ARK-A3001 Design of Structures_Basics

Force Distribution

Toni Kotnik

Professor of Design of Structures

Aalto University
Department of Architecture
Department of Civil Engineering

Poisson-effect

stress

stress-strain diagram

beam

cantilever

bending

structure & architectural concept

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Tension & Compression

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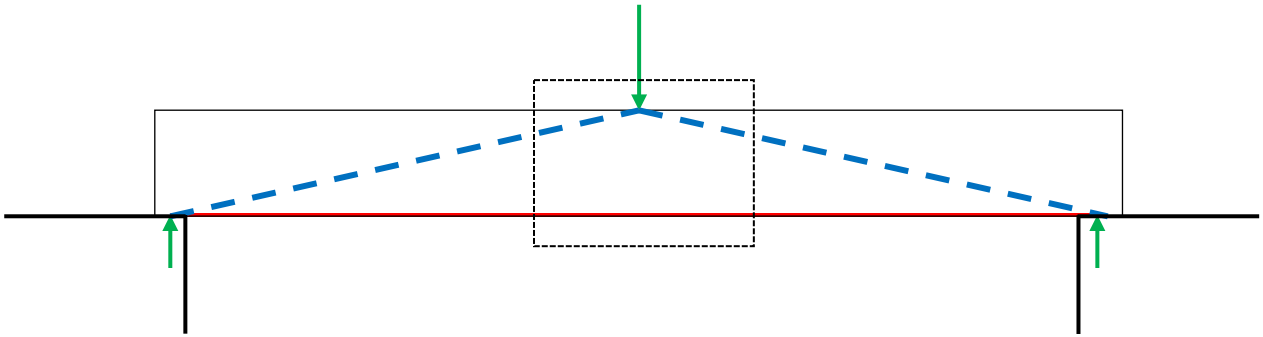
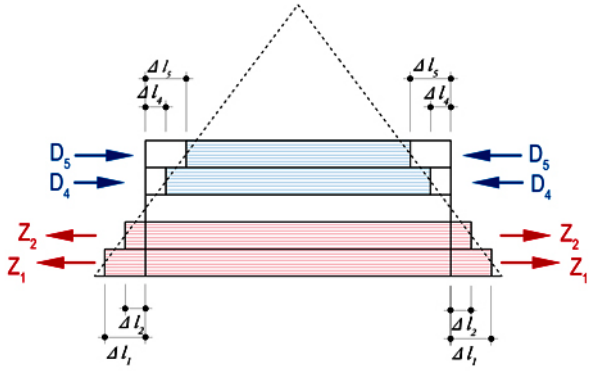
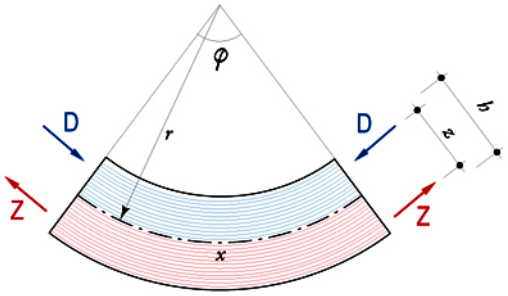
Bending

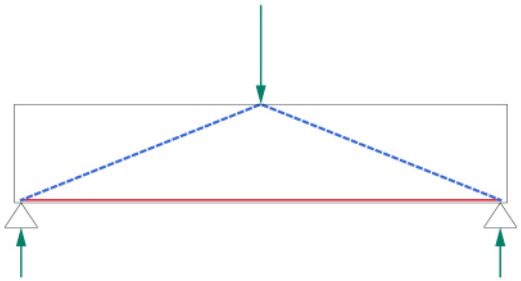




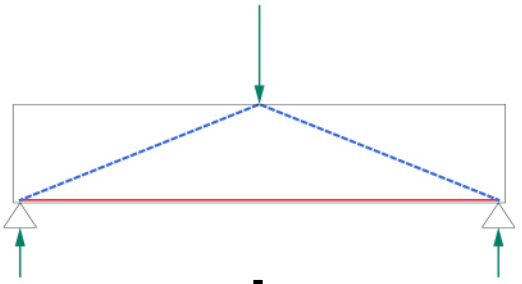


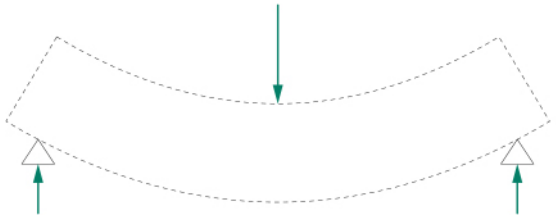
compression and tension in the same section results in **bending**

Post-Tensioned Beam

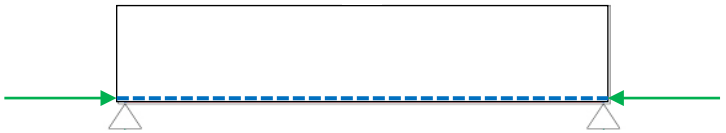


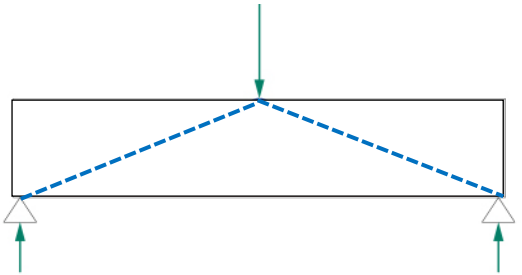
strategy against bending





tension cable
to press both ends of
beam together

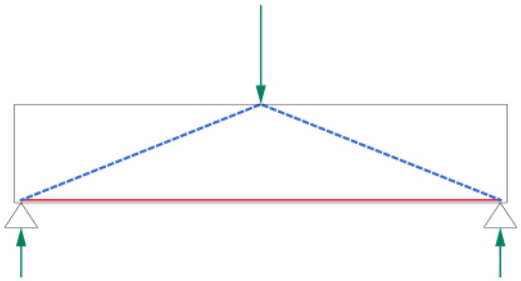


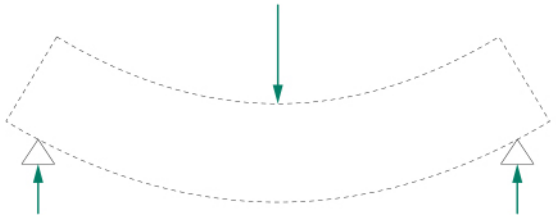


compression and tension in the same section results in **bending**

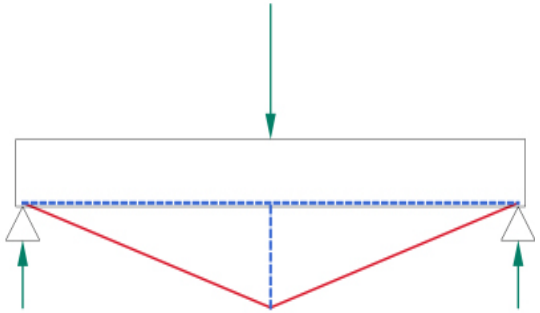
compensate tension by additional compression

Bracing





strategy against bending



isolate effect of tension and compression into independent elements

compression and tension in the same section results in **bending**

separate tension and compression

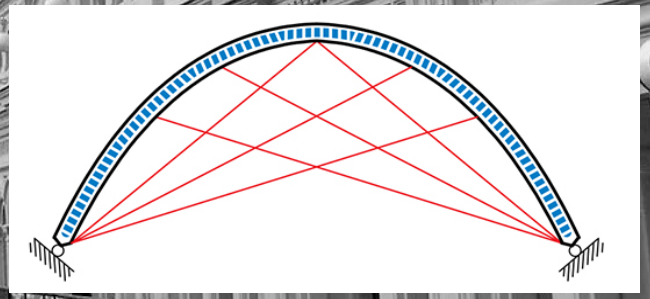
Bracing

Bridge over Mura River
Beltinci, Slovenia, 2003

Bracing

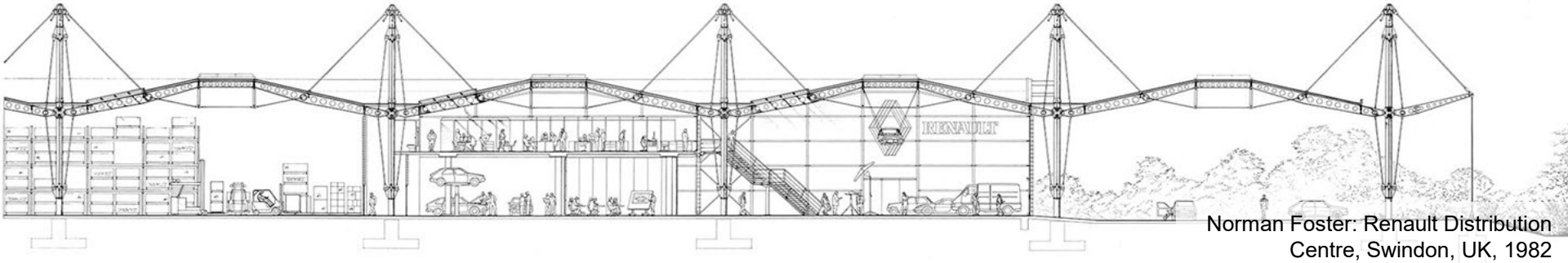
Grimshaw Architects: Airside Center
Zurich Airport, Switzerland, 2003

Bracing



Vladimir Shuhov: Arcade, GUM Shopping Center
Moscow, Russia, 1893

Bracing

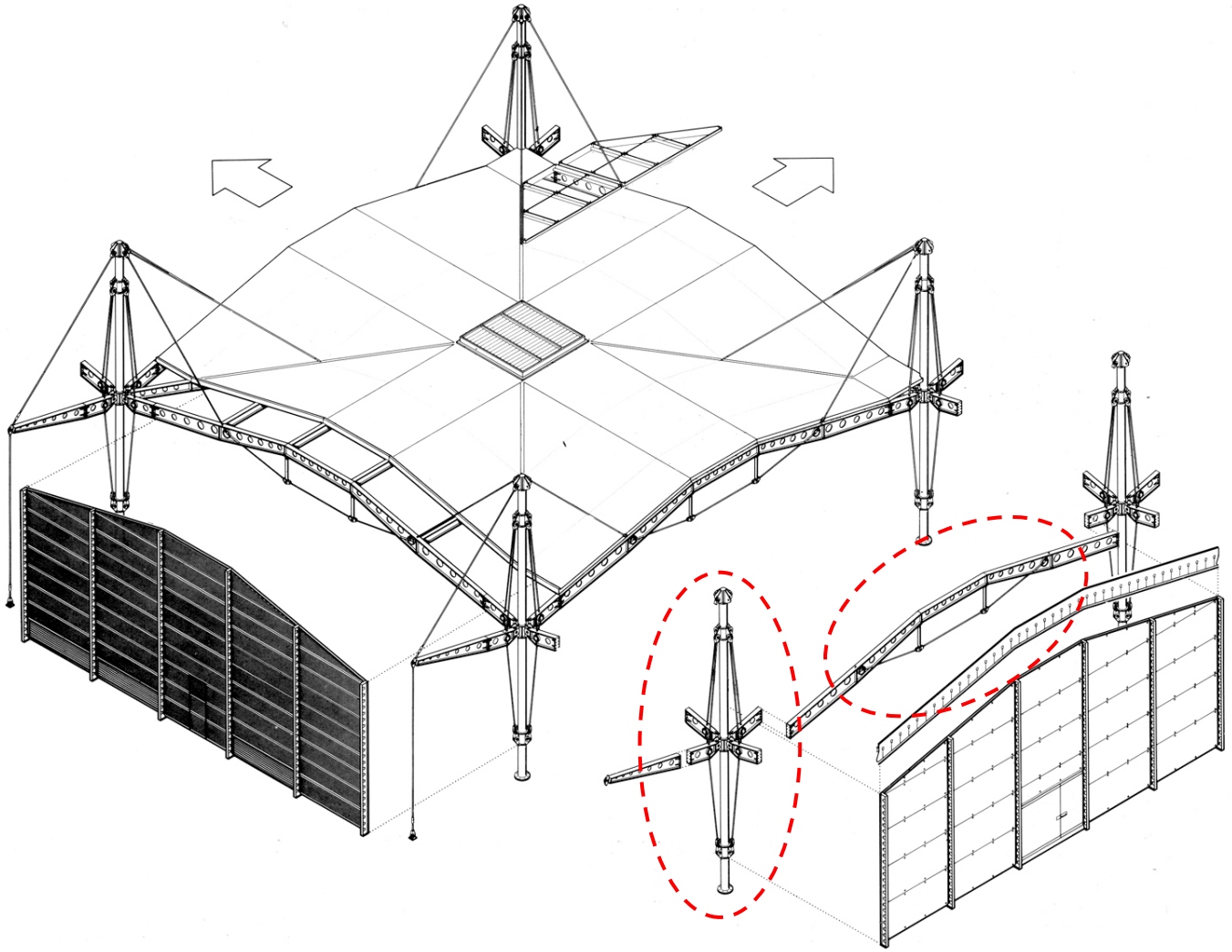


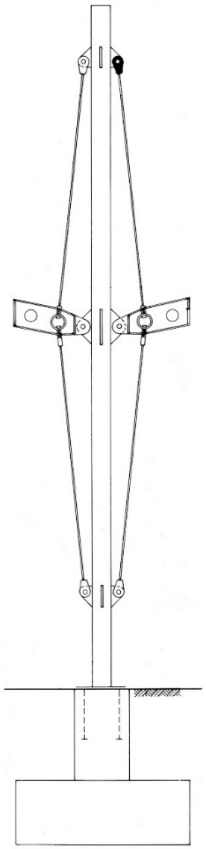
Norman Foster: Renault Distribution Centre, Swindon, UK, 1982

Bracing

Norman Foster: Renault Distribution Centre, Swindon, UK, 1982

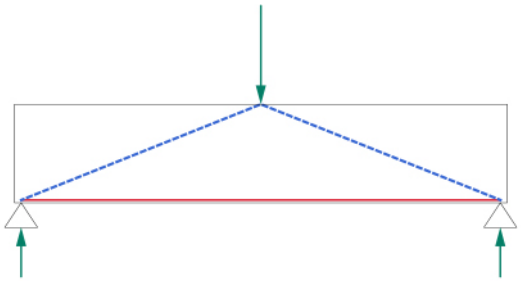
Bracing



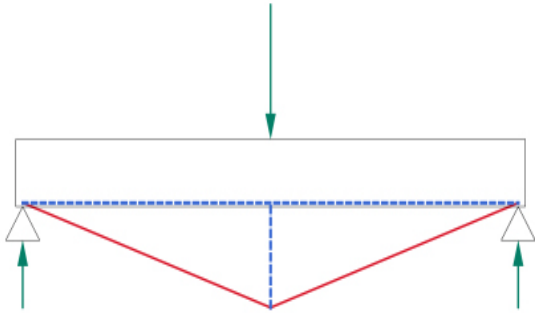


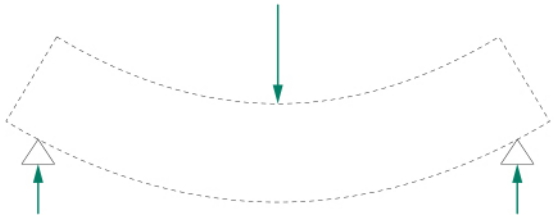
Norman Foster: Renault Distribution Centre, Swindon, UK, 1982

Bracing



strategy against bending





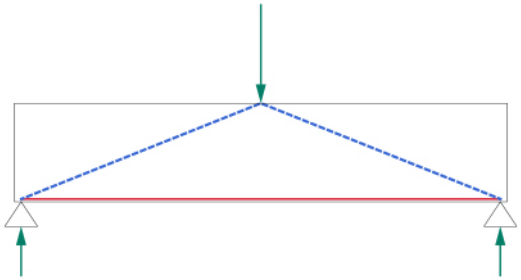
isolate effect of tension and compression into independent elements

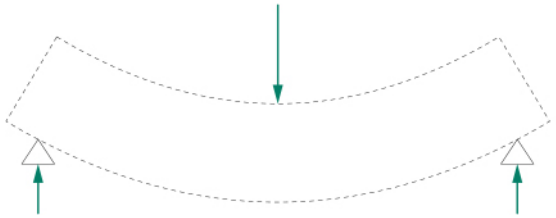
compression and tension in the same section results in **bending**

keep inner forces small to save material

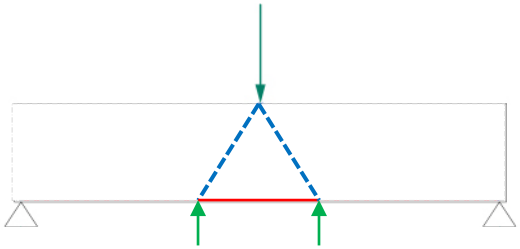
separate tension and compression

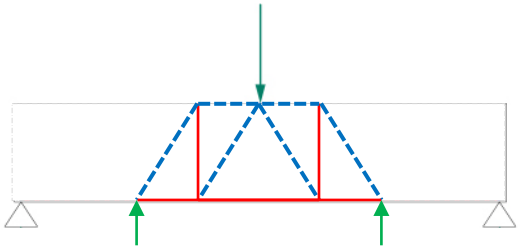
Truss

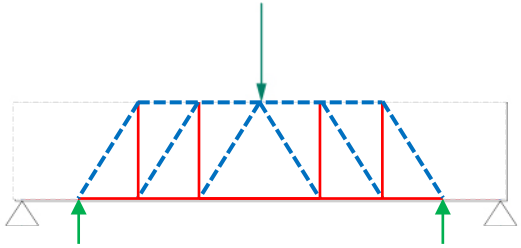


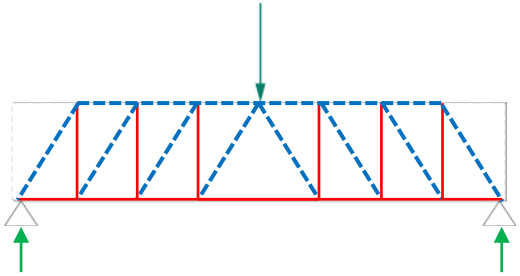


strategy against bending



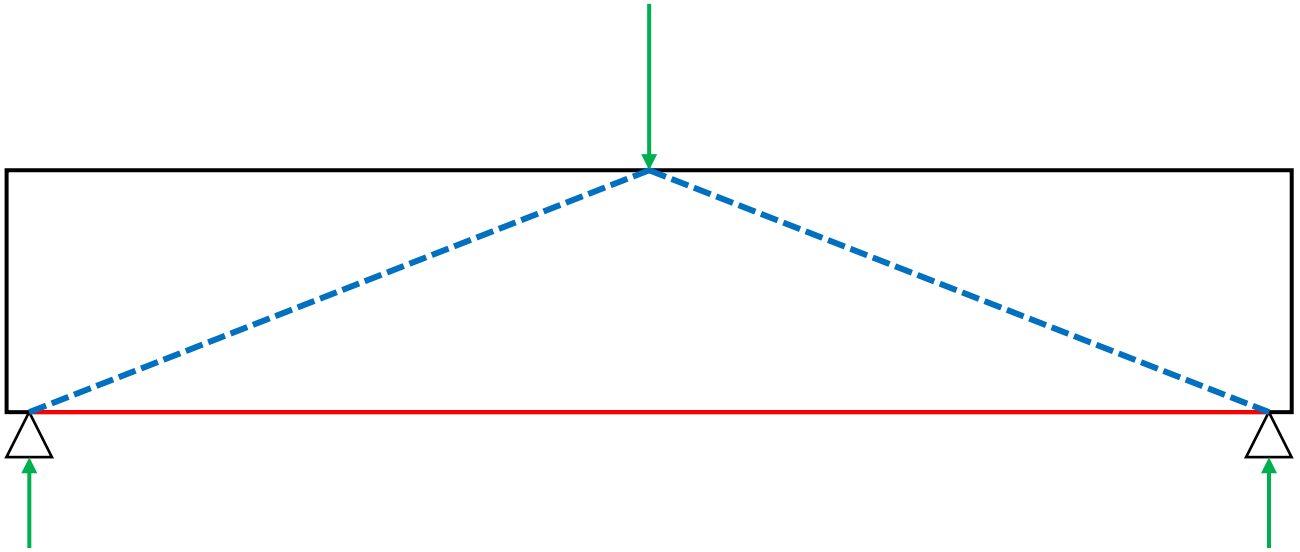




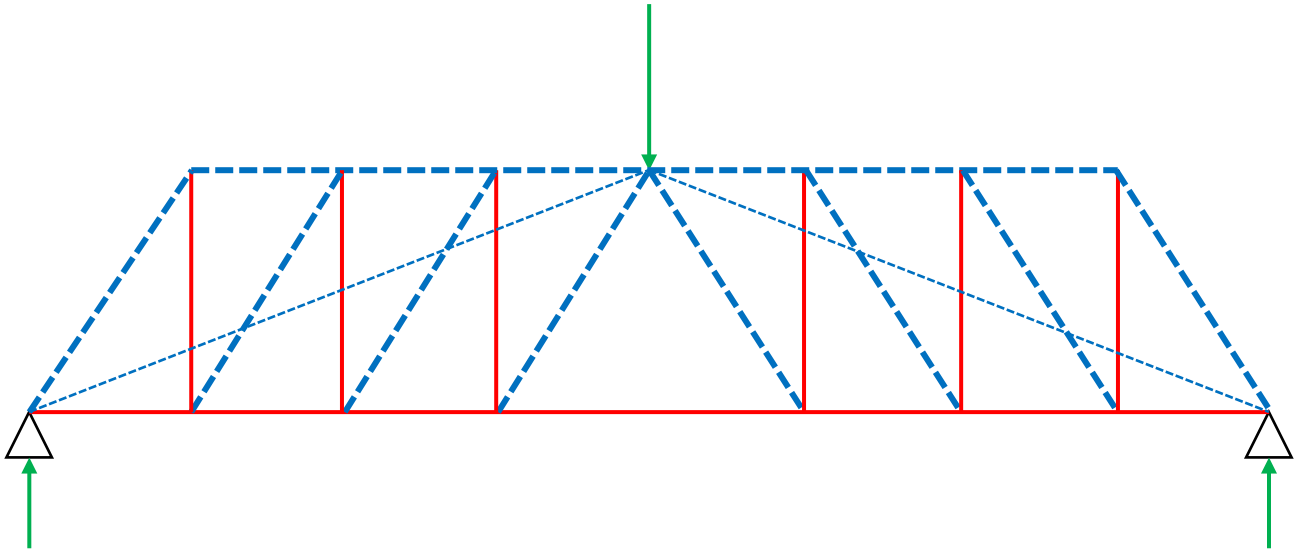


compression and tension in the same section results in **bending**

Truss



distribution of forces into the neighborhood



Truss

Christian Kerez: School Leutschenbach
Zurich, Switzerland, 2010

Truss

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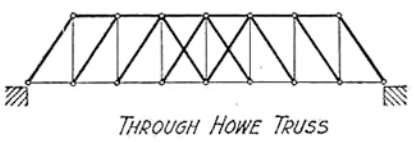
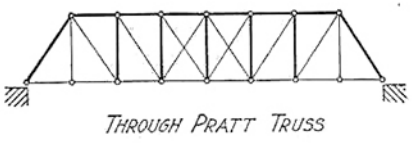
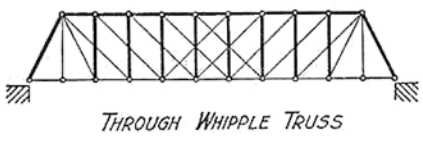
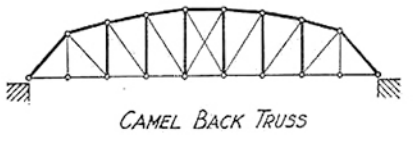
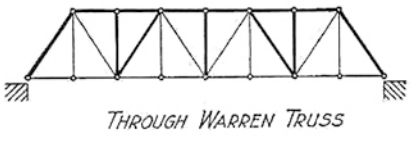
Truss

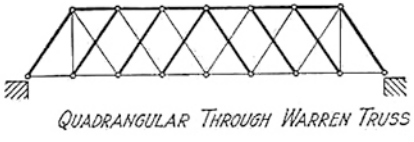


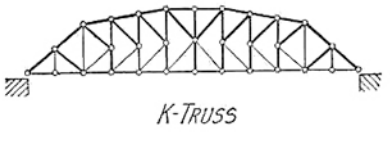


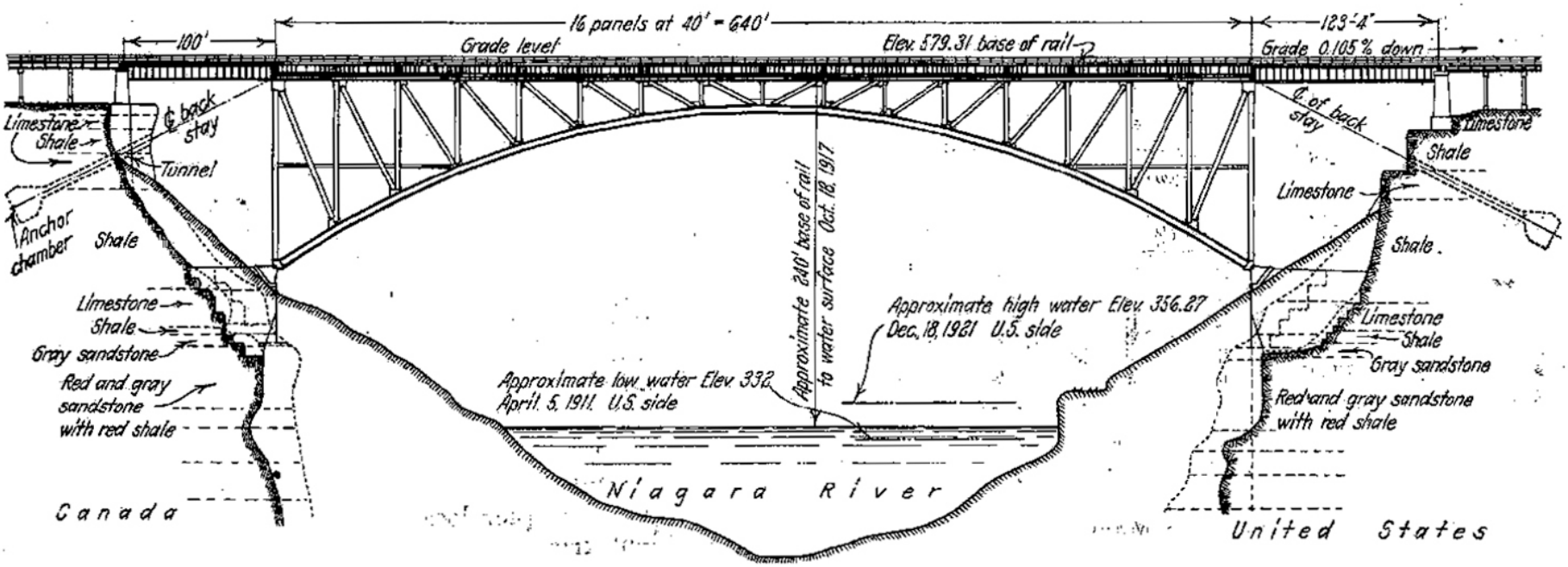






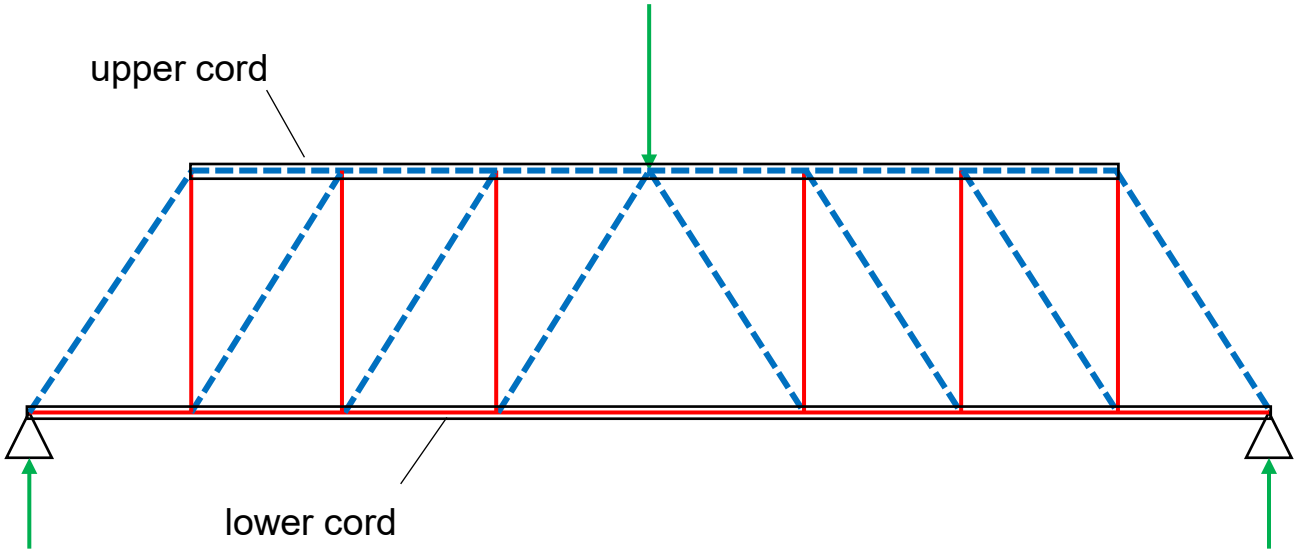






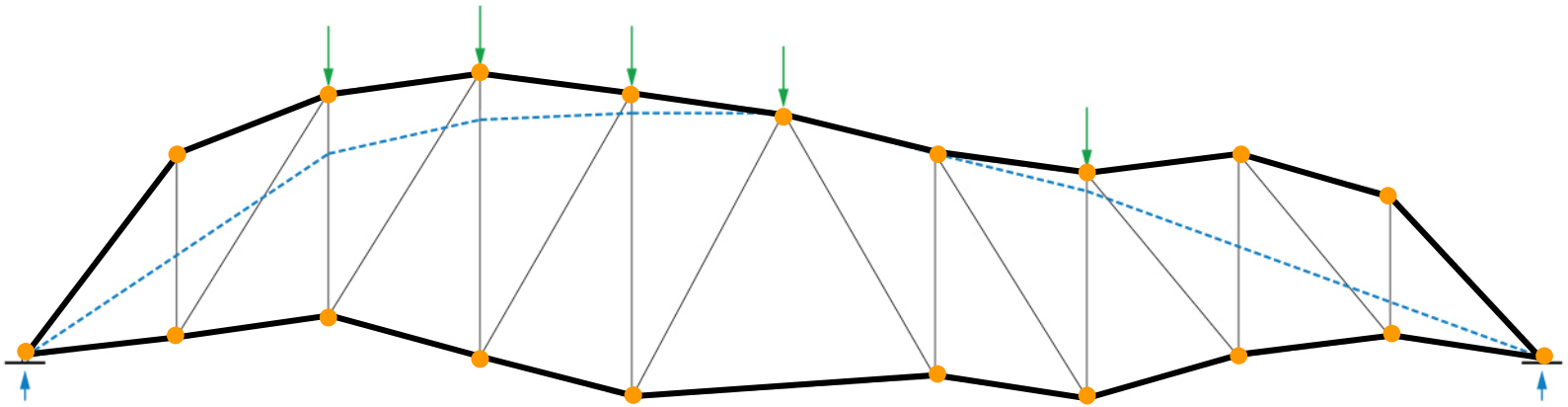
Olaf Hoff: Whirlpool Rapids Railroad Bridge
Niagara Falls, Canada/USA, 1925

Truss

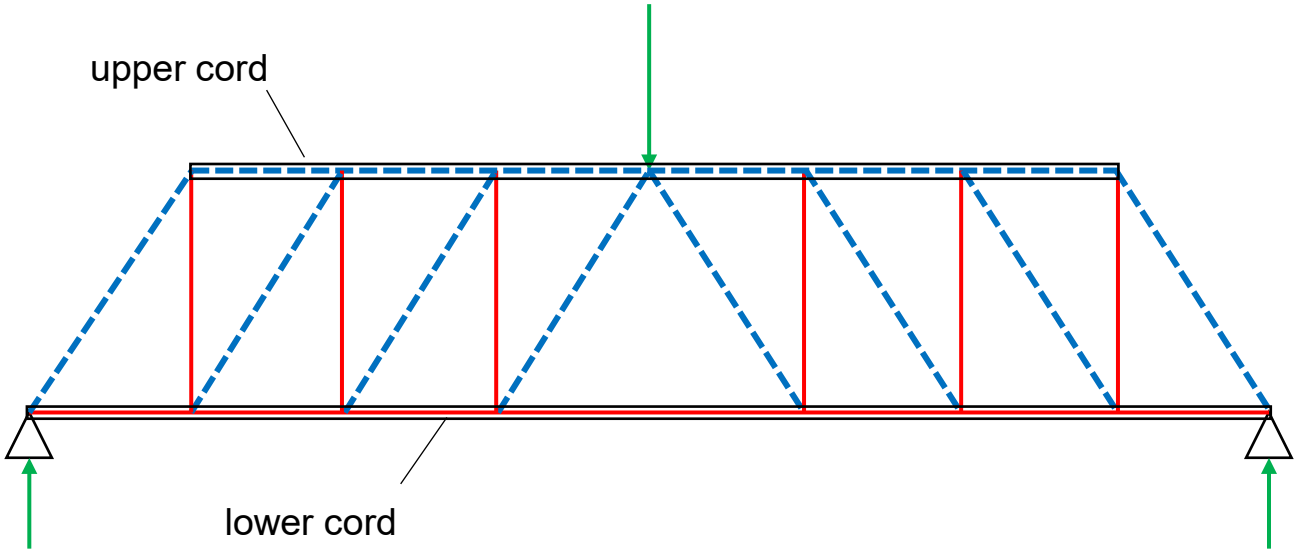


principle of distribution not
dependent on linear truss shape

in a truss, loads should always
be introduced at the knots



Truss



principle of distribution not
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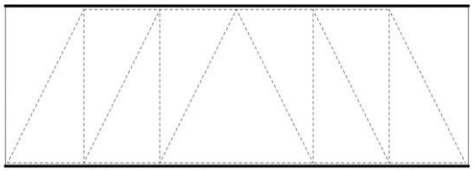
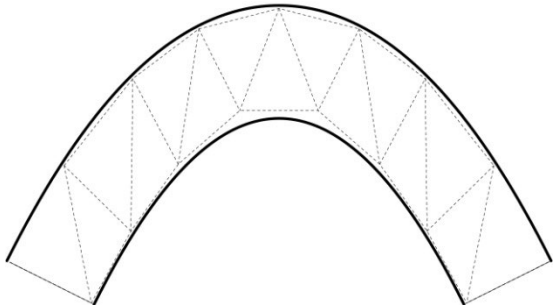
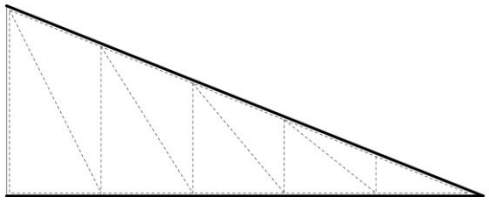






Truss

Renzo Piano & Richard Rogers: Centre Georges Pompidou
Paris, France, 1977

Truss

Renzo Piano & Richard Rogers: Centre Georges Pompidou
Paris, France, 1977

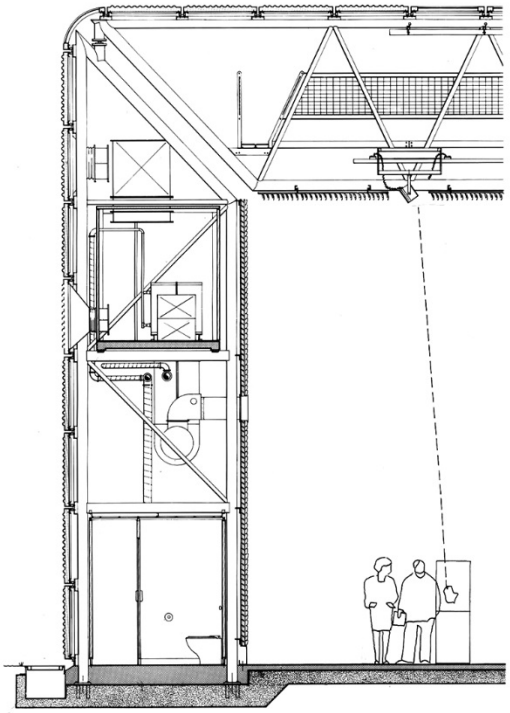
Truss

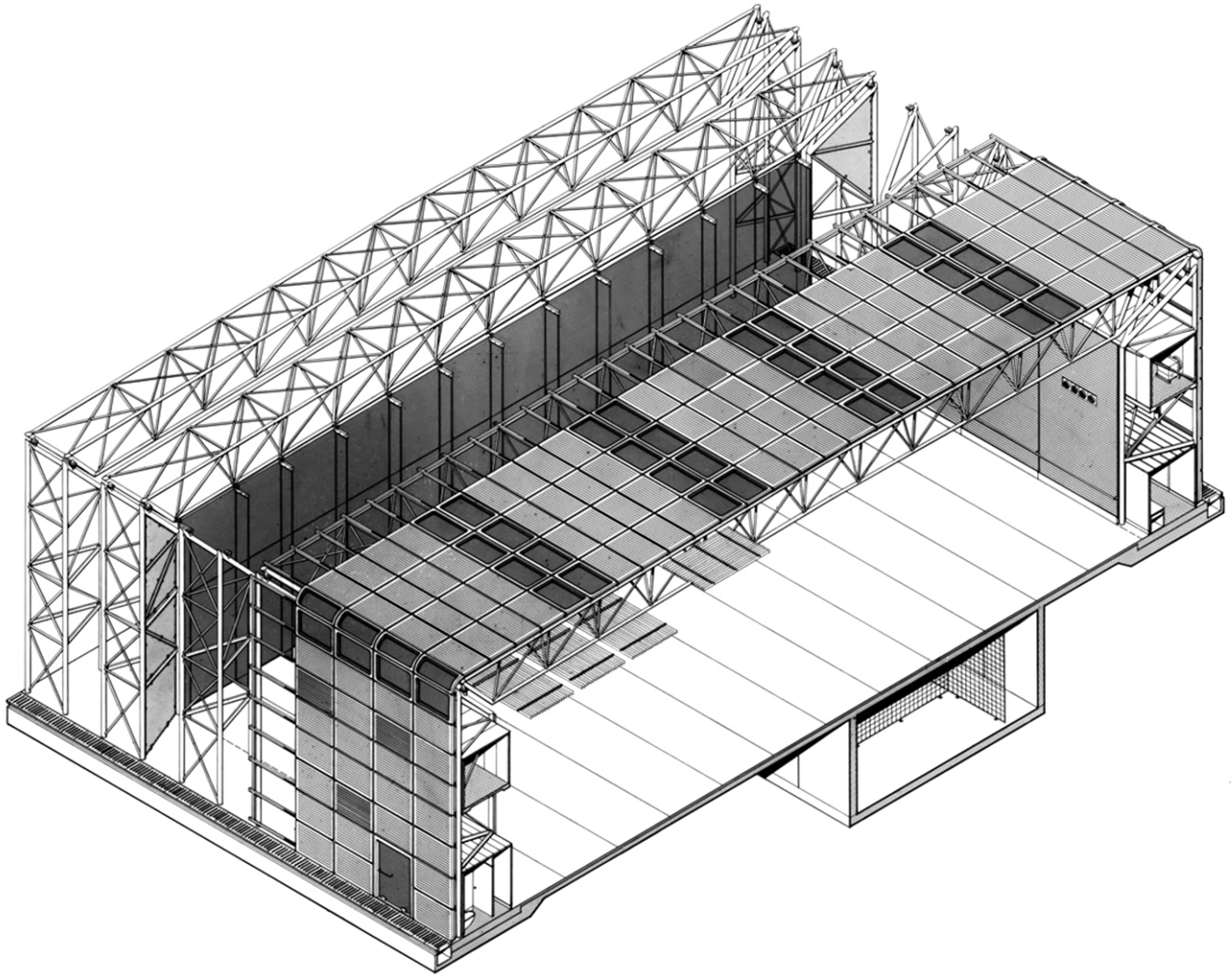
Renzo Piano & Richard Rogers: Centre Georges Pompidou
Paris, France, 1977

Truss

Norman Foster: Centre for Visual Arts
Sainsbury, UK, 1978

Truss





Norman Foster: Centre for Visual Arts
Sainsbury, UK, 1978

Truss

Norman Foster: Centre for Visual Arts
Sainsbury, UK, 1978

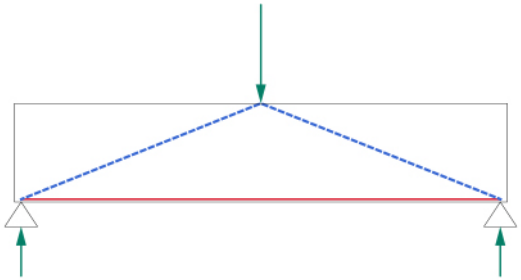
Truss

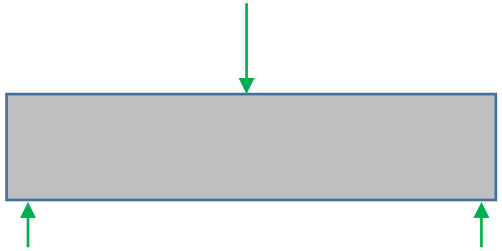
Gustave Eiffel: Ponte Maria Pia
Porto, Portugal, 1877

Truss

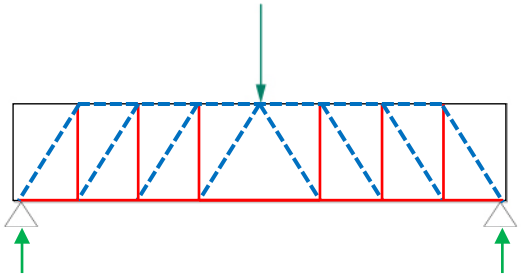
Gustave Eiffel: Eiffel Tower
Paris, France, 1889

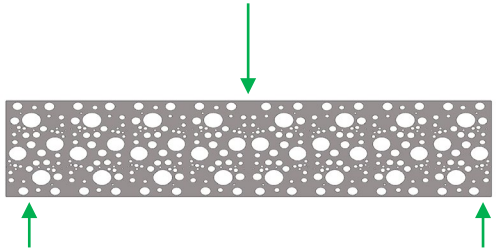
Design Freedom

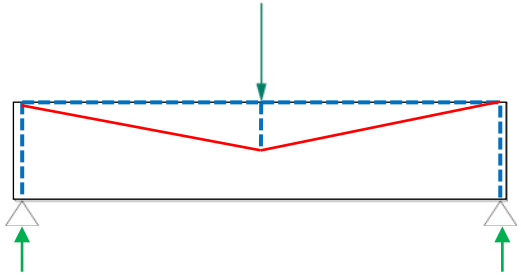


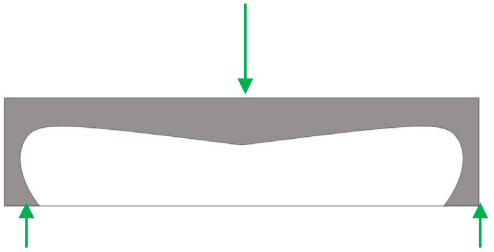


for a load condition many **different** correct **solutions** for the flow of inner forces are possible!





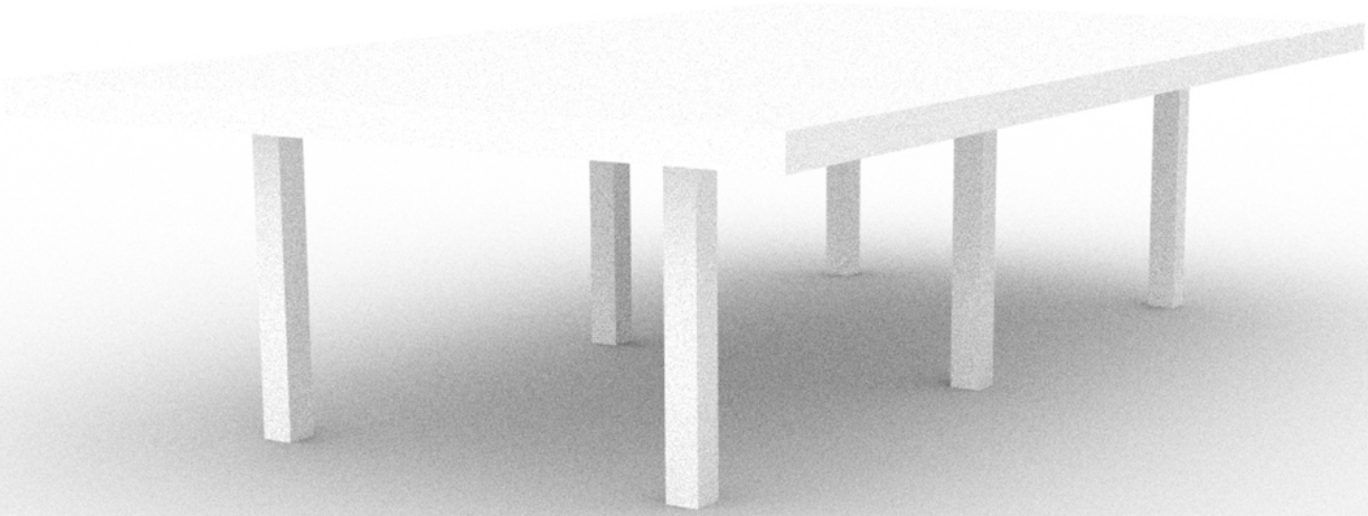




each distribution of inner forces can provoke a different design solution

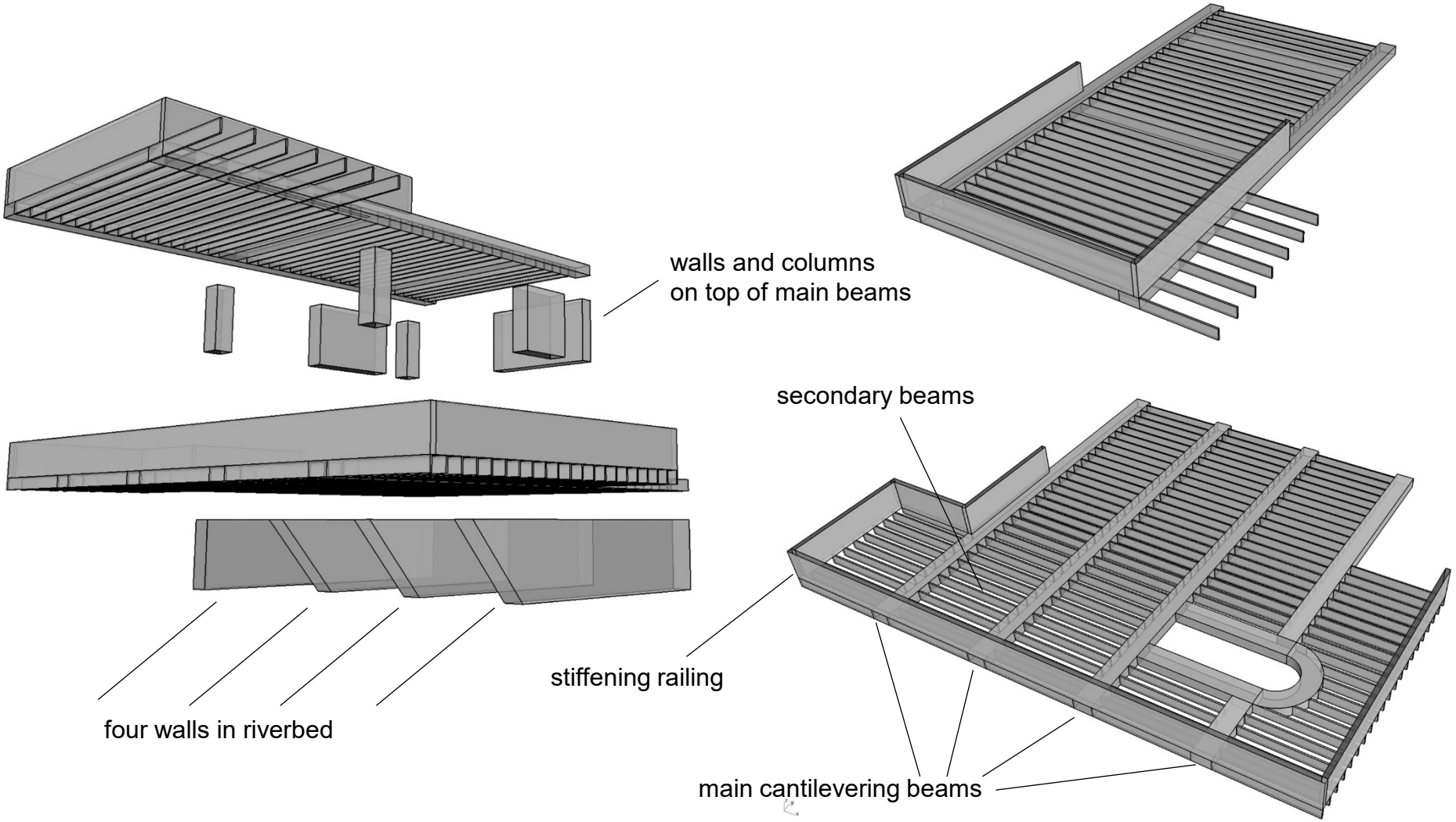
Design Freedom

How does a plate distribute load to the columns?



each distribution of inner forces can provoke a different design solution

Frank Lloyd Wright: Kaufman House
Bear Run, USA, 1935



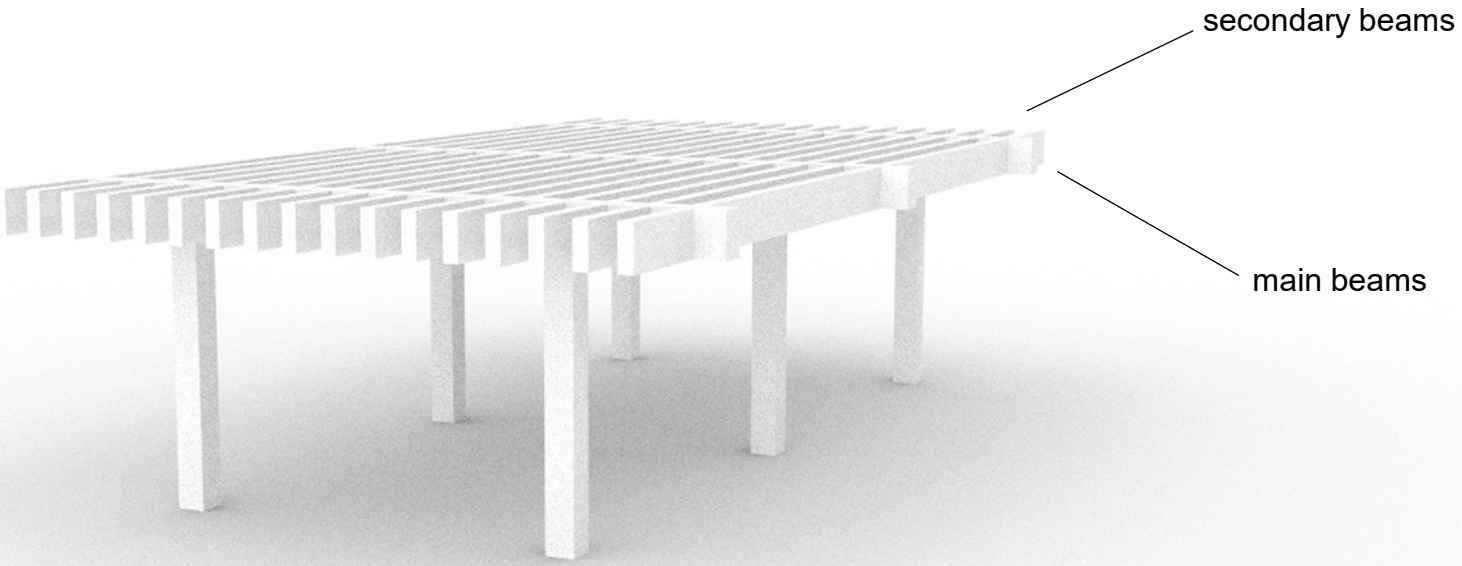
Frank Lloyd Wright: Kaufman House
Bear Run, USA, 1935

Design Freedom

How does a plate distribute load to the columns?

Design Freedom

How does a plate distribute load to the columns?

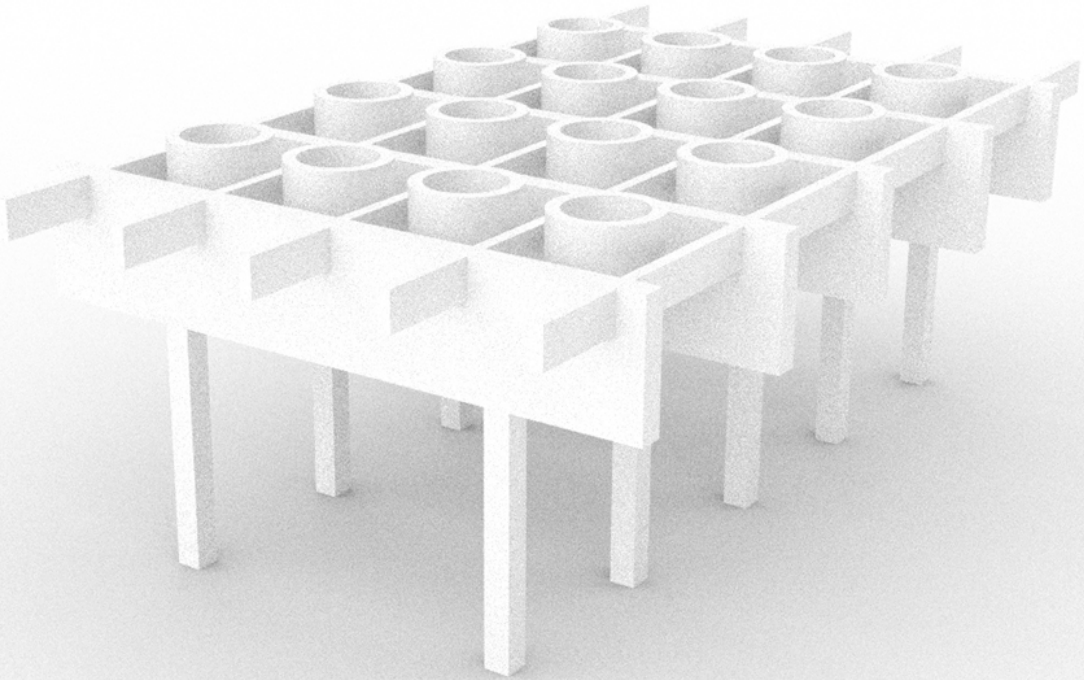


Albert Kahn: Highland Park Ford Plant
Detroit, USA, 1917

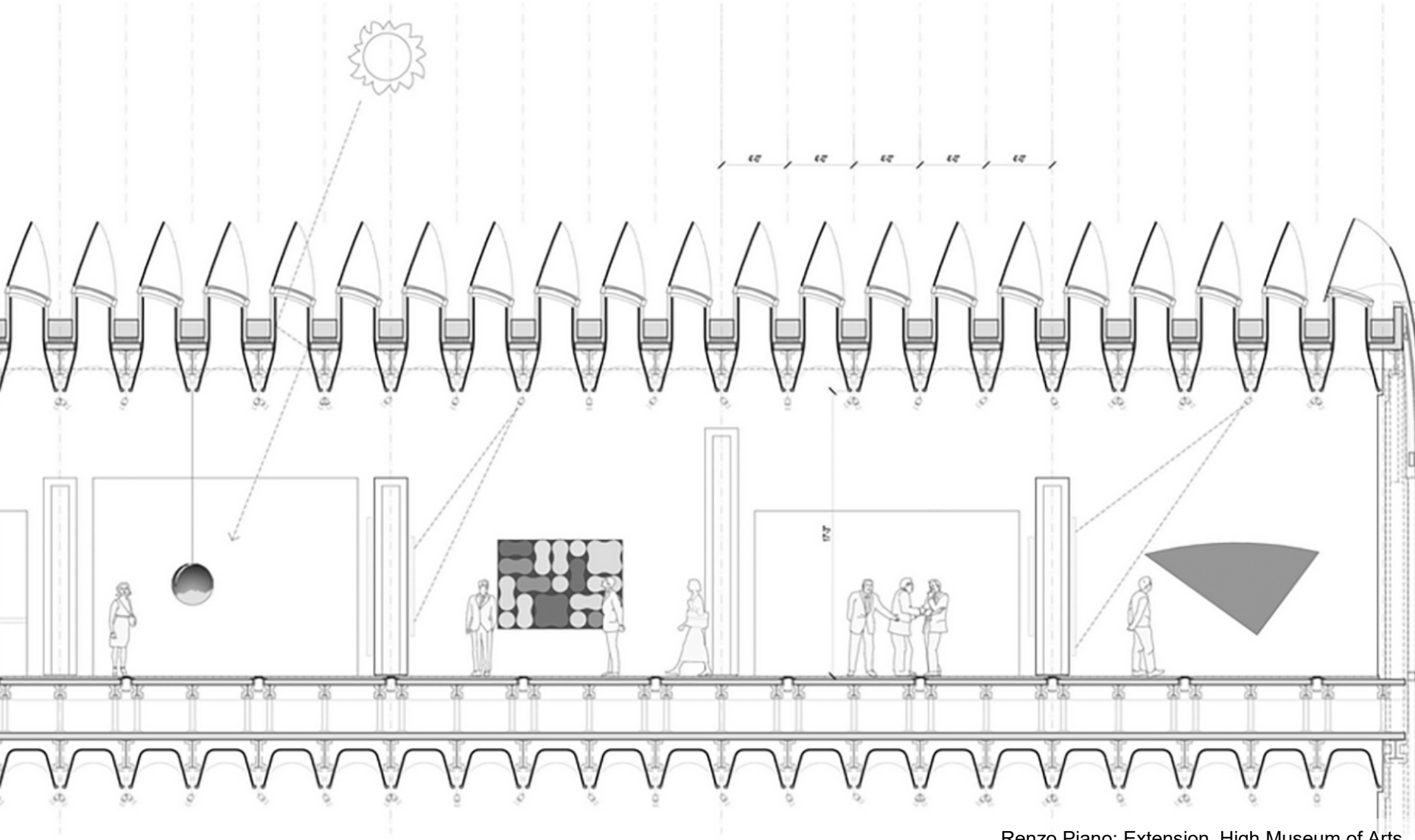
Renzo Piano: Extension, High Museum of Arts
Atlanta, USA, 2005

Design Freedom

How does a plate distribute load to the columns?

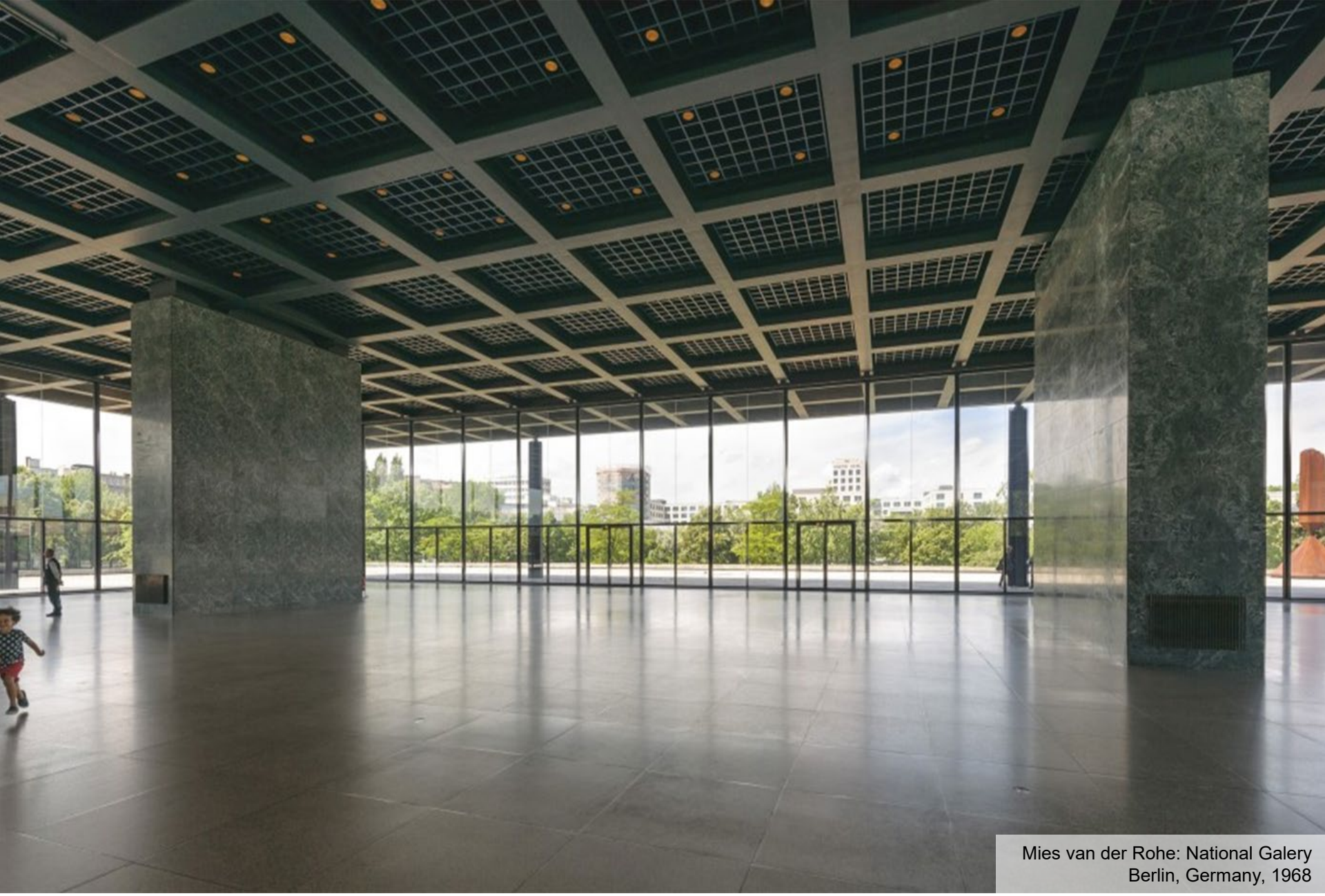


Renzo Piano: Extension, High Museum of Arts
Atlanta, USA, 2005



Renzo Piano: Extension, High Museum of Arts
Atlanta, USA, 2005

Alvar Aalto: University Library
Espoo, Finland, 1969



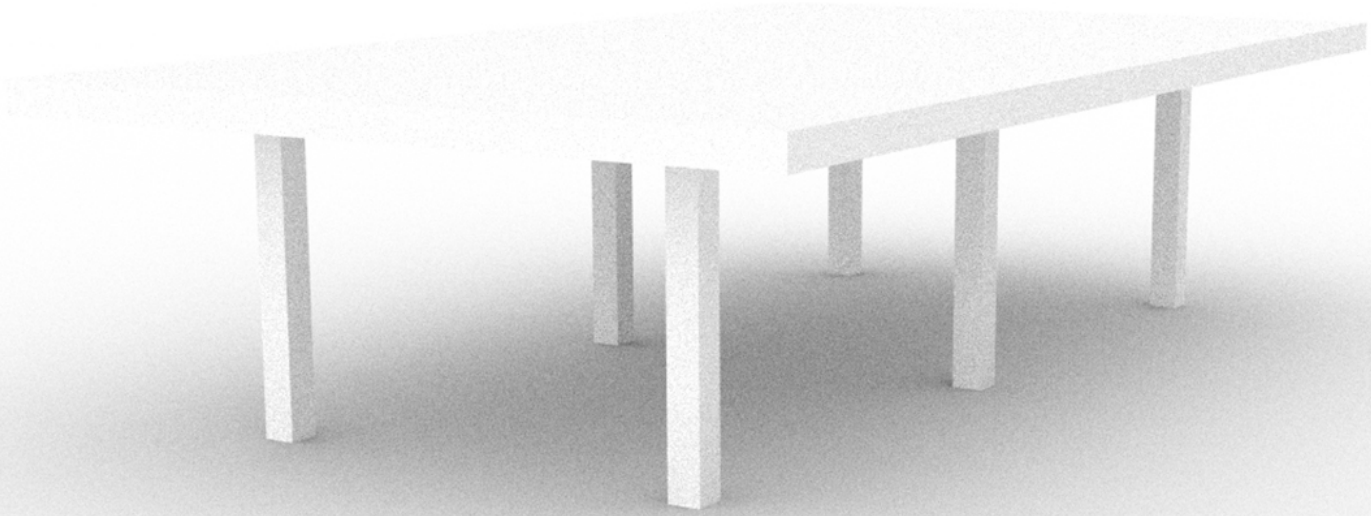
Mies van der Rohe: National Galery
Berlin, Germany, 1968

Louis Kahn: Art Gallery, Yale University
New Haven, USA, 1953

Heinrich Degelo: WEF Congress Center
Davos, Switzerland, 2010

Design Freedom

How does a plate distribute load to the columns?



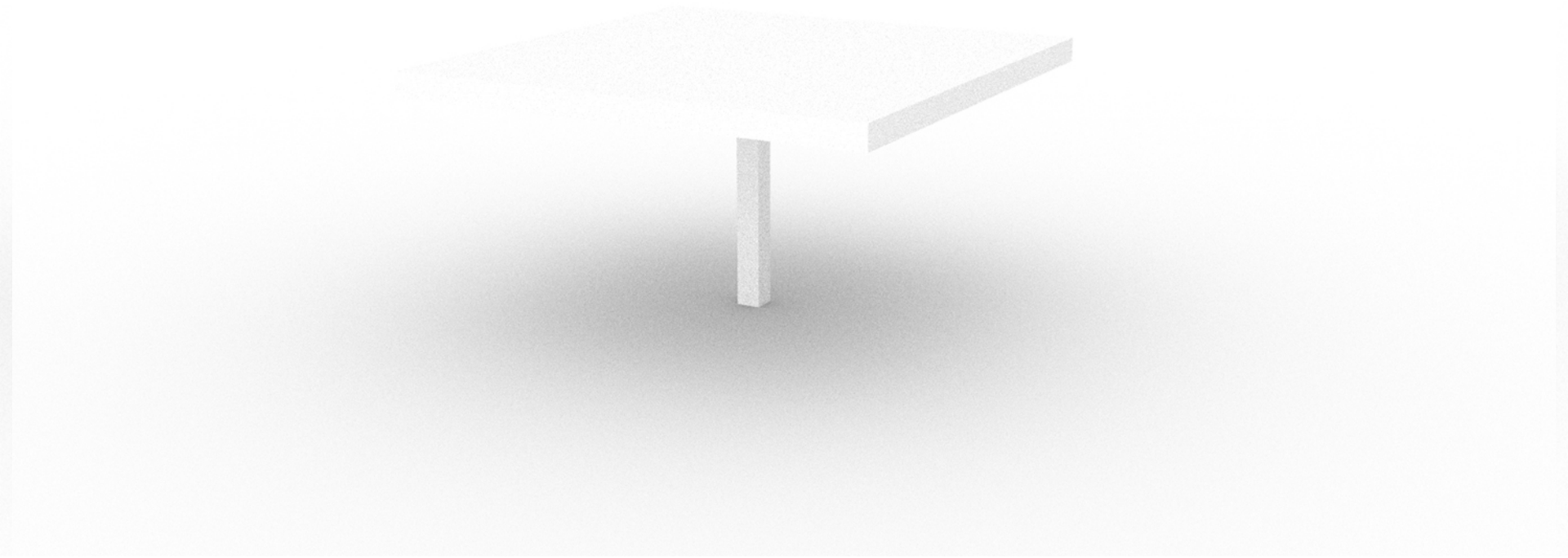
this is not so much a technical question
but rather a **question of design**!

Design Freedom

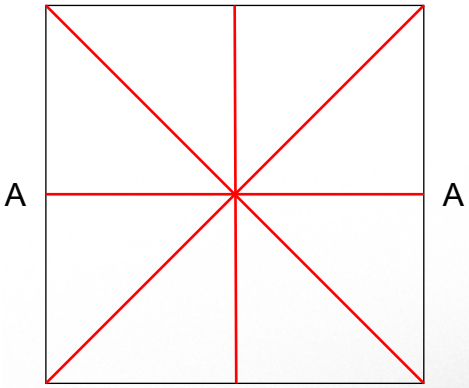
How does a plate distribute load to the columns?

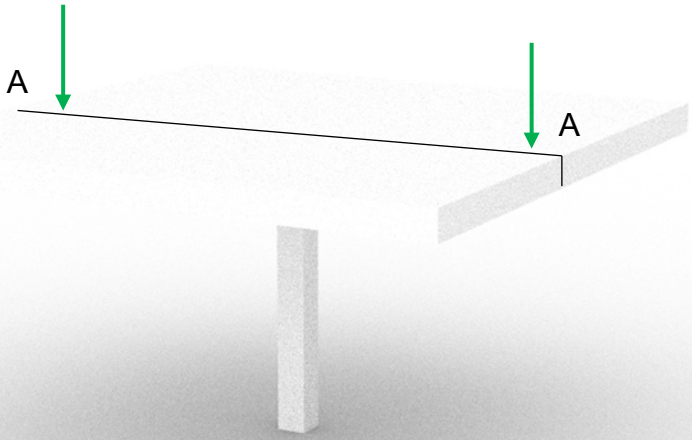
or

How does a column attract forces from the plate?

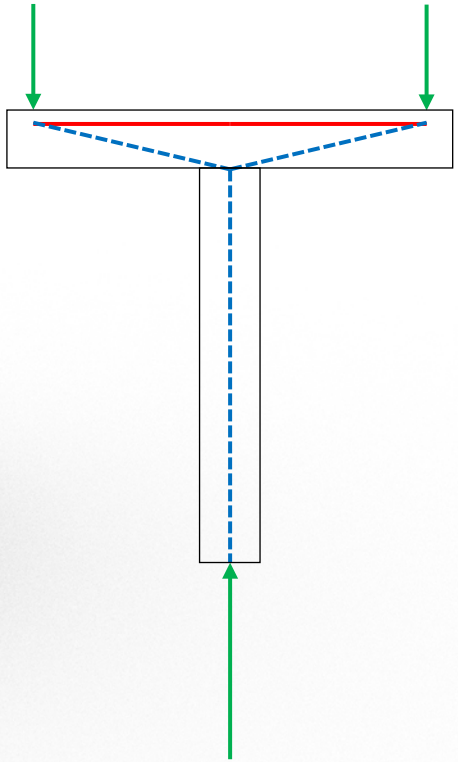


top view

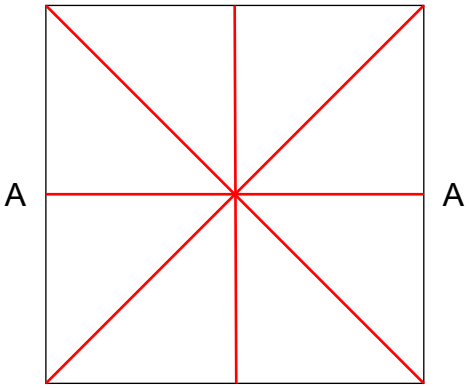


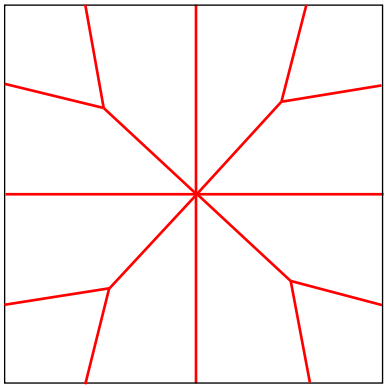


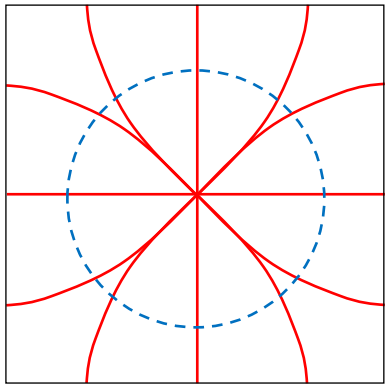
side view

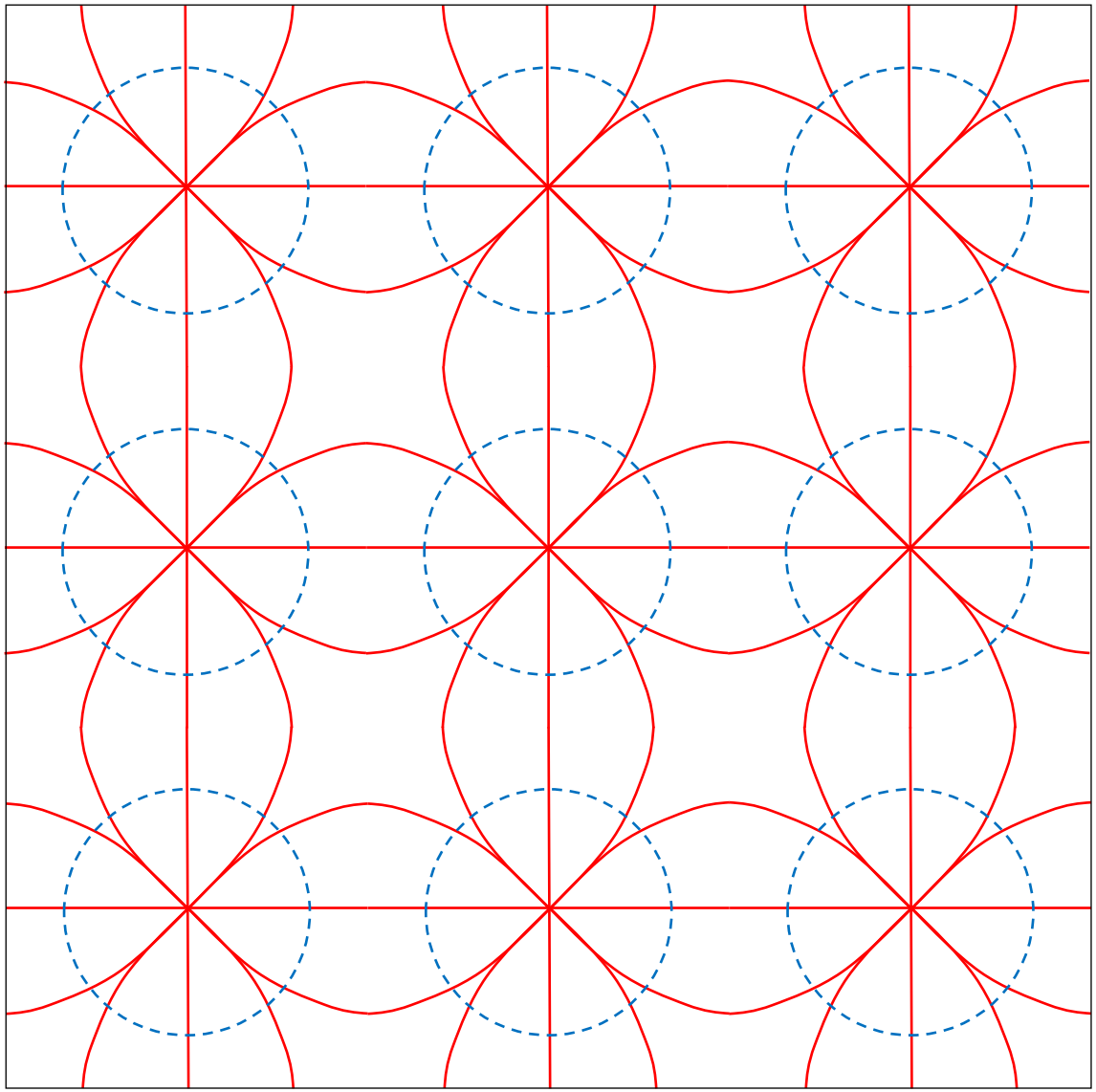


top view



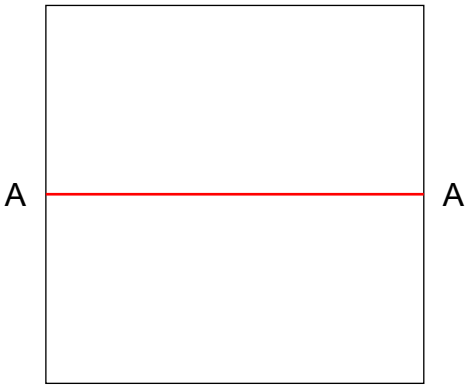


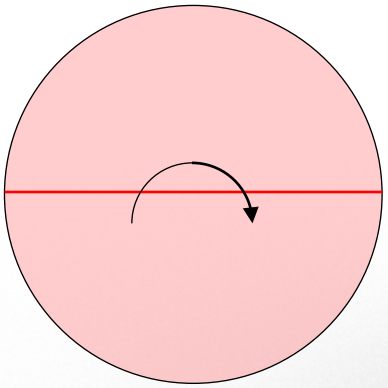


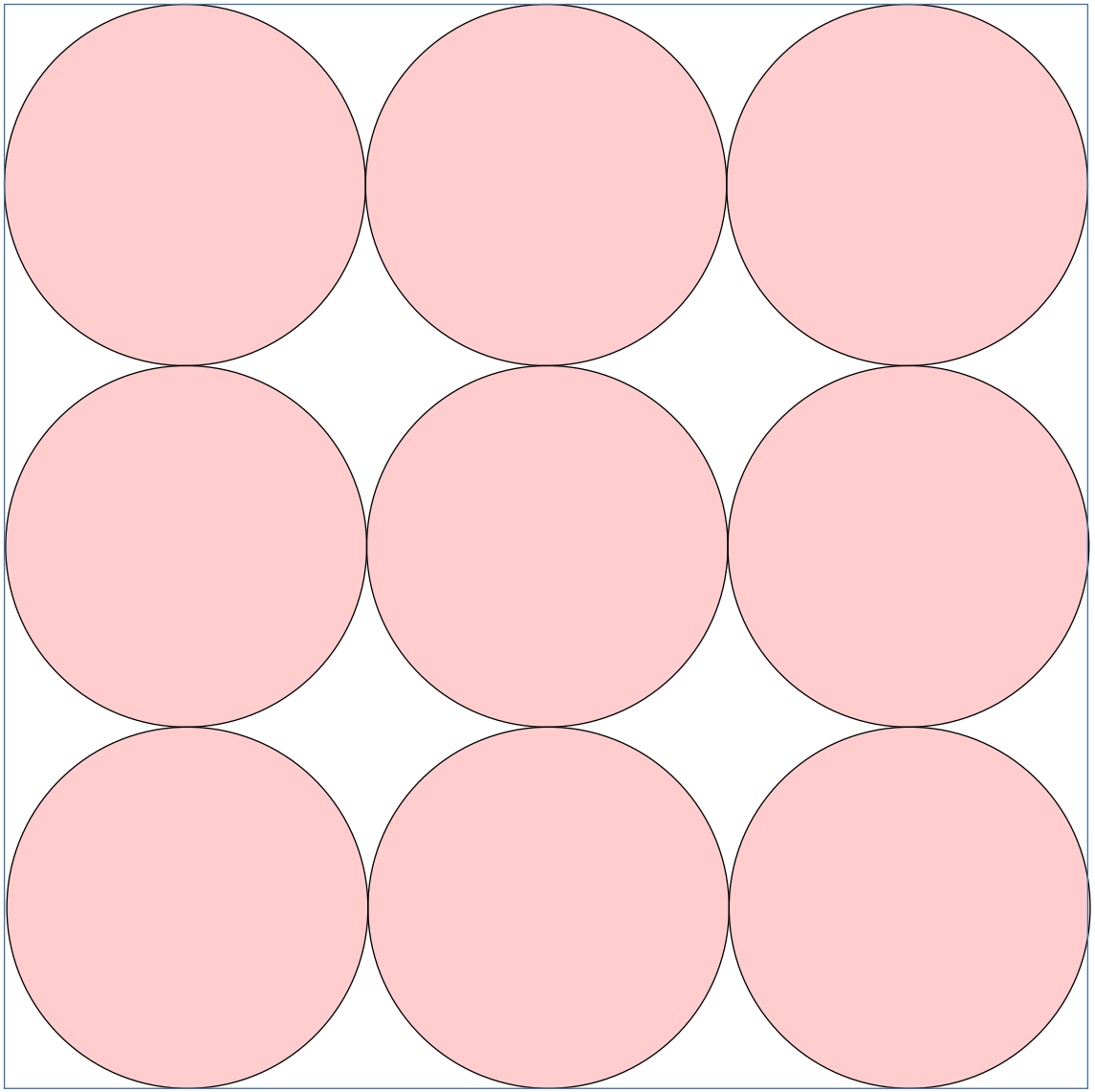


Pierluigi Nervi: Wool Factory Gatti
Rome, Italy, 1951

top view







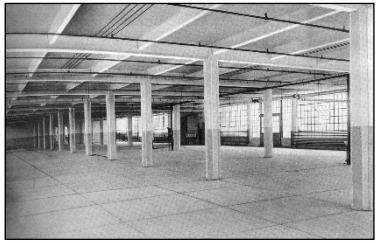
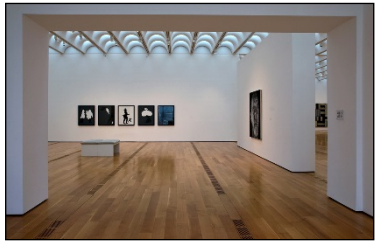
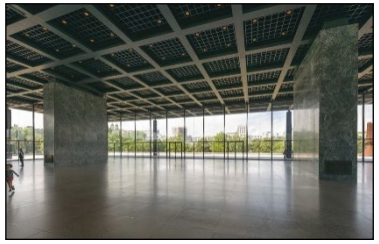
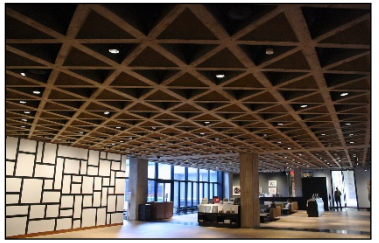
Frank Lloyd Wright: Johnson Wax Building
Racine, USA, 1936

Design Freedom

How do inner forces flow?

What does this mean for design?

structural design is primarily a question of **design thinking**,
it is a creative & intellectual process!


Efficient Design Solution

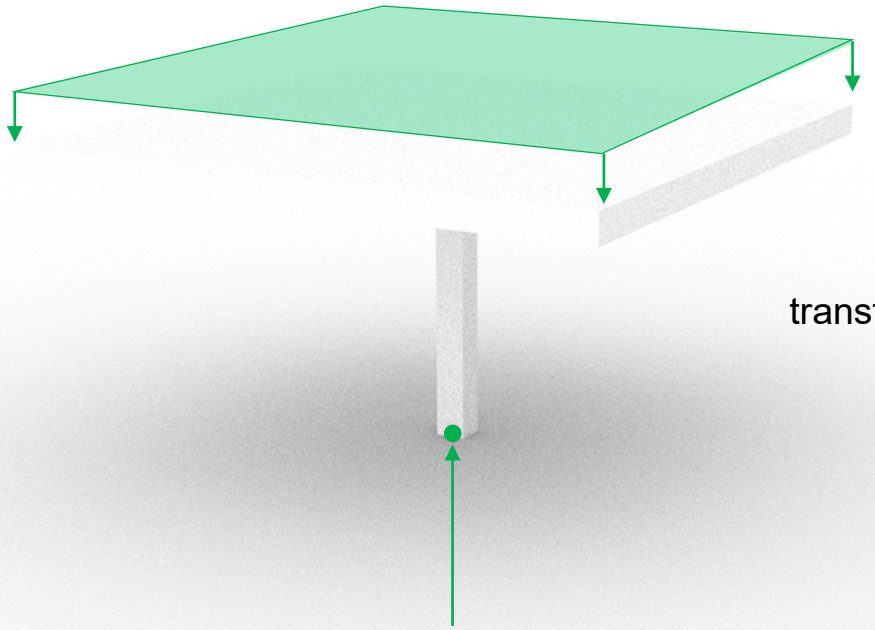
What means efficiency here?

Gerkan, Marg & Partners: Airport
Stuttgart, Germany, 2004

Efficient Design Solution

What means efficiency here?

least amount of material to transfer loads from a surface to a point

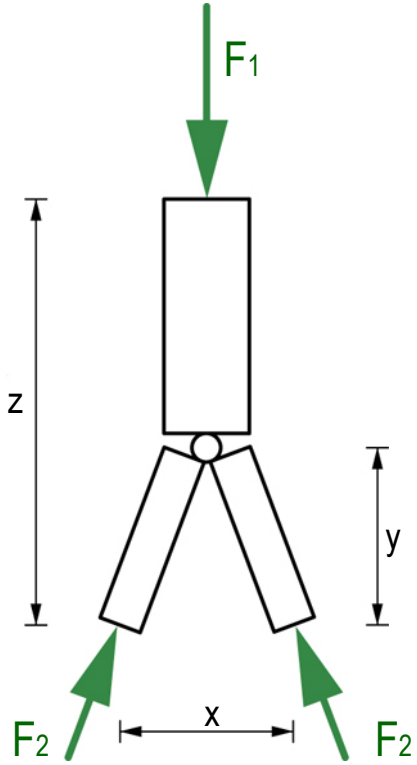


transfer of load from surface to point

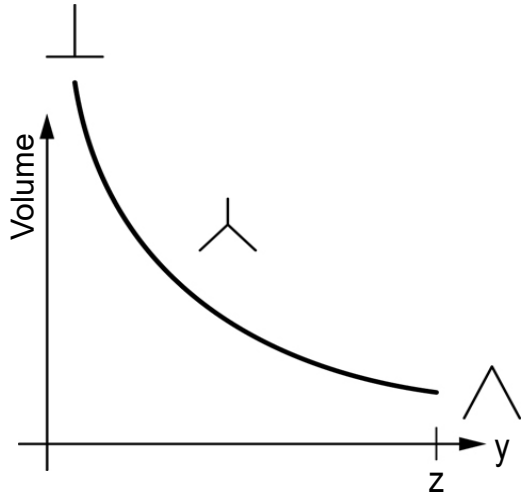
Efficient Design Solution

What means efficiency here?

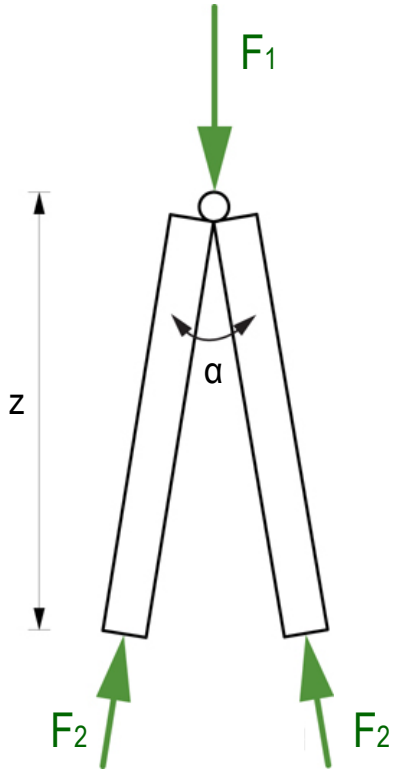
least amount of material to transfer loads from a surface to a point



x & z fixed
y variable



material efficiency: economic use of material if maximal allowable stresses are distributed uniformly at available material

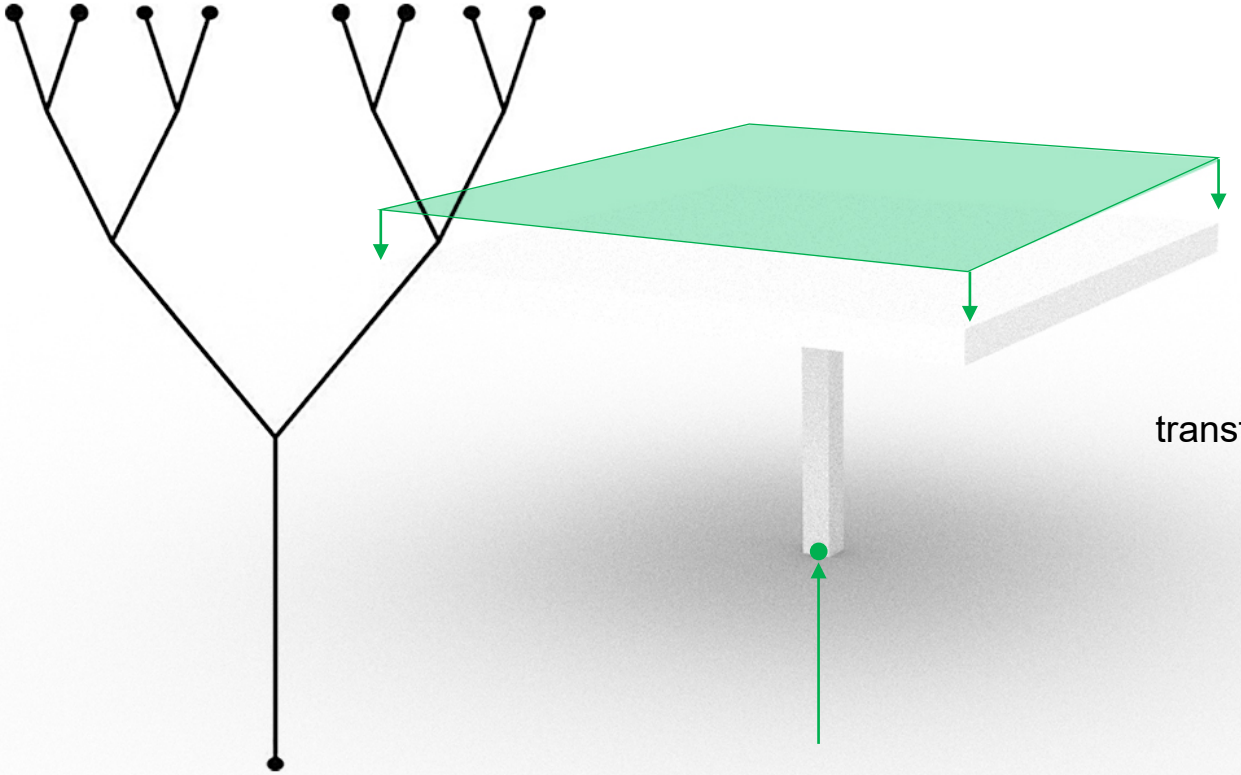


z fixed
α variable

Efficient Design Solution

What means efficiency here?

least amount of material to transfer loads from a surface to a point



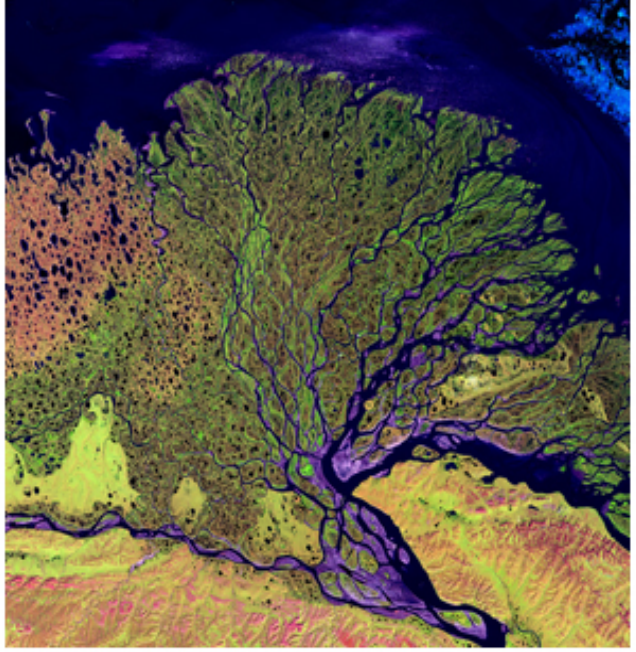
transfer of load from surface to point

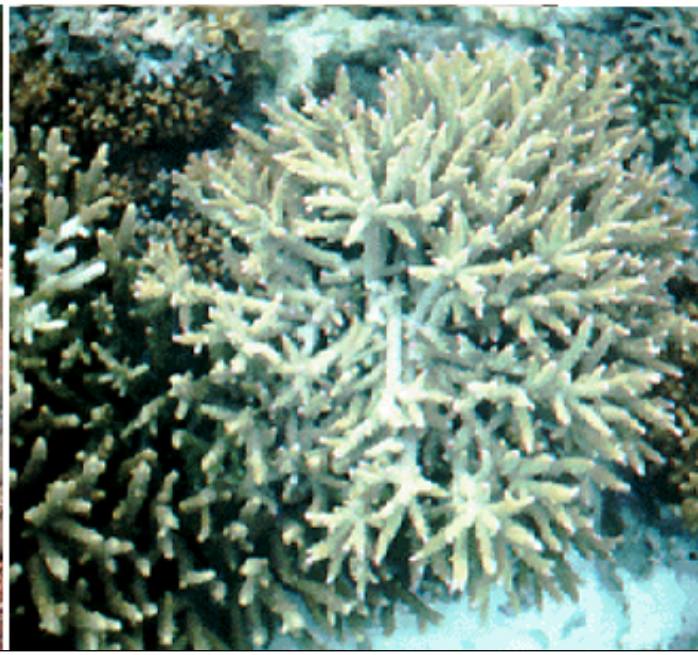
Efficient Design Solution

Dirk Hebel & Philippe Block: tree-like column out of mycelium, Seoul Biennale, 2017

Efficient Design Solution

efficient flow from surface to point





truss

distribution of forces in space

relation column-plate

structural design thinking

ARK-A3001 Design of Structures_Basics

Force Distribution

Toni Kotnik

Professor of Design of Structures

Aalto University
Department of Architecture
Department of Civil Engineering

Exercise 5.1

EMBT: Renovation, Santa Caterina Market
Barcelona, Spain, 1997 - 2005

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Barcelona, Spain, 1997 - 2005

Exercise 5.1

After its renovation in 2005, the Santa Caterina Market in Barcelona is covered by a wavy roof designed by Enric Miralles and Benedetta Talgiabue (EMBT). It consists of a combination arches, cables and beams and spans an area of about 60 x 50 m without any support. Sketch the structural system of the roof.

EMBT: Renovation, Santa Caterina Market
Barcelona, Spain, 1997 - 2005