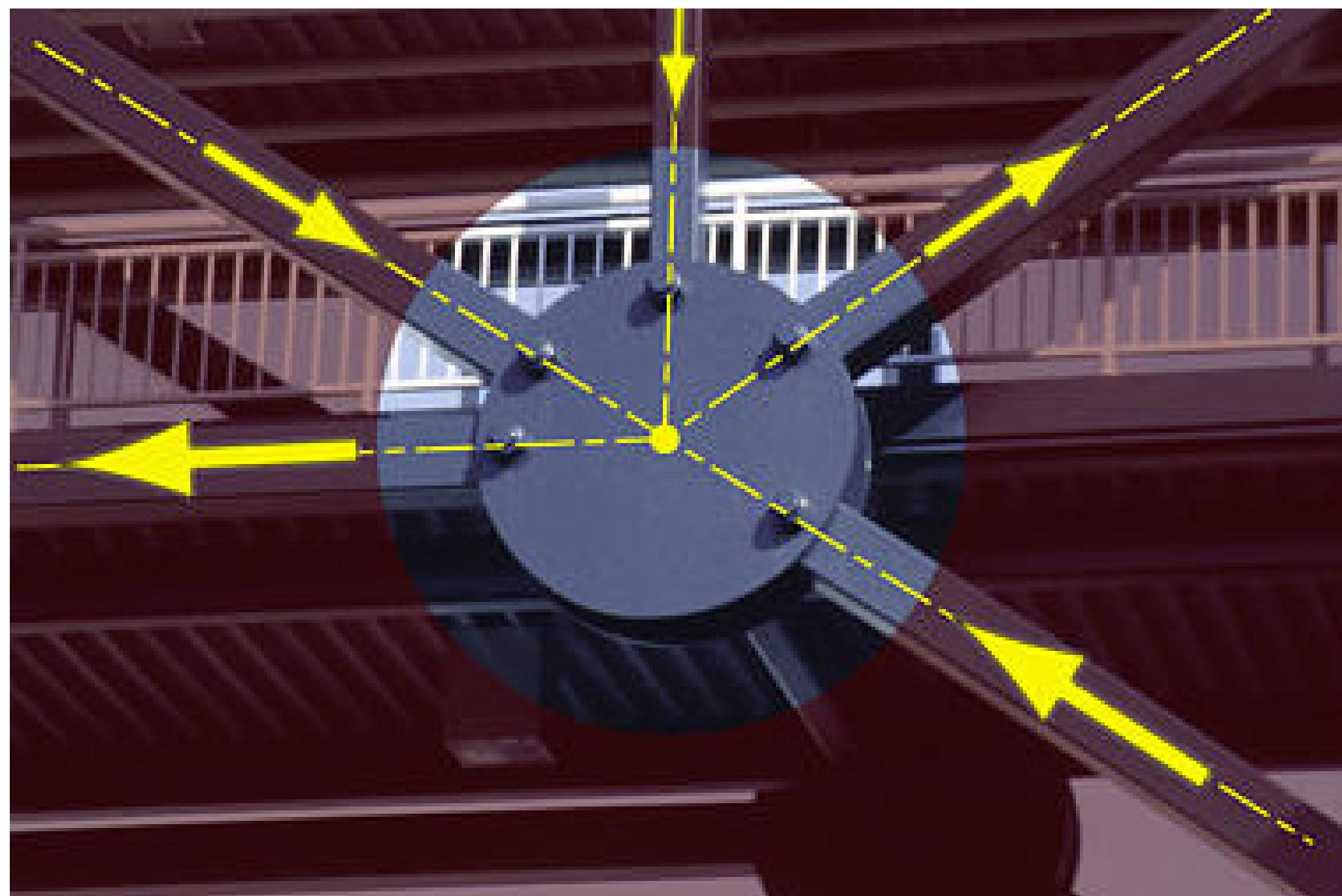
Gustav Eiffel, Theophile Seyring: Maria Pia bridge, Porto, 1877







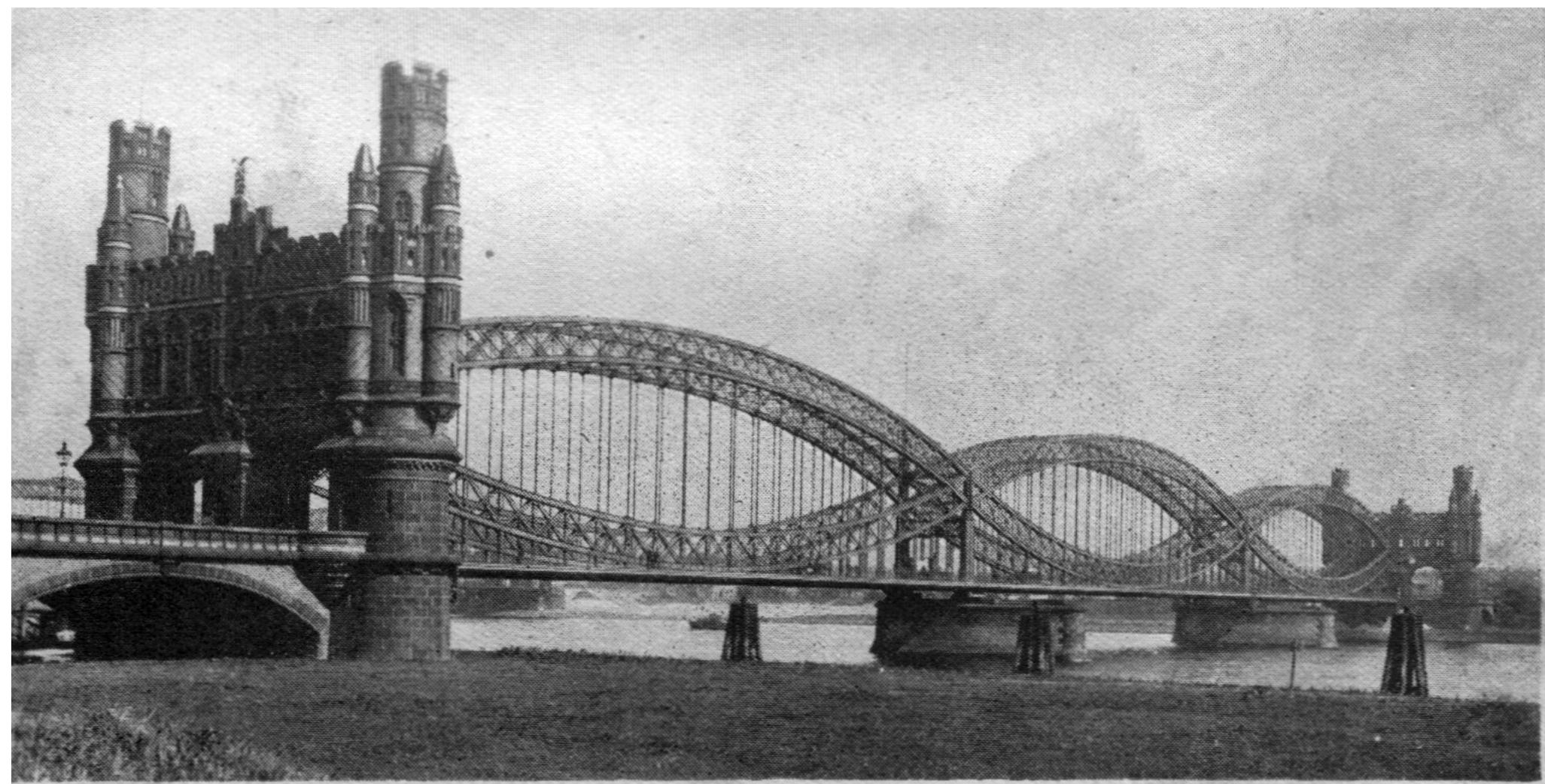
Squire Whipple, Cairo Rail Bridge, Illinois, USA, 1899



Squire Whipple, Cairo Rail Bridge, Illinois, USA, 1899



Friedrich August von Pauli, Heinrich Gerber, Ludwig Werder: Isarbridge, Grosshesselohe, Germany, 1857



G. H. Lohse: Elbebridge, Hamburg, 1868



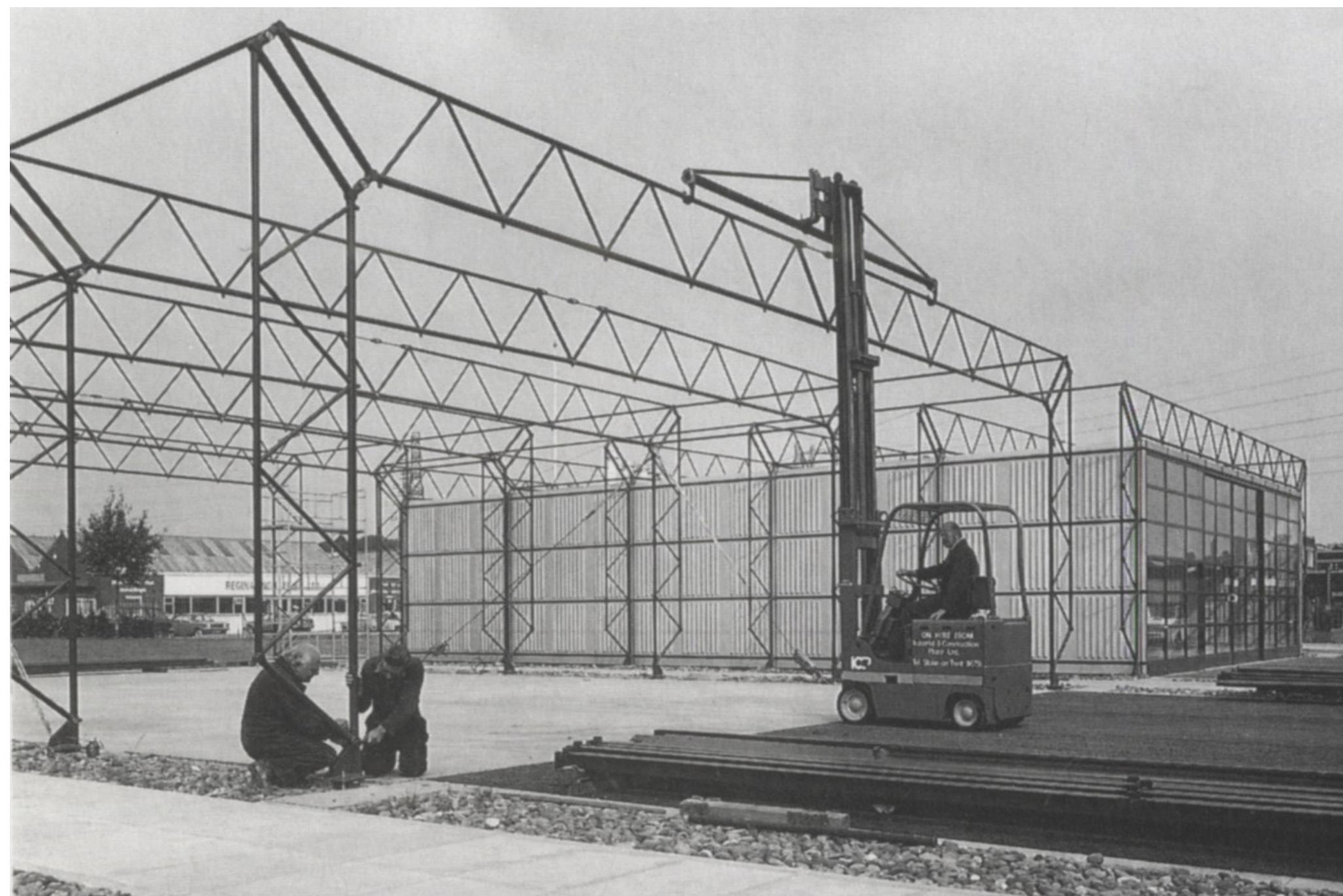
Sir Horace Jones, Sir John Wolfe Barry: Tower Bridge, London, 1894



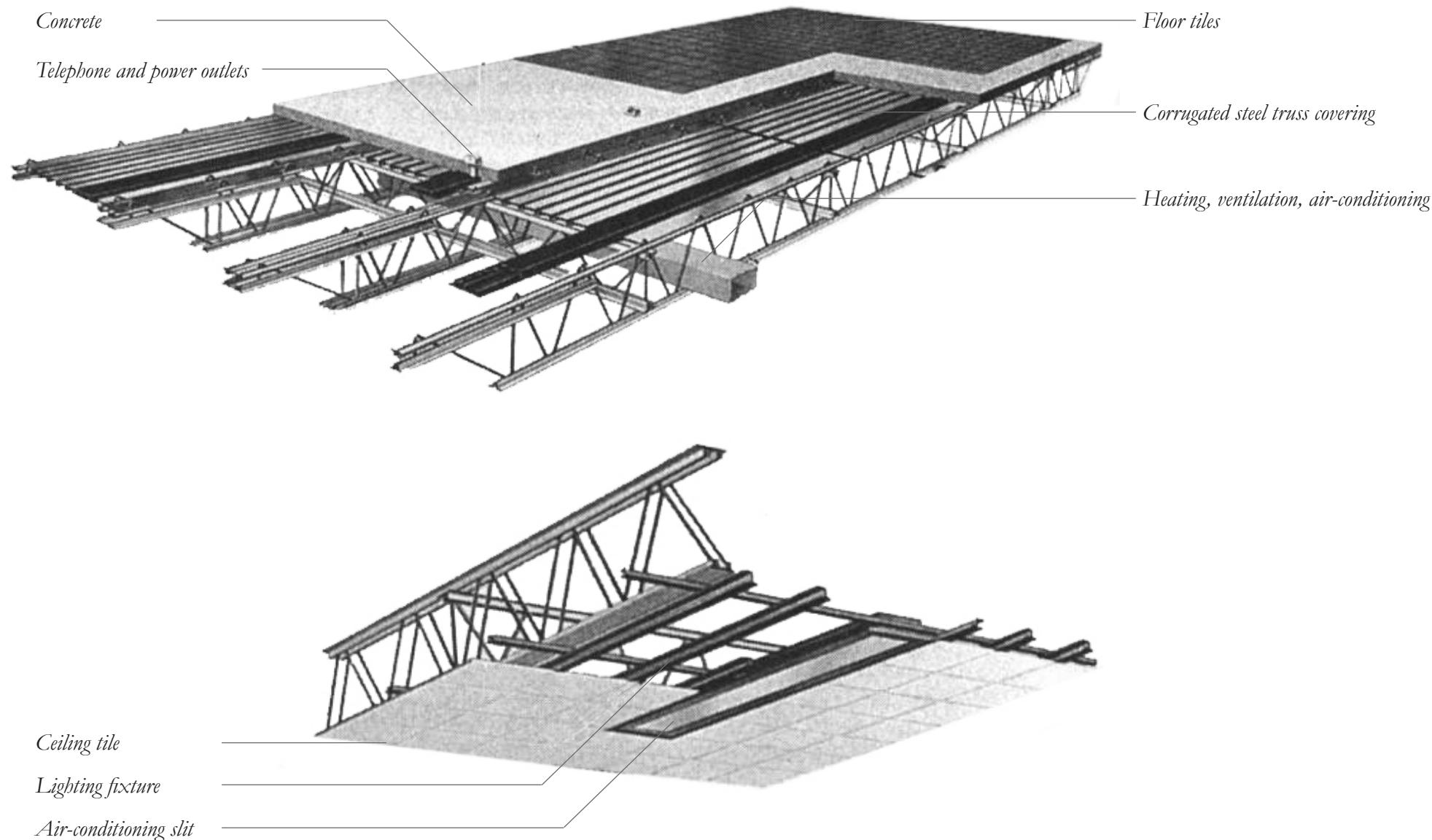
Office Eiffel, Maurice Koechlin: Eiffel tower, Paris, 1889



Sir John Fowler, Benjamin Baker, Firth of Forth Bridge, Edinburgh, 1890



Michael Hopkins, Anthony Hunt, Mark Whitby: Patera Building, Stoke on Trent, 1982

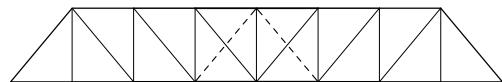




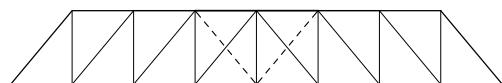
William Pereira, Chin&Hensolt: Transamerica Tower, San Francisco, 1972



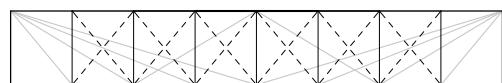
William Pereira, Chin&Hensolt: Transamerica Tower, San Francisco, 1972



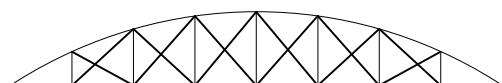
Pratt



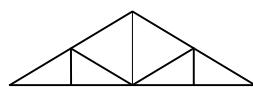
Howe



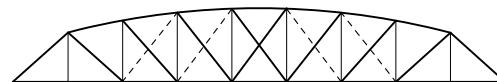
Fink



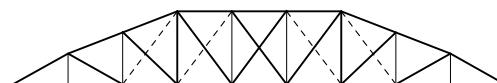
Bowstring



Waddell "A" Truss



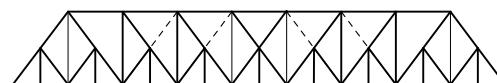
Parker



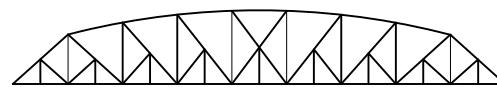
Camelback



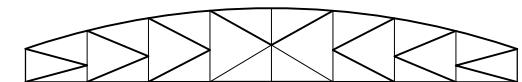
Double Intersection Pratt



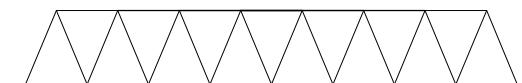
Baltimore



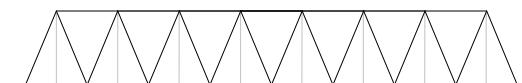
Pennsylvania



K-Truss



Warren



Warren (with Verticals)



Double Intersection Warren

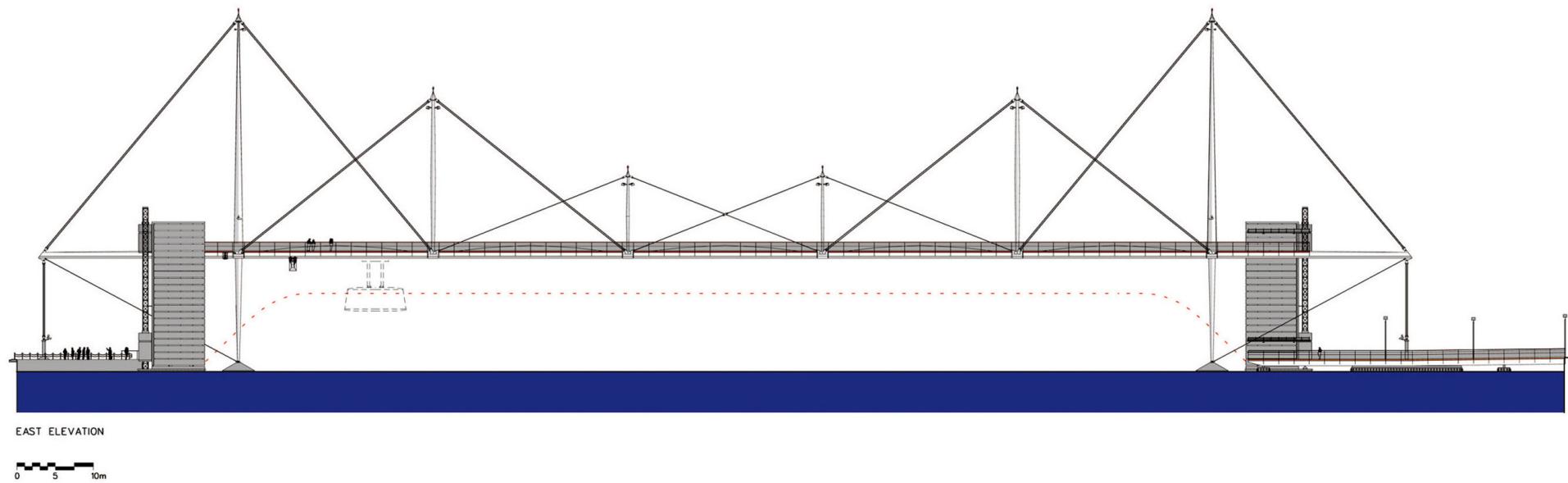


Lattice





Lifschutz, Techniker: Royal Victoria Dock Bridge, London, 1996



Lifschutz, Techniker: Royal Victoria Dock Bridge, London, 1996



Ney + Partners: Thuin Bridge, Wallonia, Belgium, 2005



Ney + Partners: Thuin Bridge, Wallonia, Belgium, 2005



Timber Frame Houses, UK



Traditional Timber Framed House, Safranbolu, Turkey, 19th century



I.M. Pei, Robertson, Fowler and Associates: Bank of China, Hong Kong, 1989

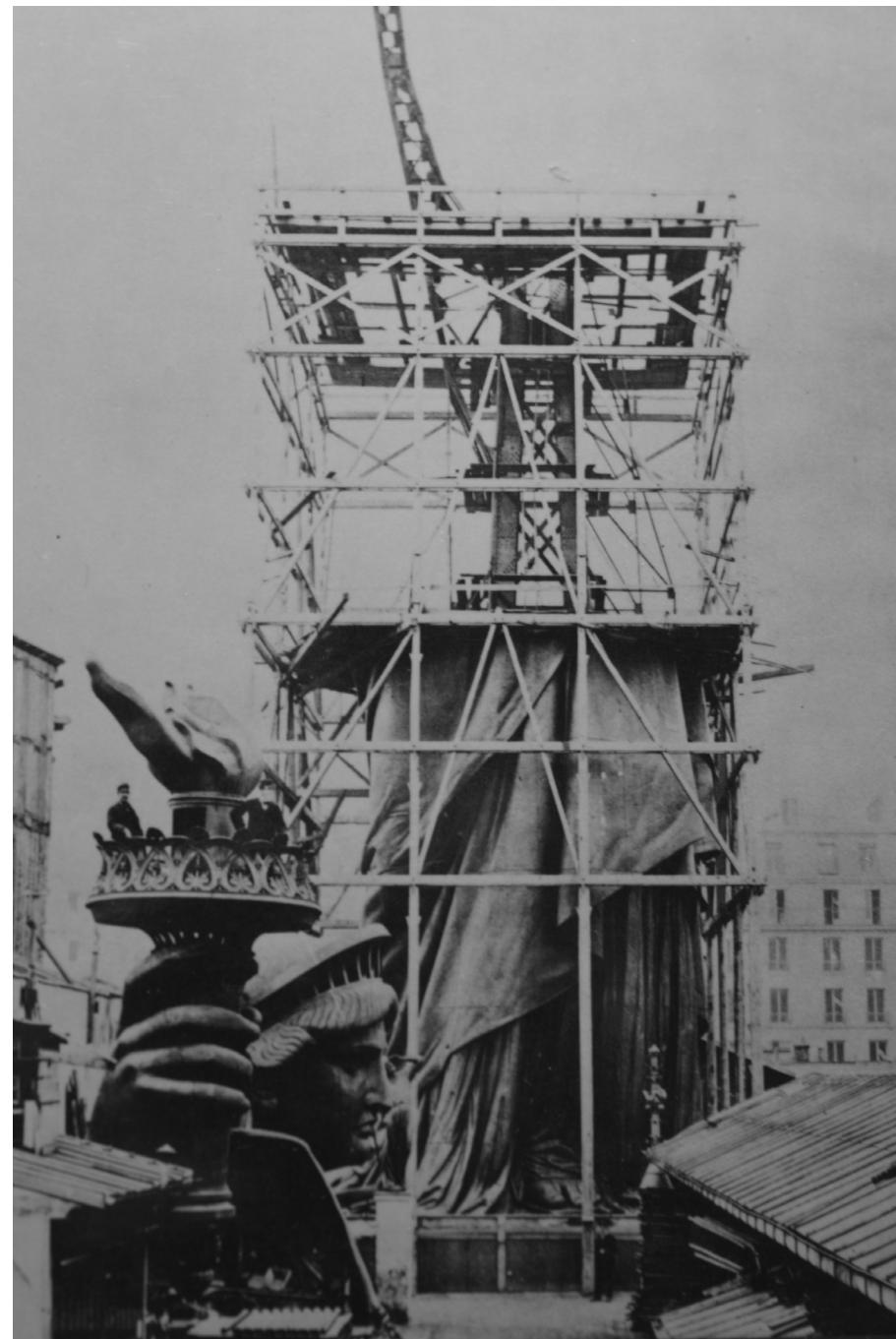
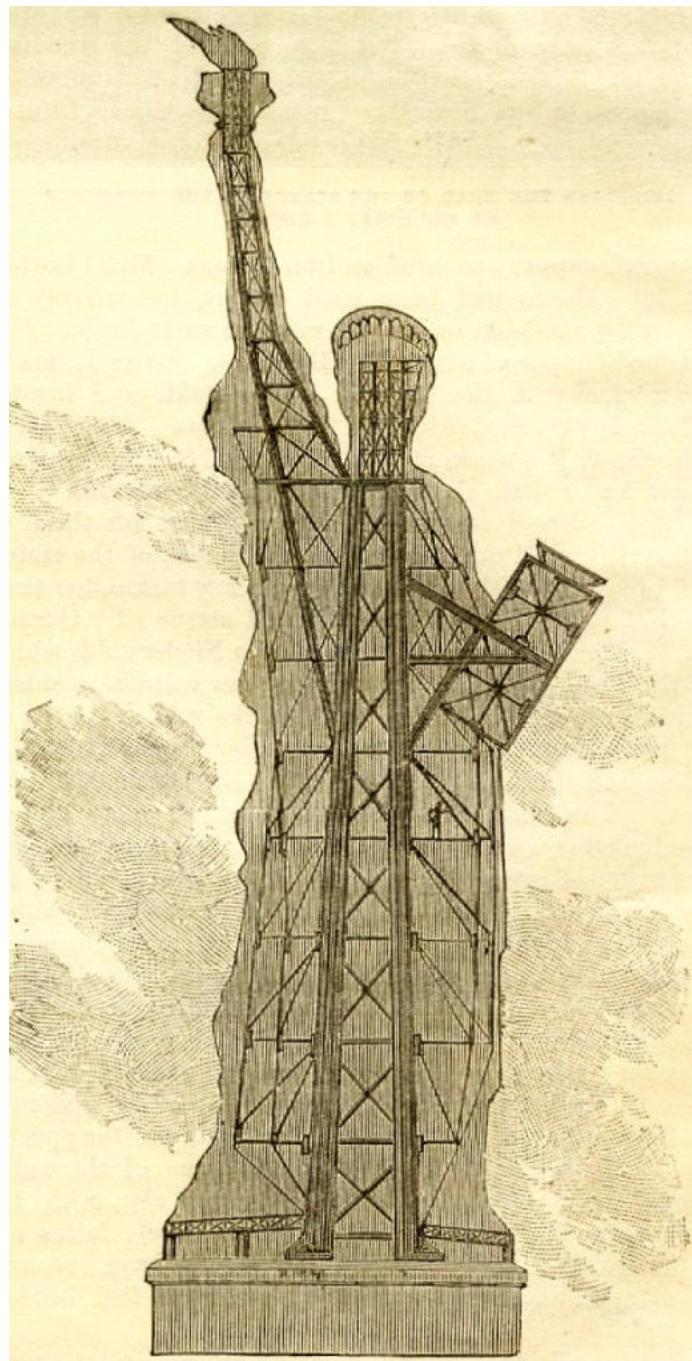


SOM, William F. Baker: Burj Khalifa, Dubai, 2010









Frederic-Auguste Bartholdi, Gustave Eiffel: Statue of Liberty, New York, 1886