

Tragwerksentwurf I

Structural Design I

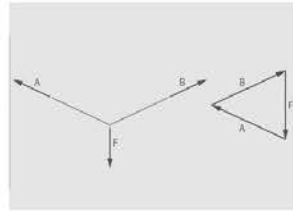
Philippe Block · Joseph Schwartz



Tragwerksentwurf
Structural Design



1. Gleichgewicht
1. Equilibrium



2. Graphische Statik
2. Graphic statics



3. Seile
3. Cables



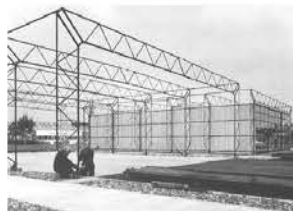
4. Bogen
4. Arches



5. Bogen-Seil
5. Arch-cables

Tragwerksentwurf I *Structural Design I*

Tragwerksentwurf II *Structural Design II*



6. Fachwerke
6. Trusses



7. Balken
7. Beams



8. Rahmen
8. Frames



9. Platten
9. Plates



10. Stützen
10. Columns



11. Nachhaltigkeit
11. Sustainability

Bögen

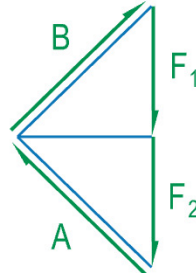
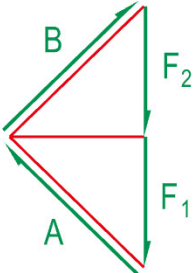
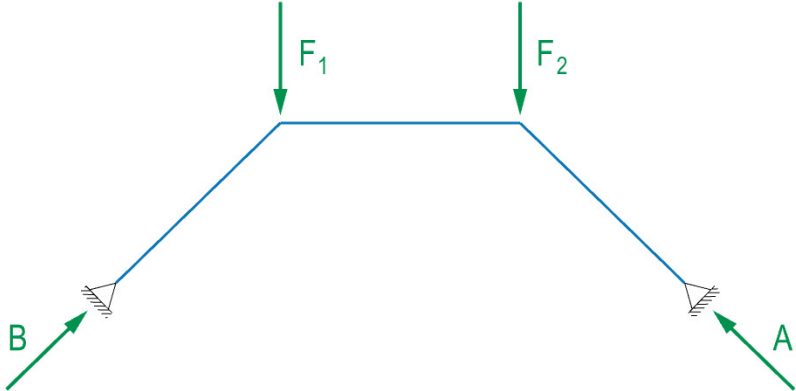
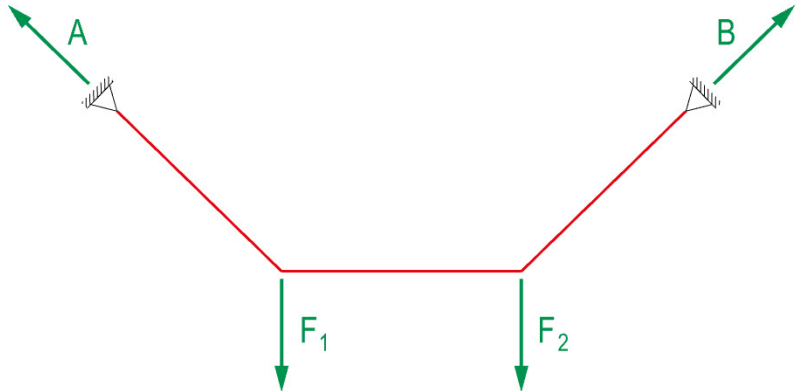
Arches

>> Seil und Bogen – Inversionsprinzip
Cables and arches – inversion principle

Fallbeispiel: Gotische Kathedrale
Case study: Gothic cathedral

Aussteifungskonzepte
Concepts for stiffening

Stützlinien
Thrust lines

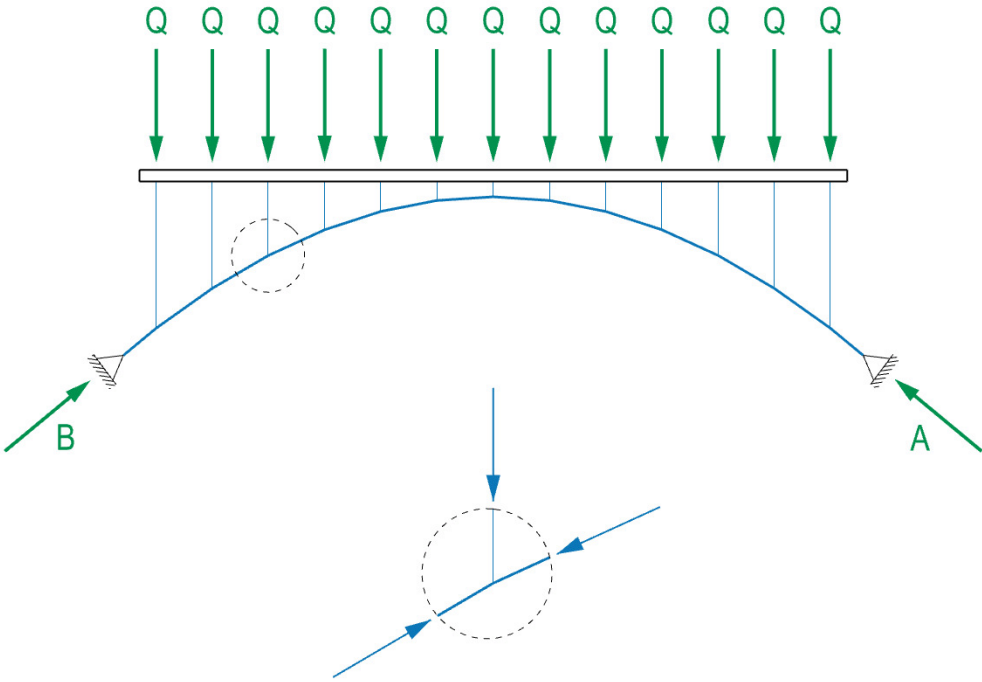
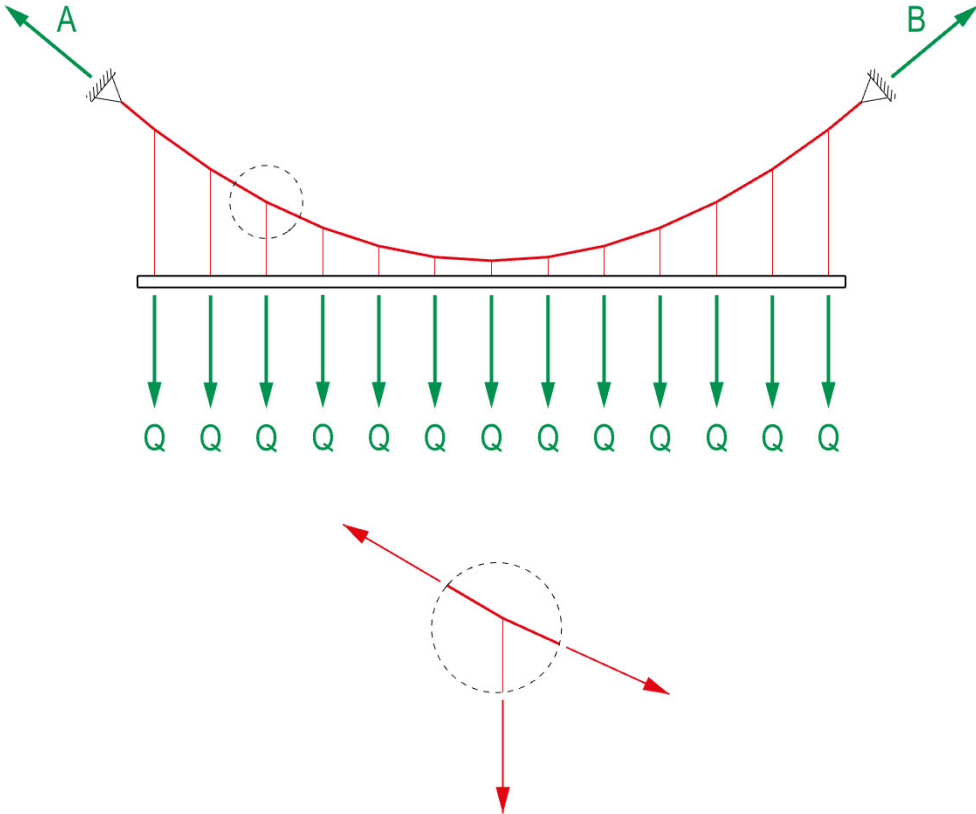


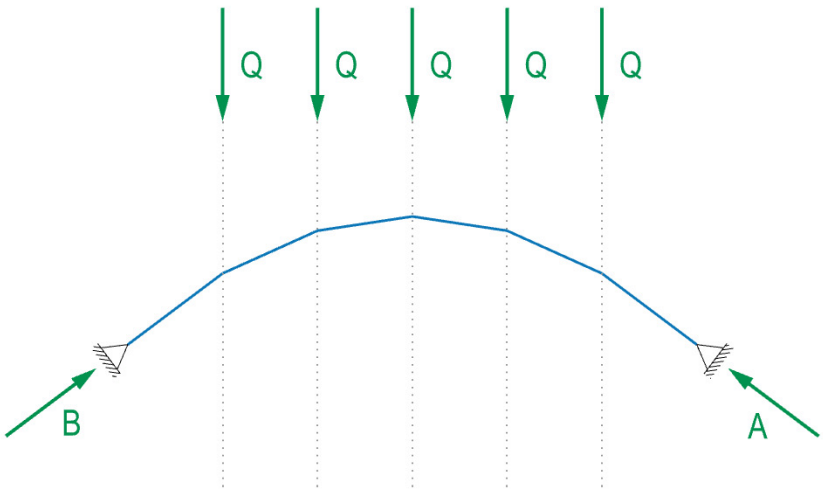
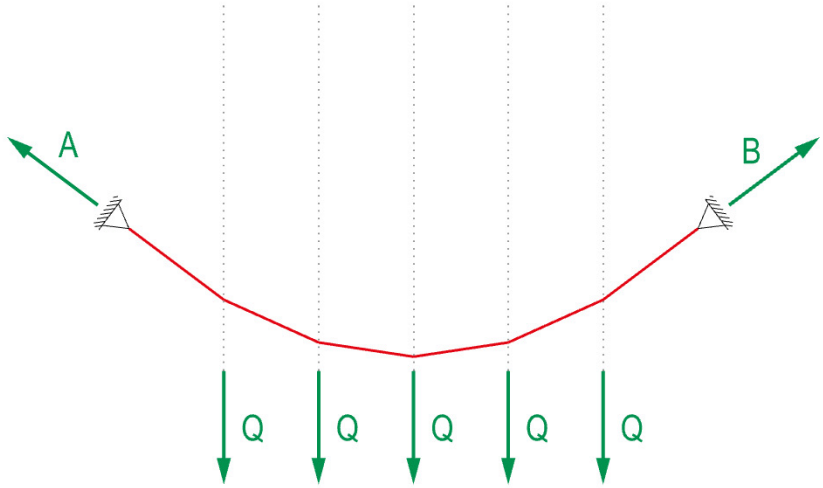
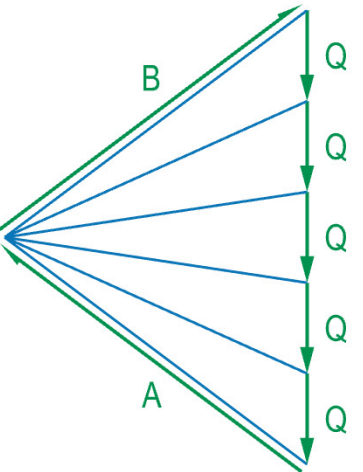
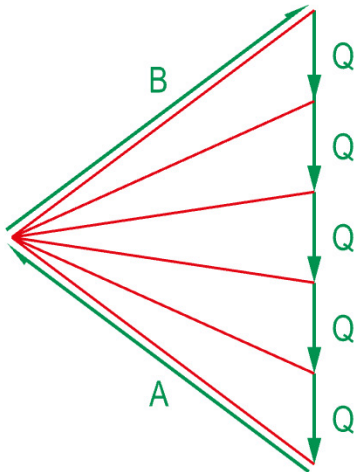


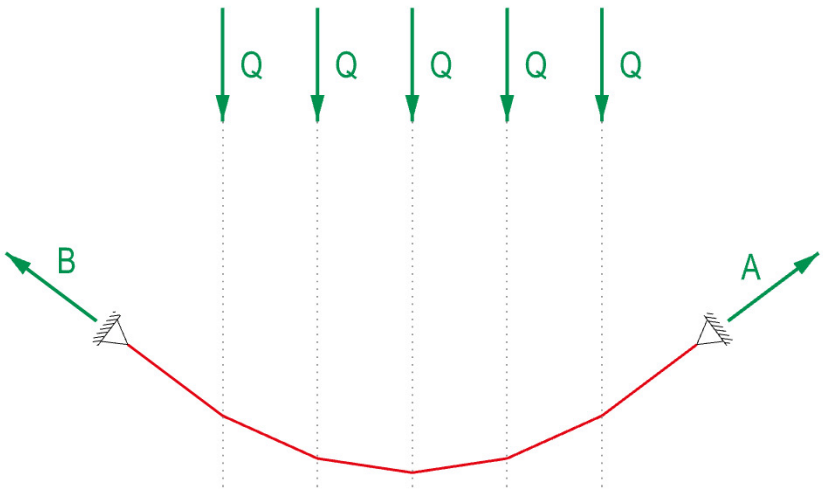
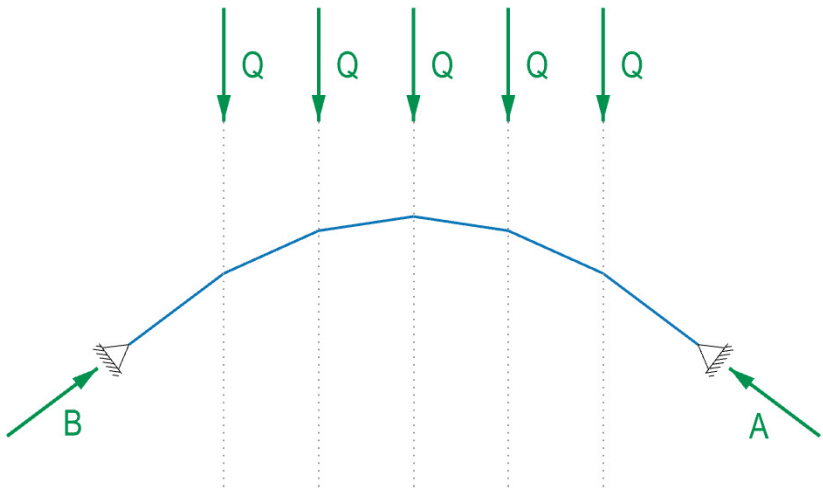
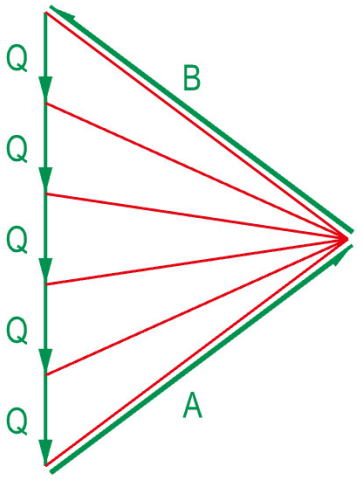
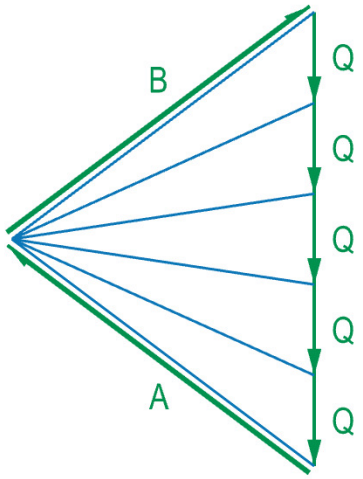
Wilhelm Riphahn, Fritz Leonhardt: Mülheimer bridge, Cologne, 1951

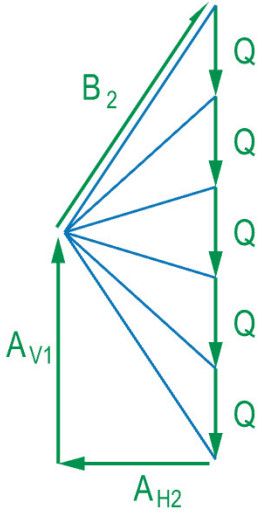
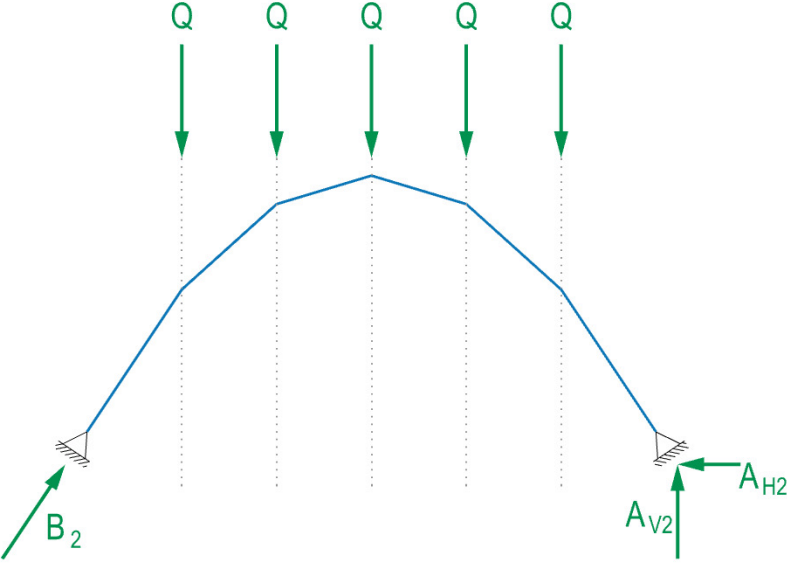
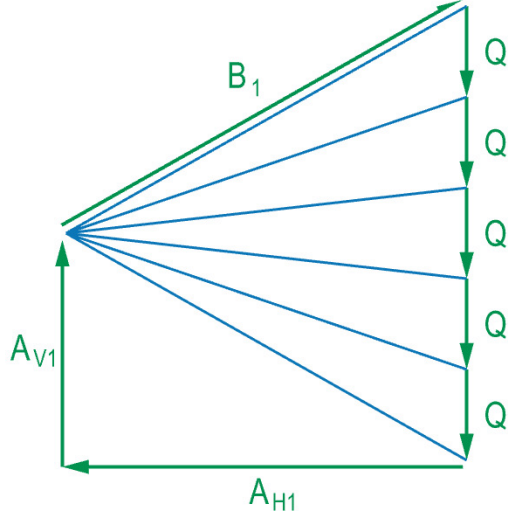
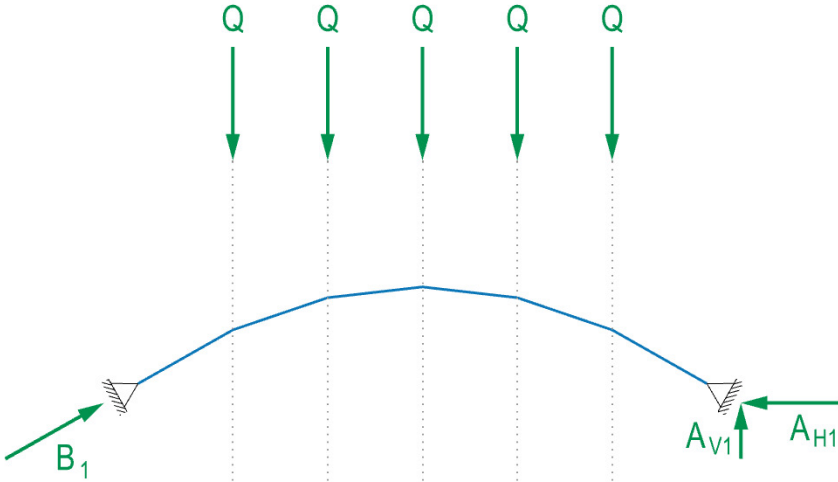


Robert Maillart: Valtschielbachbridge, Donath, 1925









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ut pendet continuum flexile, sic stabit contiguum rigidum inversum

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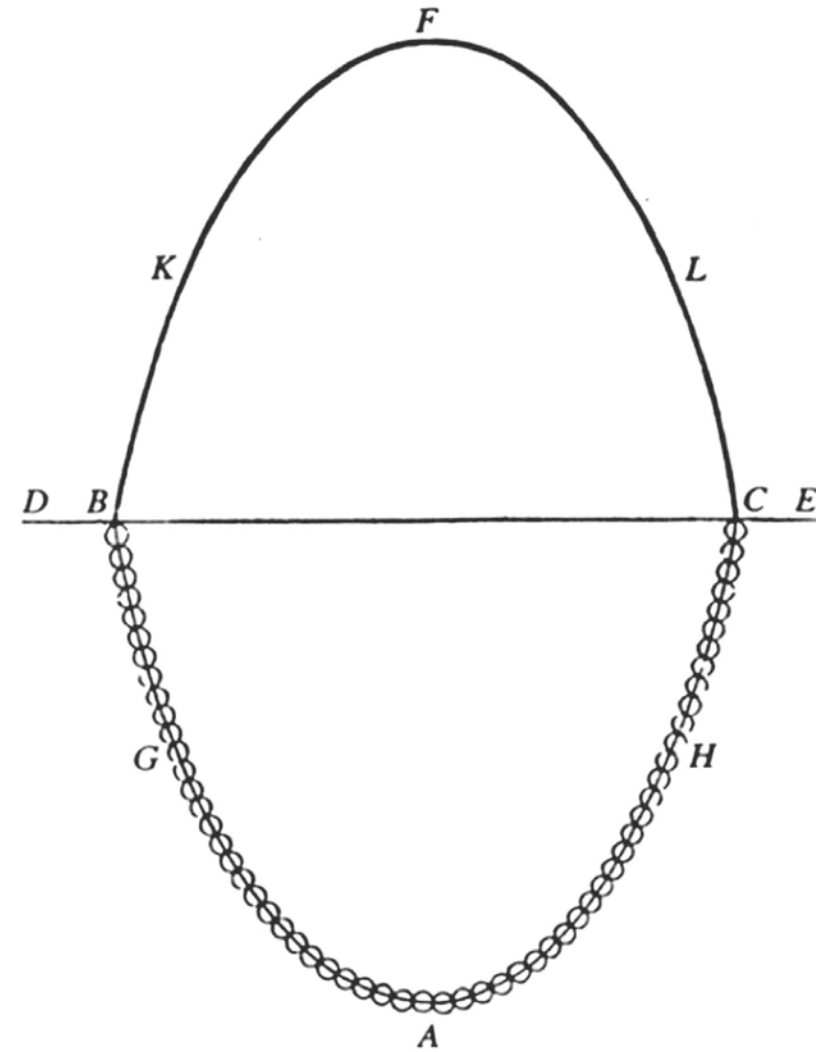
ut pendet continuum flexile, sic stabit contiguum rigidum inversum

„As hangs the flexible line, so but inverted will stand the rigid arch.“

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ut pendet continuum flexile, sic stabit contiguum rigidum inversum

„As hangs the flexible line, so but inverted will stand the rigid arch.“





Modell of Colonia Güell church and crypt of Colonia Güell, Antonio Gaudí, 1898-1914

Bögen

Arches

Seil und Bogen – Inversionsprinzip

Cables and arches – inversion principle



Fallbeispiel: Gotische Kathedrale

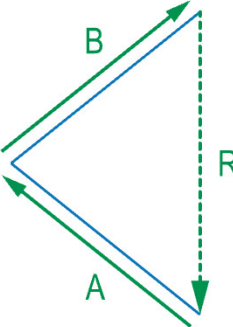
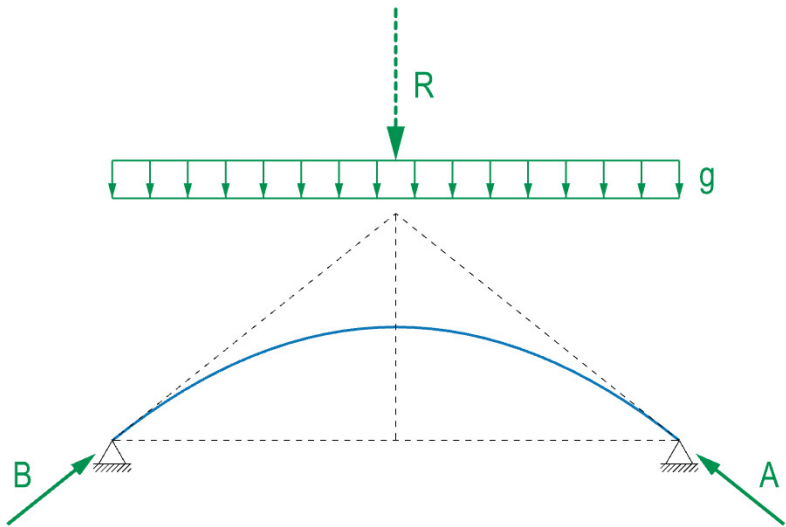
Case study: Gothic cathedral

Aussteifungskonzepte

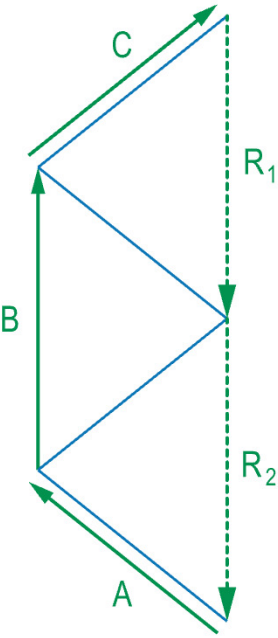
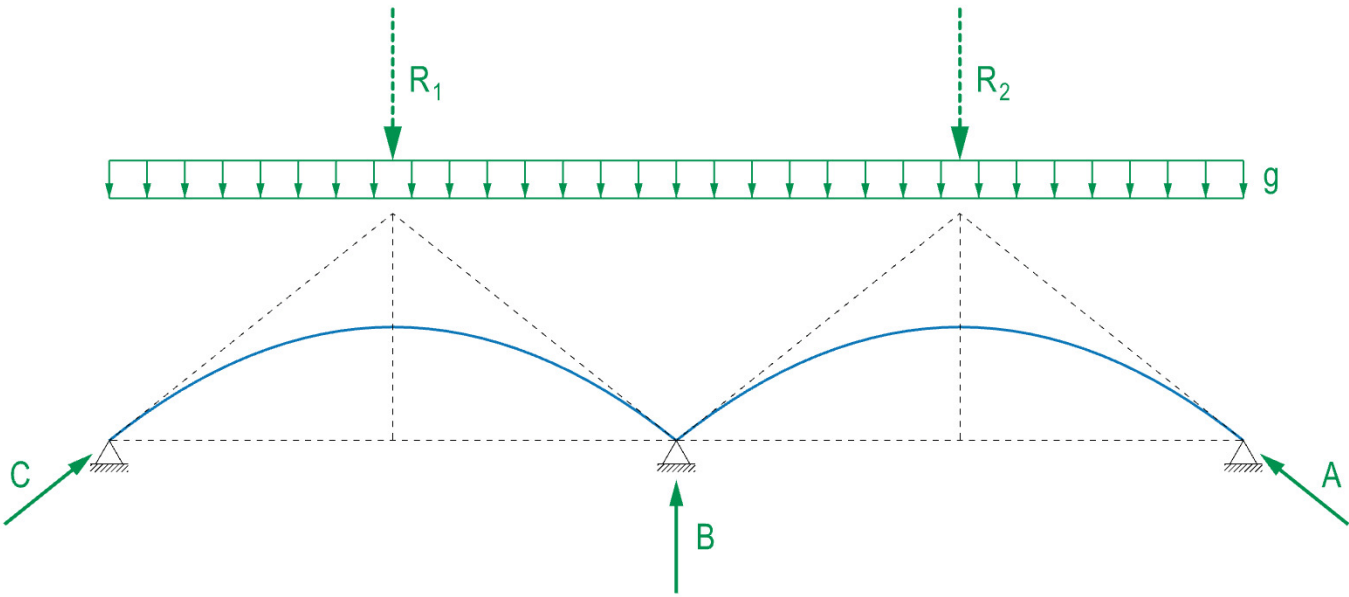
Concepts for stiffening

Stützlinien

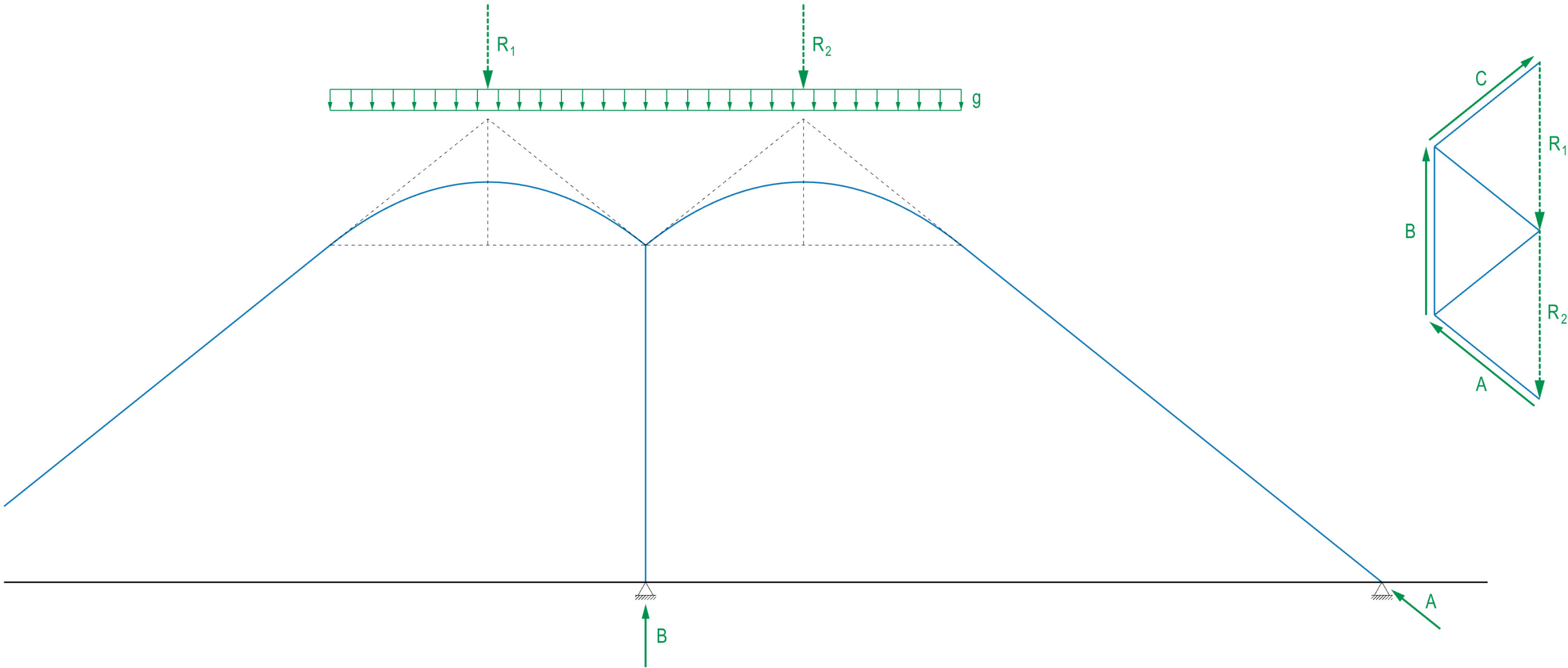
Thrust lines

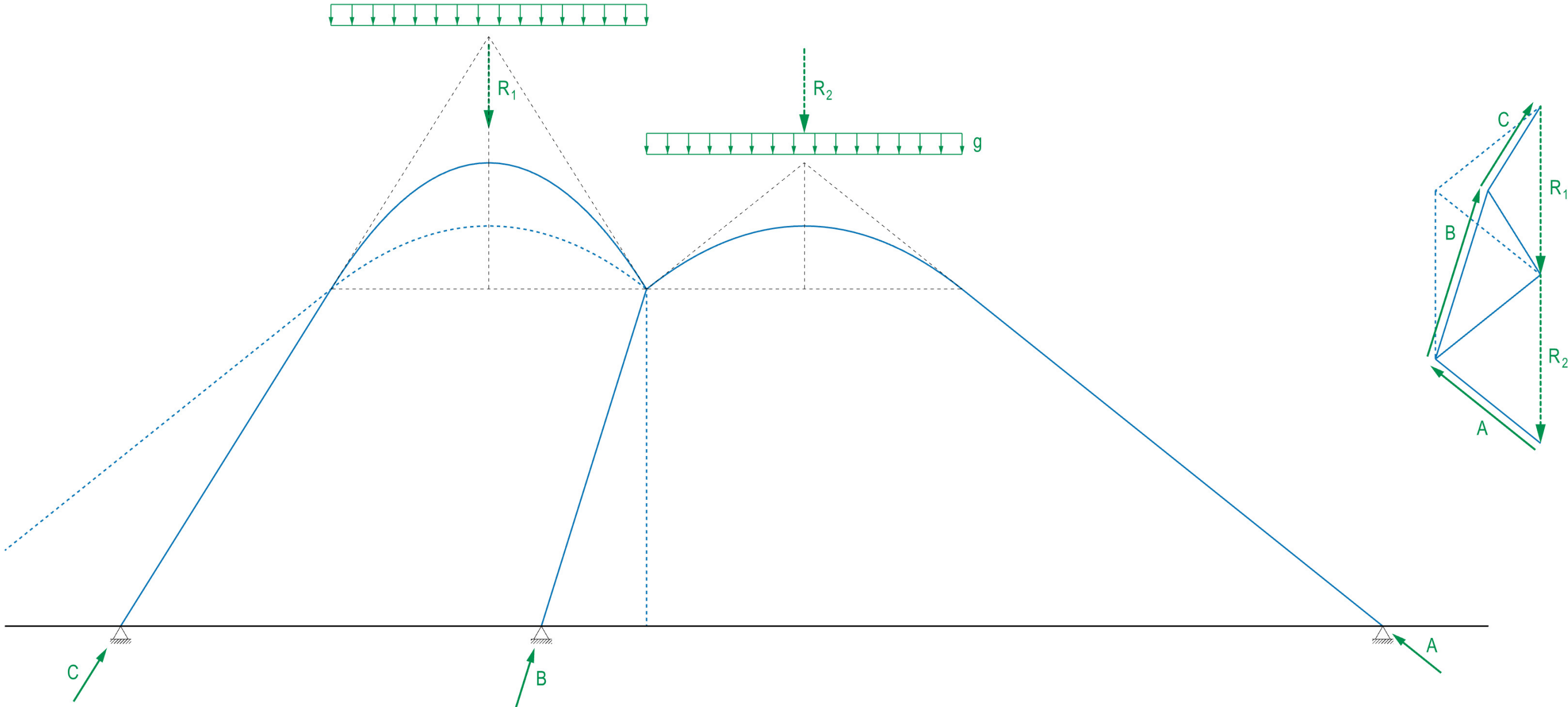


Case study: Gothic cathedral

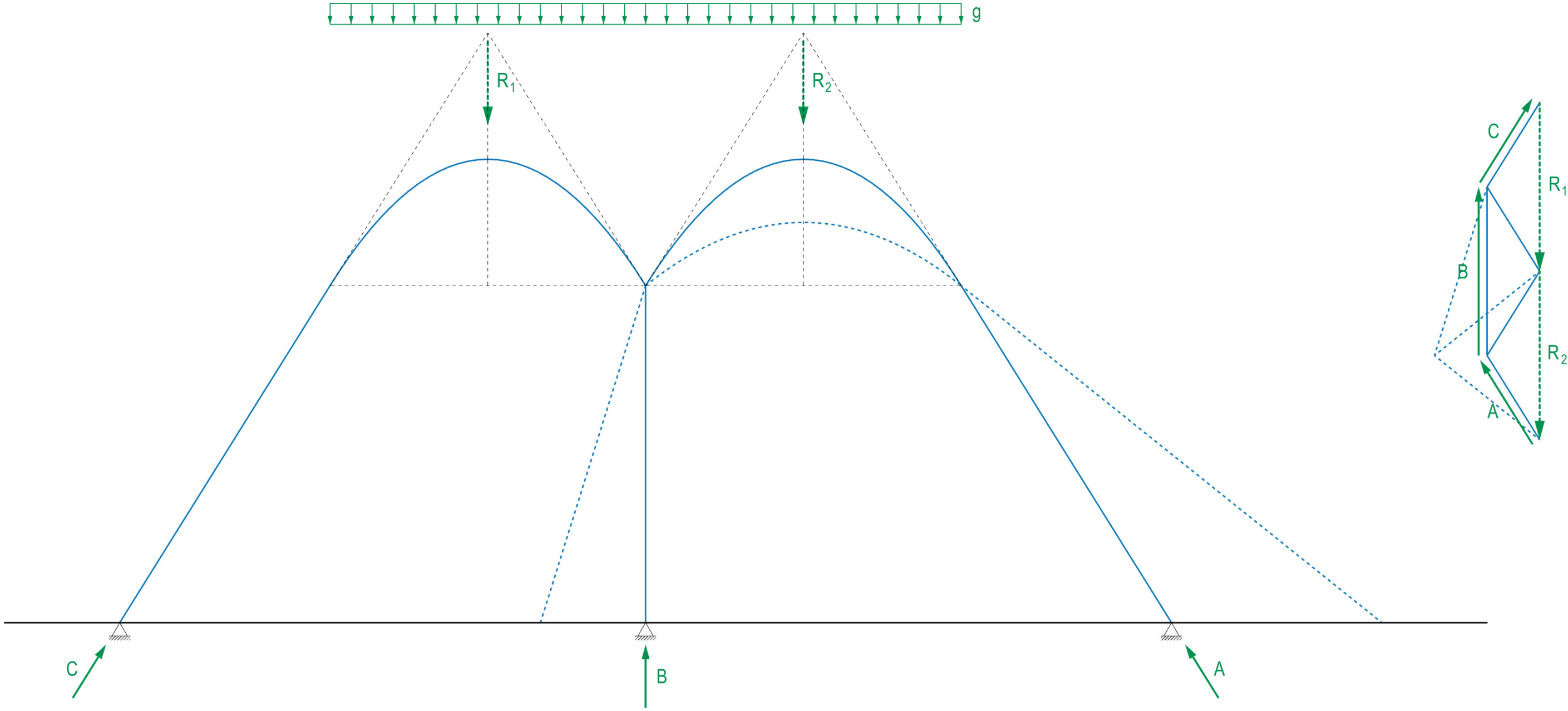


Case study: Gothic cathedral

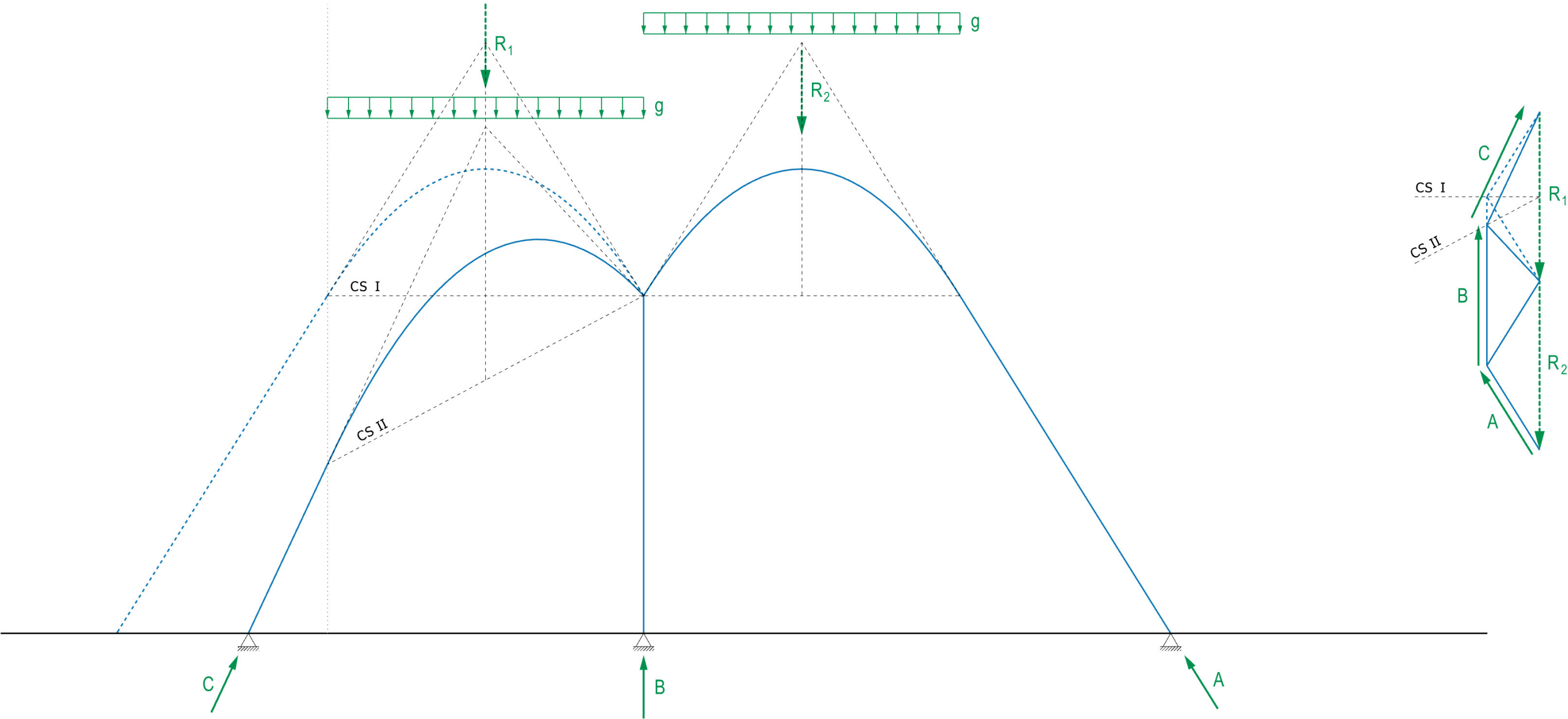




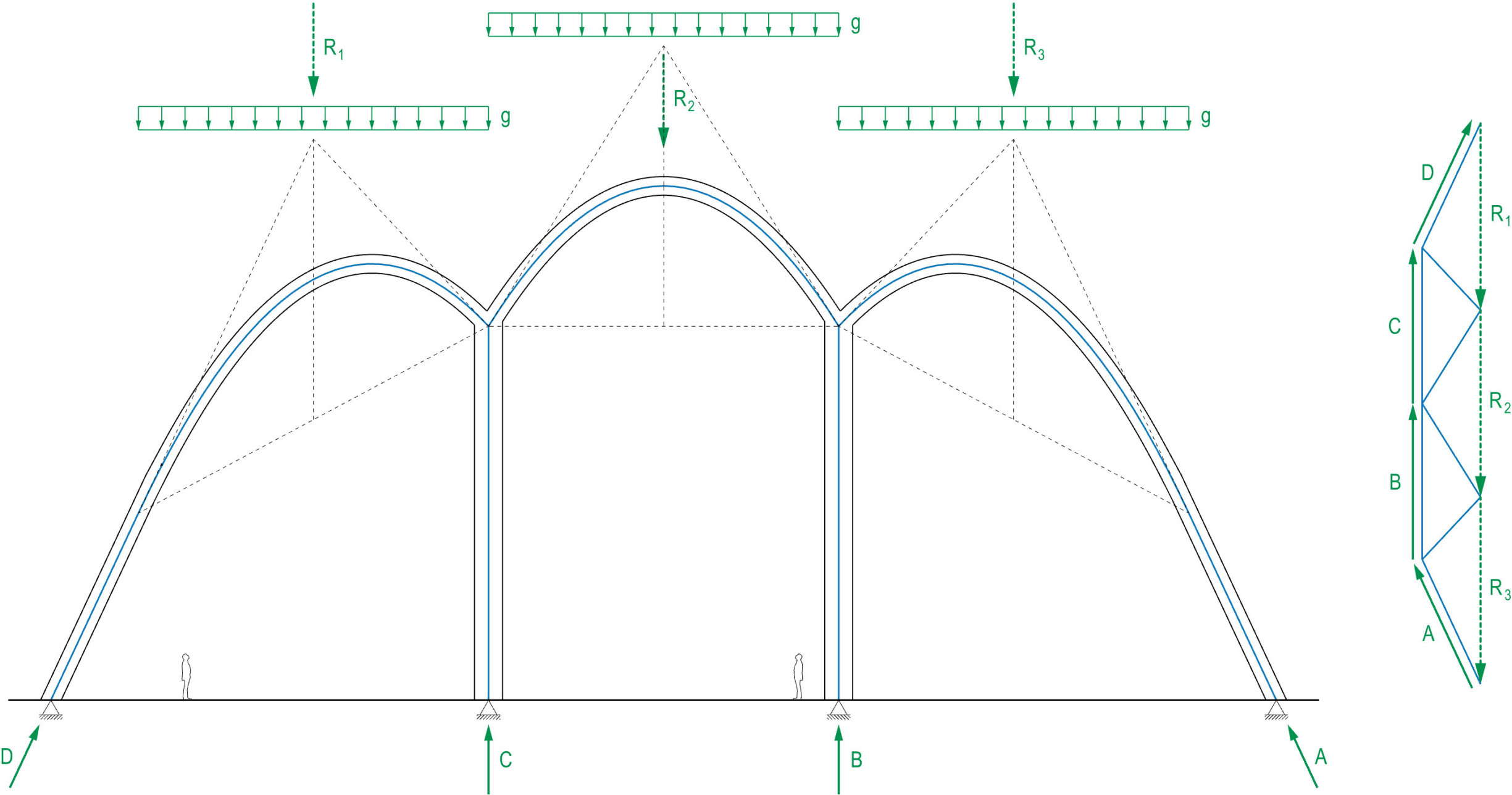
Case study: Gothic cathedral



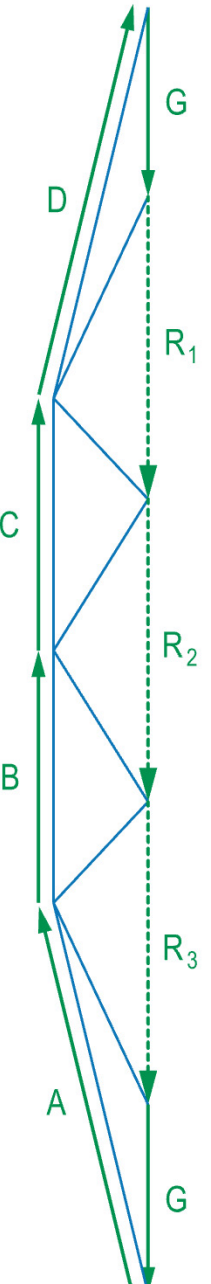
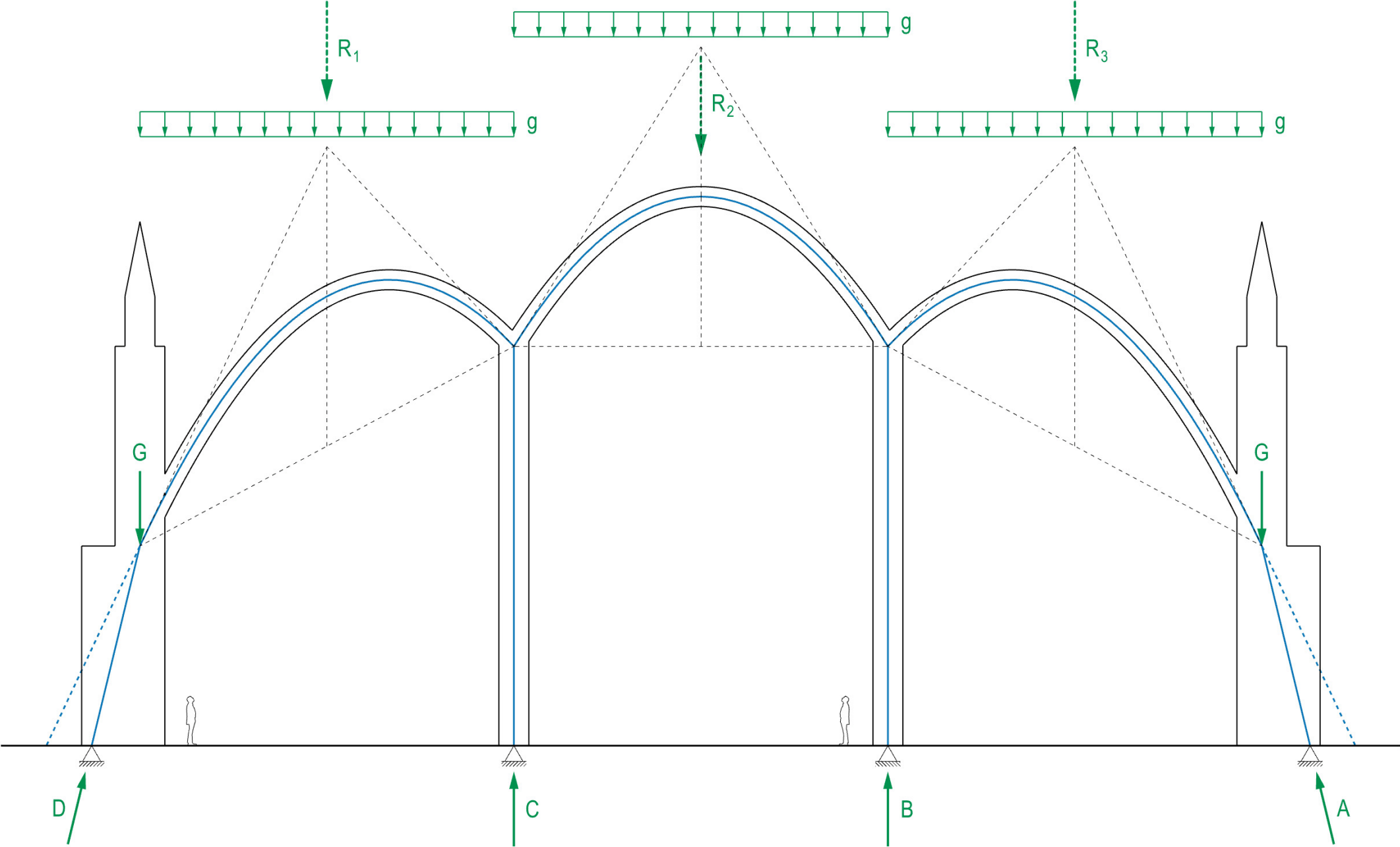
Case study: Gothic cathedral

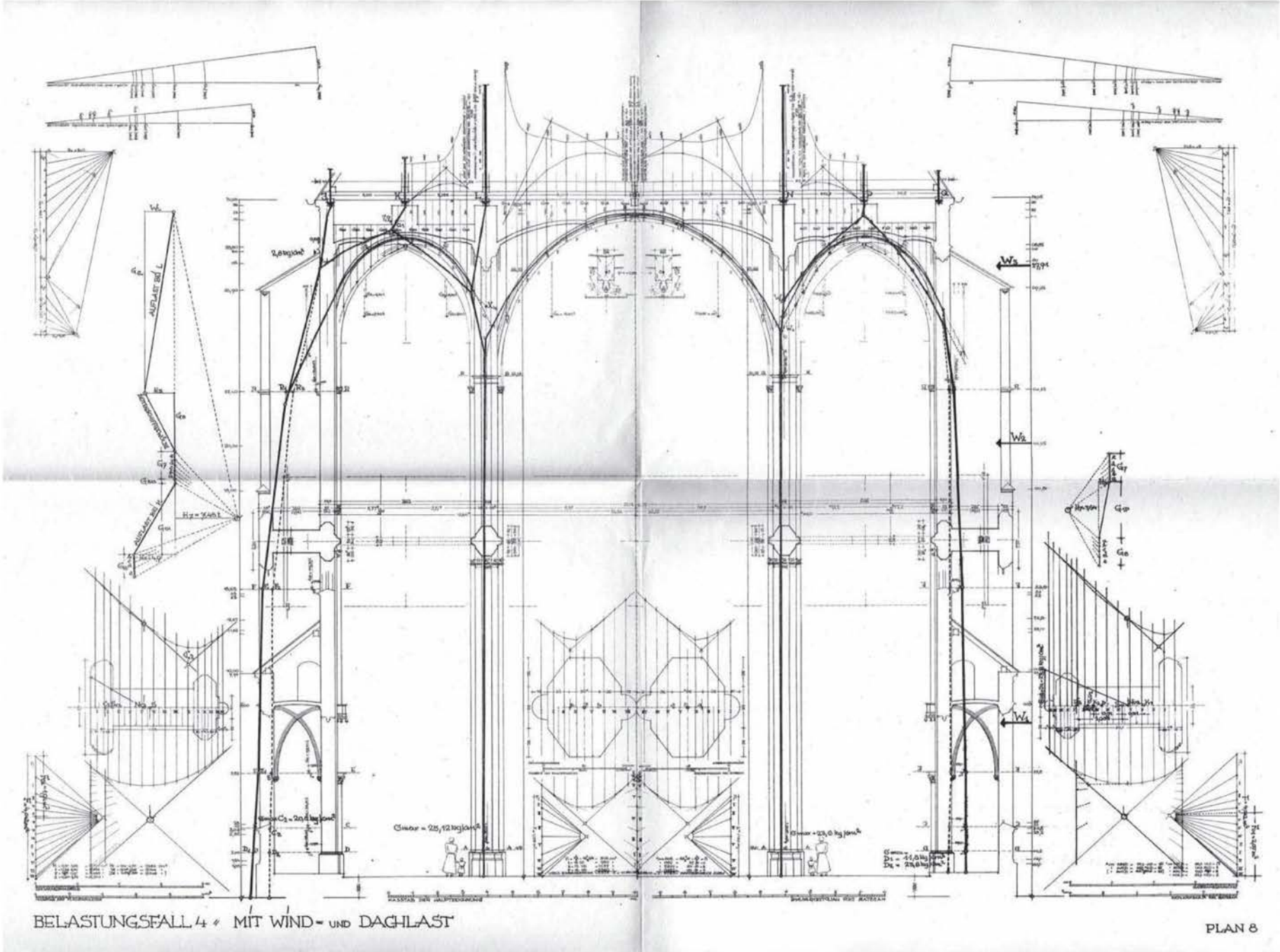


Case study: Gothic cathedral



Case study: Gothic cathedral







Beauvais Cathedral, France, 1247



Beauvais Cathedral, France, 1247

Bögen

Arches

Seil und Bogen – Inversionsprinzip

Cables and arches – inversion principle

Fallbeispiel: Gotische Kathedrale

Case study: Gothic cathedral

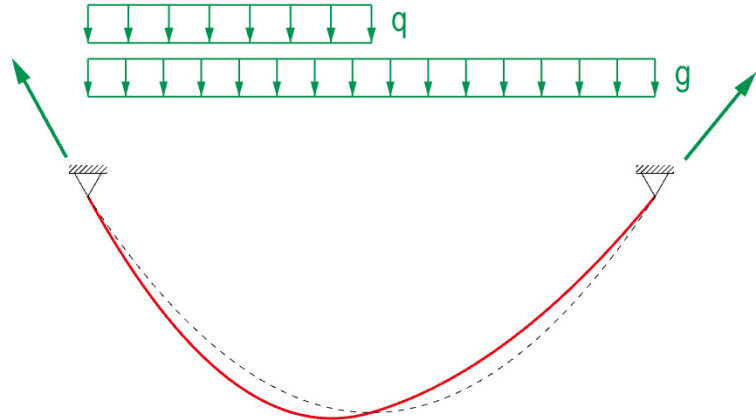


Aussteifungskonzepte

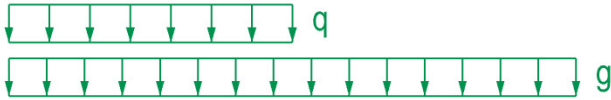
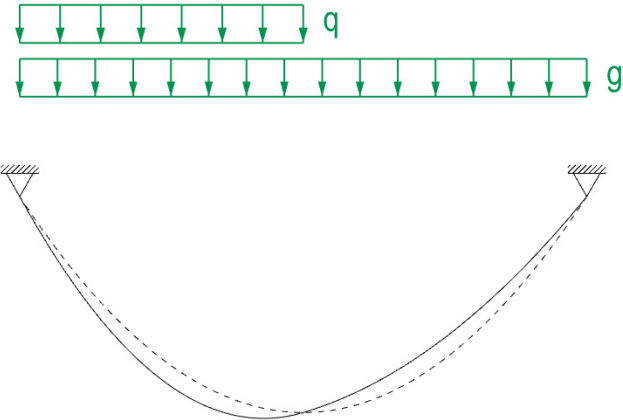
Concepts for stiffening

Stützlinien

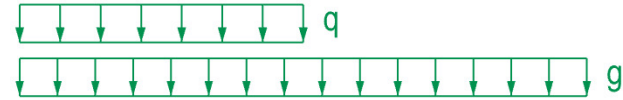
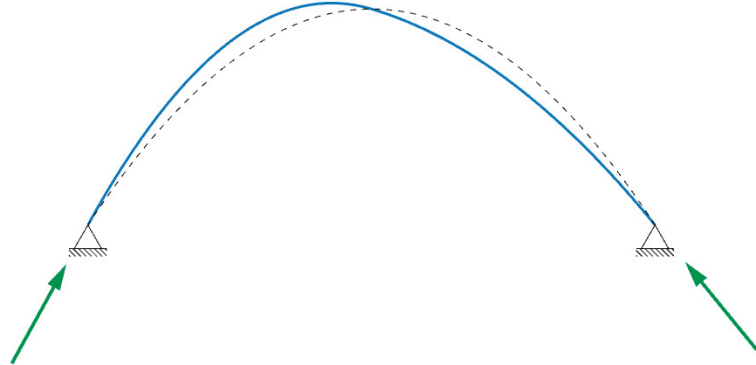
Thrust lines

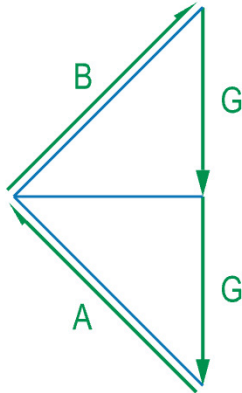
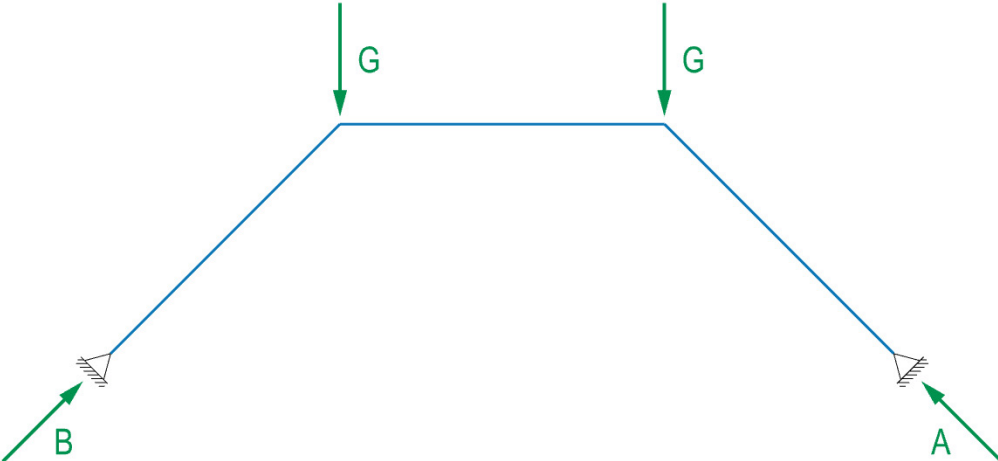


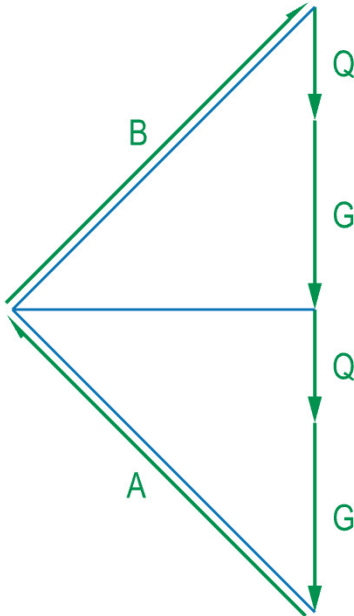
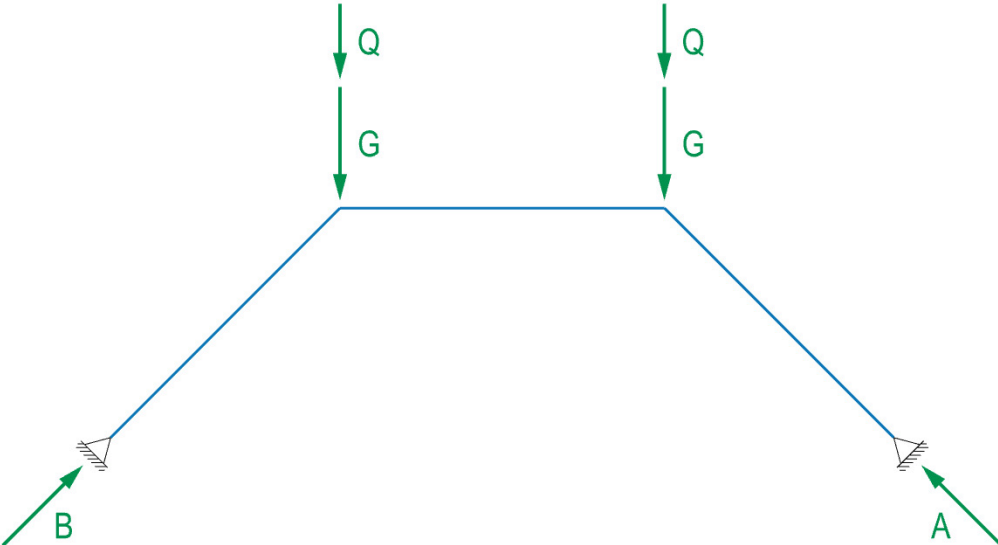
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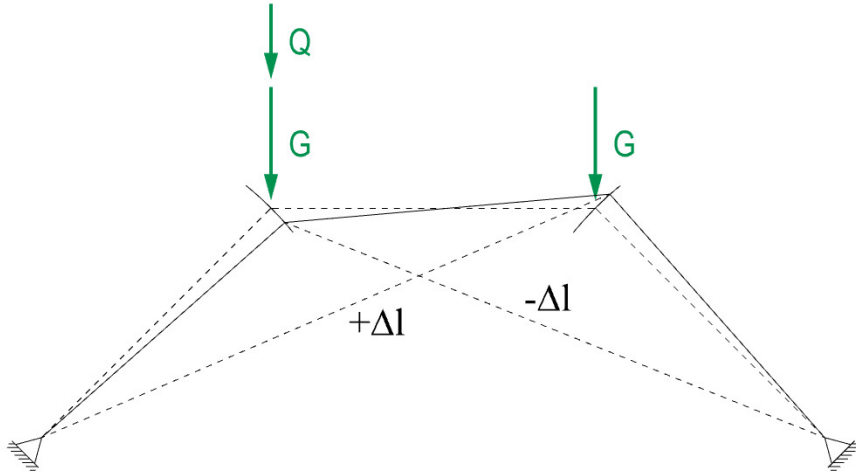


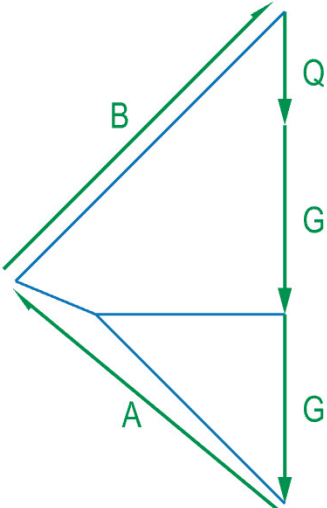
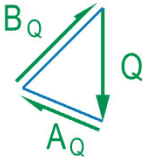
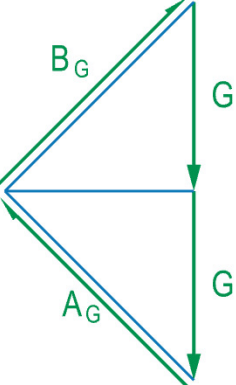
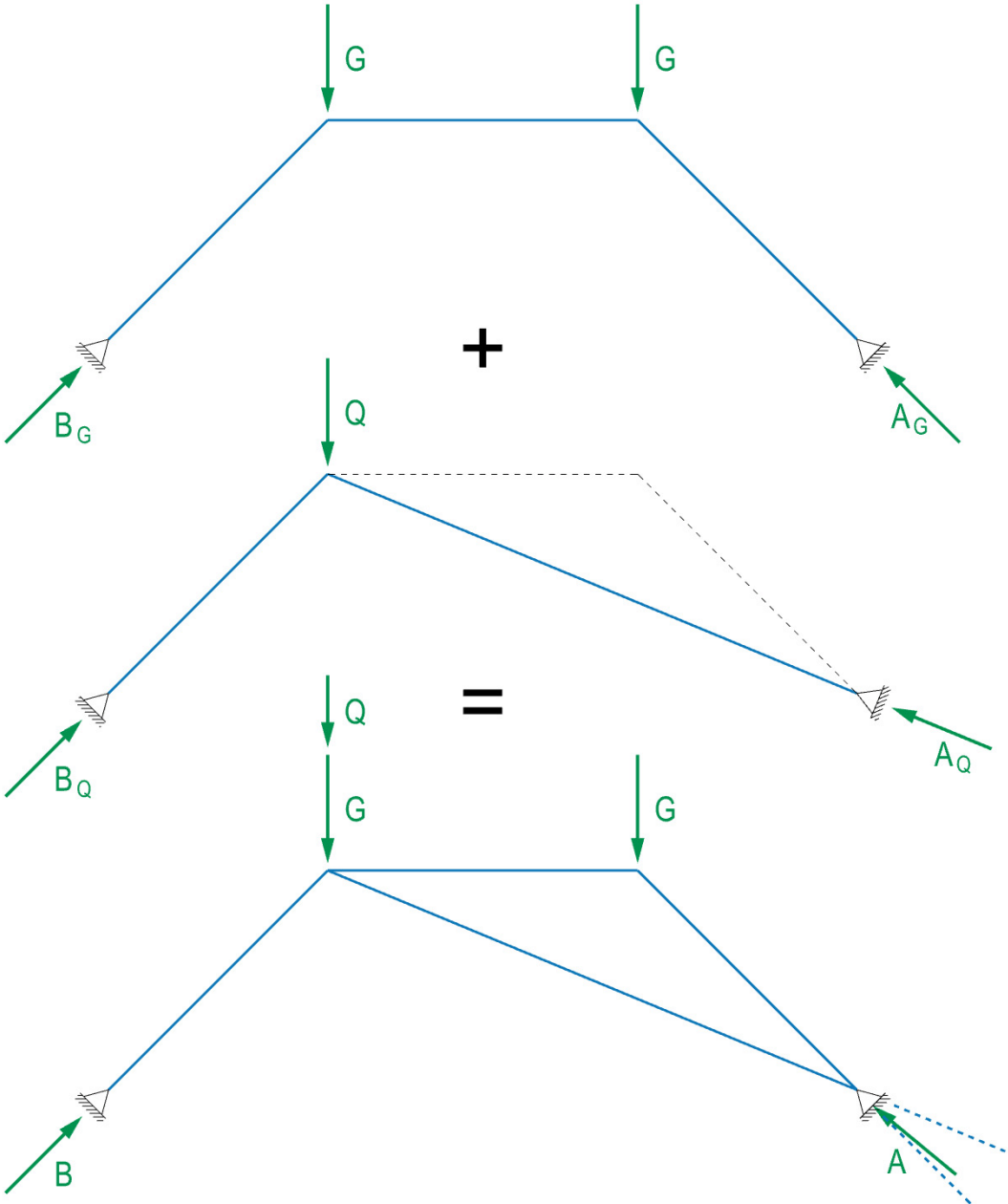
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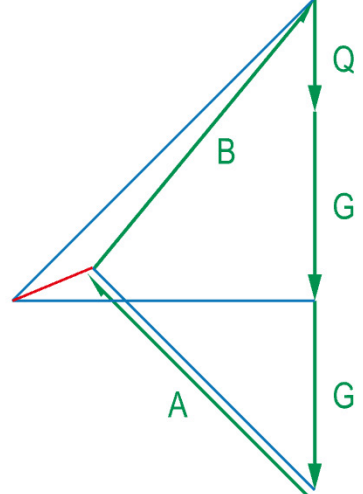
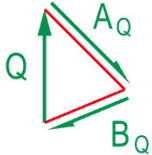
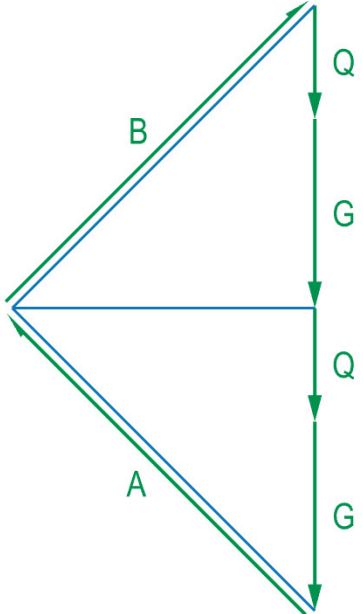
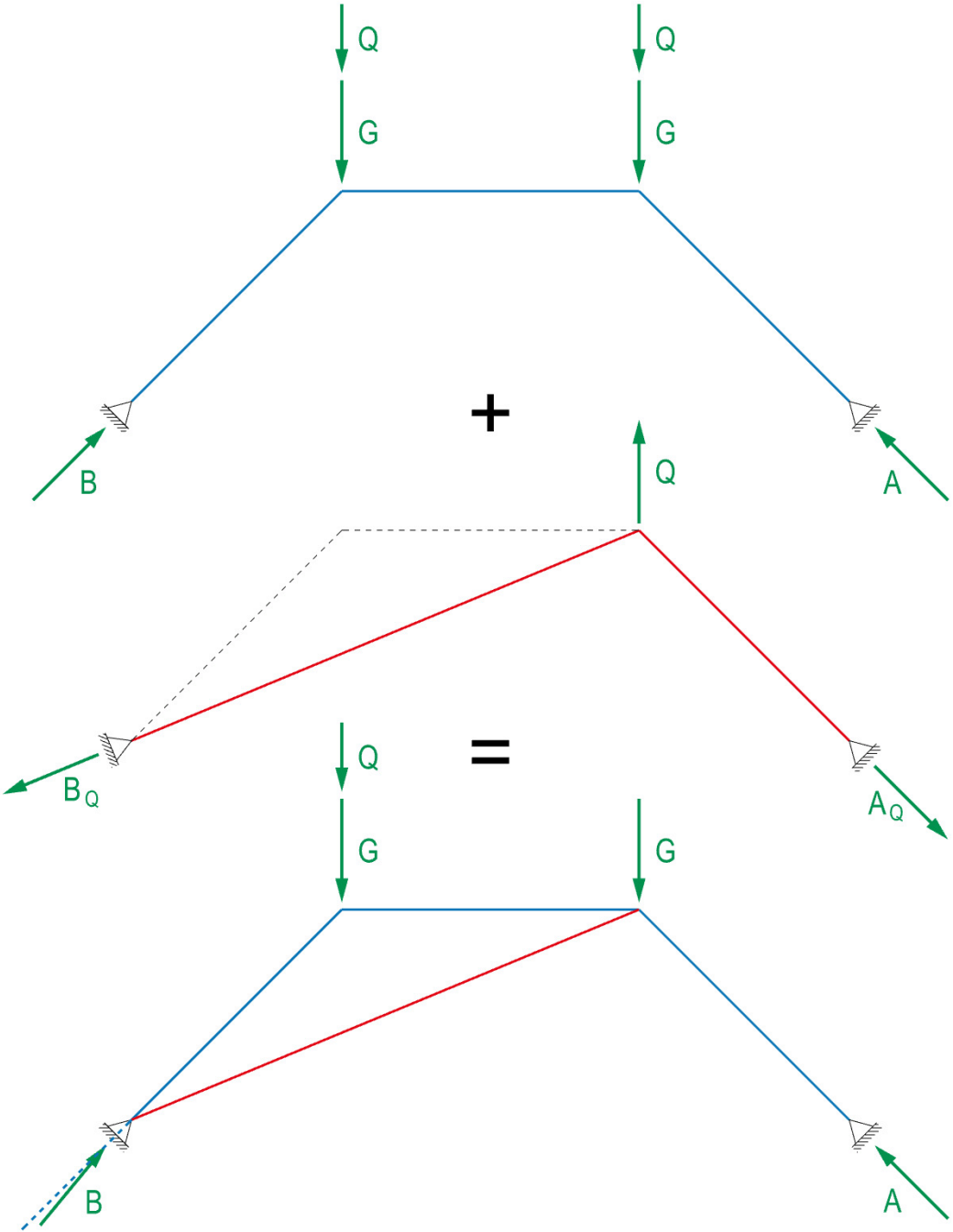


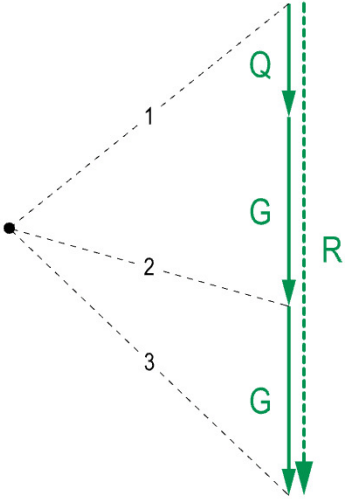
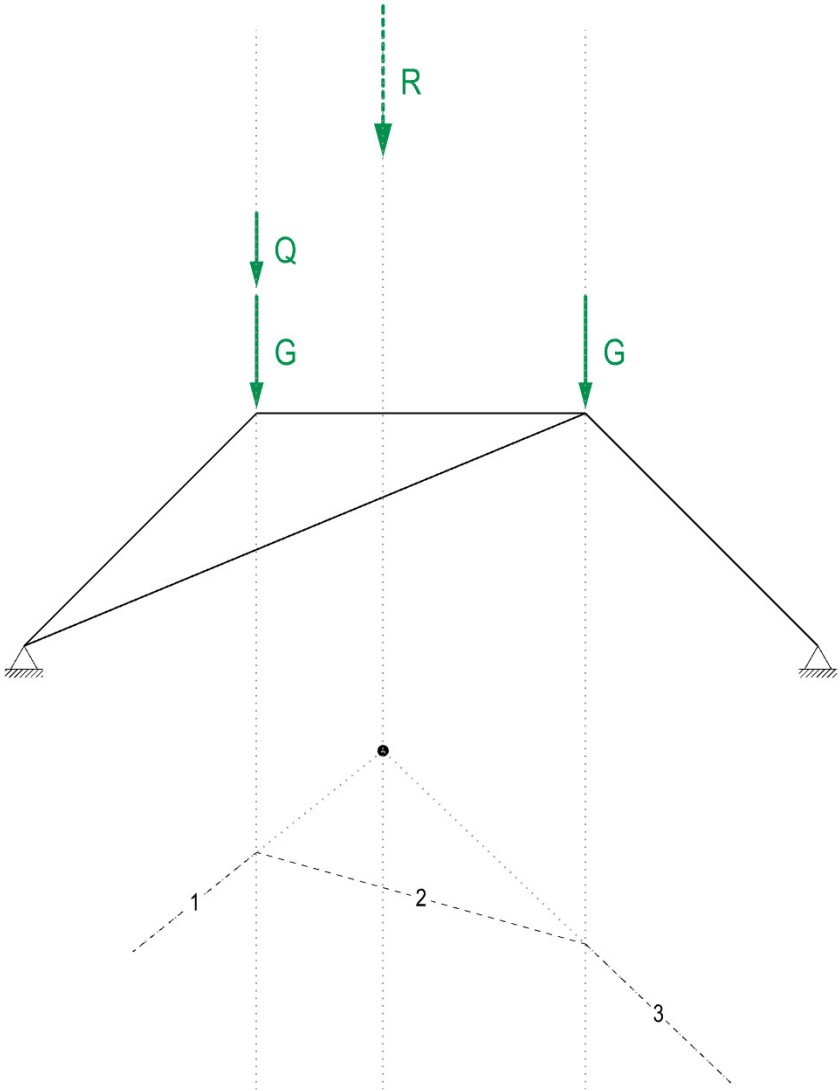


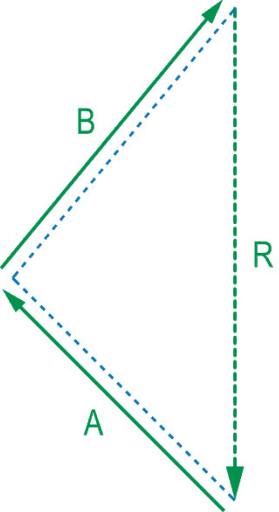
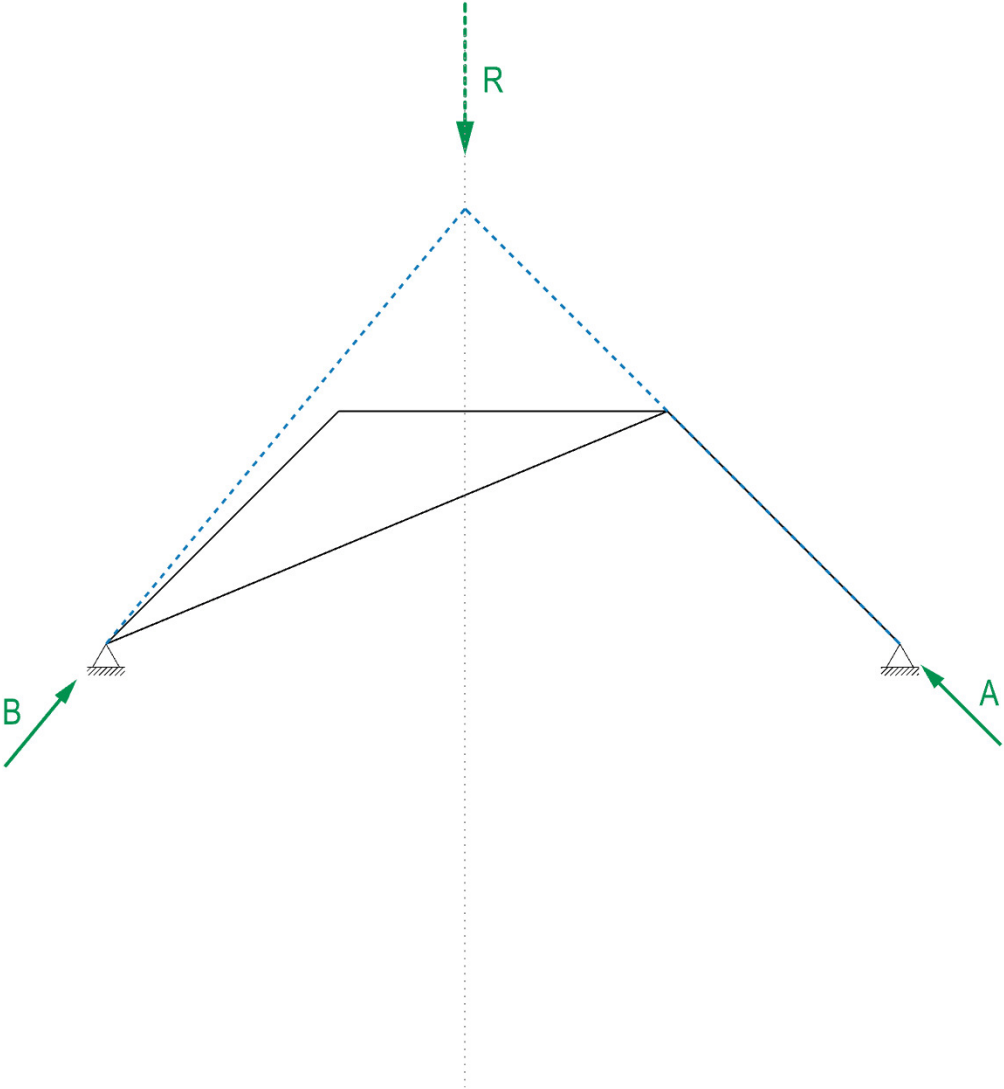


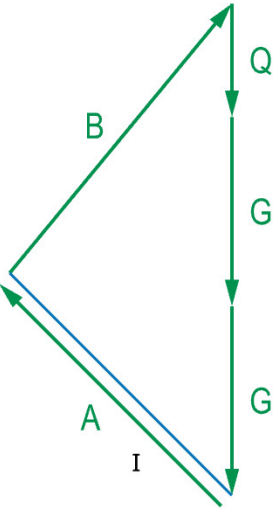
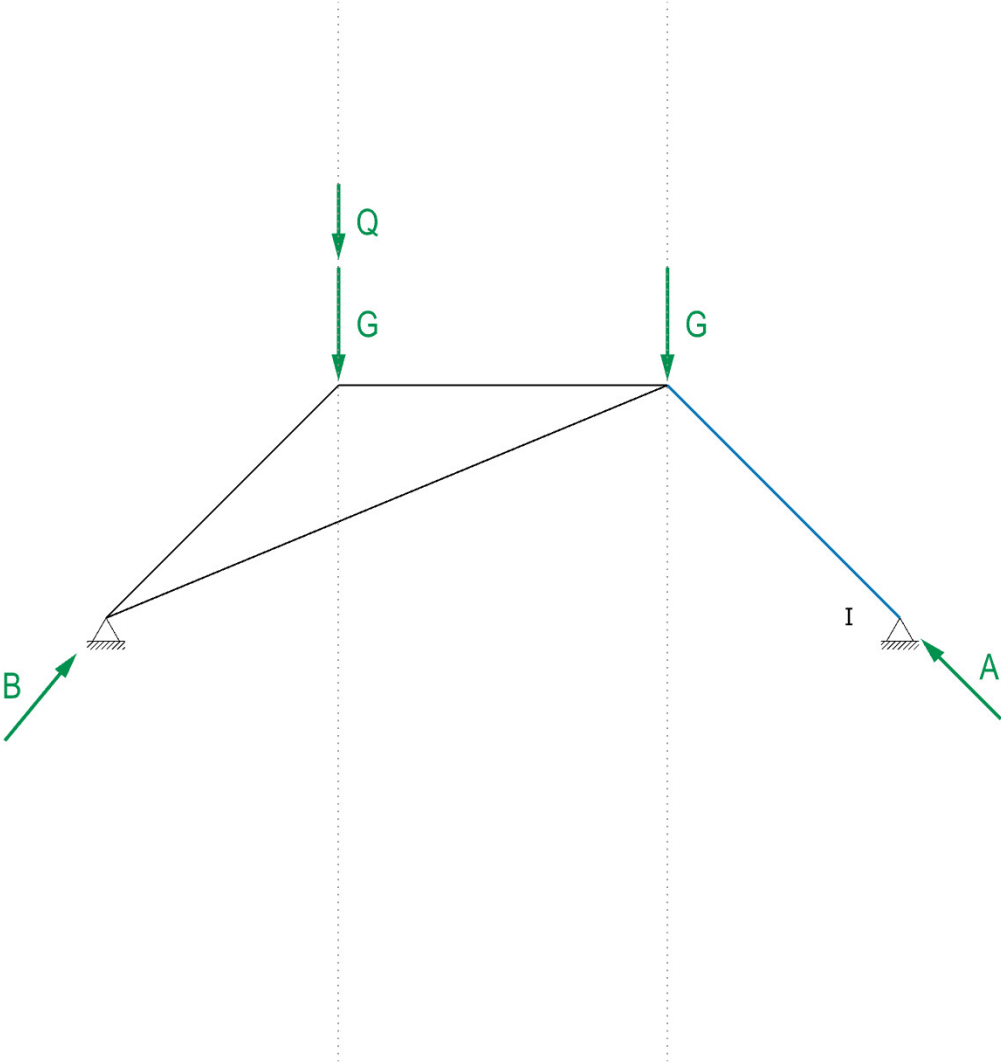


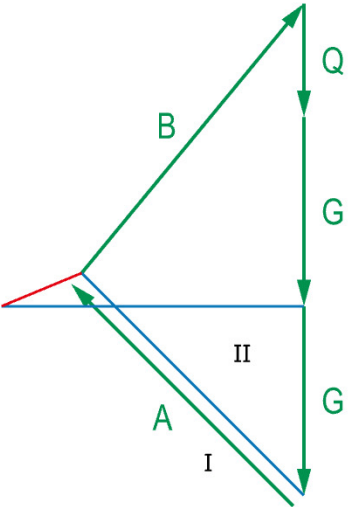
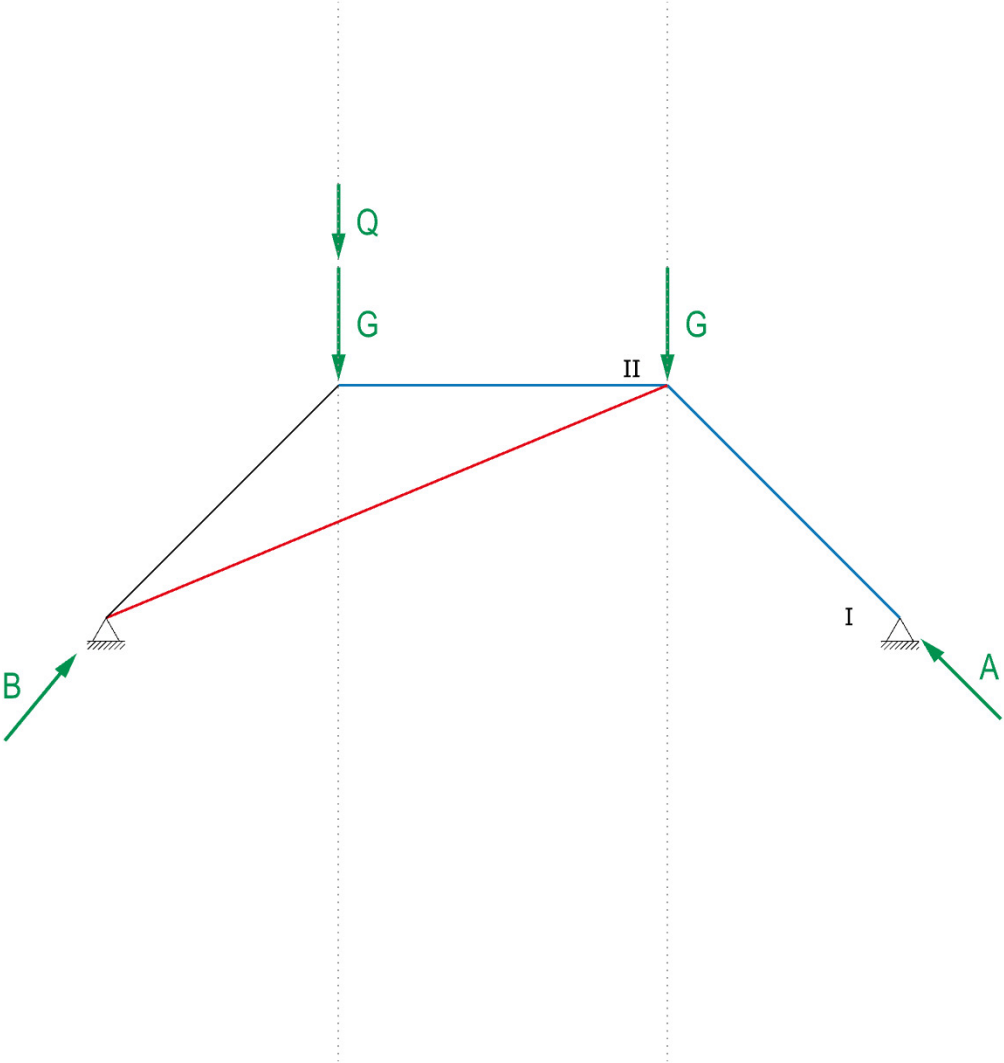


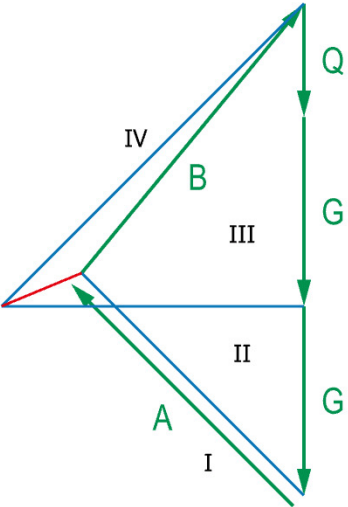
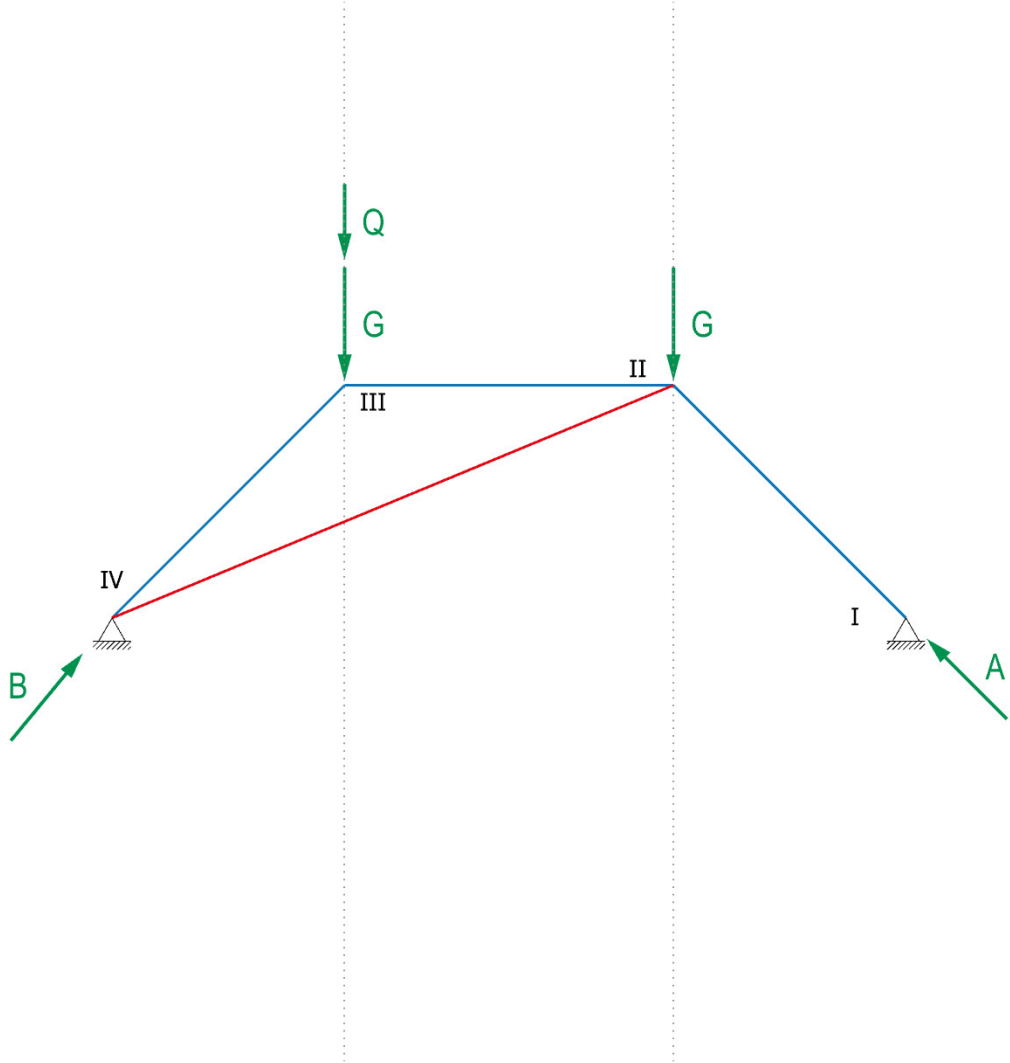


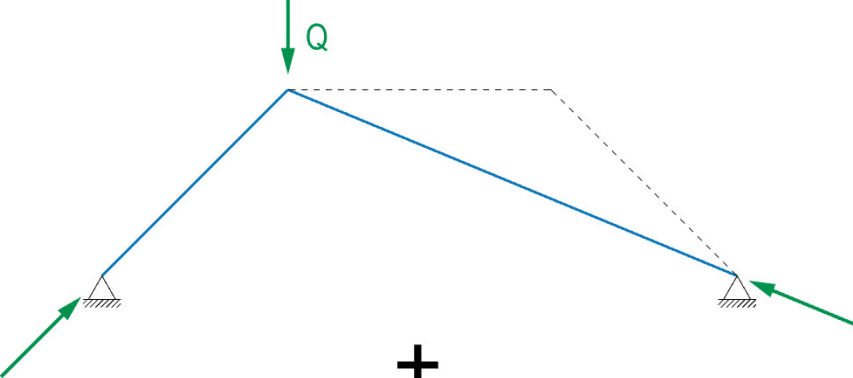




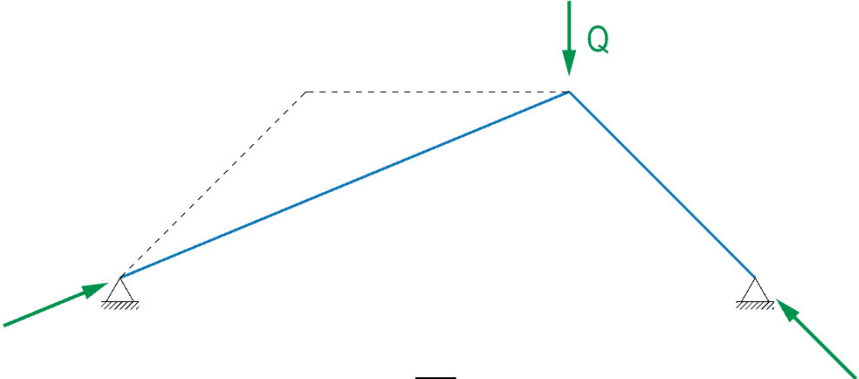




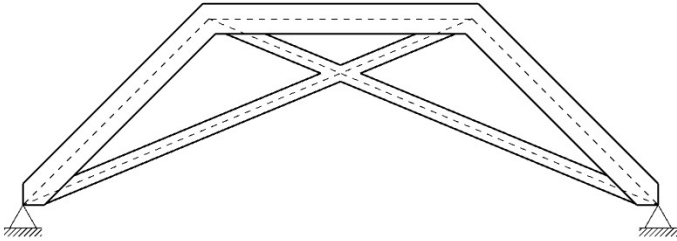


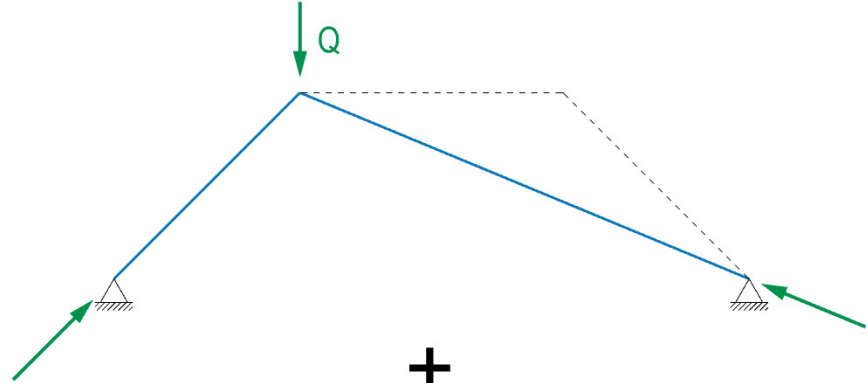


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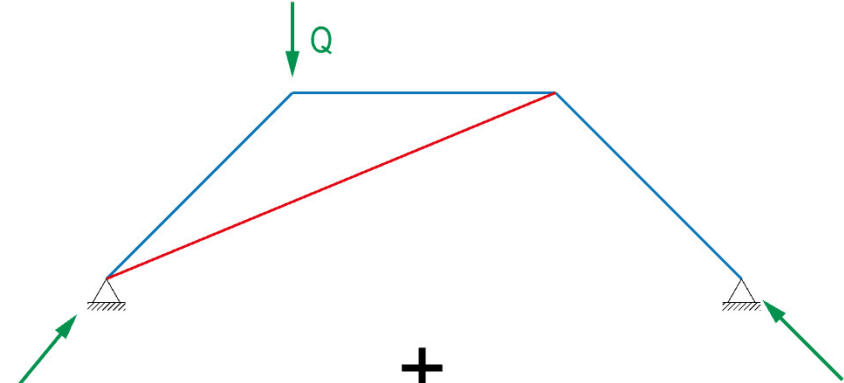


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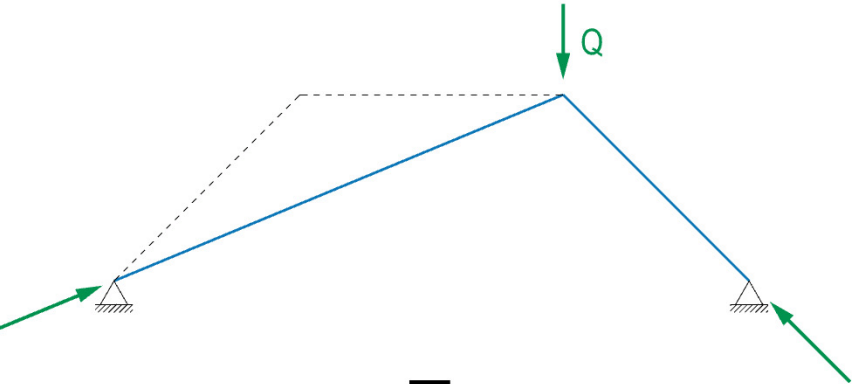




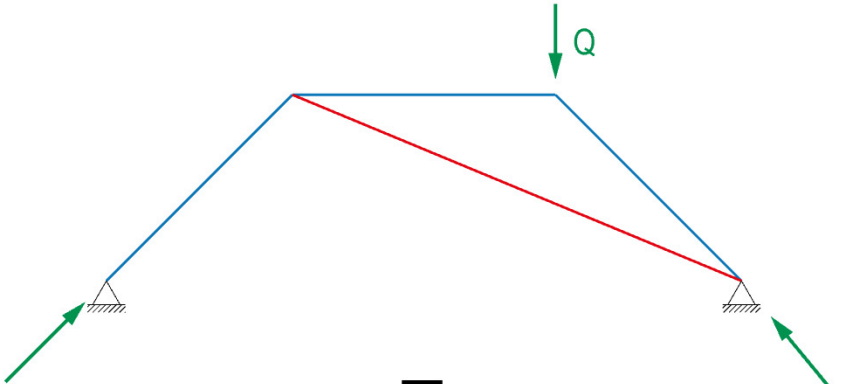
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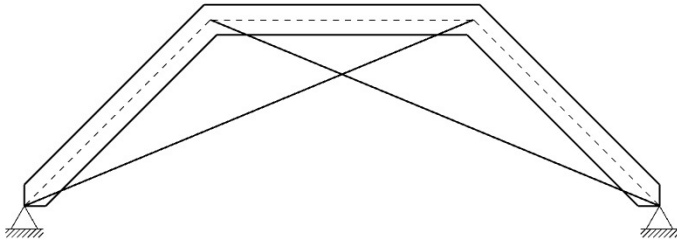
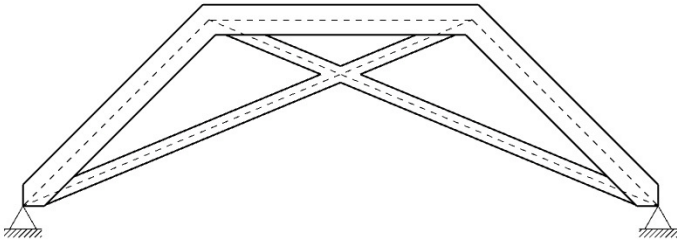
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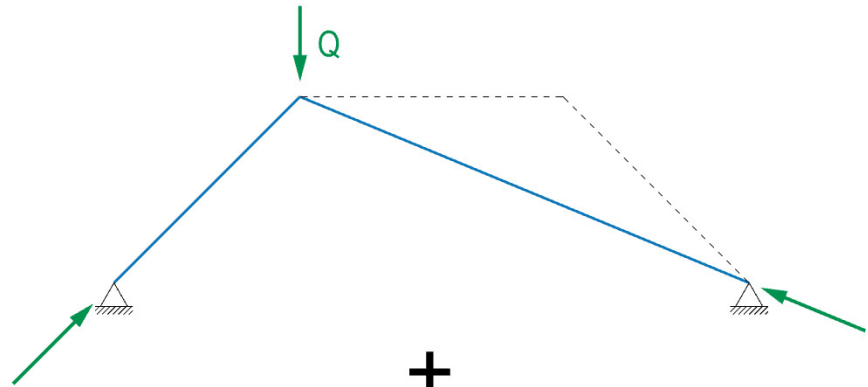


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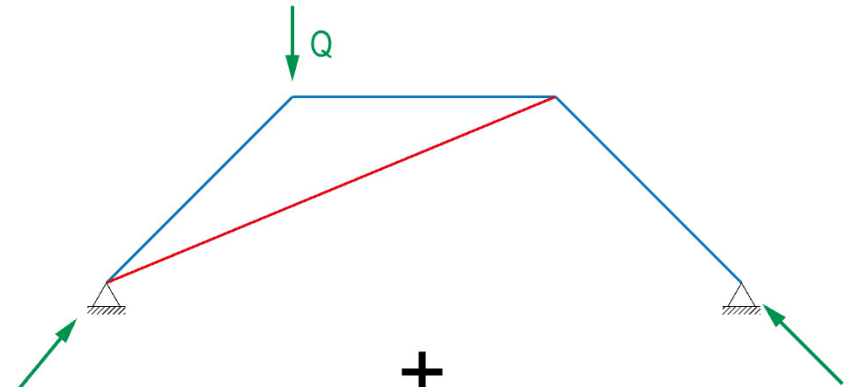


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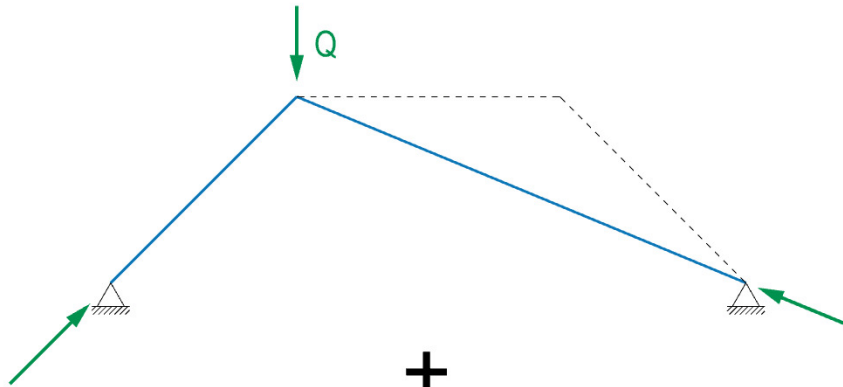




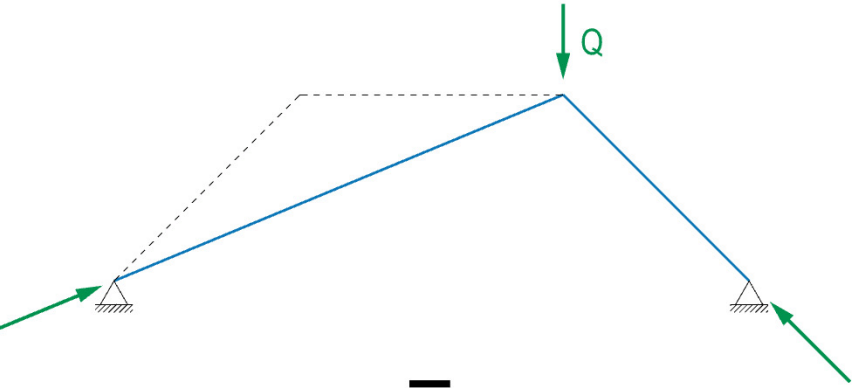
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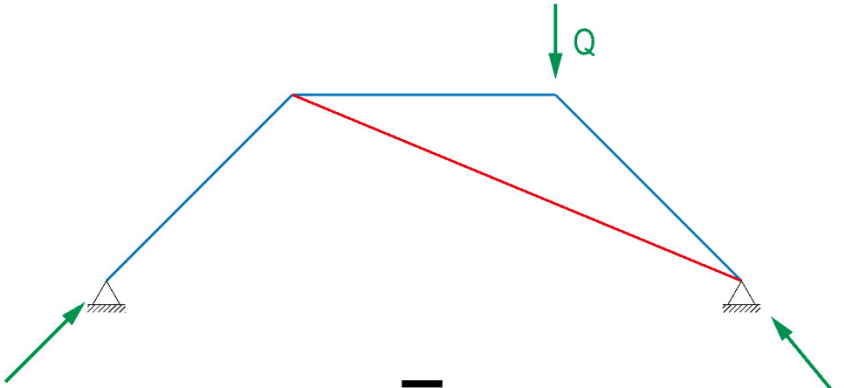
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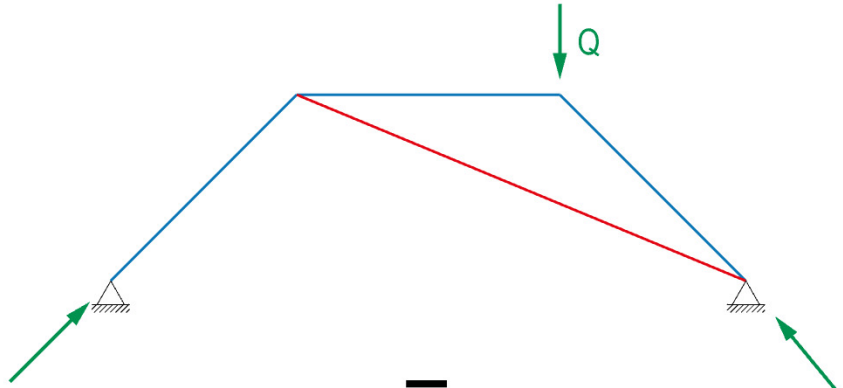
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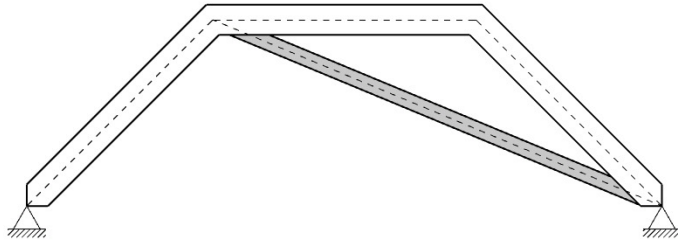
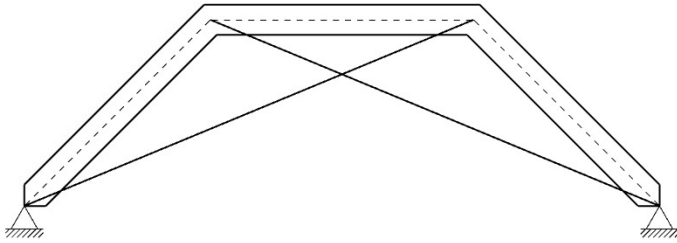
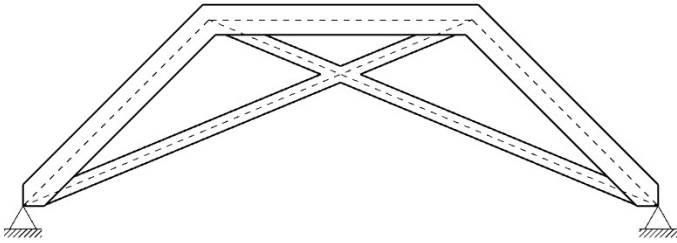
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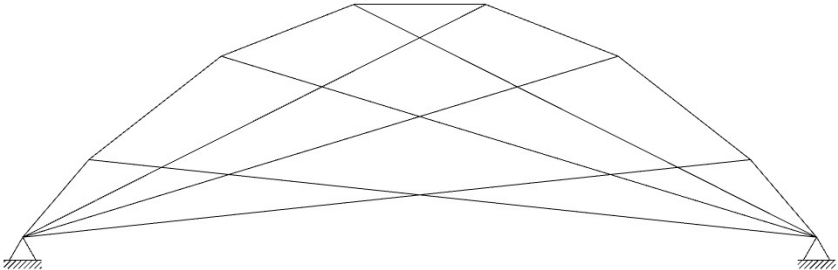
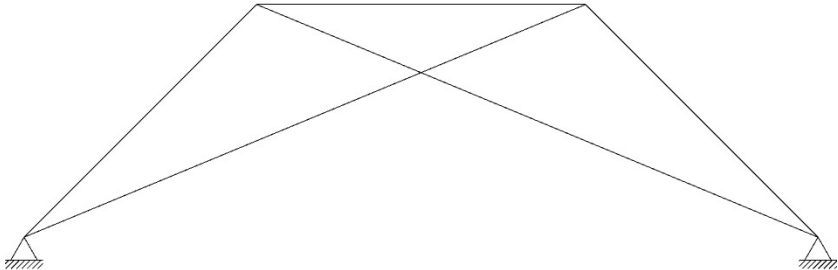


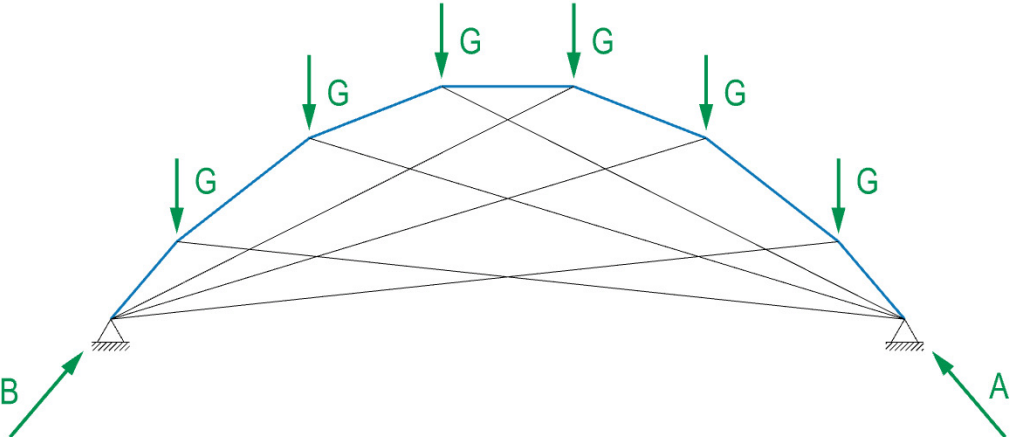
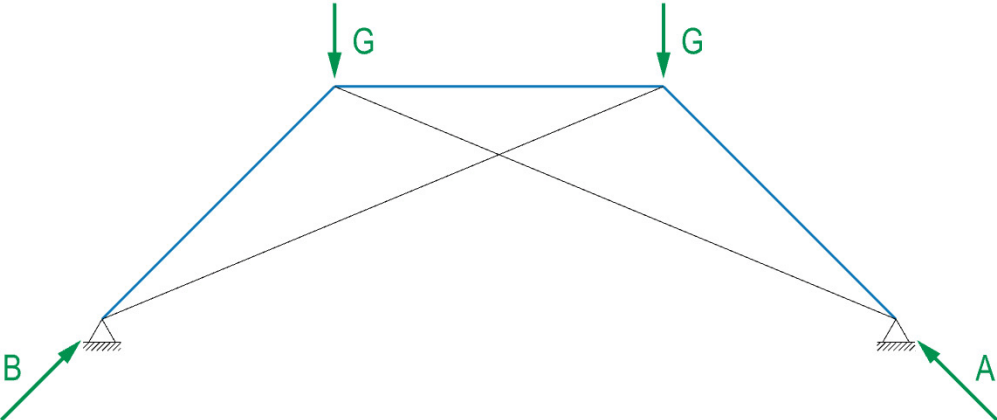
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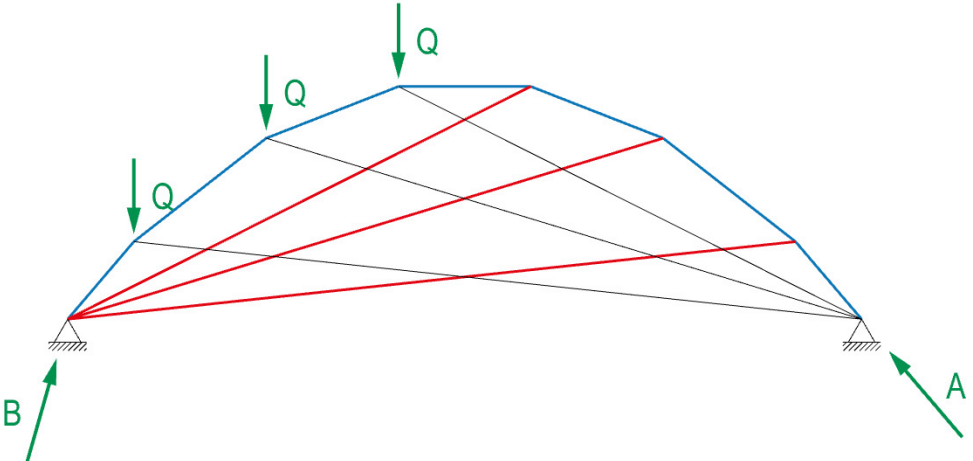
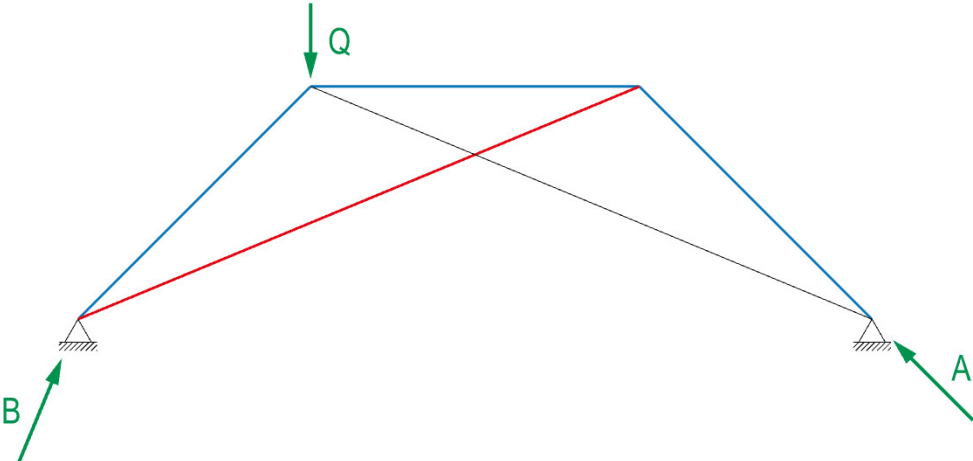


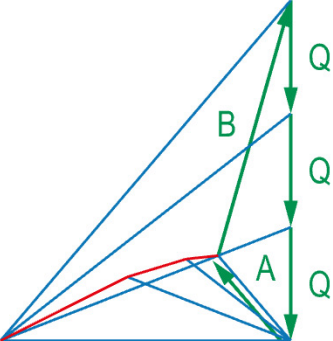
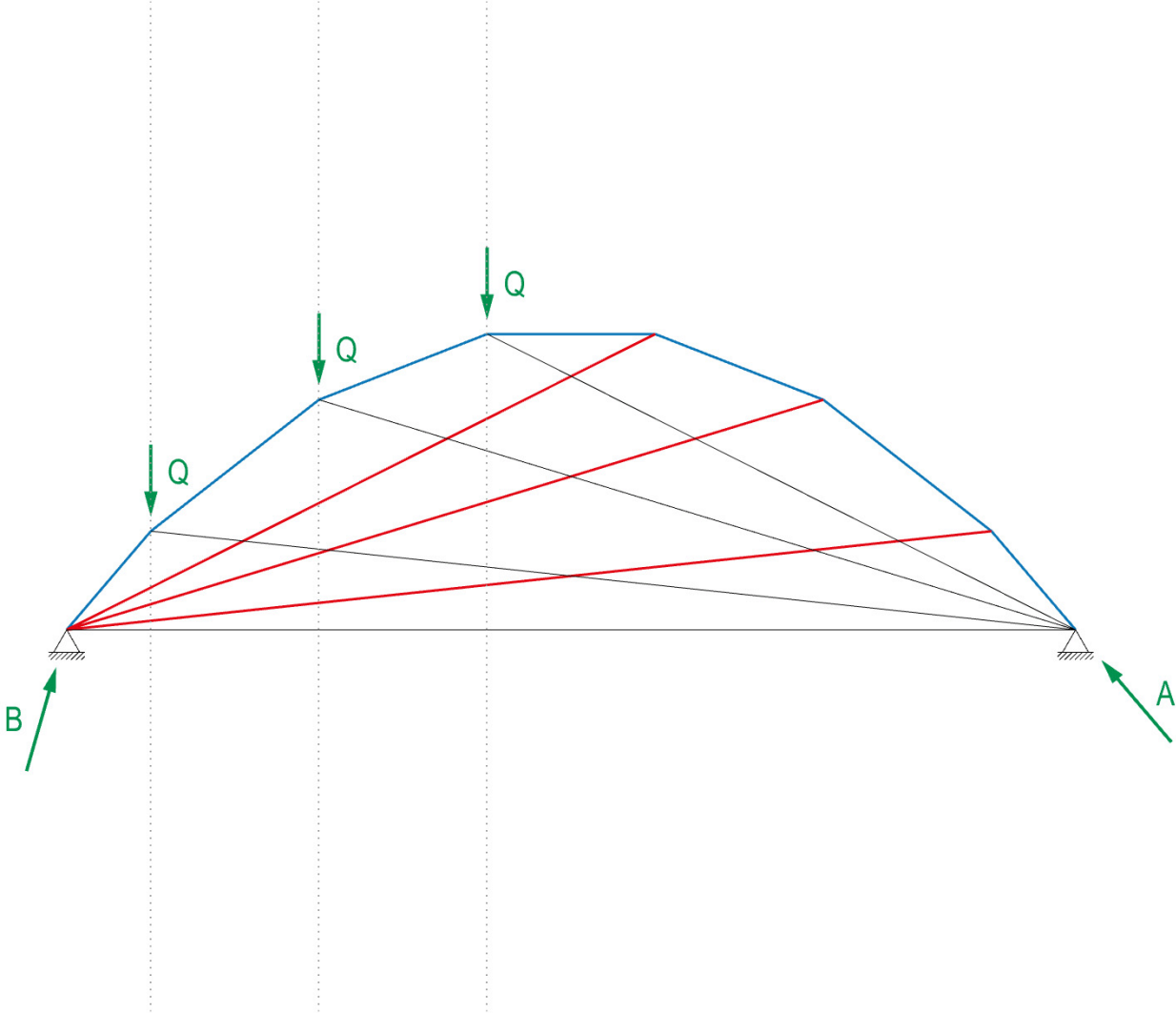
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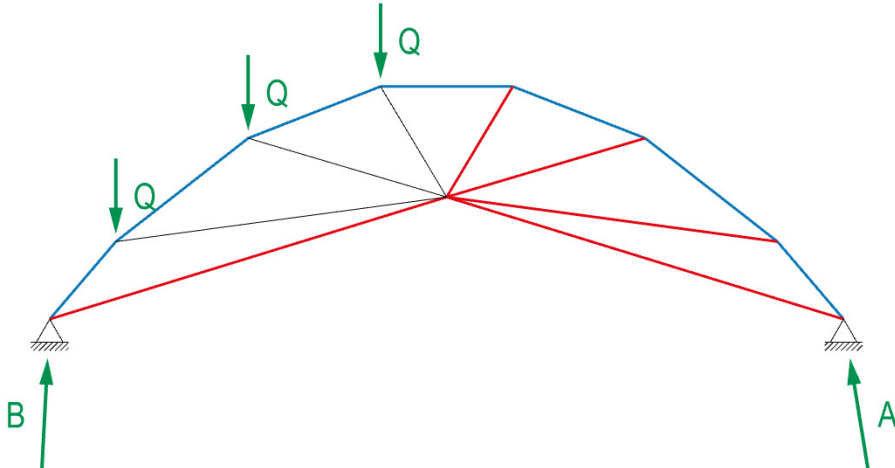
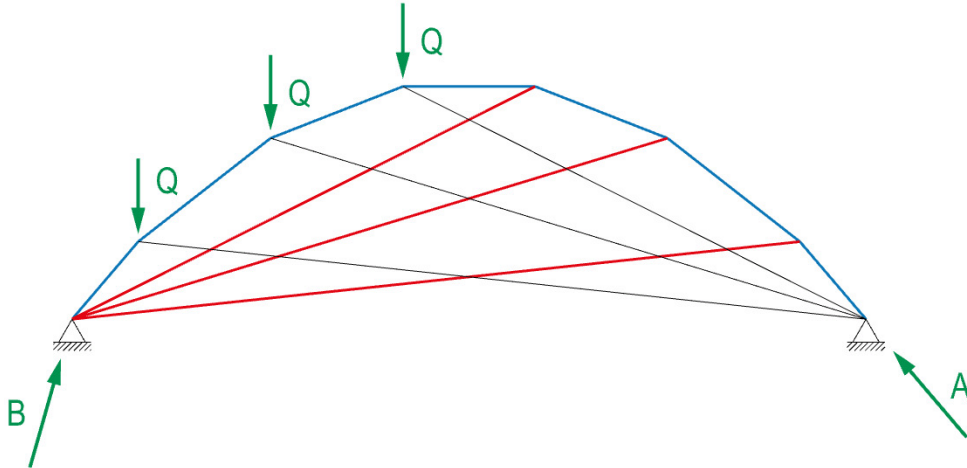


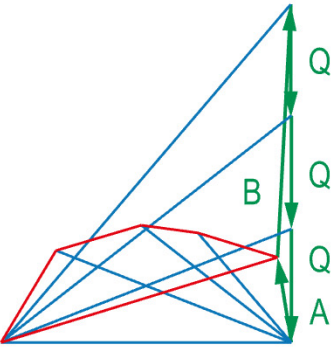
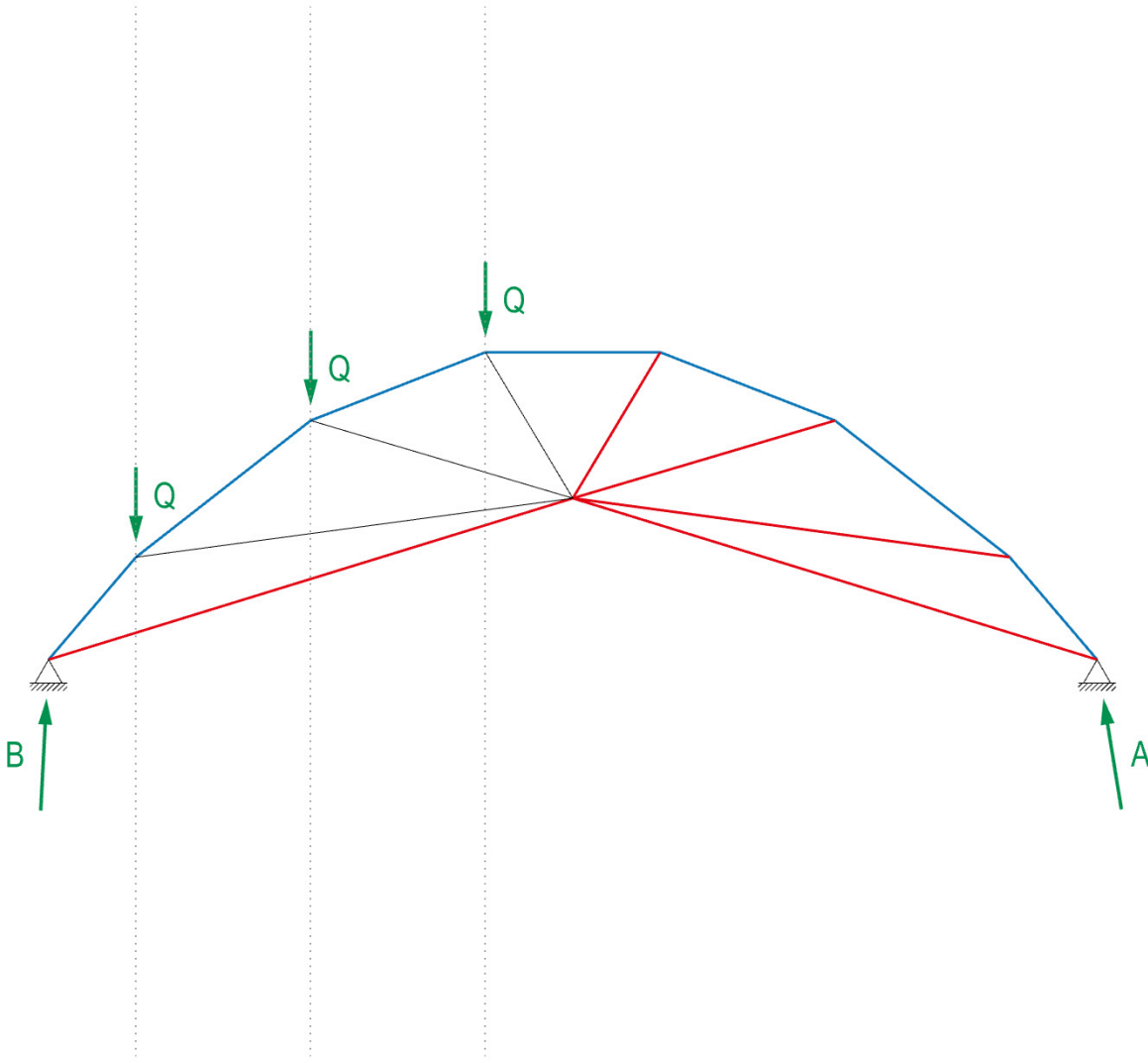


A. Pomerantsev, V. Shukhov: State warehouse GUM, Moscow, 1893



A. Pomerantsev, V. Shukhov: State warehouse GUM, Moscow, 1893



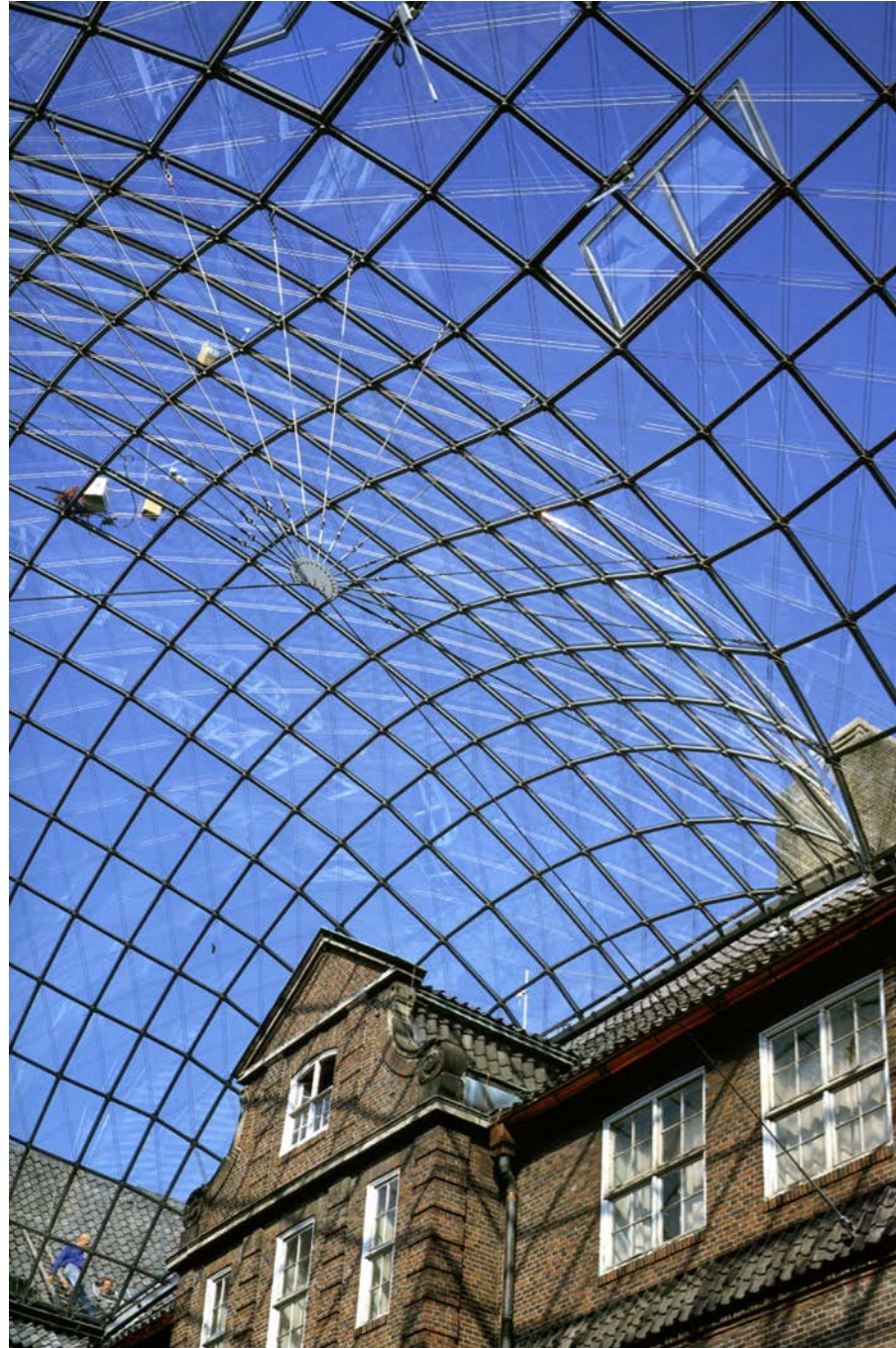




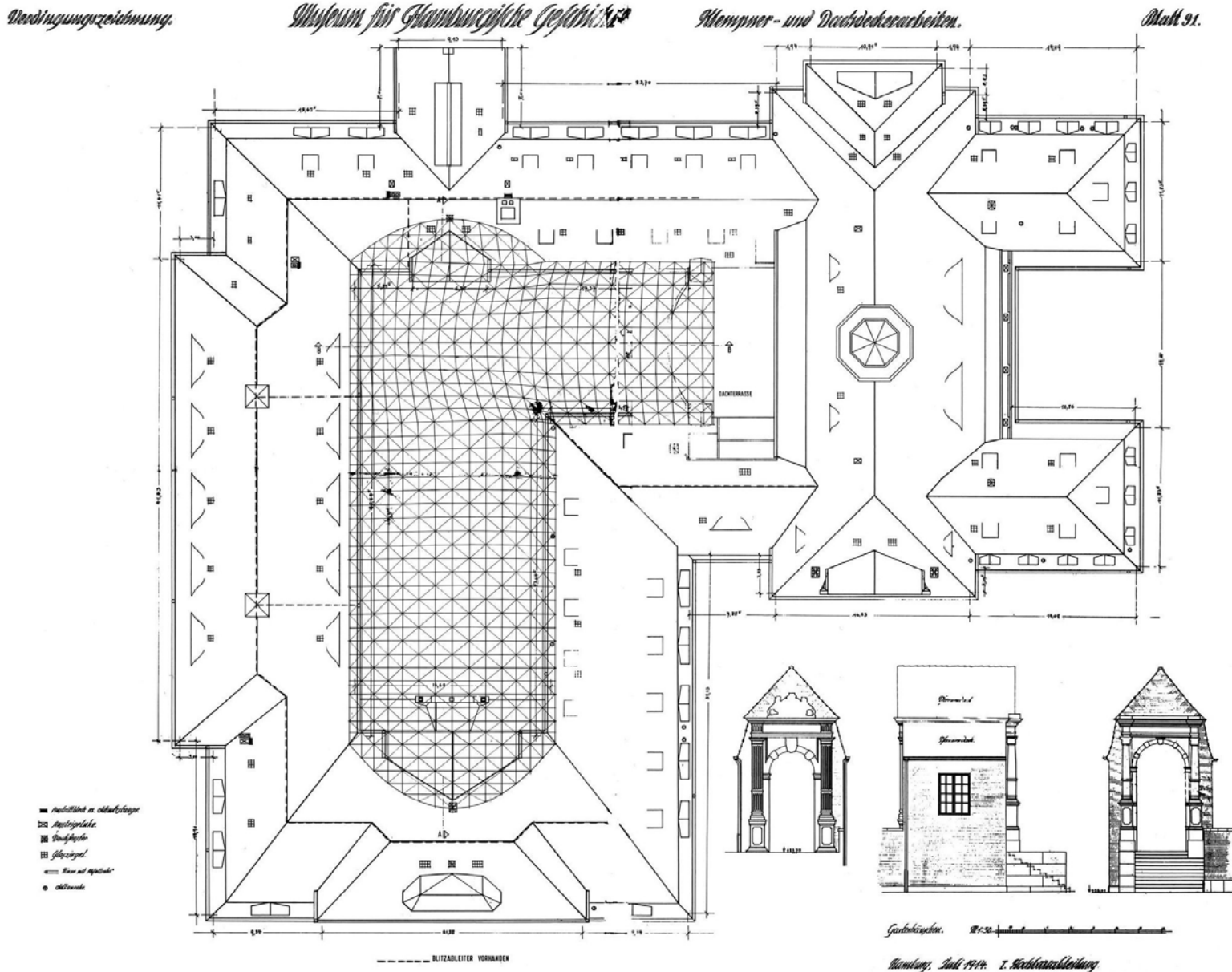
R. Brosi & Obrist and Partner, Peter Rice: Bus station Chur, 1992



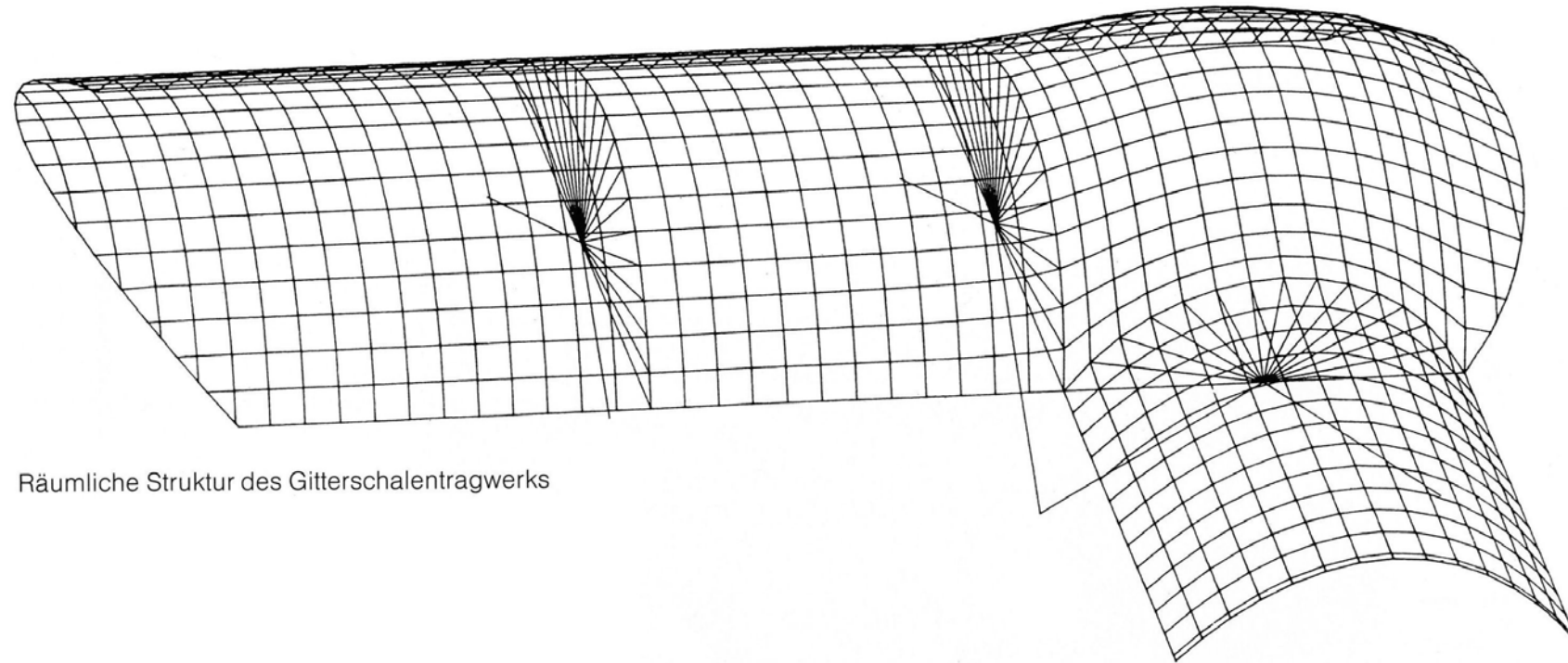
R. Brosi & Obrist and Partner, Peter Rice: Bus station Chur, 1992



gmp Architekten, Schlaich Bergermann and Partner: Museum for history, Hamburg, 1989



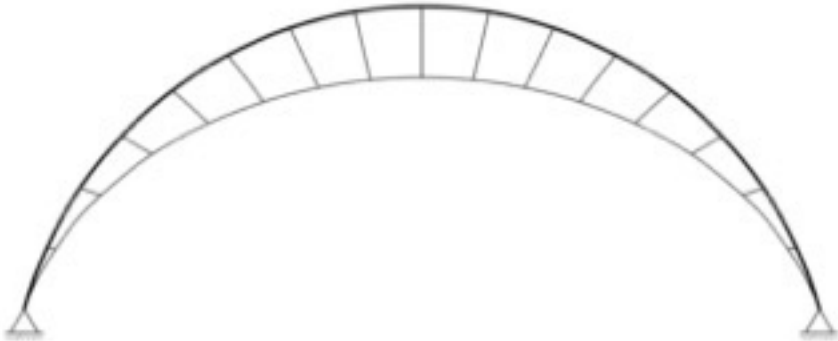
gmp Architekten, Schlaich Bergermann and Partner: Museum for history, Hamburg, 1989

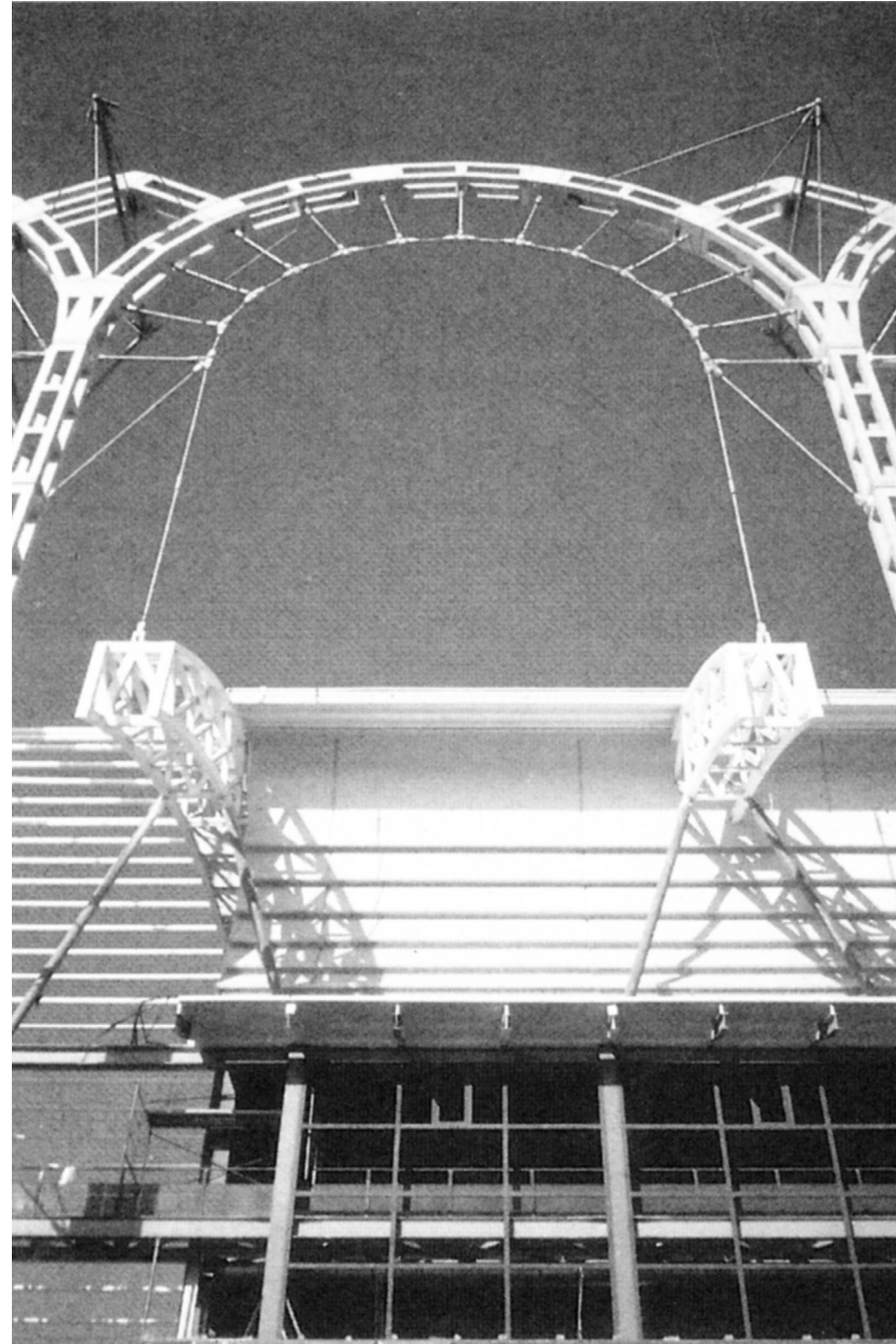


Räumliche Struktur des Gitterschalentragwerks

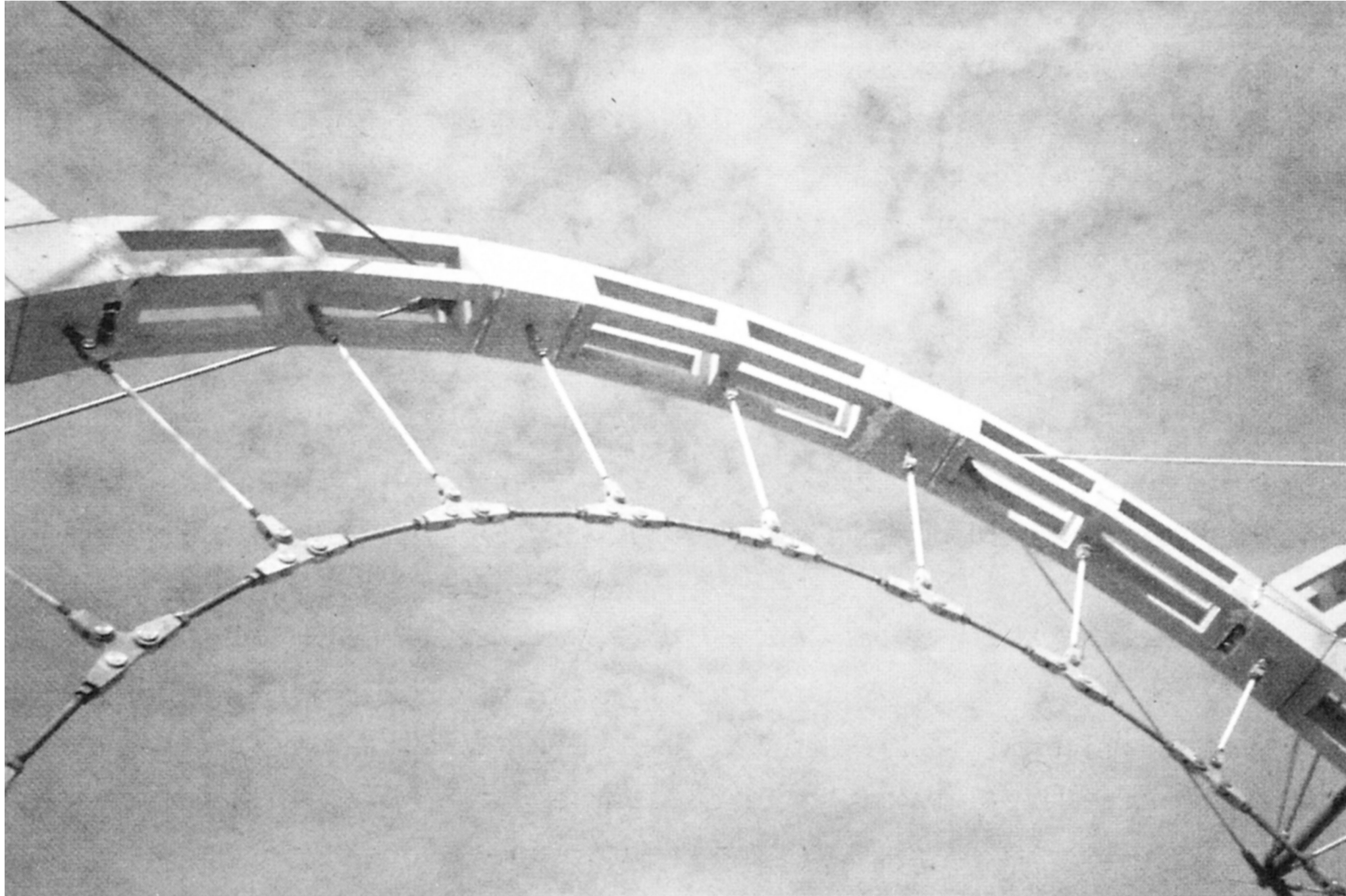


Frank Gehry Architects, Schlaich Bergermann and Partner: DZ Bank, Berlin, 2001

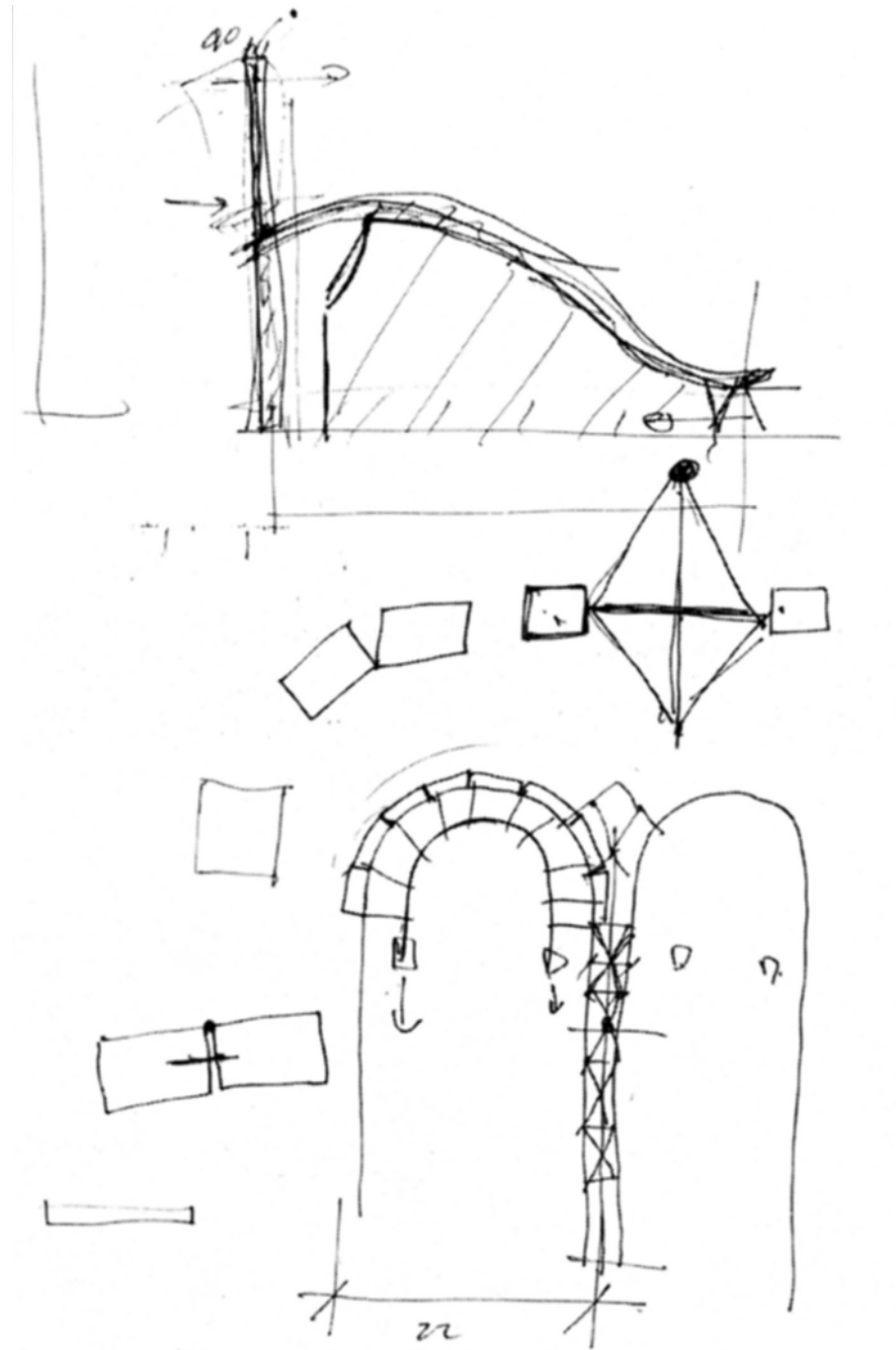




Peter Rice/ Arup: Pavilion of the Future, Sevilla, 1992



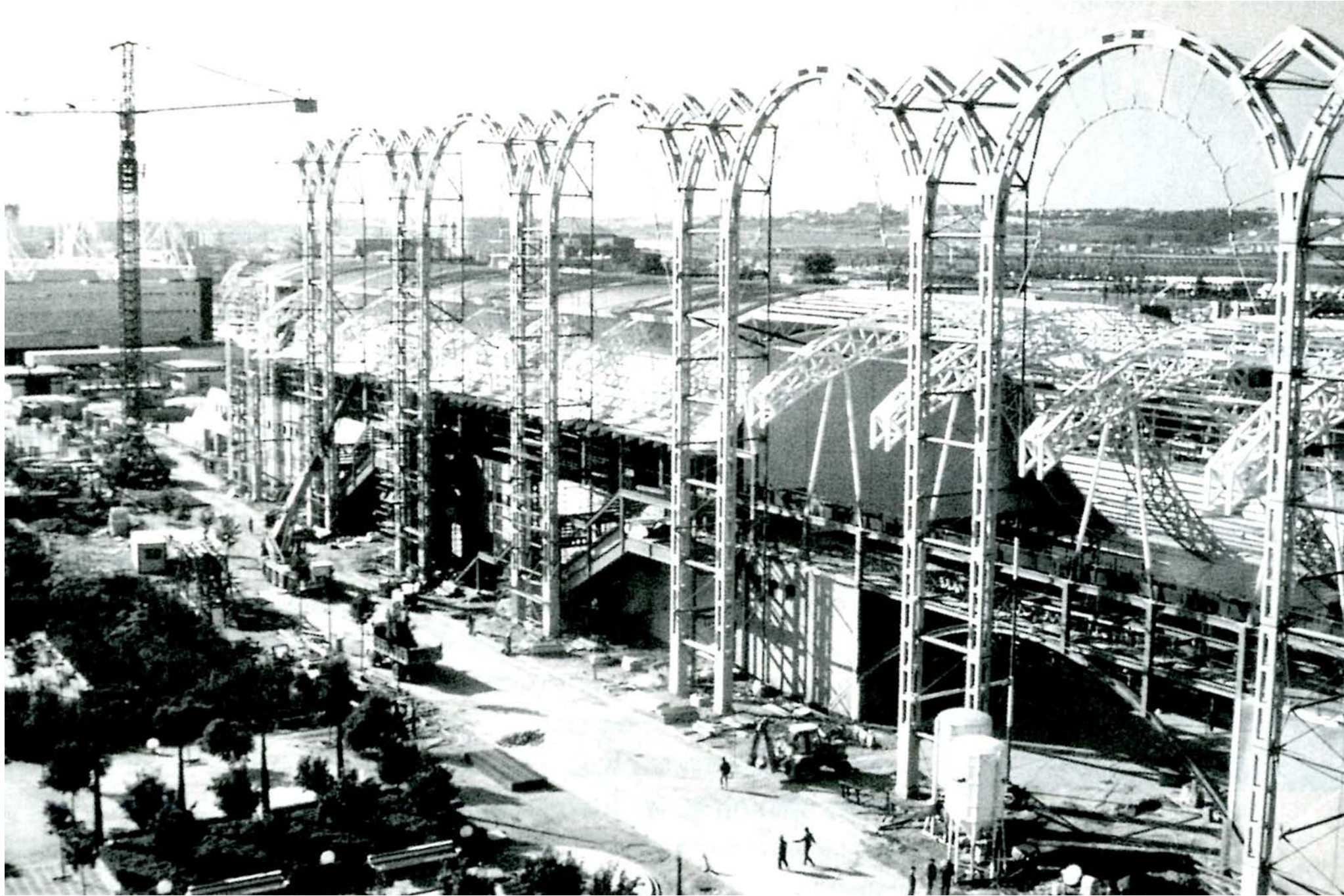
Peter Rice/ Arup: Pavilion of the Future, Sevilla, 1992



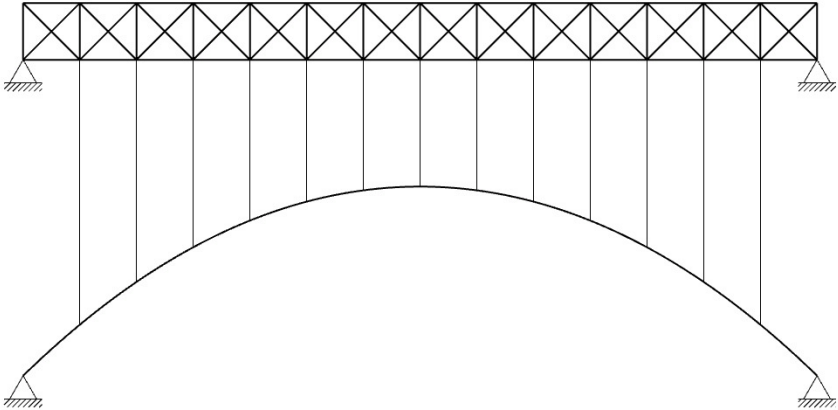
Peter Rice/ Arup: Pavilion of the Future, Sevilla, 1992

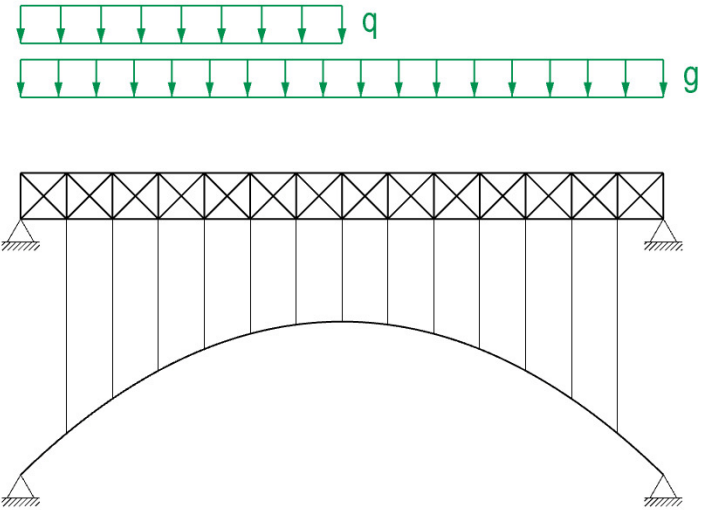


Peter Rice/ Arup: Pavilion of the Future, Sevilla, 1992

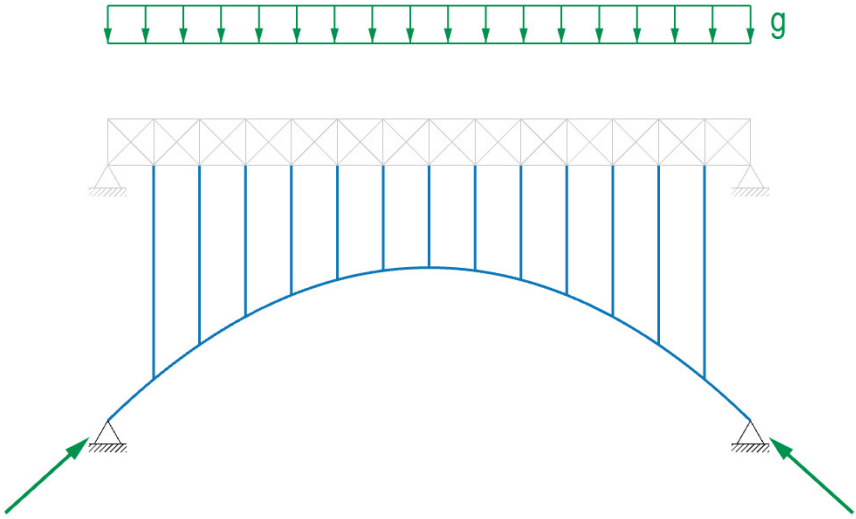


Peter Rice/ Arup: Pavilion of the Future, Sevilla, 1992

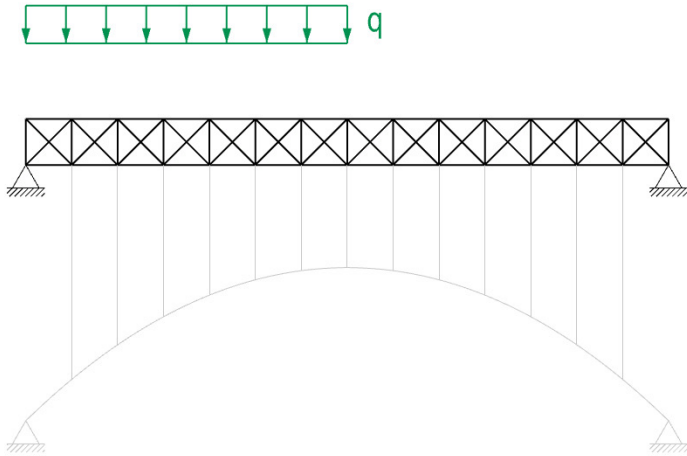




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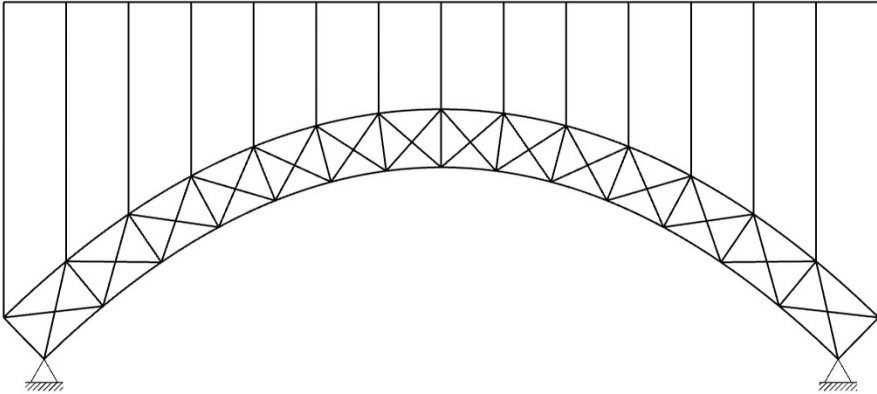




Robert Maillart: Valterschielbachbridge, Donath, 1925

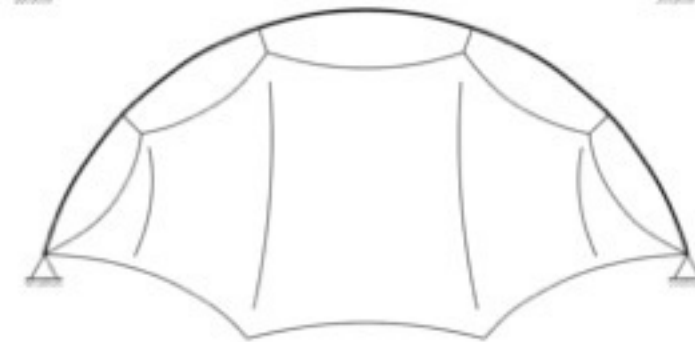
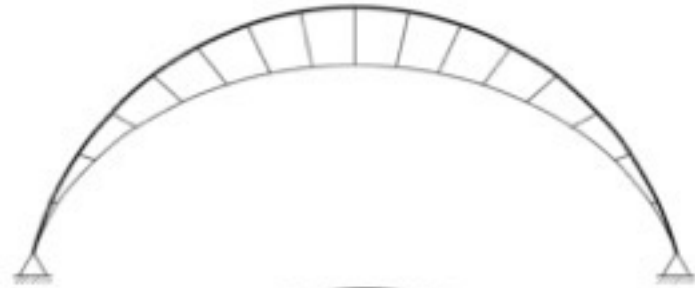
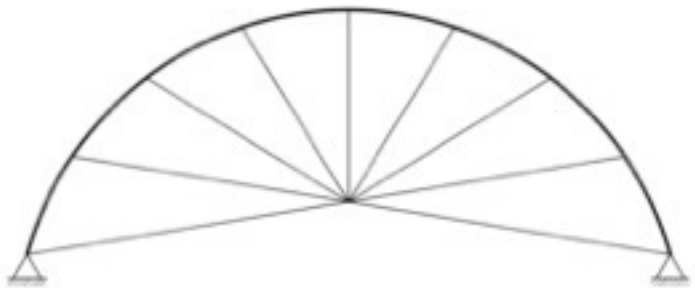
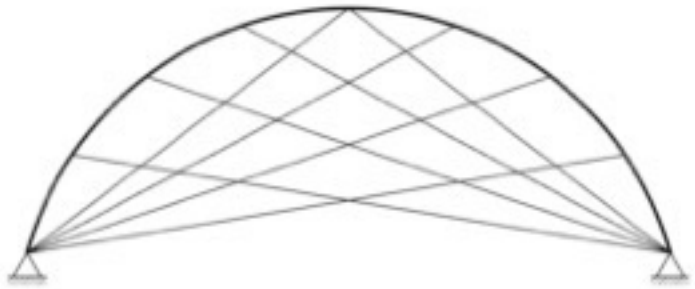


Ralph Modjeski: San Francisco-Oakland Bay Bridge, San Francisco, 1936



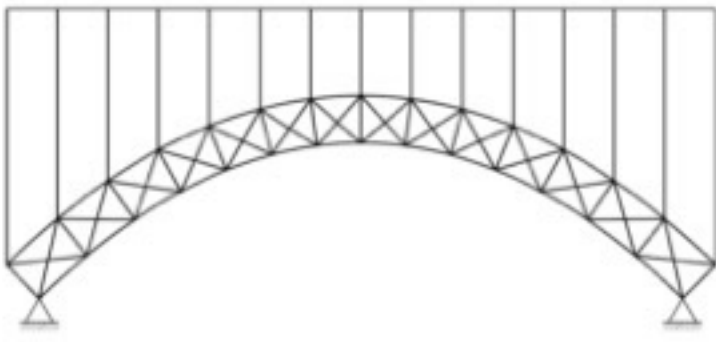
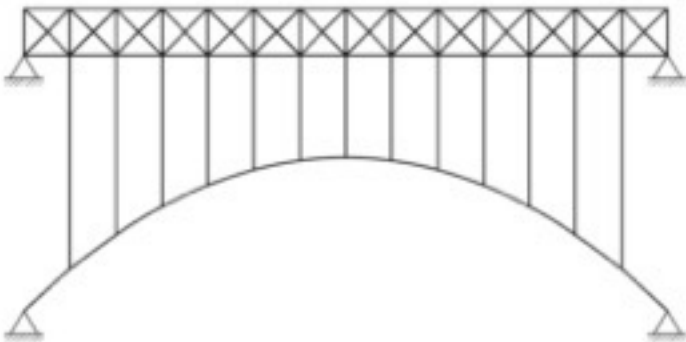


Eiffel, T. Seyring: Maria Pia bridge, Porto, 1877



Aussteifungskabel

Stiffening cables



Aussteifungsbalken

Stiffening beam

Steifer Bogen

Stiff arch

Bögen

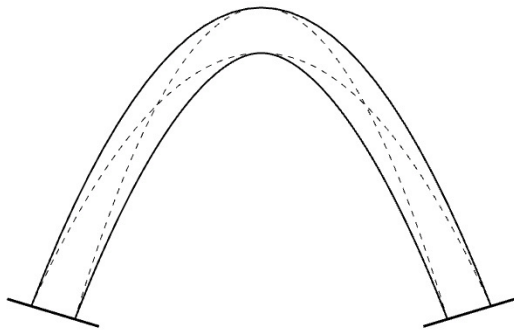
Arches

Seil und Bogen – Inversionsprinzip
Cables and arches – inversion principle

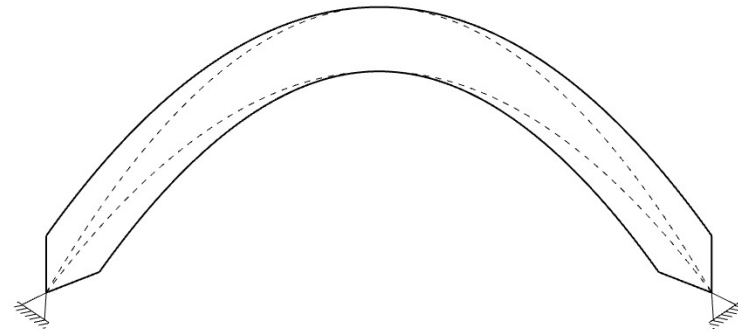
Fallbeispiel: Gotische Kathedrale
Case study: Gothic cathedral

Aussteifungskonzepte
Concepts for stiffening

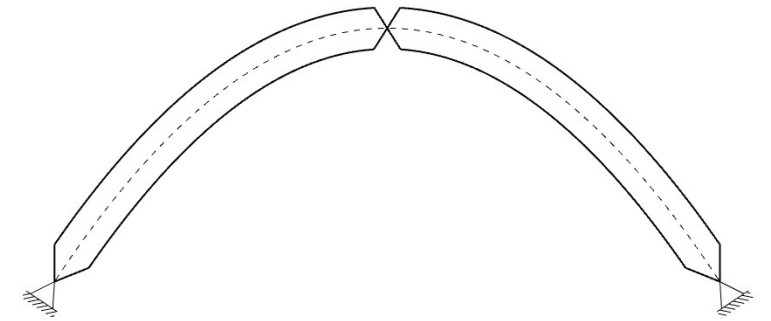
>> Stützlinien
Thrust lines



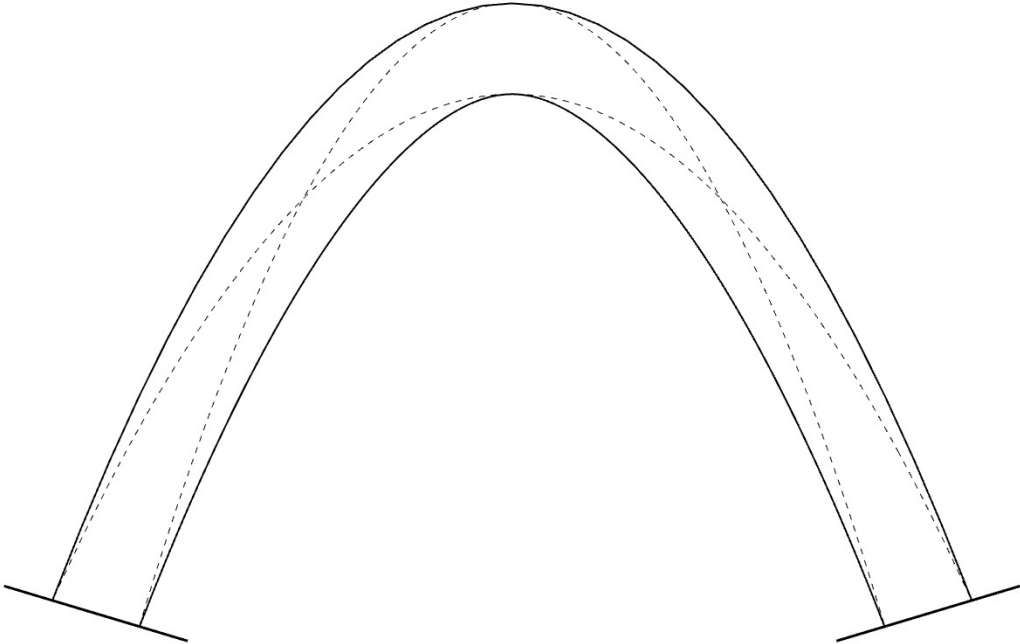
Bogen ohne Gelenke
Arches without hinges

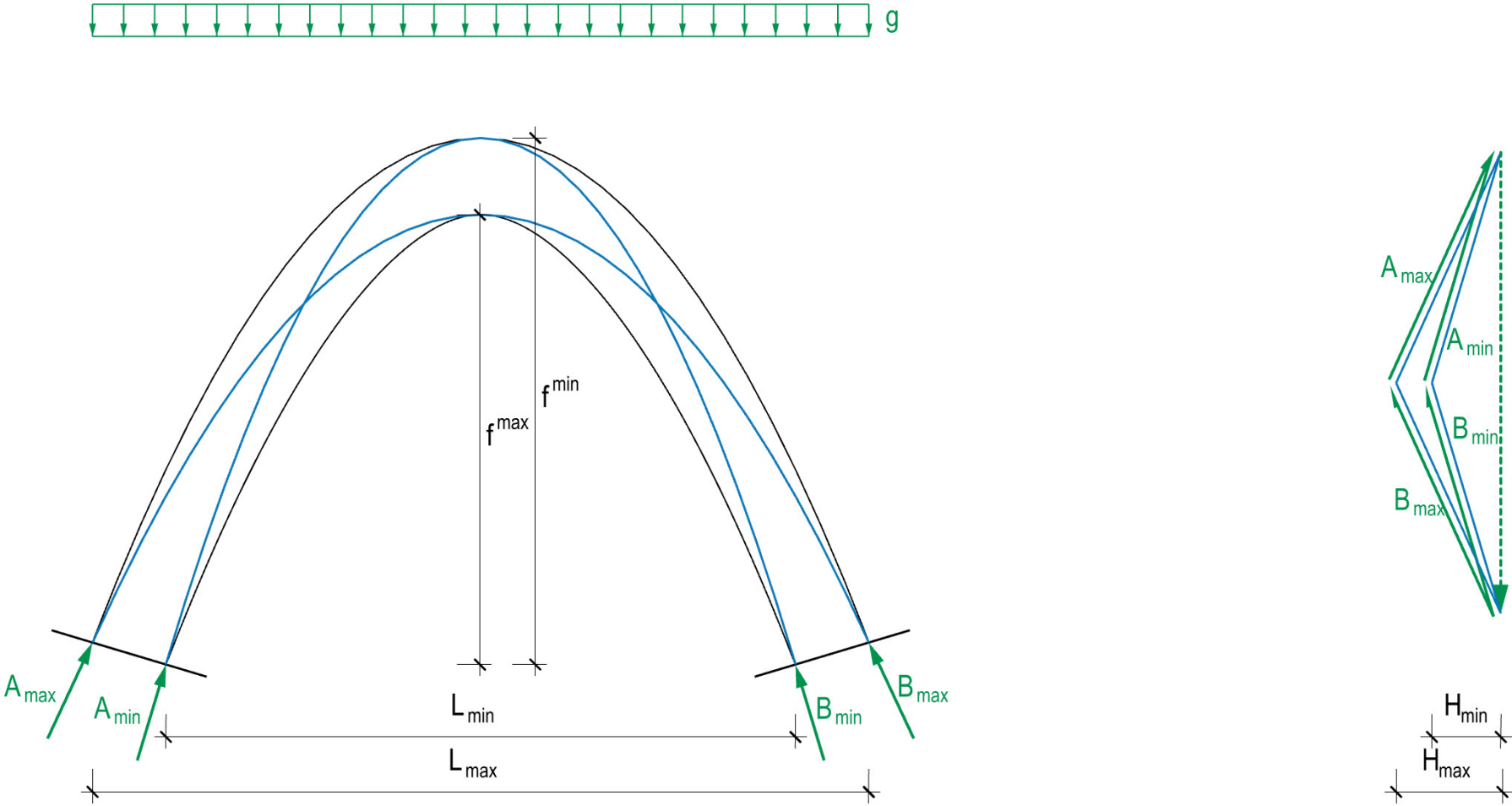


Zwei-gelenk Bogen
Arches with two hinges



Drei-gelenk Bogen
Arches with three hinges



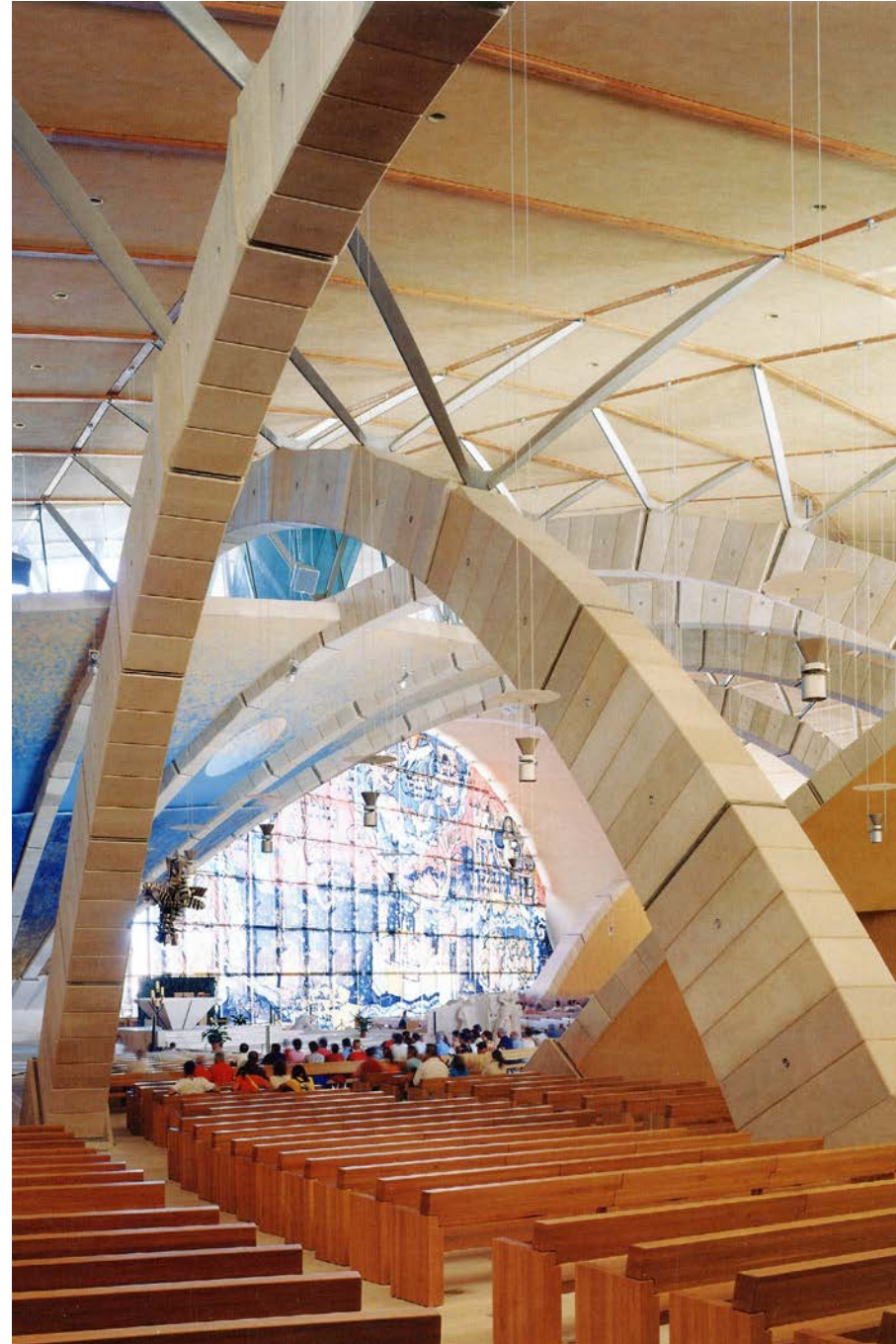




Taq-i Kisra Palast (Ayvan-e Kasra), Asbanbar, near Baghdad, 550 n.Chr.



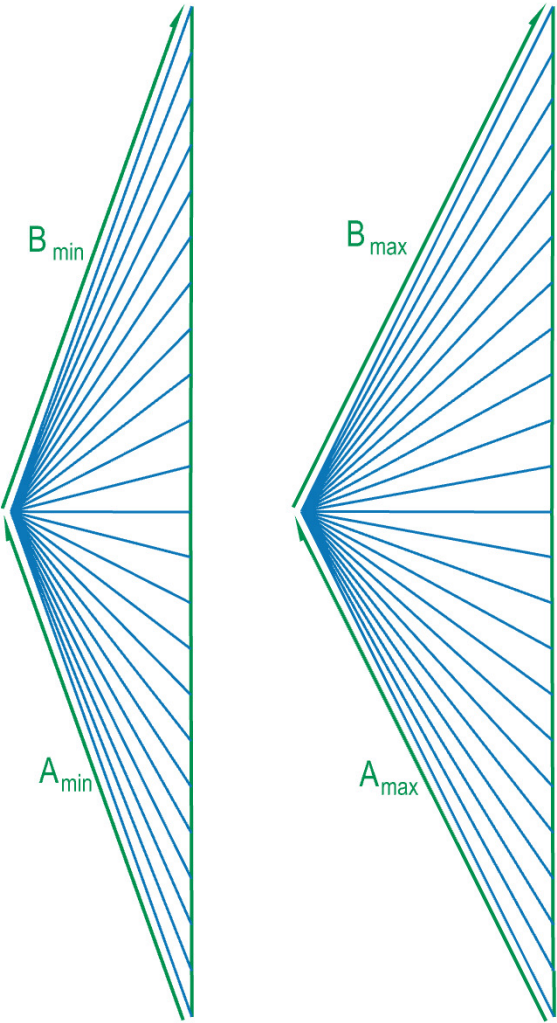
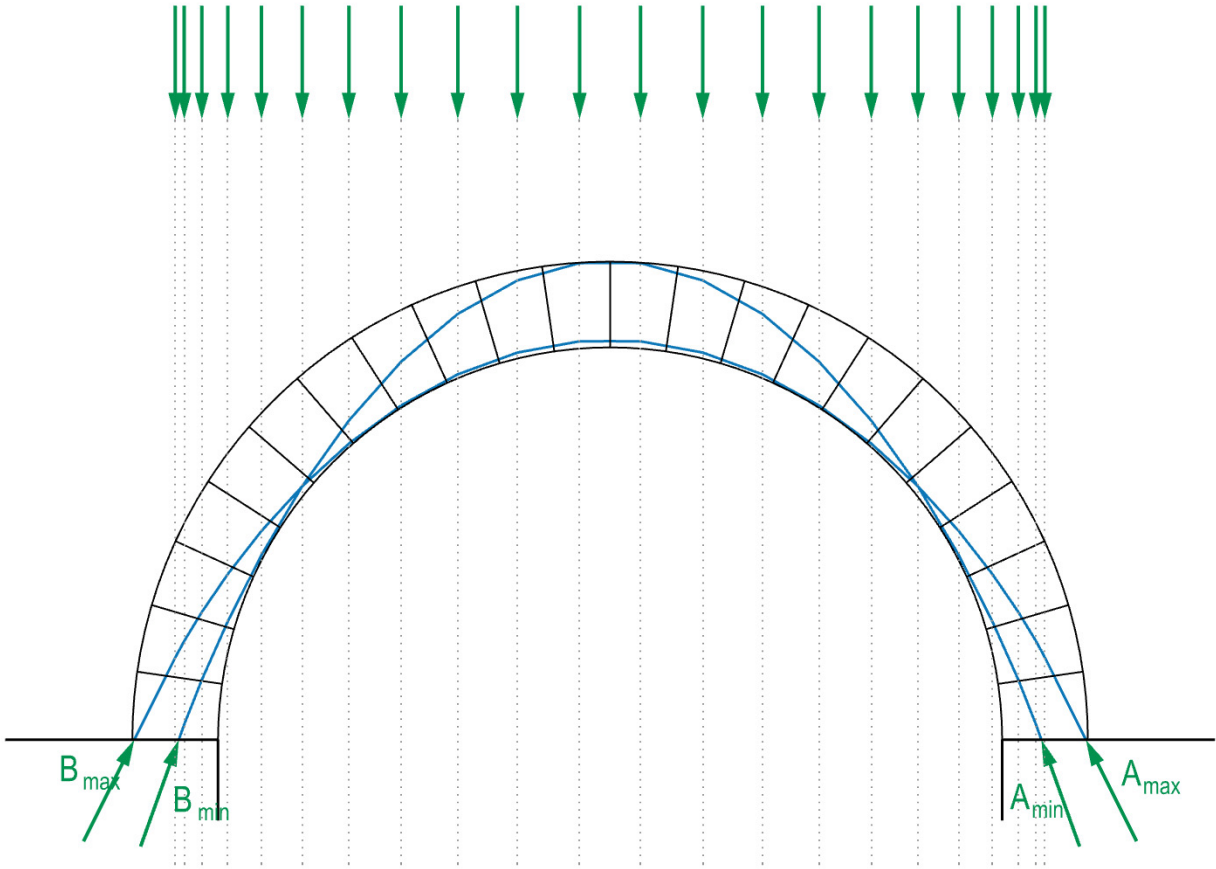
Renzo Piano, Arup: Chiesa di Padre Pio, San Giovanni Rotondo, 2004



Renzo Piano, Arup: Chiesa di Padre Pio, San Giovanni Rotondo, 2004

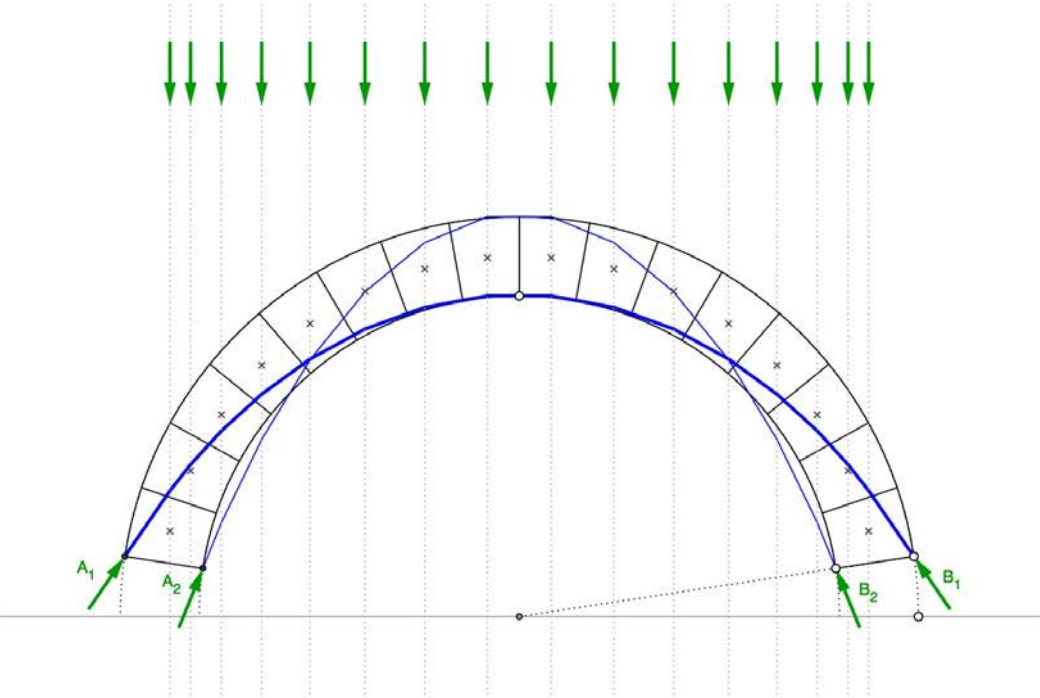


Renzo Piano, Arup: Chiesa di Padre Pio, San Giovanni Rotondo, 2004

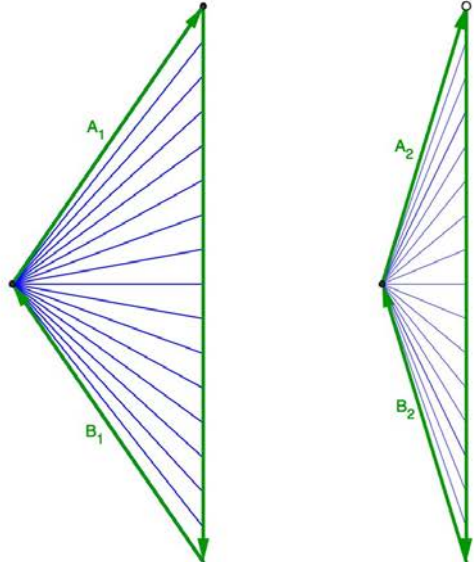


eQ: Minimum and maximum thrust line

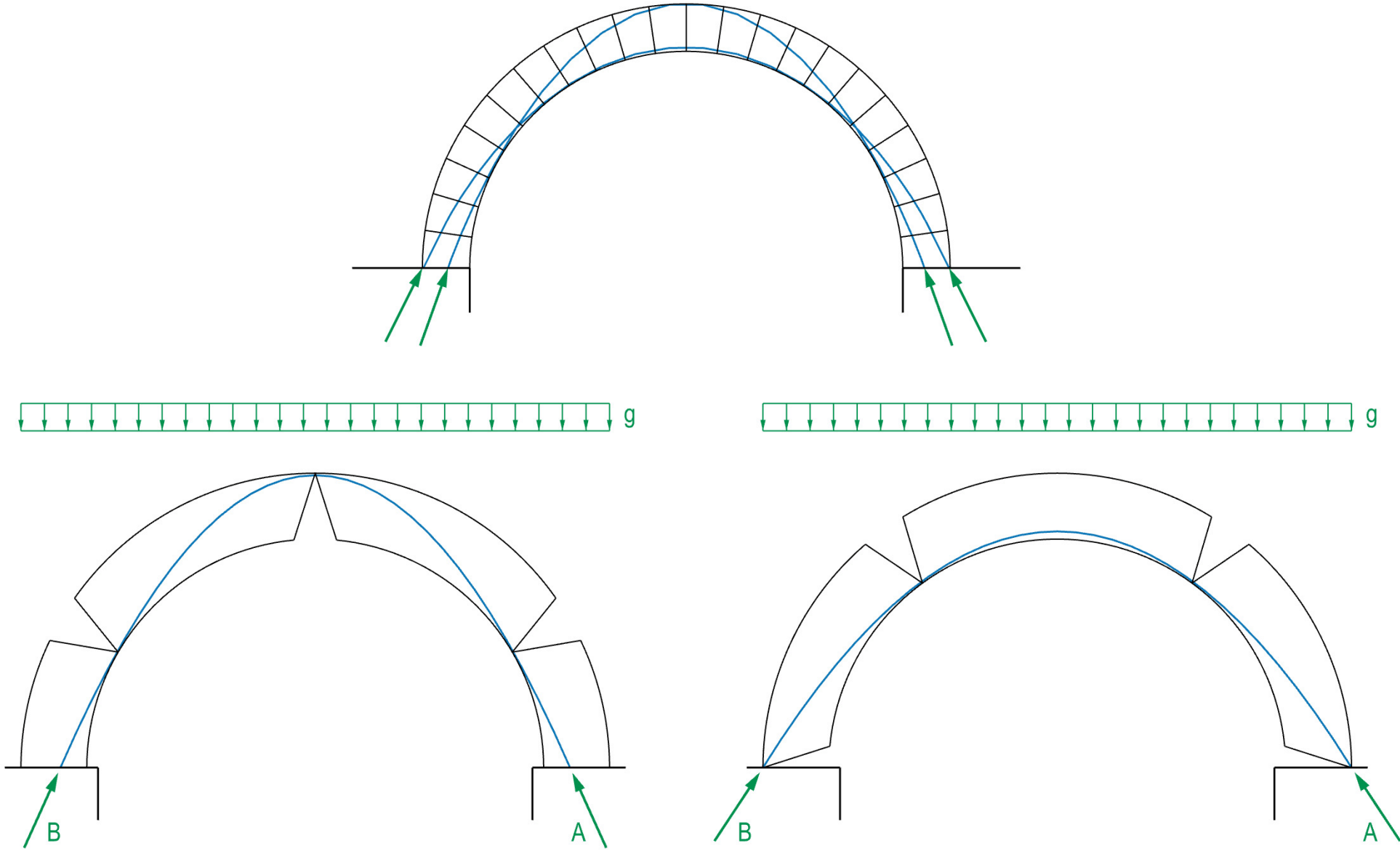
Form Diagram



Force Diagram

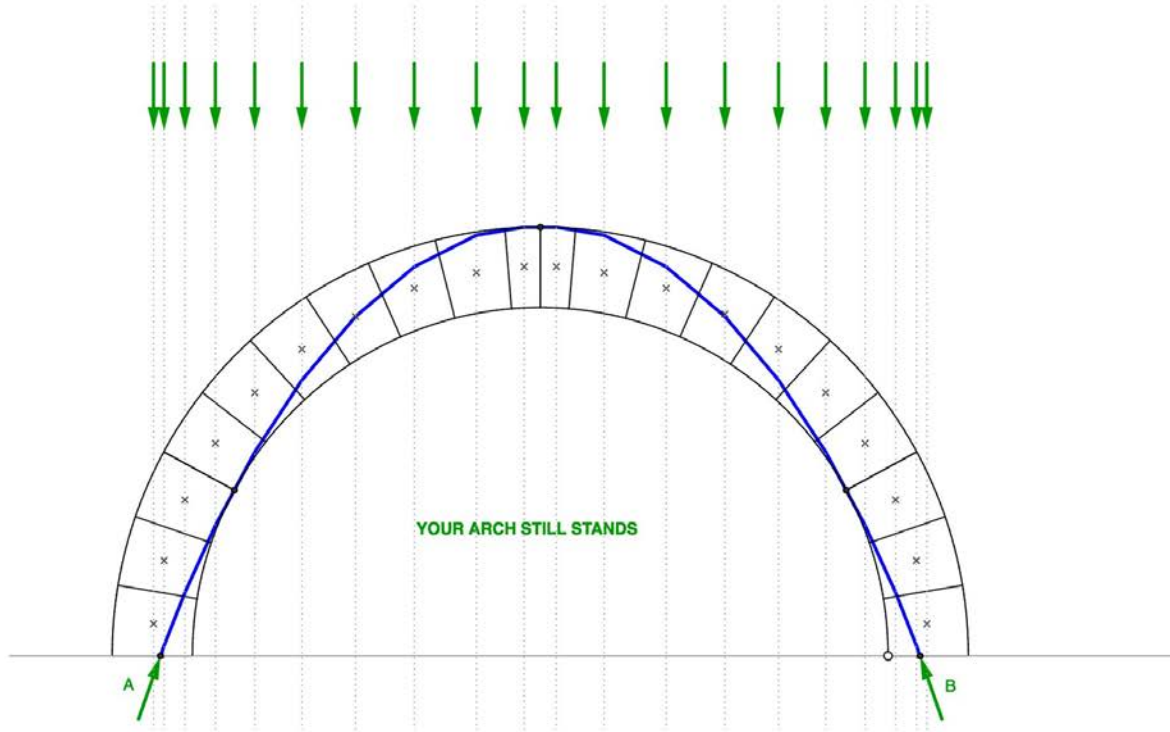


<http://www.block.arch.ethz.ch/eq/drawing/view/16>

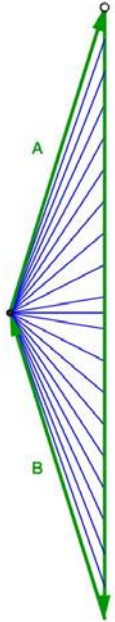


eQ: Masonry arch on spreading supports

Form Diagram



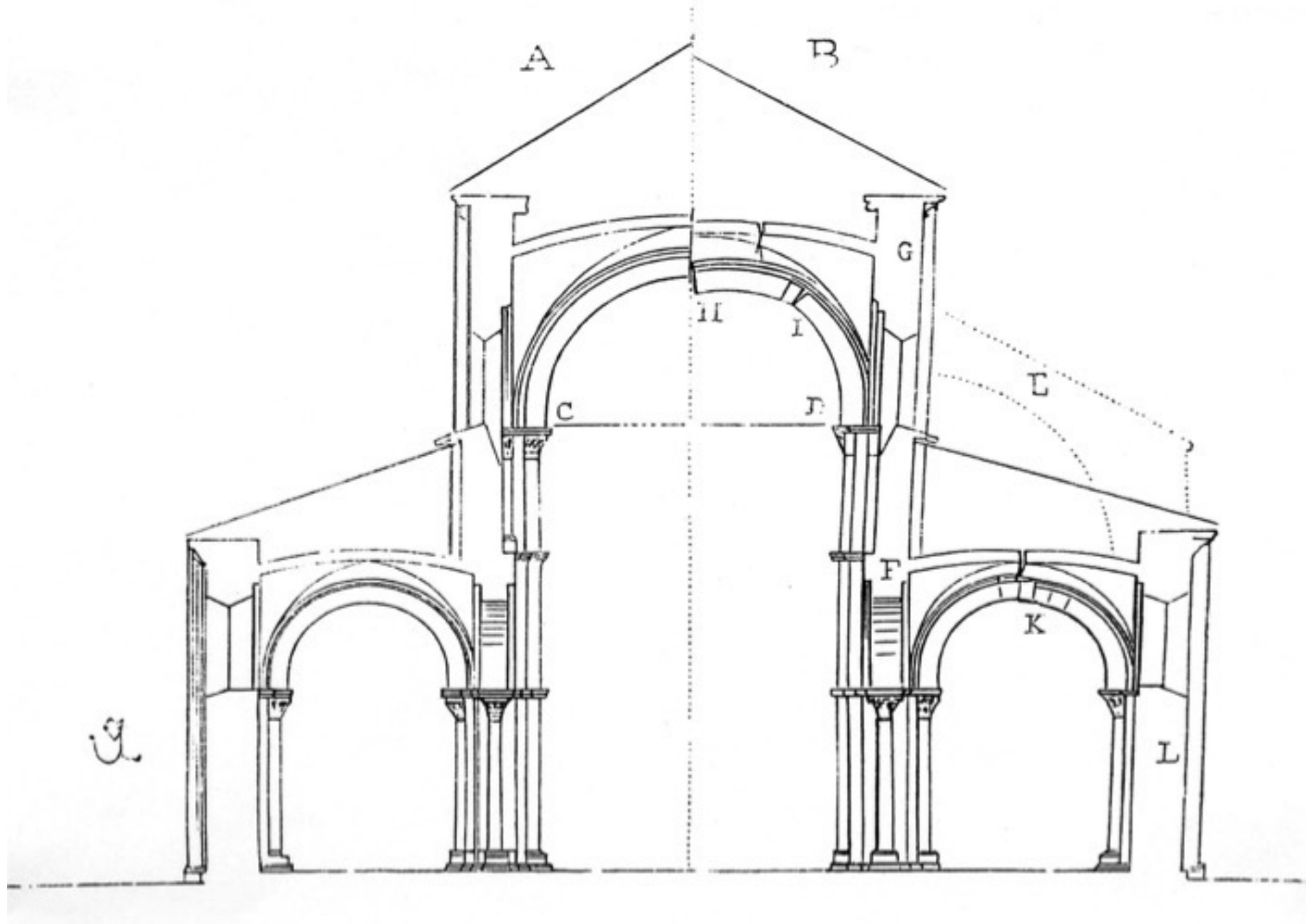
Force Diagram



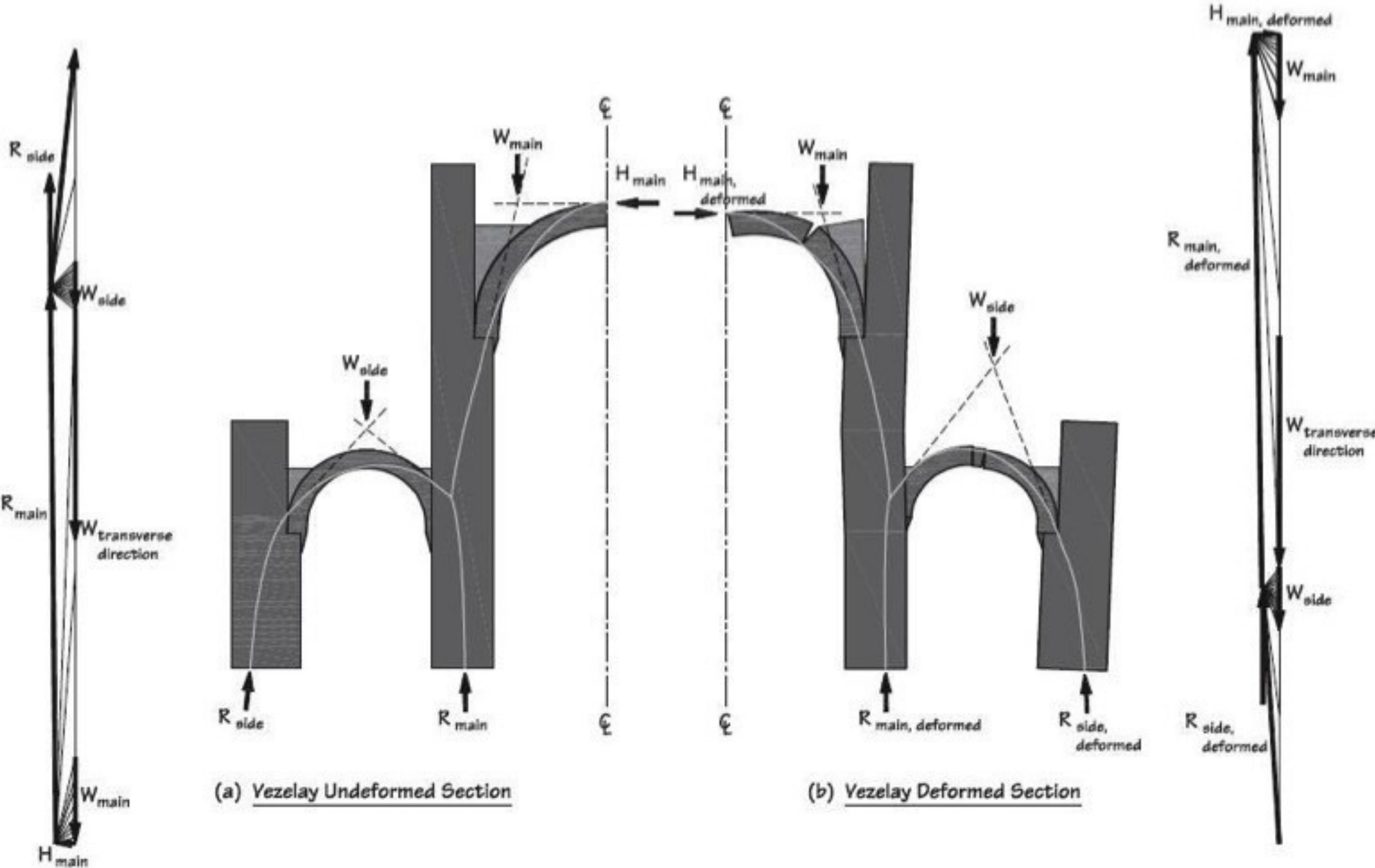
<http://www.block.arch.ethz.ch/eq/drawing/view/17>



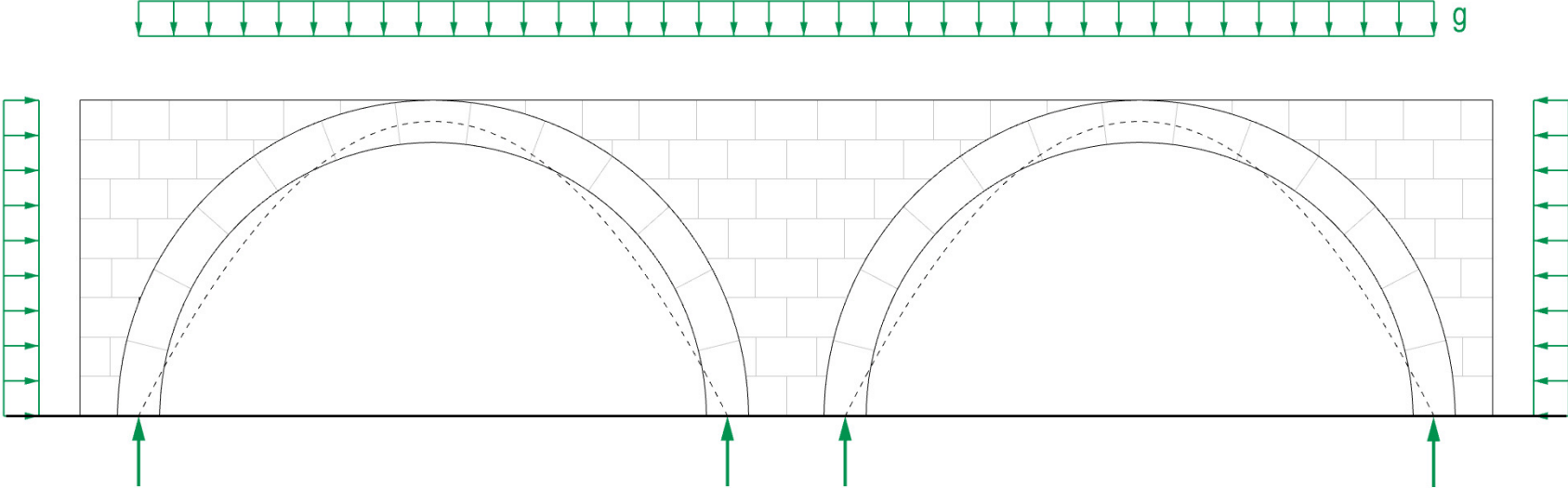
Vezelay Abbey, Burgundy, France, 11th century

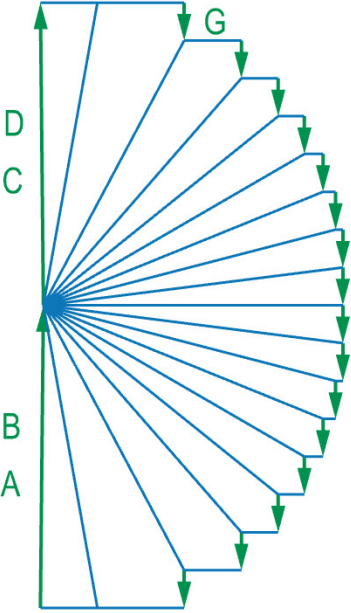
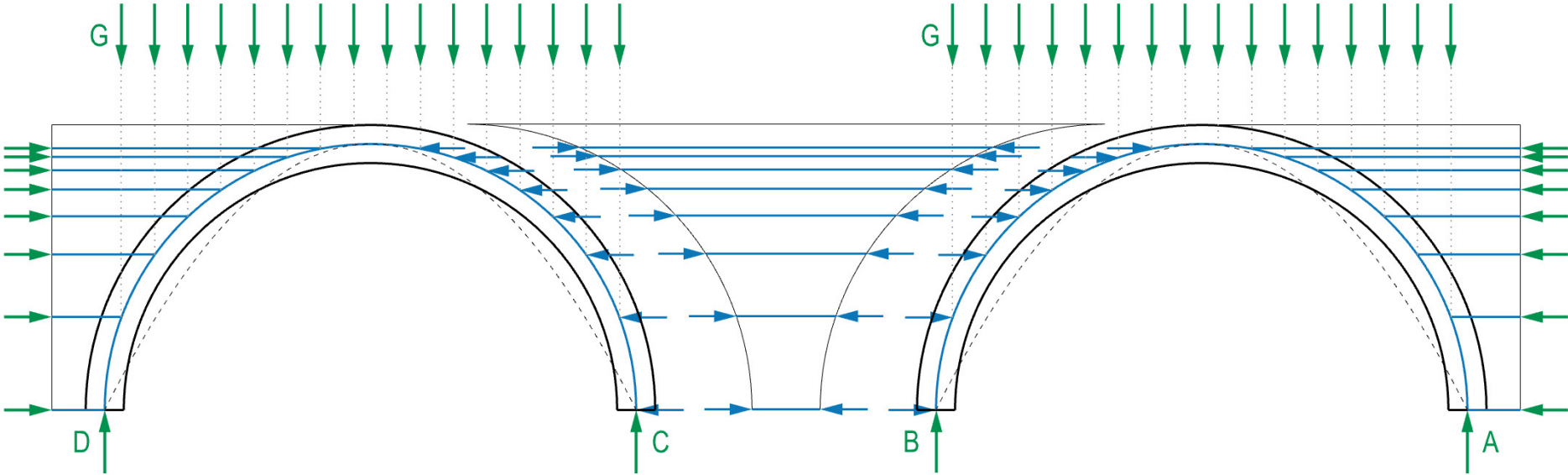


Vezelay Abbey, Burgundy, France, 11th century; Drawing Viollet-le-Duc



Vezelay Abbey, Burgundy, France, 11th century



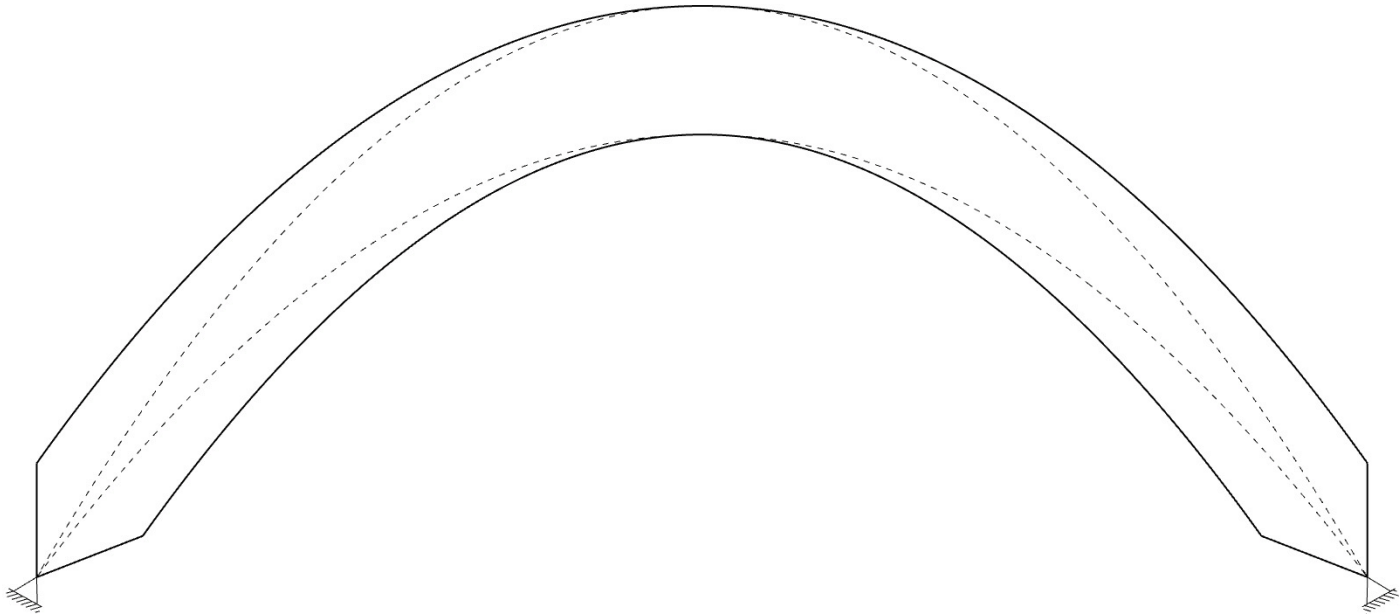


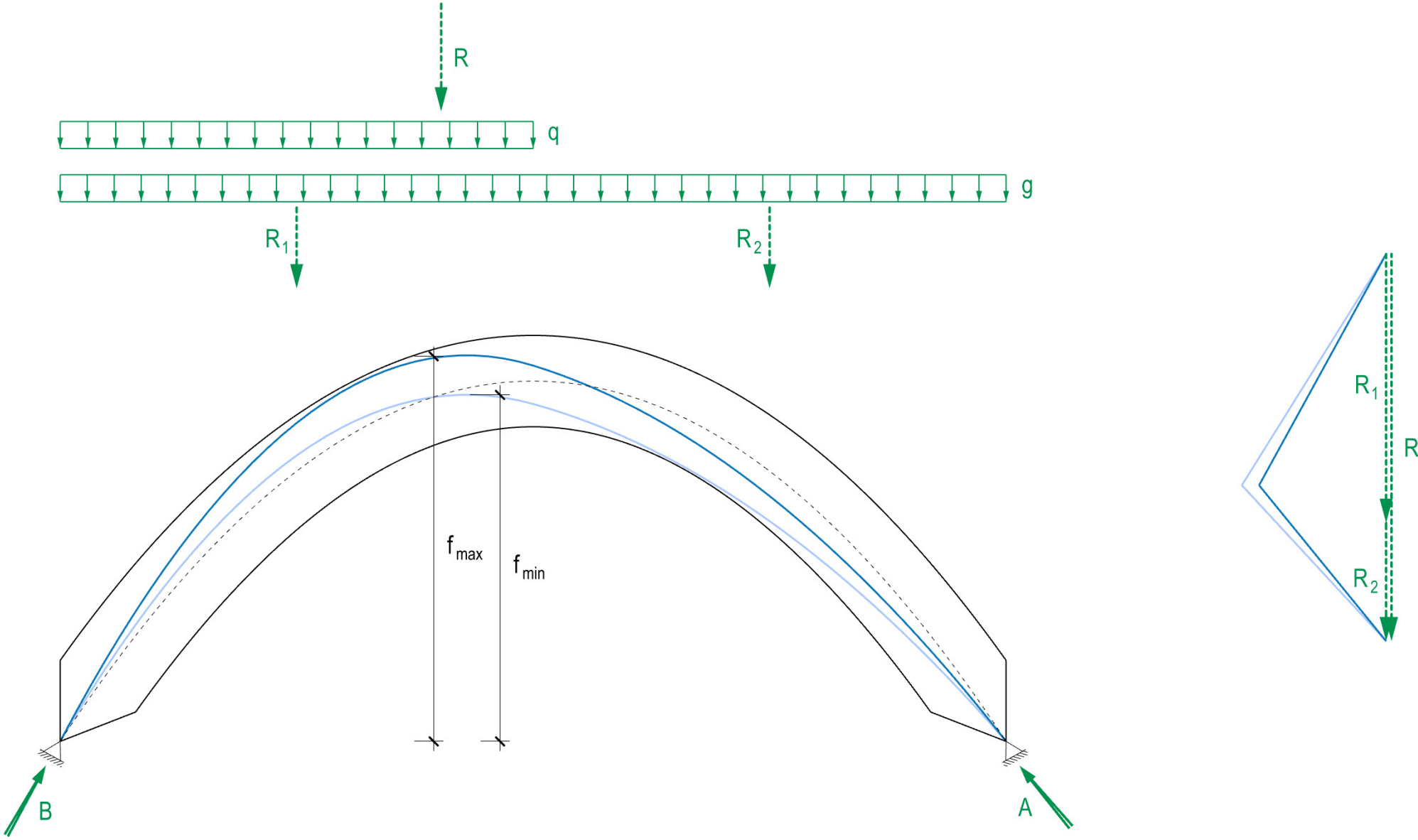


Pont du Gard, Nimes, France, 1st century AD



L. Laurana: Palazzo Ducale, Urbino, 1472



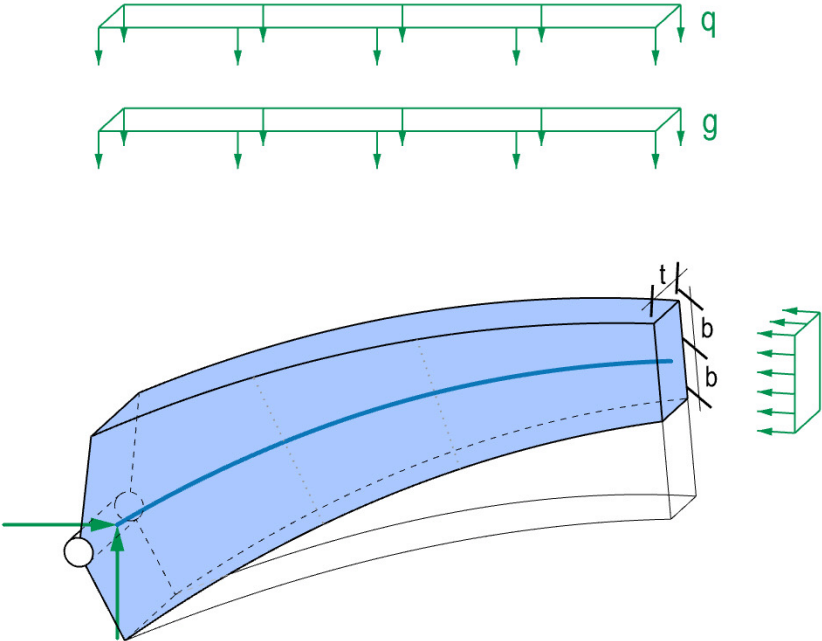


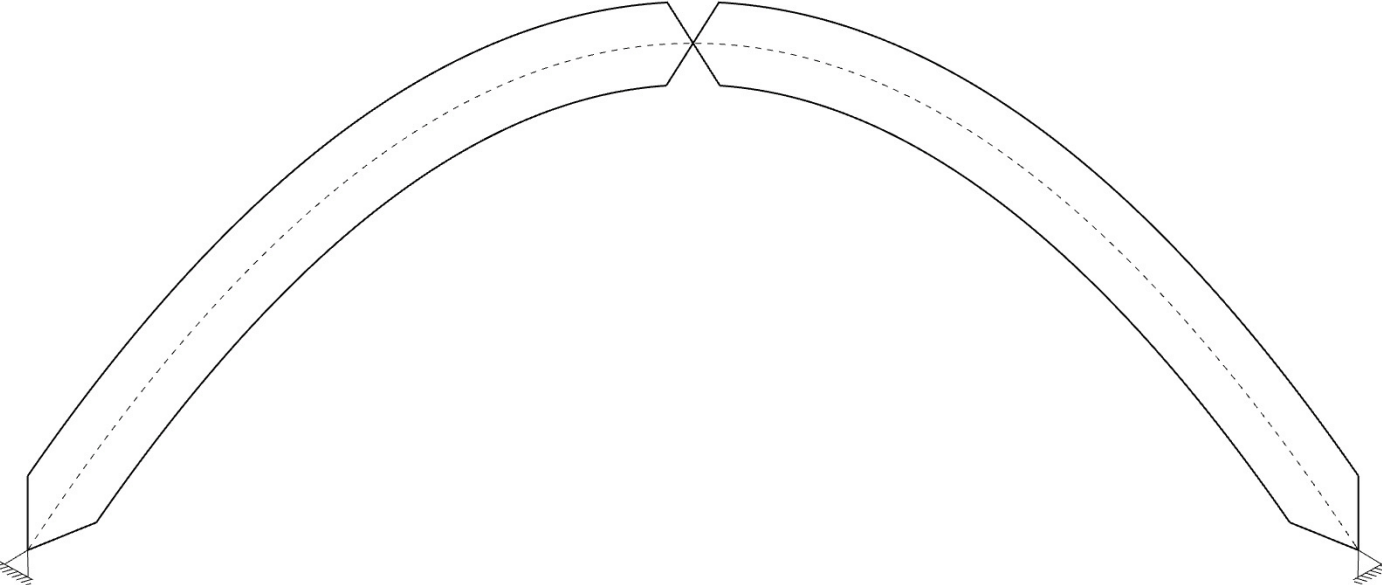


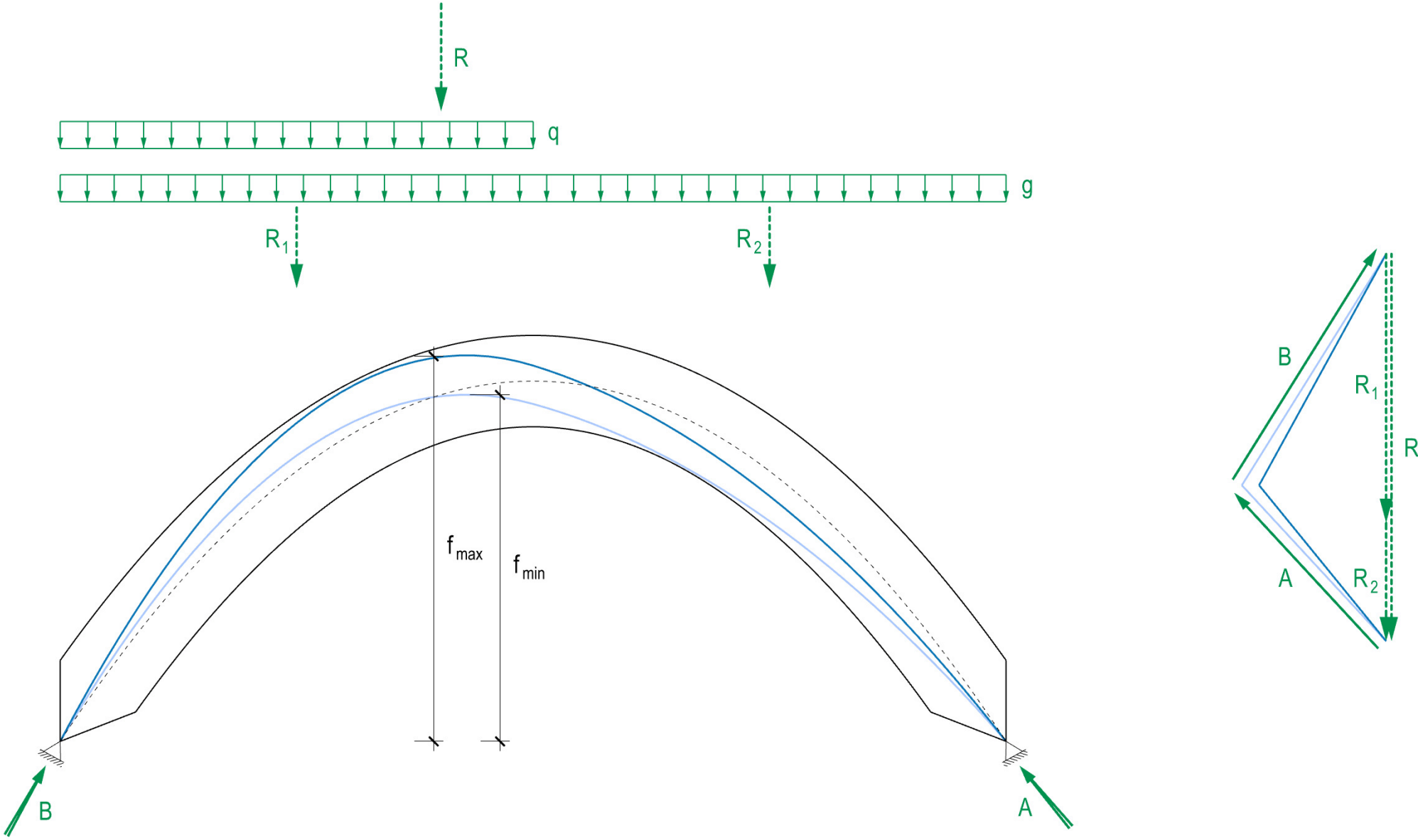
Gustave Eiffel, M. Koechlin: Viadukt Garabit, Ruynes, 1884



Gustave Eiffel, M. Koechlin: Viadukt Garabit, Ruynes, 1884

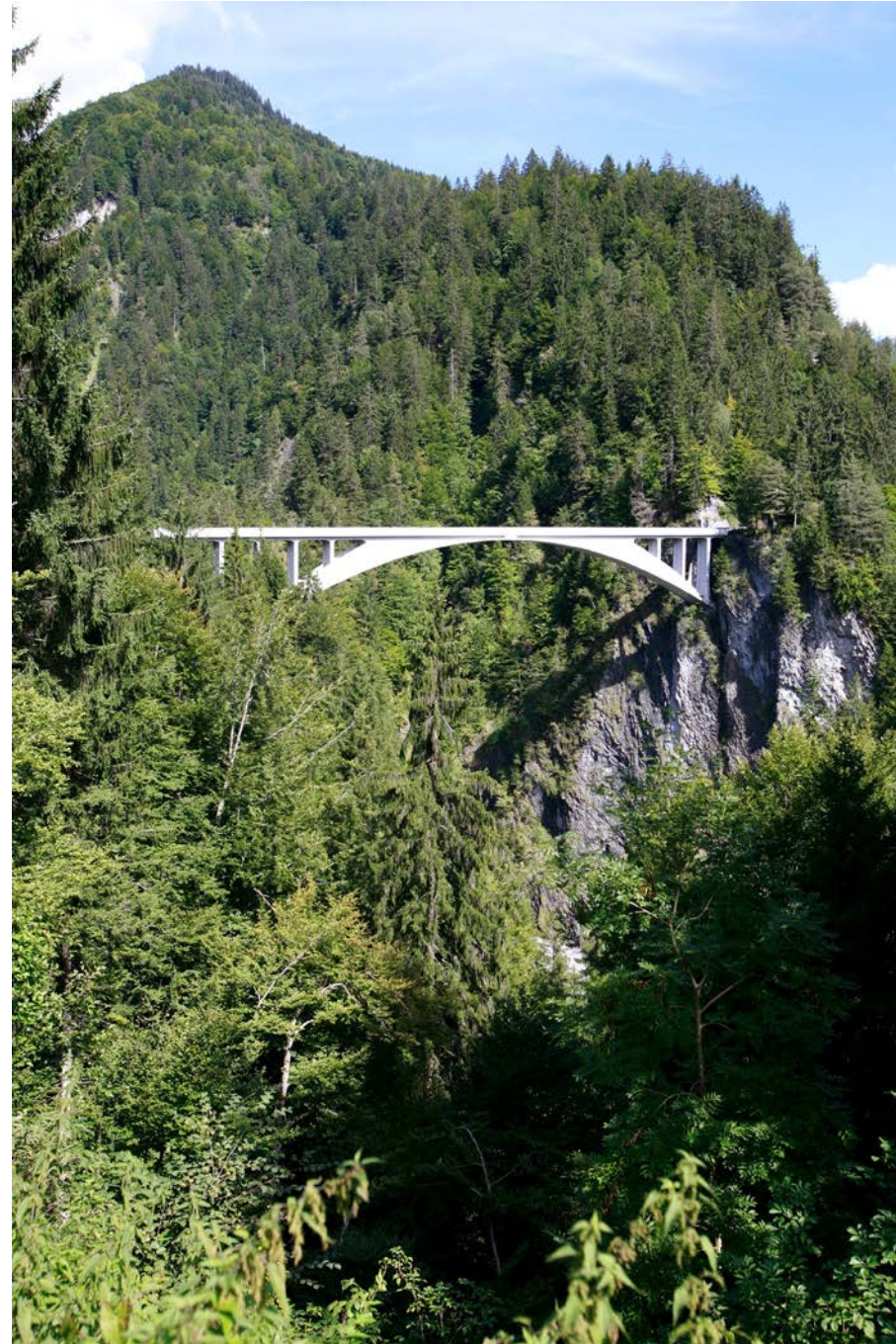




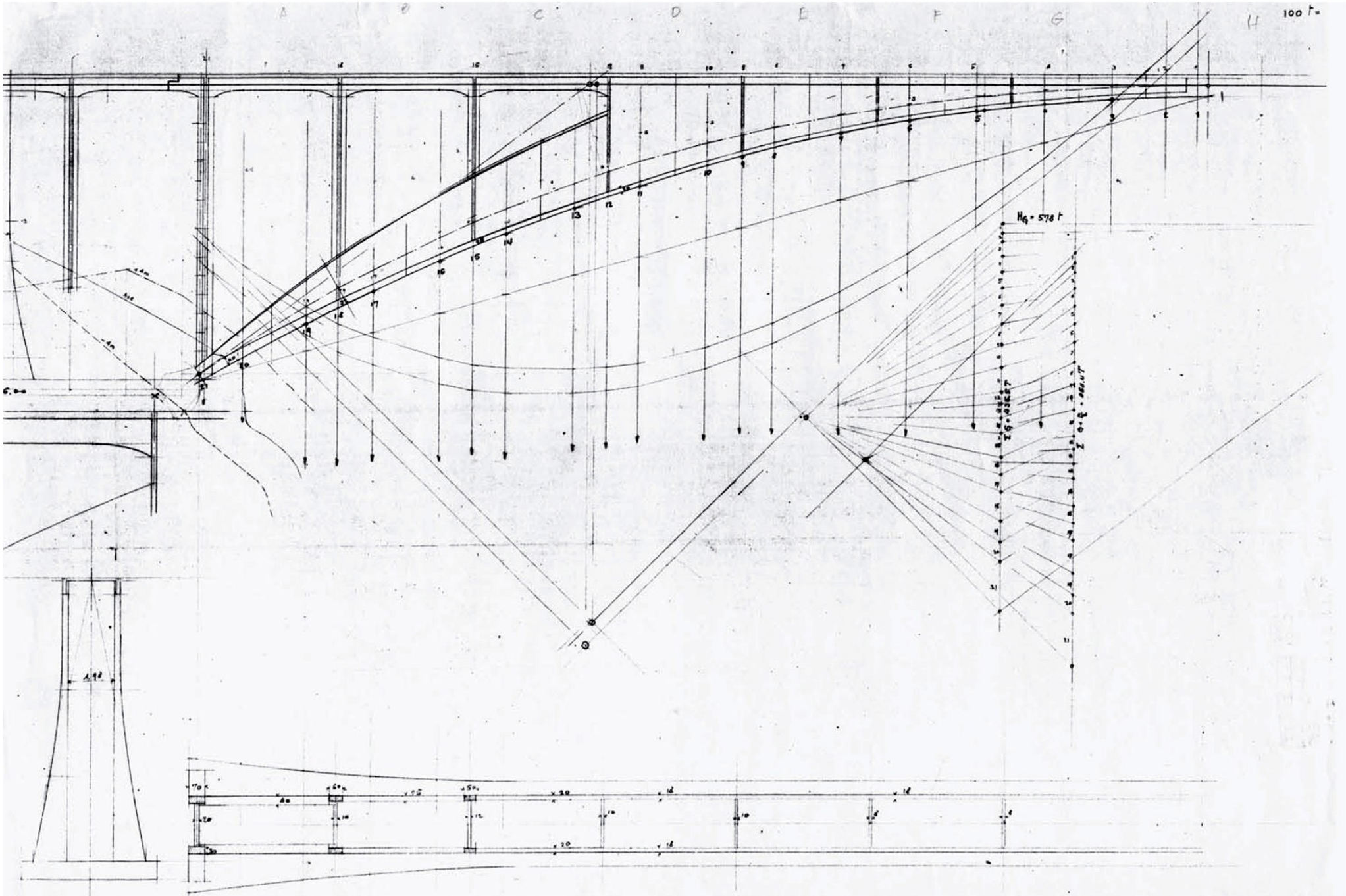




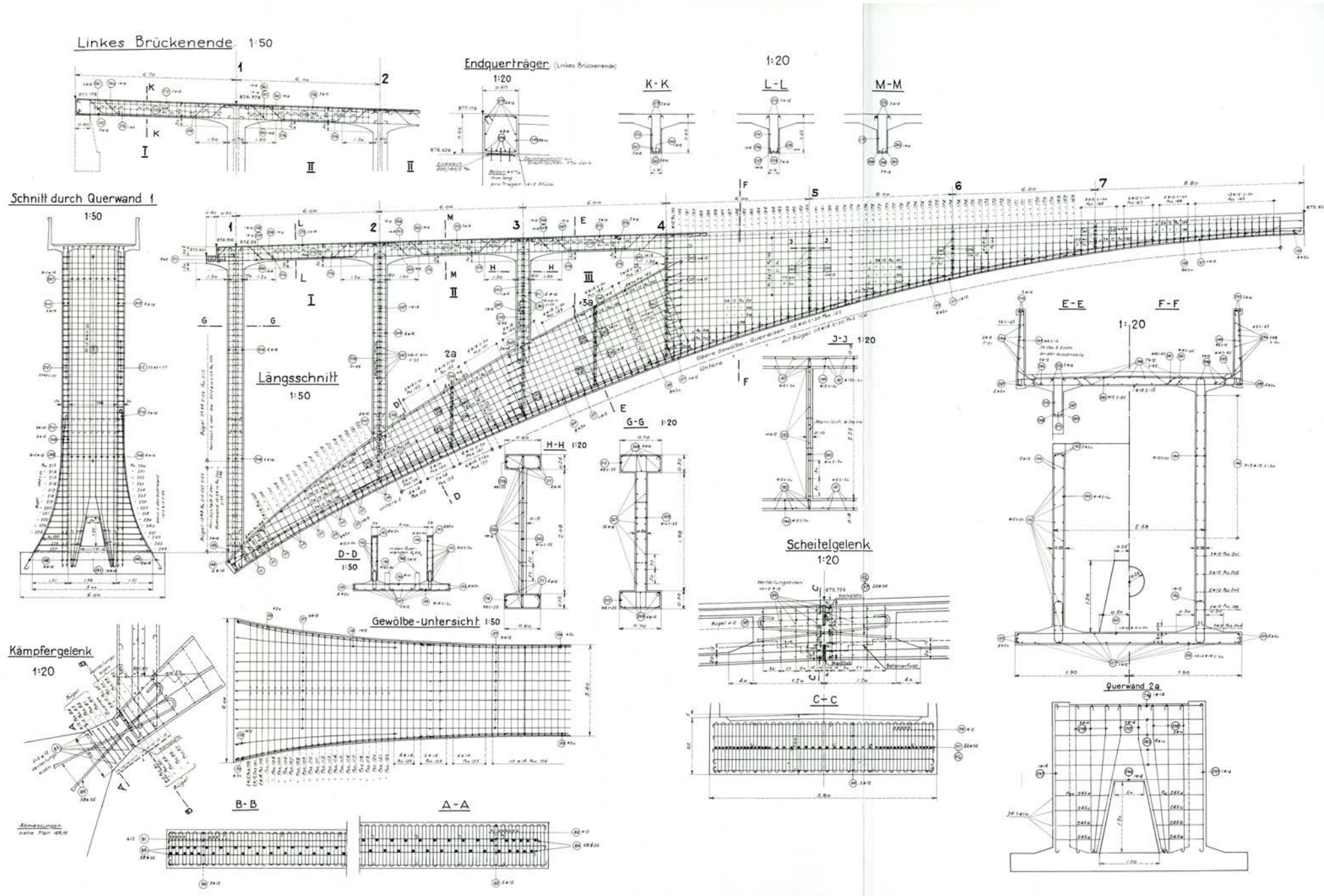
Robert Maillart: Salginatobel bridge, Schiers, 1930



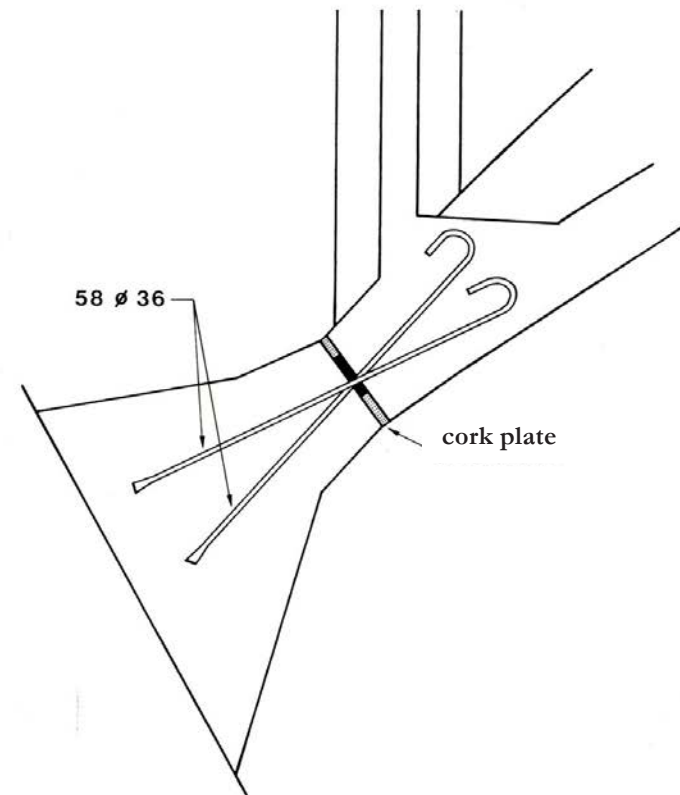
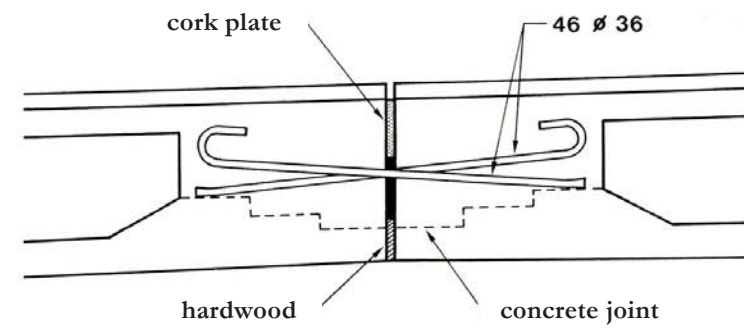
Robert Maillart: Salginatobel bridge, Schiers, 1930



Robert Maillart: Salginatobel bridge, Schiers, 1930



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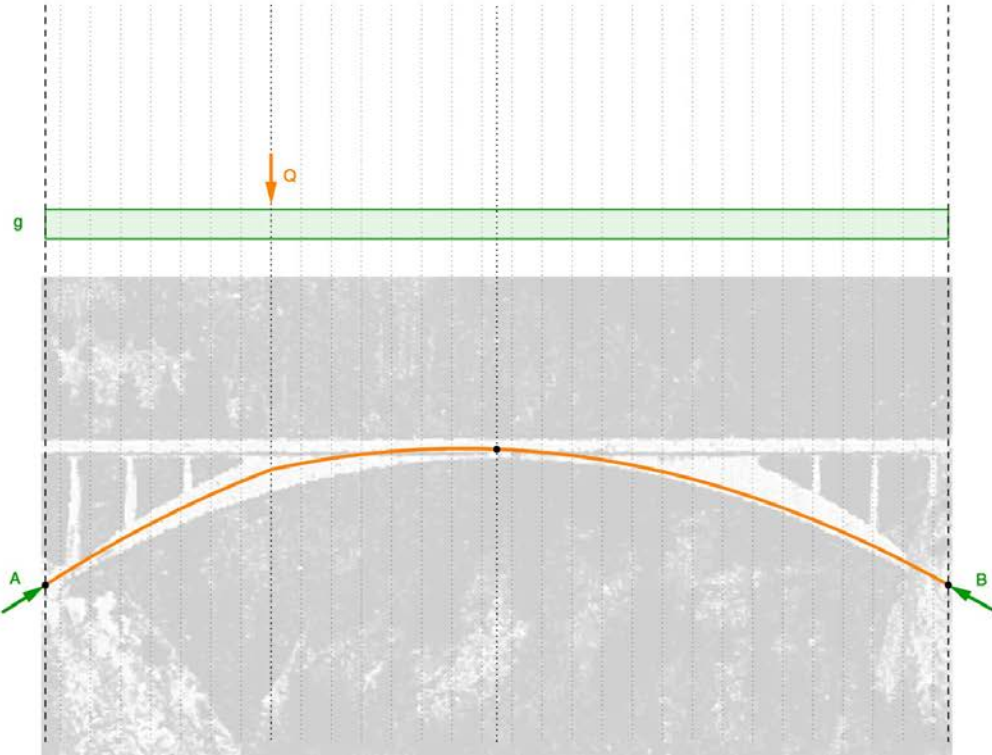
Robert Maillart: Salginatobel bridge, Schiers, 1930



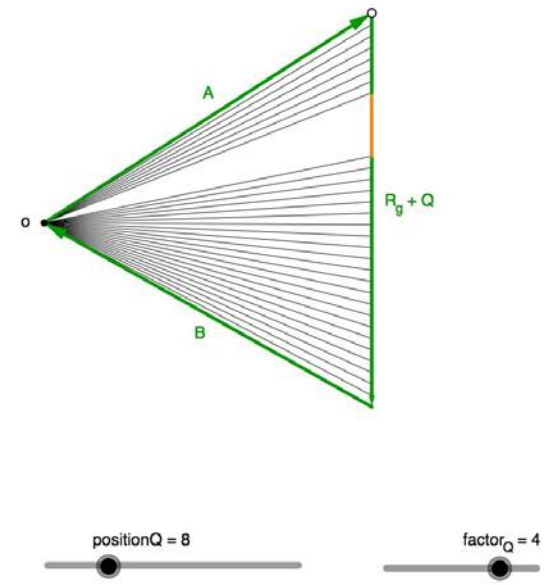
Robert Maillart: Salginatobel bridge, Schiers, 1930

eQ: Salginatobel Bridge

Form Diagram



Force Diagram



<http://www.block.arch.ethz.ch/eq/drawing/view/18>



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

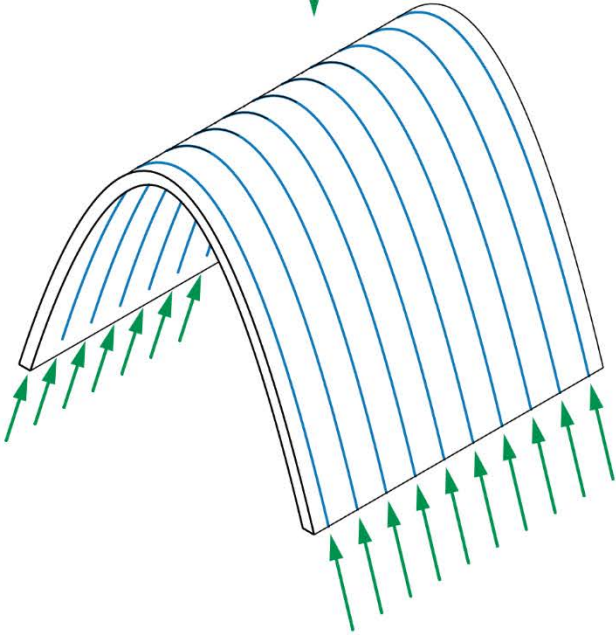
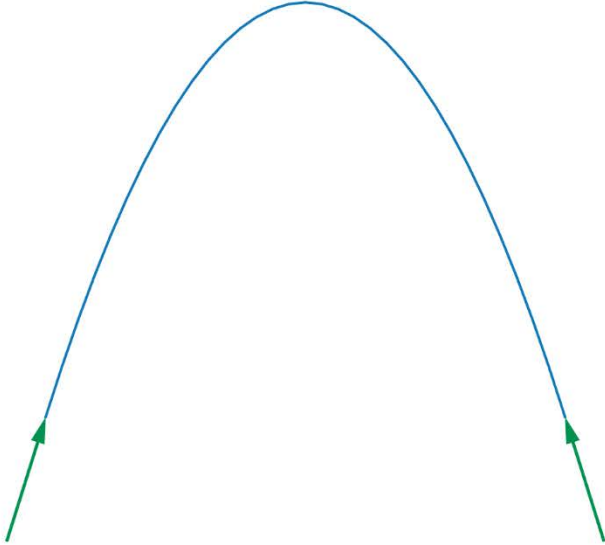
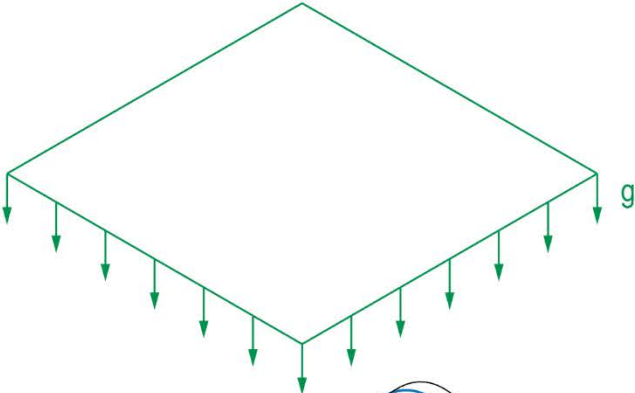
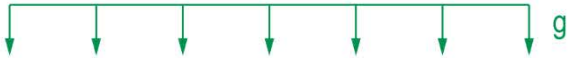
Gewölbe und Kuppeln

Vaults and domes

>> Gewölbe
Vaults

Kuppeln
Domes

Vaults



Tonnengewölbe

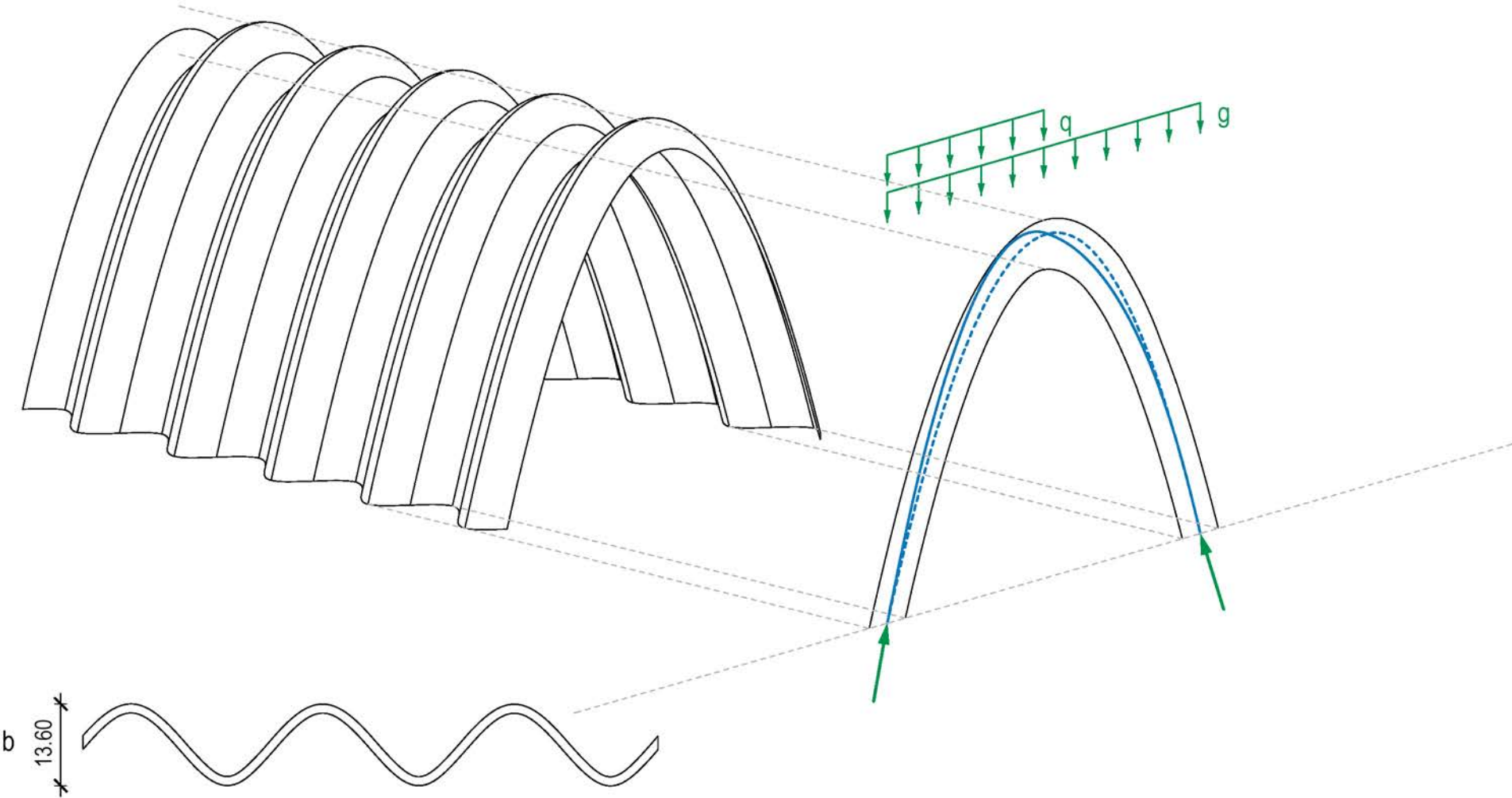
Barrel vault



Vault to cover the courtroom in the palace of Ctesiphonte (Bagdad), III-VI-century A.D.

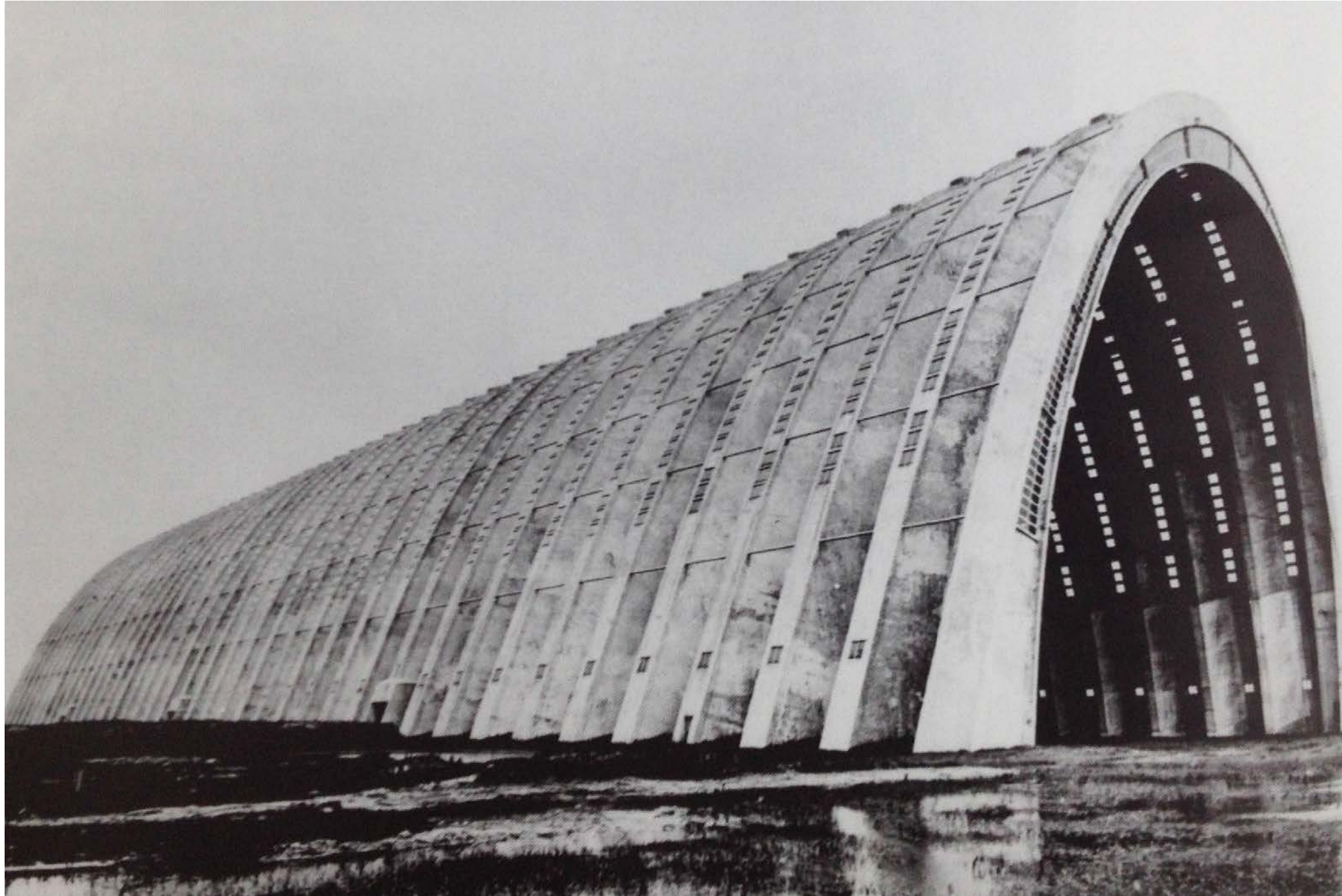


Boston Public Library





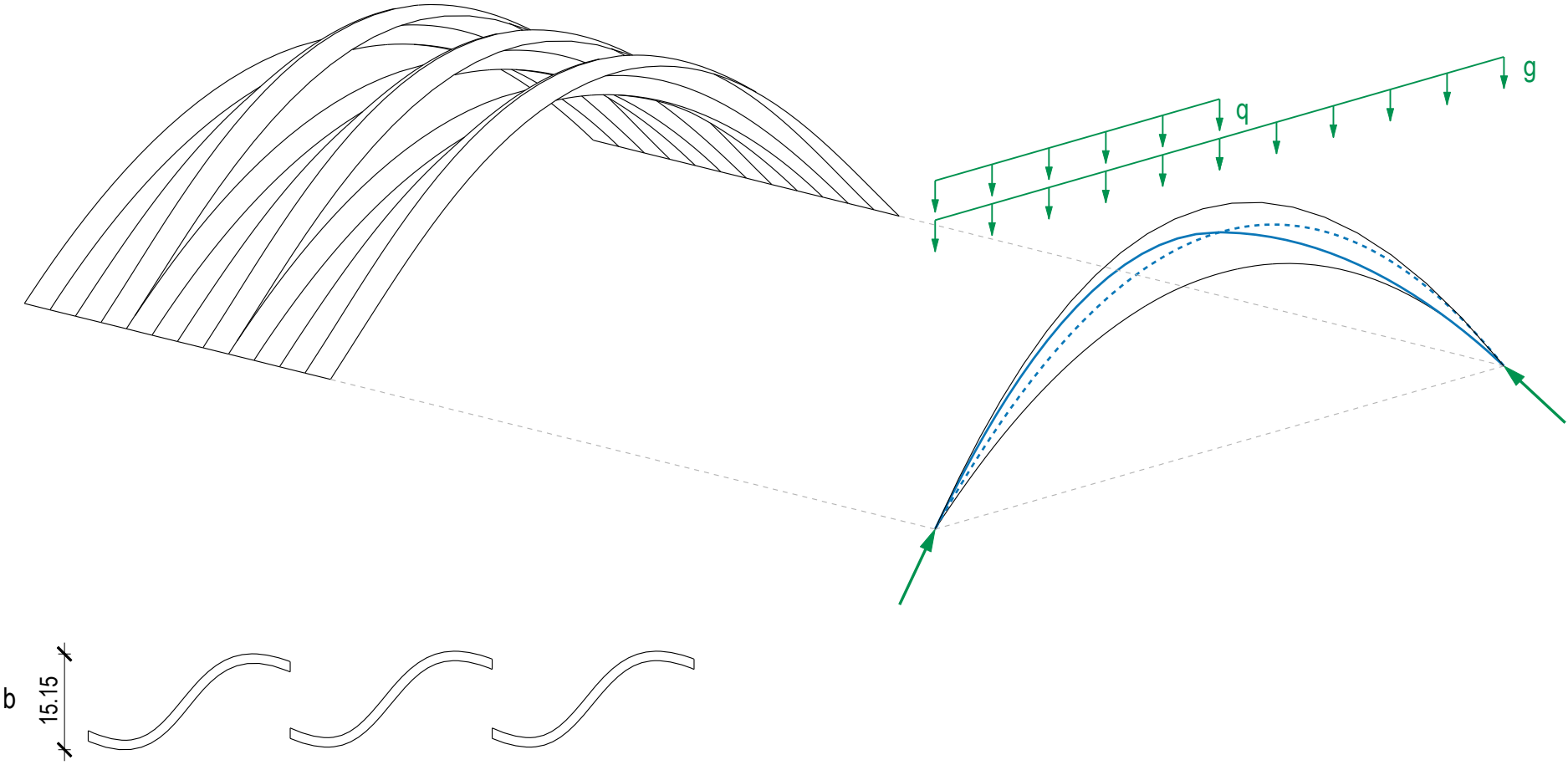
Eladio Dieste: Caryl Horizontal Silo, Young, Uruguay, 1978



Eugène Freyssinet: Hangar d'Orly, Orly, France, 1923

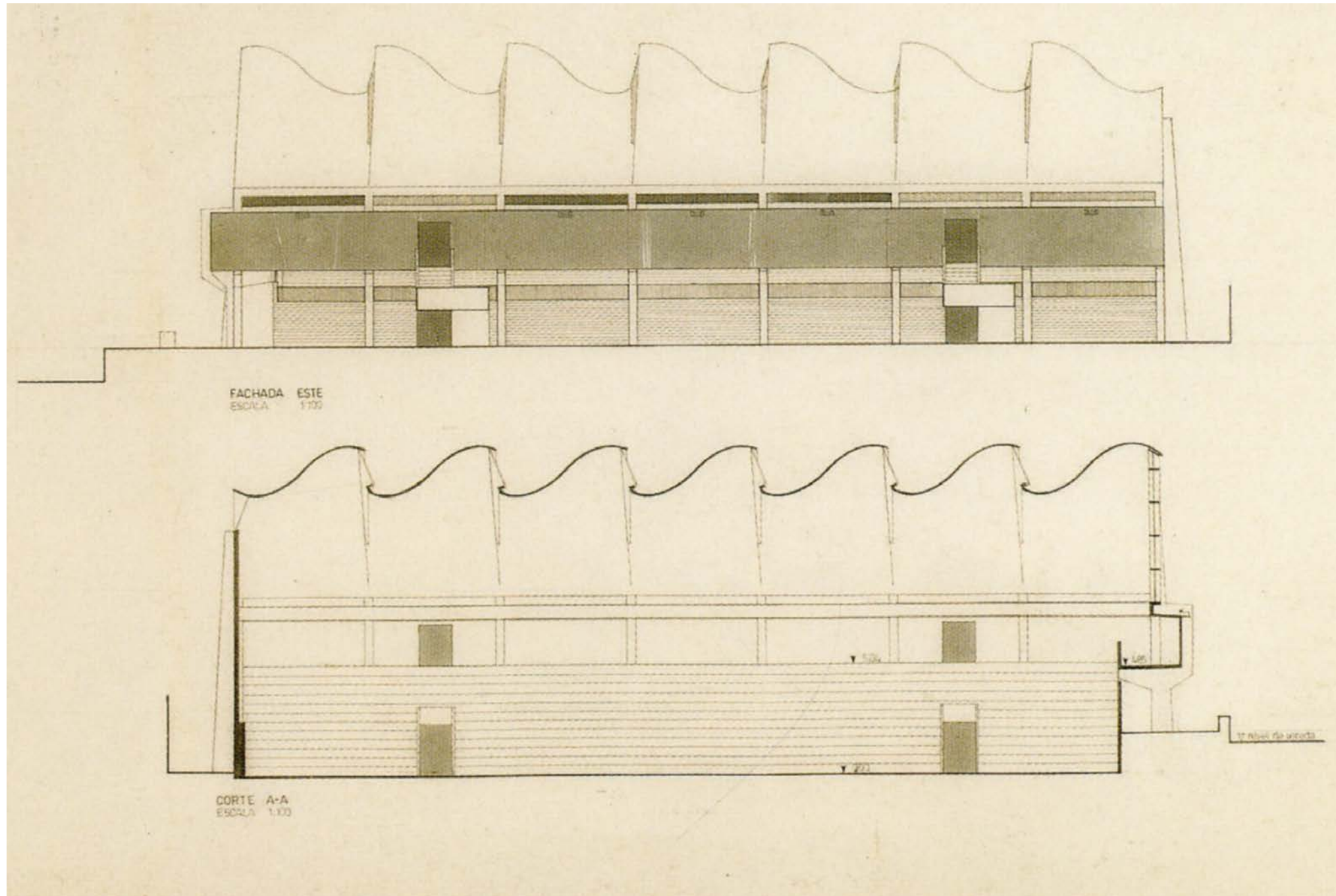


Pier Luigi Nervi: Main hall Expo Turino, Italy, 1949

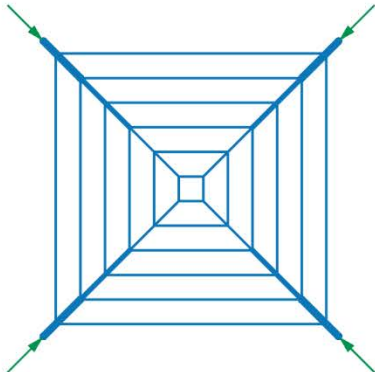
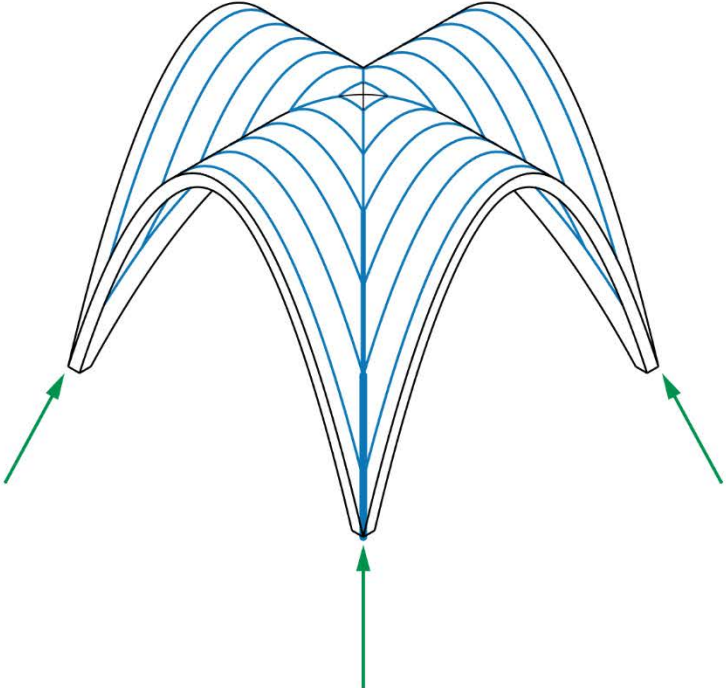
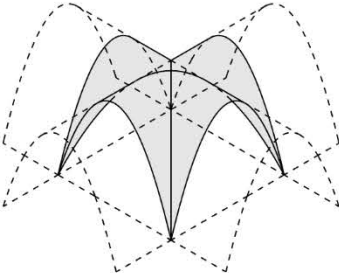
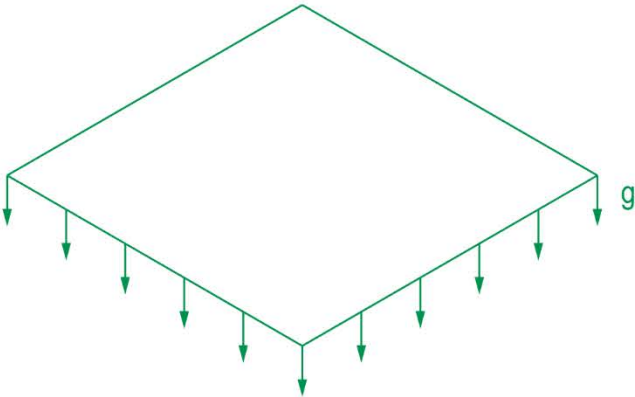


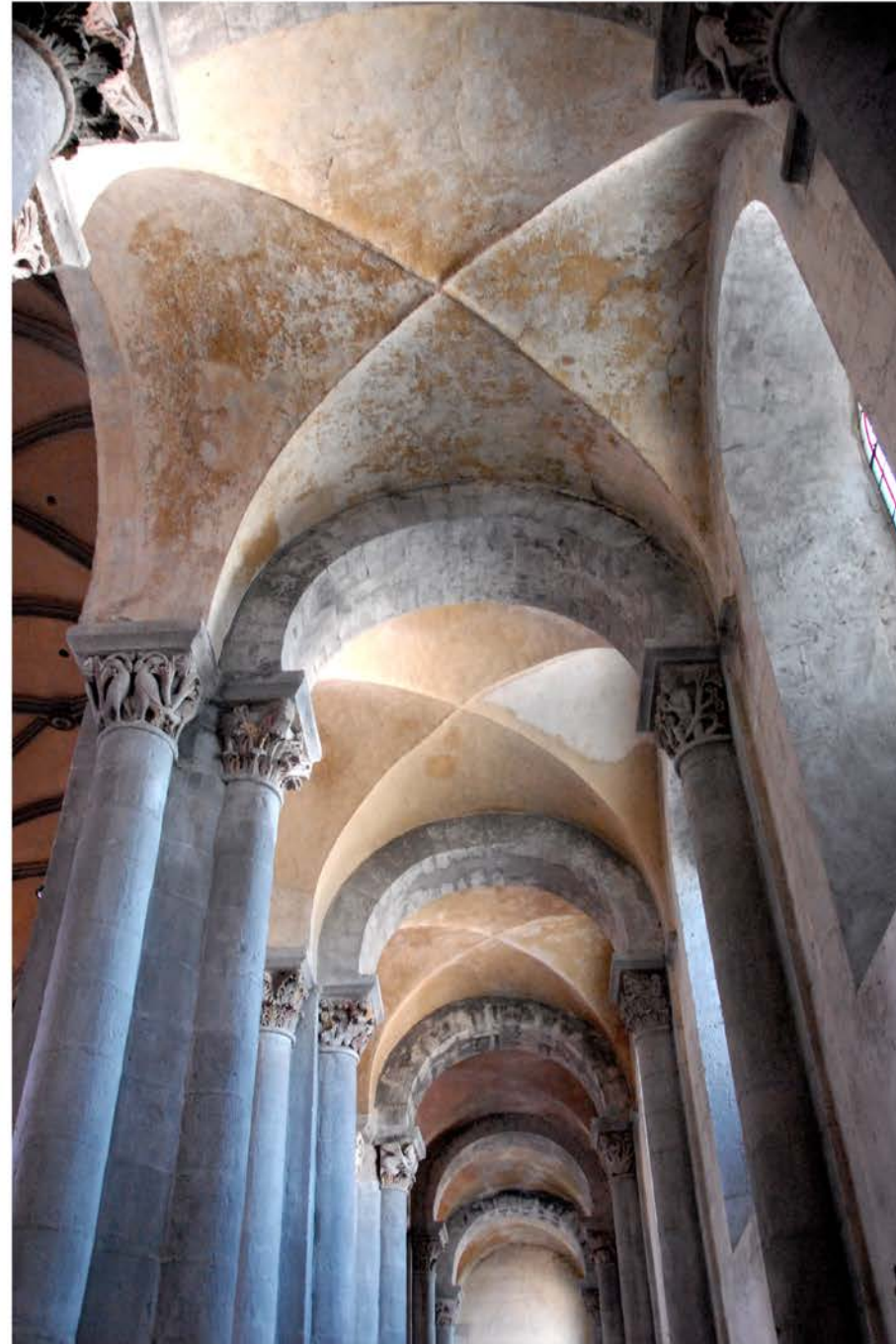


Eladio Dieste: Gimnasio de Durazno, Durazno, Uruguay, 1975



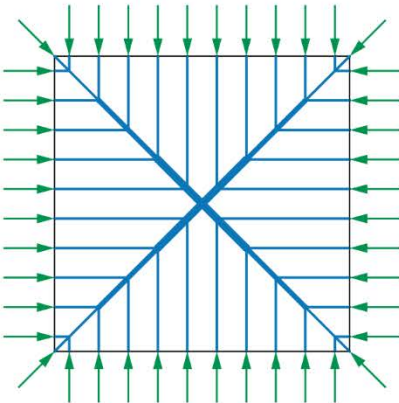
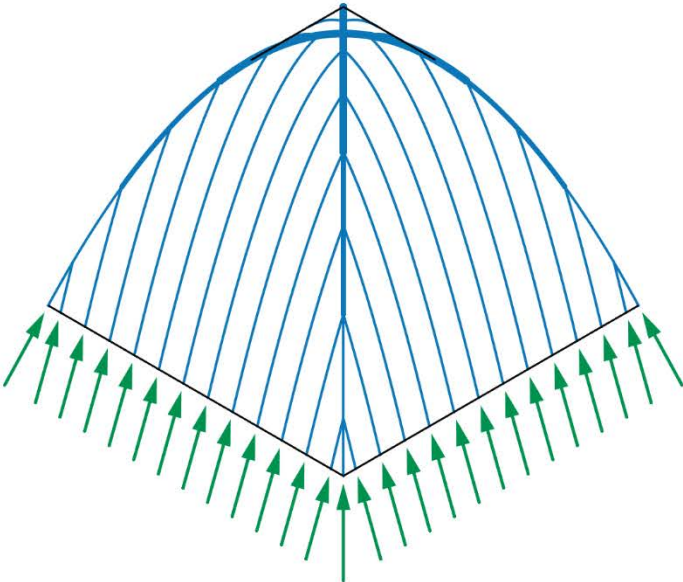
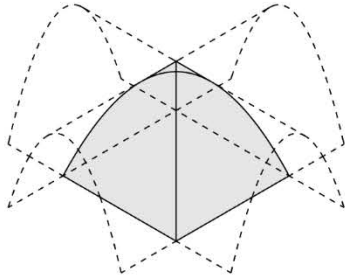
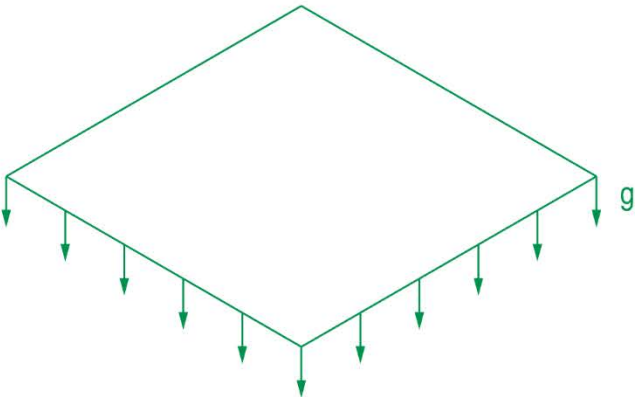
Eladio Dieste: Gimnasio de Durazno, Durazno, Uruguay, 1975





Vezelay Abbey, Burgundy, France, 11. century

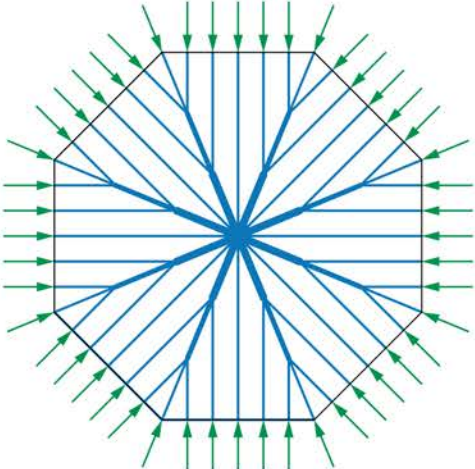
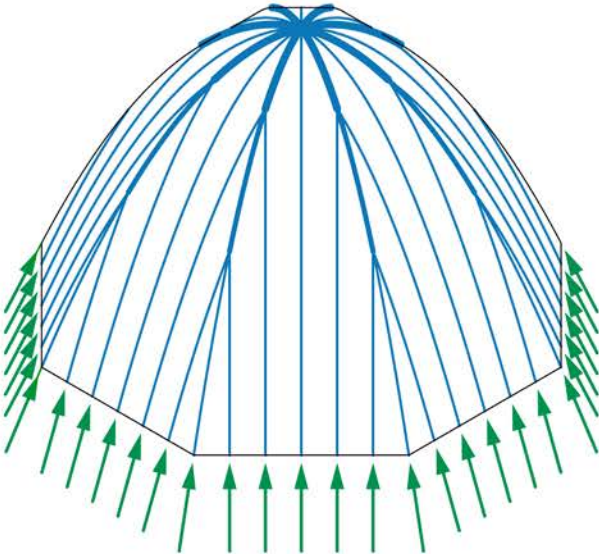
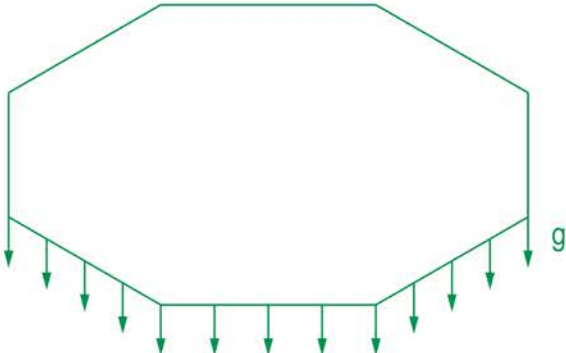
Vaults



Pavillon vault



Pavilion vault with square plan, Otranto, Italy





“Dome” of Santa Maria del Fiore, Arch. & Ing.: Filippo Brunelleschi, Florenz, 1418

Gewölbe und Kuppeln

Vaults and domes

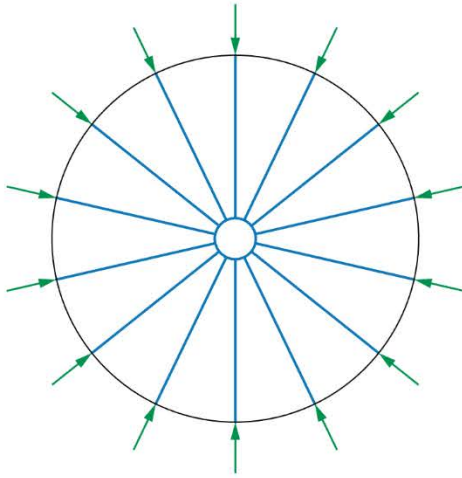
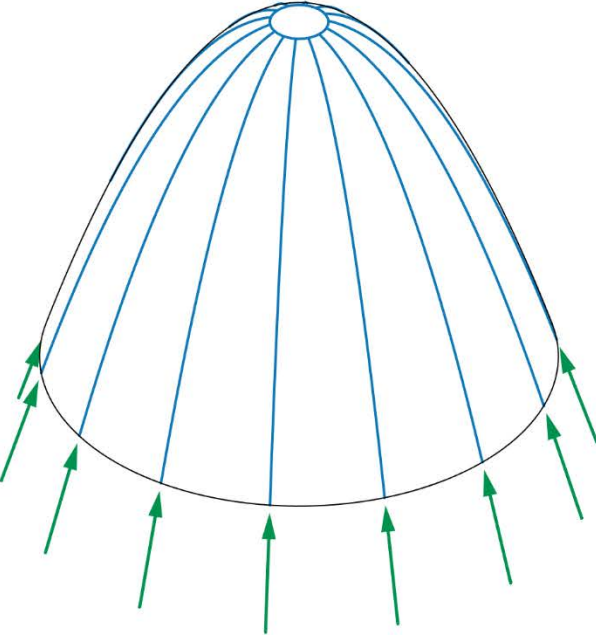
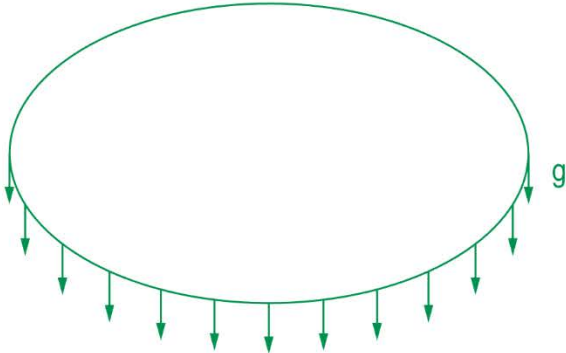
Gewölbe

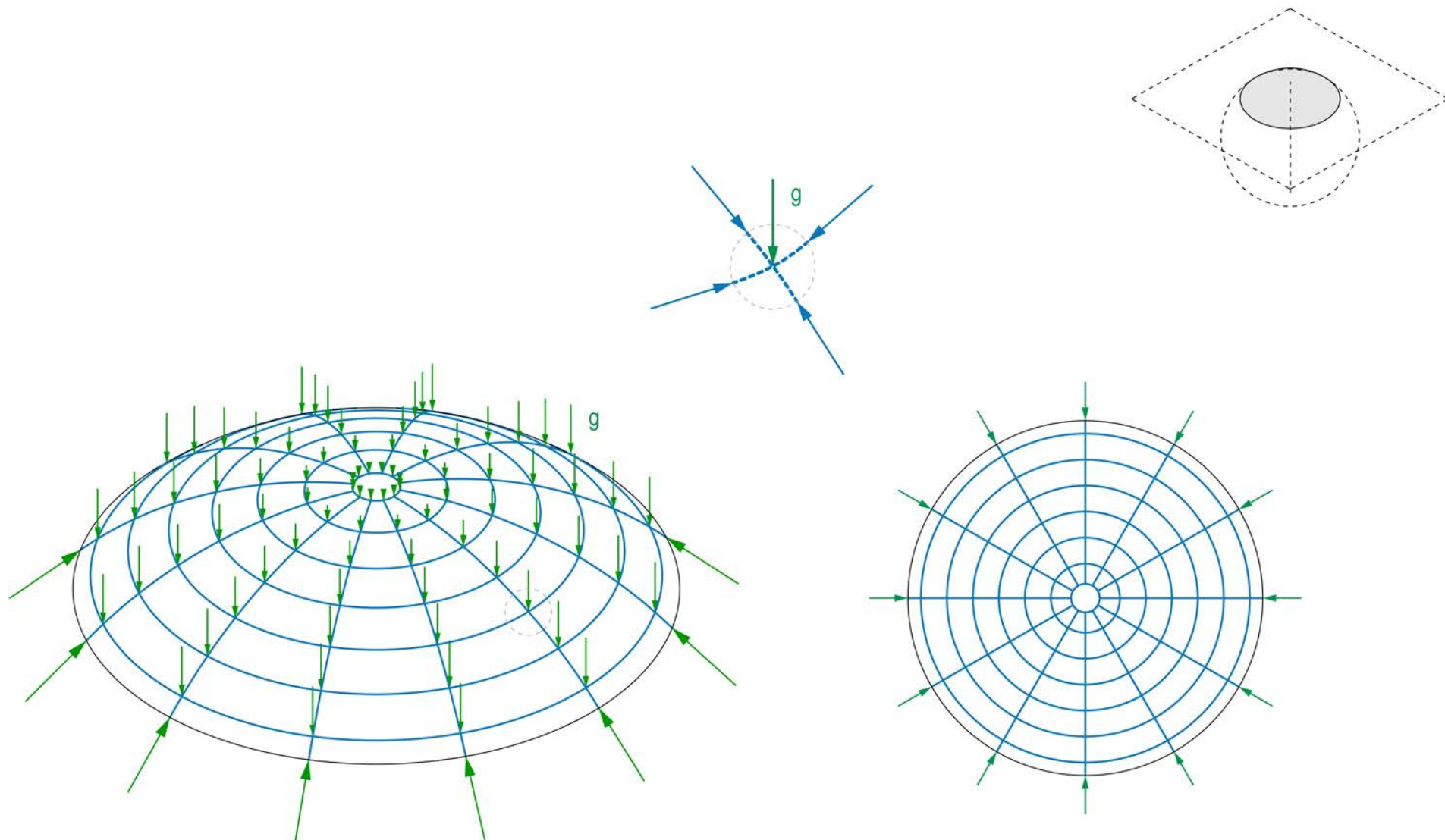
Vaults

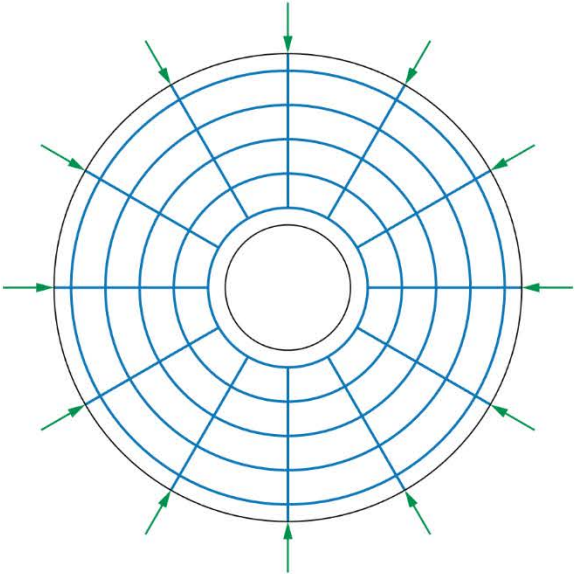
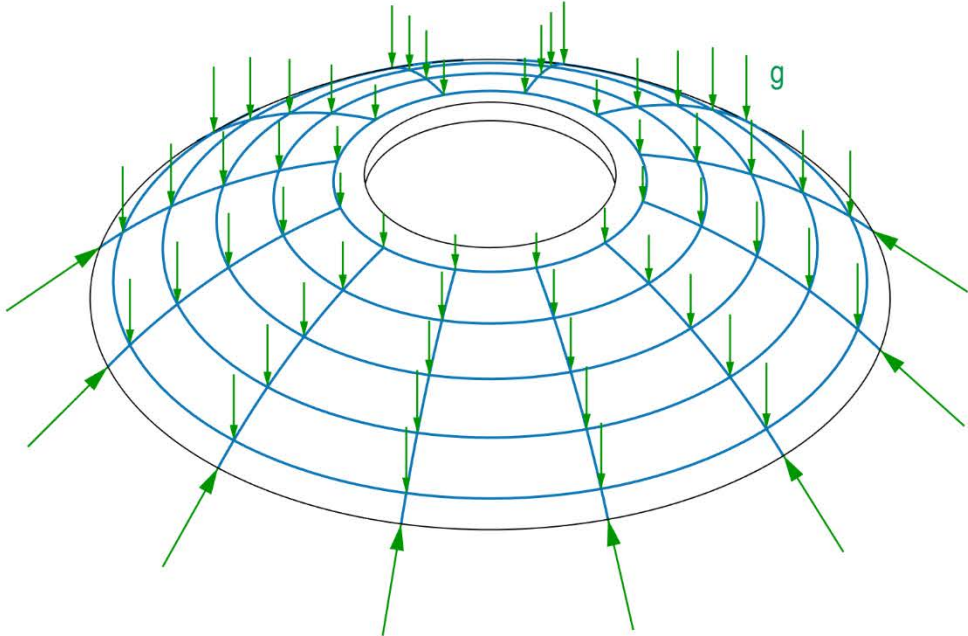
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Kuppeln

Domes

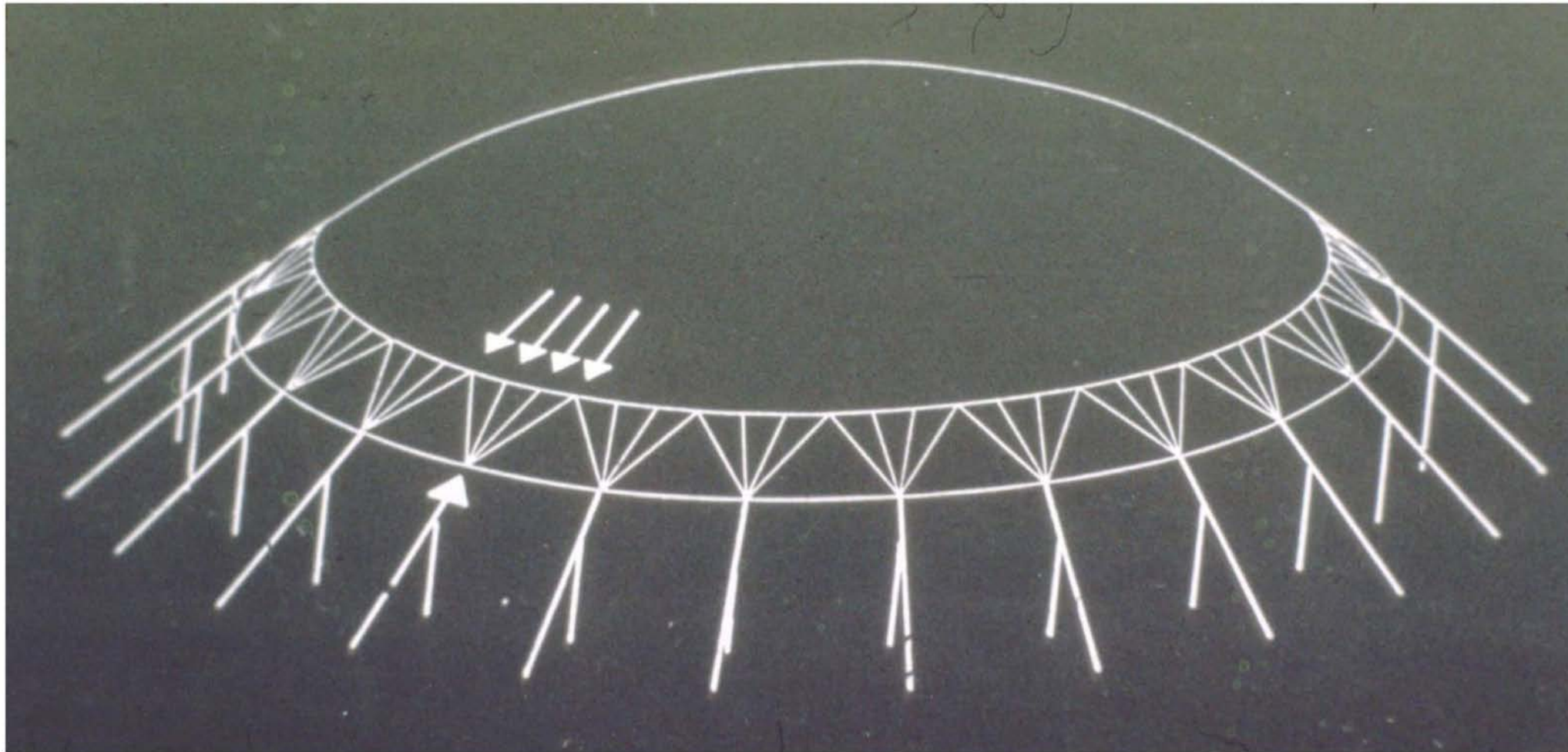




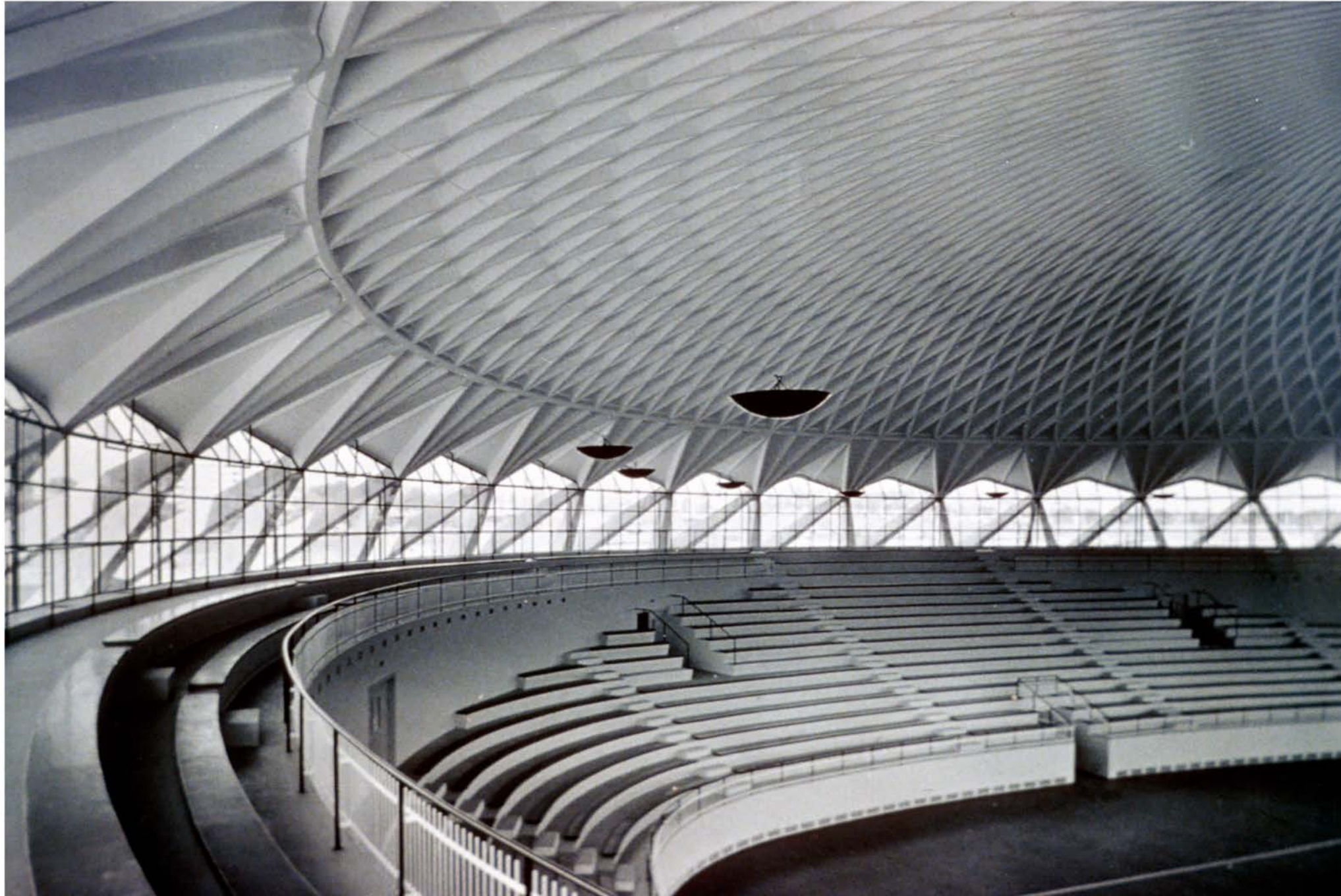




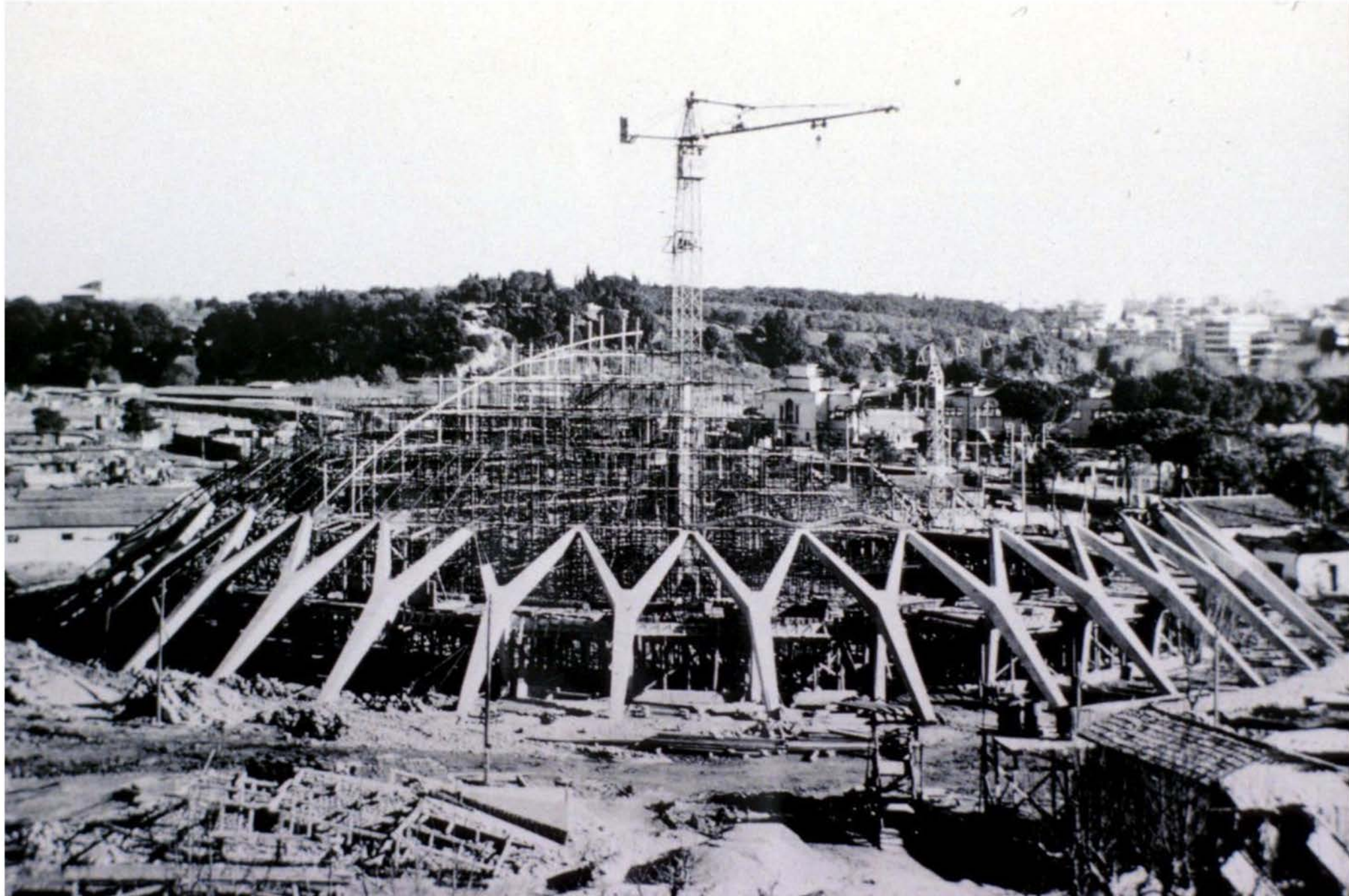
Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



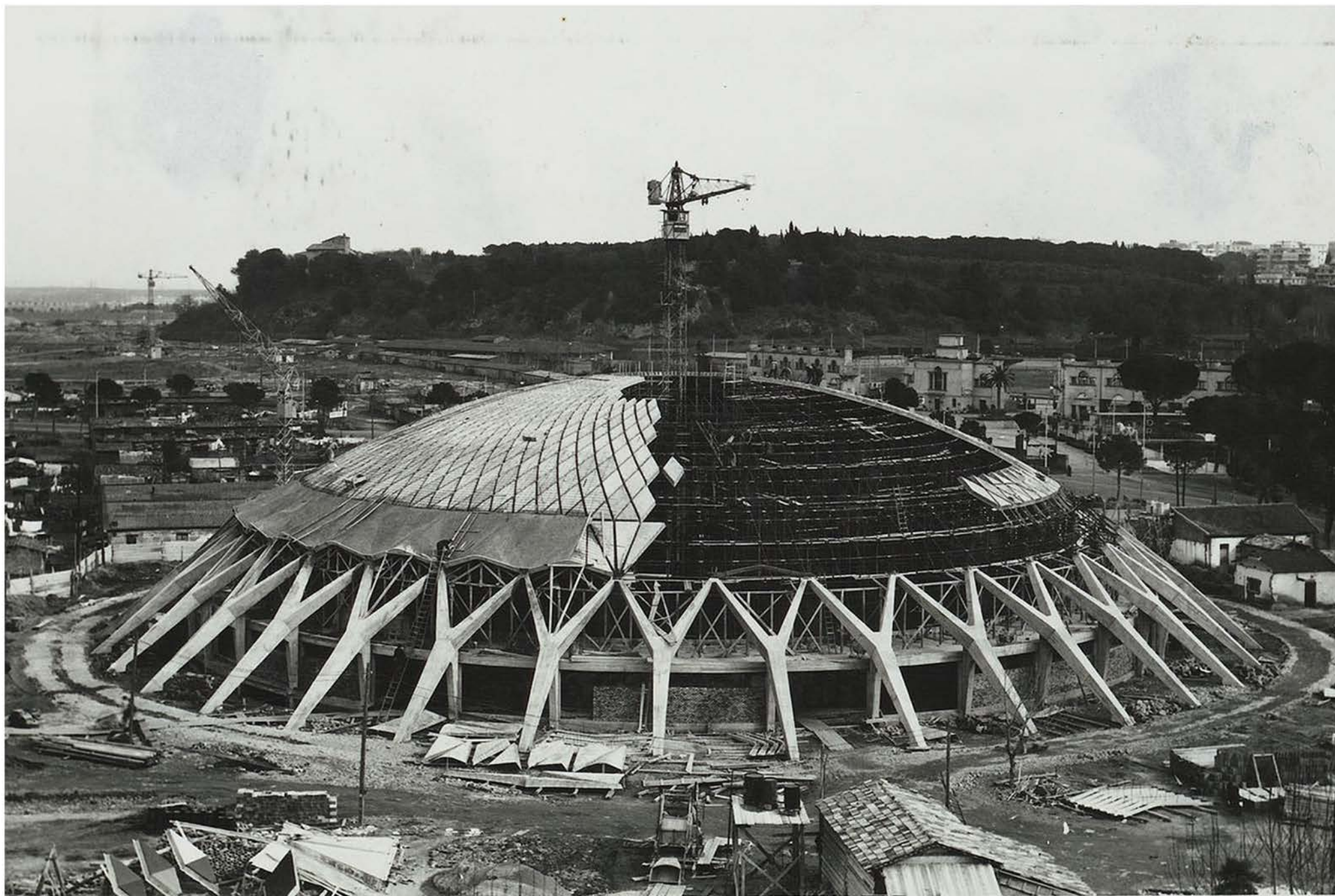
Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



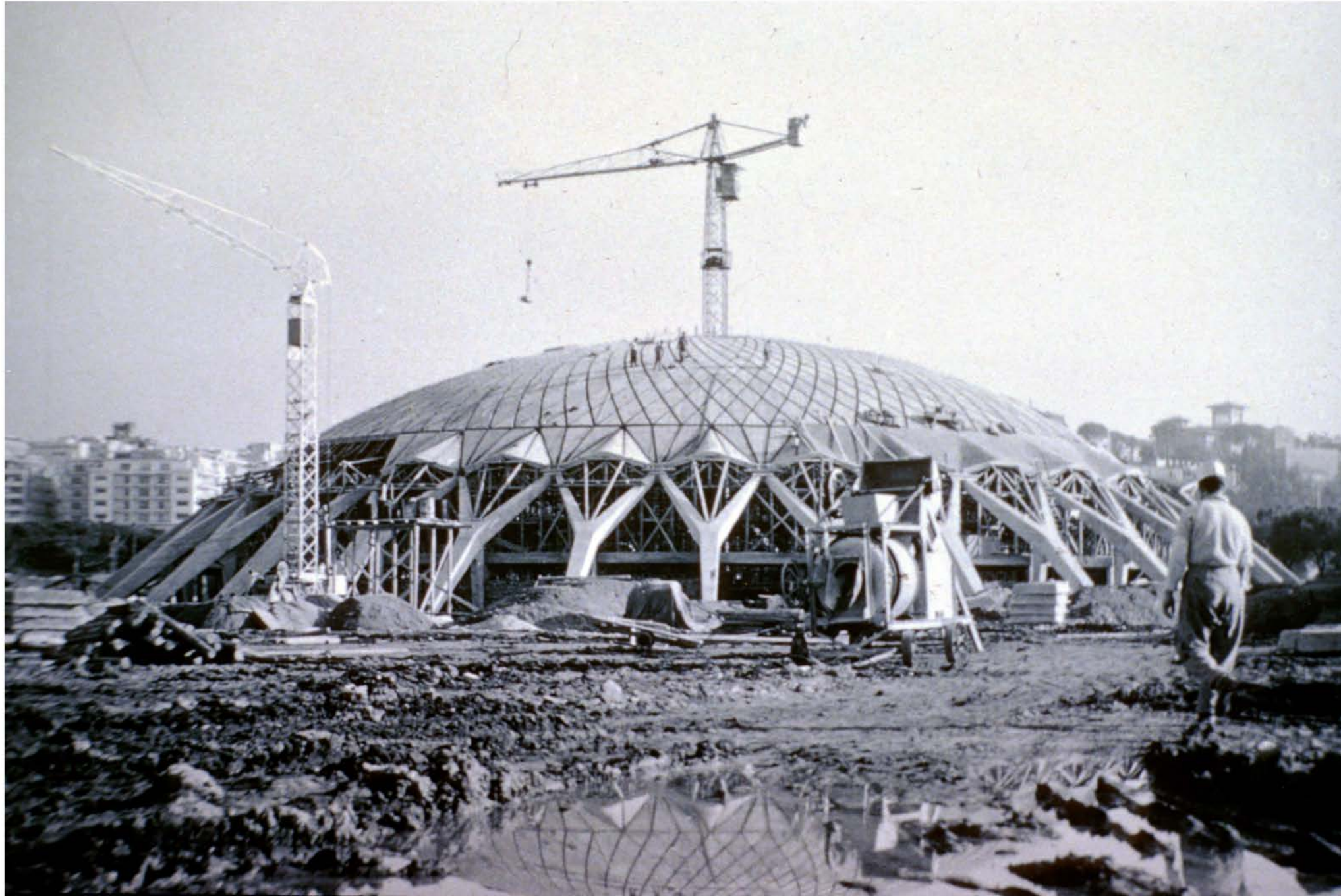
Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



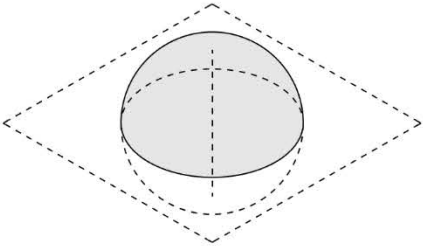
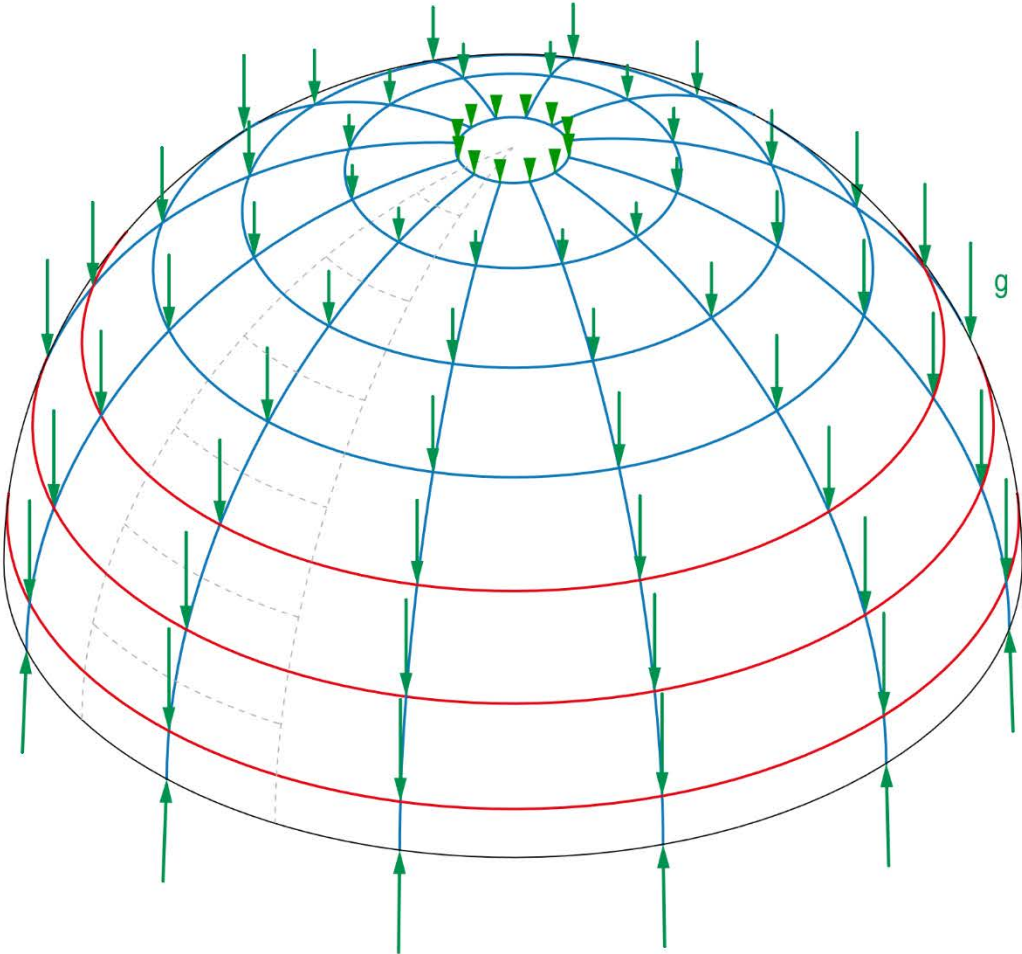
Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955

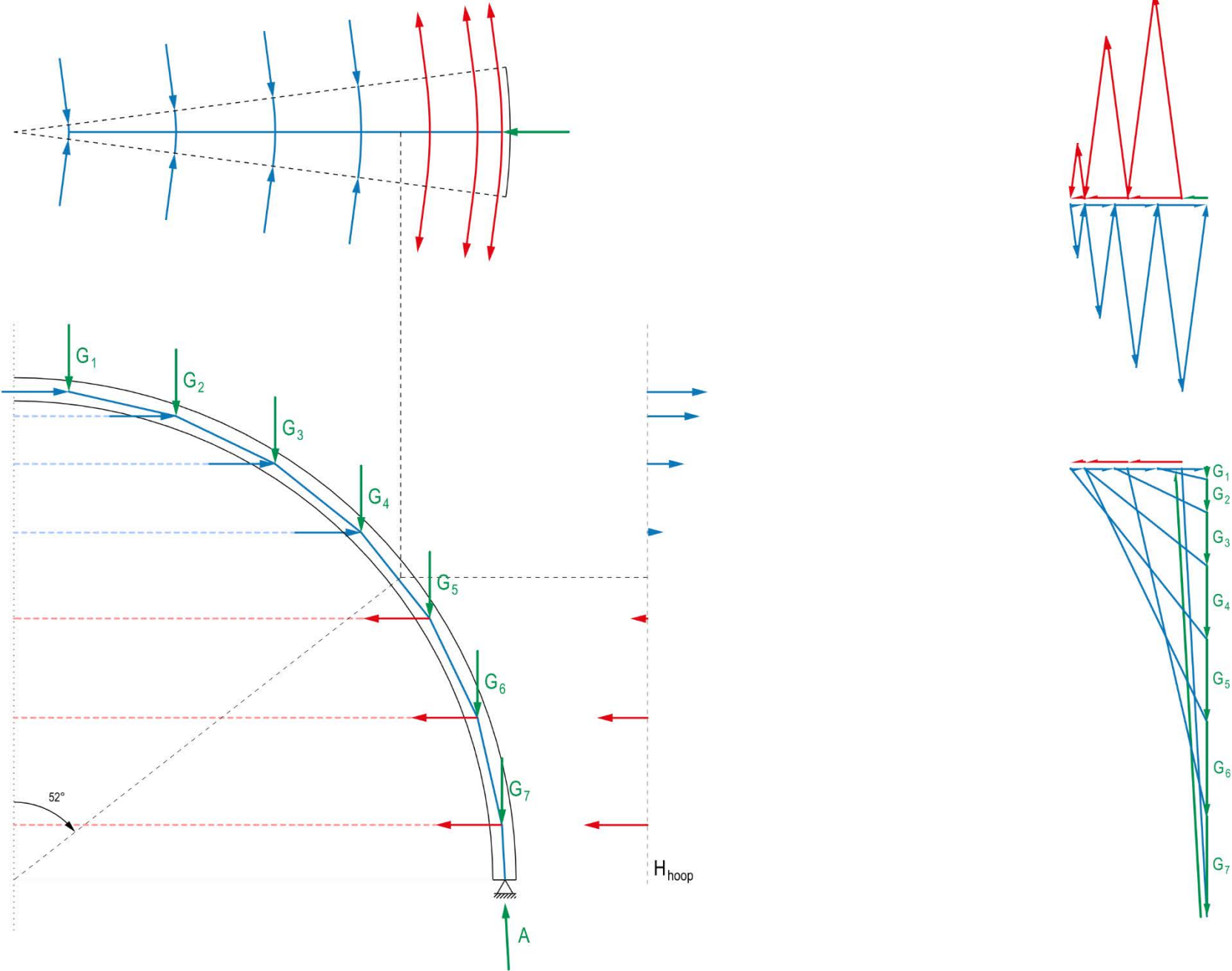


Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955



Palazzo dello Sport, Pier Luigi Nervi, Rome, Italy, 1955







St.-Peter's Cathedral, Rome

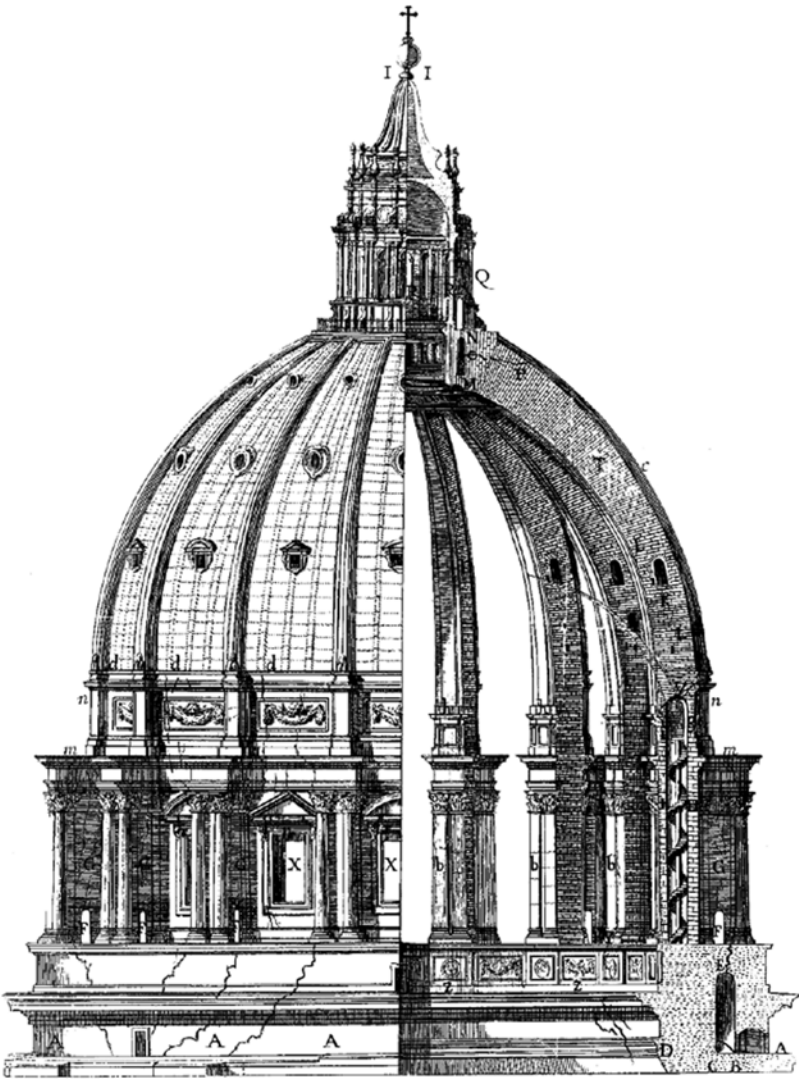
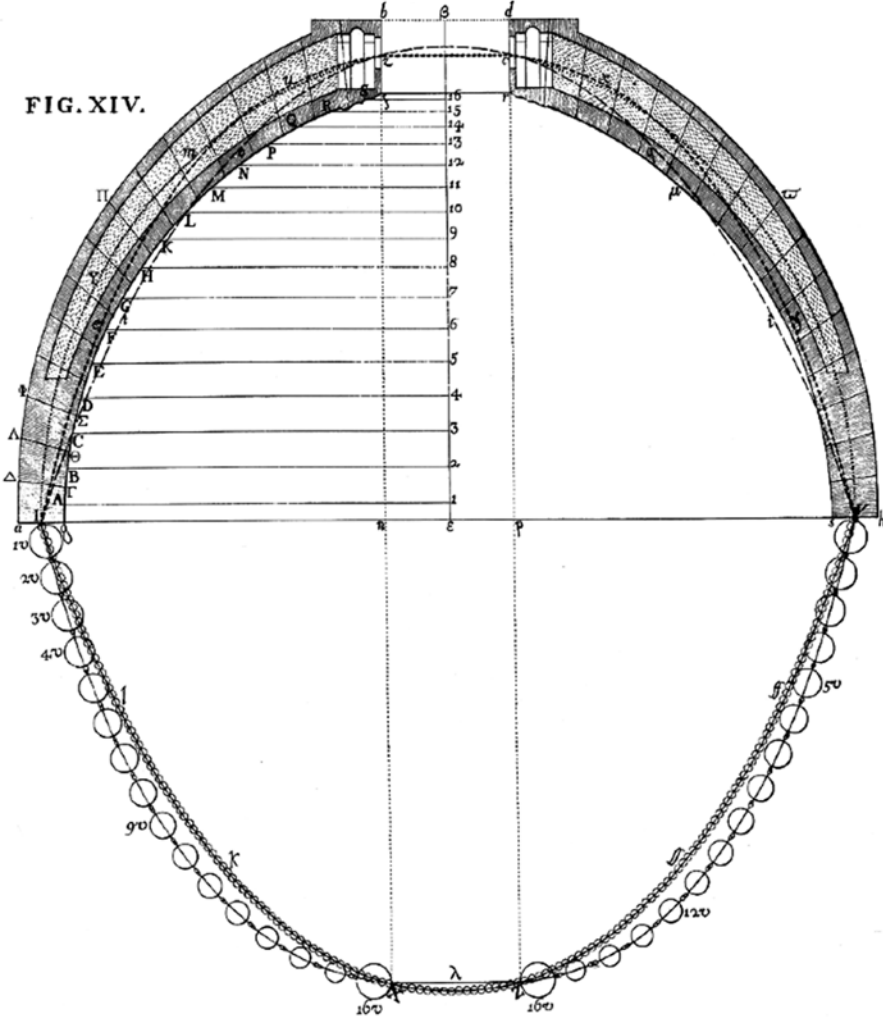
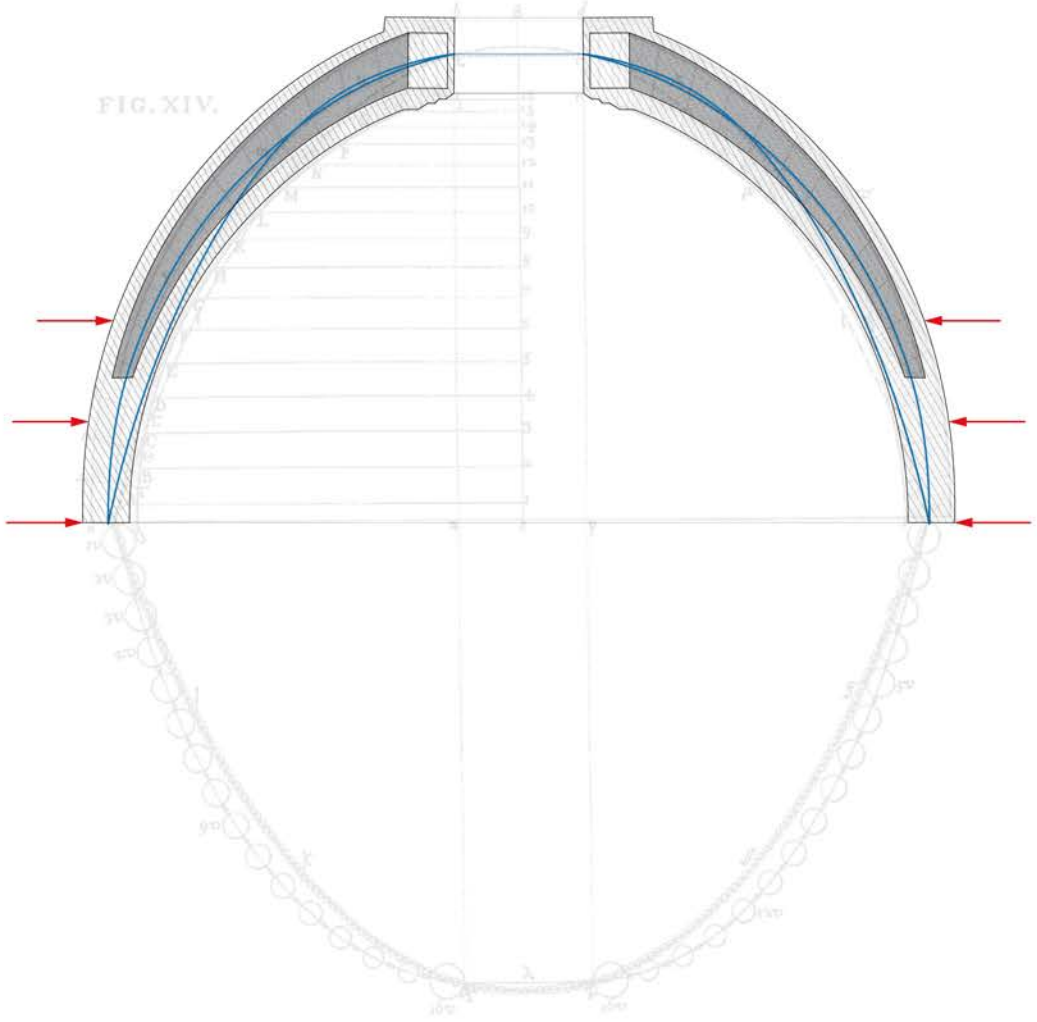
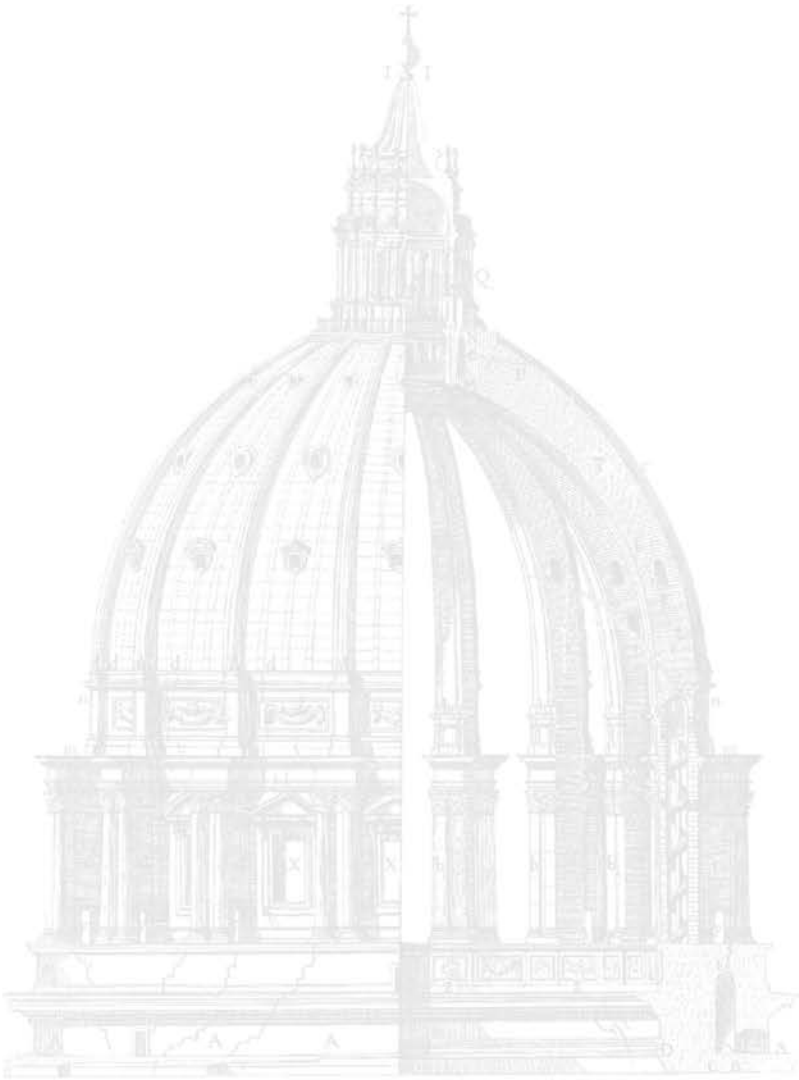
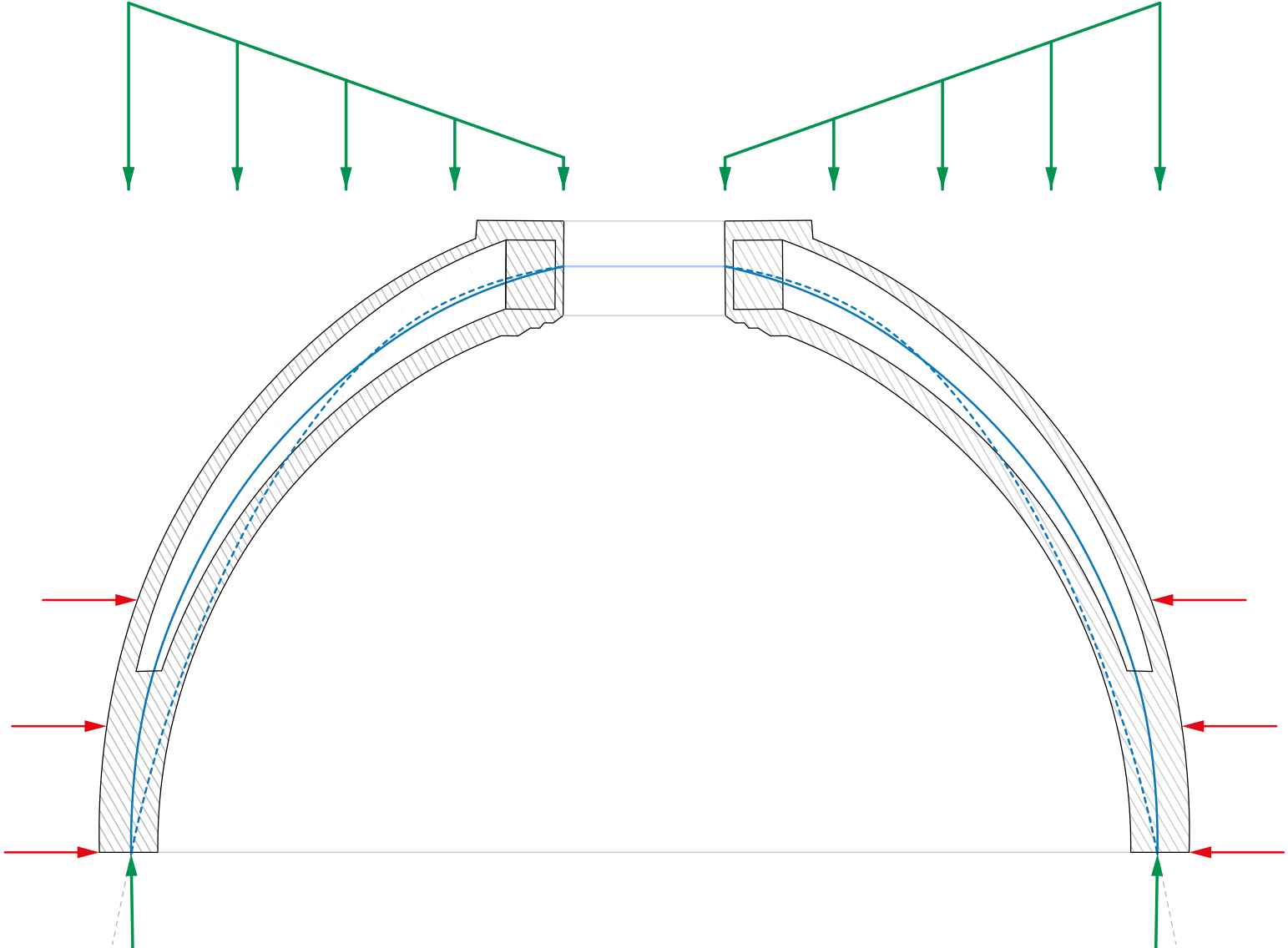


FIG. XIV.



Giovanni Poleni, 1748: Analysis of the Dome of St.-Peter's, Rome

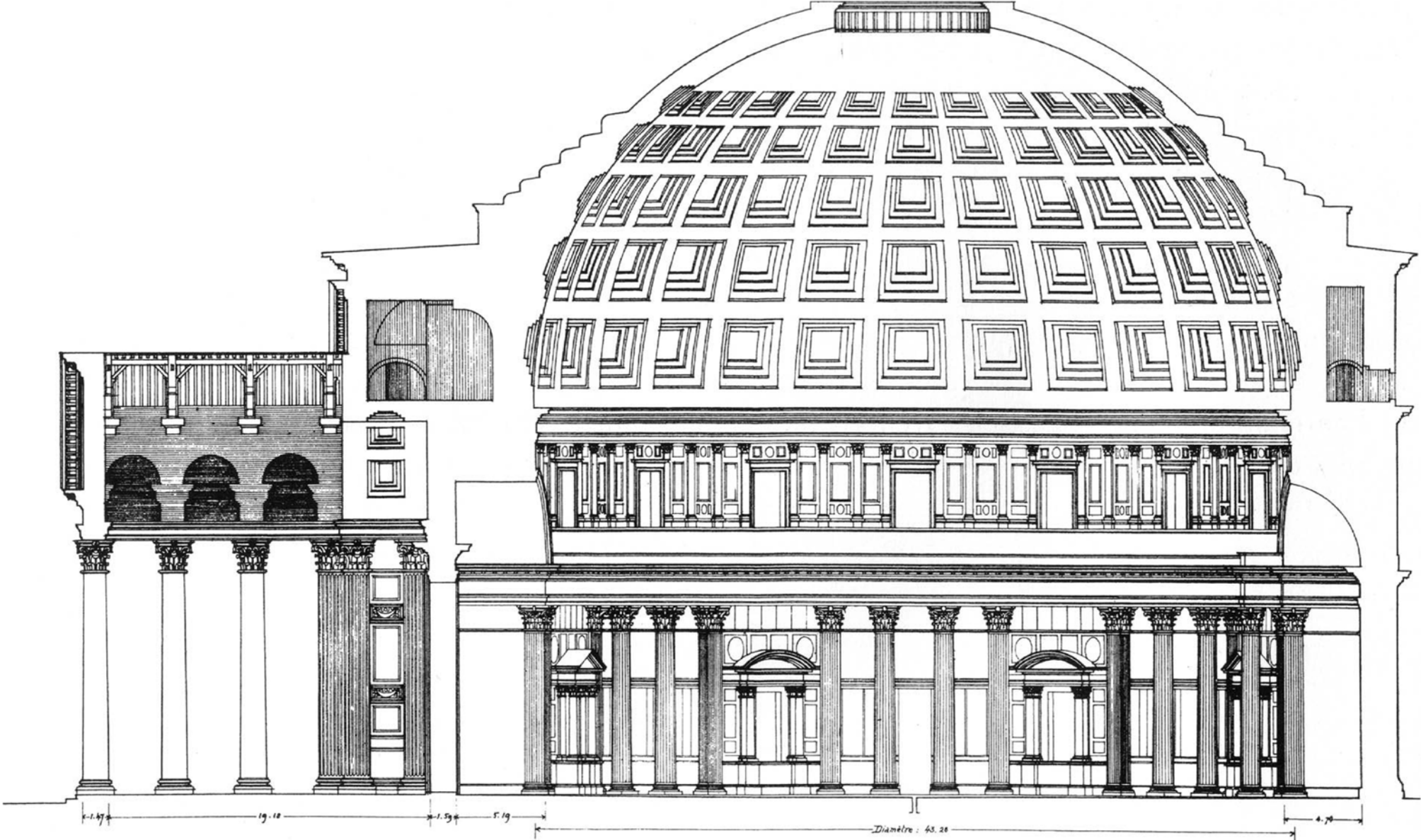




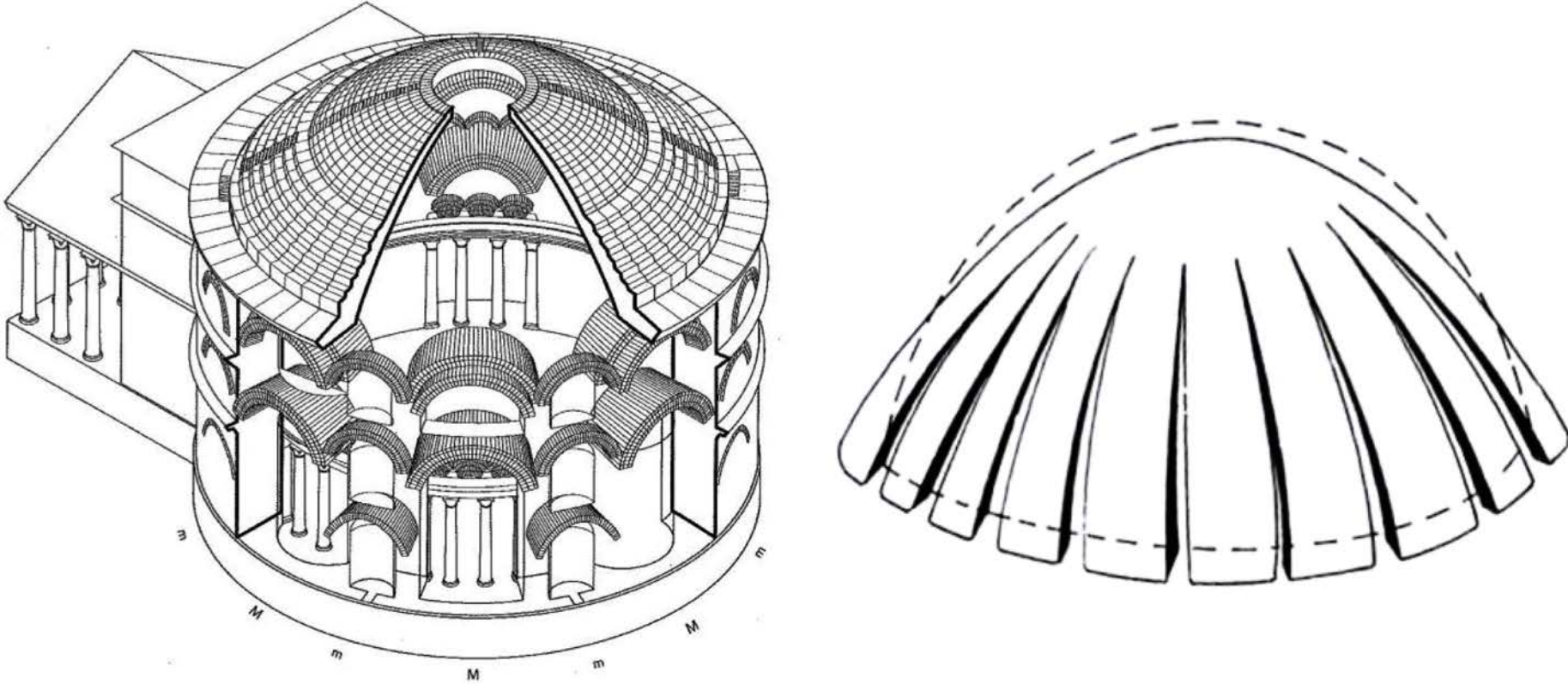
Dome Saint Peter's Basilica



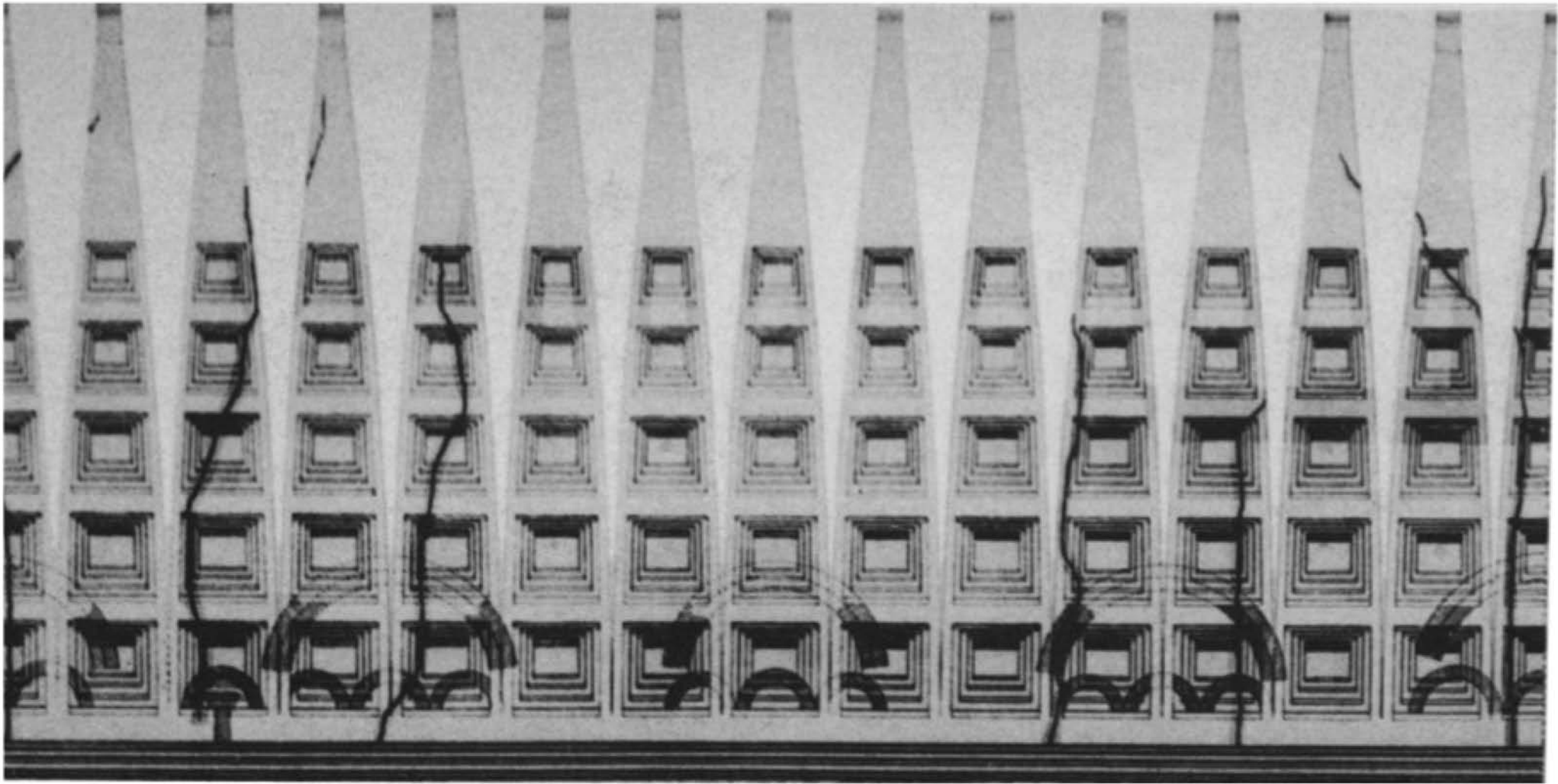
Pantheon, Rome, Italy, 125 AD



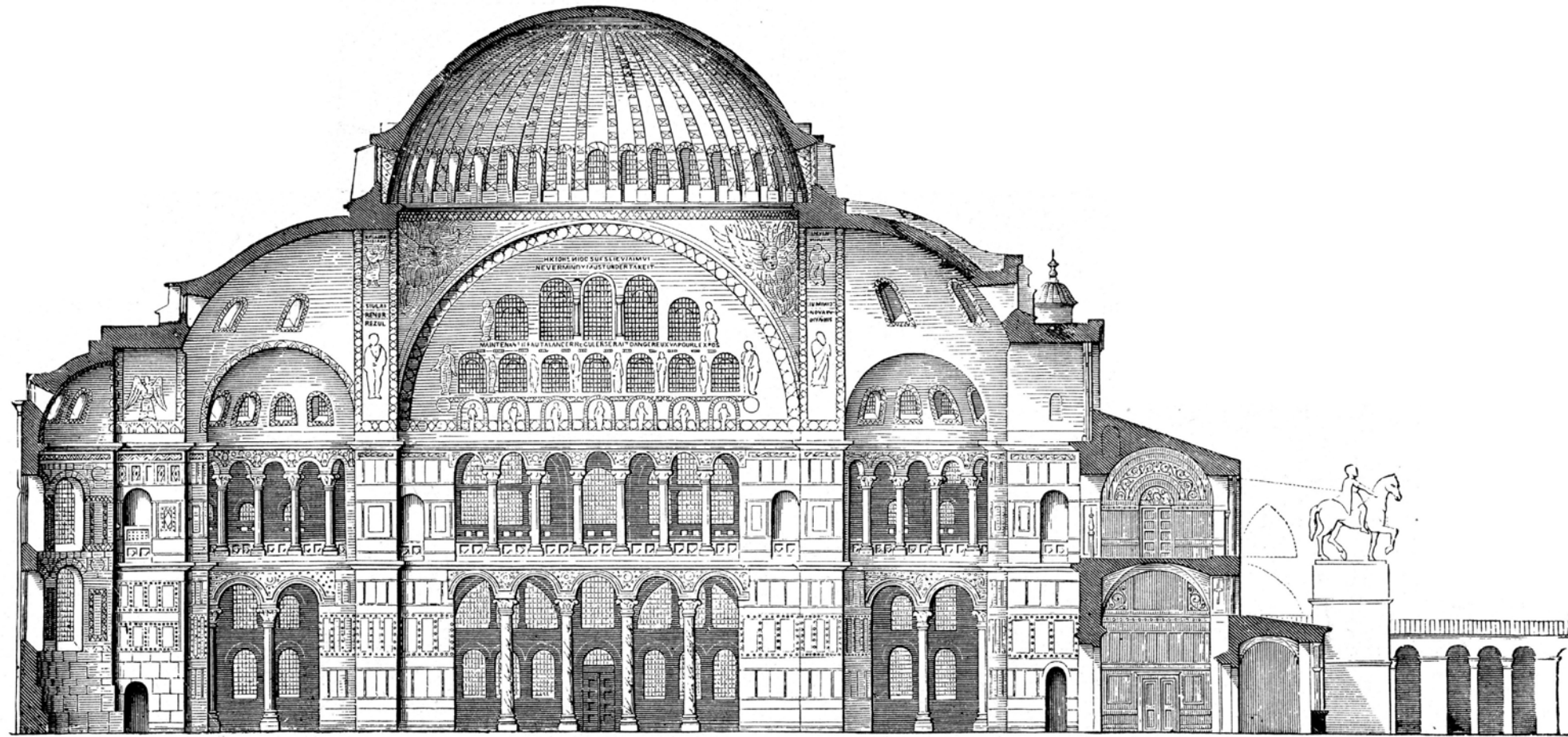
Pantheon, Rome, Italy, 125 AD



Pantheon, Rome, Italy, 125 AD



Pantheon, Rome, Italy, 125 AD



Hagia Sophia, Istanbul, Turkey, 6th Century



Hagia Sophia, Istanbul, Turkey, 6th Century