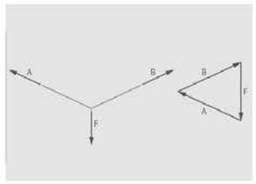
Tragwerksentwurf I

Structural Design I

Philippe Block · Joseph Schwartz

Tragwerksentwurf
Structural Design

1. Gleichgewicht
1. Equilibrium



2. Graphische Statik
2. Graphic statics

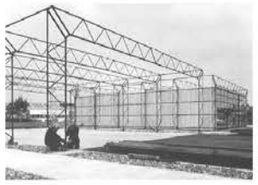
3. Seile
3. Cables

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

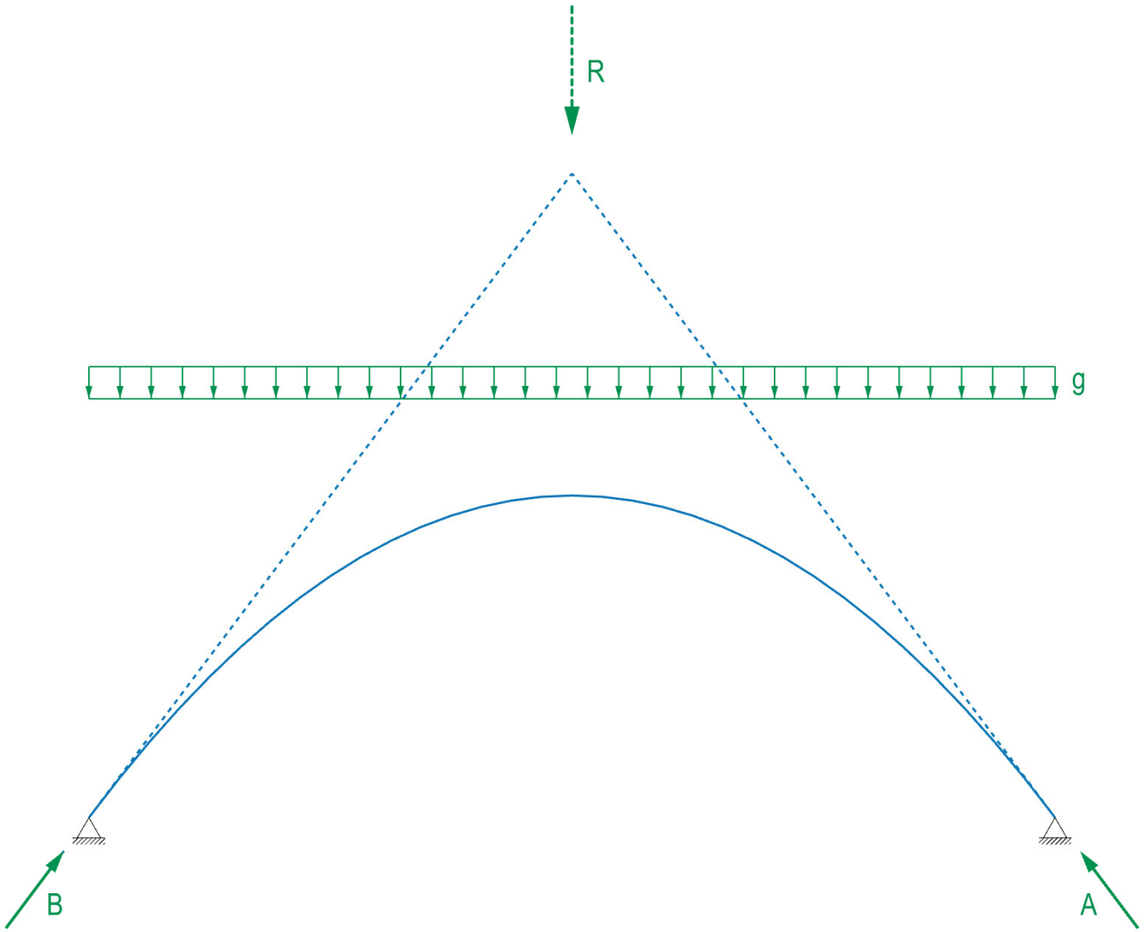
9. Platten
9. Plates

10. Stützen
10. Columns

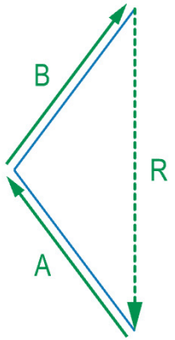
11. Nachhaltigkeit
11. Sustainability

Bogen-Seil-Tragwerke

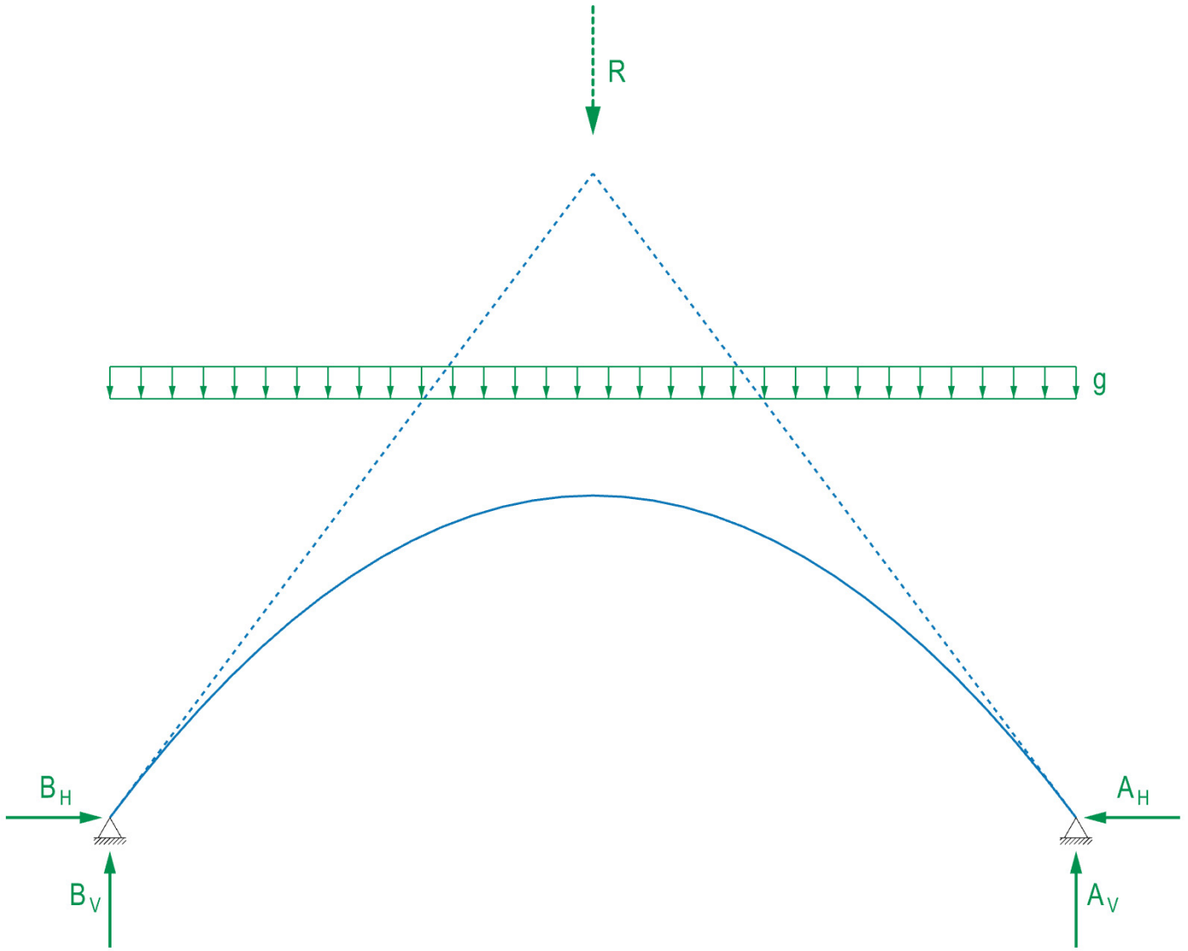
Arch-cable structures



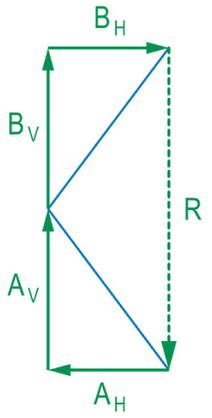
Lageplan 1:100
Form diagram 1:100



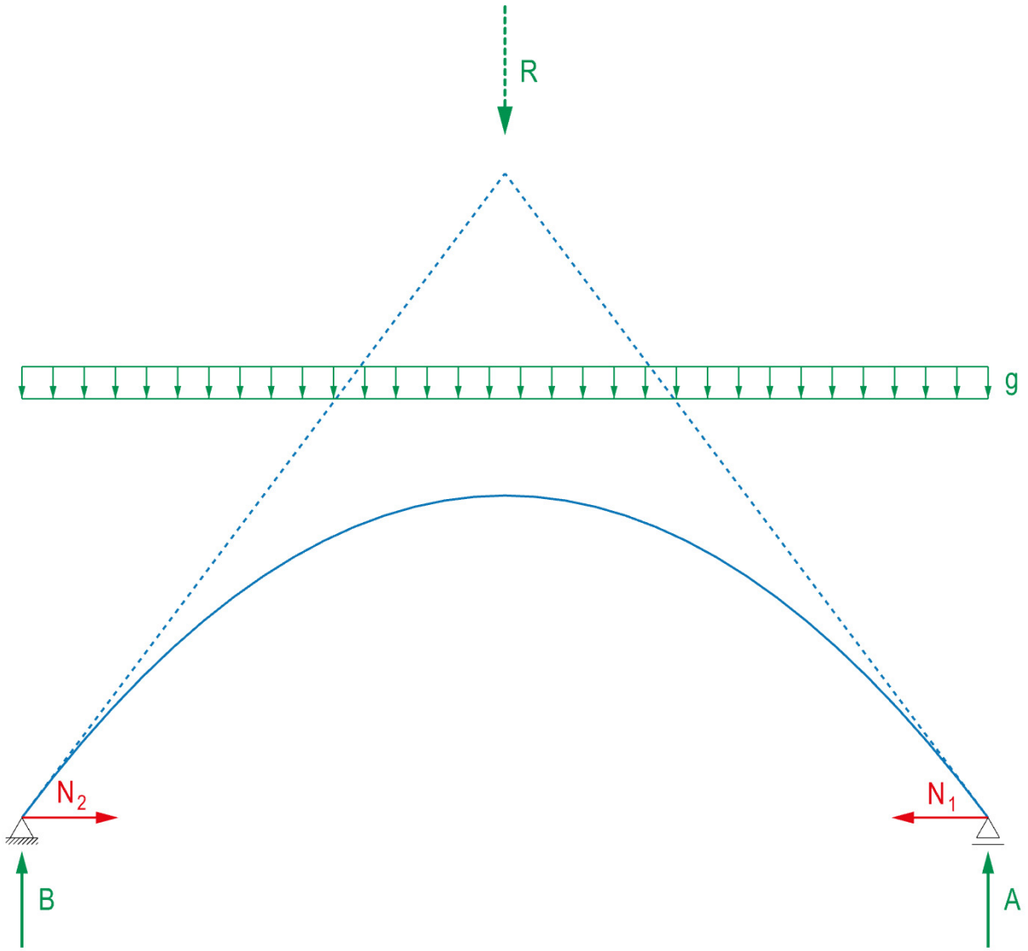
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



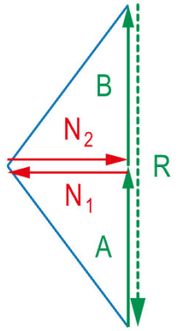
Lageplan 1:100
Form diagram 1:100



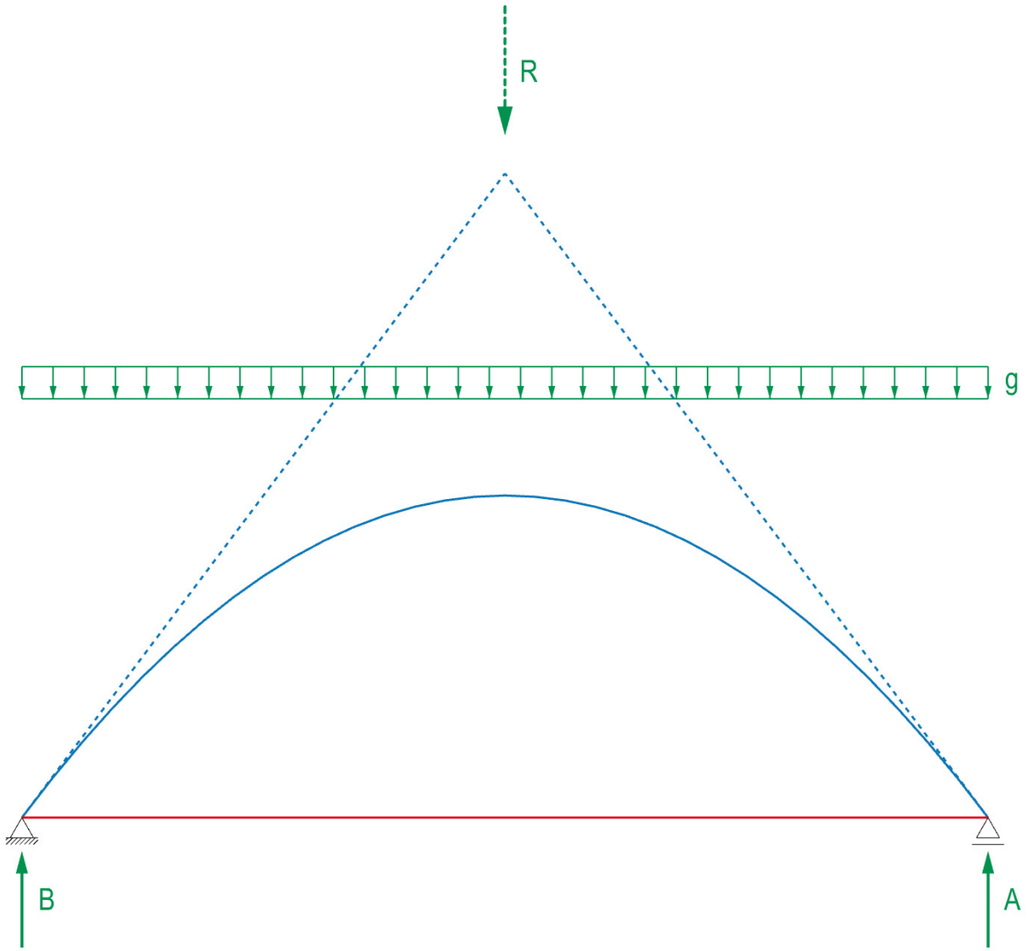
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



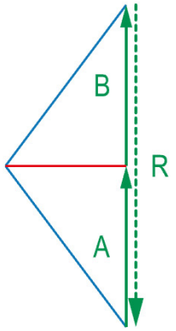
Lageplan 1:100
Form diagram 1:100



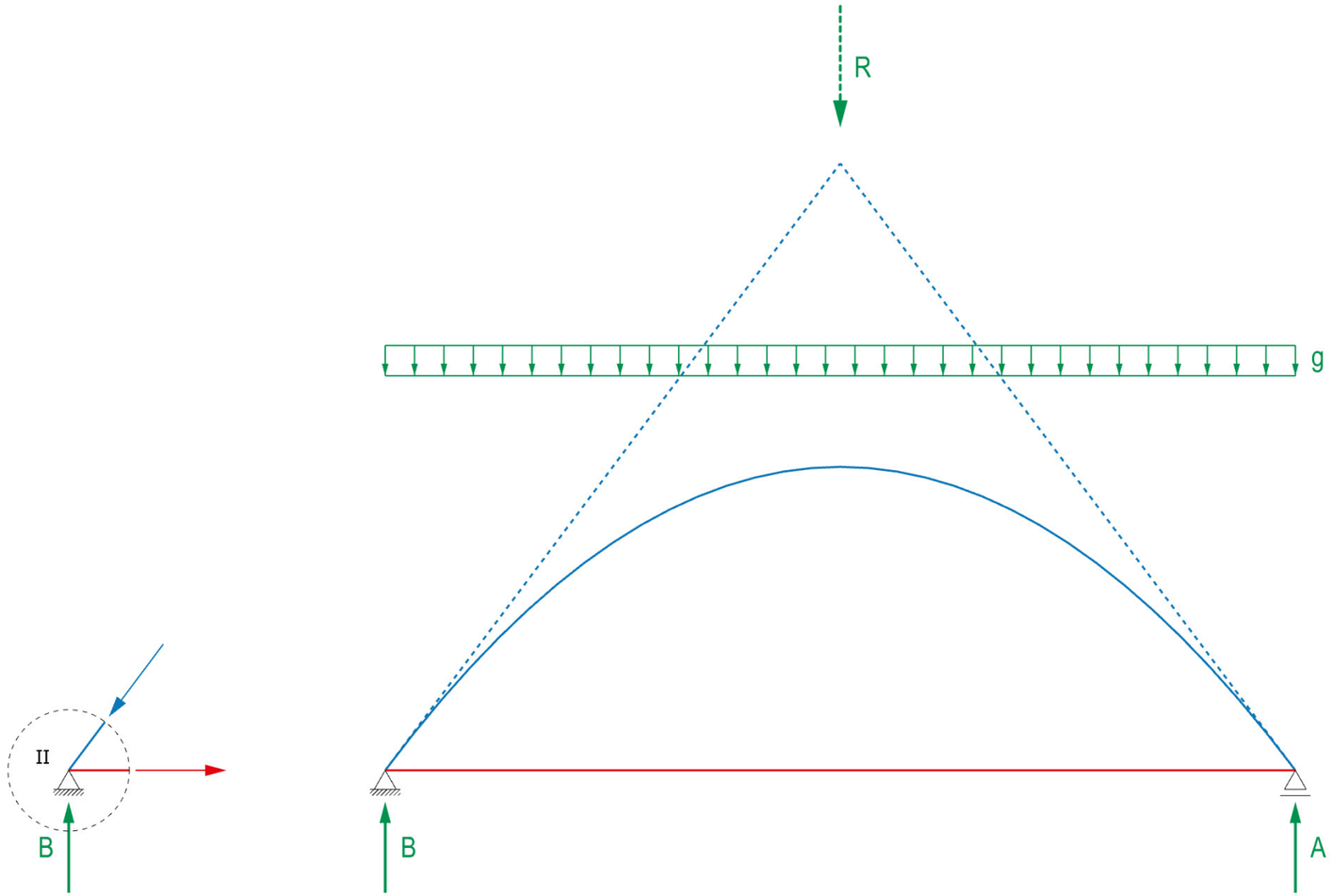
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



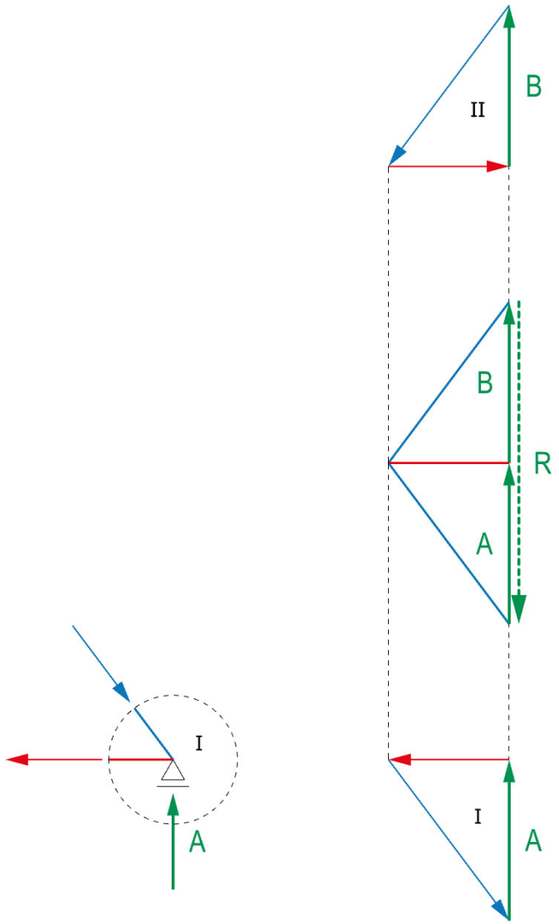
Lageplan 1:100
Form diagram 1:100



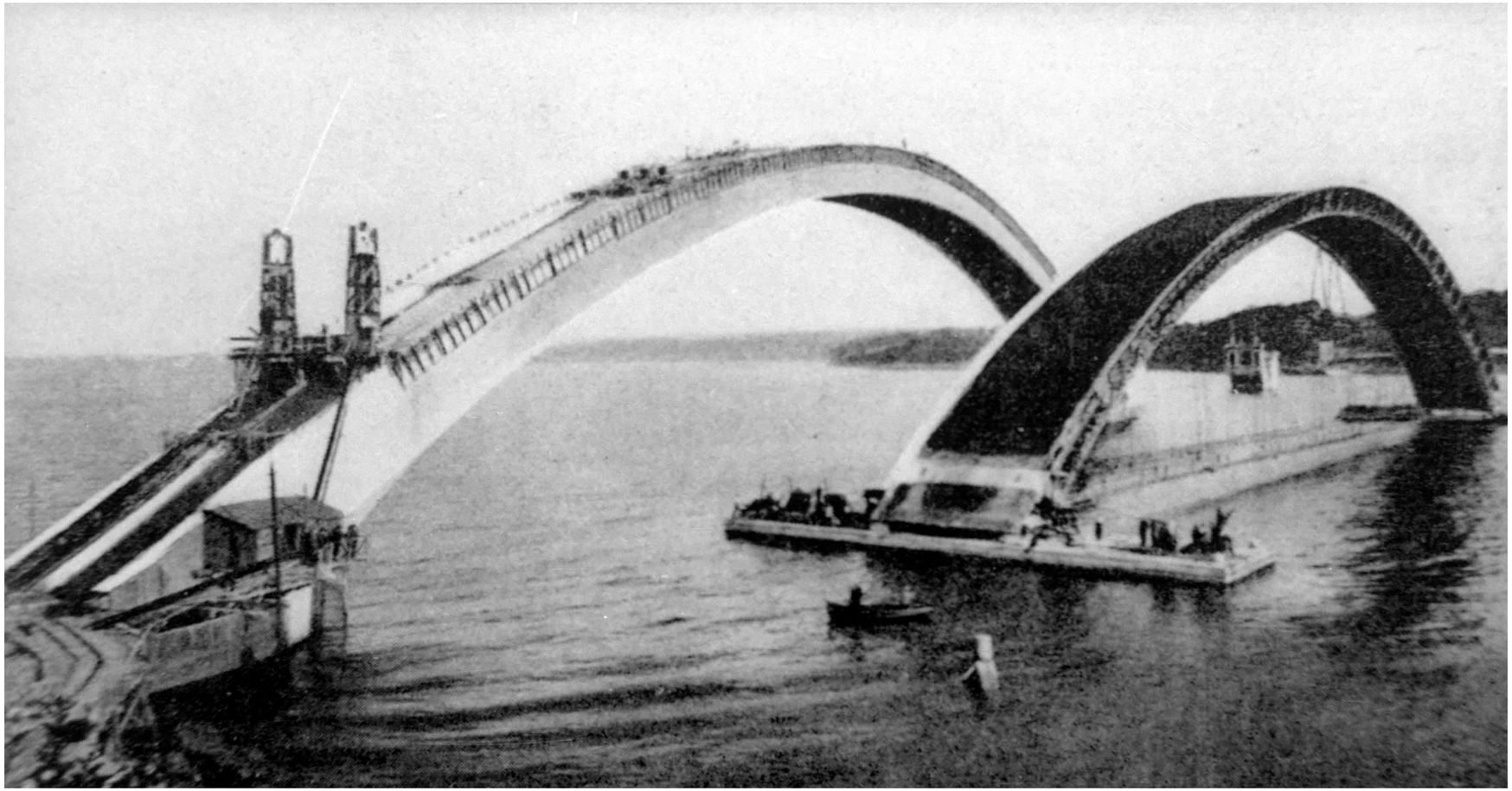
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

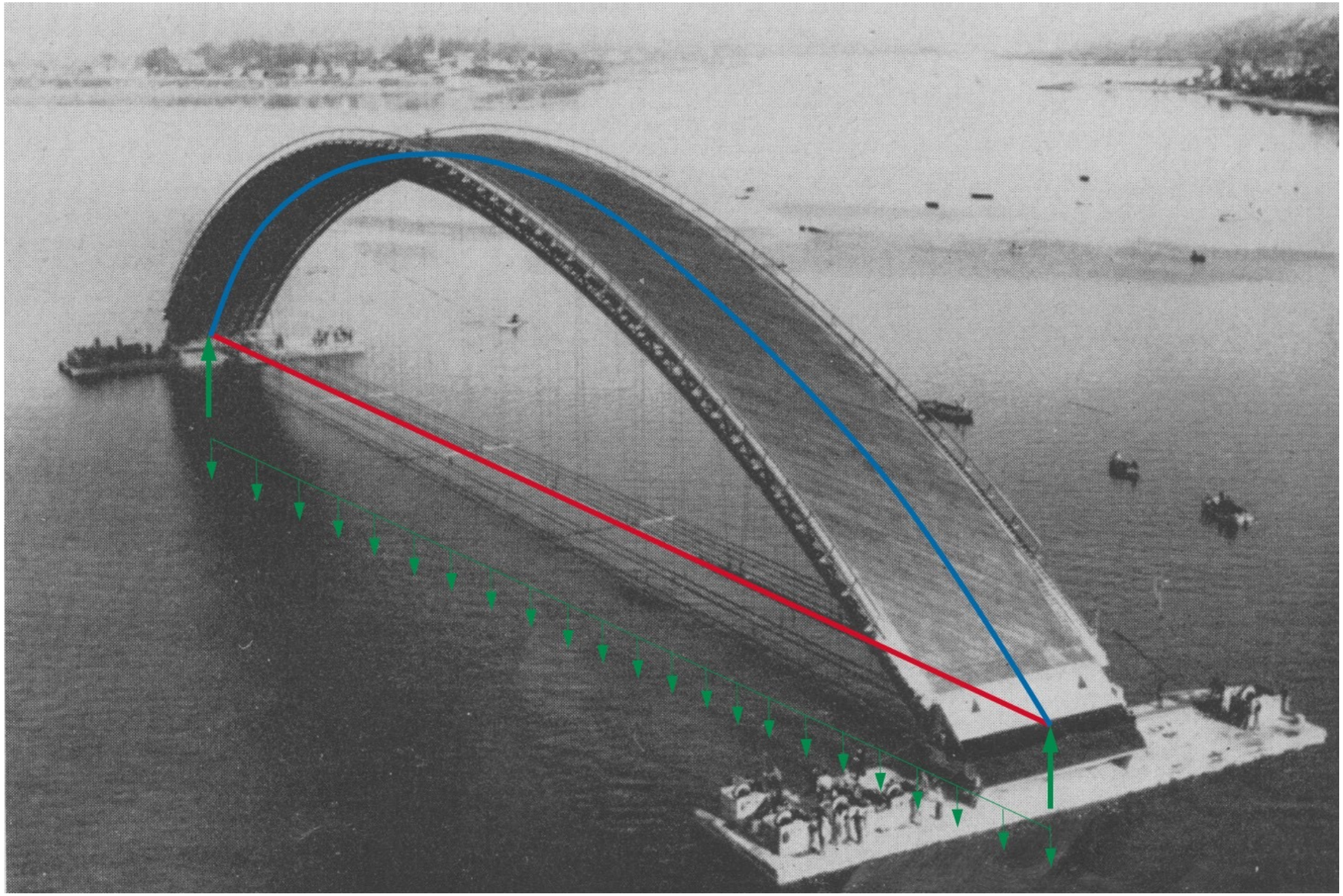


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

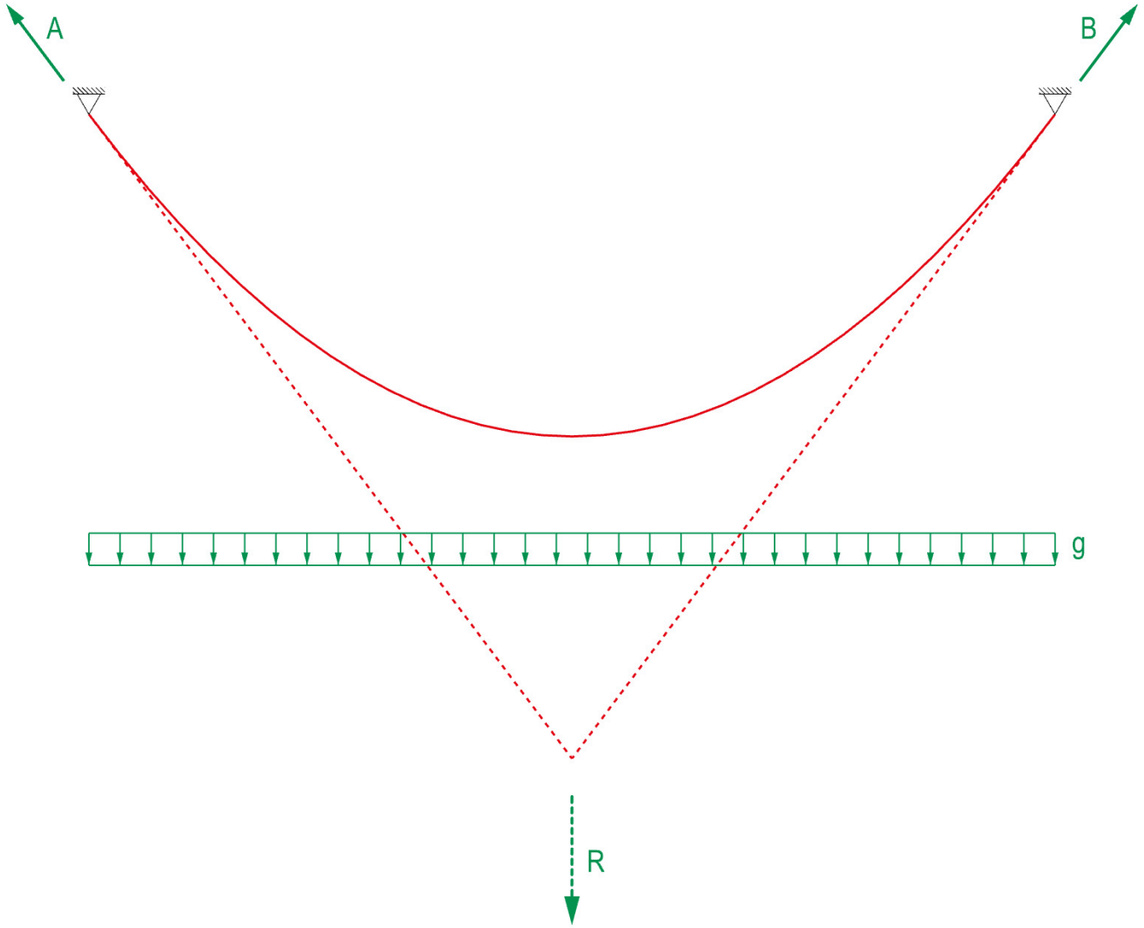


Eugène Freyssinet: Pont Albert Louppe, Bretagne, 1930

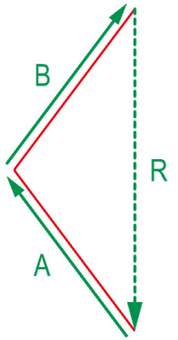
Eugène Freyssinet: Pont Albert Louppe, Bretagne, 1930



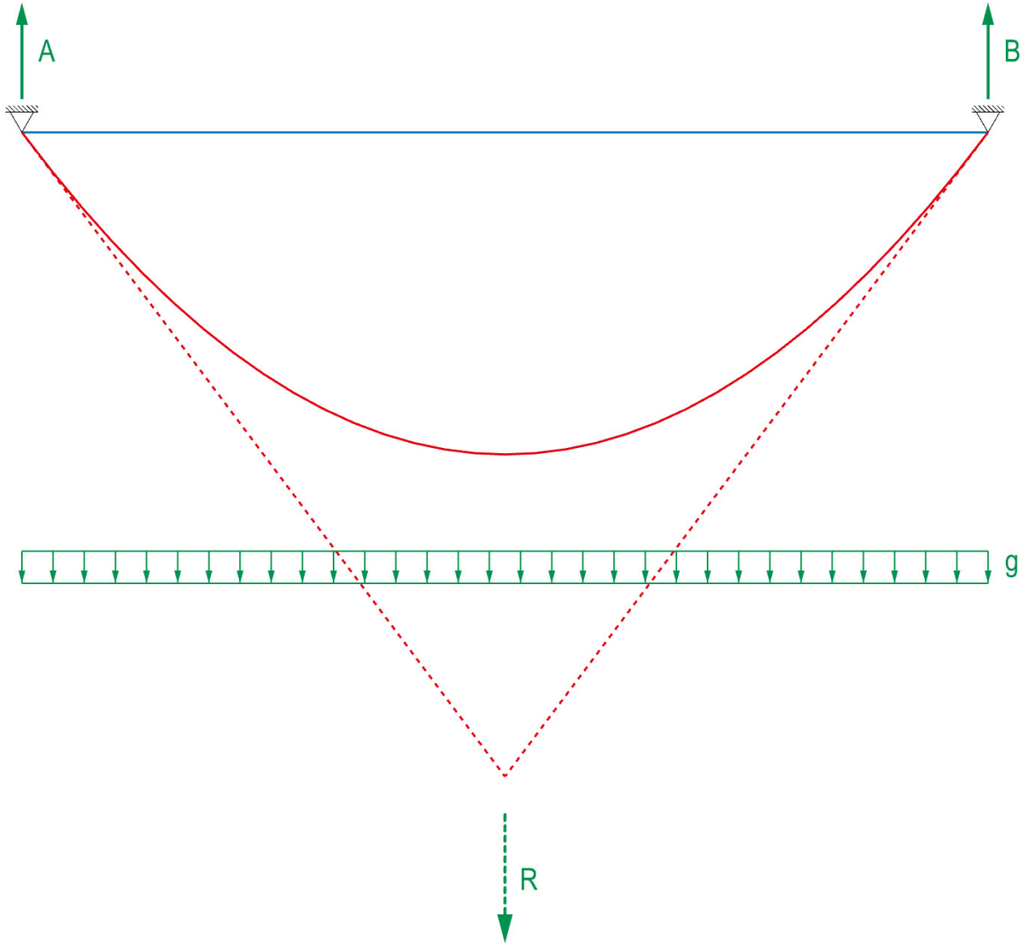
Eugène Freyssinet: Pont Albert Louppe, Bretagne, 1930



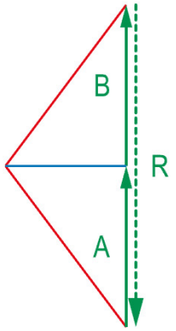
Lageplan 1:100
Form diagram 1:100



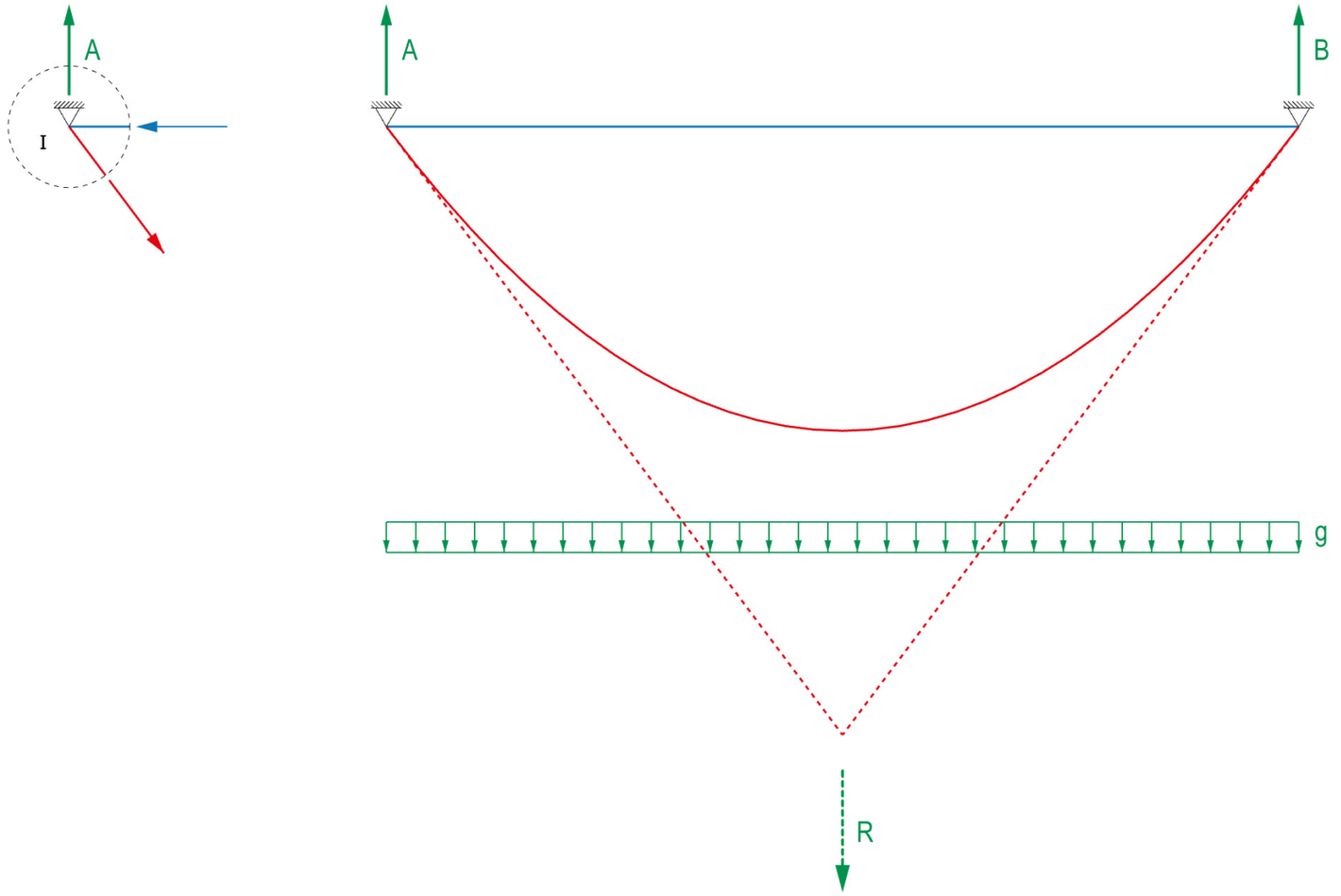
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



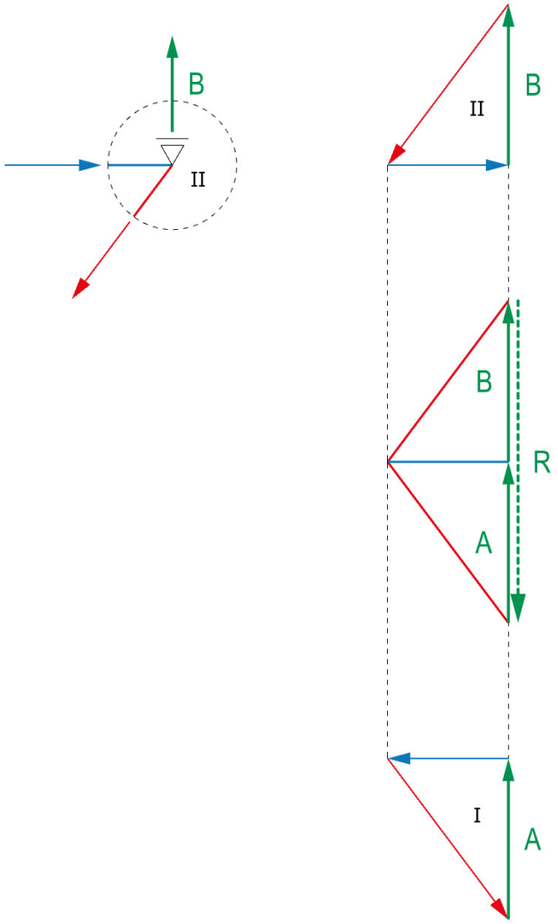
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

Bogen-Seil-Tragwerke

Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

>> Auflagerbedingungen
Support conditions

Aufteilung der äusseren Lasten
Distribution of external loads

Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

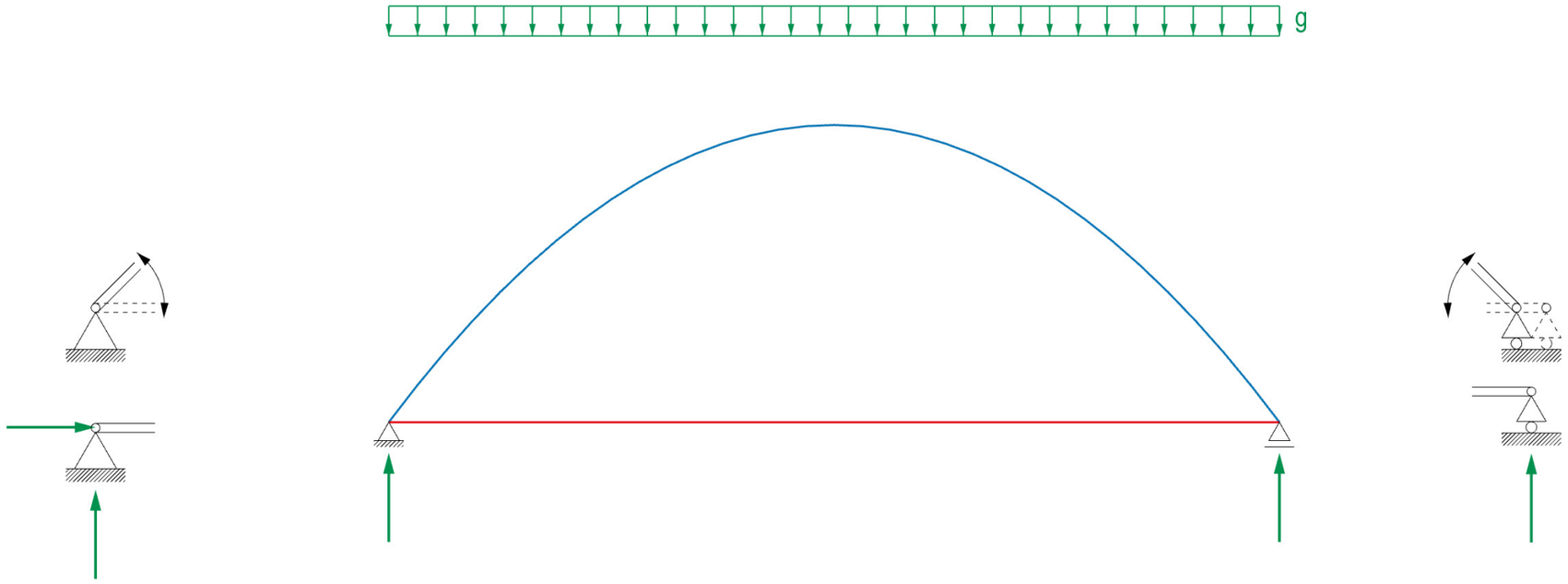
Geometrische Variation
Geometric variation

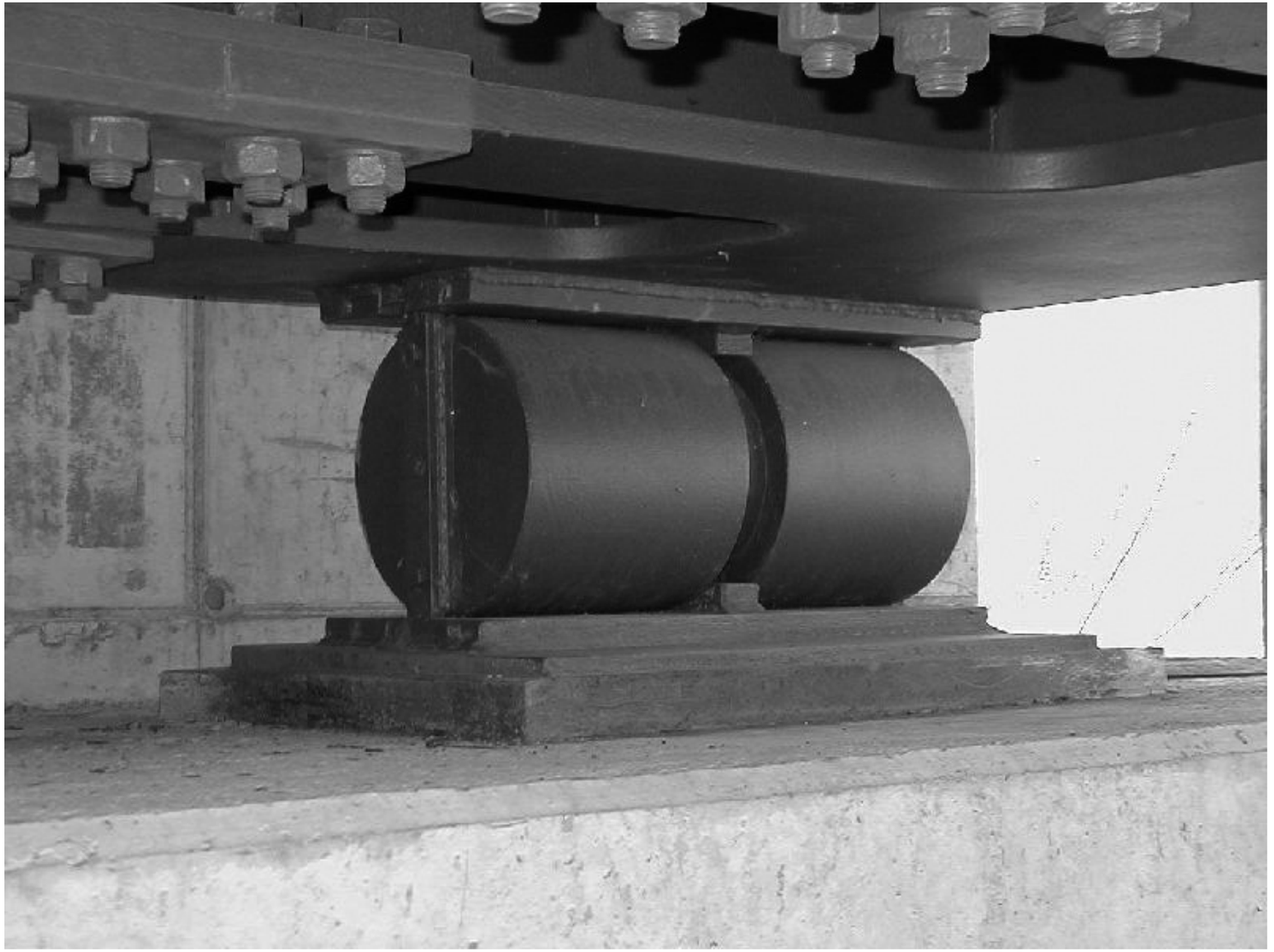
Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

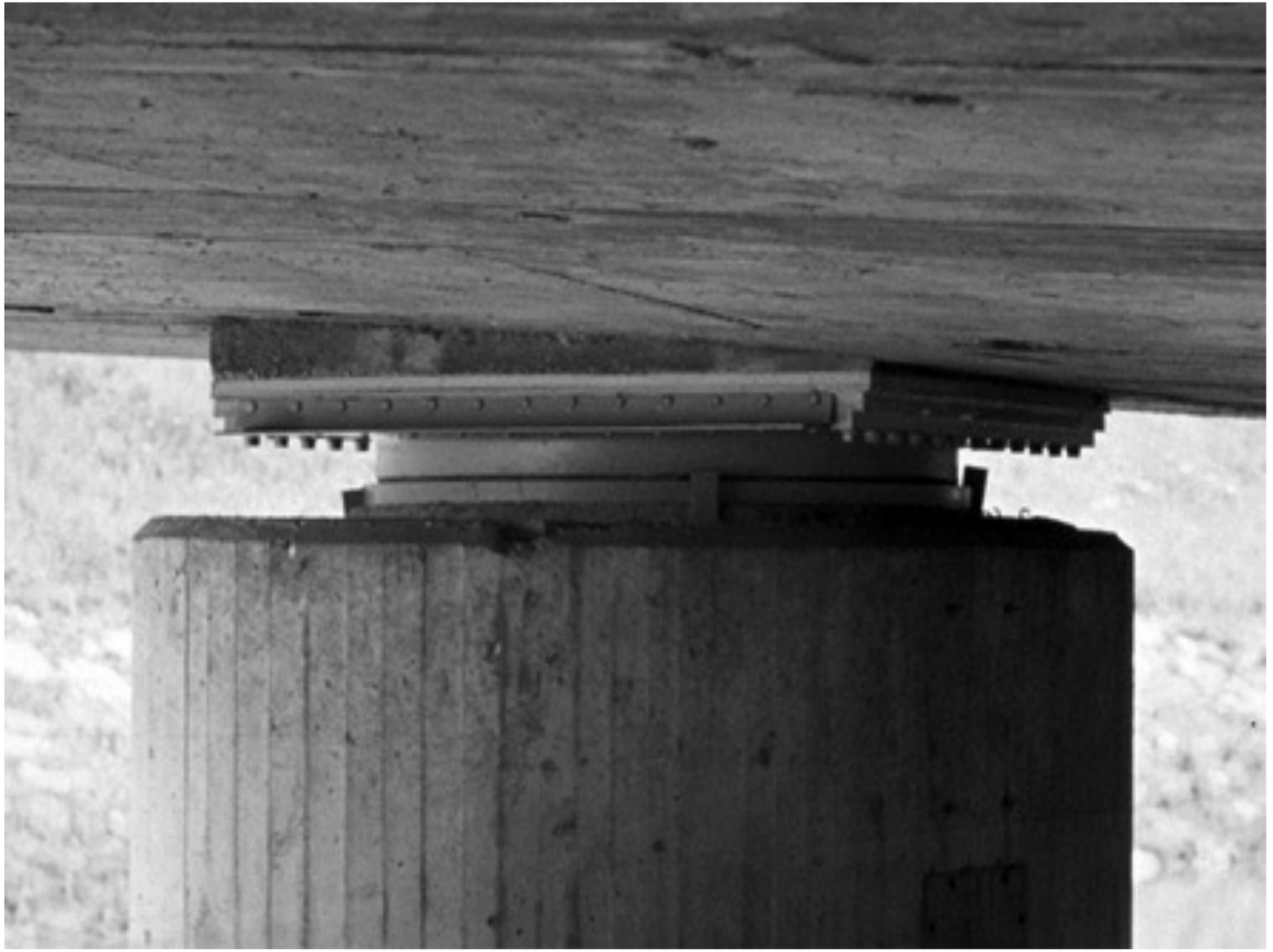
Fallbeispiele
Case studies

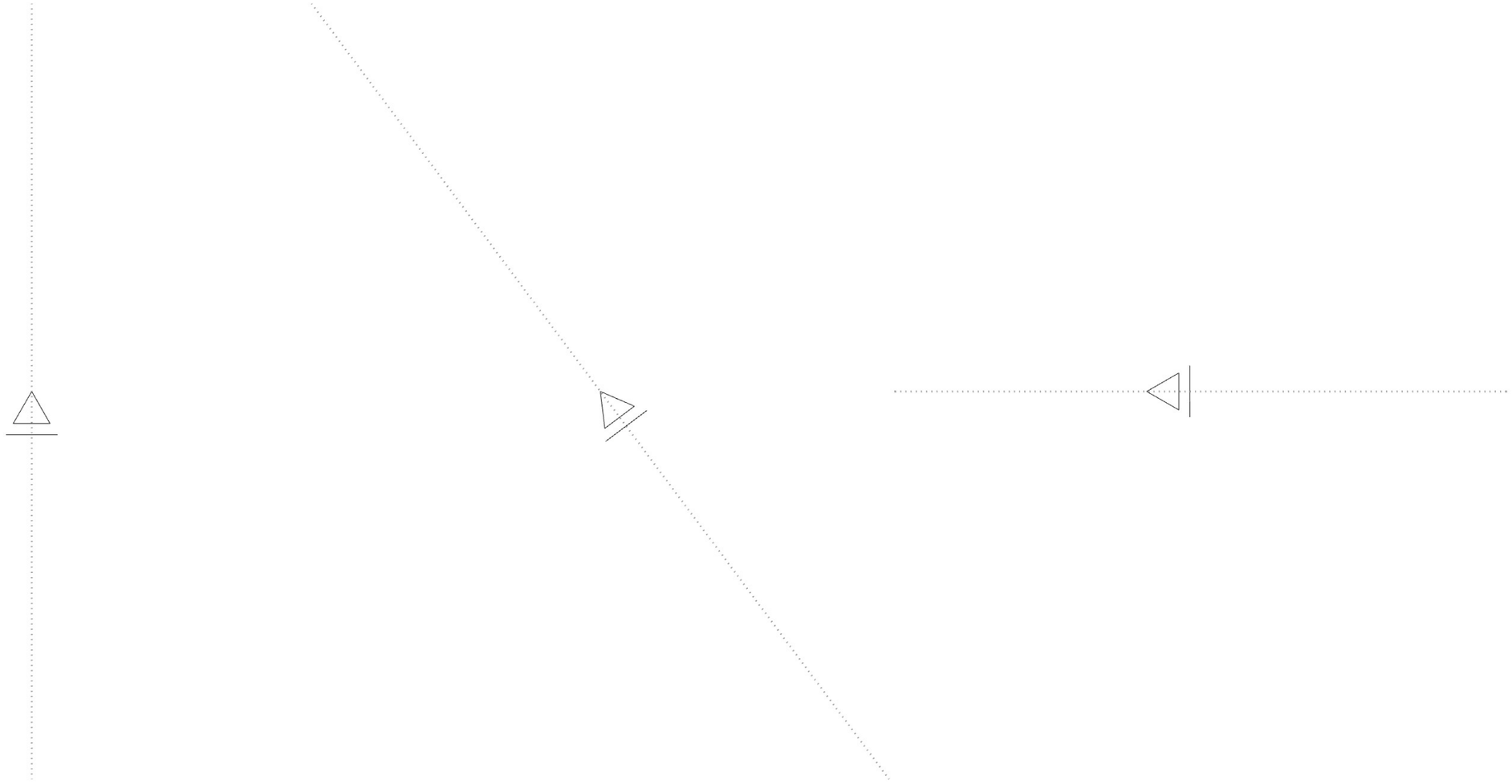
Auflagerbedingungen

Support conditions



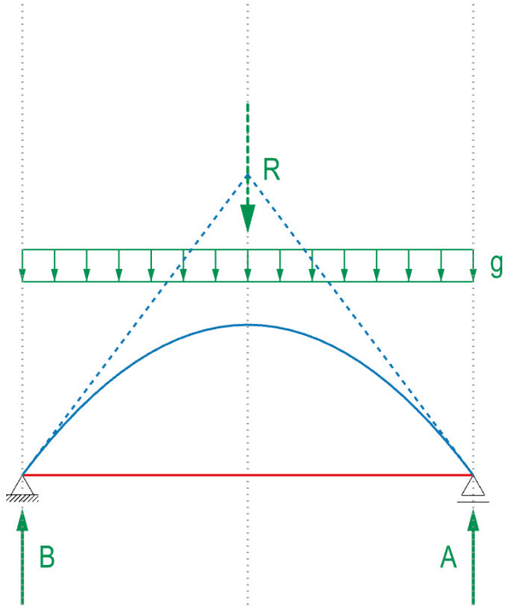


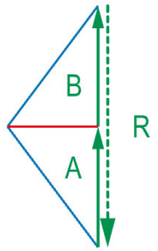


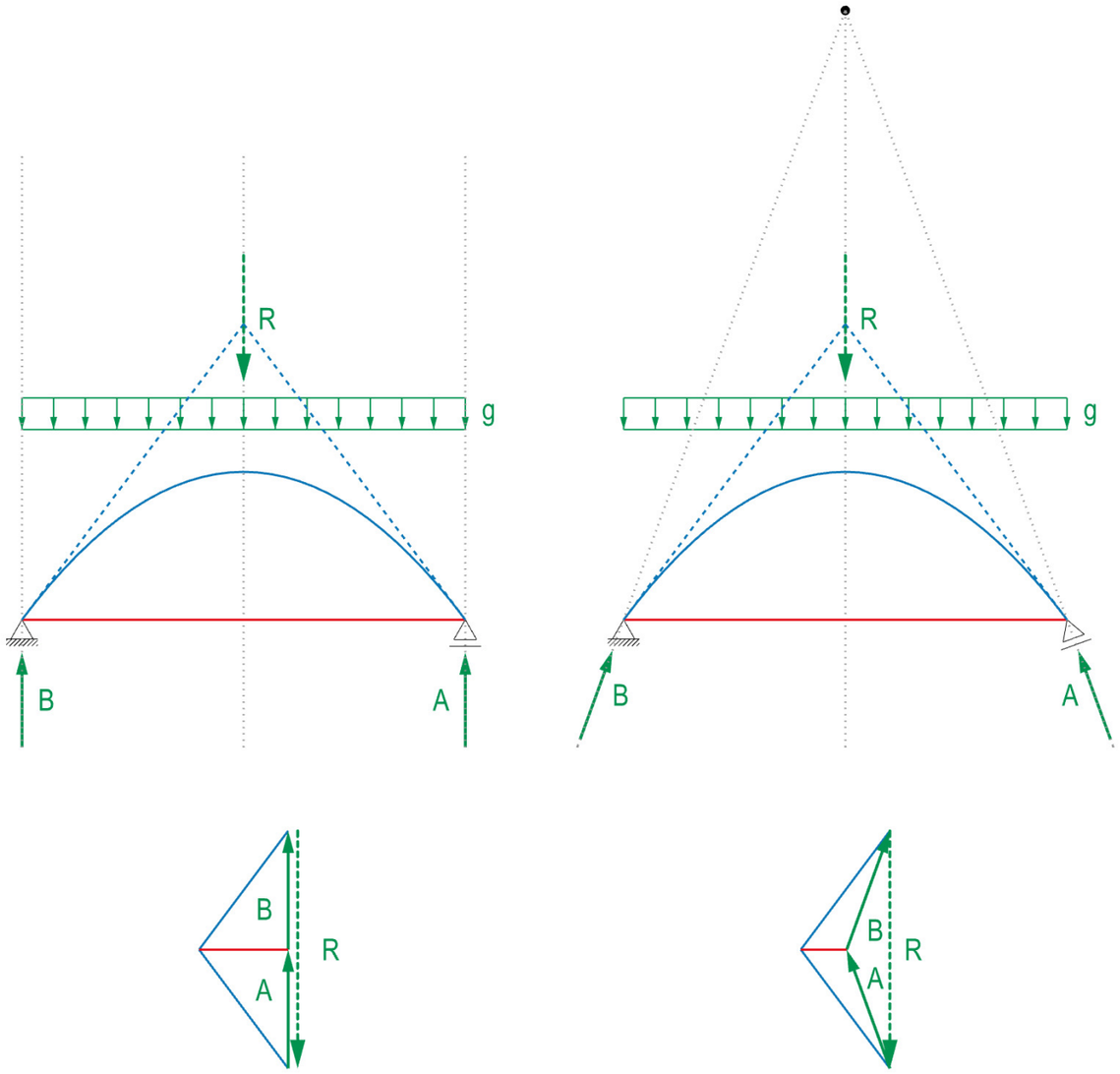


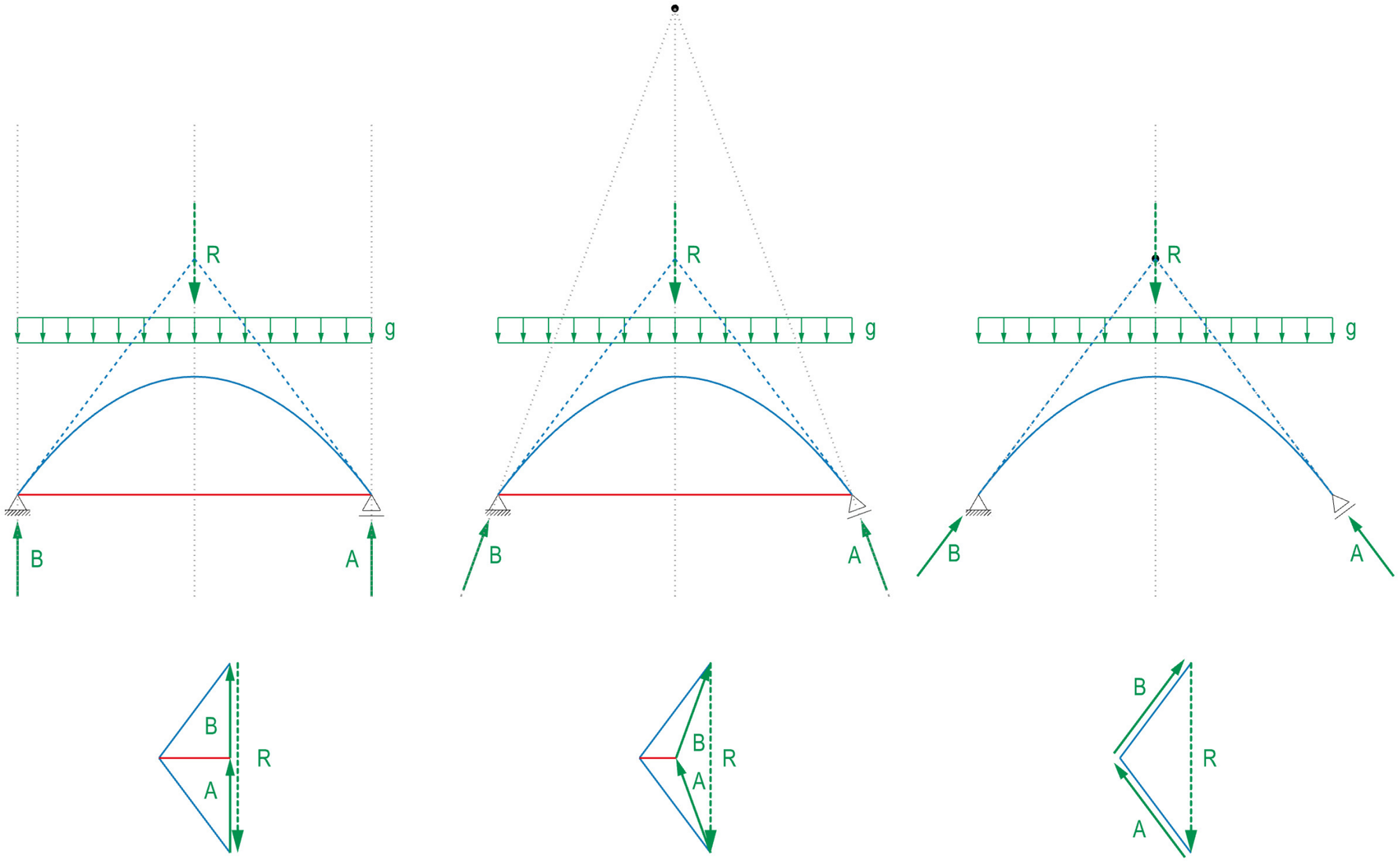
Auflagerbedingungen

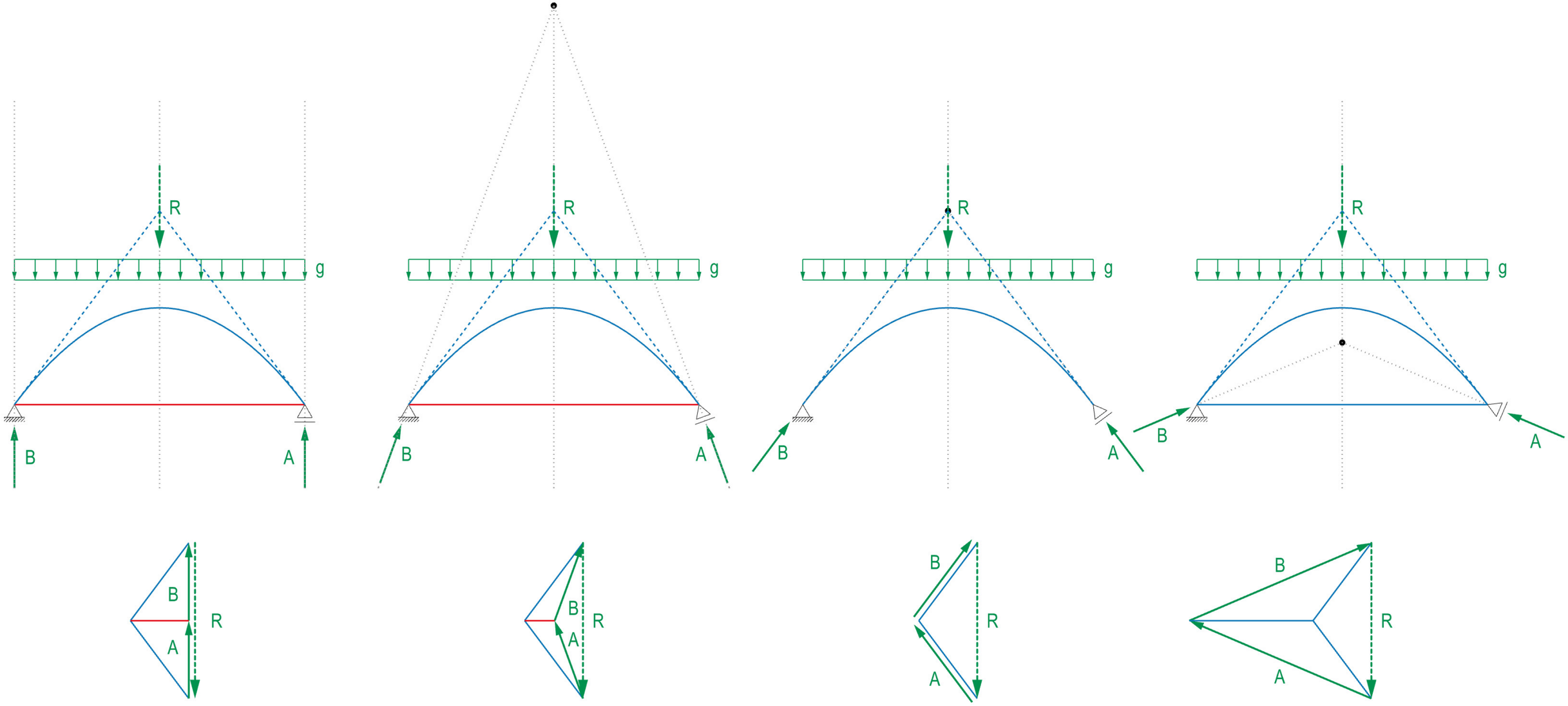
Support conditions






R
g
B
A
R
g
B
A
B
A
R
B
A
R


R
g
B
A
R
g
B
A
R
g
B
A
B
A
R
B
A
R
B
A
R


R
g
B
A
R
g
B
A
R
g
B
A
R
g
B
A
B
A
R
B
A
R
B
A
R
B
A
R

Bogen-Seil-Tragwerke

Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

Auflagerbedingungen
Support conditions

>> Aufteilung der äusseren Lasten
Distribution of external loads

Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

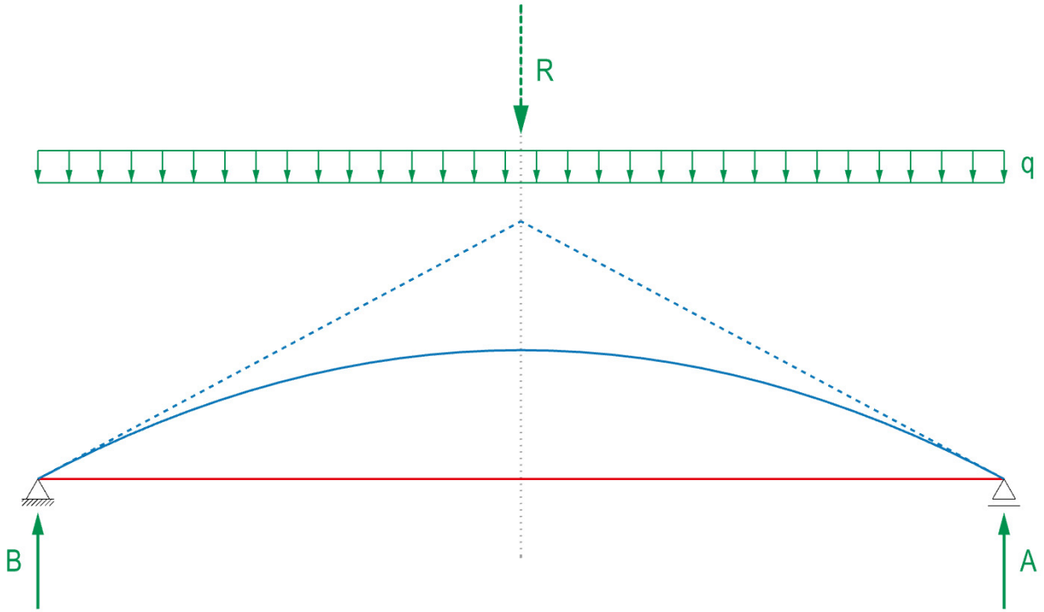
Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

Geometrische Variation
Geometric variation

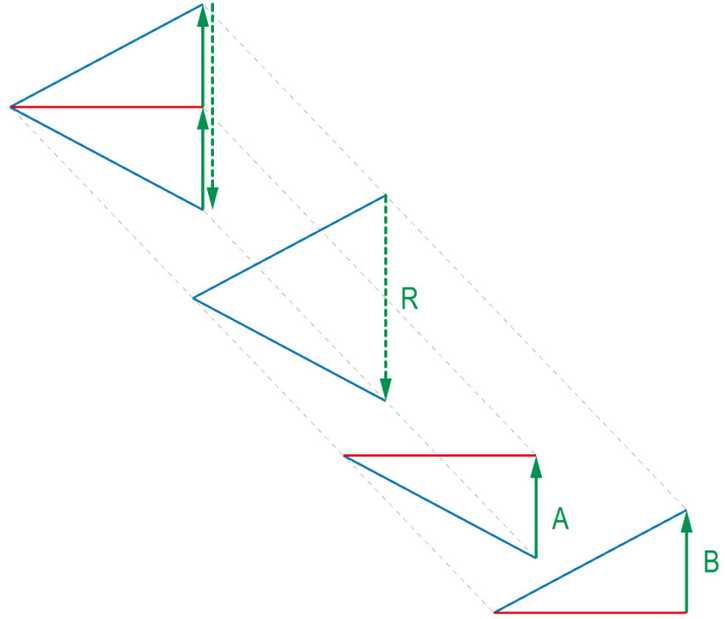
Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

Fallbeispiele
Case studies

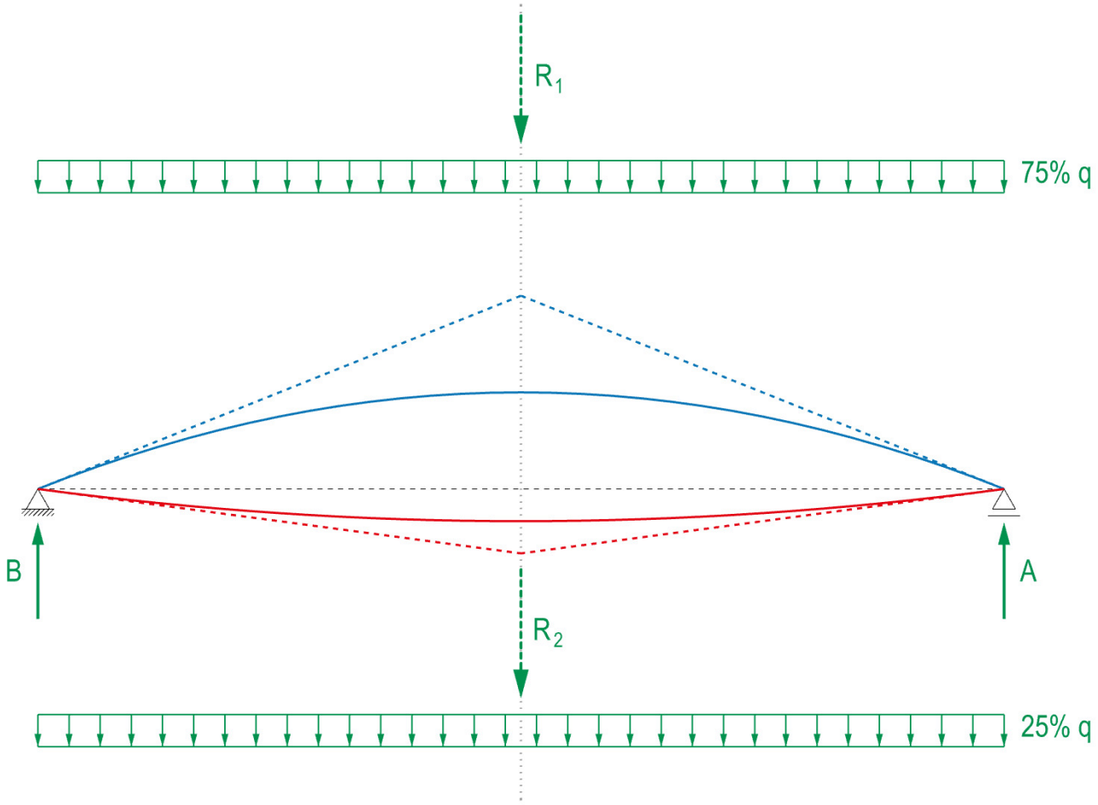
Eugène Freyssinet: Pont Albert Louppe, Bretagne, 1930



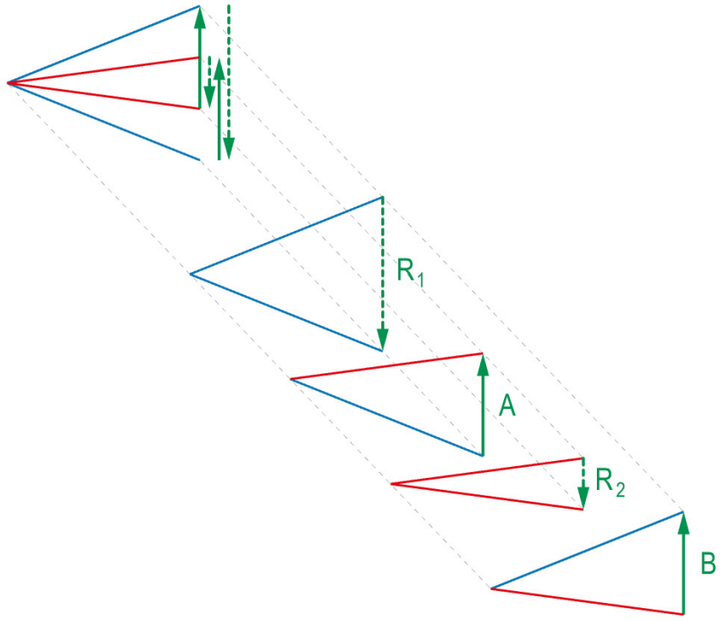
Lageplan 1:100
Form diagram 1:100



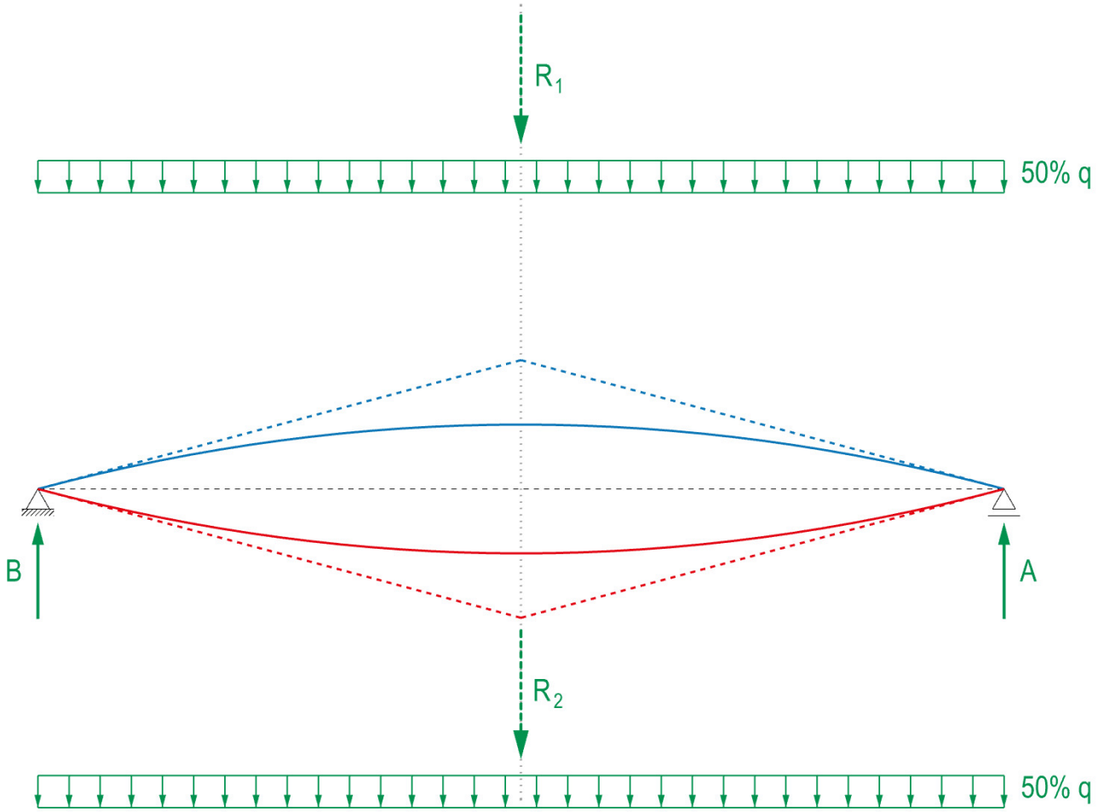
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



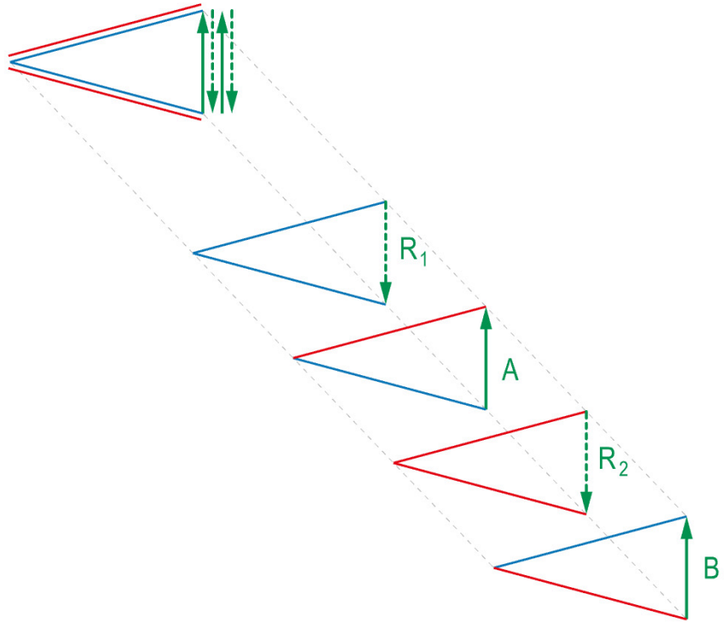
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

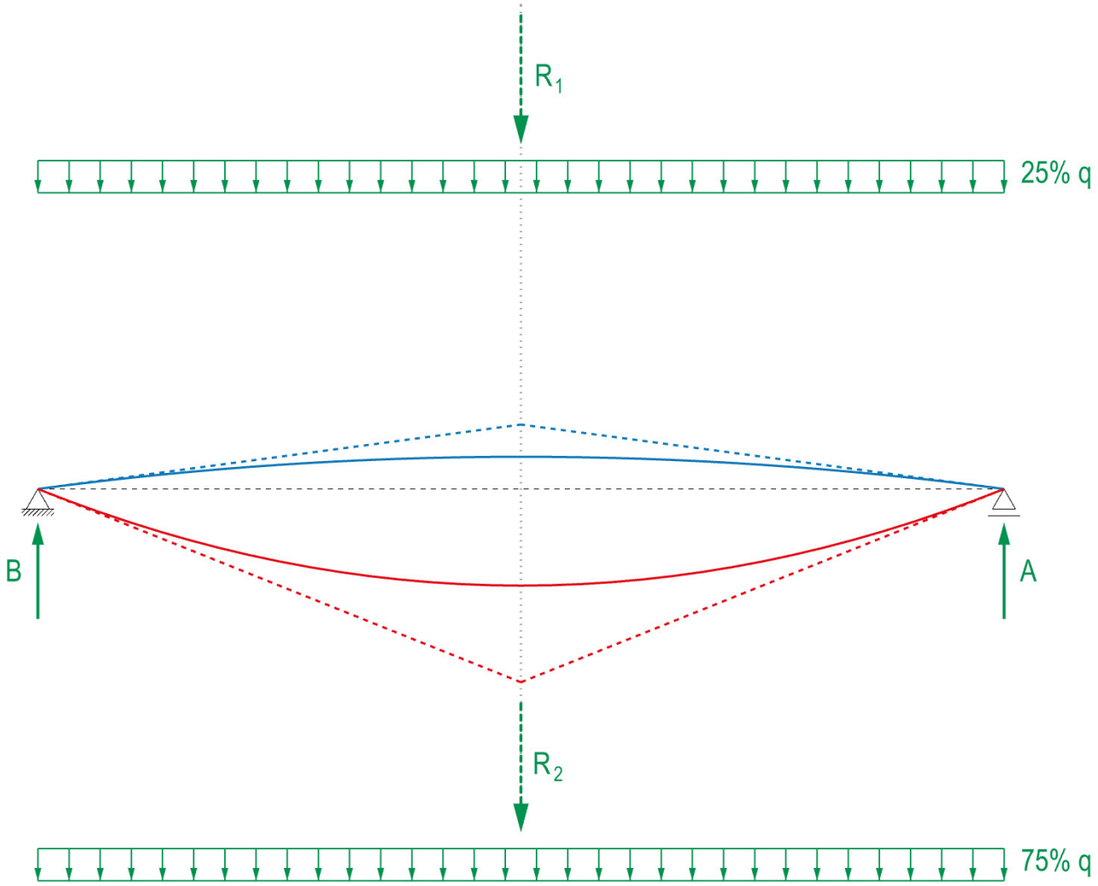


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

G.H. Lohse: Neue Elbbrücke, Hamburg, 1868

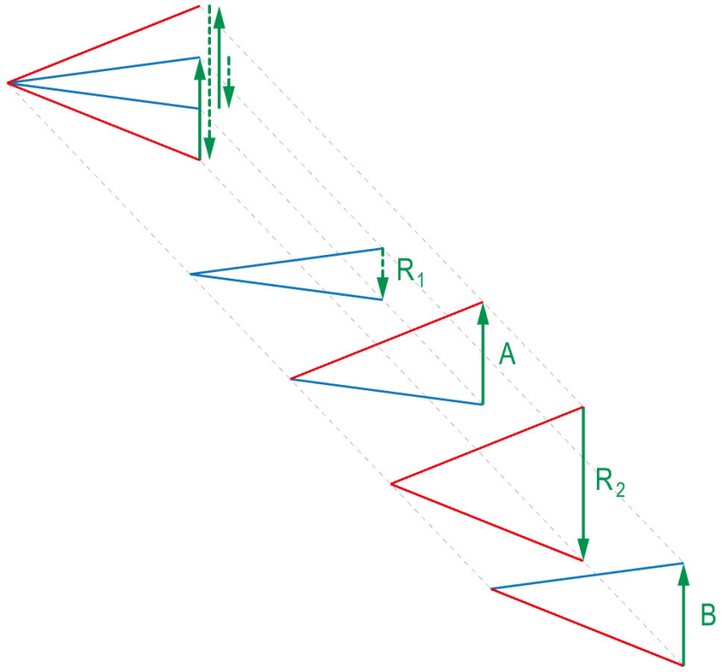
Aufteilung der äusseren Lasten

Distribution of external loads



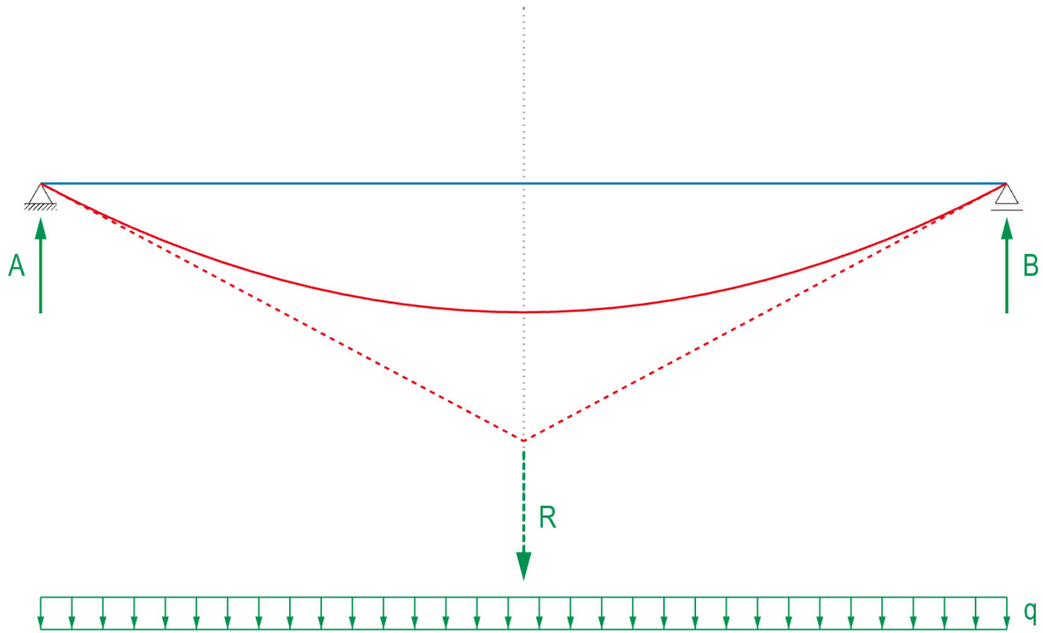
Lageplan 1:100

Form diagram 1:100

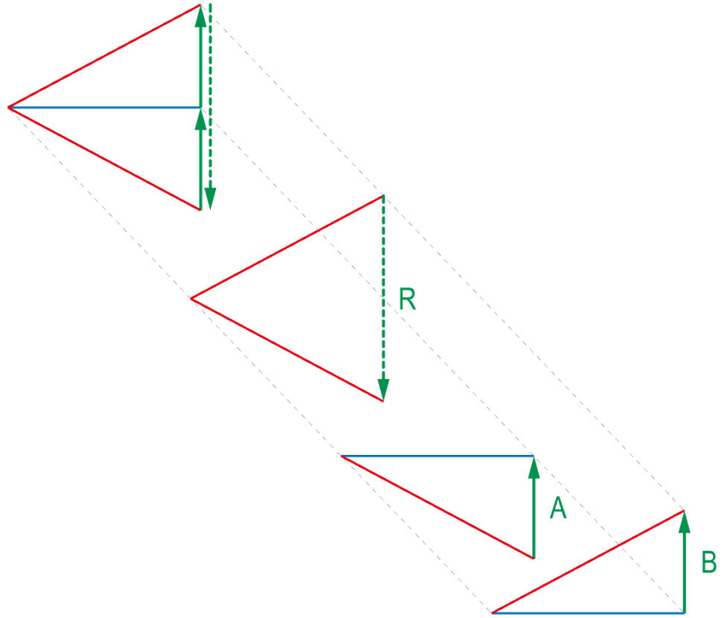


Kräfteplan 1 cm ≙ 1 kN

Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

Bogen-Seil-Tragwerke
Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

Auflagerbedingungen
Support conditions

Aufteilung der äusseren Lasten
Distribution of external loads

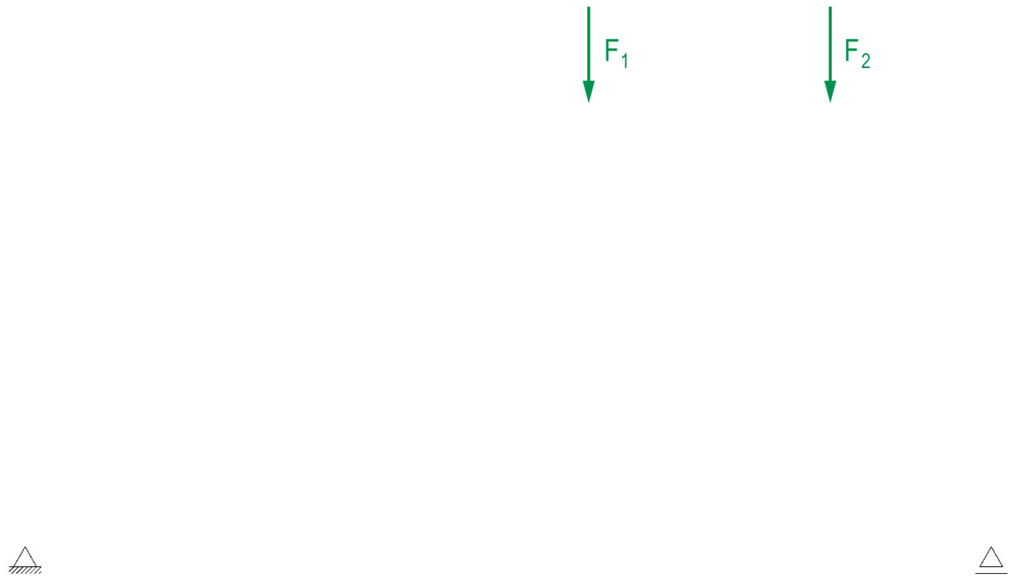
>> Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

Geometrische Variation
Geometric variation

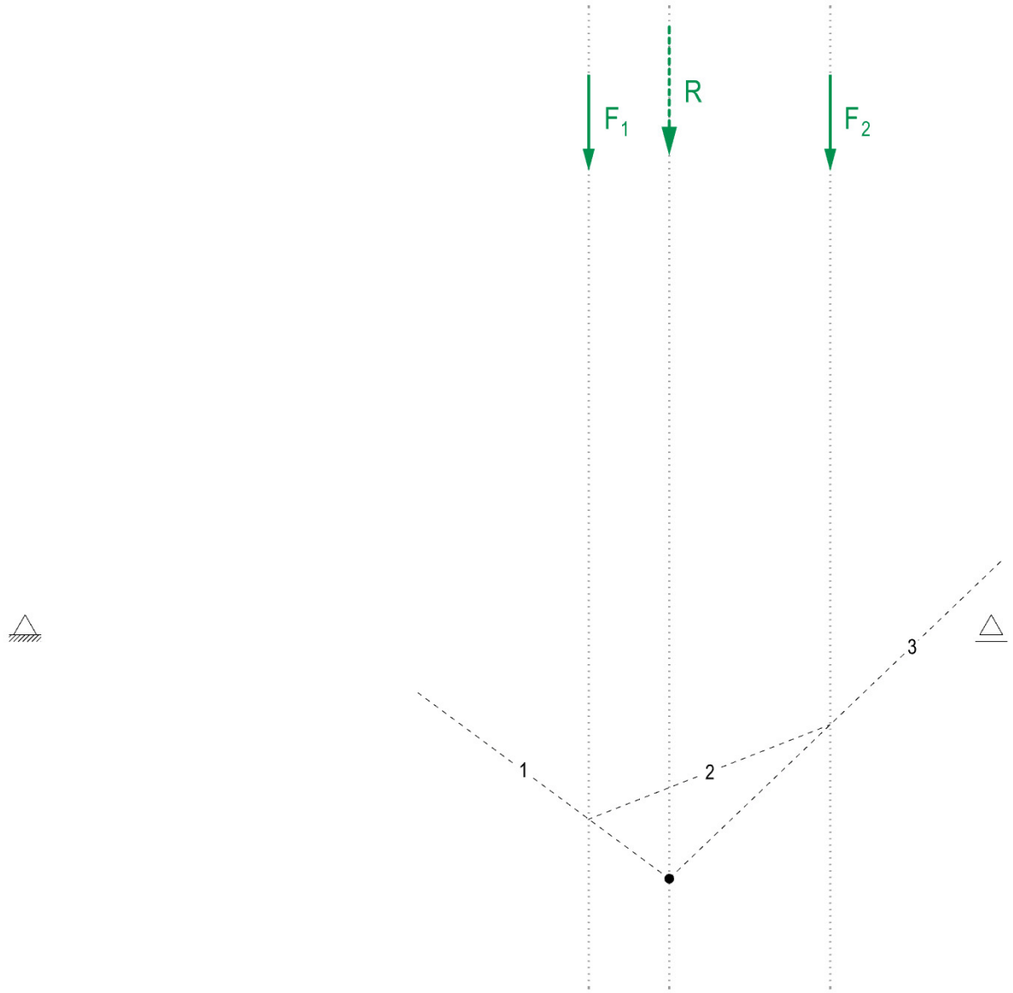
Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

Fallbeispiele
Case studies

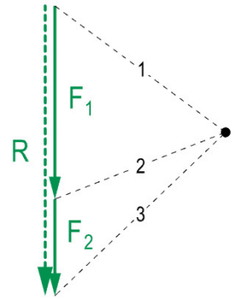


Lageplan 1:100
Form diagram 1:100

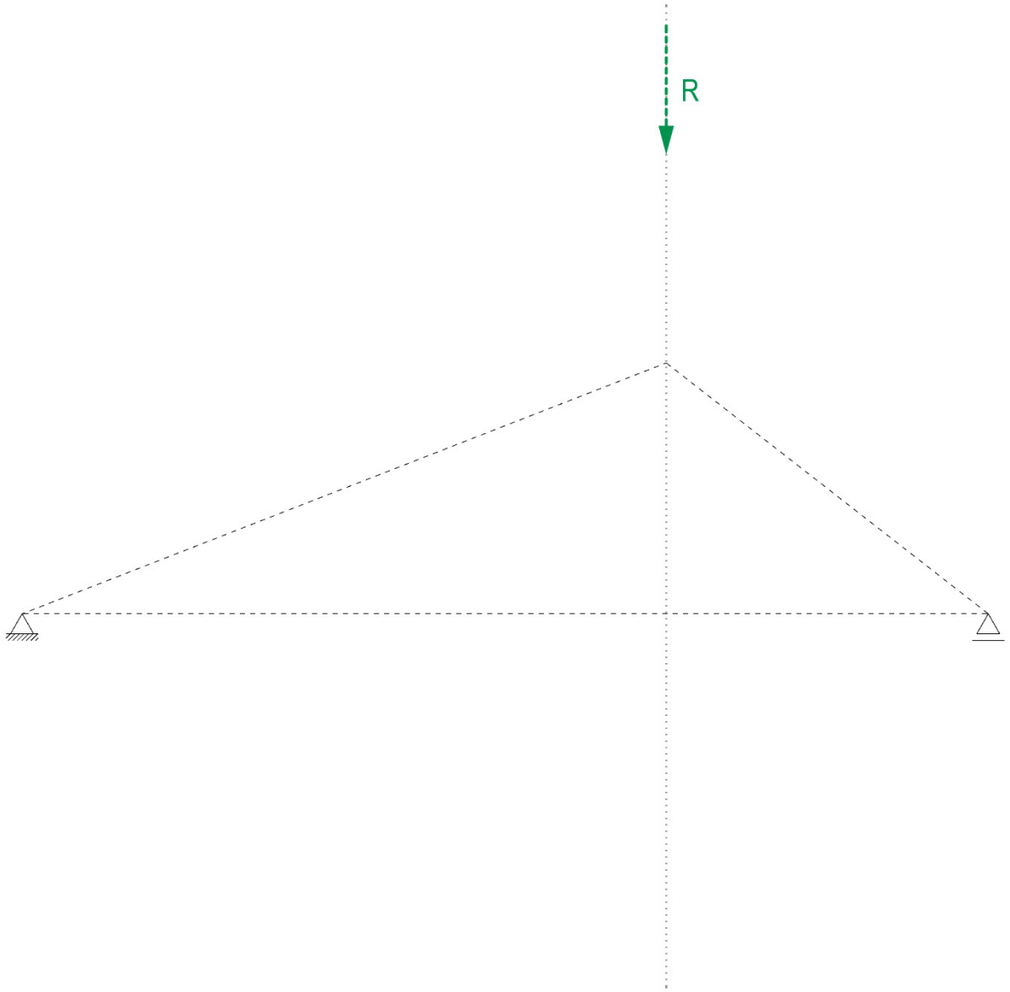
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

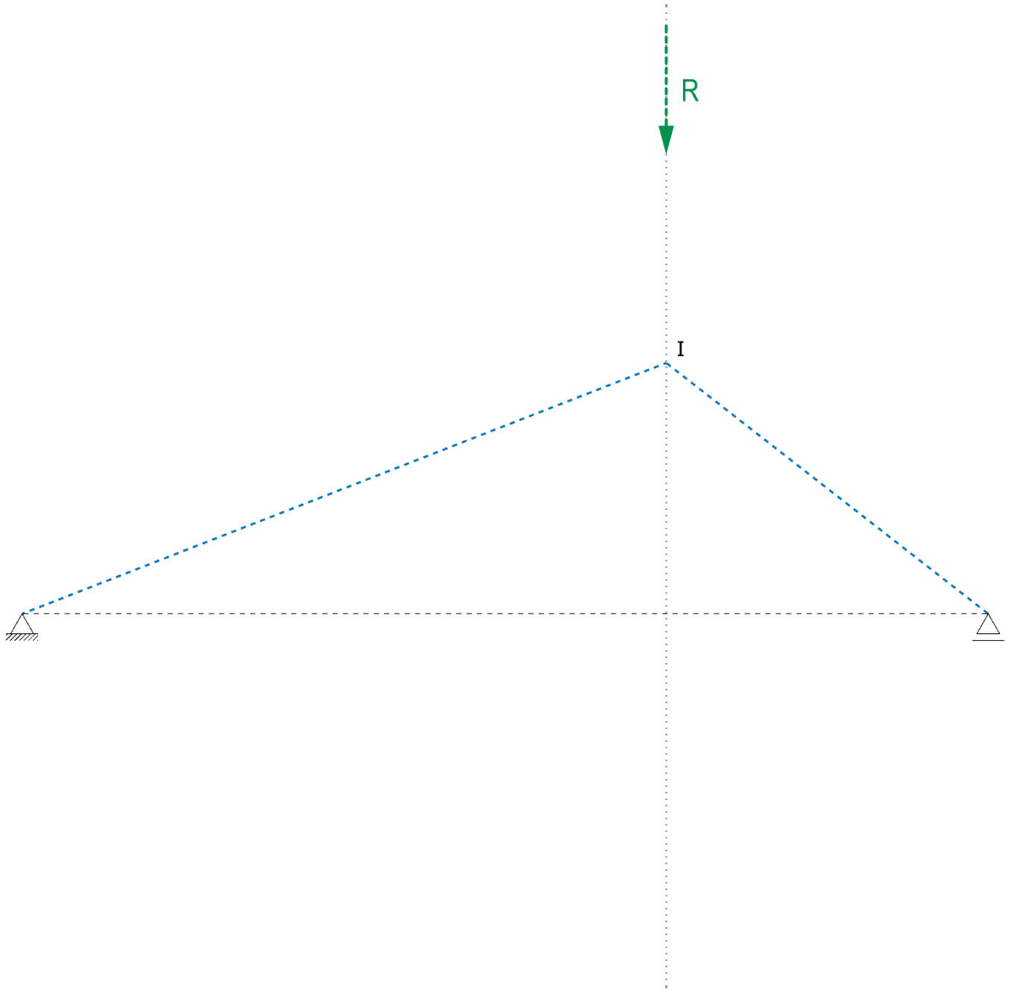


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

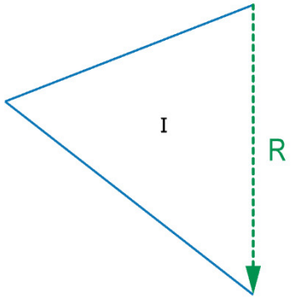


Lageplan 1:100
Form diagram 1:100

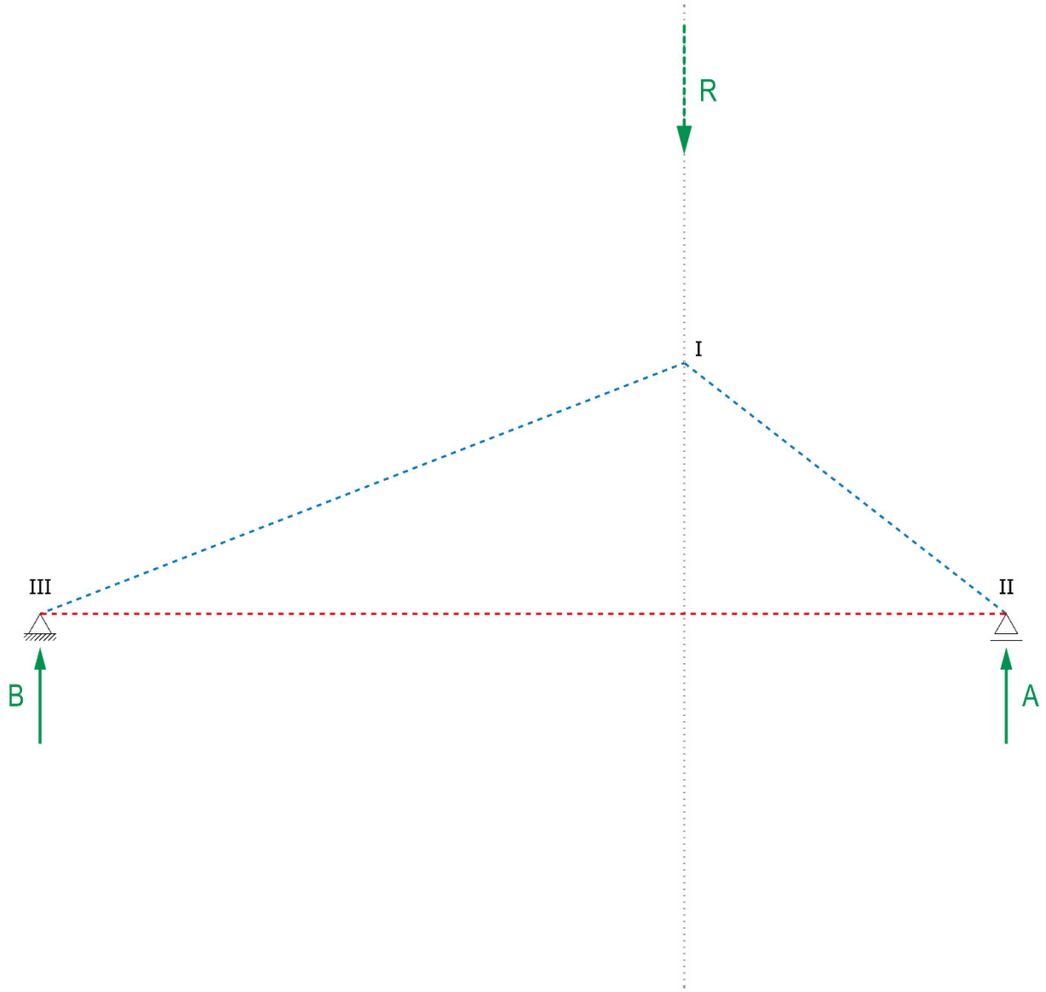
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



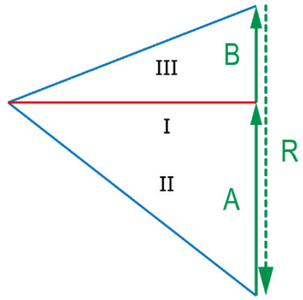
Lageplan 1:100
Form diagram 1:100



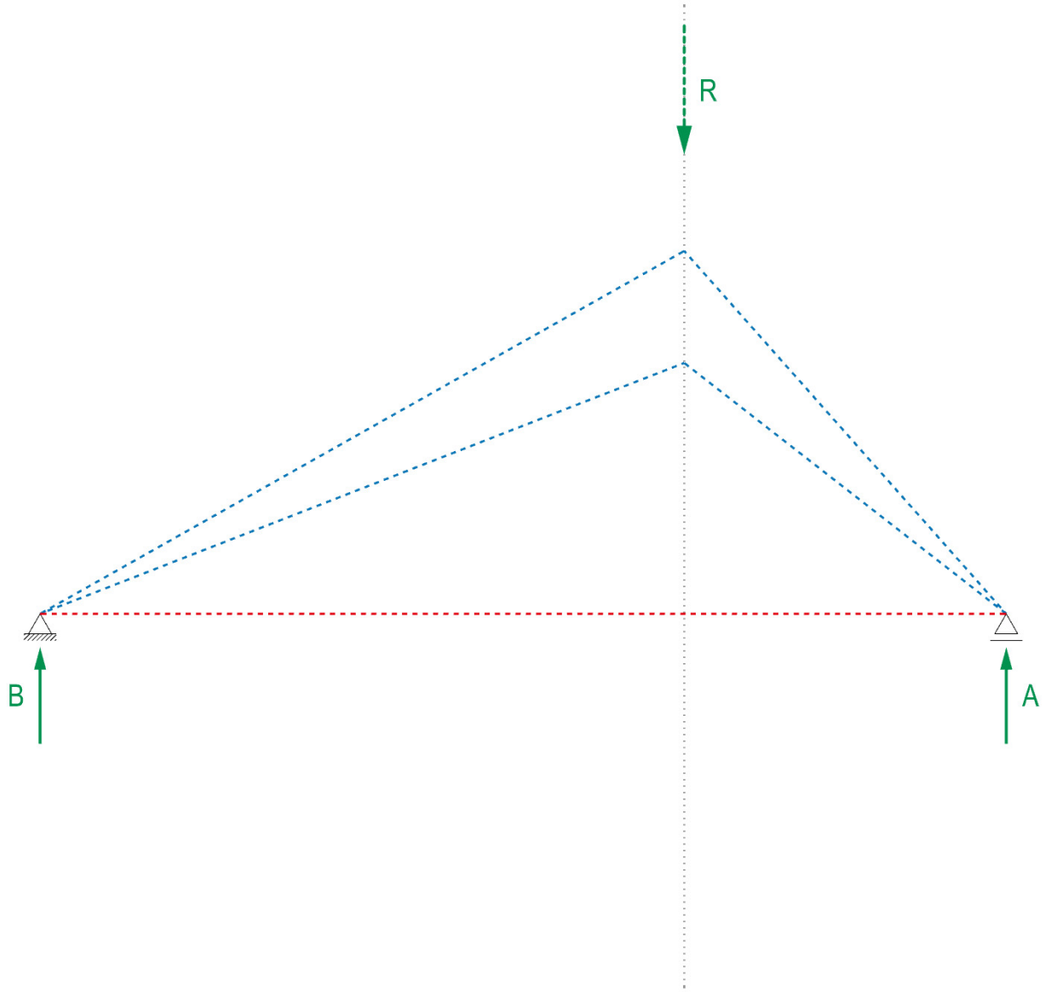
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



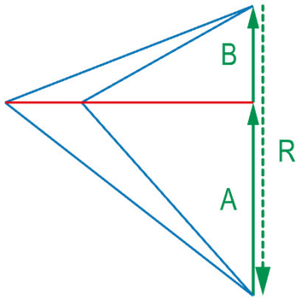
Lageplan 1:100
Form diagram 1:100



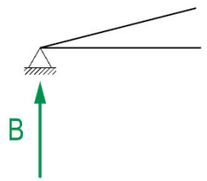
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

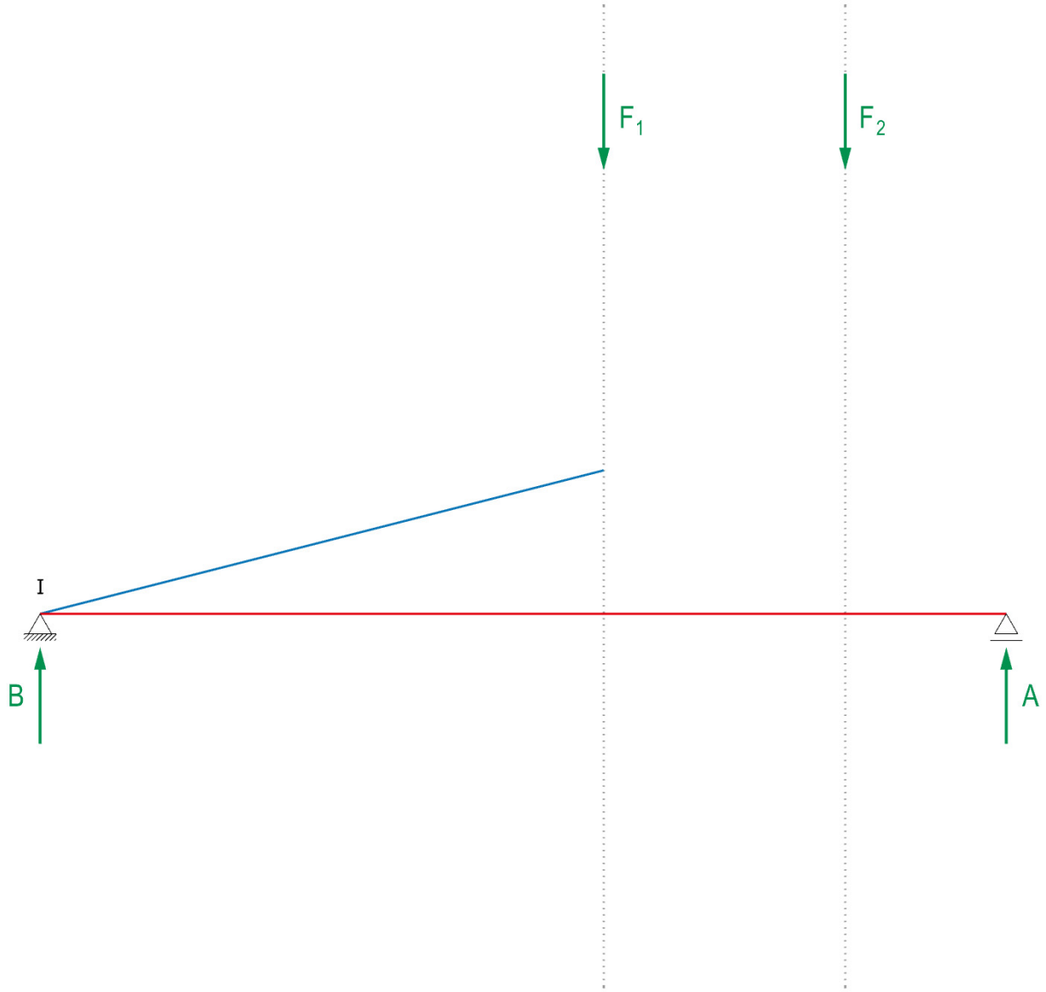


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



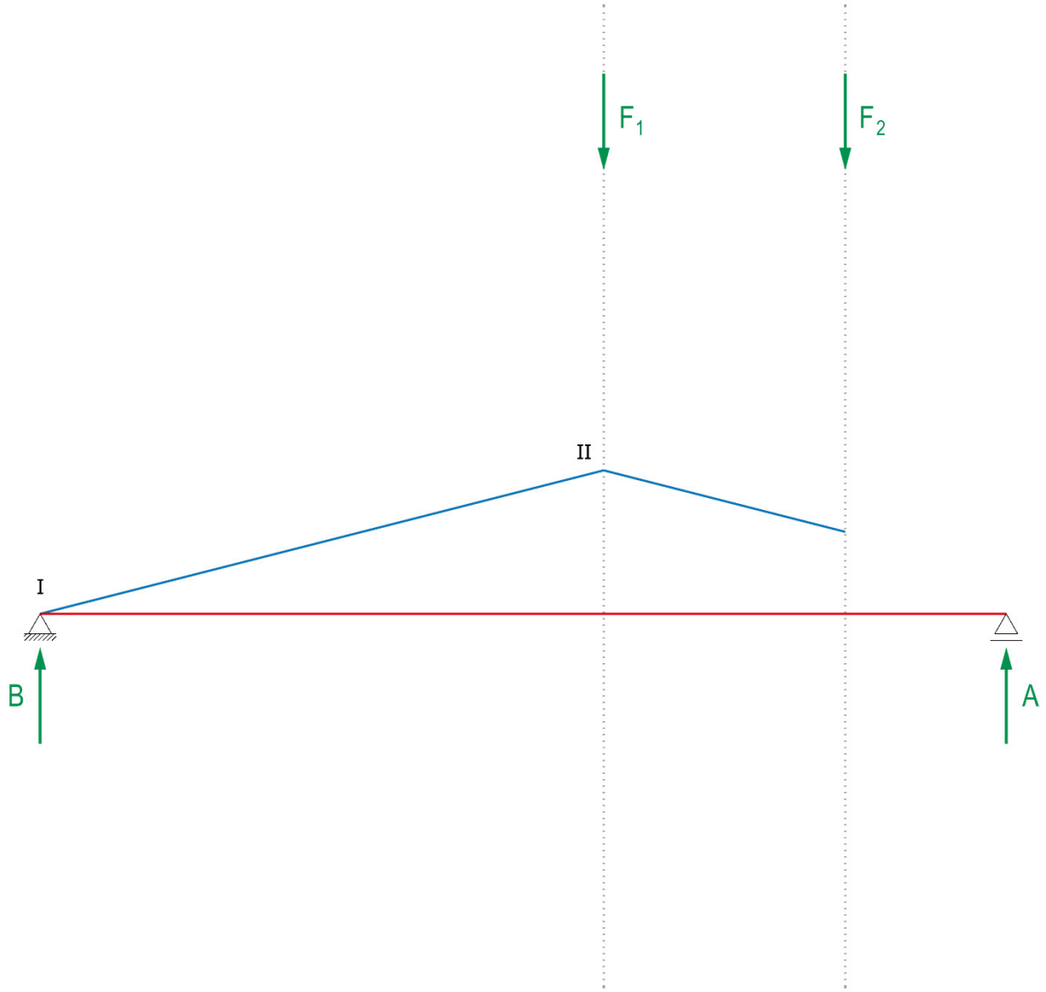
Lageplan 1:100
Form diagram 1:100

Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

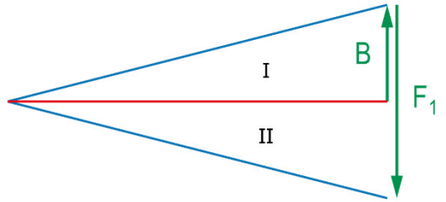


Lageplan 1:100
Form diagram 1:100

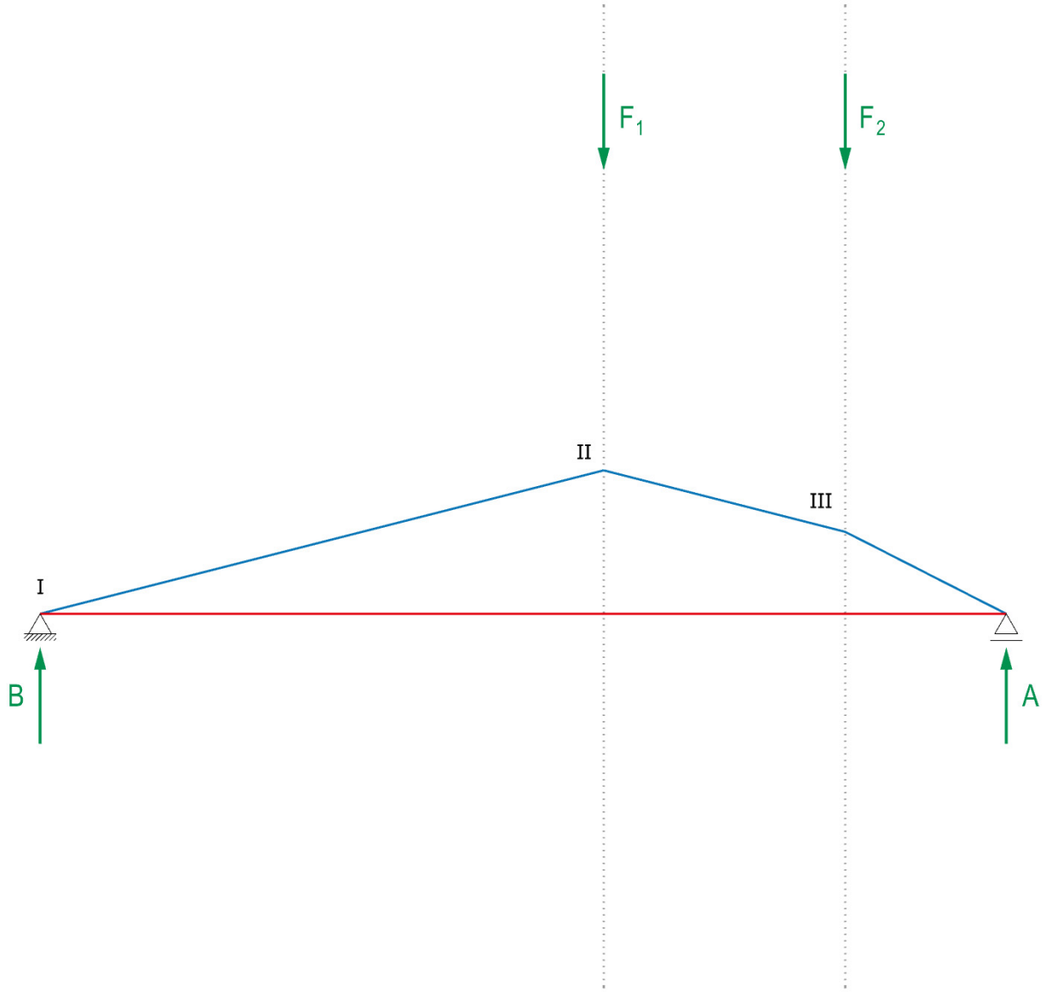
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



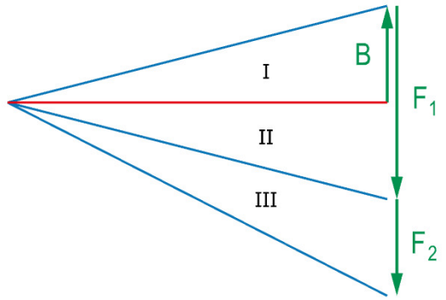
Lageplan 1:100
Form diagram 1:100



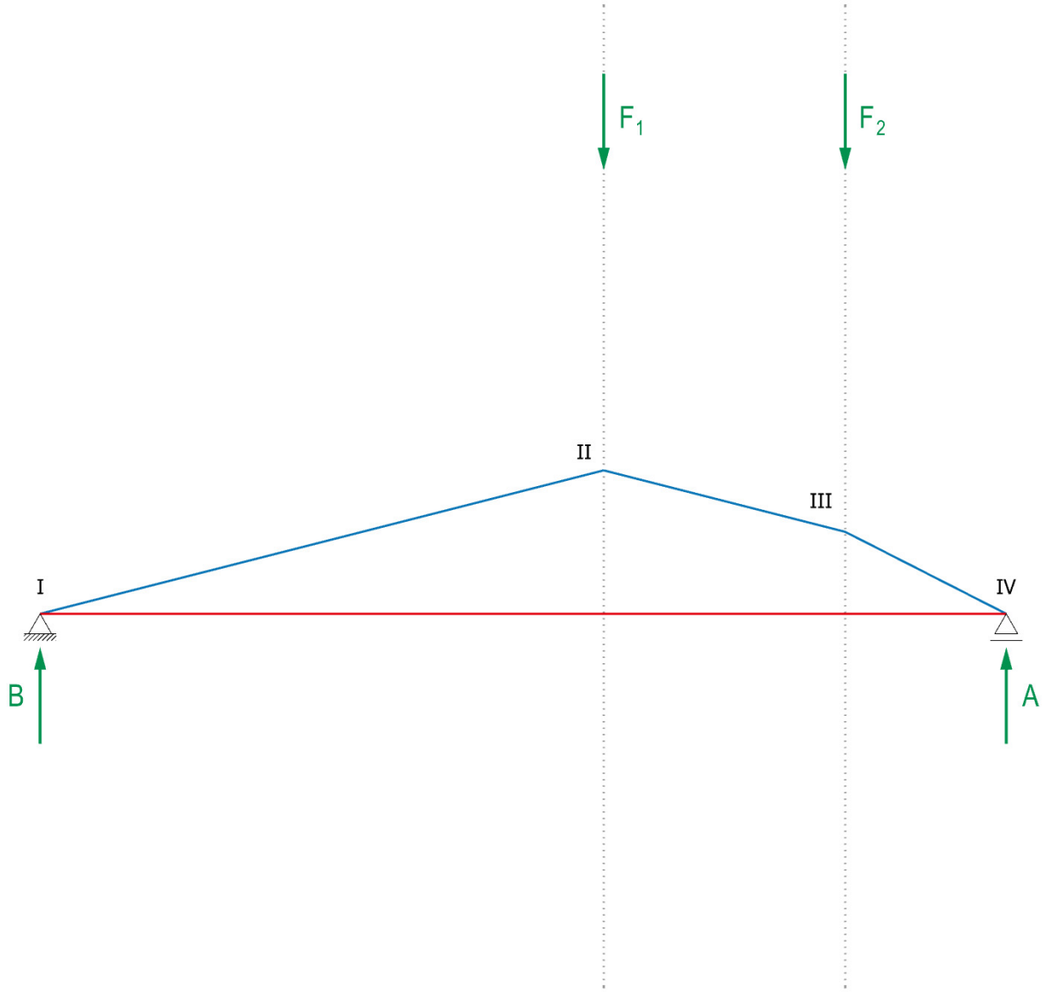
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



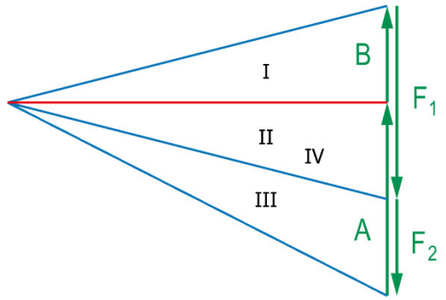
Lageplan 1:100
Form diagram 1:100



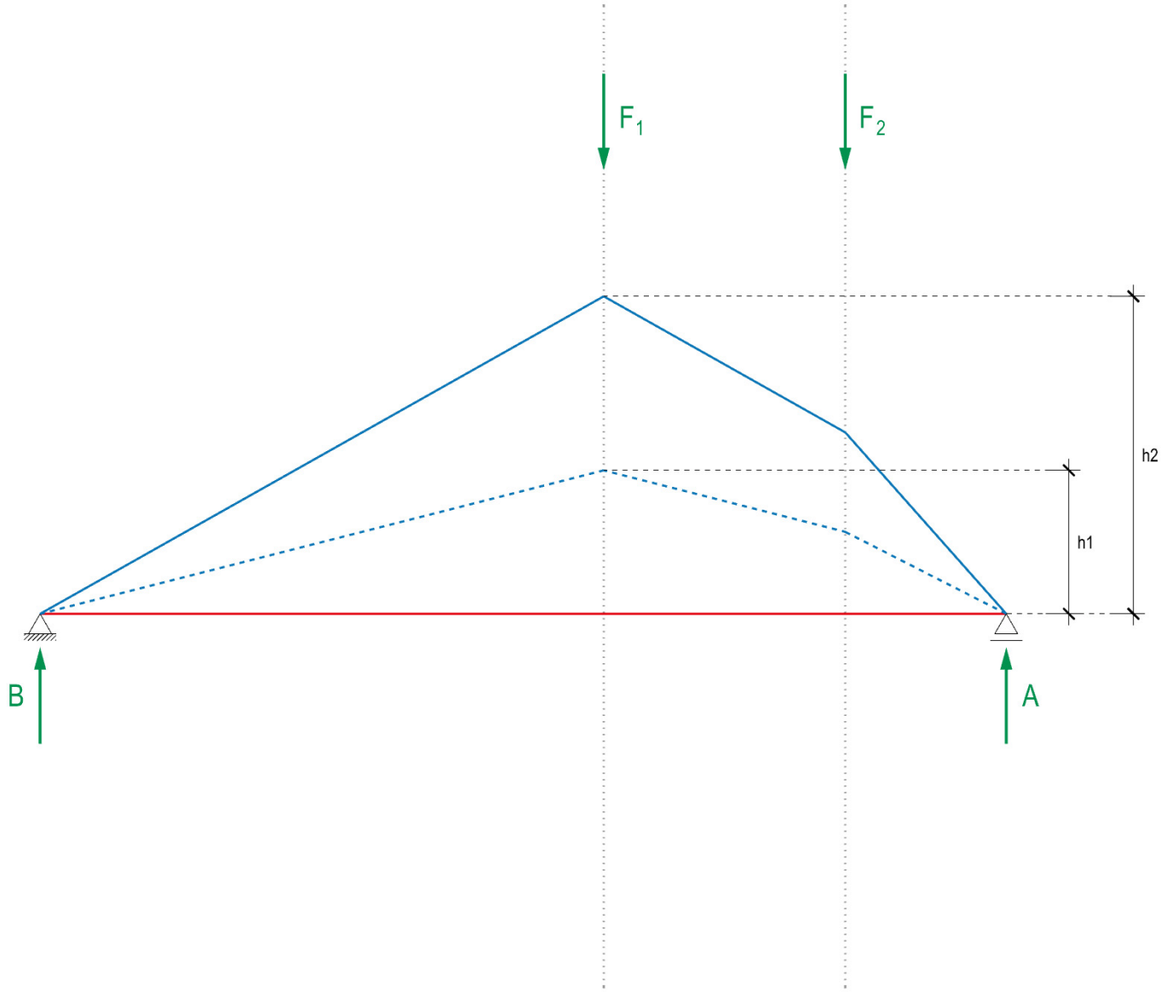
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

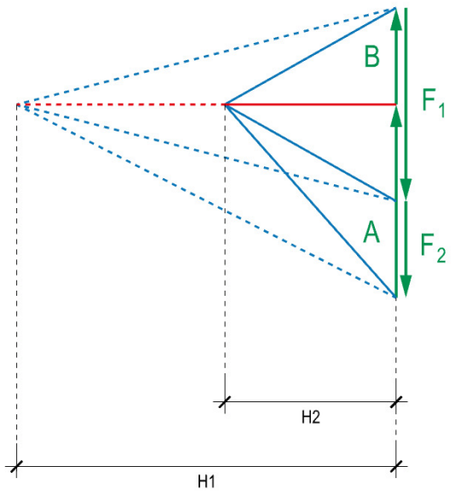


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

$$\frac{h1}{h2} = \frac{H2}{H1}$$



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

Bogen-Seil-Tragwerke

Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

Auflagerbedingungen
Support conditions

Aufteilung der äusseren Lasten
Distribution of external loads

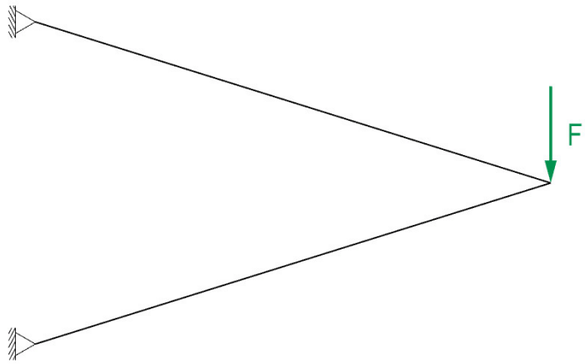
Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

>> Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

Geometrische Variation
Geometric variation

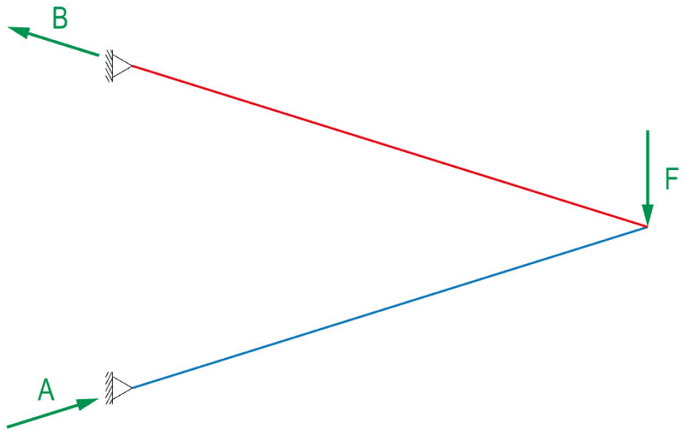
Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

Fallbeispiele
Case studies

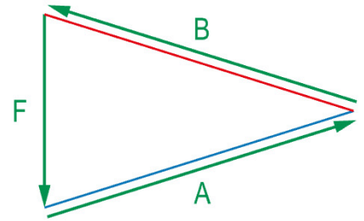


Lageplan 1:100
Form diagram 1:100

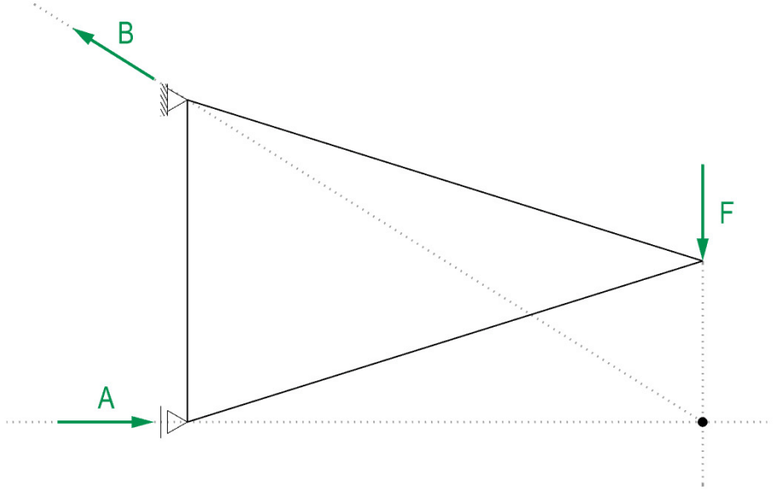
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

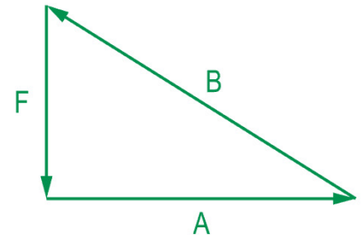


Lageplan 1:100
Form diagram 1:100



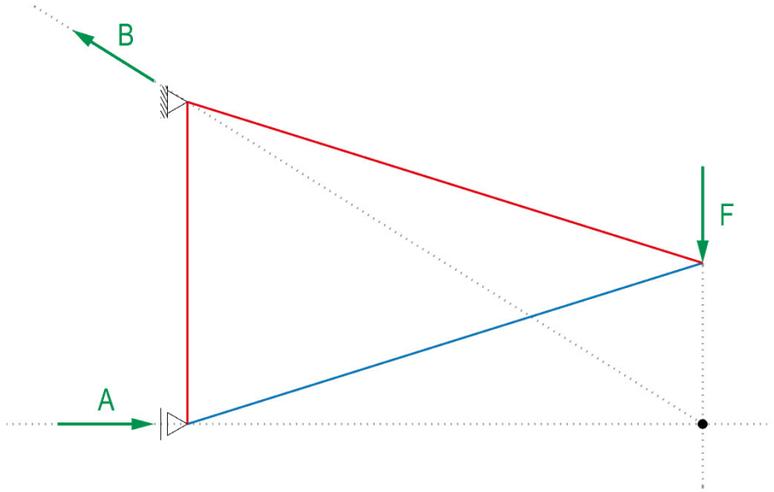
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

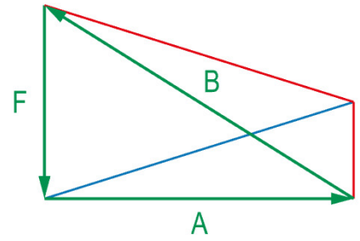




Lageplan 1:100
Form diagram 1:100

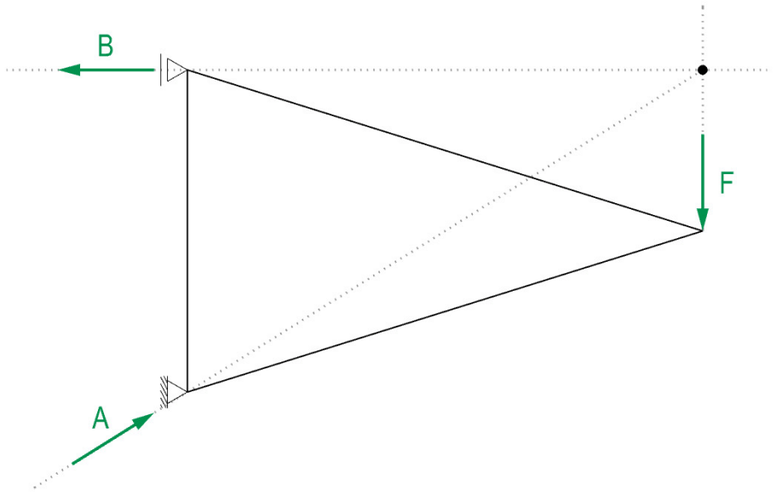
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



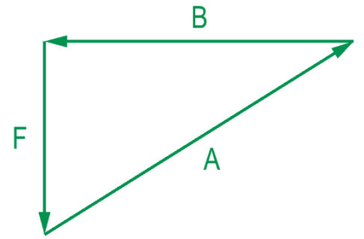


Lageplan 1:100
Form diagram 1:100

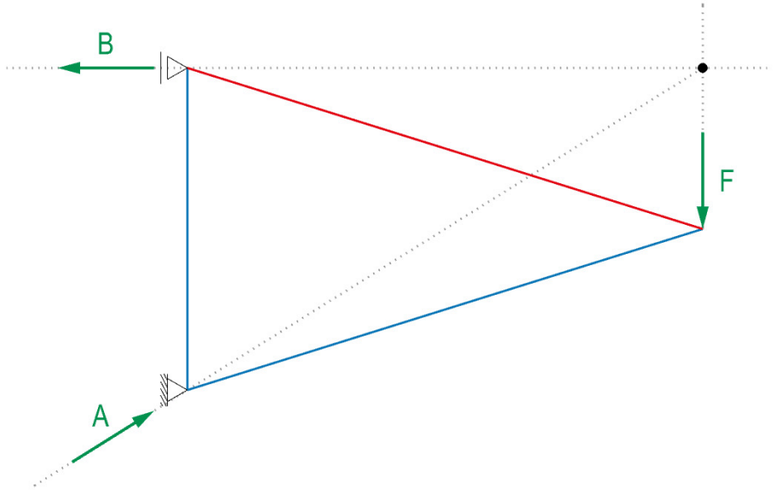
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



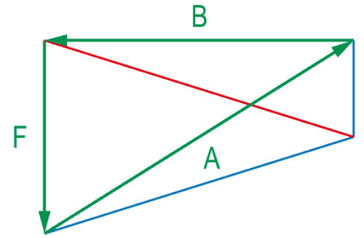
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



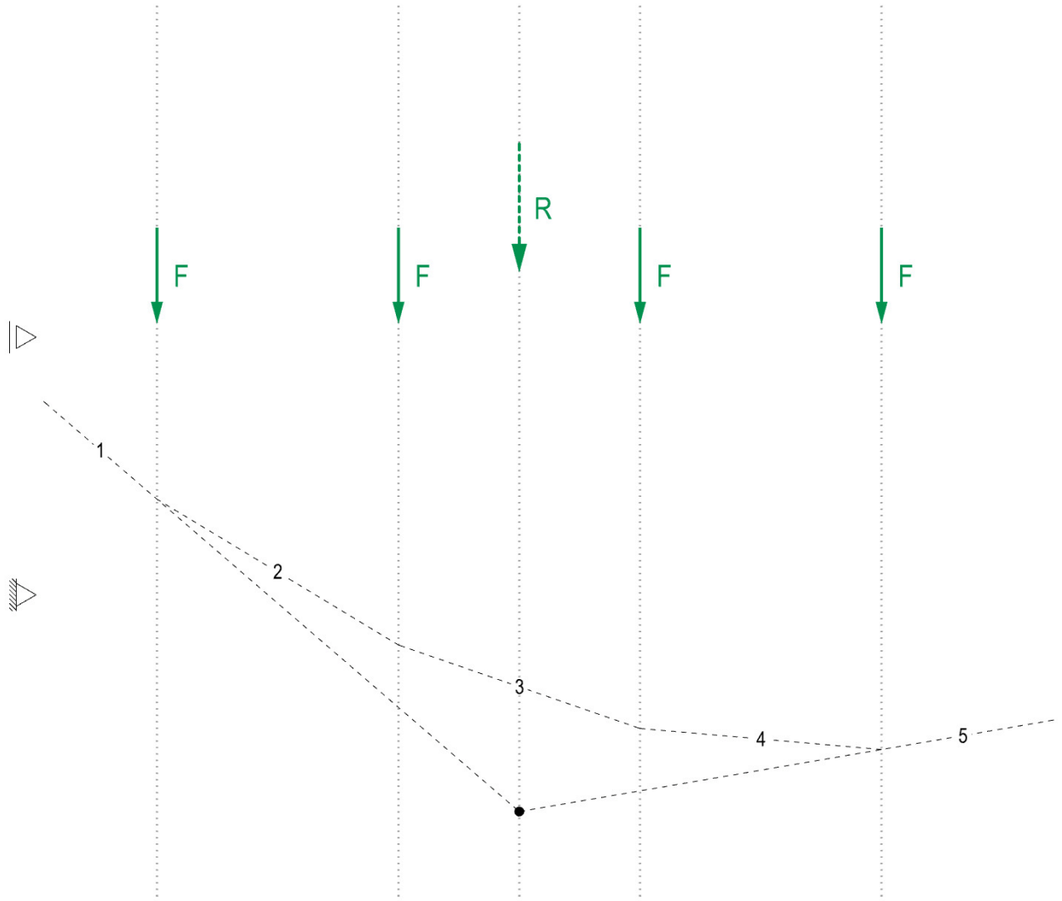
Lageplan 1:100
Form diagram 1:100



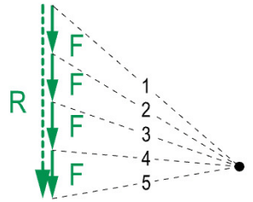
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

Lageplan 1:100
Form diagram 1:100

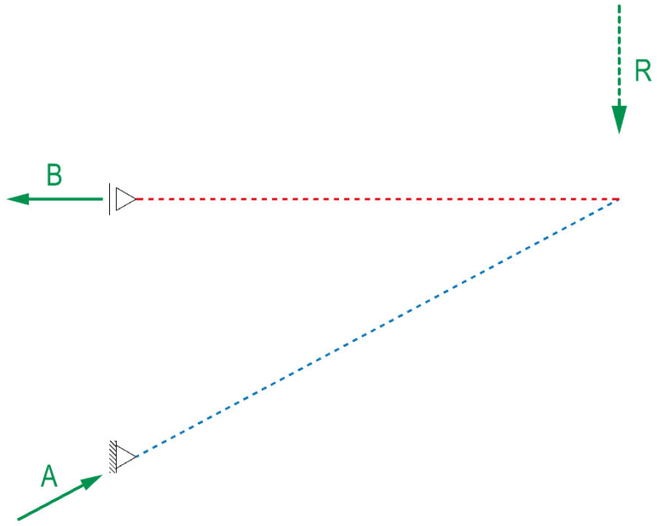
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



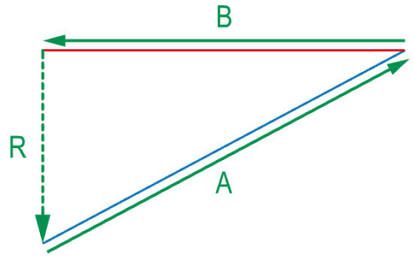
Lageplan 1:100
Form diagram 1:100



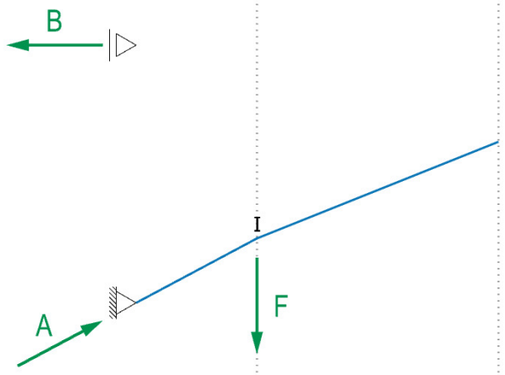
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



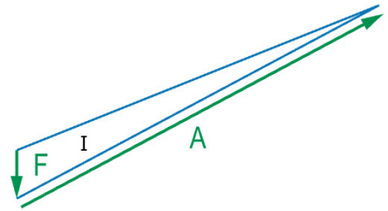
Lageplan 1:100
Form diagram 1:100



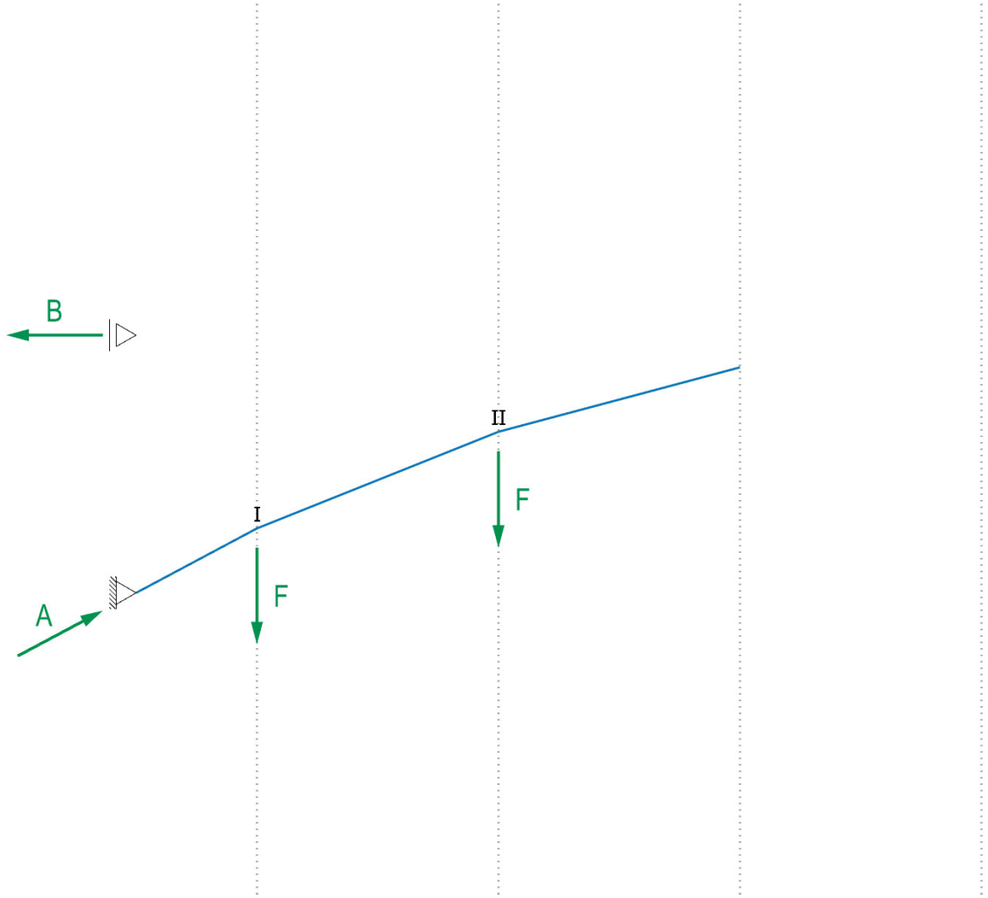
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



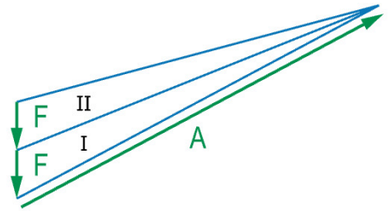
Lageplan 1:100
Form diagram 1:100



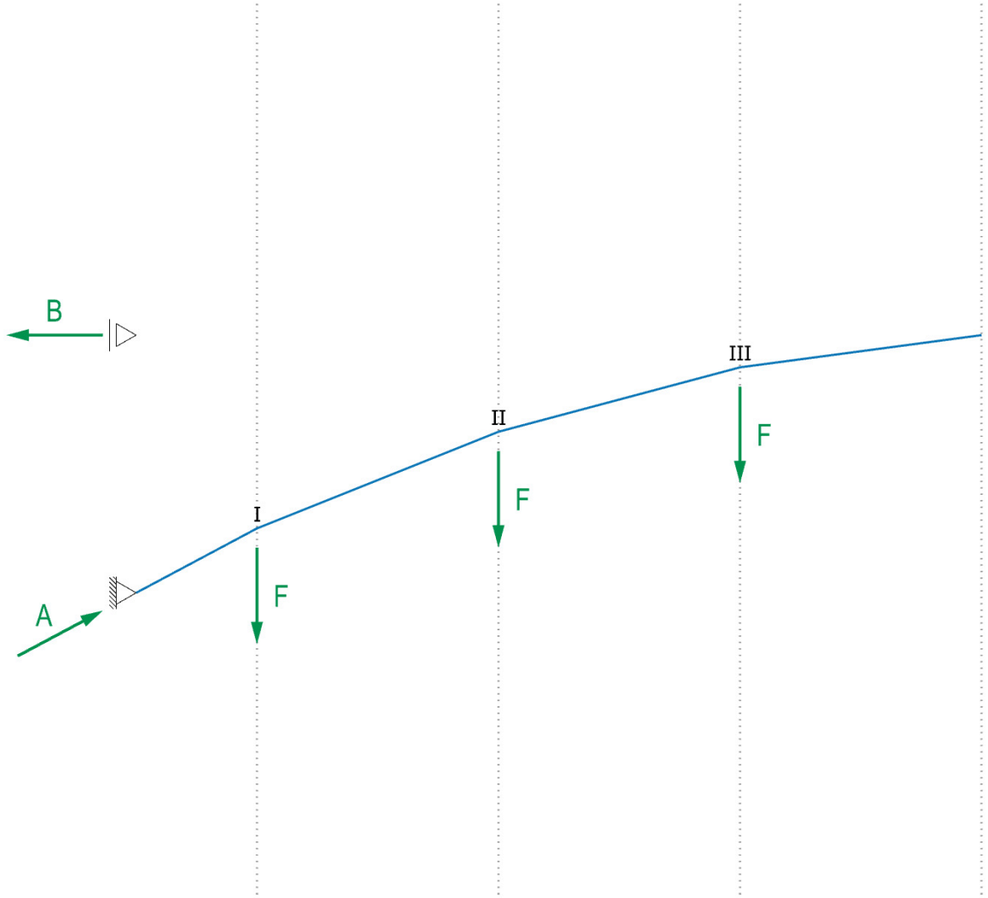
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



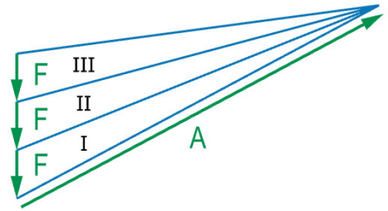
Lageplan 1:100
Form diagram 1:100



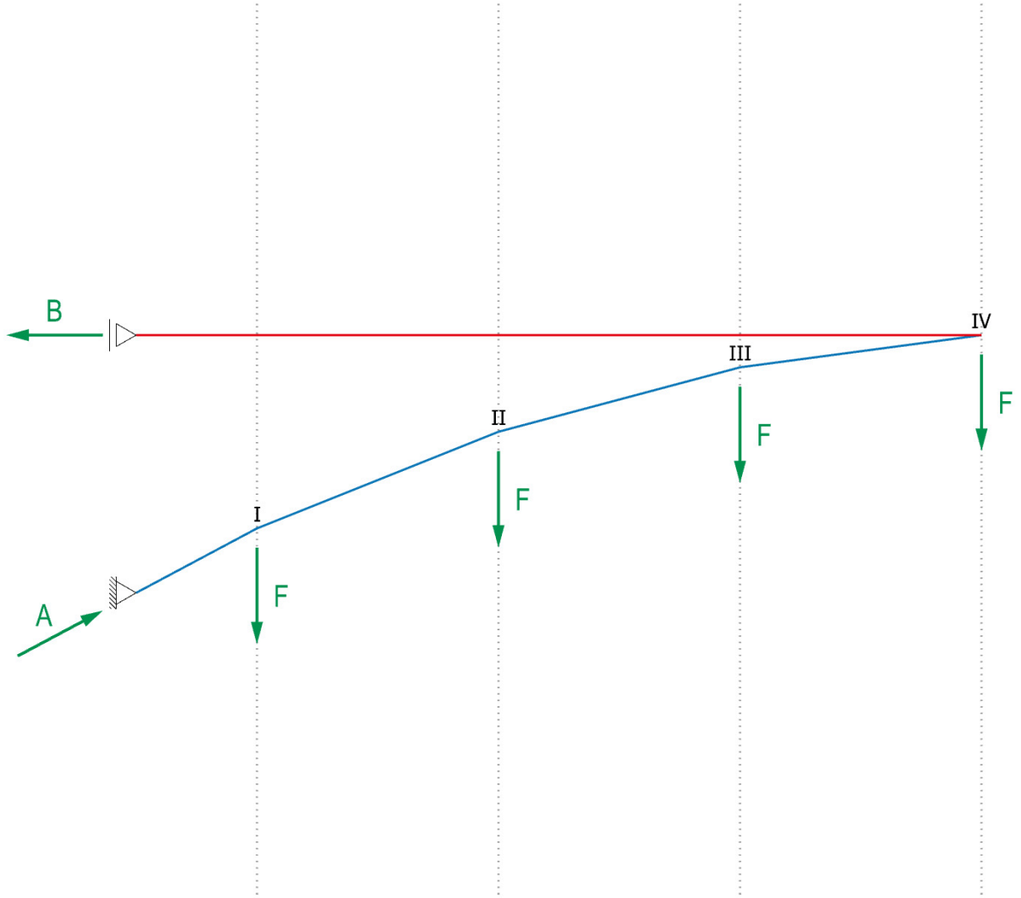
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



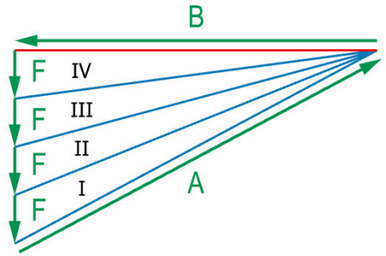
Lageplan 1:100
Form diagram 1:100



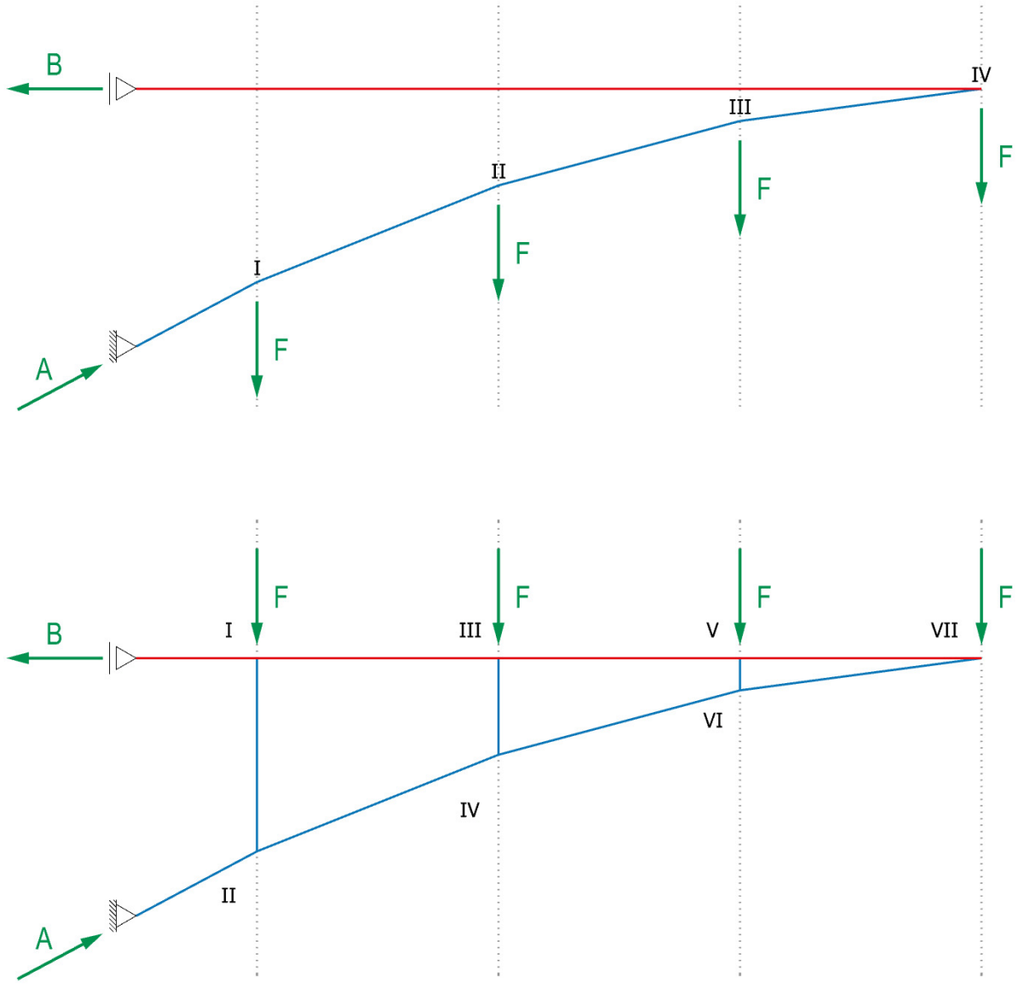
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



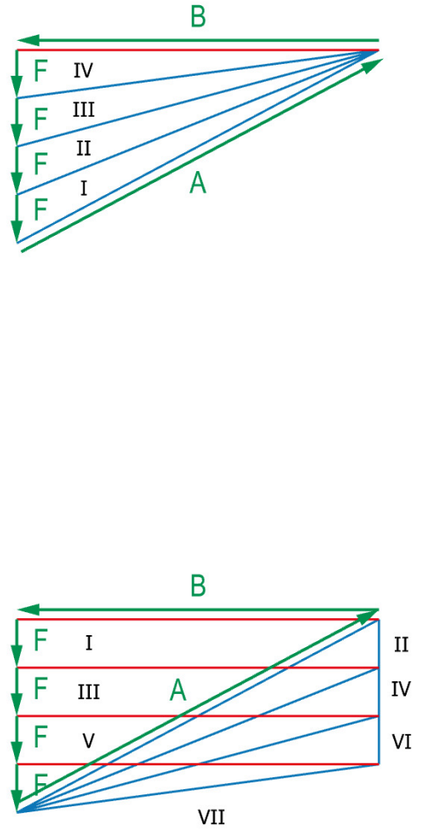
Lageplan 1:100
Form diagram 1:100



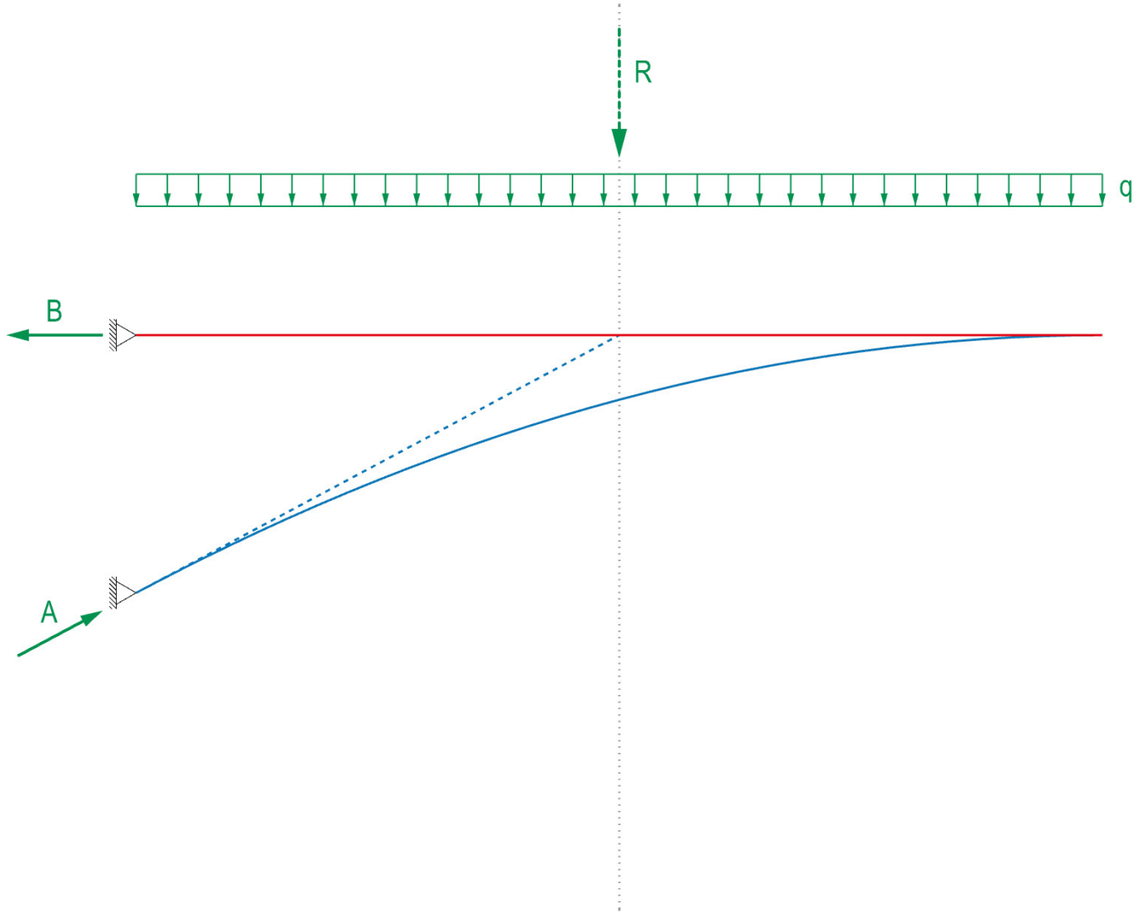
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



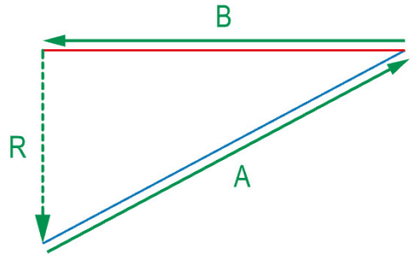
Lageplan 1:100
Form diagram 1:100



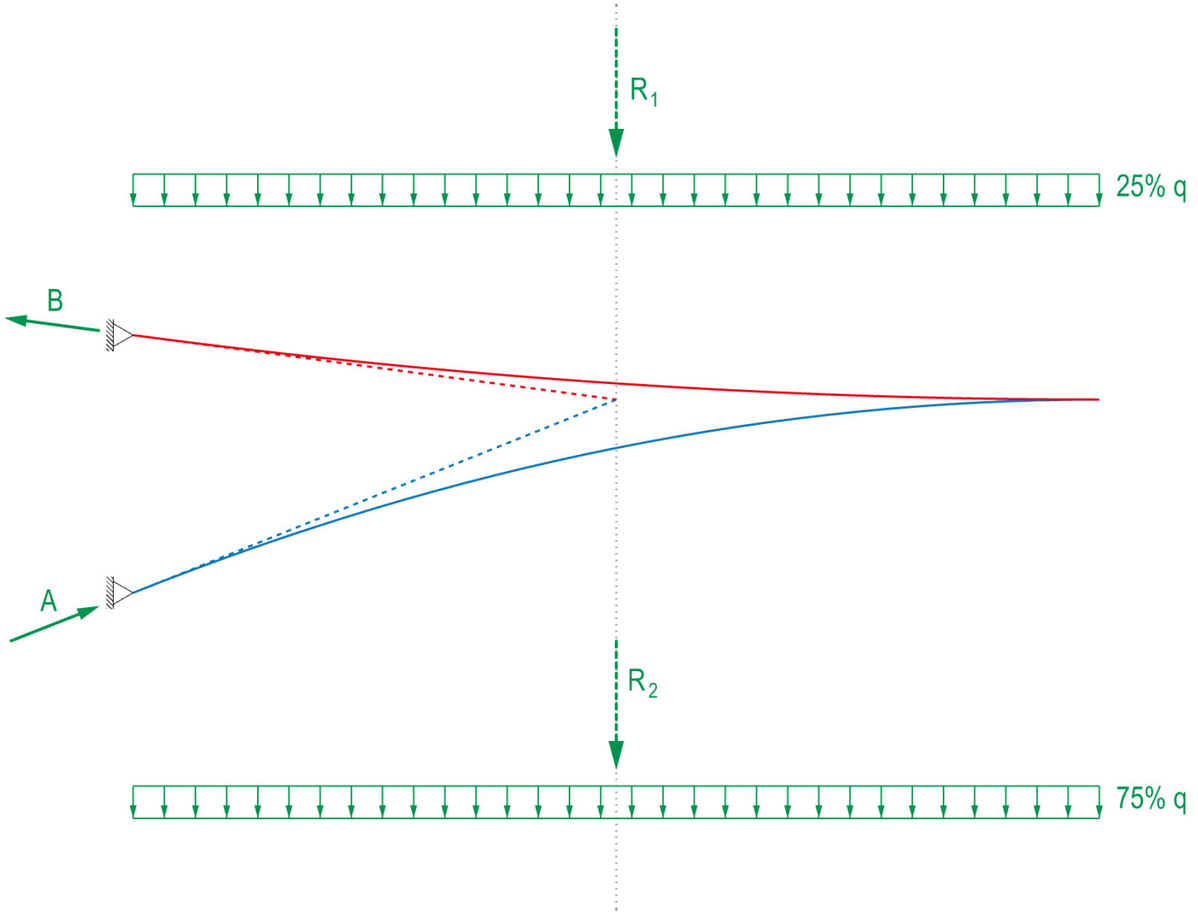
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



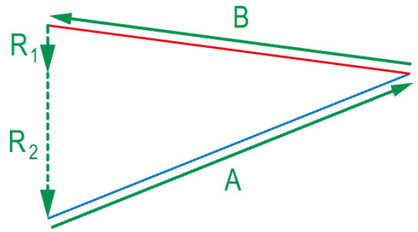
Lageplan 1:100
Form diagram 1:100



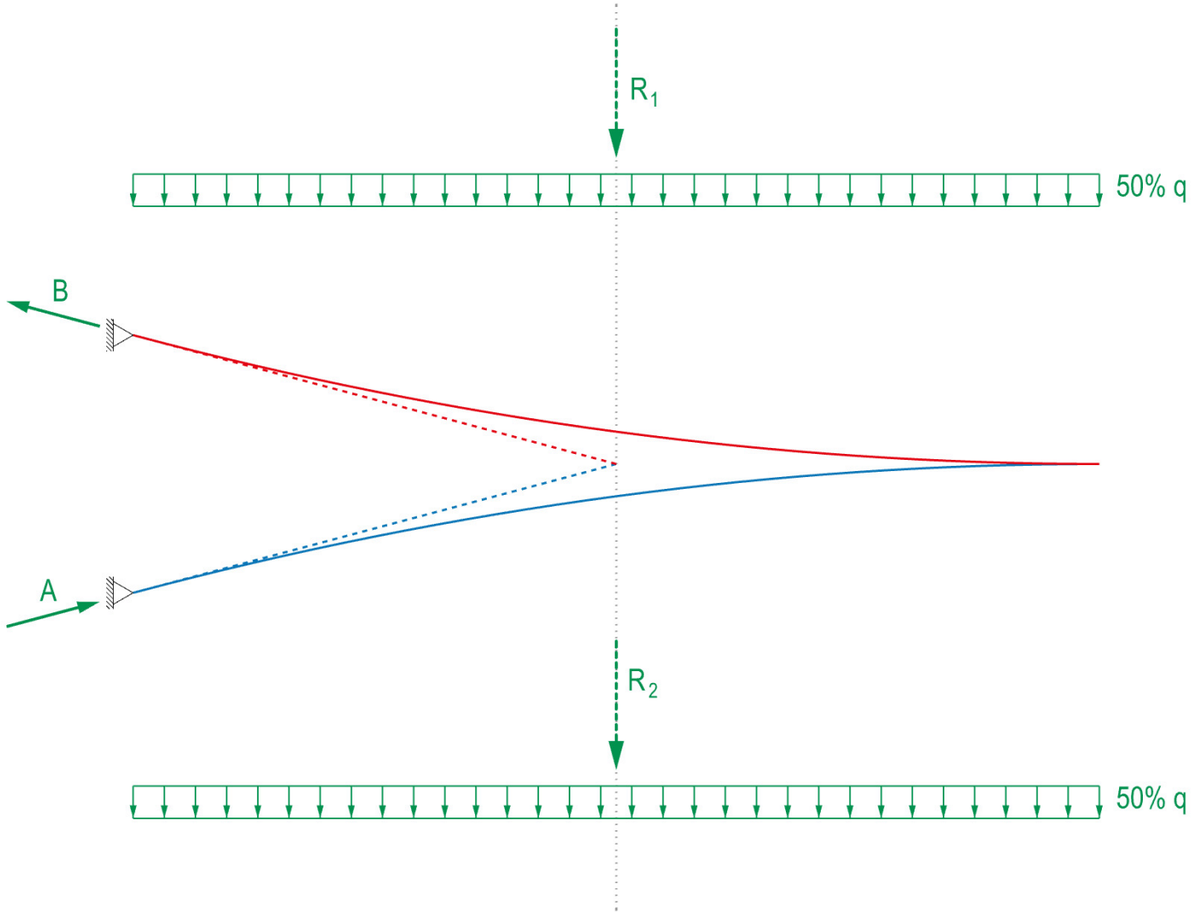
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



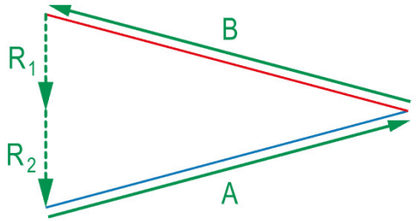
Lageplan 1:100
Form diagram 1:100



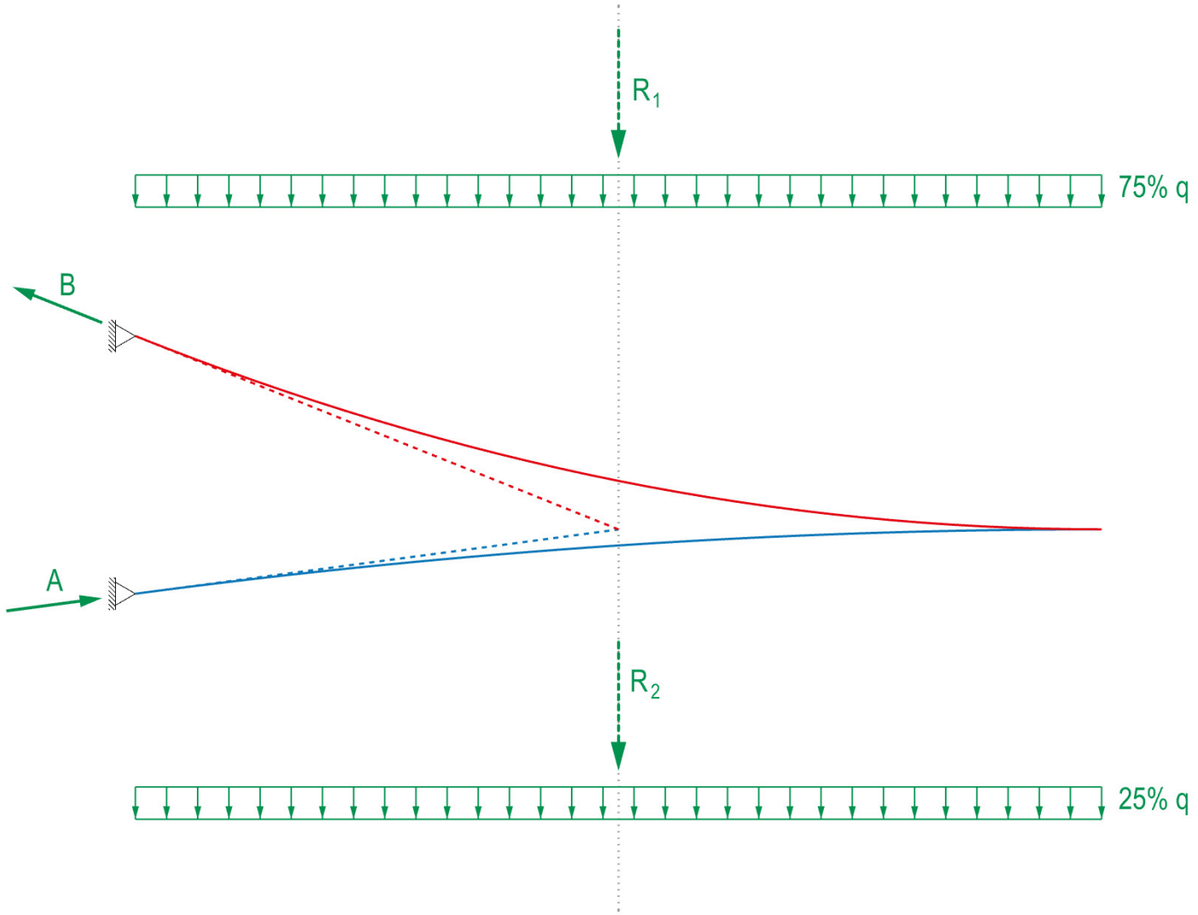
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



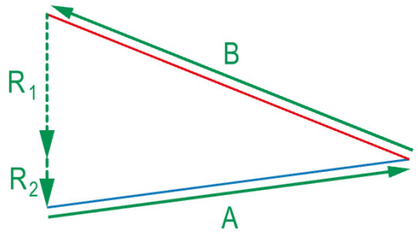
Lageplan 1:100
Form diagram 1:100



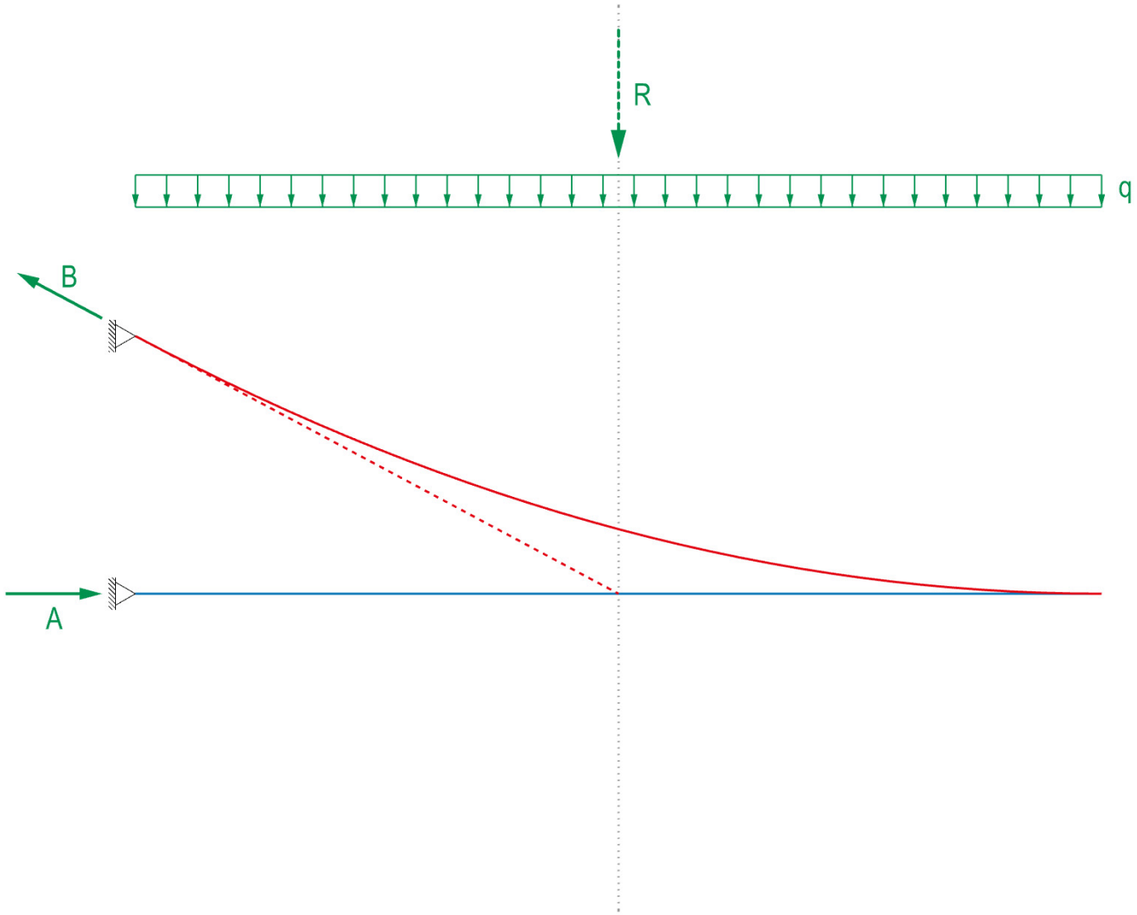
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



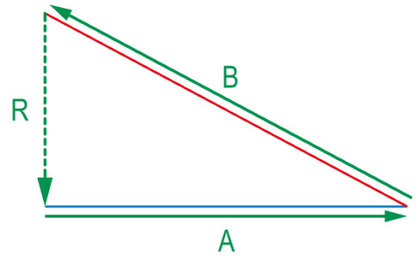
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

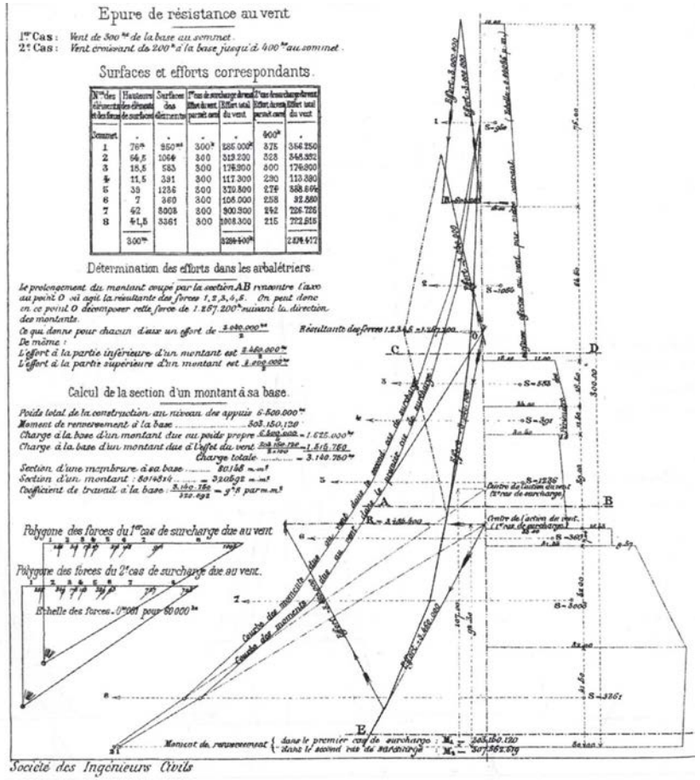


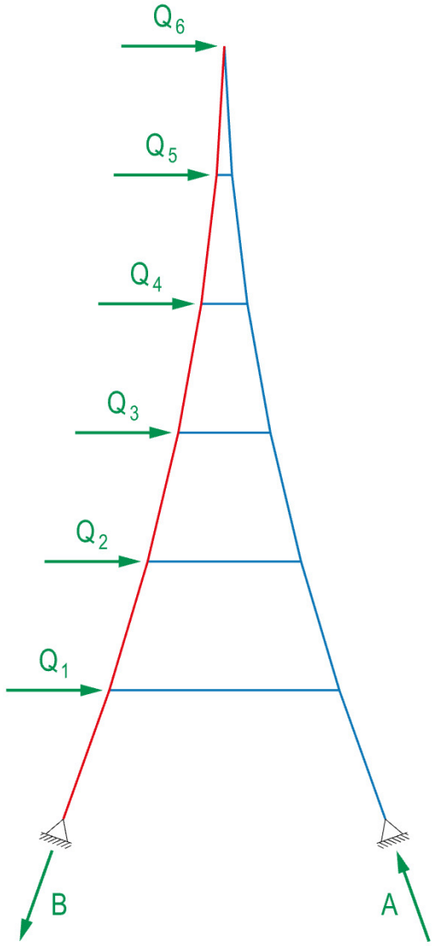
Lageplan 1:100
Form diagram 1:100

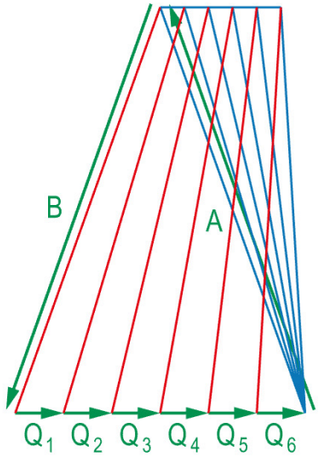


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

P.L. Nervi: Papierfabrik Burgo, Mantua, Italy, 1962

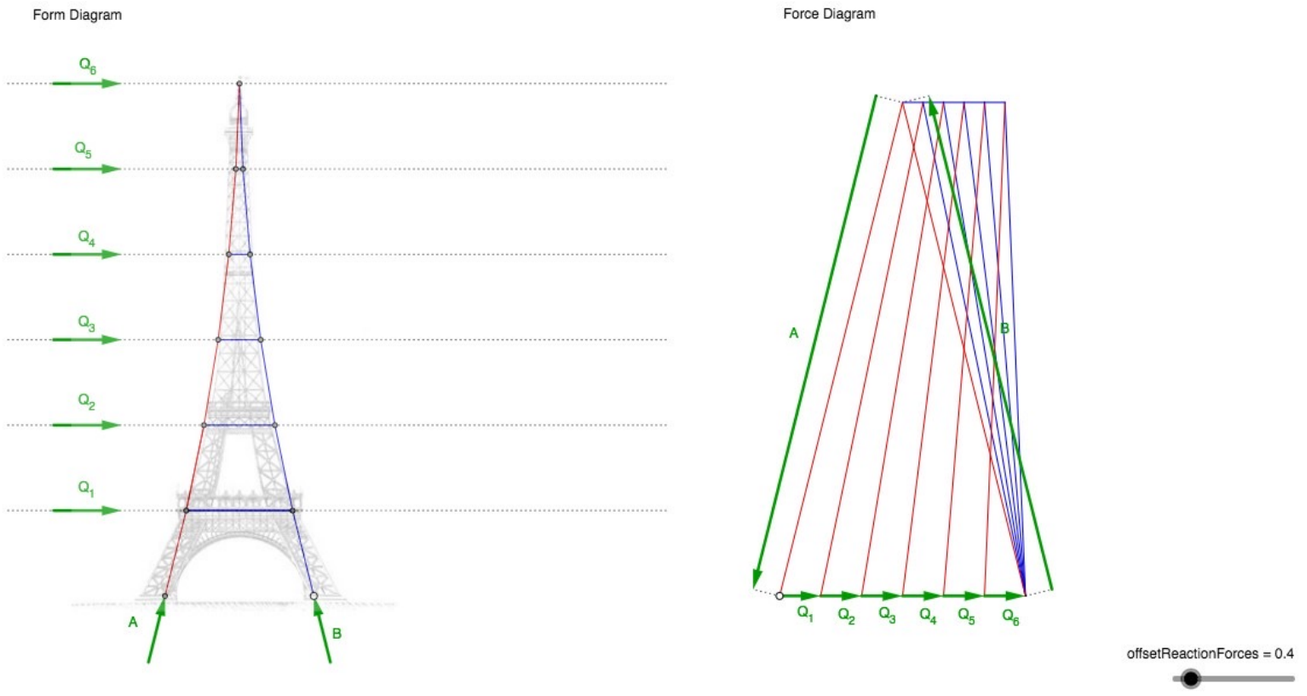






Maurice Koechlin, Gustave Eiffel: La Tour Eiffel, Paris, 1889

eQ: Eiffel Tower



http://www.block.arch.ethz.ch/eq/drawing/view/31

Bogen-Seil-Tragwerke
Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

Auflagerbedingungen
Support conditions

Aufteilung der äusseren Lasten
Distribution of external loads

Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

>> Geometrische Variation
Geometric variation

Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

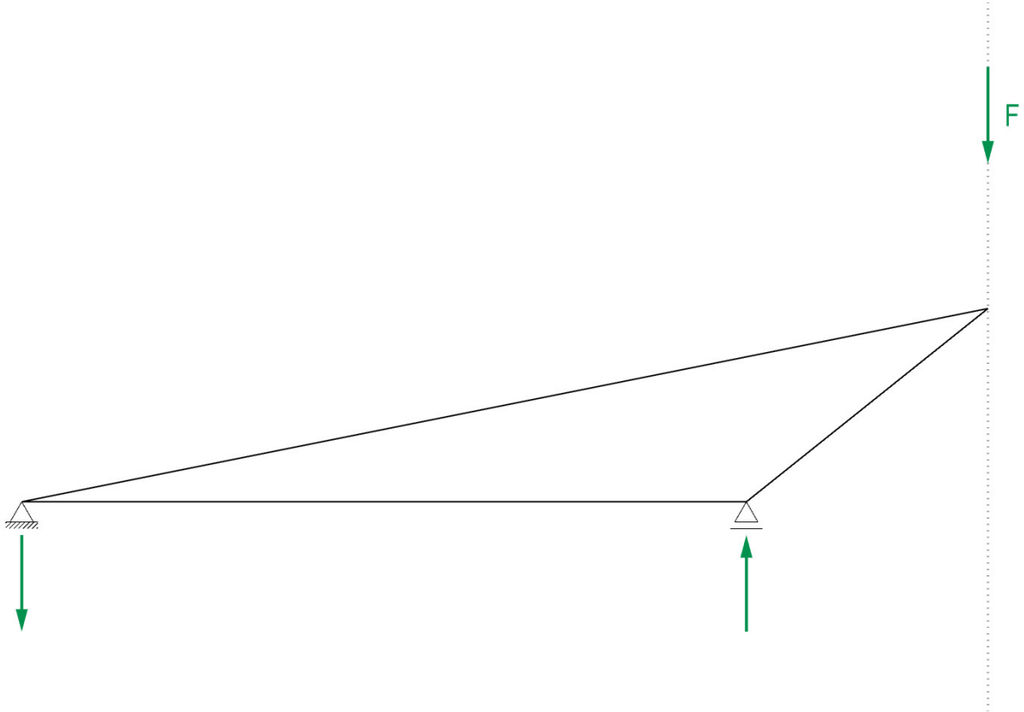
Fallbeispiele
Case studies

Lageplan 1:100
Form diagram 1:100

Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

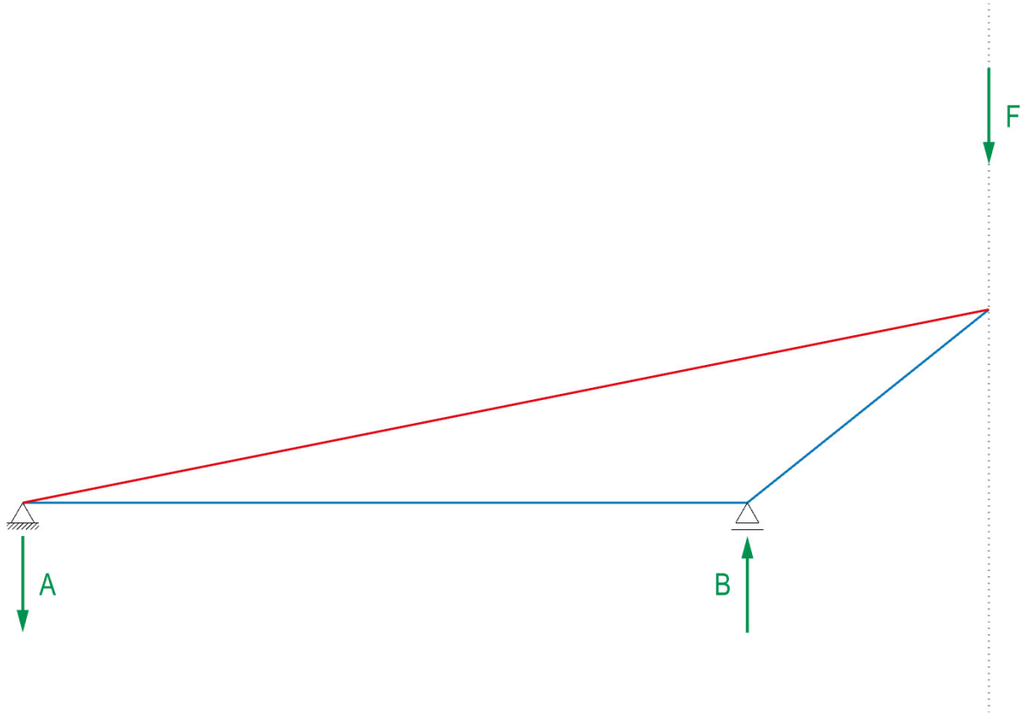
Lageplan 1:100
Form diagram 1:100

Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

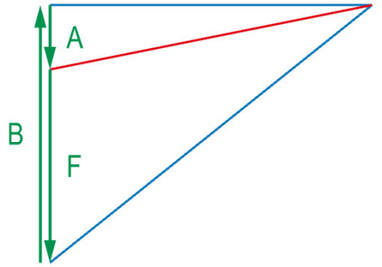


Lageplan 1:100
Form diagram 1:100

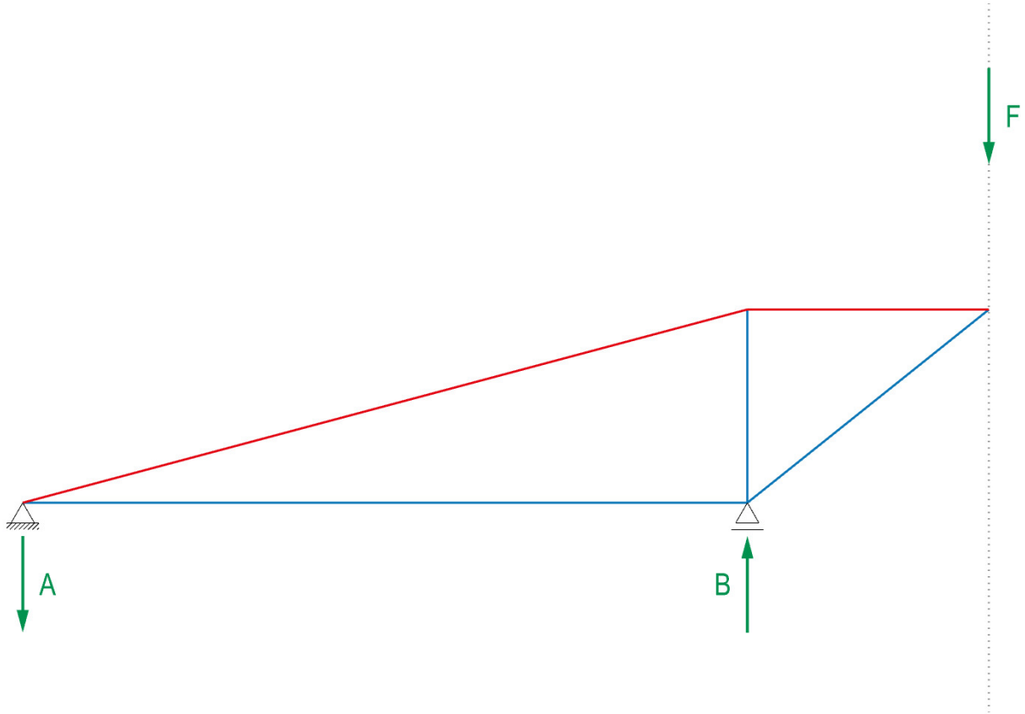
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



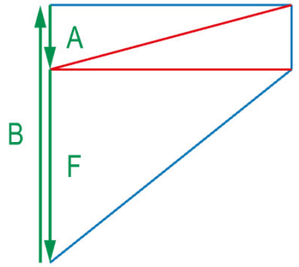
Lageplan 1:100
Form diagram 1:100



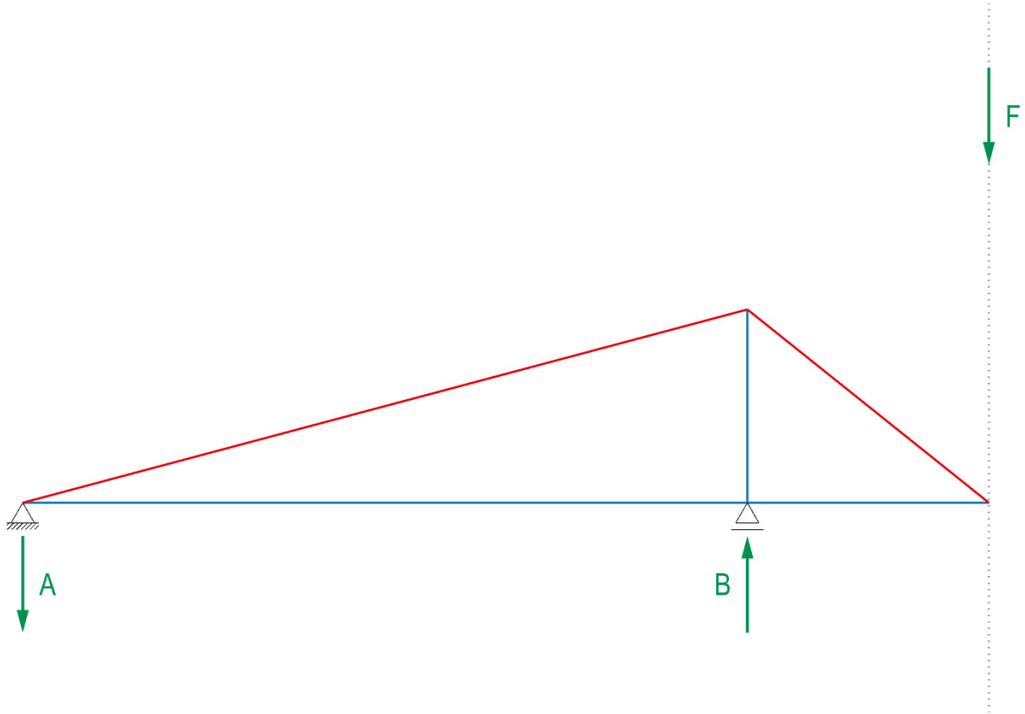
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



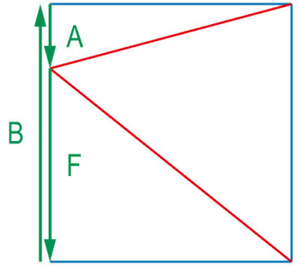
Lageplan 1:100
Form diagram 1:100



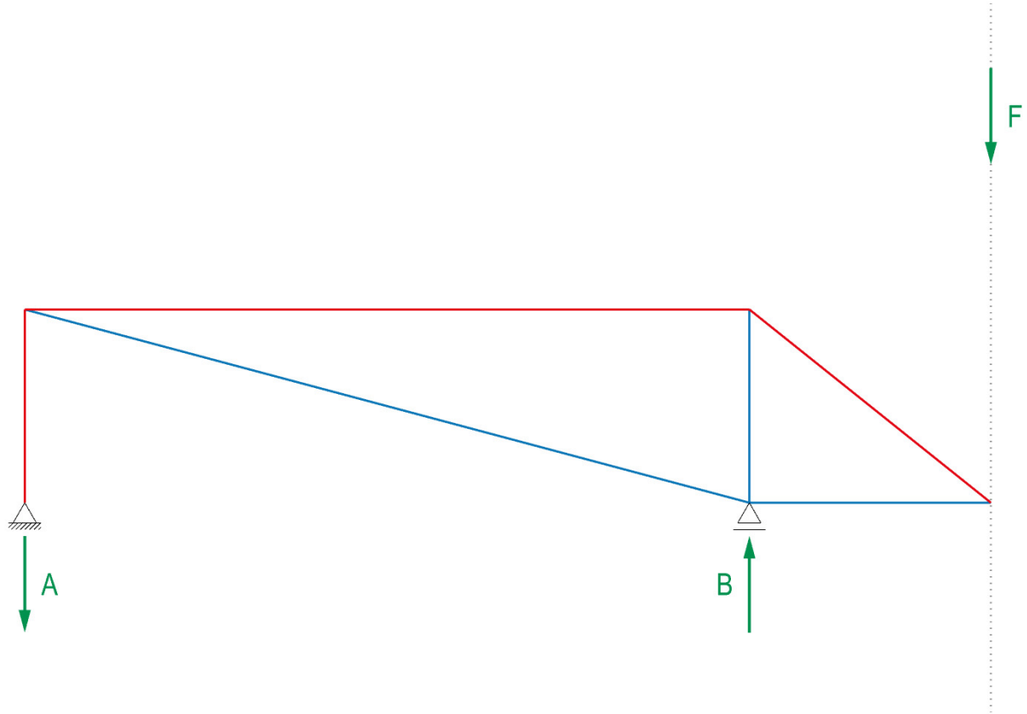
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



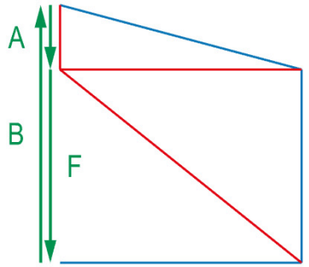
Lageplan 1:100
Form diagram 1:100



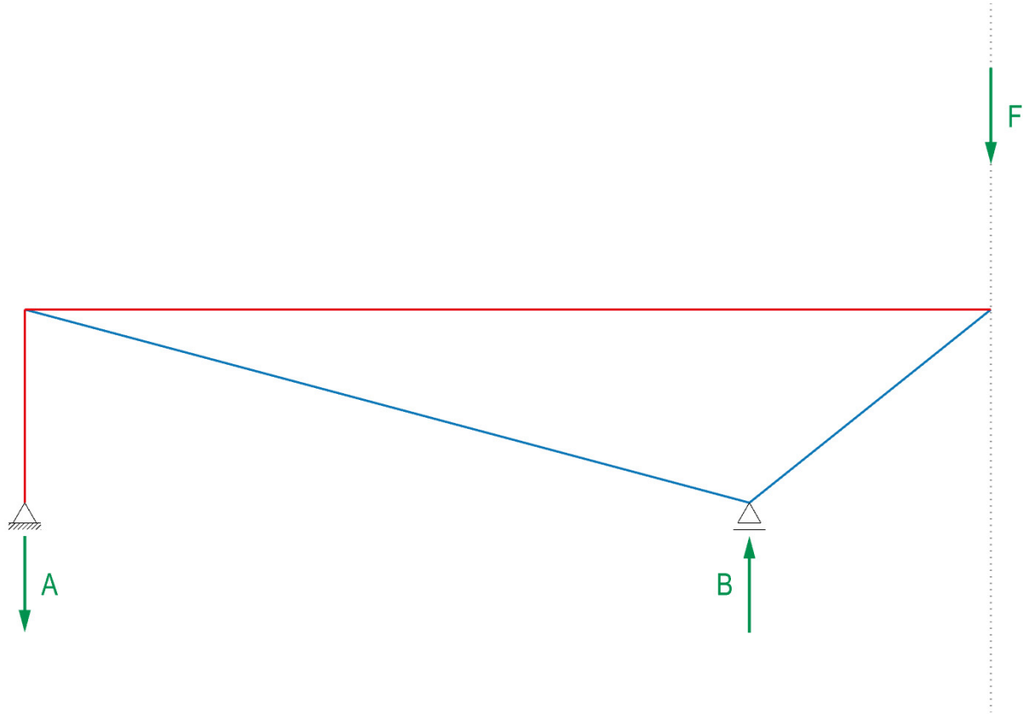
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



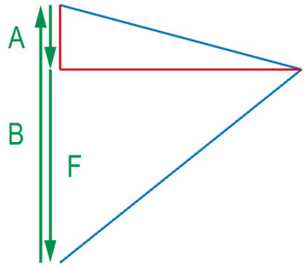
Lageplan 1:100
Form diagram 1:100



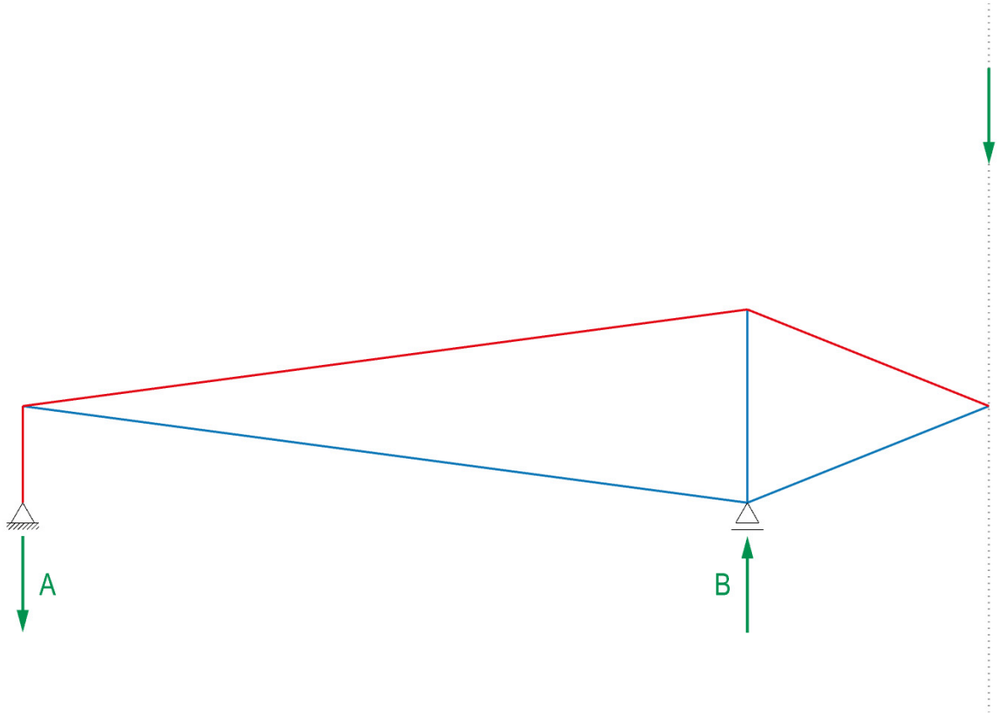
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



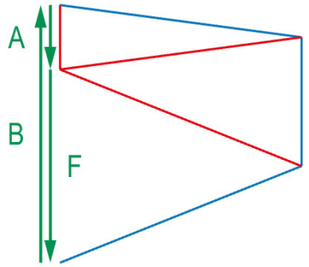
Lageplan 1:100
Form diagram 1:100



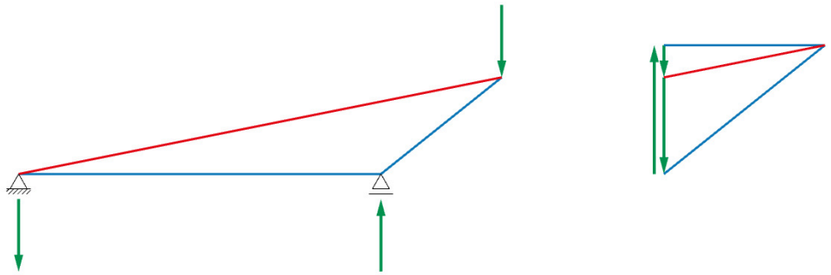
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

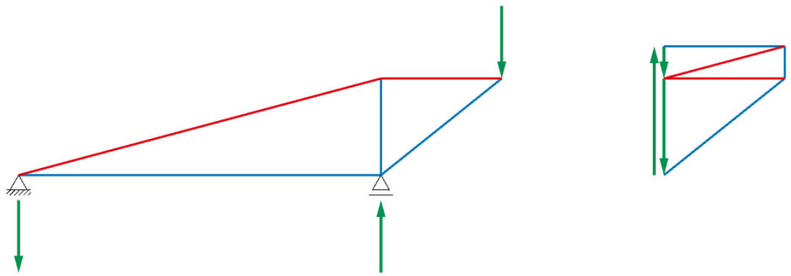


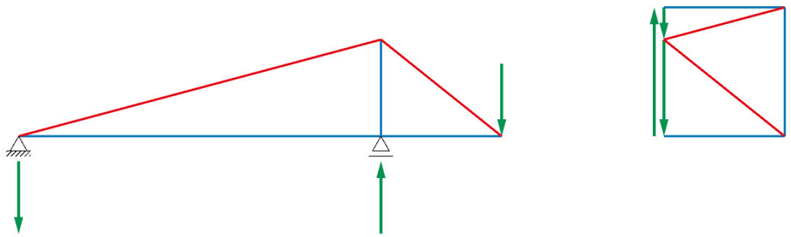
Lageplan 1:100
Form diagram 1:100

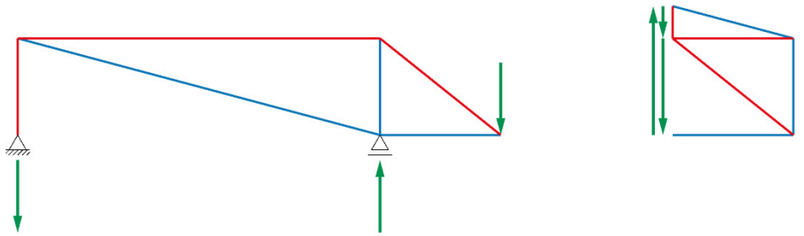


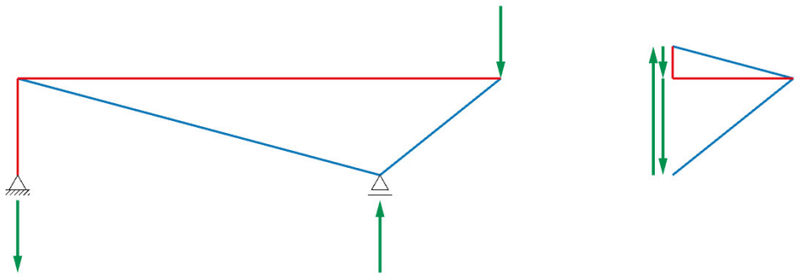
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

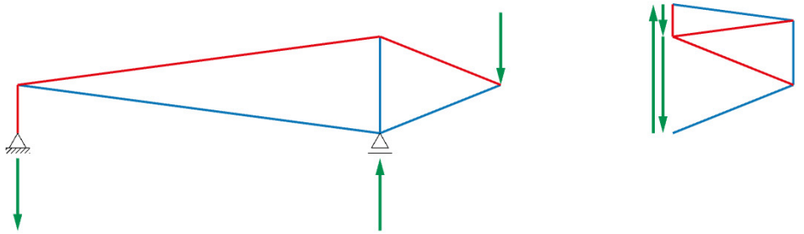












Bogen-Seil-Tragwerke
Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

Auflagerbedingungen
Support conditions

Aufteilung der äusseren Lasten
Distribution of external loads

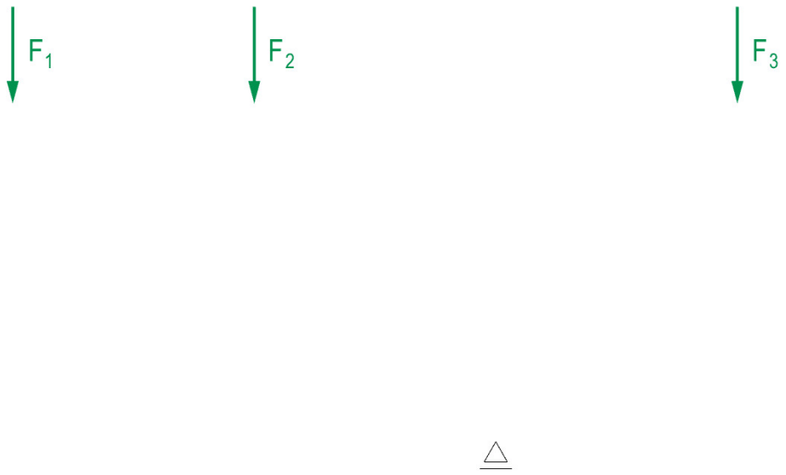
Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

Geometrische Variation
Geometric variation

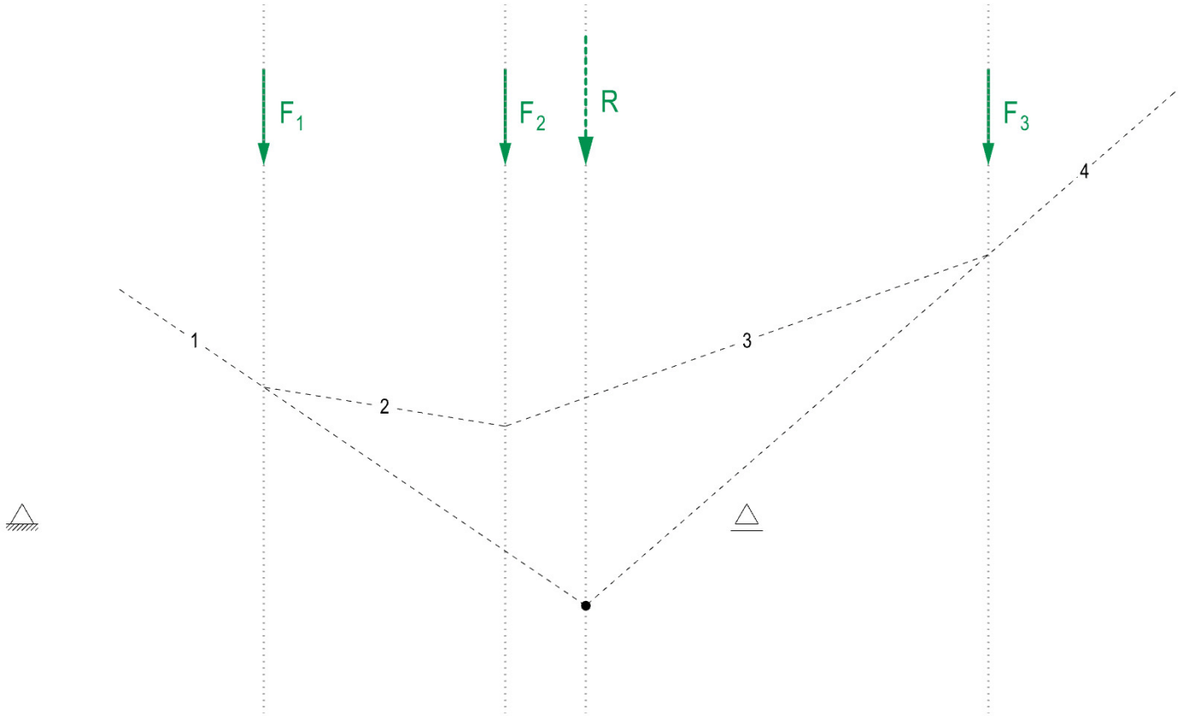
>> Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

Fallbeispiele
Case studies

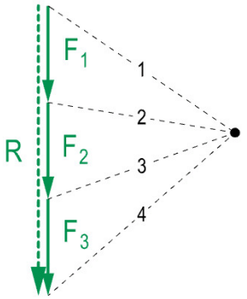


Lageplan 1:100
Form diagram 1:100

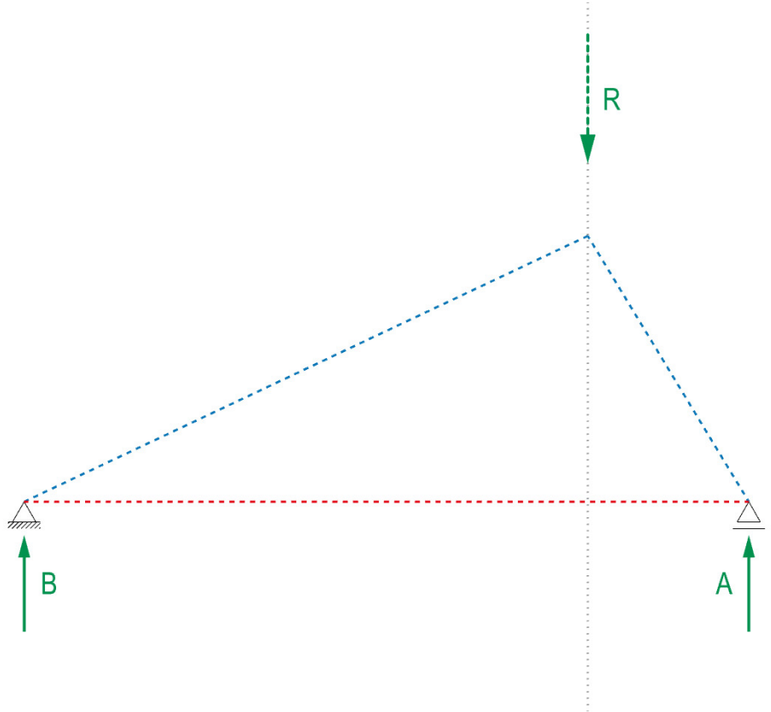
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



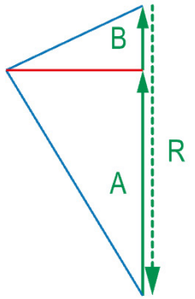
Lageplan 1:100
Form diagram 1:100



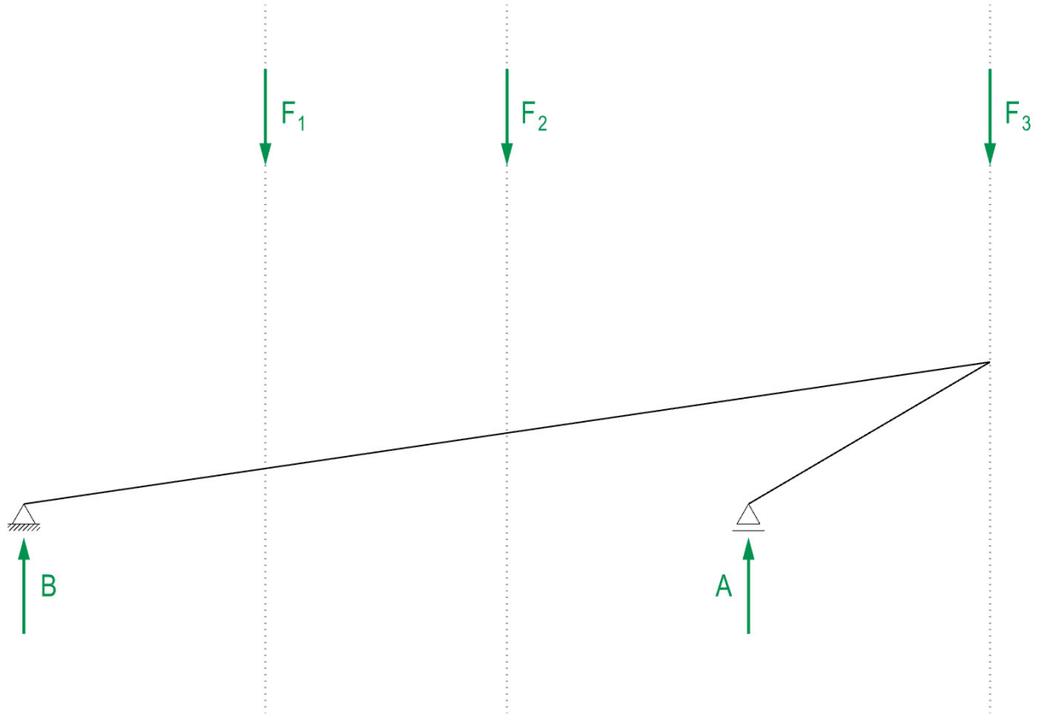
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

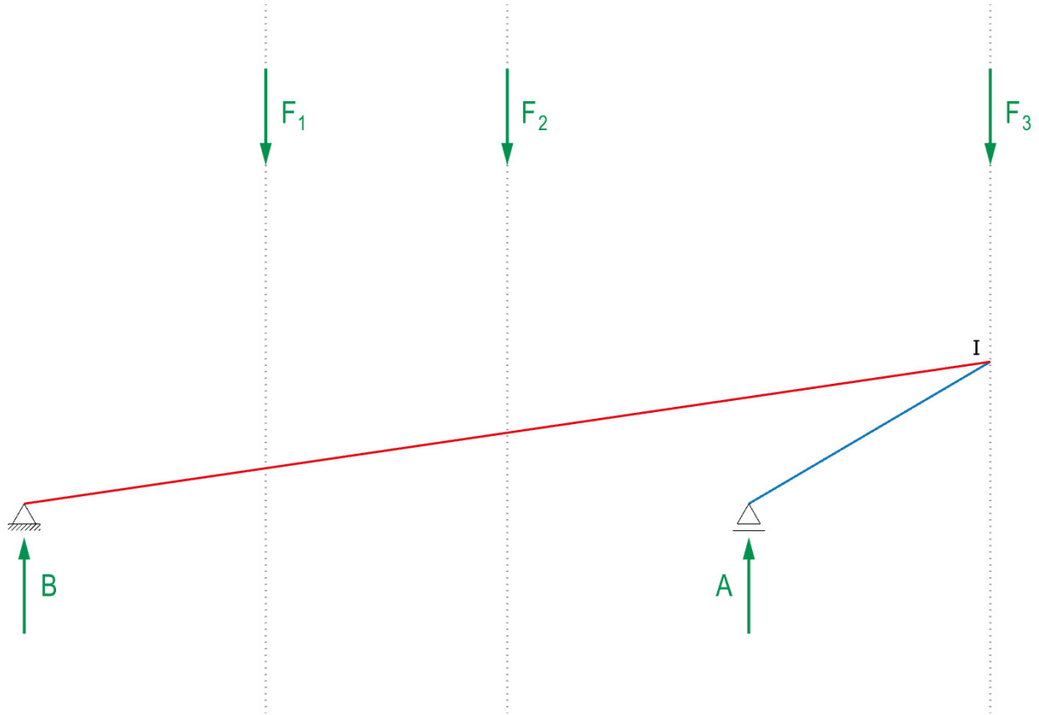


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

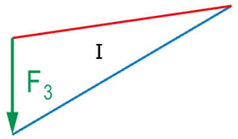


Lageplan 1:100
Form diagram 1:100

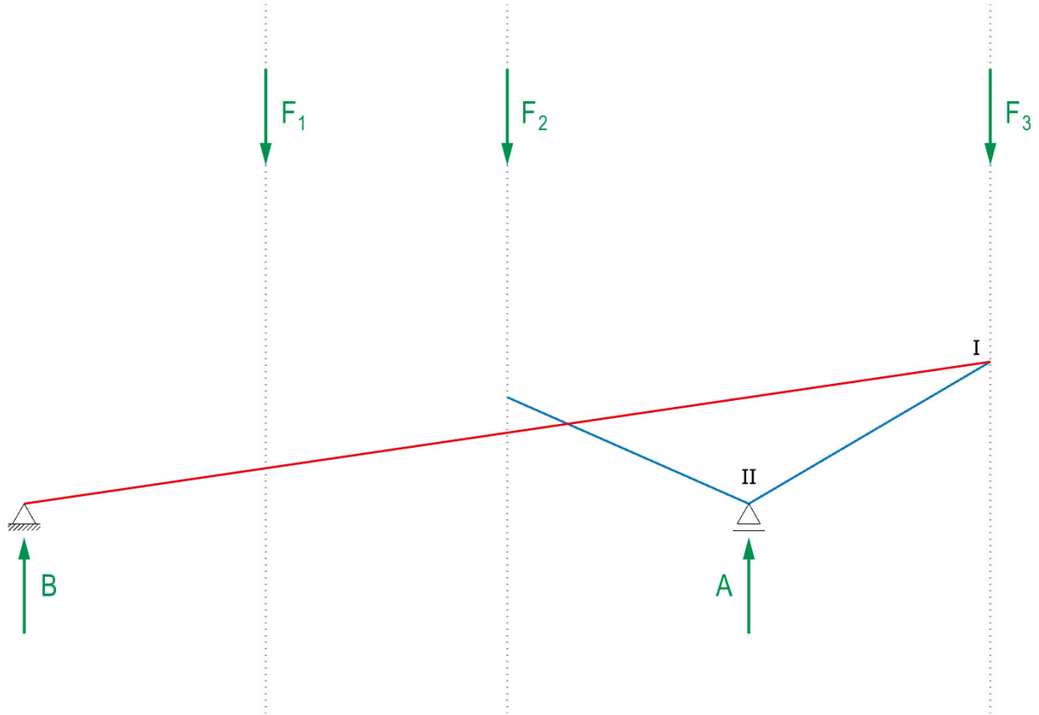
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



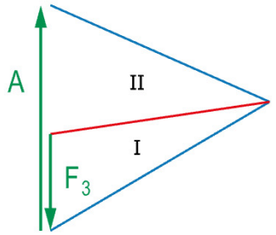
Lageplan 1:100
Form diagram 1:100



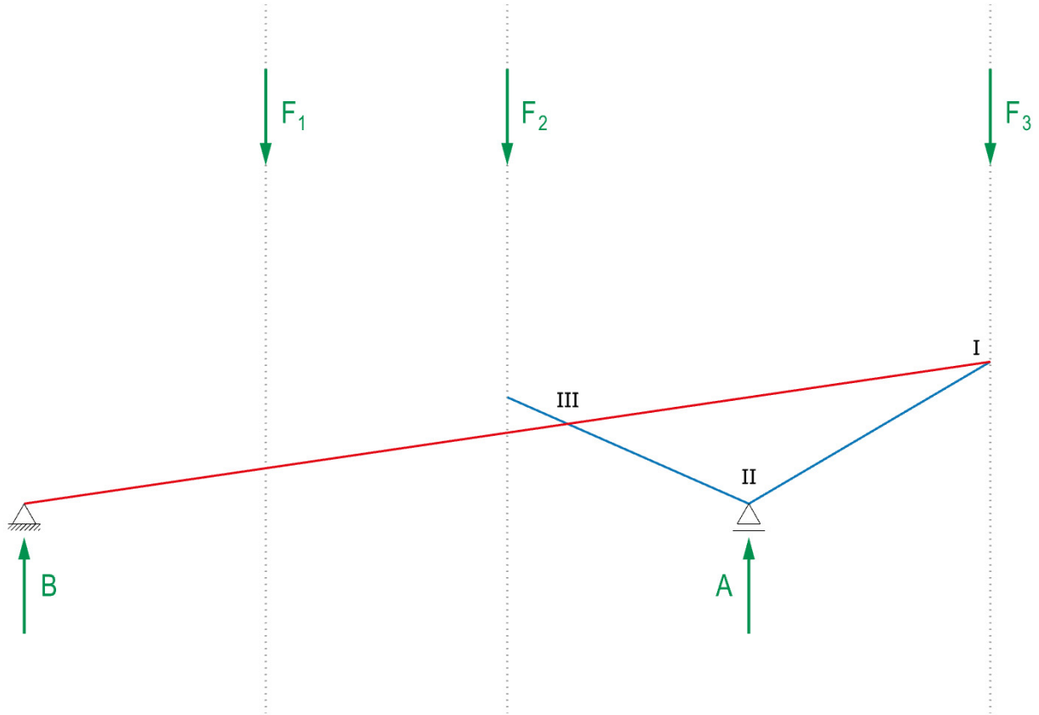
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



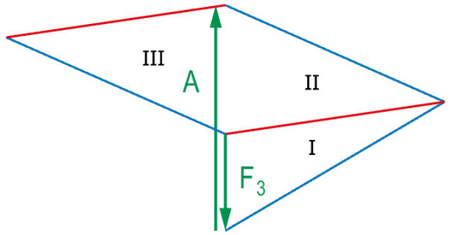
Lageplan 1:100
Form diagram 1:100



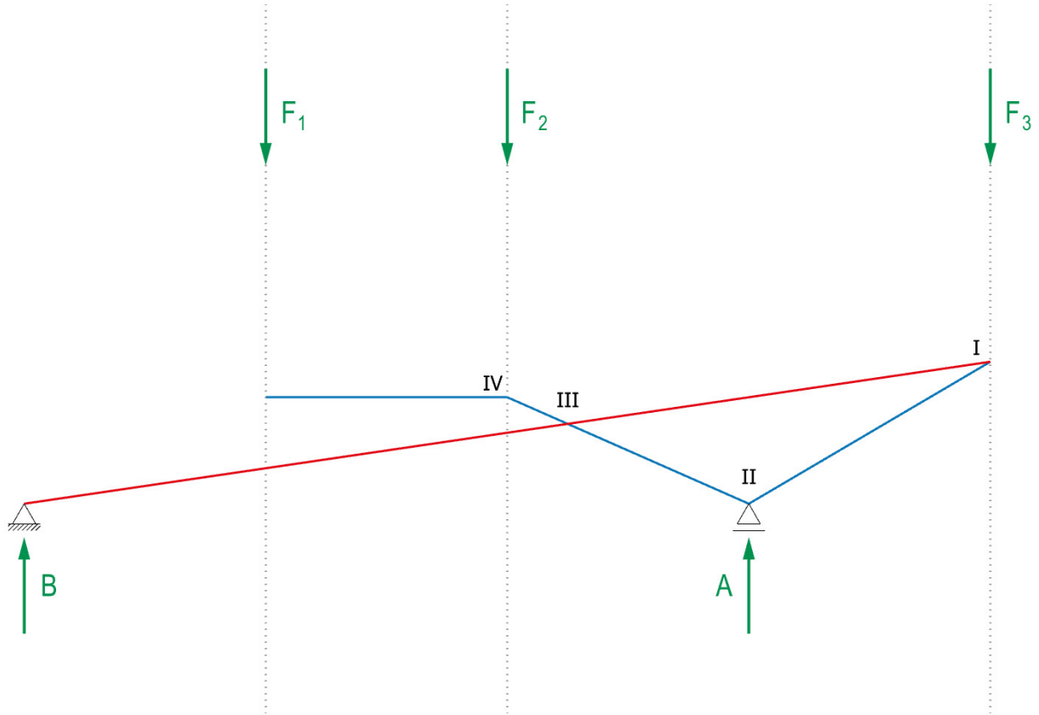
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



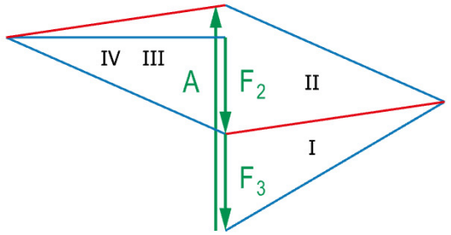
Lageplan 1:100
Form diagram 1:100



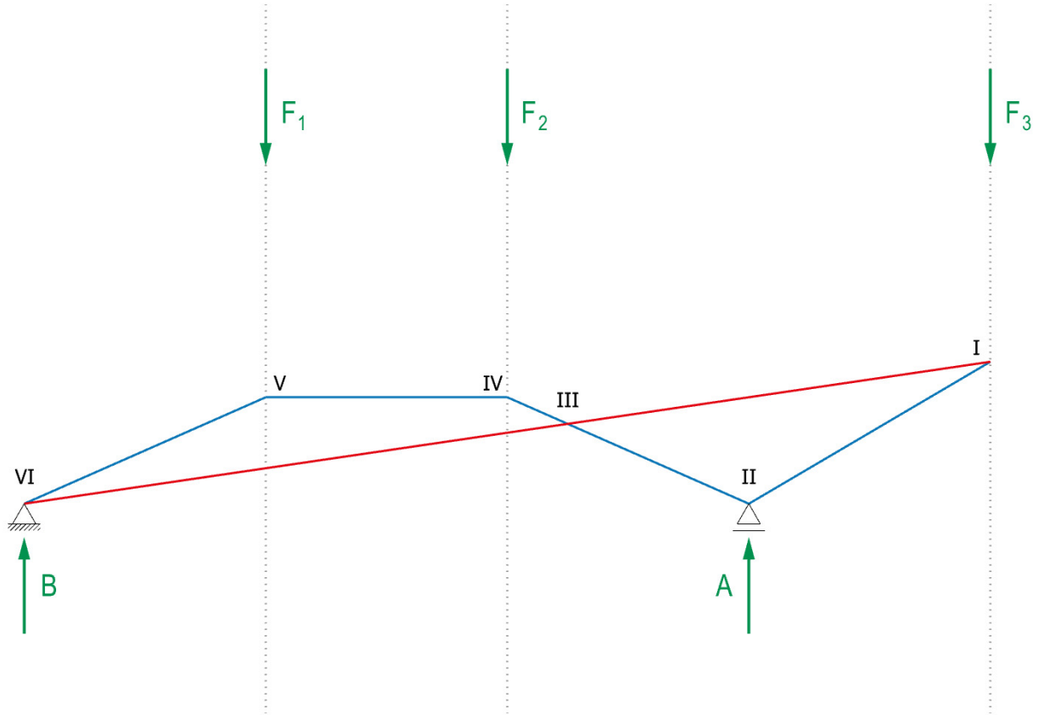
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



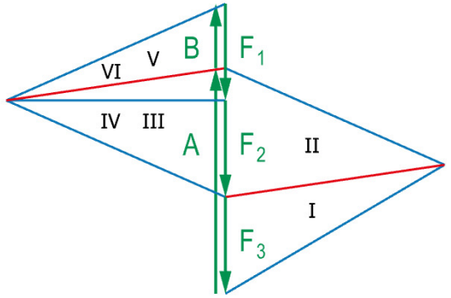
Lageplan 1:100
Form diagram 1:100



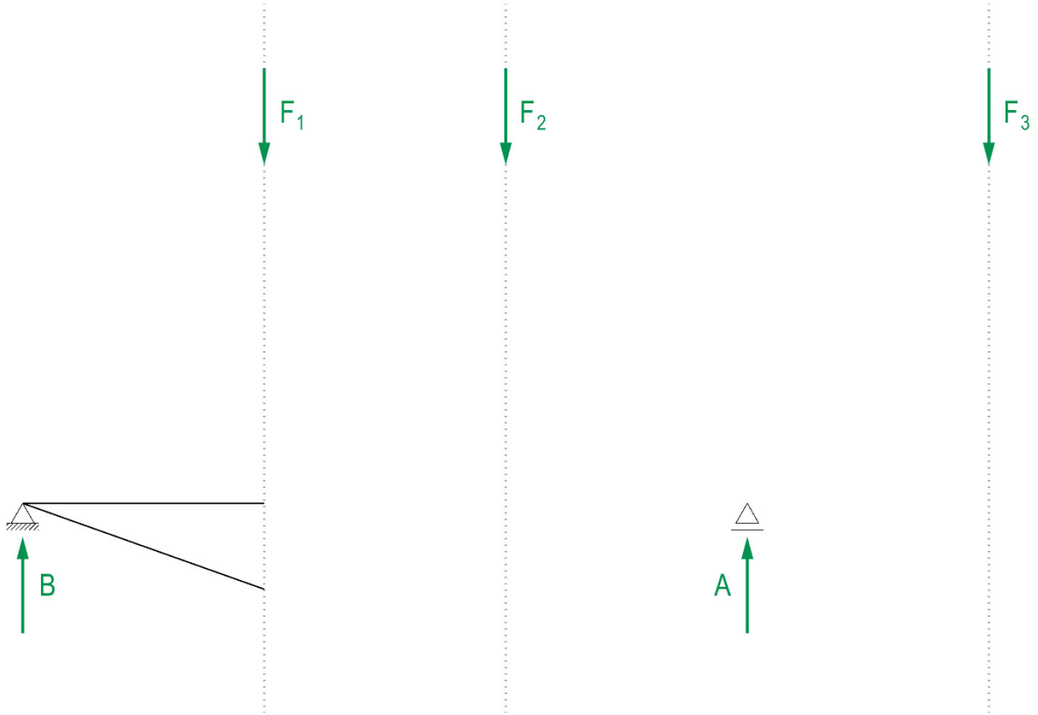
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



Lageplan 1:100
Form diagram 1:100

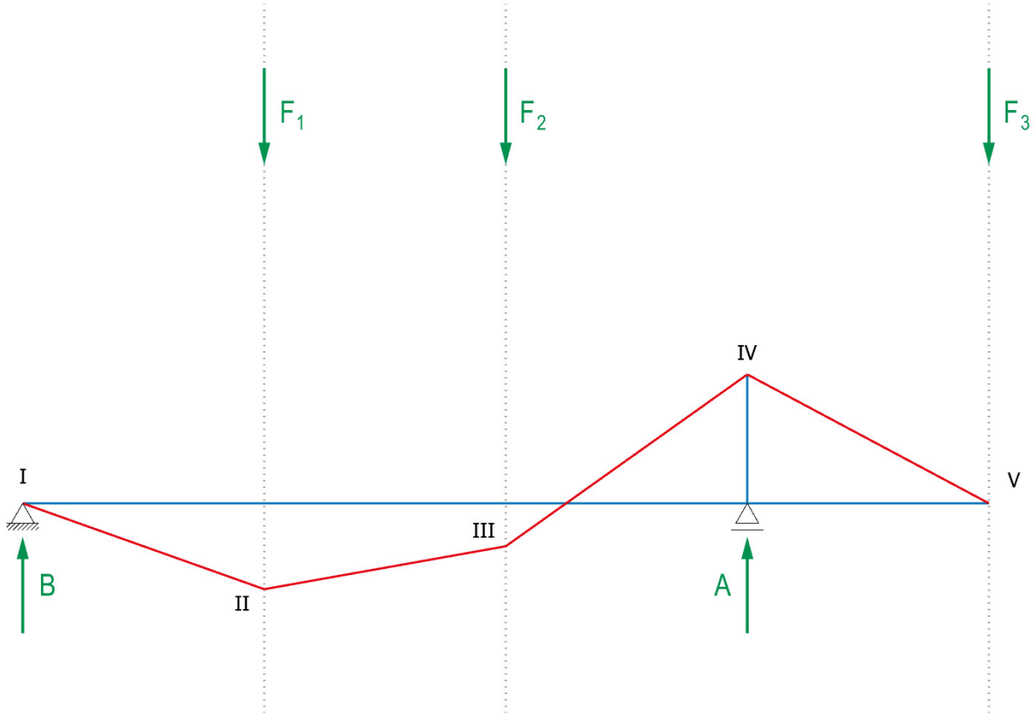


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

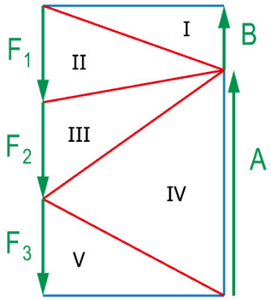


Lageplan 1:100
Form diagram 1:100

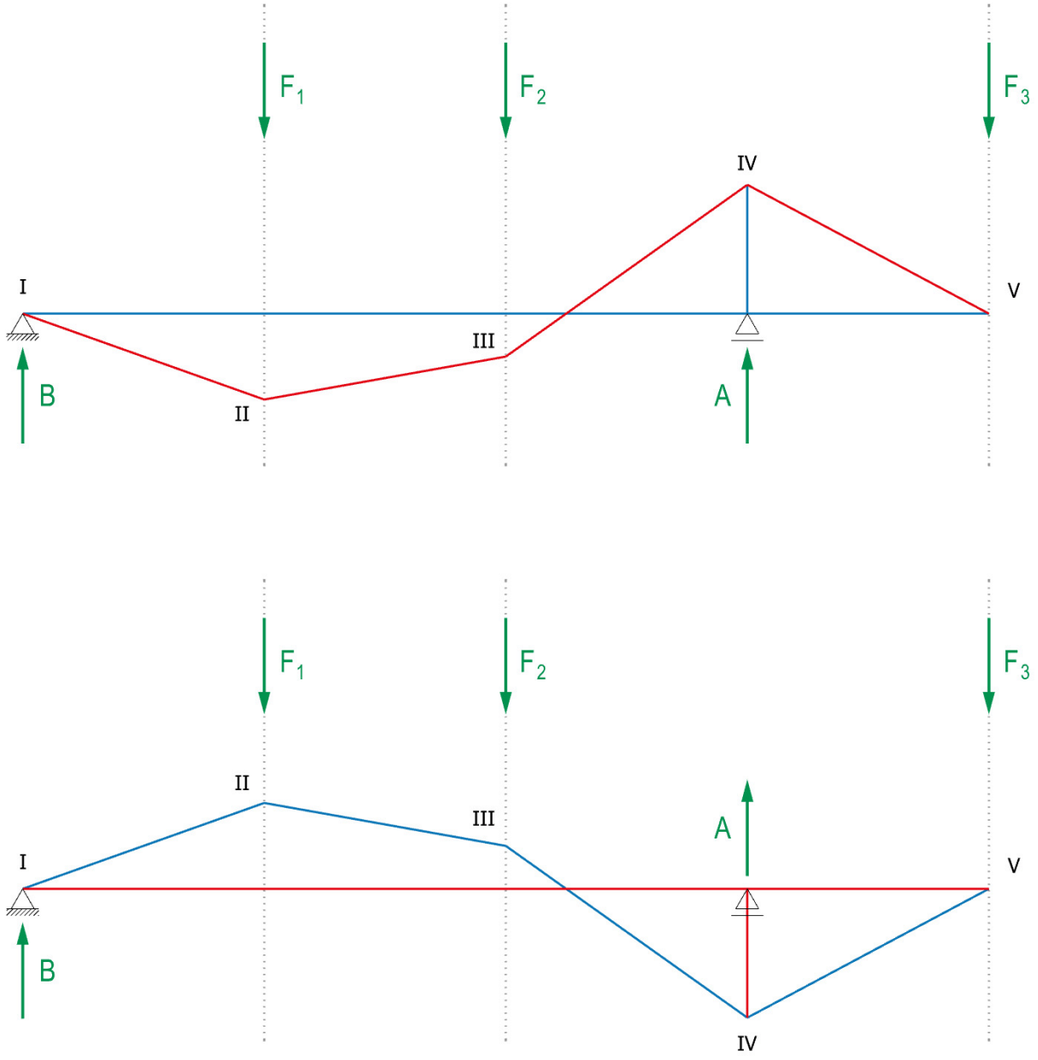
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

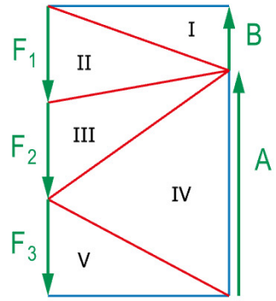


Lageplan 1:100
Form diagram 1:100



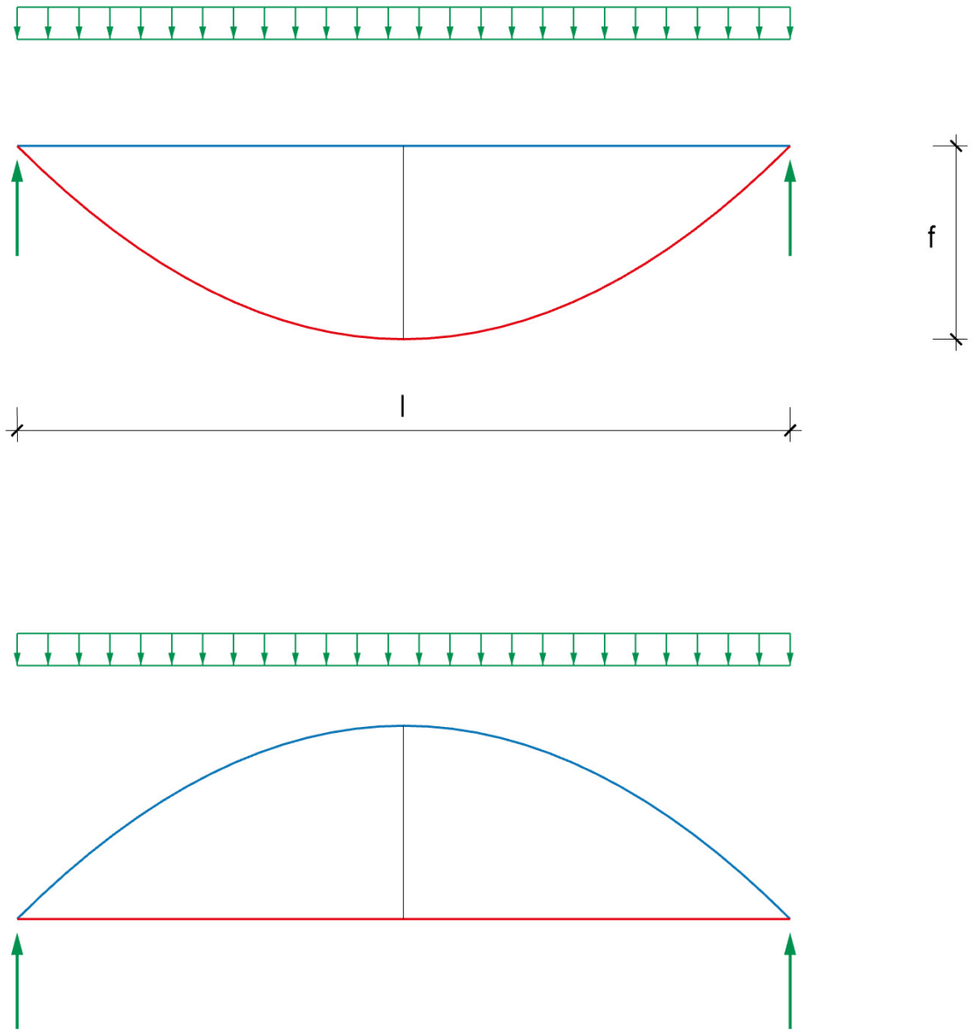
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN





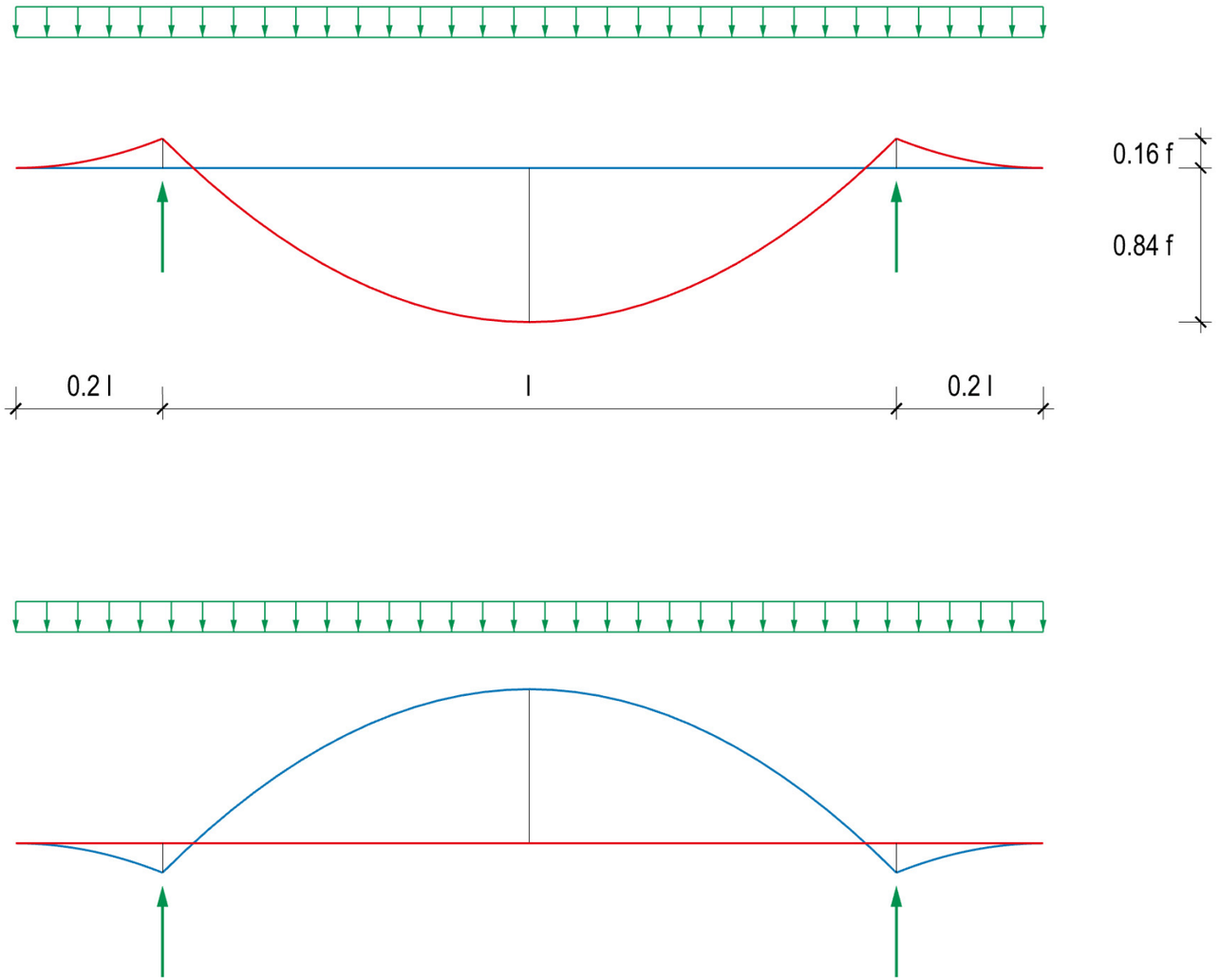
Lageplan 1:100
Form diagram 1:100

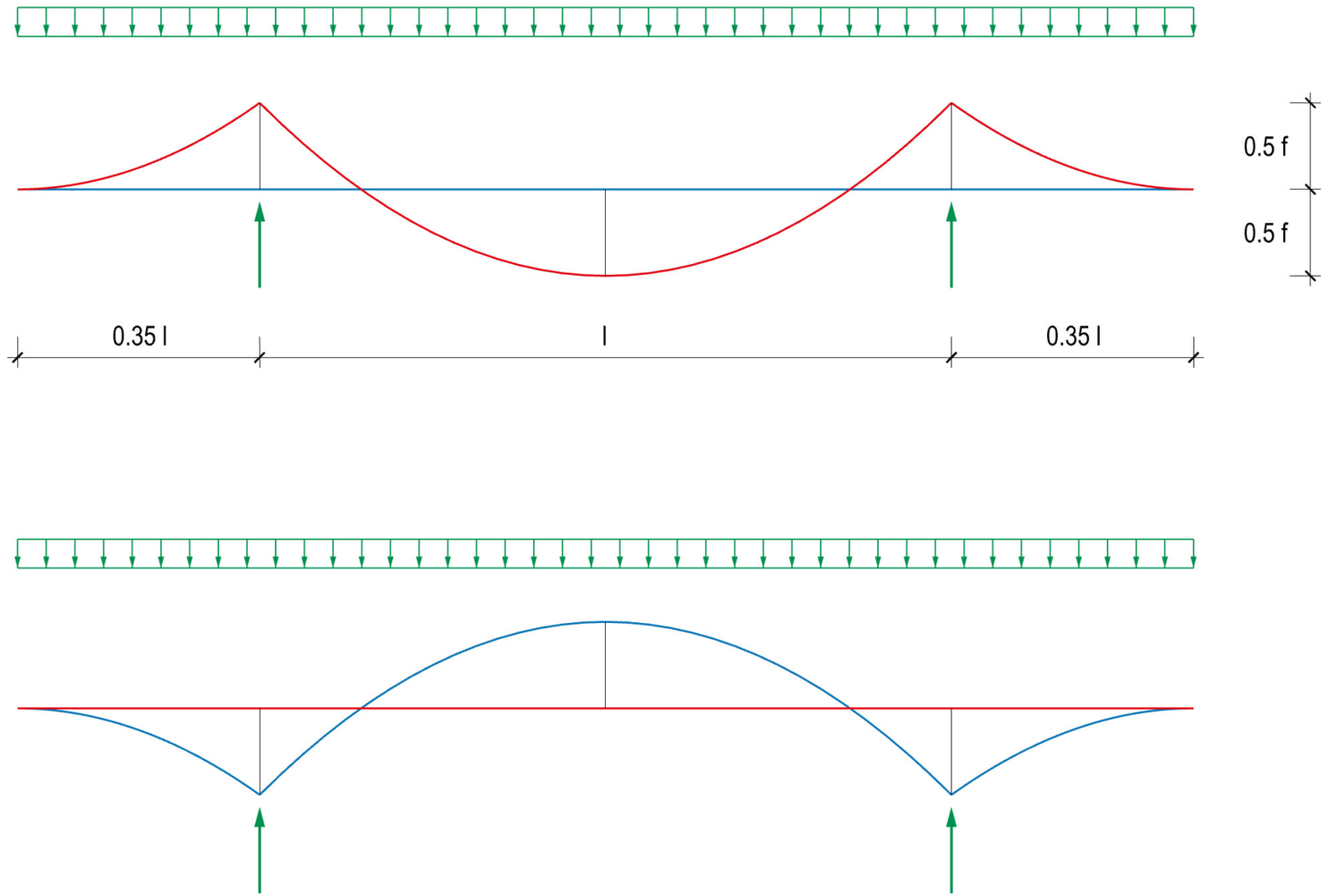
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

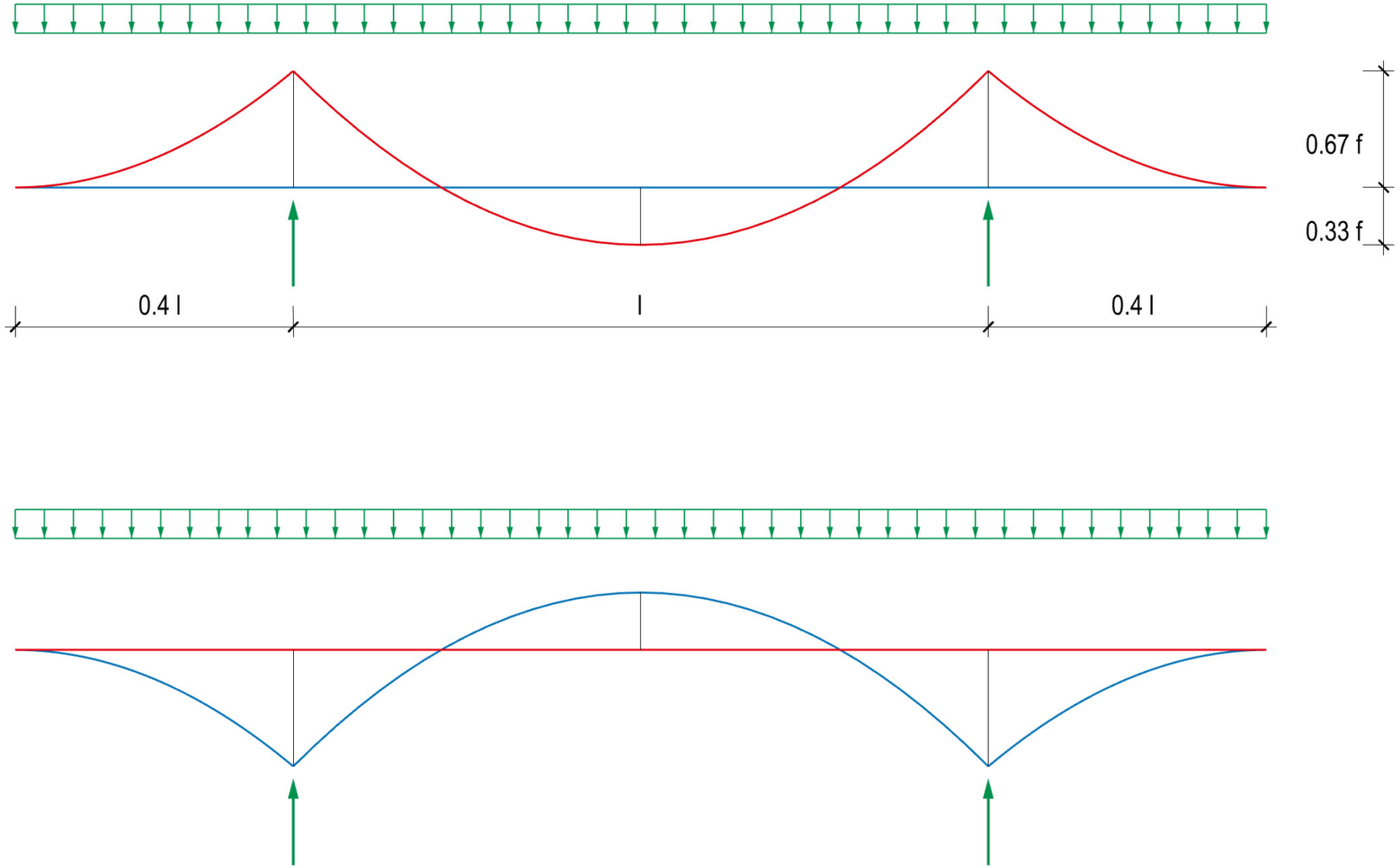


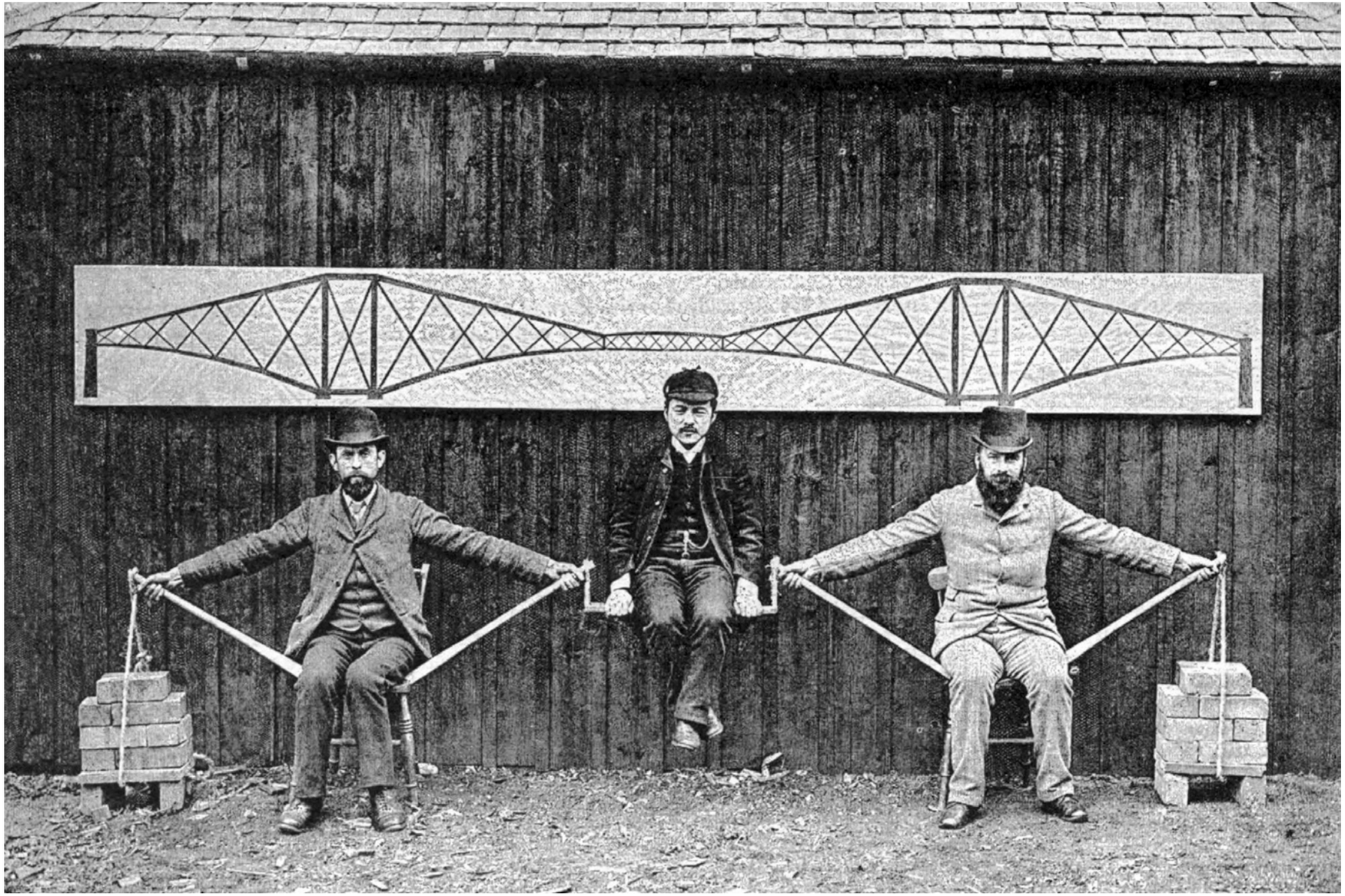
Lageplan 1:100
Form diagram 1:100

Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

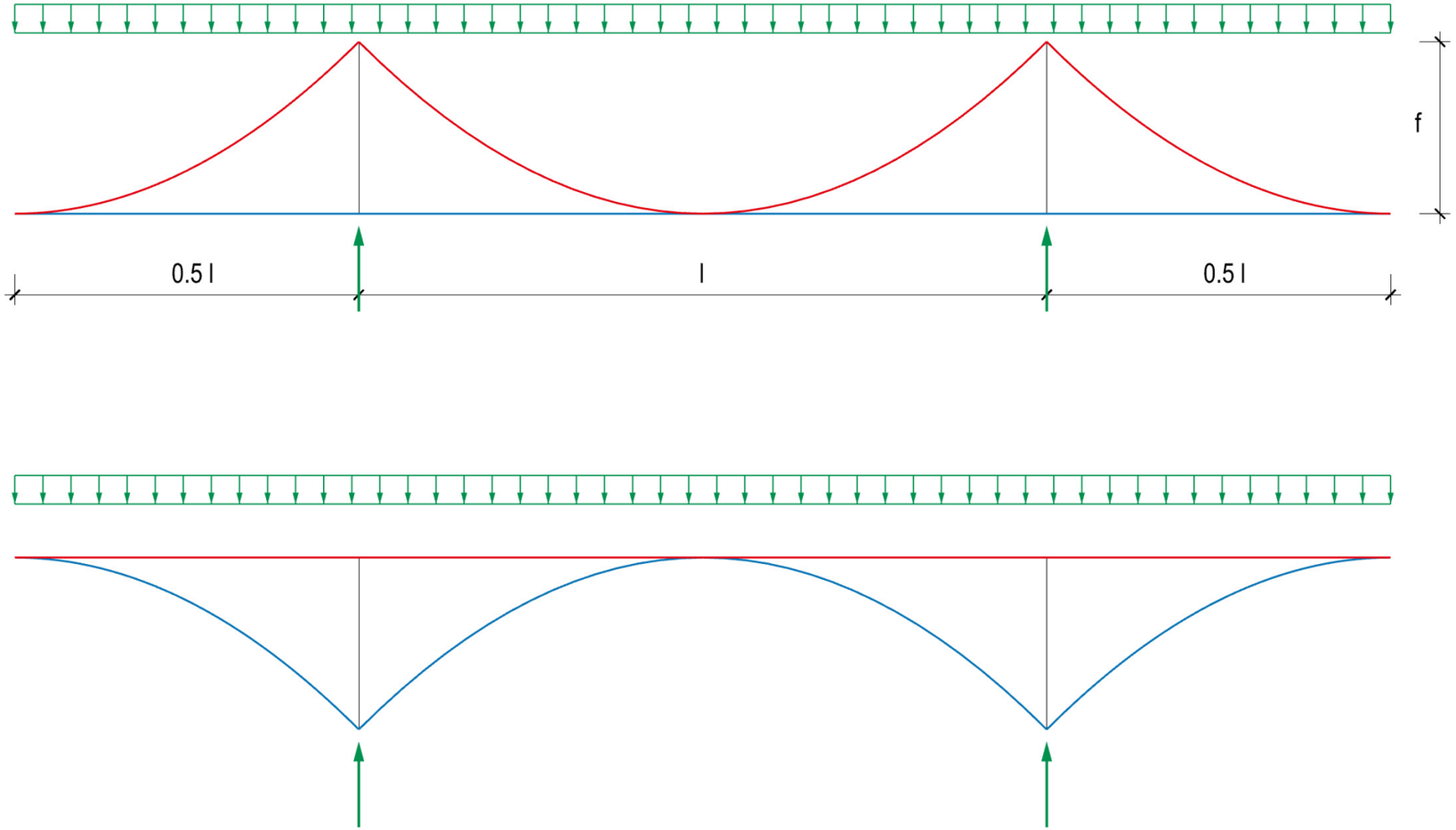

0.16 f
0.84 f
0.2 l
l
0.2 l


0.5 f
0.5 f
0.35 l
l
0.35 l

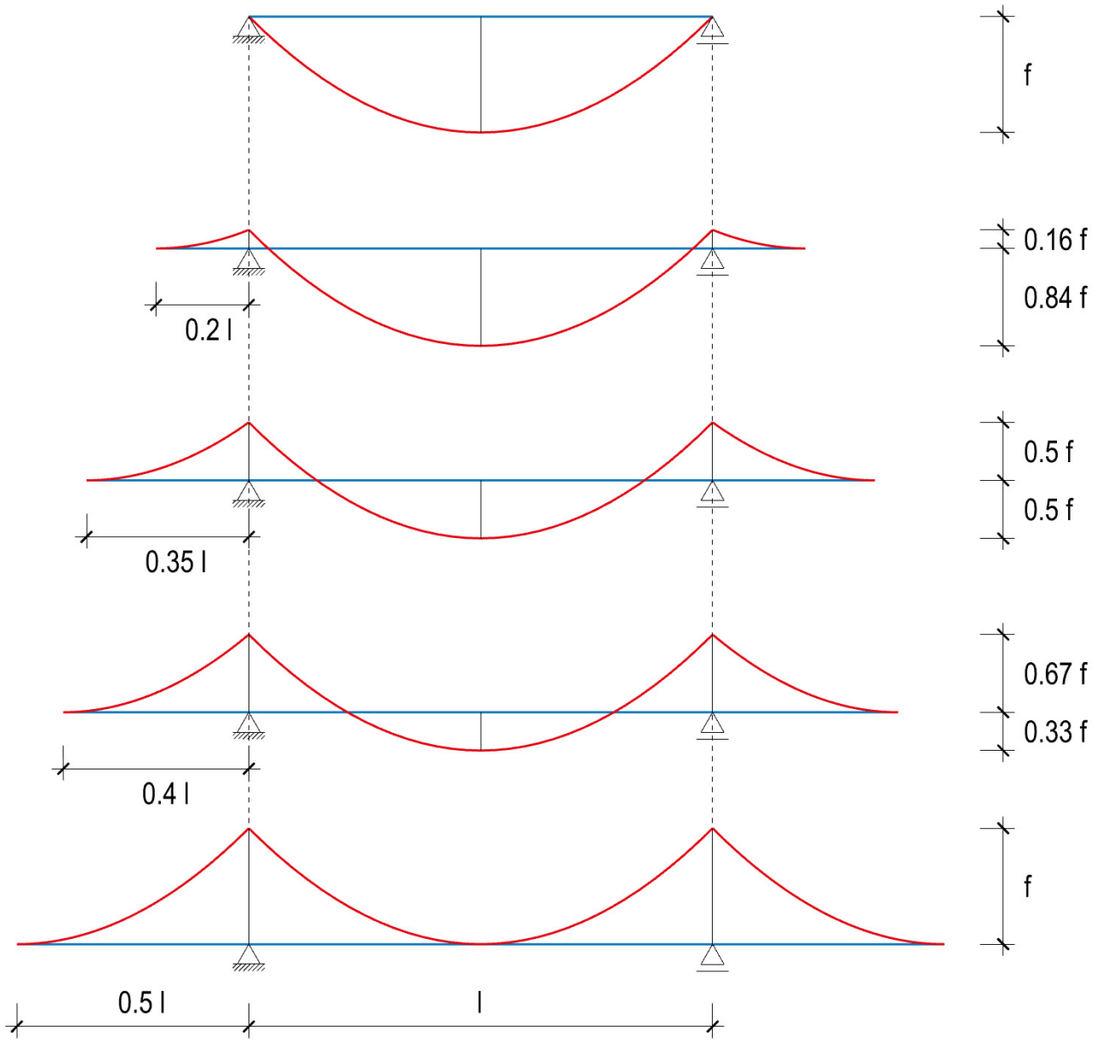

0.67 f
0.33 f
0.4 l
l
0.4 l

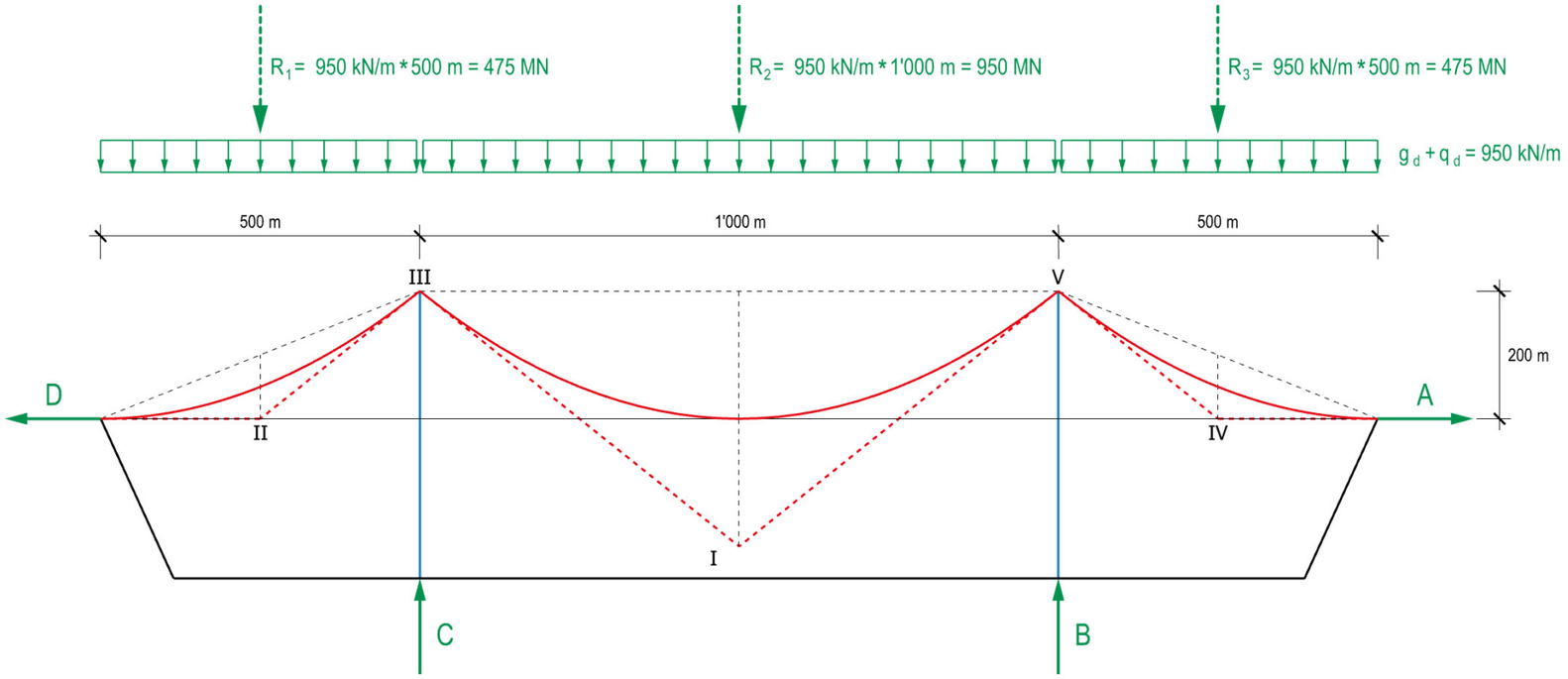


Sir John Fowler, Sir Benjamin Baker: Forth Bridge, South Quennsferry, 1890

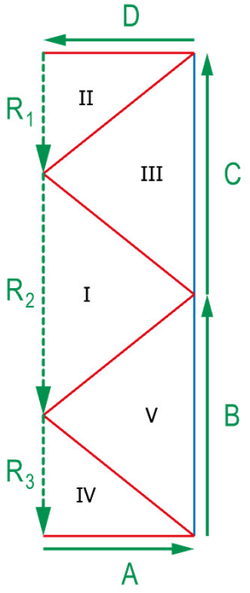

f
0.5 l
l
0.5 l

A. Fried: Rip-Bridge, Woy-Woy, Australien, 1971

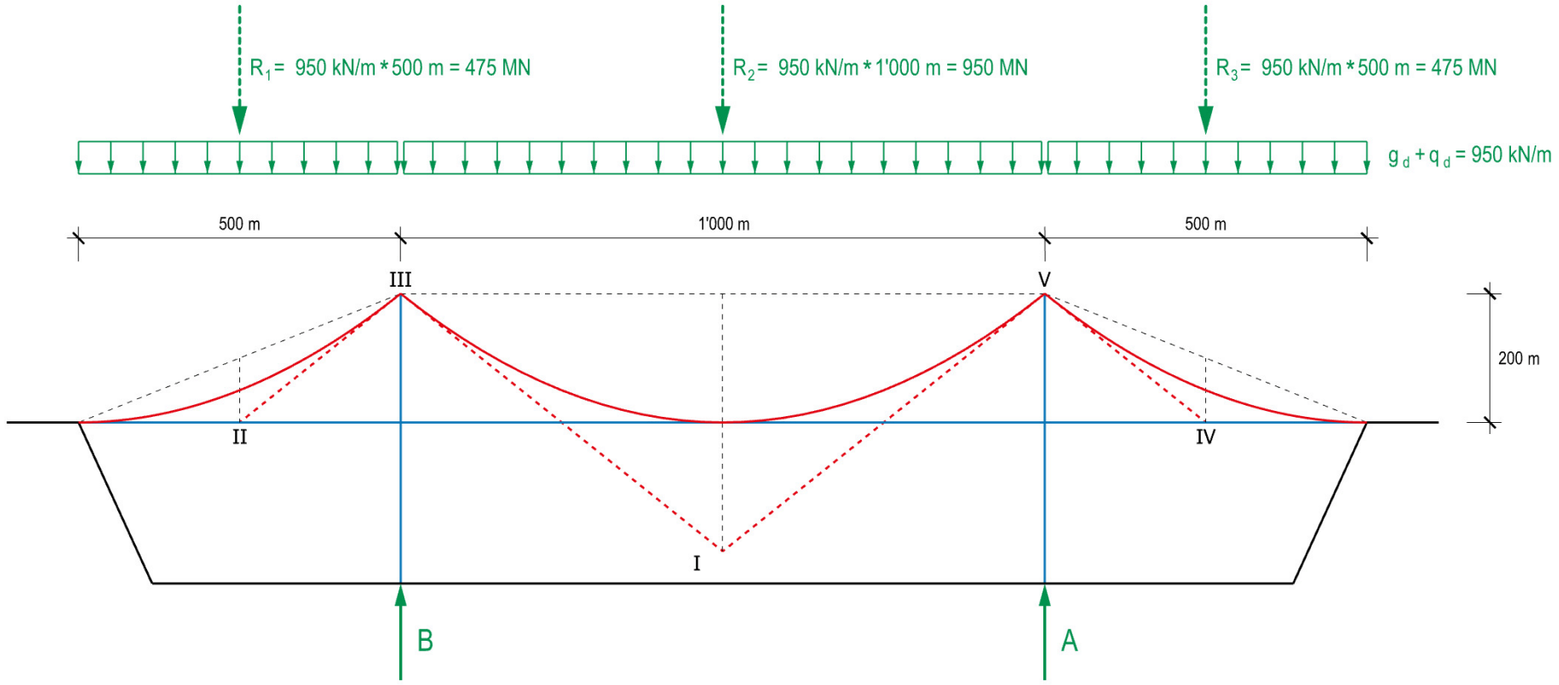

f
0.16 f
0.84 f
0.2 l
0.5 f
0.5 f
0.35 l
0.67 f
0.33 f
0.4 l
f
0.5 l
l



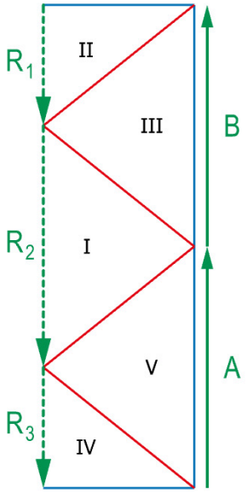
Lageplan
Form diagram



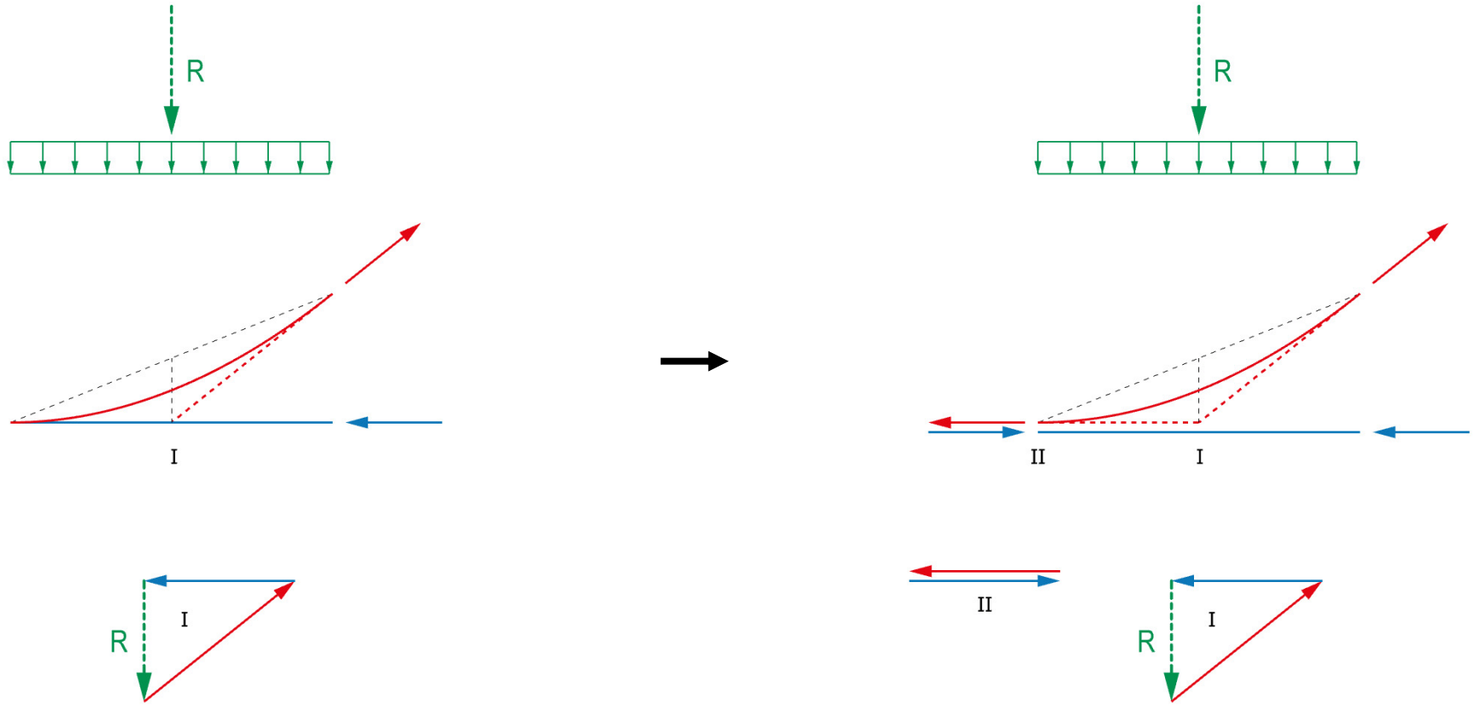
Kräfteplan
Force diagram

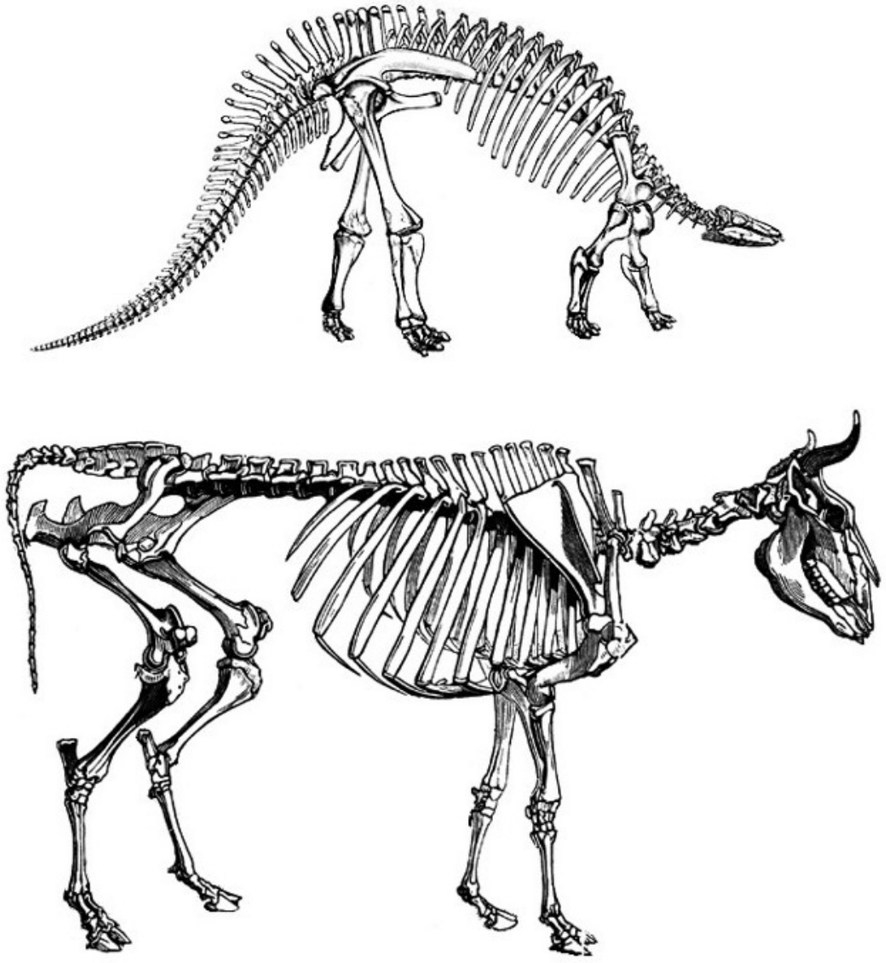


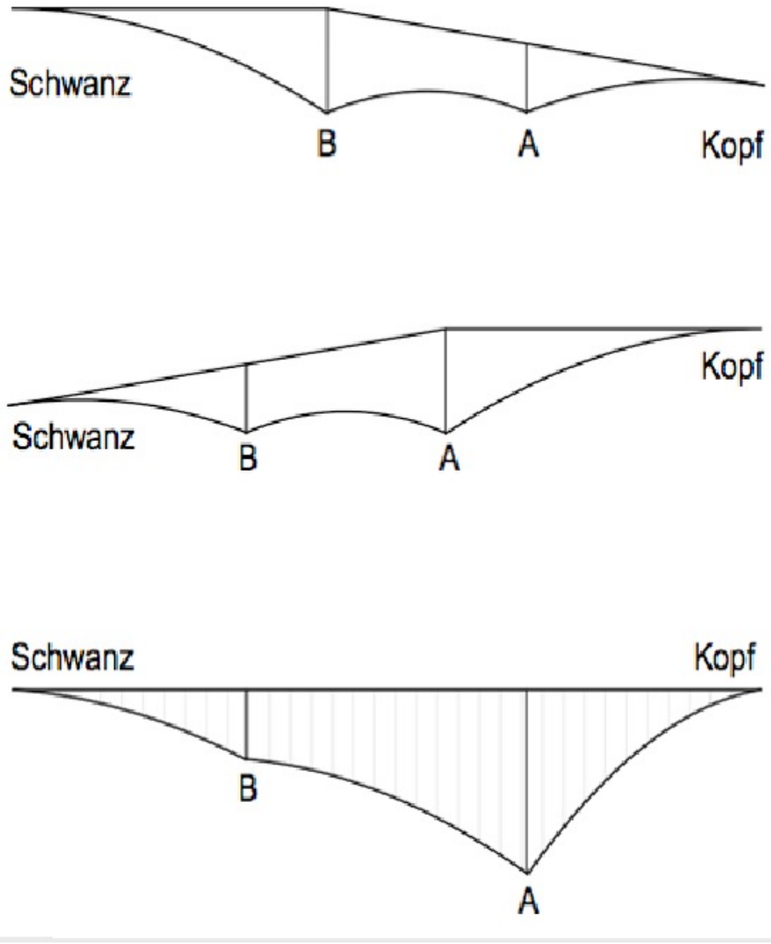
Lageplan
Form diagram



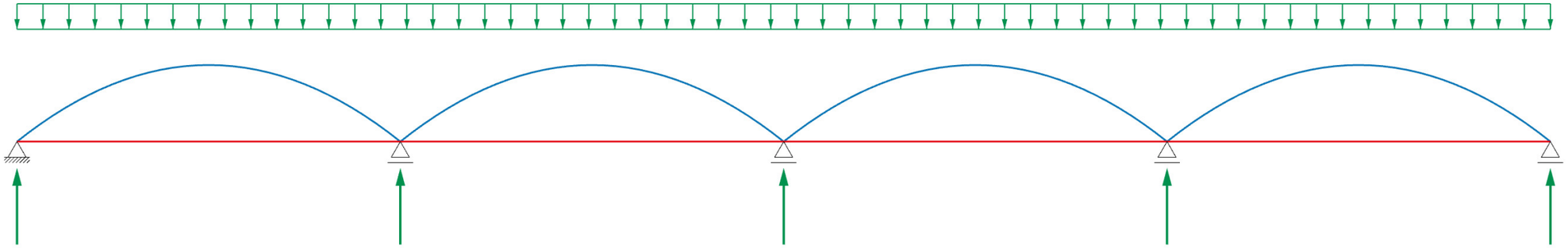
Kräfteplan
Force diagram


R
I
R
I
R
II
I



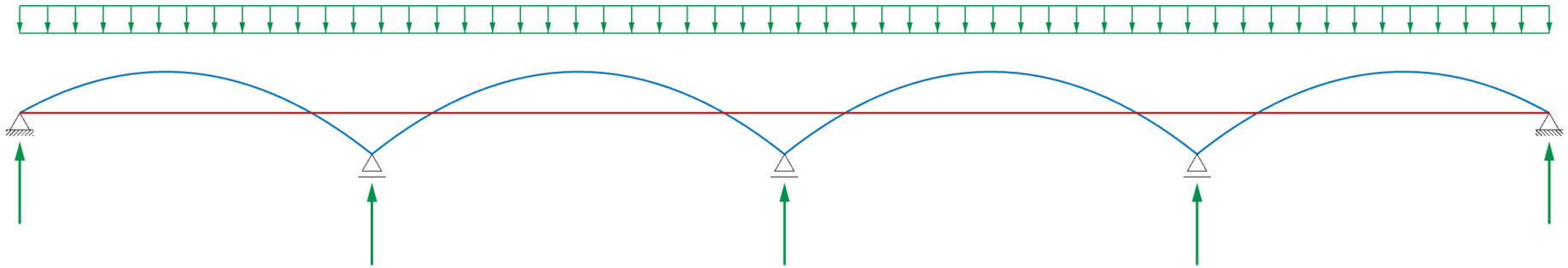


D'Arcy W. Thomson, „On growth and form", 1917

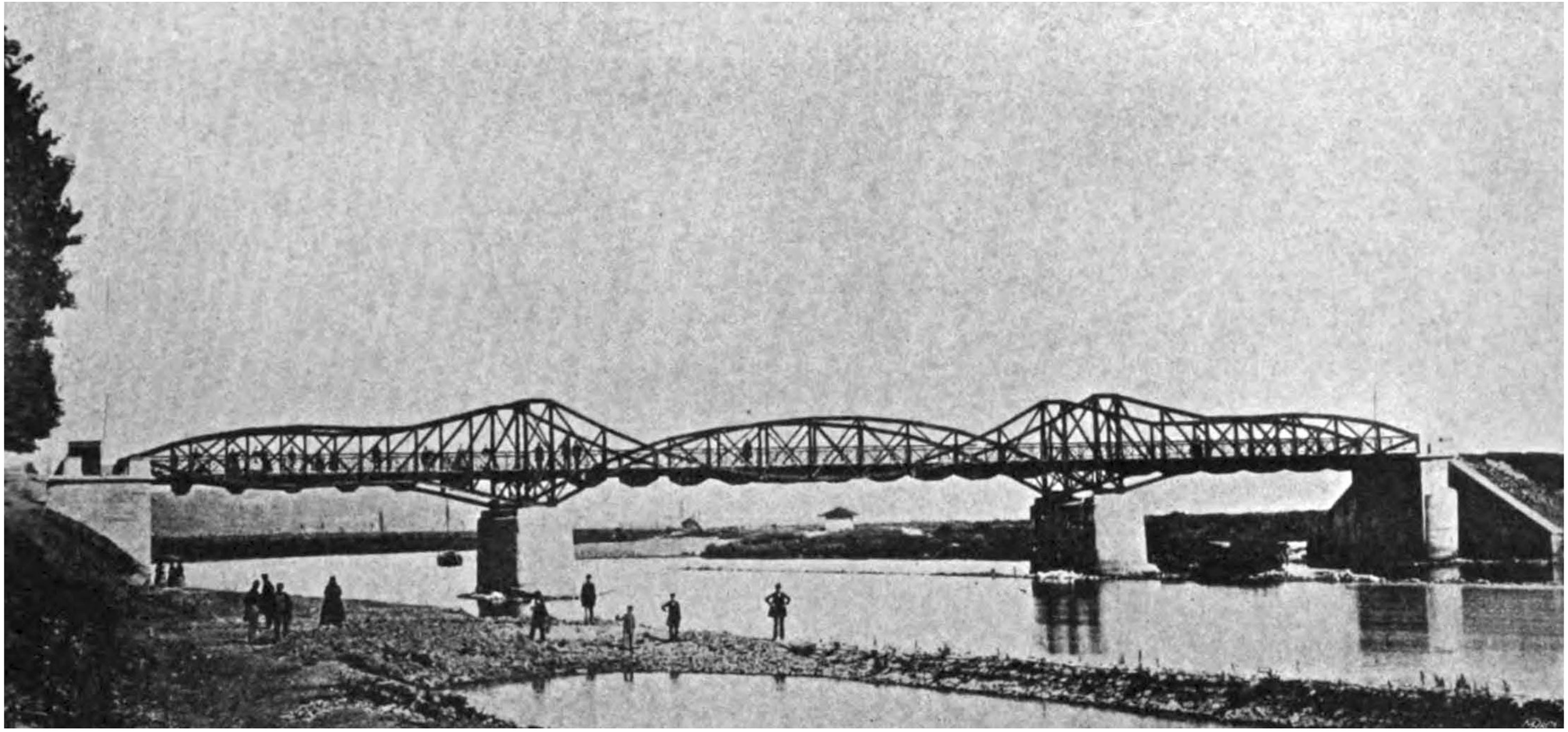


Durchlaufträger
Continuous beam

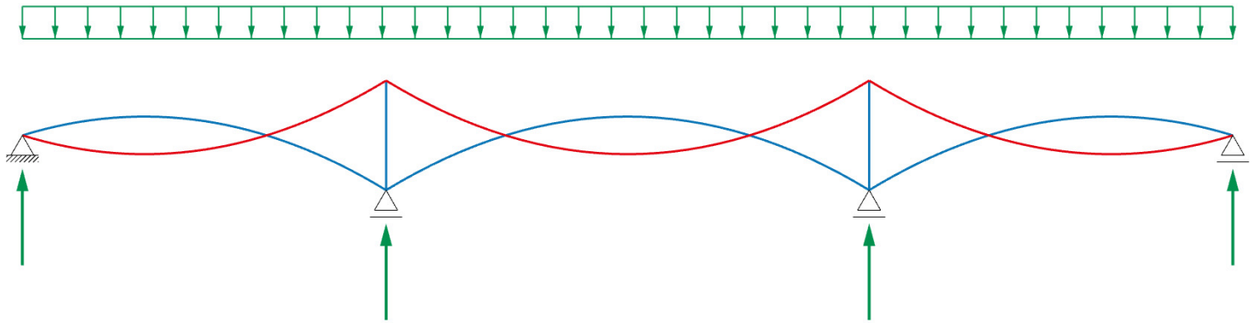
Eisenbahnbrücke, Riga, Lettland, 1914



Durchlaufträger
Continuous beam



Heinrich Gerber: Hassfurt Brücke, Hassfurt, 1867



Durchlaufträger
Continuous beam

Bogen-Seil-Tragwerke
Arch-cable structures

Tragwirkung einfacher Bogen-Seil-Tragwerke
Structural behaviour of simple arch-cable structures

Auflagerbedingungen
Support conditions

Aufteilung der äusseren Lasten
Distribution of external loads

Formfindung eines überspannenden Bogen-Seils
Form-finding of a spanning arch-cable

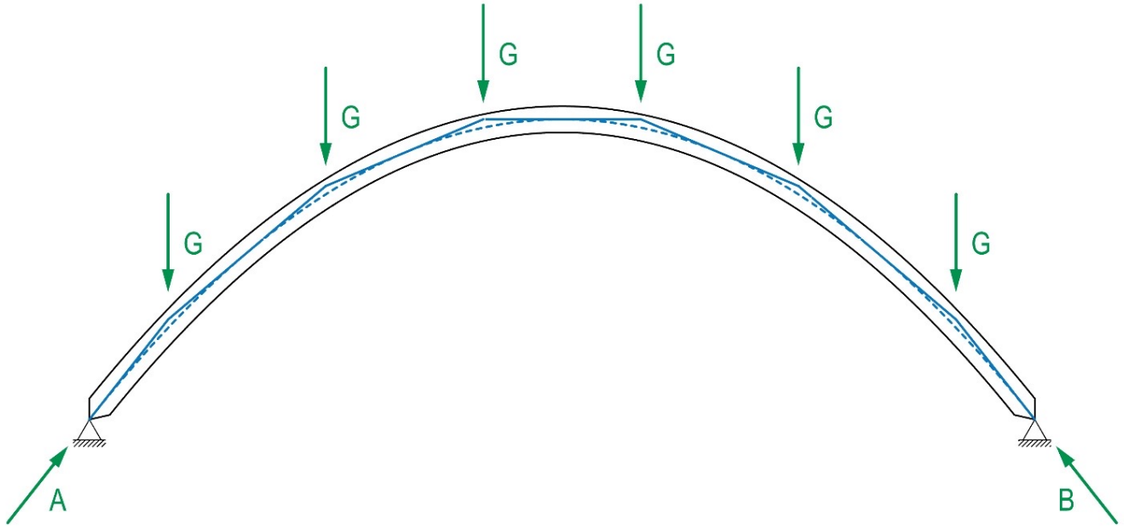
Konsolenartige Bogen-Seil-Tragwerke
Cantilevering arch-cable structures

Geometrische Variation
Geometric variation

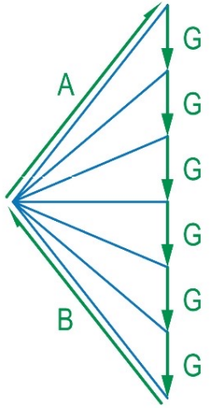
Zusammengesetzte Bogen-Seil-Tragwerke
Combined arch-cables

>> Fallbeispiele
Case studies

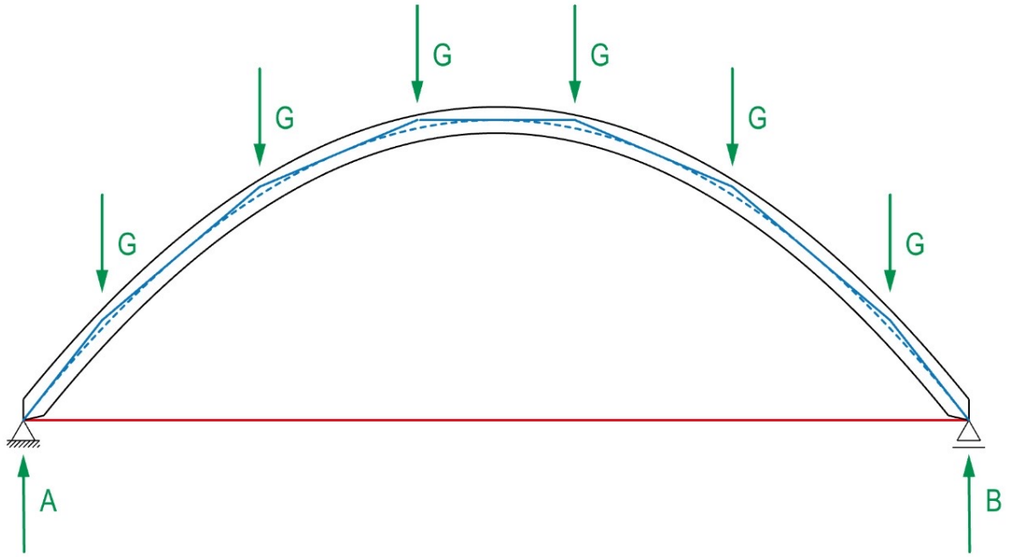
R. Brosi & Obrist and Partner, Peter Rice: Bus station Chur, 1992



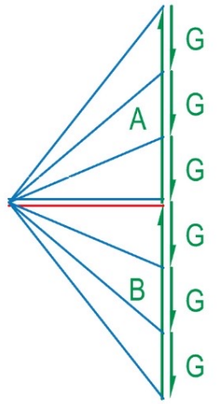
Lageplan 1:100
Form diagram 1:100



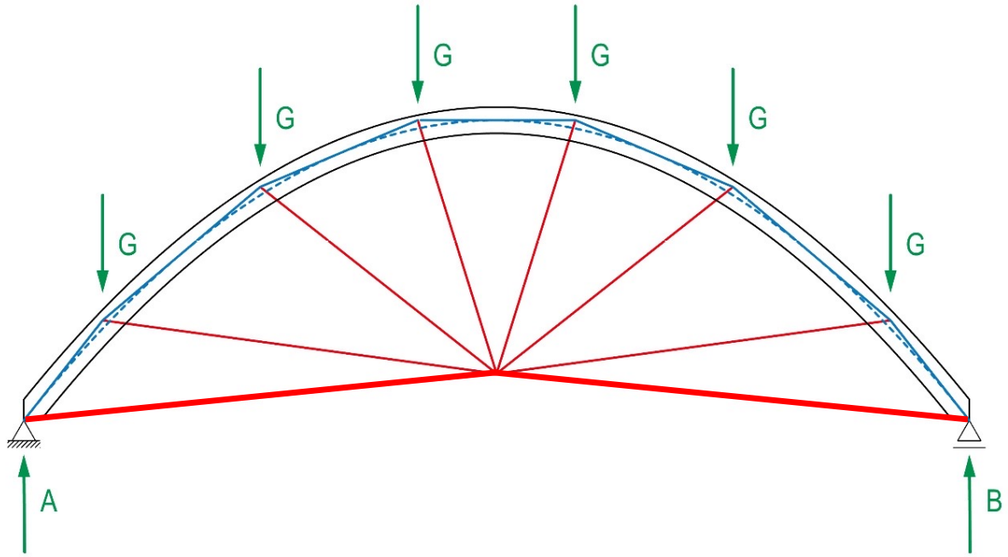
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



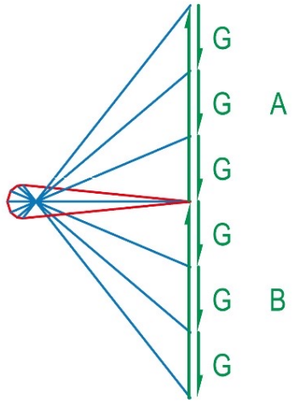
Lageplan 1:100
Form diagram 1:100



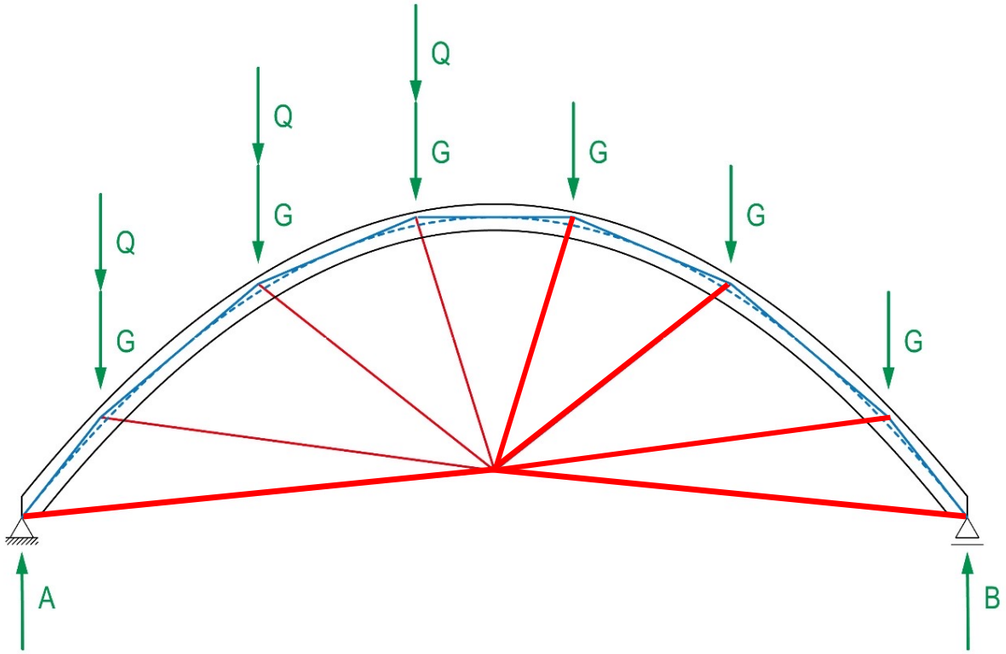
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



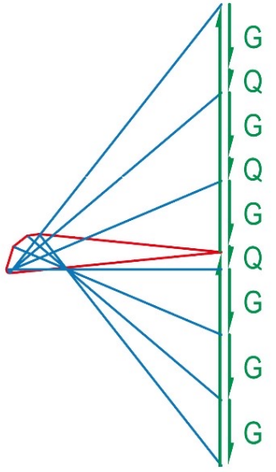
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



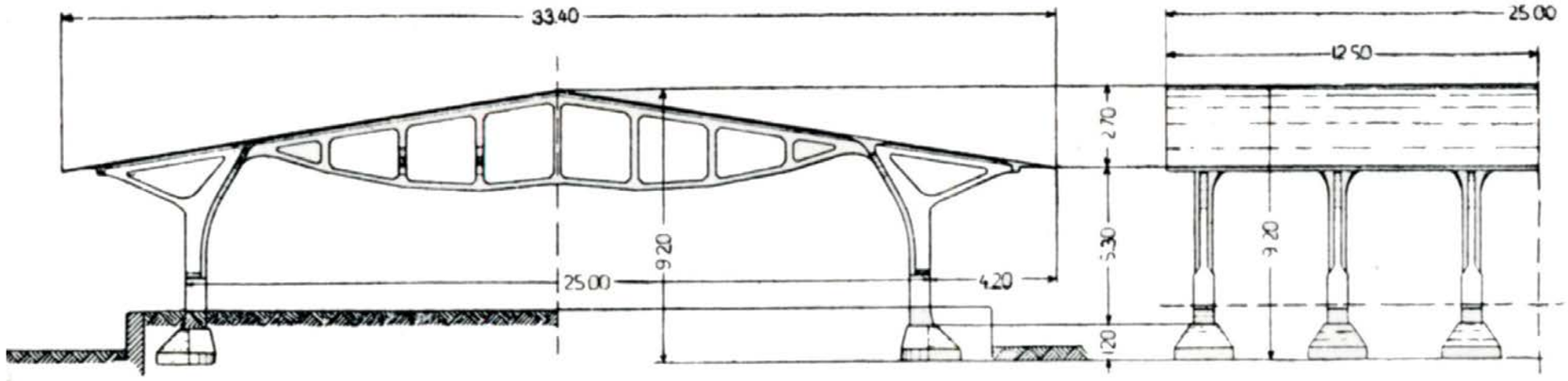
Lageplan 1:100
Form diagram 1:100



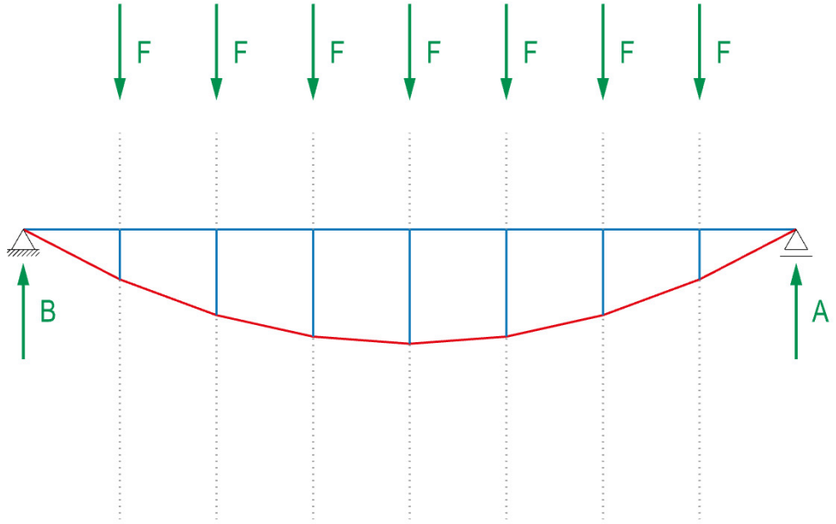
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

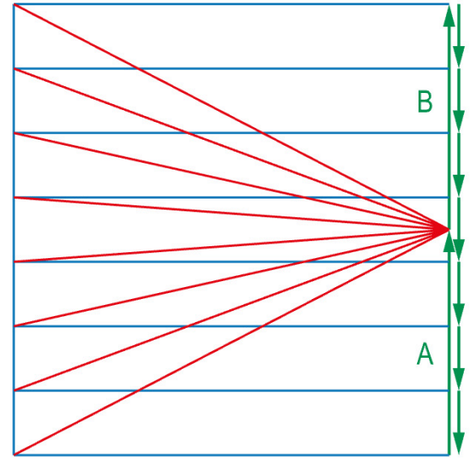
R. Brosi & Obrist and Partner, Peter Rice: Bus station Chur, 1992

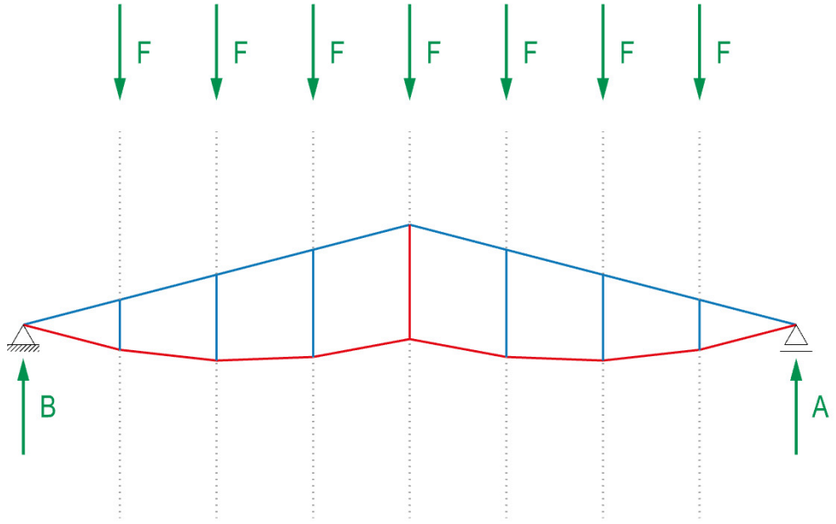
Robert Maillart: Magazzini Generali, Chiasso, 1924

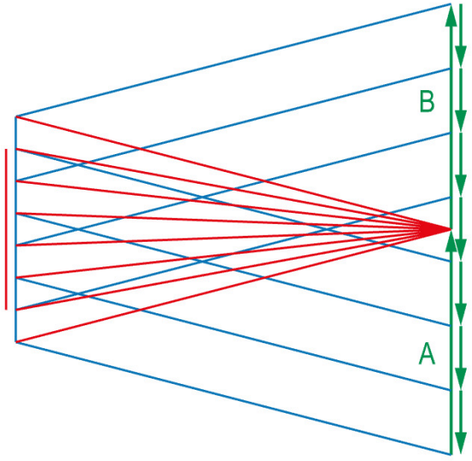


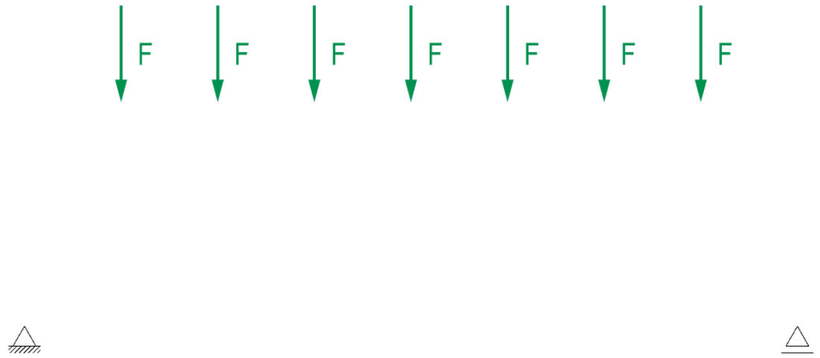
Robert Maillart: Lagerhaus Magazzini Generali, Chiasso, 1925

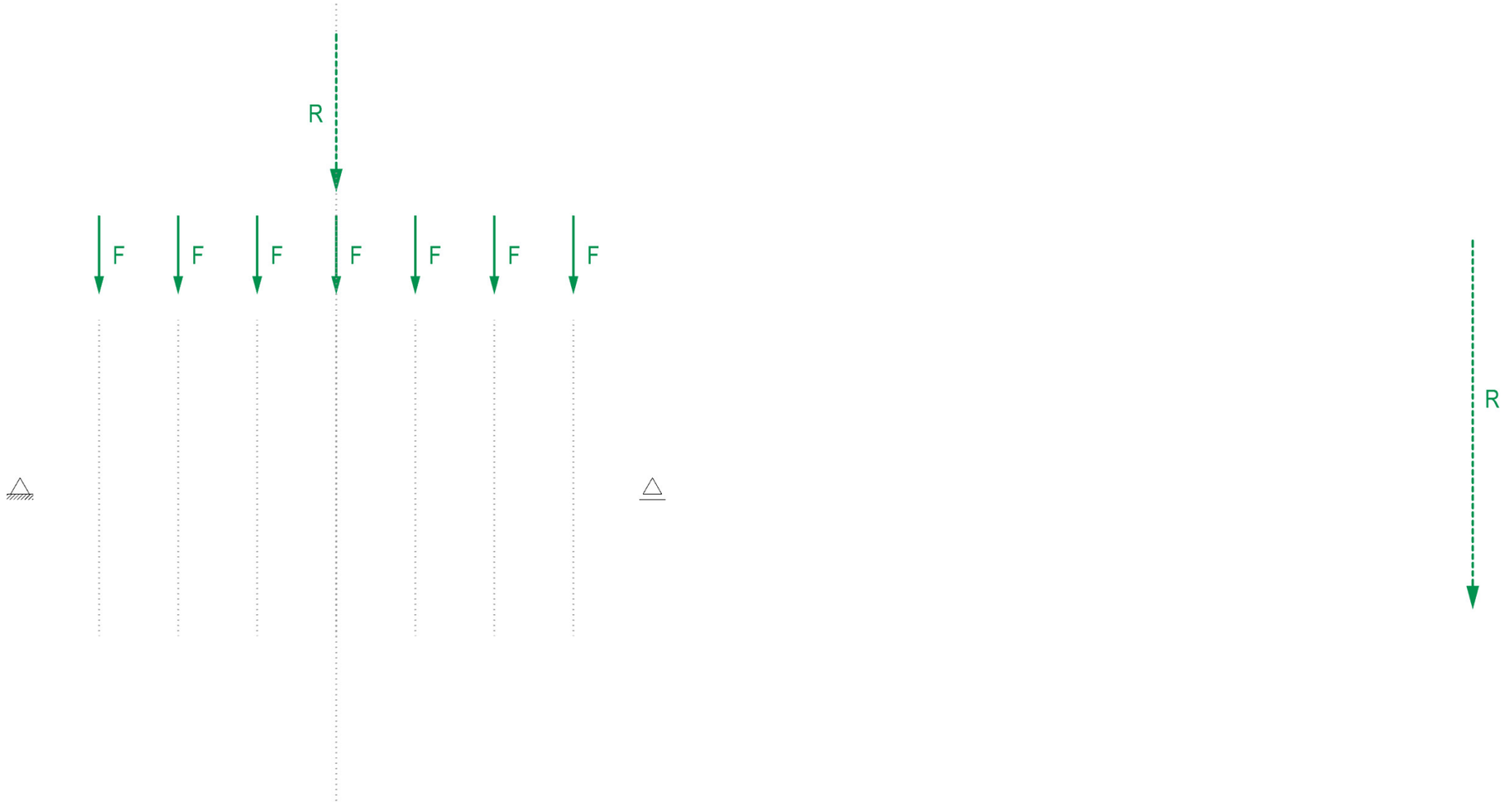

F
F
F
F
F
F
F
B
A

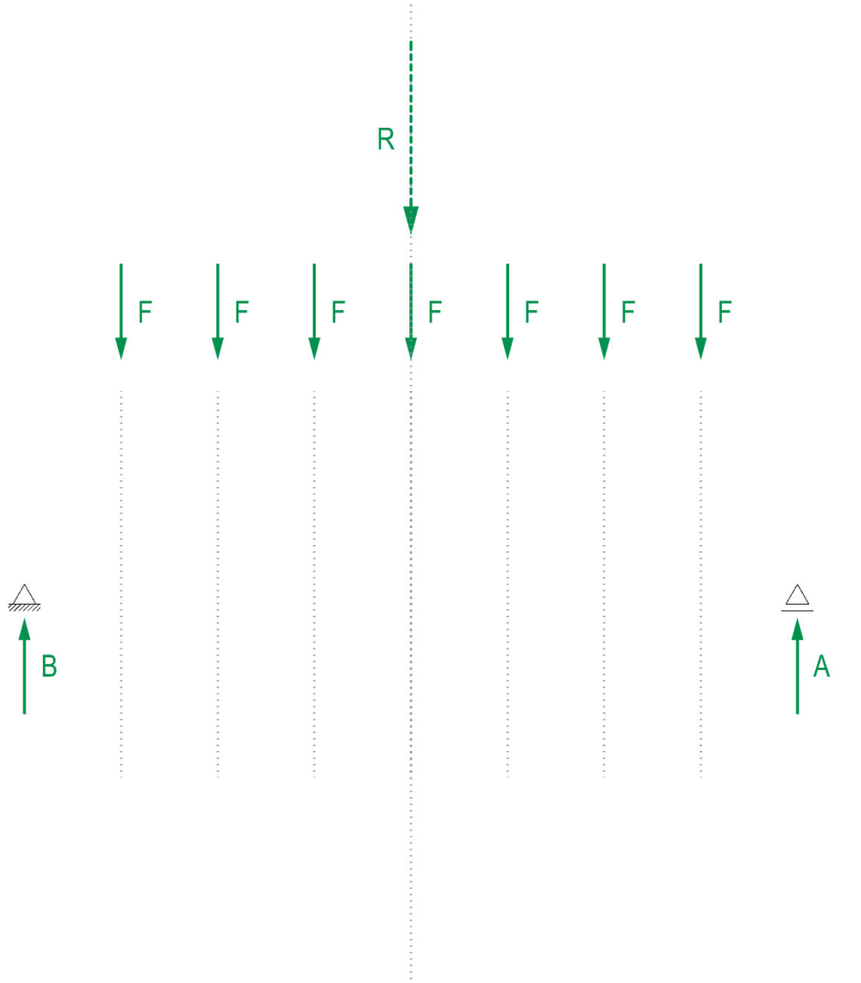

B
A


F
F
F
F
F
F
F
B
A

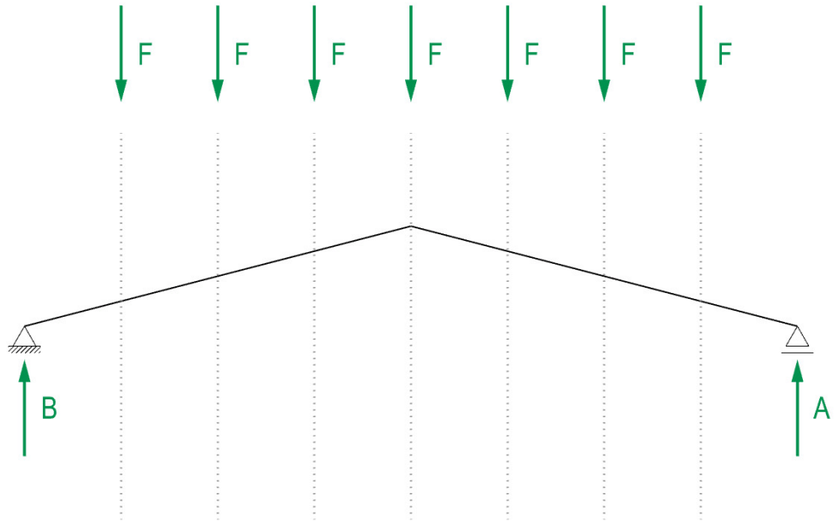

B
A

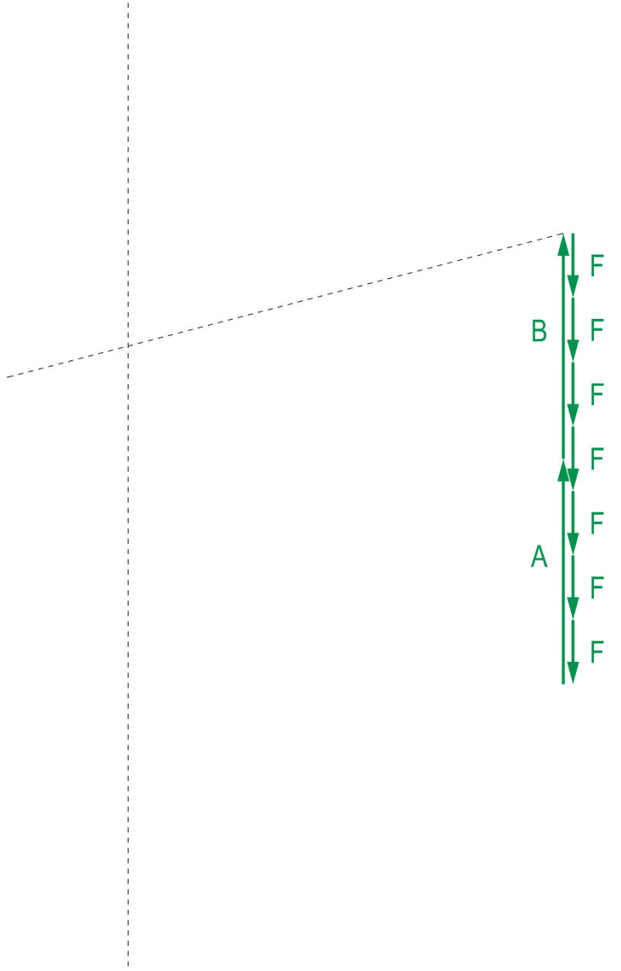

F
F
F
F
F
F
F

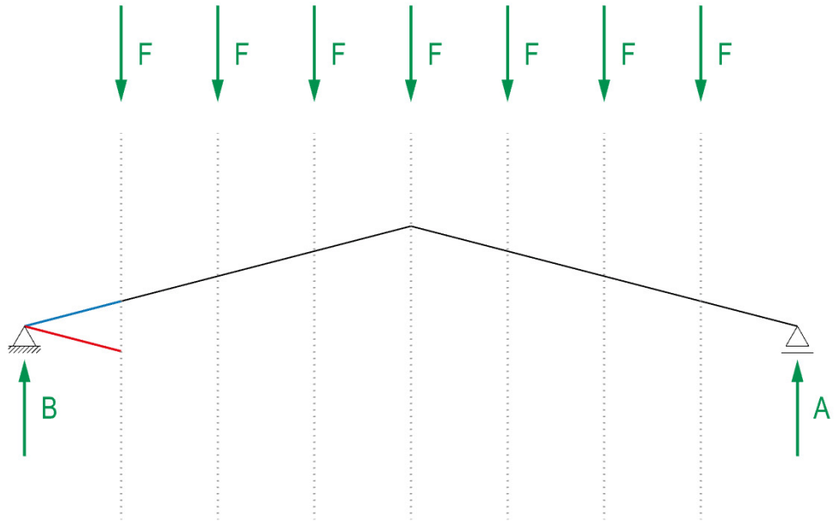

R
F
F
F
F
F
F
F
R

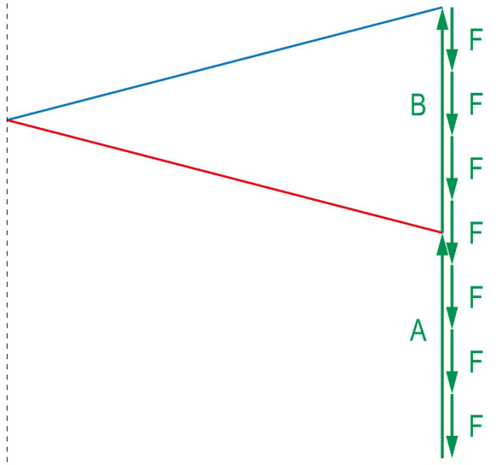

R
F
F
F
F
F
F
F
B
A

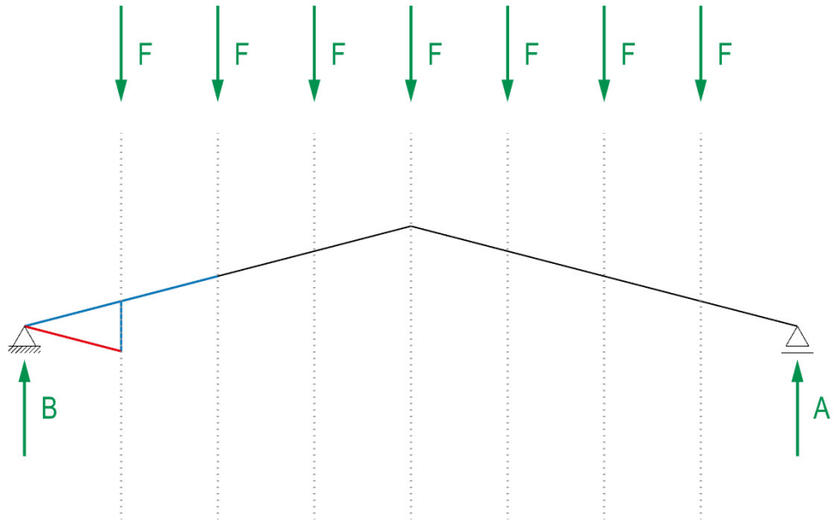

B
R
A

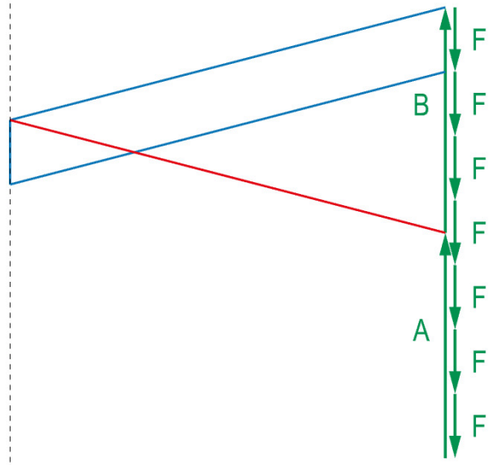

F
F
F
F
F
F
F
B
A

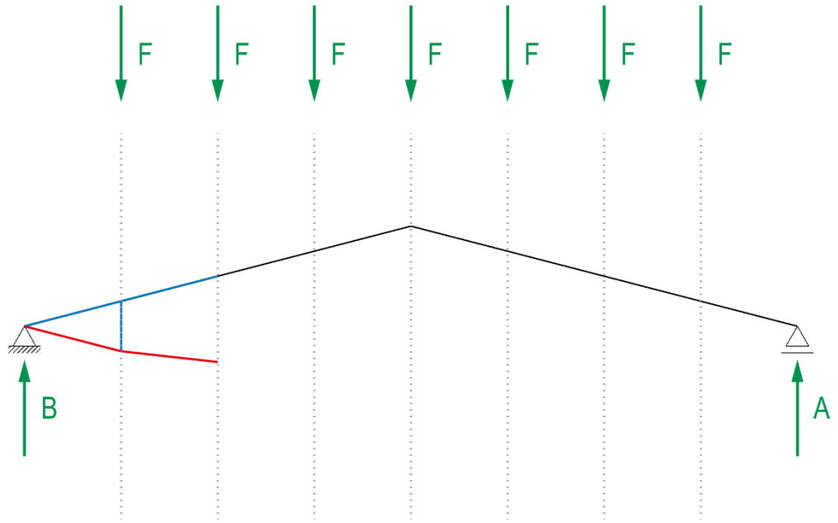

F
B
F
F
F
A
F
F
F

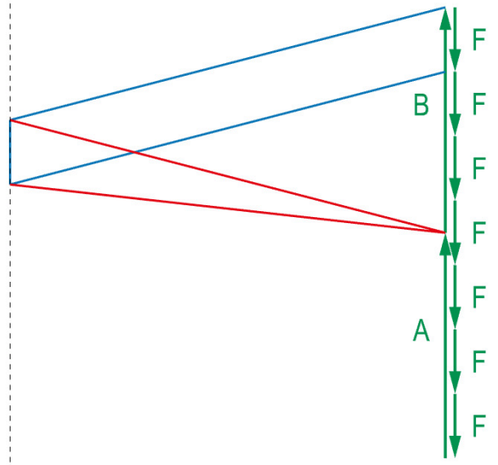

F
F
F
F
F
F
F
B
A

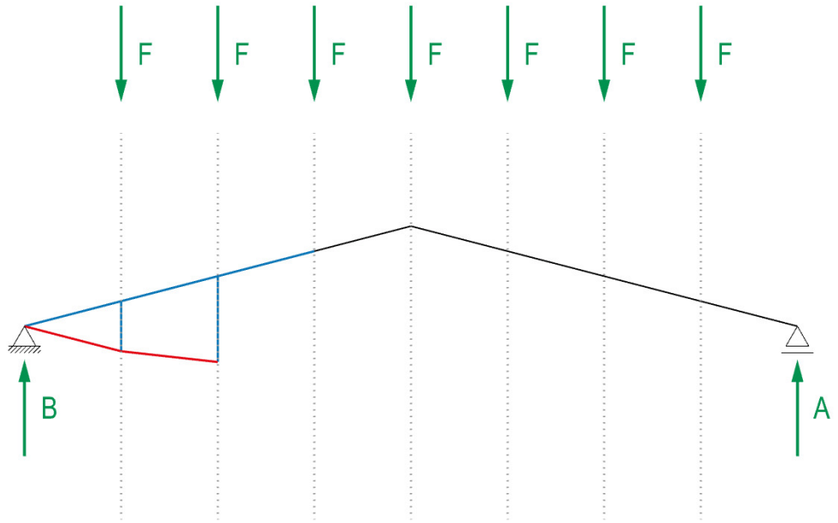

F
B
F
F
F
A
F
F
F

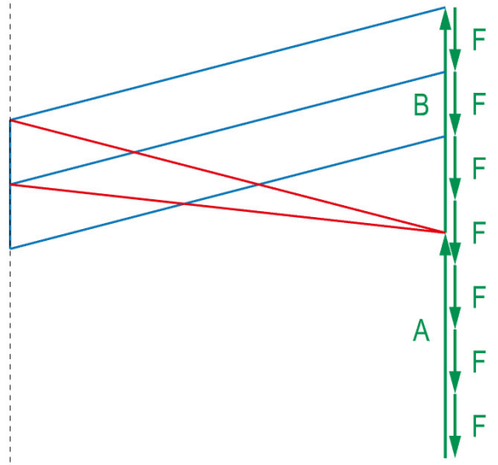

F
F
F
F
F
F
F
B
A

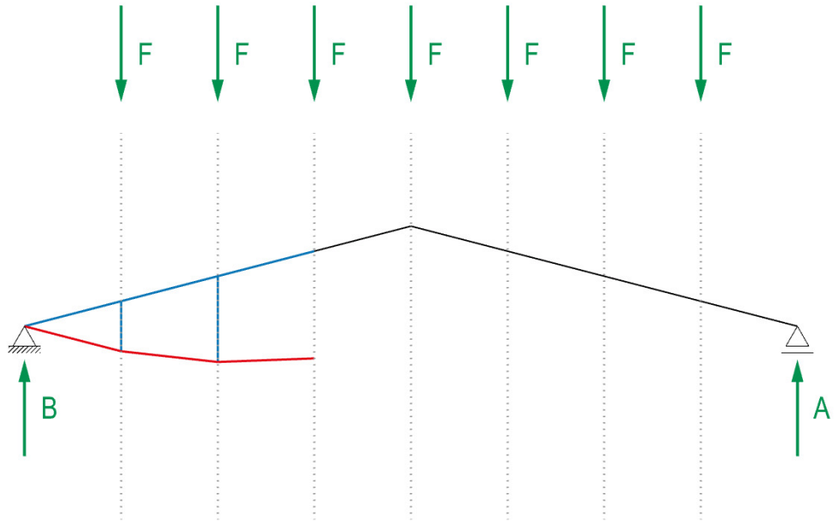

F
B
F
F
F
A
F
F
F

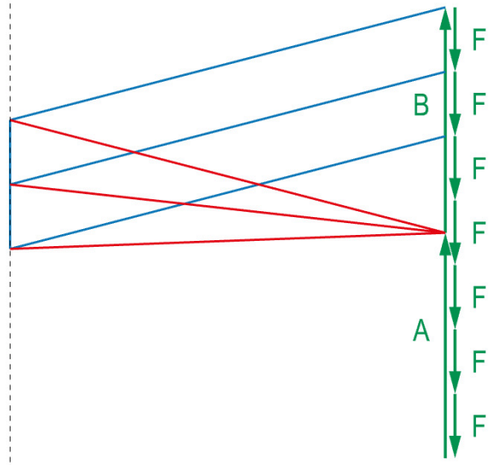

F
F
F
F
F
F
F
B
A

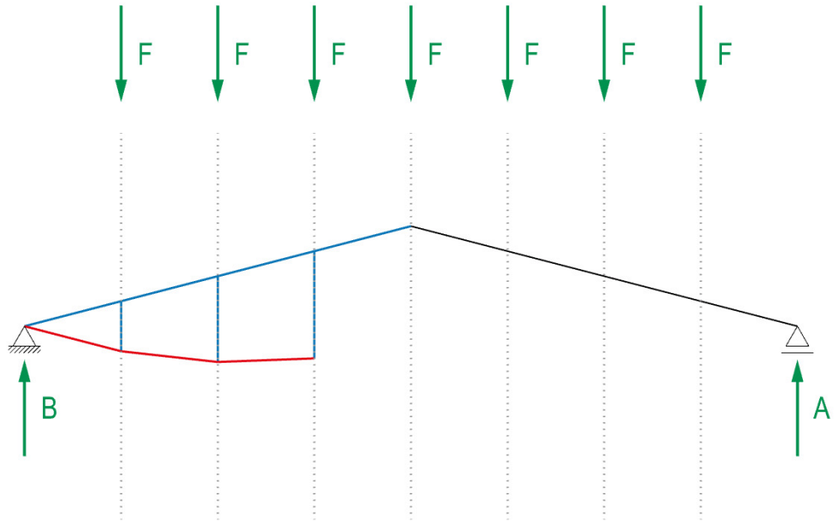

F
B
F
F
F
A
F
F
F

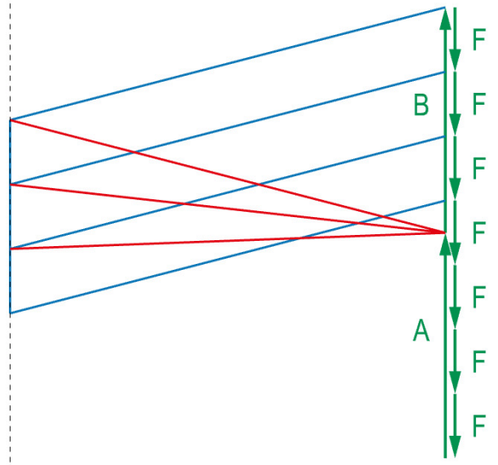

F
F
F
F
F
F
F
B
A

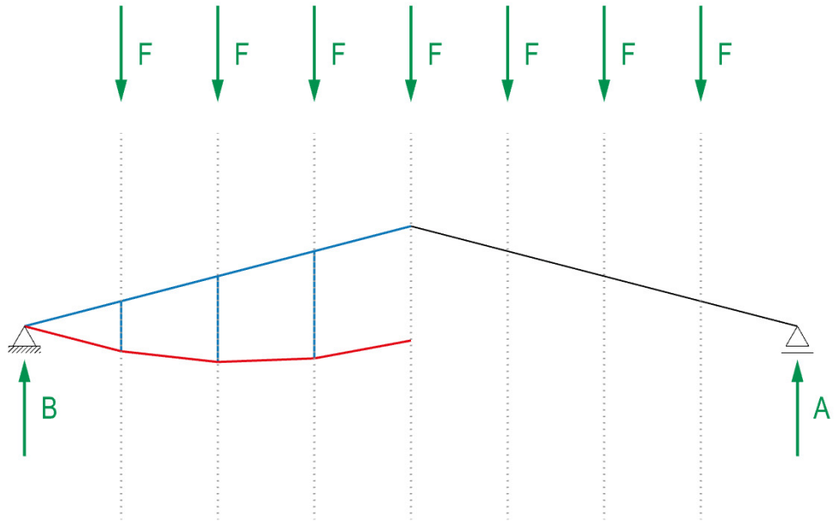

F
B
F
F
F
A
F
F

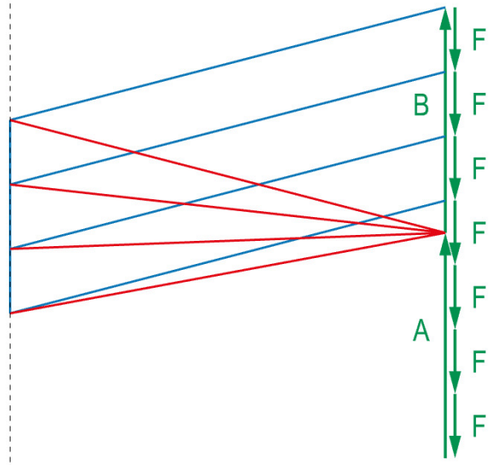

F
F
F
F
F
F
F
B
A

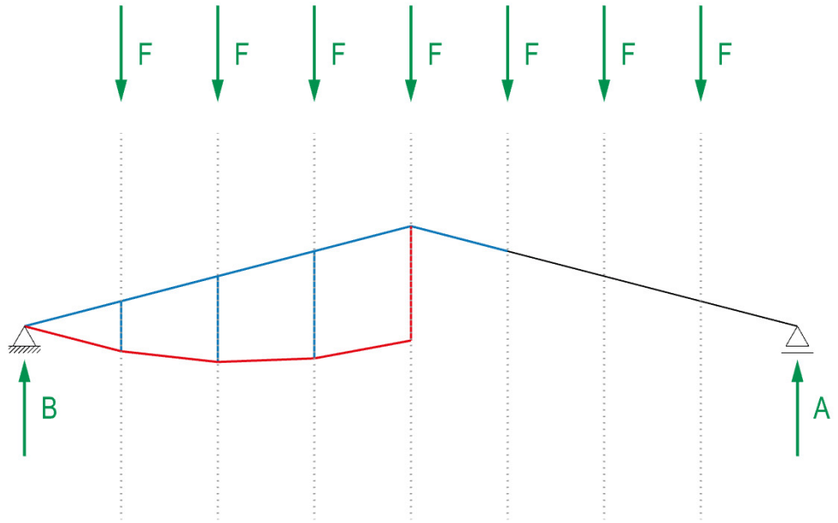

F
B
F
F
F
A
F
F

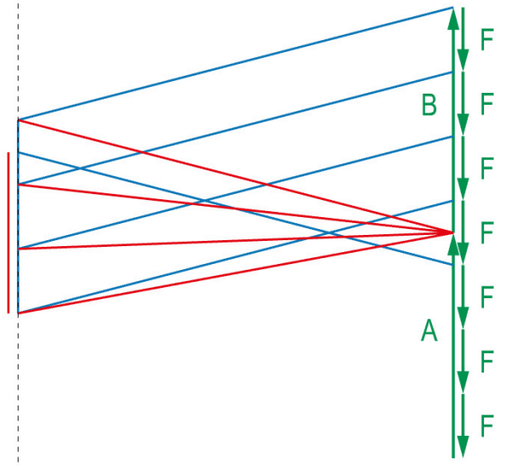

F
F
F
F
F
F
F
B
A

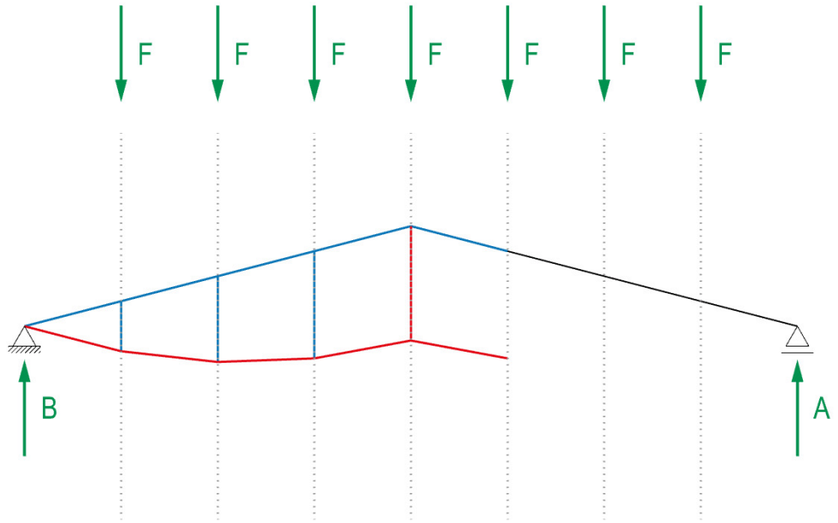

F
B
F
F
F
A
F
F

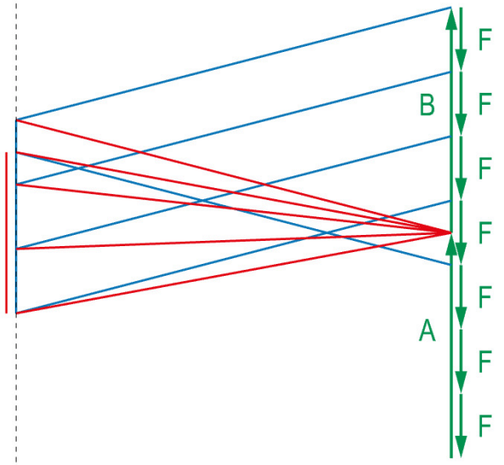

F
F
F
F
F
F
F
B
A

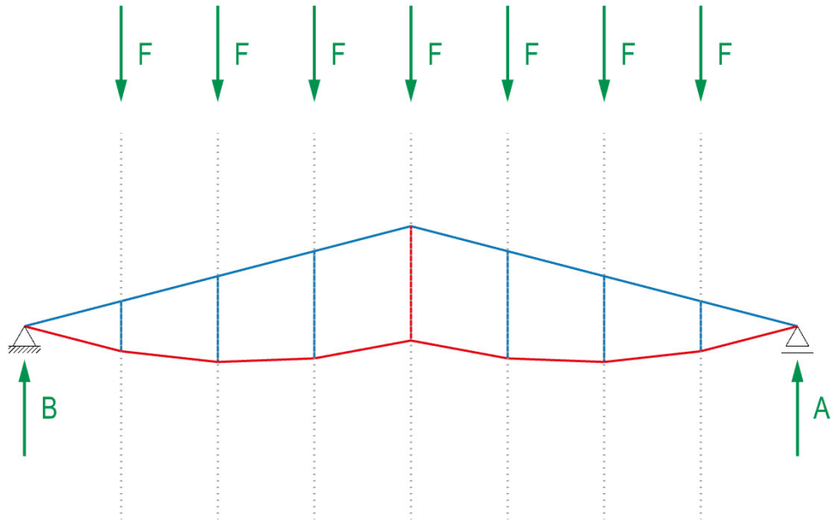

F
B
F
F
F
A
F
F

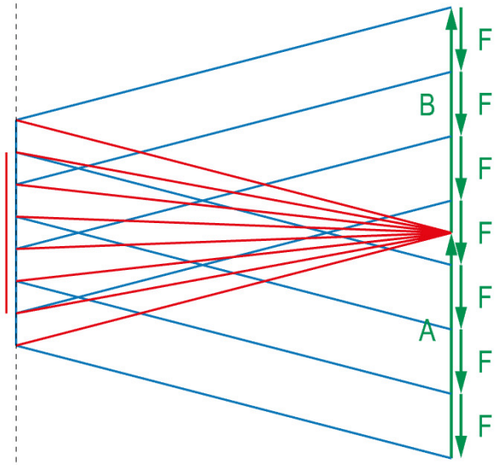

F
F
F
F
F
F
F
B
A


F
B
F
F
F
A
F
F


F
F
F
F
F
F
F
B
A

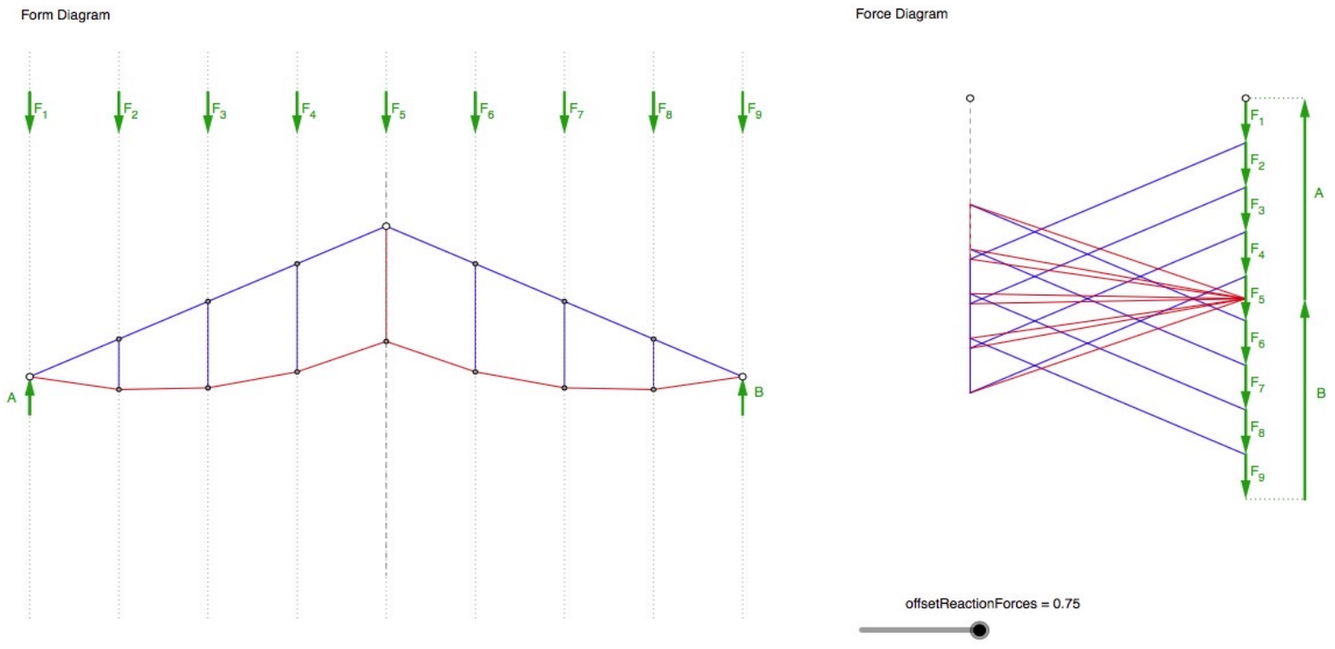

F
B
F
F
F
A
F
F


F
F
F
F
F
F
F
B
A


F
B
F
F
F
A
F
F

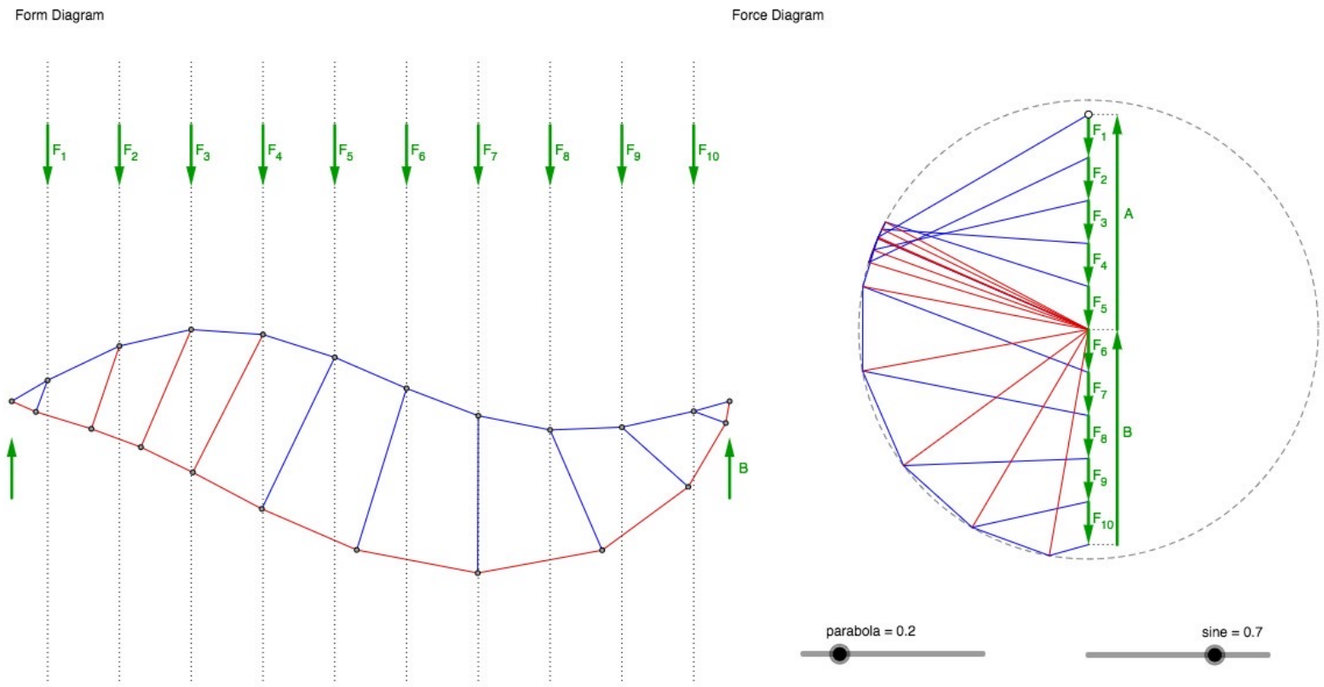
Robert Maillart: Lagerhaus Magazzini Generali, Chiasso, 1925

eQ: Constant-force gable truss



http://www.block.arch.ethz.ch/eq/drawing/view/26

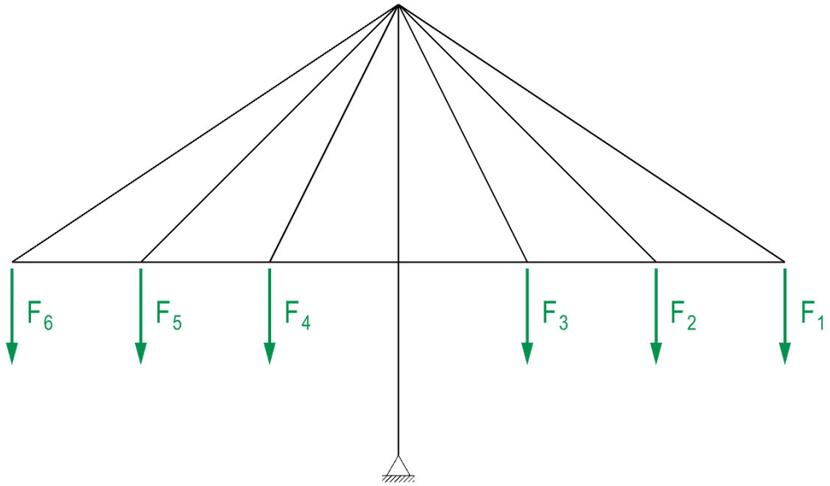
eQ: Freeform truss



http://www.block.arch.ethz.ch/eq/drawing/view/52

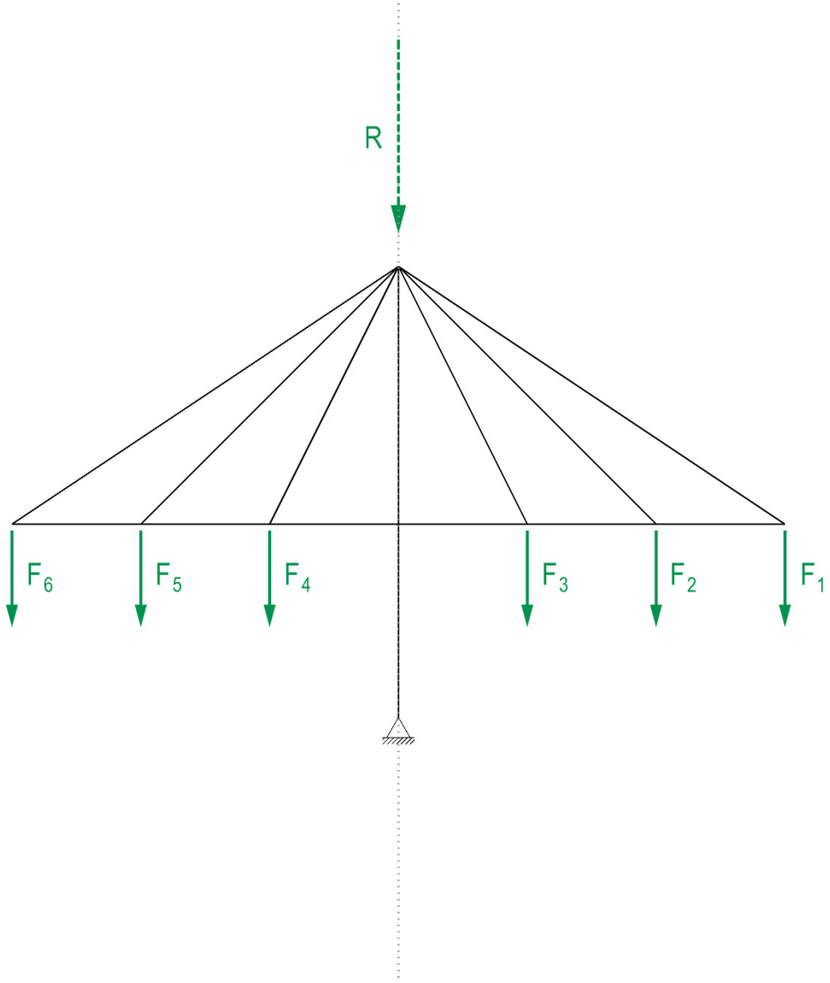
Norman Foster, Michel Virlogeux: Viaduct de Millau, Aveyon, 2004

Foster+Partners, Michel Virlogeux: Millau Viaduct, nahe Montpellier, France, 2004



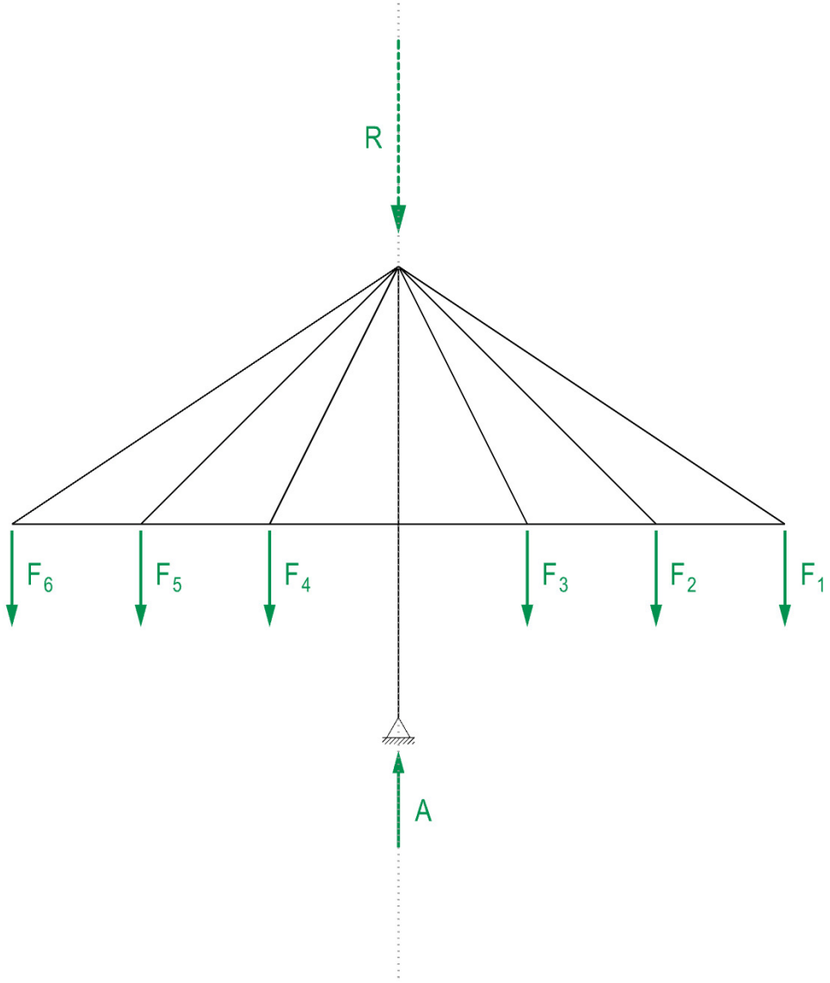
Lageplan 1:100
Form diagram 1:100

Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



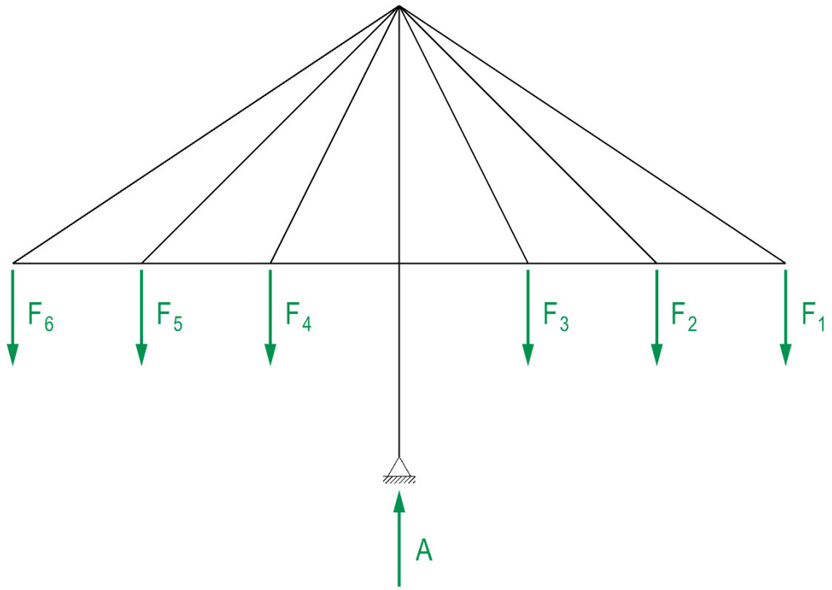
Lageplan 1:100
Form diagram 1:100

Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

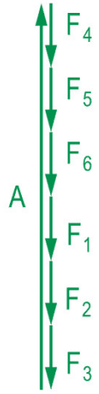


Lageplan 1:100
Form diagram 1:100

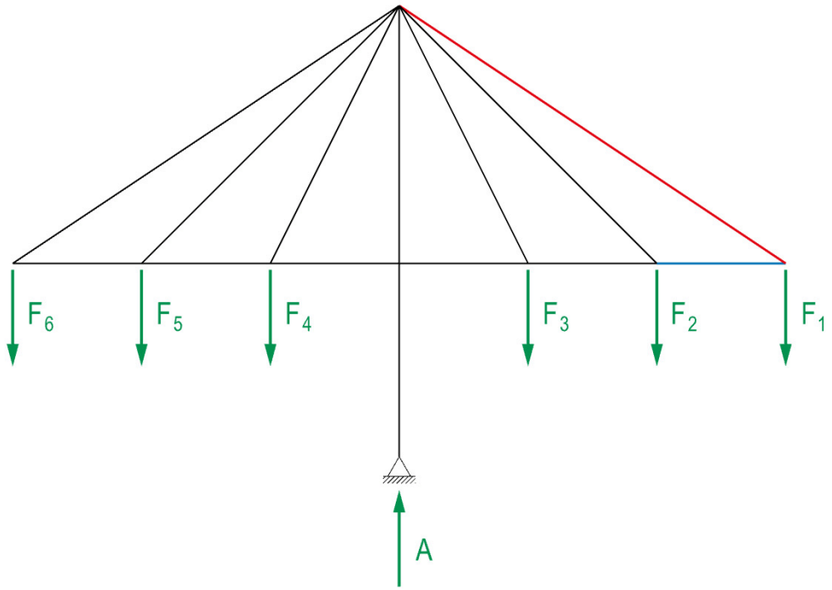
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



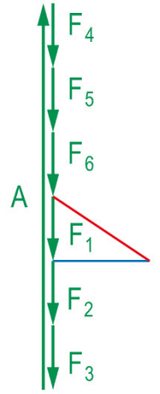
Lageplan 1:100
Form diagram 1:100



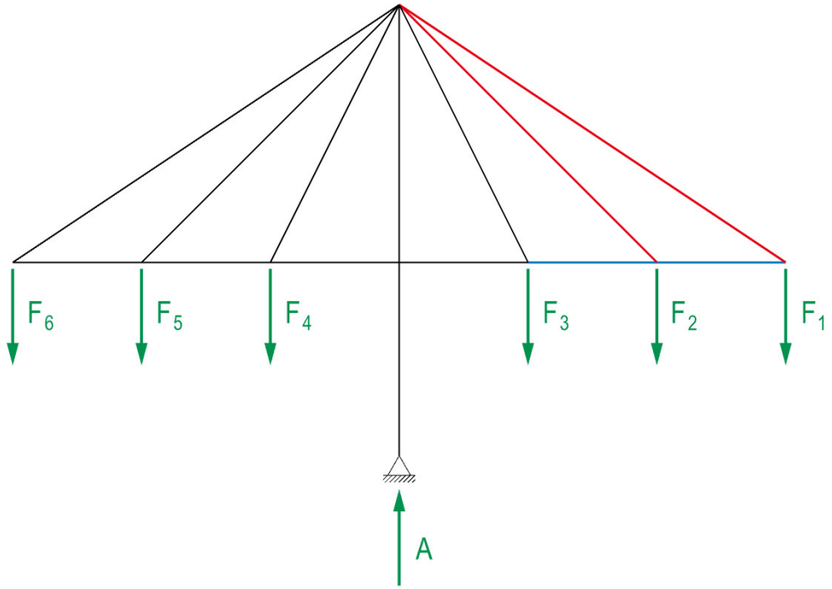
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



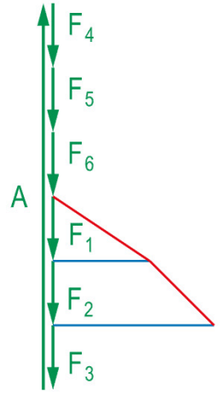
Lageplan 1:100
Form diagram 1:100



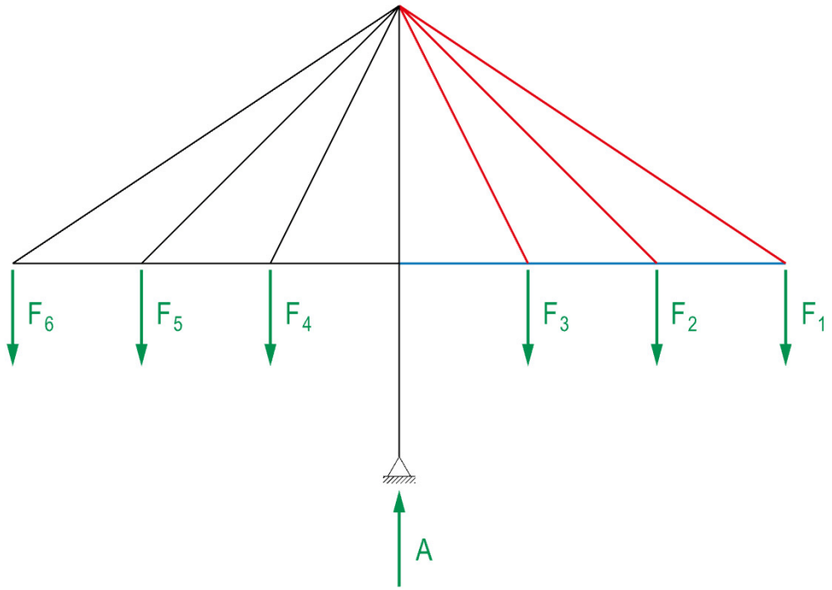
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



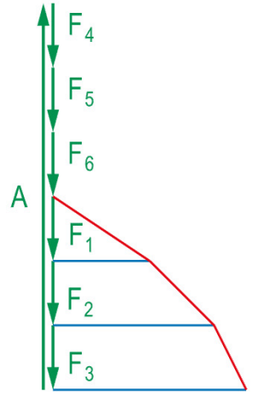
Lageplan 1:100
Form diagram 1:100



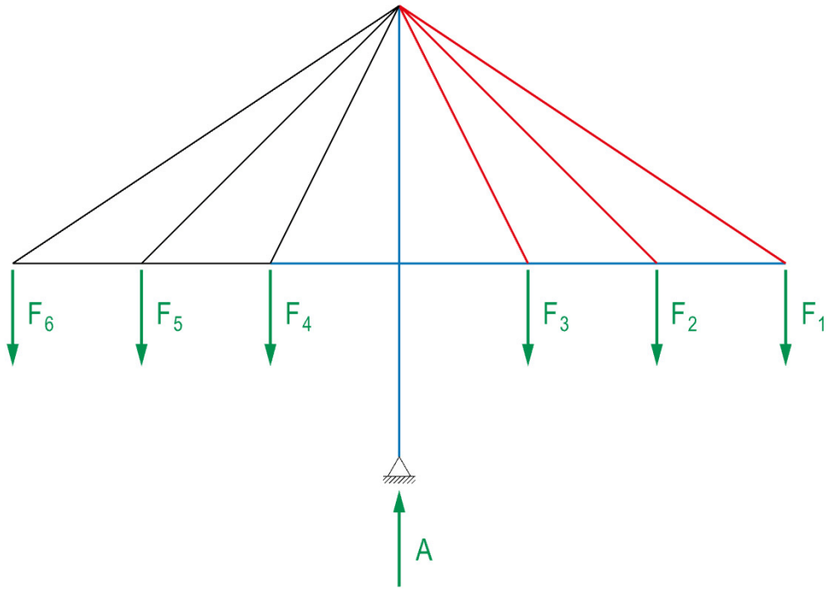
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



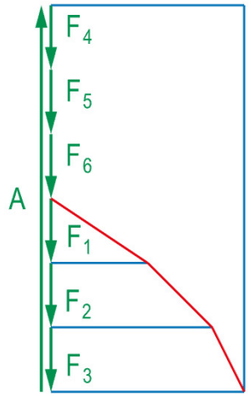
Lageplan 1:100
Form diagram 1:100



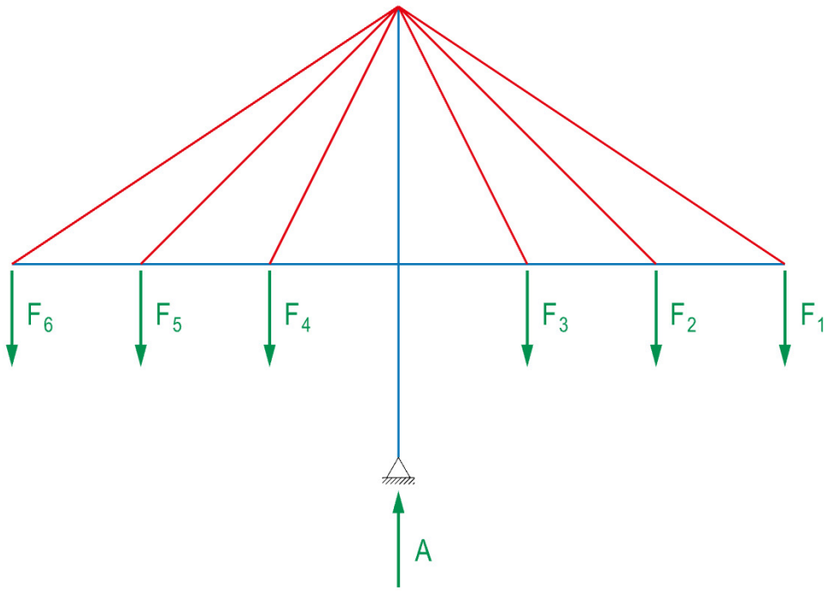
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



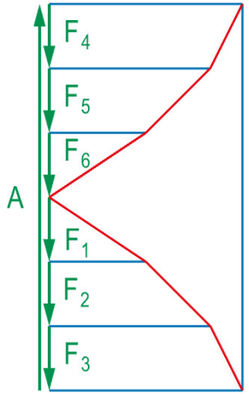
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

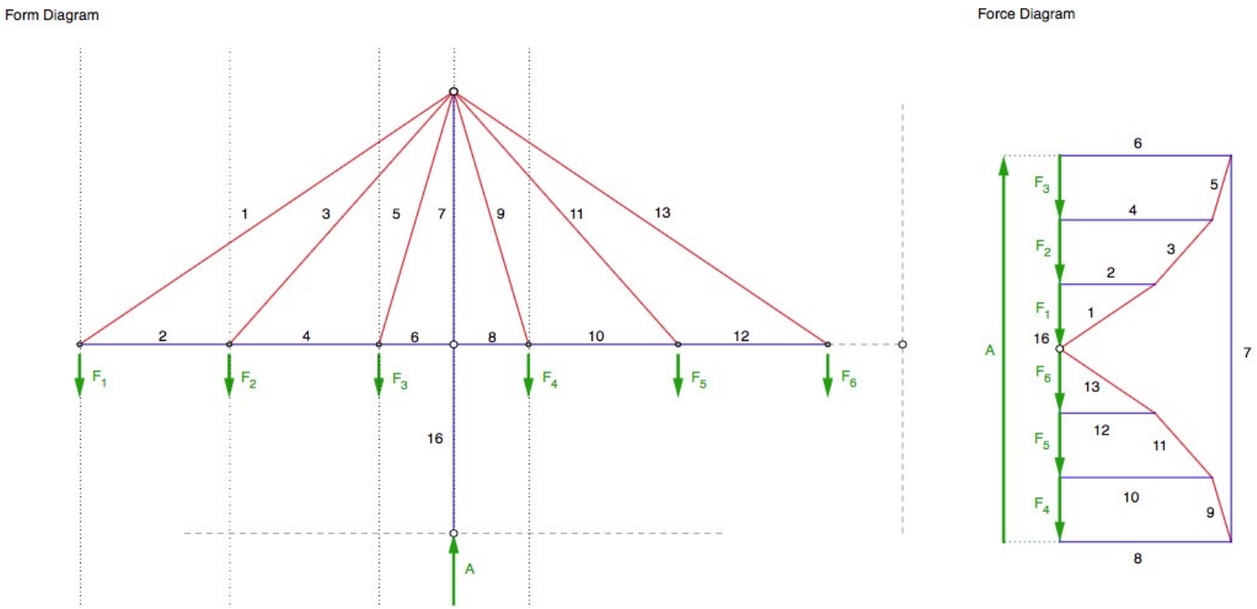


Lageplan 1:100
Form diagram 1:100

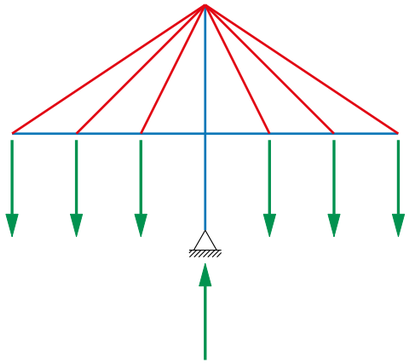


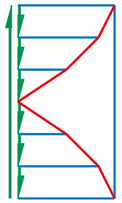
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

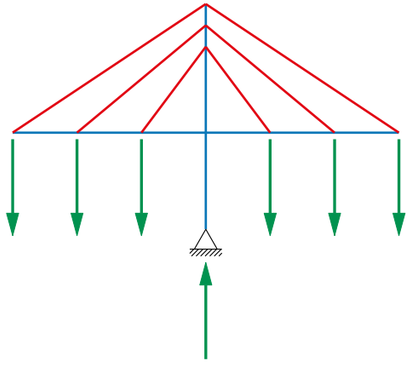
eQ: Fan-harp bridge

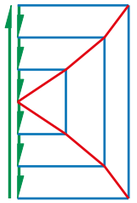


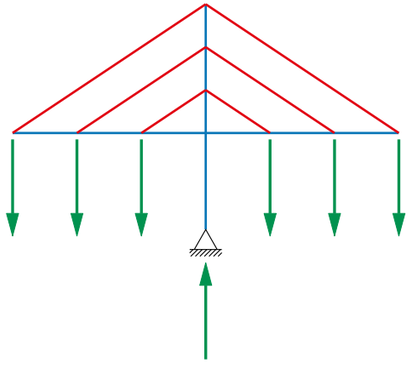
http://www.block.arch.ethz.ch/eq/drawing/view/21

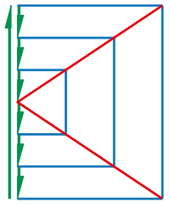






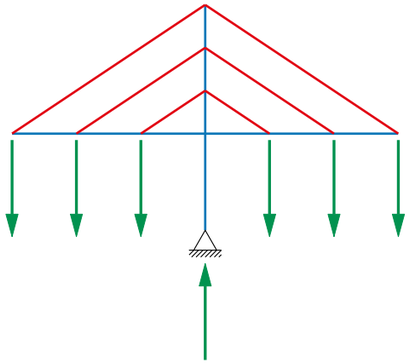


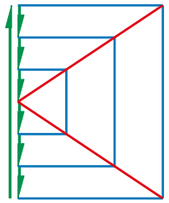


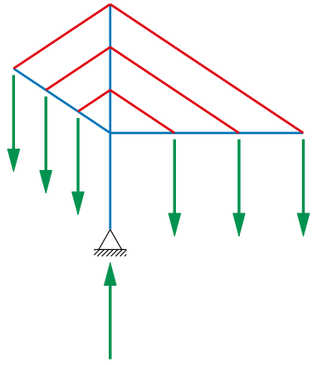


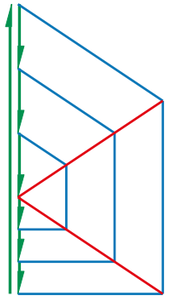
Christian Menn: Sunnibergbrücke, zwischen Klosters und Serneus, 2005

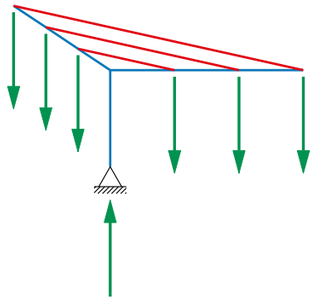
Christian Menn: Sunnibergbrücke, zwischen Klosters und Serneus, 2005

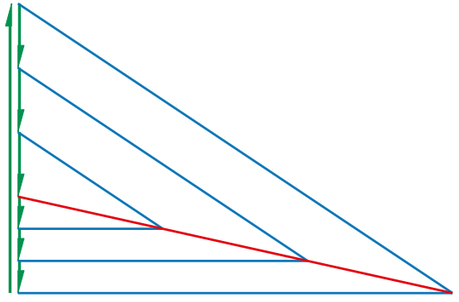






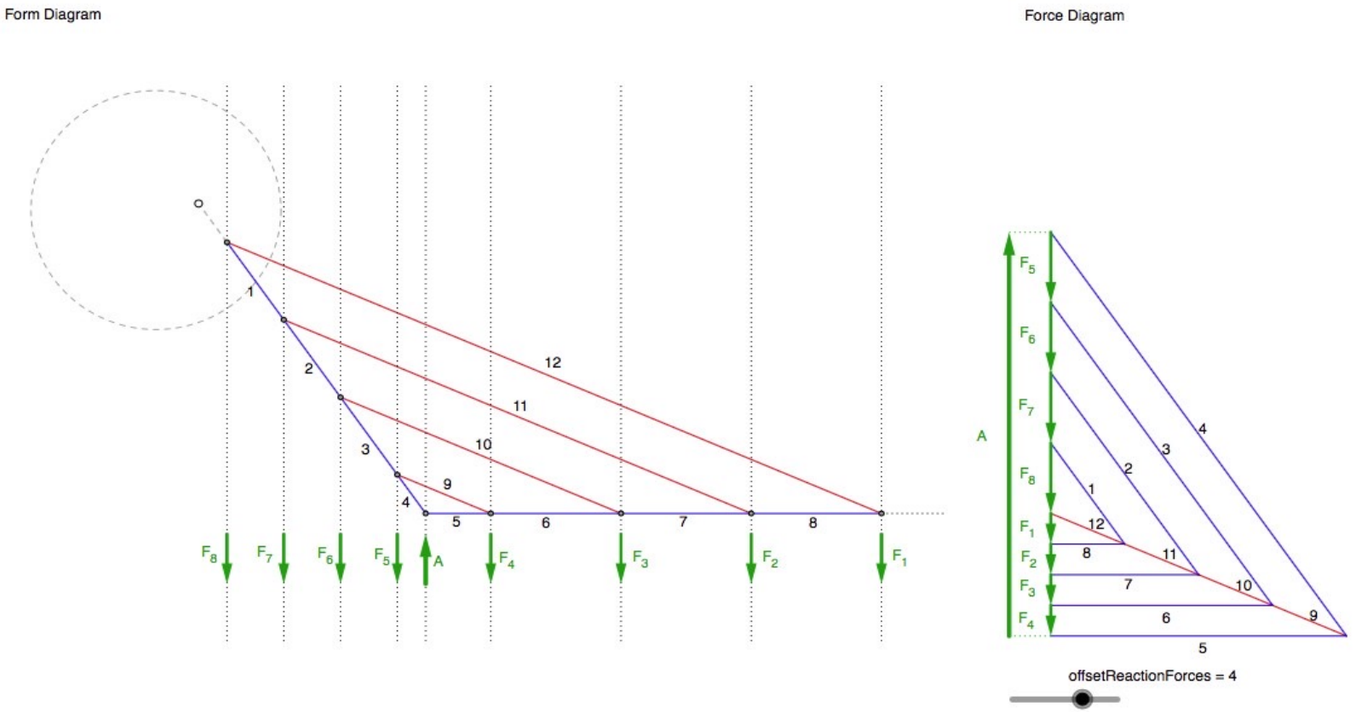






Santiago Calatrava: Alamillo Bridge, Sevilla, 1992

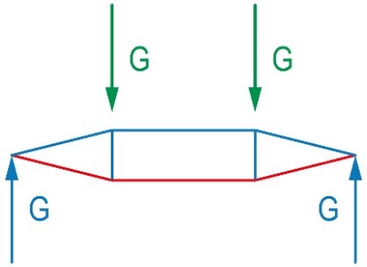
eQ: Cantilevered fan bridge

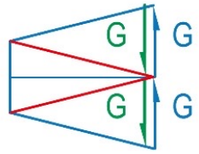


http://www.block.arch.ethz.ch/eq/drawing/view/22

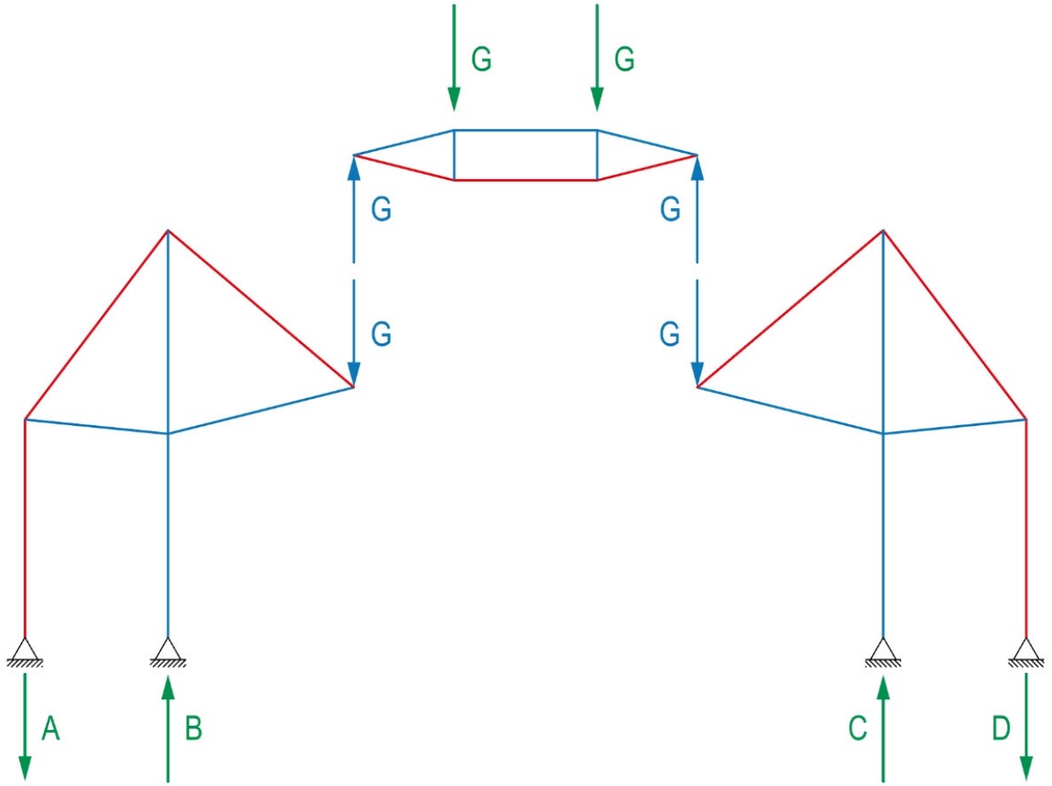
Foster+Partners: Renault Distribution Center, Swindon UK, 1983

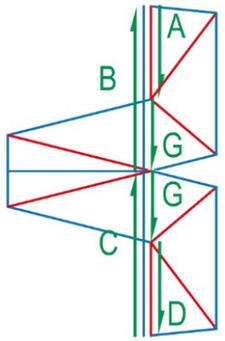
Foster+Partners: Renault Distribution Center, Swindon UK, 1983



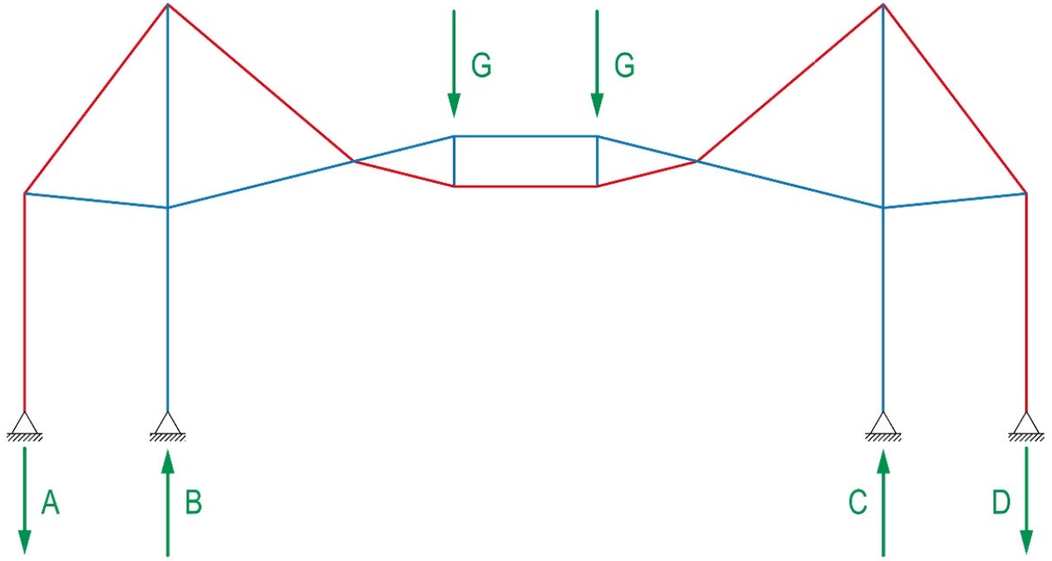


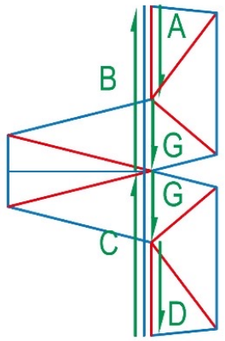
Foster+Partners: Renault Distribution Center, Swindon UK, 1983





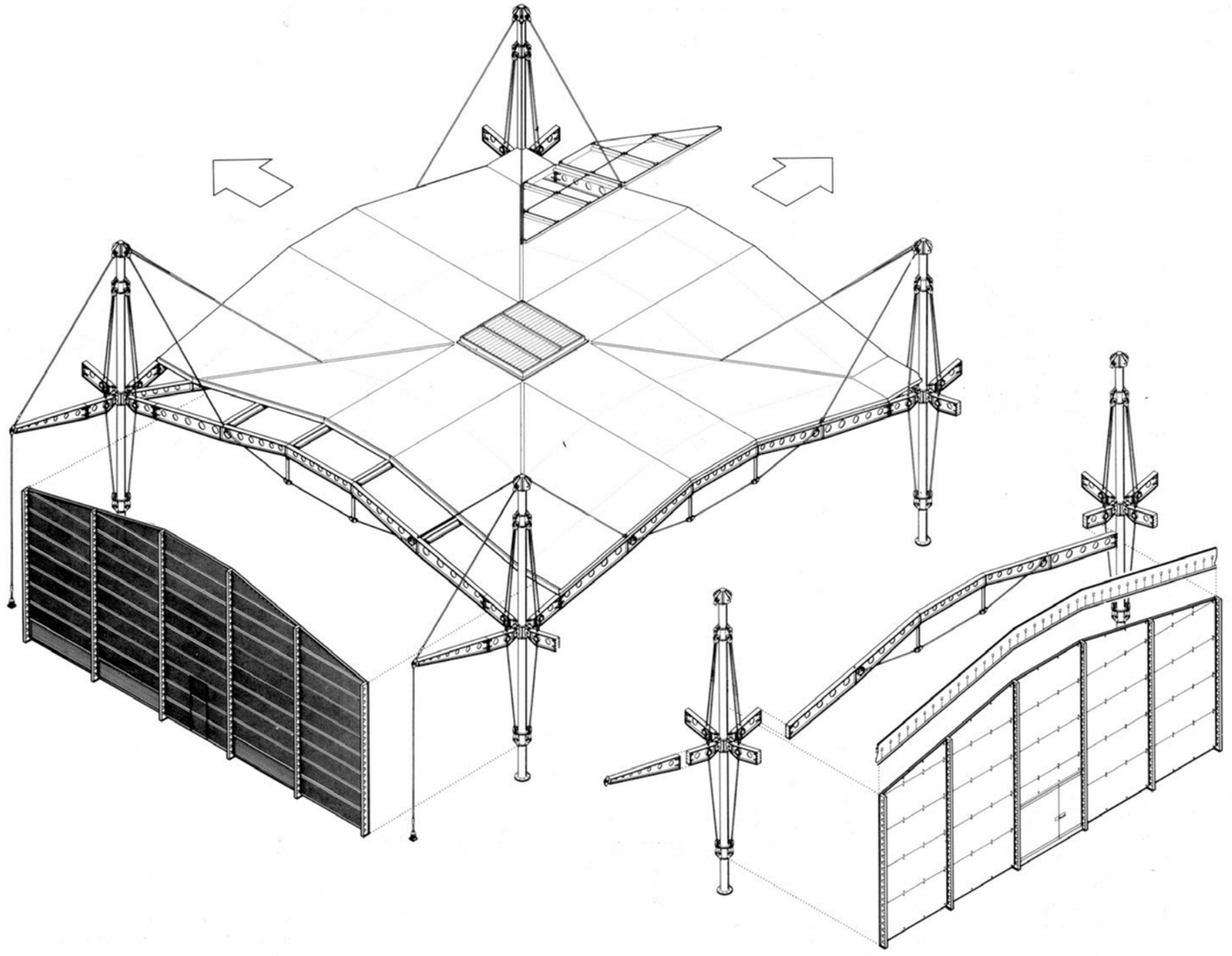
Foster+Partners: Renault Distribution Center, Swindon UK, 1983



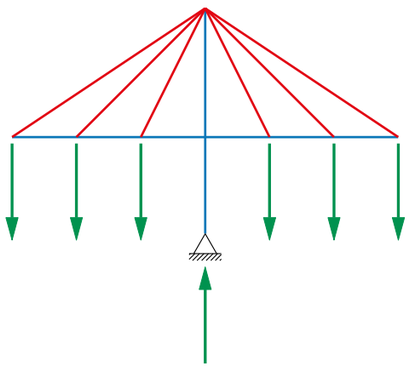


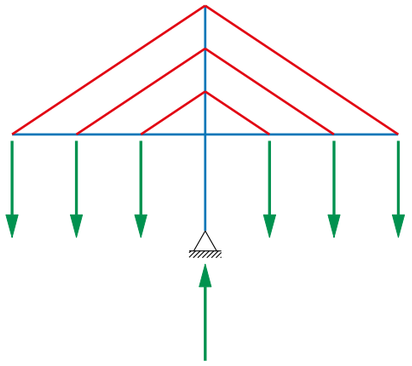
Foster+Partners: Renault Distribution Center, Swindon UK, 1983

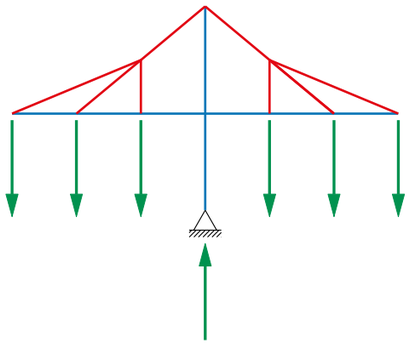
Foster+Partners: Renault Distribution Center, Swindon UK, 1983

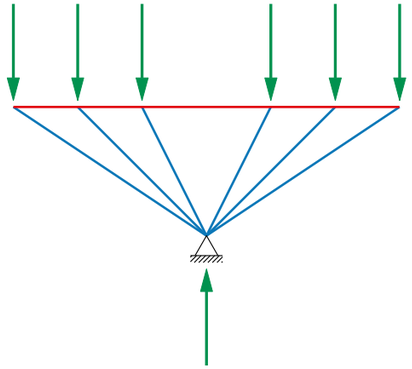


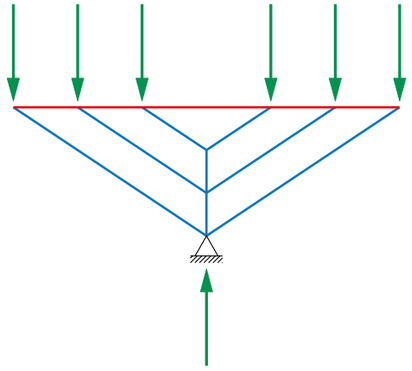
Foster+Partners: Renault Distribution Center, Swindon UK, 1983

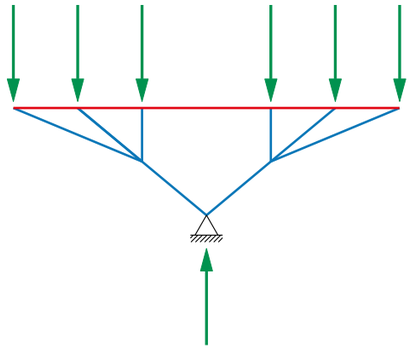




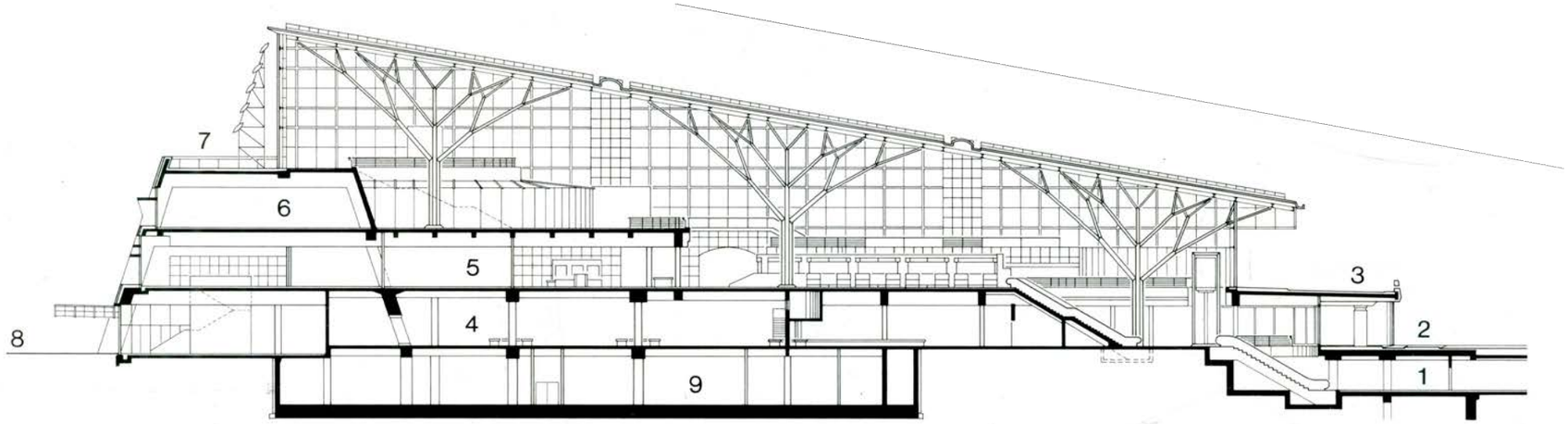




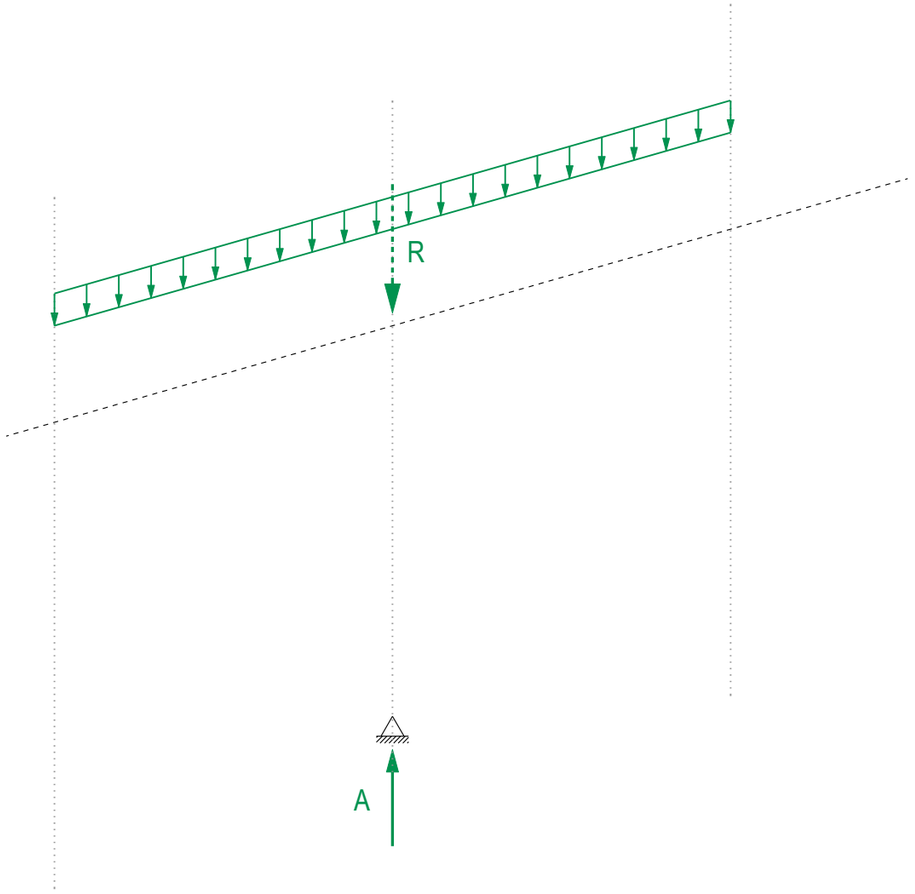




Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004

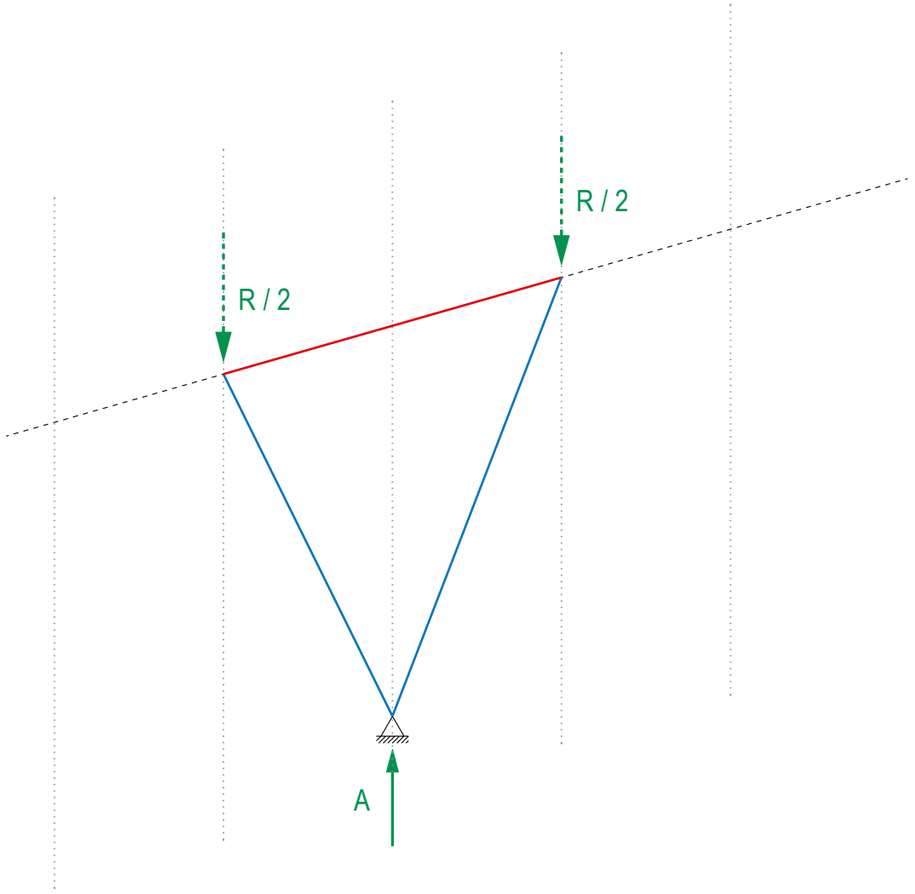


Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004

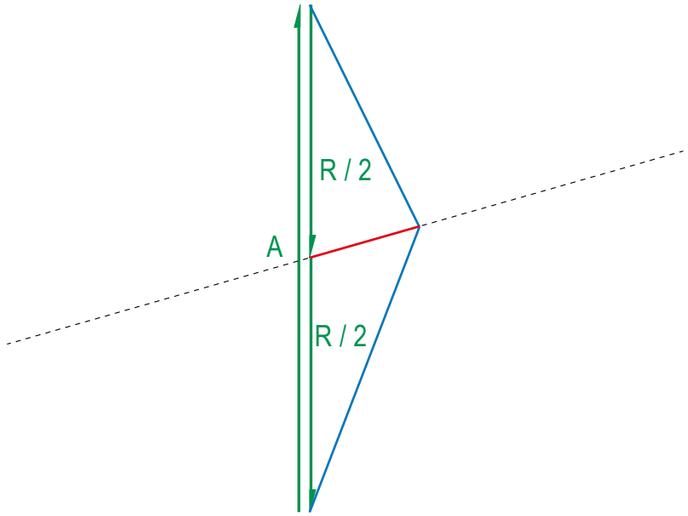


Lageplan 1:100
Form diagram 1:100

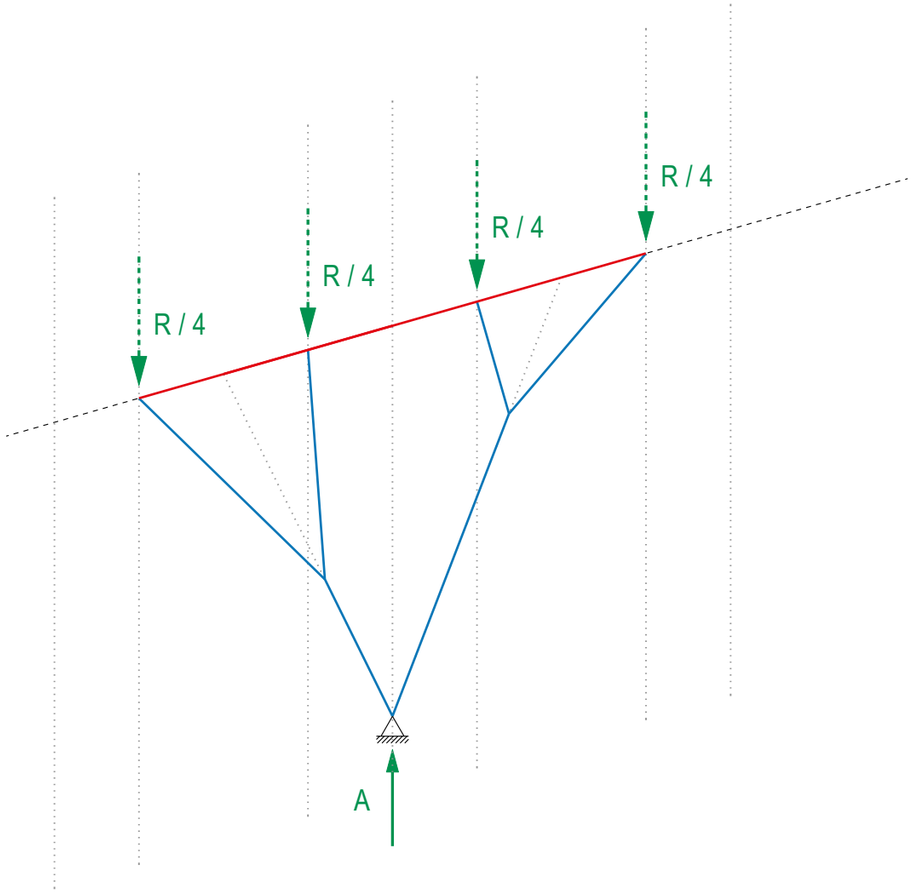
Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN



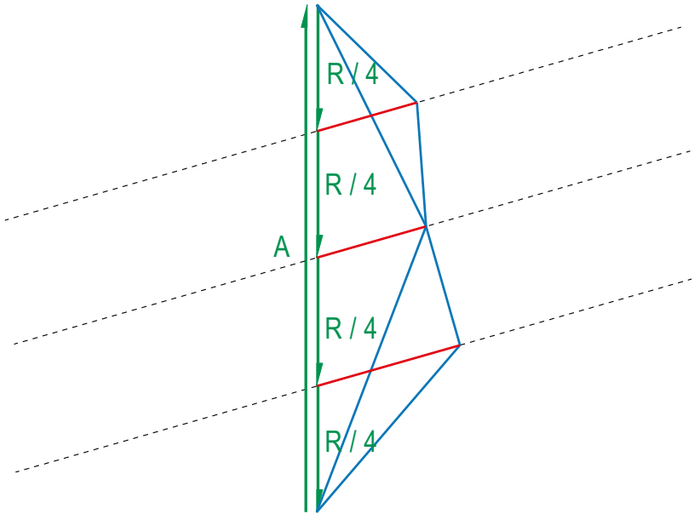
Lageplan 1:100
Form diagram 1:100



Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

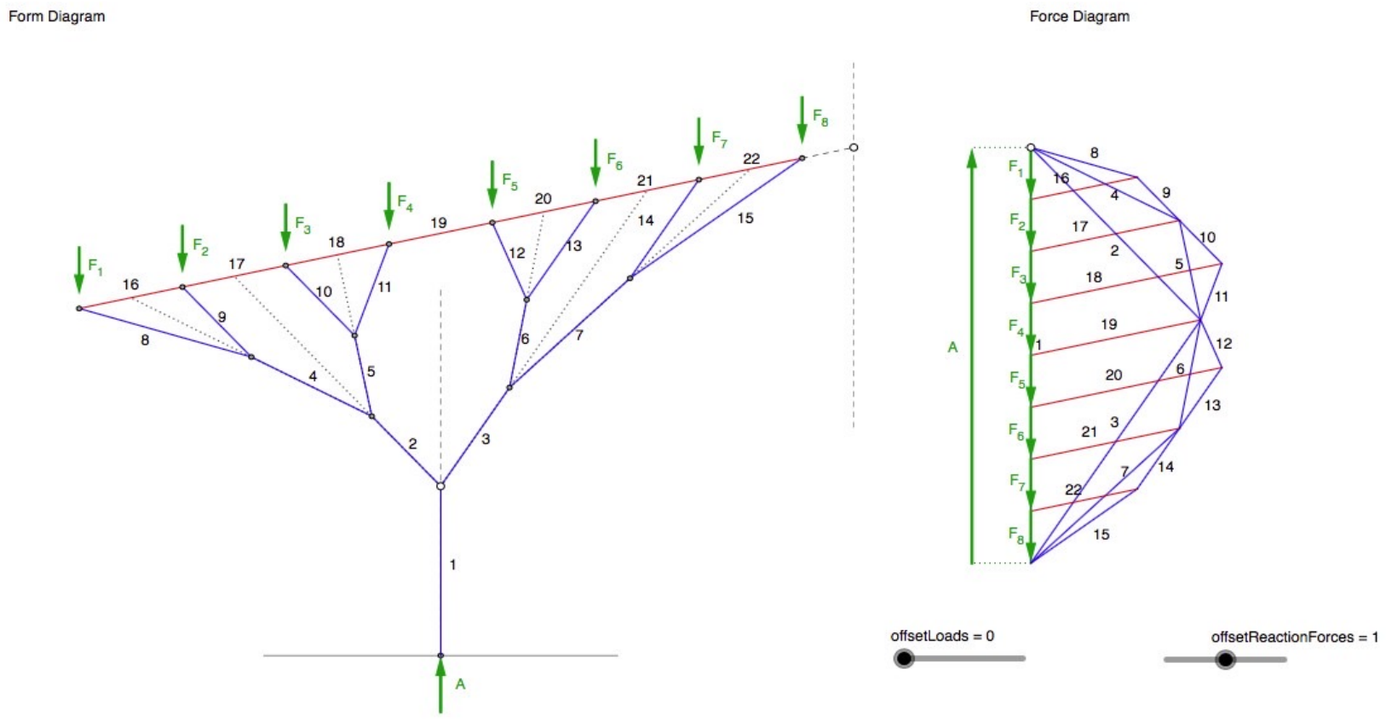


Lageplan 1:100
Form diagram 1:100

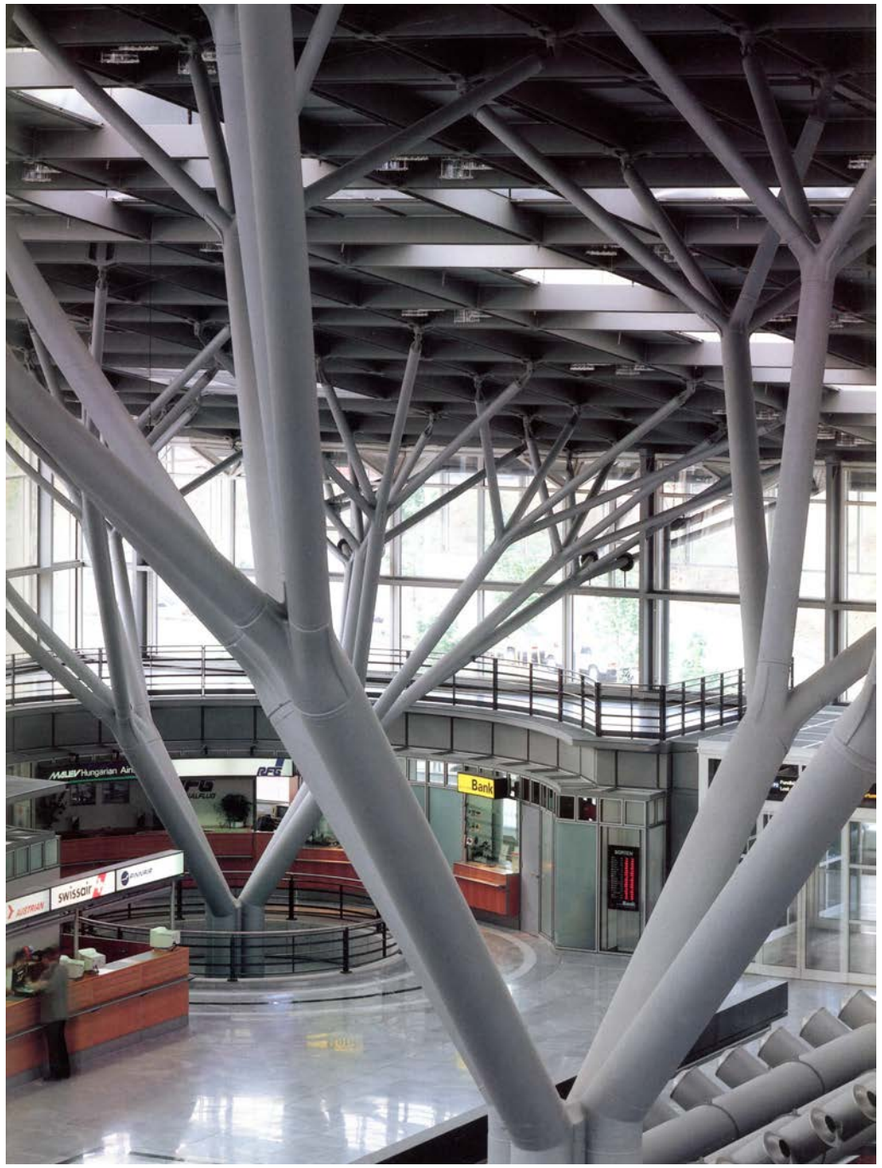


Kräfteplan 1 cm ≙ 1 kN
Force diagram 1 cm ≙ 1 kN

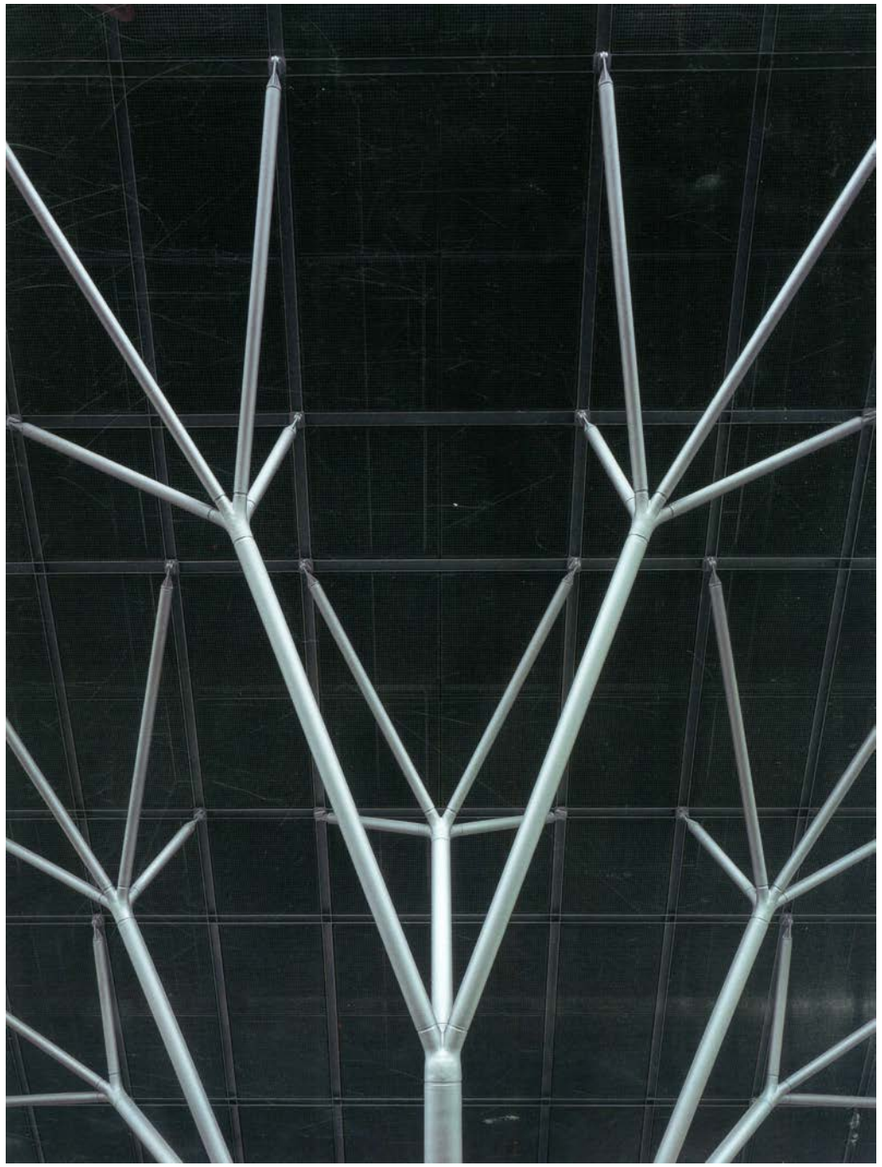
eQ: Tree structure



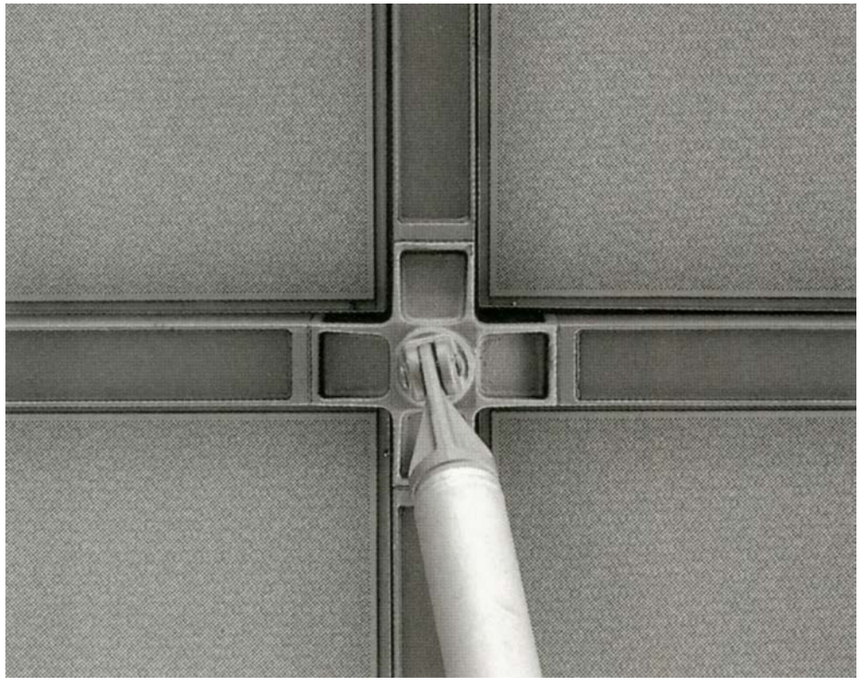
http://www.block.arch.ethz.ch/eq/drawing/view/25



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



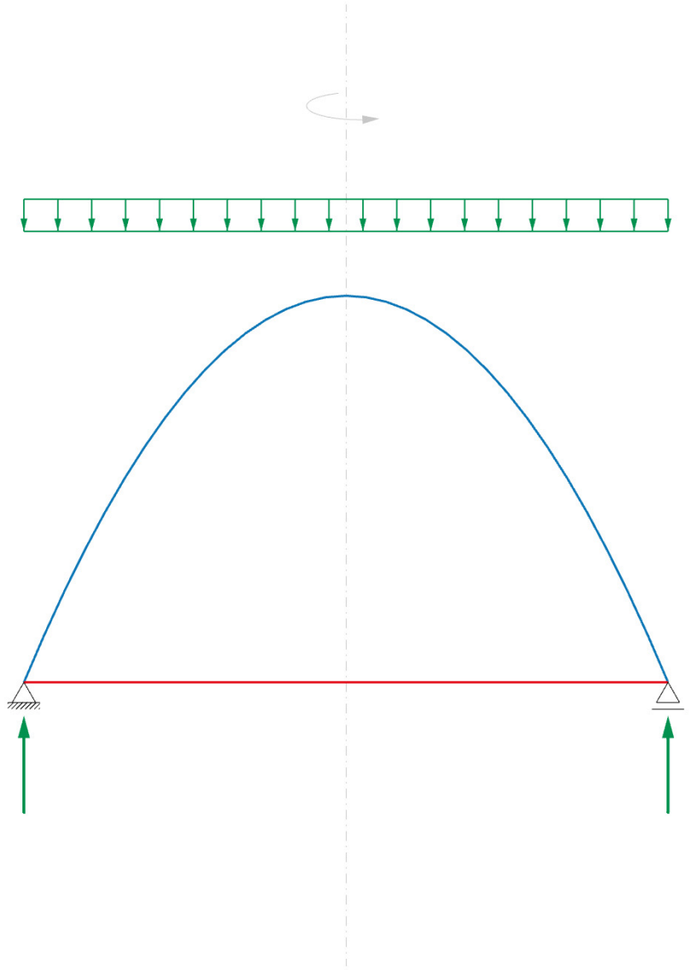
Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004

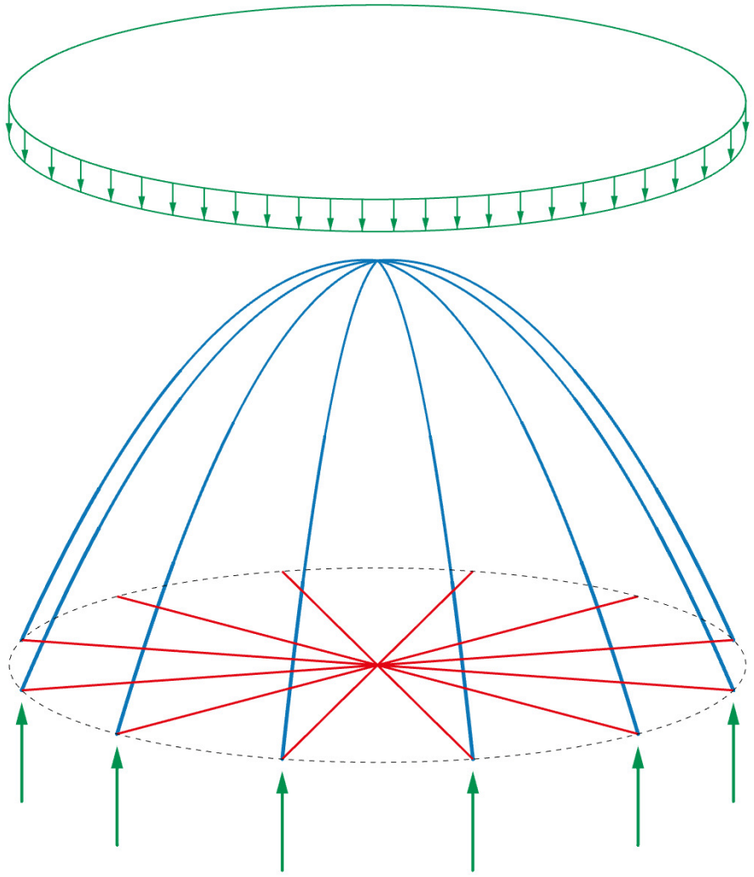


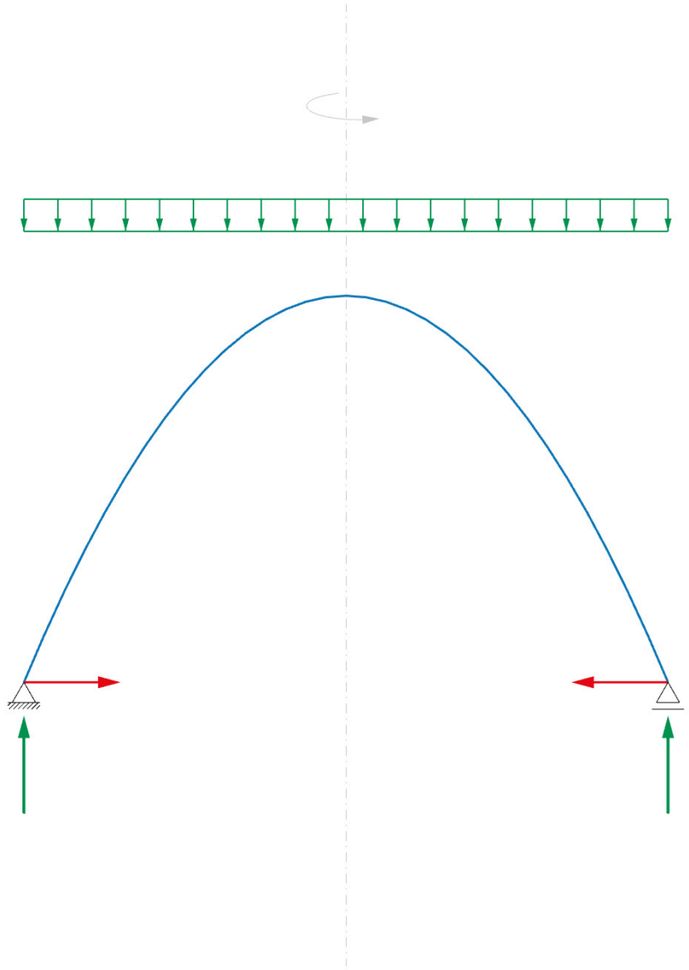
Gerkan, Mark & Partner, Schlaich Bergermann: Stuttgart Airport Terminal 3, 2004

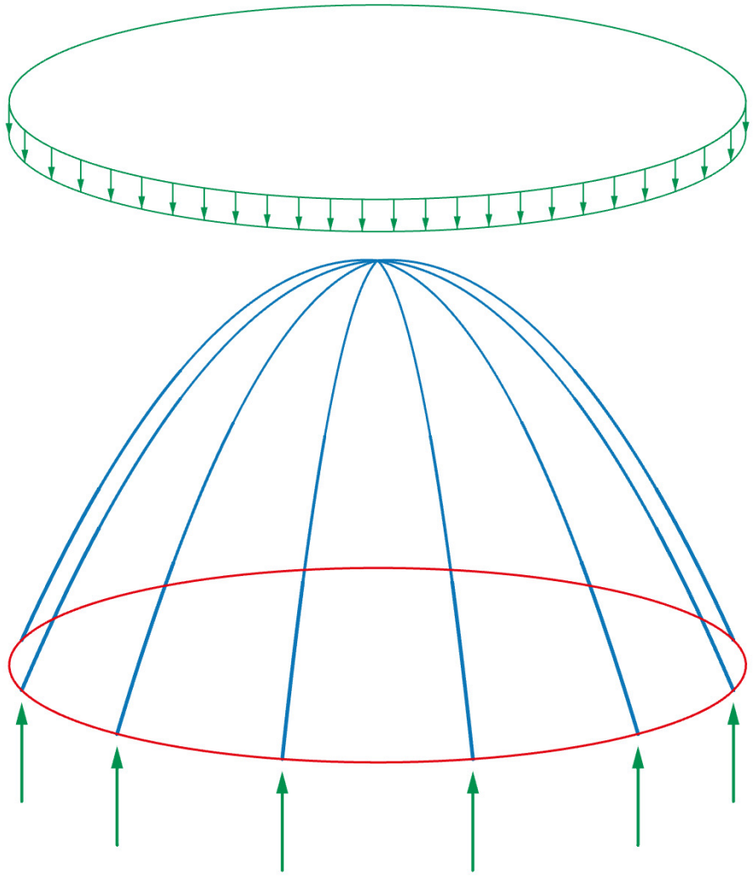
Räumliche Bogen-Seil-Tragwerke

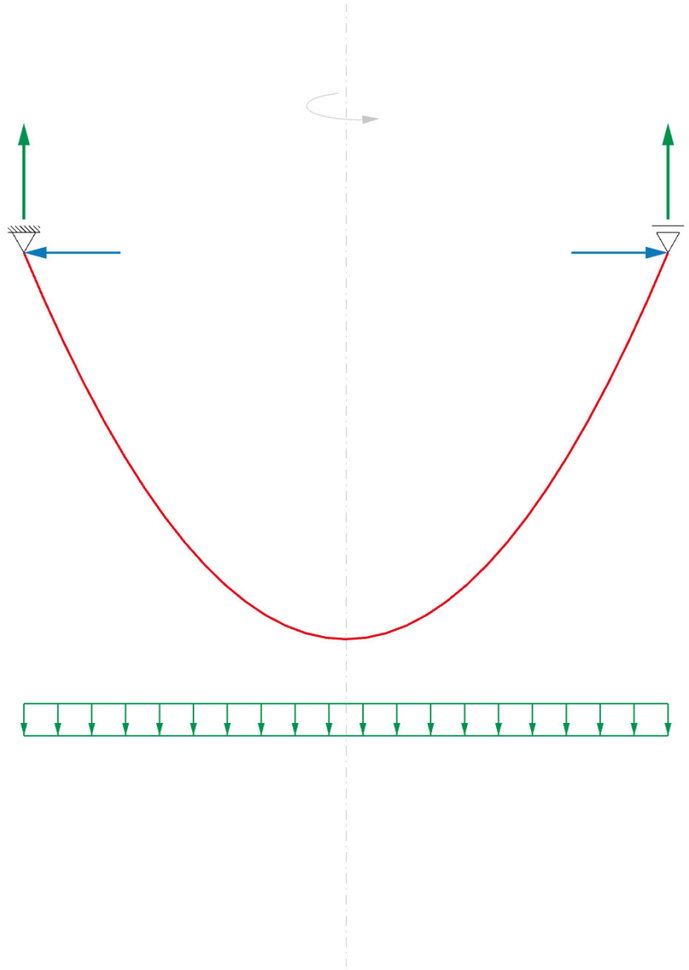
Spatial arch-cable structures

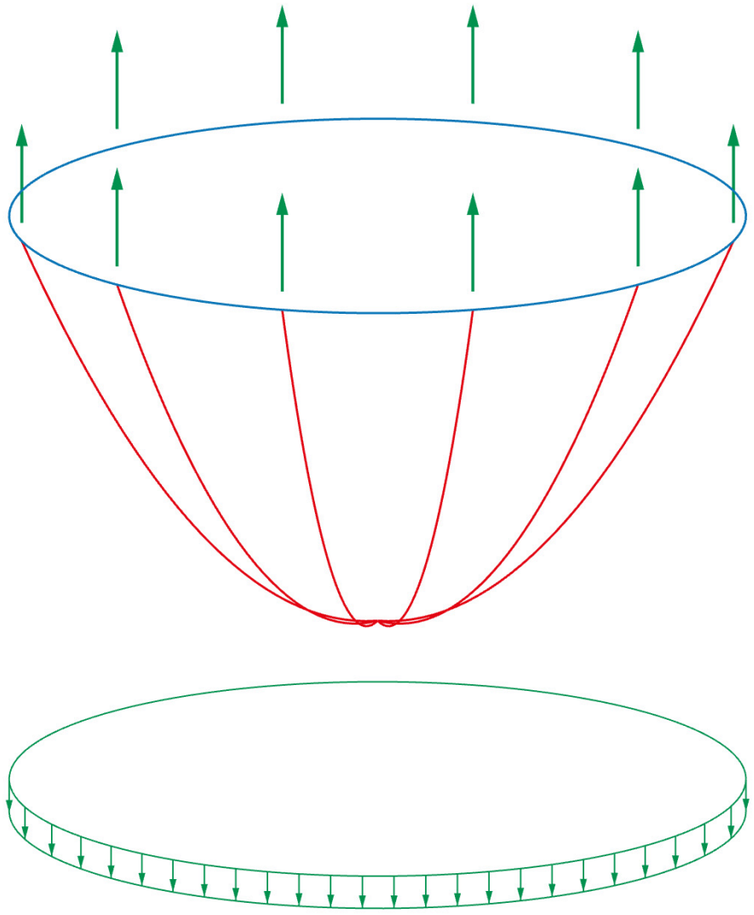


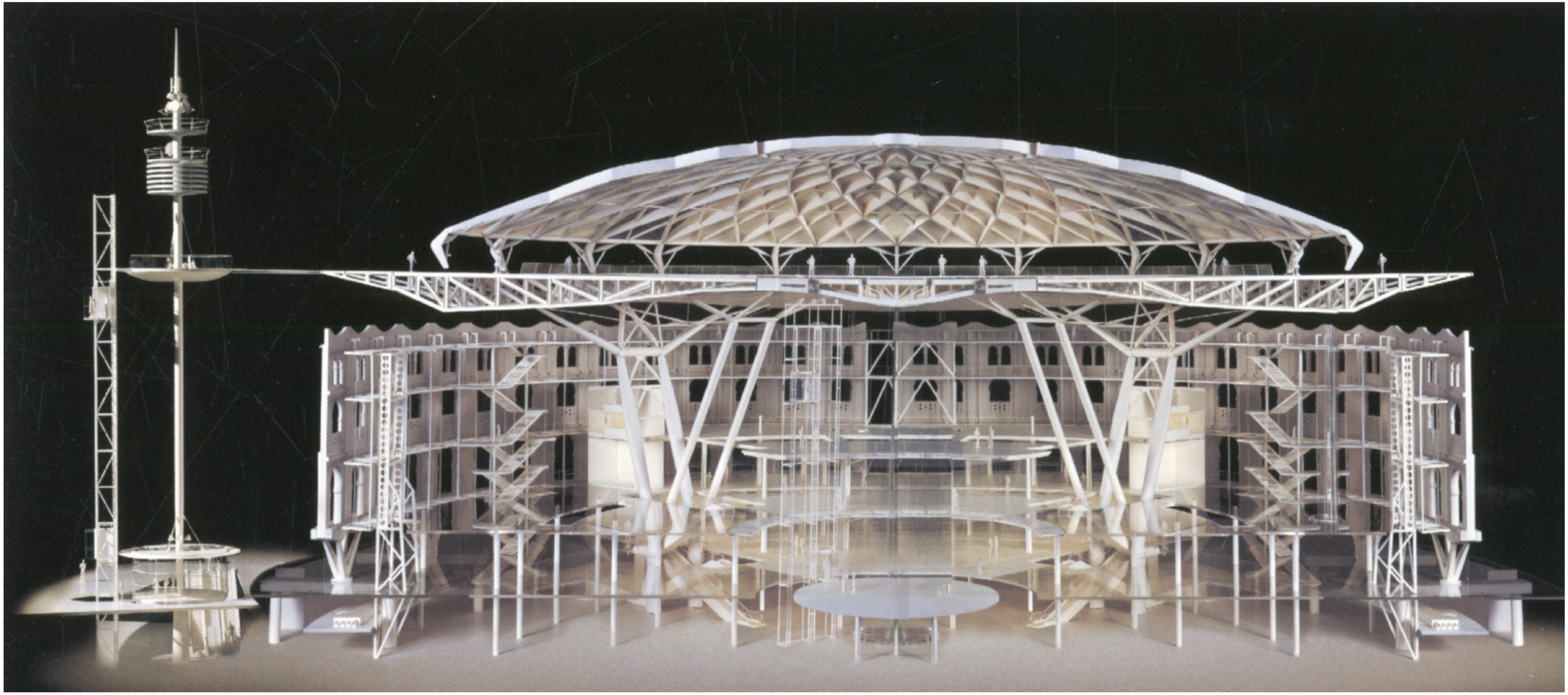








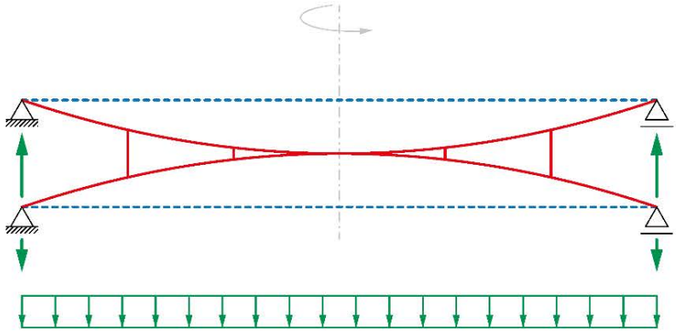


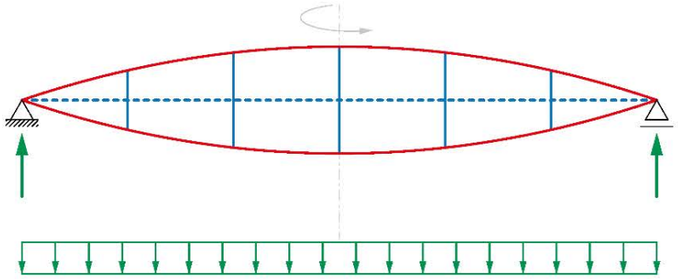


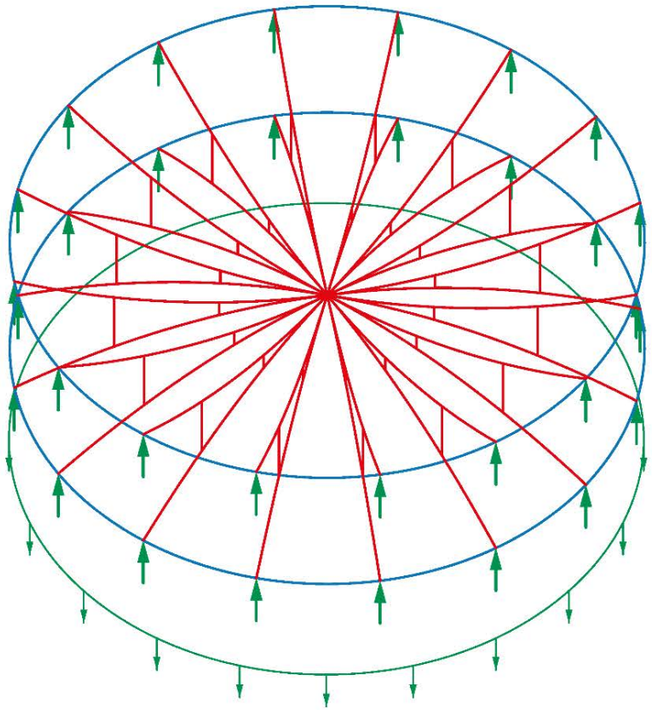
R. Rogers: Las Arenas, Barcelona, 2009

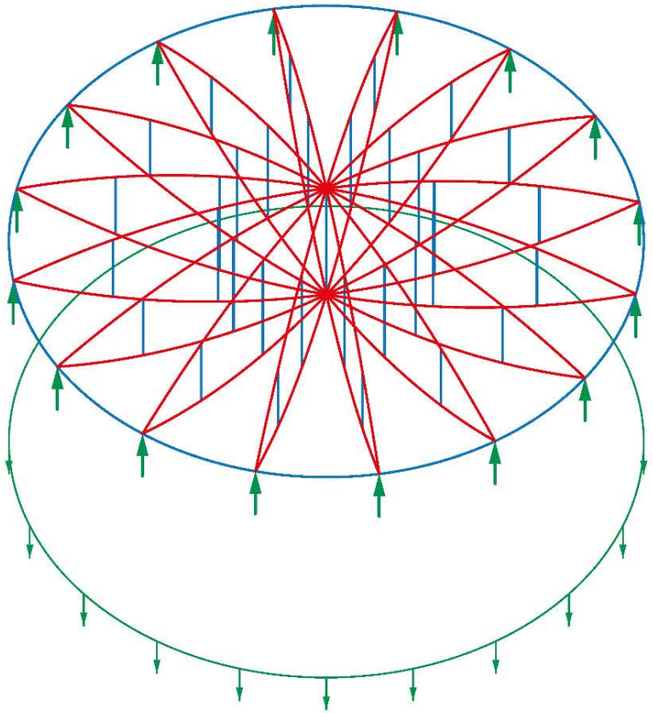
R. Rogers: Las Arenas, Barcelona, 2009

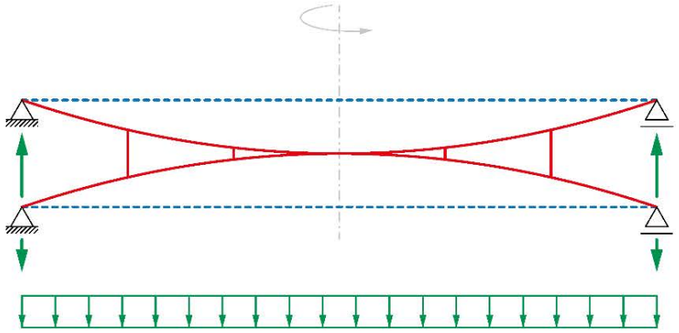
R. Rogers: Las Arenas, Barcelona, 2009

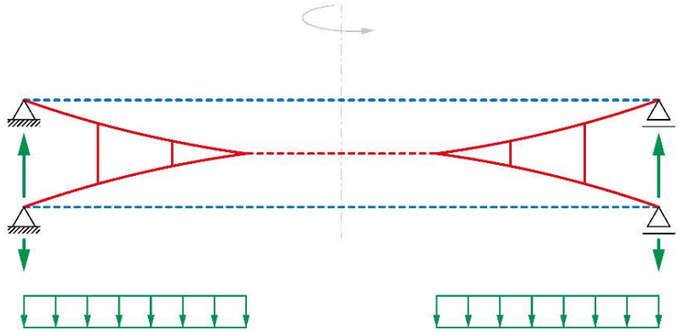


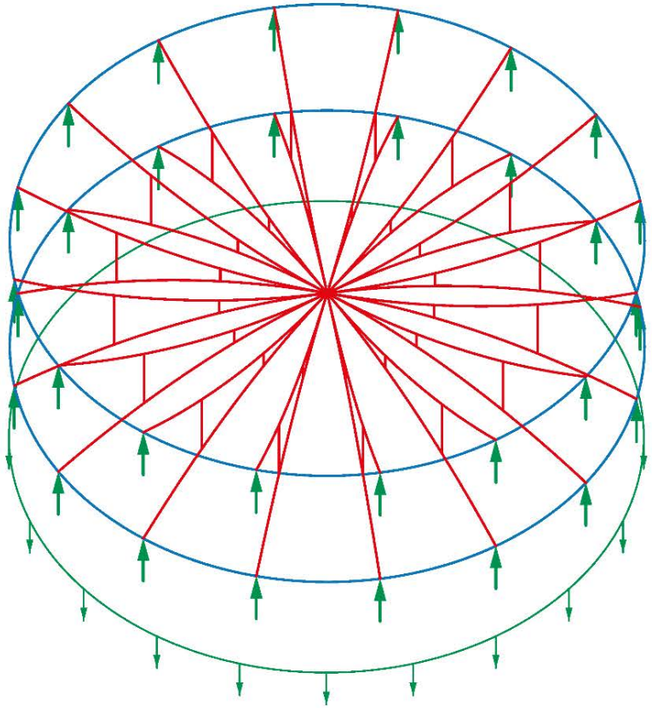


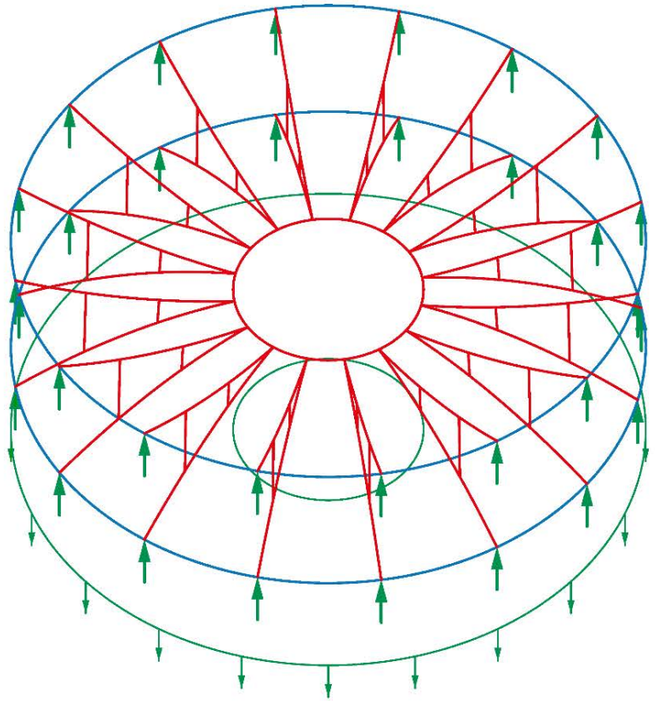






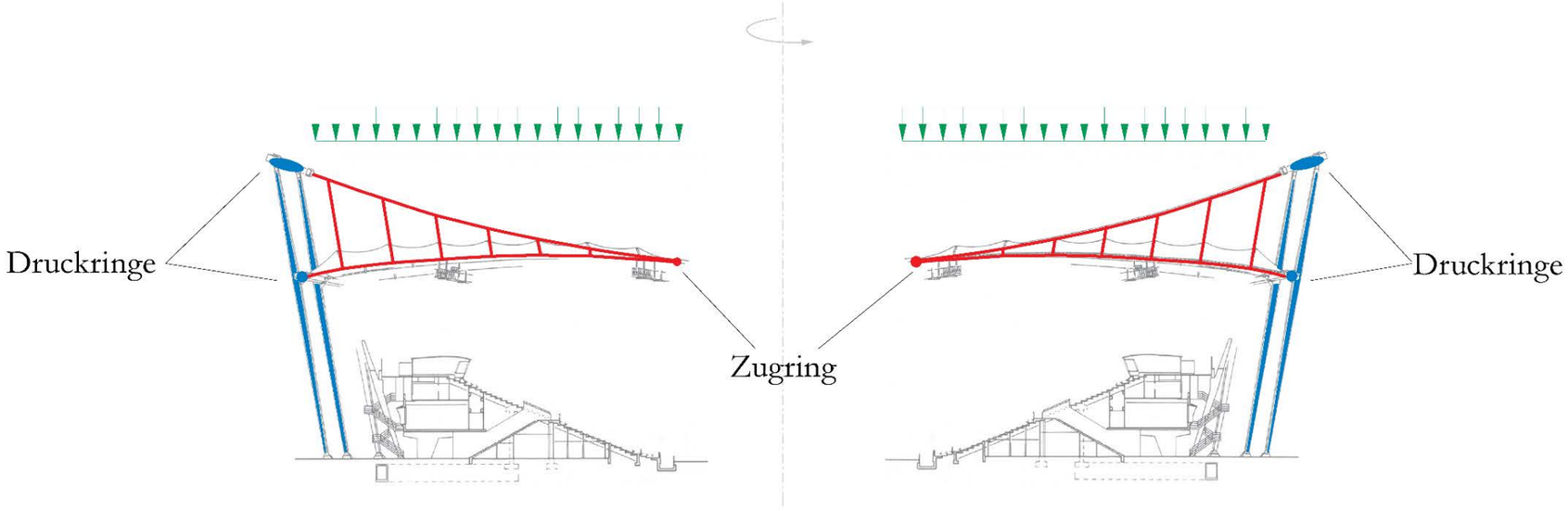






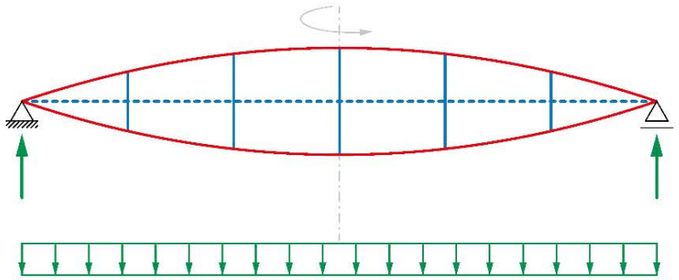
Öffnung der Fläche
Openings

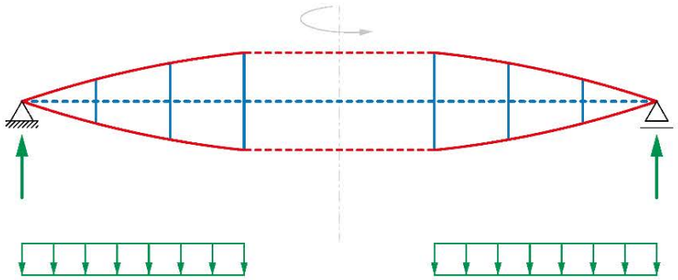
Asp Architekten, Schlaich Bergermann & Partner: Mercedes Benz Arena, Stuttgart, 1993

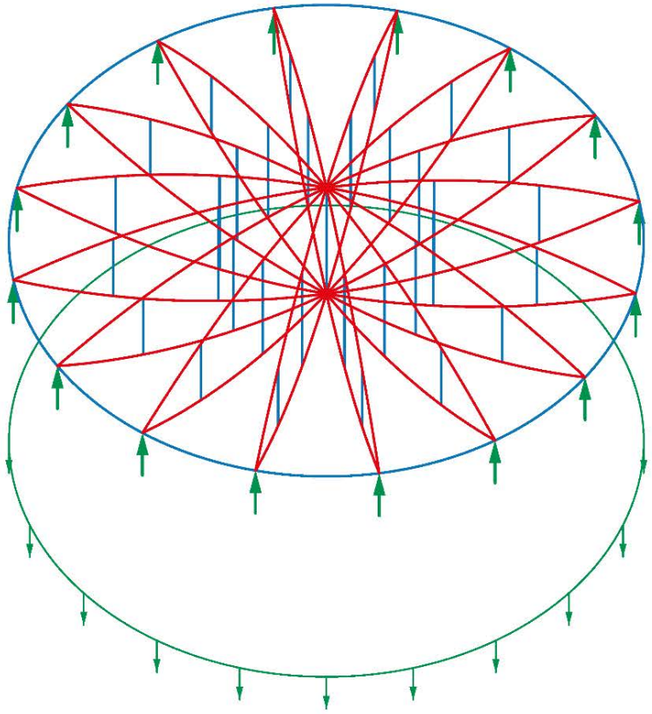


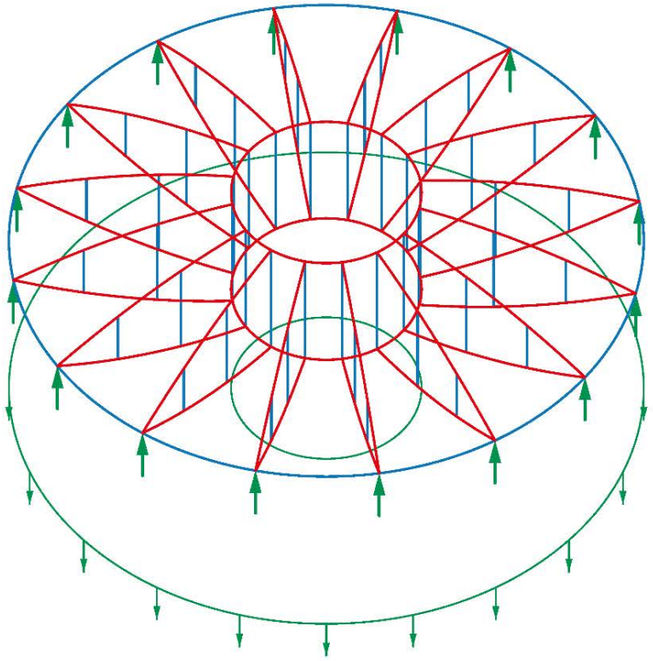
Asp Architekten, Schlaich Bergermann & Partner: Mercedes Benz Arena, Stuttgart, 1993

Asp Architekten, Schlaich Bergermann & Partner: Mercedes Benz Arena, Stuttgart, 1993









Öffnung der Fläche
Openings

Daniel Fernandes, S. Bergermann & Partner: Maracana Stadion, Rio de Janeiro, 2013

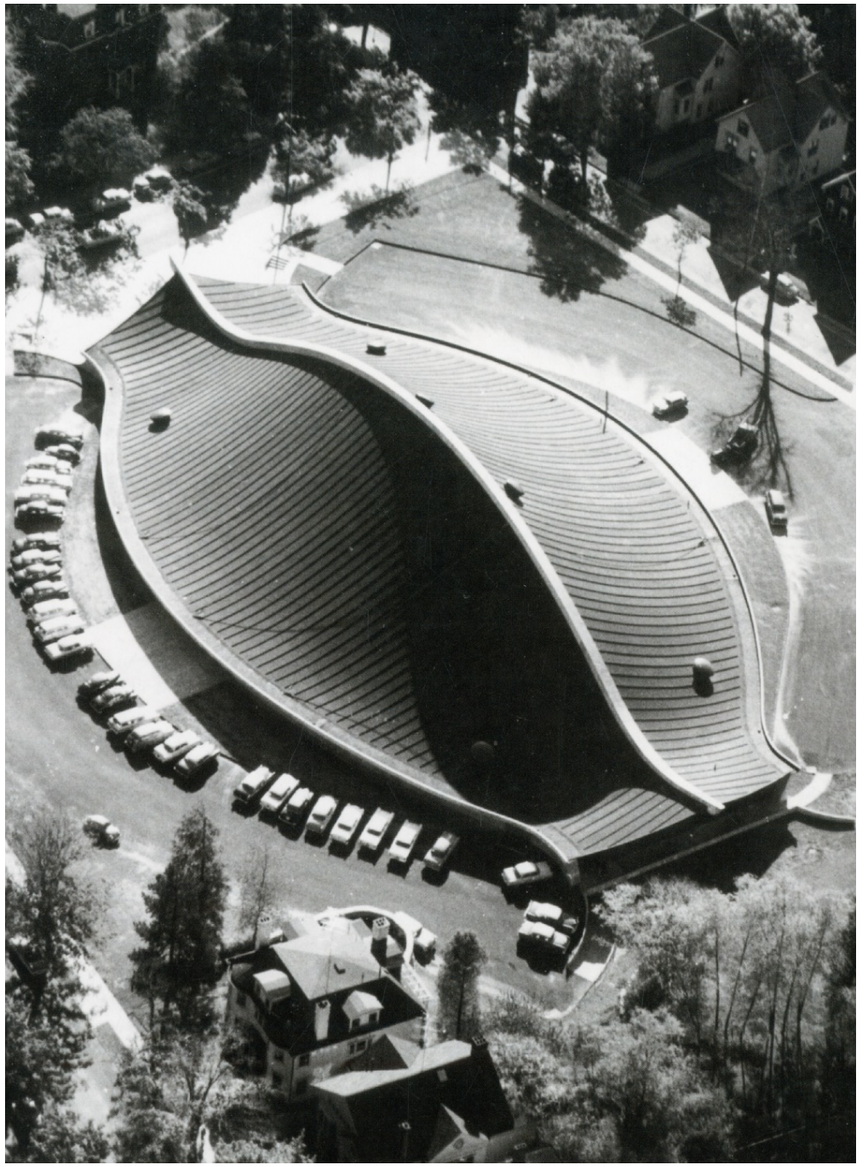
Daniel Fernandes, S. Bergermann & Partner: Maracana Stadion, Rio de Janeiro, 2013

Räumliche Bogen-Seil-Tragwerke

Spatial arch-cable structures

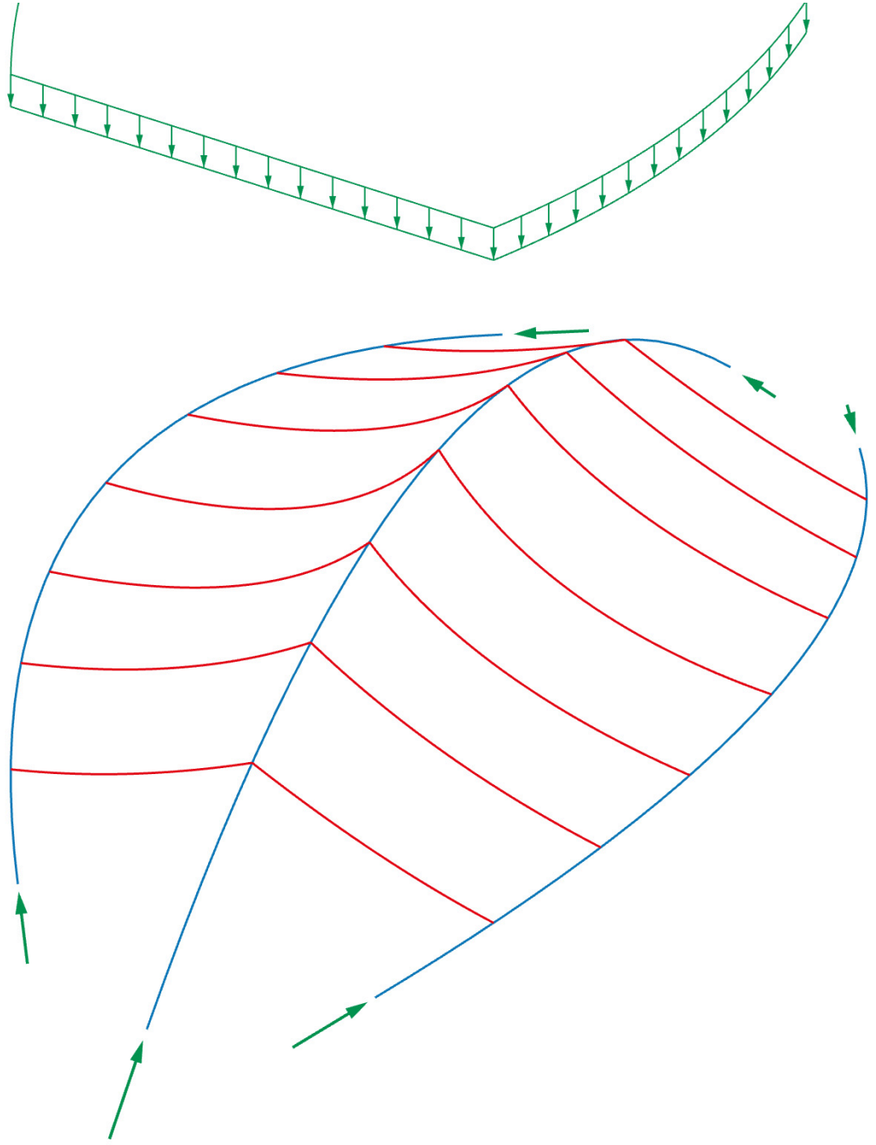
Bogen-Seil-Tragwerke mit Druck- und Zugringen
Arch-cables with tension and compression rings

>> Kombinationen von Bogen und Seil
Combinations of arch and cable

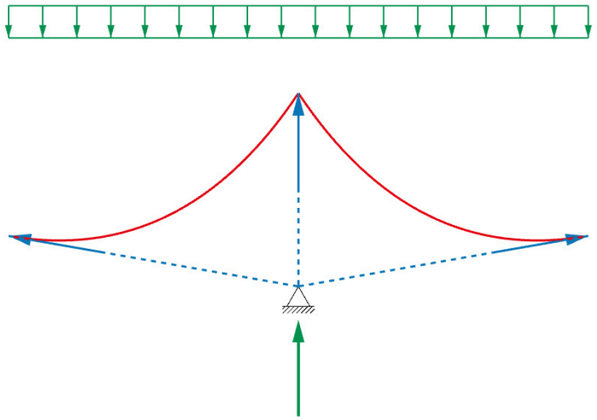


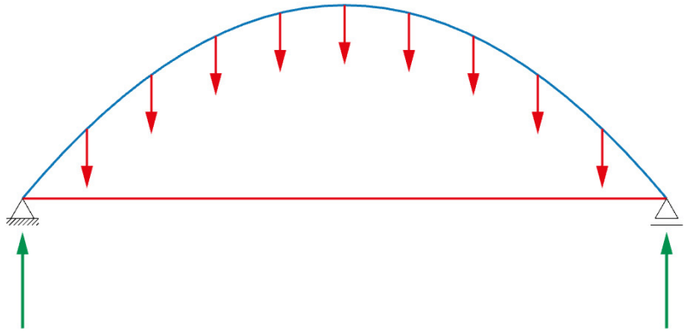
Eero Saarinen, Severud Associates: D.S.Ingalls Hockey Stadion, New Haven, 1958

Eero Saarinen, Severud Associates: D.S.Ingalls Hockey Stadion, New Haven, 1958

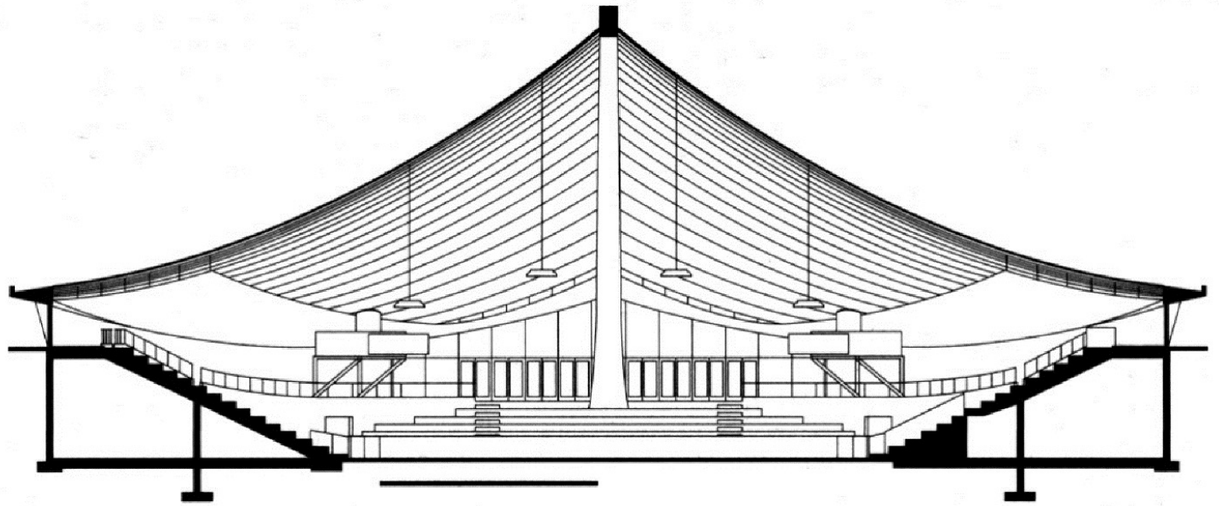


Eero Saarinen, Severud Associates: D.S.Ingalls Hockey Stadion, New Haven, 1958

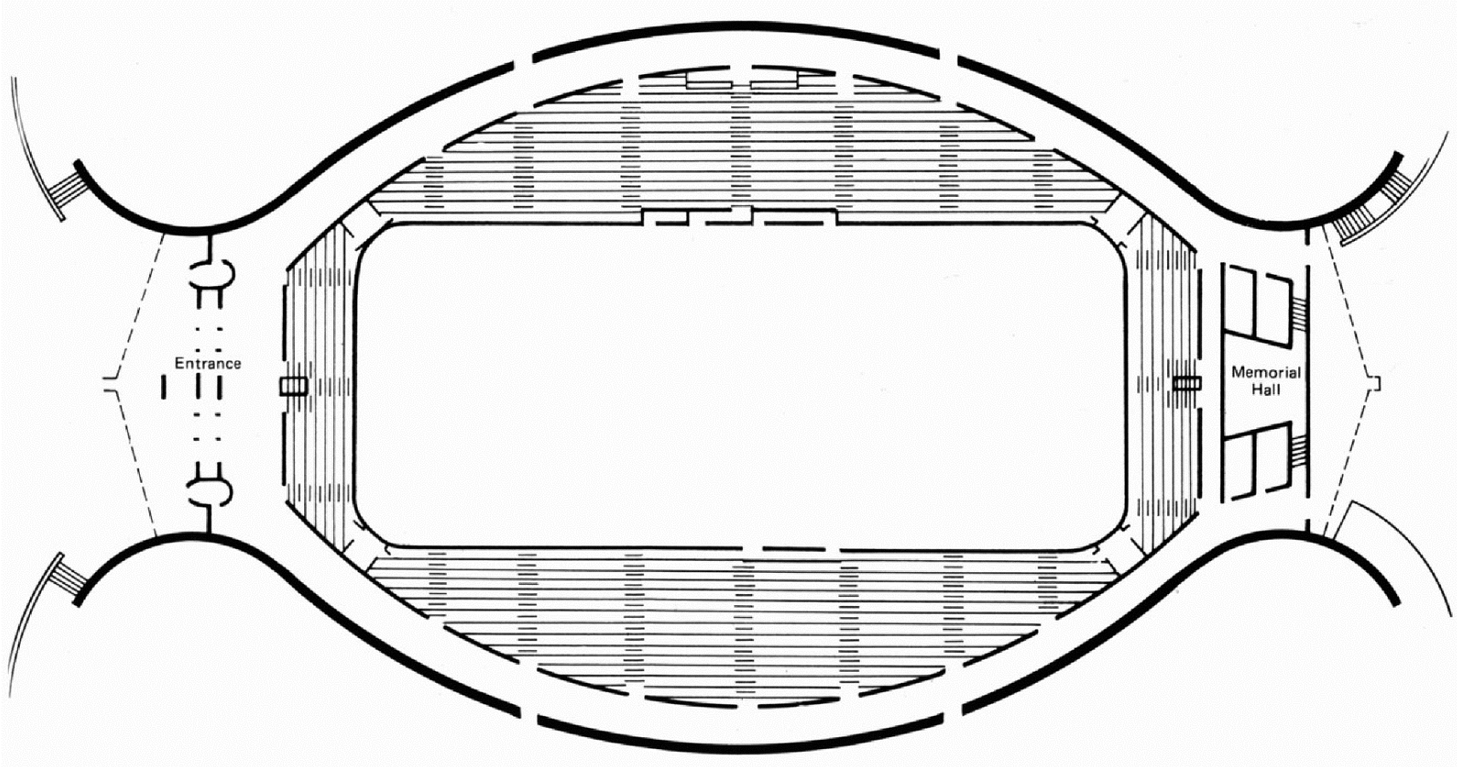




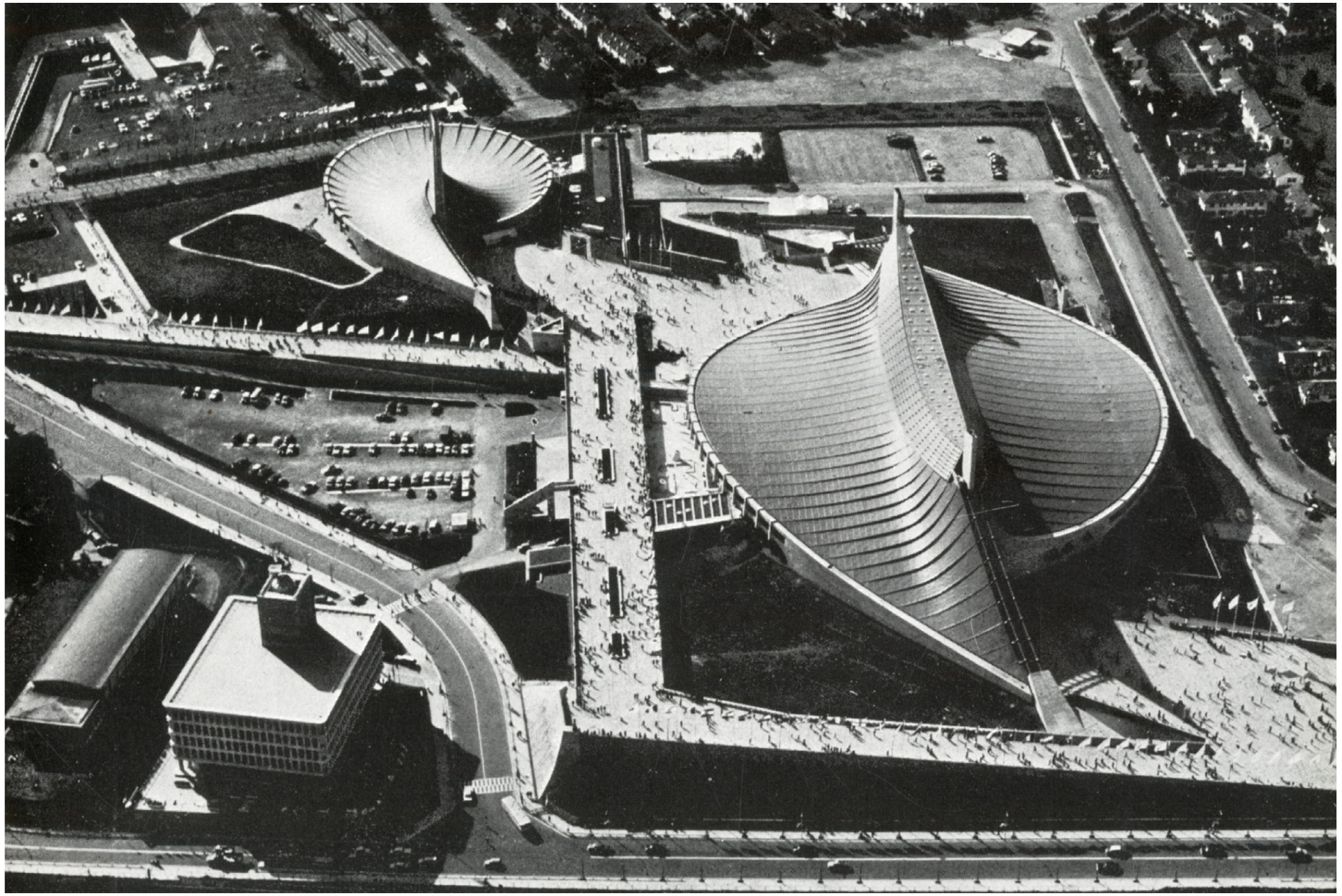
Eero Saarinen, Severud Associates: D.S.Ingalls Hockey Stadion, New Haven, 1958



Eero Saarinen, Severud Associates: D.S.Ingalls Hockey Stadion, New Haven, 1958

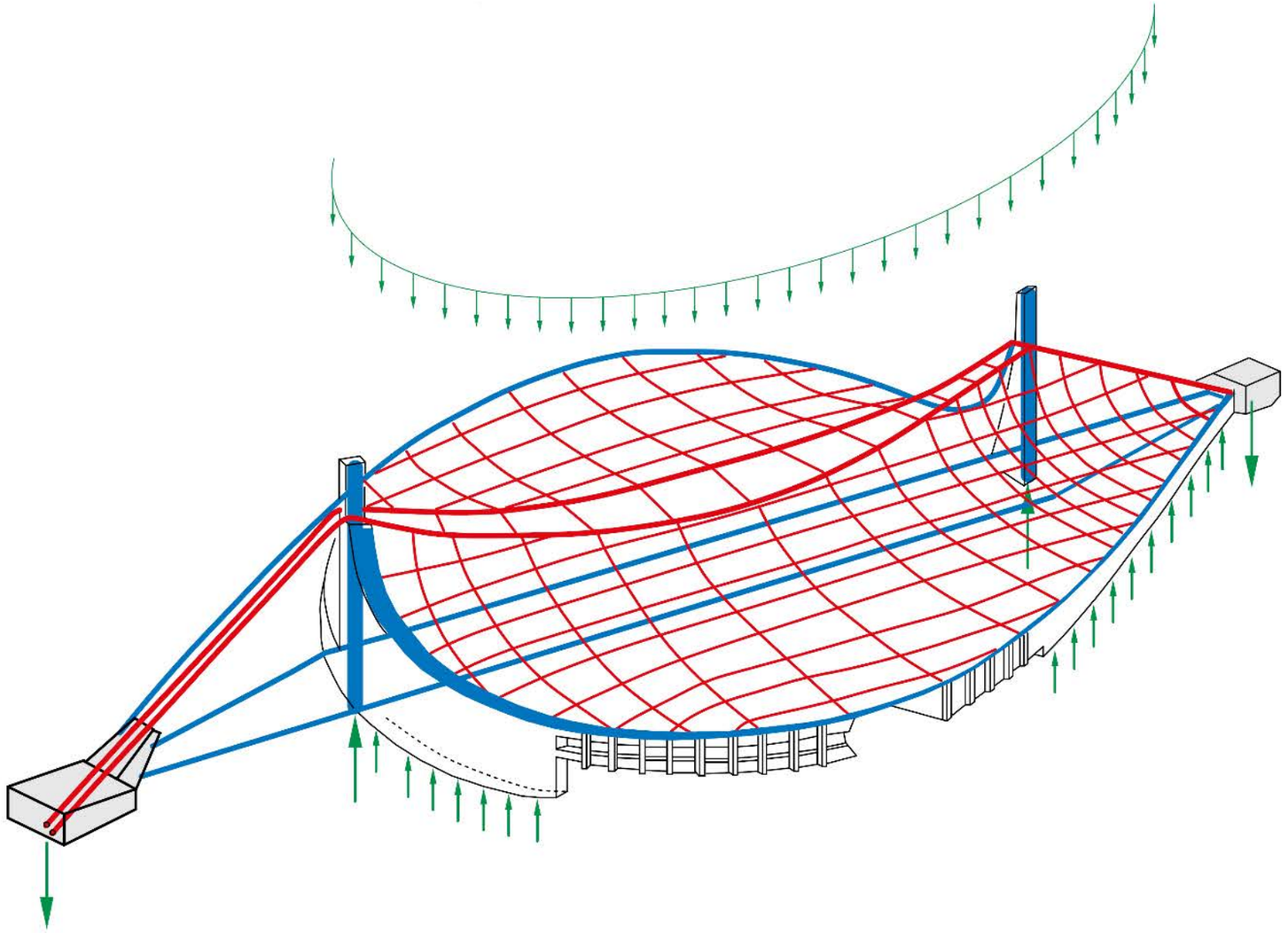


Eero Saarinen, Severud Associates: D.S.Ingalls Hockey Stadion, New Haven, 1958

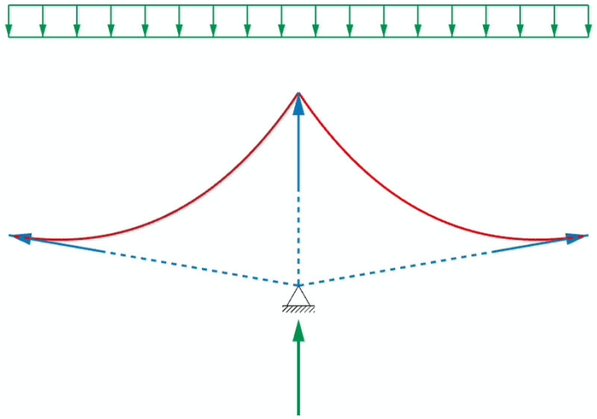


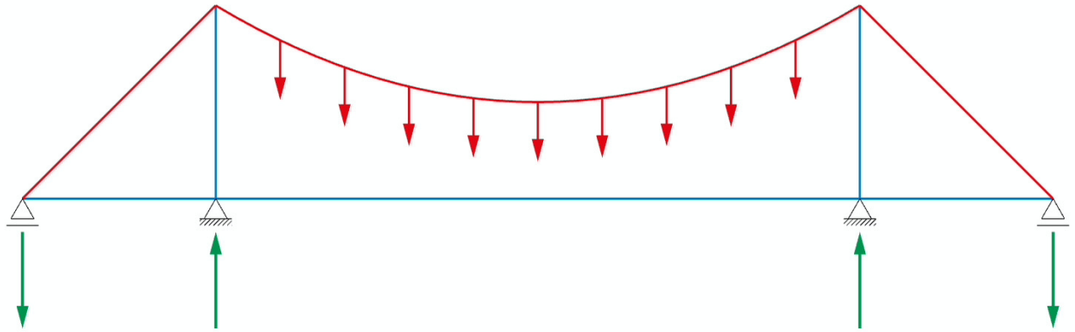
Kenzo Tange: National Gymnasium, Tokio, 1964

Kenzo Tange: National Gymnasium, Tokio, 1964

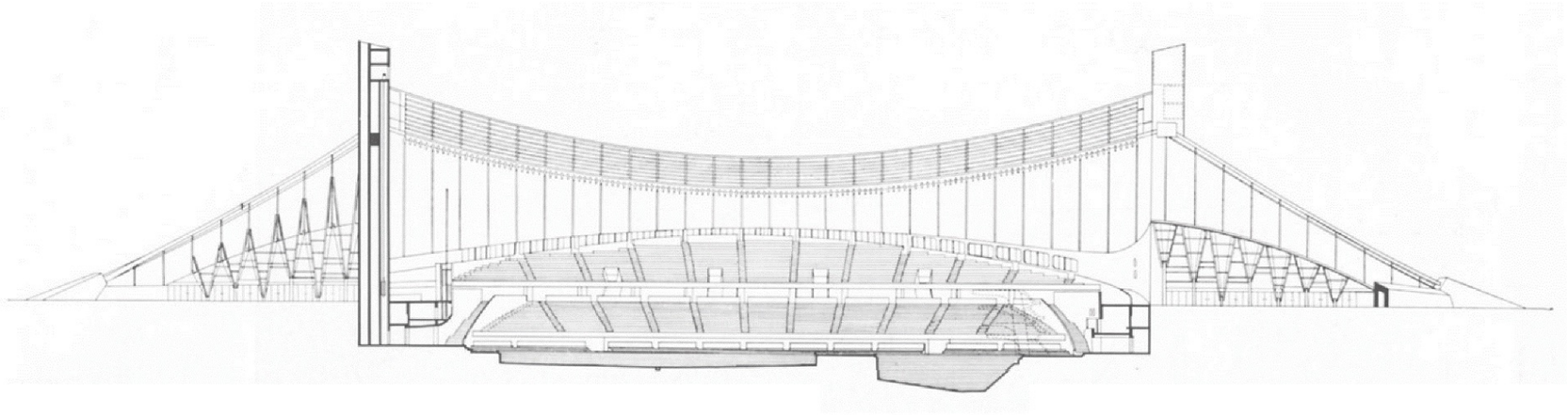


Kenzo Tange: National Gymnasium, Tokio, 1964

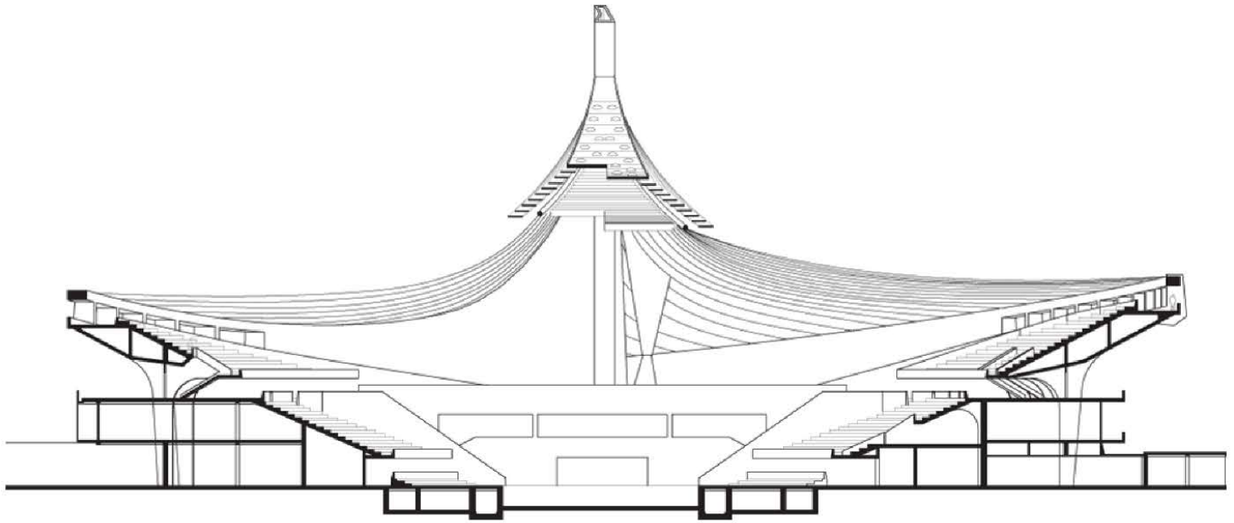




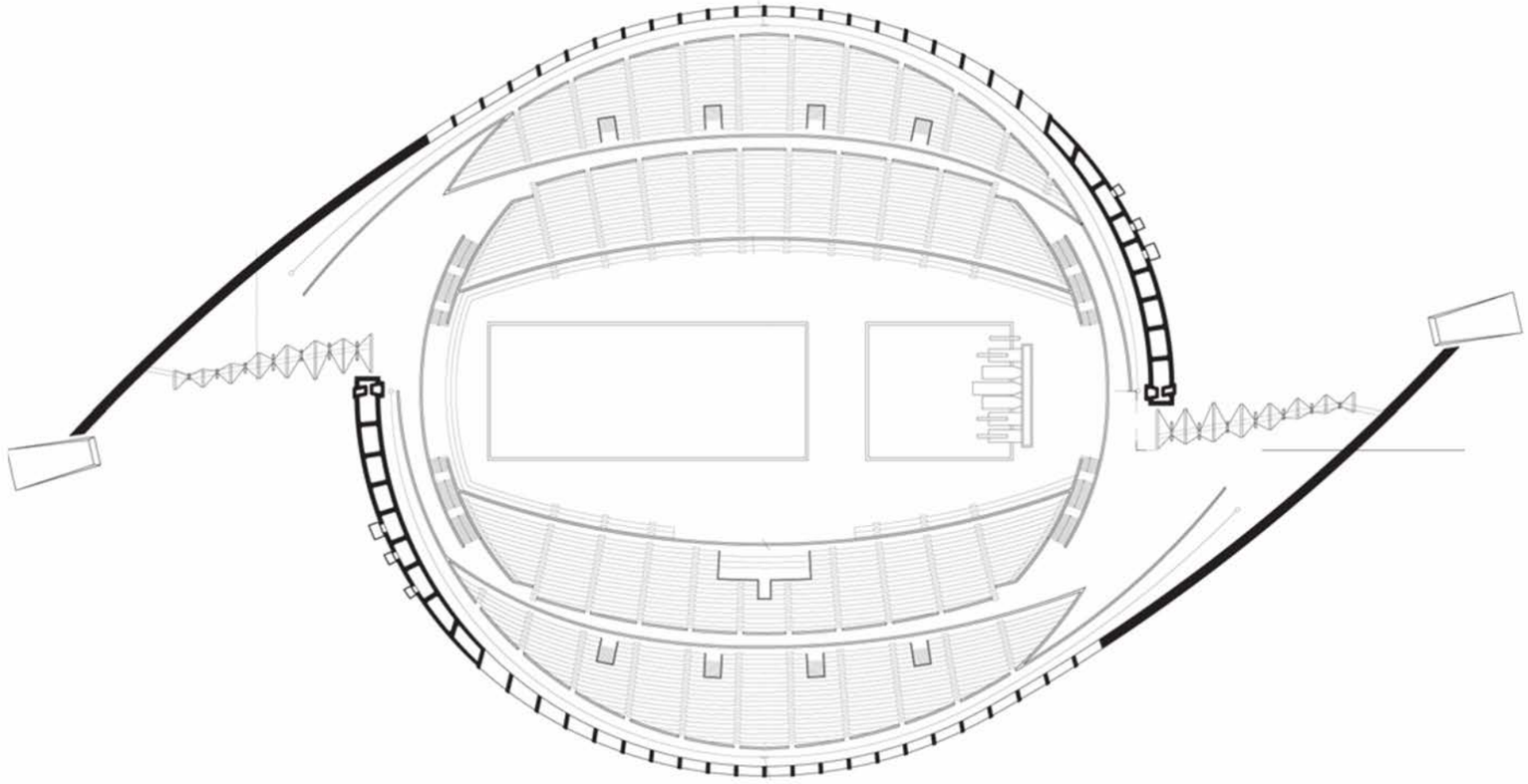
Kenzo Tange: National Gymnasium, Tokio, 1964



Kenzo Tange: National Gymnasium, Tokio, 1964



Kenzo Tange: National Gymnasium, Tokio, 1964



Kenzo Tange: National Gymnasium, Tokio, 1964

Kenzo Tange: National Gymnasium, Tokio, 1964